LISST-200X

Particle Size Analyzer

Including

LISST-HAB & LISST-Black

User's Manual

Version 2.35

December, 2022

Store Software USB Card Here

SEQUOIA

2700 Richards Road, Suite 107
Bellevue, WA 98005
USA
Telephone: (+1) 855-753-3313

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Welcome to the LISST-200X Particle Size Analyzer

Using this manual

I. LISST-200X Introduction & Quick Start provides an overview of the LISST-200X's operating principles and basic functions.

II. Operation Details provides details and step-by-step instructions for using and caring for the instrument.

The **Appendices** contain specialized details, specifications, and information about options.

Warranty

See the product warranty at:
http://sequoiasci.com/support/warranty

Technical assistance

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

Sequoia Scientific, Inc. contact information:
Telephone: (+1) 855-753-3313
Email: support@sequoiasci.com

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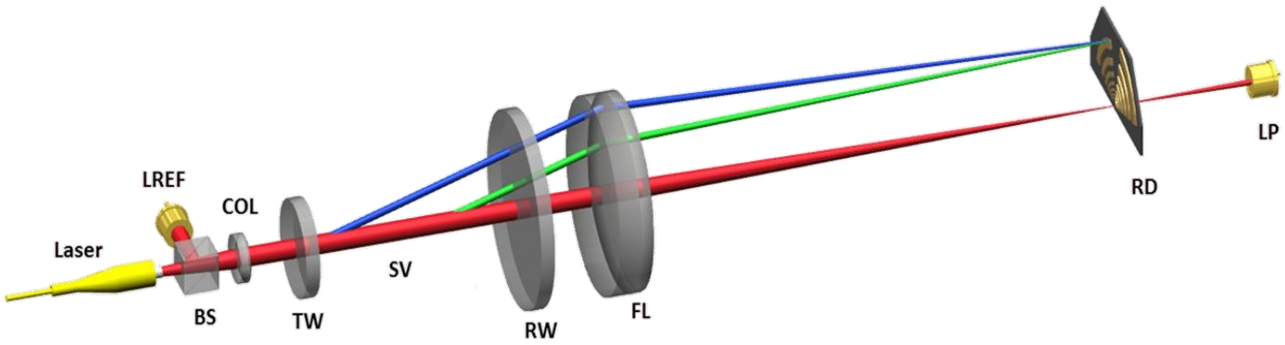
I. LISST-200X Introduction & Quick Start

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).

To measure scattering at multiple angles, the LISST-200X sends a collimated beam of light into the 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). 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* – converting 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

Scattering originates not only from particles in the water, but also from the water itself, and from the windows and internal optics of the LISST-200X. This non-particle scattering constitutes a *Background.* (Formerly this was called *zscat,* meaning scattering by zero concentration of scatterers). Accurate measurements require subtracting the background scattering from the total signal seen by ring detectors.

The background scattering typically changes gradually throughout the life of the instrument, due to small changes in the laser and optics, and wear on the exposed window surfaces. It is also very sensitive to cleanliness of the windows. Therefore, high-quality measurements require careful background measurements by the user. A *factory background* acts as a reference for comparison. The LISST-200X stores its factory background data in its memory, as well as the user's acquired background data.

Background Quality Control

Because the background measurement is so important, the LISST-200X firmware and software include procedures for measuring and evaluating the background scattering. The software checks for signs of problems such as laser degradation, 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.

For details on the background measurement procedure, see Saving and Evaluating Clean Water Backgrounds on page 29.

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 daytime measurements at shallow depths can include some sunlight. However, the LISST-200X (starting with firmware version 1.4, introduced in May, 2017) can measure the ambient light independently of scattered light, and remove its effects. This Ambient Light Rejection (ALR) function is enabled by default. Also see Performance Optimization on page 73.

Quick Estimates of Total Concentration and Mean Size

Converting the LISST-200X's measurements of scattering to PSD requires extensive computations that are time-consuming for a small microprocessor. However, a much simpler computation, easily done in real time, provides estimates of the total particle volume concentration and mean particle size. These quantities are 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%, because the SMD can become erratic when the relative scattering signal is small. [*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].

Calculating the full PSD in real time

Newer LISST-200X's, starting with serial number 2131 (and older units with upgraded circuitry), contain more powerful processors that can do full PSD processing in real time. The processed data can be stored in the instrument's memory, or transmitted through its serial port. This is especially useful for unattended deployments, such as buoys or remote moorings, where it is not possible to connect a Windows computer to the instrument for data offloads. For full details, see Autonomous Real-time Data Processing on page 53.

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. The spherical model is appropriate only in exceptional circumstances. For more details, see Appendix G: Particle Shape Models on page 91.

B. LISST-200X General Description

Instrument Overview

The LISST-Deep is a submersible laser-diffraction particle size analyzer. It consists of optics for producing a collimated laser beam, a specially constructed photodetector array, electronics for signal pre-amplification and processing, and a digital processor with large nonvolatile storage.

The principal measurement—angular scattering distribution— is obtained with 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.

The resulting small-angle scattering data are processed through iterative matrix inversion to produce the particle size distribution (PSD) over a size range of 1.00 to 500 µm. See Appendix B: Particle Size Bins on page 80 for the exact sizes.

The PSD inversion process can be performed by the instrument firmware, by Windows software, or with MATLAB scripts that are available for download from Sequoia's website: www.SequoiaSci.com.

In addition to its primary scattering measurements, the LISST-Deep measures optical transmission, depth, and temperature, at depths up to 4,000 meters.

The LISST-Deep is capable of autonomous operation when used with external batteries. Windows software is provided to program the instrument for a specific sampling schedule.

An auxiliary connector can be configured for recording data from an external devices such as fluorometer, or for producing summary data (mean size and total concentration) as analog voltages.

The LISST-200X does not have internal batteries. Its watertight housing need not be opened for any normal use.

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 and is calibrated to 600 meters depth. A stainless-steel fitting and tube filled with silicone oil protect the pressure transducer from contamination and corrosion. 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 also has an auxiliary 6-pin connector for interfacing to other devices This port can be configured to produce analog outputs, or to receive analog inputs.

The Analog Output Configuration allows the LISST-200X to receive power from a CTD, and to send two analog voltages indicating the mean size and total concentration to the CTD, while the detailed size distribution data is stored internally for later downloading. For more details about this application, see Configuring the LISST-200X as a Sensor for a CTD on 57.

The Analog Input Configuration enables operation with additional sensors such as fluorometers and turbidity sensors. It provides 12V regulated power, and accepts two or three analog inputs (0 to 5 V) from sensors. The digitized analog values are stored in the same files as the LISST-200X's particle size data. This configuration also supports the instrument packages described in Appendix H: LISST-Black & LISST-HAB on page 96.

Battery-powered operation

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

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

The Large Battery Housing holds 16 standard alkaline D-cells. For profiling applications, where the instrument is sampling continuously, the Large Battery Housing 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. The LISST-200X software contains a battery life calculator on the Configuration page. This feature provides rough estimates of the battery run time for a given sampling program.

USB Power and Data connection

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:

- LISST-200X instrument,
- User's Manual,
- USB memory card (credit card size) with the software,
- Plastic Instrument stands,
- Small Volume Test Chamber,
- USB Communications cable,
- Insulated stainless steel clamps,
- Small Battery Housing (without batteries),
- Larger Battery Housing with alkaline batteries installed,
- LISST-200X-to-Battery-Housing 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: Connectors on page 86 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 page 27.

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.

NOTE: The LISST-200X software will not work with the older LISST-100 or LISST-100X instrument models.

Step 6: Start LISST-200X Application

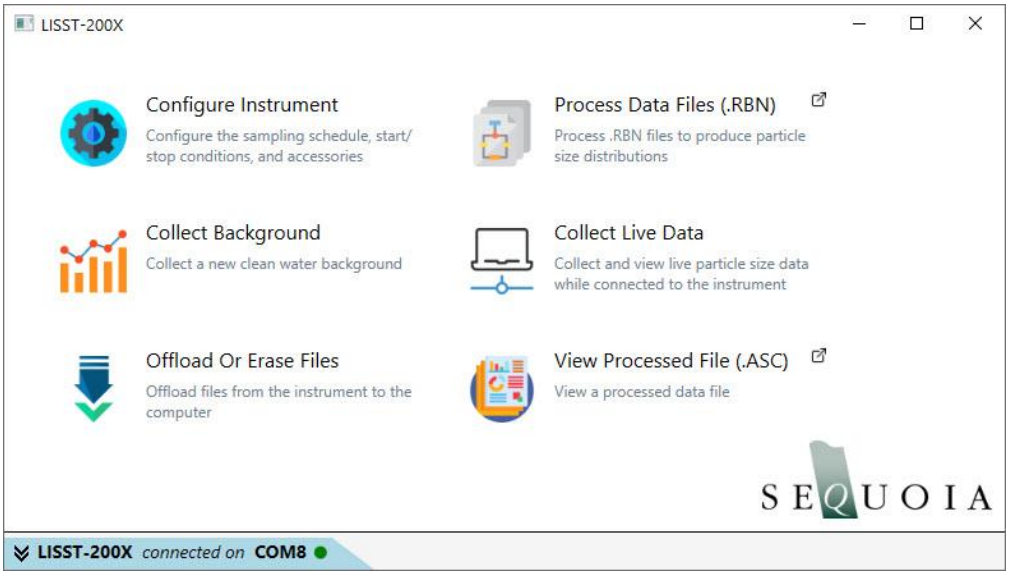
Start the LISST-200X software by selecting the shortcut the installer placed on your desktop.

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 housing 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.

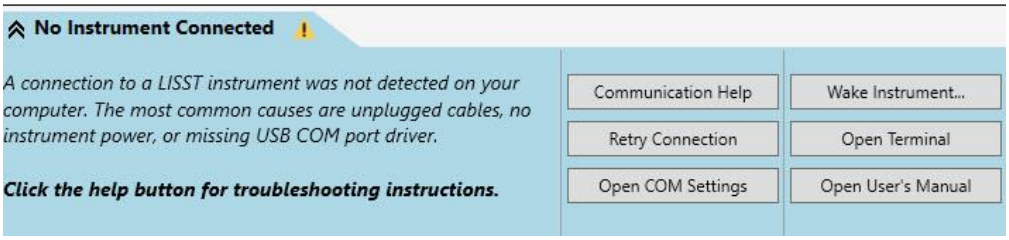
Power can also be provided by the Small and Large External Battery Housings or another external power source such as a CTD. When using an external battery the serial communication passes through the battery housing. However, the power from the USB is not used power the instrument. Power will be drawn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



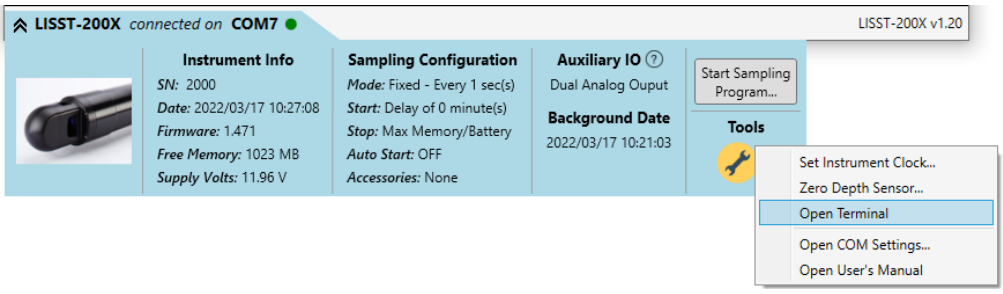
If an instrument is found, it will display ‘Connected’ in the lower left corner.

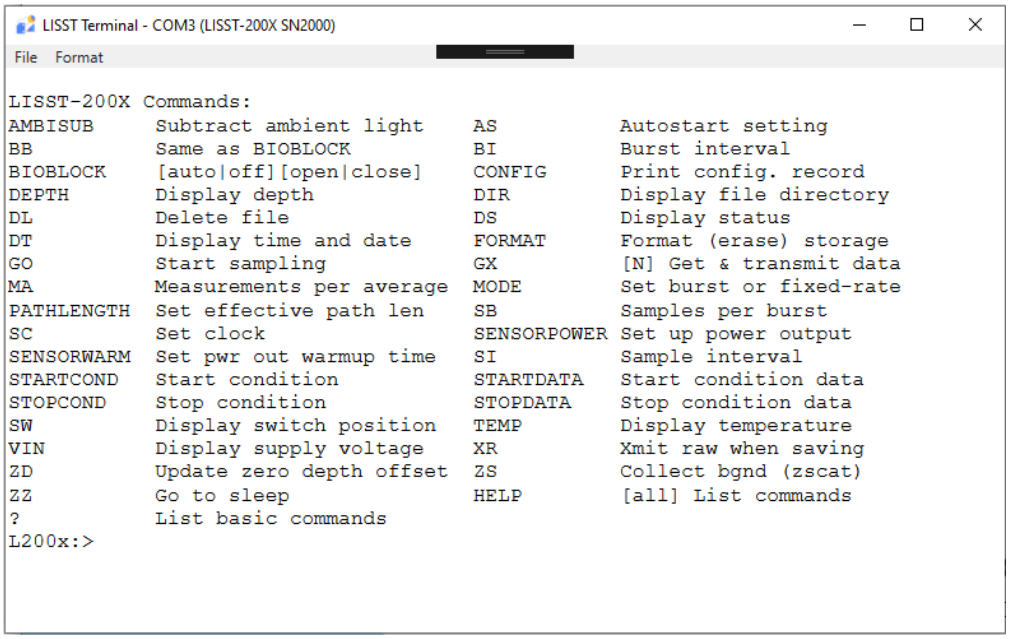
If your instrument is connected to the computer, but not found by the software, click on the ‘No Instrument Connected’ message to see list of options. Click on the ‘Communication Help’ button for troubleshooting help.



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'



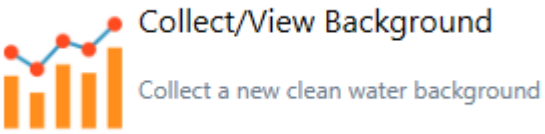


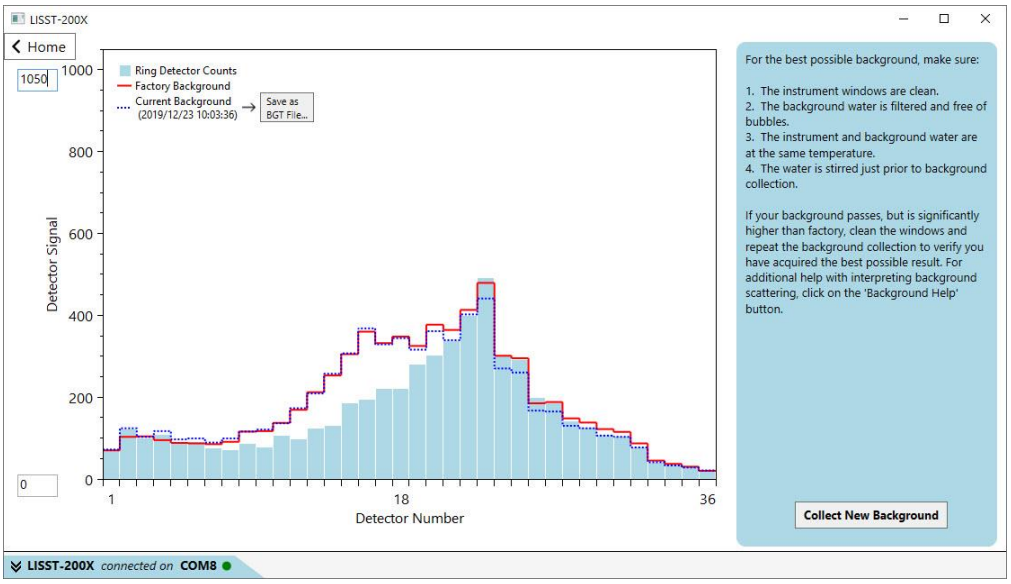
A command can be typed into the box in the lower section of the window. When the Enter key is pressed the command will be sent to the instrument. A list of the commands that can be sent to the LISST-200X is displayed when the terminal opens or they can also be found in the section Direct Command Summary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

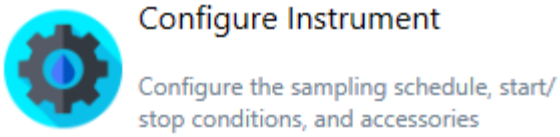
In general, the lower the background values the better the background. The goal is to get values that are at the same values as factory line. However, as the instrument is used the background may increase due to small scratches and slight alignment changes. It may not be possible to get the background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

If the values are acceptable, the background can be saved onboard the instrument and, optionally, to a file on your computer. The background stored in the instrument is saved as part of every data file, so it is not necessary to save a separate background file. The background stored on the instrument will continue to be saved in new data files until a new background is recorded.

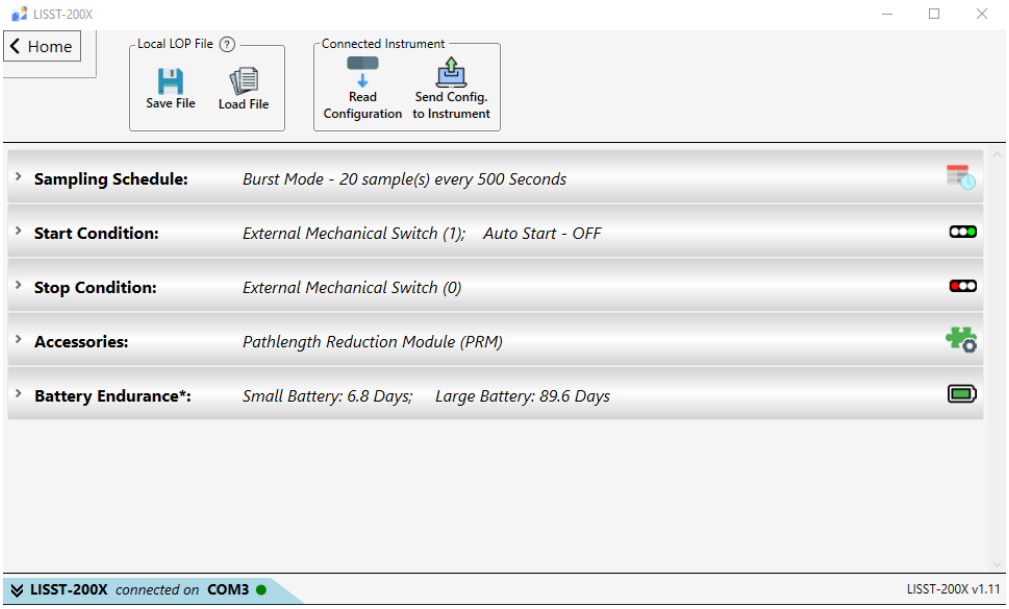
If you wish to store a background file on your computer as well as on the instrument, click the 'Save as .BGT file' after you have accepted and saved the background. It is not necessary to store the background on your computer, however, these saved backgrounds can be used during processing instead of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



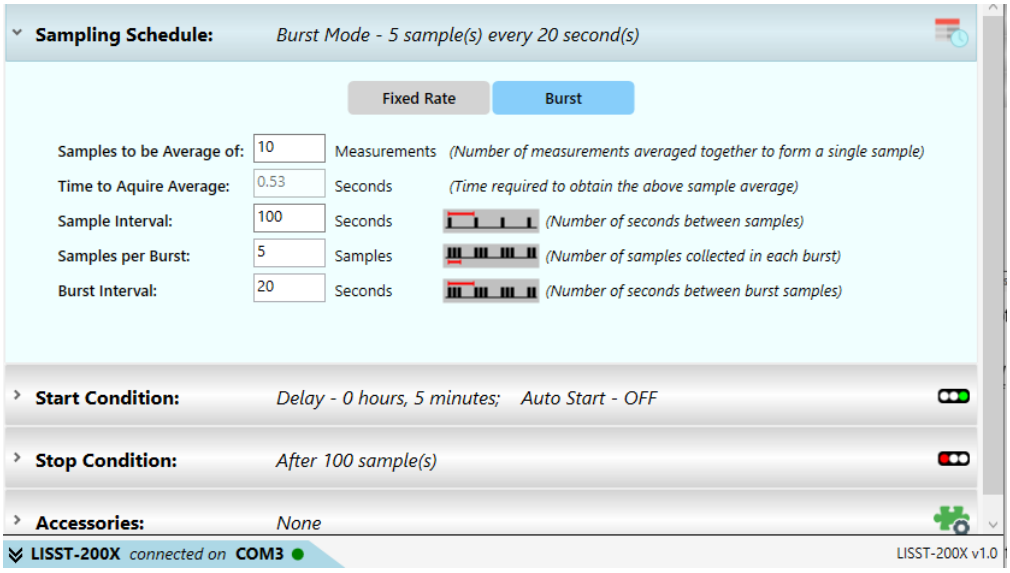
A window similar to the one shown below will appear. The window has four accordion style tabs: Sampling Schedule, Start Condition, Stop Condition, and Accessories.



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

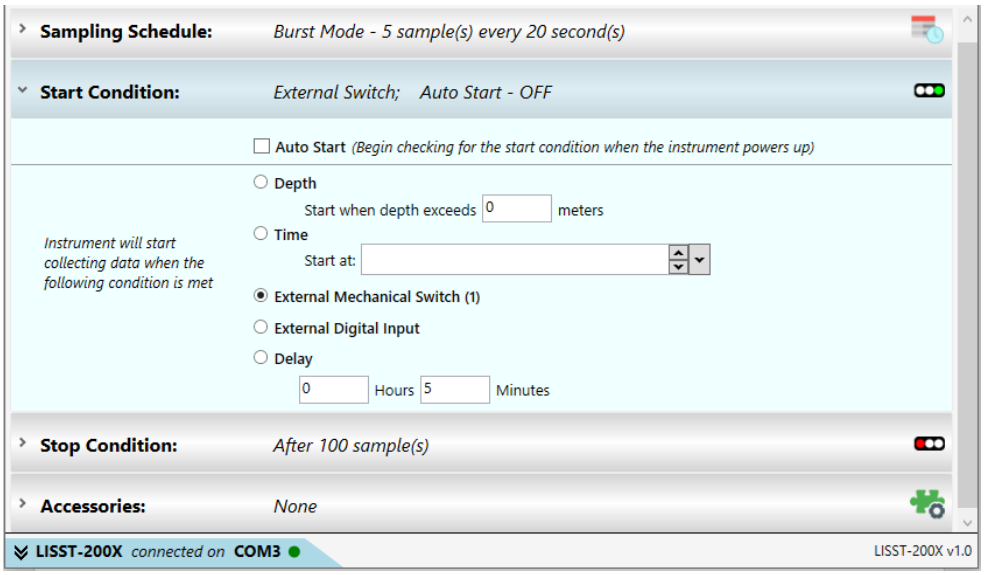
The Burst and Fixed Sample Rate modes are used to save data to a raw data file on board the instrument. The icons next to the various values give a better understanding of their meaning. The software automatically checks the values entered to make sure that there is no conflict. For example, when a 'Sample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



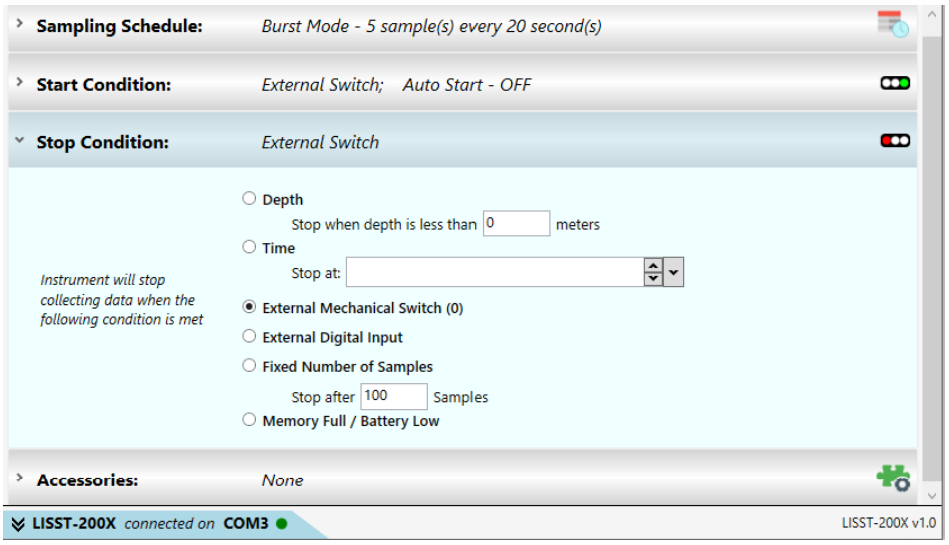
There are five options: Depth, Time, External Mechanical Switch, External Digital Input, and Time Delay. Select the mode by clicking on the button next to its label. Select the correct parameters as required. For this example let's select the External Mechanical Switch Start Condition.

AutoStart

If the AutoStart check box is selected, the LISST-200X will start the sampling program when power is applied to the instrument. **NOTE: for AutoStart to detect the application of power, all power sources (including the USB cable) must first be disconnected for at least 6 seconds.** If AutoStart 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.

Step 13: Setting Stop Conditions

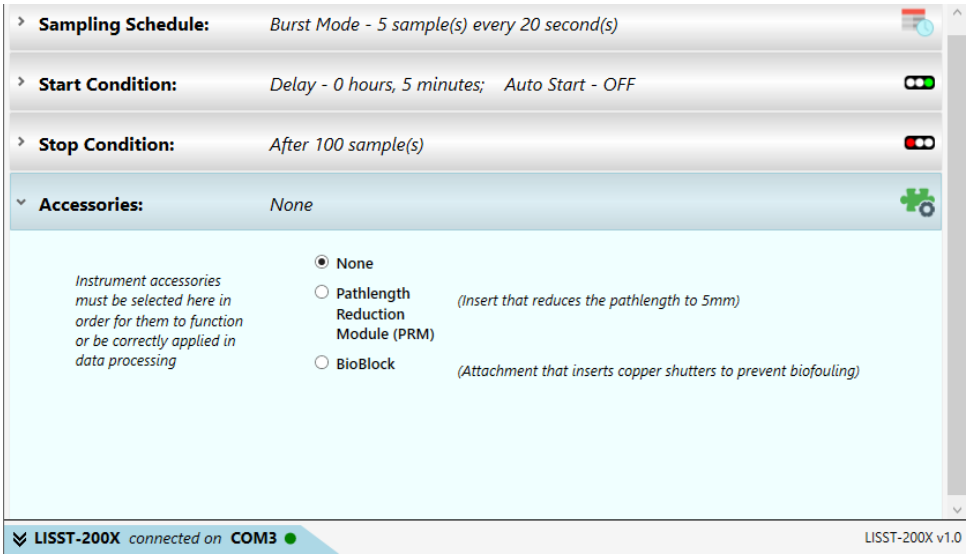
Similarly, the Stop conditions can also be selected. Click on the *Stop Condition* Tab to open the Stop Condition window. The available stop conditions are: Depth, Time. External Mechanical Switch, External Digital Input, Fixed number of Samples, and Memory Full/Battery Low



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

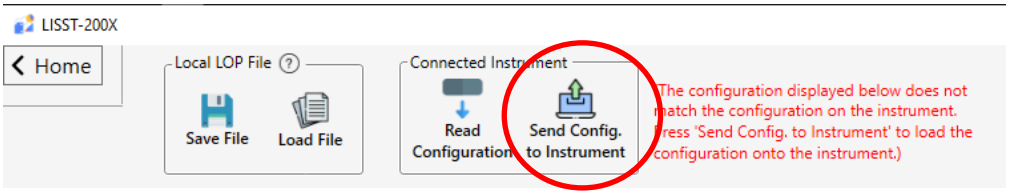
Step 14: Configure Accessories

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'.

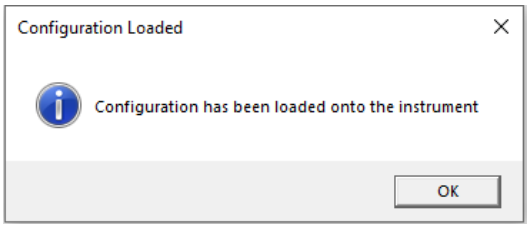


Step 15: Upload Configuration to Instrument

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.

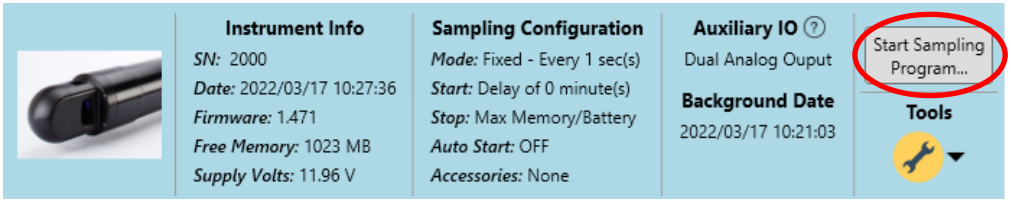


Step 16: Start Instrument

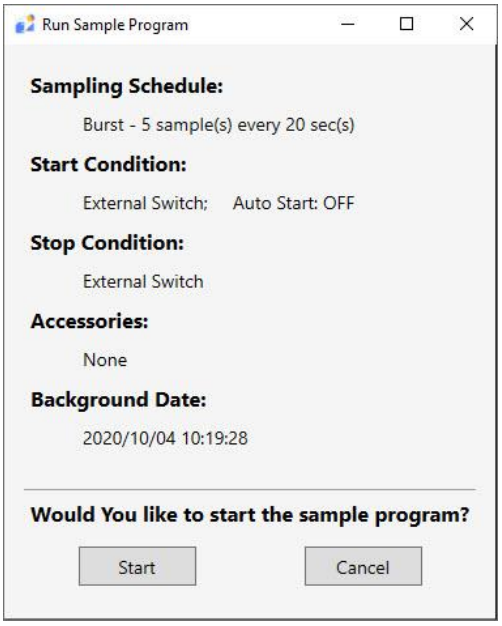
The instrument is now configured for deployment, **however, it is not yet running**.

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

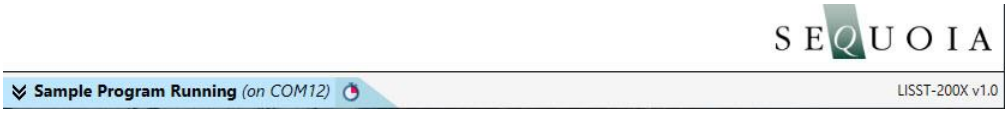
To start the sampling program. Click on the ‘Run Sample Program…’ button in the instrument status bar.



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



After the sampling program is started, you will see the status bar change to ‘Sample Program Running’ as shown below. At this point the instrument is running and ready for deployment.



Note that even when the sampling program is running, sampling will not necessarily start immediately. 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. If you want sampling to begin immediately, select a start condition of “Delay” with zero as the delay time.

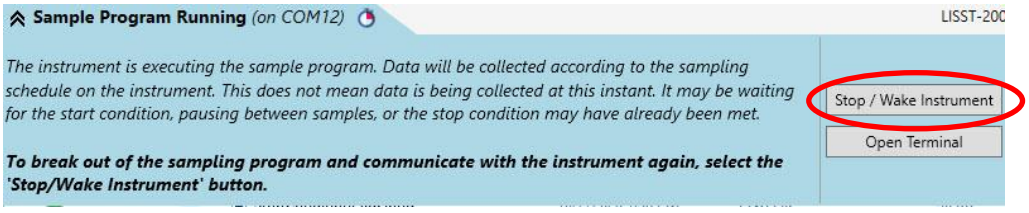
While waiting for the start condition the LED on the connector endcap will double blink every few seconds to alert the user that the instrument is running but not yet sampling. During sampling the LED will illuminate during the actual measurement of an averaged sample. For example, if the sampling is 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

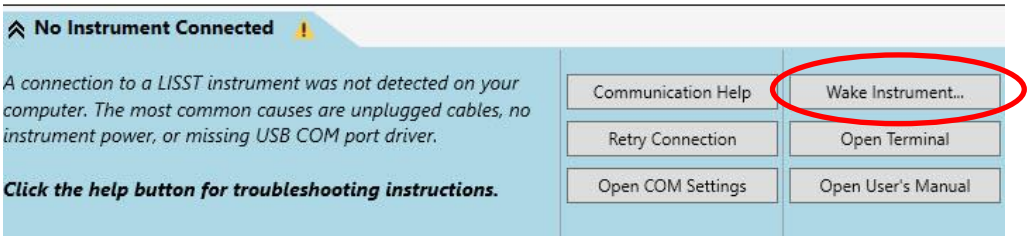
For our example we can move the white lever on the endcap to the “1“ position. Sampling will start. Data collection will continue until the Stop Conditions are met. In our case, until the switch lever is returned to the “0” position.

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.

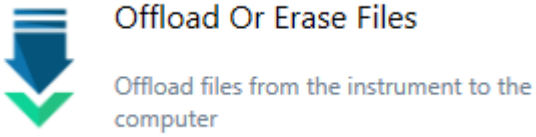


Note that the above options will only be available if you started the sample program from the software. If you plug in an instrument that is already executing a sampling program, you will need to manually wake the instrument by selecting the ‘Wake Instrument…’ button and selecting the COM port the instrument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

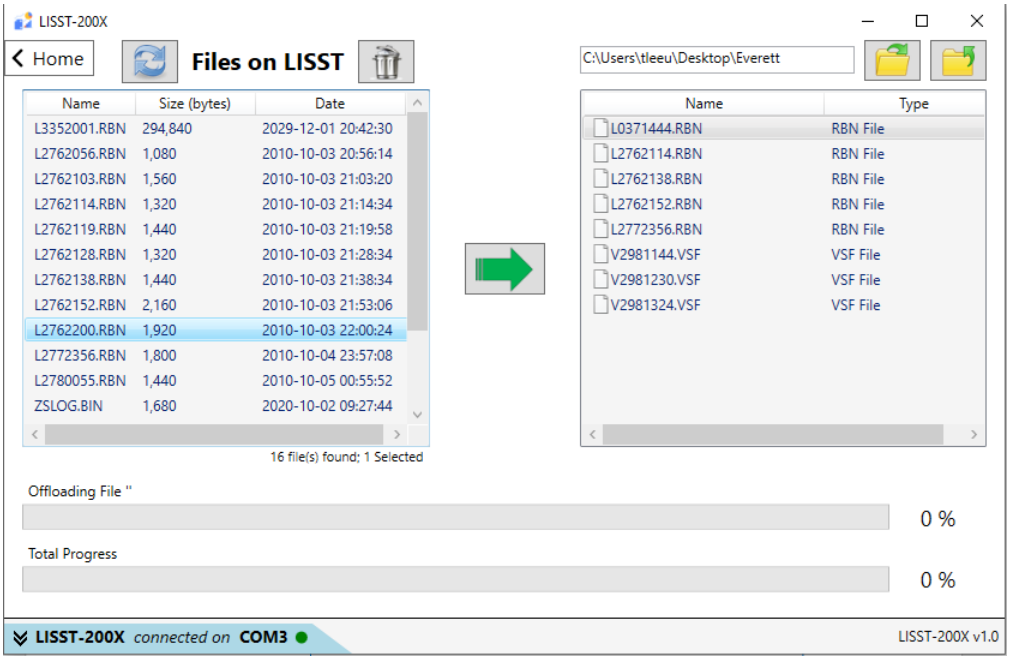


Step 18: Downloading Data

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



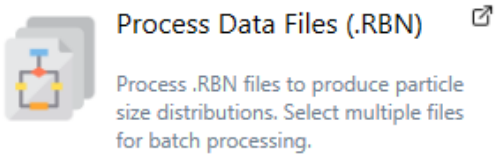
Choose the files to offload by clicking on them while holding down the CTRL key. The Shift key can also be used to select a range of files. Choose a location to offload the files to on the right side.



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.

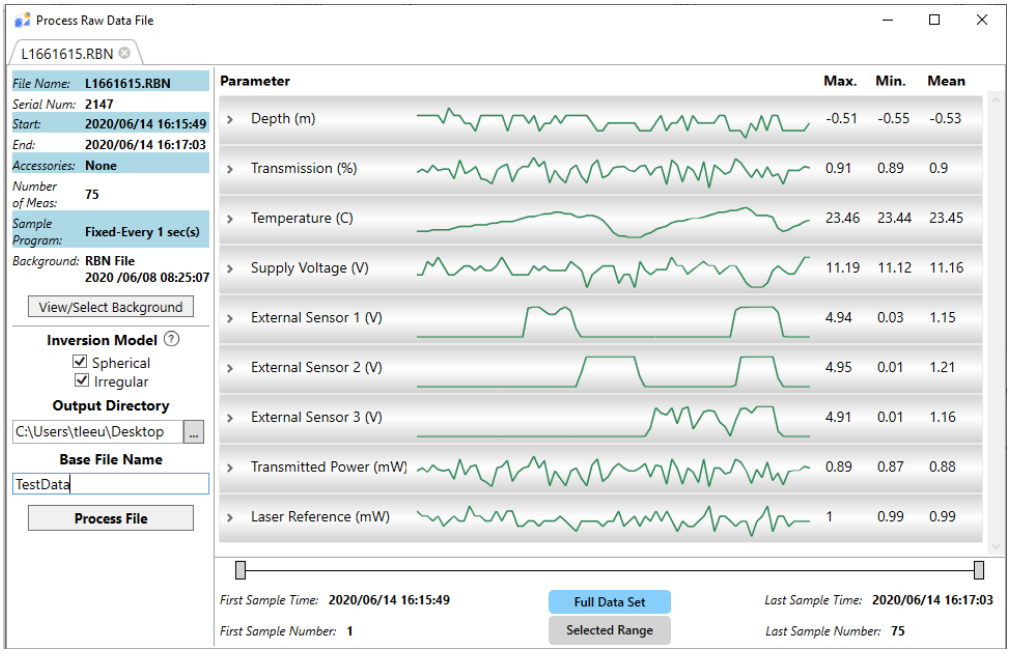


You will be prompted to select the raw data file to open (selecting multiple files will open up the batch processing window). Raw data files have the extension .RBN, and are offloaded directly from the LISST-200X data logger. Below is list of the file types you can expect to see when using the LISST-200X.

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



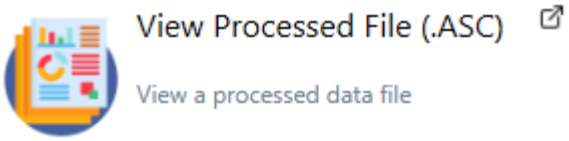
The range of samples to process can be selected by moving the sliders at the bottom of the display. This can be used to exclude data from the beginning or the end of the file. The default selection is to process the complete file.

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

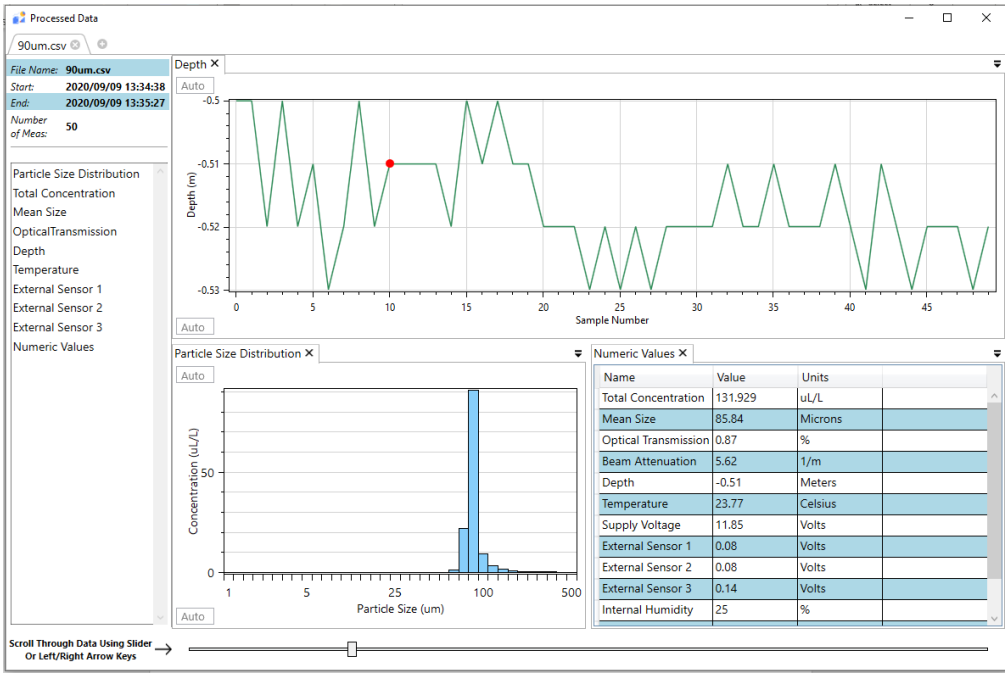
window is open, see the detailed Instructions starting on page 44. When the processing is complete a new tab will open, showing the processed results. You can navigate back to the raw data tab if you'd like to change the processing settings and process the data file again.

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.

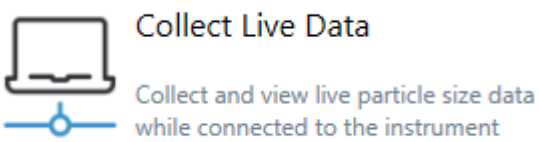


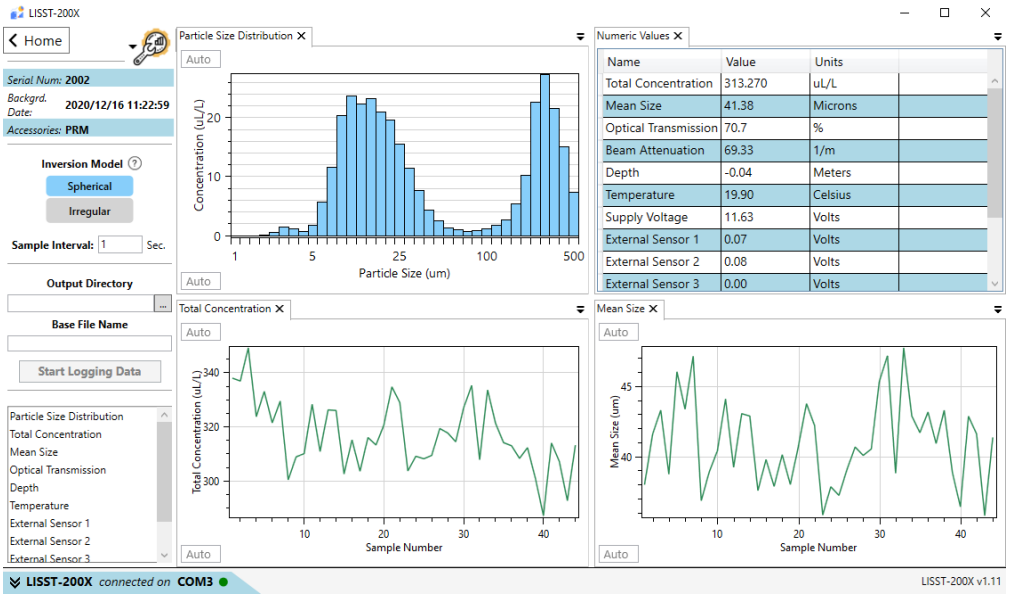
Step 21: Opening a Real Time Session

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 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 housing.

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

The Small External Battery Housing, 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 Sensors or Instruments

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 53. 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.

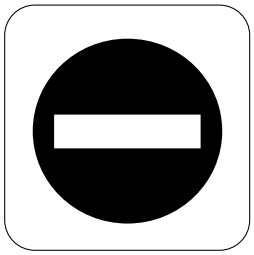
II. Operation Details

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.



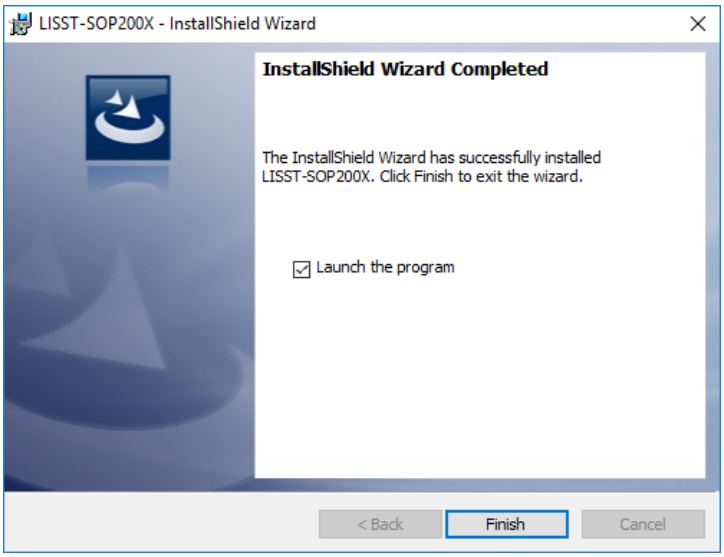
WARNING-Class 3R laser – AVOID DIRECT EYE EXPOSURE

The LISST-200X uses a laser diode emitting a maximum of 1 mW of visible (red) light at a wavelength of 670nm. Under normal circumstances the laser travels only within the 2.5 cm sample volume. However, if reflective objects are placed in the path of the laser beam, the light could be redirected. Avoid conditions that could direct the beam toward an eye.

A. 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

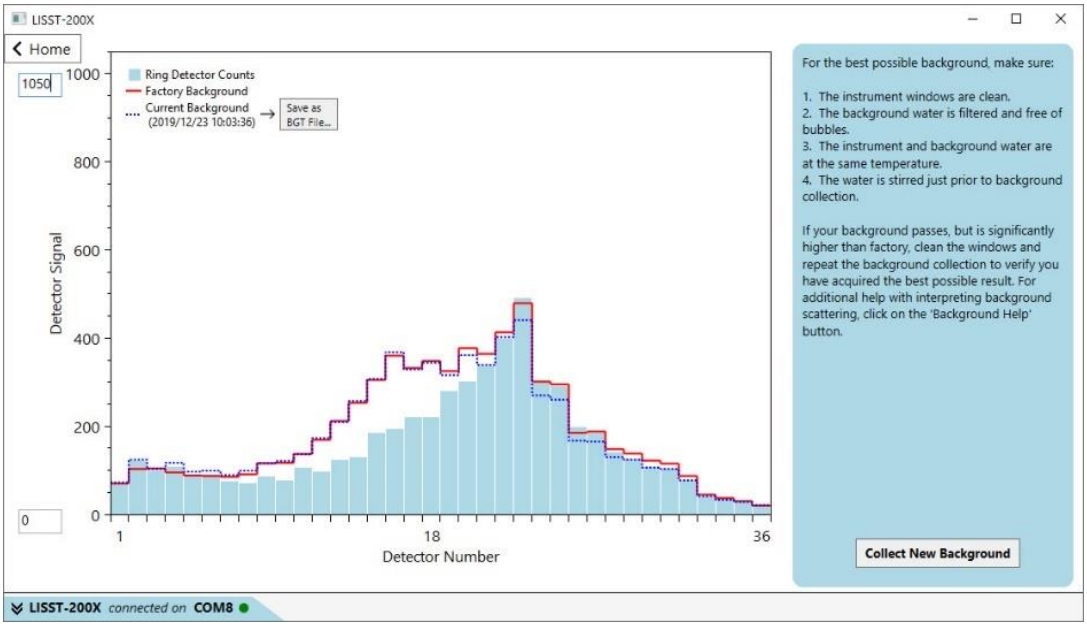
Establish communication with LISST-200X using the supplied software and USB cable. Communicating with the LISST-200X via the software should be automatic. If you have trouble, try following these steps exactly.

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, if not already installed. 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.

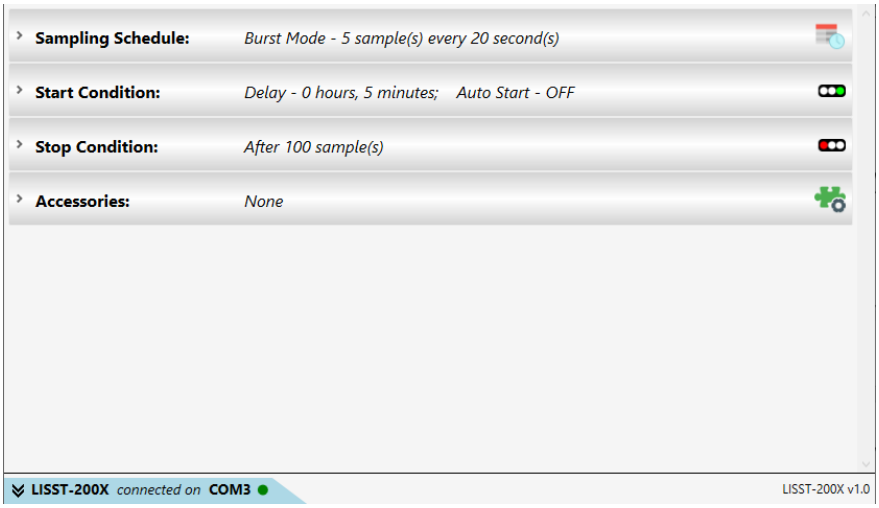
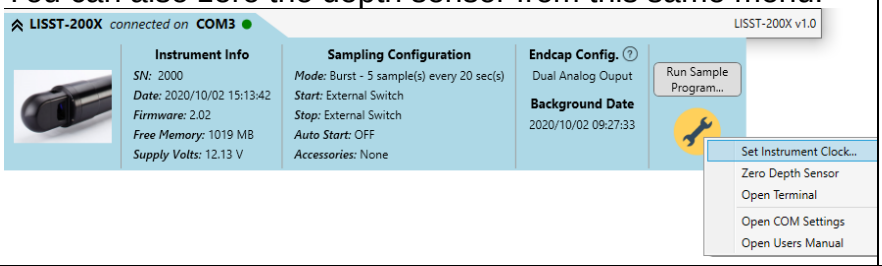
STEP	ACTION	RESULT
1	• Connect the instrument to the computer and establish communication in the LISST-200X program (page 28)	Software open, communicating with LISST-200X.
2	• Clean instrument and install Clean Water Background Test chamber. • Fill with clean filtered water and make sure no bubbles are 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. • Press the *Collect New Background* button. 20 samples will be collected, and their average displayed to the screen.	Background collected and displayed on the screen

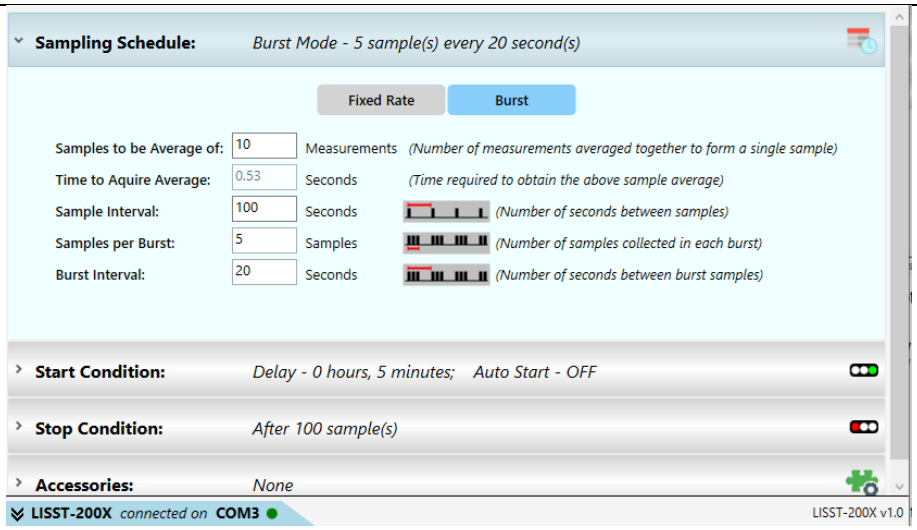
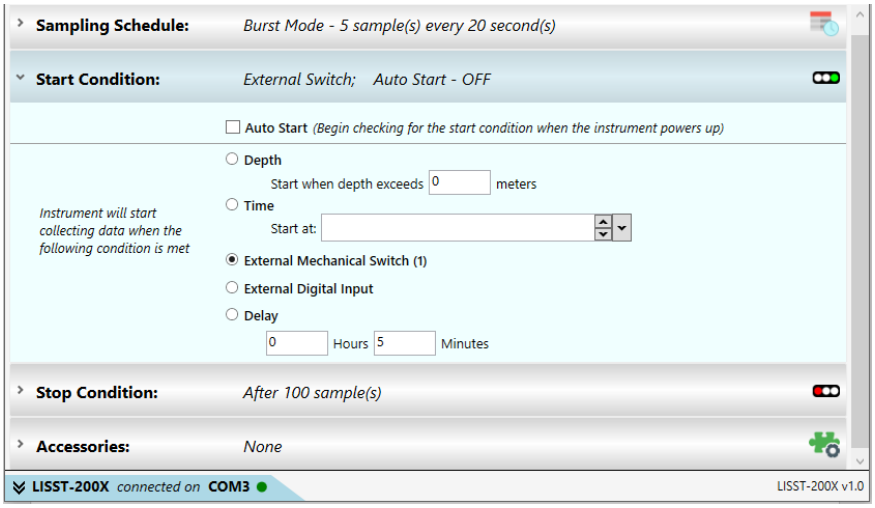
		
	• The graph shows the value of the 36 light scattering detectors. The red line is the factory values, the blue line the current background saved on the instrument. A newly collected background will be displayed as a solid black line. If the background is close to factory levels the message displayed 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.	

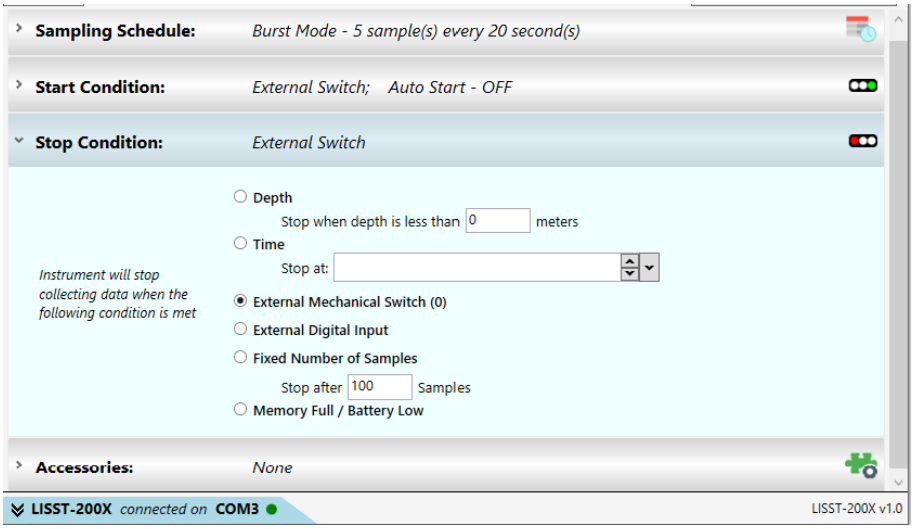
	• When you have an acceptable background press the Save button to store the background on the instrument. You also have the option to save the background to a file on your computer. After the background is saved, select the 'Save as .BGT File' button. The LISST-200X handles the background files differently 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.

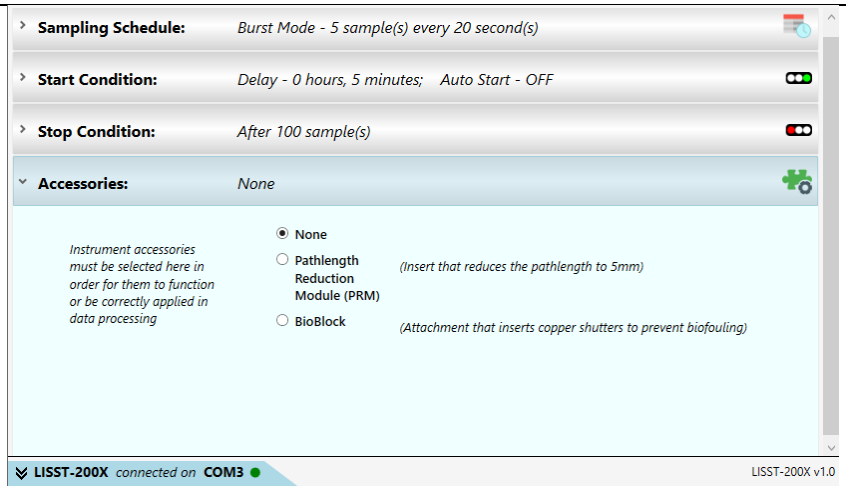
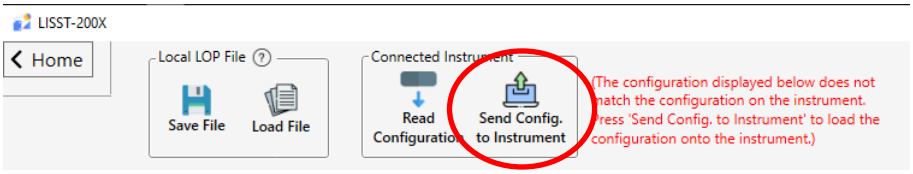
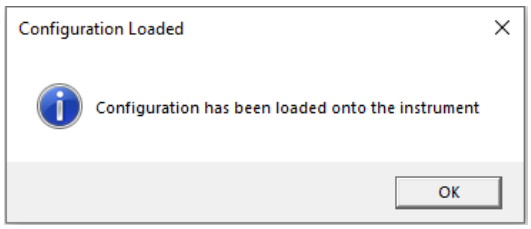
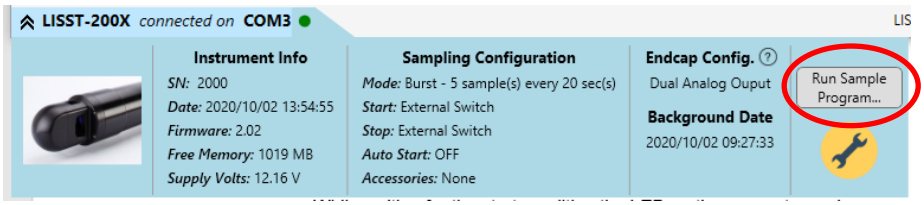
4. Configuring Data Collection

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 (page 28).	Software open, communicating with LISST-200X.
2	• Open the Sampling Programs window by choosing *Instrument Configuration* from the home page. • Certain instruments can compute the PSD onboard in real time. If your instrument has this feature, an additional configuration 'Data Output' will appear on this page. (See Autonomous Real-time Data Processing on page 53 for more information).  • 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 applying power. • NOTE: With either AutoStart or GO, logging is always subject to the start condition set above.	
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.	

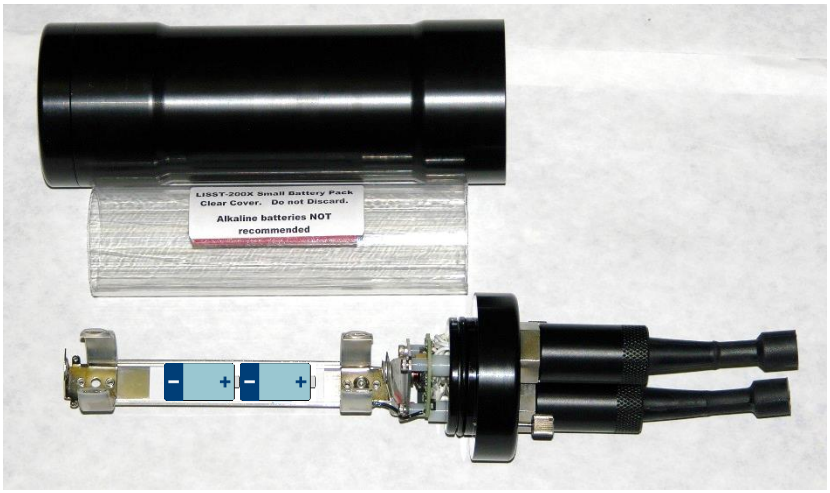
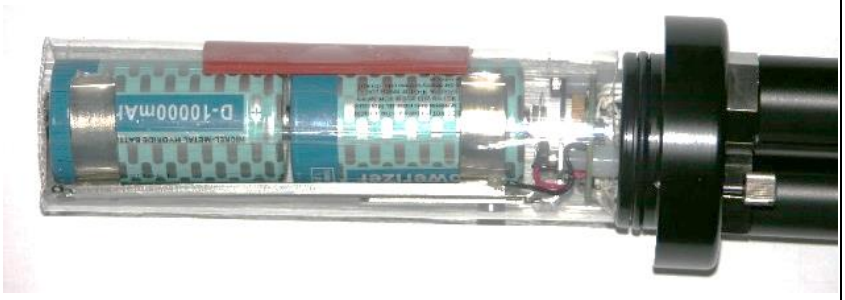
	• 	
7	After configuring the instrument settings, they must be uploaded onto the instrument. A message will be displayed on the top of the screen when you have unsaved changes to the instrument configuration  Click on the 'Upload to Instrument' button to load the configuration onto the LISST-200X. A confirmation message will be displayed when the upload is finished. 	Upload Configuration
8	• The instrument is now configured for deployment, **however, the sampling program is not yet running**.  • You MUST run the sampling program in order to collect data. But even when running, the sampling program will wait for the programmed start condition before collecting data. See Start and Stop Conditions on page 58, and the steps above, for details about start conditions. • When the sampling program is running, you will receive a confirmation message that the program has started, and the	Run Sampling Program

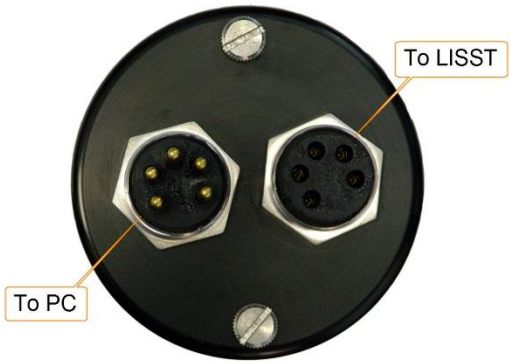
	instrument will become disconnected from the computer. At this point the instrument is ready to be deployed. • The green LED on the connector endcap will indicate the instrument status: - If waiting for the start condition, every few seconds it will blink twice quickly. - If logging, it will light while collecting each sample.	

5. Using the Small External Battery Housing

The LISST-200X comes with a Small External Battery Housing 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. **NOTE: the Small Battery Housing cannot be used to power the LISST-HAB or LISST-Black (see page 96) or BioBlock (page 99).**

STEP	ACTION	RESULT
1	• The LISST-200X Small External Battery Housing uses two rechargeable NiMH D-cell batteries. Four of the 1.5V 10000mAh batteries and a charger are included with the housing. The batteries are not installed when the instrument a new instrument is shipped. It is recommend that the batteries be removed from the housing when not in use. Leaving the batteries in the housing will cause the batteries to discharge and could cause damage to the cells.	Batteries fully charged.
	• Fully charge the batteries using the provided charger. Fully discharged batteries will take about 8 hours to charge.	
	 NiMH battery charger	
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.	Battery open and ready for batteries

	• Slide the endcap with battery holder attached out of the main housing. 	
3	• Slide the clear cover off of the battery holder and install the two D cell batteries. • Install with the positive “button” end toward the end cap of the housing.  • 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.

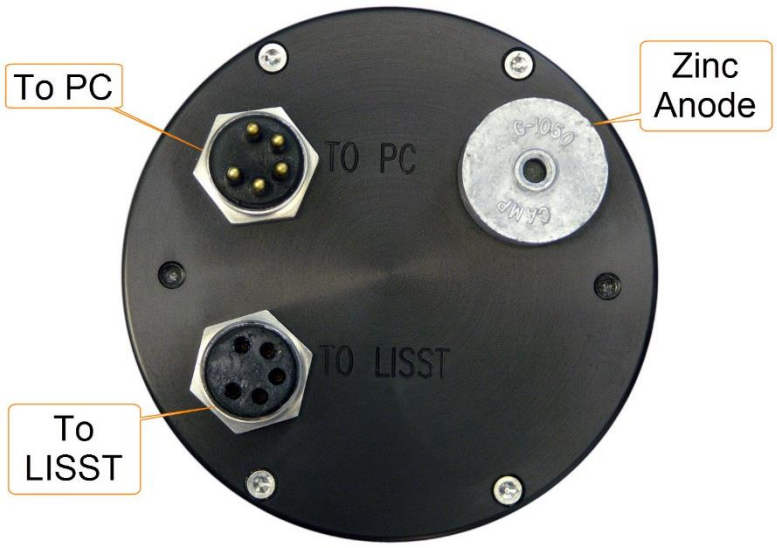
5	• The battery housing can be connected to the LISST-200X using the provided 5-pin Male to 5-pin Female cable. • Connect the Male end of the cable to the Female Bulkhead connector on the housing.  • Connect the other end of the cable to the 5-pin Male bulkhead on the LISST-200X. • Power is now going to the LISST-200X. If AutoStart is enabled the instrument may be active and waiting 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 Housing. Communications will pass through the housing to the LISST-200X. • The battery and communications cables are shown below. 	

6. Using the Large External Battery Housing

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

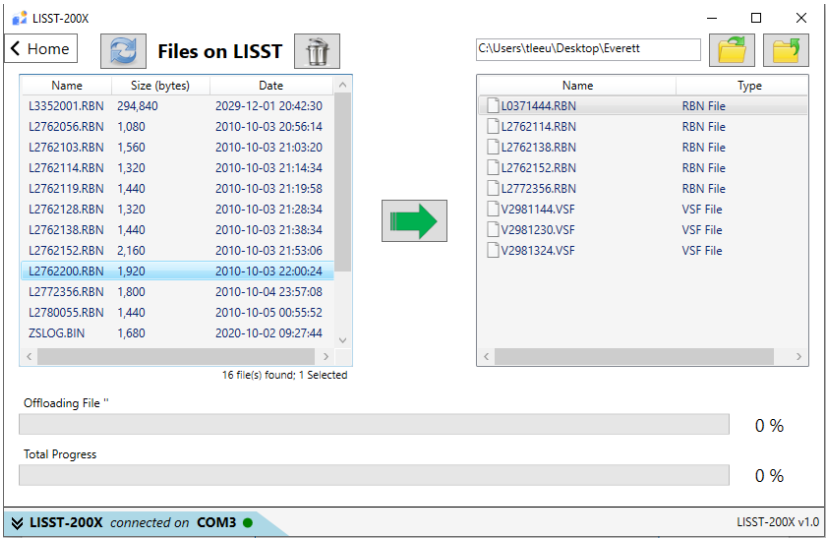
STEP	ACTION	RESULT
1	• The LISST-200X Large External Battery is shipped with 16 Alkaline D batteries pre-installed and is ready for use. The following steps describe how to open the battery and replace the batteries. Skip to Step X to connect the battery to the LISST-200X. • The new alkaline batteries 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 housing 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.	Endcap removed and batteries replaced.

	 • 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 orientation of the batteries for each stack.	
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 housing 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 Battery Housing. The connector will be labeled with “TO LISST”.	Instrument is powered and ready to collect data

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

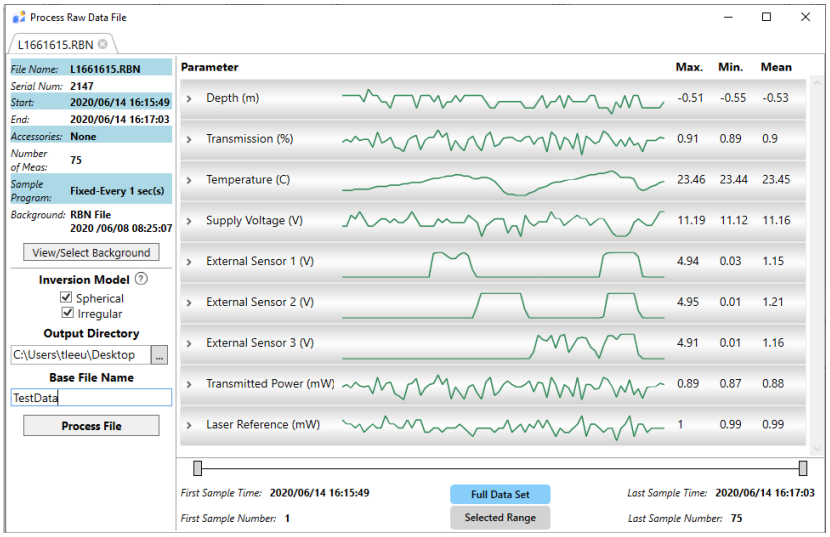
7. Offloading and Deleting Data Files from Internal Memory

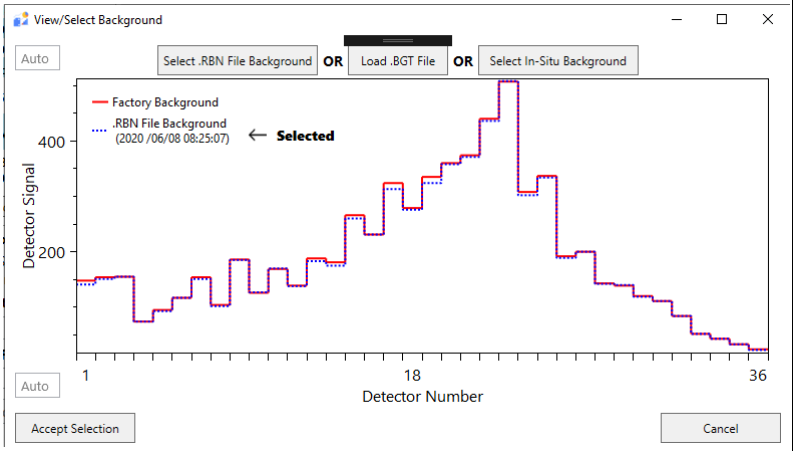
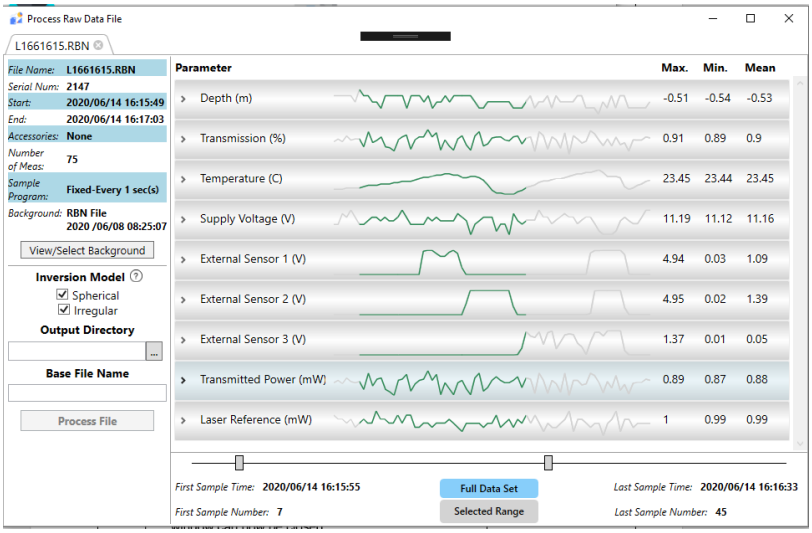
Data collected using the LISST-200X is stored on the internal data logger. This section describes how to offload and delete files from the internal data logger.

STEP	ACTION	RESULT
1	• Connect the instrument to the computer and establish communication in the LISST-200X program (page 28).	Software open, 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

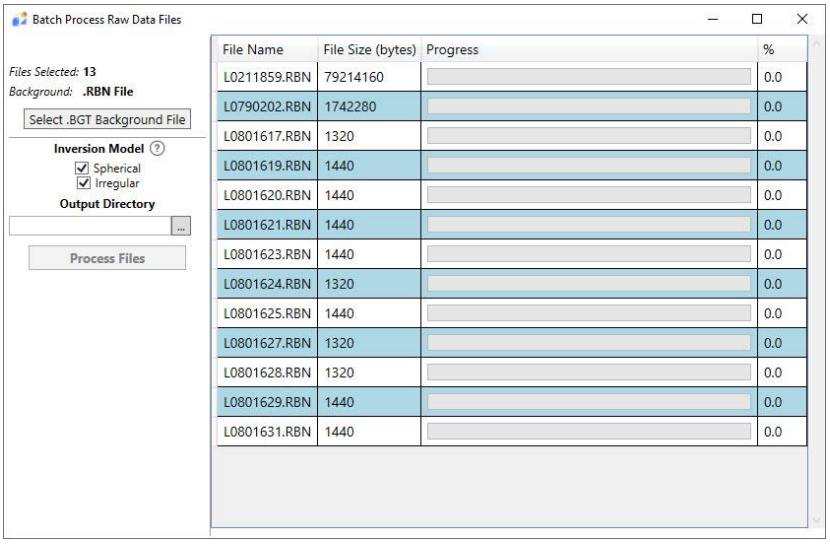
Data that has been downloaded from the datalogger is in a raw binary file (.RBN extension). It must be processed into particle size by the LISST-200X program.

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 particle models, see Appendix G: Particle Shape Models on page 91. • 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

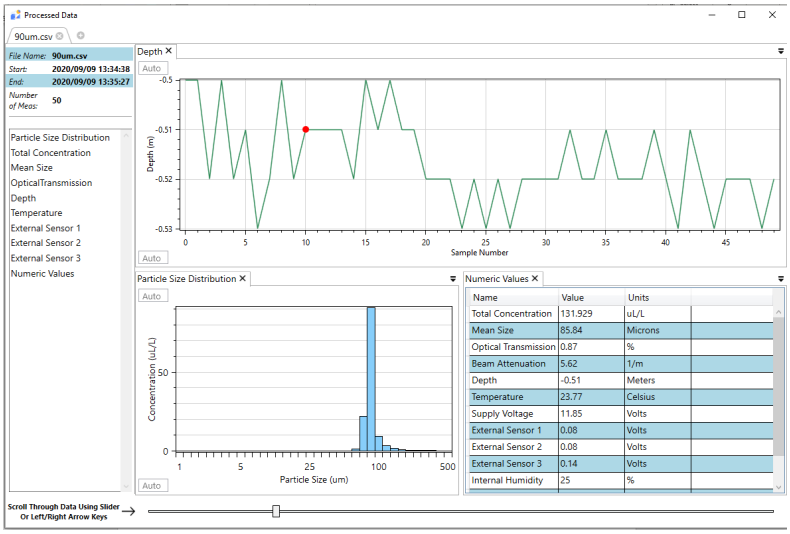
Data that has been downloaded from the datalogger is in a raw binary file (.RBN extension). It must be processed into particle size by the LISST-200X program. If you have multiple raw data files to process (e.g. from a series of profiling deployments), follow these processing steps that allows you to 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 real-time processing: spherical, randomly shaped, or both. For more about inversion models, see page 95. • 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.	Select Output Directory

	• The RTX file is a space delimited ASCII file containing the raw data from the LISST-200X data logger.	
	• 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

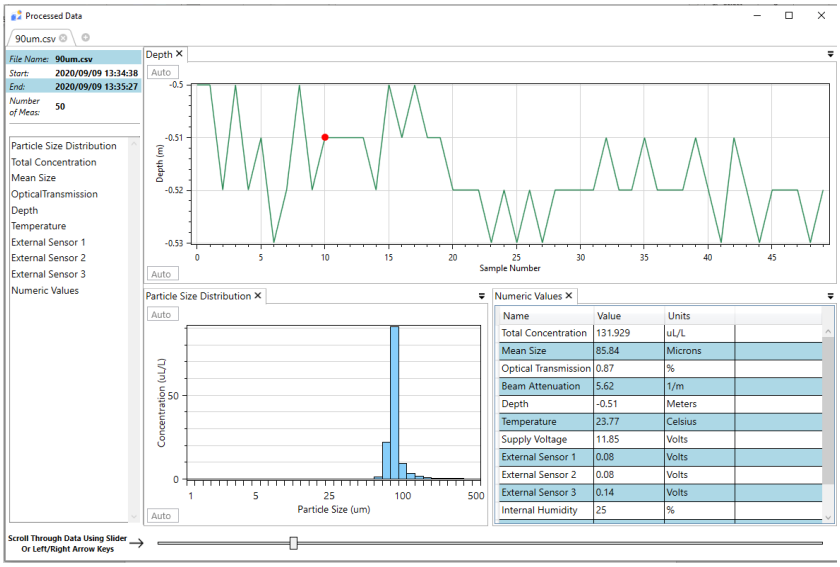
10. View Processed Data File

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

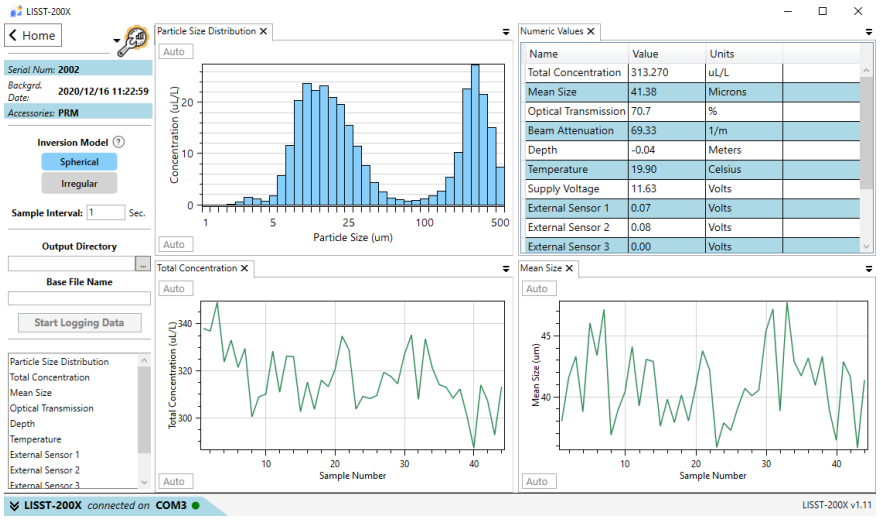
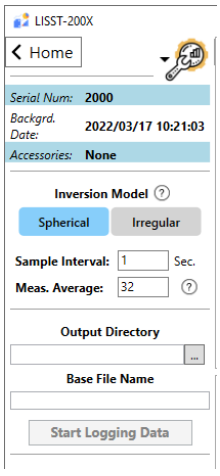
Making sure your data make sense.

STEP	ACTION	RESULT
1	• Follow steps 1-5 in the previous section: View Processed Data File	Data file loaded
2		
3	• The first value to inspect is the Optical Transmission. By definition, transmission must be a number between 0 and 1 (except that electronic noise may cause it to be slightly higher than 1 in particle-free water) • Tip: The transmission value is in column 60 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 background measurement obtained with dirty water and/or dirty windows. • If your background measurement was obtained using dirty water, it may be possible to redo the background using clean water and re-process the data, then check to see if the transmission values drop below 1 (one).	Transmission values much greater than 1 or less than 0 indicate bad data.
4	• If your transmission values generally are in the 0.98-1.0 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 yield 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%).	

12. Real-Time Data Processing with LISST-200X Software

This procedure covers the acquisition, display and storage of processed data in real time, using the LISST-200X software. For on-board processing by the LISST-200X firmware, see Autonomous Real-time Data Processing on page 53.

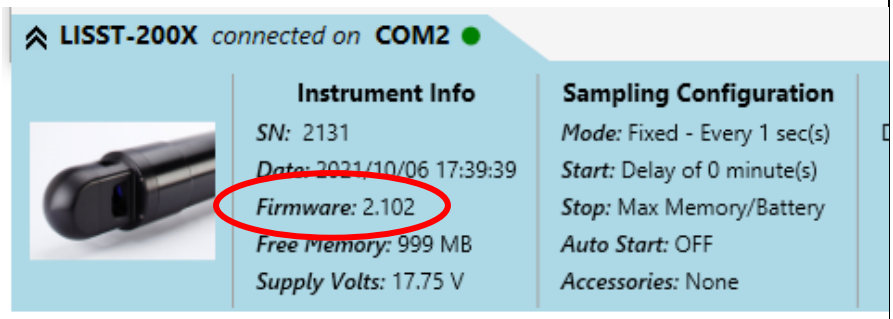
STEP	ACTION	RESULT
1	• Connect the instrument to the computer and establish communication in the LISST-200X program (page 28).	Communication established.
2	• The background currently stored onboard the instrument will be used to process the data as it is collected in real time. • Be sure to collect a 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. • Instruments with newer firmware will also allow you to specify the measurement average on this page. Which is the number of measurements averaged together to form a single sample.	

	• 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

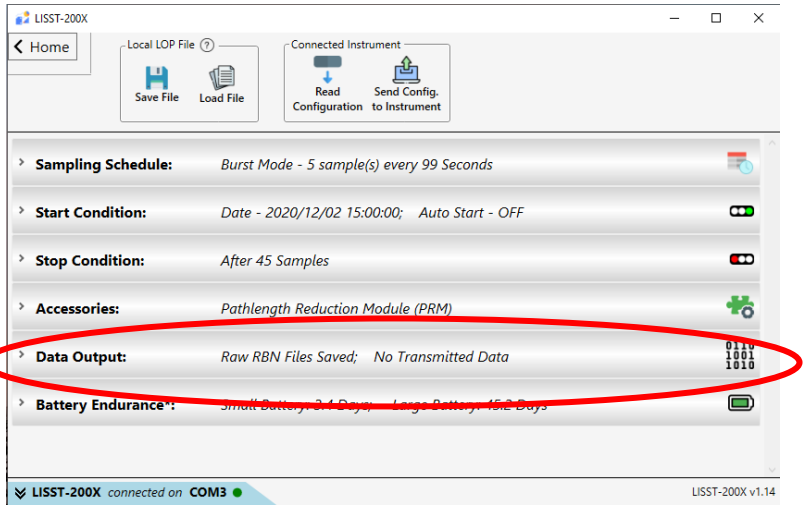
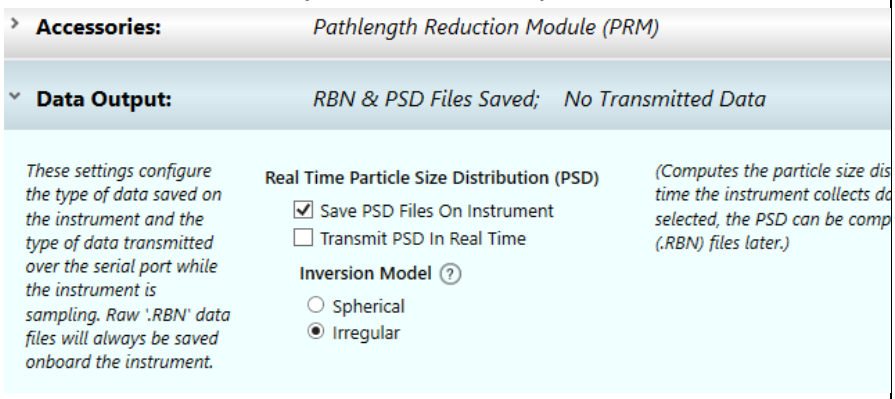
13. Autonomous Real-time Data Processing

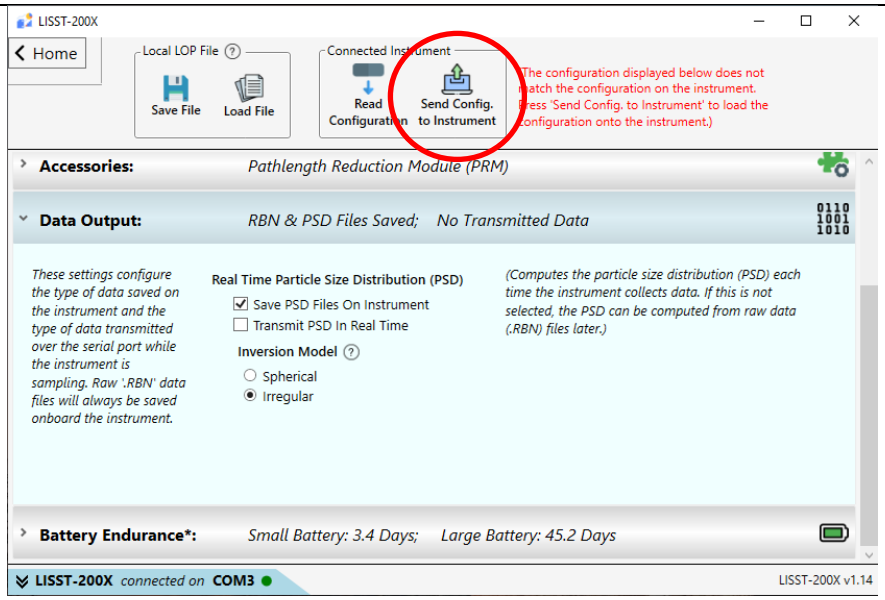
Newer LISST-200X's (starting with serial number 2131), or older units with upgraded electronics, have enough computational power to do PSD processing autonomously, without requiring a connection to a Windows computer.

You may choose to save the processed data files (.CSV) in the LISST-200X memory, or transmit them in real time through the serial port, or both. Note that processing slows the maximum sampling rate. Without it, the LISST-200X can sample continuously once per second. Depending on the settings you select, the time per sample may be up to 2 seconds.

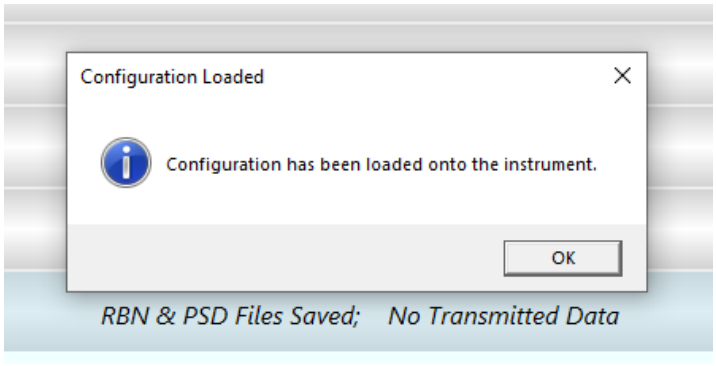
To determine whether your LISST-200X supports real-time processing		
STEP	ACTION	RESULT
1	• Connect the instrument to the computer and establish communication in the LISST-200X program (page 28).	Communication established.
2	• Open the information panel at the bottom of the window, and check the firmware version:  • **If the firmware is 2.1 or greater**, your instrument supports autonomous processing. • **If the firmware is less than 2.1 but at least 2**, a user-installable firmware upgrade can enable autonomous processing. Contact Sequoia Scientific support for instructions. • **If the firmware version is less than 2**, your instrument's hardware does not support autonomous processing. Contact Sequoia Scientific sales regarding upgrade options.	If your instrument supports real-time processing, proceed.

To use real-time processing		
STEP	ACTION	RESULT
1	• Connect the instrument to the computer and establish communication in the LISST-200X program. (see Establishing Communication with the LISST-200X on page 28).	Communication established.

2	• Navigate to the Configure Instrument page. If your instrument's hardware and firmware support it (see above), you will see a Data Output category. 	Configure Instrument page open.
3	• Click on Data Output to make its options visible.  • 'Save PSD Files On Instrument' – if checked: ▪ PSD is computed onboard in real time ▪ PSD is saved in a file onboard the instrument, in .CSV format (see Appendix C: Data File Formats on page 81) • 'Transmit PSD In Real Time' – if checked: ▪ PSD is computed onboard in real time ▪ A PSD data record is transmitted over the serial port immediately after each measurement is collected • 'Inversion Model' ▪ Select the inversion model that will be used for onboard PSD processing (see Appendix G: Particle Shape Models on 95)	Instrument configuration selected
4	• **IMPORTANT**: after you have selected the desired configuration, press the 'Send Config. To Instrument' button to load the configuration onto the instrument.	Configuration uploaded to instrument.



- A message box will confirm the upload has been completed.



Configuration complete.

14. Collecting Data from an External Analog Sensor

The LISST-200X can supply regulated 12V power to an external sensor, and measure one to three 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).

Remember that power consumed by an external sensor will reduce battery endurance, in a battery-powered deployment. It might also exceed the capacity of the USB-powered data cable. If so, you can augment the USB cable's power by connecting the large battery housing.

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, it must be changed; see Appendix F: Auxiliary Input/Output on page 91.	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 62). Or see Appendix E: Connectors on page 86.	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 housing 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 32)	Ready to collect data

15. 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, it must be changed; see Appendix F: Auxiliary Input/Output on page 91.	Auxiliary Connector configuration determined
2	• Make the appropriate connections between the 6-pin auxiliary connector of the LISST-200X and your CTD. To see the pin assignments, type the CONFIG command in the LISST-200X terminal window (see Direct Command Details on page 62), 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 32): ○ Operating mode: Fixed sample rate ○ Sample to be average of 32 measurements ○ Sample interval: 1 second ○ Automatically start sampling program upon power up Start condition: delay 0 minutes ○ Stop condition: memory full	200X will collect data at 1 Hz whenever the CTD supplies power to it
4	• See Appendix K: Analog Outputs on page 109	

B. Start and Stop Conditions

Overview

The LISST-200X can be set up to start and stop data collection according to various conditions. The most obvious is the white switch lever on the connector end cap. However, the switch is only one of several options. The start condition and stop condition can be different from each other. Also see Configuring Data Collection on page 32.

Start Conditions

The five possible start conditions are:

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

The details of each are described below. Note that regardless of which start condition is selected, the LISST-200X will not start checking for the start condition until the sample program is run from the Windows software (see page 32), by the GO command (see Acquisition/Action commands on page 71), or by automatic start after power-up.

Depth Start

The LISST-200X checks its depth every 3 seconds. Each time it checks, the green LED on the end cap will double-flash. If the depth exceeds the threshold, the program will start data collection. When setting the threshold, remember that atmospheric pressure, temperature, and even the orientation of the LISST-200X can affect the offset of the pressure sensor. Therefore, it is best to zero the sensor (see page 32) immediately before starting, and to set the threshold to at least 1 meter, to avoid incorrect triggering.

Time Start

The LISST-200X will go into lower-power sleep until the programmed time. (If the programmed time has already passed, it will start immediately.) While waiting, it will quickly flash the LED once every 30 seconds.

External Mechanical Switch Start

The LISST-200X will wait until the white plastic lever on its endcap is moved to the “1” position. (If it is already in that position, it will start immediately.) While waiting, it will quickly flash the LED twice every few seconds.

External Digital Input Start

If the auxiliary connector is configured for analog and digital inputs (see Appendix F: Auxiliary Input/Output on page 91), 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), data collection will start. While waiting, the LED will quickly flash twice every few seconds.

Time Delay Start

The time delay start condition will cause the program to wait the specified number of minutes. While waiting it will quickly flash the LED once every 30 seconds.

Stop Conditions

The possible stop conditions are:

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

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 (Real-Time Data Processing with LISST-200X Software on page 51). The details of each condition are described below.

Depth Stop

If the depth is less than the threshold, sampling will stop. If the Start Condition is Depth Start the program will return to checking for the start depth, and will start a new file each time the start threshold his crossed. 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.

If using depth for both start and stop conditions, consider whether the start and stop thresholds should be different, depending on your deployment scenario. For example, if the instrument might be suspended from a winch at a depth near the start and stop thresholds, there could be “false” starts and stops due to wave motion. This could be prevented by setting the start depth deeper than the stop depth.

Time Stop

After each sample or burst, if the given date and time have passed, the LISST-200X will stop and go into low-power sleep.

External Mechanical Switch Stop

After each sample or burst, if the switch lever is in the off or “0” position, sampling will stop. If the Start Condition is 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

When the number of samples to be saved has been reached the program will stop and go into deep sleep (regardless of start condition).

Memory Full or Voltage Low

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

NOTE: the memory capacity is large enough that it should never be necessary to fill it. We recommend deleting files from the LISST-200X as soon as they have been offloaded to a backed-up computer or other storage.

C. 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 (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 following sections for detailed descriptions of each command.

D. Direct Command Summary

Display Commands	
CONFIG	Display instrument hardware configuration information
DD, DIR	Display current disk directory
DEPTH	Display current depth
DS, DS 1	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	
AS x	Set autostart
DEFAULTS	Set most parameters to factory defaults
BI x	Set burst interval
MA x	Set samples per average equal to x
MODE, OM x	Set operating mode (burst or fixed-rate)
PD x, STOPDATA x	Set stop condition Data
PSDMODEL x	Set model used for PSD processing (if active)
SAVEPSD x	Set whether PSD data will be saved in on-board memory
SI x	Set sample interval
SP x, STOPCOND x	Set stop condition
ST x, STARTCOND x	Set start condition.
SB x	Set samples per burst
SC yyyy/mm/dd hh:mm:ss	Set clock with time and date
SENDDATA x	Control real-time transmission of data via RS232
SENSORPOWER x t	Set whether power output turns on during logging
SENSORWARM t	Set external sensor power warmup time
TD x, STARTDATA x	Set start condition data
ZD	Reset depth sensor offset
Acquisition/Action Commands	
DL filename	Delete file
GO	Start data collection using current parameters
GX	Grab sample and transmit it
ZS	Acquire 20 samples and evaluate them for quality.
ZZ	Go into deep sleep mode (minimum power consumption)

E. Direct Command Details

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

1. Display Commands

CONFIG	Display instrument hardware configuration
Syntax:	CONFIG
Description:	The current hardware configuration including Auxiliary I/O connector configuration
Example:	L200x:> CONFIG 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 File Directory
Syntax:	DD or DIR
Description:	Display current disk directory in DOS type format. Includes total bytes used and bytes available.
Example:	L200x:> DD . <DIR> 2099-03-14 03:35:48 .. <DIR> 2099-03-14 03:35:48 L2390658.RBN 1,612,440 2019-08-29 14:55:28 L2411501.RBN 3,253,800 2019-09-03 07:58:20 L2480807.RBN 736,800 2019-09-06 09:40:14 3 file(s) 7,608,360 bytes 2 dir(s) 1,016,381,440 bytes free

DEPTH	Display current depth
Syntax:	DEPTH
Description:	The current depth is displayed to the screen.
Example:	L200x:> depth 0.000 m (680 counts)

DS	Display current status information
Syntax:	DS
Description:	The instrument settings and status are displayed to the screen. The format may change with different firmware and hardware versions.
Example:	L200x:> DS LISST-200X Status and Settings Serial number: 2021 Endcap configuration: 2 (Dual analog out) Firmware Version: 1.470 Feb 8 2021 21:06:43 Current Date/Time: 2019/01/09 22:12:50 Current Day of the Year: 009 Supply voltage: 14.74 V Operating mode: Fixed rate mode AutoStart: OFF. Delay Start with 0 minute delay Stop on full memory or low battery Measurements per Average: 32 Ambient light subtraction: on. Sample Interval: 1 Path length: 25 mm Standard status messages will be sent during logging. Data will be saved in files of unlimited size. AUV mode: off Free memory: 1016 Mbytes

DS 1	Display current status information, compact form
Syntax:	DS 1
Description:	Instrument status displayed in simplified format for reading by software
Example:	L200x:> ds 1 LISST-200X Current Status and Settings SN = 0 OM = 0 ST = 5 TD = 0 SP = 6 PD = 0 MA = 32 SI = 1 BI = 1 SB = 1 AS = 0 BIOBLOCK = 0 STUBE = 0

	SENSORPOWER = 0 SENSORWARM = 0 Current Time = 1987/01/09 22:14:00 Battery= 1474 Switch= 0 Memory= 1016381440 Bytes Endcap= 2 PATHLENGTH = 25 Firmware = 1.470

DT	**Display current time and date**
Syntax:	DT
Description:	Displays current time and date to the screen.
Example:	L200x:> DT Date/time = 2021/01/01 18:16:06

HELP, ?	**Display general help messages and command list**
Syntax:	HELP or ?
Description:	Displays the list of command to the screen.
Example:	L200x:> HE LISST-200X Commands ---------- [list of commands]

SW	**Display current Mechanical Switch position**
Syntax:	SW
Description:	The current position of the Mechanical Switch is displayed to the screen.
Example:	L200x:> SW Switch: 0

TEMP	**Display current temperature**
Syntax:	TEMP
Description:	The current temperature is displayed to the screen.
Example:	L200x:> temp 25.09 C (26629 counts)

VIN	**Display Battery Voltage**
Syntax:	VIN
Description:	The current supply voltage is displayed to the screen.
Example:	L200x:> vin 14.74 V (2058 counts)

2. Setup Commands

AS	Enable Autostart
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:	`L200x:> AS 1` `Autostart upon power-up is on`
Cautions:	If Autostart is enabled, the user cannot communicate with 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, either from the LISST-200X software's graphical interface, or by pressing CTRL-C in the terminal window.

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 the beginnings of consecutive bursts, each burst composed of a number of samples per burst (specified by the SB command).
Example:	`L200x:> BI 900` `New Seconds between Bursts: 900`

DEFAULTS	Set parameters to defaults
Syntax:	DEFAULTS
Description:	Sets most user-controlled parameters to their factory defaults, as follows: Operating mode: Fixed rate mode AutoStart: OFF Delay Start with 0 minute delay Stop on full memory or low battery Measurements per Average: 32 Ambient light subtraction: ON Sample Interval: 1 second Path length: 25 mm (no PRM installed) External sensor power during logging: OFF External sensor warmup time: 1 seconds Standard status messages will be sent during logging. Raw data will be saved in files of unlimited size. AUV mode: OFF Autonomous PSD processing (see page 53): OFF

Example:	`L200x:> DEFAULTS`
	`WARNING: This will set most operating parameters to their default values, replacing your settings.`
	`Is this what you want (Y/[N]) [N] ? y`
	`Resetting to defaults...`
	`[followed by list of settings]`

IOCONFIG	View or Set Configuration of the Auxiliary Input/Output Connector
Syntax:	IOCONFIG x, where x is a digit indicating the configuration selection.
Description:	Available only in firmware 2.2 or later, this command returns a number indicating the configuration of the 6-pin connector used for interfacing with external devices. In older instruments, this command is only informational, and may return the values 0, 1, 2 or 4. In instruments with newer electronics, it will return 5, 6, or 9, and will accept one of those values to set the configuration. For full details, see Appendix F: Auxiliary Input/Output on page 91.
Example:	`L200x:> IOCONFIG` `6`

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:	`L200x:> ma 32` `Measurements per average: 32 (3 ambient subtractions)`

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:	`L200x:> OM 1` `Operating mode: Burst mode (1)`

PD, STOPDATA	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:	If Stop Condition =1 (Depth Stop):
	`L200x:> PD 3`
	`Depth stop at 3 meters`
	
	If Stop Condition = 2 (Time/Date Stop):
	`L200x:> PD 2016/12/31 23:59:59`
	`Time stop at 2016/12/31 23:59:59`
	
	If Stop Condition = 5 (Fixed Number of Samples):
	`L200x:> PD 100`
	`Stop after 100 samples.`

PSDMODEL	**Set particle model used for on-board size distribution calculations (firmware 2.1 or higher)**
Syntax:	PSDMODEL x
Description:	If x = 0, PSD processing with use the spherical particle model. If x = 1, the irregular (also called “random”) particle model will apply. This setting applies only when real-time PSD processing is active. It is available only in firmware 2.1 and higher. Also see SAVEPSD, SENDDATA, and Autonomous Real-time Data Processing on page 53.
Example:	`L200x:> PSDMODEL 1` `Optical Model: 1 (irregular)`

SAVEDATA	**Save Data Setting—USE WITH CAUTION**
Syntax:	SAVEDATA x, where x is 1 or 0
Description:	SAVEDATA 0 turns off storing of raw data in the instrument’s memory. This is only for unusual circumstances.

Example:	`L200x:> SAVEDATA 1`
	`1: Raw data will be saved during logging.`
	`L200x:> SAVEDATA 0`
	`WARNING: Data will NOT be saved during logging!`
	`Is this really what you want [N] ? n`

Cautions:	**Be very careful with this setting!** 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:

SAVEPSD	**Control saving of processed PSD files (firmware 2.1 or higher)**
Syntax:	SAVEPSD x
Description:	If x = 1, during sampling the instrument will generate a .CSV file containing processed particle size distributions, in addition to the normal raw .RBN file. If x = 0, only the normal .RBN files will be saved.

	For more details, see Autonomous Real-time Data Processing on page 53. This command requires firmware version 2.1 or higher.
Example:	`L200x:> SAVEPSD` `PSD data will be saved during logging.`

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:	`L200x:> SB 10` `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:	`L200x:> SC 2020/12/20 13:20:18` `Time set to 2020/12/20 13:20:18`

SENDDATA	**Transmit data during sampling (firmware 2.1 or higher)**
Syntax:	SENDDATA x
Description:	The value of x sets whether data will be transmitted from the instrument's RS232 interface during sampling. **Only options 0 and 4 are suitable for normal operation.** 0 = Do not send data (default) 1 = Multi-line troubleshooting data 2 = NMEA-format brief data (for glider applications) 3 = Single-line raw (CANNOT be processed by LISST-200X software) 4 = Processed PSD data; activates real-time processing and sends processed data after each sample. For details, see Autonomous Real-time Data Processing on page 53. This option requires firmware version 2.1 or higher.
Example:	`L200x:> SENDDATA 0` `Setting: 0 (no data)`

SENSORPOWER	**Control 12V power to auxiliary connector during logging**
Syntax:	SENSORPOWER x, where x is 1 or 0
Description:	If x = 1, the 12V power output on the auxiliary connector (if it is suitably configured) will turn on during data collection with the GO command. If running in burst mode, the power will turn off between bursts. Logging will also incorporate a warmup time, set with the SENSORWARM command. If SENSORPOWER is entered without an x argument, it will prompt for a value and for a sensor warmup time.
Example:	`L200x:> SENSORPOWER 1`

	Power output will turn on during logging, with 5 second warmup

SENSORWARM	Warmup time when powering external sensors
Syntax:	SENSORWARM x, where x is in seconds
Description:	If SENSORPOWER is on, SENSORWARM sets the number of seconds the LISST-200X will wait for external sensors to warm up before it proceeds with sampling.
Example:	L200x:> SENSORWARM 10 Power output, when used, will turn on with 10 second warmup. Power output during logging is on.

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:	L200x:> SI 5 Seconds between samples: 5

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:	L200x:> SP 5 Stop condition: 5

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:	`L200x:> ST 5` `Start condition: 5`

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:	If Start Condition = 1 (Depth Start)
	`L200x:> STARTDATA 3`
	`Start condition: Depth Start at 3 meters`
	
	If Start Condition = 2 (Time/Date Start)
	`L200x:> STARTDATA 2020/12/31 23:59:59`
	`Start condition: Time Start at 2020/12/31 23:59:59`
	
	If Start Condition = 5 (Delay Start)
	`L200x:> STARTDATA 2`
	`Start condition: Delay Start with 2 minute delay`

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:	`L200x:> ZD`
	
	`Depth sensor offset adjust.`
	
	`Instrument must be at zero depth and similar temperature to field conditions.`
	`Reset depth sensor offset? (1=yes,0=no): [0] ? 1`
	`Previous offset was -140.65. New offset is -4.37.`
	`Previous depth was -136.28 meters.`
	`New depth using corrected offset is 0.00 meters.`

3. Acquisition/Action commands

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 memory.
Example:	L200x:> DL L3231513.RBN Delete the file 'L3231513.RBN'? Y for Yes or N for No: [N] ? Y Deleting L3231513.RBN Deleted.
Cautions:	WARNING: Make sure the file being deleted has already been offloaded. Once the file is deleted it cannot be recovered.

GO	Start Data Collection using current Settings
Syntax:	GO
Description:	Starts Fixed Rate or Burst Mode Data collection using current settings.
Example:	L200x:> GO Starting sampling. Start condition: Delay Start with 2 minute delay Stop condition: Stop after 100 samples Low-power sleep until 2021/12/10 17:39:56 zzz...Waiting until 2021/12/10 17:39:56
Cautions:	To stop data acquisition before it is complete, send 2 Ctrl-C characters.

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.

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:	L200x:> ZZ Low-power sleep. zzz...Press Stop or <Ctrl>C to wake up. zzz...Press Stop or <Ctrl>C to wake up.

F. Performance Optimization

Background Measurement and its Importance

As discussed in earlier sections, the LISST-200X measures light scattered at small angles, to characterize particles in water. However, a certain amount of scattering is also generated by pure water, and by the LISST-200X's own optics and windows. We call this the background scattering. In order to determine the scattering contributed by particles, the background scattering must be accurately measured and subtracted from the total scattering measured. The measurement of background scattering is sometimes called a "zscat", meaning the signal measured in water with zero "scatterers" or particles.

The minimum concentration of particles measurable by the LISST-200X is very sensitive to the quality of the background scatter file. The lower the concentration in the water being measured, the more important the quality of water and the care used when measuring the background. When measuring in water with high particle concentrations, the relative signal-to-background noise ratio increases, and final results will be less sensitive to flaws the background. However, a background should always be collected before an experiment.

Techniques for measuring background

It is essential to use clean, bubble-free water for the background measurement. The water can be fresh or salt water. For most applications, steam-distilled water works well. 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 hold water for a background measurement. 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.

Cleanliness

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, which will scratch the windows and degrade instrument performance.

Watch for Outgassing and Bubbles

Water may contain dissolved air that develops into bubbles as the water warms. Bubbles, especially if they cling to the windows of the LISST-200X, 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.

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.

Optical Alignment

The background measurement (described step-by-step on page 29) 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 LISST-200X software automatically detects and warns of serious misalignment, during the background measurement process.

The first indicator of an alignment problem is a severe drop in the 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.

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. If 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 cause the transmitted laser power to decrease.

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.

If necessary, the LISST-200X can be aligned by Sequoia Scientific or an authorized service representative.

G. Instrument Mounting, Deployment Orientation, Storage and Maintenance

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.

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.

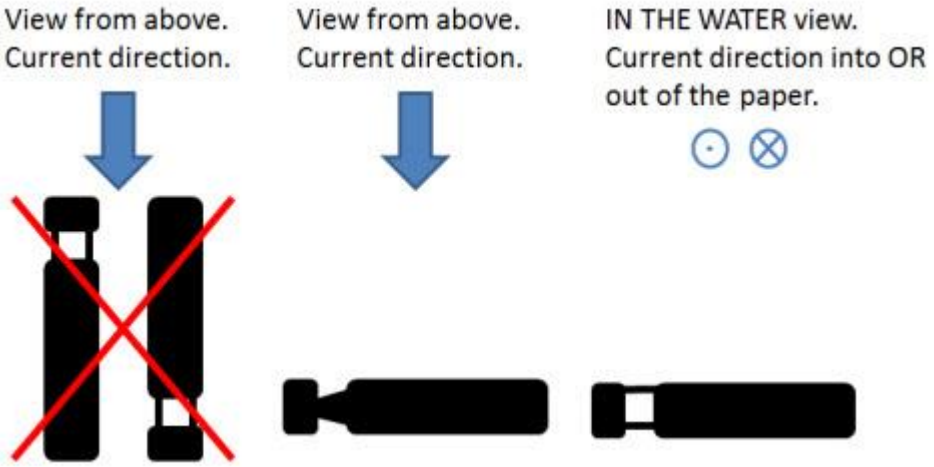
Cleaning the Optical Windows

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.

Orientation Relative to Current Flow

In situations with significant current flow, it is best to orient the instrument perpendicular to the current, so 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



Storage

For full protection, always store the LISST-200X in its foam-lined shipping case.

Calibrations and Adjustments

The LISST-200X should not require any adjustment or calibrations. The pressure sensors can be re-calibrated by Sequoia, 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/).

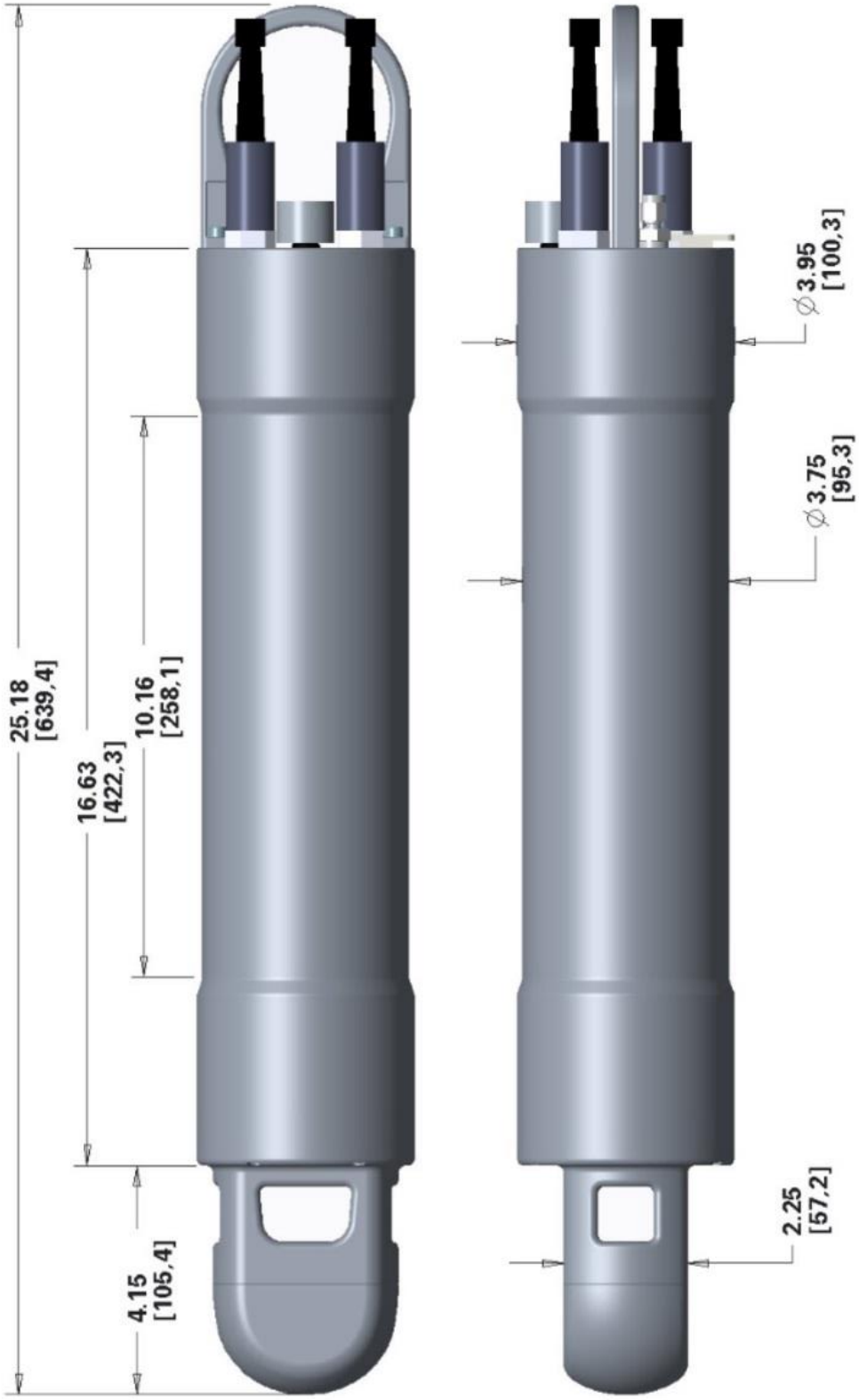
Comparison of the LISST-200X's performance with that of other particle-size measuring devices that are not based on laser diffraction may result in inconsistencies because the instruments may measure different properties of the particles to interpret particle size.

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; threshold 2V
- 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:

Model	Serial number < 2131	Serial 2130+ (or upgraded)
LISST-200X	100 mA	75 mA
LISST-Black	230 mA	205 mA
LISST-HAB	185 mA	160 mA

  - Current while waiting for user command: < 50 mA @ 12V
  - Current during deep 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 (200 m operating max. for BioBlock—see page 99)


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.

Extension	Description	Format	Comments
.RBN	Raw Data	Binary	Raw data file produced by the LISST-200X. In addition to raw scattering data, RBN files contain a complete description of the instrument configuration, its most recent background scattering, and the factory background.
.CSV	Processed Data	ASCII	Comma-delimited file containing size distributions and meta data. Details on page 82. For information about generating these files in the LISST-200X, see Autonomous Real-time Data Processing on page 53.

Secondary files not used for standard processing			
.BGT	Background File	ASCII	Comma-delimited file containing the raw ring values from a single background measurement (1 column, 59 rows)
.RTX	Raw Data	ASCII	Comma delimited ASCII representation of raw data (59 columns, 1 measurement per row). NOTE: Sequoia software does not process RTX files. They are only for troubleshooting or special applications.

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.

RTX files are only useful for troubleshooting or special applications. **Sequoia does not supply software for processing them**.

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: MATLAB Data Processing

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 = L200X_LoadRBN(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 = L200X_LoadRBN(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 (µm)
estTotalConc	Estimated total concentration (µL/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] = LISST_ComputePSD(Cscat,Random,Sharpen,ShowProgressBar)
```

The first argument is the corrected scattering (**cscat**) from the structure returned from 'L200X_LoadRBN.' 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: Particle Shape Models on page 95 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 µL/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.

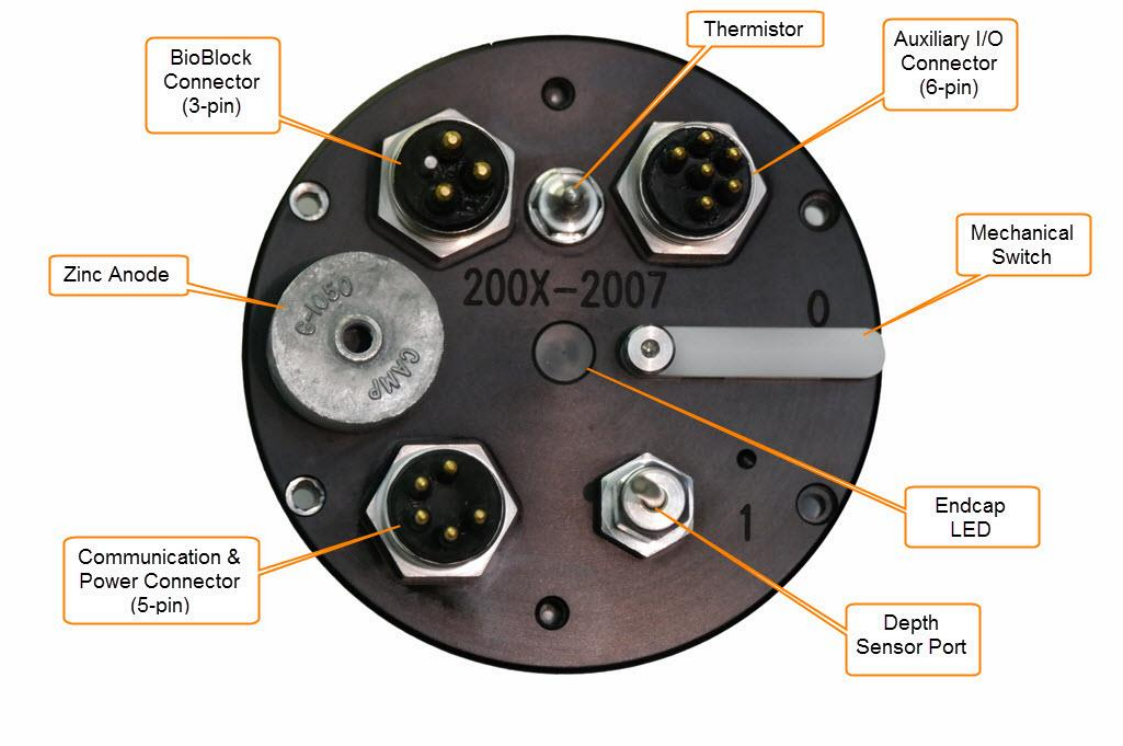
To Identify the connector type, note:

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

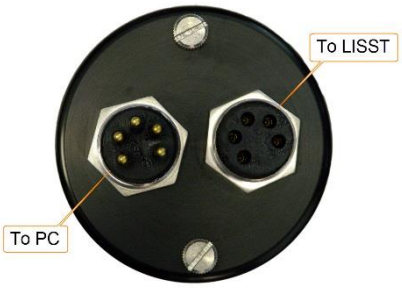
SubConn
(as of September 2019)

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 Housing

Large External Battery Housing

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 (+9 to 24 V)
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) (see page 99 for BioBlock details)

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

Bulkhead Endview

Cable Endview

Connector Pin #	Use
1	Ground
2	Signal Out
3	+6V Power Out

Auxiliary I/O Connector (6 pin connector)

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

Bulkhead Endview

Cable Endview

The 6-pin Auxiliary I/O Connector can have several different configurations. See Appendix F: Auxiliary Input/Output on page 91.

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

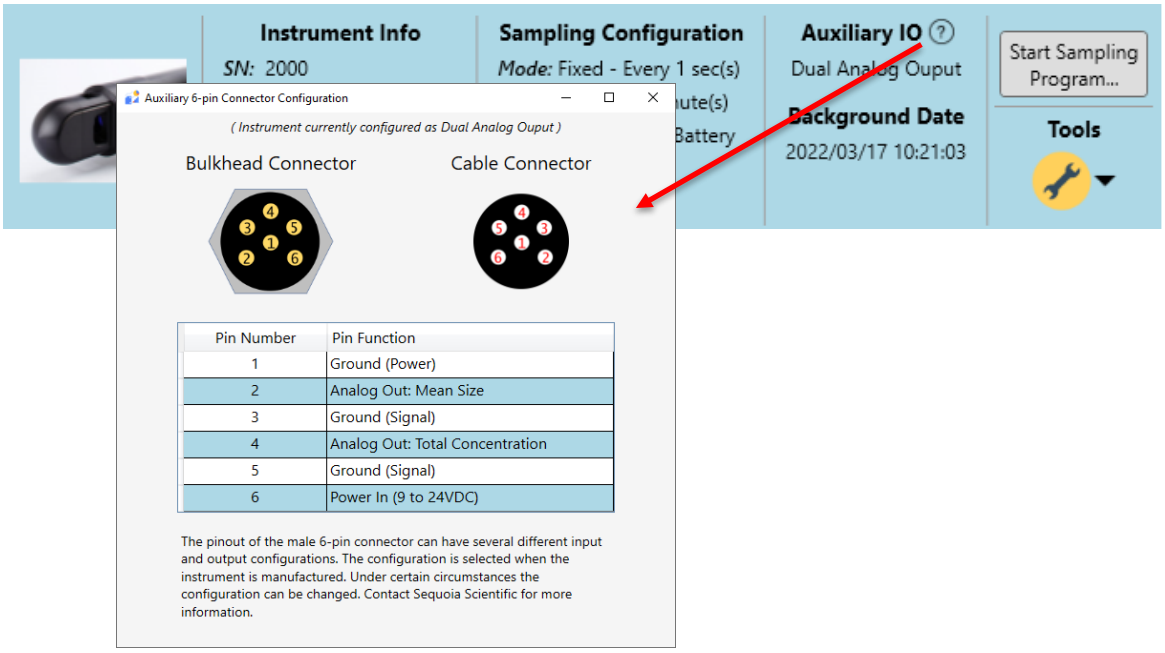
Cable Endview

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)

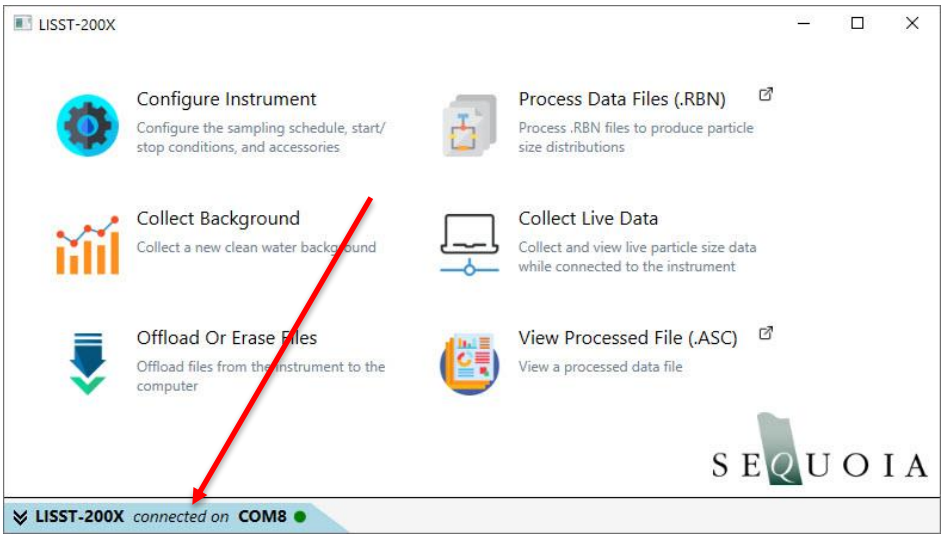
Appendix F: Auxiliary Input/Output

The Auxiliary I/O connector (6-pin) has multiple possible configurations, and the available options depend on the version of electronics in the specific LISST-200X. The current pinout of the aux I/O connector on your instrument can be viewed in the LISST-200X software. In the instrument status bar, press the '?' icon next to 'Auxiliary IO'.



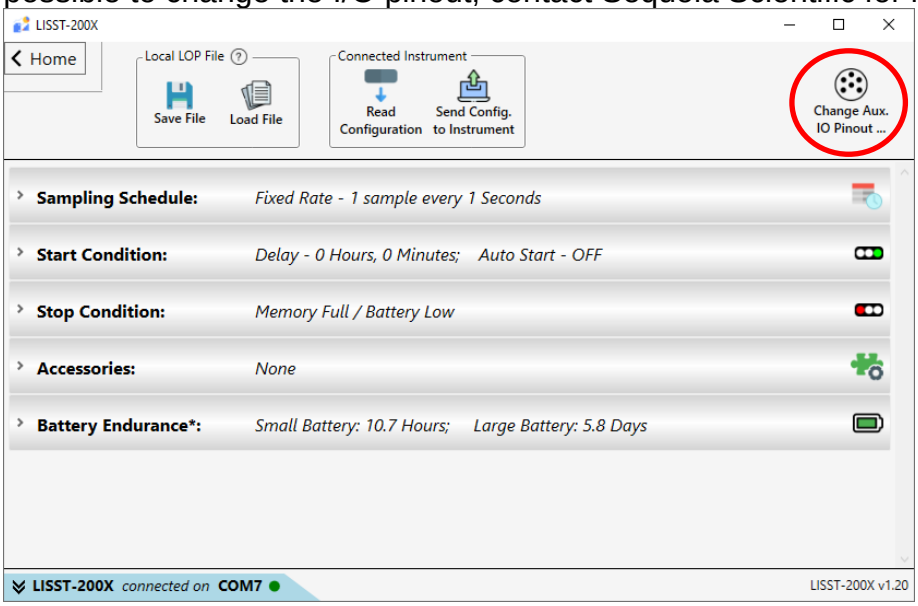
In newer models of the LISST-200X (starting with serial number 2210 or as a factory upgrade for older units), the connector configuration can be changed in the LISST-200X software. To see if your instrument supports software-configurable I/O, follow the instructions below:

1. Connect the LISST-200X to your computer using the supplied USB cable.
2. Open the LISST-200X software and wait for software to connect to the instrument.

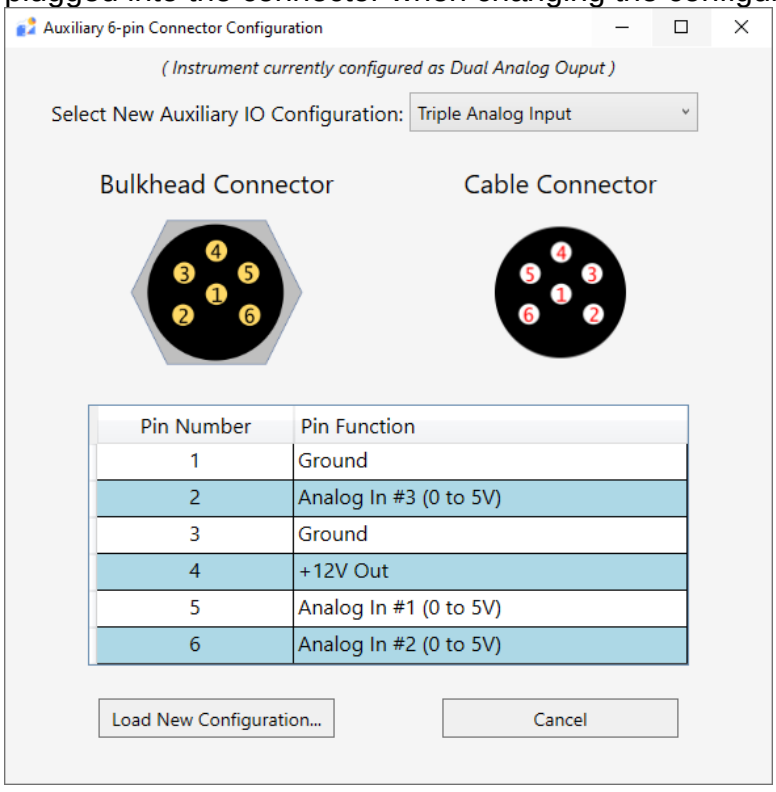


3. Open the 'Configure Instrument' page

4. If your instrument supports software configurable I/O, a button will be present in the top right of the screen. If this button does not appear, your instrument does not support software configuration of the I/O (Under certain circumstances, it may still be possible to change the I/O pinout, contact Sequoia Scientific for more information).



5. Pressing this button will open a page for viewing and changing the I/O configuration. Use the dropdown box to select a new configuration, then load it onto the instrument using the 'Load New Configuration…' button. We recommend that nothing be plugged into the connector when changing the configuration.



All possible 6-pin connector configurations and their pinouts are listed below. A specific LISST-200X will support a subset of these options. The best way to see your instrument's configuration is through the LISST-200X software, but you can also use the console command CONFIG (see page 62) to view it, and IOCONFIG (see page 66) to view and possibly change it.

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

Bulkhead Endview

Cable Endview

Analog and Digital Input, configuration 0 (set in hardware)

Connector Pin #	Use
1	Ground
2	Digital Input Trigger
3	Not Connected
4	+12V out
5	Analog In (0 to 5V)
6	Ground

Dual Analog Input, configuration 1 (set in hardware). This is used to record data from up to 2 external analog sensors such as fluorometers or turbidimeters.

Connector Pin #	Use
1	Ground
2*	Not Connected
3	Ground
4	+12V out
5	Analog In #1 (0 to 5V)
6	Analog In #2 (0 to 5V)

Dual Analog Output, configuration 2 (set in hardware) or 6 (software-selectable). This is used for operating the LISST-200X as an analog sensor for a CTD or similar host.

Connector Pin #	Use
1	Ground (Power)
2	Analog Output: Mean Size
3	Ground (signal)
4	Analog Output: Total Concentration
5	Ground (signal)
6	Power Input (9 to 24VDC)

Triple Analog Input, configuration 4 (set in hardware) or 5 (software-selectable). This is used to record data from up to 3 external analog sensors such as fluorometers or turbidimeters.

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 with Trigger, configuration 9 (software-selectable only). This is used to record data from up to 2 external analog sensors, as well as to start and stop logging under the control of another device.

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

Appendix G: Particle Shape Models

Particles of different shapes scatter light differently, so the mathematical model used for processing must be appropriate to the particles under observation. Two models are offered by Sequoia: the spherical model, and the random or irregular 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, without 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. However, it is not completely accurate for non-spherical particles found in nature.

Sequoia provides an alternate model that is derived empirically from natural, irregularly-shaped mineral particles, rather than assuming spheres. 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/library). The method is also briefly described in this article: 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!

Which model should you use? Sequoia's software allows you to use both, then compare the results. But in general, the random model is best for any in-situ application.

	Spherical	**Random (Irregular)**
Best use	Particles known to be predominantly spherical, e.g. analytical microspheres	Appropriate for natural mineral particles
Effect of misapplication	If used with natural irregular particles, tends to *invent* fine particles.	If used with spherical particles, tends to underestimate their size.
Relation to other instruments and methods	Usually produces the closest match to other laser diffraction particle sizers (although they may still differ due to index of refraction)	Usually produces the best match to analysis by sieving.

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.

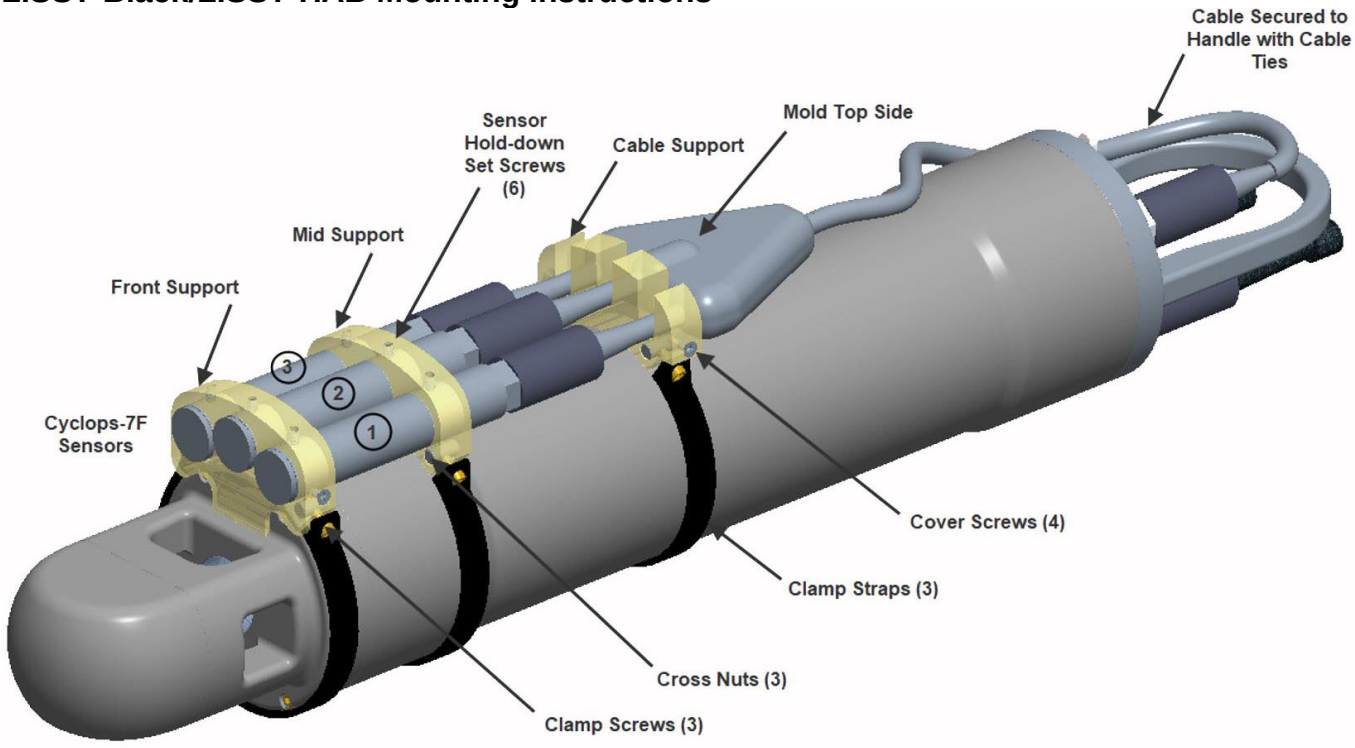
Power Consumption

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 housing 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:

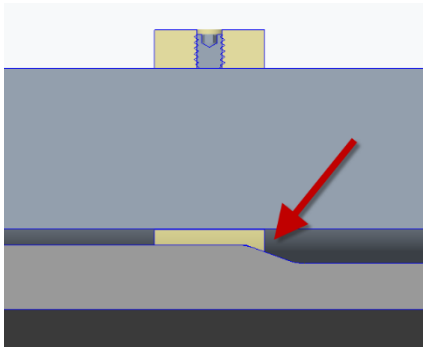
Clamp Screws, 8-32 x ½" Socket Head Cap Screws, 316 Stainless Steel
Sensor Hold-down Set Screws, 8-32 x 3/16" Set Screws, flat tip, 316 Stainless Steel
Cover Screws, 6-32 x ¼" Flat Head Phillips Screws, 316 Stainless Steel

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: BioBlock Anti-fouling Wiper

The BioBlock is an optional accessory that periodically wipes the windows of the LISST-200X, drastically reducing biological growth (biofouling) on the windows. Biofouling on the windows creates excess background scattering, which can degrade the data from any long-term deployment in biologically active waters.

Hardware Requirements and Compatibility
All LISST-200Xs contain electronics for driving a BioBlock, via a 3-pin connector on the endcap (see page 88 for connector details). The hardware and fittings required for mounting to the LISST-200X are supplied with the BioBlock.

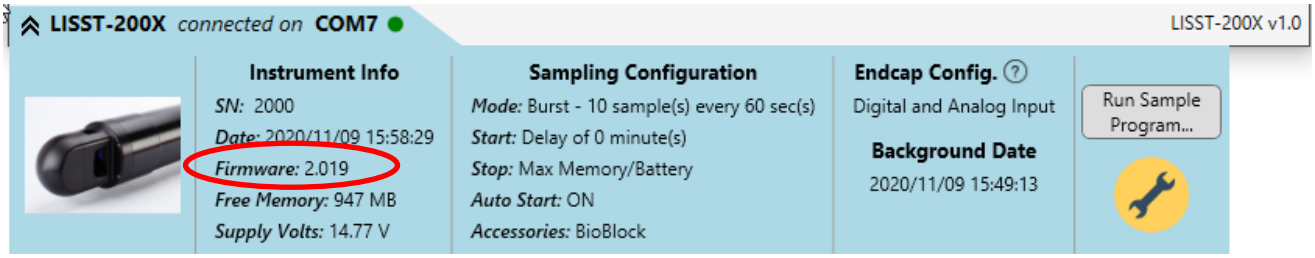
Due to mechanical constraints, the BioBlock is not compatible with the LISST-Black/HAB configuration (described on page 96), nor with a path length reduction module (page 102).

The BioBlock can be installed on a LISST-200X mounted to the optional welded cage supplied by Sequoia Scientific.

Operating Depth: 200 meters maximum
The BioBlock is intended for use in relatively shallow waters where biofouling is likely. It can withstand depths up to 600 meters (the maximum rating of the LISST-200X), but should not be *operated* at depths greater than 200 m. The pressure at greater depths causes excessive wear on the rotating seals, and increases current consumption.

Power Requirement
During the brief period (less than 2 seconds) while it is opening or closing, the BioBlock roughly doubles the power consumption of the LISST-200X. This is compatible with the large battery housing (see page 40), but not the small battery housing (page 37), or the USB-powered cable. The USB-powered cable can be used for communication when the BioBlock is connected, but you must connect the large battery housing or another power source while operating it.

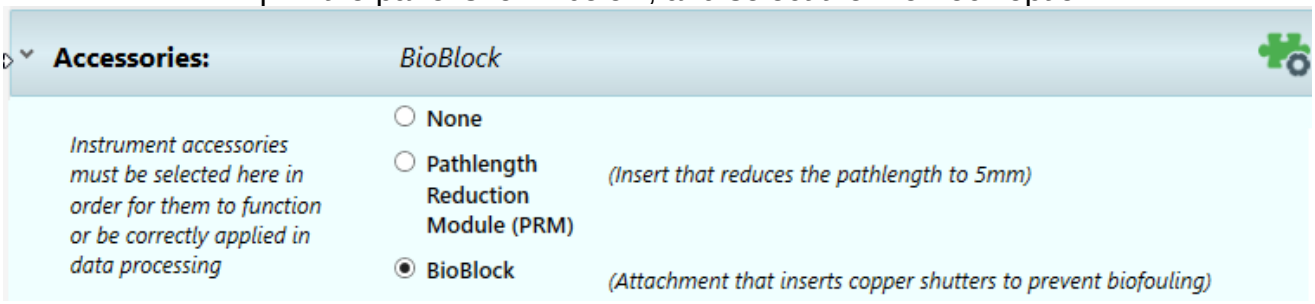
Firmware Requirement
If connecting a BioBlock for the first time, check that your LISST-200X has an appropriate firmware version. In the LISST-200X software, connect to the instrument, then click on the blue tab at the bottom of the main window to open the instrument information pane, which shows the firmware version:



If the firmware version starts with the digit 1, it must be at least 1.461 to support the BioBlock. If it starts with 2, it must be at least 2.020.

BioBlock Activation

To operate automatically, the BioBlock must be activated with a software command. In the LISST-200X software, connect to the instrument and click “Configure Instrument”. Then click “Accessories” to open the panel shown below, and select the BioBlock option.



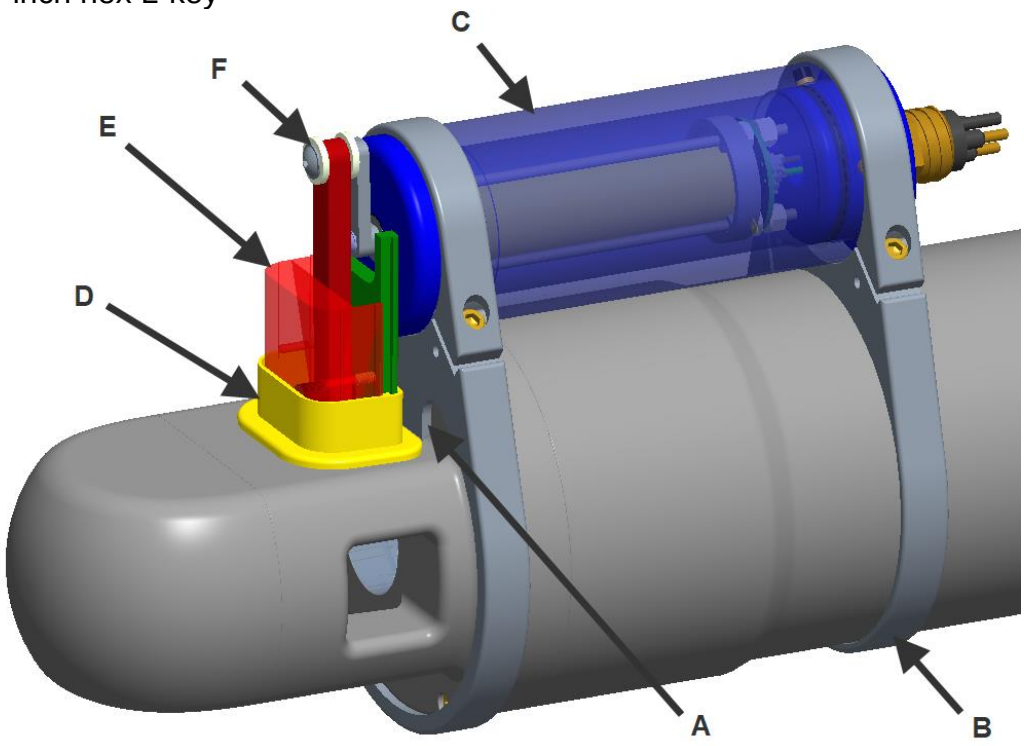
You can also activate the BioBlock in the terminal window, by typing the command BB AUTO in the terminal window, or deactivate it with BB OFF. The commands BB OPEN and BB CLOSE in the terminal will immediately open or close it.

When the BioBlock is activated, it will automatically open (wiping the windows) whenever the sampling program (set up as described starting on page 32) is running. It will close whenever the sampling program pauses for at least 50 seconds. **NOTE: your sampling program must either use burst mode, or a long sample interval, to schedule periodic gaps of at least 50 seconds when the BioBlock will wipe and close. You must test the sampling program to verify the BioBlock schedule behaves as you expect.**

Mechanical Installation

Required Tools:

1/16-inch hex L-key
9/64-inch hex L-key



1. Put bracket A onto the end of the 200X. The tab on the front edge will set the position.
2. Using 9/64” L-key, remove the screw on bracket B. Slide the bracket over the connector end of the 200X. Place it approximately 4 inches/10 cm away from the large bracket.
3. Insert the motor assembly C into bracket A and then B, until the end of the motor is flush with the bracket A (not protruding, as shown in the picture; the position will be adjusted later). Rotate the motor assembly so the rotor arm is pointing up. Lightly tighten all the bracket screws.
4. Insert the plastic insert D from the top until the tabs on the bottom click in place in the optics head.
5. Insert the wiper assembly E from the bottom. The arm attached to the wiper will tend to catch on the optics head. Rotate the 200X to keep the arm centered while ‘pushing up’ on the wiper assembly.
6. {9/64” and 1/16” Allen wrench} Remove the front screw on the rotor (at F) and one plastic washer. Loosen the Large and Small Bracket screws. Push the motor assembly forward to align the rotor to the arm. Slide the arm onto the pin and reattach the washer and screw. When tightening the screw, hold the motor arm stationary, to prevent forced rotation of the motor. Slide the motor so its endcap seam is aligned with the front face of the large bracket. Align the small bracket (B) so the motor assembly is parallel to the 200X body. Tighten the large and small bracket screws that clamp them to the 200X body. Rotate the motor assembly until the arm is pointing straight up. Tighten the screws on the brackets A and B.

Final adjustment and test

a. Connect the Bio-Block to the 200X endcap with the 20” long cable. Use a cable tie or tape to secure the cable on the 200X handle.
b. Power up the 200X and connect to it with LISST-200X software. Open the terminal window.
c. In the terminal window, type BB OPEN and BB CLOSE several times to make sure the copper parts do not rub against the windows or any part of the optics endcap. Finish with BB OPEN command.
d. {9/64” Allen wrench} If the Bio-Block wipers are not in the raised position, loosen the clamps around the motor assembly and adjust them until the wipers are up.
e. Test the BB CLOSE and BB OPEN commands again.

Appendix J: Path Reduction Module

Introduction

The LISST-200X can measure over a wide range of particle concentrations. However, as concentration increases, an increasing fraction of detected light is scattered more than once before reaching the detector. This multiple scattering can distort the apparent size distribution, specifically by skewing it toward smaller sizes. The Path Reduction Module (PRM) reduces this effect, extending the operating range to higher concentrations.

Transmission Limit

There is no abrupt threshold when multiple scattering suddenly becomes excessive. Rather, it is a gradual effect: as overall scattering increases, the proportion of multiple scattering increases as well. The effect is also highly dependent on particle size. The relationship is complex. However, to assess the risk of multiple scattering it is generally sufficient to consider only the optical transmission. When transmission is below 30%, multiple scattering is likely to have a noticeable effect on size distribution data, “inventing” fine particles. Transmissions as low as 10% may yield usable data, but would require special care in processing and evaluating data.

Increasing Limits by Reducing Path

If transmission is too low, meaning multiple scattering is too high, for accurate measurements, the optical path that the laser passes through must be reduced. This reduces the number of scattering interactions between the laser beam and particles, thereby reducing the proportion of multiple scattering.

Transmission and maximum concentration vary inversely with path length. Therefore, reducing the path by a factor of 2 increases the measurable concentration by a factor of 2. Sequoia’s Path Reduction Module (PRM) for the LISST-200X reduces the path from 25 mm to 5 mm, for a factor of 5 increase in maximum concentration.

Concentration Limits

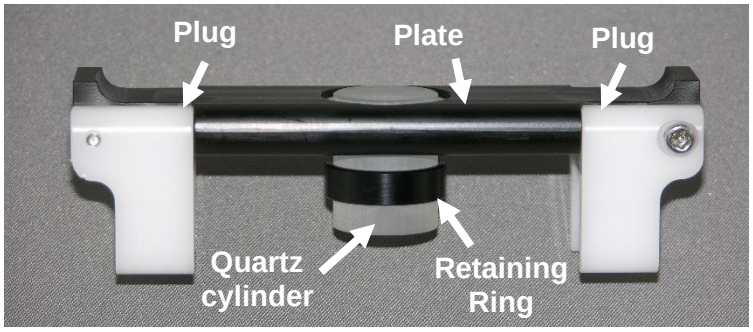
The table below shows the concentration limits for various particle sizes, with and without the PRM.

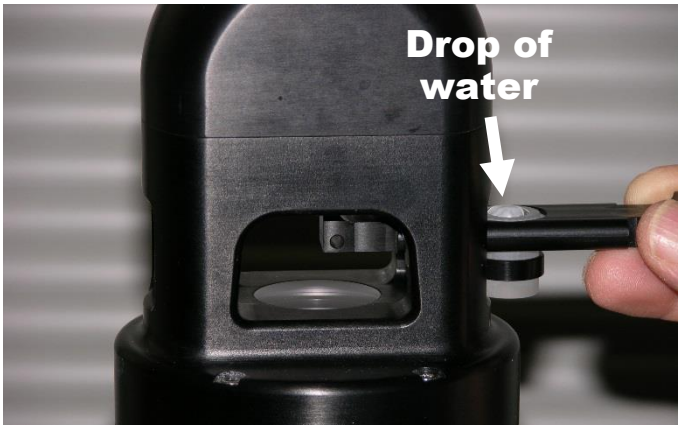
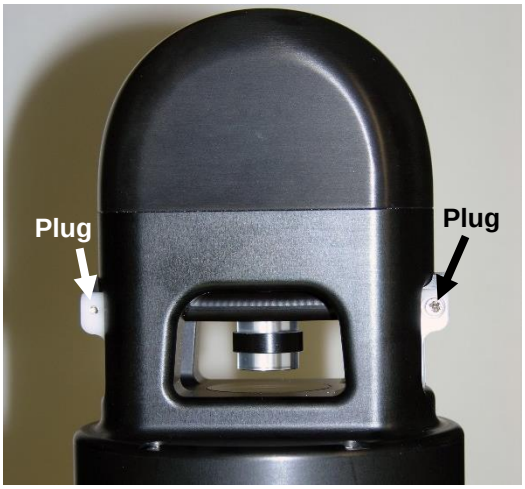
Mean particle diameter		Wentworth grades	LISST-200X Estimated Maximum concentration in mg/L	
µm	Phi		25mm Path (Standard)	5mm Path (with PRM installed)
1.95	9.00	Clay	83	416
3.9	8.00	Very Fine Silt	166	831
7.8	7.00	Fine Silt	332	1662
15.6	6.00	Medium Silt	665	3324
31.25	5.00	Coarse Silt	1332	6659
62.5	4.00	Very fine sand	2728	13638
125	3.00	Fine sand	5327	26637
250	2.00	Medium sand	10655	53273

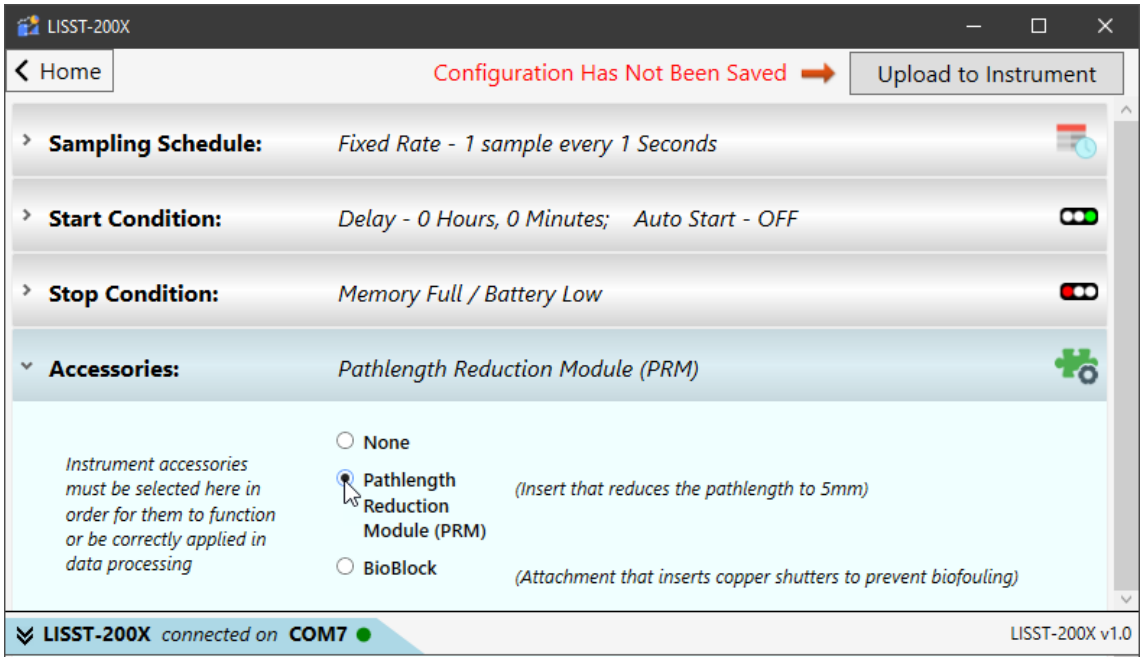
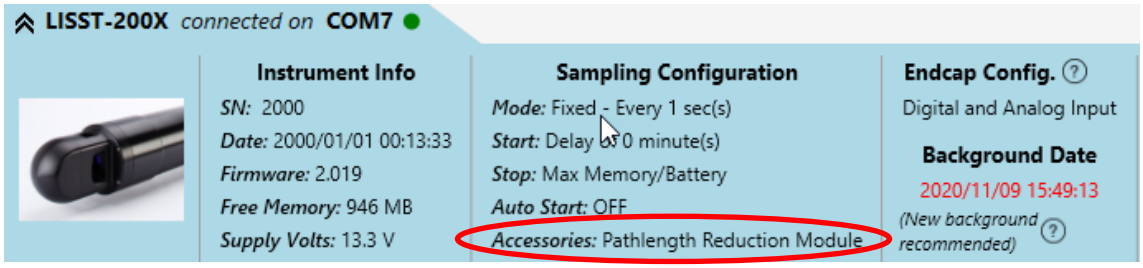
Description The PRM consists of a highly polished quartz cylinder and mounting hardware. The quartz cylinder is pressed against the smaller transmit windows, with a drop of water trapped between them to prevent an air gap (which would make the background scattering much higher and less stable). The plastic holder and spacers hold the quartz cylinder in place during deployments. The parts and installation instructions are shown below.

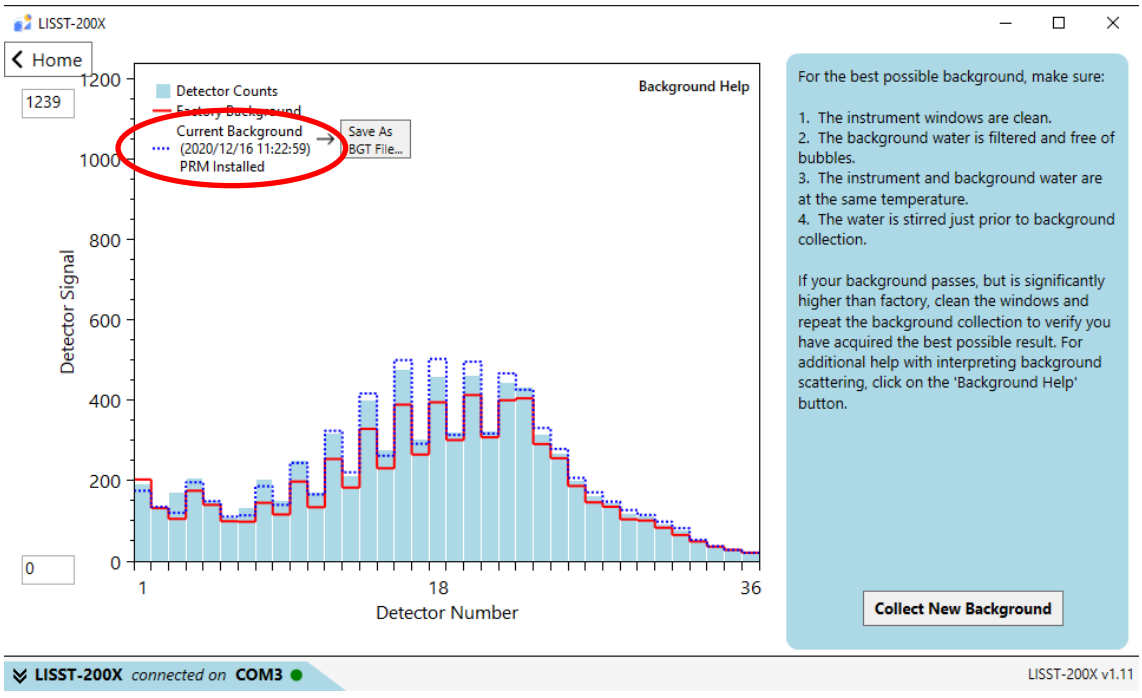
Using the PRM The following pages show details of:

1. Installing the PRM
2. Software Configuration for PRM Use
3. Background Collection with PRM
4. Removing the PRM
5. Maintaining and Storing the PRM

1. Installing the PRM	
1	• Locate all the components of the LISST-200X Path Reduction Module as shown below. • The parts include quartz cylinder with retaining ring, PRM Plate, two white PRM Plugs and two 4-40 x 7/8 socket head cap screws and an o-ring (size 2-016) that is pre-installed between the quartz cylinder and the PRM Plate.  • Remove the plugs from the plate before installation.
2	• Secure the 200X in a vertical orientation with the optics endcap on the top. • Clean the optics endcap cavity. • Clean the windows with alcohol or glass cleaner, and use compressed air to remove any particles.
3	• Clean both ends of the PRM quartz cylinder with alcohol or glass cleaner. • Put a large drop of filtered water on top of the quartz (see photo below) • Insert the PRM Plate into the 200X optics head, without allowing any part of it to touch the upper window of the 200X, until it is centered.

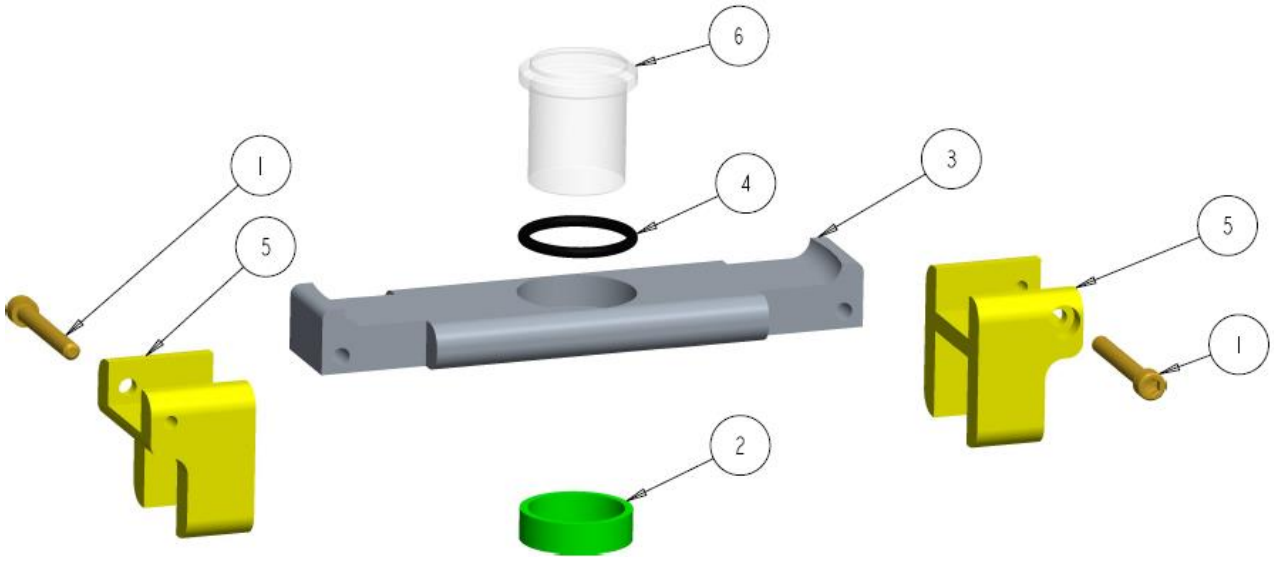
	 • Insert a white PRM End Plug under one end of the PRM Plate to lift the plate up to the upper window. • Insert the second PRM End Plug.  Before installing the screws into the PRM Plugs to lock them in place, we recommend checking the clean water background, as described next.
4	• Check the Clean Water Background using the standard procedure described on page 29. The results should be close to the factory values. However, they may not receive a PASS result because of the instrument being in air. • **WARNING:** A background performed in air is not acceptable for particle measurements. A new background with clean water must be performed before deploying the instrument. • If the background does not look good, remove the PRM, clean the glass surfaces and re-install the PRM until an acceptable background is obtained.
5	• Install the two 4-40 x 7/8 socket head cap screws into the PRM Plug using a 3/32” Allen wrench to lock the PRM assembly to the LISST-200X.

2. Software Configuration with PRM	
Before deploying the instrument with the PRM, you must indicate to the instrument's onboard firmware that the PRM is installed. Then, data files produced by the instrument will properly include that information, and the software will properly account for the reduced path.	
1	Open the LISST-200X software and connect your instrument. Press the Configure Instrument button to see this screen: 
2	Select the Pathlength Reduction Module option. Note that the PRM cannot be used with the BioBlock (described in Appendix I: BioBlock Anti-fouling Wiper).
3	Press the Upload to Instrument button, to make the setting permanent. You can confirm the setting at any time by clicking on the blue tab at the bottom of the screen to open the configuration panel: 
	After installing the PRM, you MUST make a background measurement.

3. Background Collection with PRM	
The small test chamber that is supplied with the LISST-200X, described on page 10, cannot be used with the PRM installed. Instead, you must immerse the head of the LISST-200X in a suitable container of water.	
1	Use a clean container and, as with any background measurement, clean, bubble-free water.
2	Clean the parts of the LISST-200X housing that will be immersed, so contamination shed by the instrument will not degrade the background.
3	Collect the background using the standard procedure, as described on page 12. The instrument should be configured for use with the PRM prior to collecting a background. If the instrument has been configured properly, it will indicate that the PRM is installed in the legend of the background plot. 

4. Removing the PRM	
1	• Clean the LISST-200X optics head and PRM components to remove any large debris that could scratch the glass windows or cylinder when the PRM is removed. • It may be necessary to remove any hard growth, such as barnacles, before removing the PRM. Be careful not to scratch the glass surfaces.
2	• Remove the two 4-40 x 7/8 long socket head cap screws from the PRM plug using a 3/32” ball driver or Allen wrench.

	• While holding the PRM Plate, remove the two PRM Plugs. The PRM Removal Tool will be helpful for pulling out the PRM plugs. Be sure to hold the PRM Plate so that it does not fall out or drop unexpectedly. • Carefully slide the PRM Plate with quartz cylinder from the optics of the LISST-200X. The PRM plate may need to be tipped to separate the PRM from the glass window.
3	• After removing the PRM, clean the optics of the LISST-200X and all the PRM parts before storage. • Be sure to protect the quartz cylinder from scratches or impacts that could damage the optical surfaces. It is also highly recommended to change the instrument configuration on the LISST-200X to reflect that the PRM is no longer installed.

5. Maintaining and Storing the PRM	
1	Remove the PRM as described above, and clean all the parts
Note: Full disassembly of the PRM is not usually required and not recommended unless absolutely necessary. For the rare cases when it is needed, see the following diagram and notes.  Parts: 1. 4-40 x 7/8” socket head cap screws 2. Retaining ring 3. PRM plate 4. O-ring, size 2-016 5. Positioning plug 6. Quartz PRM cylinder	
2	• The retaining ring, item 2, holds the cylinder loosely in the plate. The ring is held on the cylinder by friction, and may be difficult to remove. If it is too tight to remove with your fingers, use only blunt tools that cannot scratch the

	quartz. Clean any deposits or growth from the outside of the cylinder to ease removal of the ring. • The o-ring, item 4, is not used as a seal, but as a spring to keep the cylinder pressed against the small window. Remove the o-ring to inspect it. Replace it if it is brittle, cracked or sticky.
3	• Install the black plastic retaining ring onto the quartz cylinder. There should be about a 3mm gap between the cylinder and the plate, as shown below. The cylinder should be able to move freely.  • Reattach the PRM Plugs using the two screws to keep all parts together. • Wrap the optics with soft tissue and store the assembly in a safe place.

Appendix K: Analog Outputs

Introduction

The LISST-200X includes two analog outputs for interfacing with CTDs or other data acquisition systems (see Configuring the LISST-200X as a Sensor for a CTD on page 57). These produce voltages indicating the approximate total concentration and mean diameter of particles.

Whether the analog outputs are accessible on a specific LISST-200X depends on its electronic configuration. The auxiliary connector must be in its dual-output configuration. See Appendix F: Auxiliary Input/Output on page 91 for details.

Calculation

The analog output voltages are calculated using one of two methods, depending on the version of the LISST's electronics. Newer instruments with Autonomous Real-time Data Processing capability enabled (see page 53) calculate the full particle size distribution, with the same precision as data post-processed on a PC. Older instruments without that capability use an approximate calculation, based on a weighted sum of the raw signals from the 36-segment detector.

For either calculation method, users of the data should note the inherent limitations in range and precision available from analog outputs. Also, there is in inverse relationship between optical transmission and quality of the mean size calculation. High transmission means few particles are present, so the estimated size may vary widely from sample to sample, and may contain large errors. For this reason, when the particle concentration is very low (with transmission typically0.99 or higher), the mean size analog output will be set to zero. In other words, zero output indicates no valid measurement is possible.

Background quality

As with any application of the LISST, a high-quality background measurement (see page 29) is essential for correct data from the analog outputs.

Interpreting output voltages

The analog outputs can range from 0 to 3 Volts.
The mean size output voltage is 0.005 * (mean size in microns) + 0.5 Volts. Therefore,

$$\text{Mean size} = 200 * (V - 0.5) \text{ micron}$$

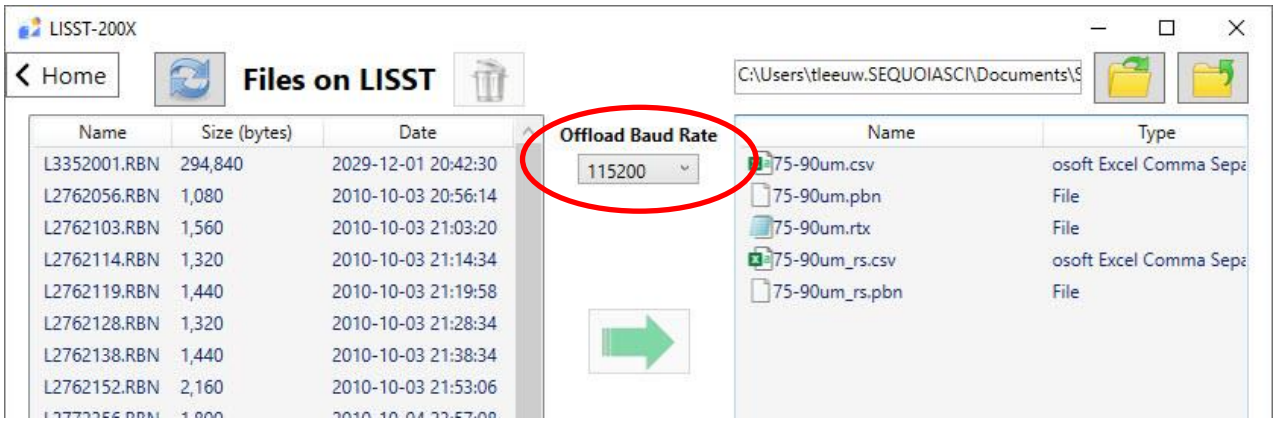
To accommodate a wide range of possible concentration values, the conversion to voltage is logarithmic: V = 0.5 * log10(PPM*100). Therefore,

$$\text{Concentration} = 10^{2V}/100 \text{ PPM}$$

Appendix L: Troubleshooting & Support

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 support@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.

Revision History

Version	Changes
2.35	Remove obsolete XR command
2.34	Update power specifications for newer serial numbers (page 78)
2.33	Add maximum operating depth for BioBlock (page 99)
2.32	Add Appendix K: Analog Outputs; restore section numbering.
2.31	Add description of DEFAULTS command (page 65)
2.3	Added Appendix F: Auxiliary Input/Output. Changed names of Matlab processing .m files in Appendix D: MATLAB Data Processing. Updated a few software screenshots. Editing for clarity
2.2	Support for Autonomous Real-time Data Processing (page 53 and related); reorganize sections on start and stop conditions (II.B), communication (II.C), and commands (II.D and II.E.3); general editing.
2.1	Corrected input voltage in Appendix E: Connectors; Clarified Appendix G: Particle Shape Models; Added Appendix I: BioBlock Anti-fouling Wiper and Appendix J: Path Reduction Module; removed warranty statement (www.sequoiasci.com/support/warranty); updated software screenshots for v1.11; general editing.
2.0	Updated descriptions and screenshots for new LISST-200X software.
1.5A	Corrections in Appendix H.
1.5	Add LISST-HAB and LISST-Black
1.4	Show change from Impulse to SubConn connectors.
1.3B	Note that accelerometer data are not presently calibrated or used (they are reserved for possible future use)
1.3A	Edit XR command description. Remove incorrect warning about maximum voltage on digital input, and clarify its logic sense (see Start and Stop Conditions, page 58). Correct units of data fields in Appendix C: Data File Formats.
1.3	Add Ambient Light Rejection.
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.
1.1	First released version