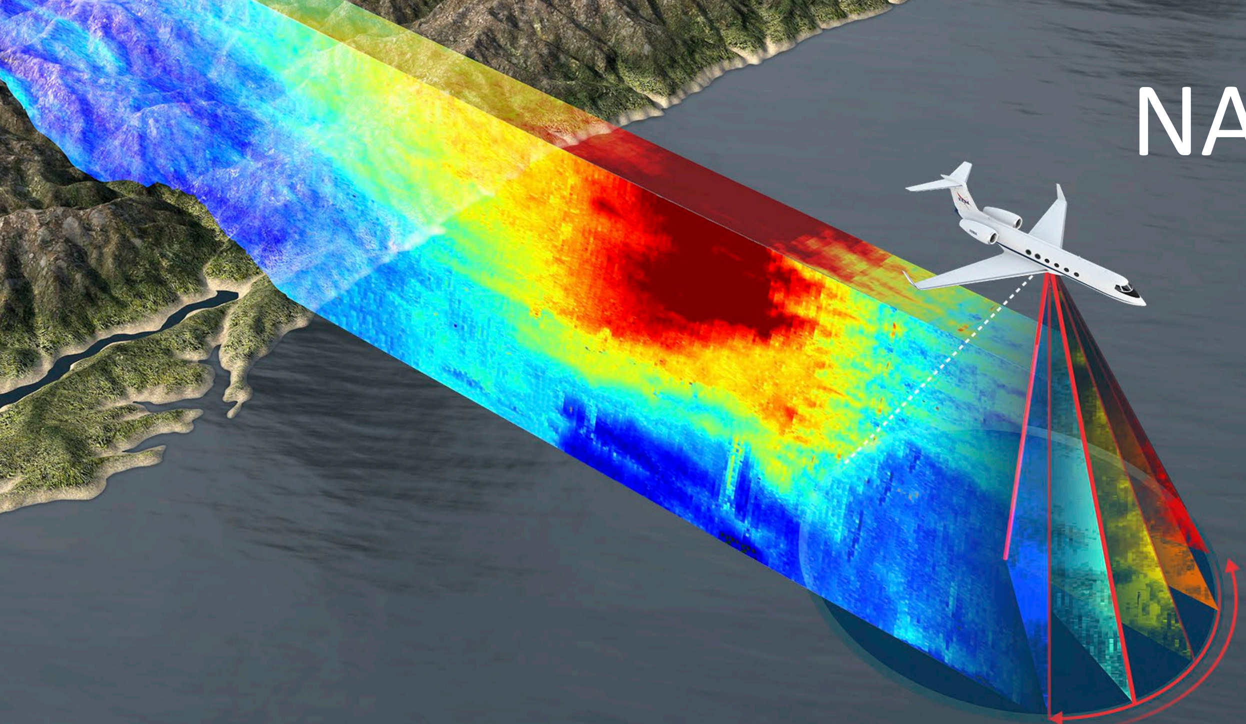

NASA's Aerosol Wind Profiler (AWP) Coherent Doppler Wind LiDAR

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1: NASA Langley Research Center 2: Beyond Photonics

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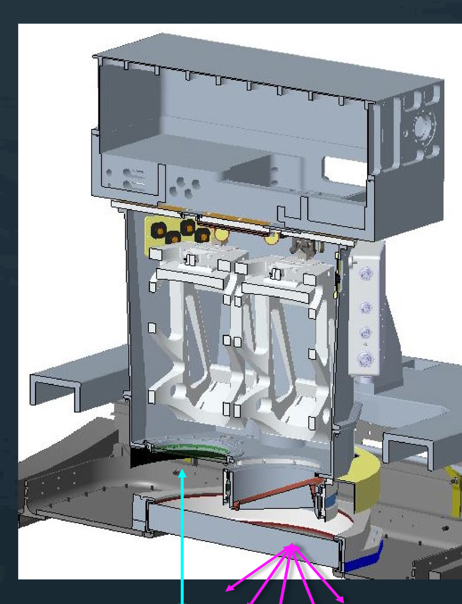
AWP System Characteristics

Reduced Mass and Volume	Instrument head ~200 L, ~110 kg *About 1/3 volume and 1/2 mass of previous generation CDWL instrument* Equipment racks 4 x 12 EIA U, ~330 kg
Modular Architecture	Updatable transceiver, telescopes, beam steering, etc.
Aircraft Compatibility	Straightforward adaptation to multiple aircraft *LaRC Gulfstream 3 demonstration flights – Jan 2023* *AFRC DC-8 EcoDemonstrator flights – Oct 2023*
Dual Beam Paths	Independent nadir and scanned off-nadir views enables near-simultaneous measurement of ***u**, **v**, **and** **w*** wind
Safety	Eyesafe LiDAR *when moving:* NOHD = 0 m

Transceiver optical bench CAD model



AWP cross-section showing dual beam paths for 3-D wind measurement

AWP Key Components

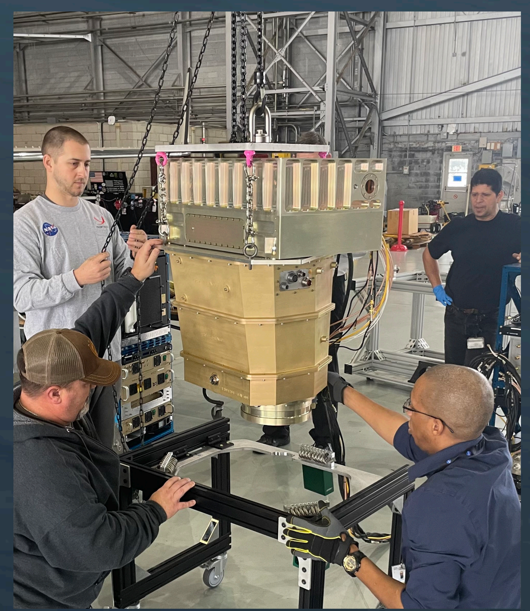
Transceiver:
- Transmit laser (oscillator + amplifier)
- Dual beam paths – "Fore" and "Aft" lines of sight (LOS)
- AO Q-Switch & EO beam path switch
- Transmit/Receive optics w/auto alignment
- Heterodyne receiver & HV power supplies

Dual telescopes:
- Compact, folded Cassegrain design, ~f/8, divergence ~22 μrad
- 20x expansion (7.5 mm small aperture, 150 mm large aperture)
- One telescope per line of sight, configured to nadir and off-nadir views

Beam steering assembly:
- Mechanical rotation stage, completes 90° move in 1/3 s
- High-purity, undoped Si crystal prism with 2 μm AR coatings, steers beam 30° off-nadir
- Prism configuration to reduce non-circular receiver area loss

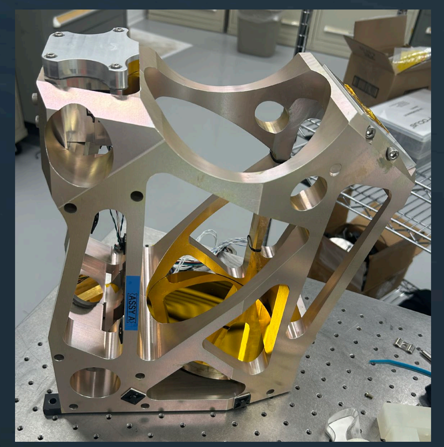
Aircraft interface adapter:
- Specific to each aircraft
- Attaches instrument mounting points to aircraft mounting fixtures
- Angled to compensate for aircraft nominal angle of attack (nadir closer to vertical)
- Have integrated onto Gulfstream 3 and DC-8
  Can easily integrate onto Gulfstream 5 and P-3

Aircraft window assembly:
- Ø17" Infrasil window with 2 μm AR and oleophobic/hydrophobic coatings



AWP Instrument on G3 Transfer Cart GSE

AWP installation on LaRC Gulfstream 3 Aft Nadir Port



AWP Compact f/8 folded off-axis Cassegrain, ø15 cm aperture, 120 cm FL, ~λ/22 @ 2053 nm
4 mirrors, ~ 34 x 36 x 19 cm volume

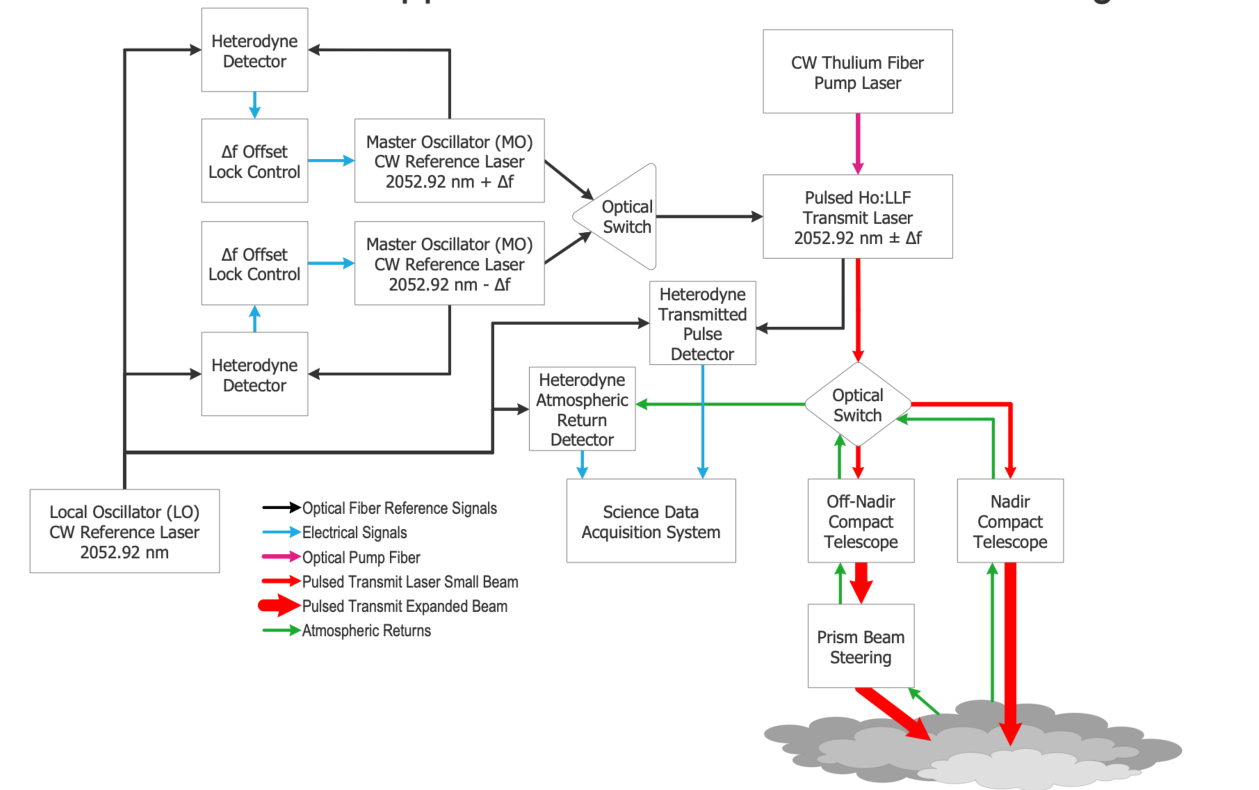
AWP Instrument & Equipment Racks

Pulsed Coherent Doppler LiDAR Transceiver

Completed in 2021, the ESTO Wind-SP project delivered a robust coherent Doppler wind lidar transceiver meeting the space wind lidar FOM and measurement accuracy requirements.
- Master Oscillator Power Amplifier (MOPA) architecture
- Injection seed through Q-Switch
- Rigid, zero-CTE optical mounts on a zero-CTE Carbon Fiber Composite optical bench
- Auto-alignment system to maintain laser energy
- Orbital lag angle compensation system
- EO path switching between two output beam paths
- Extremely stable Local and Master Oscillator (LO and MO) reference lasers
- Widely tunable, extremely stable MO offset locking system

Currently derated to 35 mJ to prevent optical damage
- Laser optical damage on some coatings due to outgassed contaminants
- *Threshold **FOM is maintained** even when derated*
- Outgassing contributors being removed to enable baseline operation in 2024

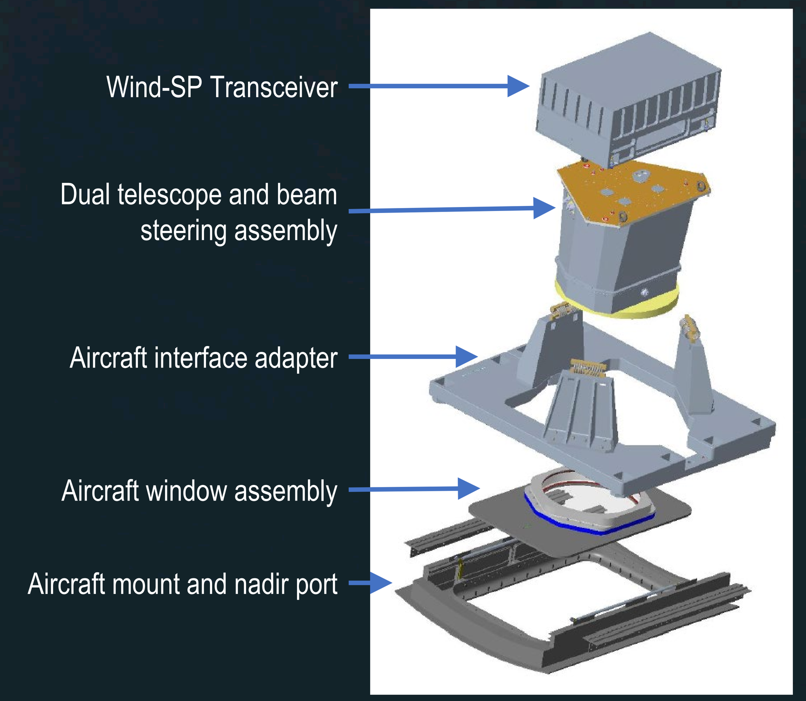
AWP Coherent Doppler Wind Lidar Functional Block Diagram



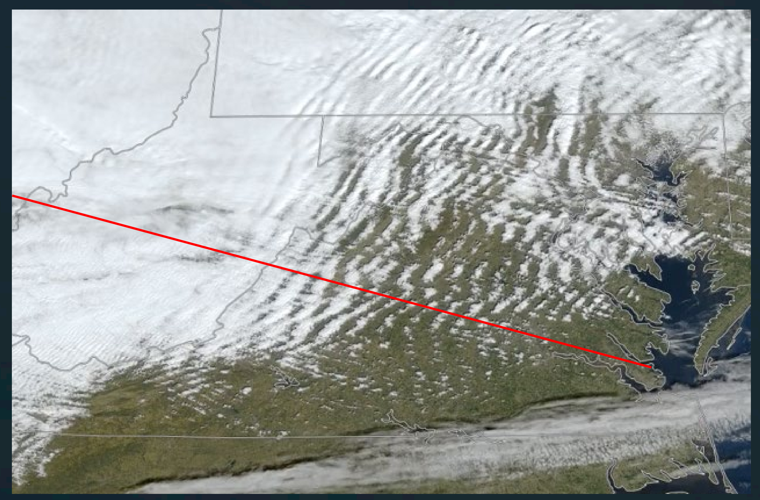
Parameter	Design	Lab Demos*	2023 Flights	2024 Flights
Laser Crystal	Ho LLF (LuLiF)			
Wavelength (nm)	2052.92			
Pump Geometry	End pumped			
Pump Source	Tm fiber laser @ 1940 nm			
Pulse Rate (Hz)	200 Hz			
Pulse Energy (mJ)	56 mJ Baseline 42 mJ Threshold	75 mJ *Baseline +34%*	**Derated to 35 mJ**	56 mJ
Pulse Duration FWHM (ns)	180 ns baseline 150 ns Threshold	200 ns *Baseline +11%*	**250 ns**	200 ns
Beam Quality M^2	≤ 1.1	1.07	**1.07**	1.07
Laser Figure of Merit	**3.14 Baseline** **2.22 Threshold**	4.34 *Baseline +38%*	**2.23**	3.34

** Refer to Yu, et. al., CLRC 2022*

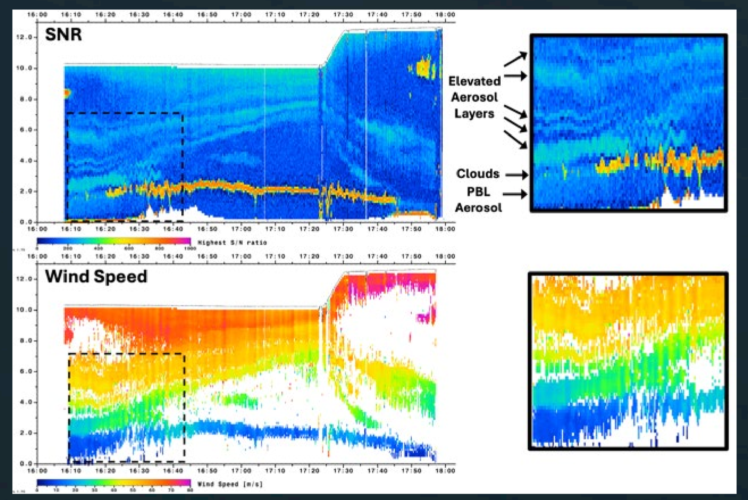
$$\text{Figure Of Merit (FOM)} \propto E\sqrt{f}\,\tau^{0.285}\,\frac{2}{1+(M^2)^2}$$



Preliminary AWP Data From 20 January 2023 NASA Gulfstream 3 Test Flight

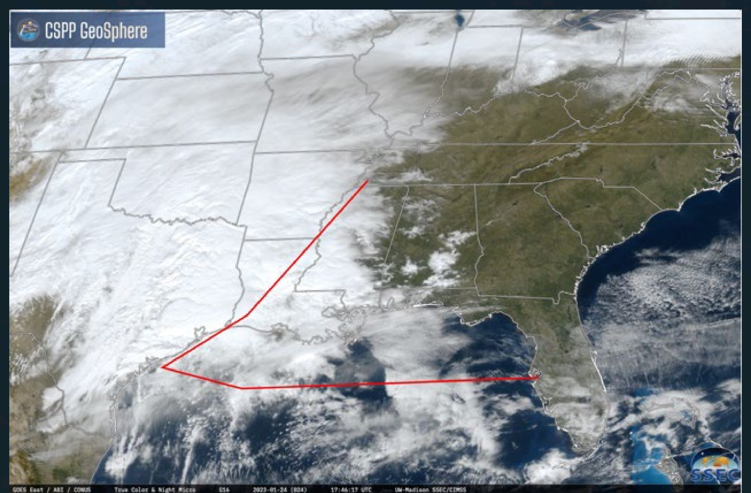


GOES-16 natural color image showing mountain waves
with Gulfstream 3 flight track segment (red line)
Image courtesy of CSPP Geosphere GOES image display tool

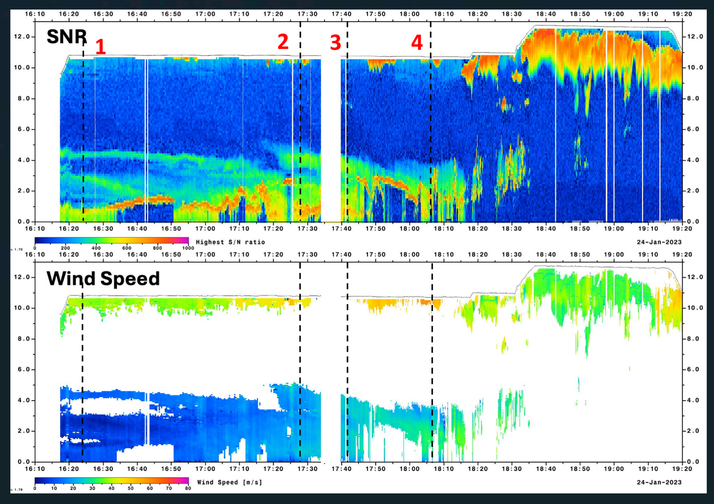


AWP SNR & wind speed along track
Waves (dashed box, detail at right) caused by flow over mountains up to 1.4 km in altitude cause 10+ m/s variations in horizontal wind speed up to 10 km altitude

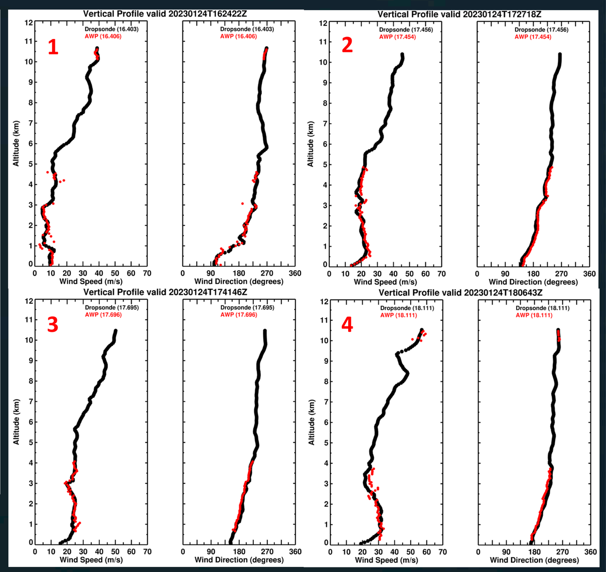
Preliminary AWP Data From 24 January 2023 NASA Gulfstream 3 Test Flight



GOES-16 natural color image of Texas and Gulf of Mexico
with Gulfstream 3 flight track segment (red line)
Image courtesy of CSPP Geosphere GOES image display tool



AWP SNR & wind speed along track



AWP comparisons with AVAPS dropsondes

AWP was integrated onto LaRC Gulfstream 3 in Dec 2022 and completed three demonstration flights on 11, 20, and 24 Jan 2023
- AWP successfully collected data for over 12 hours
- Measured wind speeds from calm up to 80 m/s
- Derated AWP operation at 35 mJ, off-nadir view only

On 20 Jan, AWP observed up to 6 independent aerosol layers of unknown origin at 1-7 km altitude deformed by mountain wave turbulence over Virginia
- AWP collected horizontal wind profiles at 1.7 km horizontal and 66 meter vertical spacing. 5 lines of sight x 400 pulses/LOS

The waves impacted the wind speed profile in a column extending almost 9 km above the mountain tops

Such sharp vertical and horizontal wind gradients are uniquely resolvable by Doppler wind lidar