The OAWL instrument: a direct-detection aerosol wind lidar for airborne and space-based wind profiles

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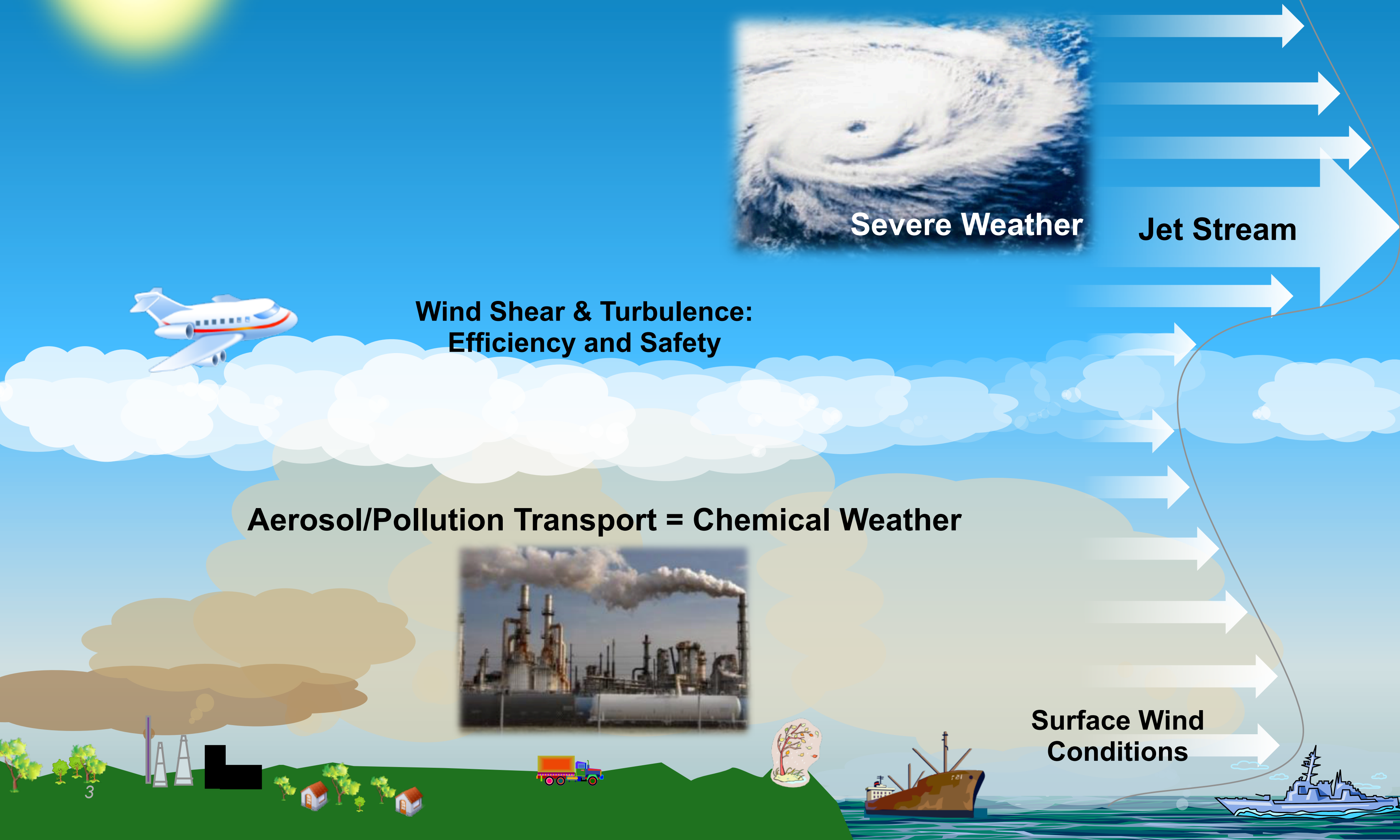
Outline

- Brief OAWL introduction
- HAWC-OAWL IIP overview
  - Athermal Interferometer
  - Reconfiguration for DC-8 aircraft
- Update on GrOAWL Venture Tech
  - Gulf of Mexico flights – 2016
- Conclusion

Northern Hawk-Owl

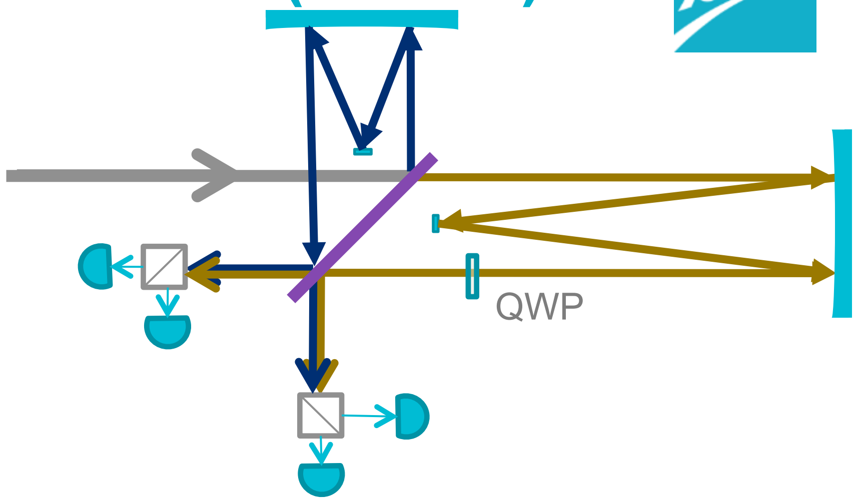
Winds and weather affect us all – locally, globally, & economically.

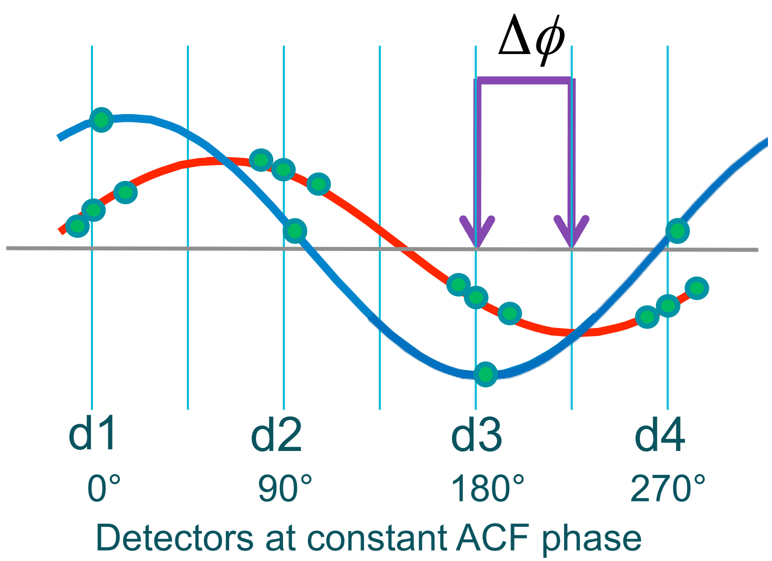


Optical Autocovariance Wind Lidar (OAWL)

- Direct detection wind lidar system
- Field-widened, Mach-Zehnder Interferometer reciever (MZI): (Patent #s: US7929215B1, US8077294B1)
- Four detector channels sample interferometer fringe phase (wind) and amplitude (aerosol).
  - --- Outgoing "T0" pulses
  - --- Atmospheric Returns at range
- T0 phase offset used to adjust detector returns for every pulse - prior to accumulation/phase fit:
  - no laser pulse-to-pulse stability requirements
- After accumulation, the shifted detector values are fit to determine the return phase, $\Delta\phi$, related to the line-of-sight wind speed, V_{LOS} by

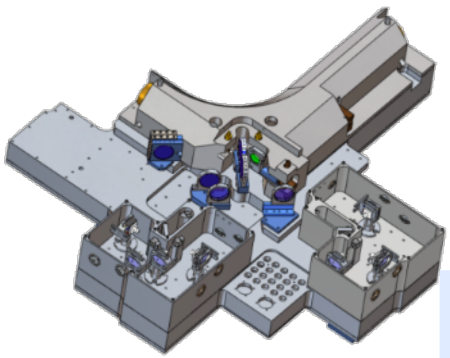
$$V_{LOS} = \frac{\Delta\phi\lambda c}{2\pi(2OPD)}$$

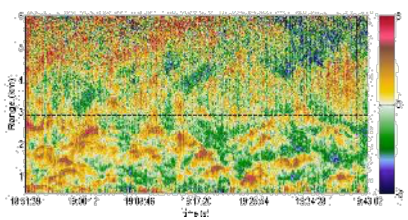


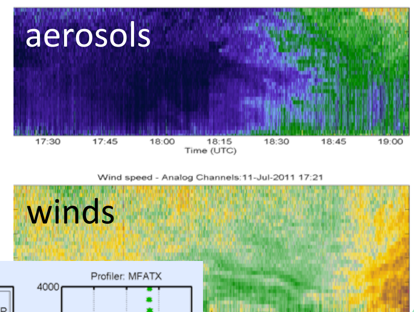


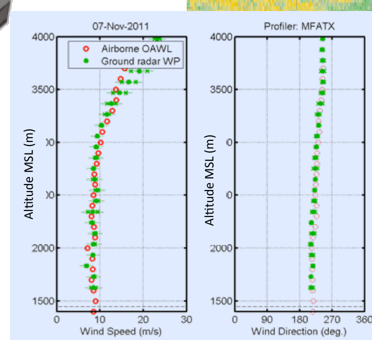
The Evolution of OAWL

Ball designed, built and tested OAWL systems, mission concepts, and retrieval/ processing algorithms on multiple airborne campaigns with ESTO funding

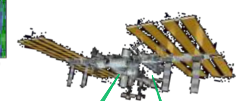


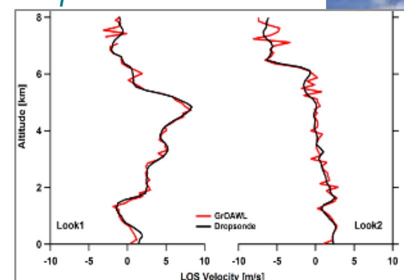


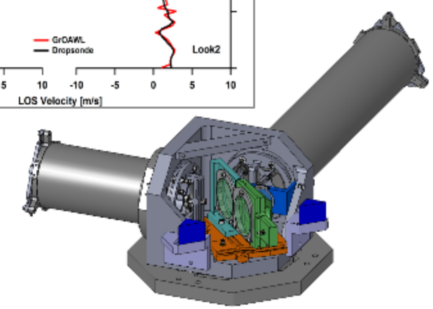




2013 & 2016 ATHENA-OAWL Mission Proposal







2008-2012: OAWL IIP-07

- ✓ Breadboard system
- ✓ 355 nm only, 4x channels
- ✓ Single look 12" telescope
- ✓ Ground validation with NOAA Coherent system
- ✓ Autonomous flight tests on NASA WB-57

2012-2015: HOAWL ACT

- ✓ Breadboard System
- ✓ Demonstrate 532 nm wavelength channels & depolarization channels
- ✓ Total 10 channels
- ✓ HSRL Aerosol retrieval algorithms

2015-2017: ATHENA-OAWL Venture-Tech: GrOAWL

- ✓ Airborne demonstrator System (WB-57)
- ✓ 2-lasers = 400 Hz eff. PRF
- ✓ 4x 532 nm channels
- ✓ 2 looks, 2 telescopes to demonstrate geometry

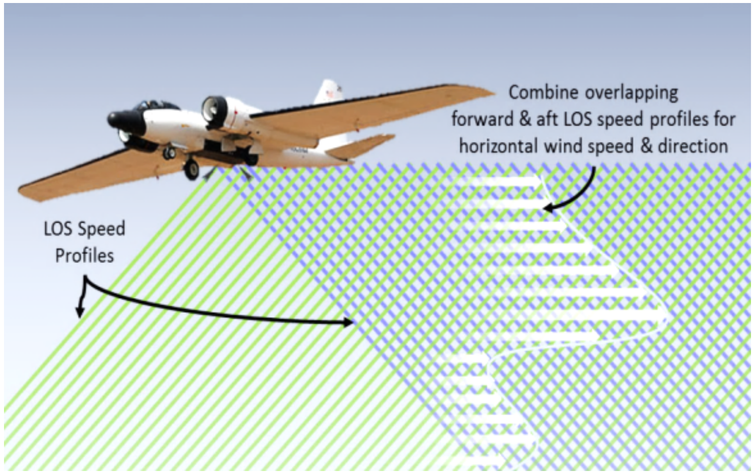
2014-2017: HAWC-OAWL IIP

- ✓ Two look airborne system (build on GrOAWL)
- ✓ Dual Wavelength + depol. Channels
- • Athermal interferometer
- • DC-8 hardware design and build

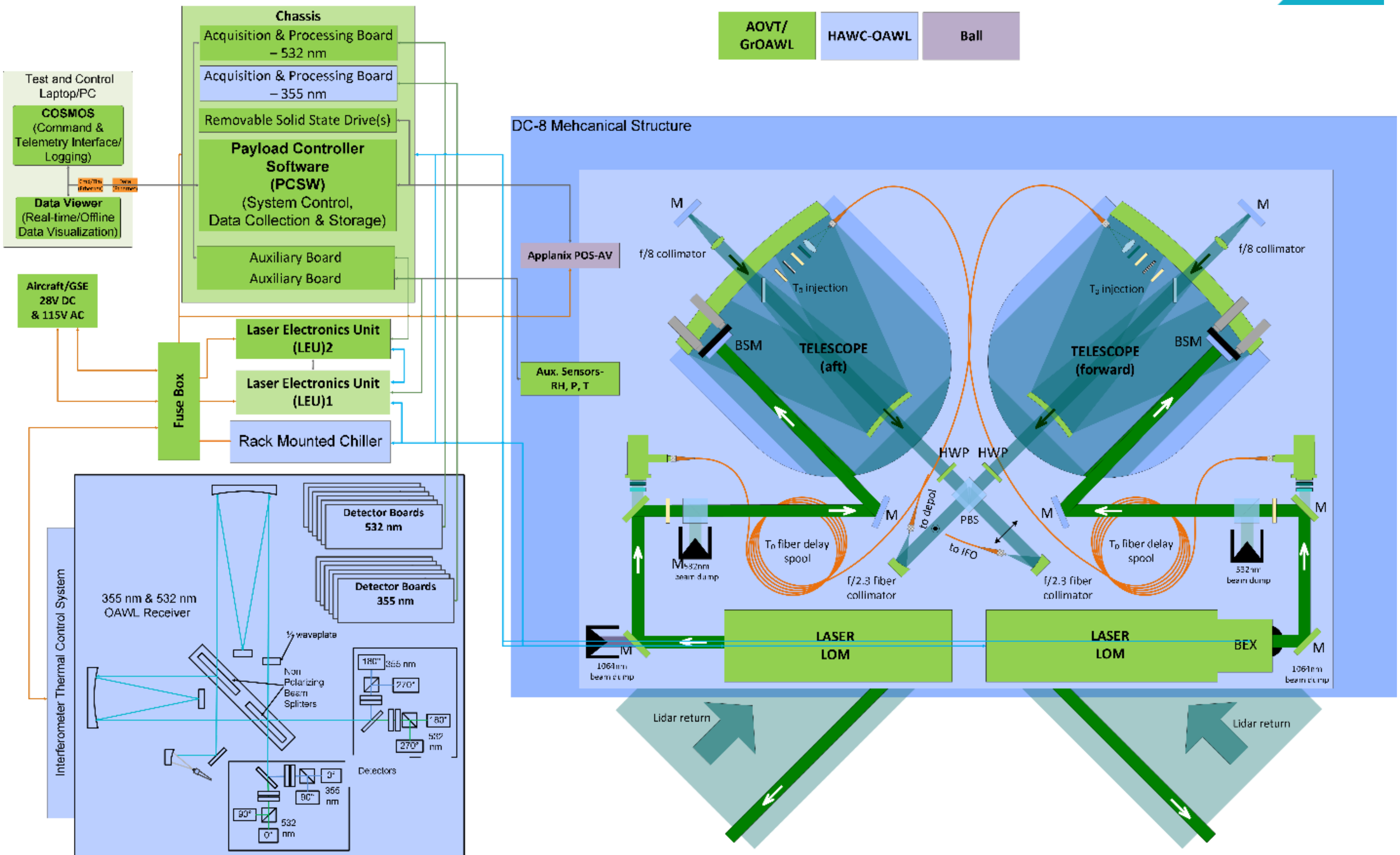
HAWC-OAWL IIP

HAWC-OAWL IIP-13 Objectives

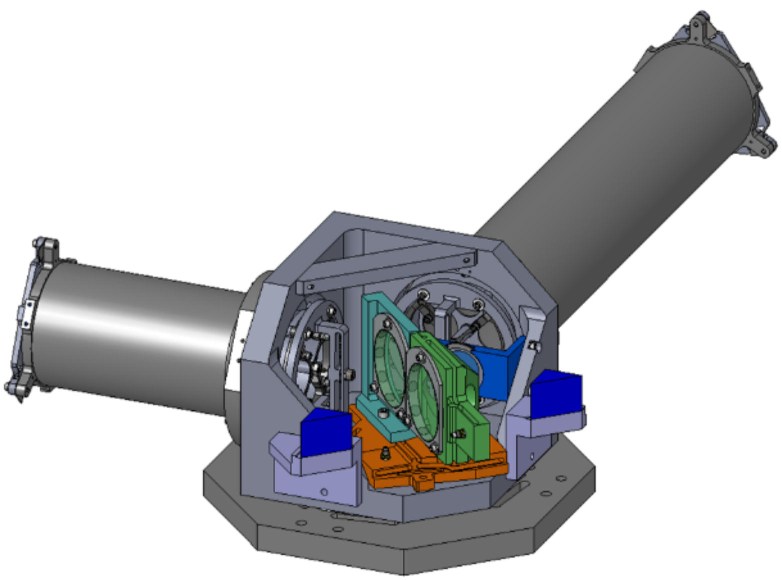
- Perform aircraft trade studies for new OAWL build for next set of airborne tests
- Build a robust airborne and aircraft qualified OAWL system
  - Design for down-selected DC-8
  - Update detectors, electronics
  - Add DC-8 hardware and thermal control (focus on modularity)
- Build and test new “athermal” interferometer
  - Better performance over a larger temperature and vibration range
- Integrate new interferometer with the DC-8 system build
- Ensure design is compatible with path to space

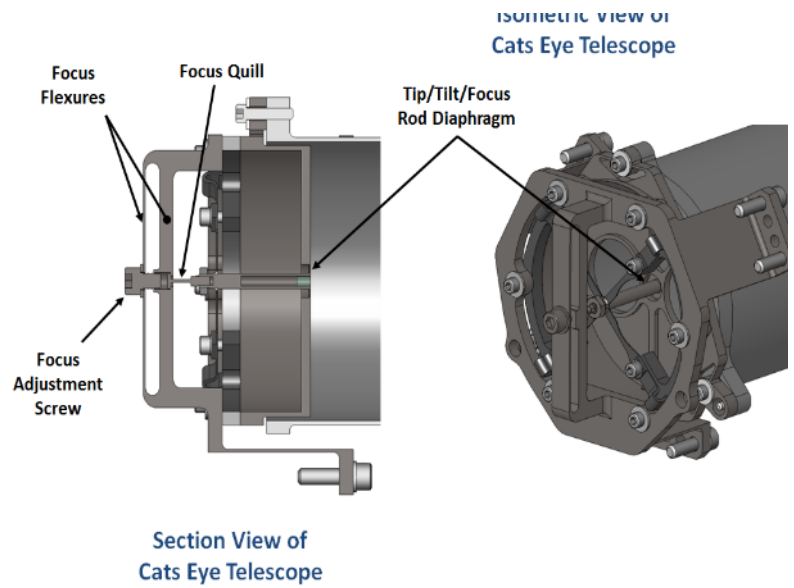


HAWC-OAWL Layout



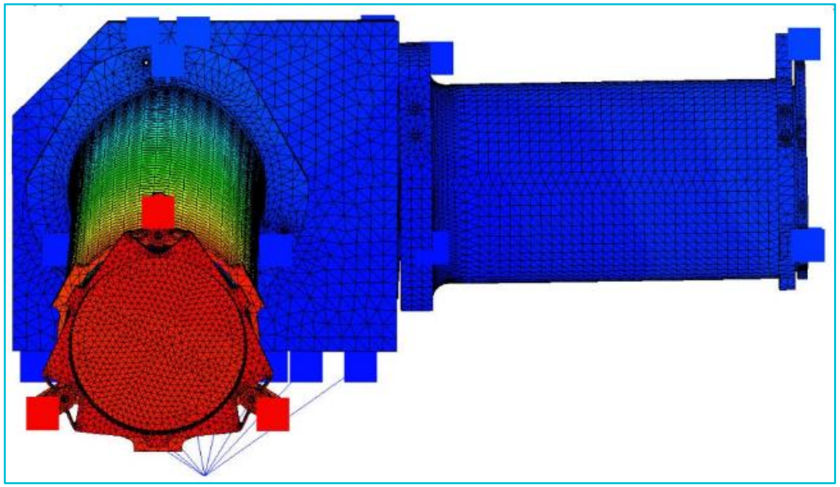
Athermal Interferometer

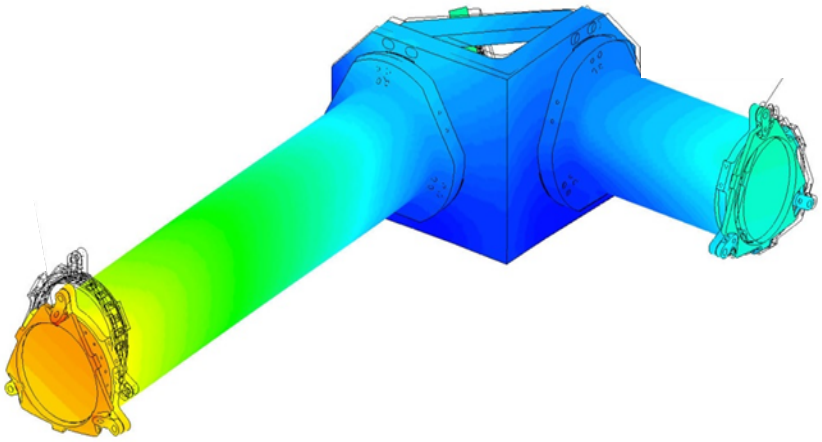




Athermal Interferometer

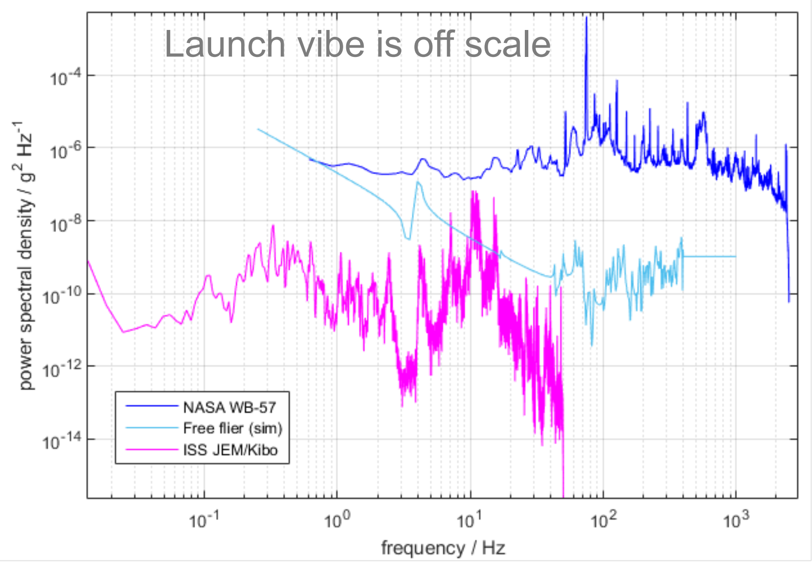
- Field-widened, Mach-Zehnder Interferometer
- Optical path difference (OPD) of 0.9 m
- Designed for reduced dependencies on thermal and vibe on spacecraft and aircraft
- Structural-thermal modelling used to verify athermal design will ensure interferometer alignments for ISS environment
- High quality optical surfaces and coatings required





Interferometer: Aircraft vs. Space

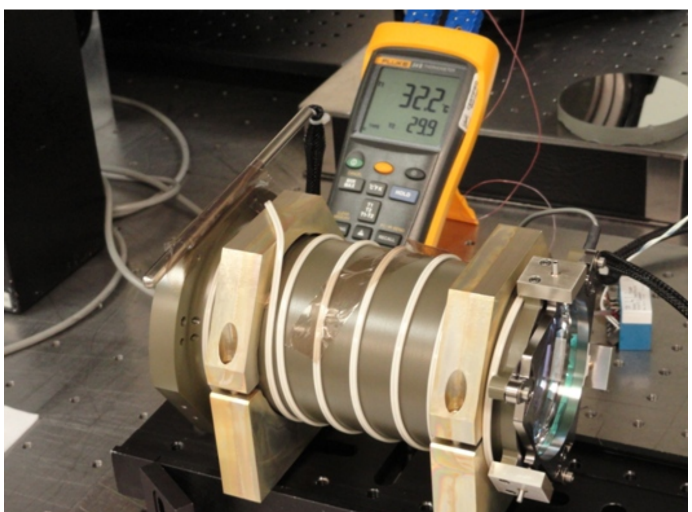
- Important to remember that requirements for interferometer are different for aircraft and space
- HAWC-OAWL is tackling the aircraft requirements
- Many requirements are easier for space

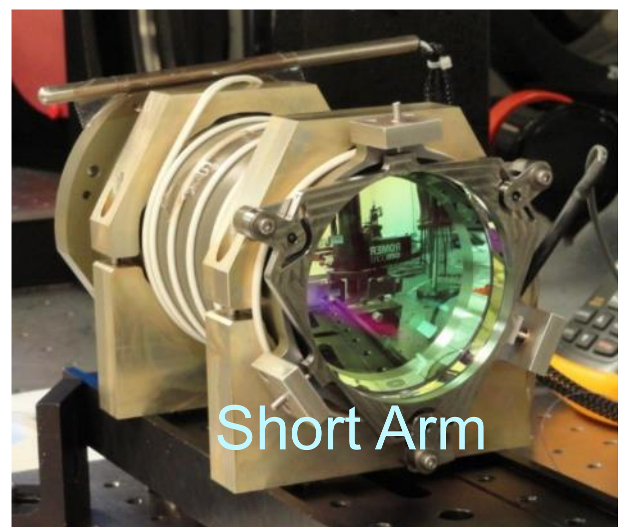


Environment	Aircraft	Space
Thermal	Large 10?+C gradients over flight	~1? variation on orbit (per CALIPSO)
Vibration	Operational vibe is high, isolation used.	Operational vibe *very* low, isolation may still be applied if desired.
Shock	Peak takeoff and landing shock can be several g's	Significant launch shock (e.g. 9g from CALIPSO)
Radiation	Not a concern for optics. Aircraft EMF concerns addressed through best practices.	Detectors will be shielded. Fused silica optics present a low risk

Interferometer Status

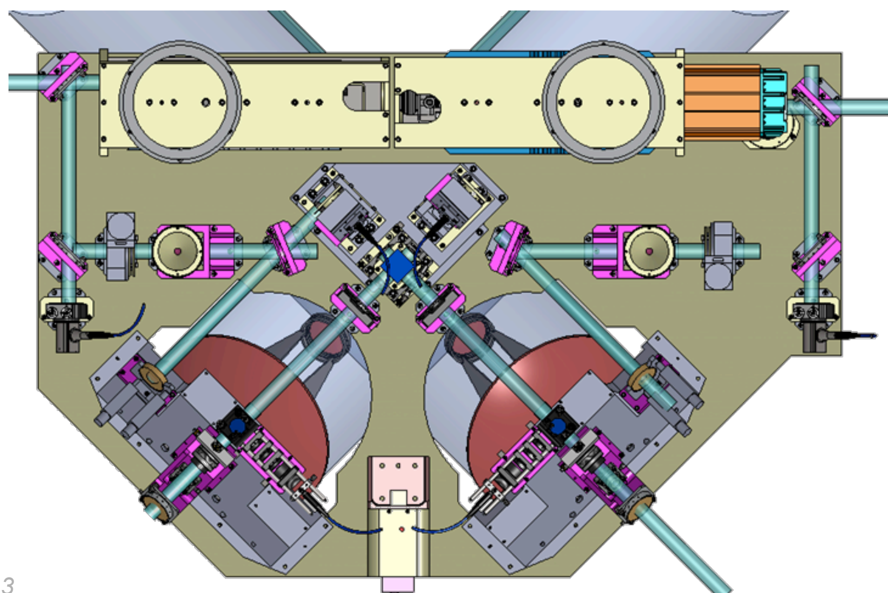
- ✓ Vendors have fabricated the mirrors and beamsplitters with very good results
- ✓ Successful assembly of both the short and the long arm of the interferometer to desired specs
- Currently integrating both arms into full interferometer
- Final assembly and test in the coming weeks



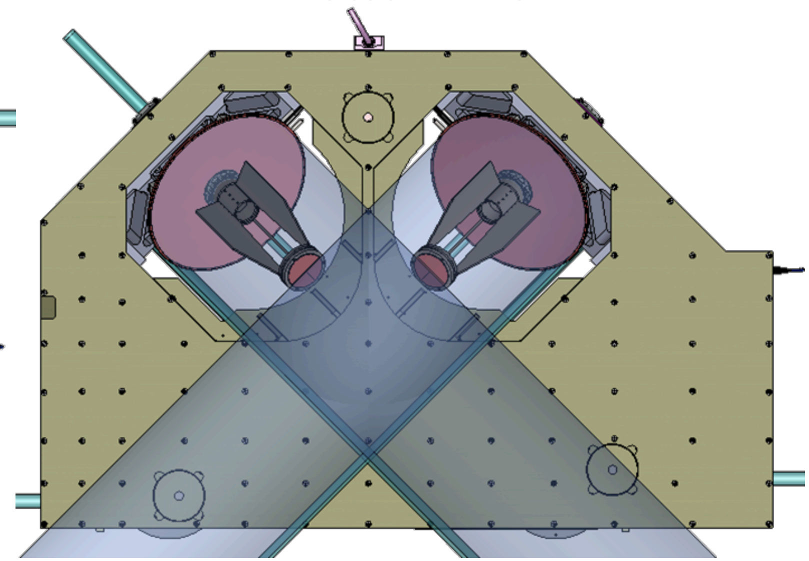


DC-8 OAWL Reconfiguration

Top View

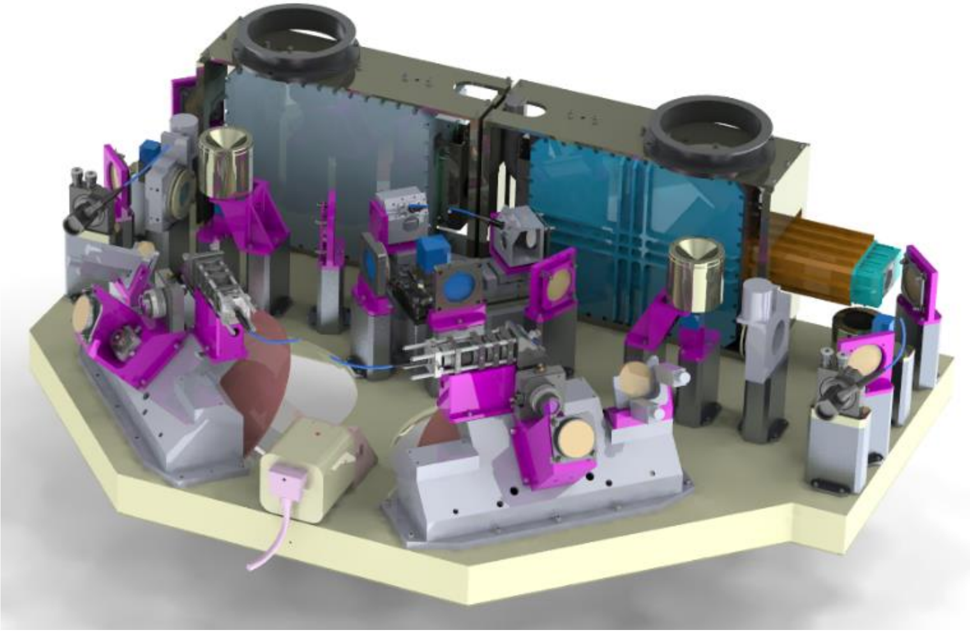


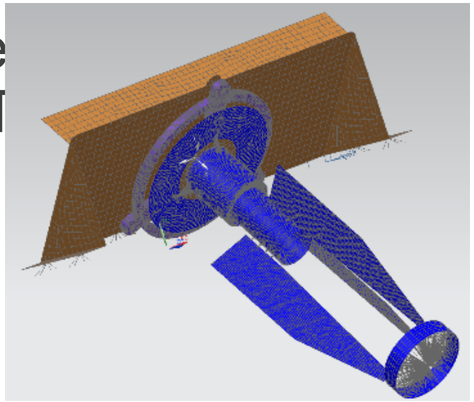
Bottom View

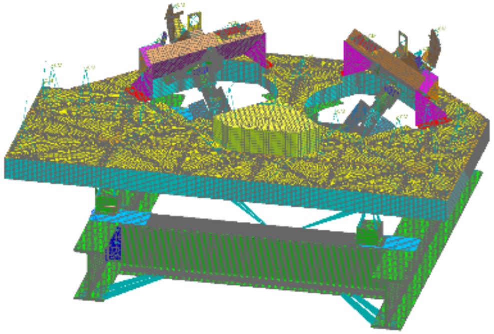


Mechanical Redesign for DC-8

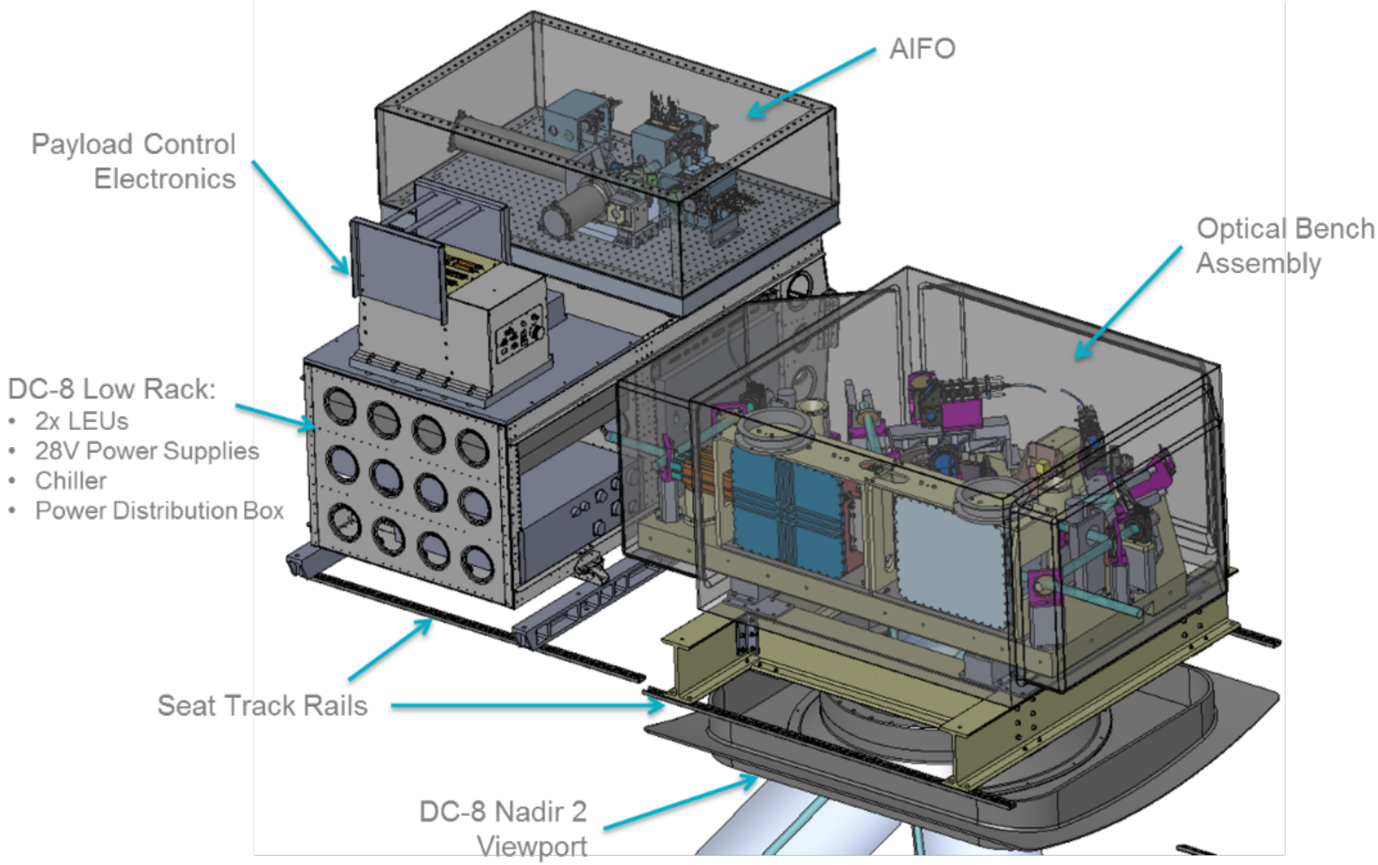
- New optical bench to point beams through single window
- Most on-bench components are being reused, with upgrades to the telescope mount assemblies.
- Structural analysis with mechanical design to assure pointing stability
- Vibration isolation combine with improved stiffness of T Rx path components
- New base to provide additional stiffness







DC-8 nadir 2 viewport layout



System will be ready for DC-8 integration at end of IIP

GROAWL-AOVT UPDATE

GrOAWL: Optical Autocovariance Wind Lidar

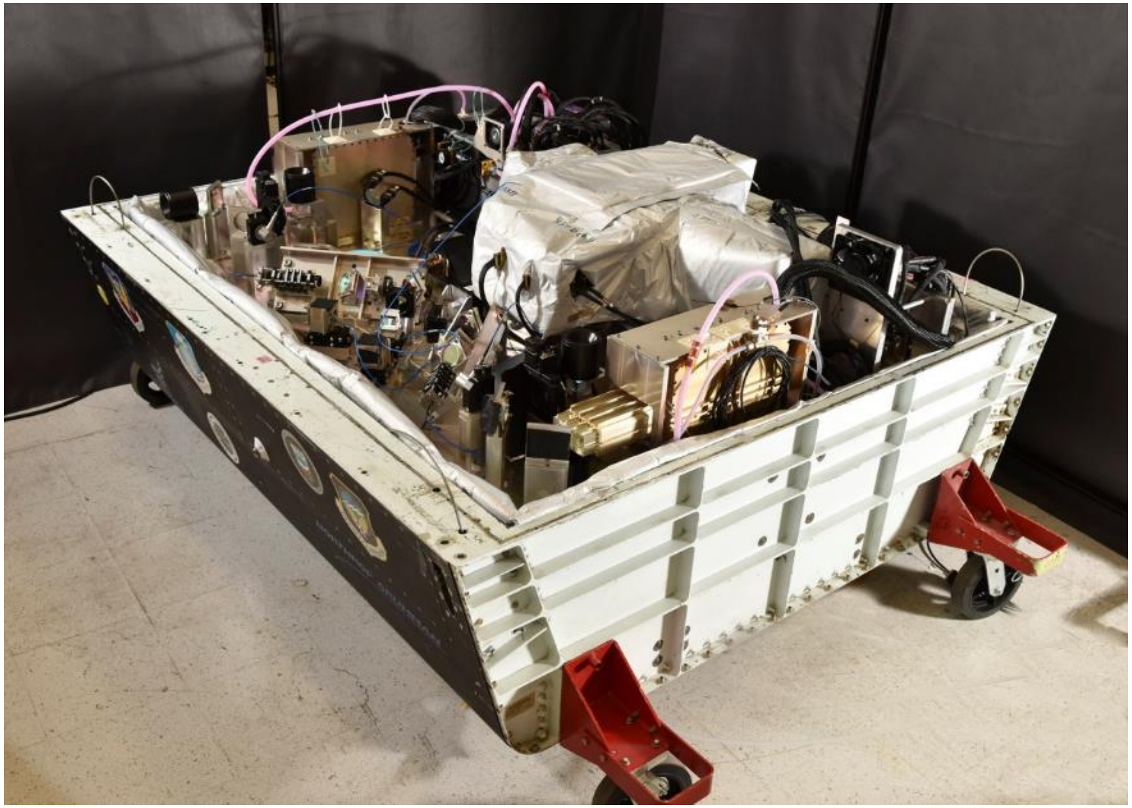
- Earth Venture Instrument – 2 (EVI-2) Proposal to NASA in 2013
  - Not selected for space mission – Category 3
  - Was selected for Earth Venture Risk Reduction Funding (“Venture Tech”) to advance its Technology Readiness
- Focused Science Mission and path to space
  - Tropospheric dual line of sight winds plus aerosols
- Two lasers – both operate at the 532 nm (green) wavelength *and* 355 nm (UV) wavelength.
- Autonomous operation with real-time winds processing
- Flight testing on WB-57

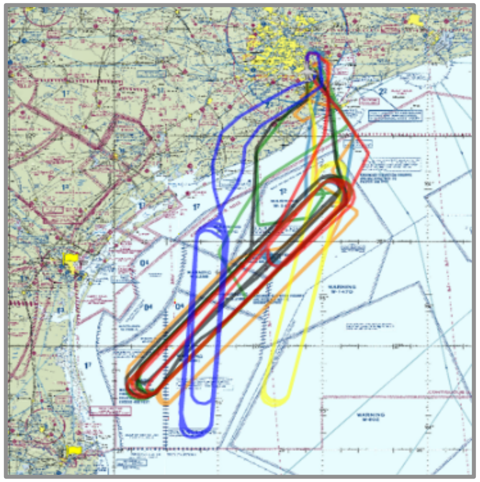
Parameter	Value (look1/ look2)
Pulse Energy 532 nm	200 ?J – 2.5+ mJ
Pulse Energy 355 nm	0.5 mJ – 11 mJ
Laser Pulse Repetition	200 Hz per look
Telescopes eff. Diameter	~27 cm diameter
Detector Channels	Up to 10
Sample Rate	140 MHz (1.07 m)
Interferometer OPD	~0.9 meters

WB-57 chosen mainly for schedule

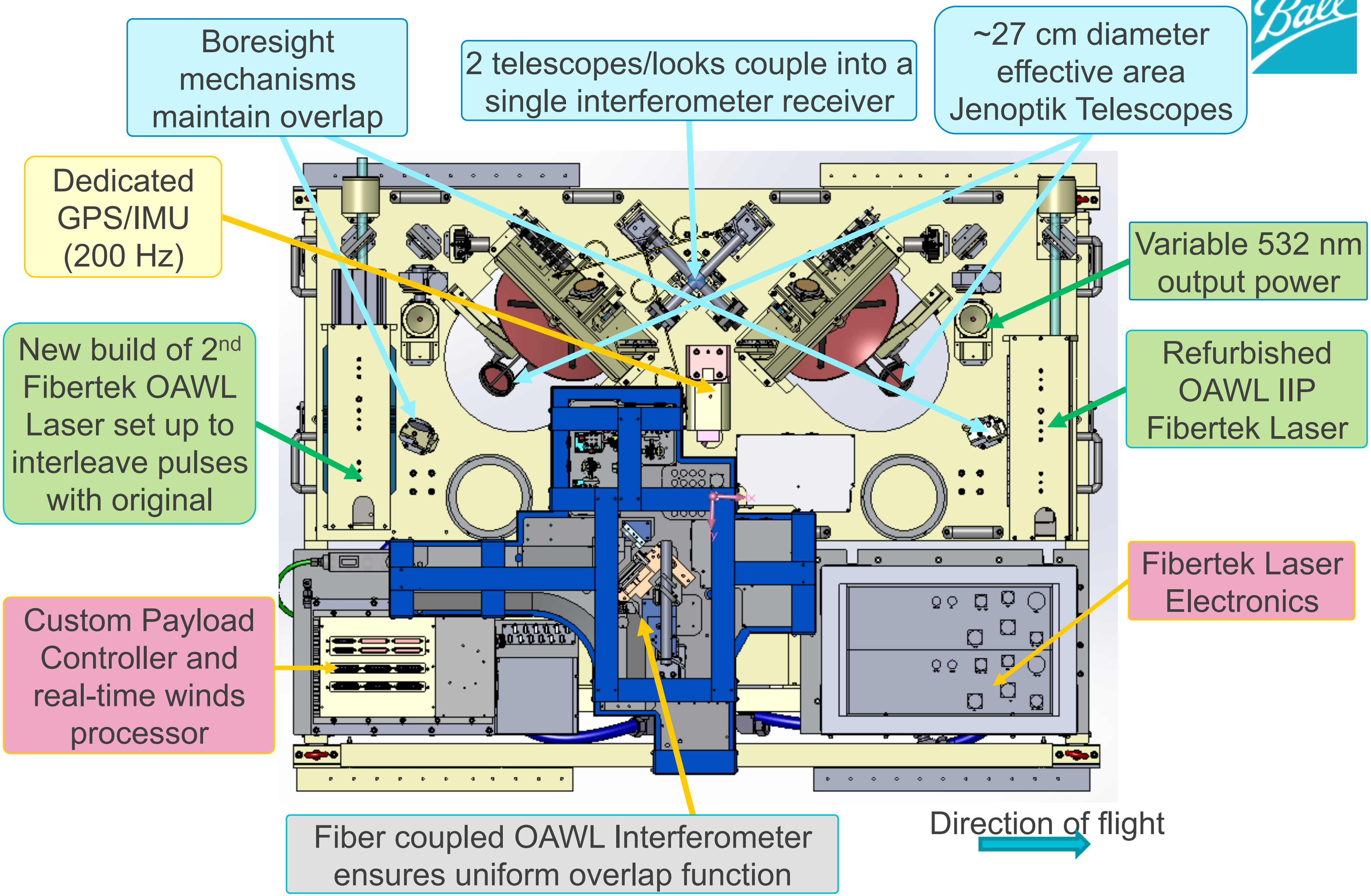
WB-57 Aircraft Flights

- WB-57 pallet: pressurized to 5 psi above ambient exterior above 8000 ft
- Two custom pallet floor panels with windows
- GrOAWL instrument, vibration isolation, & environmental control
- Flights above the Gulf of Mexico in early summer 2016

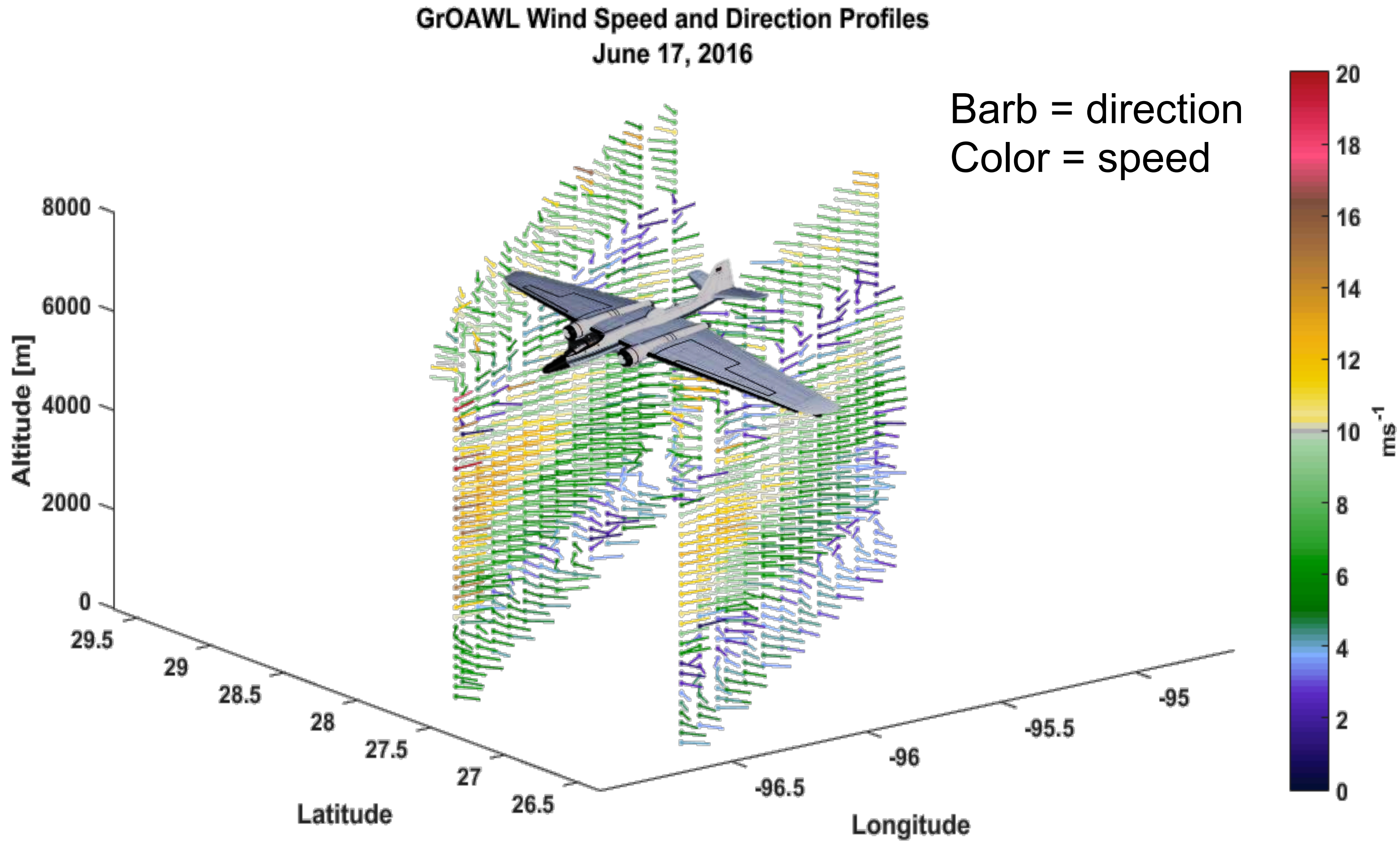




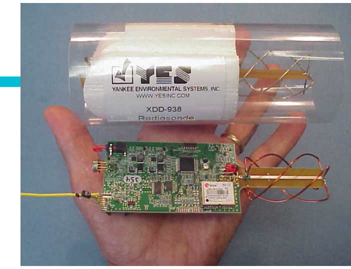
Key GrOAWL Instrument Features



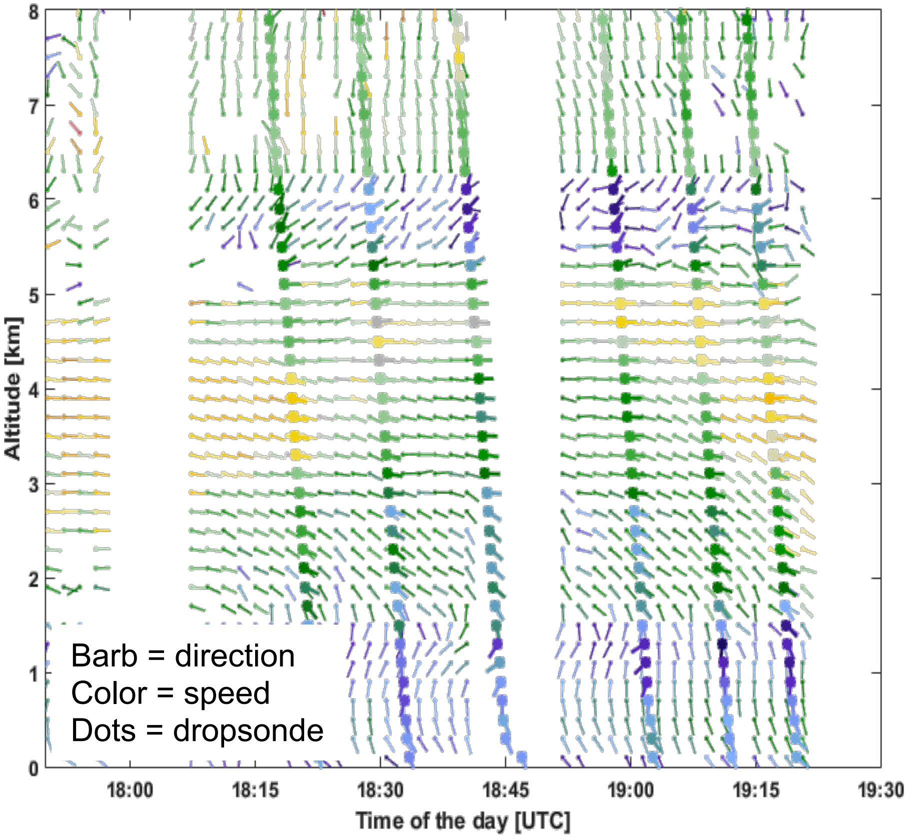
Airborne mapping of winds over the Gulf



GrOAWL and YES High Definition Sounding System (HDSS, ONR) dropsonde profiles



June 17, 2016



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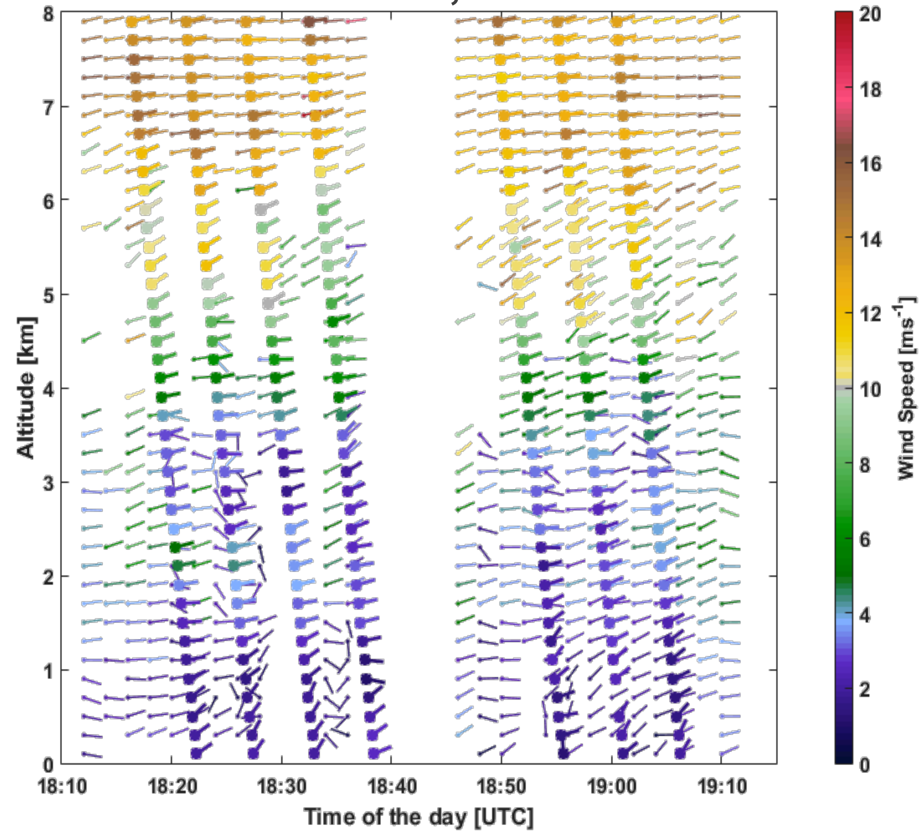

Excellent agreement with dropsonde data

Summary

- HAWC-OAWL IIP finishing hardware build and testing during summer 2017
  - Interferometer arm primary mirrors have been aligned to required WFE
  - New optical bench for DC-8 designed and being implemented
- HAWC will be ready for DC-8 integration by Fall 2017
  - Available for future flight tests
- GrOAWL (AOVT) successfully flew numerous tests in May/June 2016
  - GrOAWL data analysis has shown excellent results from WB-57 flights in 2016
  - Completing validation testing -> being performed in conjunction with NCAR at both Boulder facilities
  - Successfully increased TRL for ATHENA-OAWL

Thank you to…

- ESTO funding for HAWC (NNX14AF58G) and management of GrOAWL (NNX15AE57G)
- Rest of the OAWL team
  - R. Narciso, J. Applegate, S. Ashby, D. Lloyd, B. Warden, N. Siegel, D. Maes, Fibertek, NCAR team, and many more…