National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

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

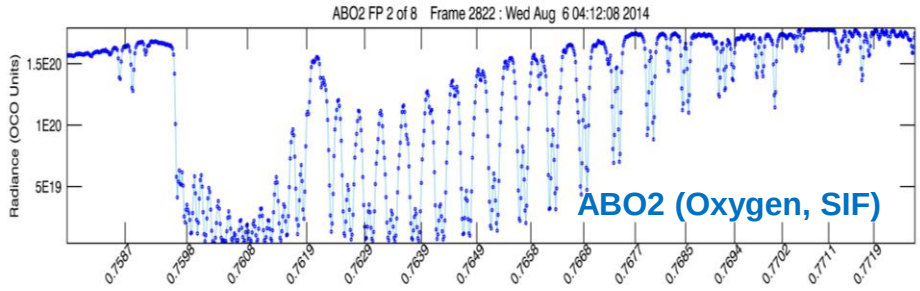
- Orbiting Carbon Observatory approved within the Earth System Science Pathfinder program in July 2002
- Launched on February 24, 2009 but did not achieve orbit due to launch vehicle failure

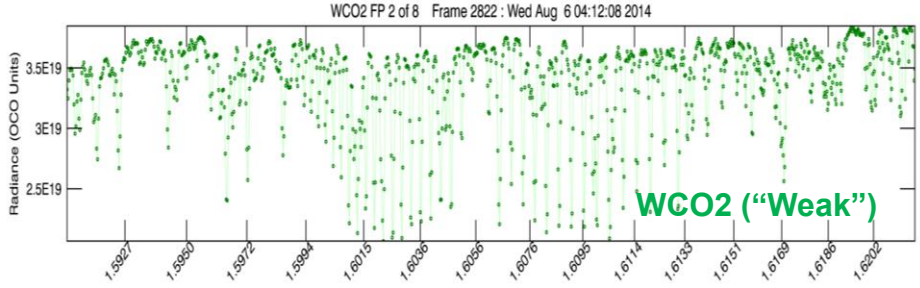
- Work on OCO-2 began in March 2010
- Launched into A-Train successfully from Vandenberg Air Force Base in California on July 2, 2014

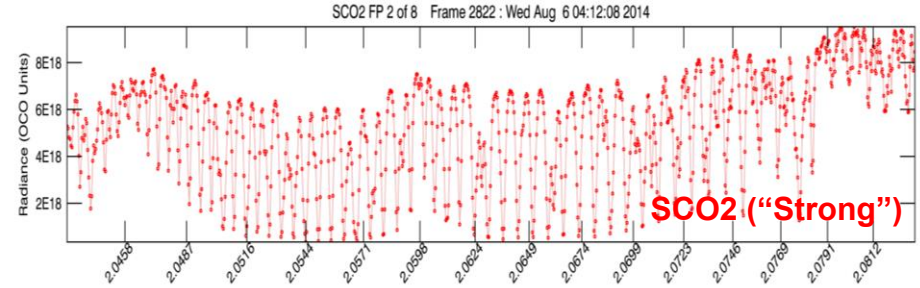
- Following the successful OCO-2 launch, work began on converting the spare spectrometer into OCO-3
- Launch to ISS scheduled for February 2019, planned duration 3 years

Measurement Basics

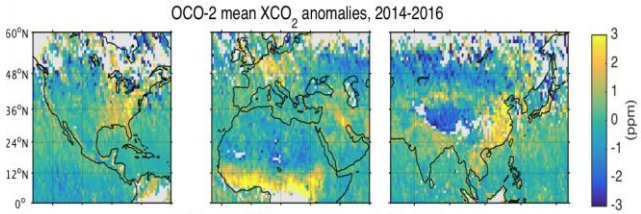
- Three-channel grating spectrometer with common entrance optics
  - 758-772, 1594-1619, 2045-2081 nm
- High spectral resolution
  - $\lambda/\Delta\lambda$ = 17000-20000
- Infer several atmospheric properties from the depths of the absorption lines
  - Surface pressure
  - Aerosols
  - Clouds
- 24 Soundings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



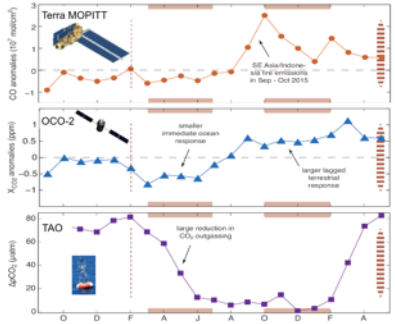




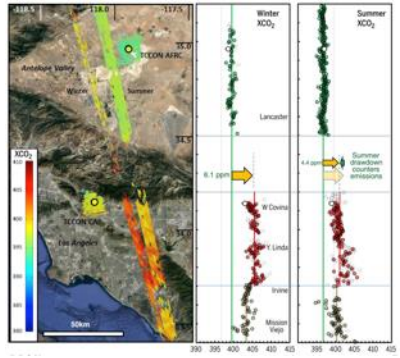
Notable OCO-2 Science



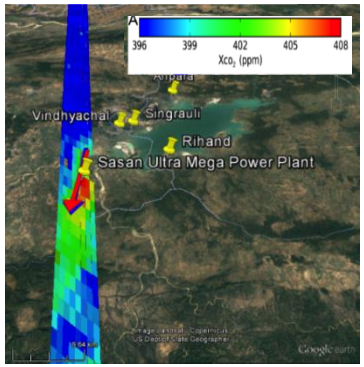
Large-Scale Anthropogenic Emissions (Hakkarainen et al, GRL, 2016)



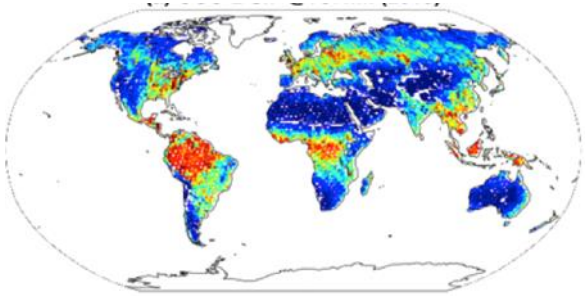
Ocean Response to 2015-16 El Nino (Chatterjee et al, Science, 2017)



Detection of Urban & Volcanic Emissions (Schwandner et al, Science, 2017)



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



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

Tropical Response to 2015-16 El Nino (Liu et al, Science, 2017)

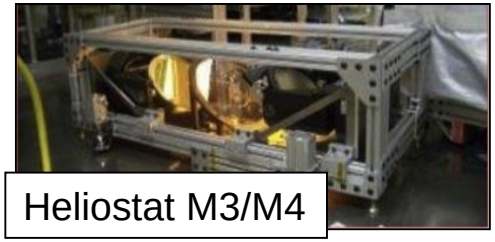
OCO-3 Thermal Vacuum Testing

- 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

Optical GSE Configuration

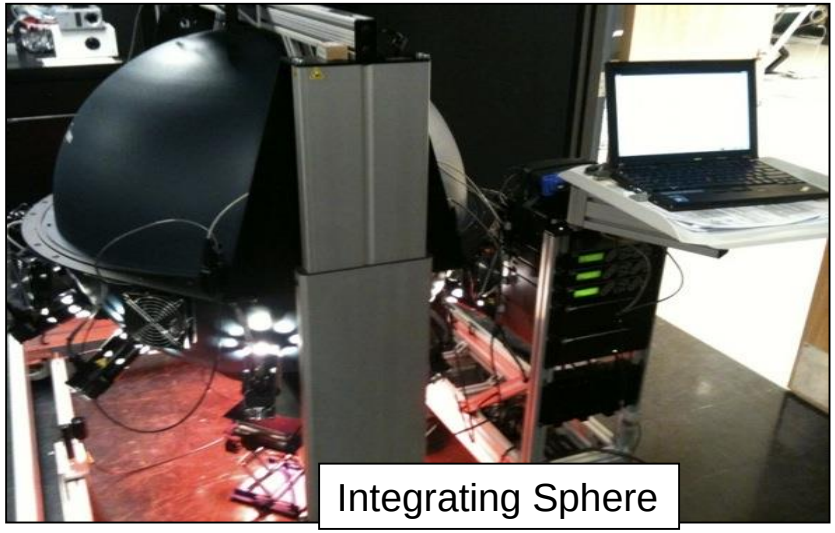
OGSE was inherited from OCO, OCO-2 and was used for previous OCO-3 TVACs

Heliostat M1/M2



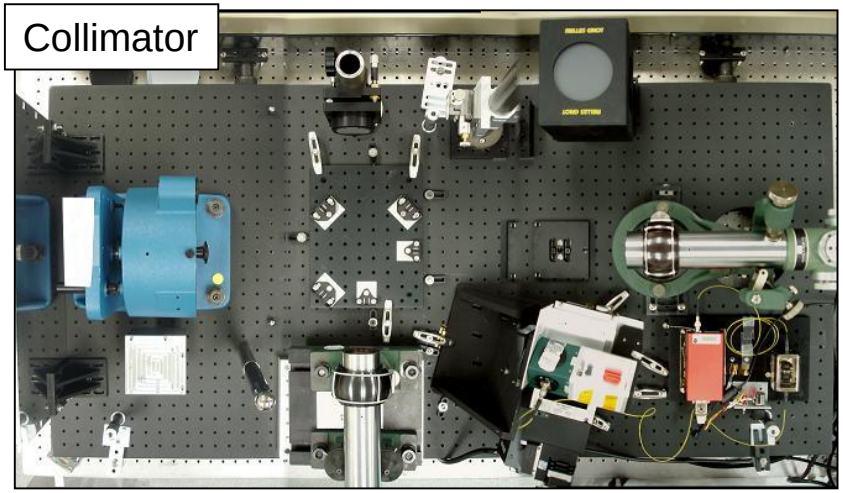
Heliostat M3/M4

Laser Rack



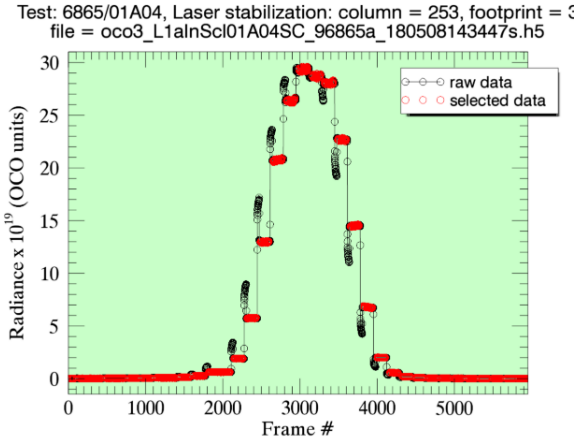
Integrating Sphere

Collimator

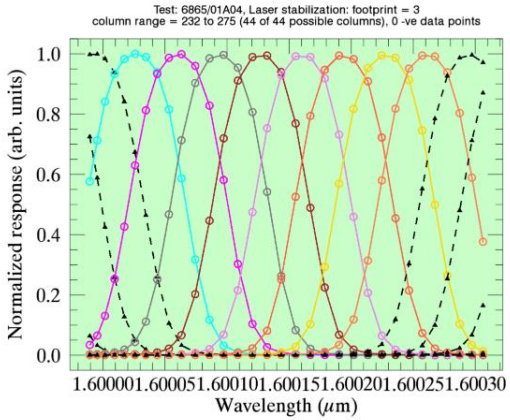


Measuring Instrument Line Shapes

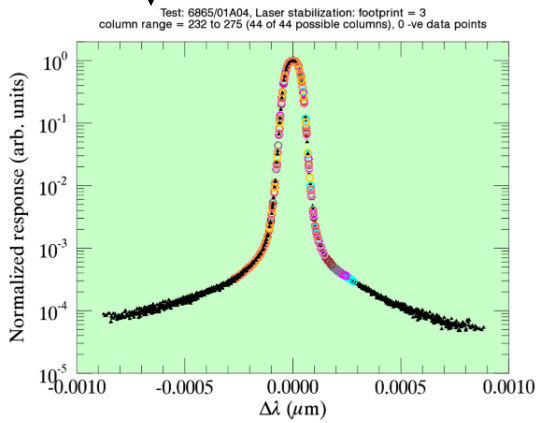
Single laser scan – raw data



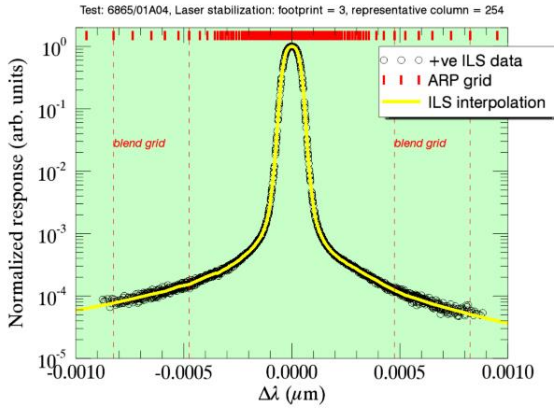
Illuminates ~8 spectral samples



spectral samples combined

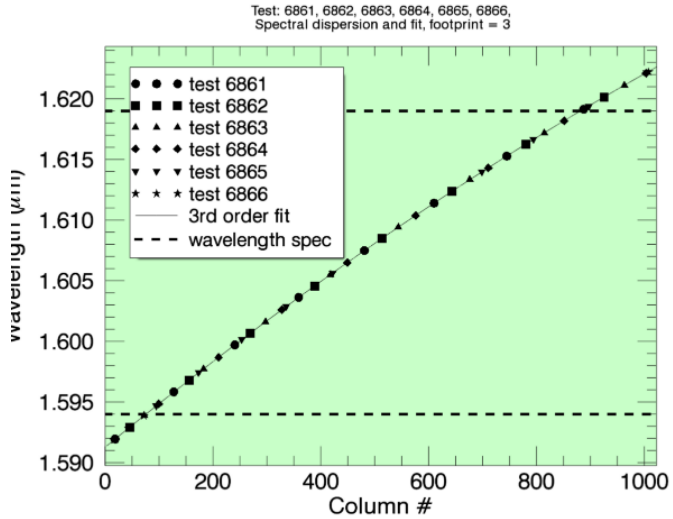


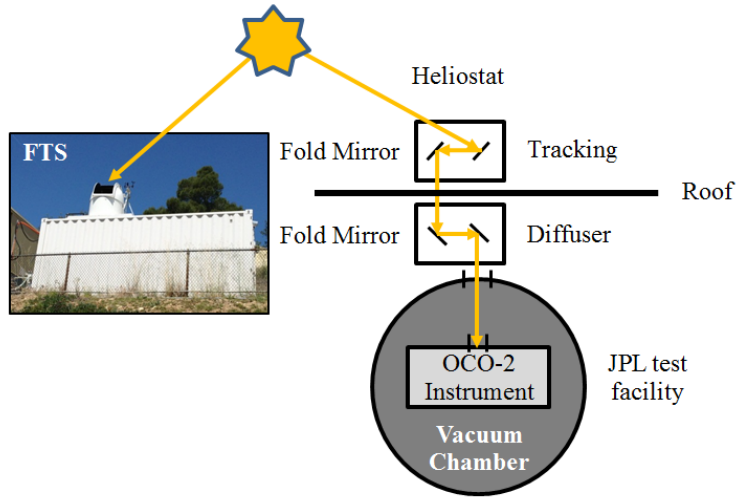
ILS fit



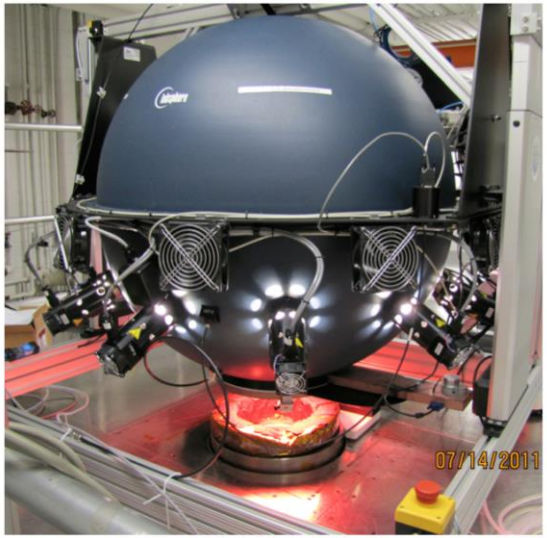
Spectral Calibration (ILS & dispersion)

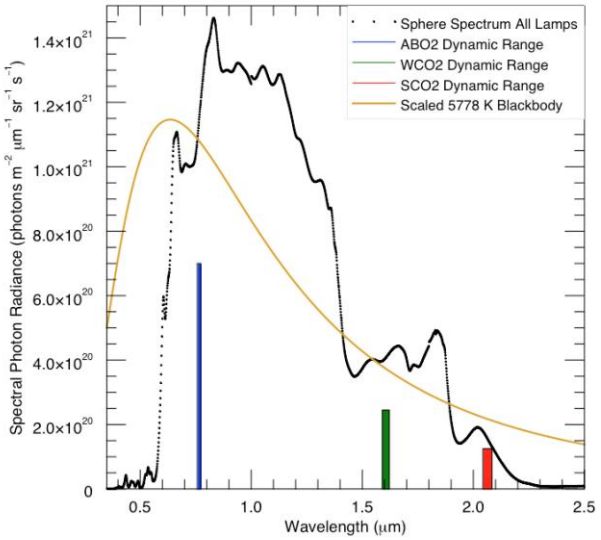
- ~ 40 laser scans allows ILS determination/interpolation for 1016 spectral channels, eight footprints, and three bands, yielding 24,384 individual ILS functions.
- Initial laser based dispersion also determined from these ~40 laser scans
- The laser based ILS & dispersion further optimized by comparing solar spectra recorded simultaneously on the ground by the OCO-3 flight instrument and a collocated high-resolution Fourier transform spectrometer (FTS).

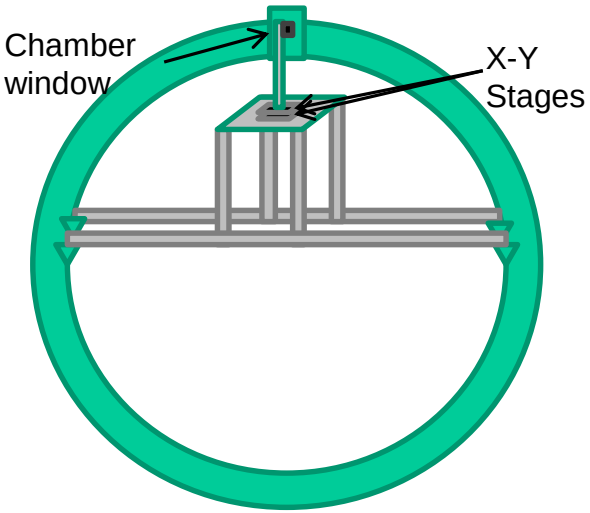




Preflight Radiometric Calibration with NIST





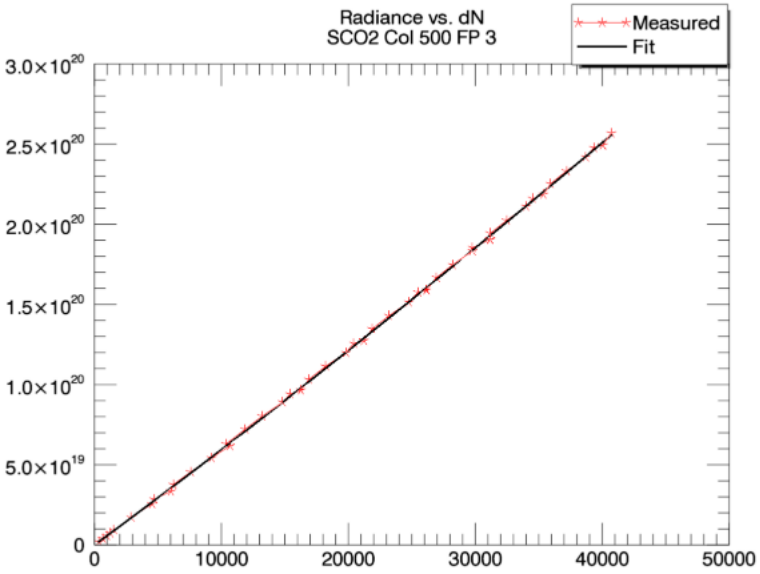


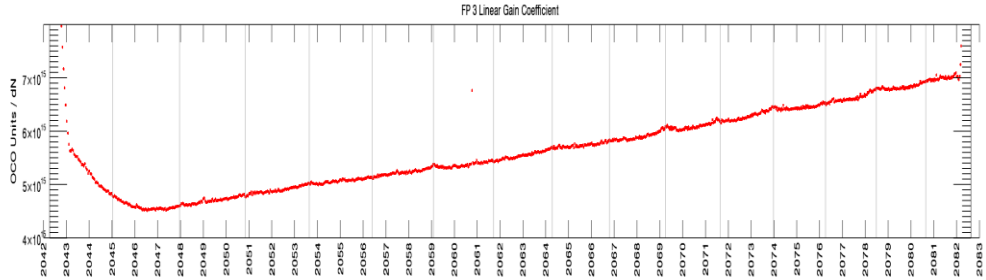
Integrating sphere has 10 external halogen lamps with filters, one has a variable attenuator

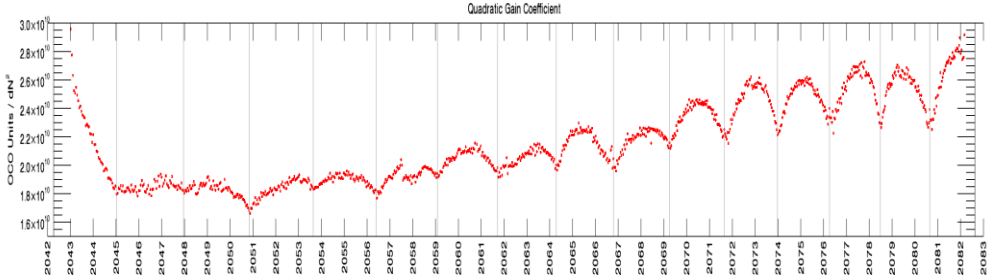
- 5% absolute performance requirement
- Sphere has dedicated ASD spectroradiometer
- NIST ASD in chamber before and after testing transfers calibration from standard sources and helps to correct artifacts

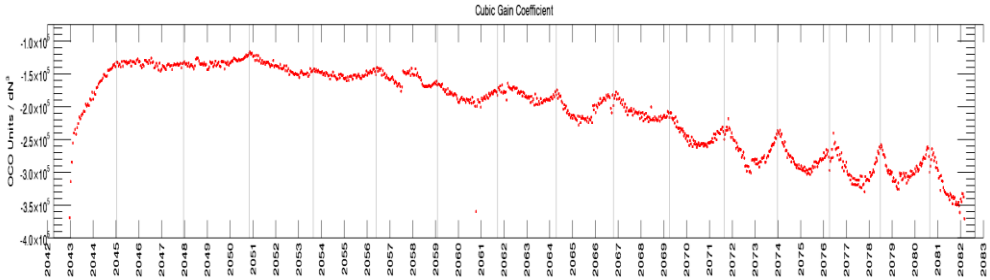
Example Gain Fits: SCO2 FP 3

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

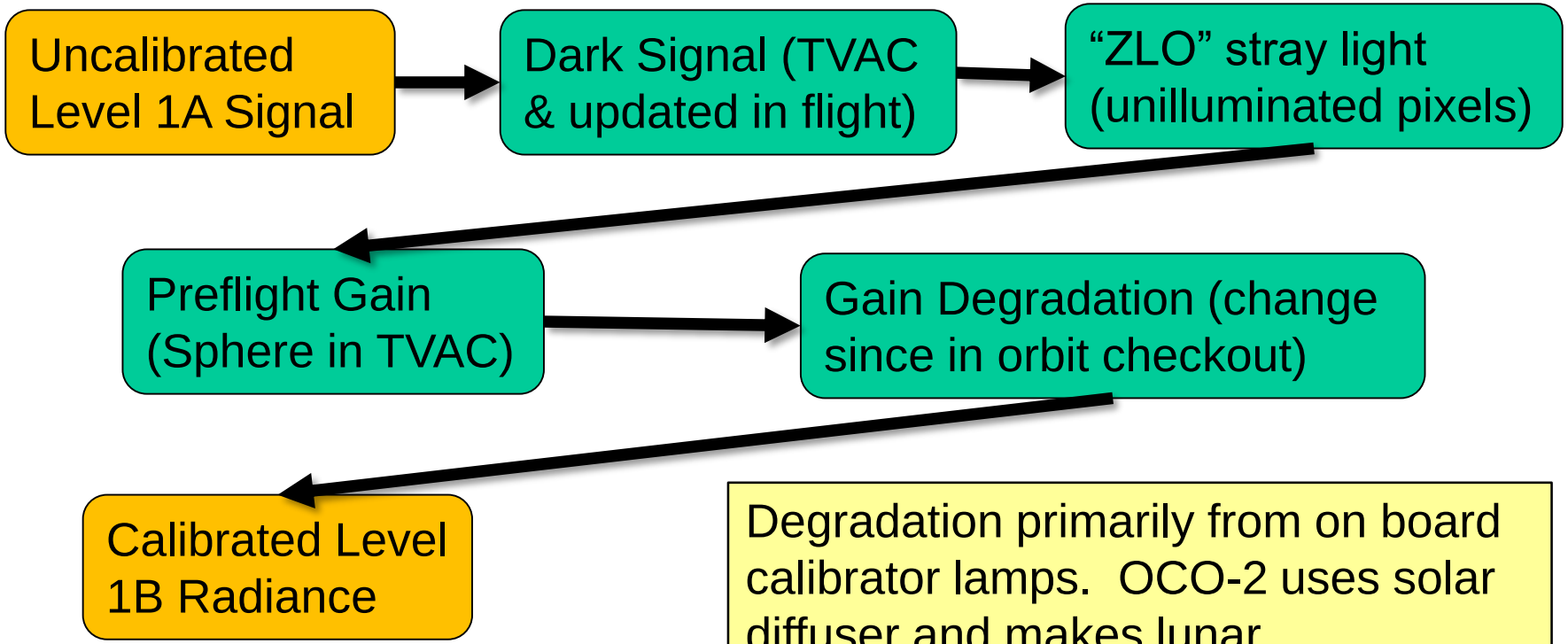








Inflight Calibration Chain



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_{CO2} 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.