

# **OCO-2 Validation Discussion**

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# OCO-2 Validation Program Outline

- **Background on OCO-2**
- **OCO-2 Validation Approach**
- **OCO-2 Matrix**
- **OCO-2 Validation Testing**

# Carbon Copy to the Extent Possible

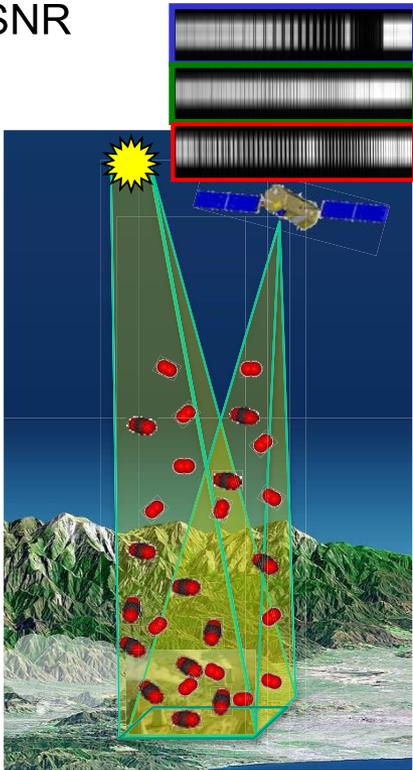
- **NASA's Orbiting Carbon Observatory (OCO) was designed to provide the measurements needed to estimate atmospheric carbon dioxide (CO<sub>2</sub>) with the sensitivity, accuracy, and sampling density needed to quantify regional scale carbon sources and sinks over the globe**
- **February 2009: The OCO spacecraft was lost when its launch vehicle malfunctioned**
- **December 2009: The U.S. Congress directed NASA to build a copy of OCO, called OCO-2**
- **The OCO-2 spacecraft was launched July 2<sup>nd</sup> 2014**



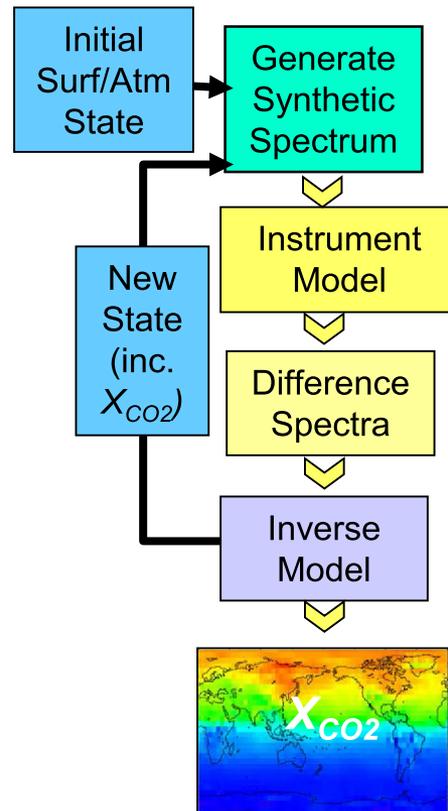
Credit: Bill Ingalls, NASA

# Taking an End to End Measurement Approach

**Collect** spectra of CO<sub>2</sub> & O<sub>2</sub> absorption in reflected sunlight over the globe – with high spatial resolution, spectral resolution, and SNR



**Retrieve** variations in the *column averaged CO<sub>2</sub> dry air mole fraction, X<sub>CO2</sub>* over sunlit hemisphere



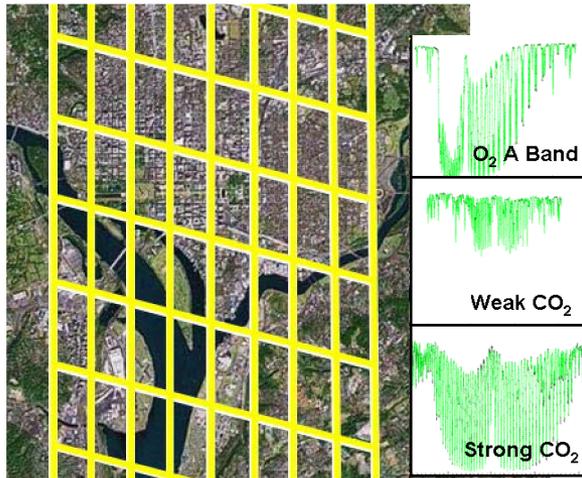
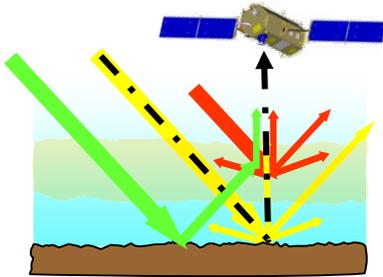
**Validate** measurements to ensure X<sub>CO2</sub> precision of 1 - 2 ppm (0.3 - 0.5%)



# OCO-2 Has Three Observation Modes

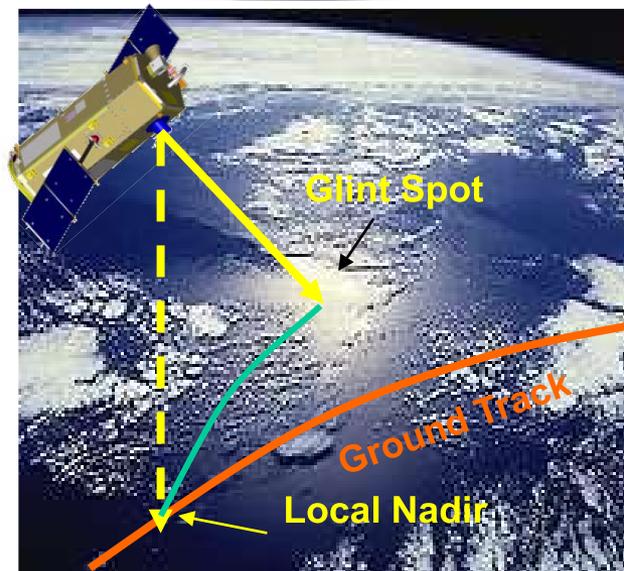
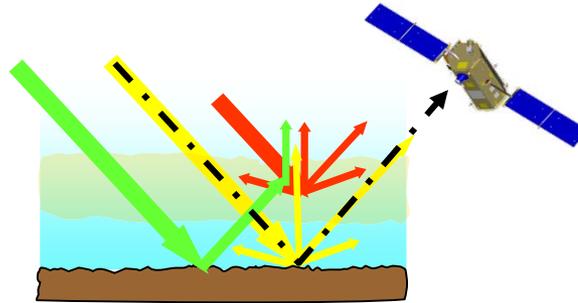
## Nadir Observations:

- + Small footprint (< 3 km<sup>2</sup>)
- Low Signal/Noise over dark surfaces (ocean, ice)



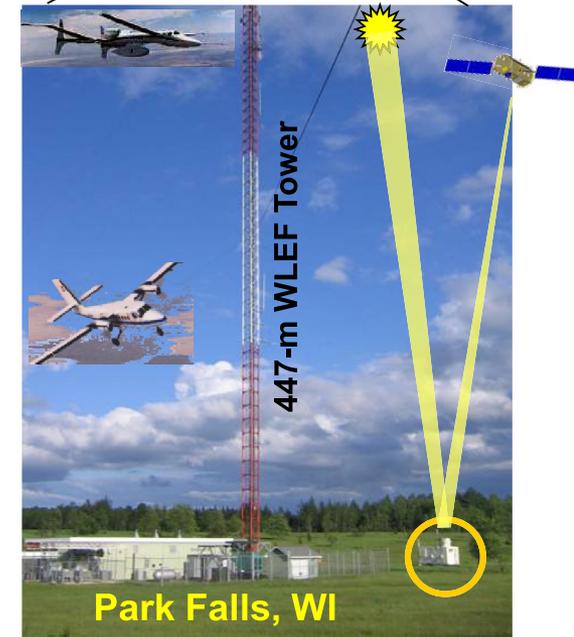
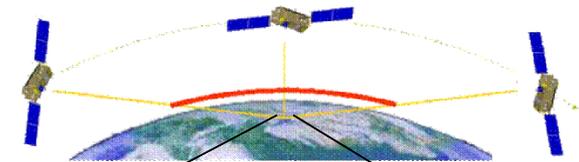
## Glint Observations:

- + Improves Signal/Noise over oceans
- More cloud interference



## Target Observations:

- + Validation over ground based FTS sites, field campaigns, other targets



# Validation is being performed throughout the project lifecycle

- **Validation** confirms that the system is capable of accomplishing its purpose and should be determined by operating the system in a flight like manner.
  - **Requirements Validation** confirms before the system is actually built that the requirements, if met, will satisfy the customer's need or purpose.
  - **Model Validation** confirms that the models and simulations to be used for requirements and system validation are correct.
  - **System Validation** confirms that the as-delivered system (all project elements operating end-to-end in the expected flight environment with reasonable stressing conditions) will meet the driving need (i.e., "Does what we built meet the objectives?").

# OCO-2 Validation approach focused on system validation

- **Requirements Validation**

- Verifiable
- Traceable
- **Completeness**

- **Model Validation**

- Thermal
- Power
- Navigation
- Instrument Testbed
- Spacecraft Testbed
- Etc.

- **System Validation**

- Fault Tree Analysis
- **Validation Matrix**
- Validation Testing

# OCO-2 Used the validation matrix to inform and prepare for the mission ORTs

	B	C	D	E	F	G	H	I	J
1									
2	Pre-Launch	Launch	In-Orbit Checkout	Nominal Operations	Decommissioning	Objectives	Allocation (Event)	Allocation (Participants)	Link
3									
4						Nominal Operations			
5						<b>Demonstrate ATS Generation and Uplink</b>			
12						Demonstrate the MOS is able to Generate the Orbit Events File (OEF)	ORT 1, ORT 2, ORT 3, ORT 4	MOS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
13						Demonstrate the MOS is able to Generate the Absolute Time Sequence (ATS)	ORT 1, ORT 2, ORT 3, ORT 4	MOS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
14						Demonstrate the MOS is able to Perform Constraint Checks on the ATS	ORT 1, ORT 2, ORT 3, ORT 4	MOS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
15						Demonstrate the MOS is able to Generate the Command Authorization Request (CAR)	ORT 1, ORT 2, ORT 3, ORT 4, ORT 5	MOS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
16						Demonstrate the MOS is able to Uplink the ATS to the S/C	TVAC, ORT 1, ORT 3, ORT 4	MOS, FlatSat & OBS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
17						Demonstrate the S/C is able to Receive and Store the ATS	TVAC, ORT 1, ORT 3, ORT 4	MOS, FlatSat & OBS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
18						Demonstrate the MOS is able to Confirm Receipt of the ATS by the S/C	TVAC, ORT 1, ORT 3, ORT 4	MOS, FlatSat & OBS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
19						Demonstrate the MOS is able to Activate the ATS	TVAC, ORT 1, ORT 3, ORT 4	MOS, FlatSat & OBS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
20						Demonstrate the S/C is able to Activate the ATS	TVAC, ORT 1, ORT 3, ORT 4	MOS, FlatSat & OBS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
21						Demonstrate the MOS is able to Confirm Activation of the ATS	TVAC, ORT 1, ORT 3, ORT 4	MOS, FlatSat & OBS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
22						<b>Target Enable Process</b>			
23						Demonstrate the MOS is able to Monitor Target Opportunities	TVAC, ORT 1	MOS, FlatSat & OBS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
24						Demonstrate the MOS is able to Identify Target Opportunity to be Enabled	TVAC, ORT 1	MOS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
25						Demonstrate the MOS is able to Generate the Target Enable Command	TVAC, ORT 1	MOS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
26						Demonstrate the MOS is able to Uplink the Target Enable Command	TVAC, ORT 1	MOS, FlatSat & OBS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
27						Demonstrate the S/C is able to Enable the appropriate Target RTS	TVAC, ORT 1	MOS, FlatSat & OBS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>
28						Demonstrate the MOS is able to Confirm the appropriate Target RTS has been Enabled	TVAC, ORT 1	MOS, FlatSat & OBS	<a href="https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf">https://alpha-lib.jpl.nasa.gov/docushare/dsweb/Get/Document-899437/ORT1_WITL_TestProcedure_FINAL.pdf</a>

# Generating the Validation Matrix

- **Operational Objectives**
  - **Start with the ops concept and work down**
    - **Phases**
    - **Activities during each phase**
    - **Specific actions needed to execute those activities**
- **Event Allocations**
  - **Assign the objectives to operational leads**
  - **Start with already planned tests (ORTs, TVAC, Thread Tests, CPTs, MSTs etc.)**
  - **In conjunction with the operational leads match the objectives to their test**
- **Use the matrix for ORT planning and execution**
- **This is not a check list!**

# OCO-2 MOS Overview

- **3 mission phases**
  - **Launch / In Orbit Checkout**
  - **Nominal Operations**
  - **Decommissioning**
- **Modeled after GALEX mission operations**
  - **Orbital ATK providing uplink, product generation & safety monitoring**
  - **JPL providing science planning & automated data processing**

# Integrating the Validation Matrix into MOS Planning

- **Validation matrix tasks and & functions feed into MOS test planning**
- **Focusses on the core competencies of the MOS**
  - **Uplink**
  - **Downlink**
  - **Navigation**
  - **Spacecraft/science operations**
- **Thread test and ORT preparation**

# OCO-2 Mission Validation Activities

Number	THREAD TESTS	Test Executed Successfully	Status
<b>Uplink Process</b>			
T01	Sequence Development	9/30/13 - 10/11/13	PASS
T02	Real Time Command Process - Target Enable	10/22/13 - 10/24/13	PASS
T03	Real Time Command Process - Bad Pixel Map Generation	11/30/13 - 12/22/13 TVAC2	PASS
<b>Downlink Process</b>			
T04	Retransmission from ESMO-EDOS to SDOS	11/11/2013	PASS
T05A	Retransmission from ESC-NEN to SDOS	12/11/2013	PASS
T05B	Retransmission from ESC-NEN to MOC	Scheduled WK of April 28, 2014	PASS
T06	SDOS Data Processing	2/25/2014	PASS
T07	Ground Software Update	10/10/2013	PASS
<b>Navigation</b>			
T08	Maneuver Generation Process	1/21/14 - 1/22/14	PASS
T10	Risk Mitigation Maneuver (RMM) Planning	1/27/14 - 1/29/14	PASS
<b>Deliveries</b>			
T09	Ancillary Radiometer Product (ARP) Delivery (Cal -> SDOS)	01/13/13-01/14/13	PASS

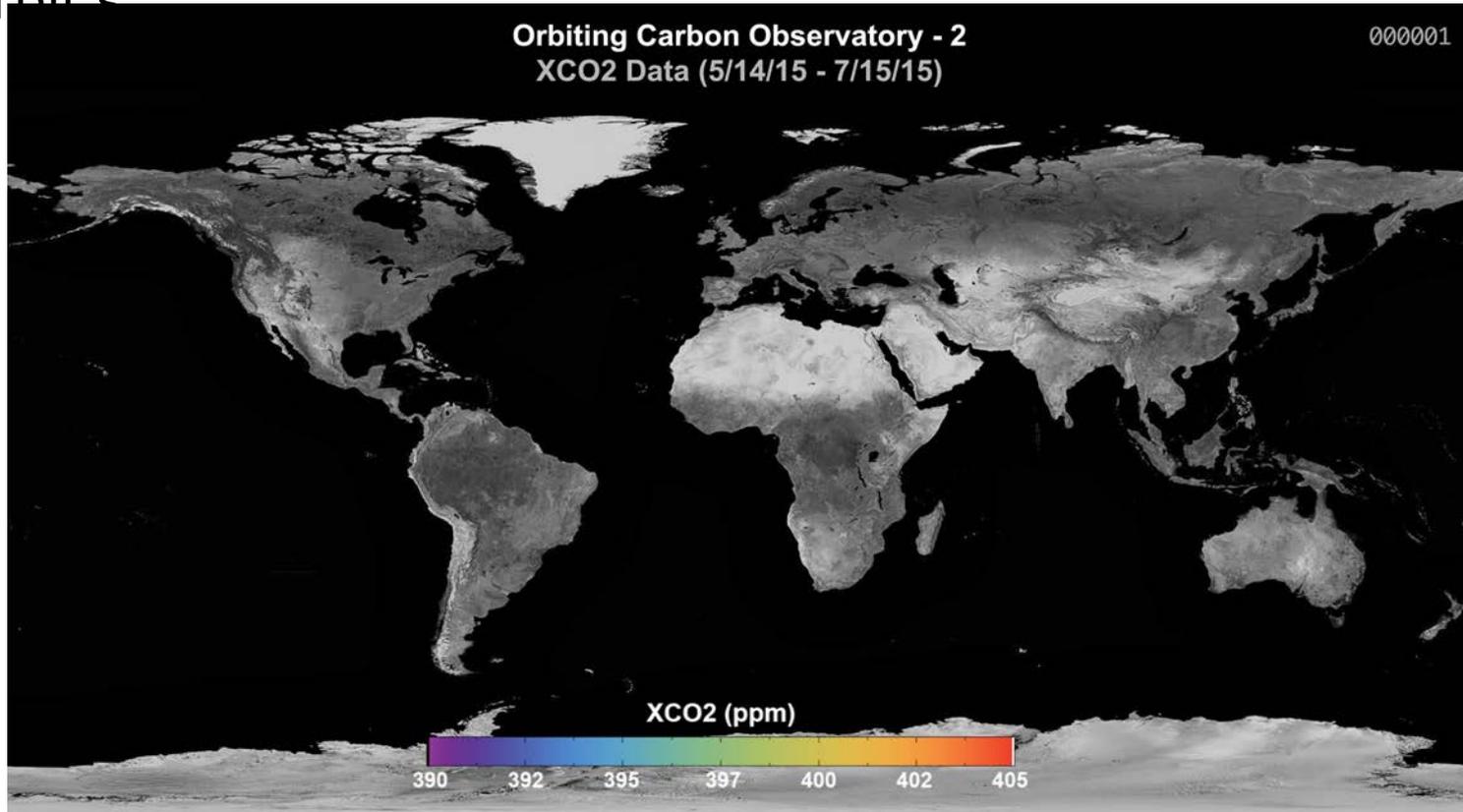
Number	MSTs/CPT - PERFORMED ON S/C	Test Executed Successfully	Status
MST1	Instrument to Spacecraft Fault Detection & Correction (FDC)	08/10-17/13	PASS
MST2	Nominal Ops (Pre-Vac)	Oct 2012 (WSVT)	PASS
MST3	Spacecraft Team	08/10-16/13	PASS
MST4	Instrument Day In The Life (TVAC)	12/11-13/13	PASS
MST5	Ascent Maneuver Execution Simulation	12/7-12/2013	PASS
MST6	Maintenance Maneuver Simulation	12/17-18/13	PASS

Number	EEIS Tests	Test Executed Successfully	Status
E01	RF Compatibility Test	<b>Part 1</b> March 2012 <b>Part 2</b> ~ April 17, 2014	PASS
E02	S-Band/ X-Band Data Flow from NEN to the SDOS	04/02/14	PASS

Number	ORTs	Scheduled Date	Test Executed Successfully	Status
ORT1	Week in the Life	2/10/14 - 2/14/14	02/10-14/14	PASS
ORT2	Navigation	3/11/14 - 3/14/14	3/11-14/14	PASS
ORT3	LEOPS Nominal	3/26/14 - 3/27/14	3/26-27/14	PASS
ORT4	LEOPS Anomalous	5/14/14 - 5/16/14	5/14/14 - 5/16/14	PASS
ORT5	Launch Day Dress Rehearsal	6/26/2014	6/26/2014	PASS

# In Summary

- OCO-2 has been in operations for over a year with over 6000 orbits



- Questions?

# Back Up

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