National Aeronautics and Space Administration

The Orbiting Carbon Observatory-3 (OCO-3) Mission

Watching The Earth Breathe…Mapping CO_2 From Space.

OCO-3 Status Briefing

Matt Bennet, Lauren White, Jordan Padams
for Cecilia Cheng, Mission System Lead
Jet Propulsion Laboratory, California Institute of Technology

Tuesday, 23 October 2018

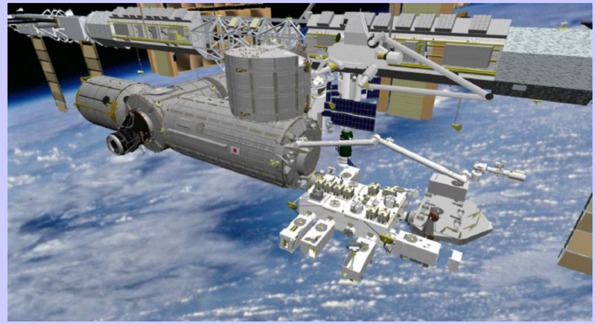
Launch in February 2019

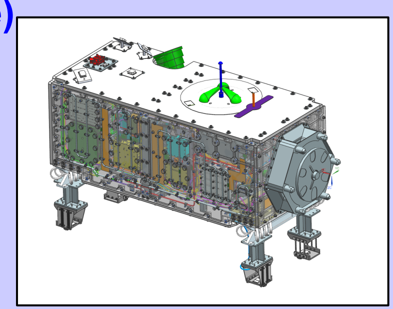
The Orbiting Carbon Observatory-3 (OCO-3)

Watching The Earth Breathe…Mapping CO2 From Space

Salient Features:

- OCO-3 represents a partnership between the SMD and HEOMD
- Assigned ISS location: JEM-EF Site No. 3
- Category 3 mission per NPR 7120.5E
- Risk classification C per NPR 8705.4
- Payload built around the existing flight spare OCO-2 instrument
- Majority of payload flight hardware received and software written
- Payload delivery: March 2018
- **Launch: February 2019 on SpX-17 (Falcon-9, Dragon Capsule)**
- **Nominal Mission: Three years after 90-day IOC period**
- Project Scientist: Dr. Annmarie Eldering
- Project Manager: Dr. Ralph R. Basilio
- JPL Program Manager: Dr. Steven Bard, Deputy: Amit Sen
- ESSP Program Mngr: Greg Stover, Msn Mngr: Bradley Crawford
- Program Scientist: Dr. Kenneth W. Jucks, NASA HQ
- **Program Executive: Mayra Montrose, NASA HQ**



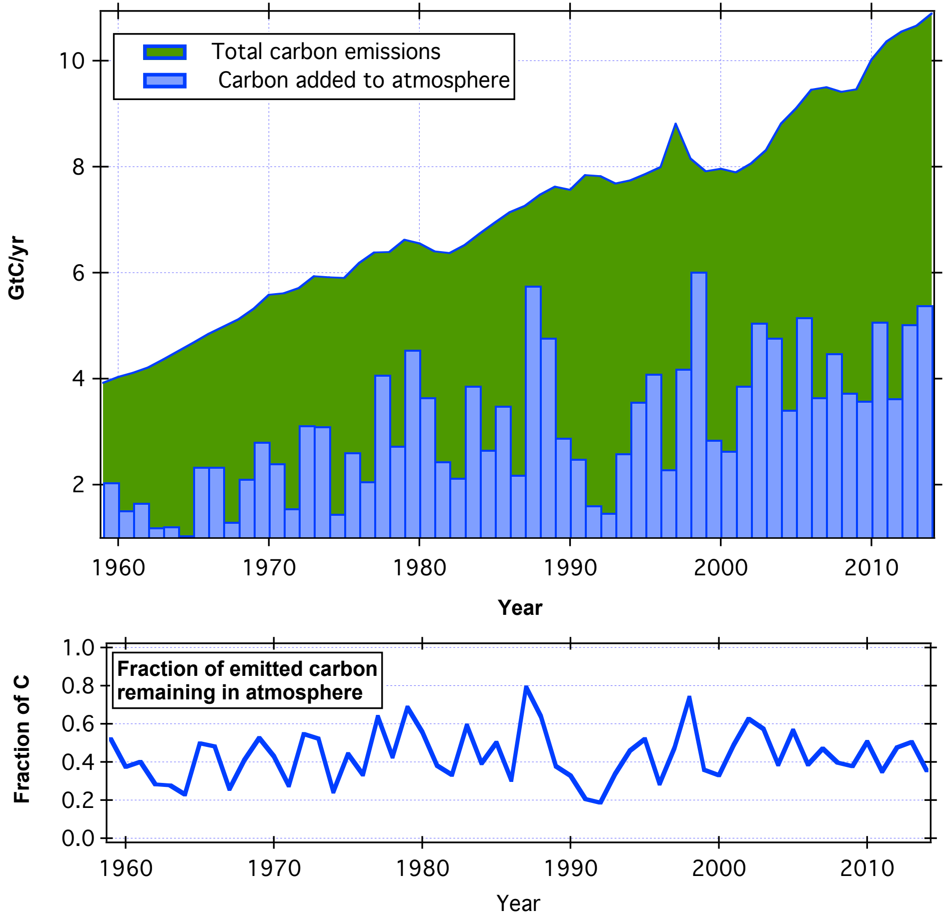


OCO-3 is a NASA-directed climate mission on the International Space Station (ISS)

Primary Mission Objectives: Collect the space-based measurements needed to quantify variations in the column averaged atmospheric carbon dioxide (CO2) dry air mole fraction, X_{CO2}, with the precision, resolution, and coverage needed to improve our understanding of surface CO2 sources and sinks (fluxes) on regional scales (≥1000 km). The precision requirement is identical to that of OCO-2. Operations on ISS allows latitude coverage from 51 deg N to 51 deg S.

Motivation: How Will the Atmospheric CO_2 Growth Rate Evolve?

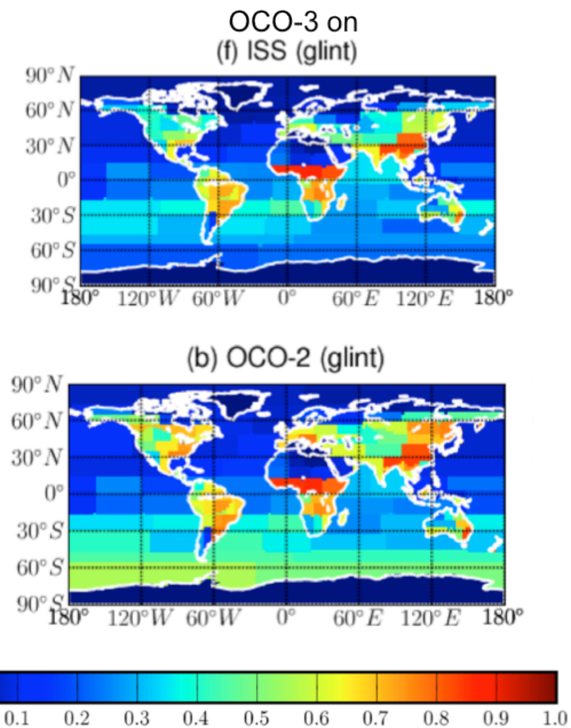
- Humans have added >300 Gt C to the atmosphere since 1958
- Less than half of this CO_2 is staying in the atmosphere
- Where are the *sinks* that are absorbing over half of the CO_2?
  - Land or ocean?
  - Eurasia/North America?
- Why does the CO_2 buildup vary from year to year with nearly uniform emission rates?
- How are variations driven by large scale drivers of atmospheric variability (e. g., ENSO)?
- Can we reduce the uncertainty on each key system within the carbon cycle?
- How will these CO_2 sinks respond to climate change?



Data from LeQuere et al., 2015

OCO-3 Science Overview

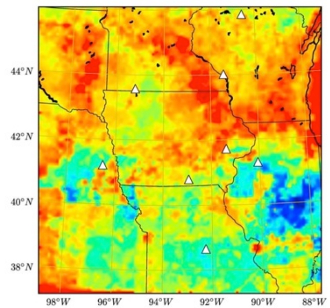
Global Flux Estimates: OCO-2 and OCO-3 impacts (simulated)



Flux error improvement for January

Palmer et al., 2011

Unique Science Opportunities with OCO-3

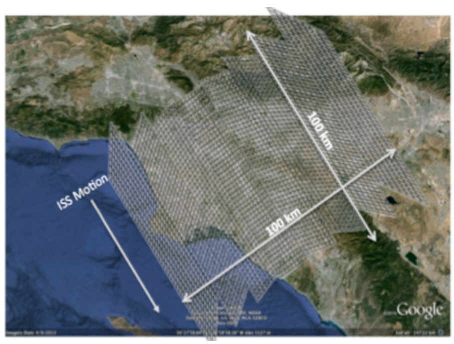


Midwest Carbon Flux

From Schuh et al., 2013

Terrestrial Carbon Cycle

Process studies enabled by measurements at all sunlit hours, including SIF. ISS will contain complementary instrumentation.

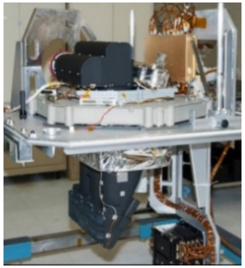


Anthropogenic Emissions

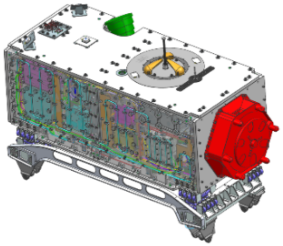
Enabled by enhanced target mode using pointing mirror assembly

OCO-3 Mission Architecture

Spare OCO-2 Instrument



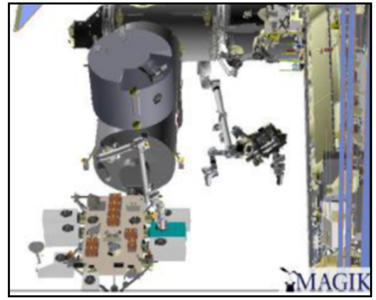
OCO-3 Payload



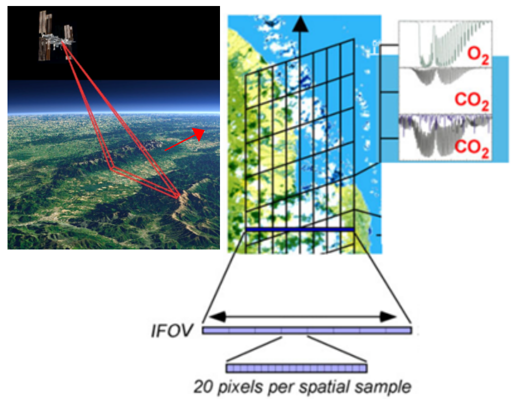
SpaceX Dragon Transfer Vehicle

Falcon-9 LV

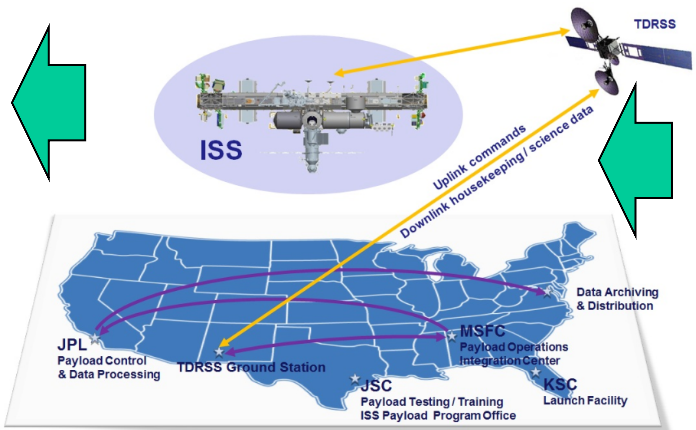
Installation on ISS JEM-EF



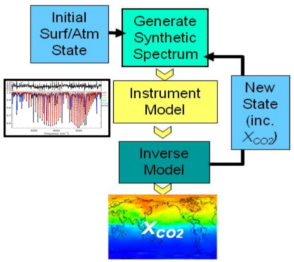
Science Data Collection



Command and Data Flow



Science Data Processing



EOL Payload disposal via Dragon Trunk re-entry

Science Simulations: Overview

- Use early TVAC results to define radiance characteristics
- Evaluation expected SNR and retrieval performance globally and seasonally
- Conclusion: OCO-3 L2 characteristics will be very similar to OCO-3
- Flux community is beginning to work with simulation data

The OCO-3 mission; science objectives and expected performance based on one year of simulated data

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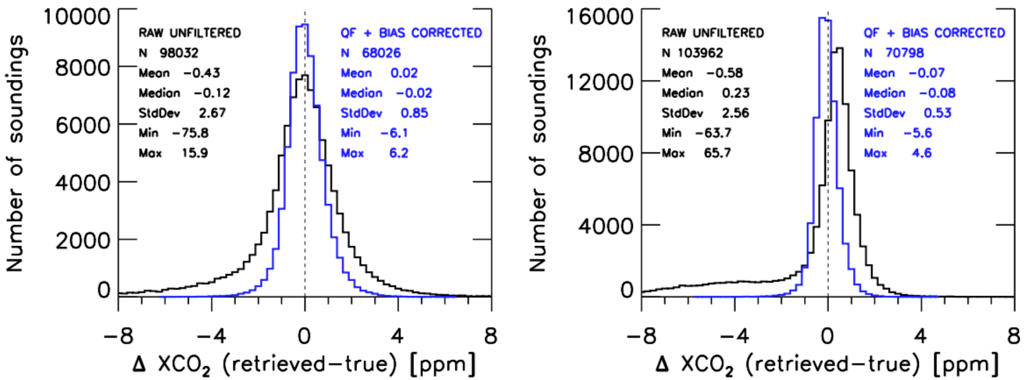

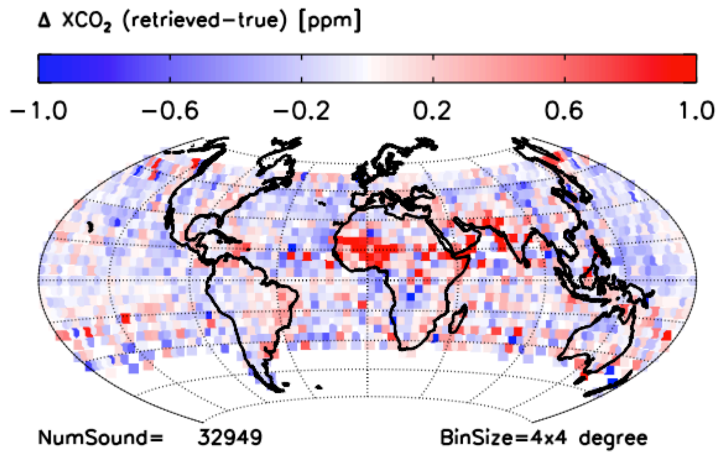

Figure 13. Histograms of the error in XCO_2 (retrieved - true) at 0.25 ppm resolution for land (left) and water (right) for the full year of simulations. The raw, uncorrected XCO_2 are shown in black, while the filtered and bias corrected values are shown in blue.

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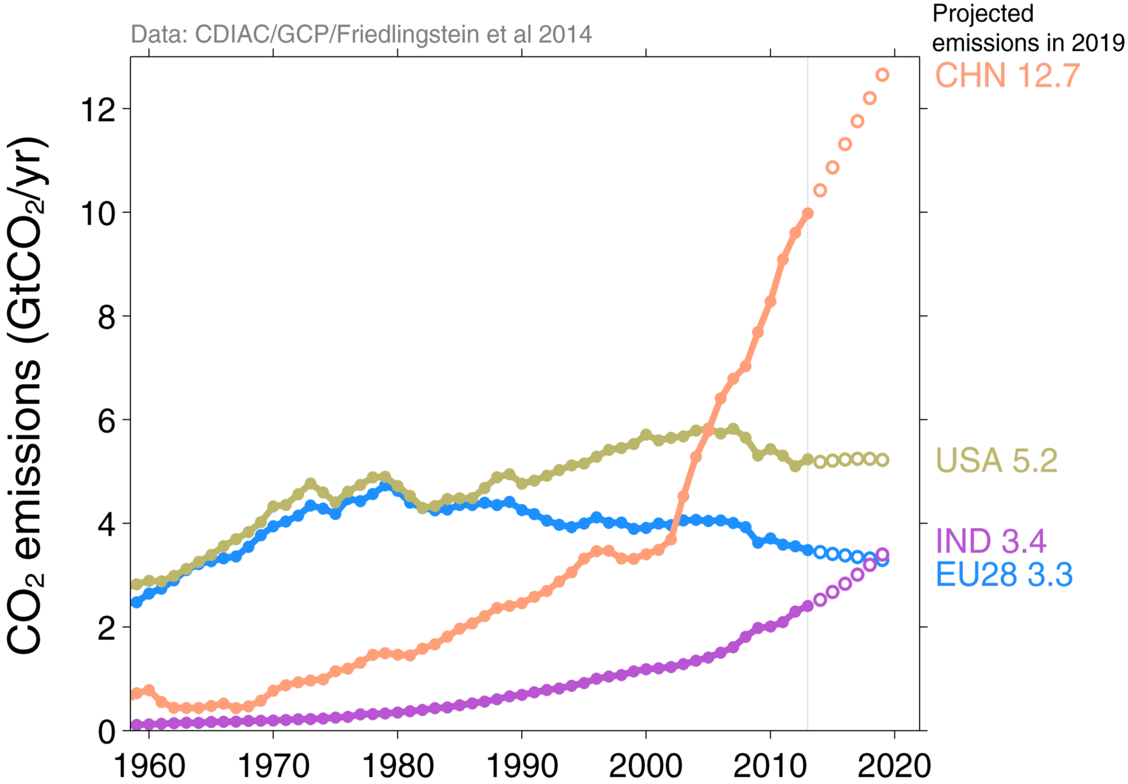
Why emissions hotspots? Emissions Growth is Large and Uncertain

Rapid emissions growth with large uncertainty at regional and local scales

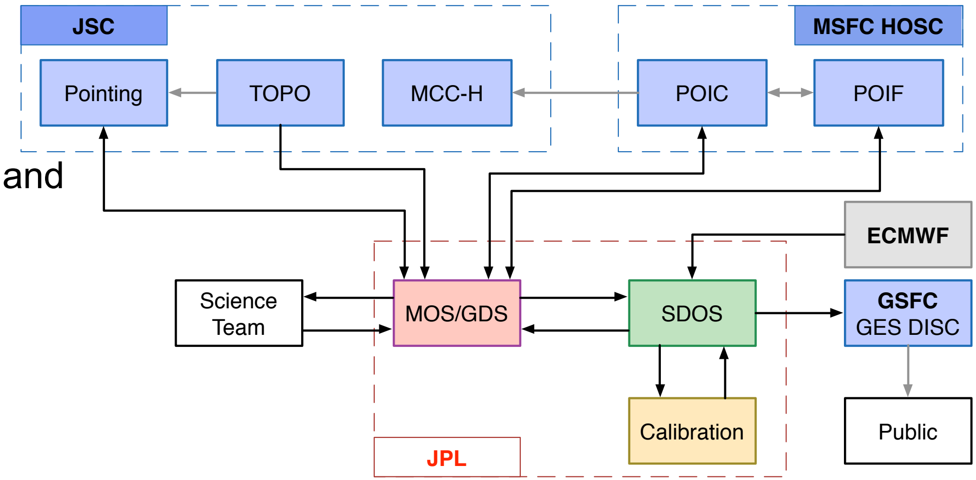


Economic growth based on IMF projections, fossil fuel intensity based on 10-year trend
Source: CDIAC; Friedlingstein et al 2014

- **Global flux analysis assumes $FFCO_2$ is known!**
- 3%/year average global growth rate
- Locally much larger growth rates (50-100% for developing cities, power plants etc)
- Uncertainty at continental scale ranges from 5 to 20%/year
- Uncertainty at process-relevant scales (individual cities and power plants) can be as large as 50-100%

Mission System Overview

- **Mission Operations System (MOS)**
  - Monitor and operate OCO3 during
    - Integration and test
    - In-Orbit Checkout
    - Nominal operations
  - Science observations will be planned and uplinked weekly



JPL MOS/GDS and SDOS Interfaces

- **Ground Data System (GDS)**
  - Command/Telemetry processing
  - Sequence validation
  - Manage HOSC software tools
  - Data delivery to SDOS

- **Science Data Operations System (SDOS)**
  - Create L0, L1 and L2 science products
  - Data delivery to with GES DISC (DAAC)
  - Data delivery to Science Team
  - Science Computing Facility to support large scale testing & algorithm development

Science Planning

- OCO-3 pointing mirror lets us do a lot more than the orbit by orbit nadir/glint measurements of OCO-2. Planning with all this flexibility requires a capable toolset for HANDS OFF operations
- We are leveraging off the JPL CLASP effort and ECOSTRESS experience
- CLASP team has observation plan optimization experience that we will benefit from
- The MOS shall plan up to 100 Area Mapping Mode Opportunities per day during normal operations, in addition to a few TCCON validation targets each day
- Weekly Planned Target Table generated every Tuesday from TOPO data (automated)
  - Includes both TCONN and Area Mapping sites
  - Based on ISS ephemeris, SZA constraints, etc.
- Sequence and uplink mode transitions and all possible targets once per week
- Sequence daily – MOS automatically selects targets of highest value

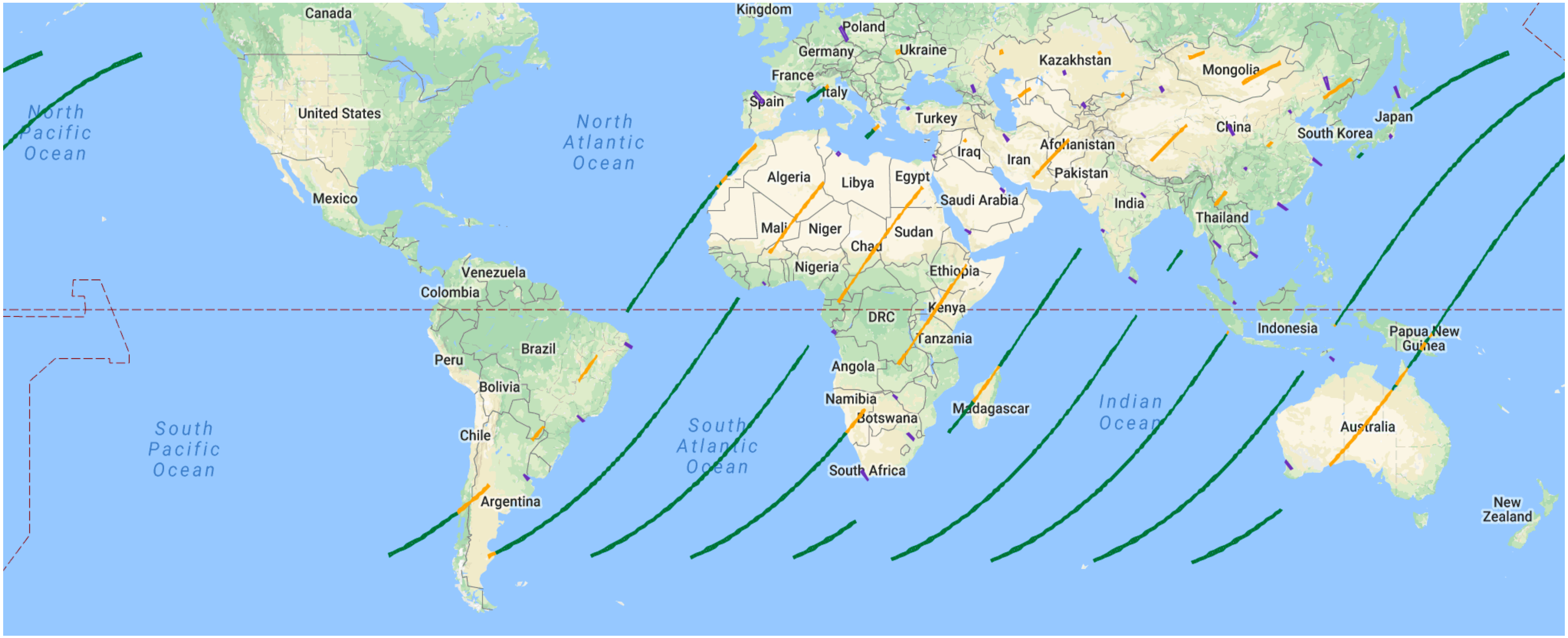
Mode Transition Table

Time	Duration	Mode	Target ID
2015-10-01T 19:05:00	300s	CALIBRATION	N/A
2015-10-01T20:12:36	600s	NADIR	N/A
…	…	…	…

Onboard Target Table

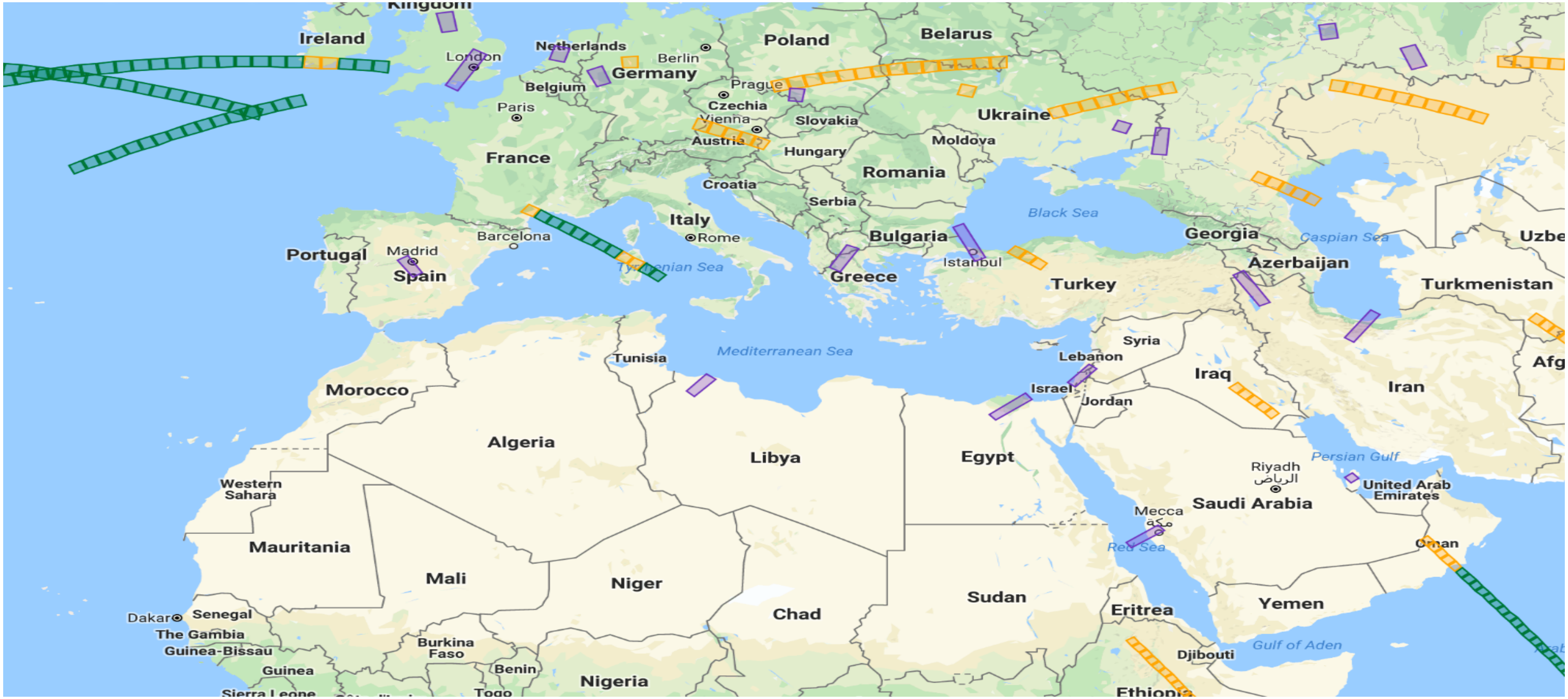
Target	Latitude	Longitude	Elevation
1	34.200° N	118.18° W	0.39 km
…	…	…	…
1335	34.406° S	150.879° E	0.03 km

Sample 1 Day Run of CLASP



Orange: nadir mode
Purple: snapshot area mode
Green: glint mode
SZA between 0 and 75 degrees
Swath size is a constant 10 degrees; off-nadir observations result in larger swaths

Details of CLASP example



Orange: nadir mode

Purple: snapshot area mode

Green: glint mode

SZA between 0 and 75 degrees

Swath size is a constant 10 degrees; off-nadir observations result in larger swaths

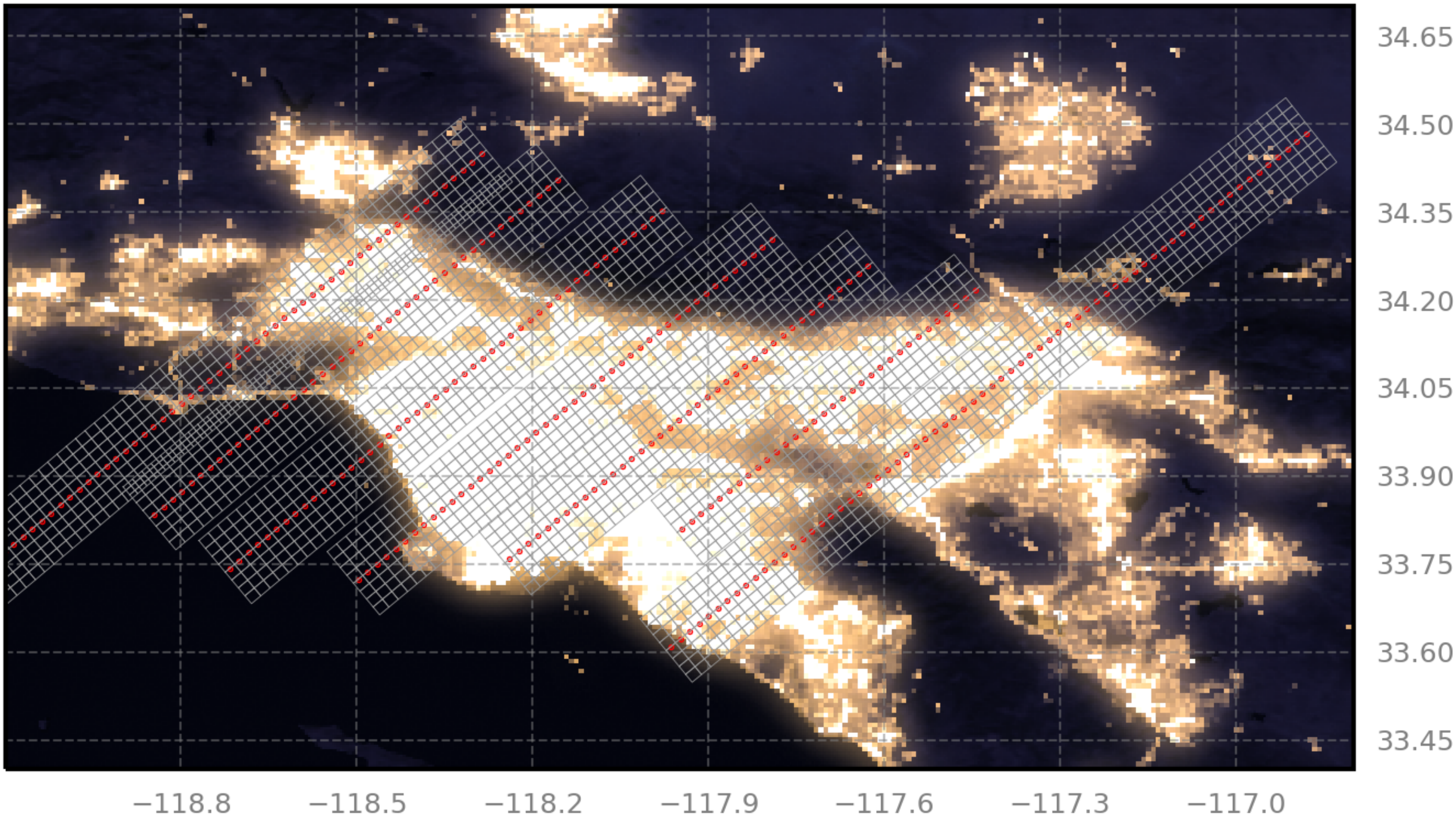
Some details of areas to be mapped

Northern Europe

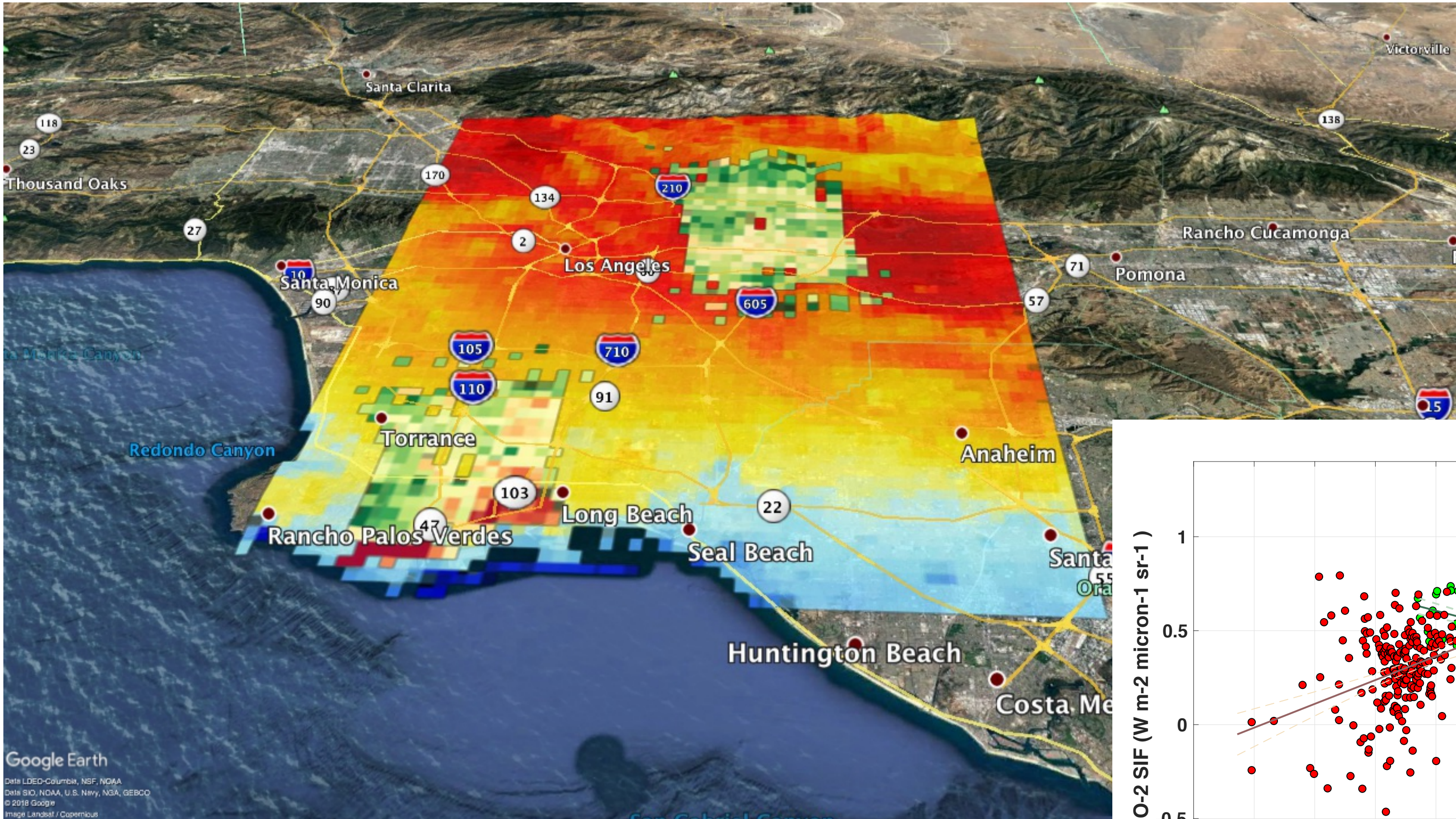
Eastern US

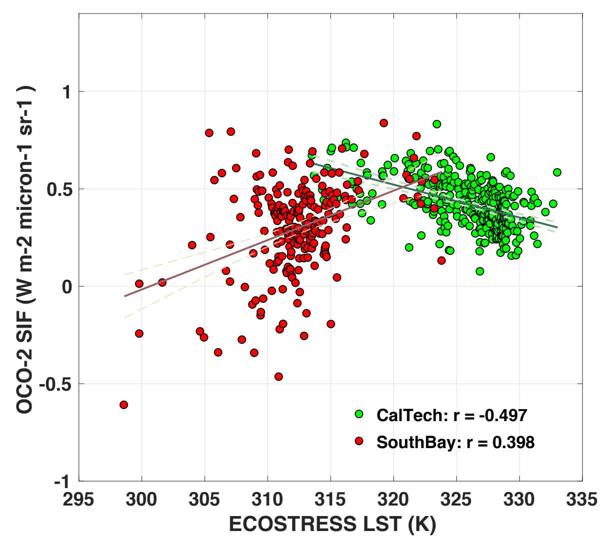
Footprints sketched for snapshot over LA

- There will be footprint rotation – not yet in these simulations

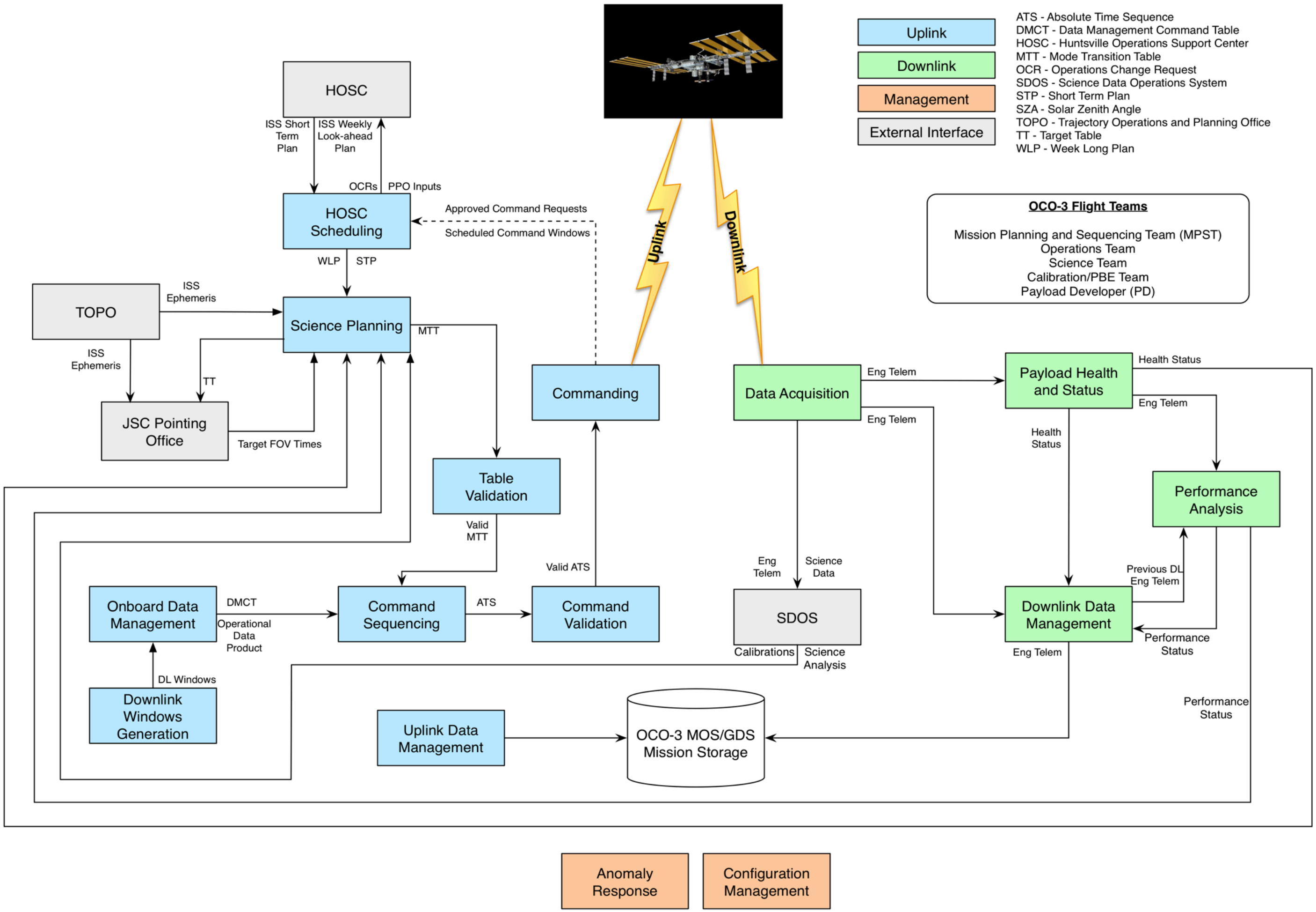


Preparing for ISS Synergy!



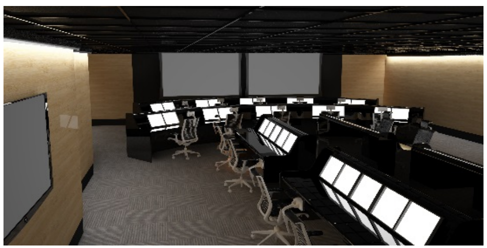


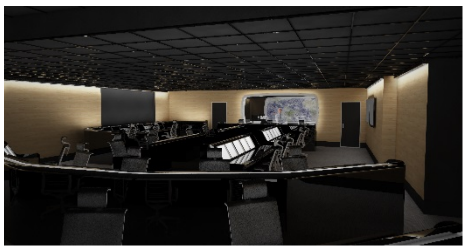
Operations Processes

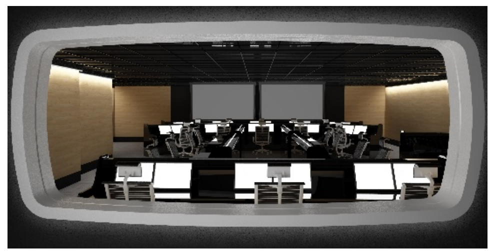


Operations Facilities

- New Integrated Earth Mission Operations Center at JPL
  - 23 operations workstations
  - Conference room with HD (4K × 4K) video touch screen / conference table
- Co-locate with ECOSTRESS
- Occupy 2 workstations
- No conflicts with SMAP, CAL missions
- Science Data Processing in JPL Building 600







Flight Operations Teams

- Mission Operations Manager (MM)
  - Provide management oversight for all MOS activities and processes
- Mission Operations Assurance Manager (MOAM)
  - Responsible for providing an independent assessment of the project's risk posture (risks, mitigations, system failures, failure reports, corrective actions, and lessons learned) directly to the project manager, Mission Assurance Management Office Manager.
- Mission Operations System Team (MOS)
  - Responsible for coordinating with the Science, Calibration, and Operations Team to complete the Science Planning and Validation for uplink.
- Real-Time Operations Team
  - Responsible for uplink commanding and downlink data acquisition and monitoring
- Calibration / Payload Bus Engineering Team
  - Responsible for monitoring the performance and health of the PL and determines what calibrations are needed and when to perform them
- SDS Team
  - Responsible for monitoring the science data processing through L2
- Science Team
  - Responsible for providing analysis of the science data and plays an integral part in the science planning
- HOSC POIC
  - 24/7 monitoring from MSFC
- System Administration
  - Responsible for the monitoring of MOS/GDS/SDS systems during operations