Pre-launch Testing and Post-Launch Performance
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Preflight Characterization of the OCO-3 Imaging Spectrometer

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Introduction / Outline

- Orbiting Carbon Observatory Missions 2002-2022
- Atmospheric state retrievals from 3 narrow NIR spectral bands
- OCO-2 Science Highlight
- From OCO-2 Spare Spectrometer to OCO-3 Payload
- OCO-3 Test Program
  - Ground Support Equipment Overview
  - Radiometry and sphere calibration with NIST
  - Heliostat spectra & verification with TCCON
- Inflight Calibration Strategies
- Conclusion: Expected launch 2/19
OCO, OCO-2, and OCO-3

- Orbiting Carbon Observatory approved within the Earth System Science Pathfinder program in July 2002
- Launched on February 24, 2009 but did not achieve orbit due to launch vehicle failure

- Work on OCO-2 began in March 2010
- Launched into A-Train successfully from Vandenberg Air Force Base in California on July 2, 2014

- Following the successful OCO-2 launch, work began on converting the spare spectrometer into OCO-3
- Launch to ISS scheduled for February 2019, planned duration 3 years
Measurement Basics

- Three-channel grating spectrometer with common entrance optics
  - 758-772, 1594-1619, 2045-2081 nm
- High spectral resolution
  - $\lambda/\Delta\lambda = 17000-20000$
- Infer several atmospheric properties from the depths of the absorption lines
  - Surface pressure
  - Aerosols
  - Clouds
- 24 Soundings acquired per second
  - Onboard averaging in spatial dimension compresses 160 rows into 8 footprints (~2.5 km² on ground)
Notable OCO-2 Science

Large-Scale Anthropogenic Emissions (Hakkarainen et al, GRL, 2016)


Quantifying Power Plant Emissions (Nassar et al, GRL, 2017)

Global SIF Measurements (Sun et al, Science, 2017)

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OCO-3 Thermal Vacuum Testing

• The OCO-2 spare spectrometer was stored after testing in May 2013

• Intermediate tests in 2016 and 2017 to confirm performance and evaluate new entrance optics

• The OCO-3 payload completed its final thermal vacuum test in May 2018
  – Two weeks of optical testing with additional thermal tests
  – Derived spectral and radiometric calibration coefficients for launch

• Additionally, verified dozens of requirements including:
  – Field of View
  – Slit Alignment
  – Focus
  – Saturation
  – Bad Pixels
  – Polarization extinction
OGSE was inherited from OCO, OCO-2 and was used for previous OCO-3 TVACs

- Heliostat M1/M2
- Heliostat M3/M4
- Laser Rack
- Integrating Sphere
- Collimator
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**Spectral Calibration (ILS & dispersion)**

- ~40 laser scans allows ILS determination/interpolation for 1016 spectral channels, eight footprints, and three bands, yielding 24,384 individual ILS functions.

- Initial laser based dispersion also determined from these ~40 laser scans.

- The laser based ILS & dispersion further optimized by comparing solar spectra recorded simultaneously on the ground by the OCO-3 flight instrument and a collocated high-resolution Fourier transform spectrometer (FTS).
Preflight Radiometric Calibration with NIST

- 5% absolute performance requirement
- Sphere has dedicated ASD spectroradiometer
- NIST ASD in chamber before and after testing transfers calibration from standard sources and helps to correct artifacts

Integrating sphere has 10 external halogen lamps with filters, one has a variable attenuator
Example Gain Fits: SCO2 FP 3

- Cubic gain polynomial for every spectral sample with constant term set to zero because dark correction is performed separately.
Inflight Calibration Chain

- Uncalibrated Level 1A Signal
- Dark Signal (TVAC & updated in flight)
- \textit{“ZLO”} stray light (unilluminated pixels)
- Preflight Gain (Sphere in TVAC)
- Gain Degradation (change since in orbit checkout)
- Calibrated Level 1B Radiance

Degradation primarily from on board calibrator lamps. OCO-2 uses solar diffuser and makes lunar measurements 2x/month. Adjusted less frequently based on vicarious cal & comparisons to other satellites.
Conclusion

• OCO-2 has demonstrated that atmospheric $X_{CO_2}$ can be measured from space with precision of better than 1 ppm

• OCO-3 will continue global CO$_2$ measurements focused on regional sources and sinks of CO$_2$

• OCO-3 measurements can be combined with evapotranspiration and biomass measurements also taken from the ISS to study process details of the terrestrial ecosystem.