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www.specinc.com

SPEC Particle Probes

General Information

April 27, 2009

Pricing information is available upon request.

SPEC Cloud Particle Imager (CPI) Version 2:

- Sensor Head
- Standard Data Acquisition/Power System
- Test Cables (6 ft.) and Connectors
- CPIview Quicklook Software (Requires IDL license for PC – not included)
- eXtractor Toolbox for CPIview
- Operator Manual
- Atlas Shipping Case for Sensor Head
- 90 Day Limited Warranty on Parts and Labor.

CPI VERSION 2 TECHNICAL SPECIFICATIONS

Imaging

- 1K x 1K image area
- 2.3 μm/ pixel size resolution
- 8 bit grey scale (256 levels)
- 74 frames per second max rate
- Max Particle rate > 1000 particles per second
- 25 ns laser flash freezes motion of particle
- Data system only saves image area with particles
- Image data are displayed in real time

Sampling

- Dual beam PDS triggers laser when particle is in focus
- Maximum PDS sample volume is $(.23)^2$ x 10,000 x .707 = 372 cc/sec at V = 100 m/sec

Mechanical

- Sensor Head Weight – 31 LB
- Data / Power System Weight – Approx. 44lbs.
- Sensor Head Size – 361 mm X 648 mm X 159 mm
- Data / Power System Size –432 mm X 546 mm X 178 mm - Standard 19in Rack Mount Enclosure
- Sensor Head hermitically sealed and operates up to 70,000 feet altitude

Electrical

- Maximum of 2.2 KW (when operating full deice) 115 VAC 60 Hz (400 Hz can be used for heaters). 28 VDC option available at additional cost – depends on specific application.
- 26 signal pairs of RS-422 – 24 AWG
- AC & DC power lines – 16 AWG
- Fiber optic cable required for camera for cable lengths over 15 feet – available at additional cost – depends on cable length and application

Data Processing Software

CPIview Quicklook and eXtractor post-processing software included. See CPIview manual (www.specinc.com) for details.

Options:

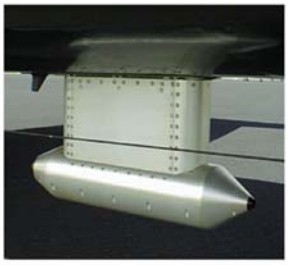
- Cable Runs Exceeding 14 feet (4.3 m) Between Probe and Data System Require Fiber Link System.
- SPEC **Version 2.5 CPI** with maximum 500 frames per second digital camera, upgraded frame grabber and data acquisition system.
- Training is Available Upon Request and is Recommended. Quoted Separately.

Baker, B. A., and R. P. Lawson, 2006: In situ observations of the microphysical properties of wave, cirrus and anvil clouds. Part 1: Wave clouds. *J. Atmos. Sci.,* **63**, 3160-3185.

Lawson, R.P., B.A. Baker, C.G. Schmitt and T.L. Jensen, 2001: An overview of microphysical properties of Arctic clouds observed in May and July during FIRE.ACE. *J. Geophys. Res.*, **106**, 14,989-15,014.

Lawson, R. P., B. A. Baker, B. Pilson, Q. Mo, 2006: In Situ observations of the microphysical properties of wave, cirrus and anvil clouds. Part II: Cirrus Clouds. *J. Atmos. Sci*., **63**, 3186-3203.

Lawson, R. P., B. A. Baker, P. Zmarzly, D. O'Connor, Q. Mo, J.-F. Gayet, and V. Shcherbakov, 2006: Microphysical and optical properties of ice crystals at South Pole Station. *J. Appl. Meteorol*., **45**, 1505-1524.

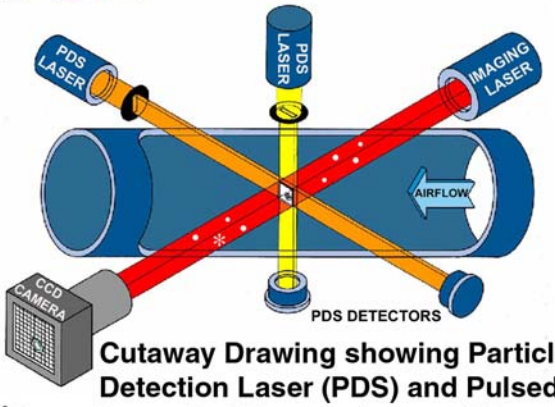


SPEC CPI

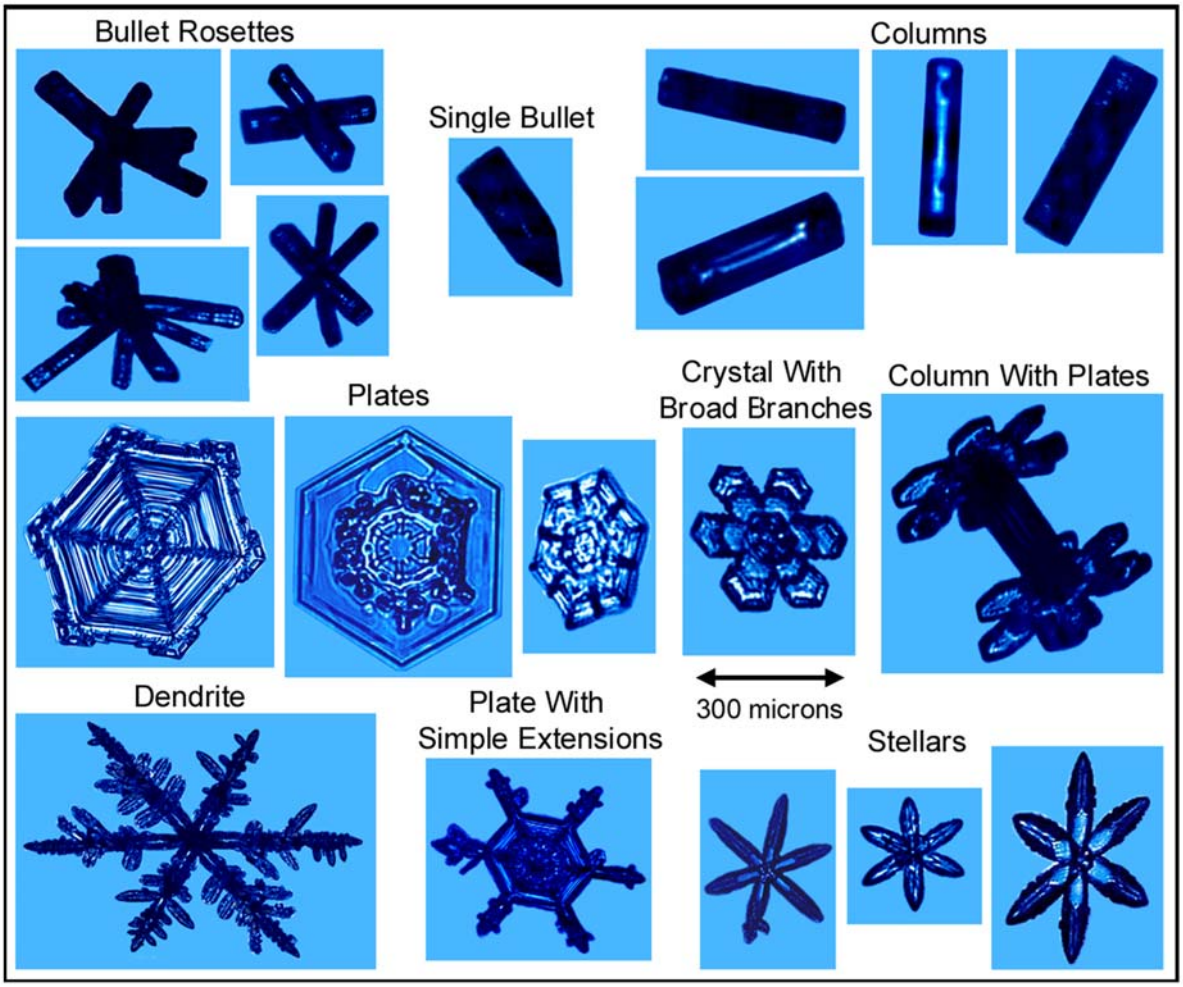
1 million pixel CCD camera with 2.3 μm pixel resolution in sample volume

Up to 74 Frames per second

Images Automatically sized and classified



Cutaway Drawing showing Particle Detection Laser (PDS) and Pulsed Laser that Freezes Image of the Particle on the CCD Array



Photographs of the CPI, cutaway view of electro-optics and examples of Images recorded by the Cloud Particle Imager (CPI).

SPEC 2D-S (Stereo) Optical Array Probe:

- 2D-S (dual 128-photodiode) sensor head without aircraft canister.
- Ground test cable.
- Data system is a (small footprint) PC Computer with Intel 2.8 GHz or better processor, including 60 GB or larger hard drive, minimum of 2 USB 2.0 ports, keyboard, mouse and 17" LCD monitor.
- Software includes MS Windows 2000 or XP Professional, real time acquisition software (installed), post processing analysis software written in IDL source code (IDL License not included).
- Technical and operations manual including schematics.
- Atlas shipping case.
- 90 Day limited warranty on parts and labor.

2D-S TECHNICAL SPECIFICATONS AND CHARACTERISTICS

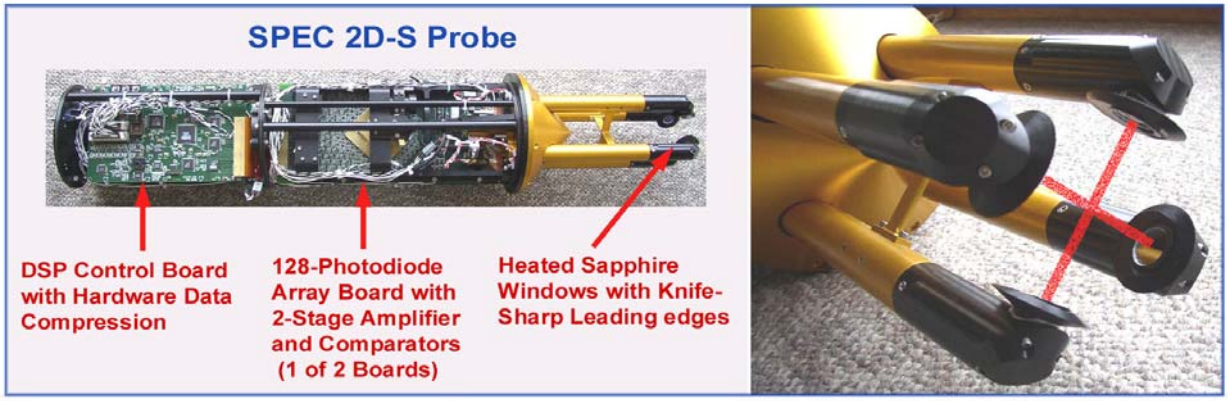
- Probe fits into a standard PMS airborne canister. The canister is not provided under this contract though a hermetically sealed canister is available as an option.
- Power and data interfacing via standard PMS 2D-C cable at up to 100 foot cable lengths. Ethernet data transfer rate may be 10 BASET or 100 BASET, depending on existing wiring and installation. 100 Mbps guaranteed with Cat5 cable.
- Power: < 400 watts of 115VAC, 400 or 60 Hz, and <250 watts of 28 VDC
- Probe includes deicing heaters similar or superior to conventional PMS 2D-C probes.
- Probe complies with normal requirements for approvals for use on research aircraft.
- Photodiode array response time (to 1/e) demonstrated to be < 50 nanoseconds in physical testing.
- Image pixel resolution is 9 to 11 µm, depending on final optical configuration.
- Overall capability of probe to accurately measure particles with 10 µm pixel resolution at an aircraft airspeed of 170 ms^{-1}
- Two independent imaging systems provided in the same package, with intersecting lasers defining an overlap volume to provide redundant measurements for PSD verifications of stereo particle identification. 2D-S probe will record all data to detect those particles that enter the overlap region of the probe.
- Hardware level run-length-encoding compression of raw data to reduce data file size and maximize data recording.
- AC deicing of probe tips and optical areas will use 115VAC, 50-400Hz.
- Probe provides a compressed output of raw image data from both lasers and records the data to a PC-based data acquisition system.
- Post-flight software includes image playback with various user-selectable artifact rejection schemes, identification of stereo images for 2D-S probe and computation of size distributions. Korolev algorithm to re-size out-of-focus images included.

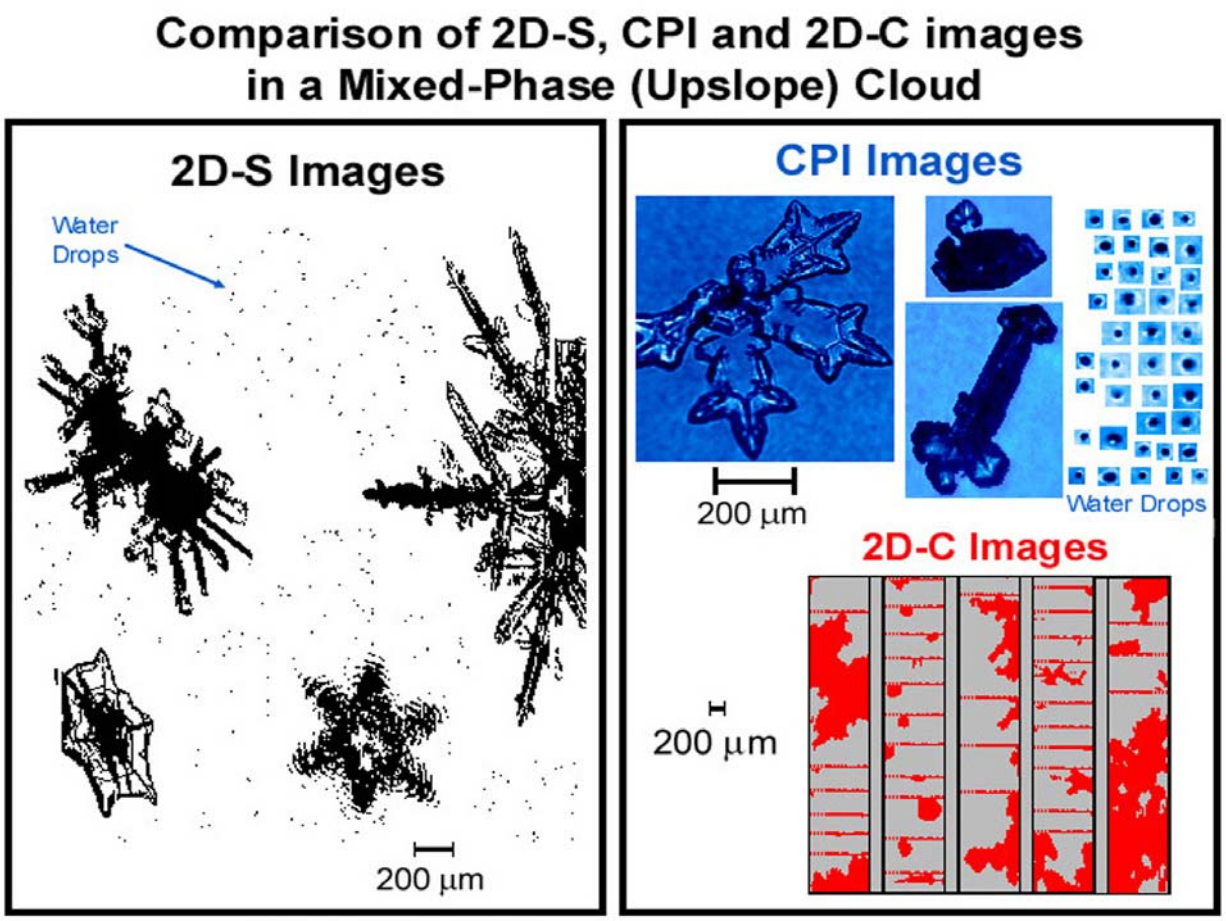
Option: Hermetically Sealed Canister is Available

Lawson, R. P., D. O'Connor, P. Zmarzly, K. Weaver, B. A. Baker, Q. Mo, and H. Jonsson, 2006: The 2D-S (Stereo) Probe: Design and preliminary tests of a new airborne, high speed, high-resolution particle imaging probe. *J. Atmos. Oceanic Technol.*, **23**, 1462-1477.

Lawson, R. P., B. Pilson, B. Baker, Q. Mo, E. Jensen. L. Pfister and P. Bui, 2008: Microphysical Properties of subvisible cirrus. *Atmos. Chem. Phys.*, **8**, 1609-1620.

Baker, B., Q. Mo, R.P. Lawson, D. O'connor, and A. Korolev, 2009: Drop Size Distributions and the Lack of Small Drops in RICO Rain Shafts. *J. Appl. Meteor. Climatol.*, **48**, 616–623.





Photographs of the SPEC 2D-S probe and a comparison of images from the 2D-S, CPI and 2D-C probes.

SPEC 2D-128 Optical Array Probe:

- 2D-128 (single 128-photodiode) sensor head without aircraft canister.
- Ground test cable.
- Data system is a PC Computer with Intel 2.8 GHz or better processor, including 60 GB or larger hard drive, minimum of 2 USB 2.0 ports, keyboard, mouse and 17" LCD monitor.
- Software includes MS Windows 2000 or XP Professional, real time acquisition software (installed), post processing analysis software written in IDL source code (IDL License not included).
- Technical and operations manual including schematics.
- Atlas shipping case.
- 90 Day limited warranty on parts and labor.

2D-128 TECHNICAL SPECIFICATONS AND CHARACTERISTICS

- Probe fits into a standard PMS airborne canister. The canister is not provided under this contract though a hermetically sealed canister is available as an option.
- Power and data interfacing via standard PMS 2D-C cable at up to 100 foot cable lengths. Ethernet data transfer rate may be 10 BASET or 100 BASET, depending on existing wiring and installation. 100 Mbps guaranteed with Cat5 cable.
- Power: < 300 watts of 115VAC, 400 or 60 Hz, and <200 watts of 28 VDC
- Probe includes deicing heaters similar or superior to conventional PMS 2D-C probes.
- Probe complies with normal requirements for approvals for use on research aircraft.
- Photodiode array response time (to 1/e) demonstrated to be < 50 nanoseconds in physical testing.
- Image pixel resolution is 9 to 11 µm, depending on final optical configuration.
- Overall capability of probe to accurately measure particles with 10 µm pixel resolution at an aircraft airspeed of 170 ms^{-1}
- Hardware level run-length-encoding compression of raw data to reduce data file size and maximize data recording.
- AC deicing of probe tips and optical areas will use 115VAC, 50-400Hz.
- Probe provides a compressed output of raw image data from both lasers and records the data to a PC-based data acquisition system.
- Post-flight software includes image playback with various user-selectable artifact rejection schemes, identification of stereo images for 2D-S probe and computation of size distributions. Korolev algorithm to re-size out-of-focus images included.

SPEC Fast CDP or Fast FSSP-100 Upgrade

SPEC has created an electronics upgrade for the PMS FSSP-100 and DMT CDP using advanced state of the art technologies. The new technologies, which includes a field programmable gate array (FPGA), 40 MHz analog-to-digital-converter (ADC) sampling, custom amplifiers, and a very small and low power Linux based 400 MHz processor, transform the CDP or FSSP-100 into an instrument that surpasses the capabilities of all previous FSSP-type instruments. The SPEC upgrade supports the following advanced features:

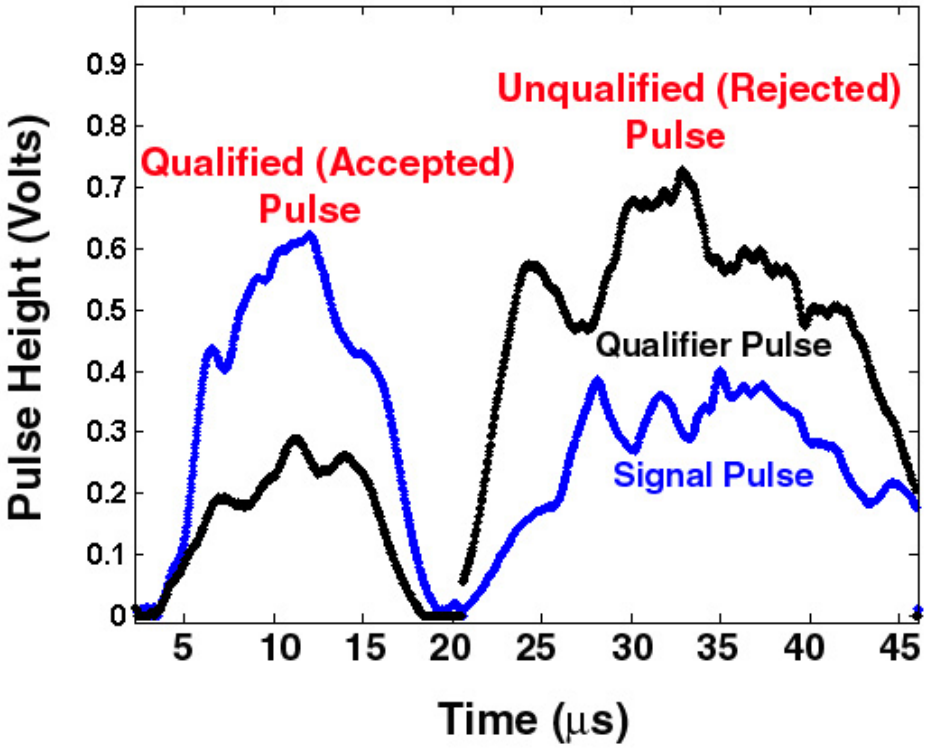
1. Redesigned amplifier chain to drastically reduce the offset errors associated with AC coupling and baseline restoration circuitry. Initial tests and simulations show a decrease in baseline drift by a factor of 100. High concentrations are not expected to alter the measured size distribution.

2. Particle by particle data are collected for every particle in real time; i.e., the arrival time, transit time and pulse height of both the signal and qualifier pulse for each particle are recorded. Each particle is time-stamped with 25 nS resolution using 40-bit counters that will not roll over during a flight (i.e., 1954 continuous flight hours to fill the counter). The number of DOF disqualified particles between DOF-qualified peaks is also counted. Recording individual particle statistics, especially arrival times, can be used to eliminate closely-spaced particles that may be the result of particles shattered on the probe inlet.

3. Complete digitization of selected particle signal and qualifier pulses (i.e., the ADC samples during the particle transit through the sample volume producing a digital oscilloscope representation of both the signal and qualifier pulse). These data are stored for analysis in post-processing. See figure below.

4. All electronics including the FPGA and Linux processor are housed within the probe. All data are stored on a flash drive in the probe, eliminating the need for a computer data system. Ethernet connection to the probe supports reprogramming and upgrades, and also supports transport of data to an external data system, if desired.

The figure below shows a time series of particles recorded by the instrument. This series is recorded in addition to the peak values discussed in item 3, above. The time series is the voltage vs. time recorded as particles pass through the sample volume. Both qualified and unqualified particles are sampled. In the time series shown, 4 out of 15 particles are DOF qualified such that the signal voltages (blue) are greater than the qualifier voltages (black).



Photograph of (top) an FSSP and (bottom) examples of 40 MHz ADC samples of (blue) signal and (black) qualifier (black) voltages recorded by the Fast FSSP-100. The pulse on the left is accepted because the qualifier peak voltage height is equal to or lower than the signal; the pulse on the right is rejected because the qualifier peak voltage height is higher than the signal. Recording the full waveforms from both the signal and qualifier photodiodes (instead of just the peak values like previous FSSP's) supports post-processing analysis of potential instrument calibration errors and anomalies.

Upgrade for DMT CDP or FSSP-100 TECHNICAL SPECIFICATONS AND CHARACTERISTICS

- Either the upgraded CDP or FSSP-100 fits into a standard PMS airborne canister.
- Power and data interfacing via standard PMS FSSP or CDP cable at up to 100 foot cable lengths. Ethernet data transfer rate may be 10 BASET or 100 BASET, depending on existing wiring and installation. 100 Mbps guaranteed with Cat5 cable.
- Power: < 300 watts of 115VAC, 400 or 60 Hz, and <400 watts of 28 VDC
- Probe includes deicing heaters similar or superior to conventional PMS 2D-C probes.
- Probe complies with normal requirements for approvals for use on research aircraft.
- Improved baseline restoration circuitry.
- Individual particle arrival time, transit time, signal and qualifier pulse heights recorded.
- Up to 2% of all signal and qualifier waveforms recorded for post analysis.
- All data recorded at the probe on flash disk and also transmitted to (user supplied) external data system via Ethernet connection.
- Real time data displayed via Ethernet connection.

SPEC Version 3 High Volume Precipitation Spectrometer (HVPS-3)

SPEC previously built the Version 1 and Version 2 HVPS probes that have now been discontinued due to obsolete parts and significant advances in technology. The HVPS-3 uses the same 128-photodiode array and electronics that are used in the 2D-S and 2D-128 probes. The optics are configured for 150 micron pixel resolution, resulting in a maximum field of view of 1.92 cm (i.e., particles up to 1.92 cm are completely imaged, although even larger particles can be sized in the direction of flight). Sample volume of the HVPS-3 is 400 L s^{-1} at 100 m s^{-1}. The 2D-S or 2D-128 and HVPS make an excellent pair of probes that completely image particles from 10 microns to 1.92 cm.

HVPS-3 TECHNICAL SPECIFICATONS AND CHARACTERISTICS

- Probe is hermetically sealed and fits into a standard PMS airborne canister. The canister is not provided under this contract though a hermetically sealed canister is available as an option.
- Power and data interfacing via standard PMS 2D-C cable at up to 100 foot cable lengths. Ethernet data transfer rate may be 10 BASET or 100 BASET, depending on existing wiring and installation. 100 Mbps guaranteed with Cat5 cable.
- Power: < 600 watts of 115VAC, 400 or 60 Hz, and <200 watts of 28 VDC
- Probe includes deicing heaters similar or superior to conventional PMS 2D-C probes.
- Probe complies with normal requirements for approvals for use on research aircraft.
- Photodiode array response time (to 1/e) demonstrated to be < 100 nanoseconds in physical testing.
- Image pixel resolution is 150 µm.
- Overall capability of probe to accurately measure particles with 150 µm pixel resolution at aircraft airspeeds up to 1,000 ms^{-1}
- Hardware level run-length-encoding compression of raw data to reduce data file size and maximize data recording.
- AC deicing of probe tips and optical areas will use 115VAC, 50-400Hz.
- Probe provides a compressed output of raw image data from both lasers and records the data to a PC-based data acquisition system.
- Post-flight software includes image playback with various user-selectable artifact rejection schemes and computation of size distributions. Korolev algorithm to re-size out-of-focus images included.

Lawson, R. P., R. E. Stewart and L. J. Angus, 1998: Observations and numerical simulations of the origin and development of very large snowflakes. *J. Atmos. Sciences*, **55**(21), 3209-3229.

Photographs of Version 1 and 2 HVPS probes installed on research aircraft.

Terms of Payment for all SPEC Probes:

- 50% ARO and 50% 30 Days After Delivery
- FOB: Boulder, CO Freight is prepay
- Freight insurance to be paid by Customer.
- Available for Shipment 180 Days Upon Receipt of Order.