LISST-100

Particle Size Analyzer

User's Manual

Version 3.0

SEQUOIA

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Welcome to the LISST-100 Particle Size Analyzer

Using this manual

This manual is divided into three sections.

Section One contains a basic introduction to the LISST- 100 instrument and the theory behind its operation.

Section Two provides a detailed set of instructions for using and caring for the instrument.

Section Three presents information for the advanced user on programming the datalogger of the LISST - 100.

Technical specifications

For a listing of instrument specific constants, as used in the software for data processing, refer to Appendix A.

Technical assistance

To obtain technical assistance please contact your local distributor or a Sequoia Technical Service Representative listed below. Please be sure to include the serial number with any correspondence.

Serial Number:
Shipment:

Factory Technical Service Representatives

Chuck Pottsmith
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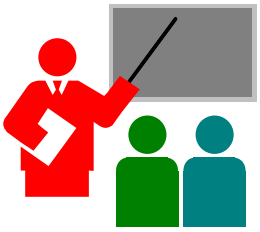
Section 1

Introduction

Theoretical Background

LISST is a product name derived from the term that describes its operation: **L**aser **I**n-**S**itu **S**cattering and **T**ransmissiometry.

The LISST-100 uses the technique of laser diffraction to obtain *particle size-distribution* (PSD). This section describes the theory behind the PSD measurement.



Laser diffraction particle sizing is based on the following consequence of the exact Mie theory: at small angles of scattering, scattering by particles is predominantly due to diffraction, so that particles appear essentially as though they were apertures. An aperture, when lit by a laser beam, produces a diffraction pattern that is described by the Airy function for the aperture. Consequently, the refractive index of the particles is not important. Because of this property of small-angle scattering, particles of various compositions can be measured with a single device.

Another advantage of this technique results from the following coincidence. In nature, the volume of particles is roughly (emphasis on *roughly*) of the same order for all sizes over the typical range of interest. The diffraction technique, which obtains the size distribution from the small-angle scattering properties of an ensemble of particles, benefits from this coincidence in that the required dynamic range of the sensors is reduced in contrast with single-particle counters.

The LISST-100 records the scattering intensity over a range of small angles. These measurements are recognized by optical scientists as the *volume scattering function* and can be used as such for studies of underwater image propagation and beam spread. The scattering data are inverted to obtain size distribution.

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There is a vast literature on the subject of inverting the measured scattered-light intensity distribution. We note here the most germane study of the subject:

> "Optimal scaling of the inverse Fraunhofer diffraction particle sizing problem: The linear system produced by quadrature," by E. D. Hirleman, *Particle Characterization*, 4, 128-133, 1987.

Simple descriptions of principles and practice are offered in a separate study by Agrawal et al., 1991[1].

The main conclusions are that the information content of the data is most stably retrieved by use of ring-type detectors, with each ring measuring the scattering over a range of angles, and that the information content is limited to relatively few size classes depending on the noise in the data. For example, for a dynamic range in scattering angles of 100:1, typically only 12-14 truly independent size classes can be identified.

Nonetheless, with careful work, it is possible to solve the following under-determined problem: given a number of measurements, say from 32 rings as in the LISST-100, what is the 64-size class distribution that best matches the measurements in a least squares sense. The software provided with the LISST-100 solves this under-determined problem. These results tend to be non-unique. It is simple to test how well the results of the inversion represent the measurements.

We explain the solution as follows: Let $\underline{E}$ be the 32-element data vector that contains the angular scattering energy sensed by the 32 rings, as retrieved from the LISST-100. It is related to the area distribution[2] via

$$\underline{E} = \underline{\underline{K}}\,\underline{N_A}$$

where $\underline{\underline{K}}$ is the scattering property kernel matrix and $\underline{N_A}$ is the area distribution.

[1] Agrawal, Y.C., I.N. McCave, and J.B. Riley, "Laser diffraction size analysis," in *Principles, methods and applications of particle size analysis*, J.P.M. Syvitski, editor, Cambridge University Press, 1991, pp. 119-128.

[2] The volume distribution is related to the number distribution via $N_V = a^3\, n(a)$. It represents the volume of particles of size a in the size range a and $a + da$. The results from the LISST instruments provide the total volume of particles in each of 64 size classes.

The volume distribution is obtained by inverting the above equation to solve for $\underline{N}_A$.and subsequently multiplying the area in each size class with the mean diameter of the size class, to obtain the volume distribution. Let us call the resulting estimated solution for $\underline{N}_A$ to be $\underline{N}_e$. Now to test whether the estimated solution is a good one, one may compute the prediction of a scattered energy estimate $\underline{E}_e$ as

$$\underline{E}_e = \underline{\underline{K}}\,\underline{N}_e$$

If the measurements $\underline{E}$ are consistent with $\underline{E}_e$, the estimates of $\underline{N}_e$ can be considered good. Included with the LISST-100 instrument, we have provided software that obtains the inverted volume distribution $\underline{N}_V$. We have also provided the matrix $\underline{\underline{K}}$ for your instrument (in ASCII and MATLAB® formats) in order for you to test your results, should you so desire.

The LISST-100 instrument is a laser diffraction device. It consists of optics for producing a collimated laser beam, a specially constructed detector array, electronics for signal pre-amplification and processing, a data storage and scheduling computer, and a battery system.

The instrument is capable of autonomous operation. For such operation, standard software is provided to program the instrument for a specific sampling schedule. The primary measurements delivered by the LISST-100 are the small-angle scattering properties of the water, the laser optical transmissivity, pressure, and temperature.

After recovery of the instrument, the small-angle scattering data are off-loaded from the instrument and subsequently inverted mathematically on a PC to produce the particle **size distribution**[3]. For this purpose, software is provided. The optical scattering can also be used to obtain the ***volume scattering function***—a quantity of interest to optical oceanographers concerned with the propagation of light (radiance field) and images (modulation transfer function) in the sea.

The principal measurement—angular scattering distribution— is obtained over 32 ring-detectors that are logarithmically placed in the focal plane of the receiving lens covering a range of 0.0017 to 0.34 radians. This angular range corresponds to size range of analysis from 1.2 to 250 microns.

[3] The term size-distribution is loosely used; its usual interpretation is the number of particles in an elementary size range. In all of this work, we are usually concerned with area- or volume-distributions and shall use the terms carefully.

External I/O Ports

The instrument system is equipped with external ANALOG IN ports for recording the output of one other instruments, and for communicating with up to two instruments via DIGITAL I/O ports. The I/O ports can be used for synchronization of the LISST-100 with two other instruments; e.g., the LISST-100 may provide a timing pulse to a transmissometer, or it may provide a 'start sample' pulse to another LISST-100. The same ports can be used to receive similar commands[4].

More advanced operations can be carried out, such as measurement of the period of some event or control of a stepping motor by issuing direction, amount of rotation and speed commands. The stepping motor control feature can be used for moving the instrument vertically on a user-provided profiler, say, on a fixed tripod.

Battery Life

When the instrument is in stand-by mode, (i.e., when the program is not executing instructions other than SLEEP and when the serial communication cable is disconnected) the current drain is 2 mA. The standard alkaline D-cell battery-pack has a capacity of 14 A-hr. If used as advised, the battery provided in the instrument has a capacity to power the instrument for up to a year. A data-protecting backup battery (one year life) can extend *in-situ* deployment beyond a year. For laboratory or tethered usage, most models are equipped with a connector on the end-cap for provision of power from an external source.

When not in use, disconnect the communication cable from the instrument. This in combination with the SHUTDOWN.TTB program can be used to reduce battery current drain to about 10μA.

Auxiliary Equipment

The instrument is shipped pre-aligned and tested. A chamber is provided for obtaining measurements of background light (**ZSCAT**, see later) from optical surfaces. This background is subtracted from actual particle scattering measurements to obtain the true particulate scattering. A miniature scattering chamber can also be provided for working with small samples in the laboratory. Additionally, small tools to open end caps, small hardware, end-cap 'O' ring, spare batteries, and communication cable are supplied so that a user need only provide a PC.

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 scattering function. For laboratory use or for monitoring the progress of an experiment, Windows-95 software can be used for real-time processing.

This self-contained instrument, as has already been noted, consists of the following parts: one solid-state laser operating at 670nm wavelength fiber-optically connected to a laser beam collimating system, beam manipulation and orienting mounts, a scattered-light receiving lens, a specially designed 32-ring detector, preamplifier electronics, a ring-selecting multiplex circuitry, and a data logger. The physical placement of the components is schematically displayed in the figure below (for details of operation of the LISST-100, see the section titled "Operations" below).

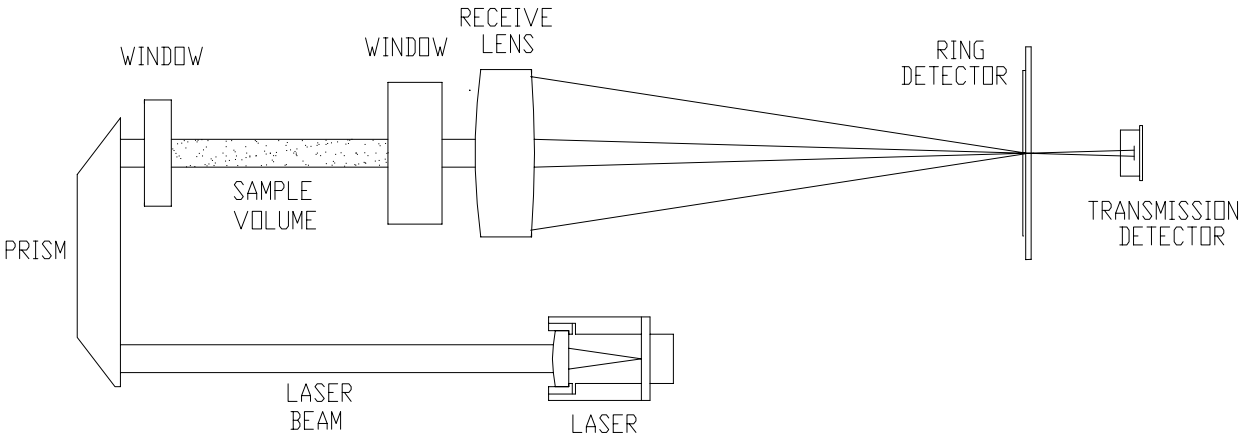
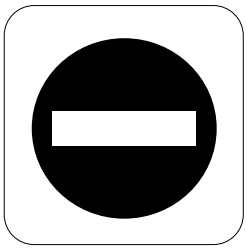


Fig. 1. The placement of the component systems in the LISST-100.

Section 2: Operation

General Precautions

This section of the Operator's Manual is meant to bring to the user's attention to the precautions and warnings that are important to the life and performance of the instrument. These warnings are in bold face print such that they will be noticed and read.

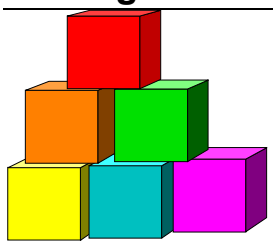


LISST-100 is a sensitive optical instrument. Please handle it gently. Critical alignments may be disturbed if the instrument is subjected to shock or rough handling. Evidence of shock/rough handling will void the warranty. Whenever in transit, store the instrument in the provided cushioned box.

WARNING

The LISST-100 uses a laser diode emitting a maximum of 3 MW of visible (red) light at a wavelength of 670nm. the laser beam under normal circumstances is not a threat. However, if objects are placed in the path of the laser beam, the light could be reflected into the eye causing permanent damage.

Getting Started



This section is designed to give the user a quick introduction to the operating procedures for the LISST-100. It give step by step instructions to unpack, load software, and acquire data in the lab. Following the introduction are details on each step of the process. Table 2-1 lists the introduction steps that will be discussed.

Contents of shipping case

Let's assume that you are opening the LISST-100 shipping case for the first time. Inside you will find the following: User's Manual with software disk, LISST-100 instrument, Plastic Instrument stands, Horizontal Test Chamber, Communications cable, and External Power cable, Allen wrench set, spare o-rings and bolts.

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-100 from the case and set it on the stands. The LISST-100 has two distinct ends which we will refer to as the Optics endcap and the Connector endcap. The connector endcap has three underwater connectors that are used for communication and external power. The battery pack is attached to the inside of this endcap. The optics endcap contains the optical windows that the laser beam passes through to make a measurement. The internal optics and electronics are mounted to the inside of this endcap.

Step 2: Check for clean windows

At this time let's check the optical windows to make sure that they are clean. There are two windows. The receive window is mounted in the center of the optics endcap. Transmit window is located in the Crossbar suspended above the endcap. The best way to check the windows is by using a flashlight. By shining light from on 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 water and then by wiping them with a soft cloth and alcohol. Stronger solvents , such as acetone, can be used if necessary but is not recommended as a general practice. In general do not use any abrasive cleaners or wipes. Treat the windows as you would an expensive camera lens.

Step 3: Attach the Communications Cable

Remove the Communications cable from the shipping crate. It is the cable with the 9-pin DB-9 connector on one end and the 4-pin underwater connector on the other. Remove the underwater cap from the Communications connector. The connectors will all look similar. The Communication connector is the only 4-pin connector. If the unit is rotated so that the metal zinc anode is located at the top (or North), the Communications connector will be on the left (or West). After removing the cap install the cable making sure that the proper alignment is maintained. The large pin should line up with the bumps on the outside of the cable. The connector should go on with a small "pop".

Step 4: Install the Horizontal test chamber

Remove the clear acrylic Horizontal test chamber form the shipping case. If not already installed, screw in the included valve and install the large o-ring. This chamber is designed to slip over the optics end of the instrument such that the optic can be submerged for testing or calibration. The chamber should slide on until the protective ring touches the back wall of the chamber. We can now fill the chamber with clean filtered water.

Step 5: Install the provided software

At this point instrument is ready to go. Let's install the software that is required for operation of the instrument. A software disk is included with each instrument. In addition the communication and processing programs the disk also contains calibration files specific for your instrument Follow the installation instructions on the disk label to install the all of the software.

Step 6: Start TTOOLS.EXE communications program

There are two different programs for the PC that are used with the LISST-100. They are TTOOLS.EXE and LISST.EXE. TTOOLS.EXE is a DOS program that allows us to communicate with the datalogger inside the LISST-100. It is used a terminal window for the datalogger and also is used to upload programs and download data. The LISST.EXE program is a Windows-95 program that processes and displays the particle size information. At this point we will use the TTOOLS.EXE program. Start this program by double clicking its icon or starting it from a DOS window.

A terminal window will appear with menus across the top. Select the *CommPort* menu and then *Port Setup* item. Note this can also be acomplished by typing Alt+P. A window with the baud rate and port settings will appear. The LISST-100 uses 9600 baud, 8 data bits, 1 stop bit. Handshake and Parity should be set to None. Set the Port to the available communications port of the PC. Select OK to save the settings. The next time TTOOLS.EXE is started it will use the previous settings.

Step 7: Wake up instrument from Sleep mode

After returning to the Terminal window you may see a message on the screen from the LISST-100. The LISST-100 is shipped running a program that keeps the instrument in it's low power mode. It will wake up every two minutes, print a message to the screen, wait ten seconds for a response, and then go back to sleep if there is no response. Wait for the program to display the message to the screen and then type Ctrl+C to stop the program running on the datalogger. The OK> prompt should appear. Pressing enter should produce another OK> response. This is the main prompt of the datalogger. Remember that you may need to wait two minutes for anything to be displayed to the screen. If after two minutes you do not get a response go to the Troubleshooting Section for help in fixing the problem.

Step 8: Load and run new program

We can now clear the Sleep program from memory of the datalogger by typing NEW at the OK> prompt followed by <enter>. Note all commands MUST be in all capitals. This command clears the program but does not clear any data or variables. We can load a new program by selecting the Load Program item from the Tattletale menu. Note this can also be done by typing Alt+L. Type in or select the filename of the program you would like to run. The LISST-100 comes with a number of pre-written programs that cover most applications. These programs are text file that contain programs written in a version of BASIC called TTBASIC. The extension TTB refers to TTBASIC. Detailed information on programming is provide in Section 3. The first program we will use is ZSCAT.TTB. After selecting the filename press OK. The program will be uploaded to the datalogger. Typing LIST+<enter> at the OK> prompt will cause the current program to be displayed to the screen. Typing RUN +<enter> will start the current program.

Step 9: Running ZSCAT.TTB

After typing RUN the program will display prompts on the screen. Follow the prompts to set the time and date and any other required parameters. After setting the date the ZSCAT.TTB program stores 100 samples in the datafile of the datalogger. This data will be used as a calibration file or background scatter file. This background scatter file is also known as a ZSCAT which is short for zero scatterers or particles.

The program will print messages to the screen as it stores the samples. Also notice that the laser is now on and the LED on the endcap blinks each time a sample is taken. The program will terminate when the samples have been taken.

Step 10: Download data from datalogger

When the samples have been stored the ZSCAT.TTB program prints a message stating the range of data to offload. Each sample is 40 channels, two bytes each. 100 samples equals 40x2x100 = 8000 bytes. Therefore we need to offload from 0 to 7999. Select Offload Datafile from the Tattletale menu. Enter a Start Address of 0 and an End Address of 7999. Select Offload and a enter a filename to store the data to. A display will show the progress and then return to the OK> prompt when finished.

Step 11: Load REALTIME.TTB and run

Now that we have downloaded the background scatter file let's load and run different file. First we need to clear the current program from memory. We do this by typing NEW+<enter> at the OK> prompt. This clears the program but not the data or variables. The data will be overwritten when a new program is run. After typing new, load the REALTIME.TTB program. REALTIME.TTB print the 40 channels to the screen each time an <enter> is pressed. The Windows-95 program ,LISST.EXE, uses this feature to do real-time size analysis. After loading the program type RUN to start it. Press follow the prompts until the 40 channels are displayed on the screen.

Step 12: Exit TTOOLS.EXE and start LISST.EXE

We will now switch to the LISST.EXE program. First we must exit TTOOLS.EXE by selecting QUIT from the FILE menu. The program on the datalogger is still running. We can now start LISST.EXE by clicking on it's icon. A screen will appear with menus across the top.

Step 13: Build Background Scatter File

The first step in processing data is to build a background scatter file. This step will read the binary file that we downloaded earlier, average the 100 samples, and store the average to an ASCII file that we will use later for processing.

Select Build Background Scatter file from the File menu. It will prompt you for the name of the Raw data file, select the name of the file that was downloaded earlier.

A screen will appear with a display showing the averaged data in a bar chart graph. The red line is the factory background scatter file. If the water is not clean, if the windows are dirty or if the instrument is out of alignment, it will produce signals that are higher than the red line. If values are at or below the red line press Accept. It will then prompt you for an output file name. Select a unique name and press Save.

Step 14: Open Instrument command

After processing the background scatter file we can now move on to looking at some real-time data. Select Open Instrument from the File menu. A prompt for the Com port and instrument type will be displayed. Select the proper port and instrument type. *Note: Instruments are configured in one of two types, Type B (1.25 - 250 microns) or Type C (2.5 – 500 microns). Instruments manufactured before 1997 may be configured as Type A (5 – 500 microns). Refer to page 55 to determine your instrument's configuration specifics. Use of the wrong instrument type will produce incorrect results*. Next, a prompt for the background scatterfile to use will be displayed. Enter the name of the file saved in Step 13. A display with two graph windows will appear.

Step 15: Open View Ring and Auxiliary Parmeters

Before adding particles to the water let's take a look at a few additional windows that can be useful. Select View Rings from the DataFrames menu. A display appears that shows the current values of the 32 rings and the background scatterfile (red line). Then select Show Auxiliary Parameters Frame from the DataFrames menu. This window shows the current values for the eight auxiliary parameters such a pressure and temperature. The computed value of transmission is also shown.

Step 16: Add particles and view size distributions

The displays at this time do not have much to show because there are no particles in the water. Re-arrange the windows such that the Instrument window can be seen. Select the Timer button. The display will now update at a fixed rate. Add particles to the water while watching both the Instrument and View Rings windows. You will see both displays change as the particles are added. Adding more will change the display again.

Step 17: Close program and shutdown

After finishing the testing close all the windows and exit LISST.EXE. Restart TTOOLS.EXE. Pressing enter will cause the 40 values to be printed to the screen. Type 99+<enter> to stop the running program. The OK> prompt should appear. The laser should now be off. If it is not off, type PCLR 10 +<enter> to turn off the main power.

Step 18: Put instrument back to sleep

To put the instrument back into its low power mode we must load and run the SHUTDOWN.TTB program. Start by typing NEW+<enter> and then load the SHUTDOWN.TTB program. Start it by typing RUN+<enter>. The instrument is now in its low power mode. Be sure to disconnect the communications cable for maximum power conservation.

The above steps are meant to give a brief introduction to most of the procedures that are required to operate the LISST-100. All of these steps are covered in detail in the following sections.

Communication with the LISST-100 is via an RS-232C link. A cable that connects the instrument to a PC has been provided. This cable connects the 4-pin underwater connector on the instrument to a DB-9 serial port connector. If required, DB-9 to DB-25 pin adapters are available.

The RS232 link communicates at 9600 baud, 8 data bits, No parity, and 1 stop bit. A communications program called TTOOLS.EXE has been provided for communicating with the LISST-100. TTOOLS is a DOS application that has features built in to simplify many of the communications tasks such as data off-loading and program loading.

Other communication software such as Windows Terminal or Procomm can also be used. If programs other than TTOOLS are to be used for uploading and off-loading, a working knowledge of ASCII and XMODEM file transfers will be required.

Running TTOOLS

Running TTOOLS, or alternate software, with the proper COM port and communications settings will allow the user to communicate with the instrument. If the power has been connected as discussed in the Battery Power and Access Section above, the LISST-100 should respond by either displaying text from a running program or echoing an OK> prompt.

Programs are retained in memory by the lithium backup battery and will start executing when power is applied. A running program can be stopped by pressing CTRL-C (hold down CTRL key and press C). After a program is stopped or if no program is loaded, pressing the ENTER key will cause an echo of the OK> prompt.

The datalogger of the LISST-100 is programmed with a version of BASIC called TTBASIC. The specifics of programming are covered in detail in the Programming section. However, there are a few commands and procedures that the users should know in order to use the LISST-100. A brief description of each is shown below.

Commands

Commands entered at the OK> prompt	Keystroke or command	Action/Use
	<CTRL-C>	stops the execution of a running program
	LIST	causes the current loaded program to be listed to the screen
	NEW	erases current program from memory; must be done before new program is loaded
	RUN	executes the loaded program
	Commands must be entered in ALL CAPITALS.	

TTOOLS software commands	Keystroke or pull down menu item	Action/Use
	<ALT-L> or 'Load Program' from Tattletale' menu	Load program from PC into datalogger memory
	<ALT-D> or 'Off-load Datafile' from 'Tattletale' menu:	Receive data from datalogger and store on PC
	<ALT-Q> or 'Quit' from 'File' menu:	Exit TTOOLS program; return to DOS
	The above commands will allow the user to load a program, execute a program, and acquire data. Pre-written programs for a variety of experiments have been provided. They are discussed in the following section.	

Pre-Written Programs

The instrument is delivered with a set of programs that have been written and tested thoroughly under typical field conditions. A brief description of each program is shown below.

Programs typically have the file extension TTB referring to the Tattletale BASIC programming language. The files are standard ASCII files and may be viewed with a basic editor such as Notepad.

BATTEST.TTB	for measuring main battery voltage, reports in Volts and stops;
BURST.TTB	for use in field in a burst mode; for taking 1Hz data after a certain delay;
DELAY.TTB	for field use in a periodic mode,
FIELDUSE.TTB	starts taking data on specified date and at specified time, also at specified interval;
LAB_TEST.TTB	test program for general testing of instrument performance or laboratory;
LONGTERM.TTB	for long-term field use, similar to FIELDUSE.TTB;
MEMTEST.TTB	for testing memory size and memory read/write;
P_START.TTB	for taking data from a wire in a yoyo mode; instrument turns on at specified depth and collects data, stops taking data and turns off when at lesser depth;
REALTIME.TTB	for use with LISST.EXE for realtime processing or laboratory testing.
SHUTDOWN.TTB	for storing the instrument in low-power hibernation state;
ZSCAT.TTB	program to measure background light field.

All of the programs will prompt the user for specific inputs. Thus you need not learn to program the LISST-100 datalogger in order to use the instrument.

At the time of shipment, the program SHUTDOWN.TTB is loaded and running. This keeps the instrument in its low power mode.

The above programs have been provided on the software disks included with the instrument. They are text files that can be viewed with a text editor. They are well documented, and you may find them helpful in learning to write your own programs.

Data Acquisition & Storage

This section contains information on selecting, loading, and executing programs for the LISST-100.

The procedure for stored data retrieval is also covered.

ZSCAT and its Importance

As was discussed in earlier sections, the LISST-100 uses a custom detector to measure light scattered at small angles from particles in water. In order to measure only the scattered light contributed by the particles, a measurement of the background scattering must be obtained. This background scattering can come from a number of areas. Scratches on the windows, imperfections on the optics, and other sources all contribute to the scattered light. By subtracting this background scattering from the measured data, a true measurement of the light scattered from the particles can be obtained. The measurement of background scattering has come to be called a "ZSCAT". The name comes from the fact that the measurement is obtained with use of water with zero "scatterers" or particles.

ZSCAT.TTB

The ZSCAT.TTB program is used to obtain a ZSCAT. This program acquires and stores into memory a group of 100 samples or 'scans'. It is very important that clean and bubble free water be used. The water can be fresh or salt water. For most applications, it has been found that 'medical grade' distilled water is sufficient. 'Medical grade' distilled water is typically available in one gallon containers at most pharmacies for use in cleaning contact lenses. We have found that this distilled water tends to be a bit cleaner than typical bottled or packaged water.

Watch for outgassing

Another consideration when acquiring a ZSCAT is "outgassing" causing small bubbles to form on the instrument and windows. Bubbles on the windows will greatly modify the scattering pattern, rendering the ZSCAT useless. A rectangular plastic container has been provided for doing ZSCATs. It requires that the optics end of the instrument be inserted into the chamber. A thick ‘O’-ring seals the chamber to the instrument. The instrument should be placed horizontally on the supplied white plastic supports. Roughly 2 liters of water is needed to do a ZSCAT.

Clean optics end before ZSCAT

Because the complete end of the instrument is submerged, it is important to thoroughly clean and rinse the instrument before acquiring a ZSCAT

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

Avoid Direct sunlight

Direct sunlight should also be avoided when obtaining a ZSCAT. The unit is relatively insensitive to sunlight; however, bright light can increase the noise in the measurement and give a false background scattering measurement. It is recommended that the end of the instrument be shrouded with a dark cloth during the acquisition of the ZSCAT. In general, the ZSCAT should be taken in conditions that match the deployment conditions as closely as possible.

The low concentration limit of LISST-100 is very sensitive to the ZSCAT calibration. For this reason, when working in near-surface or mid-depth water, a good ZSCAT file should be obtained with clean water. As particle concentrations increase, the relative signal-to-background noise ratio also increases, thus reducing the importance of a ZSCAT. *However, ZSCATs should always be done before an experiment.*

Plastic bags, Tupperware or clean containers of any kind can be used, and instrument 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.

ZSCATs should always be done before an experiment.

STEP BY STEP PROCEDURES FOR DATA ACQUISITION

The following topics are covered with Step by Step instructions.

Selecting and Loading Programs	Step-by-step procedure for loading a program into the datalogger memory is covered. It is assumed that you are communicating with the instrument using the TTOOLS.EXE program and that a program is not running on the datalogger.
Executing Programs	After loading the program, it may be started using the RUN command at the OK> prompt. The Step by Step table describes some of the procedures and events for various programs.
Retrieving Stored Data (Downloading)	The data which the instrument acquires are stored in a portion of RAM called the datafile. The proper procedure for off-loading data from the datafile of the datalogger to a binary file on the PC in this Step by Step table.
Recording and storing a Background Scatterfile	Recording a background scatterfile is the first step in acquiring data. This step-by-step describes the proper procedure to record and download a background scatterfile.

STEP BY STEP PROCEDURE: LOADING A PROGRAM

Step	Action	Result
1	• Decide which program is to be loaded. Select from the provided programs or custom-written programs.	Desired program selected.
2	• Clear memory of any program currently loaded by sending a NEW command at the OK> prompt. *Note that the NEW command will only clear the program memory; the data storage memory and program variables are not affected by the NEW command.*	Memory cleared of any currently loaded program.
3	• To load the program, select "Load Program" from the "Tattletale" menu or press <ALT-L> keys. • "Double click" on the name of the desired program or use the arrow keys and the tab button to switch to different portions of the window. • Once the desired file is highlighted, press <Enter>.	The desired program loaded.
4	• To ensure that the proper program was loaded, you may list the current program in memory to the screen. To do this, send a LIST command at the OK> prompt. The LIST command will display the lines of the program on the screen. *Most programs are larger than one screen and will scroll most of the program off the screen. TTOOLS has a built-in buffer that allows the scrolled text to be viewed by using the arrow keys and PGUP/PGDN keys. The mouse may be used with the "scroll bars" on the side of the screen.* *If a program exists in memory when a new program is loaded, it is possible to get a hybrid program that may not function properly. The best procedure is to always execute a NEW command before loading a program.* *A variation of the LIST command can also be used. For example, LIST 2250,3000 will only list lines with line numbers between 2250 and 3000.* *The loaded program remains in the memory until a NEW command is executed. The lithium backup battery that maintains the data storage memory also maintains the program memory. Therefore, after a program has been loaded and the power removed, the program will stay resident in memory until the lithium battery is removed.* *Restoring main battery power will cause the program to execute.*	

STEP BY STEP PROCEDURE: RUNNING A PROGRAM

Step	Action	Result
1	• To start the program, type RUN and press <ENTER> at the <OK> prompt. *Most programs will display some text to show that they are running. This may be a program title and date of last update or some other text.*	Program identifier displayed.
2	*Some of the provided programs will prompt for the current date and time. The LISST-100 datalogger has an on-board clock that only operates when the main battery is connected. The clock is reset to midnight (00:00:00) of Jan. 1, 1980 when power is removed. The datalogger will also be reset to Jan. 1, 1980 when returning from its low power hibernation state or DONE mode.* • To reset the clock, see the section on Programming below. Details on the DONE mode are also provided in that section.	Clock reset.
3	• If prompted for time delays, start dates, or depth thresholds, respond with a number followed by pressing the <ENTER> key.	Required parameters are set.
Notes	A program will run until: • programmed to stop, such as when the memory is full or an event is complete, • a <CTRL-C> is executed, • an error occurs. Errors occur if a line has an incorrect command or if a parameter for a command exceeds its range. • the main power is removed. *The execution of a program is not affected by the connecting or disconnecting of the communications cable. With the cable disconnected from either the computer or the underwater connector, text normally printed to the screen will be lost.* *The use of PRINT statements when the communications cable is disconnected will not disturb program execution. The power consumption will increase when the communications cable is plugged onto the external connector. The RS232 driver circuit drops into a low power mode when the cable is not connected.* **Always install the plugs onto the underwater connectors before submerging the instrument.**	

STEP BY STEP PROCEDURE: DOWNLOADING STORED DATA

Step	Action	Result
1	• Connect communications cable and run TTOOLS.EXE.	Program started.
2	• If the data acquisition program is still running, stop its execution with a <CTRL-C>.	
3	• From the OK> prompt, type in PRINT D followed by a <RETURN>.	Number of bytes stored to the datafile displayed.
4	• To offload data, select "Off-load datafile" from the "Tattletale" menu or press <ALT-O>. • When prompted for the start address and the end address, enter Start address as 0 and the End address as the value of D-1 using the tab key or mouse. • Select Off-load and press enter.	A window will appear asking for the start address and the end address. The value of D displays at the bottom of the screen.
5	• When prompted for a filename to store the data into, enter the filename and select <OK>. *It is typical convention to name the file with a .BIN or .DAT extension. This signifies that the file is in binary format.*	The data off-loading starts, and a display will show its progress.
Notes:	*When the screen returns to the <OK> prompt, the data off-loading has been completed. The data will remain in memory of the LISST instrument until it is overwritten or both the main battery and backup battery are removed.* *In the provided programs, 40 values are stored for each measurement (or scan). Each value has a size of 2 bytes. Therefore, each scan requires 80 bytes of memory. A memory pointer is used to keep track of how many bytes have been stored. In the programs provided, this pointer is the variable D. Each time a byte of data is stored the value of D is incremented by 1.*	

STEP BY STEP PROCEDURE: RECORD AND STORE BACKGROUND SCATTERFILE

Step	Action	Result
1	• Clean instrument and install Horizontal test chamber. • Fill with clean filtered water	Optics submerged in water
2	• Connect communications cable and run TTOOLS.EXE. • If the data acquisition program is still running, stop its execution with a <CTRL-C>.	Communications program started. OK> prompt showing
3	• Load and run ZSCAT.TTB. 100 scans will be stored in the datafile. Prompts on the screen will display the progress.	Background scatter data is stored in memory.
4	• A message will be displayed showing the range of data to offload. Offload this range of the datafile. See the Step by Step instructions for datafile offloading.	Data will be offloaded to a binary file on the PC
Notes:		

The processing of the acquired data into particle size distributions and volume scattering functions is done by a separate program, LISST.EXE running on a PC with Windows-95.

Intro to LISST.EXE

LISST.EXE is a 32-bit program that runs on Windows-95, Windows-98, and Windows-NT. It contains all of the software necessary for processing of the raw data into size distributions. Future versions will also include all of the features that are currently covered by the DOS program, TTOOLS.EXE. The TTOOLS.EXE program is only used to load and start programs in the datalogger and to download stored data. It is not used to process the data.

In order to process the raw laser scattering information into particle size and concentration a series of mathematical operations and inversions must be performed. This processing of the data can be from stored data or from real-time data. The processed data can be viewed on the screen and output to an ASCII file. The ability to acquire and store an averaged sample from the real-time mode is also included.

Features of LISST.EXE

The LISST.EXE program has four major functions: to process raw data, display processed data, acquire real-time data, and process background scatter data.

Raw data processing features include selecting a range of data to process from a plot of the auxiliary parameters such as depth, temperature, or transmitted laser power. This allows the user to select particular events or profiles to process.

After processing the data it may be viewed on the screen. Some features that are available while viewing the data are: timed playback of size distribution and Volume Scattering function, display of total suspended volume, display of mean size, display of auxiliary parameters such as pressure and temperature, and display of size and concentration at a point by mouse selection.

The ability to process data in real-time is also included. The size distribution can be processed in real-time at about a 1 Hz rate. The size distribution is displayed to the screen and stored to a file at fixed rates or by individual samples. The ability to acquire a background scatterfile or an averaged data sample is also included.

STEP BY STEP PROCEDURES FOR DATA ANALYSIS

The following step-by-step procedures have been written to assist the user in learning the LISST.EXE program. All of the features of the software are covered in simple step-by-step instructions. The software is described in the following sections.

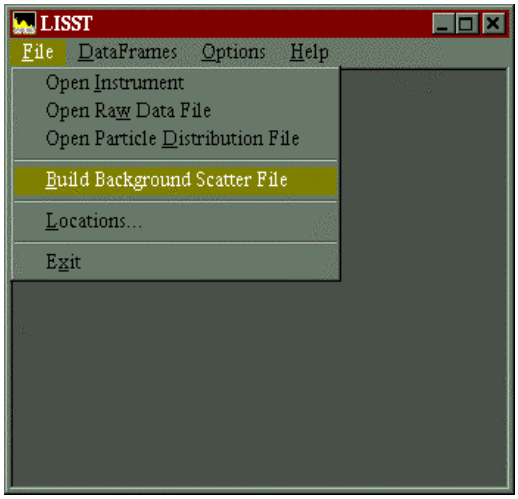
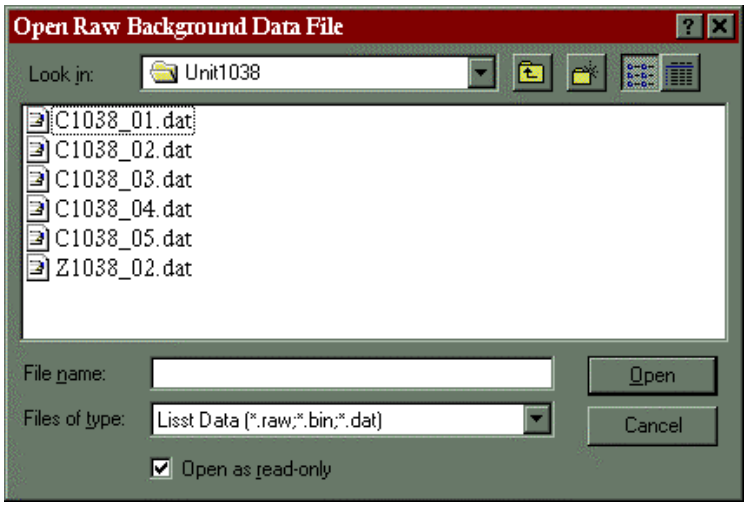
Build background scatter file — The first step before processing the raw data is to process the background scatterfile. This step-by-step procedure converts the raw binary file into an averaged ASCII file. It also shows the user how to check the quality of the background scatterfile and current status of critical instrument parameters

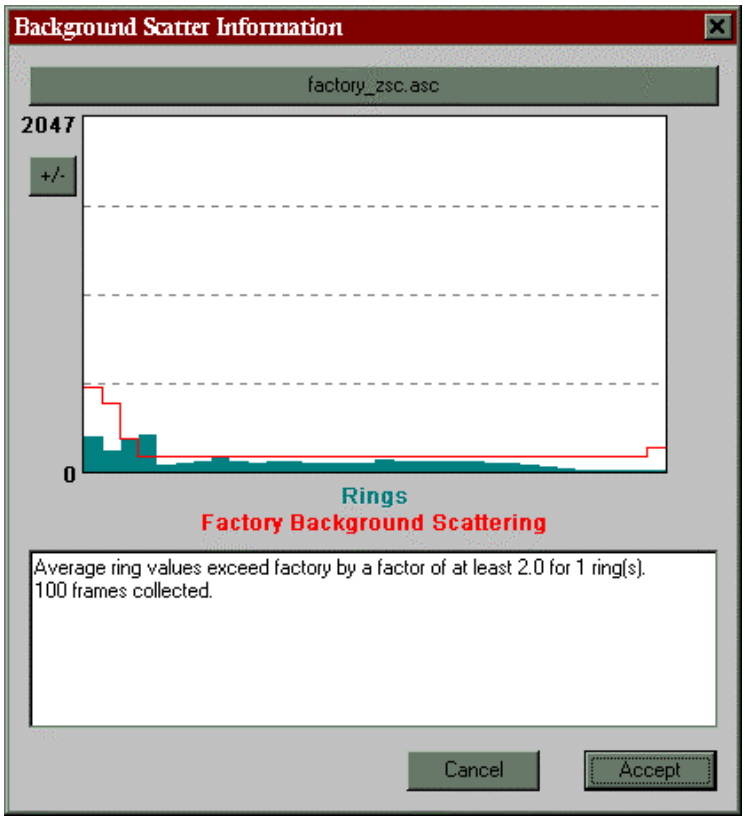
Process raw data — Data that has been downloaded from the datalogger is in a raw binary file. It must be processed into particle size by the LISST.EXE program. This step-by-step procedure covers the processing steps including optional displays and procedures.

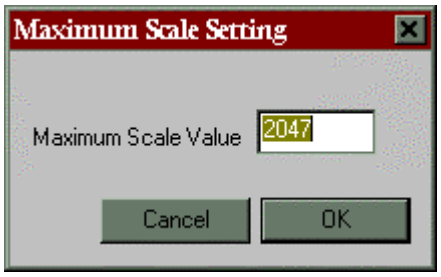
View Particle size data — After processing of the data into a Particle Size Distribution (PSD) file the data can be viewed to the screen. This step-by-step procedure covers the viewing of data and optional displays.

Process data in Real-time — Realtime processing of data requires running a special program on the datalogger that output the raw information to the LISST.EXE program. This step-by-step procedure covers the acquisition and storage of processed data.

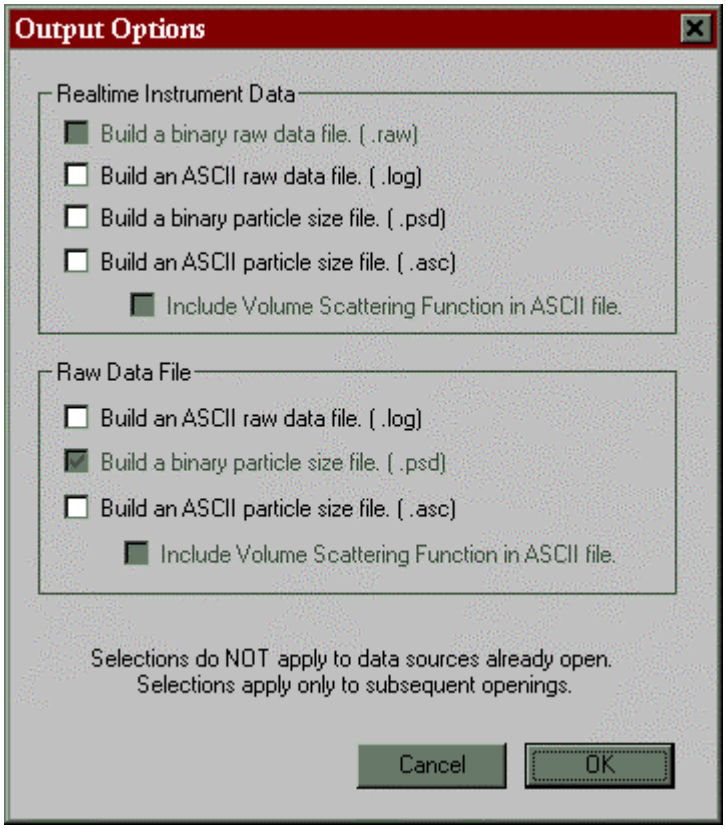
STEP BY STEP PROCEDURE: PROCESSING BACKGROUND SCATTERFILE

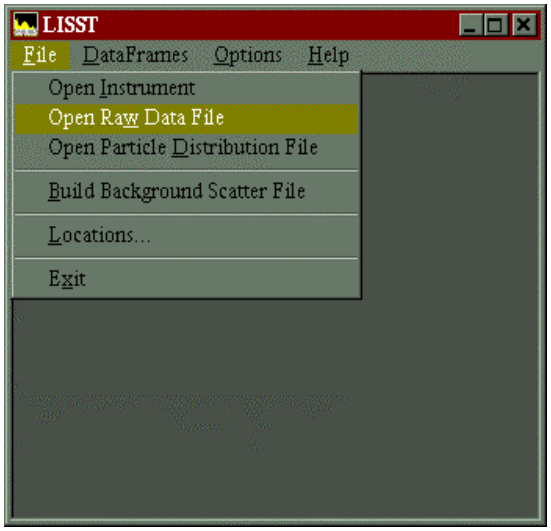
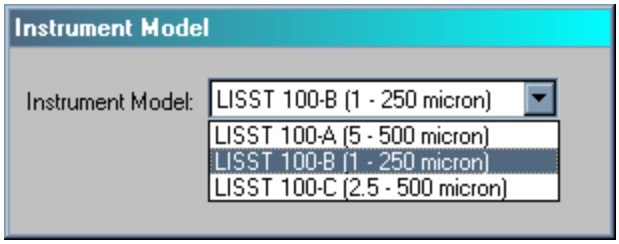
Step	Action	Result
1	• Run ZSCAT.TTB and download data. .	Raw background scatter data in a file.
2	• Start LISST.EXE program • Select Build Background Scatterfile from the File menu 	Program started. Build Background Scatterfile selected.
3	• Select the name of the raw data from the file selection display. Double click name or type name and select Open. 	Raw data file selected.

4	• After selecting a raw data file a display will appear showing the averaged background scatter data and the factory background scatter data. This screen allows the user to check the quality of the background scatter file and current status of critical parameters such as laser power and alignment. A typical display is shown below.  Warnings and other information will be listed	Averaged background scatterfile display to the screen.
5	• The red line is the factory background scatterfile. The file used for this display can be changed by selecting the button above the plot. Press the button and select the desired file from the file selection window.	Background comparison file selected.

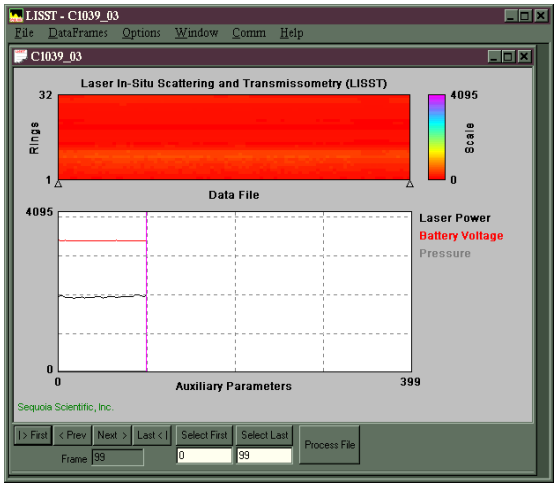
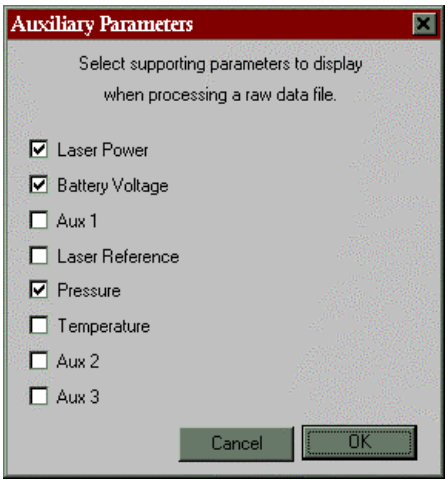
6	• The scale of the plot can be selected by pressing the +/- button. This will bring up the window shown below.  It will allow the maximum scale of the display window to be changed. Type in the desired value and select OK.	Scale of display selected.
7	• After reviewing the scattering file the it may be stored by selecting the Accept button. If the file is not acceptable select Cancel and no file will be created.	Background scatterfile is either accepted or canceled.
8	• If the file is accepted a file selection window will be displayed and prompt for a name to store the average ASCII file to.	Name selected and file saved.
Notes:		

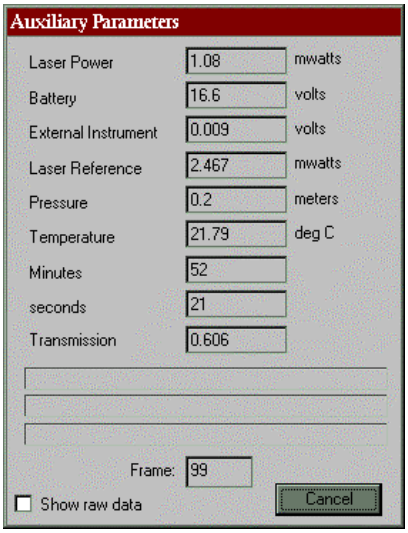
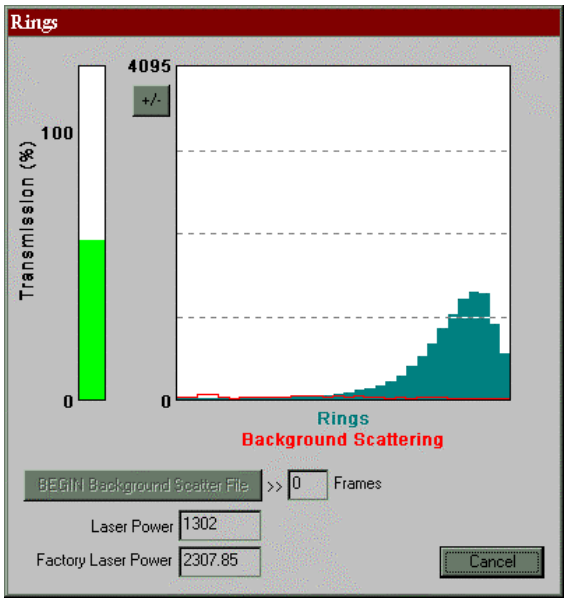
STEP BY STEP PROCEDURE: PROCESSING RAW DATA

Step	Action	Result
1	• Start LISST.EXE program • Select Output from the Options menu. The window below will appear prompting for the desired output to use for the future data processing. Note: this selection must be made BEFORE starting the processing command. 	Program started. Note: A binary PSD file is always created when processing raw data. This is used to display the processed data to the screen. The ASC type is a spaced delimited file containing all the processed data. Optionally the volume scattering function data can be included in this file. The LOG file is a space delimited file containing the raw data from the datalogger.

Step	Action	Result
2	• Select Open Raw Data File from the File menu 	Begins process of specifying raw data file and all information needed for data processing.
3	• Choose instrument type from the window displayed on your screen (shown below).  All new instruments will be of Type B (1.25 - 250 microns) or Type C (2.5 –500 microns). Older instruments may be of Type A (5 - 500 micron). After choosing instrument type, press OK.	Instrument type selected.
4	• Select the raw data file from the file selection window that appears on your screen. Double click the file or type the file name and press Open.	Raw data file selected.
5	• Select the ring normalization file from the file selection window. Double click the file or type the file name and press Open.	Ring calibration file selected.
6	• Select the background scatter data file from the file selection window. Double click the file or type the file name and press Open. This file must have been previously processed into an ASCII file using the Build Background Scatterfile command.	Background scatterfile selected.

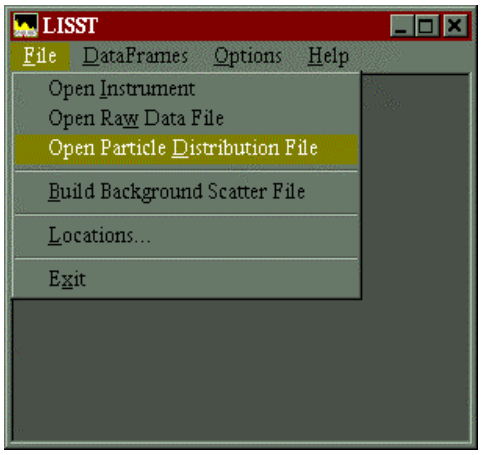
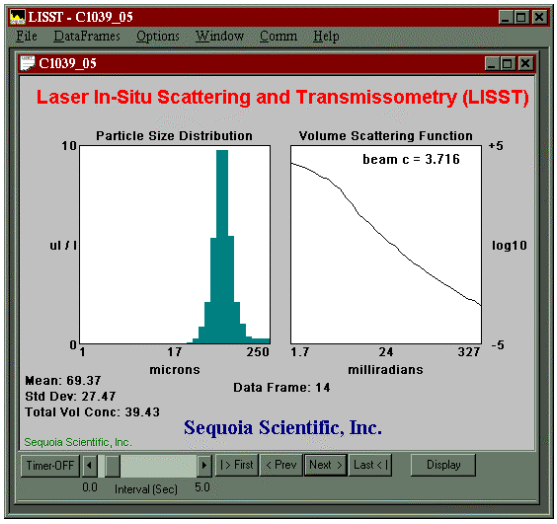
7	• Select the output data file name. The default file name shown is the same as the raw data name but with a different extension. You can change this name if you wish. Provide the file name and press Save. If other output types are selected they will have the same base name with different extensions. Note: file types other than the default PSD file must have been selected before starting the Open Raw Data file command. See step 1.	Output data file name selected.

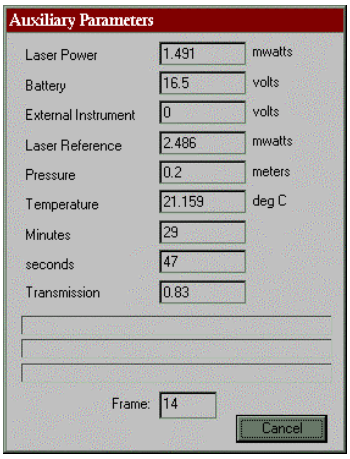
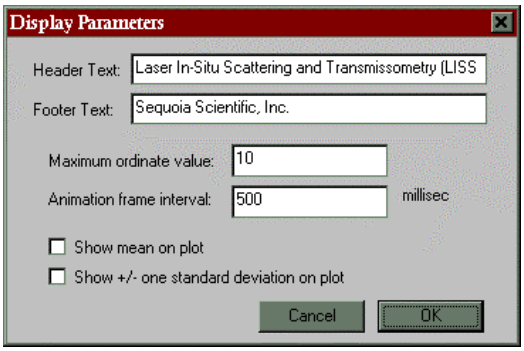
Step	Action	Result
8	• A display similar to the one shown below will appear.  • The top portion of the display is a graphical representation of the raw data on the 32 rings. The value of the 32 rings is represented as a vertical line with time moving from left to right. • The lower portion of the display shows the time history of some of the Auxiliary parameters. This can be useful for determining when the instrument came out of the water or when a particular profile was started. This is useful for determining what range of the datafile to process. Which Auxiliary parameters to display can be set by selecting the Auxiliary Parameter Display from the Options menu.  • Note that only 400 samples of the Auxilary Parameters are displayed at a time. Use the Next and Previous buttons to move through the complete datafile.	Main data processing selection window displayed to the screen.

Step	Action	Result
9	• Additional information is stored in the processed datafile. The Auxiliary parameter window displays these values for the current sample pointed to by the vertical cursor. They will update as the cursor is moved. The window is opened by selecting the Show Auxiliary Parmeter Frame from the DataFrames menu. An example of this window is shown below. 	Auxiliary parameter window displayed.
10	• The raw scattering values can be graphically displayed by selecting the View Rings command from the DataFrames menu. An example of this display is shown below. 	Value of rings for current frame displayed.

Step	Action	Result
11	To select the range of raw data to process position the cursor at the desired starting sample. The display at the lower portion of the screen will show the current sample or frame. Pressing Select First button will set the current cursor position as the starting point for processing. Similarly selecting Select Last will set the end point for processing. Use the Next and Previous buttons scroll through the complete datafile. The first and last points do not need to be on the same displayed plot.	Range to process selected.
12	After selecting the range to process select the Process File button. The display will show the processing progress and the Process File button text will change to Finished when the processing is complete. The window can now be closed.	Processing Completed
Notes:		

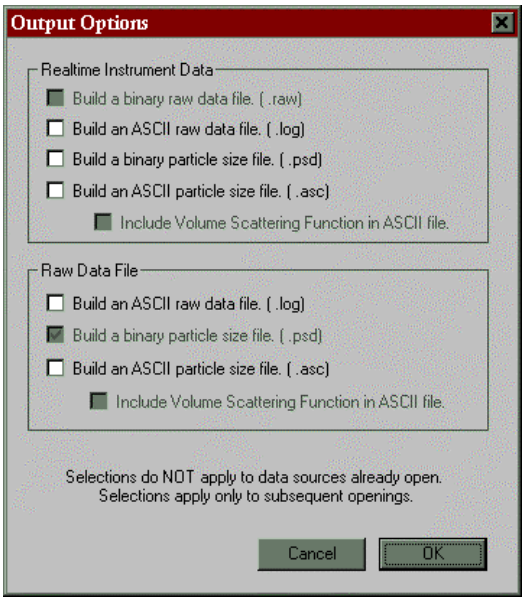
STEP BY STEP PROCEDURE: VIEW PROCESSED DATAFILE

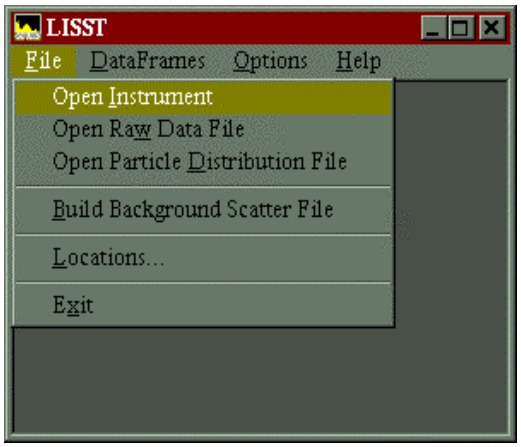
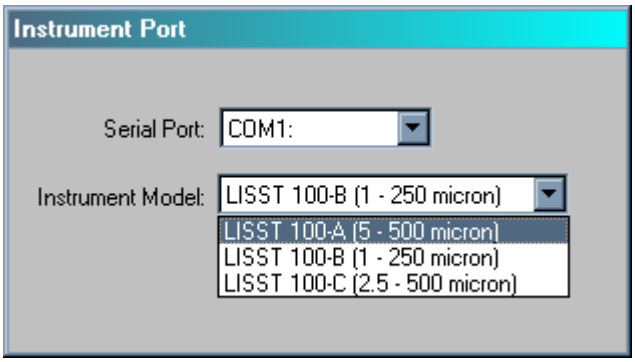
Step	Action	Result
1	• Start LISST.EXE program • Select Open Particle Distribution File from the File menu. 	Program started. Open Particle Distribution File selected.
2	• Select the processed data file from the file selection window. Double click the file or type the file name and press Open.	Processed datafile selected.
3	• After selecting the processed file a window similar to the one shown below will appear.  • The left hand display is the volume distribution in unit of micro-liters/liter in each size class. The right hand display is the Volume Scattering Function. In future versions the right hand display will have a number of different display options.	

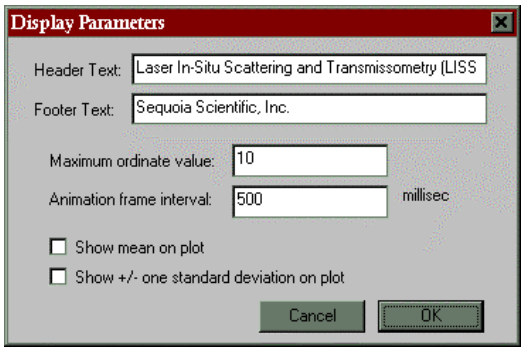
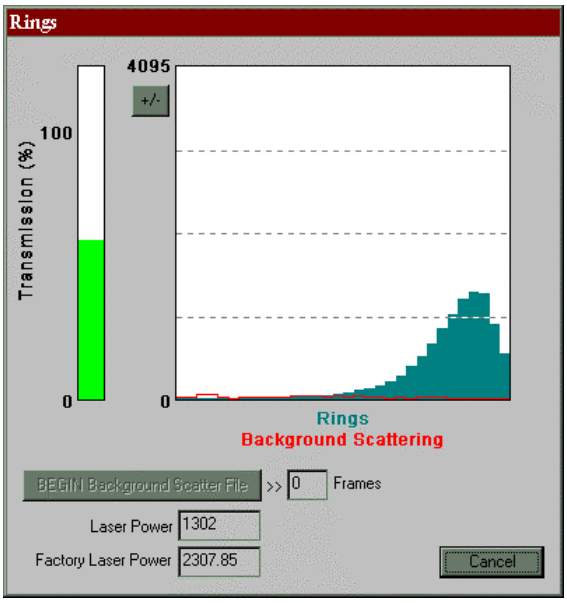
Step	Action	Result
4	• Only a single sample is displayed at a time. By using the buttons on the bottom of the display it is possible to manually or automatically step through the datafile. The Timer button will step through the datafile by updating the display at a fixed rate. The rate is set by the slider bar next to the timer button.	
5	• Additional information is stored in the processed datafile. The Auxiliary parameter window displays these values for the current sample. They will update as the Volume distribution is changed. The window is opened by selecting the Show Auxiliary Parameters Frame from the DataFrames menu. An example of this window is shown below. 	
6	• The scale of the Volume Distribution plot can be changed by using the Display button. After selecting the button a display similar to the one shown below will prompt you for the maximum concentration for the Y-axis of the plot.  • Other options are also available for customizing the display such as changing the header and footer text or adding lines to show the mean and standard deviation.	Display setting modified.

Step	Action	Result
8	• The current display can be sent to the print by choosing Print from the File menu.	Display printed.
9	• When finished viewing the processed data close the window .	Viewing of data complete.
Notes:		

STEP BY STEP PROCEDURE: REAL-TIME DATA PROCESSING

Step	Action	Result
1	• Load and Start the REALTIME.TTB program on the datalogger of the LISST-100. This will output the raw data to the LISST.EXE program. See the Step by Step procedures for loading and running programs for details • Exit TTOOLS.EXE and any other programs that are using the serial port connected to the LISST • Start LISST.EXE program.	REALTIME.TTB program running on the LISST-100. LISST.EXE running.
2	• Before starting communication with the LISST-100 the output file options must be set. This must be done before selecting Open Instrument. Select Output from the Options menu. The window below will appear. 	Output file type selected. Note: A binary PSD file must be selected before any other file type will be stored. This is used to display the processed data to the screen. The ASC type is a spaced delimited file containing all the processed data. Optionally the volume scattering function data can be included in this file. The LOG file is a space delimited file containing the raw data from the datalogger

3	• Select Open Instrument from the File menu. 	Open Instrument selected.
4	• After selecting Open Instrument the window shown below will open. Select the proper Serial Port and Instrument type and select OK. 	Serial port and Instrument type selected.
5	• Select the background scatterfile that should be used with the realtime data from the file selection window.	Background scatterfile selected.
6	• A display will appear on the screen. It is similar to the main window of the View Processed Data function. • By selecting the Next button the window will be updated with the current size distribution. Note that if the water is clean the display may not show any volume distribution.	
7	• The Timer button function is similar to its use in viewing processed data. The timer will automatically acquire data at a fixed rate. Note that this rate is limited to about 1 Hz due to the processing of the raw data into Volume distributions. The slide button next to the Timer button controls the sample speed. If it is set too fast it will automatically reset to the maximum allowed rate.	Timer button pressed and samples updating automatically.

8	• The Auxiliary parameter window can be opened to display the current values of the auxiliary parameters such as pressure and temperature. The window is opened by selecting the Show Auxiliary Parameter Frame from the DataFrames menu.	Auxiliary Parameter window opened.
9	• The scale of the Volume Distribution plot can be changed by using the Display button. After selecting the button a display similar to the one shown below will prompt you for the maximum concentration for the Y-axis of the plot.  • Other options are also available for customizing the display such as changing the header and footer text or adding lines to show the mean and standard deviation.	Display setting modified.
10	• The raw scattering values can be graphically display by selecting the View Rings command from the File menu. An example of this display is shown below. 	Value of rings for current frame displayed.

11	• A feature that is available in this mode is the ability to acquire a Background scatter file in real-time. With the timer active, select the Begin Background Scatter File button. The frames counter will increment with each measurement. After a sufficient number of measurements has been collect select the button now labeled Finish Background Scatter File. The data will be processed and displayed to the screen with the Factory Background Scatter file. If it looks similar to the factory file select Accept. After select and file to store the processed background data to the display will return to the Volume Distribution window. The acquired background scatter file is now being used to process the real-time data. This feature is quite useful for doing laboratory samples. The user can fill the small volume chamber with clean water, check that the windows are clean by acquiring a background, and then add the sample.	Background scatterfile acquired in real-time.
12	• Similar to acquiring a Background Scatter file an averaged volume distribution can be acquired and save to a file. This is initiated by selecting the Acquire an average button. • Select the number of averages and the filename to store the processed data to. The output format will be the same as the processed ASCII data format listed in Appendix B. • After acquiring the data the averaged results will be displayed on the screen.	Averaged data acquired and stored to an ASCII file.
13	• A additional files may be stored by selecting the Average Button. Similarly a new background scatter file may be obtained.	Additional files acquired.
14	• When finished, close the main window to stop communication with the LISST-100. CAUTION: The program is still running on the LISST-100. If external power only is being used turning off power will be sufficient. However, if batteries are being used the program will need to be stopped by sending a Ctrl-C to the running program.	Finished and shutdown.

This section contains some tips on the use and maintenance of the LISST-100.

A zinc anode has been installed on the end cap of the LISST-100. The exposed parts of the instrument are electrically connected to this anode. When submerged in salt water, the zinc will protect the instrument from corroding. Over time the zinc in this anode will be used up. Replacement anodes are available. In addition to an anode, it is recommended that the LISST-100 be electrically isolated from any metal mounting hardware. The use of rubber or plastic will keep the LISST-100 from being an anode for the metal frame work or other instruments.

The LISST-100 is a high-precision optical instrument. Rough handling will damage the internal optics and critical alignments. When mounting the instrument to a CTD frame, tripod, mooring, or other fixture, protect the instrument from mechanical shocks or impacts.

During long-term deployments, biological growth can occur on the instrument and windows. "Bio-fouling" of the windows can change the background scattering pattern. Similarly, sediment settling on the windows can cause problems. To reduce these problems, it is recommended that the instrument be mounted so that the faces of the windows are vertical. The use of poisonous material on or near the windows has been made in the past to reduce the amount of biological growth.

The transmissometer community has tried different approaches with varying degrees of success. We are experimenting with the poisons and other techniques currently in use in the community to determine which will work best for the LISST-100. In addition to poisons, another strategy is to obtain a ZSCAT at the end of an experiment. The ZSCAT must be done without disturbing the growth on the window. This post-experiment measurement can be used to make estimates of errors induced by bio-fouling.

The LISST-100 is relatively insensitive to natural lighting. However, it is recommended when working in shallow water that the optics end of the case be pointed away from any bright light source.

Instrument Storage & Maintenance

Again it must be emphasized that the LISST-100 is a sensitive instrument. When not in use, the instrument should be stored in a well padded case. For longer storage (year or so), the communication cable should be disconnected and the battery pack should be disconnected or removed. If you do not wish to remove the battery or disconnect it, battery life can be prolonged with the use of the SHUTDOWN.TTB program. This program will use no more than 10% of a typical battery life over a 6 month duration.

As has been noted earlier, the condition of the windows is critical to the performance of the LISST-100. 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. We recommend against the use of stronger solvents such as Acetone or Toluene.

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

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

Continued on the next page...

The LISST-100 should not require any adjustment or calibrations. The pressure and temperature sensors can be re-calibrated if desired. The performance of the instrument can be checked with the use of a sample of particles of a known size distribution.

Comparison of the LISST-100'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.

A large drop in the laser transmission reading, which may be noticed while doing a new ZSCAT between deployments, may suggest that the instrument has become misaligned. As discussed earlier, the laser beam passes through a small hole in the center of the ring detector. If the instrument is subjected to a hard impact, the optics alignment could change thus causing the beam to not go through the hole. The laser beam will then scatter some or possibly all of its power onto the ring detector thus saturating the detector. If the recorded value of laser power transmitted drops abruptly, the LISST-100 will need to be returned to the factory for realignment.

Maintenance Notes

Battery Power and Access

The main battery is mounted to the connector end cap. SEQUOIA supplies batteries for use with the LISST-100 instrument. The use of batteries other than these may void your warranty. When using laboratory power supplies, the user must exercise extreme caution in using correct polarities on the external 3-pin connector. Reverse polarities or misconnection may damage the electronics, the repair of which would not be covered under the warranty. Although the data backup battery will preserve the data for over two years, we recommend that the data backup battery be replaced before each long field deployment. If you do remove the back-up battery, the instrument loses track of how much memory (RAM) it has. To restore this information, after replacing the back-up battery, load and RUN the program ZSCAT.TTB once.

The step-by-step procedure for accessing and replacing the battery pack is described below.

STEP BY STEP PROCEDURE: CHANGING THE BATTERY

Step	Action	Result
1	• Mount the LISST-100 in a horizontal position. *U-blocks have been provided for this purpose.* • Disconnect all cables from the end cap. • Install caps on connectors to protect pins. **Caps MUST be installed on connectors before submerging into water.**	Caps installed on the connectors.
2	• Remove the three recessed bolts from end cap. *Use the Allen wrench provided. The threads of the bolts have been coated with an anti-seize compound. Spare bolts are included with the LISST-100.*	The recessed bolts removed from the end cap.
3	• Next, remove the end cap by grasping the ring attached to the end cap with standoffs and pull away from the case. Slight rotation will sometimes be helpful. *The end cap has an o-ring seal on the inside diameter of the case. The compression of the o-ring seal contributes to the effort required to remove the end cap.* *The end cap should remain parallel to the end of the case. Tipping of the end cap can cause binding.* **Do Not Pry the End Cap Off.** *When the o-ring on the end cap clears the case, the end cap and battery combination should slide easily from the case.*	End cap and battery removed from the case.
4	• Connect the white female 4-pin connector (labeled BATPWR) to the white male 4-pin connector (labeled TOPWR). Connecting these connectors will apply power to the electronics module. *The main power connector is located on the side of the battery pack. The white female 4-pin connector is connected to the battery pack. The white male 4-pin connector is attached to the electronics module located inside the case. Cables connecting the battery and underwater connectors to the electronics will limit its travel.*	Power on.

Continued on the next page...

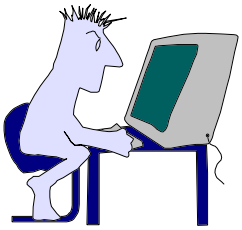
5	• To remove the battery, release the Velcro wrap and loosen the nuts on the threaded rods. *Before removing the battery, make note of its orientation so that the replacement battery can be positioned similarly.* • With the new battery in place, tighten the nuts on the threaded rods to finger tightness. Re-apply wrap allowing for access to the power connectors. **Make sure that the battery does not overhang the edge of the end cap diameter. If the battery is offset, the end cap may not seat properly, making installation difficult.**	Battery removed and replaced.
6	• Before installing the end cap into the case, clean and lightly grease the o-ring. • Remove the o-ring and inspect for any cuts or defects. *Use clean fingers to apply o-ring grease. Paper or cloth can leave fibers on the o-ring which can cause the o-ring to leak. The inside diameter of the case should be similarly cleaned and greased.*	O-ring greased and inspected for any defects.
7	• Install the end cap into the case by first lining up the holes in the end cap with the threaded holes in the case. • Applying uniform force, push the end cap into the case. After the end cap is inserted, slightly rotate the end cap. *A slight twisting motion will help the o-ring obtain a good seal. This will also allow the bolt holes to be lined up.* • Install the bolts, tightening evenly, until they are snug but not tight. **Do not over tighten. The stainless steel screws can damage the threads of the aluminum case if over tightened.**	The end cap installed into the case and the case is now sealed.

Technical Specifications

- Parameters measured/derived
  size distribution
  volume scattering function (VSF)
  optical transmission
  pressure
  temperature
- An external analog input (0-5V)
- Two external digital I/O ports (5V logic)
- Optical path length: 5 cm standard, 2.5 cm optional
- Optical transmission: 12 bit resolution
- Particle size range: Type B: 1.25 - 250 micron diameter, Type C: 2.5 –500 micron
- Resolution: 32 size classes, log-spaced
- VSF angle range: 1.7 to 340 mrad
- Data storage memory: 512K (6500 samples) expandable to 2 MB (26,000 samples)
- Maximum sample speed: 4 size distributions per second (standard)
- Temperature-sensor range: -10 to 45^{o}C resolution: 0.01^{o} C
- Pressure-sensor range: 0 to 300 m of H_2O, resolution: 8 cm of H_2O
- Dimensions: 13 cm (5") dia x 81 cm (32")
- Weight in air: 12 Kg (25 lb)
- Weight in water: 4 Kg (8.5 lb)
- Depth rating: 300 m (standard)

Section 3:

Programming



The LISST-100 uses a Tattletale Model 4A datalogger manufactured by Onset Computer Corporation of Pocasset, MA. This datalogger is widely used by the oceanographic community and other scientific and industrial groups requiring a small low-power datalogger. The Model 4A uses a modified version of BASIC called TTBASIC.

TTBASIC

A TTBASIC program is an ASCII file with a listing of commands. Each line is equivalent to entering the text at the OK> prompt of the datalogger. Therefore, a program listing can contain both immediate and program commands. An immediate command in a program listing will execute at the time the text is transmitted to the datalogger.

A program command starts with a line number between 1 and 32767 followed by a TTBASIC command or commands. Multiple commands can be placed on one line if separated by a colon (:). All commands must be in capital letters. Text that is to be printed to the screen using the PRINT command or comments/remarks using the REM command can be in either lower or uppercase letters.

Programming Requirements

One important limitation of TTBASIC is variable naming. There are only 26 variables represented by the capital letters A through Z, an array represented by the @ symbol with a dimension 1024 elements, and two variables using the ? symbol that are used for accessing the time features of the datalogger. The @ array's elements are accessed by following the @ symbol with the element number surrounded by parentheses. For example, PRINT @(0) would print the first element of the array to the screen. Variables values are not reset or otherwise modified when a program is executed.

Tabs should not be used in the text of a program. Tabs are not recognized by the command interpreter and will cause an error in the program. Spaces and blank lines can be used in the program to increase readability.

COMMAND LISTING

Overview

This section contains information about the TTBASIC commands available to the LISST-100 programmer. A few of the TTBASIC commands have been omitted because their use is not available or applicable to the LISST-100. A Quick Reference section briefly lists and describes each command. A Command Detail section describes a few of the commands in more depth.

QUICK REFERENCE

Immediate Commands

LIST , LIST x,y	List program or program lines between line number x and line number y
RUN	Execute the program currently in memory
STATUS	Show currents size of datafile, program, and array memory

Program and Immediate Commands

COUNT X	Store number of cycles at I/O pin 13 in variable X
FOR v = x TO y [STEP z]	Initiate loop, value of variable v will range from x to y in optional steps of z
NEXT v	Return to top of variable v loop
GOSUB x	Execute subroutine at line number x
RETURN	Return from subroutine to command following GOSUB
GOTO x	Start executing at line number x
IF x command	If expression x is not equal to zero, execute command
INPUT "prompt"v	Prompt for input, input loaded into var. v, no space between " and v
NEW	Erase currently loaded program
ONERR x	Go to line x if error occurs
PRINT "text",v(;)	Print text and variable values to screen; Optional, will suppress linefeed
REM	Ignore text on remainder of line
STOP	End program execution Note: Program also stops after executing highest numbered line.
XMIT- / XMIT+	Suppress/enable UART transmission
XSHAKE	Enable XON/XOFF

Functions

ABS(x)	Return absolute value of x
ASIN(x)	Return arc sin of x
CHAN(x)	Return A/D conversion of channel x
EXP(x)	Return 65536*EXP(x/65536)
LOG(x)	Return 65536*LN(x/65536)
PERIOD(x,y)	Return time for x cycles at I/O pin 13, y*10 ms time-out
PIN(x)	Return value at I/O pin x
SIN(x)	Return 32767*(SIN(x*16384/90))

SQR(x)	Return square root of x
TEMP(x)	Return lookup value (in units of 1/100 deg C) of x

Digital I/O Control

PCLR x	Clear I/O channel x to low state
PSET x	Set I/O channel x to high state
TONE x,y	Send x cycles of period y*1.6276 microseconds out I/O channel 12

Datafile Storage and Retrieval Commands

STORE v,#n,x	Store value of expression x with n bytes using pointer variable v
GET v,#n	Return value formed from n bytes retrieved using pointer variable v
OFFLD x,y,z,v	Xmodem datafile off load, range x to y, time out z, diagnostics to v

Low Power and Time Commands

DONE	Execute dominant mode
RTIME	Read real-time clock into ? array
SLEEP x	Sleep till x*10 msec from last SLEEP command
STIME	Write ? array to real-time clock

The Tattletale datalogger uses a ? variable to keep track of time. The five-byte ? variable contains the number of 1/100ths-of-a-second intervals from midnight Jan. 1, 1980.

The RTIME command reads this variable and places the values for year, month, day, hour, minute, seconds into the ? array. Specifically, ?(0)=seconds (0 to 59), ?(1)=minutes (0 to 59), ?(2) = hours (0 to 23), ?(3)=day (1 to 31), ?(4) = month (1 to 12), and ?(5) = year (0 to 99).

The STIME command will set the ? variable with the proper value based on the values of ?(0) through ?(5) at the time the command is executed. An example of these commands is found in the provided programs.

Another useful command that is available is the SLEEP command. The SLEEP command allows the programmer to execute commands at precise intervals. The command will wait a specified number of 1/100ths-of-a-second intervals, from the execution of the last SLEEP command, before continuing with the next line of the program. A SLEEP 0 will reset the internal timer. An example is shown below.

```
10 SLEEP 0   : REM reset sleep counter
20 PRINT "Start counting"
30 SLEEP 100  : REM sleep for 1 second from last sleep command
40 GOTO 20
```

The above code will print 'Start counting' to the screen at 1-second intervals. Note that the SLEEP 0 command is only executed at the start of the program. If the commands between SLEEP statements exceed the requested delay, an * will be printed to the screen, no delay will be added, and the sleep counter will be reset.

For example, if line 10 were omitted from the program listed above, a 'Start counting' , '*', and another 'Start counting' would appear almost immediately after starting the program. However, the third 'Start counting' would be 1 second after the second 'Start counting'.

Continued on the next page...

The maximum number of sleep cycles is 32767. It is recommended that small increments (1 second for example) be placed in a FOR-NEXT loop

to obtain larger delays. Small delays allow for the user to stop the execution of the program with a CTRL-C. The datalogger will only respond to a
CTRL-C at the completion of a line of the program
The Tattletale datalogger's power consumption decreases when executing a SLEEP command. The use of SLEEP command can greatly extend the life of the batteries. For long duration experiments, the datalogger can be put into a very low-power hibernation mode by using a command called DONE. The DONE mode will cause the power to be shut down to its lowest level. A 'Wakeup' circuit is included on the datalogger that will cause the datalogger to return to life and start executing its resident program from the beginning after a delay of 128 seconds. The program and datafile will be maintained by the lithium backup battery while in the DONE mode. The internal time clock will be reset to 00:00:00 Jan 1, 1980.

The hardware connections to the various sensors and digital ports are shown below.

Analog Channels

Chan(0)	Mux 1 output
Chan(1)	Mux 2 output
Chan(2)	Laser Optical Transmission sensor
Chan(3)	Battery Voltage
Chan(4)	Laser reference power sensor
Chan(5)	Aux input 2
Chan(6)	Pressure Sensor
Chan(7)	Thermistor

Digital Channels

0,1,2,3	Mux Address
5	Switch lever on endcap
6	LED on endcap
7	Laser power switch
10	Main power switch
12	Aux Input 1
13	Aux Input 2

Instrument Specific Data and Constants for Use in Software

The following page contains the information that is specific to your LISST-100 instrument. Included is the instrument serial number, size range (Type B or C), Calibration Constant for the volume concentration, and the calibration values for the auxiliary parameters such as pressure and temperature. If you have purchased multiple instruments each unit will have its own page.

LISST-100 Particle Size Analyzer
Instrument Specific Documentation

Instrument Data

Serial Number	
Manufacture Date	
Instrument Type	
Memory Capacity	
Owner	

Auxiliary Parameters

The table below lists the auxiliary parameter labels and calibration constants. These values are saved in the LISST.INI file. They can be viewed or edited using the "Edit Calibration Constants" from the DataFrames menu.

Auxiliary Parameter	Display Label	Multiplier	Offset	Units
Parameter 1	Laser Power	1	0	counts
Parameter 2	Battery			volts
Parameter 3	External Instrument	1	0	counts
Parameter 4	Laser Reference	1	0	counts
Parameter 5	Pressure			meters depth
Parameter 6	Temperature		0	deg. C
Parameter 7	Day*100 + Hour	1	0	
Parameter 8	Minutes*100 + seconds	1	0	
Volume Conversion Constant				

Additional Accessories

Notes

Reference Data:

Ring Values 1 – 5 (counts)

1
2
3
4
5

Laser Power (counts) =

Reference Laser Power =

Verified by: _____

Size Ranges, Angles of Observation and Data Storage Format

Size Ranges

There are 32 size ranges logarithmically placed from 1.25 - 250 microns in diameter, or 2.5 – 500 microns (the upper size in each bin is 1.180 times the lower).
The table below shows the median size of each size class. For clarity the table is shown with multiple rows. In the output data file the data for each size class is oriented in one row from small to large.

Type B Instruments – 1.25 to 250 micron size range

1.36	1.60	1.89	2.23	2.63	3.11	3.67	4.33
5.11	6.03	7.11	8.39	9.90	11.7	13.8	16.3
19.2	22.7	26.7	31.6	37.2	44.0	51.9	61.2
72.2	85.2	101	119	140	165	195	230

Type C Instruments – 2.50 to 500 micron size range

2.73	3.22	3.80	4.48	5.29	6.24	7.36	8.69
10.2	12.1	14.3	16.8	19.9	23.5	27.7	32.7
38.5	45.5	53.7	63.3	74.7	88.2	104	128
157	186	219	259	293	332	391	462

Angles

The median angles (in Degrees) for the VSF measurement are shown in the table below.

Type B Instruments – 1.25 to 250 micron size range

0.106	0.125	0.148	0.174	0.206	0.243	0.287	0.338
0.40	0.47	0.56	0.66	0.77	0.91	1.08	1.27
1.50	1.77	2.09	2.46	2.91	3.43	4.05	4.78
5.64	6.65	7.85	9.26	10.93	12.90	15.22	17.96

Type C Instruments – 2.50 to 500 micron size range

0.053	0.063	0.074	0.087	0.103	0.121	0.143	0.169
0.20	0.24	0.28	0.33	0.39	0.46	0.54	0.64
0.75	0.89	1.04	1.23	1.45	1.72	2.02	2.39
2.82	3.33	3.93	4.63	5.47	6.45	7.61	8.98

Raw Data Storage Format

The values in the raw data file are stored in the order shown in the table below.

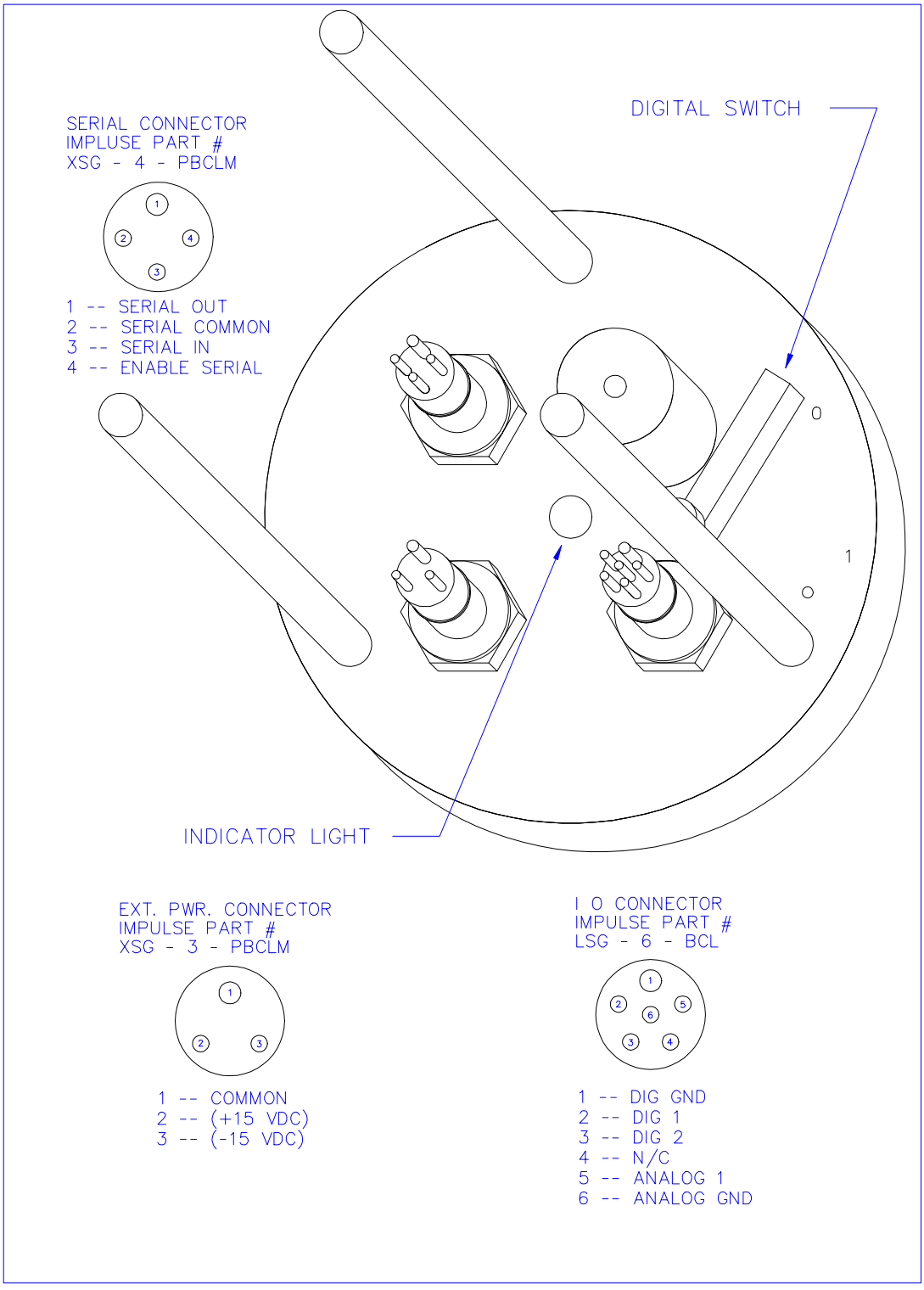
Elements	Parameter
1:32	Light intensity on detectors 1 through 32
33	Laser transmission Sensor
34	Battery voltage in raw counts
35	External Auxiliary input 1 (0 to 5V = 0 to 4096)
36	Laser Reference sensor
37	Pressure in raw counts
38	Temperature in units of 100ths of degrees C
39	Minutes at which data taken
40	Seconds at which data taken

Processed Data Storage Format

The values in the processed data file are stored in the order shown in the table below. Each sample is stored in one row.

Elements	Parameter
1:32	Volume concentration (in ul/l) for size class 1 through 32
33	Laser transmission Sensor
34	Battery voltage in calibrated units
35	External Auxiliary input 1 in calibrated units
36	Laser Reference sensor in calibrated units
37	Pressure in calibrated units
38	Temperature in calibrated units of degrees C
39	Minutes at which data taken
40	Seconds at which data taken
41	Computed % Optical transmission over path
42	Computed Beam-C in units of 1/m
(Optional) 43-75	Volume Scattering Function for 32 angles from small to large

Underwater Connector Pinouts for LISST-100



User's Notes:

Warranty

STATEMENT OF LIMITED, EXTENDED WARRANTY

This Statement of Limited, Extended Warranty applies to the products ("Products") being purchased by _____ _____("Customer") from Sequoia Scientific, Inc. ("SEQUOIA") pursuant to PO _____(the "Order"). The Products include, but are not necessarily limited to, the following:

LISST-100 Particle Size Analyzer **Serial Number # _____**

SEQUOIA and Customer agree as follows:

1. Limited Warranty

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

2. Correction of Non-Compliance

If any Product does not comply with the warranties set forth in 1(a) and 1(b) above, SEQUOIA will, at its option, either (a) repair the Product, (b) replace the Product, or (c) refund the purchase price paid by Customer to SEQUOIA for the Product; provided that Customer gives SEQUOIA written notice of the noncompliance within one (1) year after SEQUOIA's delivery of the Product (as the same may be extended for repaired or replacement Products as provided for herein, the "Warranty Period"). If Customer does not give SEQUOIA such written notice within the Warranty Period, then such warranties will be satisfied in full. Customer will cooperate with SEQUOIA's efforts to repair or replace any noncomplying Product. Without limiting the generality of the foregoing, Customer will comply with SEQUOIA's request for return of any such Product to SEQUOIA (in which event SEQUOIA will pay for round-trip shipment within the United States) or for access to accomplish the repair or replacement on Customer's premises. As to any Product repaired or replaced by SEQUOIA, the Warranty Period will end upon the later of one (1) year after SEQUOIA's delivery of the original Product or 90 days after SEQUOIA's delivery of the repaired or replacement Product. Any Product, component, part or other item replaced by SEQUOIA becomes the property of SEQUOIA.

3. Infringement Indemnification

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

4. Exclusive Warranties

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

5. Exclusive Remedies

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

6. No Consequential Damages

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

7. Limitations of Liability

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

8. Statute of Limitations

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

9. Software

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

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11. Controlling Document

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

12. Controlling Law

This Statement of Limited Warranty will be governed by the laws of the State of Washington without reference to its rules relating to choice of law, except to the extent preempted by the laws of the United States. The U.N. Convention on Contracts for the International Sale of Goods will not apply.

CUSTOMER:

By:_____
Title:_____

SEQUOIA:

Sequoia Scientific, Inc.

By:_____
Title:_____