Panchromatic Fourier Transform Spectrometer (PanFTS)

Overview

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Support: NASA Earth Science Technology Office (ESTO)

PanFTS Team

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Annmarie Eldering, Science Plan, GEO-CAPE Science Team
John Worden, Science Plan
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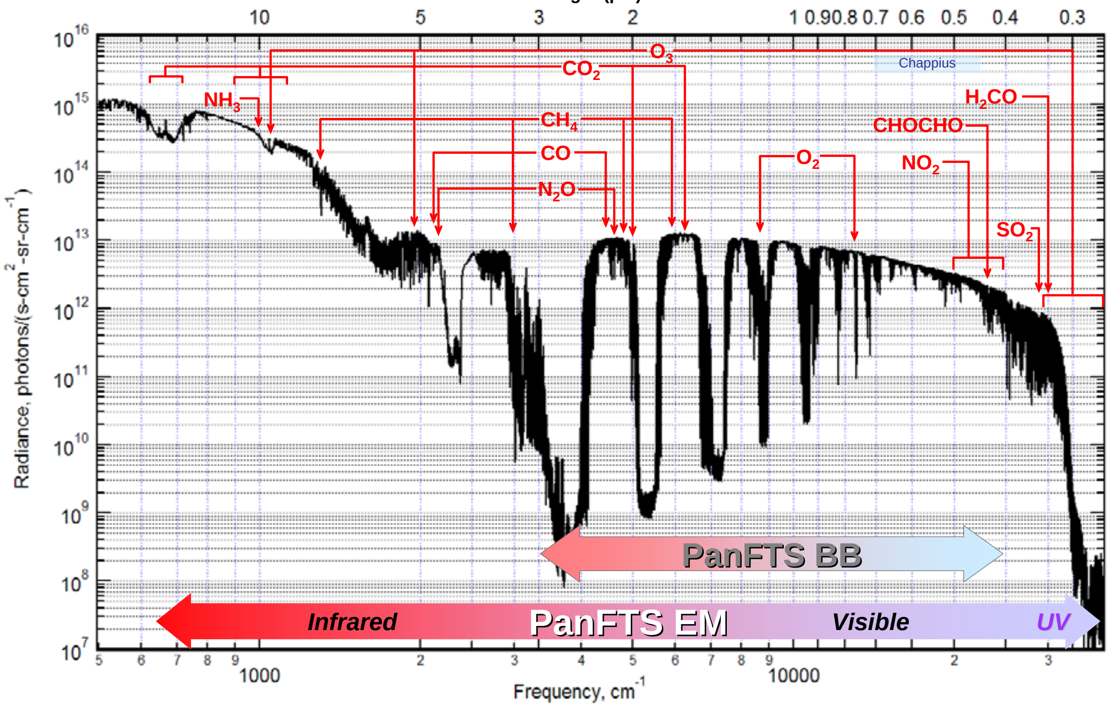
Panspectral Measurements Improve Retrievals

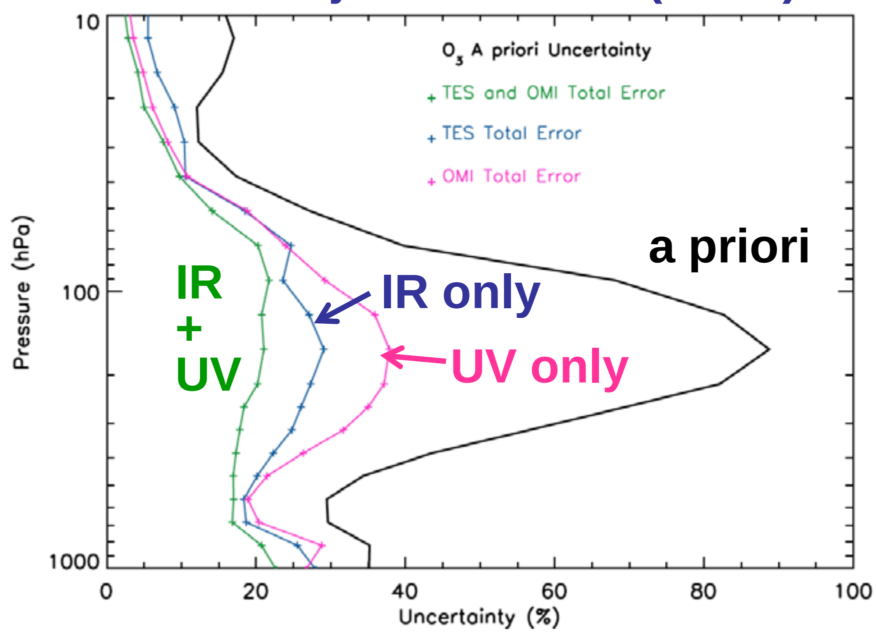


PanFTS has the measurement capabilities of several satellite instruments combined

Panspectral (UV → IR) enables :

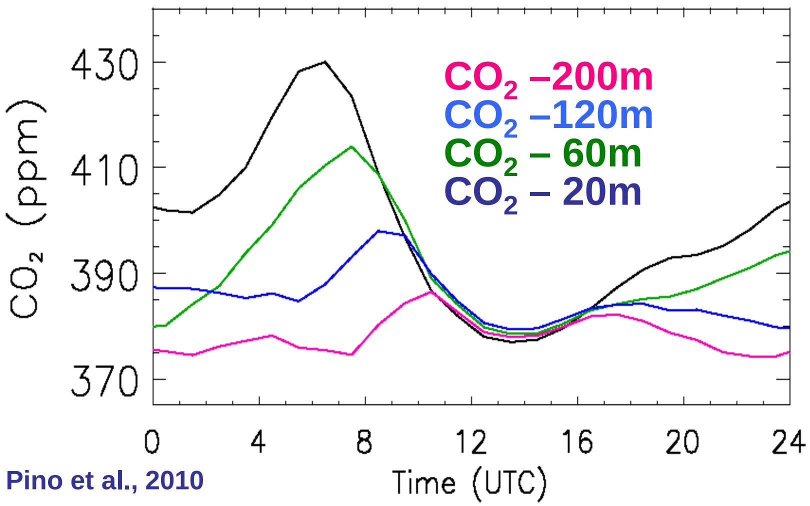
- **Retrievals of multiple chemical families**
  O_2, O_3, O_4 H_2O, HDO
  NO_2, NH_3, N_2O
  CO, CO_2, HCHO, CH_4, CH_3OH, $(CHO)_2$
  SO_2, BrO, AOD, SSA, AAOD, Temp.

- **Passive vertical profiling:**
  O_3 uncertainties
  TES+OMI joint retrieval (D. Fu)



Wide spectral coverage and high spectral resolution enables tropospheric profiling of multiple species with boundary layer visibility

Diurnal Cycle: Emissions and Biosphere Uptake



Pino et al., 2010

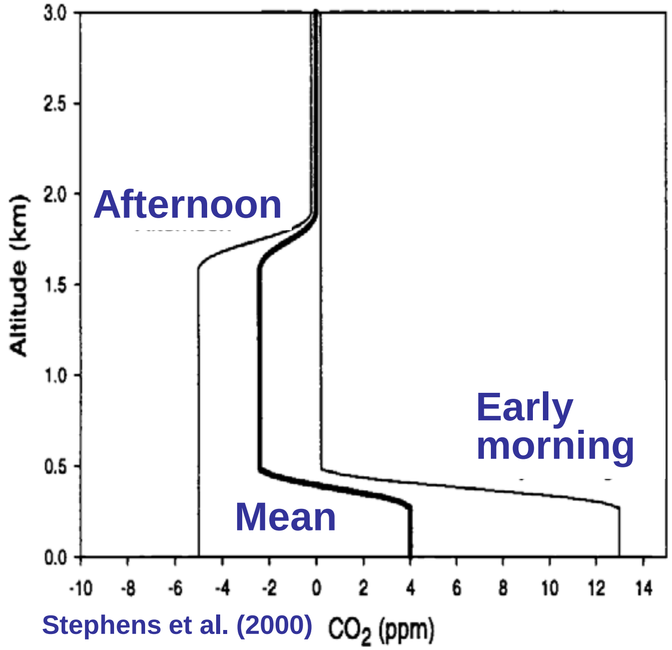
- The diurnal cycle of CO_2 reflects emissions, uptake by the biosphere, and atmospheric mixing

- **DAYTIME**
  - Plants take up CO_2
  - Turbulence mixes the PBL
  - Results: low CO_2 throughout the lowest 2 km of the atmosphere

- **NIGHTTIME:**
  - Little turbulent mixing
  - Plants are respiring
  - Results: in high CO_2 concentrations trapped near the surface.

- Surface measurements cannot distinguish between these diurnal changes and a net CO_2 source.

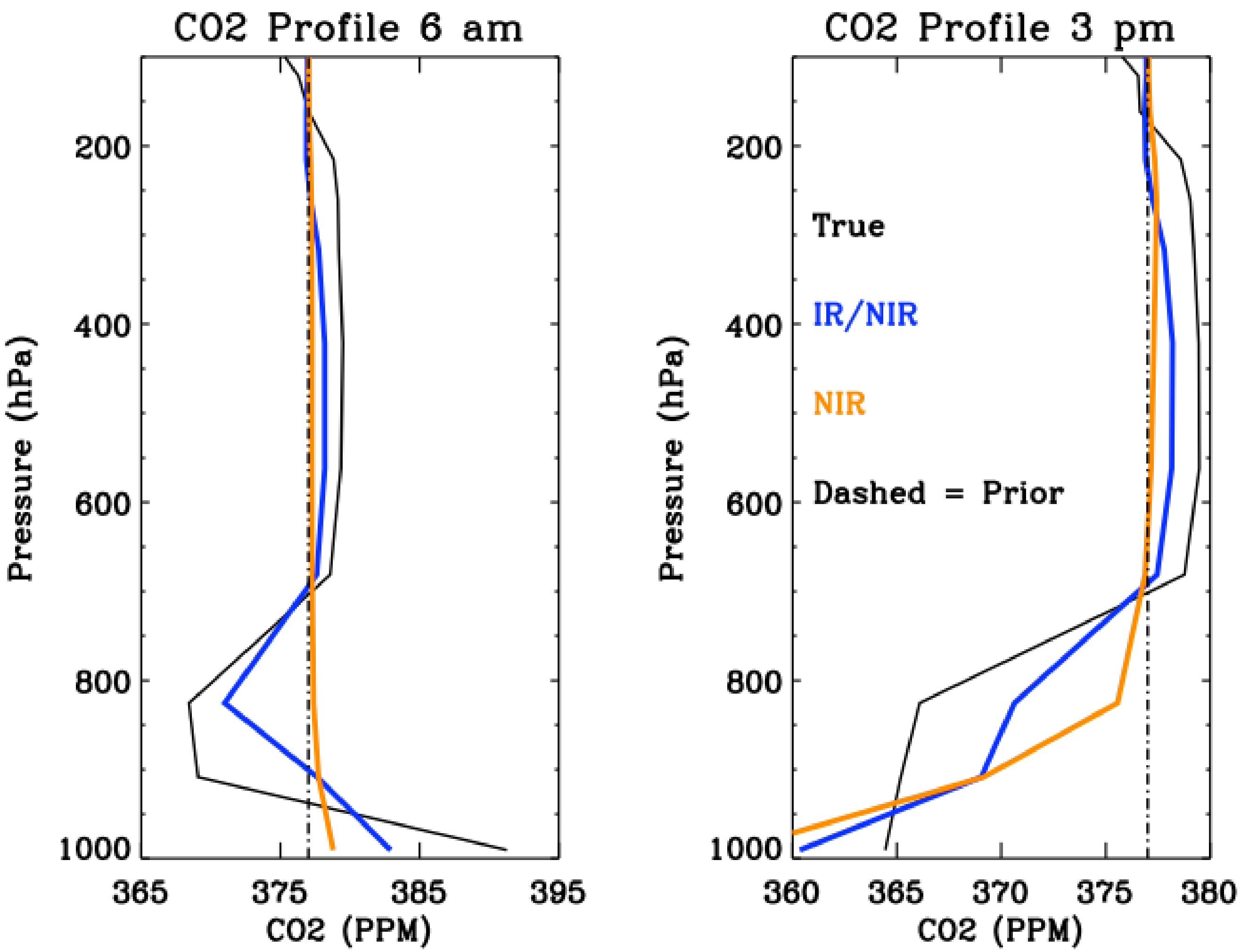
- A profile measurement at a single time cannot separate the surface flux from mixing.



Stephens et al. (2000)

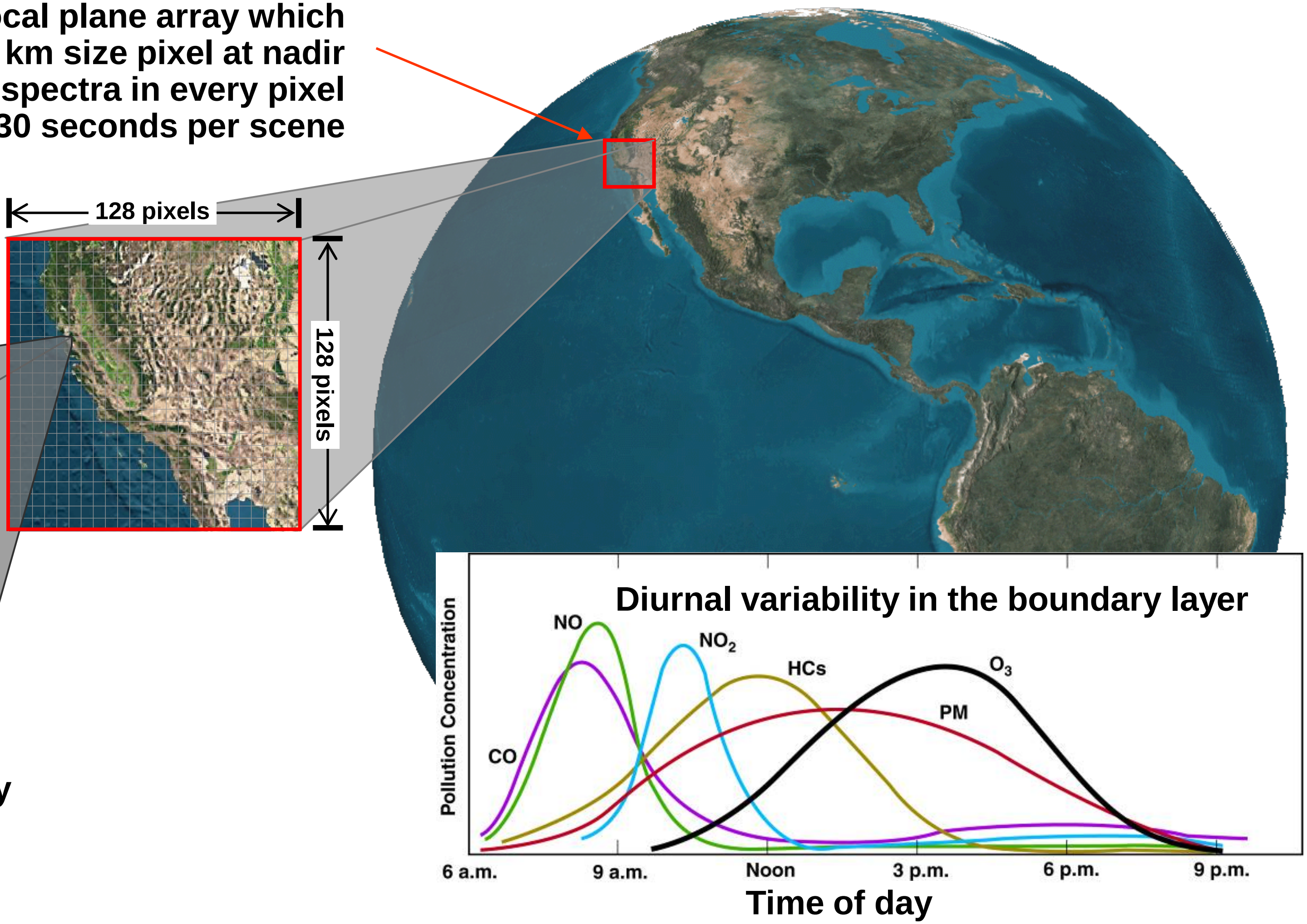
CO_2 profiles over the Midwest

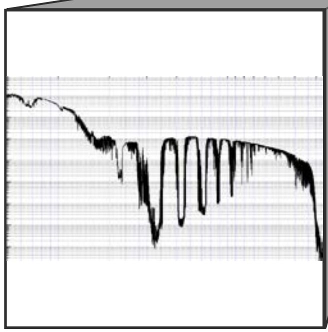
- Midwest profiles have large and highly variable vertical structure
- Combined retrievals (NIR and TIR) provide improved capability to measure vertical structure



Geostationary Orbit Observing Scenario

500 km x 500 km scene is imaged onto a 128x128 pixel focal plane array which provides a 4x4 km size pixel at nadir and records spectra in every pixel for 30 seconds per scene





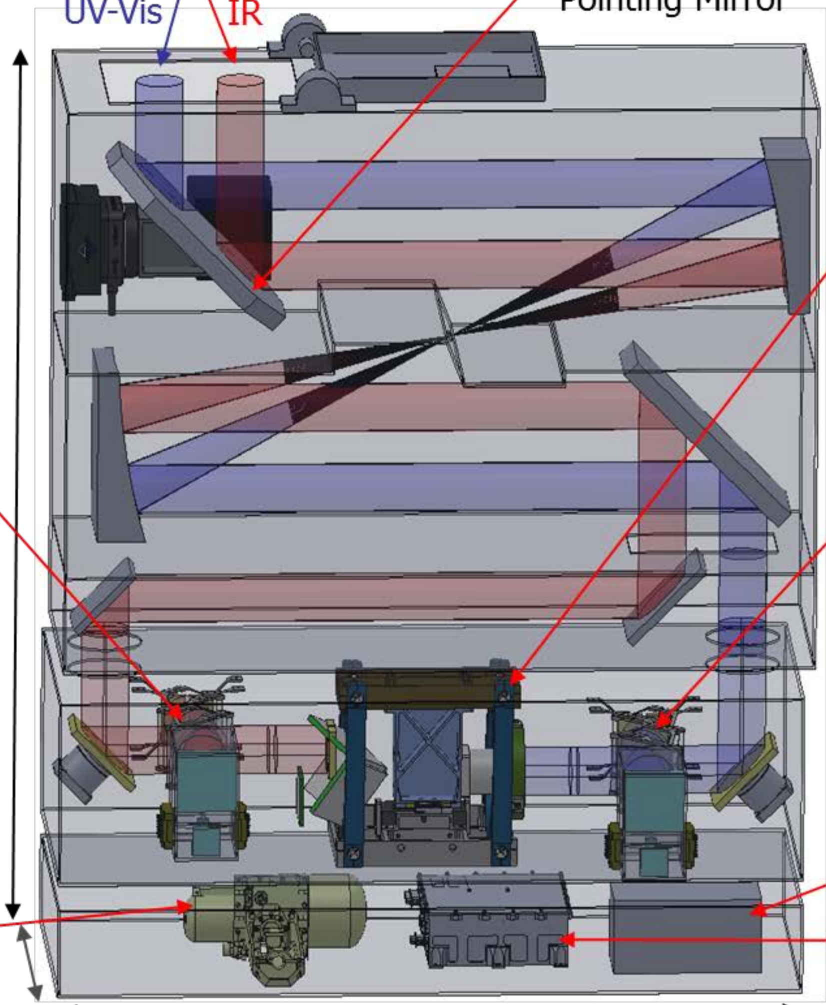
Spectra in every pixel captures evolving tropospheric chemistry

From geostationary orbit PanFTS can map all of North and South America hourly with high resolution measurements (temporal, spatial, and spectral) that capture rapidly evolving tropospheric chemistry with planetary boundary layer sensitivity

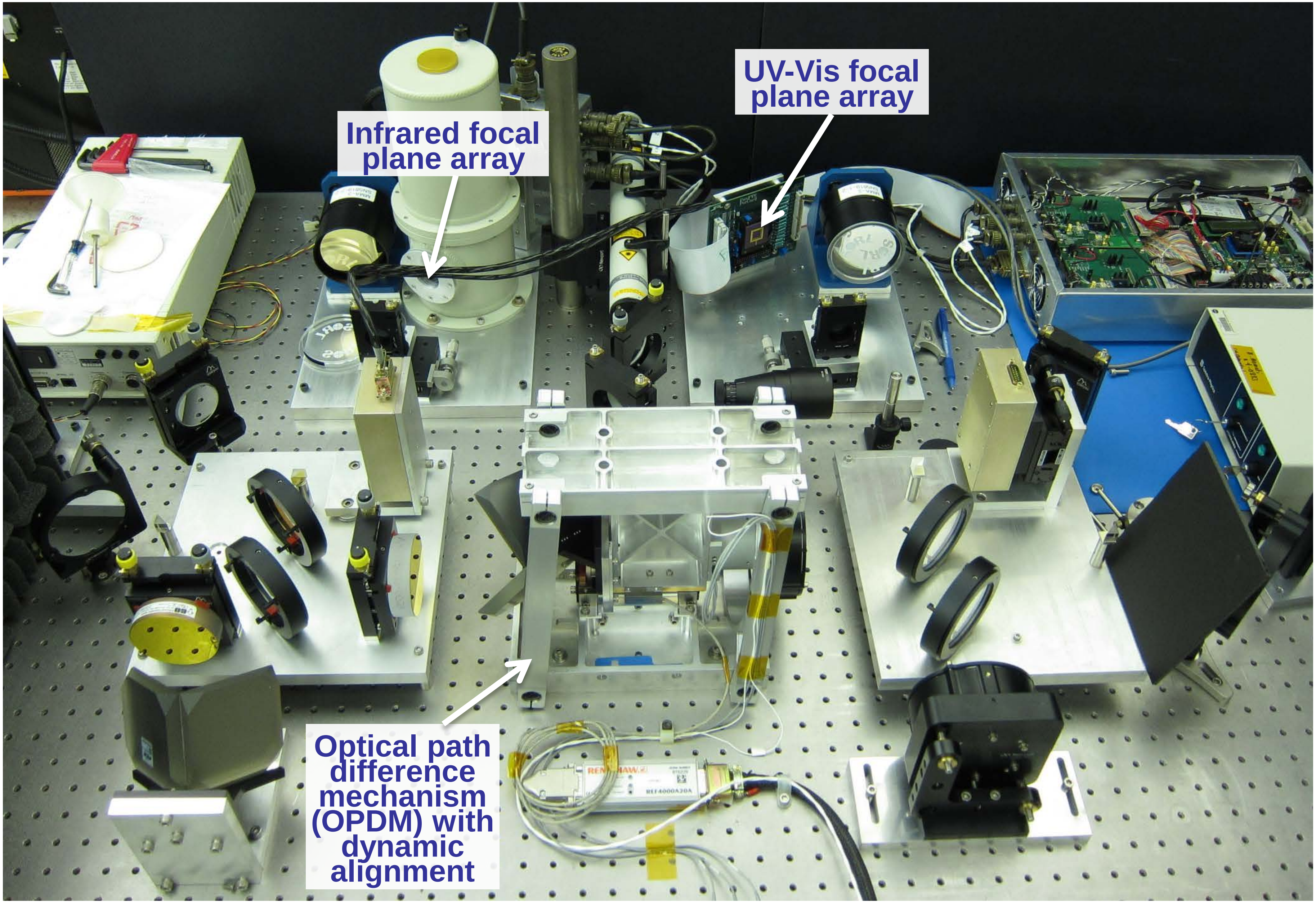
PanFTS Instrument Concept Overview:

Notional Flight Instrument and Subsystem Heritage

- **Modular instrument design options:**
  - **UV-Vis only (0.28-0.76 microns)**
  - **Thermal IR only (8-15 microns)**
  - **UV-Vis-IR (0.28-15 microns)**

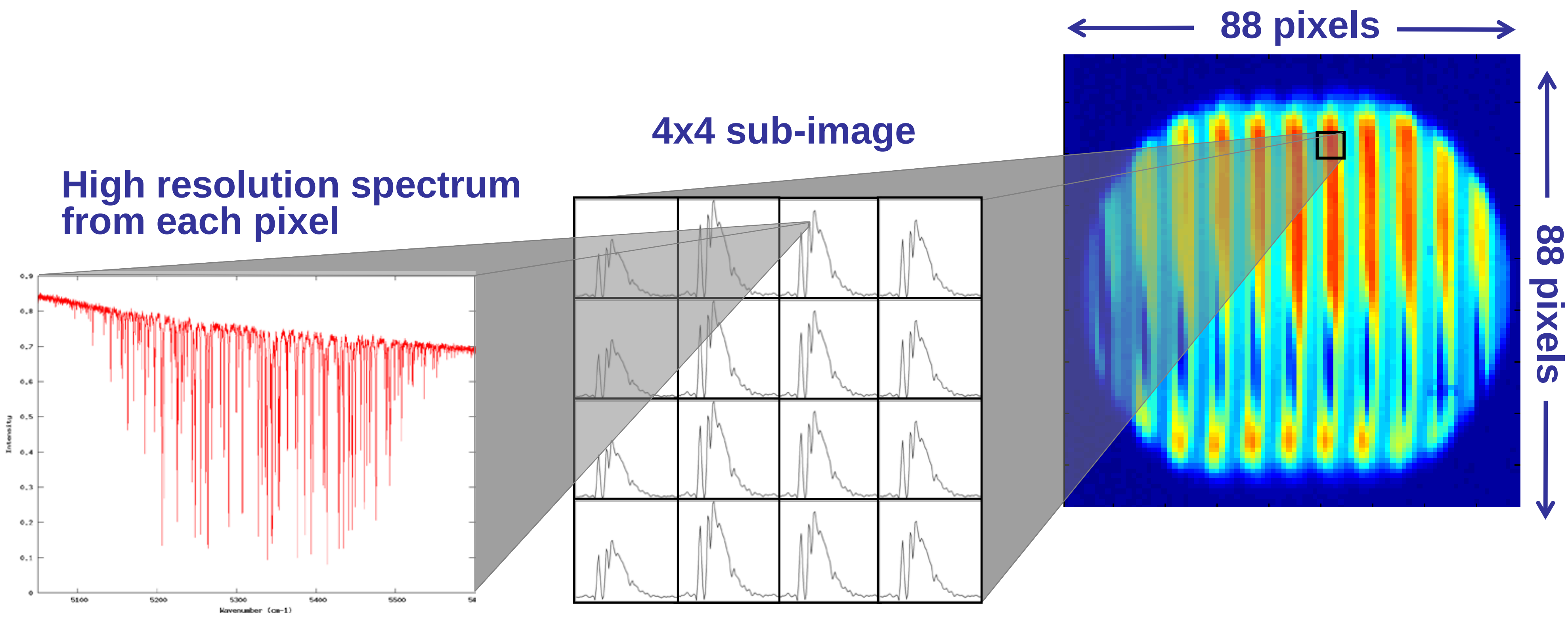


PanFTS IR + Vis Interferometer Breadboard



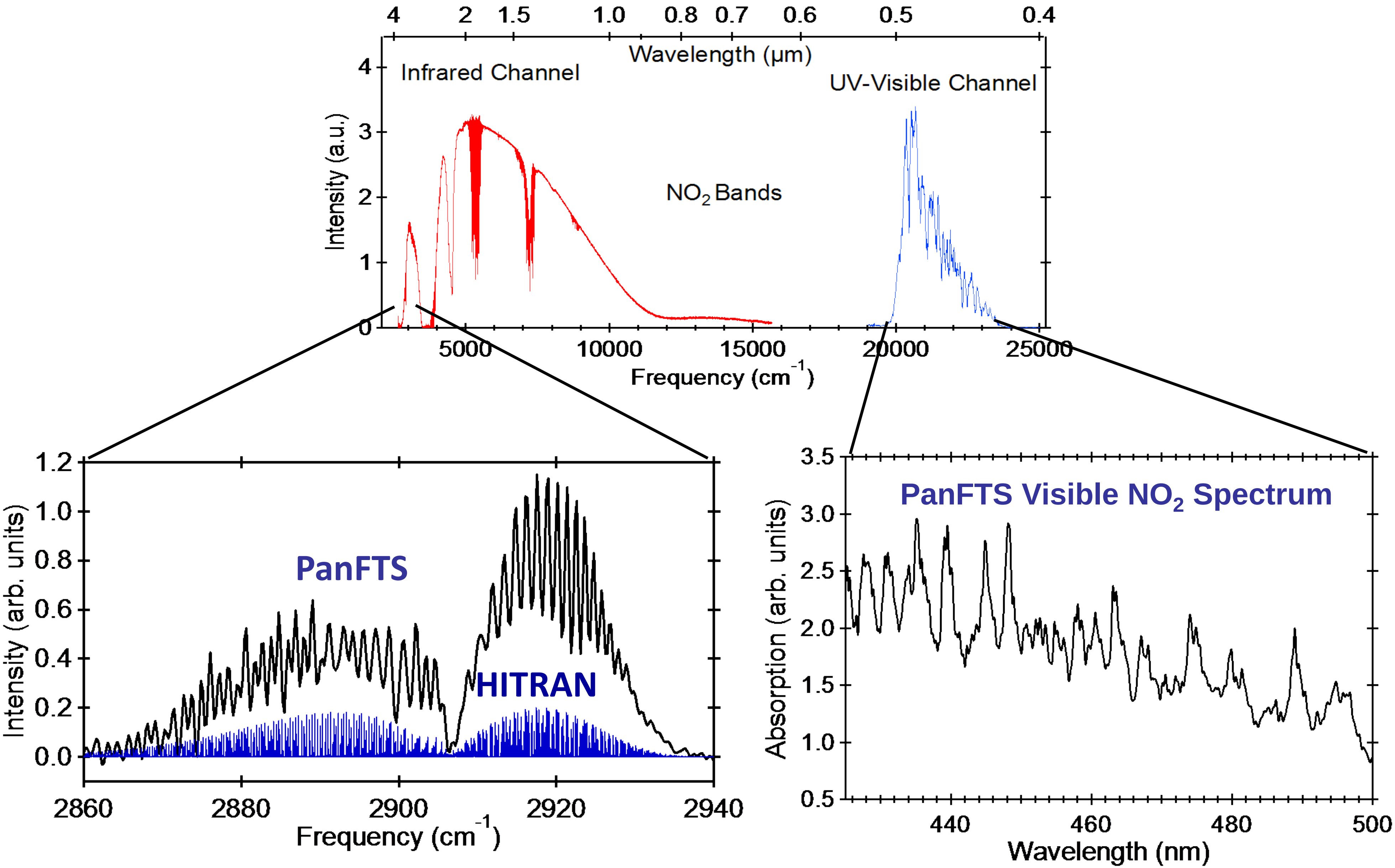
PanFTS Imaging Spectroscopy Demo

Near-IR image of tungsten lamp filament imaged through PanFTS interferometer: high resolution spectra of atmospheric water vapor



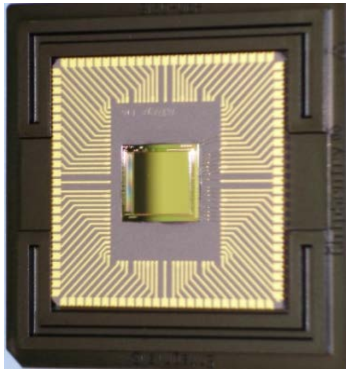
Successful acquisition of a hyperspectral image is equivalent to a scene captured by PanFTS from geo when viewing reflected sunlight and thermal emission from Earth's atmosphere

Simultaneous IR and Visible Spectra of NO_2 Using PanFTS Breadboard

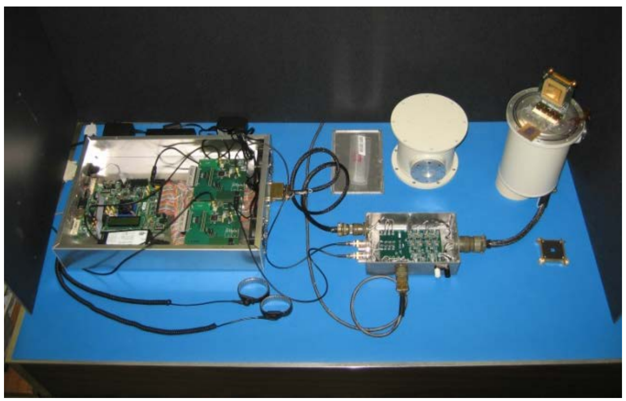


IIP and ACT FPA Evolution

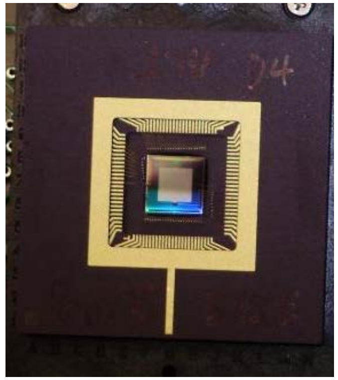
IIP InSb Detector Array (IR)



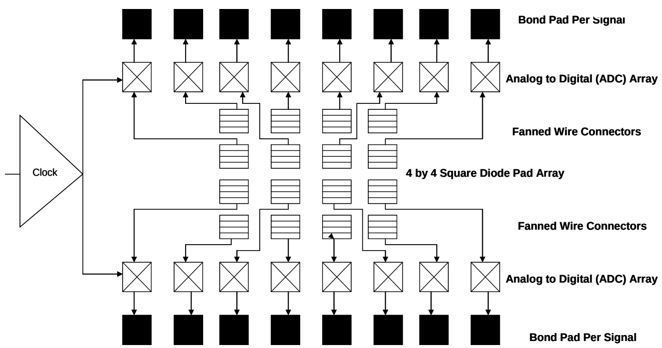
- 256x256 Raytheon InSb
- Analog output
- Off-Chip ADCs
- Lab testing now



IIP Si Detector Array

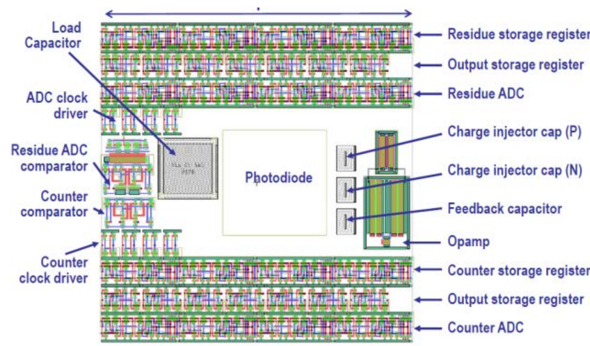


- 4x4 Visible Si PIN array
- Successfully hybridized to JPL ROIC
- One on-chip Δ-Σ ADC/pixel
- FPA integrated into PanFTS breadboard



ACT In-Pixel ROIC

- One ADC/pixel: 128x128 format
- On-Pixel ADC
- Released to foundry for fab.
- Major step forward in ROIC development

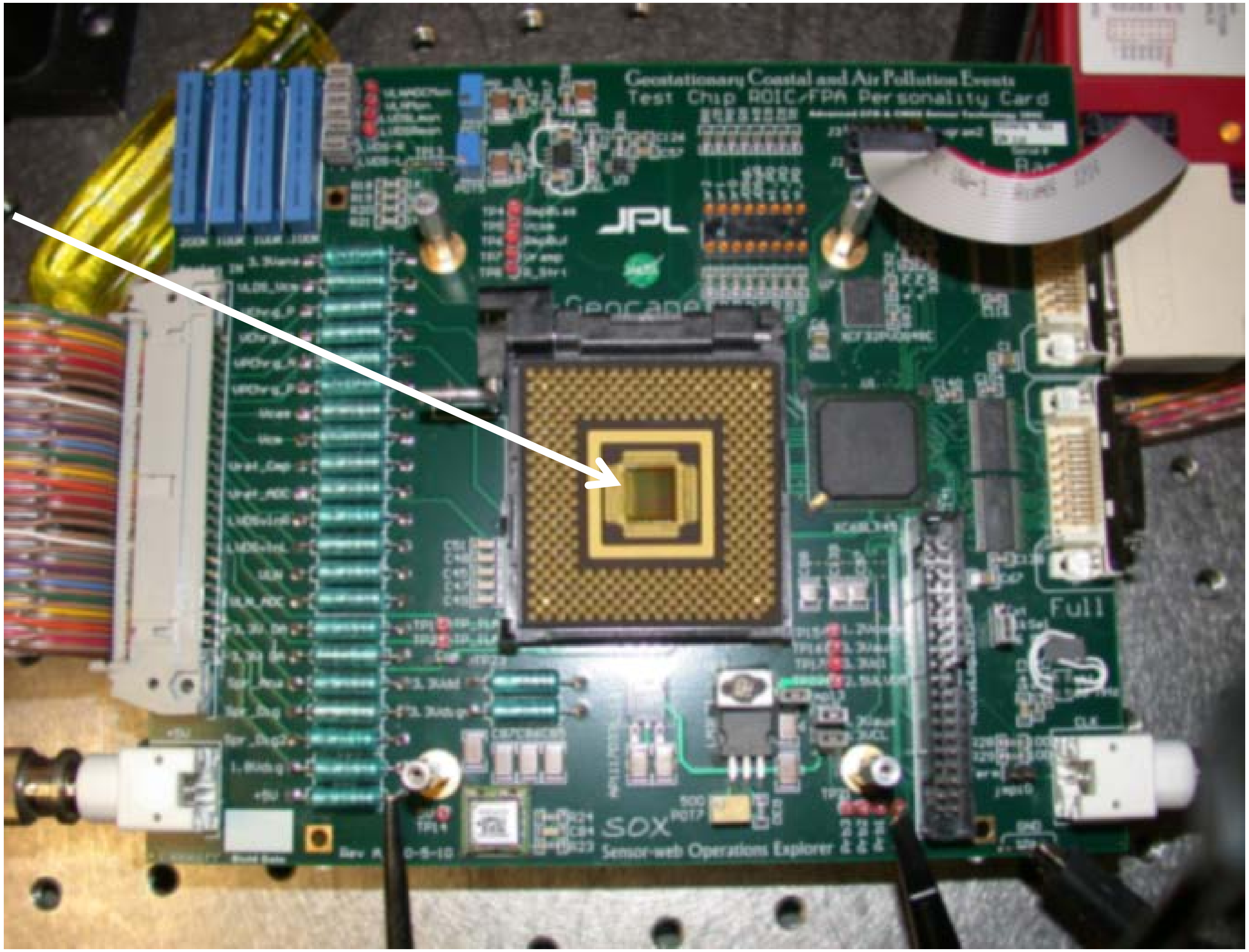


All circuit elements fit in 60x60 μm cell including both a photodiode for testing and a pad for future hybridization

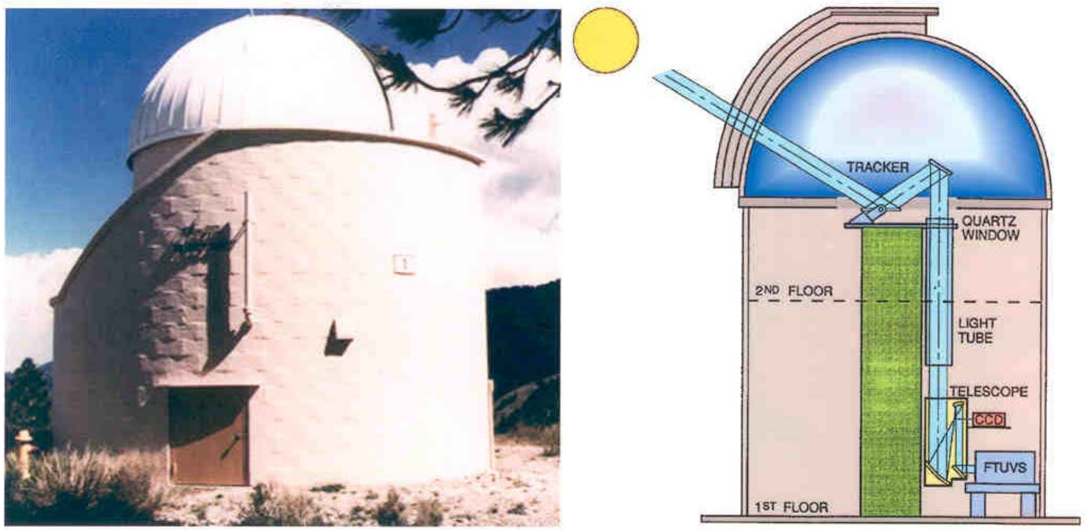
JPL In-Pixel Digitization ROIC

- 128 x 128 Readout Integrated Circuit (ROIC) – designed by JPL
- Charge integration, digitizer located <u>within each pixel</u>
- High resolution (14 bits), Fast snapshot readout (16 kHz frame rate)
- Can be adapted for UV-Vis (silicon) or IR (HgCdTe) applications

128x128 ROIC



JPL In-Pixel Digitization ROIC Demo

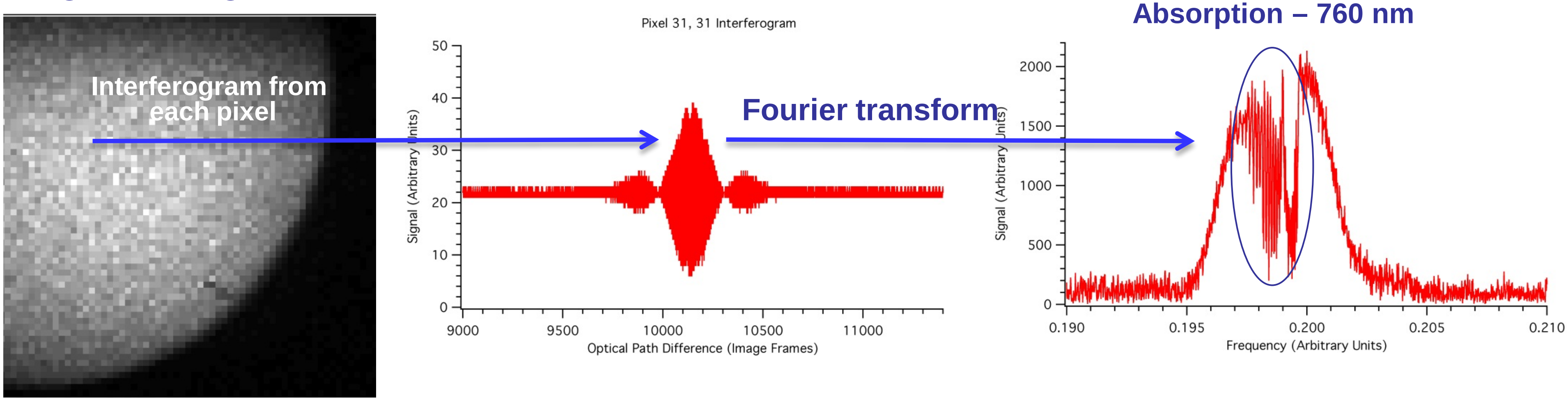


Fourier Transform UV Spectrometer (FTUVS)
at the JPL Table Mountain Facility (TMF)

JPL In-Pixel Digitization ROIC in FTUVS at TMF

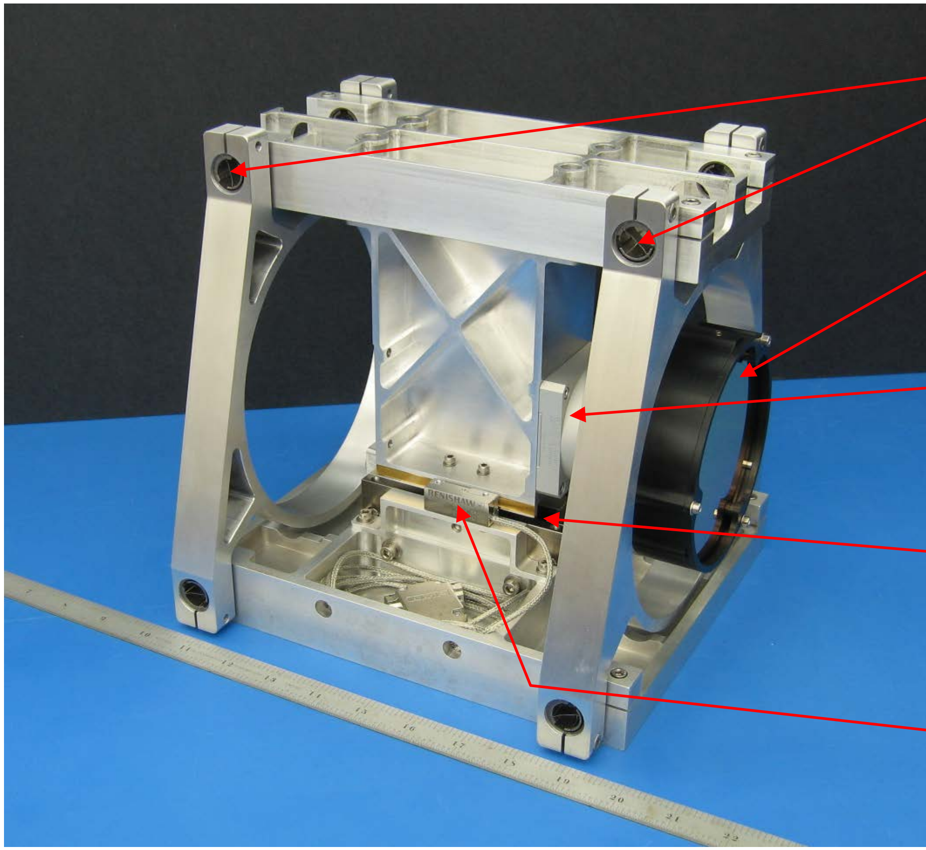
Solar disk imaged through FTUVS

Atmospheric Oxygen (A band) Absorption – 760 nm



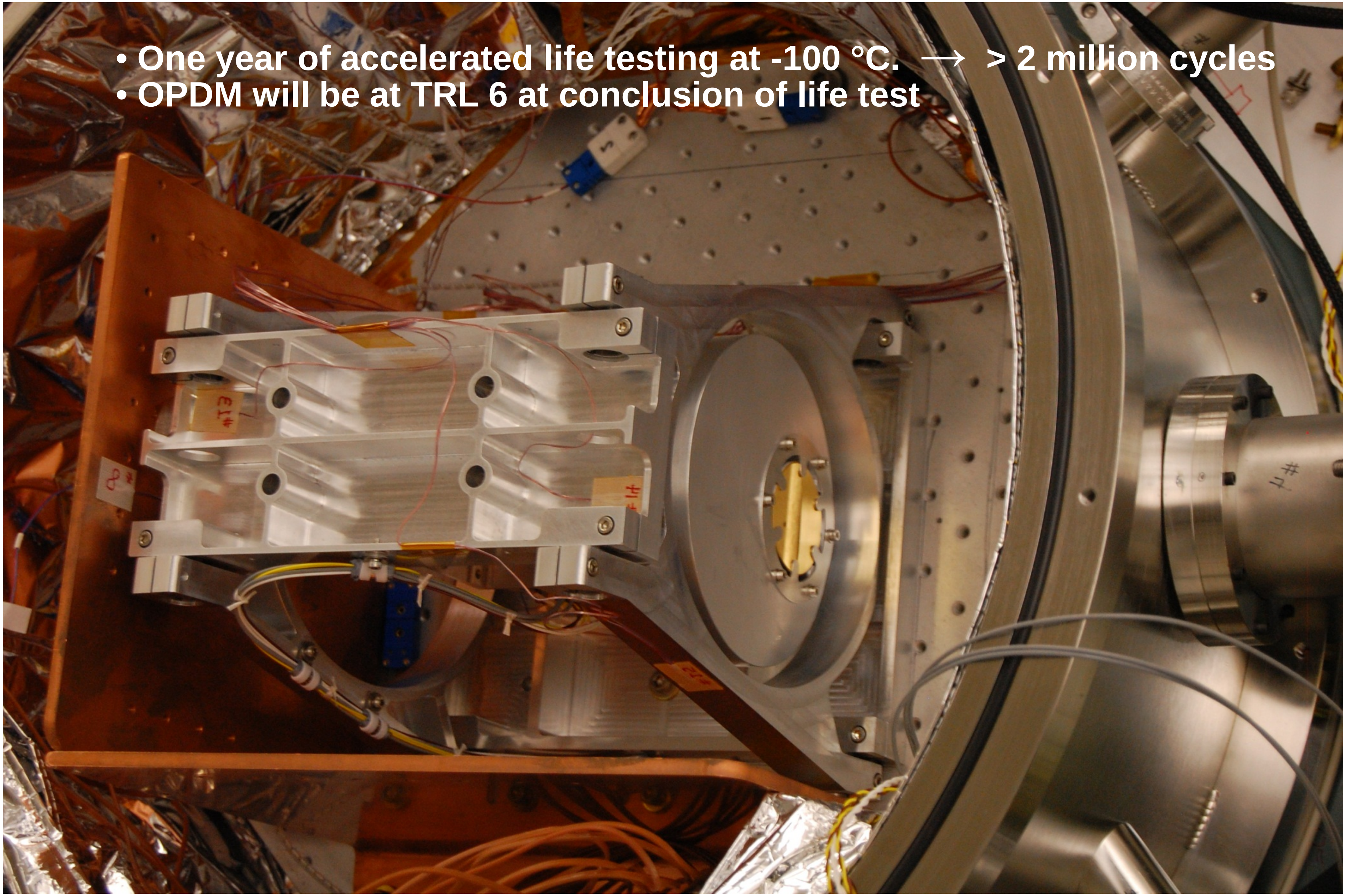
Cryogenic Optical Path Difference Mechanism (OPDM)

- **A single OPDM controls the optical path difference on both sides of the interferometer**
- **The friction-free flexure-based parallelogram design has no inherent wear out risks**
- **Three flight size OPDMs have been built (lab unit, life test unit, and field test unit)**

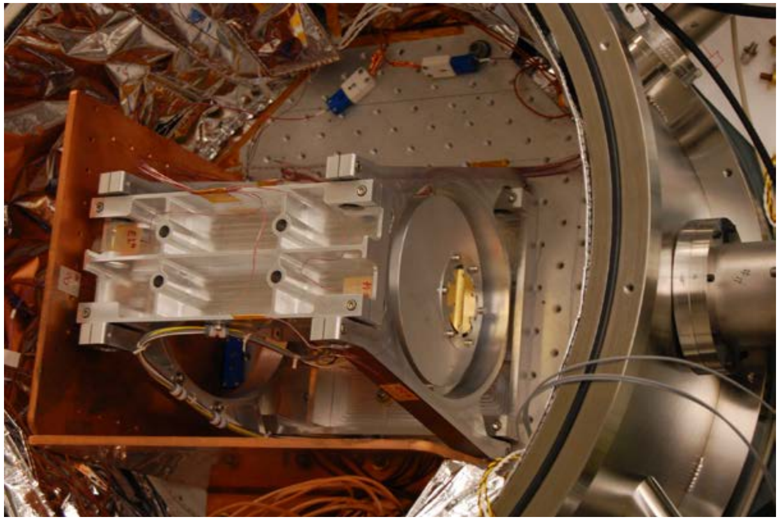


A NASA Tech Brief has been awarded for the PanFTS OPDM

OPDM #2 is in Cryo-Vacuum Life Testing

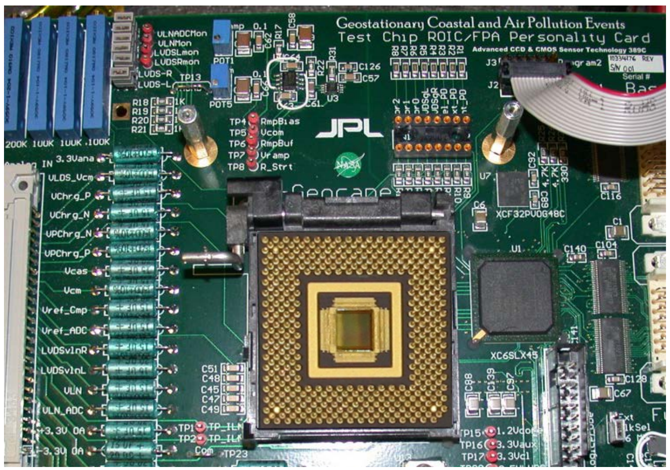


Demonstration of PanFTS Core Capabilities:
Lab - Field - Environmental Test

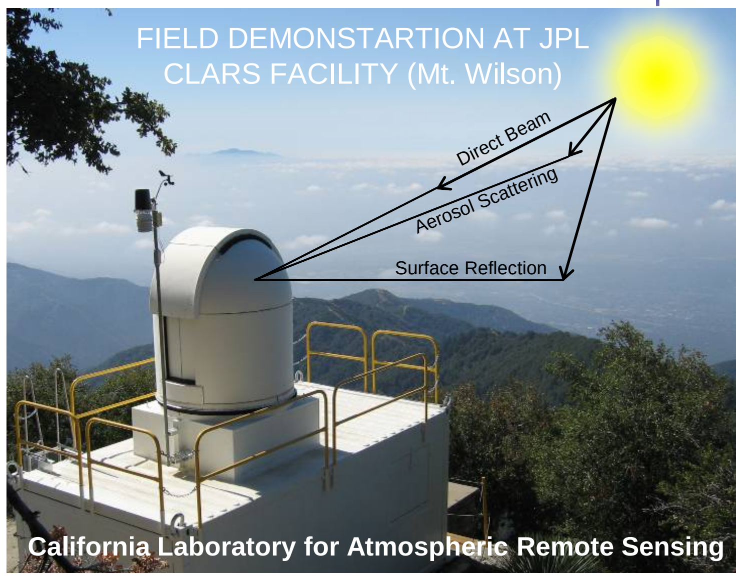


OPDM life test in flight-like conditions

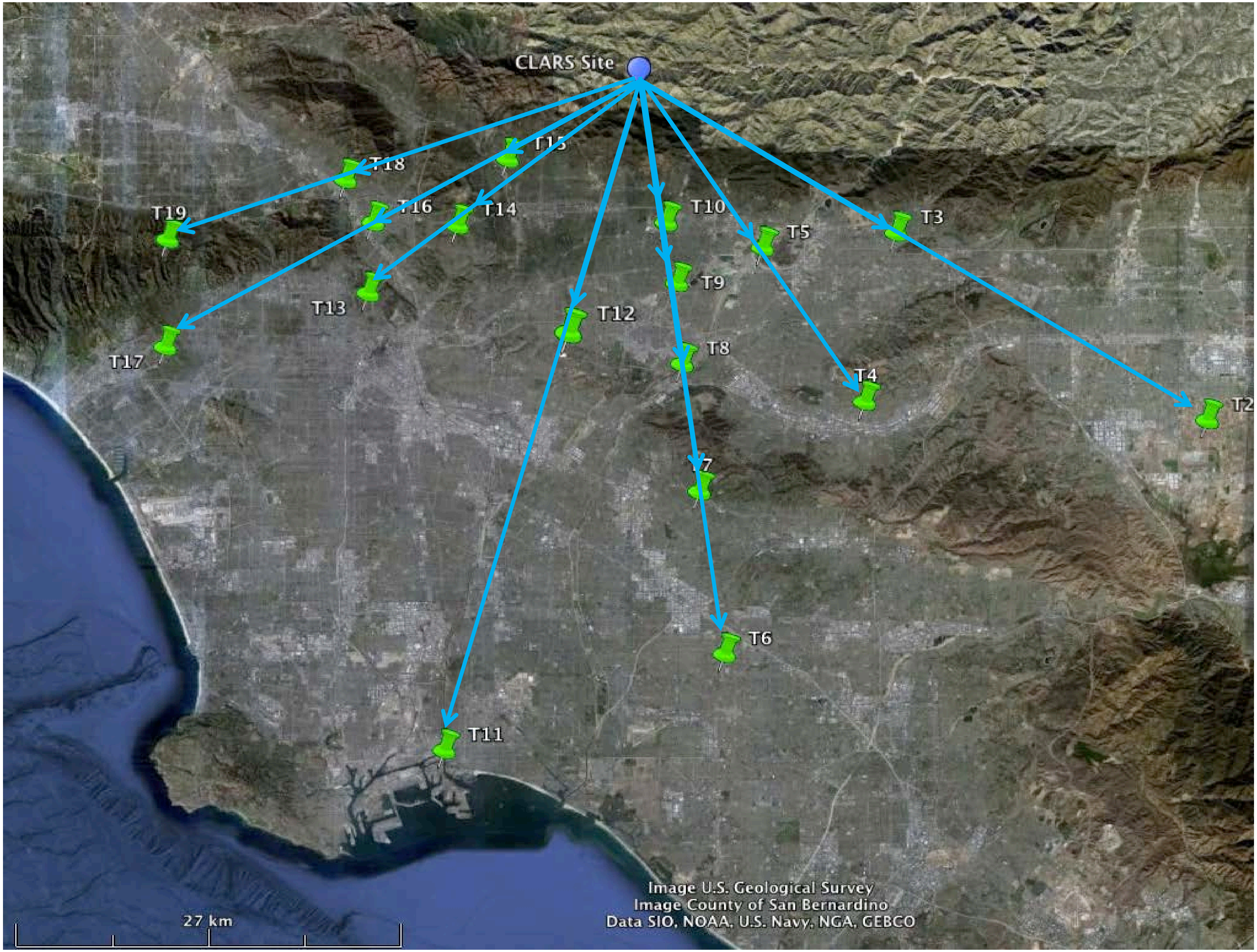
Laboratory and field demonstration of simultaneous UV-Vis-IR measurement capability



Demonstration of advanced focal plane arrays with on-chip analog-to-digital converters for each pixel

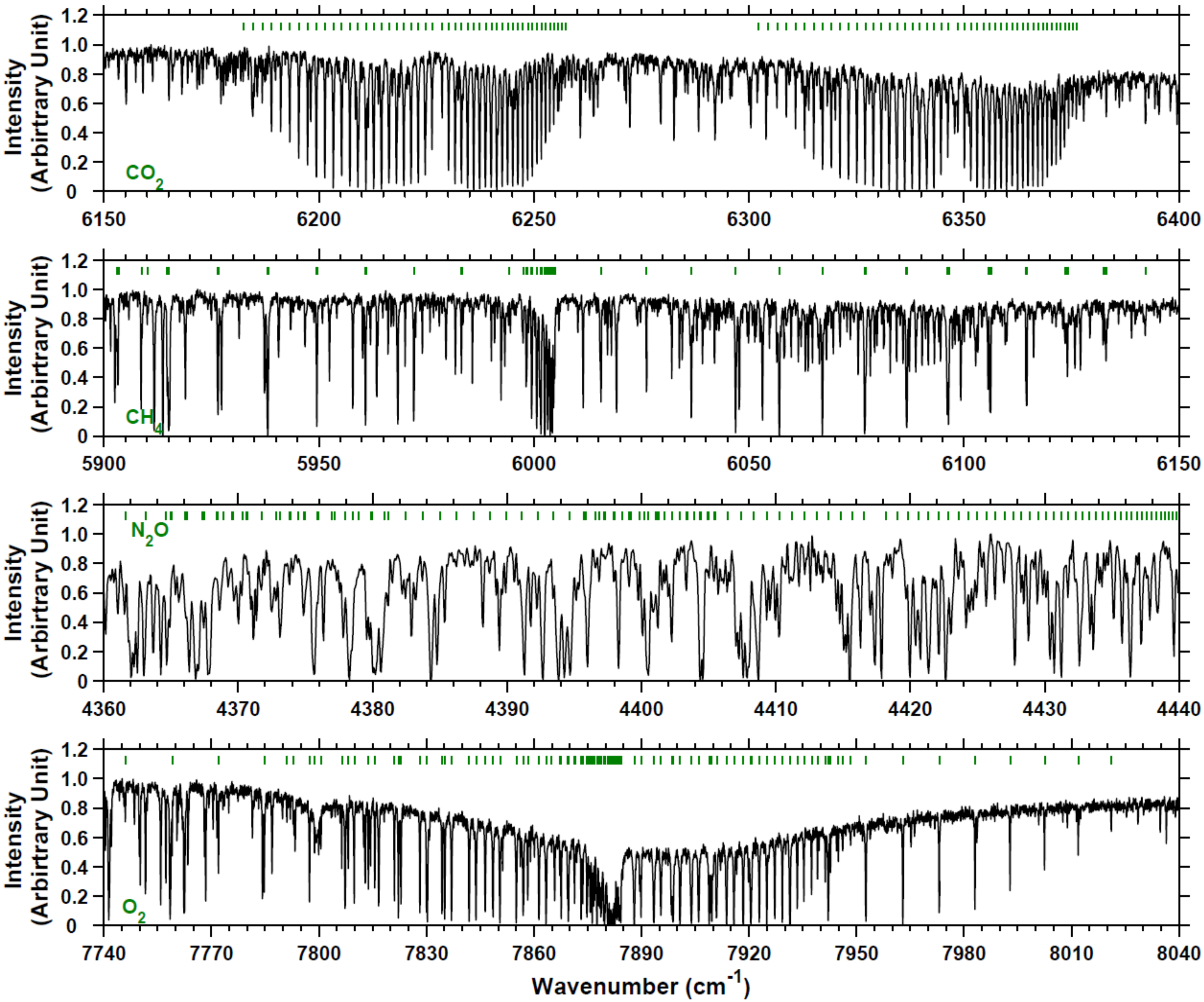


Reflection Points in the L.A. Basin

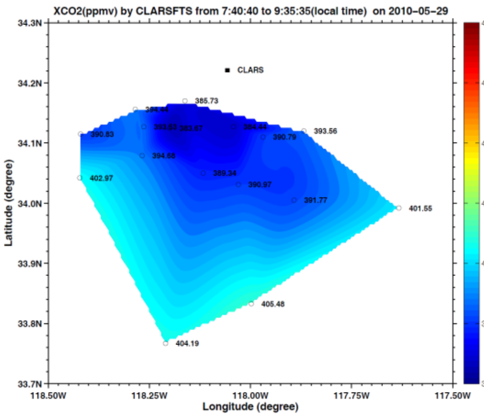


Typical FTS Greenhouse Gas Spectra: Reflectance from Land Surface

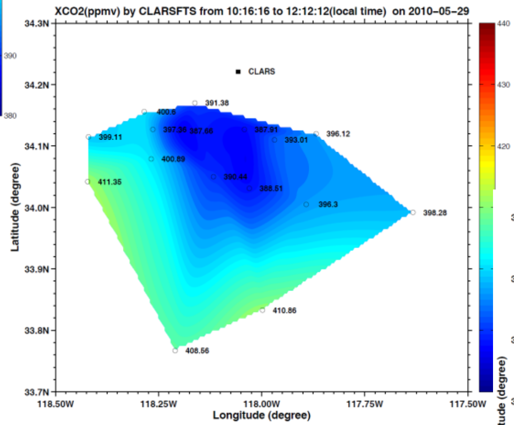
- CO_2
- CH_4
- N_2O
- O_2



Inferring GHG Emission Rates: Spatial/Temporal Mapping



8:35 am
29 May 2010



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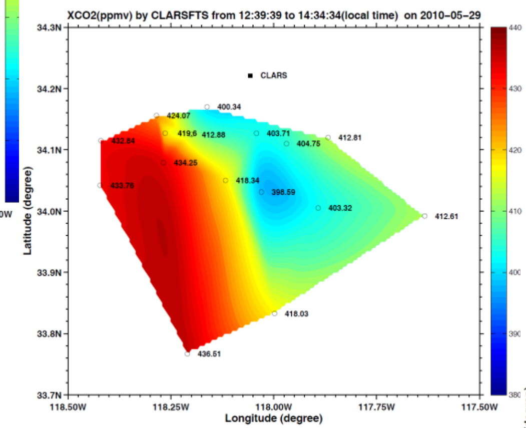
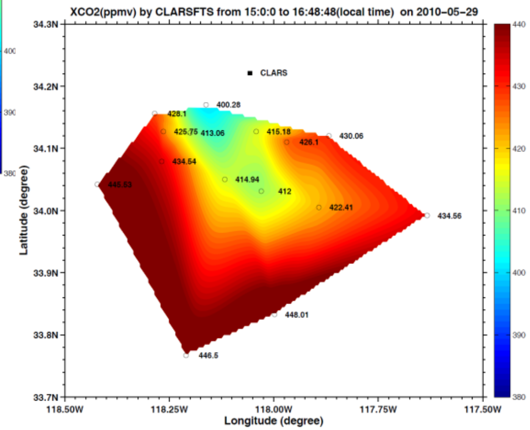


1:35 pm



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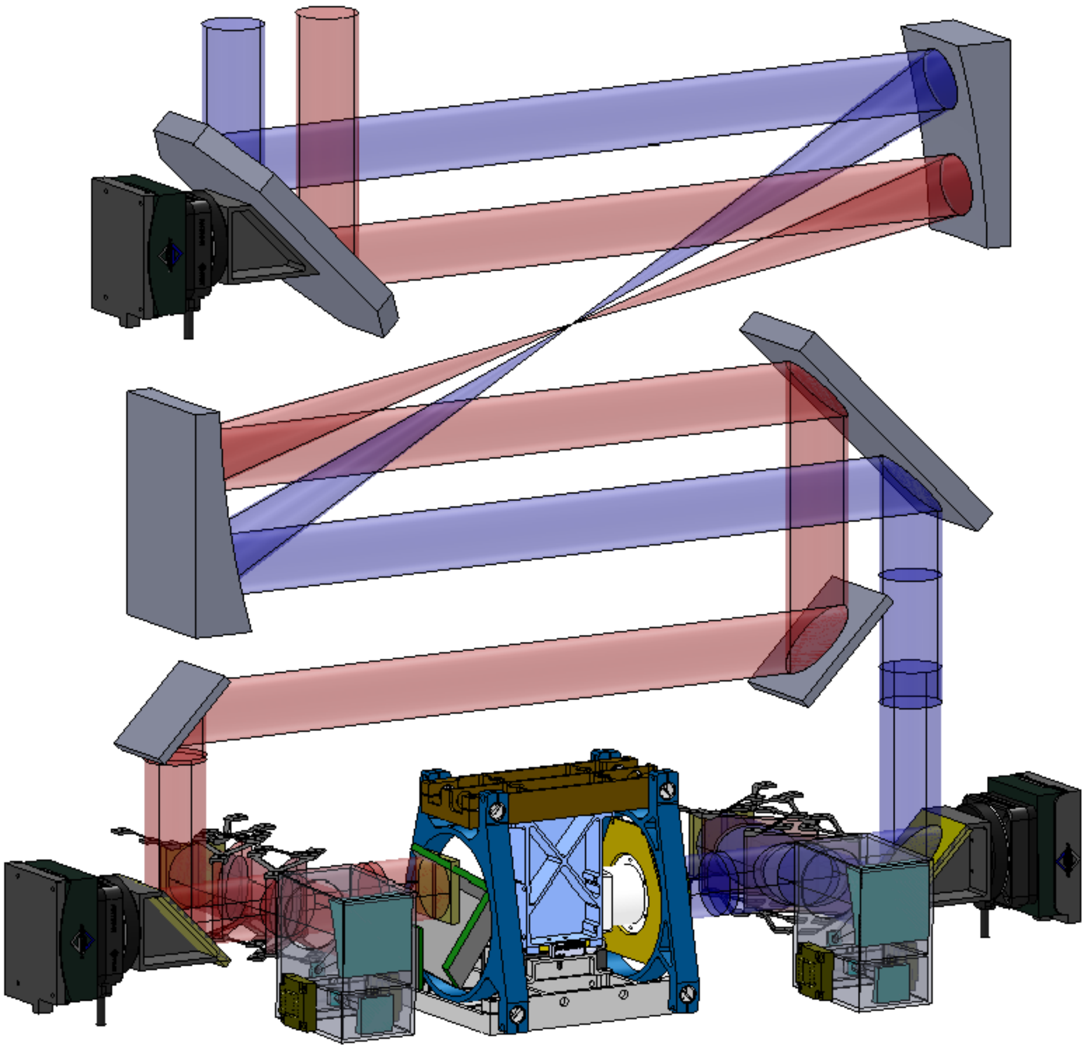
- First spatial/temporal maps of a trace gas in the LA Basin by remote sensing.

PanFTS Engineering Model (IIP-10)



- NASA has recently funded the development of a PanFTS EM IIP
- The PanFTS EM will be built with flight like optics, optical bench, metrology and alignment system
- The PanFTS EM will cover the spectral range of the flight design (0.28 µm to 15 µm)
- The PanFTS EM performance will be demonstrated in a thermal-vacuum chamber under flight-like conditions

The PanFTS EM will achieve Technology Readiness Level 6 (functional demonstration in a flight-like environment)

Summary

- **PanFTS IIP-07 has successfully demonstrated:**
  - **Simultaneous acquisition of high resolution NO_2 spectra in Visible and IR bands.**
  - **Successful development of advanced 128x128 digital focal plane arrays for imaging spectroscopy with in-pixel readouts.**
  - **Robust cryogenic optical path difference mechanism currently in life test at -100 °C.**
  - **Atmospheric field tests at JPL Mt. Wilson CLARS facility to begin in June.**
- **A PanFTS EM will be developed over the next three years and ultimately demonstrate functional performance in a flight-like environment (TRL 6)**
- **A PanFTS flight instrument could be ready by 2016 (depending on funding)**