SPEC inc

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Products and Services

for

The Atmospheric Science Community

September 2011

Company Information

SPEC Incorporated is a high-tech company in Boulder, Colorado whose mission is to provide state-of-the-art instrumentation, operational support and scientific analysis for the atmospheric science community. The company employs 18 people consisting mainly of scientists, engineers, programmers, technicians and administrative staff. Founded in 1979, the company started actively pursuing Government contracts to design and build sensors and data acquisition systems for cloud physics research in 1989. Since that time, SPEC has developed a suite of sensors that provide new insights into the physics and radiative characteristics of clouds. SPEC has been awarded over 40 US government and international grants to participate in major field campaigns, such as WISP90 and WISP91, HaRP, SPICE, SCMS, CASP II, VORTEX, SUCCESS, FIRE, SHEBA, TRMM, AIRS, CAMEX4, CRYSTAL-FACE, Mid-CiX, CR-AVE, ISDAC, RACORO, NAMMA, TC4, SPARTICUS, ICE-T, MACPEX, NSF Studies at the South Pole and in wave clouds along the Front Range of the Colorado Rockies.

SPEC owns and operates a Learjet model 25 research aircraft that has been flown in several field campaigns. The Learjet is highlighted on the following pages. Company personnel have also collaborated in the instrumentation of several other research aircraft, including the NASA DC-8 and WB-57F, Canadian Convair 580, NCAR GV and C-130, UK BAE-146, US Navy Twin Otter, DLR Falcon and UND Citation. Recently, SPEC instrumented and gained an FAA-approved Supplementary Type Certificate (STC) for the Thai Bureau of Royal Rainmaking and Agricultural Aviation (BRRAA) Super King Air 350. Photographs of the Thai Super King Air and its instrumentation are shown in this brochure.

SPEC scientists are heavily involved with the analysis of scientific data. The facing page lists some of the most recent publications.

SELECTED SPEC JOURNAL PUBLICATIONS

Baker, B. A., and R. P. Lawson, 2010: Analysis of Tools used to Quantify Droplet Clustering in Clouds. *J. Atmos. Sci*., doi: 10.1175/2010JAS3409.1

Baker, B., Q. Mo, R. P. Lawson, D. O'Conner and A. Korolev, 2009: The Effects of Precipitation on Cloud Droplet Measurement Devices. *J. Atmos. Ocean Tech.*, **26,** 1404 – 1409.

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

Baker, B. A., and R. P. Lawson, 2006: Improvement in determination of ice water content from two-dimensional particle imagery: Part I: Image to mass relationships. *J. Appl. Meteorol*., **45**, 1282-1290.

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.

Evans, K. F., R. P. Lawson, P. Zmarzly, D. O'Connor, and W. J. Wiscombe, 2003: In situ cloud sensing with multiple scattering lidar: simulations and demonstration*. J. of Atmos. Oceanic Technol*., **20,** 1505-1522.

Evans, K. F., D. O'Connor, P Zmarzly, and R. P. Lawson, 2006: In situ cloud sensing with multiple scattering lidar: design and validation of an airborne sensor. *J. of Atmos. Oceanic Technol*., **23**, 1068 – 1081.

Lawson, R. P., K. Stamnes, J. Stamnes, P. Zmarzly, J. Koskuliks, C. Roden, Q. Mo, M. Carrithers, 2011: Deployment of a Tethered Balloon System for Cloud Microphysics and Radiative Measurements at Ny-Ålesund and South Pole, *J. Atmos. Oceanic Technol.* **28**, 656 – 670

Lawson, R. P., Effects of ice particles shattering on the 2D-S probe, 2011**:** *Atmos. Meas. Tech.*, **4**, 1361-1381.

Lawson, R. P., E. Jensen, D. L. Mitchell, B. Baker, Q. Mo, and B. Pilson, 2010: Microphysical and radiative properties of tropical clouds investigated in TC4 and NAMMA, *J. Geophys. Res*., **115**, D00J08, doi:10.1029/2009JD013017

Lawson, R. P., P. Zuidema, 2009: Aircraft Microphysical and Surface-Based Radar Observations of Summertime Arctic Clouds. *J. Atmos. Sci.*, **66**, 3505-3529.

Lawson, R. P., B. Pilson, B. Baker, Q. Mo, E. Jensen, L. Pfister, and P. Bui, 2008: Aircraft measurements of microphysical properties of subvisible cirrus in the tropical tropopause layer. *Atmos. Chem. Phys.*, **8**, 1609-1620.

Lawson, R. P., and B. A. Baker, 2006: Improvement in determination of ice water content from two-dimensional particle imagery. Part II: Applications to collected data. *J. Appl. Meteorol*., **45**, 1292-1303.

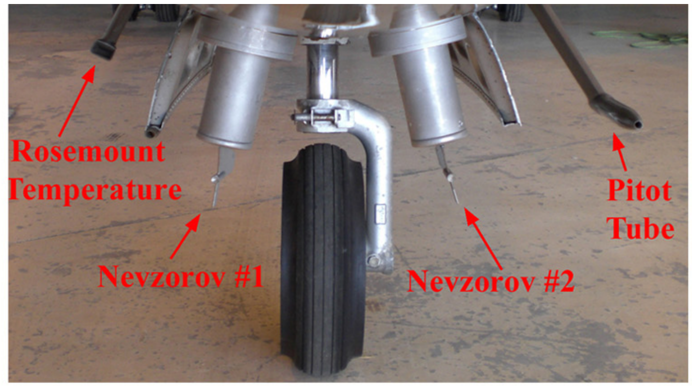
Lawson, R. P., B. A. Baker, B. Pilson, Q. Mo, 2006: In Situ observations of the microphysical properties of wave, cirrus and anvil clouds. Part II: Cirrus Clouds. *J. Atmos. Sci.*, **63**, 3186-3203.

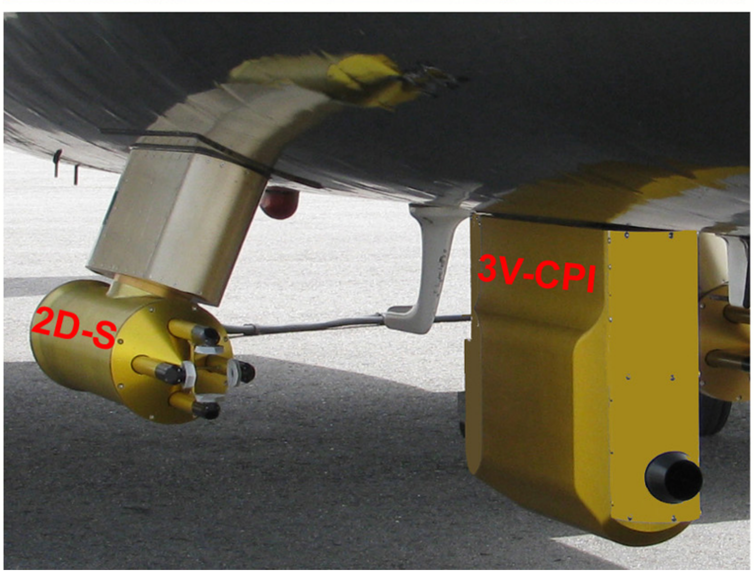
Lawson, R. P., B. A. Baker, P. Zmarzly, D. O'Connor, Q. Mo, J.-F. Gayet, and V. Shcherbakov, 2006: Microphysical and optical properties of ice crystals at South Pole Station. *J. Appl. Meteorol*., **45**, 1505-1524.

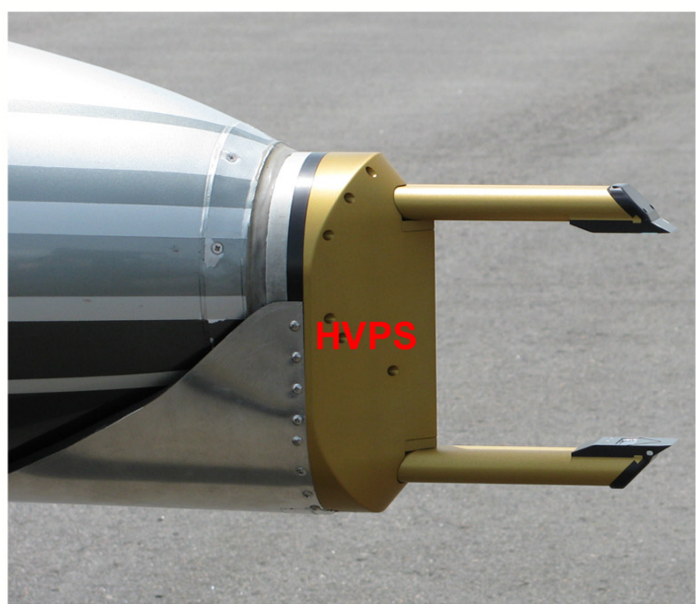
Lawson, R. P., D. O'Connor, P. Zmarzly, K. Weaver, B. A. Baker, Q. Mo, and H. Jonsson, 2006: The 2D-S (Stereo) Probe: Design and Preliminary Tests of a New Airborne, High-Speed, High-Resolution Particle Imaging Probe. *J. Atmos. Oceanic Technol.*, **23**, 1462-1477.

Lawson, R.P., B.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.

SPEC Learjet Model 25 Research Aircraft Equipped for Cloud Physics Research with State-of-the-Art Instrumentation and Available for Lease





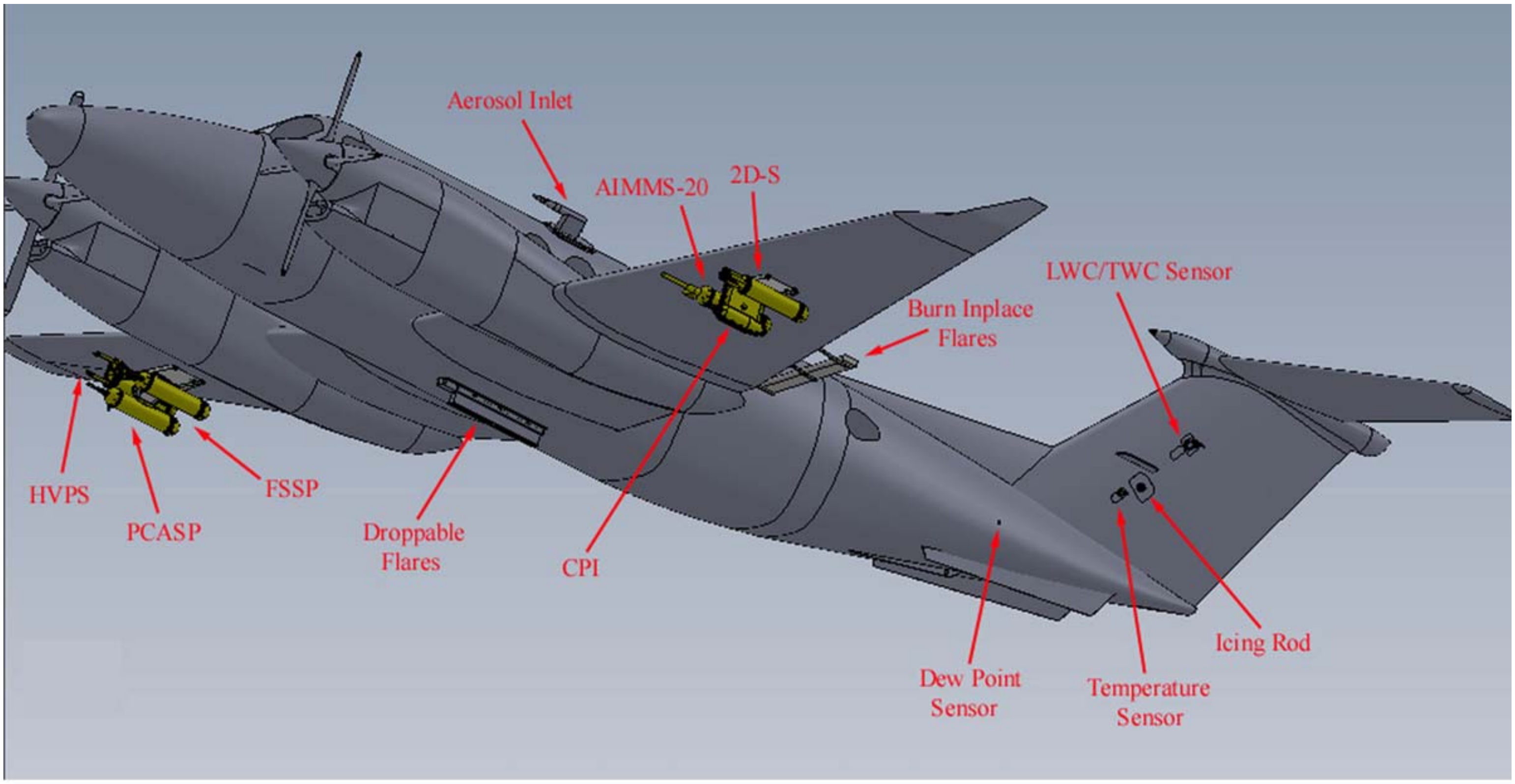


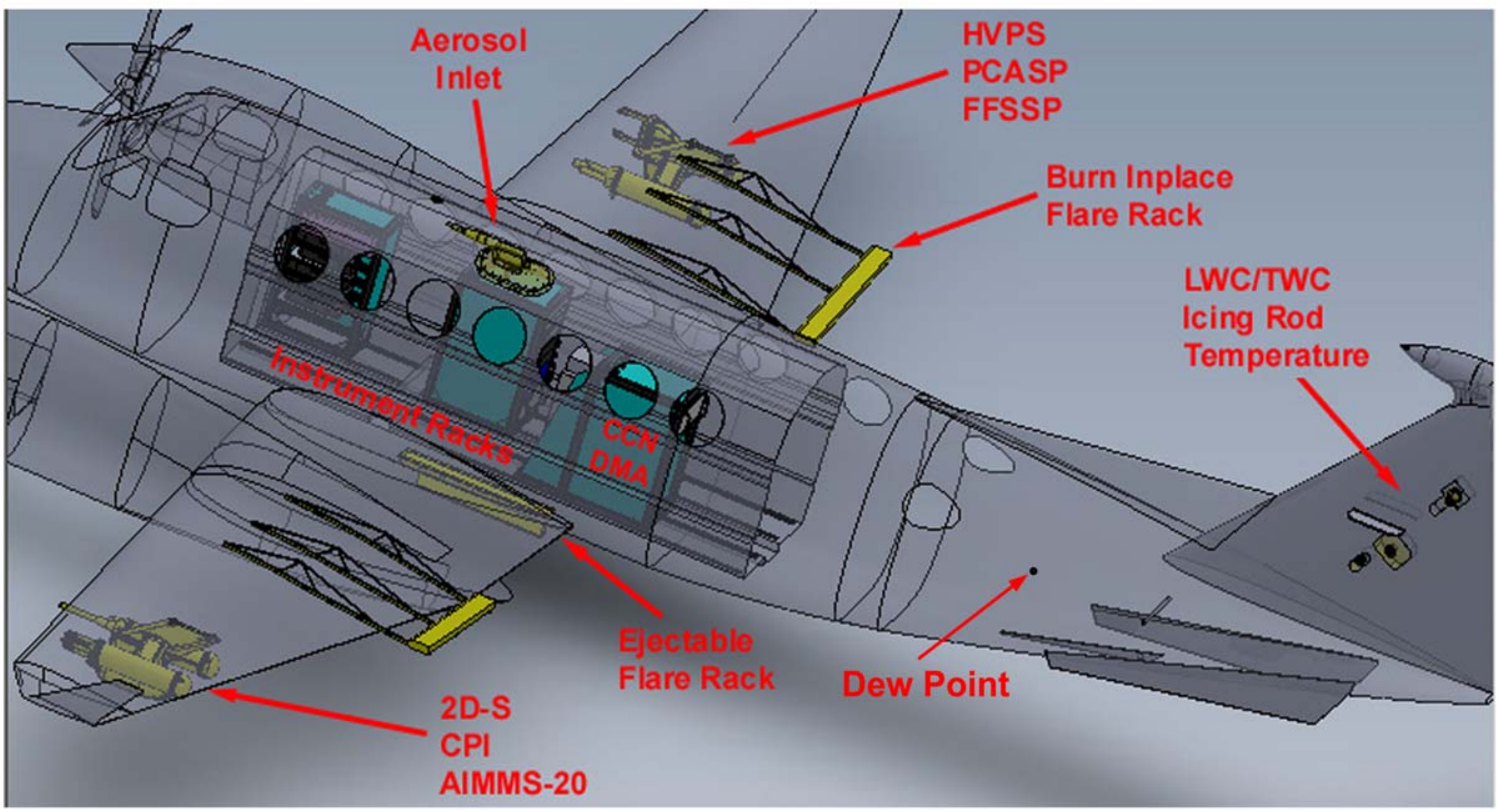
SPEC Learjet Performance in Research Configuration

Maximum Takeoff Weight	15,000 lbs
Maximum Certificated Ceiling	45,000 ft
Time to Climb S.L. to 0°C (5 km 16,450 ft DA) at Maximum T.O. Weight @ ISA	3 min
Time to Climb 0°C to -10°C (5 km 16,450 ft to 7.24 km 23,760 PA) @ ISA	2.5 min
Maximum Duration	3 hr
Maximum Airspeed	0.82 Mach (306 KIAS)
Number of Seats excluding pilots	6
Electrical Capability	(2) 400 A Generators @ 28.8 VDC = 23 KW Research Power = 7.2 KW distributed as 5.5 KW @ 110 VAC 60 Hz 1.7 KW @ 28 VDC

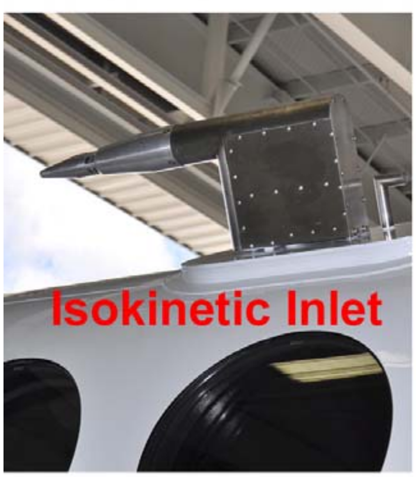
Equipment List	*Manufacturer*	*Range*	*Accuracy*
Temperature	Rosemount Model 102 & 510BH Amplifier	-50 to +50 °C	0.5 °C
Altitude	RVSM	0 to 45,000 ft (0 to 13.7 km)	60 ft (18.3 m)
Airspeed	RVSM	0 to 220 m s^{-1}	1 m s^{-1}
Cloud Liquid Water (2)	Sky Tech Nevzorov LWC Probe	0 to 4 g m^{-3}	N/A
Cloud Total Water (2)	Sky Tech Nevzorov TWC Probe	0 to 4 g m^{-3}	N/A
Aircraft Position	Aventech AIMMS-20 Differential GPS	N/A	10 m
Aircraft Heading	Learjet Sperry Directional Gyro	0 to 360°	1°
Horizontal Wind	Aventech AIMMS - 20	0 to 360° 1 to 100 m s^{-1}	1° 1 m s^{-1}
Vertical Wind	Aventech AIMMS - 20	0 to 50 m s^{-1}	0.5 m s^{-1}
2D-S (Stereo) Optical Array Spectrometer	SPEC Model OAP 2D-S	10 μm to 3 mm	10 μm
Fast Cloud Droplet Probe (FCDP)	SPEC Model FCDP-100	2 to 50 μm	2 μm
Fast Forward Scattering Spectrometer Probe (FFSSP)	SPEC Model FFSSP-100	2 to 50 μm	2 μm
High Volume Precipitation Spectrometer (HVPS)	SPEC Version-3 HVPS	150 μm to 2 cm	150 μm
Combination 2D-S and Version 2.5 CPI (3V-CPI)	SPEC model 3V-CPI	7 μm to 3000 μm	2.3 μm

SPEC's Advanced CAD Engineering Facilities are used to Design and Install Cloud Microphysical, Aerosol and Weather Modification Equipment on Research Aircraft

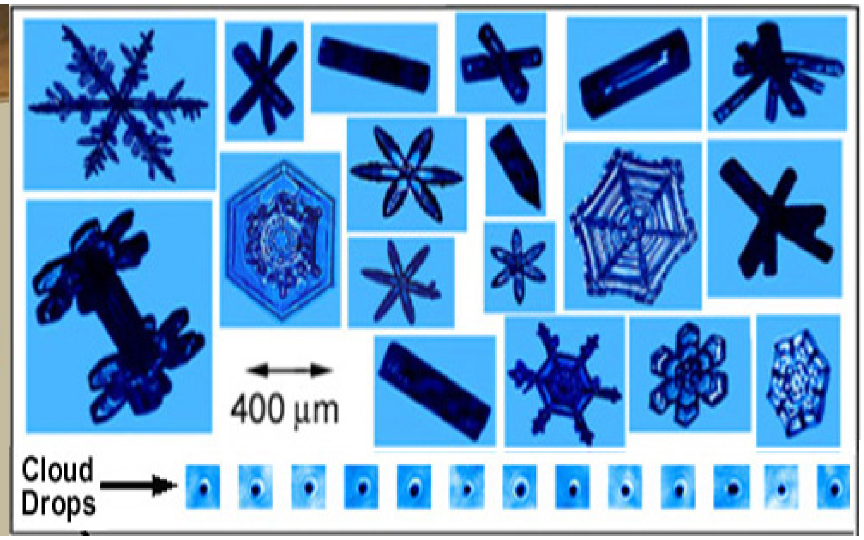




Hawker Beechcraft Super King Air 350 Instrumented by SPEC for the Thai Bureau of Royal Rainmaking and Agricultural Aviation
(Instruments also shown on facing page in Solid Model)



SPEC Cloud Particle Imager (CPI) Versions 2.0 and 2.5

CPI Probe and Data System Includes

- Hermetically-sealed Sensor Head
- Integrated Data Acquisition/Power System
- Test Cables (6 ft.) and Connectors
- CPIview Quicklook Software and eXtractor Toolbox for CPIview
- Operator Manual
- Atlas Shipping Case for Sensor Head
- 1 year Limited Warranty on Parts and Labor.

Imaging

- 1K x 1K image area
- 2.3 µm/ pixel size resolution
- 8 bit grey scale (256 levels)
- **V2.0:** 74 frames per second max rate **V2.5:** 400 frames per second max rate
- 25 ns laser flash freezes motion of particle
- Data system only saves image area with particles
- Image data are displayed in real time

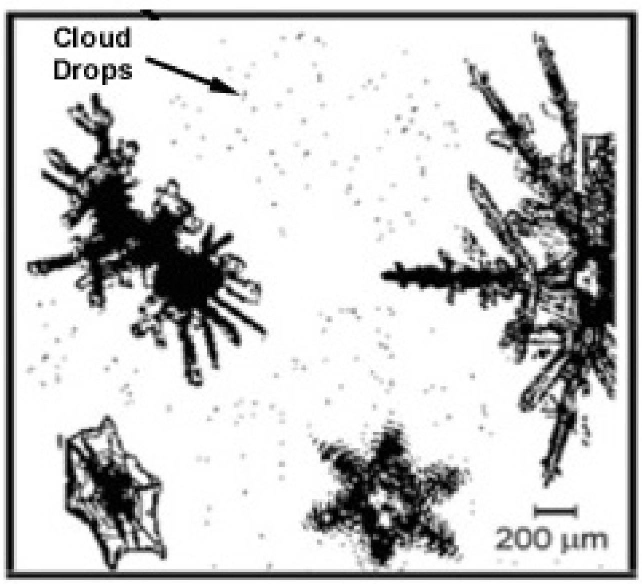
Mechanical

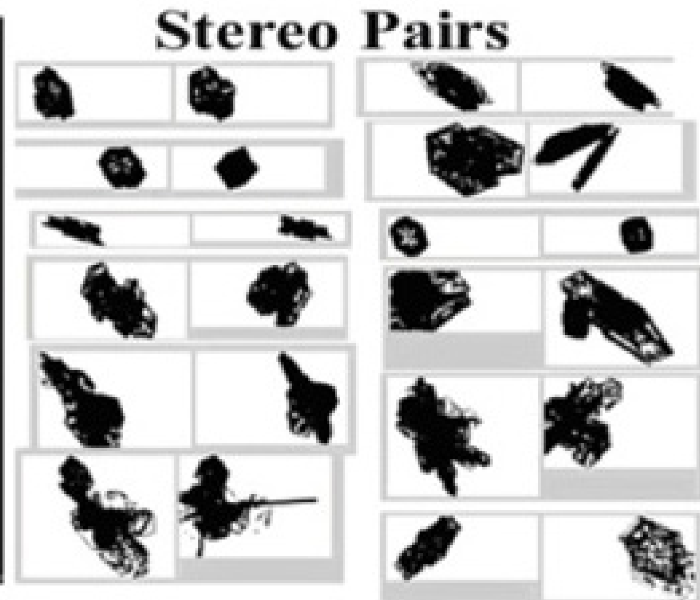
- Sensor Head Weight – 31 LB
- Data / Power System Weight – Approx. 44lbs.
- Sensor Head Size – 361 mm X 648 mm X 159 mm
- Data / Power System Size –432 mm X 546 mm X 178 mm - Standard 19in Rack Mount Enclosure
- Sensor Head hermetically sealed and operates up to 70,000 feet altitude

Electrical

- Maximum of 2.2 KW (when operating full deice) 115 VAC 60 Hz (400 Hz can be used for heaters).
- 26 signal pairs of RS-422 – 24 AWG
- AC & DC power lines – 16 AWG
- V2.0: Fiber optic cable required for camera for cable lengths over 15 feet.
- V2.5: Fiber optic cable required.

SPEC 2D-S (Stereo) Optical Array Probe





2D-S Probe and Data System Includes

- 2D-S (dual 128-photodiode) sensor head
- Ground test cable.
- Data system is a small footprint PC Computer.
- Software includes MS 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.
- 1-Year limited warranty on parts and labor.

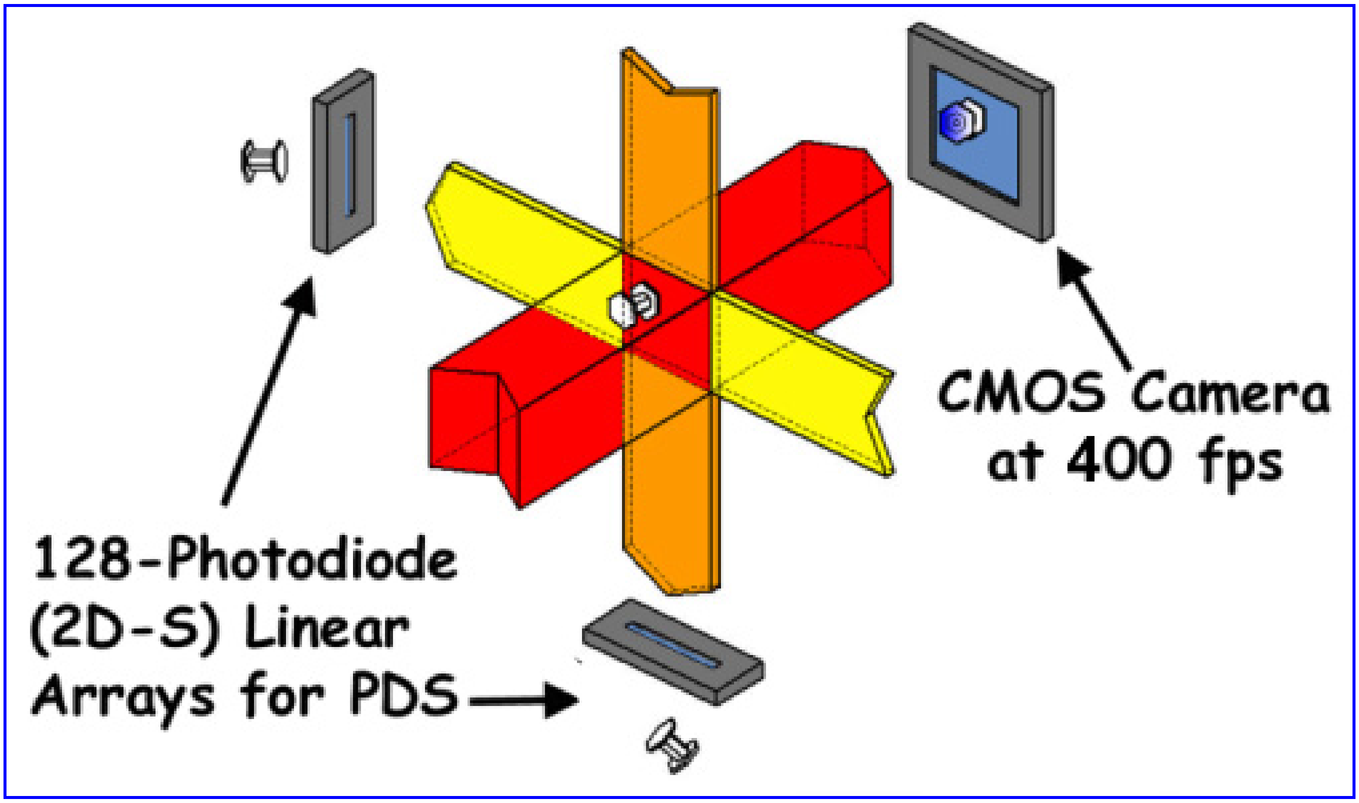
2D-S TECHNICAL SPECIFICATONS AND CHARACTERISTICS

- Hermetically-sealed probe fits into a PMS-type airborne canister
- Power and data interfacing via Ethernet Cat5 or better cable.
- Power: < 400 watts of 115VAC, 400 or 60 Hz, and <250 watts of 28 VDC
- Photodiode array response time (to 1/e) demonstrated to be < 50 nanoseconds in physical testing
- 10-µm pixel resolution at an aircraft airspeed of 170 ms^{-1}
- Two independent 10-µm imaging systems provided in the same package
- Hardware level run-length-encoding compression of raw data.
- Custom probe tips designed to prevent shattering. Post-flight software includes inter-arrival time algorithm to reduce remaining shattered particles and re-sizing of out-of-focus images

Options:

- Hermetically Sealed PMS-type Canister is Available.
- Single Channel version of 2D-S (2D-128).

SPEC 3V-CPI (3-View) Combination Probe

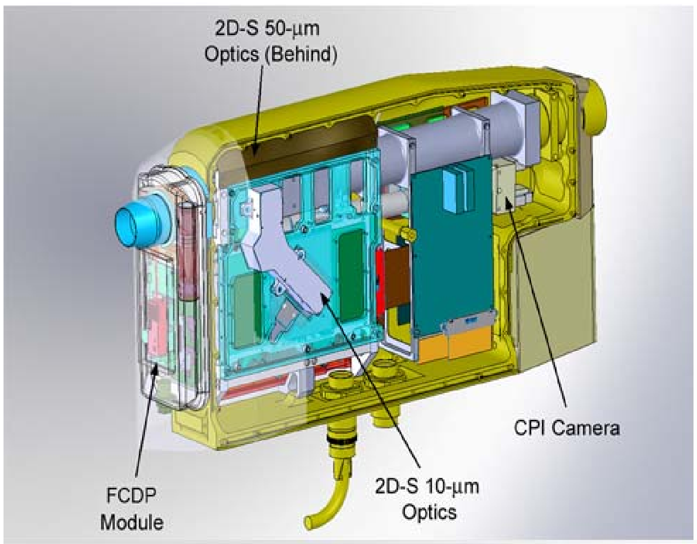


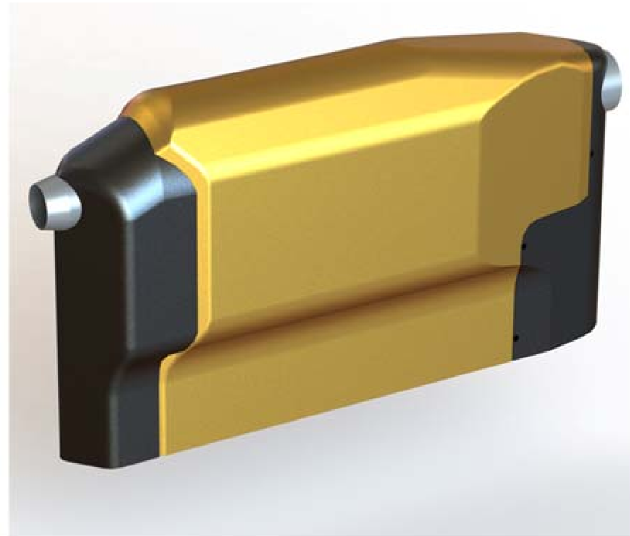
SPEC has combined the Version 2.5 CPI and 2D-S probes. A fully functional 2D-S probe doubles as the Particle Detection System (PDS) for the CPI. As shown in the figure above, the 2D-S/PDS provides two channels with 128-photodiodes with 10-μm pixels that also triggers the CPI imaging system. The result is a CPI with quantitative size distributions that can be separated into ice and water size distributions, or into size distributions of ice particle habits. Also, three different views of particles that pass through the overlap region of the 2D-S probe are available to improve determination of ice water content. The 3V-CPI has been installed in the vertical orientation on the SPEC Learjet (shown at the right in the figure above) and in a horizontal orientation on the NCAR GV research aircraft (shown in the left and middle panels in the figure above).

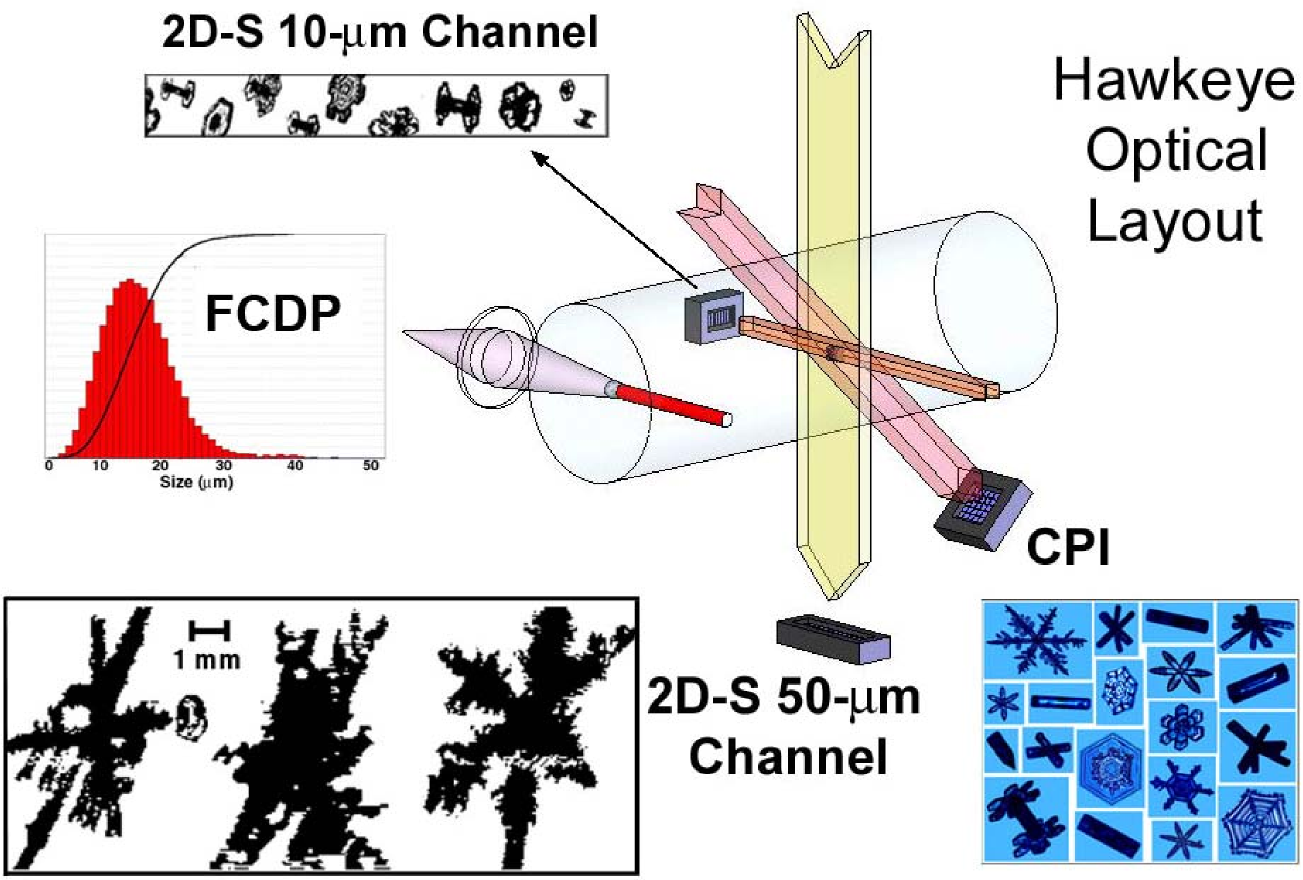
The 3V-CPI combines the specifications of the V2.5 CPI and the 2D-S. The sensor head weighs 63 lbs and the data acquisitions systems weigh 80 lbs. Total power consumption of the probe is 2.5 KW.

SPEC Hawkeye Probe

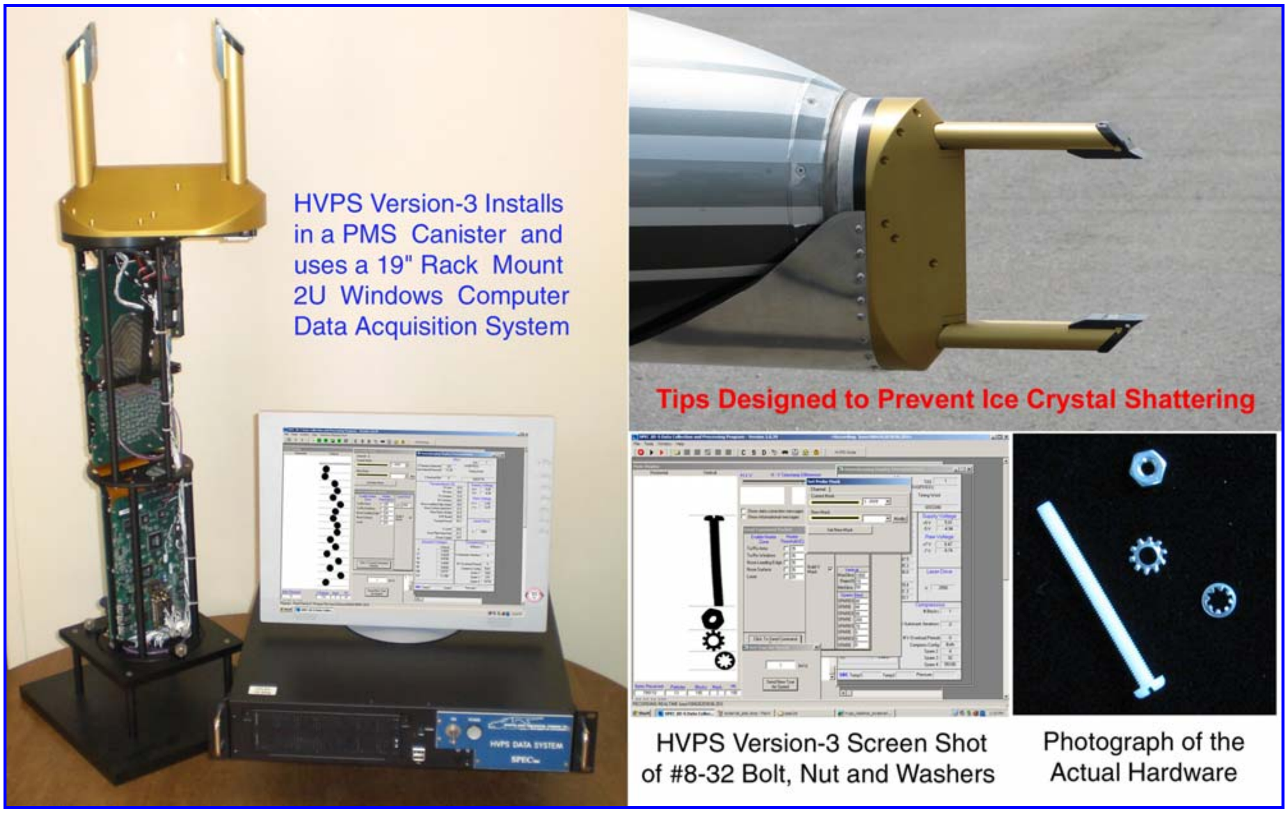
Originally designed for application on NASA's Global Hawk UAV, the Hawkeye probe adds a Fast Cloud Droplet Probe (FCDP) forward scattering module to the 3V-CPI Probe. The FCDP module is an add-on to the 3V-CPI and only requires interfacing of the electronics and a new front fairing on the housing.







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



HVPS Version-3 Screen Shot of #8-32 Bolt, Nut and Washers

Photograph of the Actual Hardware

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}.

HVPS-3 TECHNICAL SPECIFICATONS AND CHARACTERISTICS

- Probe is hermetically sealed and fits into a standard PMS airborne canister. Canister not provided, though a hermetically sealed canister is available from SPEC 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 (may be possible to run on existing PMS wiring, depending on cable integrity).
- Power: < 600 watts of 115VAC, 400 or 60 Hz, and <200 watts of 28 VDC
- Photodiode array response time (to 1/e) demonstrated to be < 100 ns 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.
- Custom probe tips designed to reduce ice particle shattering.
- 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 source code is included. IDL license required to run software. Features include image playback with various user-selectable artifact rejection schemes and computation of size distributions. Algorithm to re-size out-of-focus images included.

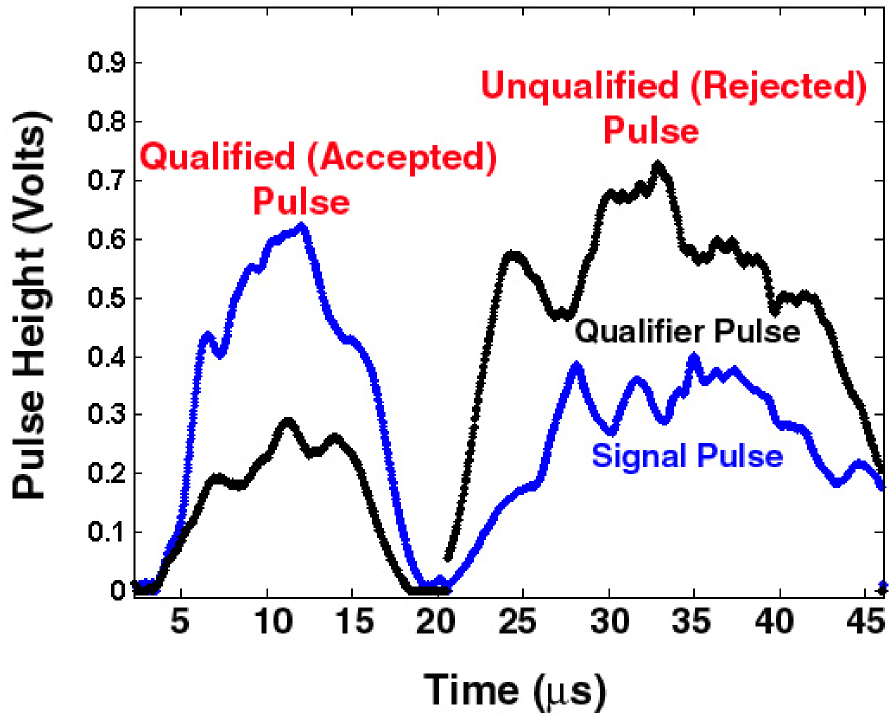
SPEC Fast CDP and Fast FSSP with Tips Designed to Reduce Shattering

SPEC has developed a Cloud Droplet Probe with state-of-the-art electro-optics and electronics. The same electronics can be retrofit into an existing Forward Scattering Spectrometer Probe (FSSP) along with new probe tips designed to reduce the effects of shattering. The new electronics include a temperature controlled fiber-coupled laser, FSSP-300 optics, 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. The fast CDP is an instrument that surpasses the capabilities of all previous FSSP-type instruments. The SPEC fast CDP has the following advanced features:

- Hermetically sealed probe capable of operation in environments up to 70,000 ft. msl.
- 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.
- 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.
- 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.
- 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).

Fast CDP TECHNICAL SPECIFICATONS AND CHARACTERISTICS

- CDP installs standalone or on a custom adaptor collar attached to a standard PMS airborne canister.
- Power and data interfacing via standard PMS FSSP 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 or better cable.
- Power: < 300 watts of 115VAC, 400 or 60 Hz, and <400 watts of 28 VDC
- 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.
- 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.



Examples of 40 MHz ADC samples of (blue) signal and (black) qualifier (black) voltages recorded by the Fast CDP. 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 and CDP's) supports post-processing analysis of potential instrument calibration errors and anomalies.

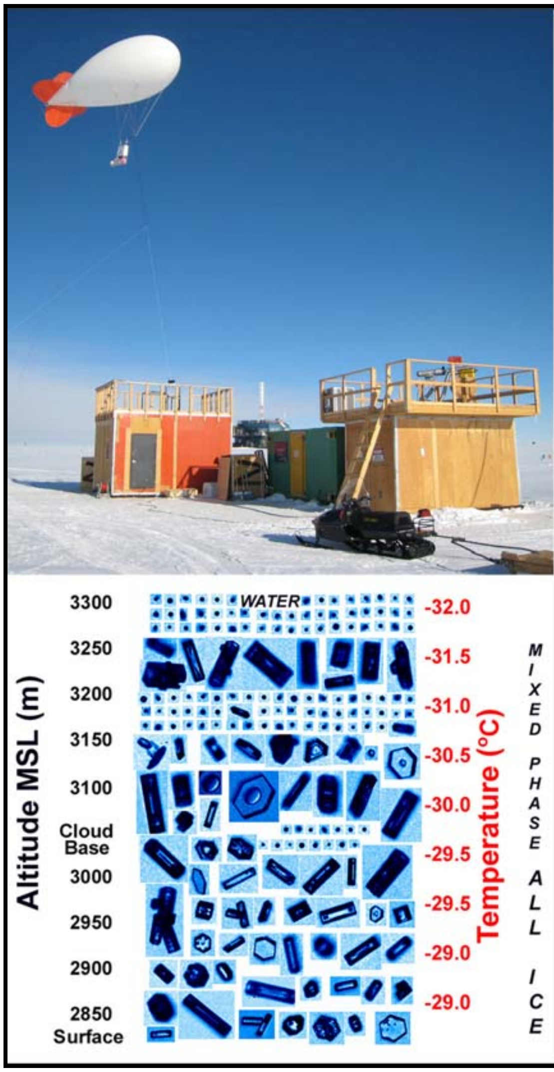
Fast FSSP-100 Upgrade

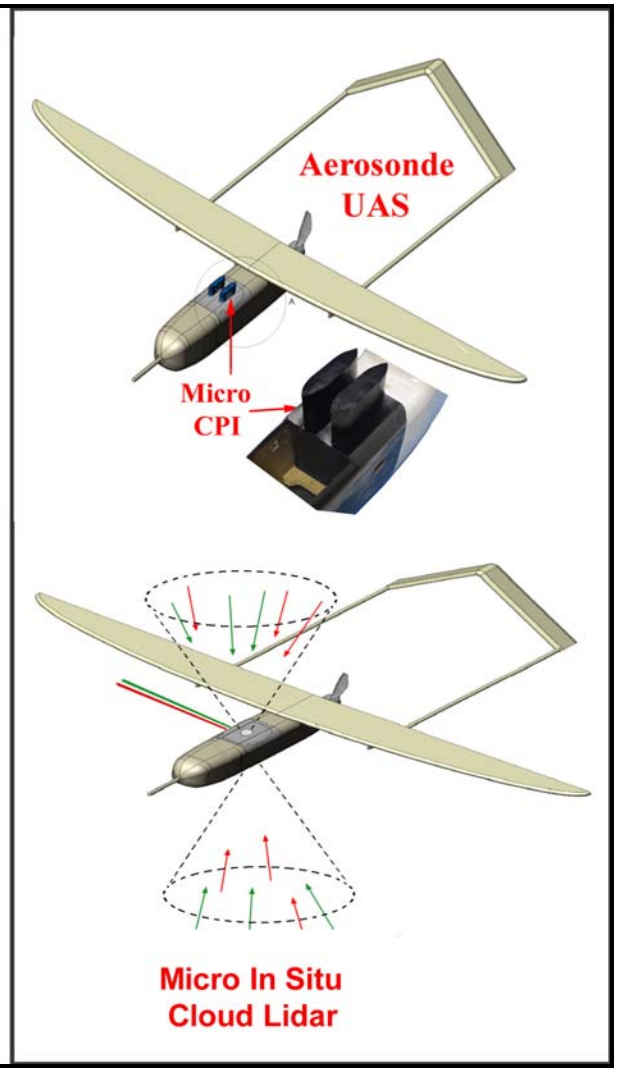
The SPEC Fast CDP electronics can be retrofit into FSSP–100 or SPP-100 probes. The electronics perform the same as the SPEC Fast CDP. However, the FSSP optics remain unchanged and the probe is not hermetically sealed.

SPEC Miniature Sensors for Tethered Balloon and UAS

Tethered Balloon Deployed at the South Pole in 2009 and CPI Images

Miniature Sensors for Small Unmanned Aerial Systems





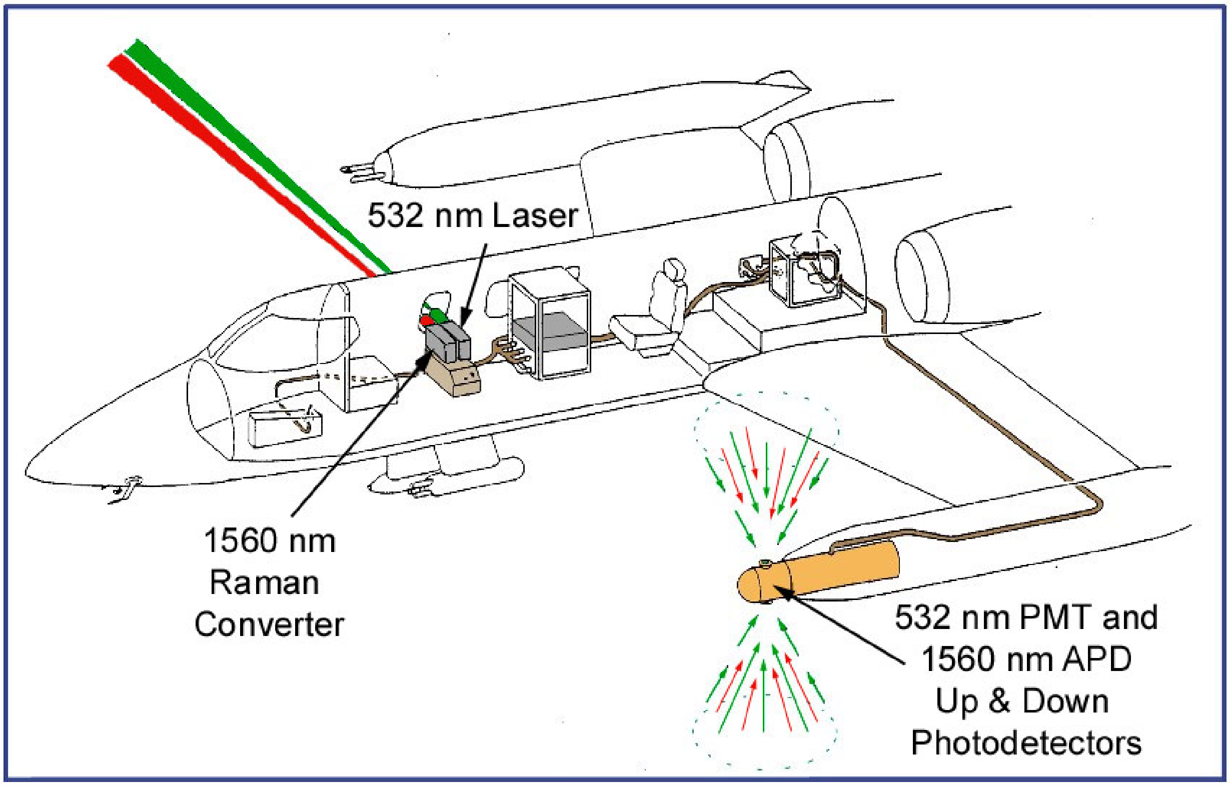
Tethered Balloon Characteristics

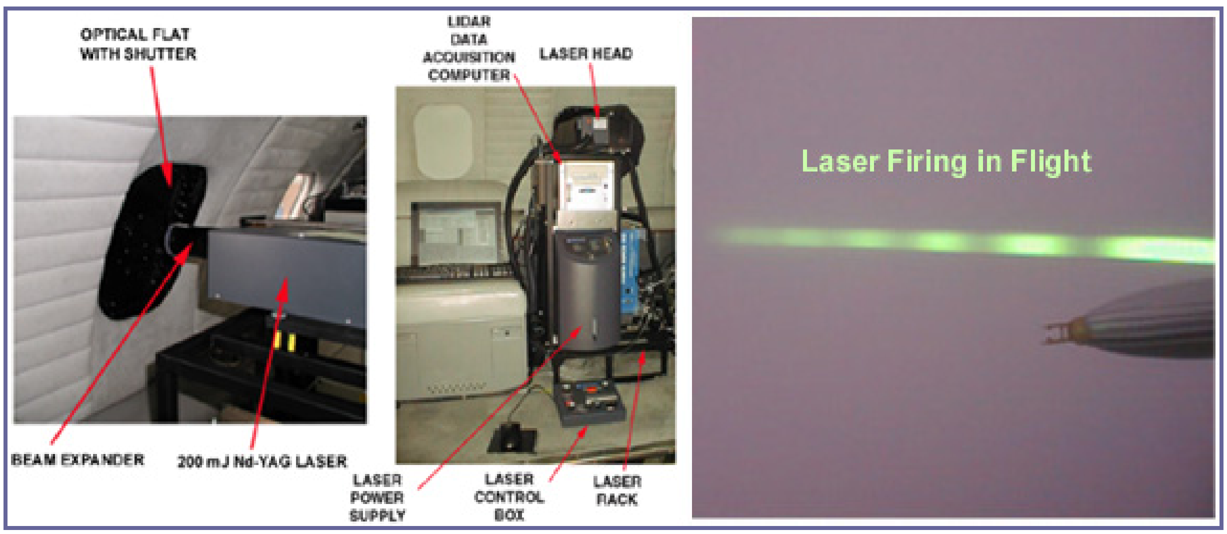
Electrical power supplied to the tether enables instrument package to collect long-duration measurements. 74 m^3 balloon can loft payload of approximately 20 kg from sea level to 2 Km. Communication between PC computer at the balloon and ground station facilitates control of onboard instruments and display of data at the ground station. Data are recorded on a solid state disk onboard the balloon instrument package. The tethered balloon system was deployed to Ny-Ålesund, Svalbard in May 2008, at the South Pole in January - February 2009 and at Oliktok Point in Alaska in October – November 2010.

Balloon Package Contains:

- **Miniature cloud particle imager (CPI)**
- **Fast Forward Scattering Spectrometer Probe (FSSP)**
- **Miniature Cloud Concentration Counter (CCN)**
- **Ice forming nuclei filters**
- **500 nm and 800 nm Actinic Flux Radiometer**
- **GPS position**
- **Wind Direction and Speed**
- **Temperature**
- **Cryogenic Frost Point Hygrometer**
- **Pressure**
- **Remote Balloon Emergency Deflation Mechanism**

Dual-Wavelength In Situ Cloud Lidar makes Volumetric Measurements of Liquid Water Content, Effective Drop Radius and Extinction





The in situ cloud lidar is designed to measure cloud volumes of millions of cubic meters to overcome the sampling limitations of traditional cloud probes in inhomogeneous clouds. This technique sends laser pulses horizontally from an aircraft inside an optically thick cloud and measures the time series of the multiply scattered light with wide field-of-view detectors viewing upward and downward (see figure above). The extinction in liquid clouds averaged over tens to hundreds of meters and the distance to cloud boundaries can be retrieved from the signal measured by a single-wavelength in situ lidar. A dual-wavelength lidar, where one of the wavelengths is slightly absorbed by the cloud drops, can in addition retrieve volumetric averages of liquid water content and effective drop radius. SPEC has successfully tested a single-wavelength in situ cloud lidar on the Learjet and is currently developing a dual-wavelength in situ cloud lidar under a Department of Energy Phase II SBIR contract.

For Further Information Please Contact Dr. Paul Lawson plawson@specinc.com