THE INTEGRATED ATMOSPHERIC CHARACTERIZATION SYSTEM (IACS)


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Statement of Need

• The development of this LIDAR system addresses shortfall H13 of the DETEC T-SS Update (2007).
• A Directed Energy Test and Evaluation Capability (DETEC) led effort.
• Addresses Joint Service directed energy (DE) weapon system test and evaluation (T&E) infrastructure needs and implements solutions.
• The Tri-Service Study (T-SS) developed, scoped, and prioritized T&E infrastructure shortfalls for DE-based weapon systems including High Energy Laser (HEL).
IACS Top-Level Requirements

• The sponsor’s requirement - a single system, transportable to and suitable for test ranges, that characterizes atmospheric laser beam paths in terms of three parameters:
  – *Aerosols*, which absorb and scatter the laser beam
  – *Turbulence*, which causes beam wander and spreading
  – *Water vapor*, which can absorb beam power
• All of these effects reduce “power in the bucket”
• Two of these effects are wavelength dependent
The IACS project was conducted by the Georgia Tech Research Institute (GTRI) in four phases that required a performance period of seven years.

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The three IACS laser radars (LIDARs) characterize slant paths to give profiles of $C_n^2$, water vapor number density, and extinction due to aerosols.

- Housed in shipping containers for transport to HEL system test sites.
- **IACS is the first LIDAR system to provide all of these measurements at once.**
What is IACS?

Control
Data acquisition
Quick look
Data analysis
Daily reports

GPS receiver
Meteorological instruments
Operator’s Console

Three LIDARs

0.355 µm
1.064 µm
1.627 µm

EL – AZ pedestal

Cimel sun photometer

LCH Windows
Safety System

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IACS Configuration

Electric Generator

Power Cable

Service Lines

Optics Platform

Control Shelter
IACS Today
Finding Path Transmittance

Part 1:
• Measure or interpolate aerosol and molecular extinction ($\sigma_{aer}$ and $\sigma_{mol}$) along path using ATM system.

Part 2:
• Measure water vapor along path using WVP system
• Calculate water vapor extinction coefficient $\sigma_{H2O}$ by using HITRAN

Part 3:
• Calculate path optical depth $\tau_{path}$ and path transmission $T_{path}$.

$$\tau_{path} = \int_{0}^{R} \left[ \sigma_{mol}(r) + \sigma_{aer}(r) + \sigma_{H2O}(r) \right] dr$$

$$T_{path} = \exp(-\tau_{path})$$
The three LIDARs are housed in the Optics Platform Shelter. They are co-aligned on a common computer-controlled mount. WVP and OTP are on top; ATM is underneath.
Control Shelter

The Control Shelter houses personnel, the operator’s station, the safety system, and the HVAC system.
The interior provides storage and a controlled environment for operators.

The HVAC system provides chilled water and dry air to the Optics Platform Shelter.
Aerosol Transmission Measurement (ATM) LIDAR specs

- **Pulse Energies**
  - 180 mJ at 1.064 μm (Nd:YAG)
  - 90 mJ at 1.627 μm (OPO)
  - 300 mJ at 0.355 μm (Nd:YAG)

- **PRF**
  - 10 Hz at 1.064 μm & 1.627 μm
  - 50 Hz at 0.355 μm

- **Receiver Apertures**
  - 10 cm (short range 1.064 μm & 1.627 μm)
  - 25.4 cm (long range 1.064 μm & 1.627 μm)
  - 20 cm (long range 0.355 μm)

- **Detectors**
  - 0.355 microns : PMT
  - 1.064 microns: 800 μm Si APD
  - 1.627 microns : 200 μm & 500 μm InGaAs APD

- **Data Acquisition**
  - 50 MHz analog-to-digital converter
A time-height diagram showing the aerosol distribution above the GTRI lidar laboratory in July 2012.
ATM Data Products 1/5

Long-range 1064 nm range-corrected signal.

Cirrus
Measured 1064-nm slant-path atmospheric extinction coefficient (1/km) vs. range (km).
Path transmission vs. slant range. The transmission drop rapidly from 100 % to about 70% in the mixed layer (where almost all of the aerosols are), and then remains almost constant at longer ranges.
Time-height plot of cloud and aerosol signals at 1627 nm.
Time-height diagram of 355 nm cloud and aerosol signals.
OTP Specs

- **Pulse energy**
  - 300 mJ, 0.3547 μm
- **PRF**
  - 50 Hz
- **Receiver**
  - 50.8 cm telescope with six 8 cm subapertures in a Shack-Hartmann wavefront sensor
- **Imager**
  - Intensified, range-gated CCD
- **Data Acquisition**
  - Guide star images saved at 50 Hz rate

OTP Optical System

- Intensifier Photocathode
- High Magnification Lens Assembly
- Fold Mirror
- 100 mm EFL Collimating Lens
- Narrowband Filter
- Quarter-wave Plate
- ATM 355 nm Channel Pickoff Beamsplitter
- Image Deflection Prism Array
- Fold Mirror
- Low Magnification Lens Assembly
- Medium Magnification Lens Assembly
- 354.7 nm Attenuating Filter
- Narrowband Filter
- 386.7 nm & 407.5 nm to WVP system
- Dichroic Cube Beamsplitter
- 354.7 nm
- Intermediate Field Stop
- Back of Primary Mirror
Optical Turbulence Profiler (OTP)
Differential Image Motion LIDAR

“First Light” images of the laser guide star.
OTP Data Products

The DIM Profile (blue dots and lines) and the functional fit from the OTP processed data display.
The corresponding Turbulence Profile calculated by the OTP software in real time.


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**Water Vapor Profiler (WVP) Specs**

- **Pulse Energy**
  - 300 mJ

- **Wavelengths**
  - 0.3547 μm transmitted
  - 0.3867 μm received (N2)
  - 0.4075 μm received (H2O)

- **PRF**
  - 50 Hz

- **Receiver Aperture Diameter**
  - 50.8 cm

- **Detectors**
  - 0.3867 μm PMT (long & short range)
  - 0.4075 μm PMT (long & short range)

- **Data Acquisition**
  - Licel hybrid analog/photon counting system

WVP and OTP instrument packages are mounted on back side of 20-inch telescope.
WVP Data Products

- WVP is a photon counting Raman LIDAR
- Performance simulations show the system is capable of H2O profiling to ranges of ~5 km with a 5% error in the daytime
- Range is primarily limited by sky background light in the daytime
- Longer ranges can be reached at night

Water vapor profiles from IACS and the Peachtree City Sonde launched while the lidar was operating.
WVP Data Products

Time-height plot of water vapor mixing ratio.
Summary

• **IACS is a state-of-the-art instrument.**
  – OTP is the only operational turbulence profiler in the world.
  – IACS employs a custom-built 355 nm laser.
  – IACS employs a RISTRA Optical Parametric Oscillator to generate 1627 nm laser light.

• **IACS is the foundation for an Atmospheric Characterization Center**
  – Will be GFE to GTRI.
  – GTRI provides a staff of trained operators.
  – GTRI maintains IACS.
  – GTRI promotes utilization.
  – The IACS team contributes to scientific knowledge.
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