Status of the TWiLiTE airborne molecular Doppler lidar project

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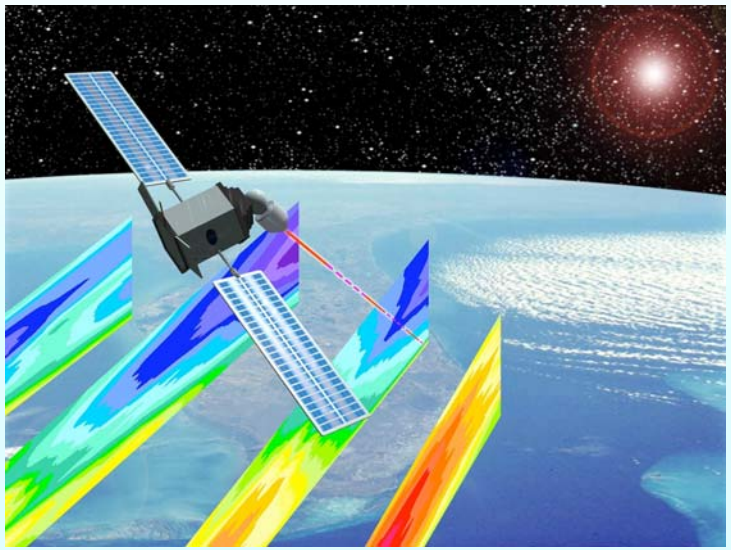
Outline

- Motivation
- TWiLiTE Overview
- Requirements and Performance Simulations
- Instrument Status
- Summary

2007 NRC Decadal Survey Recommendations for Tropospheric Winds



3D Tropospheric Winds mission called "transformational" and ranked #1 by Weather panel. with concurrence by Water panel. Overall prioritized in 3rd tier of 15 NASA recommended missions.

"The Panel strongly recommends an aggressive program early on to address the high-risk components of the instrument package, and then design, build, aircraft-test, and ultimately conduct space-based flights of a prototype Hybrid Doppler Wind Lidar (HDWL)."

"The Panel recommends a phased development of the HDWL mission with the following approach:

- *Stage 1:* Design, develop and demonstrate a prototype HDWL system capable of global wind measurements to meet demonstration requirements that are somewhat reduced from operational threshold requirements.
- *Stage II:* Launch of a HDWL system that would meet fully-operational threshold tropospheric wind measurement requirements. It is expected that a fully operational HDWL system could be launched as early as 2022."

Hybrid DWL Technology Maturity Roadmap

Past Funding

Laser Risk Reduction Program

IIP-2004 Projects

ROSES-2007 Projects

2-Micron Coherent Doppler Lidar

2 micron laser 1988 → Diode Pump Technology 1993 → Inj. Seeding Technology 1996 → High Energy Technology 1997 → Conductive Cooling Techn. 1999 → Compact Packaging 2005 → Packaged Lidar Ground Demo. 2007

TRL 5 — 2008 - 2012

TRL 6 to TRL 7 — 2011 - 2013

TRL 7 to TRL 9

Autonomous Oper. Technol. Coh.

Space Qualified

Lifetime Validation

Pre-Launch Validation

Aircraft Operation DC-8

Autonomous Aircraft Oper WB-57

2014 - 2016

GWOS

2026

Operational NexGen NPOESS

TWiLiTE

Autonomous Oper. Technol. 2008 (Direct)

Space Qualif.

Lifetime Validation

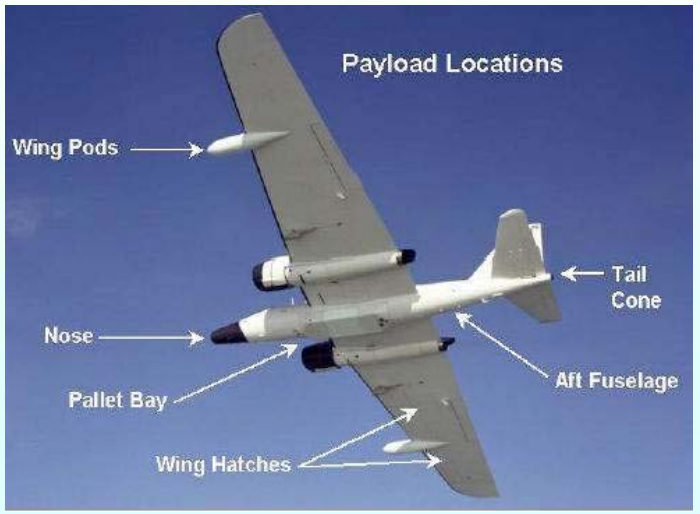
Pre-Launch Validation

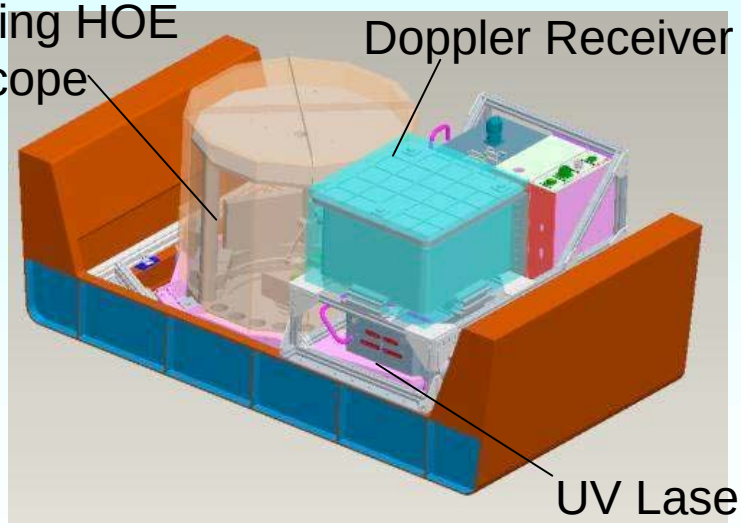
1 micron laser → Diode Pump Technology → Inj. Seeding Technology → Conductive Cooling Techn. → High Energy Laser Technology → Compact Laser Packaging 2007 → Compact Molecular Doppler Receiver 2007

0.355-Micron Direct Doppler Lidar

Tropospheric Wind Lidar Technology Experiment (TWiLiTE) Instrument Incubator Program

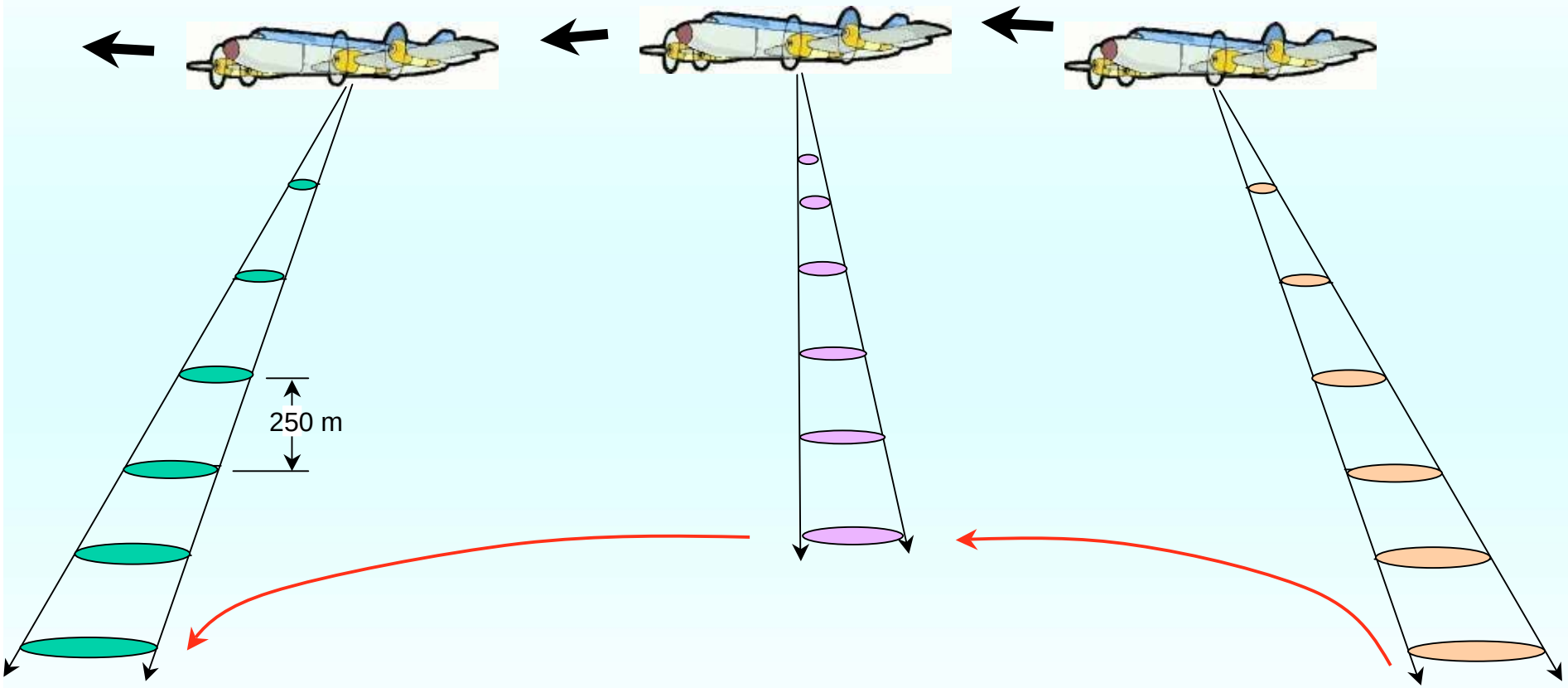
- TWiLiTE will demonstrate, for the first time, downward looking wind profiles from 18 km to the surface obtained with an airborne direct detection scanning Doppler lidar
- The TWiLiTE instrument is compact, rugged and designed for autonomous operation on the NASA WB57 or ER2.
- TWiLiTE will be completed in summer 2008.
- The instrument could be transitioned to a UAV like Global Hawk .





TWiLiTE system integrated on WB57 3 foot pallet

Airborne Doppler Lidar Wind Profiling



Lidar ranging permits determination of wind speed as a function of altitude.
Multiple look angles permit determination of vector wind.

TWiLiTE Compatible*
NASA Airborne Science Platforms

Max Altitude (km)

25

20

15

10

5

Global Hawk

36 hrs duration
Unmanned vehicle

ER2*

WB57*

6-8 hrs duration
Unattended operation

DC8*

'Flying laboratory'
<12 hrs duration
Nadir and zenith ports

TWiLiTE Measurement Requirements

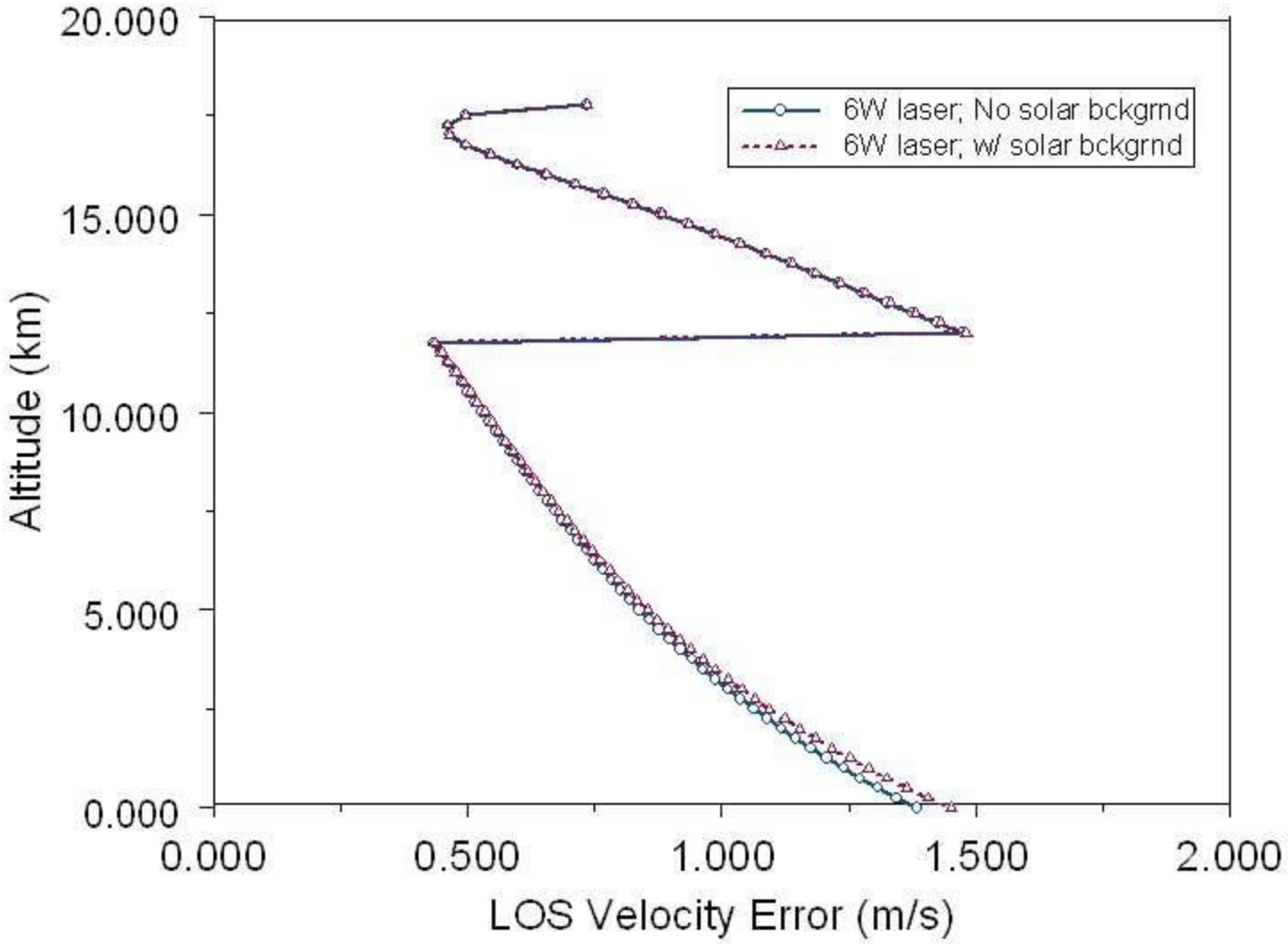
Parameter	***WB57***
Velocity accuracy (HLOS projected) (m/s)	2.0
Range of regard (km)	0-18
Vertical resolution (km)	0.25
Horizontal resolution (km) (complete scan cycle)	25
Groundspeed (m/s)	200
Nadir angle (deg)	45
Scan pattern	Up to 16 pt step-stare
Horizontal integration per LOS (seconds)//ground track (km)	10//2

TWiLiTE Instrument Parameters

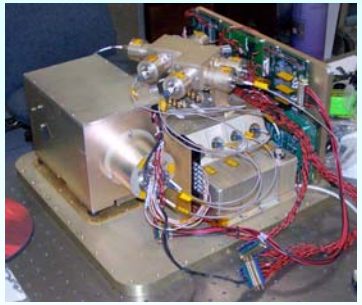
Wavelength	354.7 nm
Telescope/Scanner Area	0.08 m^2
Laser Linewidth (FWHH)	150 MHz
Laser Energy/Pulse (8 W)	40 mJ @ 200 pps
Etalon FSR	16.65 GHz
Etalon FWHH	2.84 GHz
Edge Channel Separation	6.64 GHz
Locking Channel Separation	4.74 GHz
Interference filter BW (FWHH)	120 pm
PMT Quantum Efficiency	25%
Optical Efficiency (Edge w/o BS or etalon)	0.37
BS	0.41

TWiLiTE Predicted LOS Error

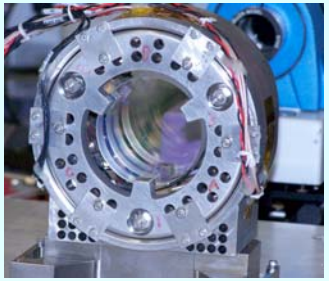
2000 shot average, 250 m vertical resolution, background aerosol

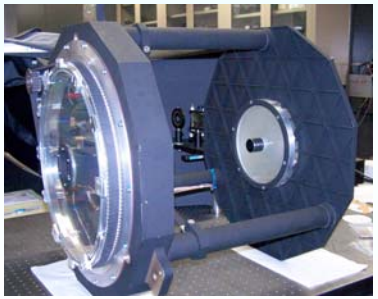


TWiLiTE Direct Detection Wind Lidar Key Technologies



	Entrance TRL	Exit TRL
• High spectral resolution all solid state laser transmitter	4	5
• High spectral resolution optical filters	4	5
• Efficient 355 nm photon counting molecular Doppler receiver technologies	4	5
• Novel UV Holographic Optical Element telescopes and scanning optics	3	5

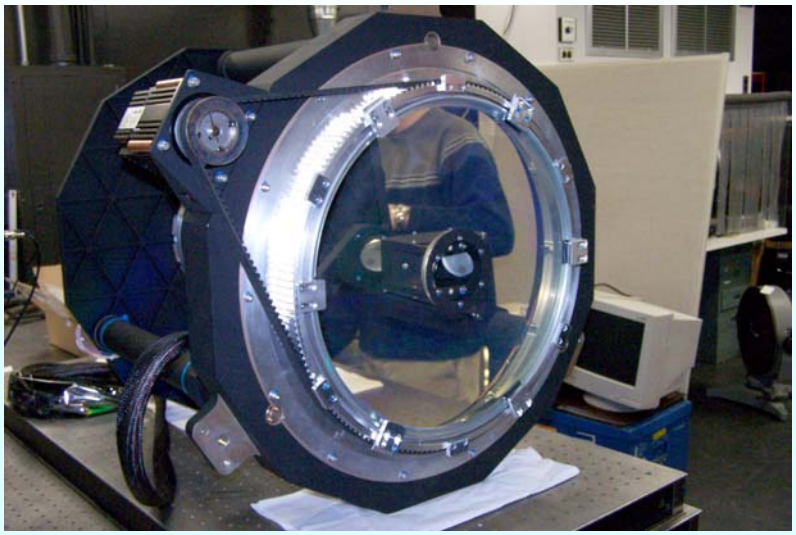




TWiLiTE Scanning Holographic Telescope

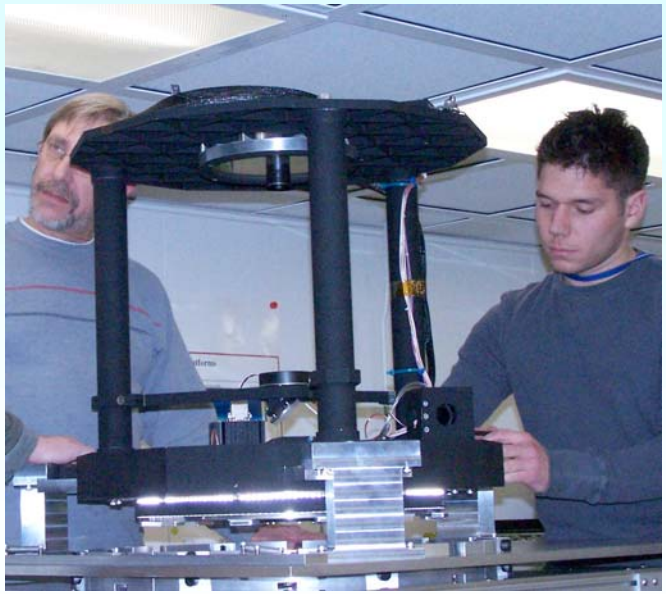
FUNCTIONS

- **Collect and focus laser backscatter**
- **Scan laser and FOV**
- **Provide pointing knowledge to CDH**



FEATURES

- **Primary Optic: Rotating 40-cm HOE, 1-m f.l.**
- **45-deg off-nadir FOV**
- **Compact, folded optical path**
- **Coaxial laser transmission**
- **Active laser bore-sight**

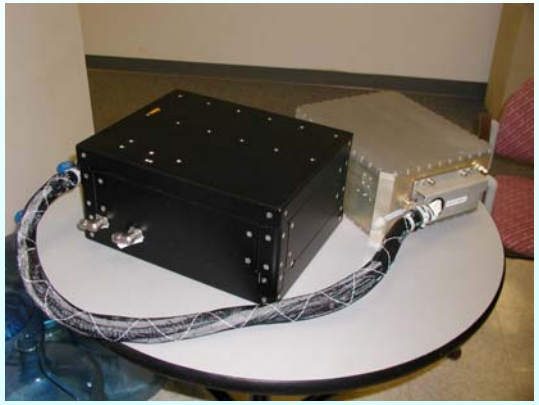


Delivered to GSFC Dec, 2007

TWiLiTE Laser Overview

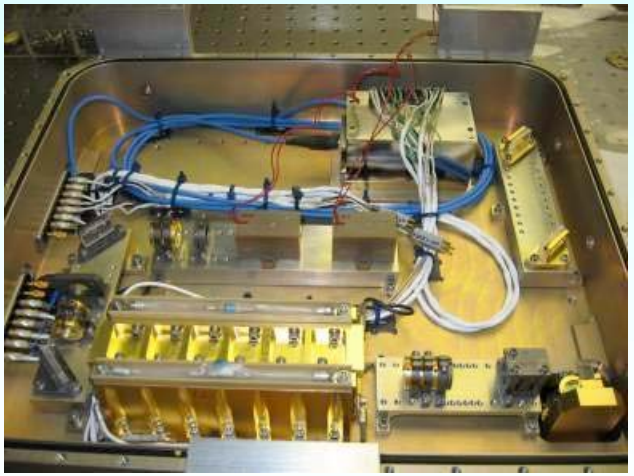
FIBERTEK, INC.

- Injection seeded Nd:YAG ring oscillator with single amplifier
- Frequency tripled to 355 nm
- Pulse energy = 35 mJ @ 355 nm
- Pulse Rep Frequency = 200 pps
- Optical canister is 28cm x 33 cm
- Delivery to GSFC scheduled for Feb 2008



Assembled laser optical and electronics modules

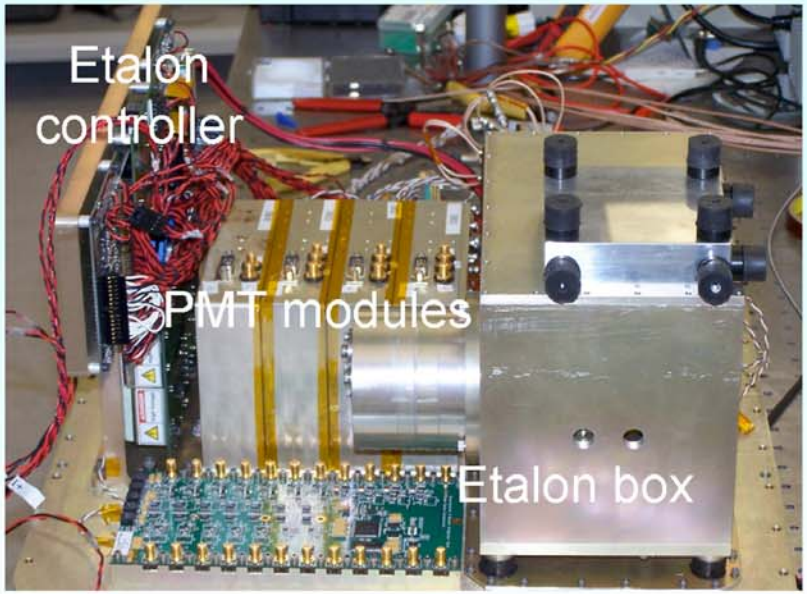
Oscillator Compartment



Amplifier Compartment

TWiLiTE Doppler Receiver Status

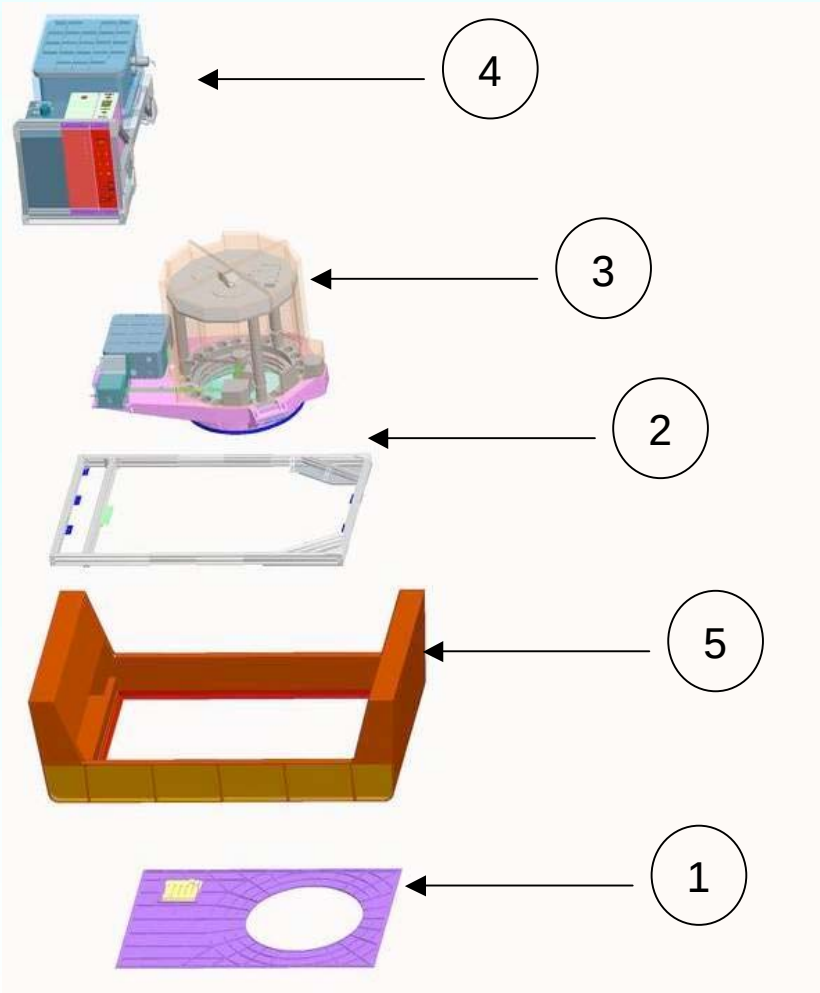
- Volume reduced by 90% versus 1st gen ground based lidar receiver
- Optical path lengths minimized to improve mechanical, thermal stability
- End-to-end throughput increased by 60%
- Signal dynamic range increased by 2 orders of magnitude

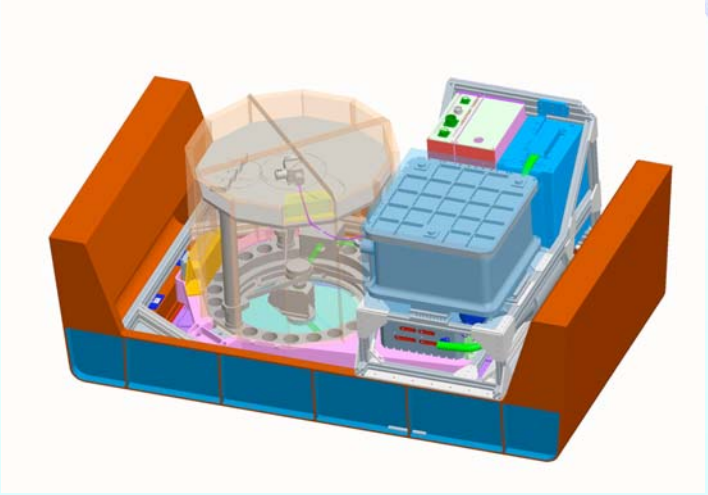


Doppler receiver modules (left) are enclosed (right) in an environmentally controlled vessel

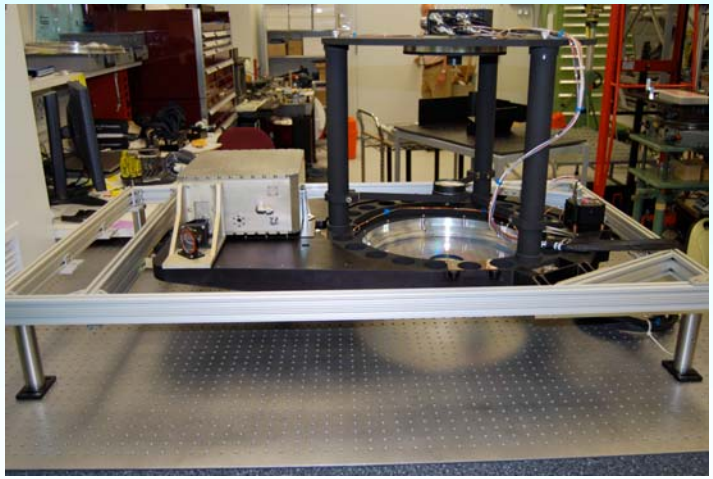
TWiLiTE Integration on WB57 Pallet

1- Floor; 2- Mounting frame; 3- Optical bench (laser &HOE rotating telescope); 4- Receiver & Electronics ; 5- WB57 Pallet



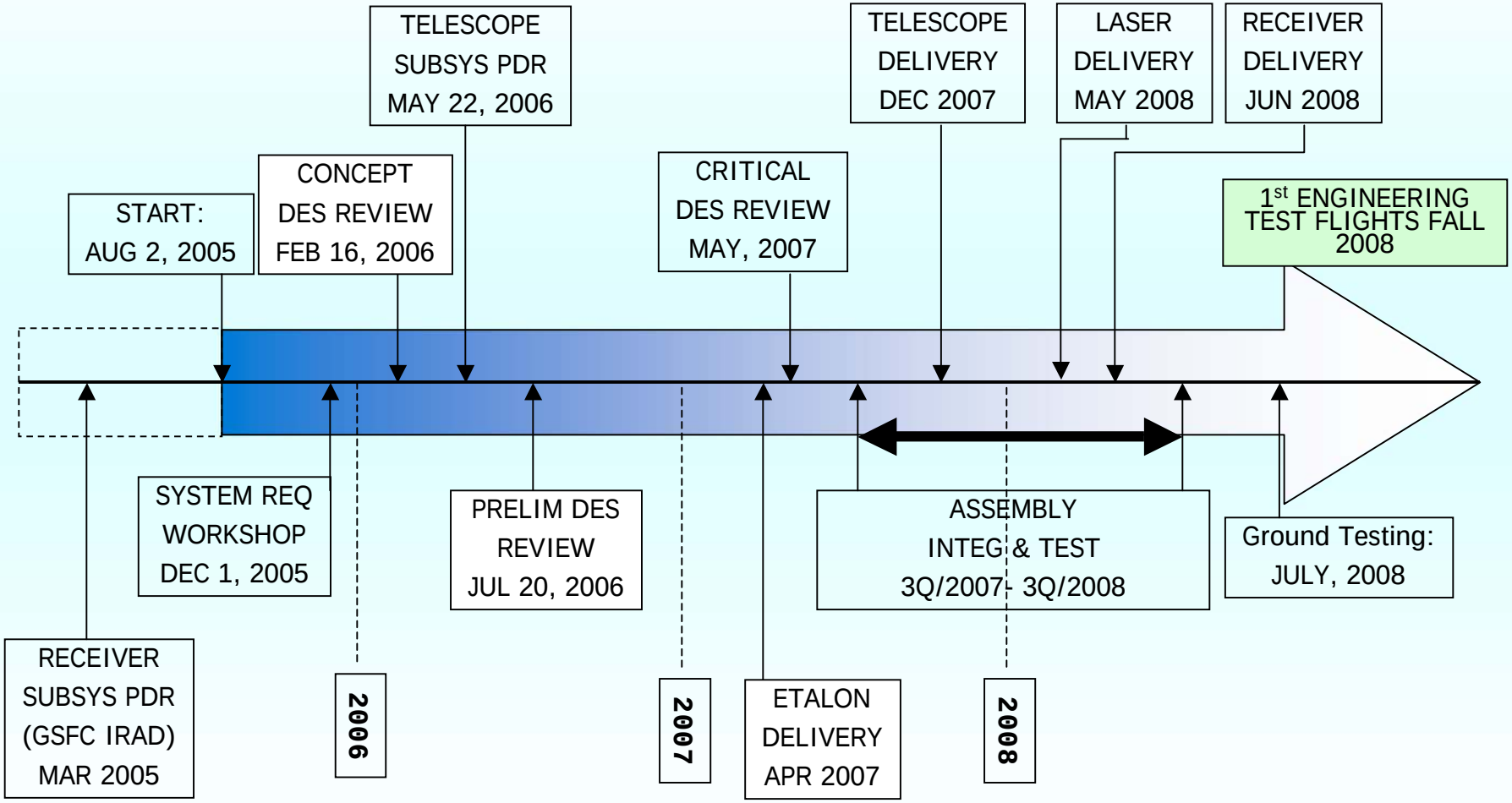


Mass: 250 kg
Power: 770W (not including heaters)



Laser Optical Module and HOE telescope mounted on optical bench and frame (June 13, 2008)

TWiLiTE Project Timeline



TWiLiTE Summary

- TWiLiTE is a three year R&D project to design and build an airborne scanning direct detection Doppler lidar
- The primary objective is to advance the readiness of key component technologies as a stepping stone to space.
- The TWiLiTE Doppler lidar will serve as a testbed to validate critical technologies in a fully autonomous, integrated Doppler lidar as a stepping stone to space.
- The instrument is designed to measure full profiles of winds from a high altitude aircraft and many of the design elements may be transitioned to UAV or other suborbital platforms for mesoscale and hurricane research.
- First flights on the NASA ER-2 are planned in the Fall of 2008

Backups

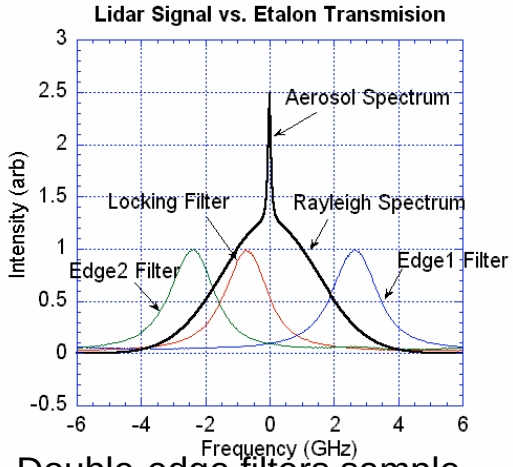
Mission Applications

Global Tropospheric Wind Sounder
- *Improved NWP*
- *Hurricane and severe storm prediction*

Airborne Doppler Lidar
- *Mesoscale research*
- *Improved hurricane prediction*
- *Satellite cal/val*
- *Technology validation*

Exploration
- *Martian winds from orbit or surface*

Double Edge Doppler Lidar Heritage

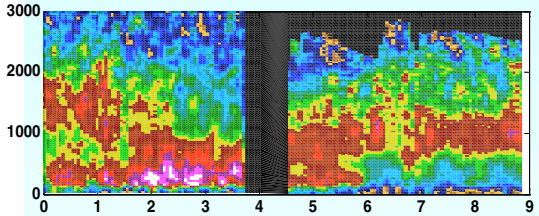


Double-edge filters sample wings of molecular spectrum to measure Doppler shift

GLOW mobile Doppler lidar

- In 1999 the first molecular “double edge” Doppler receiver was built as a proof of principle experiment.
- The molecular receiver was installed in the GLOW mobile Doppler lidar to demonstrate the functionality and scalability of the approach
- 5 years of ground based lidar wind measurements in a wide variety of conditions.

Receiver mounted in GLOW lidar for field tests and measurements

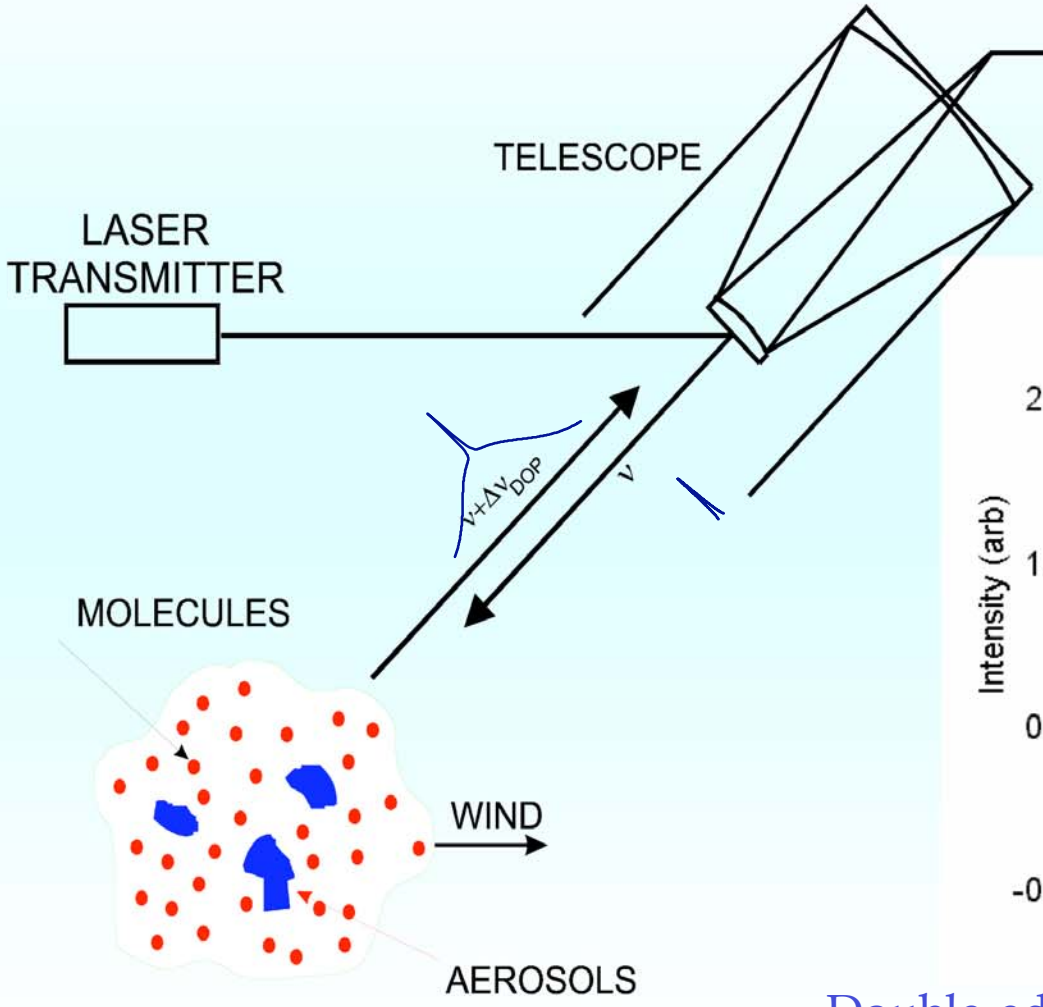


m/s

deg

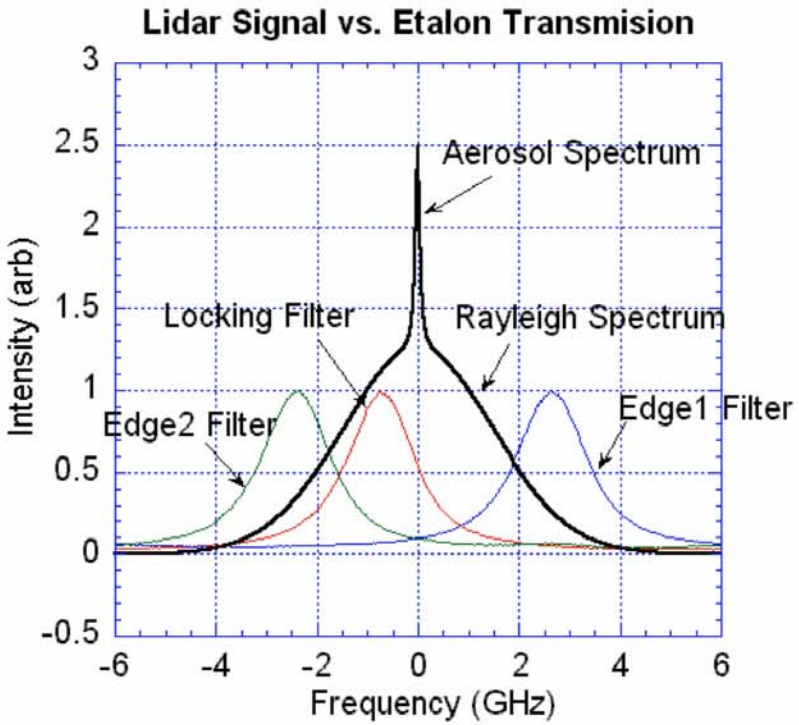
Time series of wind speed and direction profiles from IHOP_2002

Doppler Lidar Measurement Concept



MOLECULAR DOPPLER RECEIVER

- Molecular return gives lower accuracy and resolution but ***signal is always there***



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