Development of the Global Ozone Lidar Demonstrator (GOLD) for deployment on the Global Hawk

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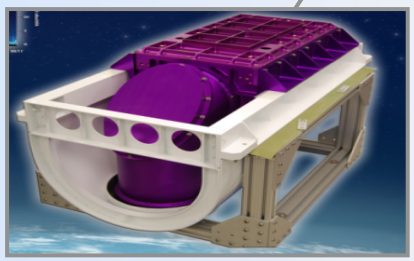
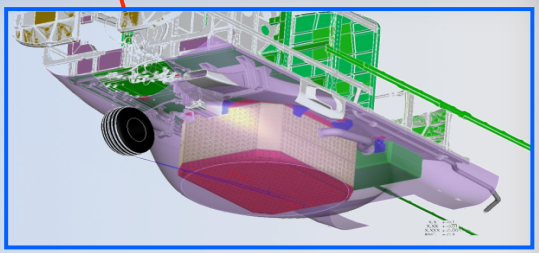
Stimulus-Funded Technology Development
Global Hawk Instruments



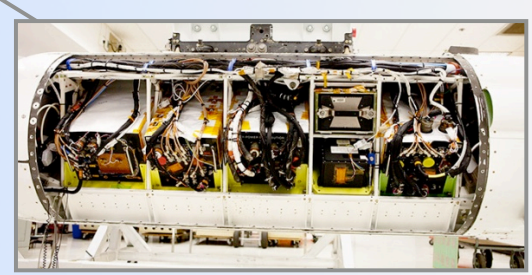
Land, Vegetation, & Ice Sensor (LVIS)

This task will Integrate the LVIS capability onto the Global Hawk and provide an automated, reliable package for high altitude measurements.



Global Ozone Lidar Demonstrator (GOLD)

GOLD will enable, for the first time, Ozone LIDAR measurements from a high-altitude aircraft that support global atmospheric composition and climate change investigations.



UAVSAR

The Uninhabited Aerial Vehicle – Synthetic Aperture Radar (UAVSAR) project will install two existing UAVSAR pods on a UAV for the first time. On Global Hawk, UAVSAR will generate precise topographic maps and single-pass polarimetric interferograms of ice and vegetation.

Outline

1. GOLD Description (ESTO – IIP)

- Science/Technology Objectives & Rationale
- Technology Developments
- Atmospheric Demonstration and Comparison

2. ARRA Tasks - Flight preparation

- LaRC
  - **Flight laser development**
  - **Instrument system integration**
- DFRC
  - **Aircraft fairing, Liquid Cooling System (LCS), mounting, and certifications**

Acknowledgement of Partners - Responsibilities

LaRC

Program Lead and Science Lead.
System Integration and Evaluation.

DFRC (Chris Naftel & David Fratello)

Global Hawk Payload Manager
Aircraft Integration and Modification

ITT Industries

Advanced Nd:YAG-pumped OPO lasers.
Advanced Optical Receiver & Filter.

Welch Mechanical Designs LLC

UAS integration and opto-mechanical engineering and design.

GSFC (Tom McGee)

Consulting on GOLD system design, laser developments, and ozone measurements.

NOAA (Mike Hardesty & Allen Brewer)

Ultraviolet (UV) detector assessment and optimization.

Jet Propulsion Laboratory (Stuart McDermid)

Develop ground-based calibration facility to validate GOLD.

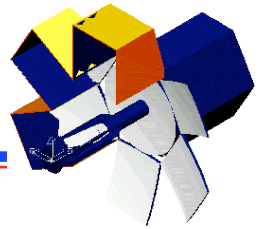
Northrop Grumman Corporation

Engineering support for Global Hawk and instrument integration

Fibertek Inc.

Flight Nd:YAG pump laser

Science Objectives of Space-based Ozone & Aerosol Lidar



Understanding global atmospheric composition and predicting future evolution cannot be accomplished by passive instruments alone!

GACM Tier III NRC Decadal Survey Mission

Key Environmental Applications/Issues:

- **Global Air Quality**
- **Climate Forcing by Radiatively Active Gases & Aerosols**

Specific Science Questions:

- **What is global distribution of tropospheric ozone and how does it change seasonally and interannually?**
- **What is relative contribution of photochemical and dynamical processes in determining tropospheric ozone?**
- **What is the impact of ozone on global tropospheric chemistry and climate?**

Rationale for GOLD Development

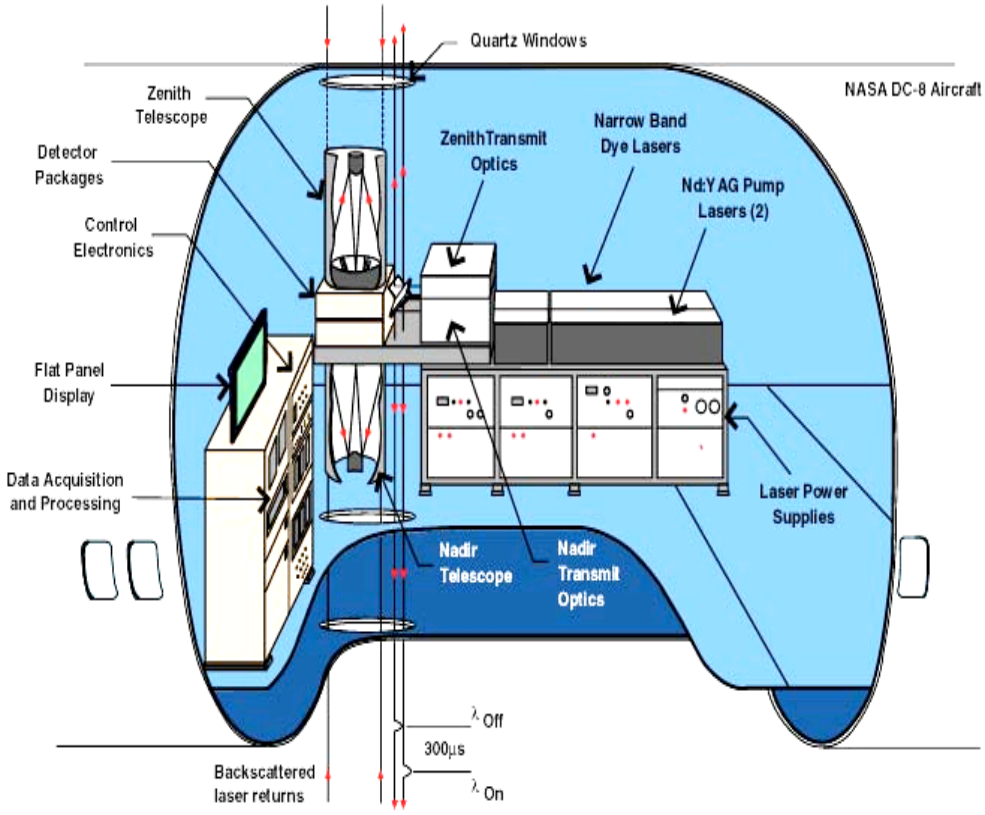
GOLD - Precursor to Space-based Ozone Lidar System

- Requires autonomous capability similar to space operation.
- Driver for smaller, lower power and volume instruments similar to space requirements.
- Simulate ozone lidar measurements with laser wavelengths suitable for space-based ozone lidar.
- Very high altitude operation to simulate space perspective across lower stratosphere.
- Provides required technological steps towards space Ozone DIAL

Unique GOLD Atmospheric Investigations

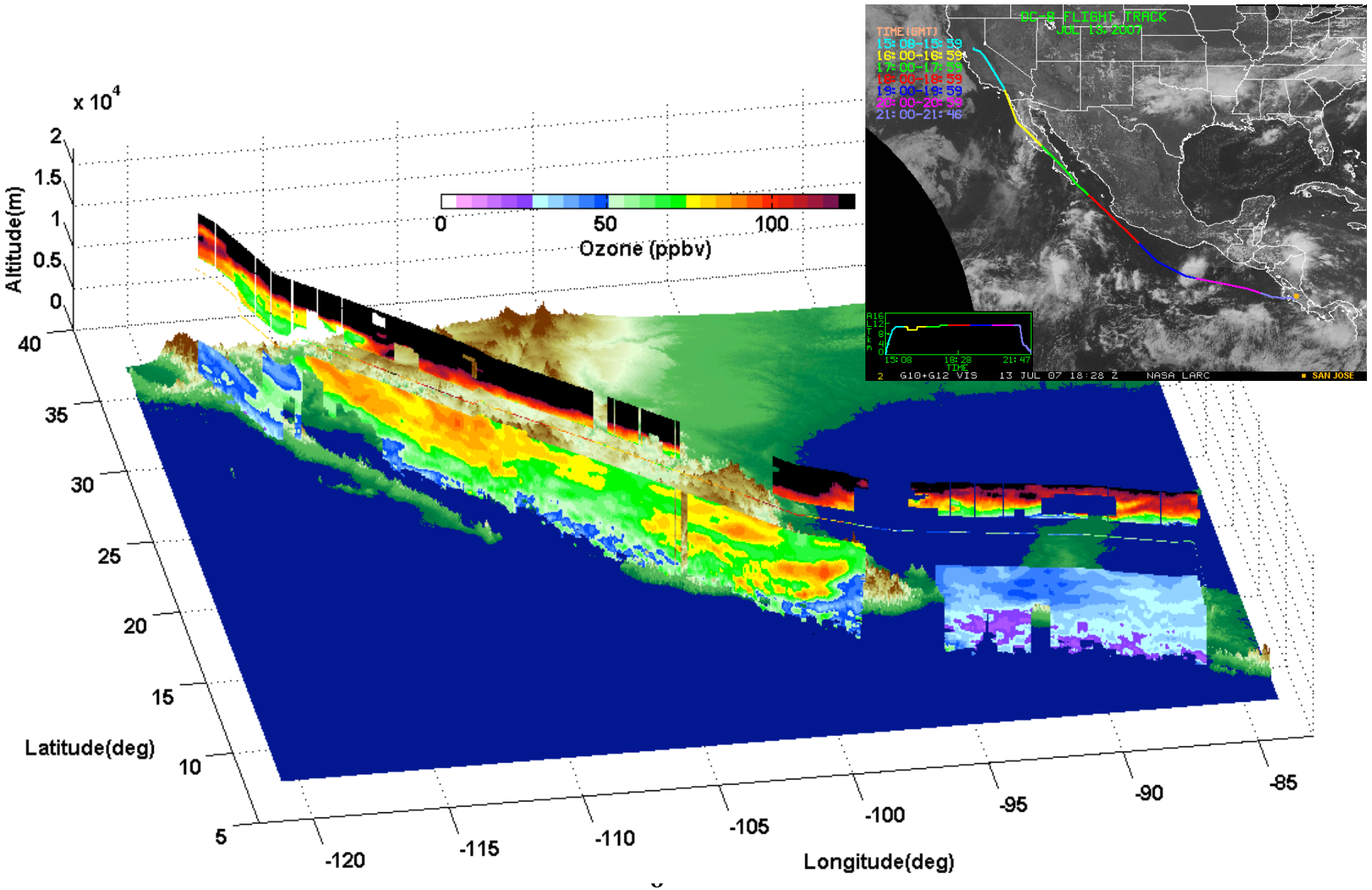
- Long duration mission capability, e.g., long-range flights over oceans and remote continents at high altitudes (>18km).
- Operation in dangerous situations, e.g., flights over remote polar regions or over storms.

Airborne Ozone & Aerosol Lidar (UV DIAL)
NASA DC-8 Aircraft

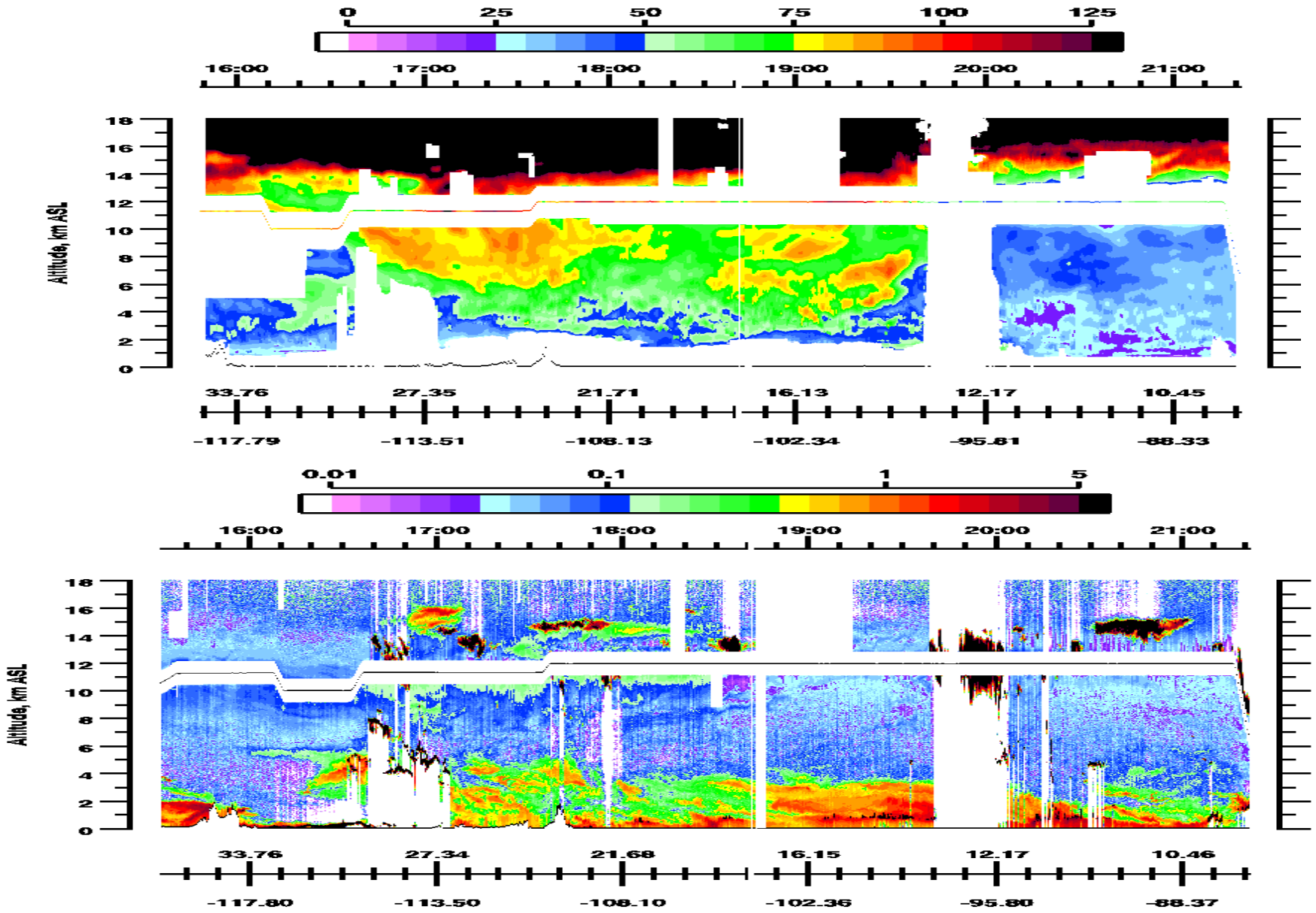


- Ozone Differential Absorption Lidar (DIAL) Profiles (l_{on}=289 nm & l_{off} =300 nm)
- Aerosol & Cloud Profiles (600 & 1064 nm)
- Simultaneous Nadir and Zenith Profiling

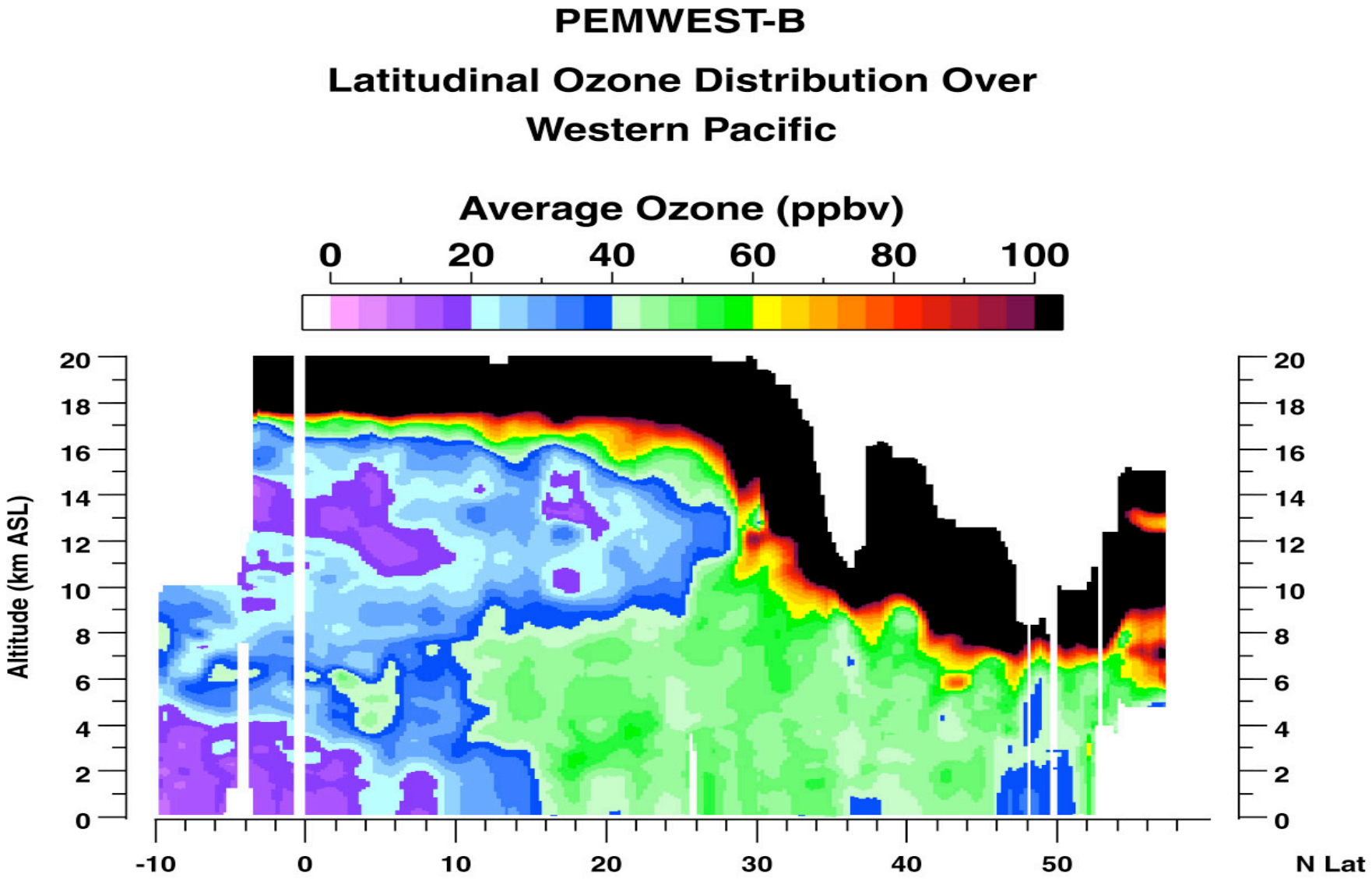
Example: Transit to Costa Rica: 13 July 2007



Ozone and Aerosol Scatter Ratio (591nm)

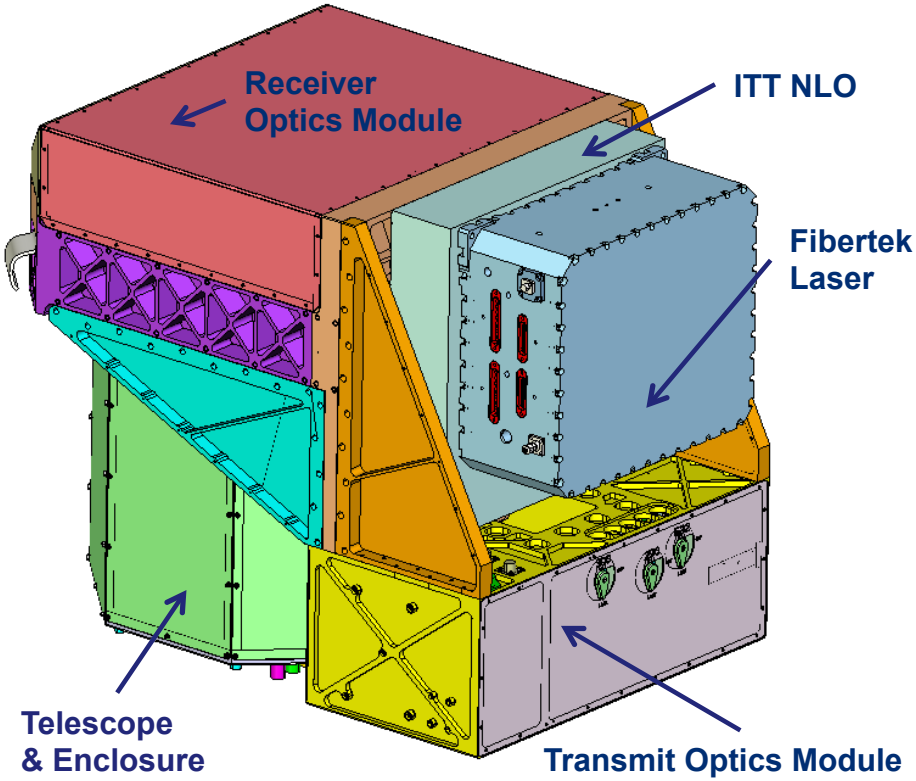


DIAL Latitudinal Ozone Distribution

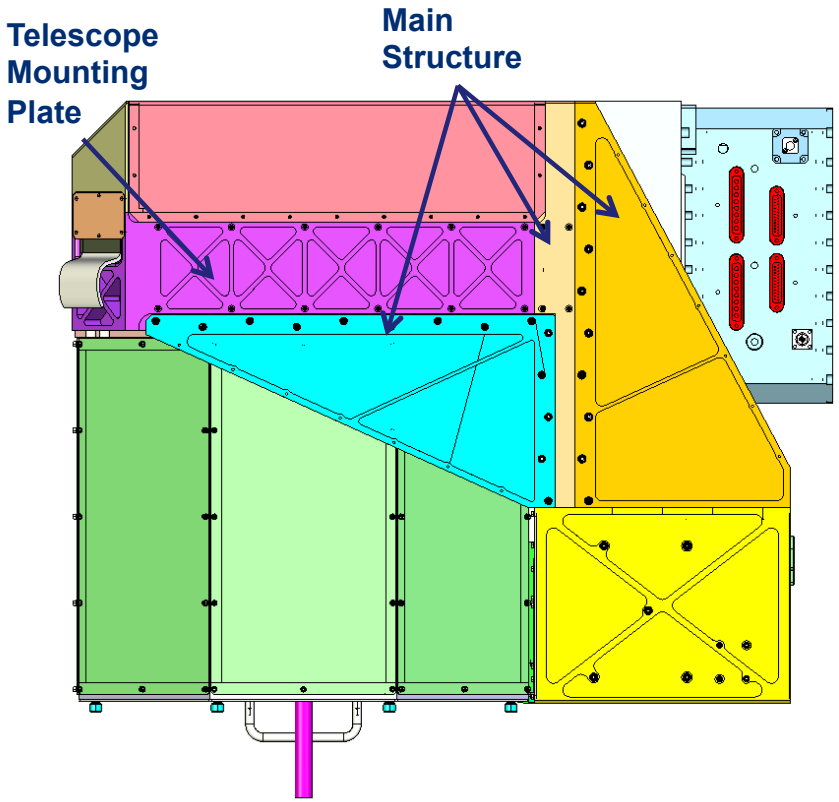


GOLD Transceiver Configuration

Isometric View



Side View

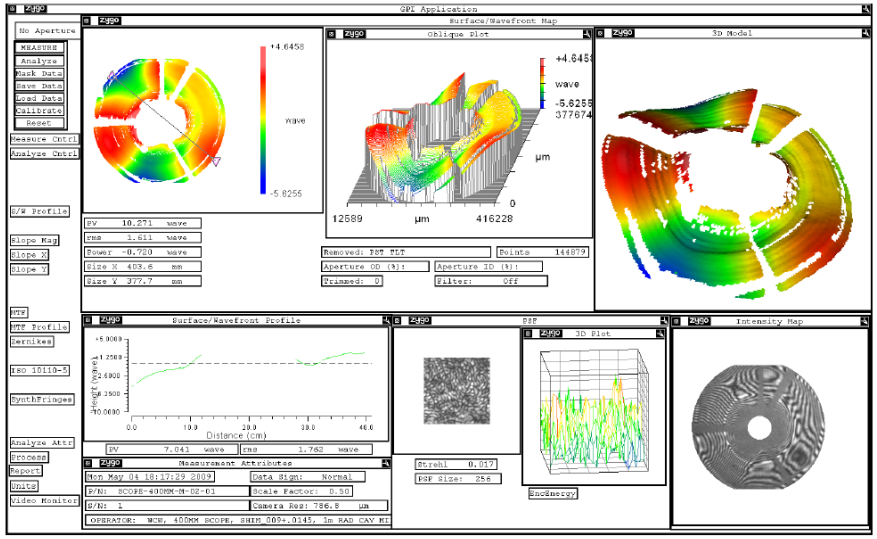


DIMENSIONS:
28.3 x 22.5 x 19.3 inches

Side View showing Telescope & Receiver Optics

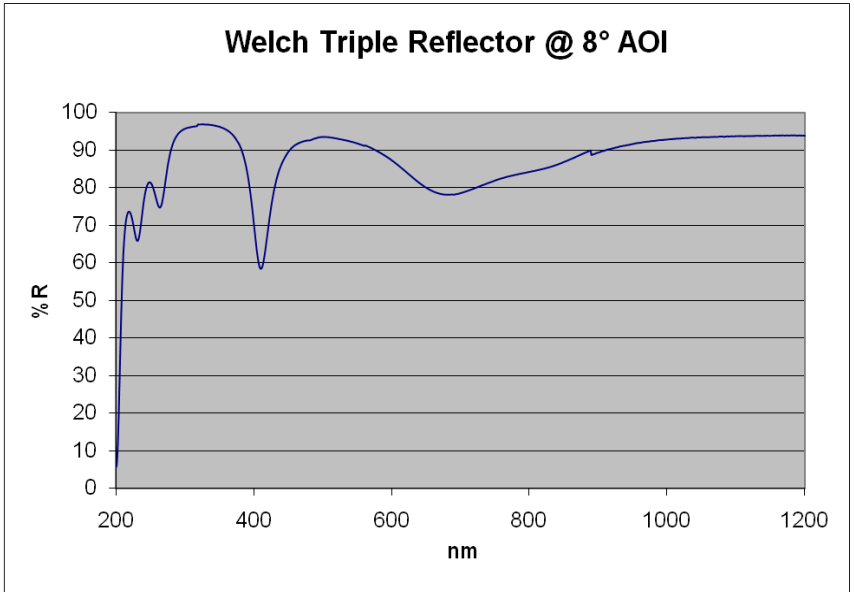
Telescope – All Metal & Reflective Collimation

Design Specification	Delivered Specifications
Cassegrain Telescope & integrated reflective collimator that is removable after assembly	Cassegrain Telescope & integrated reflective collimator that is removable after assembly
Primary Mirror Diameter: 400mm	400mm (16 inches)
Overall height less than 16 inches	16 inches
Spot size at field stop < 50microns	100 microns
Wavefront error < 8 waves P-V or 1.5 RMS	9 Waves P-V, 1.6 Waves RMS
Surface roughness < 30 Angstroms each element (6% scattering loss at 290nm)	Primary 30 Angstroms, others << 30 Angstroms (2.9% scattering loss for system at 290nm)
Weight < 20 lbs	Weight 15lbs

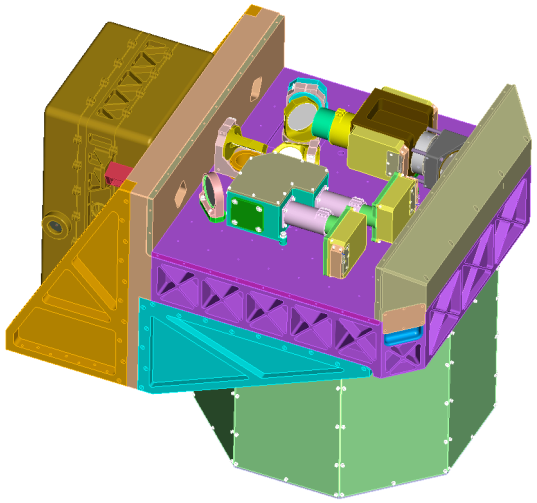


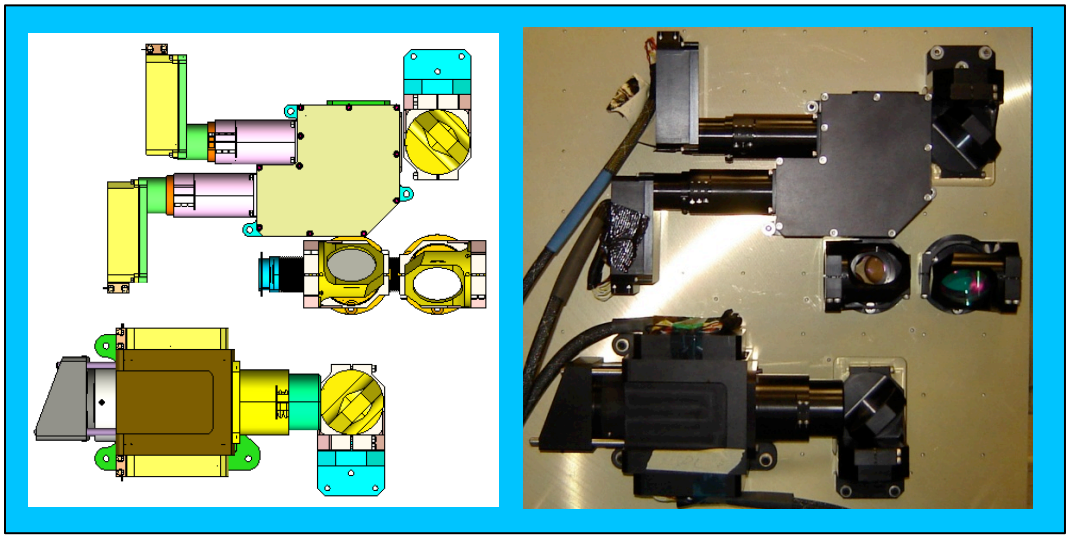
Mirror Coating Reflectance
290nm = 92%
300nm = 95%
532nm = 92%

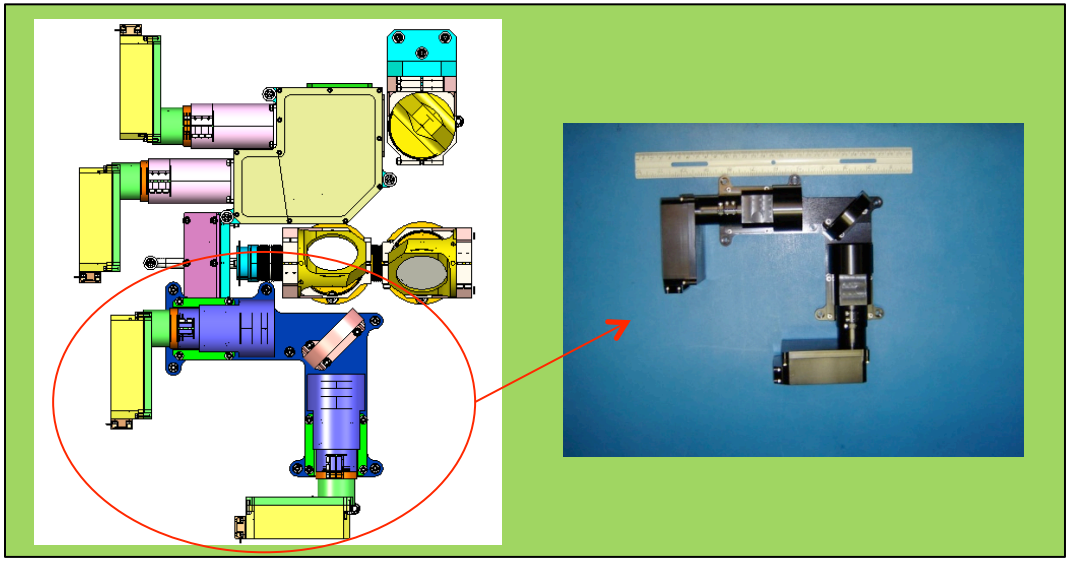
Telescope Total Efficiency
(All four mirrors at collimated output)
290nm = 72%
300nm = 81%
532nm = 72%



Receiver Opto-Mechanical Design







Two configurations for UV receiver

ITT grating receiver (upper planel) implemented for ground tests.

Dichroic beamsplitter and 1nm interference filters (lower panel).

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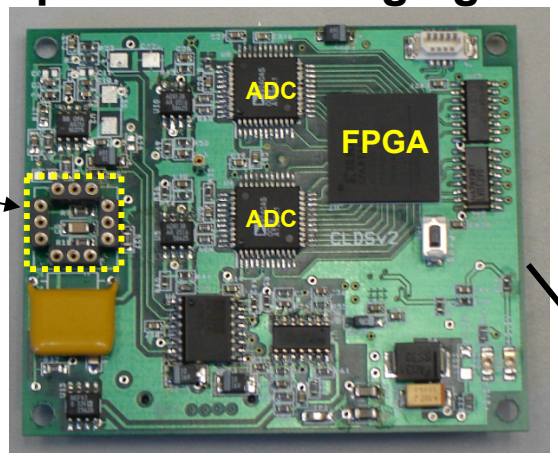
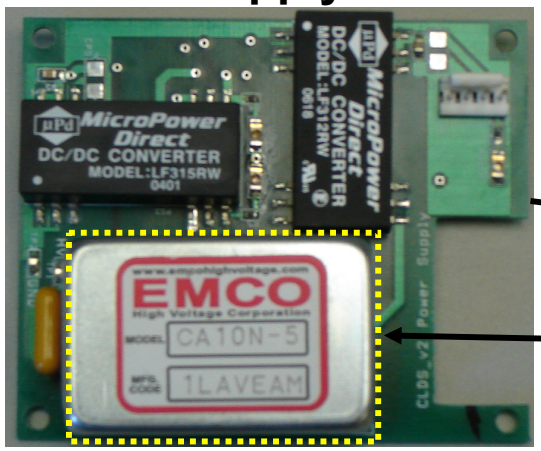
Compact Lidar Detector System (CLDS)
PMT Implementation

Amplifiers & Averaging PCB



PMT Socket

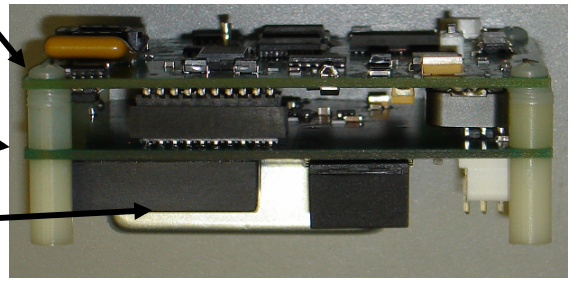
Power Supply PCB



HV Power Supply

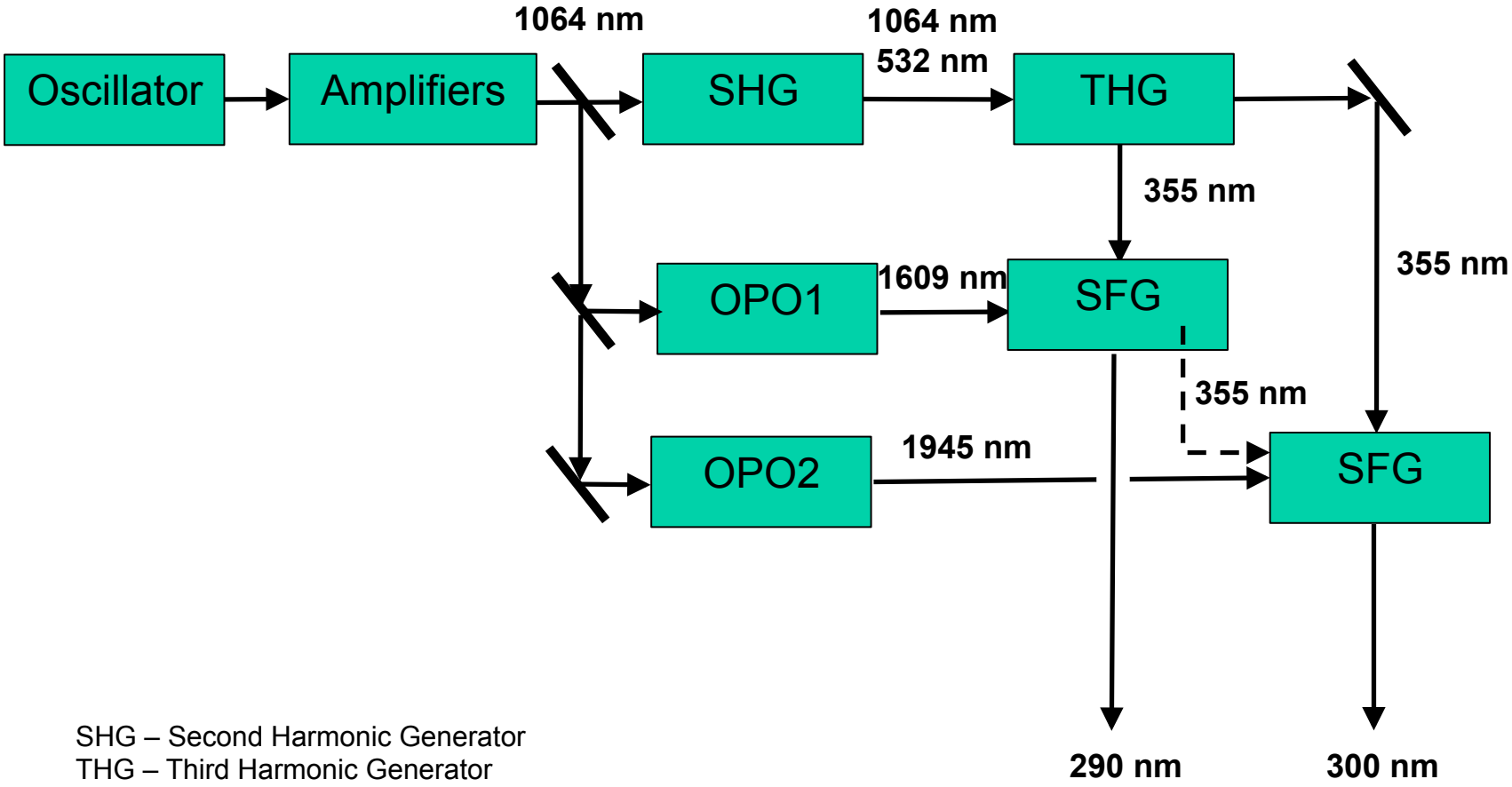
PRIMARY FUNCTIONS

- Provides variable PMT detector output amplification
- Splits signal into high and low gain channels
- Digitizes and Averages both channels (synchronous to laser trigger)



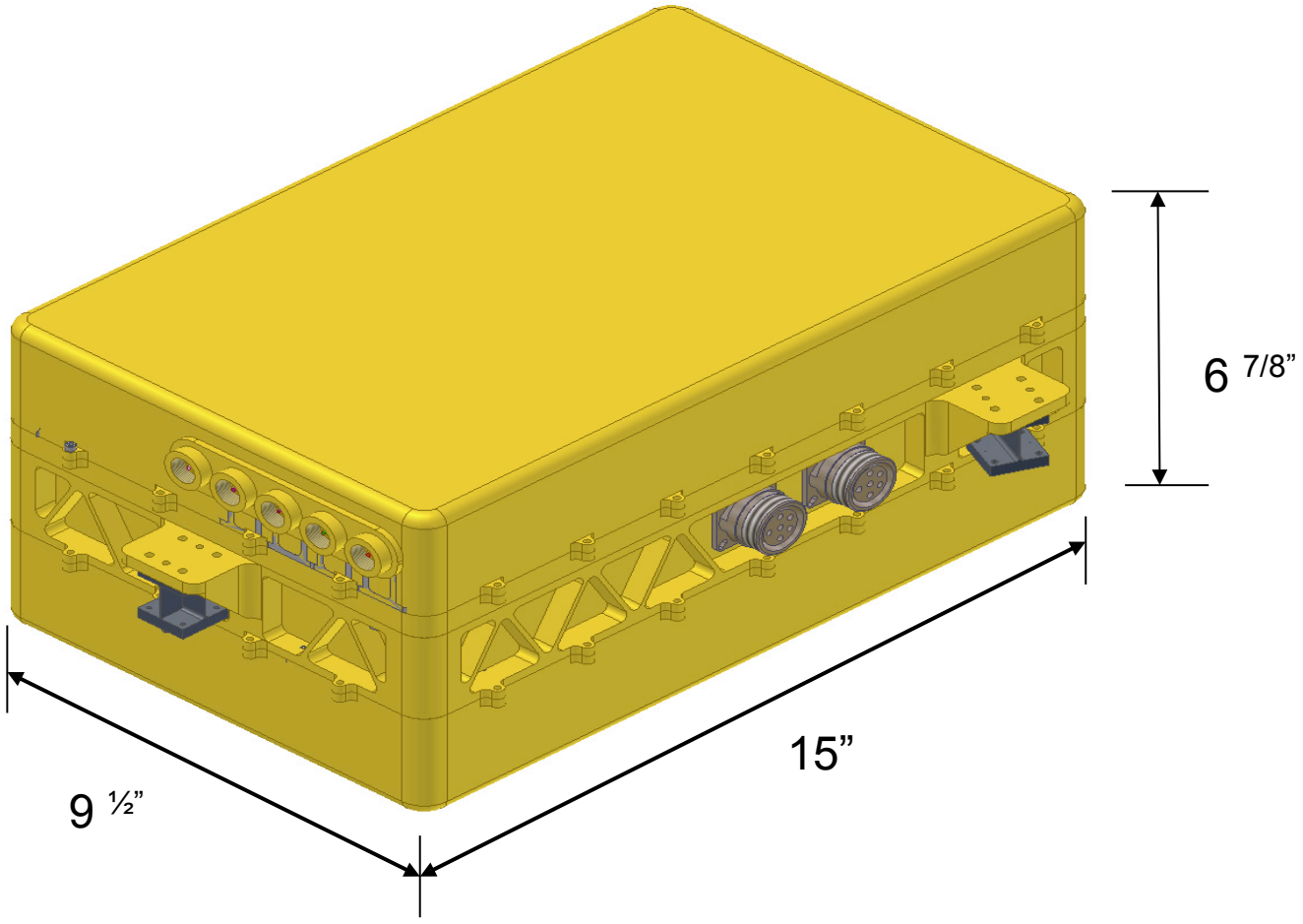
Dual PCB Stack

UV Generation Concept



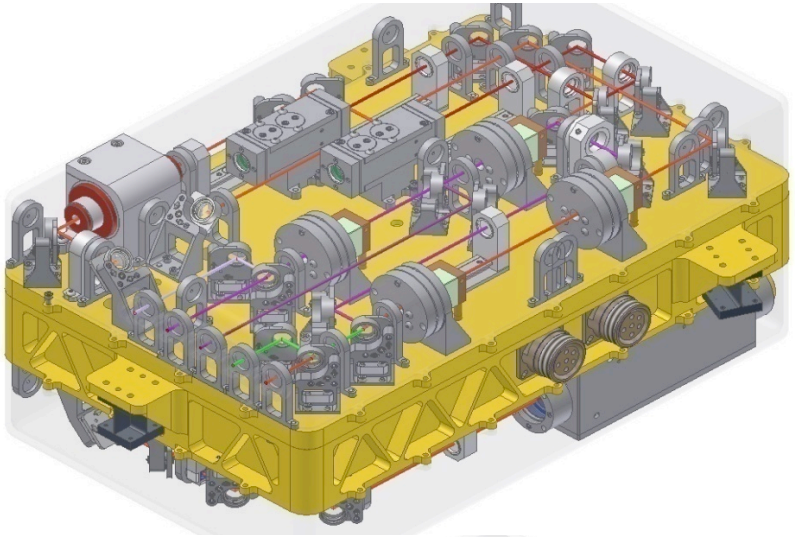
SHG – Second Harmonic Generator
THG – Third Harmonic Generator
SFG – Sum Frequency Generator
OPO – Optical Parametric Oscillator

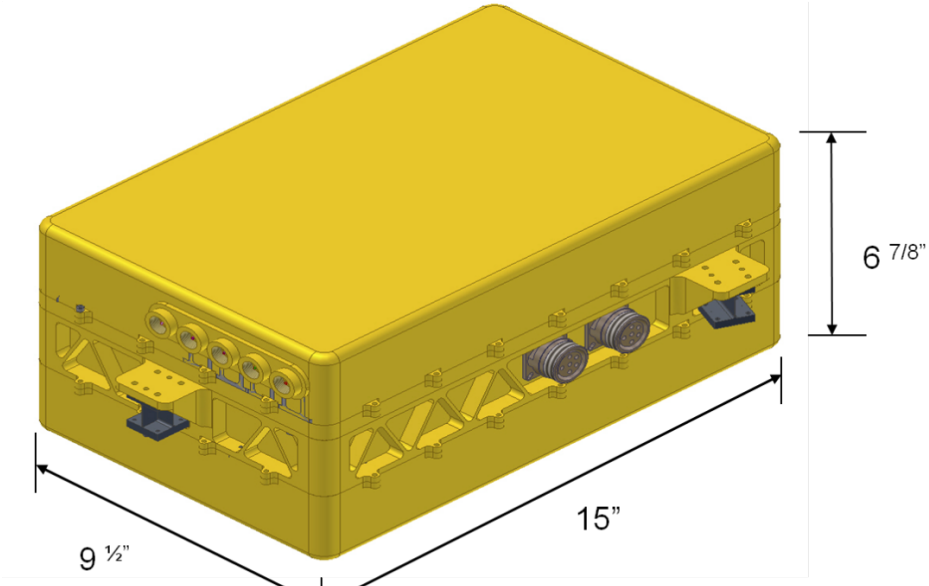
Transmitter – Integrated Pump and NLO

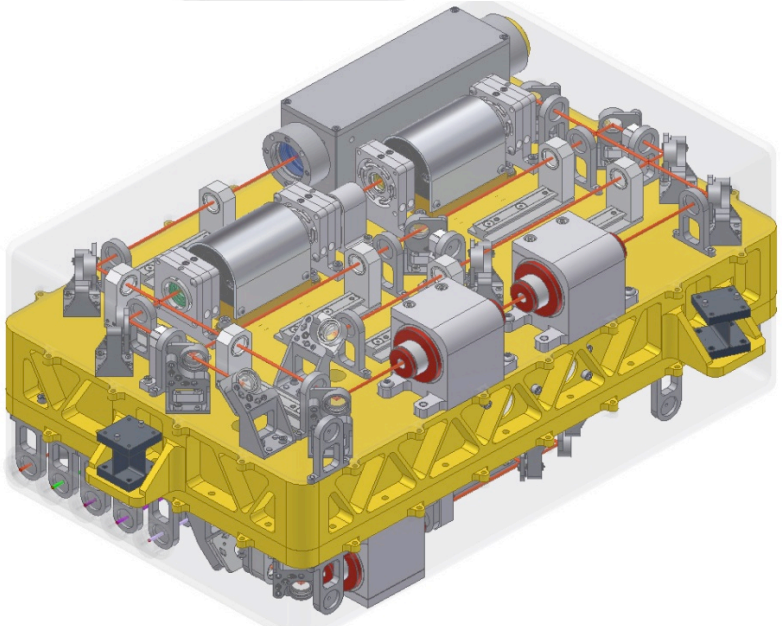


Integrated Prototype Laser

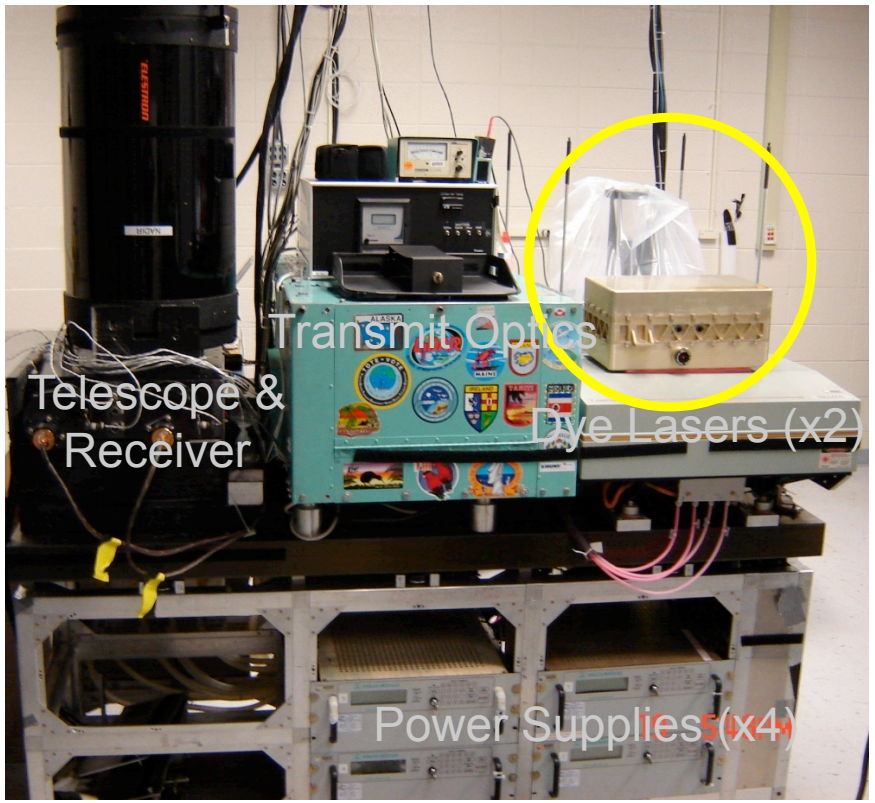
- **Unpopulated weight: 8-10 lbs.**
- **Populated weight: 25-30 lbs.**
- **Ozone DIAL wavelengths:**
  - 0.6 W at 290 nm; 0.3 W 300 nm.
- **Aerosol wavelength:**
  - 5 W at 532 nm





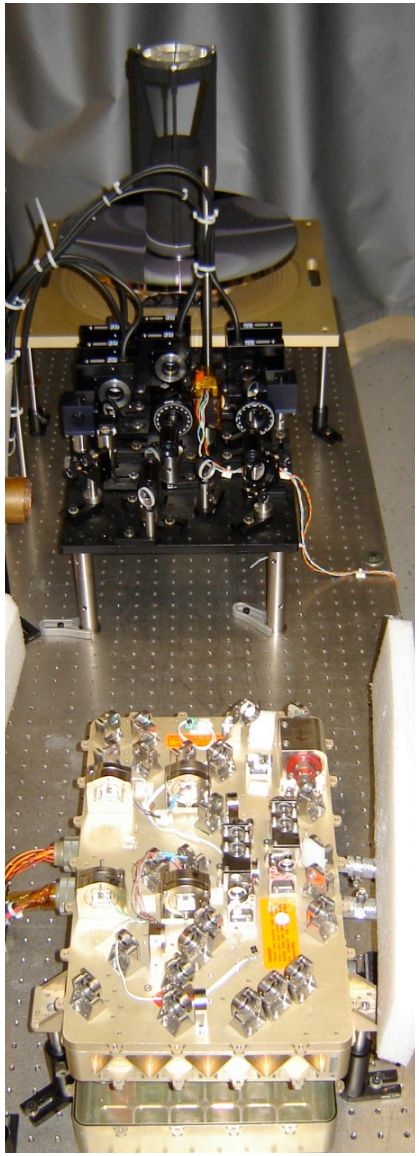


GOLD & UV DIAL Size Comparison



- Laser Modules
- Laser Power Supplies
- Telescope and Receivers
- Transmit Optics

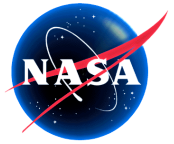
Ground Test Setup



Telescope

Transmit Optics

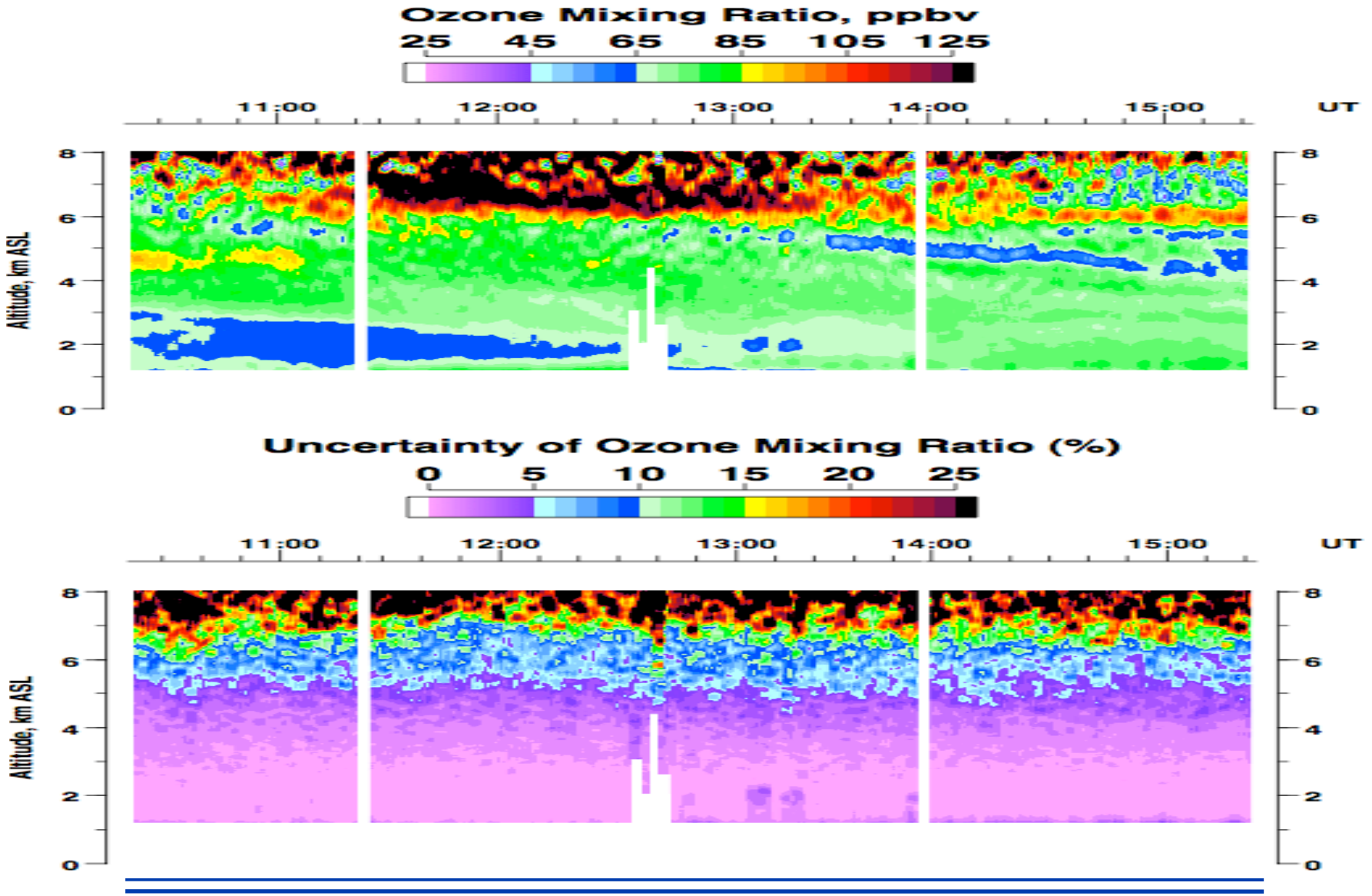
Laser (Pump & NLO)



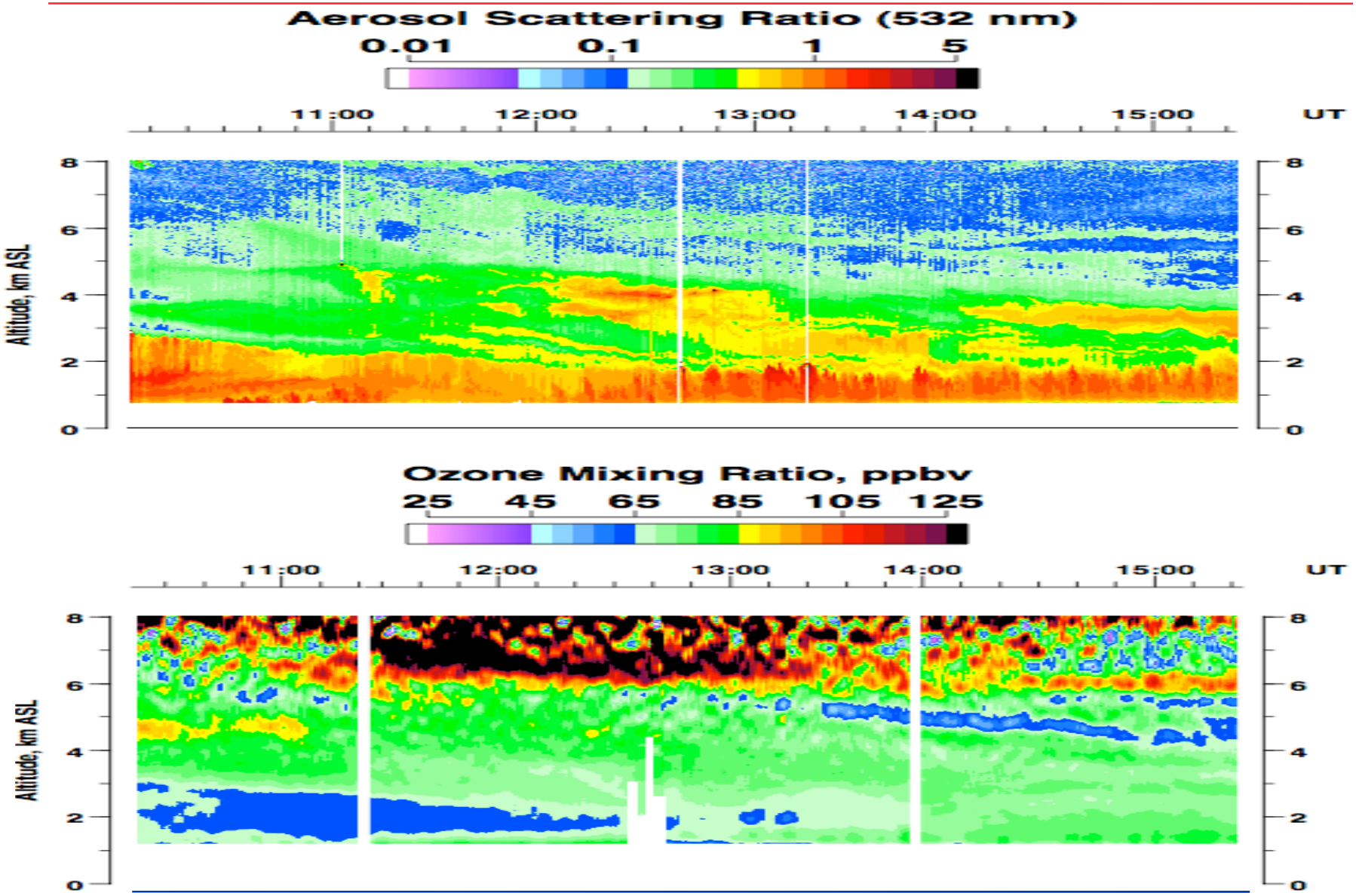
Ground Tests Overview

- **Conducted atmospheric tests on 5 different days.**
- **Allowed demonstration of system and performance testing.**
  - Transmit both wavelengths simultaneous
  - Performance test of receiver system (telescope, filters, and detectors)
  - Comparison with ozonesondes
- **1 July 2009 – 5.5 hours with all measurements acquired and Wallops sonde launch.**
- **17 August 2009 – local sonde comparison**

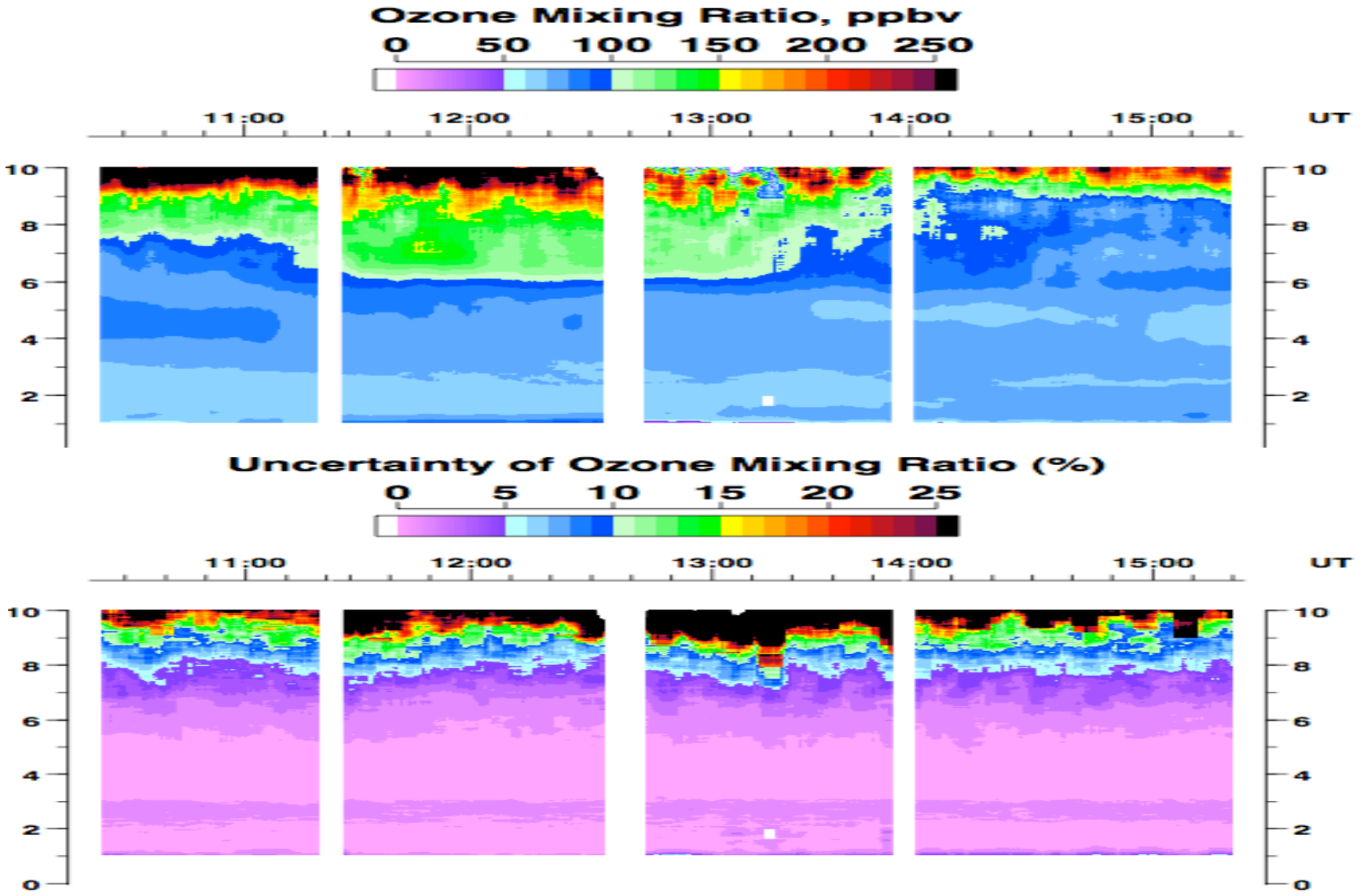
1 July 2009 – Ozone and Uncertainty



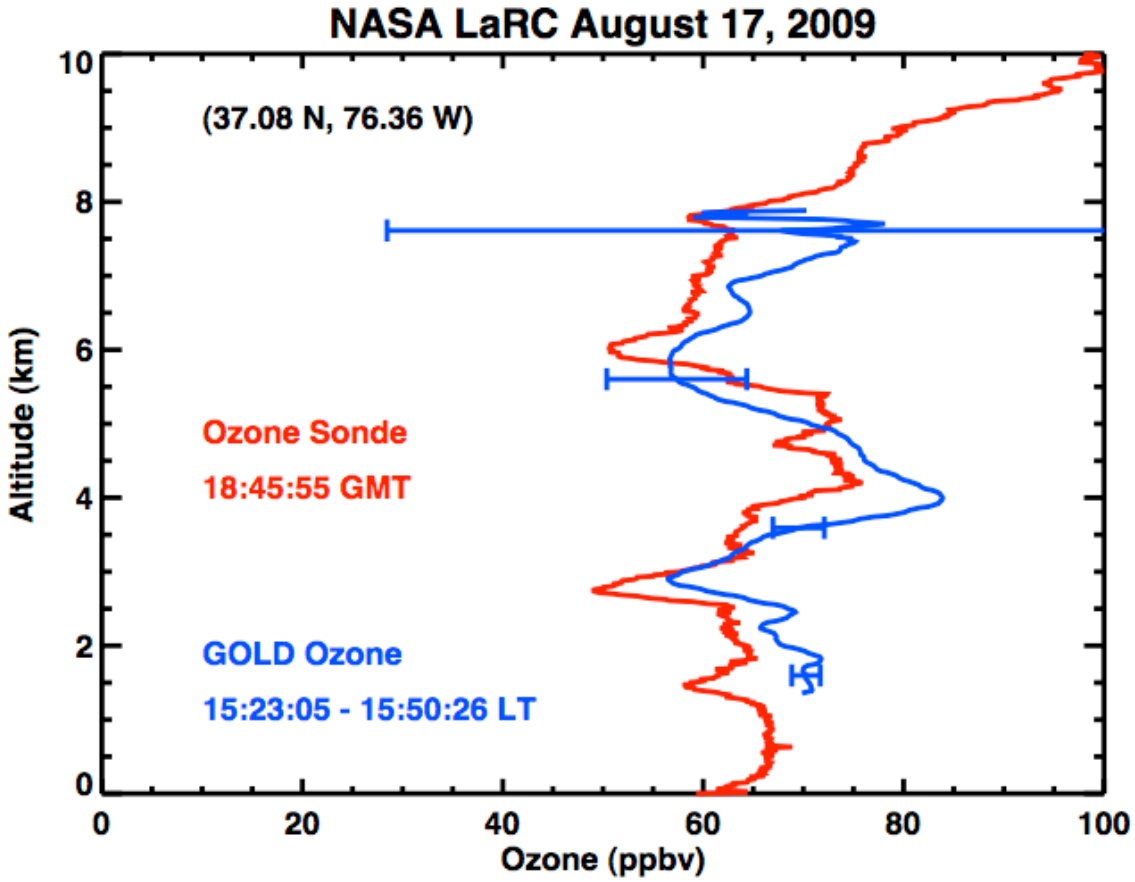
1 July 2009 – Aerosol Scattering and Ozone



1 July 2009 – Ozone and Uncertainty



Local Sonde Comparison
Penn State NATIVE (Thompson and Martins)



Recovery Act Funds (ARRA)

GOLD has a two-pronged approach for using American Recovery Act Funds:

- ✓ **LaRC led tasks are development and integration of the GOLD flight laser and instrument.**
- ✓ **DFRC led tasks prepare the GlobalHawk aircraft for integration of the GOLD instrument.**

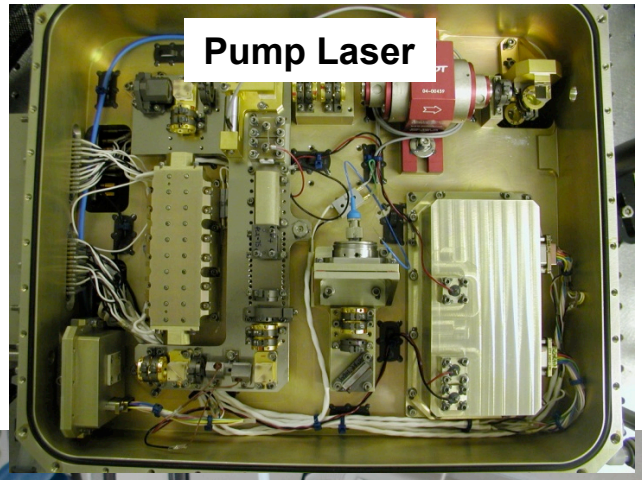
- **GOLD Instrument Development Effort (LaRC)**
  - Build & integrate flight-proven pump laser from Fibertek (TWiLiTE, HSRL)
  - Flight-harden NLO module; 1) improved mechanical stability, 2) integrate pump laser to NLO
  - Finalize GOLD pressure box and GlobalHawk interfaces

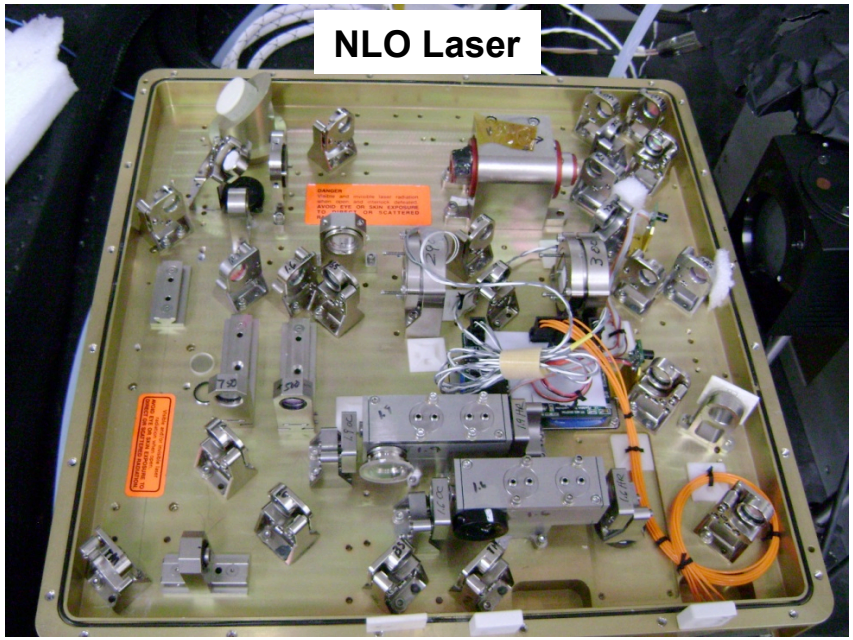
- **Global Hawk Aircraft Effort (DFRC)**
  - Design/fabricate a new AESA-type fairing complete with optical view port and heat exchanger ports
  - Procure/install a Liquid Cooling System (LCS) per existing design documents and specifications
  - Finalize analysis of hardpoints in Zone 25 of the aircraft to attach GOLD
  - Produce an analyses & certification package for flight certification of the GOLD/GlobalHawk installation.

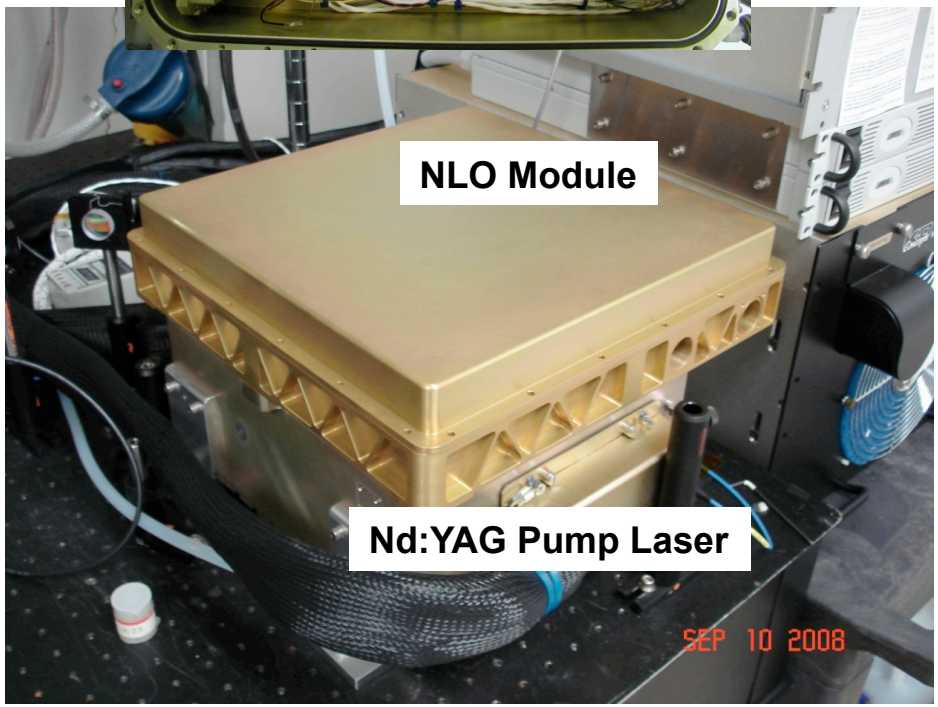
ARRA External Companies

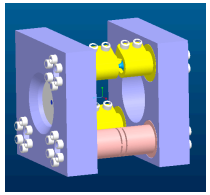
• Fibertek, Inc	Flight Pump Laser
• Welch Mech. Designs, LLC	Mechanical Design - NLO
• SSAI	GOLD Engineering Support
• Northrop Grumman Corp	Mounting Design, fairing, & LCS

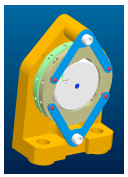
Flight Pump Laser & NLO









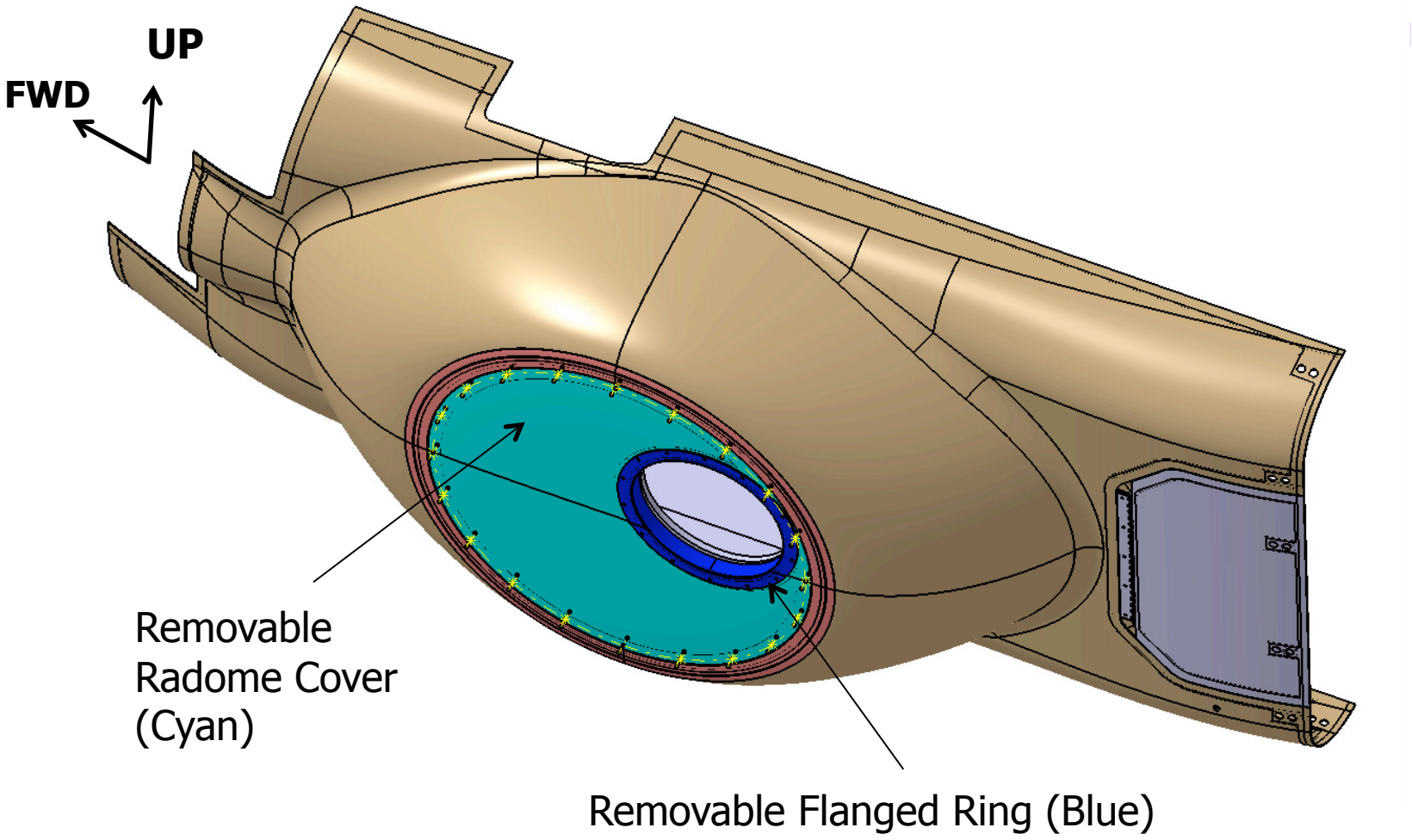


Mechanical & Thermal

SHG and Mixing crystal ovens

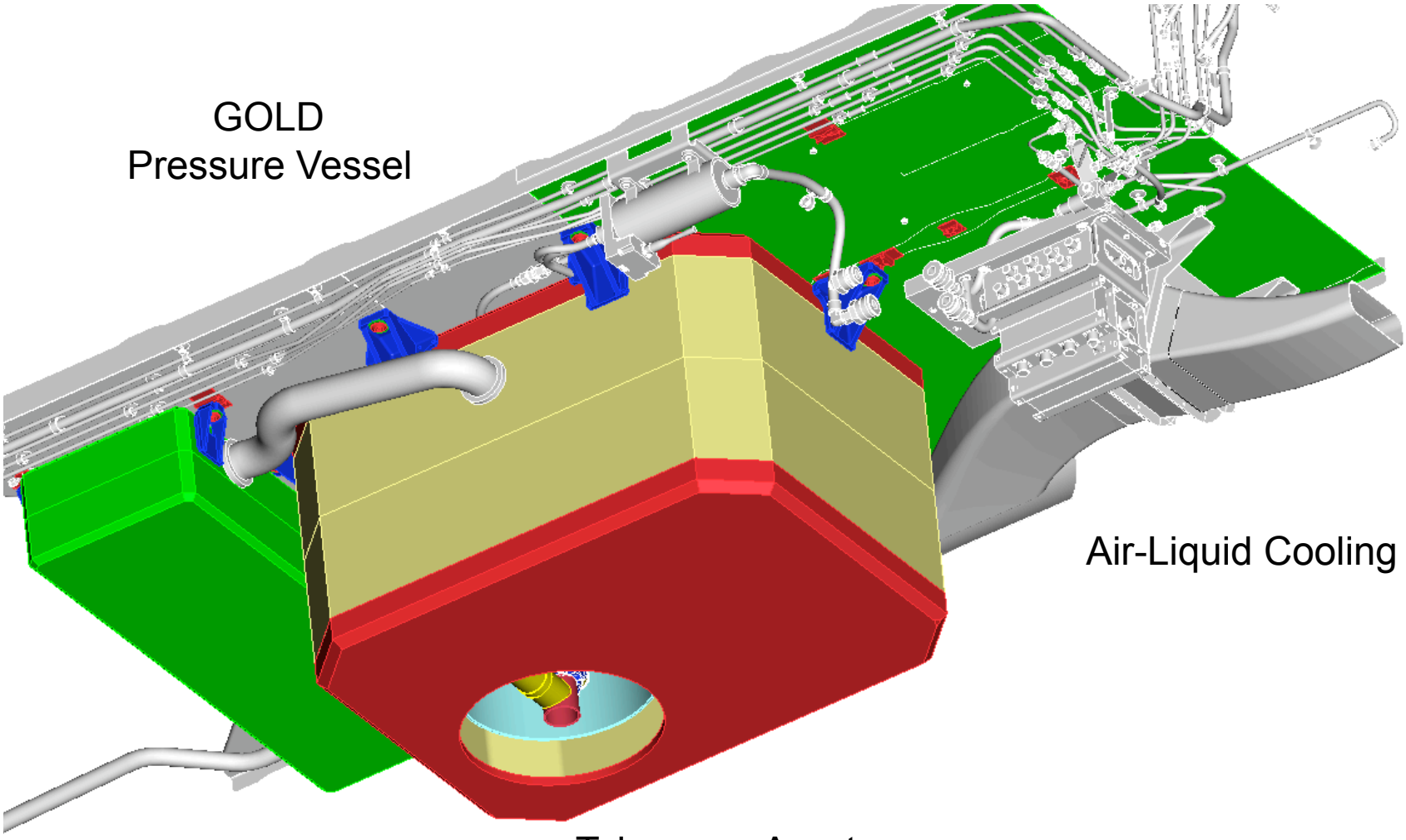
OPO mounts

COVER – GOLD RADOME



ISO VIEW LOOKING UP

NASA GOLD Pressure Enclosure & LCS: Zone 25

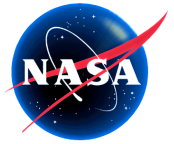


GOLD & UV DIAL System Parameters

	UV DIAL	GOLD with Prototype laser	GOLD with Flight laser
Weight (lbs)	2521	625	605 (795 with enclosure)
Power (kW)	10.1 (includes chiller)	3.3	2.0 (0.6 LCS)
Volume (m^3)	3.95 (includes chiller)	0.72	0.68
Measurements:	nadir/zenith DIAL ozone aerosol (532/1064) depolarization (532)	nadir DIAL ozone aerosol (532) depolarization (532)	nadir DIAL ozone aerosol (532) depolarization (532)

Path Forward

- Flight-harden GOLD instrument and enable integration and operation on Global Hawk under American Recovery & Reinvestment Act funding.
- Ground demonstrate GOLD and perform flight demonstration (i.e. AITT). Establish GOLD as flight-ready instrument for science investigations.
- Advance laser technology for 305-315 nm to 1-2 Watt lasers to incorporate into UAV flight demonstrations (SBIR, ACT, and IIP)
- Enable technology advancements for NRC Decadal Survey GACM PII (Ozone DIAL)



Questions?