Status of the TWiLiTE airborne molecular Doppler lidar project

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Presented by
Cathy Trout-Marx, NASA GSFC

ESTO Earth Science Technology Conference
June 24-26, 2008
College Park, MD
Outline

• Motivation
• TWiLiTE Overview
• Requirements and Performance Simulations
• Instrument Status
• Summary
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.

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.
Hybrid DWL Technology Maturity Roadmap

2-Micron Coherent Doppler Lidar


Compact Packaging 2005

2008 - 2012 TRL 5

2011 - 2013 TRL 6 to TRL 7
Aircraft Operation DC-8 → Autonomous Aircraft Operation WB-57

2014 - 2016 TRL 7 to TRL 9
Autonomous Oper. Technol. 2008 (Direct)

GWOS

Operational NexGen NPOESS

0.355-Micron Direct Doppler Lidar

ROSES-2007 Projects

IIP-2004 Projects

Past Funding

NASA Laser Risk Reduction Program

TWiLITE

Compact Laser Packaging 2007
Compact Molecular Doppler Receiver 2007

1 micron laser → Diode Pump Technology → Inj. Seeding Technology → Conductive Cooling Techn. → High Energy Laser Technology

2008 ESTO Technology Conference
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

DC8*
WB57*
ER2*
Global Hawk

‘Flying laboratory’
Nadir and zenith ports
6-8 hrs duration
Unattended operation

36 hrs duration
Unmanned vehicle

<12 hrs duration
## TWiLiTE Measurement Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>WB57</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity accuracy (HLOS projected) (m/s)</td>
<td>2.0</td>
</tr>
<tr>
<td>Range of regard (km)</td>
<td>0-18</td>
</tr>
<tr>
<td>Vertical resolution (km)</td>
<td>0.25</td>
</tr>
<tr>
<td>Horizontal resolution (km) (complete scan cycle)</td>
<td>25</td>
</tr>
<tr>
<td>Groundspeed (m/s)</td>
<td>200</td>
</tr>
<tr>
<td>Nadir angle (deg)</td>
<td>45</td>
</tr>
<tr>
<td>Scan pattern</td>
<td>Up to 16 pt step-stare</td>
</tr>
<tr>
<td>Horizontal integration per LOS (seconds)/ground track (km)</td>
<td>10//2</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Wavelength</td>
<td>354.7 nm</td>
</tr>
<tr>
<td>Telescope/Scanner Area</td>
<td>0.08 m²</td>
</tr>
<tr>
<td>Laser Linewidth (FWHH)</td>
<td>150 MHz</td>
</tr>
<tr>
<td>Laser Energy/Pulse (8 W)</td>
<td>40 mJ @ 200 pps</td>
</tr>
<tr>
<td>Etalon FSR</td>
<td>16.65 GHz</td>
</tr>
<tr>
<td>Etalon FWHH</td>
<td>2.84 GHz</td>
</tr>
<tr>
<td>Edge Channel Separation</td>
<td>6.64 GHz</td>
</tr>
<tr>
<td>Locking Channel Separation</td>
<td>4.74 GHz</td>
</tr>
<tr>
<td>Interference filter BW (FWHH)</td>
<td>120 pm</td>
</tr>
<tr>
<td>PMT Quantum Efficiency</td>
<td>25%</td>
</tr>
<tr>
<td>Optical Efficiency (Edge w/o BS or etalon)</td>
<td></td>
</tr>
<tr>
<td>BS</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>0.37</td>
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</tbody>
</table>
TWiLiTE Predicted LOS Error

2000 shot average, 250 m vertical resolution, background aerosol
<table>
<thead>
<tr>
<th>Key Technologies</th>
<th>Entrance TRL</th>
<th>Exit TRL</th>
</tr>
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<tbody>
<tr>
<td>• High spectral resolution all solid state laser transmitter</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>• High spectral resolution optical filters</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>• Efficient 355 nm photon counting molecular Doppler receiver technologies</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>• Novel UV Holographic Optical Element telescopes and scanning optics</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>
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
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
TWiLiTE Doppler Receiver Status

- Volume reduced by 90% versus 1\textsuperscript{st} 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

- **START:** AUG 2, 2005
- **SYSTEM REQ WORKSHOP:** DEC 1, 2005
- **TELESCOPE SUBSYS PDR:** MAY 22, 2006
- **CONCEPT DES REVIEW:** FEB 16, 2006
- **CRITICAL DES REVIEW:** MAY, 2007
- **TELESCOPE DELIVERY:** DEC 2007
- **LASER DELIVERY:** MAY 2008
- **RECEIVER DELIVERY:** JUN 2008
- **1st ENGINEERING TEST FLIGHTS FALL 2008**
- **RECEIVER SUBSYS PDR (GSFC IRAD):** MAR 2005
- **PRELIM DES REVIEW:** JUL 20, 2006
- **ASSEMBLY INTEG & TEST:** 3Q/2007- 3Q/2008
- **2006**
- **2007**
- **2008**
- **ETALON DELIVERY:** APR 2007
- **Ground Testing:** JULY, 2008
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*
• 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.
MOLECULAR DOPPLER RECEIVER

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

Double-edge filters sample wings of molecular spectrum to measure Doppler shift
### TWiLiTE Instrument Parameters

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