Cloud Aerosol and Precipitation Spectrometer (CAPS)

Operator Manual

DOC-0066 Revision F

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The seller warrants that the equipment supplied will be free from defects in material and workmanship for a period of one year from the confirmed date of purchase of the original buyer. The probe owner will pay for shipping to DMT, while DMT covers the return shipping expense.

Consumable components, such as tubing, filters, pump diaphragms and Nafion humidifier are not covered by this warranty.

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1.0 Introduction

The CAPS is a combination probe incorporating three basic measuring instruments to characterize cloud parameters. These include a Hot-wire Liquid Water Content Sensor (LWC-100), Cloud and Aerosol Spectrometer (CAS) and a Cloud Imaging Probe (CIP). Full specifications of the CAPS are given in *Table 1*. The instrument meets the goals of measuring a large range of particle sizes—0.3 μm to 1.55 mm—with one probe, minimizing the space, cable connections, and data systems necessary for measurement of this regime. The Particle Analysis and Display System (PADS), with an intuitive graphical user interface at the host computer, provides powerful control of measurement parameters while simultaneously displaying real-time size distributions and derived parameters. All data interfaces are done via line drivers meeting the RS-422 electrical specification, allowing cable lengths of up to 100 meters.

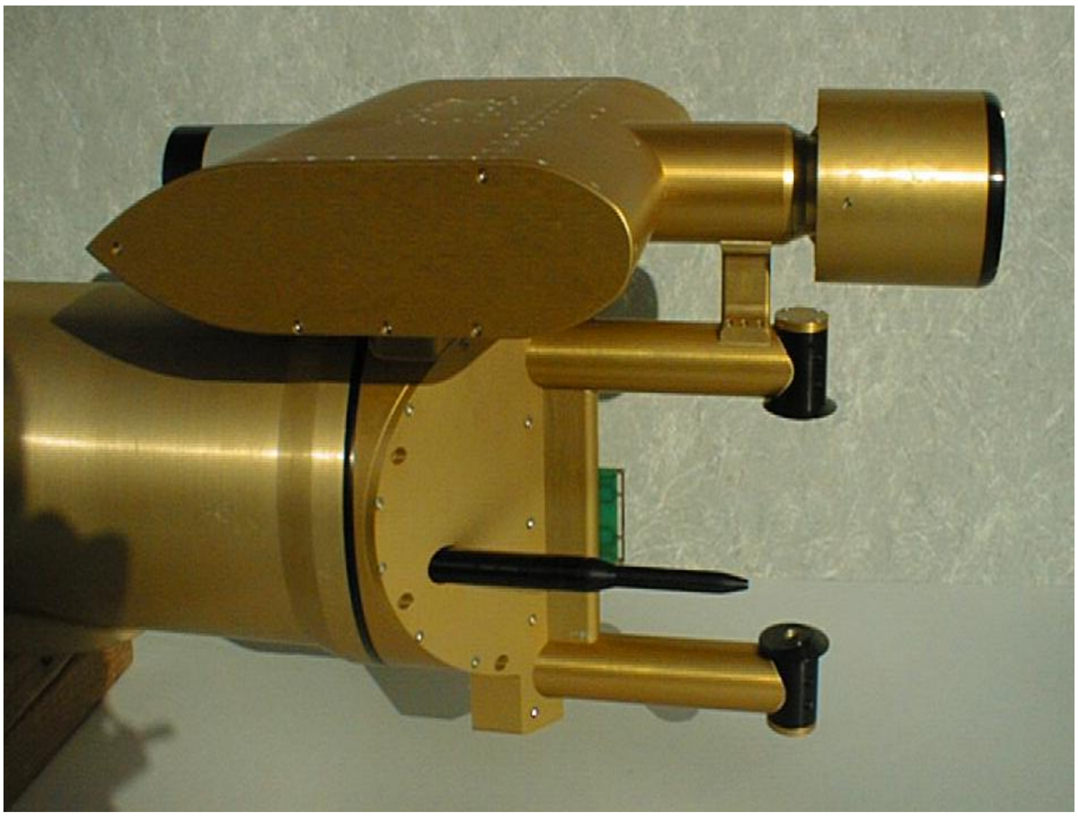

Figure 1: Cloud Aerosol and Precipitation Spectrometer (CAPS)

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1.1 CAPS Specifications

1.1.1 Cloud Imaging Probe (CIP)

Technique:	Optical Array Probe with 64 elements: 62 sizing elements, end diodes reject
Measured Particle Size Range:	12.5 µm – 1.55 mm (for 25-µm resolution CIP)[1] 7.5 µm - 9.3 mm (for 15-µm resolution CIP)[1]
Sample Area:	10 cm x 1.55 mm (for 25-µm resolution CIP)[2] 10 cm x .93 mm (for 15-µm resolution CIP)[2]
Air Speed Range:	10 – 300 m/sec (for 25-µm resolution CIP)[3] 10 – 180 m/sec (for 15-µm resolution CIP)[3]
Number of Size Bins:	62
Sampling Frequency:	1D histogram data: 0.1 to 10 Hz[4] 2D image data: variable interval, when buffer fills
Laser:	658 nm, 30mW; DMT-manufactured laser with Arima Lasers Corporation diode
Data System Interface:	1D: RS-232 or RS-422, 56.6 kb/sec Baud Rate 2D: RS-422, High Speed, 4 Mb/sec Baud Rate
Auxiliary Parameters:	Ambient Temperature, Relative Humidity, Static Pressure, Dynamic Pressure
Calibration:	Spinning glass disk with opaque dots of known size

[1] The minimum size for detected particles varies based on where on the diode array the particle falls. See the *Data Analysis Guide* for details.

[2] The sample area varies based on the size of detected particles. See the **Sample Volume** entry under *Appendix B: Calculations* in the *PADS Operator Manual (DOC-0116)*. For the CIP, sample volume = sample area • TAS.

[3] Maximum air speed depends on the CIP's resolution and maximum clock rate, as follows: Maximum TAS = resolution (µm) • clock rate (MHz) • 10^6 (MHz/sec) • 10^{-6} (m/µm). The maximum CIP clock rate is 12 MHz. Note that the 300 m/sec air speed maximum is largely theoretical and reflects only the constraints imposed by the CIP, not those of other instruments or the aircraft itself. Normal flight situations do not occur at such a high speeds.

[4] Versions of the Particle Analysis and Display System (PADS) earlier than 3.5 assume a sampling frequency of 1 sec / 1 Hz. As a result, this frequency is recommended if you are using PADS 2.7 or earlier.

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1.1.2 Cloud and Aerosol Spectrometer (CAS)

Technique:	Forward and Back Scatter Sensors
Measured Particle Size Range:	0.51 µm to 50 µm
Sample Area:	1.1 mm X 120 µm
Air Speed Range:	10 – 200 m/sec
Number of Size Bins:	Selectable, 10, 20, 30, or 40
Sampling Frequency:	Selectable, 0.1 to 10 Hz[5]
Refractive Index:	Non-absorbing, 1.30 – 1.70
Phase Discrimination:	Differentiates Liquid from Solid
Light Collection Angles:	4° - 12°, 168° - 176°
Laser:	658 nm wavelength
Data System Interface:	RS-232 or RS-422, 56.6 kb/sec Baud Rate
Auxiliary Parameters:	Ambient Temperature, Static Pressure, Dynamic Pressure
Calibration:	Precision glass beads and latex spheres for sub-micron range

1.1.3 Liquid Water Content Sensor (LWC-100)

Technique:	Temperature-Controlled Hot-wire Sensor
Liquid Water Range:	0.01–3 g/m^3
Air Speed Range:	10 – 200 m/sec

[5] Versions of the Particle Analysis and Display System (PADS) earlier than 3.5 assume a sampling frequency of 1 sec / 1 Hz. As a result, this frequency is recommended if you are using PADS 2.7 or earlier.

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Sampling Frequency:	Selectable, 0.1 to 10 Hz[6]
Data System Interface:	RS-232 or RS-422, 56.6 kb/sec Baud Rate
Auxiliary Parameters:	Ambient Temperature, Static Pressure, Dynamic Pressure, Airspeed
Calibration:	Not required

1.1.4 Operation Limits

Temp: -50 to +50 C.
Altitude: 50,000 feet.
Humidity: 0 - 100%

1.1.5 Physical Specifications

1.1.5.1 Power Requirements

Instrument Electronics and Internal heaters: 10 amps at 28 VDC
Anti-ice heaters: 45 amps maximum at 28 VDC

Note: *CAPS system power is 28VDC. Stand-alone CAS and CIP can be either 28VDC or 115VAC as system power.*

1.1.5.2 Weight

CAPS with canister: 45 pounds (20.4 Kg)

1.2 Cloud Imaging Probe (CIP)

The CIP is a new design based on established optical imaging techniques. Improvements include a laser diode, an on-board digital signal processor, fast front-end analog circuits, a synchronous RS-422 data channel providing statistics and control capability, data compression on 2-D image data, and particle header information that allows the user to precisely locate the beginning and end of every particle. In addition, the particle header

[6] Versions of the Particle Analysis and Display System (PADS) earlier than 3.5 assume a sampling frequency of 1 sec / 1 Hz. As a result, this frequency is recommended if you are using PADS 2.7 or earlier.

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includes information as to how many particles have been received, and at what time the particle was measured relative to instrument power up.

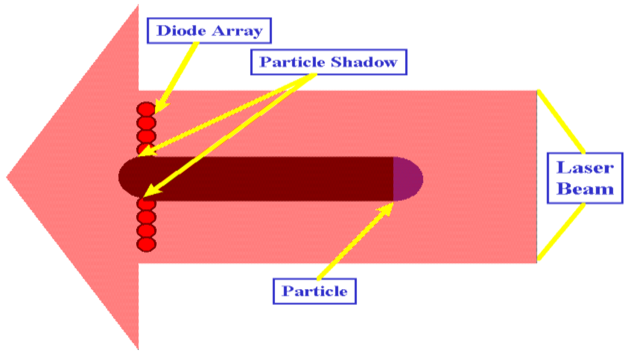

Figure 2: Particle Imaging with the CIP Probe

The CIP focuses an incident laser beam on particles ranging in size from 25 µm to 1550 µm, which are magnified by a factor of eight, onto a 200 µm pitch, 64-element photo-sensitive diode array. A diode laser produces an oval 50 mW beam illuminating the diode array. Whenever a particle passes through the laser beam, a shadow is generated and imaged onto the diode array. On-board digital electronics begins storing diode information at a clock rate associated with the true air speed (TAS) frequency. Each sample of the 64 elements, taken at the TAS frequency, is known as a slice; up to 62 slices compose a particle image. Particles shadowing an end diode (number one or sixty four) are rejected. The TAS is determined using an on-board pitot tube, providing air speed information at the instrument itself.

Along with particle image data, a particle header is included with information as described above. When a particle no longer obstructs the laser for two TAS clock periods, the electronics stops sampling the diode array. After a sufficient number of particles have been sampled, the digital signal processor sizes the particles by slice count, and stores the cumulative number of particles of each size; it also compresses the image data using run-length encoding. The synchronous, statistical data, when requested, is sent to the host processor for display and storage by Particle Analysis and Display System. The asynchronous image data is transmitted to the host computer whenever the compressed data fills a 4096 byte buffer; the host software then uncompresses a portion of this data for image display to the screen, and stores the entire compressed information to disk.

1.3 Cloud and Aerosol Spectrometer (CAS)

The Cloud and Aerosol Spectrometer achieves a wide range of particle measurements, including cloud droplet (1 µm to 50 µm) and partial aerosol (0.51 µm to 1 µm) diameters.

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The number of size bins and their threshold settings are user selectable, with the number of bins varying from 10 to 40. This provides great flexibility: users can zero in on a particular size range of interest, or span the entire range with chosen resolution. There is also no electronic dead time during which particles are not detected.

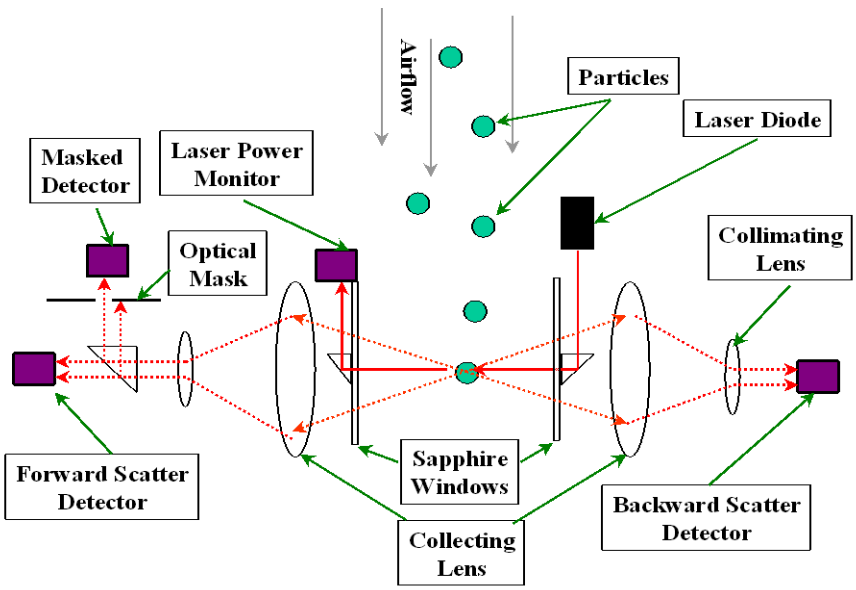

Figure 3: Forward and Back-Scatter Optical Paths in the CAS

As displayed in Figure 3, the CAS instrument relies on particle light scattering to determine particle size. Particles scatter an incident laser of approximately 50 mW. Collecting optics guide the light that is scattered from 5° to 14° into a forward-sizing and masked (qualifier) photodetector. These temperature-controlled APD detectors convert light energy into an electric current, and subsequent electronics convert the current to usable signal levels. The electronics are designed to capture particles while the instrument is flown at speeds up to 200 meters/second, and an on-board digital signal processor converts signal levels to sizing data. A comparison of the masked-detector signal level to the forward-sizing detector signal level ensures only particles within a limited sample volume are sized, as particles outside this volume would be erroneously sized due to variations in the scattered intensity.

A major feature of this probe is the addition of the backscatter block to measure the scattered light in the backwards direction (168° to 176°). For spherical particles, this allows determination of the real component of a particle's refractive index. Also, the phase (liquid or solid) can be determined, making use of the fact that aspherical particles scatter significantly more light in the back direction than spherical particles, while near-forward scattered light is less affected.

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Other measured parameters include a histogram of particle inter-arrival times , which are the periods during which no particles are present; a total sum of transit time; and the total particle count. Figure 4 below shows a typical signal response at any of the detectors as seen on an oscilloscope. The inter-arrival time is T_i, and if these were the only two particles to occur during the user selectable sample period, the sum of transit time would equal T_{t1} + T_{t2}, and the total particle count would be two.

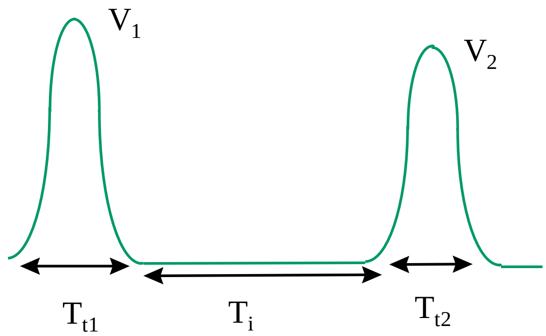

Figure 4: Scattered-Light Generated Signals in the CAS

1.4 LWC-100

The heated element liquid water sensor is a compact design with the element integrated onto a printed circuit card. The sensor's temperature is maintained via a digitally controlled variable duty-cycle current pulse. The more liquid water present, the greater the current required to maintain the fixed 125°C temperature. Liquid water content is then determined as a function of current through the device, minus the true air speed component. Because the current is limited by the digital control, large current spikes cannot occur in the sensing element, yielding a long lifetime for the LWC-100 sensor element.

The LWC sensor is powered from ***28VDC System Power***, and a relay that is activated when the ***Required Heater Buss*** is energized. If power is applied to the sensor element without a substantial airflow over it, the element will burn out. See LWC-100 operations manual for more details.

1.5 Environmental Measurements

The CAPS contains sensors for ambient temperature, static pressure, and dynamic pressure to determine TAS. These environmental measurements are necessary for analysis of the data gathered by the other sensors in the CAPS probe. Ambient temperature measurements are made by a semiconductor temperature sensor (AD-590) located at the

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bottom of the CIP lower arm. The sensor is located at this location to minimize wetting in cloud environments. Static pressure and airspeed are sampled by the Pitot tube to the right of the CIP arms. The pressure transducers are located on the power supply board of the CIP. The static and dynamic pressure transducers are calibrated at DMT with a pressure standard. These derived calibration coefficients should be entered into the PADS Configuration Editor Window for the CAS.

1.6 CAPS Heaters

Several heaters are used on the CAPS to stabilize the temperature at the optical blocks, heat the CIP windows to prevent fogging and ice buildup, and to anti-ice the sample inlets and the leading edges of the CAPS. These are wired on a total of four different circuits, and each of the heaters is individually fused on the power distribution board in the CAS section of the CAPS. Complete details on the heaters and part numbers for the individual heaters are available in the *CAPS Schematics Manual*.

2.0 Particle Analysis and Display System

PADS is a software package that interfaces to CAPS and is designed to offer display and analysis features to both novice and advanced users. Figure 5 shows the CAPS Summary tab in PADS. This tab combines data gathered by the CAPS's component instruments. Note that each instrument also has its own tab; clicking on these tabs will bring up additional information gathered by specific instruments.

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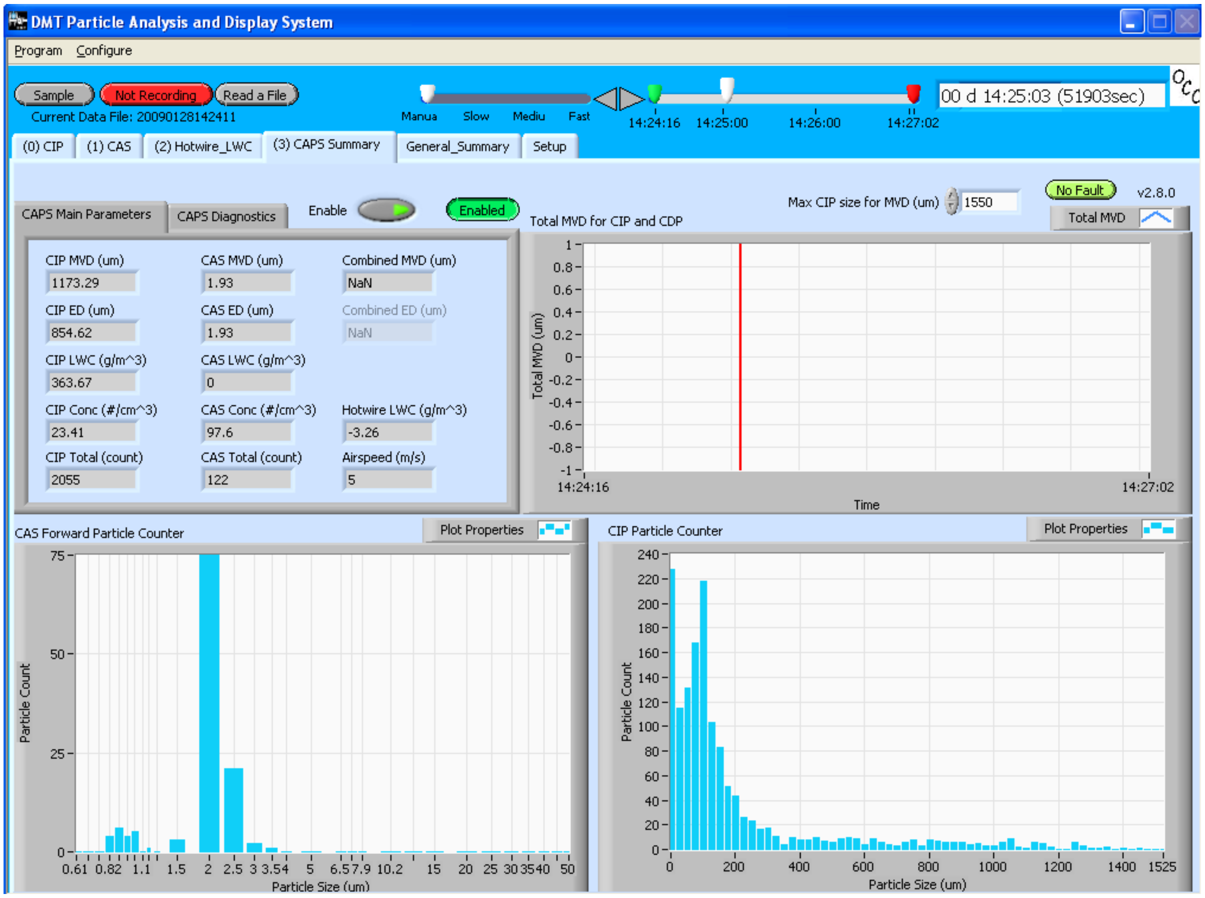

Figure 5: CAPS Summary Screen in PADS

3.0 CIP Electronic Troubleshooting and Repair

The CIP electronics are modular in design which will allow for in-field trouble-shooting and repair. There are four printed circuit boards (PCB's) that implement the CIP probe: CIP Back Plane, CIP Power Mod(ule), CIP DSP Mod(ule) and the CIP Diode Array. Schematics for each are shipped with the probe. See Appendix B, the CIP block diagram, for a functional diagram of the CIP modules.

3.1 Power Problems

The back plane routes all the signals, including power, between boards, so it and the power module should be checked first in case of problems to ensure proper mating of connectors and existence of required voltage levels.

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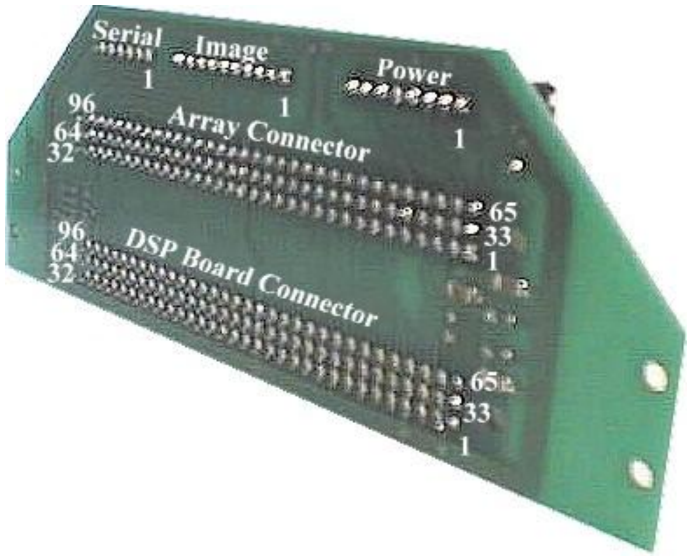

Figure 6: CIP Back Plane Board

Figure 6 above shows the CIP back plane board, with some labels to help for finding specific pins. Note that the two 96 pin connectors have pin one on the lower right hand corner, and the AMP connectors on the top also have their pin ones on the right. To verify proper operation, do for the following with the probe on:

- Check that four voltage LEDs are lit on the power module (this board is mounted on the bottom in the CIP PCB area). If any of these is unlit, there is a DC to DC power supply problem. If the 28V LED is unlit there is no power to the CIP. It will be necessary to trace the power back through the canister and the aircraft. If any of the +/-15 or + 5 V LEDs are not lit the problem is in the DC-DC converters. If all the LEDs are lit, proceed with the rest of the tests.

- Check for +5 Volts on pin one of both the DSP Board and Array connectors (ground is on pin 4 of the DSP Board connector, and 5 of the Array connector).

- Check for –5 Volts on pin two of the Array connector.

- Check for +15 Volts on pin two of the DSP Board and pin three of the Array connectors.

- Check for –15 Volts on pin 34 of the DSP Board connector.

- If any of the voltage levels is bad, check the power connector for the correct levels (+5V on pin 1, ground on 2, -5V on 3, 15V on 5, -15V on 7).

If any problems exist only at the CIP back plane board, check that all the boards are mated tightly with their respective connectors.

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3.2 Probe Communication Problems

If the probe fails to communicate with PADS, and the power has been checked, look to see that LED1, on the bottom of the DSP board, is lit. If it is unlit, the DSP board is not working. Contact DMT for assistance. If it is working, there are other things to look for.

If the clear to send signal is at an improper level on the image connector, the probe will stop communicating with the host computer (PADS); in such a case, PADS will generate a probe error. If this occurs, disconnect the image connector at the host computer (with the computer and the probe turned off). Power up, start PADS and attempt to communicate with the probe. The clear to send signals are pulled to the correct value when there is nothing connected to them, so if the probe communications resumes through this test, there is most likely a problem with the host computer's high speed serial interface card, or with PADS calling the card's driver.

If the previous test does not cause communications to resume, there may be a problem with chip U31 or U16: the RS422 and RS232 interface chips, respectively. Most CIP probes are set to run with RS422 signals. An indication that this is so is that the serial connection at the computer is not at a standard serial port, but to a PC card added to the computer. Assuming RS422 is used, check for signals, using an oscilloscope, on U31 pin 2 when the Start Sampling command is given in PADS. If there is no signal generated, check that there is a signal at pin 8. If these two conditions are true, then the part has failed and needs replaced. If there is a signal at pin 2, watch pin 3, then execute the Start Sampling command in PADS. If there is no signal here (but there was on 2), then the chip is okay—something is wrong with the system. If there is a signal on pin 3, watch pin 5. If, after executing Start Sampling again, there is no signal here, the chip needs replaced. If there is a signal on 5, but no communications with PADS, there is a problem with cables or connectors. Check the Serial connection on the CIP back plane PCB, the computer connection

If the RS422 chip has failed, replace it with a MAX3490 ESA from Maxim[1]. If this is not a possibility, try running the probe in RS232 mode. To do this, switch jumpers J6, J7, J8, J9 and J10 to RS232 on the DSP board (requires removal and installation of board), then, using DMT's RS422 to RS232 adapter on the computer side cable connection, plug into the standard serial port on the computer, switching the instrument's port number in the ***Probe Setup*, *DMT Probe X*, *Settings*** window.

3.3 Image and Data Problems

If the probe is producing no images, and/or the size histogram is empty, or the images consistently have one diode that is always dark, there may be a failure on the diode array

[1] See Appendix A for vendor information.

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board. A discussion of the array board and how it processes the diode array signals will help in diagnosing failures on this board. Refer to the CIP Diode Array schematic, and turn to the page labeled Diode Array Amplifiers – 1, 3, 5, 7. The amplifier chain at the bottom of the page will be discussed.

On the array board, there are 64 analog signal processing circuits just like this one (the PCB is a high density 12 layer board, with multiple ground and power planes). The input marker labeled IN-D is the input from a reverse biased photodiode. When a particle is shadowed, the photodiode produces a current that flows through R155, the 10KΩ resistor, generating a positive voltage swing on pin 14 of U16 on the order of 1 mV. Amplifier U17D inverts and amplifies this signal, producing a negative swing at its output, viewable at the TP7 test point (this is diode seven's output). Normally, the signal at TP7, with the laser incident on the array, is between 2 and 3.5 Volts. When the diode is fully shadowed, the voltage drops to approximately 200 mV. Amplifier U18D DC couples this signal and divides it by ½. Thus comparator U61C will switch from high to low at its output, pin 8—labeled Diode-D, when shadowing of the laser drops the voltage at TP7 to ½ its full laser incidence voltage. Note that as the laser is shadowed, the charge stored on capacitor C32 begins to bleed off, and the Output of U18D will begin to decay.

Looking now at the NAND/NOR page of the schematic, note that all 64 of the comparator outputs are ANDed, then ORed together, so that if any one comparator goes low, the –PARTICLE signal goes low. The digital electronics on the DSP board watches this signal to determine when there is a particle, and begins storing image data. If the signal stays low for more than 100 sample clocks, the electronics stops storing the image until this signal again goes high. *Therefore, if any one signal chain fails such that its comparator output is stuck low, the CIP will stop measuring particles*. Note that the DOF comparators perform the same function, but require the DC test point outputs to drop to 1/3 their nominal voltage before triggering; the digital electronics only use this signal to determine whether the particle should be rejected (if the user selects this option in PADS) based on depth of field. It does not affect particle image acquisition.

Returning to the amplifier chain, the last thing in the circuit to note is R129, a potentiometer. This adjusts the DC voltage of TP7. When there is no light on the diode array, all test points are set to approximately 200 mV.

If the problem occurring is a diode that is always light in the images, the voltage at the test point is probably stuck high. Monitor the test point and block the laser from hitting the diode array. If the test point voltage doesn't drop, there is a problem with one of the first two stage amplifiers. It is possible that the potentiometer has a problem, but more likely that one of the two operational amplifiers has failed. The first one is an OPA4650U-ND from BurrBrown[1]; the second is an AD8004AR-14 from Analog Devices[1]. If the test point voltage is okay, then the 3rd stage Op Amp or the comparator has failed. If so,

[1] See Appendix A for vendor information.

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replace the OP Amp with a LT1356CS from Linear Technologies[1], and the comparator with a MAX908CSD from Maxim[1].

If the problem occurring is no images, and/or no sizing histogram data, then a test point has probably failed at a low voltage. First check the –Particle signal, which is pin 30 on the Array Connector of the CIP back plane board. If it is high when the laser is not blocked, but goes low if the laser is blocked briefly, then the diode array board is not the problem. If the test shows the array board is not working, check the diode test points with full laser incidence on the diode array. If the voltage is well below 2V at any of them, something is wrong. Try replacing the first and second stage amplifiers. If these signals are okay, continue down the signal chain until an incorrect signal is found.

4.0 CAS Electronic Troubleshooting and Repair

The CAS electronics consists of the Baseline Restoration PCB, the CAS DSP PCB, the CAS Cont(rol) Mod(ule) PCB, the CAS_PWR PCB, and the CAS Backplane PCB (see Figure 7). The CAS is shipped with an extender card on which any of the first three PCBs may be piggy backed, allowing access to the board for troubleshooting. See appendix C, the CAS block diagram, for a functional diagram of the CAS modules.

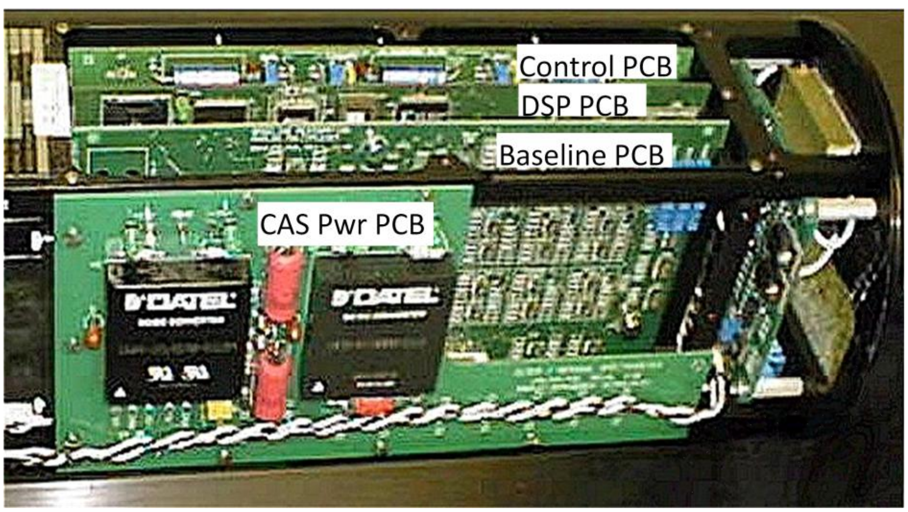

Figure 7: CAS Electronic Board Arrangement

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4.1 Power Problems

The first thing to check when problems occur with the CAS is that all correct voltages are present. On the CAS_PWR board, check that all the LEDs are lit, one each for +28V, +5V, +15V and –15V. Also make sure all of the boards that plug into the backplane PCB are firmly seated.

4.2 Probe Communication Problems

If the probe fails to communicate with PADS, and the power has been checked, look to see that CR4, the LED at the top of the DSP board, is lit. If it is unlit, the DSP board is not working. Contact DMT for assistance. If it is working, there are other things to look for.

If the DSP board is working, as indicated by a lit LED, there may be a problem with chip U8 or U9. These are the RS422 and RS232 interface chips, respectively. Most CIP probes are set to run with RS422 signals. An indication that this is so is that the serial connection at the computer is not at a standard serial port, but to a PC card added to the computer. Assuming RS422 is used, check for signals, using an oscilloscope, on U8 pin 2 when the Start Sampling command is given in PADS. If there is no signal generated, check that there is a signal at pin 8. If these two conditions are true (signal on pin 8, but none on 2), then the part has failed and needs replaced. If there is a signal at pin 2, watch pin 3, then execute the Start Sampling command in PADS. If there is no signal here (but there was on 2), then the chip is okay—something is wrong with the system. If there is a signal on pin 3, watch pin 5. If, after executing Start Sampling again, there is no signal here, the chip needs replaced. If there is a signal on 5, but no communications with PADS, there is a problem with cables or connectors. Check the Canister Drawing diagram to trace the serial communications signal.

If the RS422 chip has failed, replace it with a MAX3490 ESA from Maxim[1]. If this is not a possibility, try running the probe in RS232 mode. To do this, switch jumpers J4, J5, J6, J7 and J15 to RS232 on the DSP board (this requires removal and installation of the board), then, using DMT's RS422-to-RS232 adapter on the computer side cable connection, plug into the standard serial port on the computer, switching the instrument's port number in the appropriate Configuration Editor window in PADS.

[1] See Appendix A for vendor information.

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5.0 Particle Sizing Problems

If the size distribution looks erroneous, the first thing to check are the threshold tables. (For the location of threshold tables, consult the CAS Configuration Editor window in PADS.) If one bin covers a large range of sizes and corresponding thresholds, it will contain a disproportionate number of the sampled particles, causing a large peak in that bin.

If the tables look correct, check the outputs of the baseline restoration board. The outputs are brought to test pins for the low, mid, and high gains, for each of the forward, backward, and qualifying optical blocks. Check each of these nine pins. With no particles present, the top of the signals should all be approximately 0.3 Volts. If any of them are above or below this, the sizing of particles will be compromised. Voltages below this level on the forward or backward signals will cause particles to be undersized. Larger voltages will cause the digital electronics to stop sampling particles, or to undercount and oversize particles.

To adjust the DC voltage, or baseline, of each of the amplifiers' output, there is a grid of nine potentiometers in the upper right corner of the CAS Baseline board, laid out as in Figure 8. The relative position of each potentiometer matches that of the circuit on the same board. To vary the high gain channel of the back block's baseline, for example, the grayed potentiometer in the figure would be adjusted.

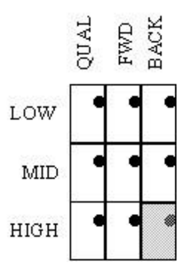

Figure 8: Potentiometer Grid

If the baselines are all correctly set, and if a method of generating particles is available, the test points may be monitored to ensure the proper waveforms are occurring on an oscilloscope. Waveforms similar to that of Figure 4 should be generated for each gain stage, requiring multiple particle sizes to do so. Note that if a waveform like that of Figure 4 shows up in a low gain channel, then the mid and high gain channels should be saturating to between 4.5 and 5 Volts. *Any voltage greater than this, in any channel, may damage the DSP board's analog to digital converters, and the problem must be immediately addressed.* If the mid gain channel has a signal, but there is none in low gain, then the high gain channel should be saturated.

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While checking the forward channels, it is a good idea to simultaneously watch the qualifier signal on the same gain stage. For example, while watching the forward mid gain channel test point, simultaneously watch the qualifier mid gain channel. Particles are only accepted as falling within the depth of field if the qualifier signal is higher than the forward signal. This is because the qualifier optical path, though masked to accept less light, receives 67% of the forward scattered light in the forward path; thus, if a particle is centered in the sampling volume, its scattered light will fit within the mask and generate a larger signal on the qualifier channel. If a laser misalignment or circuit problem occurs such that the qualifier signal never exceeds the forward signal, then the probe will not size any particles. A qualified engineer or technician, who understands the circuitry involved, is necessary to analyze such a problem.

If any of the channels does not produce quality peaks, there may be a problem with the baseline restoration circuit, and further analysis is required. Such an effort is beyond the scope of this document.

6.0 Housekeeping Data Problems

If housekeeping data looks incorrect, the circuitry to check is on the baseline restoration PCB. While the instrument is being sampled, check to see that the CS1/A0 signal on U38, pin 3 is toggling at least twice per second. Also check that pins 5 and 6 are toggling twice per second. If these aren't working, check to make sure the DSP board is well seated, as it is the source of the signals. If they are working, check U39 pin 1. It should have a burst of activity twice per second.

Next, check that the least significant bit of the A to D is changing by watching pin 16 of U38. Check U37 pin 1. The voltage there should go through rapid amplitude variations twice per second. If U37 pin 1 shows the described variation, and U38 pin 16 is not varying at the same time, and the control signals checked above are active, then U38 has probably failed. Replace it with an AD1674 BR from Analog Devices[1]. If U37 pin 1 does not have the required amplitude variations, check U37 pin 3, which is the amplifier input. If this shows activity, but there is none simultaneously on pin 1 of the same chip, replace U37 with an LT1364CS8-ND from Linear Technologies[1]. If there is no activity on U37 pin 3 (there should be amplitude variation twice per second), check to see if U35 is working.

U35 is an analog multiplexer, and once per polling period of the instrument, the select lines, labeled M_S0 through M_S3, should count from 0 to 15 in binary. Check for this count, noting that M_S0 is the least significant bit. If unsure of what the count should look like, the least significant bit should toggle at a rate twice that of M_S1; M_S1 should

[1] See Appendix A for vendor information.

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toggle at twice the rate of M_S2; and M_S2 should toggle at twice the rate of M_S3. If the signals are performing this count, then the digital signal processor on the DSP board is responding correctly to polls from the host computer. Check to make sure the enable line, pin 18, is at 5V, and that +15V is on pin 1, -15V on pin 27. If all of these conditions exist—proper signals and voltages—but there is no variation in the output signal on pin 28, then the chip needs replaced with a MPC506AU from Burr Brown[1].

U36 is also an analog multiplexer, and it handles the nine baseline signals: low, mid, high gain, forward, backward and qualifier. It also handles some spare signals. It should be tested to make sure that it too is generating a rapidly varying voltage at its output, pin 28, once per polling period. If it needs replaced, it is the same part as U35.

7.0 Verifying CIP Calibration with the Spinning Disk Calibrator

The DMT spinning disk calibrator allows users to validate the CIP's size resolution. The calibrator does not fix a faulty optical magnification that sets the size resolution; rather, it is intended solely as a diagnostic.

See *Spinning Disk Calibrator Manual (DOC-0012)* for information on mounting, calibrating, using, and cleaning the spinning disk.

8.0 CAS Optical System Maintenance

The maintenance the optical system requires is cleaning the sapphire windows on the forward and backscatter optical blocks. This is accomplished by removing the access cover from the top of the winglet as shown.

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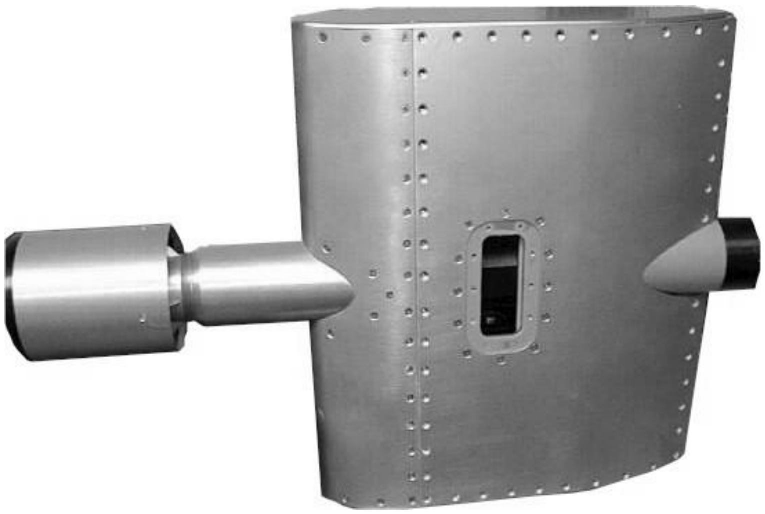

Figure 9: CAS Winglet with Access Cover Removed

Looking in at an angle towards the ends of the winglet, two windows will be visible. When the instrument is on and the windows are clean, only a faint red spot will be visible where the laser beam passes through the center of the window. Dirt on the window will scatter laser light, causing the spot to be much brighter. This scattered light will be collected by the detectors, increasing the noise on the signals and if severe enough causing false counts. Dirt on the windows will also block some of the light scattered by particles, causing them to be undersized. Clean the windows by swabbing them with a Q-tip saturated with a commercial glass cleaner such as Windex, then drying with another Q-tip. Then repeat this using isopropyl alcohol or acetone. The best solvent depends on the nature of the contamination. The windows, being sapphire, can withstand almost any solvent and moderate scrubbing. How frequently the windows need to be cleaned will depend on the environment in which the instrument is used and can only be determined through experience.

9.0 CAS Calibration and Optical Alignment Check

Ideally all particles traveling through the sample volume would be equally illuminated and therefore correctly sized. In reality, the laser beam has a Gaussian intensity profile and the instrument uses a slit in front of the qualifier detector to ensure that only particles passing through the central, nearly uniform portion of the beam are counted. This requires that the laser beam and the collection optics be precisely aligned.

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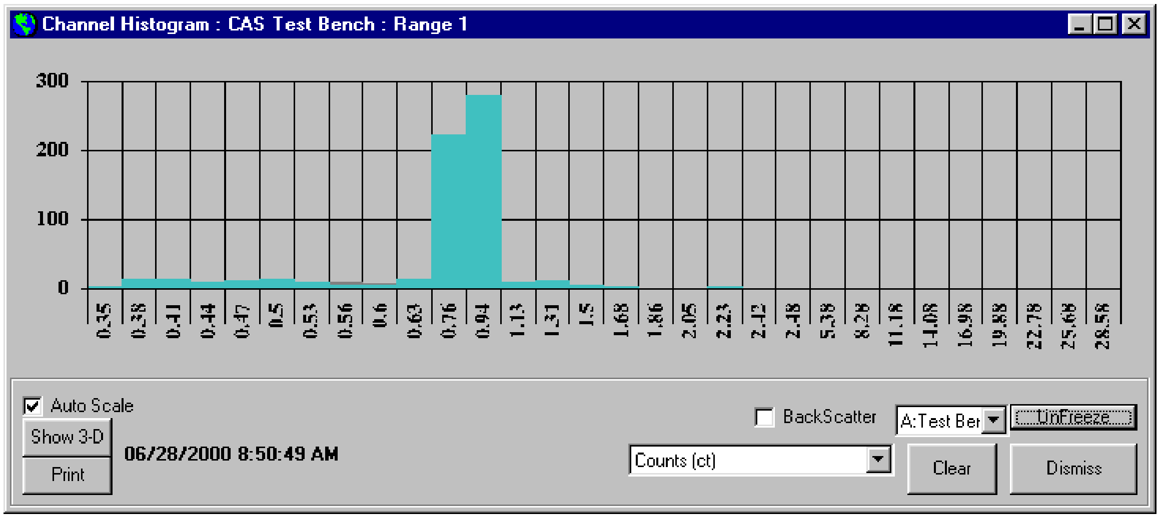

Figure 10: Histogram Produced by Well-Aligned CAS Instrument

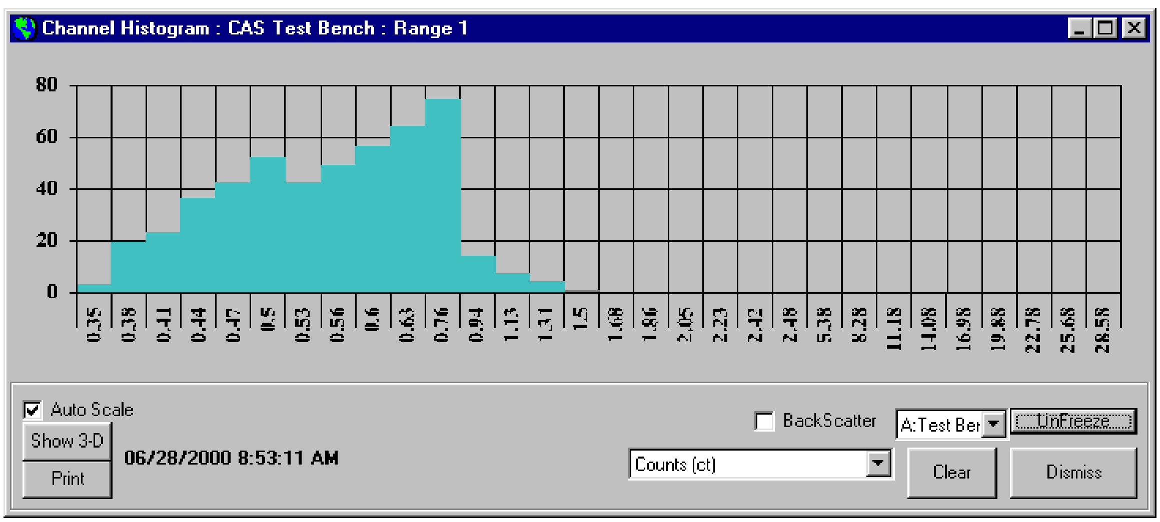

Figure 11: Histogram Produced by Poorly Aligned CAS Instrument

This alignment can be checked by sampling a mono-disperse aerosol (the technique described below) and observing the particle size histogram displayed by PADS. The majority of the counts should fall in one or two bins in the histogram as shown in figure 13. If a broad distribution occurs, as in figure 14, the probe is not operating correctly. Possible problems include optical misalignments, high voltage supply problems, baseline restoration circuit problems, and thermoelectric control system errors. Since determination of the error source is a complicated process, and because adjustment of the laser or slit requires considerable disassembly of the instrument, we recommend contacting DMT if misalignment is suspected.

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To do this test, nebulize a water solution of standard polystyrene latex (PSL) beads and dry the resultant aerosol. A standard nebulizer does not produce enough particles to fill the entire sample tube of the instrument with adequate concentration, so use a ¼ inch (6mm) tube to direct the aerosol to the sample volume at the center of the CAS sample tube, as in Figure 12.

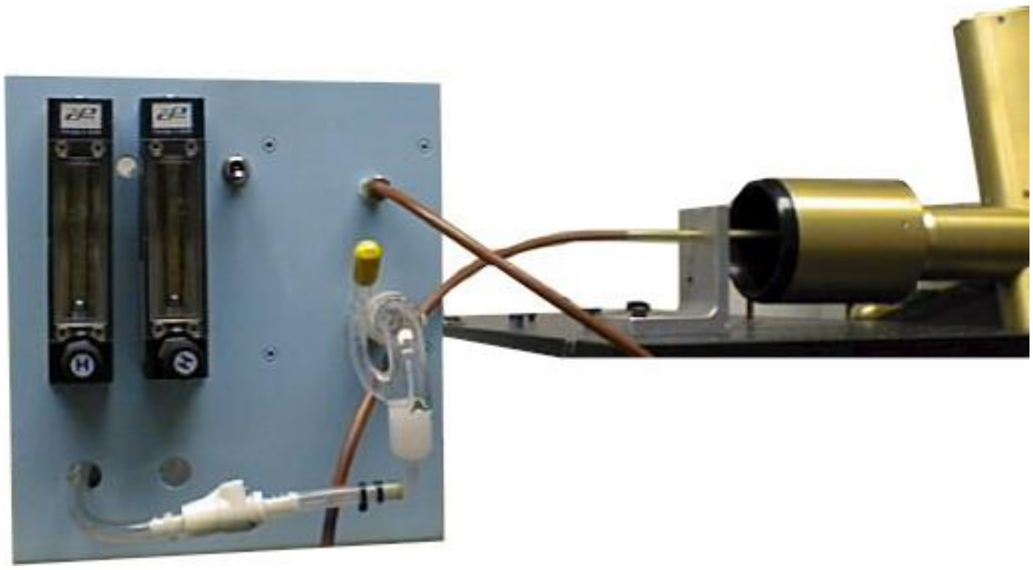

Figure 12: Nebulizer System to Deliver PSL's to the CAS Sample Area

Figure 12 shows an aerosol generator, consisting of a pump (not shown), flowmeters, and a glass nebulizer with the suspension of PSL. The tubing delivers the aerosol into the inlet of the CAS.

For larger size ranges, glass beads in the 5 – 50 μm range can be suspended in a stream of compressed air and similarly directed into the sample volume, as shown in Figure 13. PSL's and glass beads for these tests may be obtained from Duke Scientific Corporation[1].

[1] See Appendix A for vendor information.

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Figure 13: Glass Bead System for CAS Calibration and Test

Size calibration can be checked using the same techniques and checking if the observed counts fall in the correct size bins. Caution must be exercised in the interpretation of the results, because the histogram size bin boundaries are derived from a smoothed version of the Mie scattering curve. The calibration histograms supplied with the instrument can be used for reference. Since a change in calibration could be caused by a number of things, it is recommended users contact DMT if a problem is suspected. Users can also check the threshold and size tables listed in PADS, making sure that the tables store the proper values. Other simple things to check are the laser power and current, thermo-electric cooler temperatures and quad photo-detector readings, all of which are displayed in PADS channels. These values may be compared to those previously measured by looking at playback files taken when the probe was performing correctly. DMT usually provides a disk or CD of such recorded files when the instrument is calibrated before shipment. A slightly more complicated test is to measure the APD bias voltages on the test points on the CAS Control module. For more information, see the section on CAS mis-sizing in the particle sizing problems section for the CAS.

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Appendix A: Companies Supplying Parts for the CAPS Probe

Maxim. Web site: www.maxim-ic.com. Phone: (408) 737-7600 or 1 (800) 998-9872 (USA/Canada).

Burr Brown. Web site: www.burr-brown.com. Phone: 1 (800) 548-6132 or (520) 746-7980.

Analog Devices. Web site: www.analogdevices.com. Phone: (781) 461-3333.

Linear Technologies. Web site: www.linear-tech.com.

Duke Scientific Corporation. Web site:
www.informagen.com/Resource_Informagen/Full/2074.html.
Phone: (800) 334-3883

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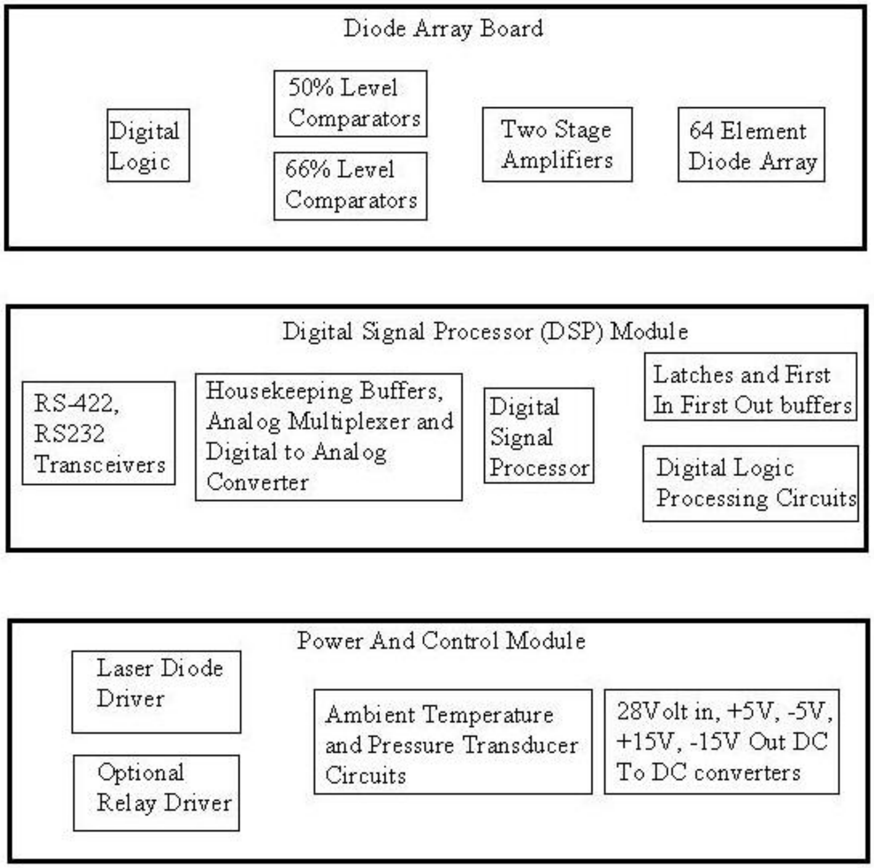
Appendix B: CIP Module Block Diagram



Notes:
The CIP Backplane routes most of the signals between boards, as evident in its schematic. Power is routed through its own cable via an eight pin connector from the power board to the backplane. Most housekeeping signals are routed from the power and control module via its J2 and J4 connectors to the DSP module's J2 and J4 connectors.

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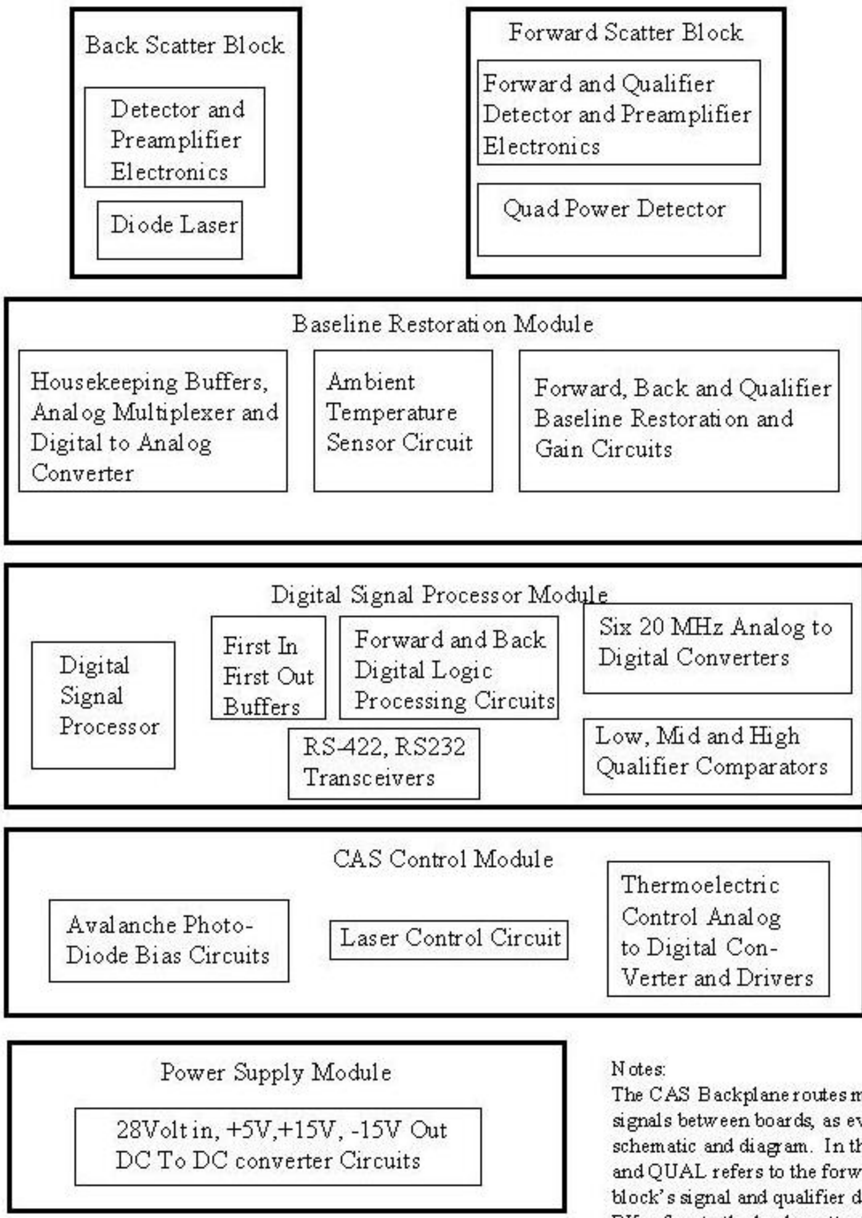
Appendix C: CAS Module Block Diagram



Notes:
The CAS Backplane routes most of the signals between boards, as evident in its schematic and diagram. In the diagram, FWD and QUAL refers to the forward scatter block's signal and qualifier detectors, while BK refers to the back scatter block's signal detector; THRM is short for thermistor; TEC is short for thermoelectric cooler; PD is short for photodiode; HV is short for high voltage; BLK is short for block.

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Appendix M: Mounting Diagram

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REVISIONS					
PART REV	DWG REV	ECO	DESCRIPTION	DATE	RESP ENG
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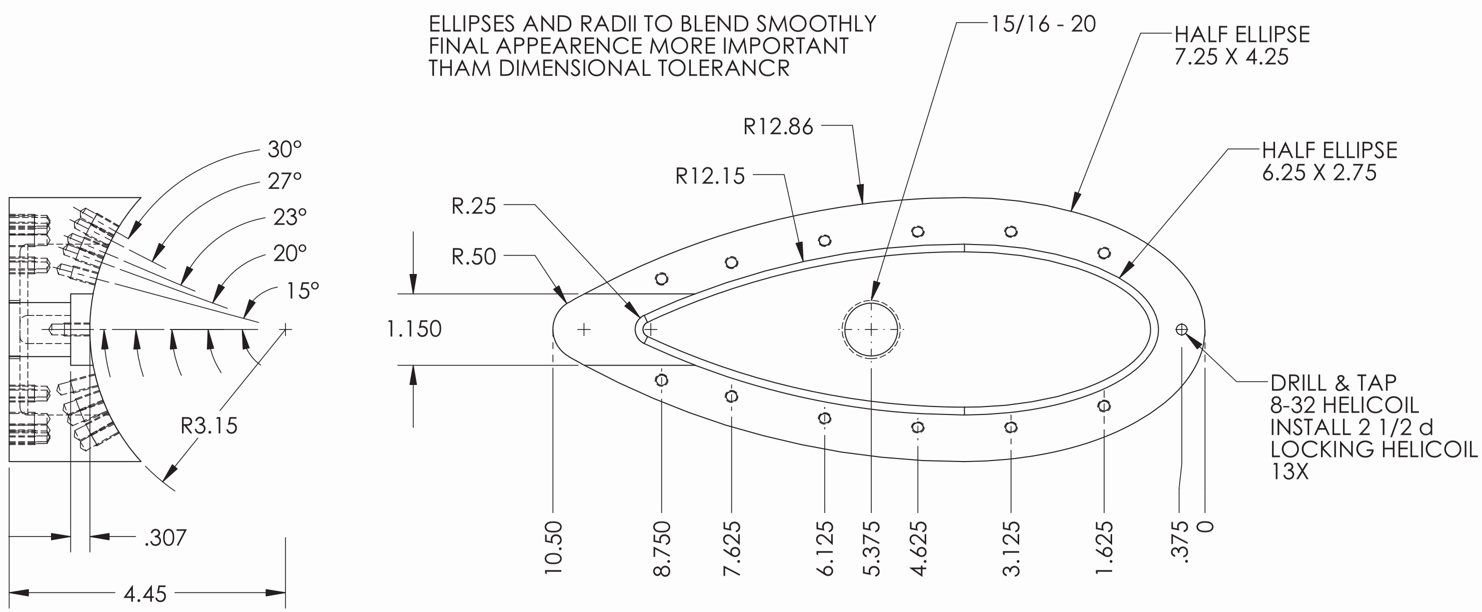
	B	1298	Changed to locking helicoils, redrawn in SW	05/10/07	R NEWTON



IDENTIFY WITH PART NUMBER & REV	ENGLISH DIMENSIONS: INCHES	CAD GENERATED DRAWING; DO NOT MANUALLY UPDATE; ALL PRINTED DRAWINGS ARE UNCONTROLLED; DO NOT SCALE; 3RD ANGLE PROJECTION; INTERPRET DRAWING PER ANSI Y14.5M, 1982	**Droplet Measurement Technologies, Inc.** 5710 B Flatirons Pkwy, Boulder, CO 80301
MATERIAL 6061-T6 Al	TOLERANCES: DECIMALS X.X ±0.015, X.XX ±0.010, X.XXX ±0.005; ANGLES X° ± 1°, X.X° ±0.1° (UNLESS OTHERWISE SPECIFIED)		TITLE Canister FOOT
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REVISIONS					
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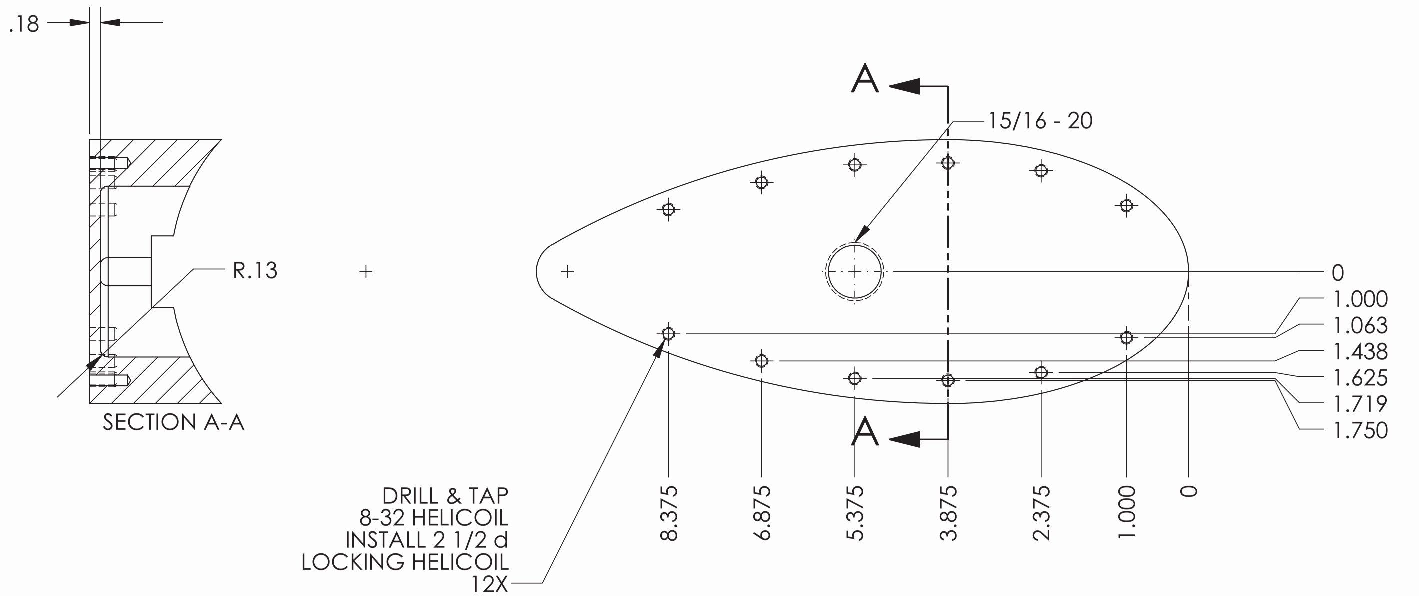

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ROY NEWTON	05/10/07	1:2	MP-0464	B

SIZE B N:\CAPS\Foot MP-0464-B.SLDPRT CAD FILE: SHEET 2 of 2

Appendix N: Revisions to Manual

Rev. Date	Rev. No.	Summary	Section
2/4/10	C	Deleted Calibration Data appendix	App. M
5/6/10	D	Updated CAS range	1.0
		Replaced OAP calibrator section and referred users to spinning-disk manual	7.0
10/26/10	E	Inserted mounting diagram	App. M
3/10/11	F	Updated CAS specifications (lower boundary of smallest bin changed to .51 µm)	1.1.2, 1.2

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