Fast Forward Scattering Spectrometer Probe Technical Manual
Rev. 1.0

PRELIMINARY

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1.0 Unpacking the FFSSP (TBD)

The FFSSP was shipped in a case with shock-absorbing foam (**Figure 1.1**). Refer to **Figure 2.1.1** before continuing to read this section. (TBD)

NOTE: THE PROBE SHOULD NEVER BE HELD BY OR CLOSE TO THE ARM TIPS. THE PROBE SHOULD NEVER BE HELD BY OR CLOSE TO THE CONNECTOR. NOT FOLLOWING THESE CRITICAL HANDLING INSTRUCTIONS NEGATES THE WARRANTY FROM SPEC

Figure 1.1 The FFSSP in a shock-absorbing foam protected shipping case

Figure 1.2 The FFSSP being removed from the shipping case, held by the arm and main body. The arm should only be held in the position shown and never close to the tips. The main body should not be held by the connector.

Figure 1.3 The FFSSP being lifted from the shipping case and carried, held by the arm and main body
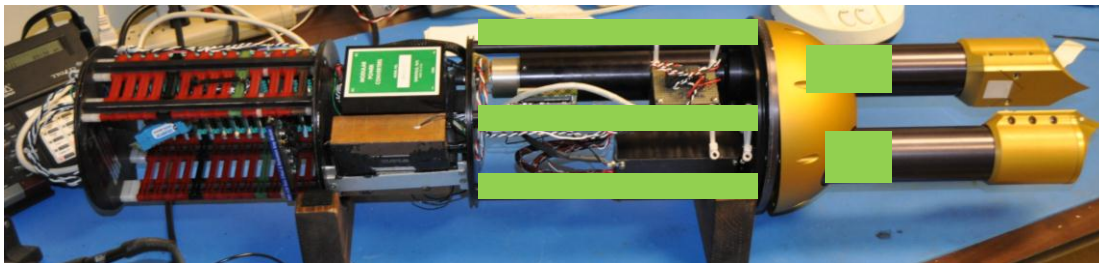
Figure 1.5 The FFSSP with SPEC upgraded tips placed on an anti-static mat for bench tests
Only handle the FFSSP by the sections covered in green in figure1.5.
The FFSSP should never be held by or close to the arm tips. When moving the FFSSP while out of protective sleeve, only handle the instrument near arm base and aluminum rod structure.
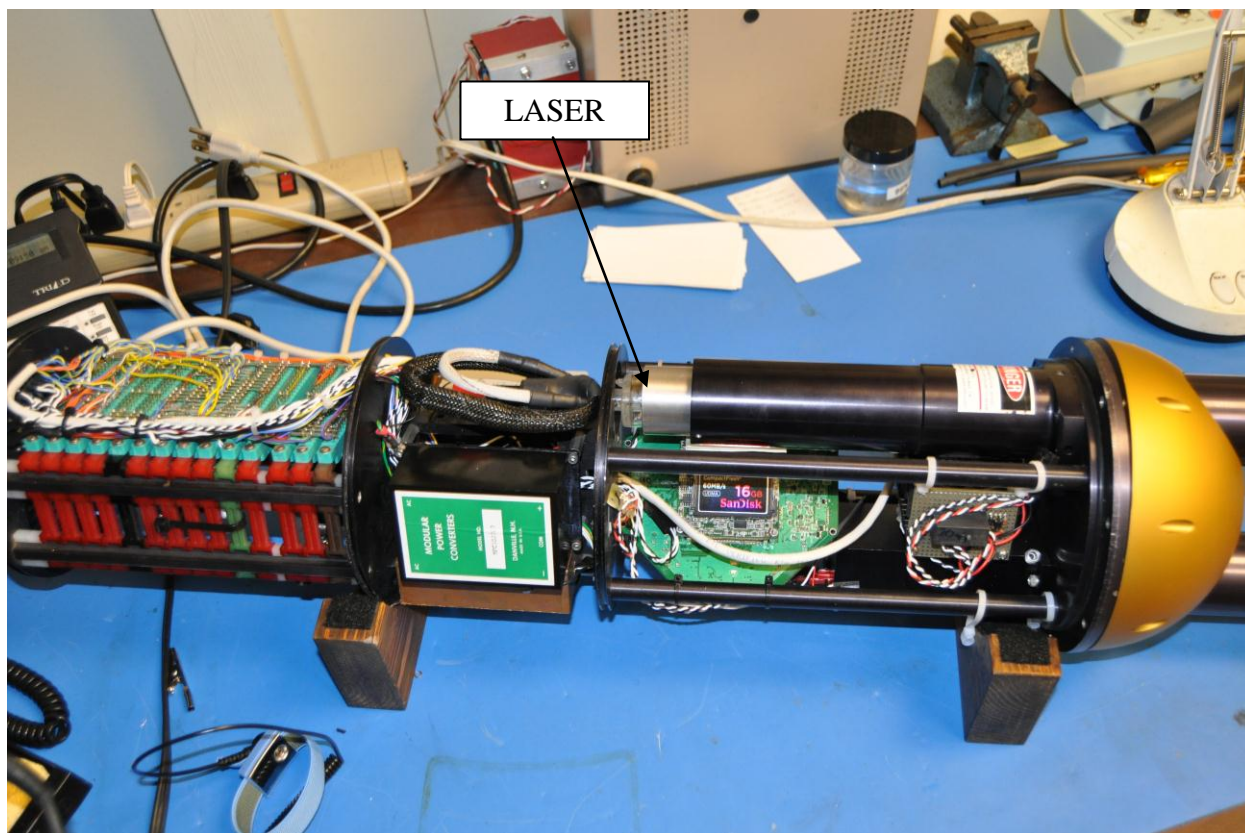
Figure 1.6 Take great caution around the FFSSP Laser

2.0 FFSSP General Description

The Fast Forward Scattering Spectrometer Probe (FFSSP) measures particle size and concentration. The FFSSP sizes particles by measuring the amount of light scattered into the collecting optics aperture during particle interaction through a focused laser beam. The instrument can size particles from 1-50 μm with a resolution of about 3 μm. The system resolves particles into twenty equally spaced bins. It is capable of sizing particles having velocities from 20-175 m/s. The FFSSP is a stand-alone system with an onboard data acquisition system that stores data on a Compact Flash (CF) card. The instrument can be controlled by a remote computer inside the aircraft cabin or can be configured to turn on and store data automatically at power ON.

2.1 Main Sections of the FFSSP

The FFSSP can be divided into three main sections: Transmit and Receive Arms, Main Body and Main body. The transmit arm contains the laser and transmit optics.

The Transmit Arm encloses a Continuous Wave (CW), fiber-coupled laser diode operating at 785 nm with a peak power of 45 mW.

The Receive Arm encloses the receive optics, detector and detector amplifier board. The output from the detector amplifier board is fed in to the data acquisition system in the main body.

The Main Body consists of the data acquisition system that contains the electronics board and the 400 MHz Intel PXA255 microprocessor based System on Module (SOM). The electronics board converts the analog voltages to digital form and this data is stored in FIFOs on the Field Programmable Gated Array (FPGA). The FPGA interfaces with the Signal, Qualifier, Housekeeping Analog to Digital Converters (ADCs) and the SOM. The SOM analyzes and processes the voltages corresponding to scattered light and classifies it into different particle size bins. This data along with the housekeeping data are saved in the form of 5 different files on the Compact Flash Card by the SOM. The SOM also provides Ethernet and RS232/422 interfaces for real time display and control by a remote computer.

The Main Body contains the Power, Laser control, and Heater control boards. The 28 VDC and 110 VAC inputs from the aircraft are distributed to the various components of the FFSSP: laser, detector, detector amplifier board, data acquisition system, and heaters, by the Power-laser-heater board. The temperatures of the heaters are also controlled by this board.

Transmit & Receive Arms

Main body

Arm Tips   Receive Arm

Figure 2.1.1 FFSSP Main Physical Sections

Power Supply
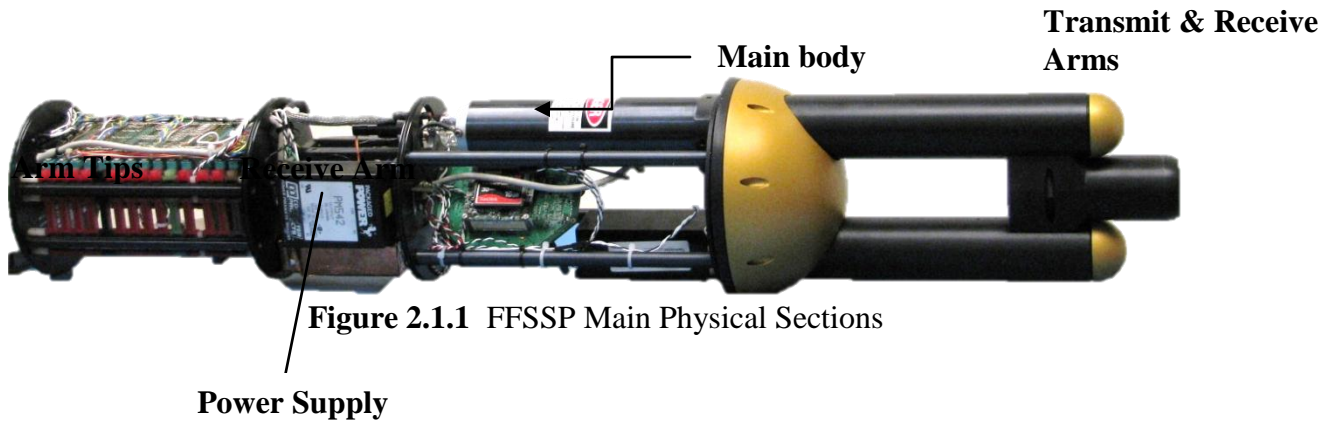
Figure 2.1.2 FFSSP Heater Locations

2.2 FFSSP Principle of Operation
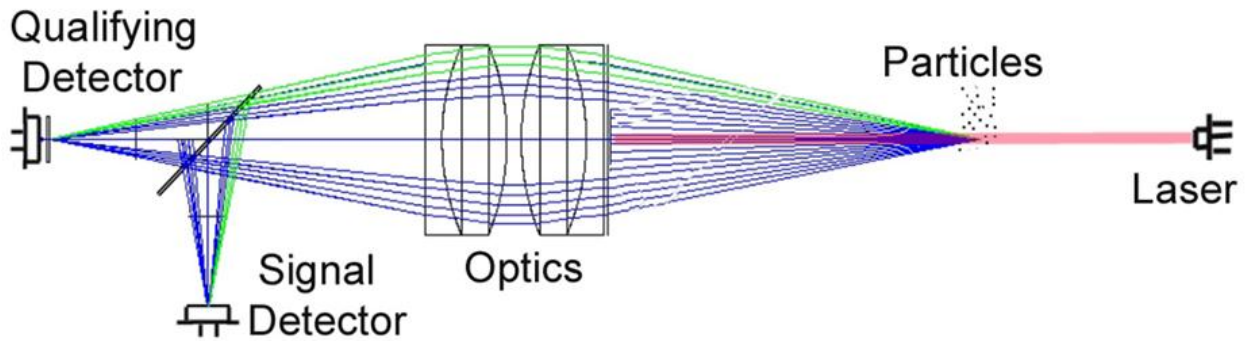
Figure 2.2.1 Diagrammatic representation of the principle of operation

A collimated, fiber-coupled laser diode is projected on the sample volume between the transmit and receive arms of the FFSSP. Cloud particles in the sample volume scatter the laser beam. The light scattered by the cloud particles is collected at a dump spot on the receive arm. This beam is splitted to be incident on two detectors: qualifier and signal. **Figure 2.2.1** is a diagrammatic representation of the principle of operation of the FFSSP.

When a particle is in focus for both detectors, the annular qualifier detector sees no signal as shown in **Figure 2.2.2**. Since a 70:30 splitter is used, for a particle to be qualified the qualifier peak should be lower than the signal peak, as shown in **Figure 2.2.3**.
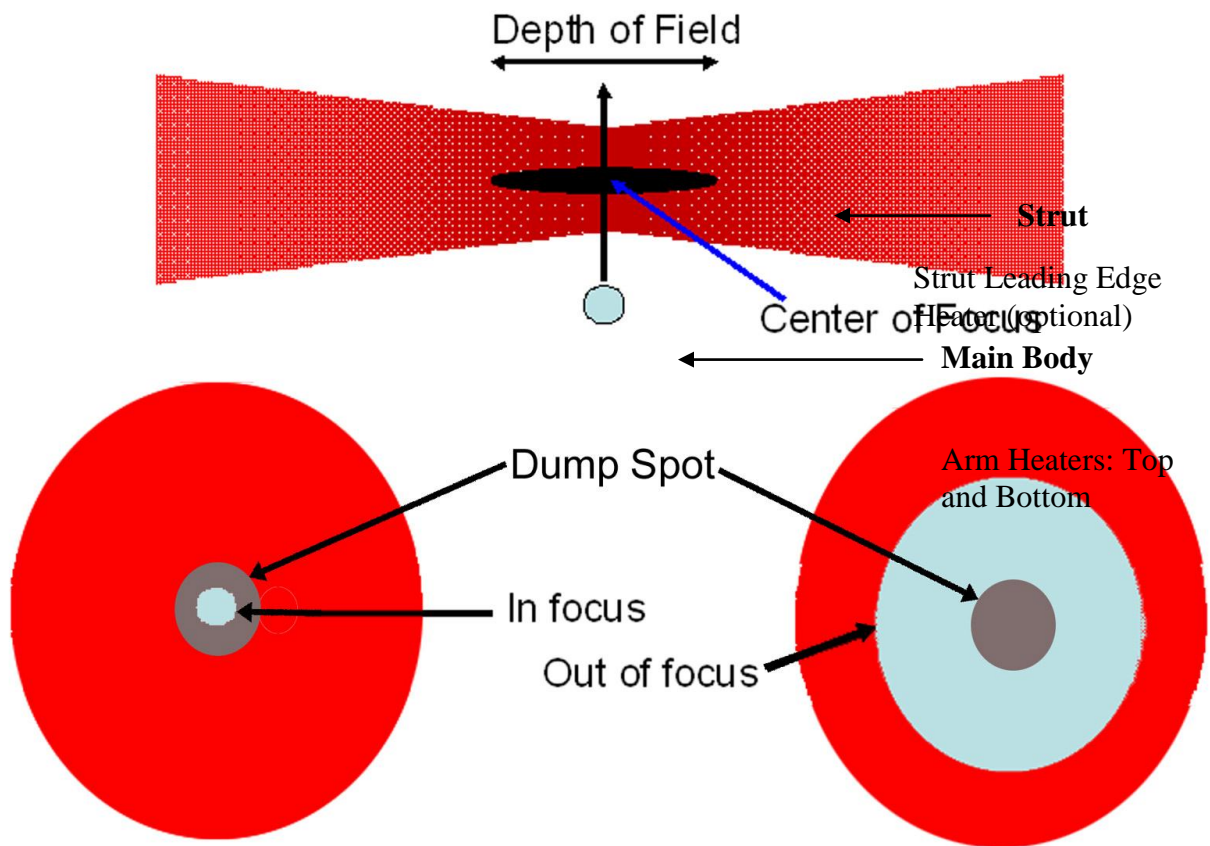
Figure 2.2.2 Graphical representation of an annular qualifier with particles in and out of focus.

Characteristics such as run time, transit time, signal voltage, qualifier voltage, area (sum of volts) and time to peak are recorded for each particle by the data acquisition system.
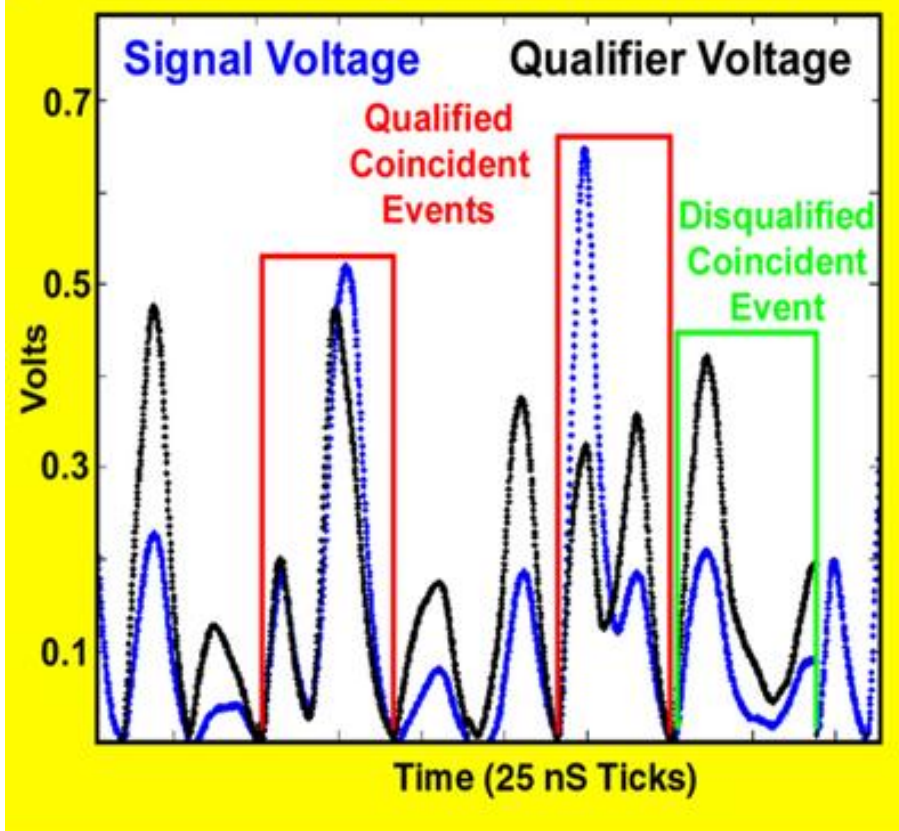
Figure 2.2.3 Examples of Qualified Particles

3   FFSSP Electronics Description

The Electronics section consists of two detectors and four main boards: two detector boards, an electronics board and a laser/power board.

Detectors:
There are two detectors in the FCP: signal and qualifier. The light scattered by the cloud particles is incident upon these two detectors. When a particle is in focus for both detectors, the slit based qualifier detector sees a high peak. Since a 70:30 splitter is used, for a particle to be qualified the qualifier peak should be higher than the signal peak, as explained in **Section 2.2**.

Detector Boards:
Detector boards are small circular boards placed close to the detectors that detect and amplify the signal and qualifier voltages over two stages. The output of these amplifiers is fed in to the Electronics Board.

Electronics Board:
The Electronics board consists of the main electronics that sample and process the detector voltages. The amplified signal and qualifier voltages are digitized by dual, 14 bit Analog to Digital Converters (ADCs). These voltages along with the House Keeping voltages from an ADC-Multiplexer (MUX) are fed in to a Field Programmable Gated Array (FPGA). House-keeping parameters such as air temperature, voltages, relative humidity and pressure are sampled.

The FPGA interfaces with a PXA255 processor based System on Module (SOM). The FPGA and the SOM together form the data acquisition system. When the FFSSP is turned ON, the SOM powers up and implements a code that programs the FPGA to acquire and store data from the ADCs in First-In-First-Out buffers (FIFOs). The SOM then implements a real time control loop (see **Figure 3.2**) to retrieve data from the FIFOs on the FPGA, perform basic data processing and store it on 5 different raw data files on the Compact Flash card. The 5 raw data files are:

'YYMMDDHHMMSSlog.txt': Log file
'YYMMDDHHMMSShk.txt': Housekeeping data file
'YYMMDDHHMMSSscat.bin': Scattering data file
'YYMMDDHHMMSSsig.bin': Signal detector data file
'YYMMDDHHMMSSqual.bin': Qualifier detector data file

The above files can be post-processed to yield more accurate particle characteristics such as time-based concentration and sizes.
Data that are processed using a preliminary real time code is also sent over the Ethernet and/or RS232/422 at a rate of 1Hz. This data can be viewed in real time using the *FFSSP.exe* software (**See Section 4.2**). The *FCP.exe* software also saves this preliminary 1Hz data in an ASCII file named *'YYMMDDHHMMSS_FFSSP.txt'*.
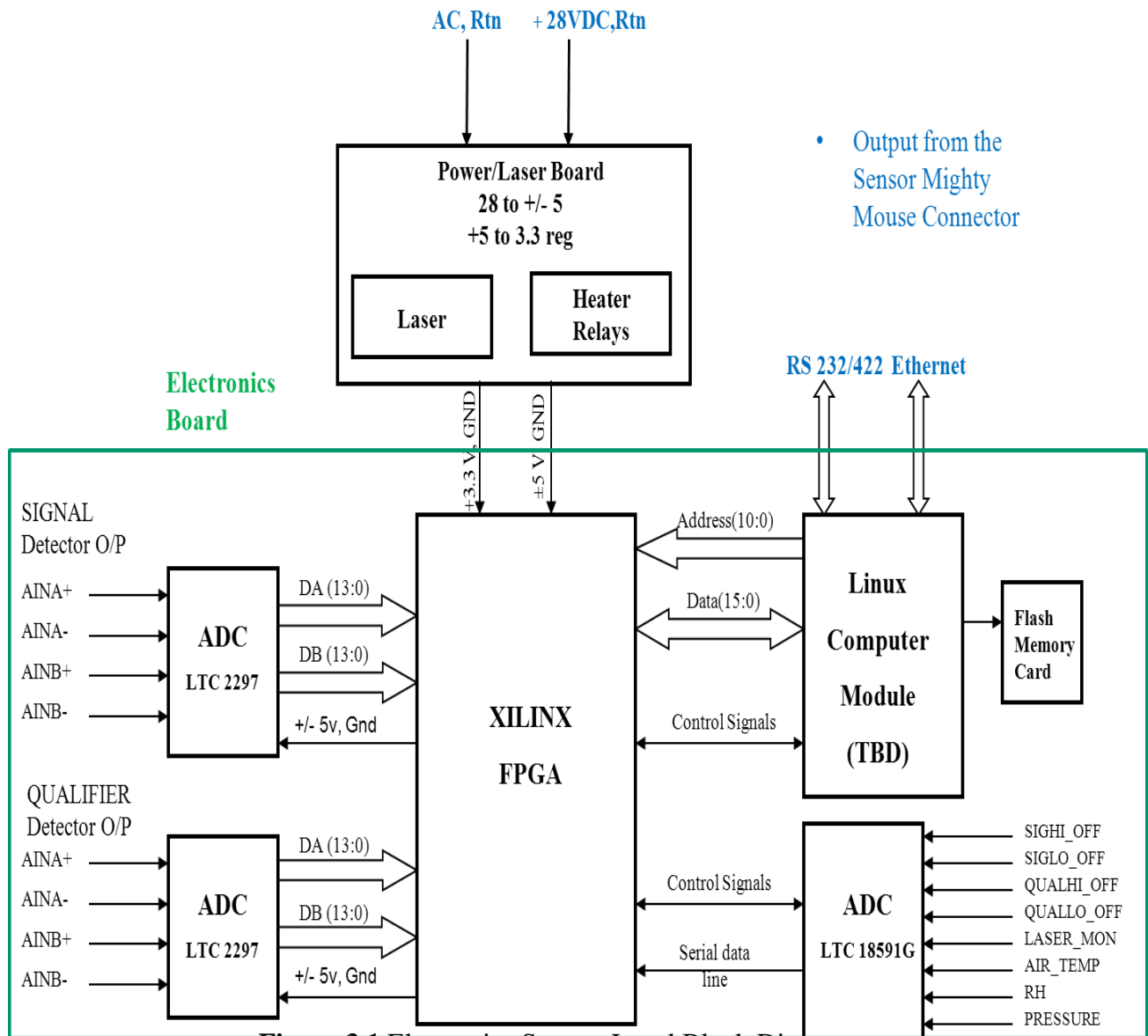
Figure 3.1 Electronics System Level Block Diagram

Laser/Power Board:

The laser/power board obtains the AC and 28VDC power input to the FFSSP sensor and converts it to appropriate voltages (±5VDC, +3.3VDC) which power up the heater relays and the electronics board. The power and control circuitry for the laser is also placed on this board. The heater relays are controlled by the real time software running on the SOM.

ffssp_realtime1.09.c

```
                                Start

                                 │              ( a. )
                                 ▼
                          ┌──────────────┐     ┌──────────────┐    ┌──────────────────┐
                          │  Create FIFO │ ──▶ │ FIFO data    │──▶ │ Send data fromlinux│
                          │              │     │ sent to      │    │ system to Windows │
                          │              │     │ another      │    │ PC using ethernet │
                          └──────────────┘     │ program      │    │  ' a.c' and 'b.c' │
                                 │             └──────────────┘    └──────────────────┘
                                 ▼
                          ┌──────────────┐
                          │Initialize files│
                          └──────────────┘
                                 │
                                 ▼
                          ┌──────────────┐
                          │ Set scattering│
                          │  parameters  │
                          └──────────────┘
                                 │
                                 ▼
                          ┌──────────────┐
                          │   Set Time   │
                          └──────────────┘
                                 │
                                 ▼
                          ┌──────────────┐
                          │Set/Reset baseline│
                          │values - SIGBASE &│
                          │  SIGBASELOW  │
                          └──────────────┘
```

No Scattering Data error message ◀ N — Check for FIFO data all the time — Y ▶ Read the data and write to file ▶ Add peaks into the histogram ▶ Save to file "date'_scatter_data'

Main Control Loop

No Signal data error message ◀ N — Check for Signal FIFO data — Y ▶ Read Signal FIFO data ▶ Save to file "data'_signal_data'

No Qual data error message ◀ N — Check for Qualifier FIFO data — Y ▶ Read Qual FIFO data ▶ Save to file "date_qual_data'

temp > 9018

Reset Baseline

Turn on heater ◀ Check temperature from housekeeping data ▶ Turn off heater

Repeat until user 'quits' ───────────▶ (a.)

Close all files and END

Figure 3.2 Real time Control loop flowchart

SPEC Inc reserves the right to make improvements and changes to the FCDP and related software at any time and without notice.

4   FFSSP Start Up and Shutdown Procedure

Low noise 28VDC and AC power sources are required to start up the FFSSP. The 28VDC is System power and the AC power controls the Deice Heaters.

Warning: DO NOT TURN ON THE AC POWER IF THE DC SYSTEM POWER IS SWITCHED OFF.

4.1   Connecting FFSSP Sensor to Remote Computer

A bench test cable is supplied with FFSSP. It connects to the 19 pin connector at the FFSSP sensor head chassis. The bench test cable mates to this connector and branches to 28 VDC power, AC power, Ethernet and RS242/232 on the other end.

Recommended aircraft cabling is TBD.

Connect the AC and DC power connectors to appropriate power supplies. Connect the Ethernet cable directly to a Windows OS computer. Connect the RS 232/422 connector to the same computer as well. Configure the computer to a static IP address of *192.168.1.xxx*.

A File Transfer Protocol Client such as CoreFTP or FileZilla needs to be downloaded to transfer raw data files. In the future the *SPEC_FFSSP.exe* program will include this capability. The IP address of the FFSSP instrument is *192.168.1.211*.

4.2   FFSSP Real-Time Graphical User Interface (GUI)

The FFSSP real-time GUI named *'SPEC_FFSSP.exe'* is supplied on CD/DVD/Flash drive with the instrument. This software is compatible with a Windows OS computer.

Installation
The *'SPEC_FFSSP.exe'* file should be copied in to any folder of the user's preference. It is preferable to name the folder *'SPEC_FFSSP'*. It will be assumed from here on in this manual that the folder is called *'/SPEC_FFSSP/'*.

Starting the Software

To run the GUI, double click on the *'SPEC_FFSSP.exe'* file. Create a shortcut to the Windows Desktop and/or Pin to the START menu for easier access.
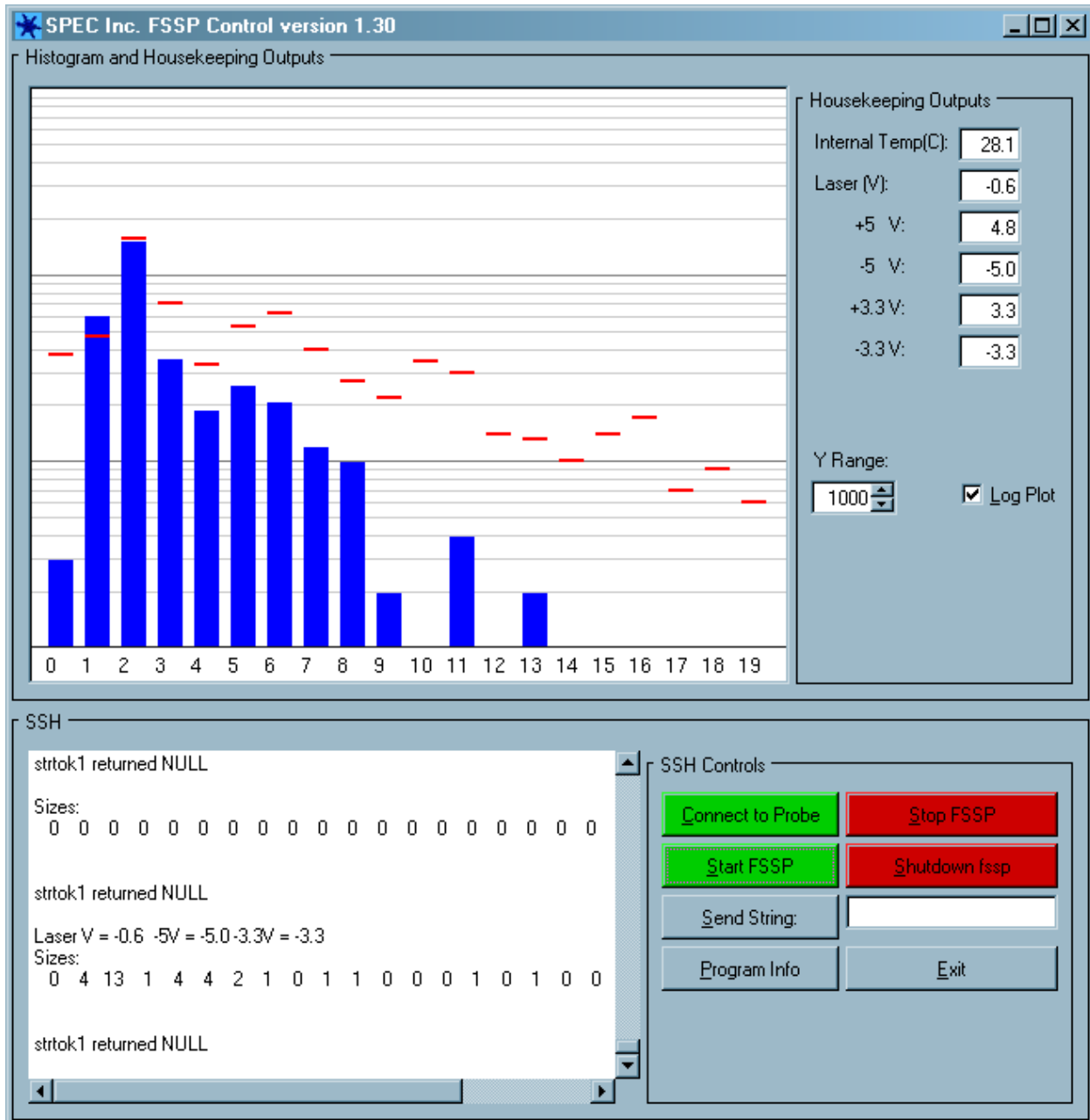
Figure 4.1 Screen shot of the *SPEC_FFSSP.exe* GUI (**Above Screen Shot is for FCDP.exe which is identical to FFSSP except the HK parameters**)

Running the FFSSP using the GUI

Once started, as above, the FFSSP GUI will look like the screenshot in **Figure 4.1**. Follow the simple steps below to start data collection on the FFSSP probe :-

1. Turn ON the FFSSP System power switch(28VDC) and the Deice (110 VAC) power..

2. Ensure that the Windows computer, the GUI is running on, has the correct system time.

3. Click on '***Connect to FFSSP'*** button on the ***'SSH Controls'*** section of the GUI to establish an SSH session with the linux based SOM on the FFSSP instrument.
   This function logs in to the SOM with username 'root' and password 'rootme' and synchronizes the linux time on the SOM to the Windows system time. These processes are invisible to the user.

4. Next, Click on the ***'Start FFSSP'*** button to start running the real time data acquisition software on the linux SOM.

5. Notice, the messages in the ***'SSH'*** message window on the GUI. These messages indicate the programming of the FPGA and other start up configuration details of the Electronics system on the FFSSP.
   This window will also display error messages, during the running of the FFSSP, if any.

6. Once, these messages have stopped, the FFSSP is ready to collect data.

7. The user must now check the ***'Housekeeping outputs'*** section such as temperatures and voltages. Ensure that these parameters look correct.

   All four temperatures displayed in the GUI are controlled by heaters. They are set to turn ON at 15°C.
   The Laser temperature should not go above 45°C and below ~10°C.
   The Window, Arm and Internal Temperatures may go below 0°C or above 45°C, depending on the ambient conditions. It should be noted that if these 3 temperature values are very close to the ambient temperature values, especially when too cold or too hot, the heaters may not be functioning correctly and trouble-shooting should be performed.

8. For ground tests, spray particles using a small water pump or compressed air can into the sample volume between the arms of the FFSSP. You should see activity on the ***'Histogram'.***

9. In real time, when in clear air, the histogram should not indicate any counts. In cloud, the histogram will indicate number of cloud particles sampled per second. It also indicates a moving average over 30 seconds by a red line on each of the 20 bins of the histogram.

10. The histogram can be switched to a 'log' scale by checking the ***'Log Plot'*** box next to the histogram. The ***'Y Range'*** on the histogram can be changed according to user's preference.

11. The real time data is displayed at a frequency of 1 Hz. This data is automatically saved in an ASCII file named ***'YYMMDDHHMMSS_FFSSP.txt'*** in the ***/SPEC_FFSSP/FFSSP_1Hz_Data/*** folder.

NOTE: There is currently a 2GB size limit on the raw files stored on the CF card by the real time data acquisition program. This limit has not been reached in the past on 3 hour flights, in high density clouds. If this limit is reached you will see a message in the *SSH* window as follows:

```
Problem receiving data from FIFO, it may have closed, exiting FIFO read loop
> /home/startFFSSP: line 8:   342 File size limit exceeded./realtime
> -sh-2.05b#
```

This indicates that the real time data acquisition software has stopped running. At this point, the only solution to this issue is to click on *'START FFSSP'* and restart the real time data acquisition.

Shutting Down the Software and Instrument

1. When the user is ready to stop collecting data, click on *'STOP FFSSP'* to stop the real time data acquisition software.
2. Collect the raw data files using an FTP client such as CoreFTP or FileZilla. Future versions of *SPEC_FFSSP.exe* will include the capabilities of an FTP client. This step is optional and data may be collected post-flight. (See Section below on **DATA Retrieval**)
3. Wait for about 10-15 seconds and then click on *'SHUTDOWN FFSSP'* to shut down the SOM.
4. Switch OFF System and Deice Power at this time.

Note: In case of accidental Shut Down of the FFSSP, the System and Deice power will have to be switched OFF and ON again to restart the whole instrument.

Data Retrieval

The 1 Hz ASCII data file (one associated with each start up) can be retrieved from the file named **'YYMMDDHHMMSS_FFSSP.txt'** in the */SPEC_FFSSP/FFSSP_1Hz_Data/* folder.

The raw data files which provide more accurate data are saved on the CF card connected to the SOM on the FFSSP instrument. These files can be collected as follows:

1. An FTP client such as CoreFTP or Filezilla is required to obtain these files. These clients are available freely on the internet.
2. The data can be downloaded before instrument shutdown. After stopping real time data acquisition by clicking on *'STOP FFSSP'*, start the FTP client. Connect to the FFSSP.

3. Navigate to the folder */mnt/hda/* to access the raw data files in the CF card.
4. Select all the relevant files (at least 5 for each start-up)
'YYMMDDHHMMSSlog.txt': Log file

'YYMMDDHHMMSShk.txt': Housekeeping data file
'YYMMDDHHMMSSscat.bin': Scattering data file
'YYMMDDHHMMSSsig.bin': Signal detector data file
'YYMMDDHHMMSSqual.bin': Qualifier detector data file

5. Transfer all selected files to a user-determined folder. It will be preferable to create a folder called **/SPEC_FFSSP/FFSSP_Raw_Data** and save all files to this folder.
6. Once the data transfer is complete, click on **'FFSSP Shutdown'** on the GUI.
7. Switch OFF System and Deice power.
8. The data can also be downloaded post-flight. Switch ON System Power, start the FTP client and connect to the FCDCP. Follow raw data retrieval procedure steps from 3. to 5 and then Switch OFF the System power .

NOTE: Raw data file transfer can take anywhere from 5 minutes to 45 minutes, depending on flight duration and densities of penetrated clouds.

5   FFSSP Maintenance Procedure

FFSSP Purging Procedure

6   FFSSP Installation on Aircraft (TBD)