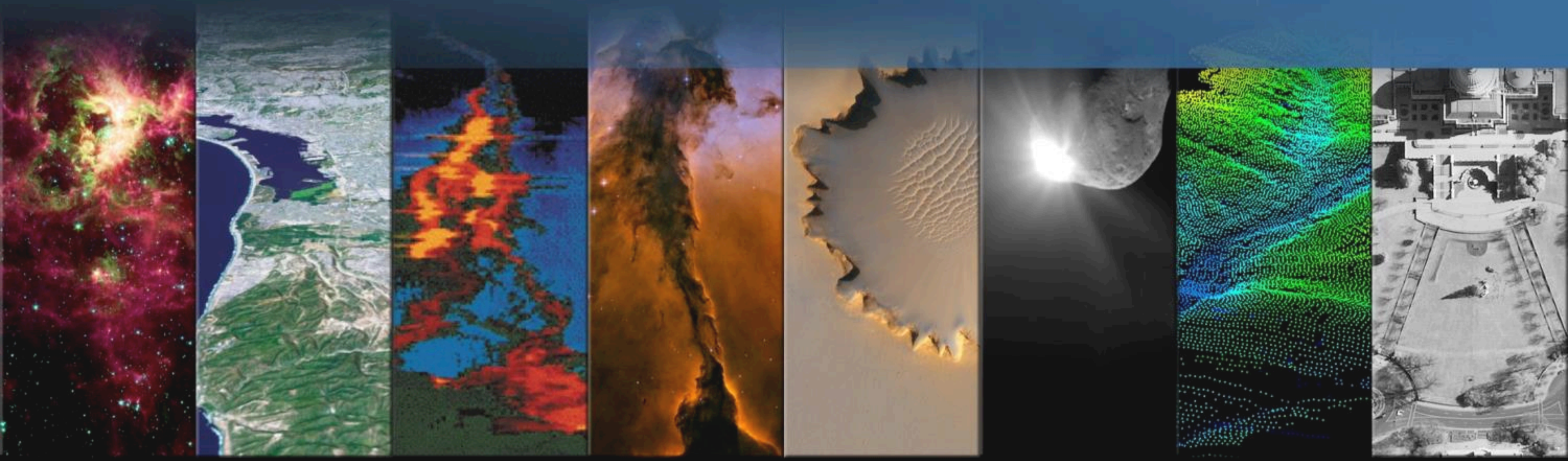
OAWL Systems from IIP to the ATHENA-OAWL Airborne Demonstrator

Sara Tucker, Carl Weimer
Ball Aerospace & Technologies Corp.

ESTO Earth Science Technology Forum, 23-25 June 2015 – Pasadena, CA



Agility to Innovate, Strength to Deliver

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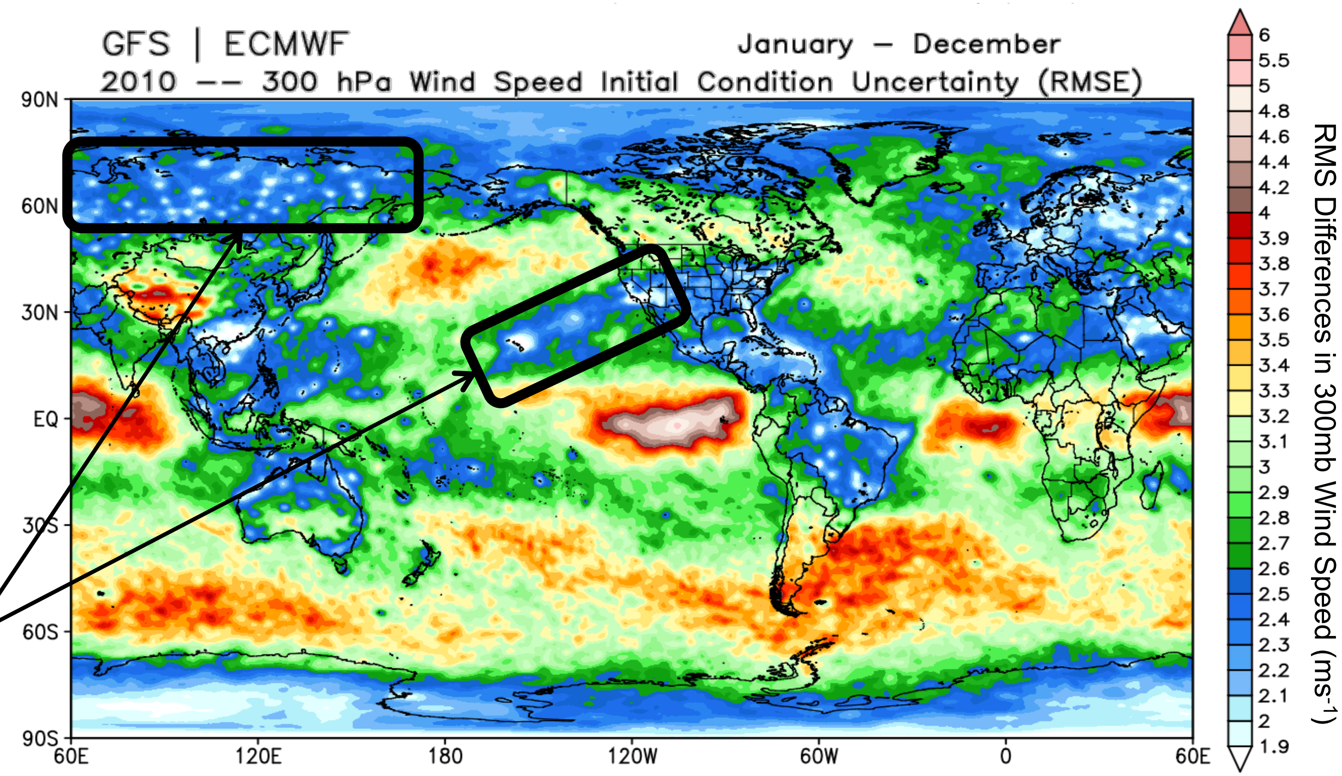
Winds and weather affect us all – locally, globally, politically, & economically

Climate Reanalyses Uncertainties

Langland, WMO Sedona 2012, Langland and Maue 2011

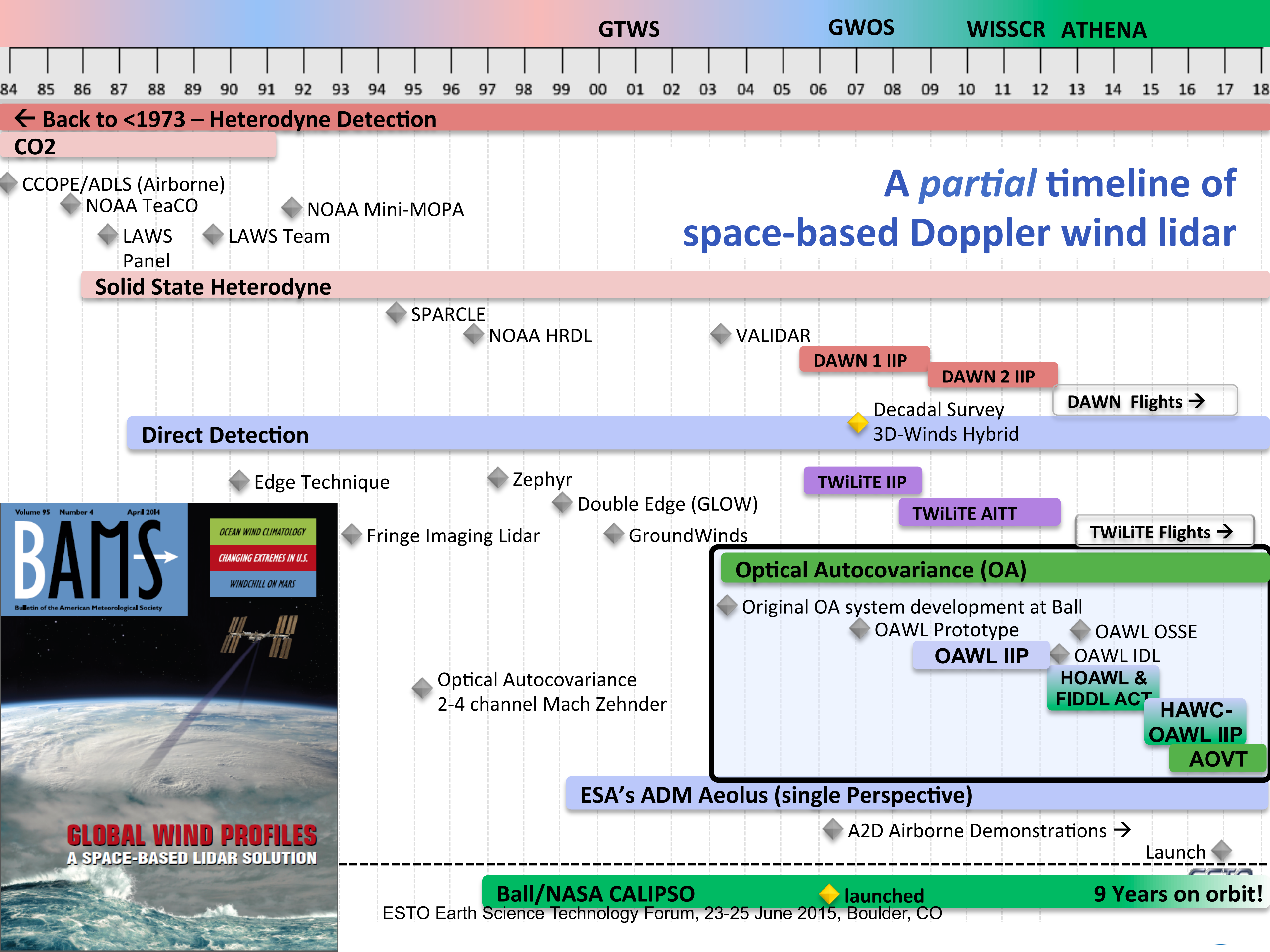
Existing observations (e.g. IR for humidity, temperature) do not correlate well with tropical and mid-latitude winds. Wind measurements (vs. IR retrievals) are particularly important in these regions

Note significant effect of in-situ wind observations: Radiosondes and Commercial Aircraft



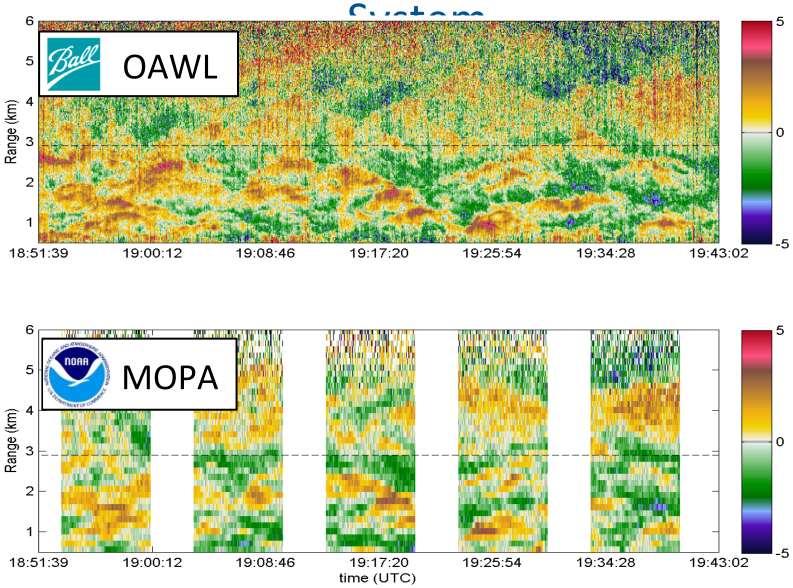
WMO-2012: "There is a need to invest in enhanced wind observations in the tropics and over the oceans especially…. Development of ***satellite-based wind profiling*** systems remains a priority for the future global observing system."

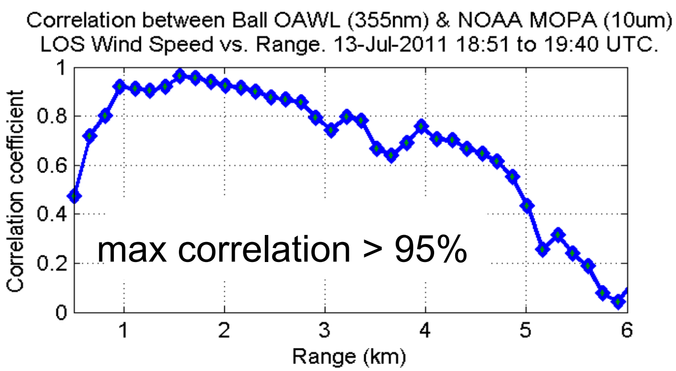
A *partial* timeline of space-based Doppler wind lidar



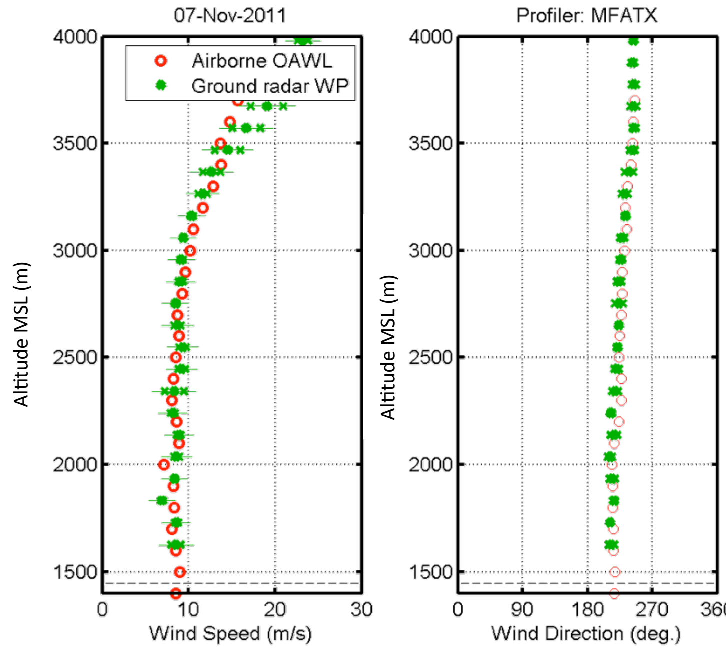
The OAWL IIP-07 Validated the OAWL measurement technique

July 2011 Ground Validation with NOAA's MOPA Coherent detection System



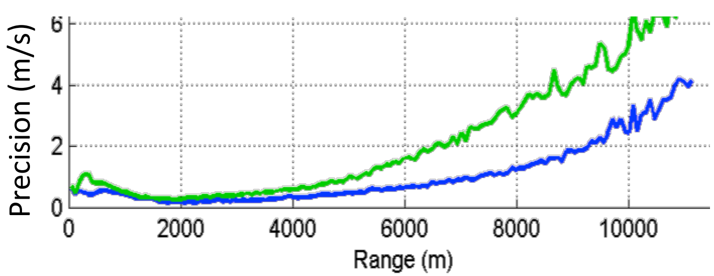


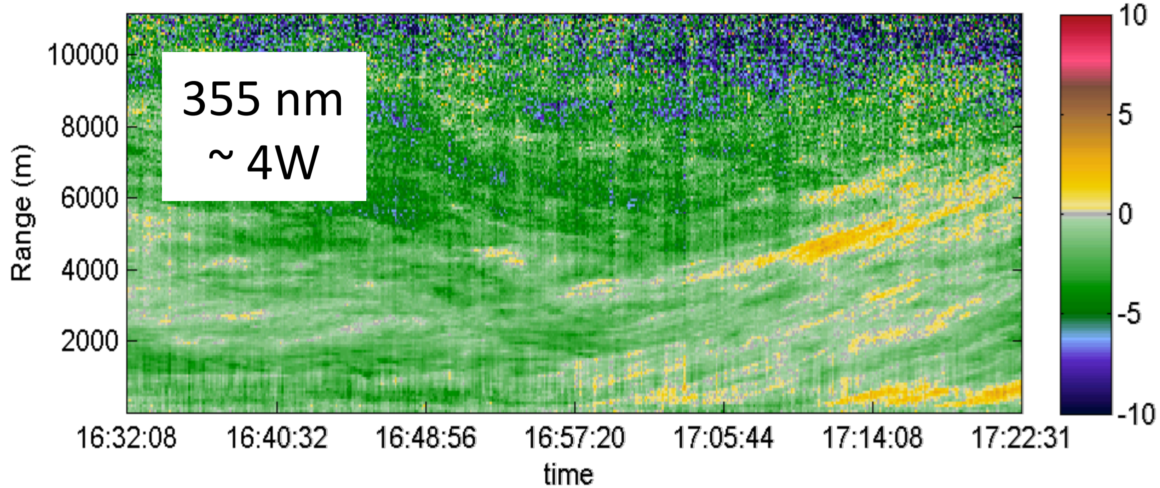
November 2011: Airborne Testing of the autonomously operated breadboard OAWL system on NASA's WB-57

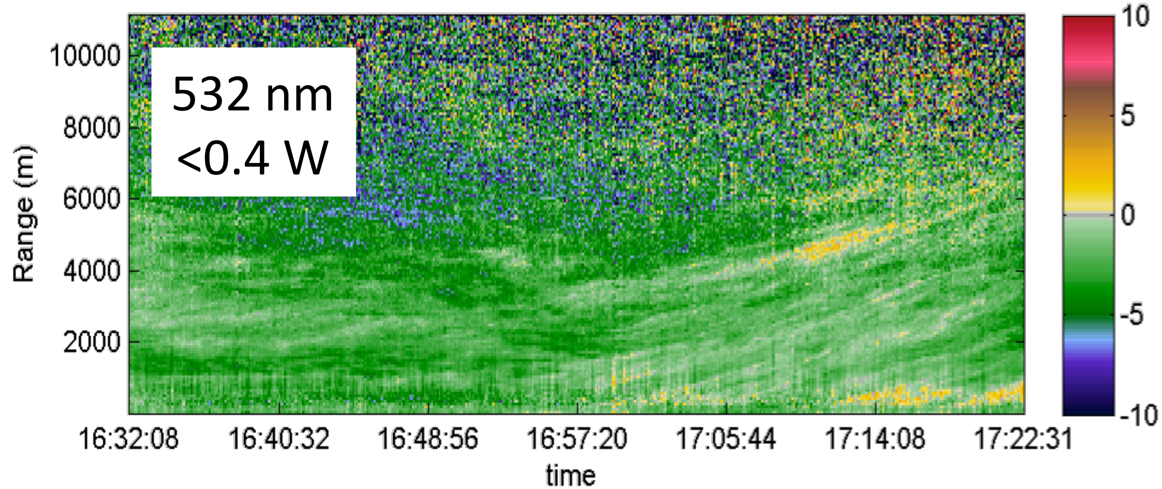


HOAWL ACT demonstrated winds at both 355 & 532 nm

- HOAWL ACT
  - proved out the 532 nm wavelength wind measurements with OAWL
  - developed HSRL algorithms
- Shown: Aerosol winds from horizontal view
  - Returns out to > 11km
  - Analog channels only (Photon counting extends further)
- Dual wavelength wind lidar



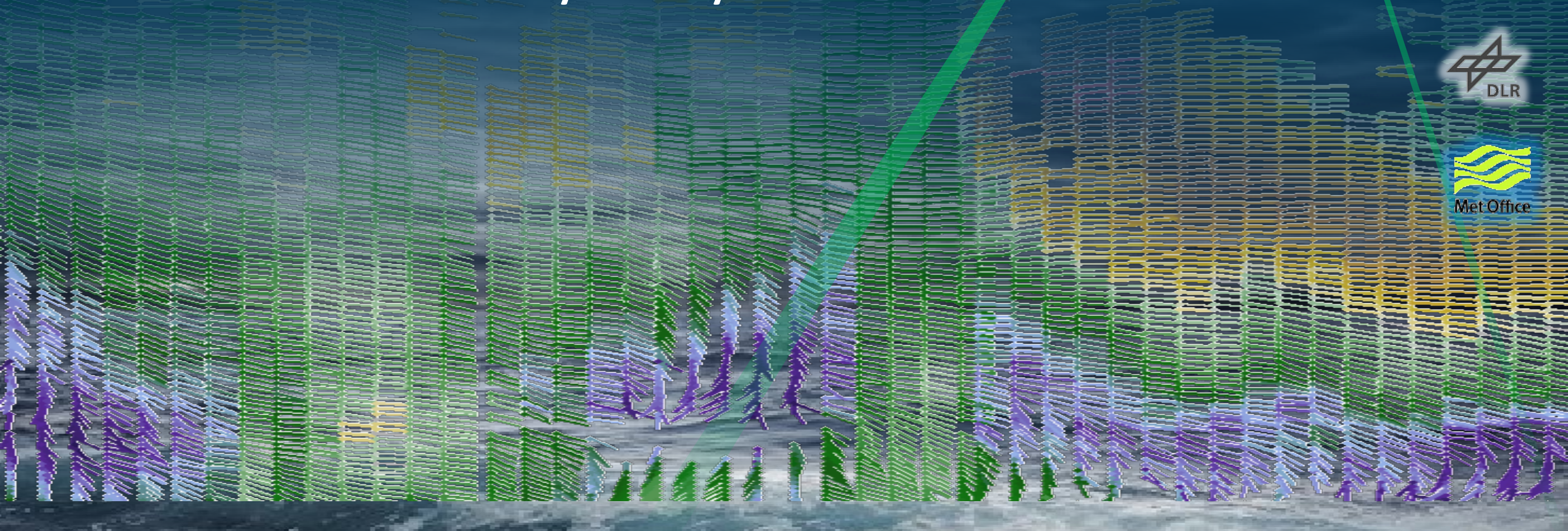




ATHENA-OAWL

Atmospheric Transport, Hurricanes, and Extratropical Numerical weAther prediction using the Optical Autocovariance Wind Lidar

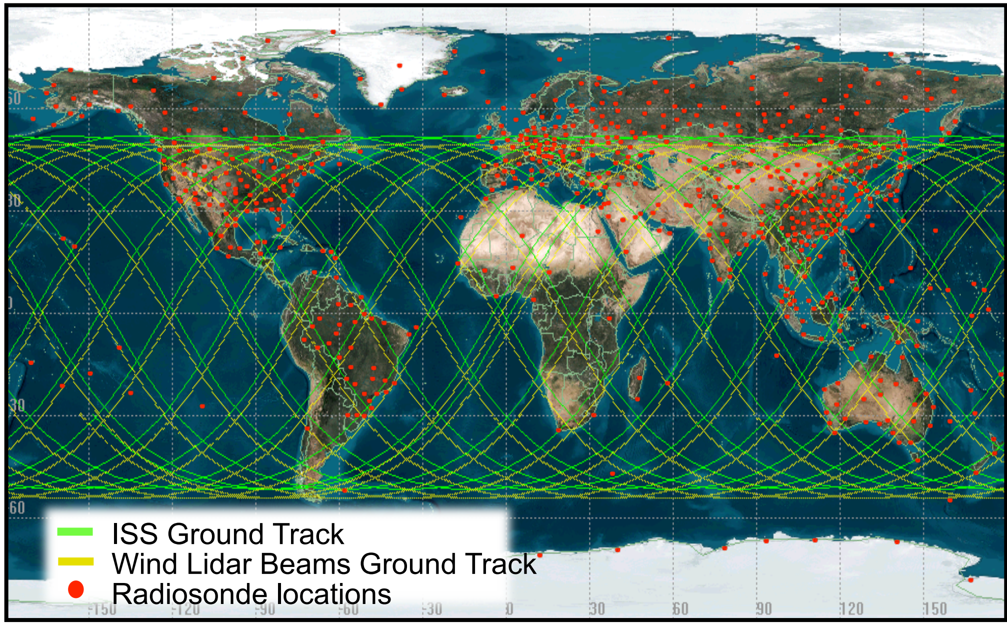
PI: Dr. Lars Peter Riishojgaard
University of Maryland



ESTO Earth Science Technology Forum, 23-25 June 2015, Boulder, CO

ATHENA-OAWL; **path-finding science for next-generation global weather prediction and climate analysis**

- Design to cost approach to Earth Venture Instrument AO using heritage sub-systems (CALIPSO) and ISS technologies
- Mission Objectives: Co-located wind and aerosol profiles
  - breakthroughs in modeling and prediction of low and mid-latitude weather and climate.
  - better understand relationships between aerosol radiative forcing, atmospheric dynamics and the genesis and lifecycle of tropical cyclones
  - Study impacts of long-range dust and aerosol transport on global energy and water cycles, air quality, and climate.

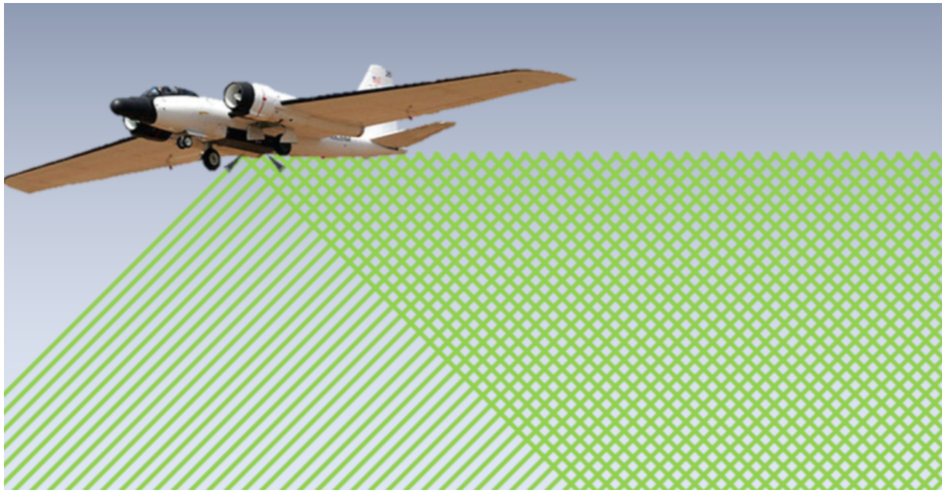


10s/~72km accumulation →2400-4000+ wind profiles/24-hrs

ATHENA-OAWL Venture Tech: GrOAWL

ATHENA-OAWL Venture Tech = AOVT, Green OAWL = GrOAWL

- ATHENA-OAWL, not selected for mission, but rated Category 3 – eligible for Earth Venture Instrument, "Venture Tech" funding.
- Overall goal of Venture Tech Funding: address weaknesses identified by the EV-I reviewers, for ATHENA-OAWL this meant:
  - more aircraft demonstration flight hours: Focused task on scaling airborne system performance to space, as done for Aeolus.
  - more measurement validation: Strong science team emphasis on validation tasks: Verify and validate GrOAWL instrument performance based on aerosol presence (Next talk)
  - Build a robust, two-look, 532 nm version of the OAWL lidar system (GrOAWL) with real-time, line-of-sight winds from high altitude (>15 km)
  - Raise main components of OAWL wind technology from TRL4 to TRL6

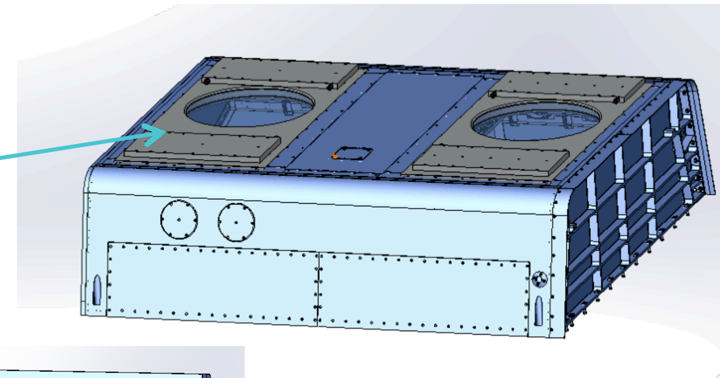


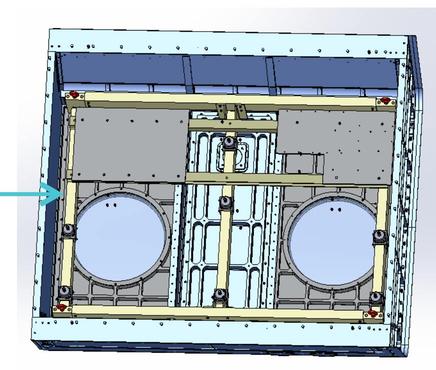
HAWC-OAWL: HSRL for Aerosols, Winds, and Clouds using OAWL

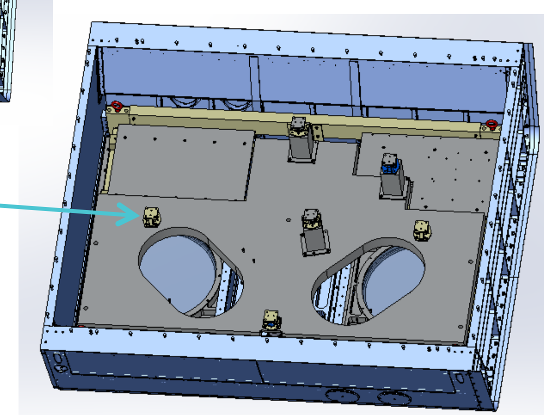
- Add depolarization and 355 nm channels
- Provide aerosol retrievals concurrent with the winds: depolarization ratio, backscatter ratio, and extinction

GrOAWL Mechanical Layout

- Fits into WB-57 quasi-pressurized pallet
- Modify pallet floor panels to provide two windows for the two look angles
- Cold-plates attached to bottom side of panels provide cooling for the lasers
- Interior frame holds vibration isolators to isolate the pallet/frame layer from the vibration isolation bench
- Vibration-isolation bench holds kinematic mounts which provide significant margin on stress/strain.

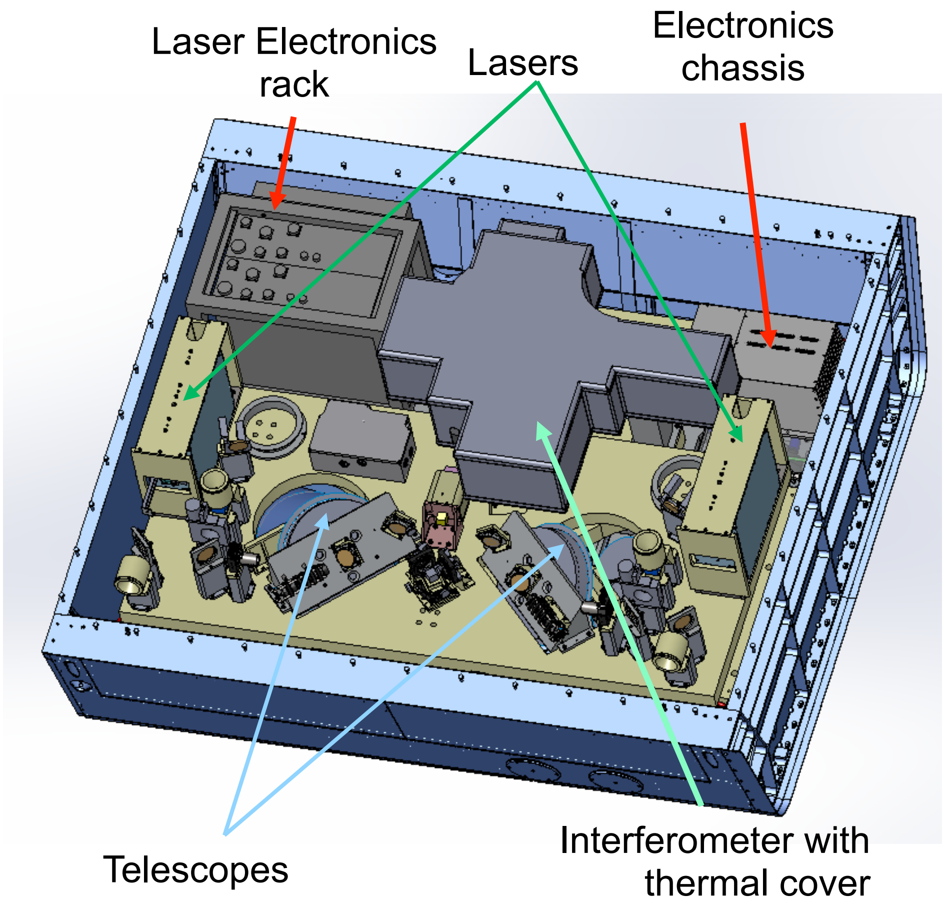




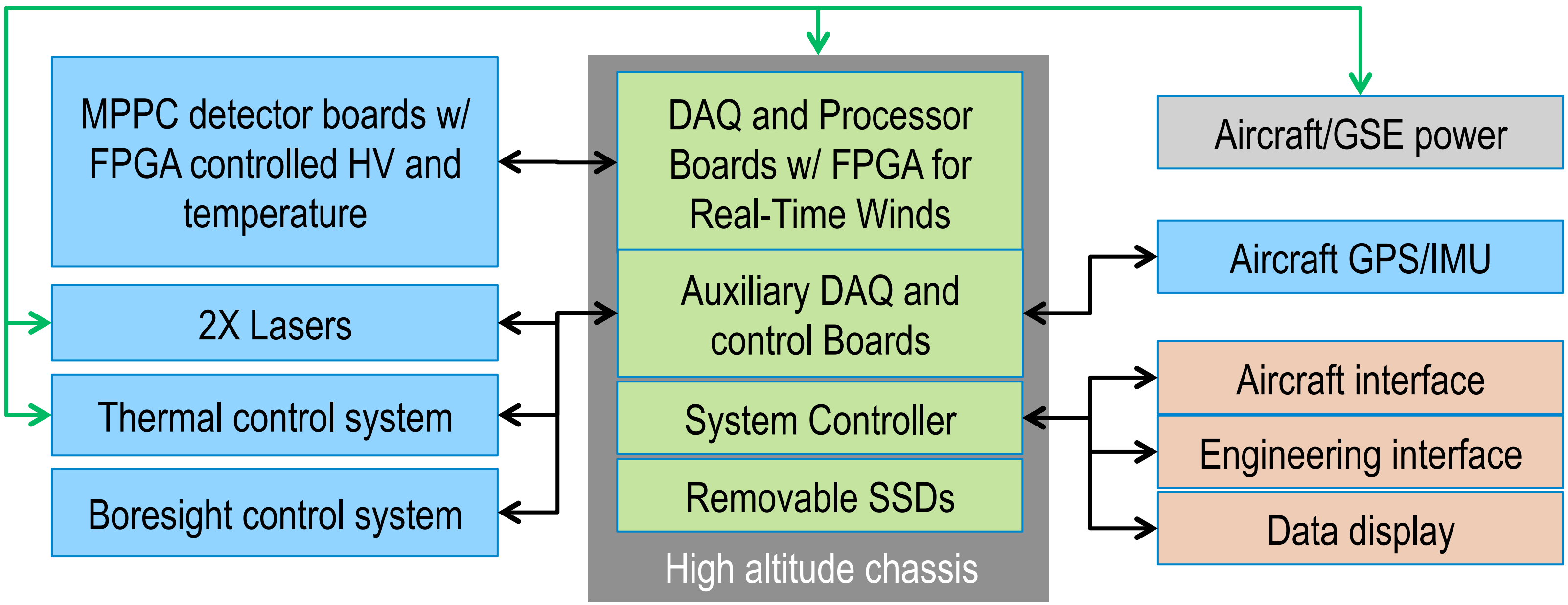


Optical Bench and System Components

- Optical Bench system components
  - 2X Fibertek Lasers
    - Both 200 Hz PRF w/ 30 MHz pulse bandwidth
    - 1 refurbished from OAWL: 10 mJ@532, ~10mJ@355
    - 1 new: 20 mJ@532, 30 mJ@355
  - 2X telescopes,
  - transmit/receive optics
  - Fiber coupling system
  - GPS/IMU
- Interferometer sits on separate kinematic mounts
- Fiber coupling between telescopes receive path and the interferometer.



GrOAWL/HAWC-OAWL Electrical Subsystems



- 2 lasers @ 200 Hz: Effective 400 Hz PRF for data system
- 140 MHz base sampling, with on-FPGA accumulation
  - Effective 10-140 Mhz sample rate is variable, based on altitude or conditions
  - Will store 3000 raw data samples per pulse, per channel (4-10 Channels)
  - Throughput not an issue
- Real-time FPGA wind processing algorithms provide real-time quick-look wind estimates
- GrOAWL processing provides substantial margin over the space-based ATHENA-OAWL requirements

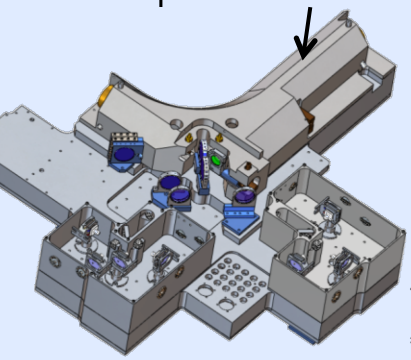
AOVT Schedule

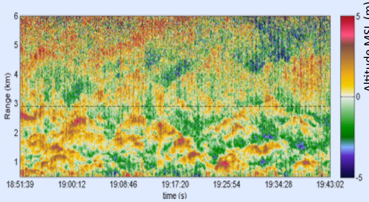
- Start Date: March 3, 2015
- Telescopes and Lasers are on order
- Preliminary design review was held May 2015
- System designs complete (CDR ready) July 2015
- Detection system/payload controller delivery: November 2015
- Hardware system assembled: January 2016
- System ground testing: February/March 2016
- Flight Implementation Plans: February 2016
- **Airborne test flights: April/May 2016**
- Flight test reports: June 2016
- Interferometer/laser TRL testing: November 2016-February 2017
- Final reporting: February 2017

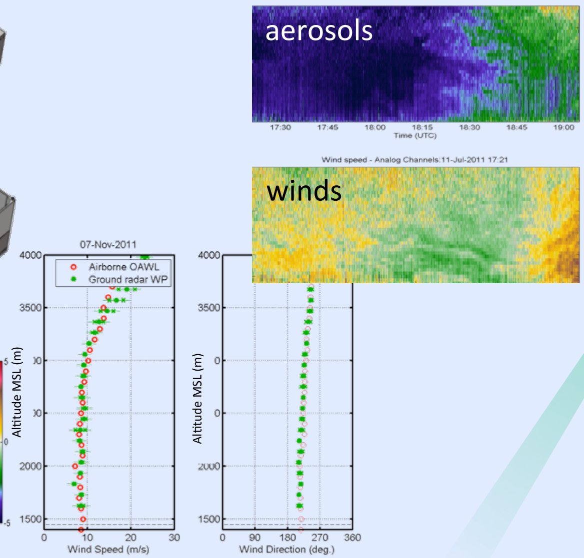
Summary: The Evolution of OAWL

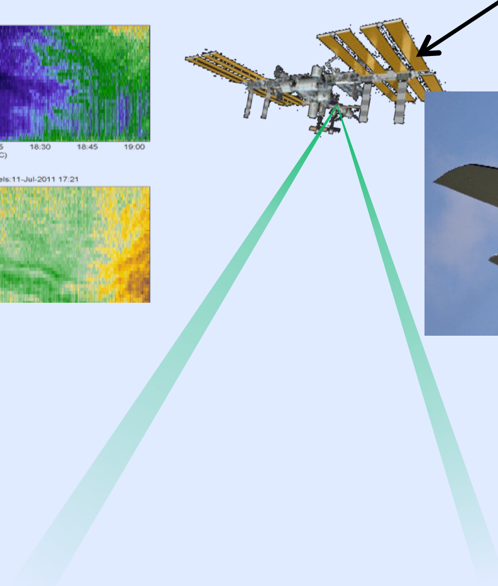
2013 ATHENA-OAWL Mission Proposal

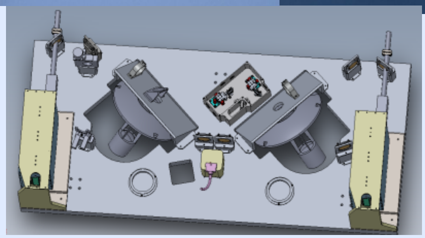
1999-present: Ball design, build and test of OAWL receivers, mission concepts and retrieval/processing algorithms











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

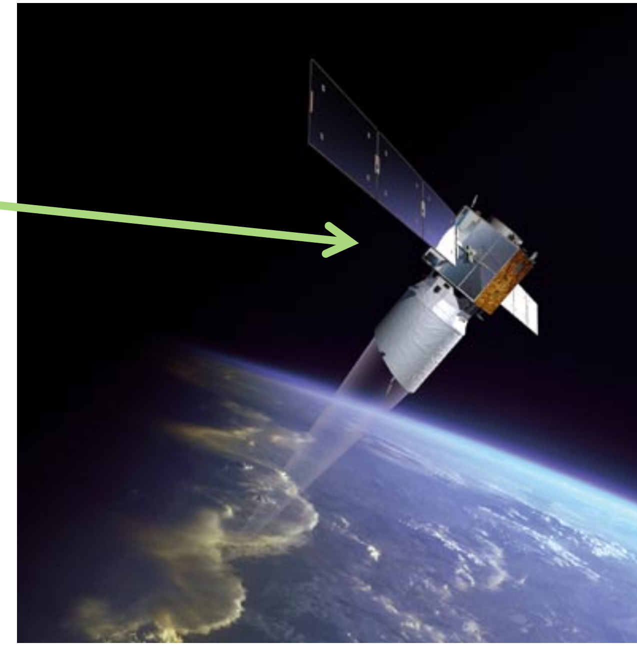
2012-2015: HOAWL ACT
- Breadboard System
- Demonstrate 532 nm wavelength channels & depolarization channels
- Total 10 channels
- HSRL Aerosol retrieval algorithms

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
- HSRL Validation study with NCAR (2016)
- Two look airborne system (build on GrOAWL)
- Dual Wavelength + depol. Channels = 10x @ 400 Hz
- Update interferometer

Future of Space-Based Wind Lidar

- 2016 AOVT "GrOAWL" flights (April/May) – demonstrator for space-based OAWL mission
- 2016: ESA's Aeolus Mission (ADM)
  - Single-perspective line-of-sight winds
  - Planned launch in 2016
  - Aerosol & molecular channels: Both at 355 nm
- 2017: Aeolus Calibration/Validation Effort
  - US CalVal team led by Mike Hardesty w/ investigators from NOAA, NASA, universities, & industry incl. Ball.
  - OAWL is the only (known) 355 nm aerosol wind lidar system in US → can provide validation for Aeolus 355 nm aerosol channel
- 2017: HAWC-OAWL flights with two wavelengths - HSRL+winds for aerosol transport & chemical weather
- 2017: Next Earth Science Decadal Survey
  - Weather missions?



OSSE's wtih focus on assimilation and optimal wind lidar configuration(s)

Thank you