LISST-Deep

Particle Size Analyzer

User's Manual

September, 2001

SEQUOIA

Table of Contents

Welcome to the LISST-Deep Particle Size Analyzer

Using this manual

This manual is divided into three sections.

Section One contains a basic introduction to the LISST-Deep instrument and the principles of its operation.

Section Two contains overview of the operation of the LISST-Deep in a tutorial format.

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

Technical specifications

The technical specifications for the LISST-Deep can be found in Appendix A. For a listing of instrument specific constants, as used in the software for data processing, refer to Appendix B.

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: The LISST-Deep Instrument

General Description

The LISST-Deep is a deep-water version of the standard LISST-100 instrument manufactured by Sequoia Scientific, Inc. It is offered in two versions: anodized aluminum housing, and a titanium housing. The aluminum housing is capable of operation to 5000 m. The titanium housing can be used to 6500 m. Either version is offered in Type-B (1.25 to 250 microns) or Type-C (2.5-500 microns). The instruments have internal data storage and batteries. Additionally, the instruments can be operated with external power.

Insert picture here

The photograph above shows the black anodized aluminum LISST-Deep. The instrument consists of two housings held together by a cylindrical mid-section. The cylindrical section has cuts for water passage. In the shorter housing, a laser collimator is enclosed. In the longer housing section, the detection optics are enclosed, along with the electronics and the internal battery. An external cable provides power from the electronics housing to the laser end. There are two underwater connectors on the electronics housing (the longer section). The first, a 5-pin connector at center of the endcap is for the cable to deliver power to the laser. The second, a 5-pin connector is for communications with the instruments. Before a deployment, this connector should either be capped with a plug. If the LISST-Deep has the optional SeaBird CTD Interface installed there will be a third connector. This connector will need to be connected to the CTD Aux port using the proper cable or the cap must be installed.

The cylindrical mid-section contains the glass pressure windows. These windows must be cleaned with alcohol or dish-soap and water before each deployment. Do *not* use abrasive powders for cleaning.

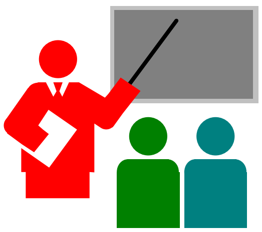
Never mount the instrument in a way that there are bending forces on it, as this will cause misalignment of the optics.

Principle of Operation

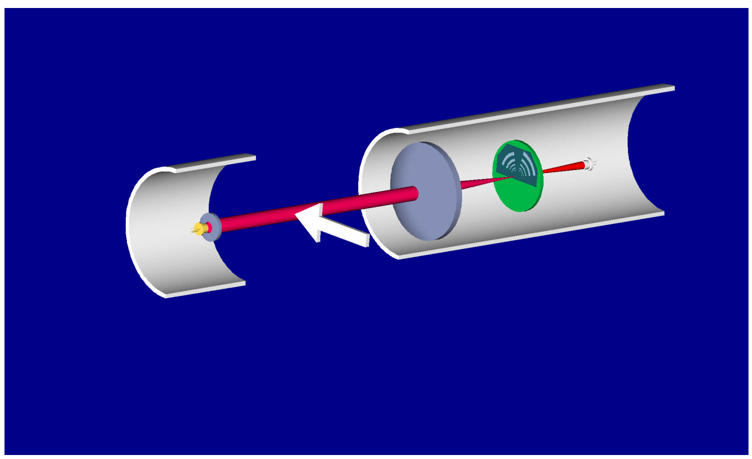
Background

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-Deep uses the technique of laser diffraction to obtain *particle size-distribution* (PSD). This section describes the basic principles of operation of the instrument.



At the heart of the instrument is an optical arrangement shown in the cut-away illustration below.



A collimated laser beam is formed to illuminate particles in the flow (arrow). Light scattered by these particles is collected by a receiving lens. At the focal plane of the lens, a specially constructed detector is placed. The detector consists of 32 photo-active silicon rings, each ring occupying a 60^o azimuth. These rings are log-spaced, i.e. each ring diameter is a fixed ratio larger than the previous inner ring. The inner-most ring has an inner radius of 102 microns. Each subsequent ring grows by a ratio 1.18, so that the outer radius of the 32^{nd} ring is 20mm.

Continued on the next page...

Each of the rings responds to light scattered from the particles over a small angle range. In this manner, the 32 ring detectors measure the intensity of light scattered over 32 angular ranges. In the Type-B instrument, the overall angle range is 0.1^o to 20^o. For the Type-C instrument, it is 0.05^o to 10^o.

At the center of the ring-detector, a small hole allows the focused laser beam to pass and be sensed by a photo-diode that is placed behind the ring detector. This constitutes a measurement of *optical transmission*. From this measurement, a value of *beam-c* can be computed in post-processing.

Electronics in the instrument digitize and store the output of the ring detectors and the transmission sensor. A built-in computer is used for scheduling of measurements, for communications, and for data storage. This computer is programmed in a version of BASIC language. Data is stored on a non-volatile flash memory. Even when battery power is removed, data is maintained in memory.

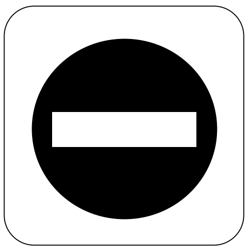
The processing of the stored data to convert to size distribution is carried out after data downloading, on the user's PC. Software for all operations, and data processing is provided.

For those interested in further details, please refer to the paper (*available from the company by request*):

Agrawal, Y.C., and H.C. Pottsmith, 2000: *Instruments for Particle Size and Settling Velocity Observations in Sediment Transport*, **Marine Geology** v168/1-4, pp 89-114.

Section 2: Operation Overview

General Precautions



LISST-Deep 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.

Operational steps

Instrument operation consists of just the following steps:

- Establish communication between LISST-Deep and a computer (*optional: erase prior data in memory*);
- Change default measurement parameters if desired;
- Start the data collection program;
- Launch the instrument;
- Upon retrieval, download data;
- Process data on a PC.

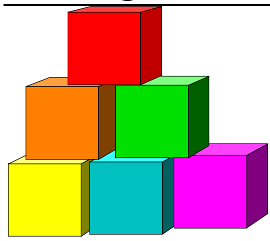
Warnings

Never mount the instrument in a way that there are bending forces on it, as this will cause misalignment of the optics.

WARNING

The LISST-Deep 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 reflecting 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-Deep. It gives 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 us assume that you are opening the LISST-Deep shipping case for the first time. Inside you will find the following: User's Manual with software disk, LISST-Deep instrument, Plastic Instrument stands, Communications cable, Allen wrench set, spare o-rings, and spare endcap 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-Deep from the case and set it on the stands. The LISST-Deep has two distinct ends that we will refer to as the Laser endcap and the Connector endcap. The connector endcap has two underwater connectors that are used for communication/external power and for the laser. The battery pack is attached to the inside of this endcap. The Laser endcap is attached to a case that contains the laser and optical components that generate the collimated laser beam.

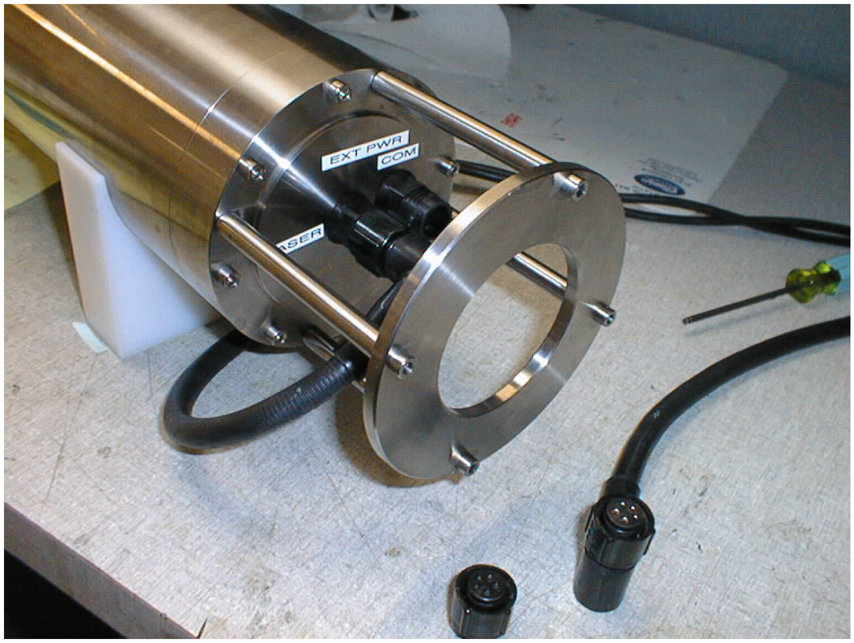
Step 2: Check for clean windows

At this time let us check the optical windows to make sure that they are clean. There are two identical windows. 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 water and then by wiping them with a soft cloth and alcohol. Standard dish soap or glass cleaner may also be helpful. 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 Laser and Communications Cables

If not already installed, the Laser cable will need to be connected. It is a 3-foot cable with 5-pin connectors on both ends. It connects the laser to the main electronics board. It is installed from the center connector on the Connector Endcap to the only connector on the Laser Endcap. The easiest way to remember the configuration is that the laser cable goes from center connector to the center connector.

Remove the Communications cable from the shipping crate. It is the cable with the 9-pin DB-9 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 and have the same number of pins. The Communication connector is the 5-pin connector located off-center. After removing the cap install the cable making sure that the proper pin alignment is maintained.



Step 4: Install the provided software on your PC

At this point the instrument is ready to go. Let us install the software that is required for operation of the instrument on to a PC. 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. Copy the contents into a directory on the PC to be used. The recommended directory is LISST. After copying the files from the floppy to the directory, copy the LISST.INI file to the c:\windows directory. This file contains the calibration constants and other settings for the LISST.EXE program. Shortcuts to the LISST.EXE and TFTOOLS.EXE programs are not created automatically. The user may find that shortcuts on the desktop will simplify the operation. The Windows help files describe how to create a shortcut on the desktop.

Step 5: Start TFTOOLS.EXE communications program

There are two different programs for the PC that are used with the LISST-Deep. They are TFTOOLS.EXE and LISST.EXE. TFTOOLS.EXE is a Windows based program that allows the user to communicate with the datalogger inside the LISST-Deep. TFTOOLS is used as a terminal window for the datalogger and also is used to upload programs and download data. The LISST.EXE program is a Windows-95/98/NT program that processes and displays the particle size information. At this point we will use the TFTOOLS.EXE program. Start this program by double clicking its icon.

A terminal window will appear with menus across the top. Select the *CommPorts* menu and then *Serial Port…* item. A window with the baud rate and port settings will appear. The LISST-Deep uses 19200 baud. Set the Port to the available communications port of the PC. Select OK to save the settings. The next time TFTOOLS.EXE is started it will use the previous settings.

The complete communication specifications for the LISST-Deep are: 19200 baud, 8 data bits, 1 stop bit, Handshake and Parity should be set to None.

Step 6: Wake up instrument from Sleep mode

The LISST-Deep is shipped running a program that keeps the instrument in its low power mode. After returning to the Terminal window you may see a message on the screen from the LISST-Deep. It will wake up every 10 seconds, print a message to the screen (*Deep Sleep...Enter zz now to wake up*), wait two seconds for a response, and then go back to its low-power sleep if there is no response. Wait for the program to display the message to the screen and then type *zz* and press enter to stop the program running on the datalogger. The Main Menu should appear.

Step 7: Main Menu options

The program running on the datalogger of the instrument displays a menu to the screen that allows the user to setup the instrument, acquire a background, acquire data, and operate the instrument in a real-time mode. It also allows the user to put the instrument in a low power sleep mode.

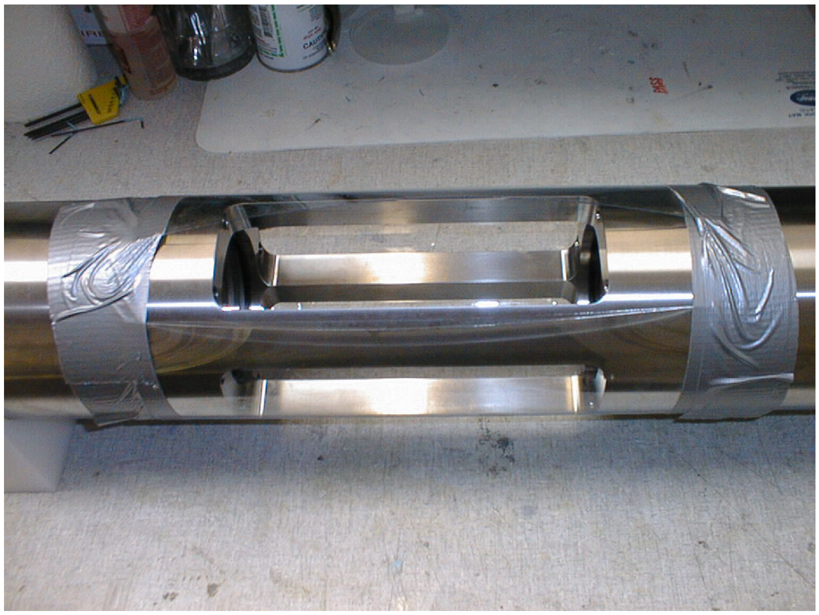
The main menu looks like the following:

```
Main Menu
  1.) Display Status and Configure
  2.) Acquire Background
  3.) Acquire Data
  4.) Acquire Data upon external power
  5.) Real Time Output Mode
  6.) Low Power Sleep Mode
  7.) Exit program
Enter Selection:
```

Enter the number of the command to execute and press enter.

Step 8: Acquire Background data

The background scattering from the optics must be measured and subtracted from the field data to obtain the scattering by only the particles of interest. Before acquiring the data the instrument must be submerged in clean water. A piece of thin clear plastic is provided with the instrument. This plastic can be wrapped around the sample section of the instrument and the ends sealed with water-resistant tape. This will allow the instrument to be "submerged" in water on the bench. The water used for the background data must be very clean and bubble-free.



Select the *Exit Program Option* (7) from the menu and press enter. This will exit the program and bring you to a # prompt. From this prompt the user can upload programs and download data. Before acquiring data we must first erase the contents of the datafile. This can be done by selecting the *Erase Datafile…* option from the *Tattletale* menu. Type *Alt*-r (hold down Alt and press r) to restart the program. The main menu should appear.

Select *Acquire background* (2) from the menu and press enter. A prompt will appear asking if you would like to continue. Check the windows of the instrument to make sure that no bubbles are stuck to the windows and press enter. Ten samples will be stored to the datafile. When finished the main menu will appear. Exit the program and down load the data using the *Xmodem Offload...* option of the *TattleTale* menu. All data that has been saved since the last time the datafile was erased will be downloaded. We will use this data for later processing. Restart the program by typing *Alt*-r.

Step 9: Setting Deployment Options

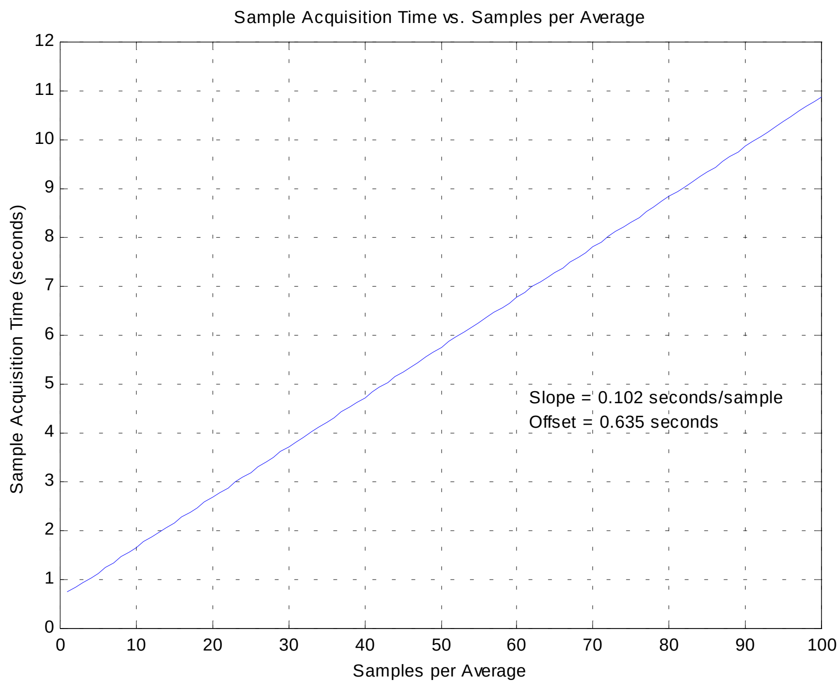
To set the options for use during data acquisitions, select the *Display Status and Configure* option. A menu will appear similar to the one shown below.

Current Status
1.) Current Date/Time = 8/24/2001 7:56:23
2.) Samples per average = 10
3.) Number of samples to acquire = 3000
4.) Time between samples (sec) =1
5.) Acquisition Delay (min) =10
Memory Used: 0 samples
Battery Voltage: 10.8 volts
Enter Selection to change or 0 to return to main menu:

This menu is used for two purposes. One is to display the current settings. The second is to allow these settings to be changed. To change a setting select the item number and press enter. A prompt will appear asking for a new value. Enter the new value and press enter. The Status menu will appear again. Press enter to return to the main menu.

The number of samples per average is adjustable. The minimum recommended value is 10. Higher values require more time (and more battery) to obtain an average. When working in very clean water 100 samples per average is highly recommended. The figure below shows the time to acquire a sample as a function of number of samples per average.

The variable *Time between Samples* is the time from the end of the last average to the beginning of the next average. It is not the sample interval. For example if samples per average is set to 100, with the time between samples set to 5 seconds the actual spacing of the stored values will be about 15.8 seconds.



Step 10: Acquire Field Data

To acquire field data select the *Acquire Data* option from the main datalogger menu. The program will start the execution of the programmed delay. After the delay samples will be acquired, averaged, and stored.

The program will acquire data until the selected number of samples is reached or until the program is stopped with a *ctrl*-c.

After stopping the program, the data will need to be offloaded as in Step 8 above. After downloading is complete, the datafile can be erased in preparation for the next data collection.

Entering Alt-r will restart the program. The main menu should appear.

Step 11: Put instrument back to sleep

To put the instrument back into its low power mode select the *Low power* option from the Main Menu. The instrument is now in its low power mode. Be sure to disconnect the communications cable for maximum battery conservation.

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

We will now switch to the LISST.EXE program. First we must exit TFTOOLS.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 its 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 10 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 background 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, 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: Select Output file types

After processing the background scatter file we can now move on to looking as some real data. The first step is to select the type of output we would like to save. The default is to save only a binary processed data file that can be later used for viewing the results using the *View Processed* Data command. To select additional outputs select the *Output* option from the *Options* menu. A window will appear that lists the various options. In the Raw Data file sections select the Build an ASCII particle size file option. This option will create an ASCII file with the processed data. Each sample will be a row in the file. Descriptions of the columns can be found in Appendix B. After selecting the output type we can move on to processing the data. Note: the output must be selected <u>before</u> the processing of the data is started.

Step 15: Process Raw Data command

Select *Open Raw Datafile* from the *File* menu. A prompt for the instrument type will be displayed. Select the proper type. Note: All new instruments are Type 2 (1 - 250 microns). Next, a prompt for the RingArea file will be displayed. Select the RingArea file for the instrument. Similarly, a prompt for the background scatterfile to use will be displayed. Enter the name of the file stored in the above step. A display with two graph windows will appear. The upper plot is a graphical representation of the 32 rings for the complete datafile. The lower plot shows the value of a few of the auxiliary parameters. Only 400 values at a time are display. Small triangles on the upper plot show the location of the 400 samples in the complete datafile. Use the next button to move through the frames of 400.

Step 16: Open View Ring and

Before processing the data let us take a look at a few additional windows that can be useful. Select *View Rings* from the

Auxiliary Parmeters

DataFrames menu. A display appears that shows 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 values for the eight auxiliary parameters. The computed value of transmission is also shown. These values are from the sample pointed to by the vertical cursor on the lower plot. Clicking the mouse on the lower plot will change the location of the cursor line.

Step 17: Select range of data to process

By default the complete datafile is selected for processing. By moving the vertical cursor and pressing the *Select First* and *Select Last* buttons a different range can be selected. Remember that only 400 samples at a time are displayed. Use the Next button to move to later samples. The Select First and Select Last values do not need to be in the same frame. After selecting the range to process press the *Process File* button. Text will be printed to the screen showing the status of processing. When the processing is complete the text on the *Process File* button will change to *Finished*.

Step 18: View Processed data

The raw data has now been processed into size distributions. The data is save as a binary file with the same name as the raw data but with a PSD extension. If the ASCII file output option was selected is will also have been saved as the same name with a ASC extension.

The processed data can be viewed using the *Open Particle Distribution File* option from the *File* menu. A window with two plots will be displayed. The right plot is the volume distribution of particle. The volume of particle in each size class is represented by a bar. The total volume concentration is the sum of these values and is displayed in the lower left. The right plot is the Volume Scattering function which is used by optical oceanographers.

Only one sample is displayed at a time. Click the *Next* button to view additional samples. The *Timer* button and slide control can be used to automatically view the data in a movie-like fashion.

The Auxiliary Parameters window can be opened and will display the values for the currently displayed sample.

Step 19: Close program and shutdown

After finishing the data processing close all the windows and exit LISST.EXE.

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

Section 3: Operation Details

This section contains more detailed information on the operation of the LISST-Deep than the previous section. Step-by-Step procedures are provided for most of the typical operations. The information is organized into the following sections: Instrument Communication and Program execution, Data Acquisition and Storage, Data Analysis, Performance Tips, and Instrument Storage and Maintenance.

Instrument Communication and Program Execution

Communication with the LISST-Deep is via an RS-232C link. A cable that connects the instrument to a PC has been provided. This cable connects the 5-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 19200 baud, 8 data bits, No parity, and 1 stop bit. A communications program called TFTOOLS.EXE has been provided for communicating with the LISST-Deep. TFTOOLS is a DOS application which has features built in that 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 TFTOOLS are to be used for uploading and off-loading, a working knowledge of ASCII and XMODEM file transfers will be required.

Running TFTOOLS

Running TFTOOLS, 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-Deep should respond by either displaying text from a running program or echoing an # 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 # prompt. To restart the program enter *ALT*-r. The main menu should appear.

The datalogger of the LISST-Deep is programmed with a version of BASIC called TFBASIC. A general-purpose program has been loaded on to the LISST-Deep. This program will meet the needs of most deployments. Custom programs can be provided for specific deployment needs not covered by the standard program. Please contact Sequoia Scientific regarding your special needs.

Data Acquisition & Storage

This section contains information on acquiring and storing data on the LISST-Deep. In addition, a description of the background scatter datafile is included.

Main Menu

The LISST-Deep contains a datalogger that is used to acquire and store the raw scattering data. A program on this datalogger displays a menu to the screen where various parameters can be set and operations can be started. The menu is displayed below.

```
Main Menu
  1.) Display Status and Configure
  2.) Acquire Background
  3.) Acquire Data
  4.) Acquire Data upon external power
  5.) Real Time Output Mode
  6.) Low Power Sleep Mode
  7.) Exit program
Enter Selection:
```

To select an option type the option number and press enter. A description of each option is below

Option 1: Display Status and Configure

The *Display Status and Configure* option is used to set operation parameters and display the current status of the battery and memory. After selecting this option a new menu will appear similar to the one shown below.

```
Current Status
        1.) Current Date/Time = 8/24/1999 7:56:23
        2.) Samples per average = 10
        3.) Number of samples to acquire = 3000
        4.) Time between samples (sec) =1
        5.) Acquisition Delay (min) =10
        Memory Used: 0 samples
        Battery Voltage: 10.8 volts
 Enter Selection to change or 0 to return to main menu:
```

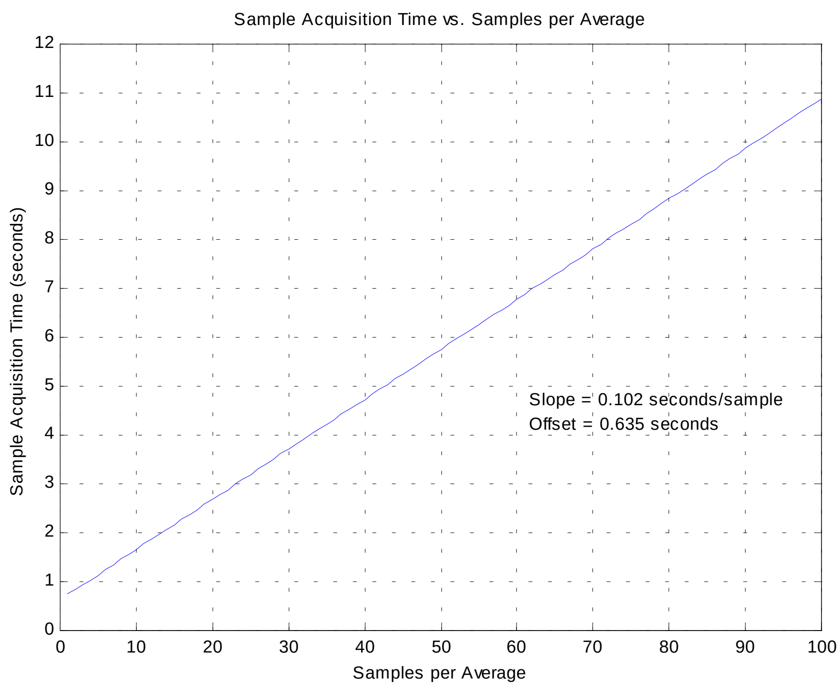
This display acts as both a source of information as well as a menu for changing the values.

Selecting option 1 will allow the user to change the current date and time through a series of prompts.

Selecting option 2 will allow the user to change the number of samples averaged before storing. Note: the default value is 10 samples per average however it is highly recommended that a value of 100 be used for deep water applications.

Selecting option 3 allows the selection of the number of samples to be stored. The collection will stop when the number of samples is reached. The collection can also be stopped with a ctrl-c. The maximum number of samples that can be stored is 5930.

Selecting option 4 will prompt for the time to wait between the end of a sample and the beginning of the next in integer seconds. Note: This is not a sample rate. The actual sample rate is based on the time to acquire a sample and the time between samples. The figure below shows the time to acquire a sample as a function of the number of samples per average.



For example if 100 samples per average is used with the time between samples set to 5 seconds the actual spacing of the stored values will be about 15.8 seconds. The date and time of each sample is stored in the datafile.

Selecting option 5 allows the selection of the time delay in minutes before sampling will start. This allows the user to setup system well before deployment.

Addition values are also displayed such as the current battery voltage and the number of samples save in memory.

Pressing enter will return to the main menu.

Option 2: Acquire Background

Selecting Option 2 from the main menu will command the datalogger to acquire 10 averaged data samples and record them. After selecting *Acquire background* (2) from the menu a prompt will appear asking if you would like to continue. Check the windows of the instrument to make sure that no bubbles are stuck to the windows and press enter. Ten samples will be stored to the datafile. The Main menu will be display when complete. The data will now need to be downloaded for later use in processing of the raw data.

Option 3: Acquire Data

Selecting option 3 from the main menu will start the acqusition of data using the programmed parameters. It will start the delay immediately after selecting the this option. Upon completion of the delay, data will be collected until the number of programmed sample is reached or the collection is stopped using a ctrl-c. Typing alt-r will restart the program and redisplay the main menu.

Option 4: Acquire Data upon external power

Selecting option 4 from the main menu will start the acqusition of data. Data collection will not start until external power is turned on. Before the power is turned on it will display a message that the instrument is running on internal power, wait 2 seconds, then return to sleep mode for 8 seconds. If Ctrl-C is pressed during these 2 seconds the program will return to the main menu. using the programmed parameters.

When external power is applied to either the standard communications port or the optional CTD port the program will display a 30 second countdown. Typing Ctrl-C will return to the main menu. At the end of 30 seconds the specified Delay will be started.

Upon completion of the delay, data will be collected until the number of programmed sample is reached or the collection is stopped using a ctrl-c. The program will return to the Main Menu at the completion of the samples or upon entering Ctrl-C.

Option 5: Real Time Output mode

Selecting option 5 will start the Real time display mode. This mode will print the values of the 32 rings and 8 auxiliary parameters to the screen. This can be useful in evaluating the conditions before a background file is acquired. It will also be used for real-time size distributions in the LISST.EXE program in the future. The Real-Time size distributions in LISST.EXE are currently not supported for the LISST-Deep

Option 6: Low Power Sleep mode

Selecting Option 6 will put the instrument into a low power mode. In this mode, it will wake up every 10 seconds, print a message to the screen (*Deep Sleep...Enter zz now to wake up*), wait two 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 *zz* and press enter to stop the program running on the datalogger. The Main Menu should appear.

This mode is useful for saving the batteries between deployments. For longer periods it is recommended that the batteries be removed or disconnected.

Option 7: Exit Program

Selecting Option 7 will stop the execution of the program and return the # prompt. This prompt must be displayed before the datafile can be downloaded.

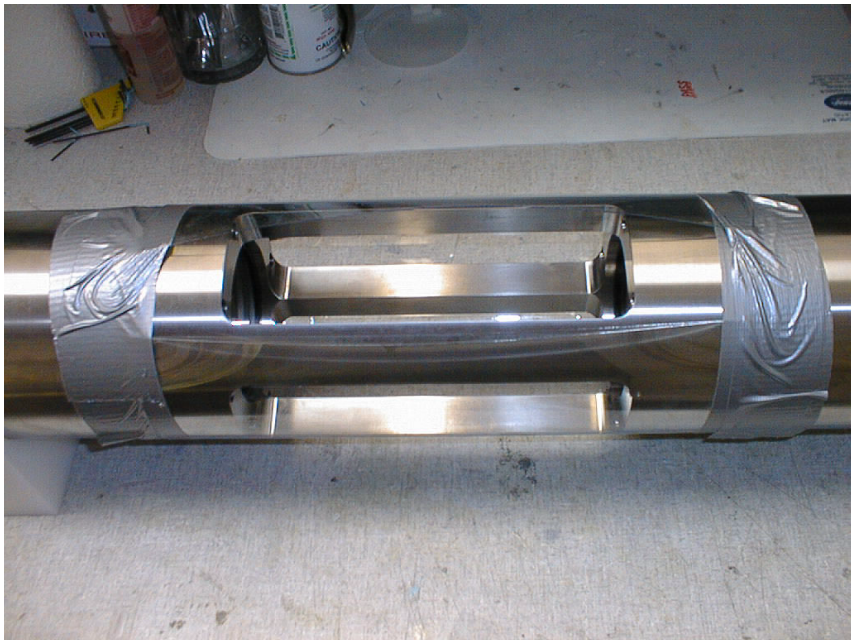
Background Scatter Datafile and its Importance

As was discussed in earlier sections, the LISST-Deep 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.

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. We have found that this distilled water tends to be a bit cleaner than typical bottled or packaged water.

Setup for Background

A piece of thin clear plastic is provided with the instrument. This plastic can be wrapped around the sample section of the instrument and the ends sealed with water-resistant tape. This will allow the instrument to be “submerged“ in water on the bench. The water used for the background data must be very clean and bubble-free. The use of a flashlight may be useful for checking the cleanliness of the windows.



The instrument should be placed horizontally on the supplied white plastic supports. Roughly 2 liters of water is needed to do a ZSCAT.

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.

Clean optics end before ZSCAT

Because non-optical parts of the instrument are submerged, it is important to thoroughly clean and rinse the instrument before acquiring a ZSCAT

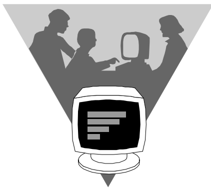
Toothbrush, liquid soap and water works well for cleaning the optical end of the instrument; do not use abrasive powders, they will scratch optics and destroy instrument performance.

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-Deep 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.*

Data Analysis



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-95/98/NT.

Intro to LISST.EXE

LISST.EXE is a 32-bit program that runs on Windows-95, Windows-NT, or Windows-98 machine. 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, TFTOOLS.EXE. The TFTOOLS.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. They are: 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

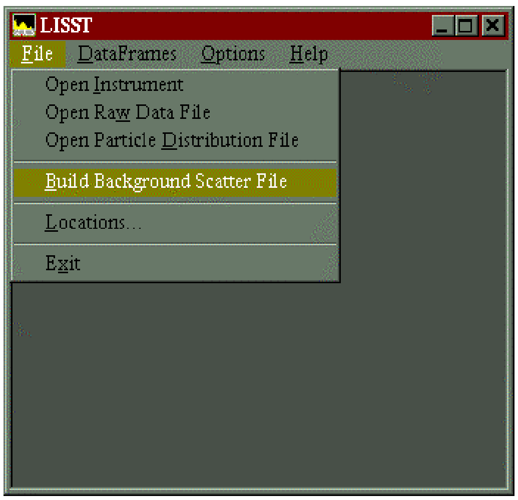
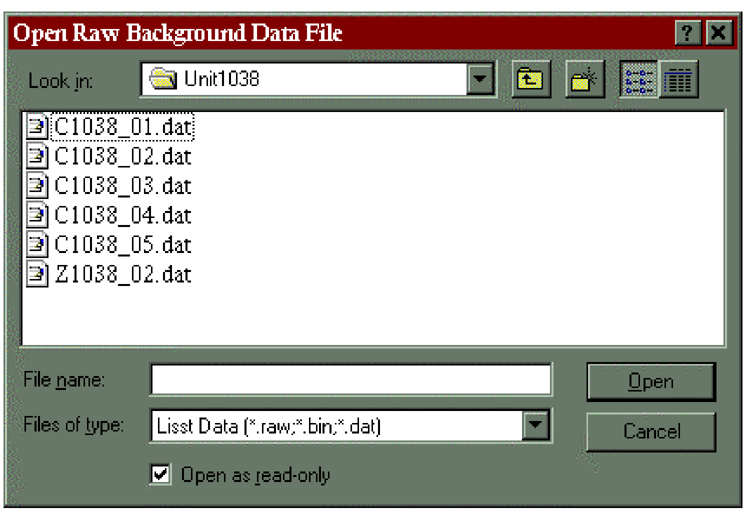
The following step-by-step procedures have been written to assist the user in learning the LISST.EXE program. All of the features of the software are covered in simple step-by-step instructions. The software is described in the following sections.

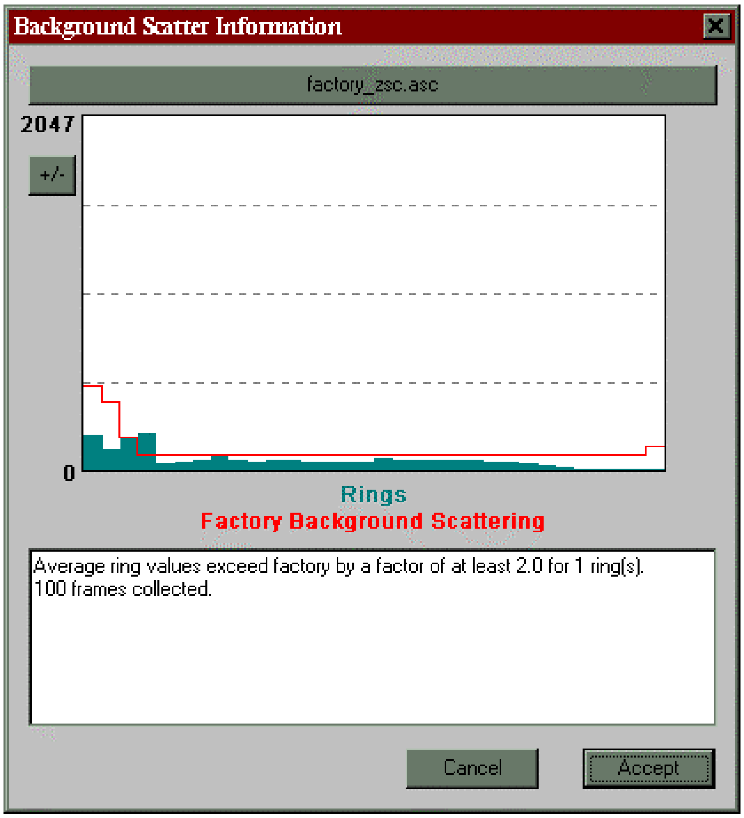
Build background scatter file The first step before processing the raw data is to process the background scatterfile. This step-by-step procedure converts the raw binary file into an averaged ASCII file. It also shows the user how to check the quality of the background scatterfile and current status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

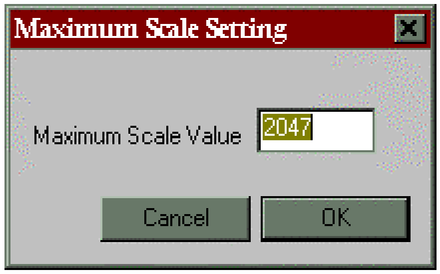
Process raw data Data that has been downloaded from the datalogger is in a raw binary file. It must be processed into particle size by the LISST.EXE program. This step-by-step procedure covers the processing steps including optional displays and procedures.

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.

STEP BY STEP PROCEDURE: PROCESSING BACKGROUND SCATTERFILE

Step	Action	Result
1	• Run *Acquire Background* option from the main datalogger menu and download data. See the Record and Store Background Scatterfile Step-by-Step procedure for detailed instructions.	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.

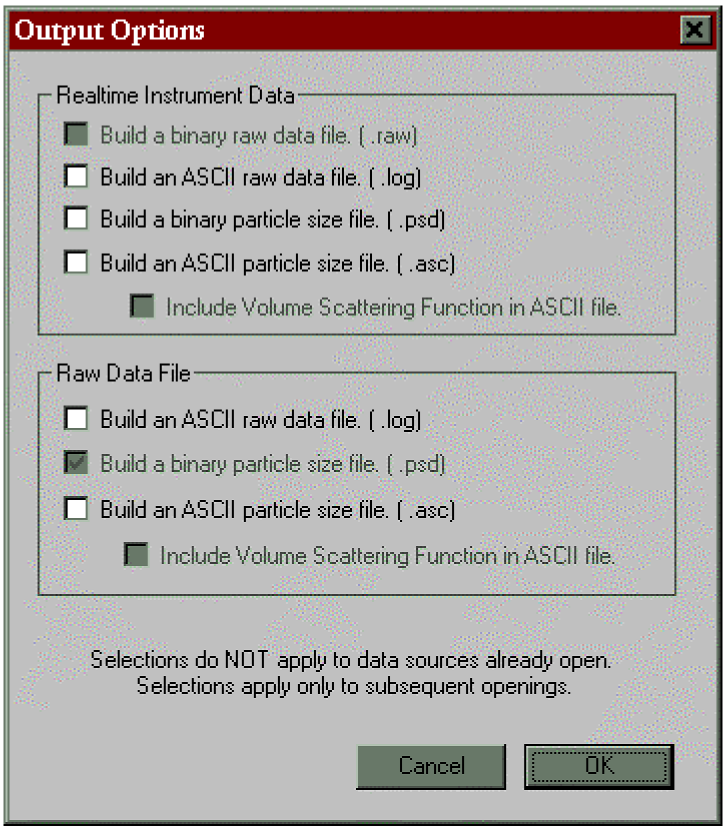
4	• After selecting a raw data file a display will appear showing the averaged background scatter data and the factory background scatter data. This screen allows the user to check the quality of the background scatter file and current status of critical parameters such as laser power and alignment. 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 it may be stored by selecting the Accept button. If 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

<table>
<tr><th>Step</th><th>Action</th><th>Result</th></tr>
<tr>
<td>1</td>
<td>

- 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.



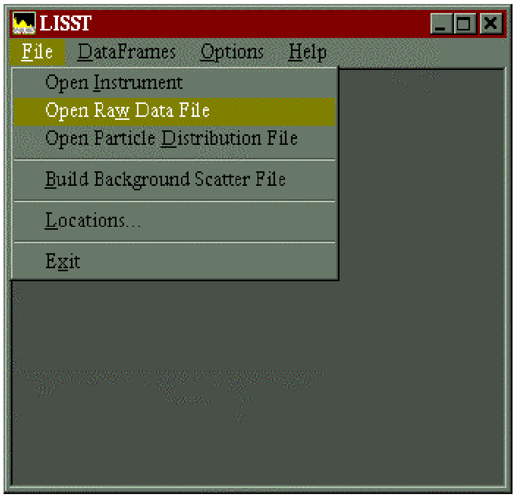
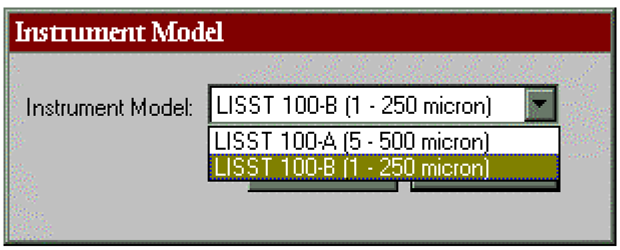
</td>
<td>

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.

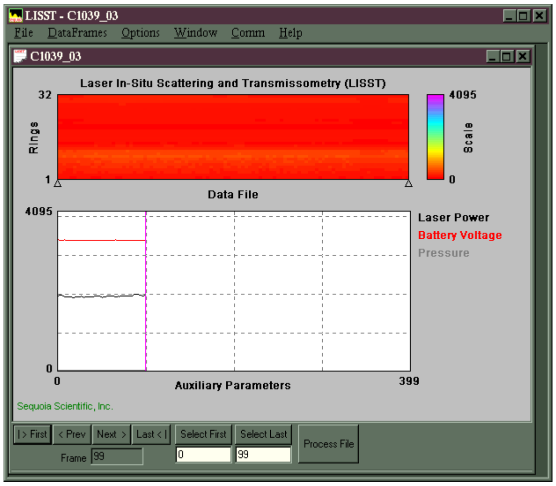
The LOG file is a space delimited file containing the raw data from the datalogger.
</td>
</tr>
</table>

Step	Action	Result
2	• Select Open Raw Datafile from the File menu  	Open Raw Datafile selected.
3	• Choose instrument type from the window shown below.  All new instruments will be of type B - 1.25 to 250 microns. Older instruments may have the 5 to 500 micron range. After choosing type press OK.	Instrument type selected.
4	• Select the raw data file from the file selection window. Double click the file or type the file name and press Open.	Raw data file selected.
5	• Select the RingArea detector calibration file. This file is specific to the instrument being used. Users with multiple instruments will have multiple RingArea files.	RingArea 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.

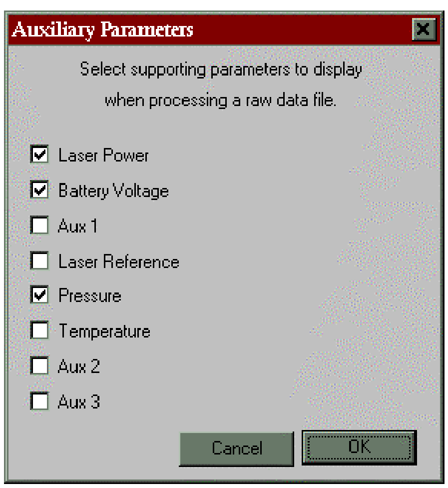
7	• Select the output file from the file selection window. Double click the file or type the file name and press Open. The default name is the same as the raw data with different extensions. If other output types are selected they will have the same base name with different extensions. Note: file types other than the default PSD file must have been selected before starting the Open Raw Datafile command. See step 1.	Output datafile selected.

<table>
<tr><th>Step</th><th>Action</th><th>Result</th></tr>
<tr><td>8</td><td>

- A display similar to the one shown below will appear.

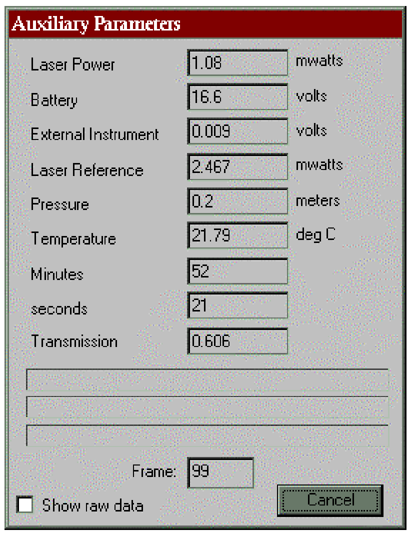
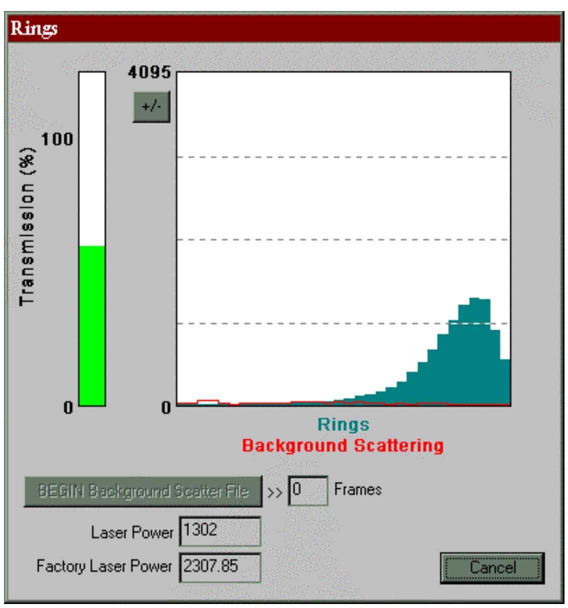


- The top portion of the display is a graphical representation of the raw data on the 32 rings. The value of the 32 rings is represented as a vertical line with time moving from left to right.
- The lower portion of the display shows the time history of some of the Auxiliary parameters. This can be useful 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.

</td><td>Main data processing selection window displayed to the screen.</td></tr>
</table>

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 a similar window is shown below. Labels may be different than below. 	Auxiliary parameter window displayed.
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.

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

<table>
<tr><th>Step</th><th>Action</th><th>Result</th></tr>
<tr><td>1</td><td>

- Start LISST.EXE program
- Select Open Particle Distribution File from the File menu.

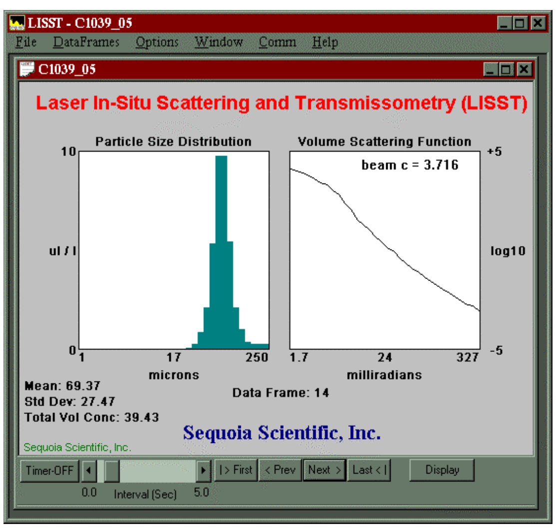
</td><td>Program started.

Open Particle Distribution File selected.</td></tr>
<tr><td>2</td><td>

- Select the processed data file from the file selection window. Double click the file or type the file name and press Open.

</td><td>Processed datafile selected.</td></tr>
<tr><td>3</td><td>

- 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.

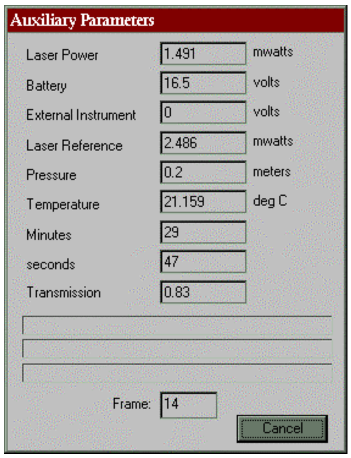
</td><td></td></tr>
</table>

<table>
<tr><th>Step</th><th>Action</th><th>Result</th></tr>
<tr><td>4</td><td>

- 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.

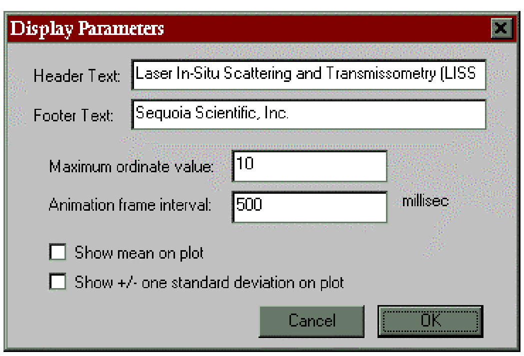
</td><td></td></tr>
<tr><td>5</td><td>

- 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 a similar window is shown below



</td><td></td></tr>
<tr><td>6</td><td>

- 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.

</td><td>Display setting modified.</td></tr>
</table>

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:		

Performance Tips

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

The LISST-Deep 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 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-Deep. 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-Deep 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-Deep 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 sleep mode.

Cleaning Windows

As has been noted earlier, the condition of the windows is critical to the performance of the LISST-Deep. 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.

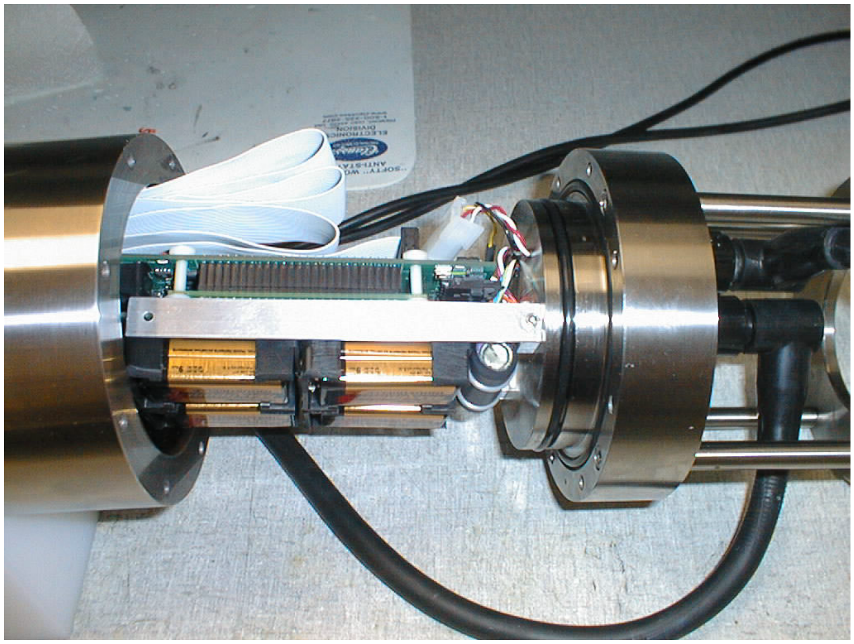
Abrasive powders must never be used near the optics windows, they will scratch the windows and degrade instrument performance.

O-Rings

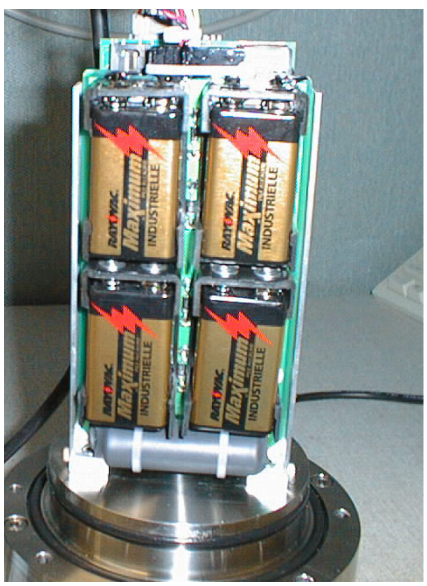
O-rings that seal the mating parts of the instrument must be maintained and inspected regularly. Whenever the end cap is removed, check the o-ring for any cuts or marks, and clean and lightly grease the o-ring before installing the end cap. Spare end cap o-rings have been provided. O-rings are inexpensive items that provide an invaluable service; replace them if there is 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. The part numbers for the endcap o-rings are: Parker Part #2-236-N70 (radial), #2-240-N70 (face)

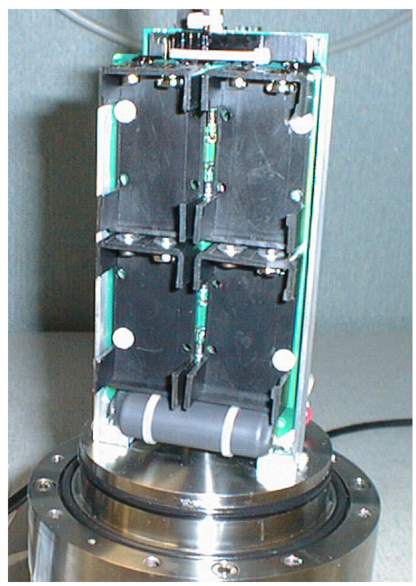
Battery Replacement

The LISST-Deep uses four standard size 9V alkaline batteries which are attached to the connector endcap. This endcap can be removed to access the battery. Remove the six bolts holding endcap to the case. Special Note for Titanium units: These bolts are special bolts made of titanium. Do not use stainless steel bolts. After removing the bolts carefully pull the electronics from the case as shown below.



The batteries are held in standard holders. Remove the batteries and replace with new. To increase battery capacity the alkaline batteries can be replaced with lithium 9V batteries. The battery holders are shown below.





The LISST-Deep 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.

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-Deep will need to be returned to the factory for realignment.

Technical Specifications

- Parameters measured/derived
  size distribution
  volume scattering function (VSF)
  optical transmission

- Optical path length: 20 cm standard
- Optical transmission: 12 bit resolution
- Particle size range: 1.2 - 250 micron diameter
- Resolution: 32 size classes, log-spaced
- VSF angle range: 1.7 to 340 mrad
- Data storage memory: 512K (6500 samples)
- Maximum sample speed: 4 size distributions per second (standard)
- Depth rating: 5000 m
- Battery Capacity: Standard: four 9V Alkaline batteries (2 amp-hr)
  Optional: four 9V Lithium batteries (4.8 amp-hr)
- External Power Input: 9V (5.5V to 12.0V)
- Current Drain: 180ma sampling, 3.3ma idle, 0.08ma sleep (measured at 9V)
- Endcap O-rings: Parker Part #2-236-N70 (radial), #2-240-N70 (face)
- Endcap Bolts: 10-24UNC x 1.5in long socket head cap screws

Special Notes for Titanium Version of LISST-Deep:
All exposed bolts are special titanium bolts. They are NOT stainless steel. Extra endcap bolts have been provided. Only titanium hardware should be used.

Communication and Power Connector wiring

Pin #	Color	Use
1	White	External Power Ground
2	Black	External Power 9V
3	Blue	Serial Ground
4	Orange	Serial Out
5	Green	Serial In

Pins labeled on connector
Connector = Impulse Part # XSJ-5-BCR

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. (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 *100
35	Sample Number
36	Laser Reference sensor
37	Spare
38	Year*100 + Month
39	Day*100 + Hour
40	Minutes *100 + Seconds

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 (smallest) through 32 (largest)
33	Laser transmission Sensor in calibrated units
34	Battery voltage in calibrated units
35	Sample Number
36	Laser Reference sensor in calibrated units
37	Spare
38	Year*100 + Month
39	Day*100 + Hour
40	Minutes *100 + Seconds
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

LISST-Deep Instrument Troubleshooting

The following flowchart provides a set of procedures to follow if the LISST-Deep instrument is not displaying text to the TFTOOLS terminal screen or is not responsive to commands. Follow the procedure outlined below before executing a Hard reset as described on the next page.

LISST-Deep Instrument Reset Procedures

❑ Step 1: Follow LISST-Deep Troubleshooting Flowchart to confirm that a Reset is required.

❑ Step 2: Document preceding and current conditions leading up to need for reset.

❑ Step 3: Open Case and disconnect 2 pin backup battery connector. Main battery should be above 6V or higher.

Insert labeled picture of board end.

❑ Step 4: Disconnect main battery and wait 30 seconds.

❑ Step 5: Connect communications cable and start TFTOOLS.

❑ Step 6: Re-apply main battery or external power. Program will start running in about 20 to 30 seconds. Stop program by Typing a CTRL-C to bring up Main menu.

❑ Step 7: Exit program to # prompt by choosing option 7 from Main menu.

❑ Step 8: Download data from instrument using TFTOOLS. Note the data is secure in flash RAM. It will only be lost if written over. However the pointer to memory is reset to zero after a reset. When prompted for the number of bytes to offload it will default to 0. Manually enter the number of bytes to offload. Each sample is 80 bytes. Compute the number of bytes to offload or enter 483000 to download the complete datafile. When downloading the complete datafile there may be some strange values at the end of the file. These strange values may cause errors when processing the data with the standard LISST software. If this occurs try downloading a smaller file in addition to the full memory file.

❑ Step 9: After confirming data download, erase the data file using the Erase Datafile command in TFTOOLS**.**

❑ Step 10: Execute Acquire Background 4 time to store dummy data. This clears and buffers that may still contain some old values.

❑ Step 11: Erase data file again.

❑ Step 12: Restart program. Put into Data Collection mode or Sleep mode.