GeoCarb

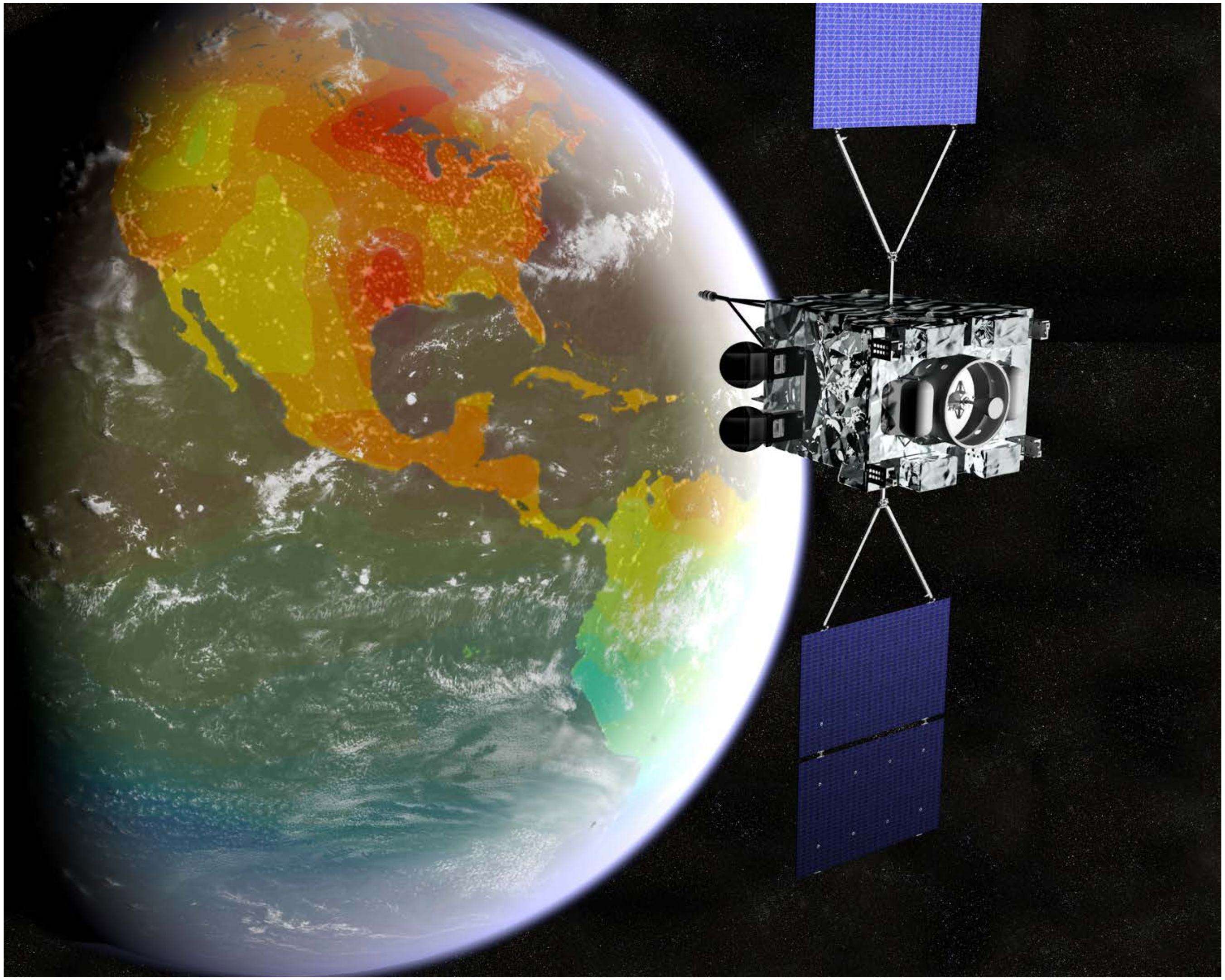
Earth Venture Mission-2

CEOS AC-VC-14 Greenhouse Gas Meeting

2 May 2018

Principal Investigator: Berrien Moore III

Geostationary Carbon Cycle Observatory



GeoCarb: Built on Strong Partnerships

GeoCarb

OU

LOCKHEED MARTIN

SES

NASA

JPL

Goddard SPACE FLIGHT CENTER

Ames Research Center

Colorado State University

LSCE
LABORATOIRE DES SCIENCES DU CLIMAT & DE L'ENVIRONNEMENT

LMD

POSTERA CRESCAM LAUDE
THE UNIVERSITY OF MELBOURNE

AEXA
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GeoCarb Mission: Overview

The GeoCarb Mission is designed to collect observations of the column averaged concentrations of carbon dioxide (CO_2), methane (CH_4), and carbon monoxide (CO), and solar induced fluorescence (SIF) from geostationary orbit (GEO) at a spatial resolution of 5-10 km over the Americas between 55º North and 55º South Latitudes using a SES communication satellite in orbit near 85º West longitude.

The Goal of the GeoCarb Mission *is to provide observations and demonstrate methods to realize a transformational advance in our scientific understanding of the global carbon cycle.*

Fate of anthropogenic CO_2 emissions (2006-2015)

Source: CDIAC; NOAA-ESRL; Houghton et al 2012; Giglio et al 2013; Le Quéré et al 2016; Global Carbon Budget 2016

34.1 $GtCO_2$/yr

91%

9%

3.5 $GtCO_2$/yr

Sources = Sinks

16.4 $GtCO_2$/yr

44%

31%

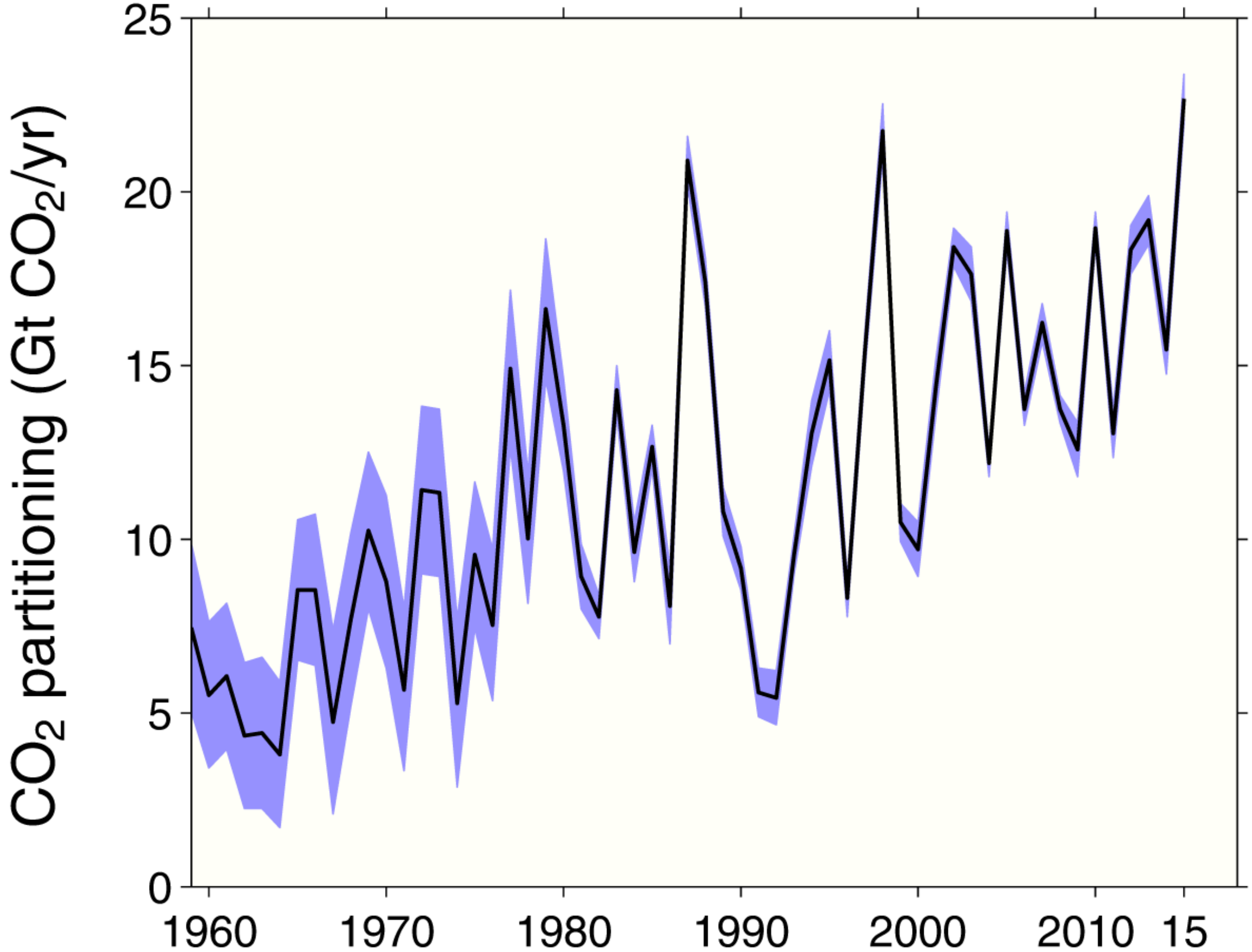
11.6 $GtCO_2$/yr

26%

9.7 $GtCO_2$/yr

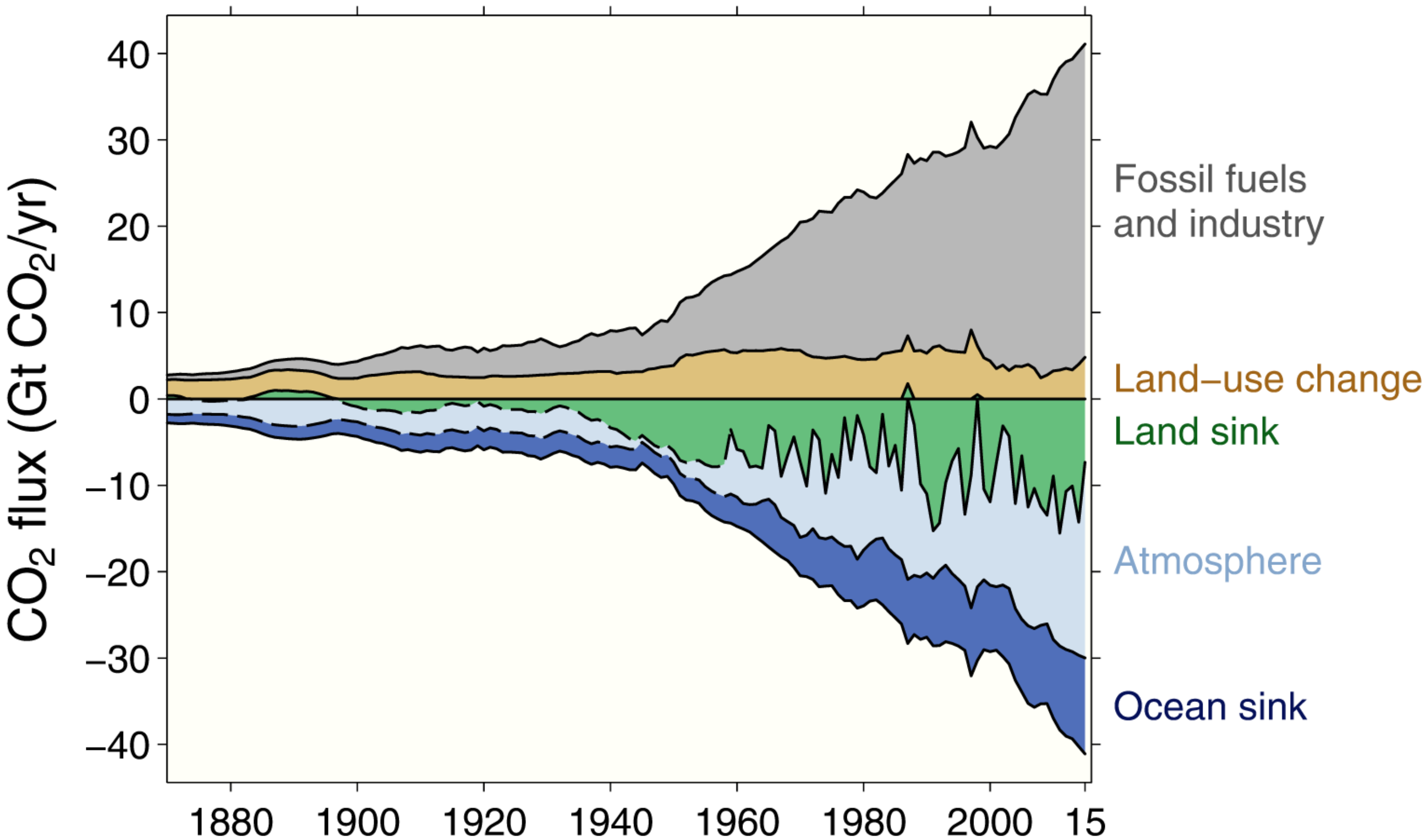
Atmospheric concentration (2 of 2)

The atmospheric concentration growth rate has shown a steady increase
The high growth in 1987, 1998, & 2015 reflects a strong El Niño, which weakens the land sink



What is the nature of the Terrestrial Sink?

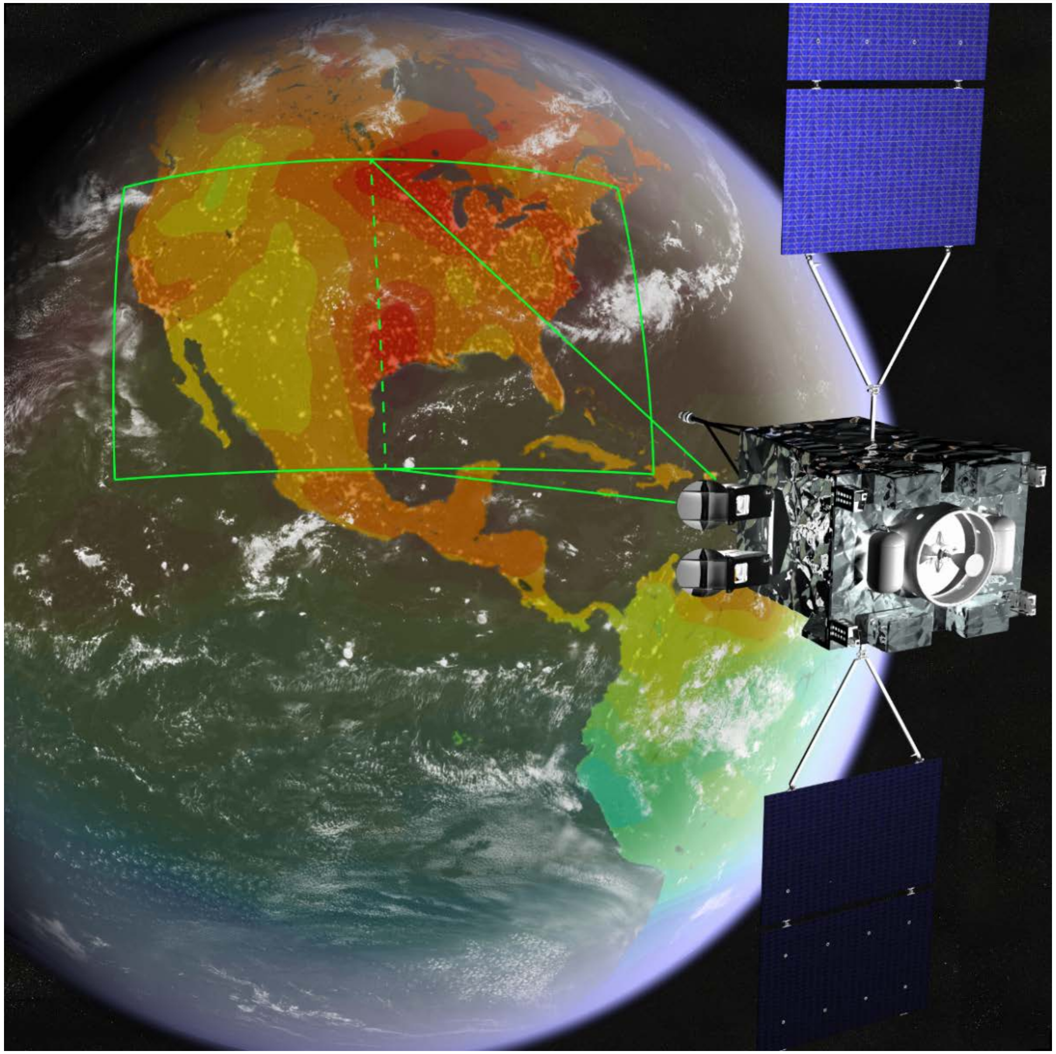
The carbon sources from fossil fuels, industry, and land use change emissions are balanced by the atmosphere and carbon sinks on land and in the ocean



GeoCarb: A Step to a Carbon Observing System

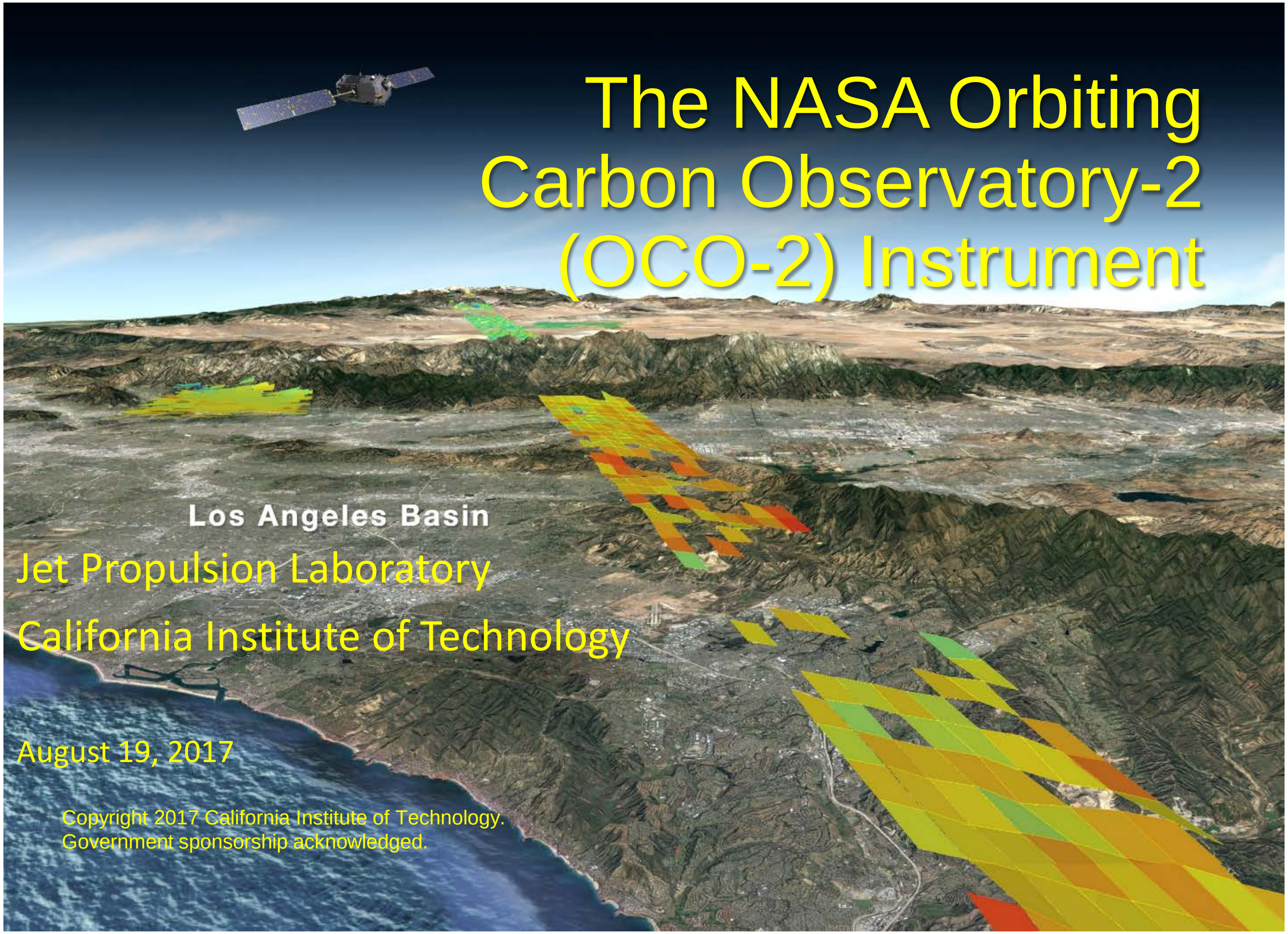
Carbon Monitoring from Earth and from Space: A Global Necessity

OCO-2: The Foundation for GeoCarb

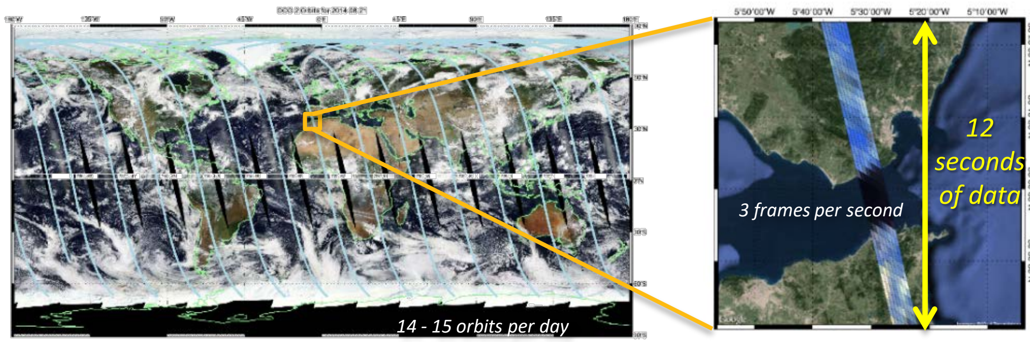


Without OCO-2, GeoCarb would be a Bridge Too Far

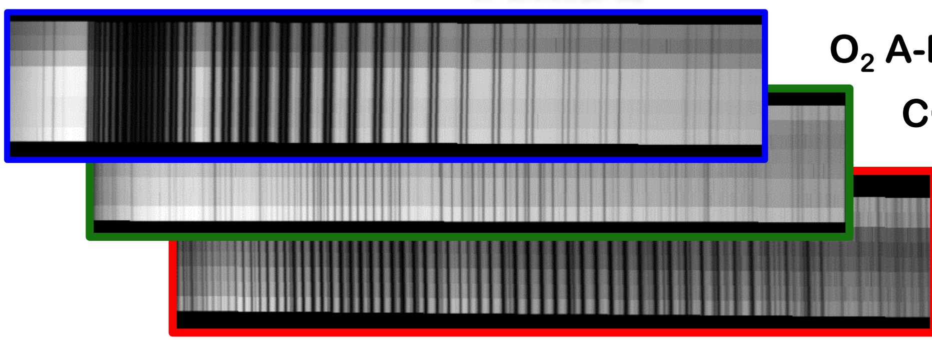
OCO-2: The Foundation for GeoCarb



OCO-2 Sampling Approach



Cross-track swath for nadir observations is ~10.5 km wide



O_2 A-Band

CO_2 1.61 μm Band

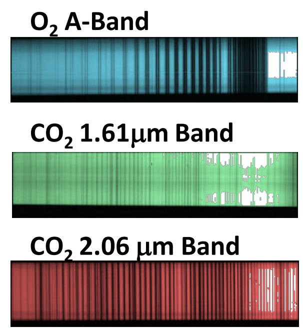
CO_2 2.06 μm Band

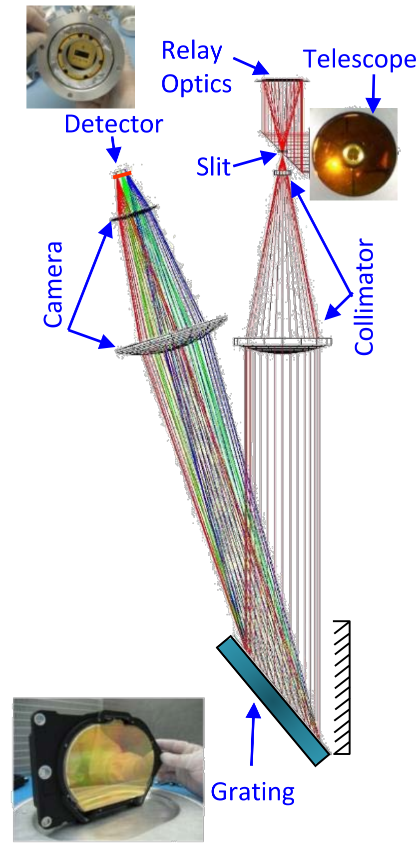
The OCO-2 instrument collects 24 soundings each second as it flies over the sunlit hemisphere of the Earth, yielding almost 1 million soundings each day

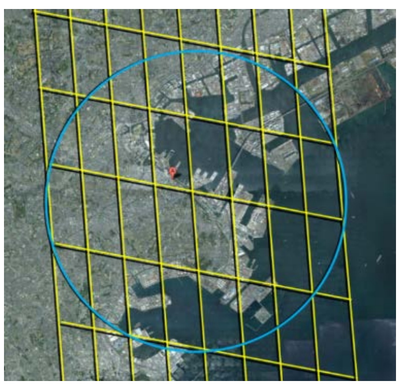
OCO-2 Instrument – Optimized for Sensitivity

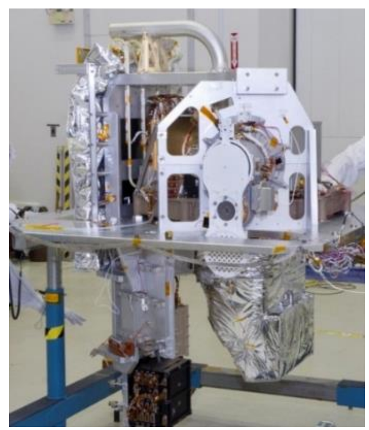
3 co-bore-sighted, high resolution, imaging grating spectrometers

- Resolving Power 17,000 - 20,000
- High Signal-to-Noise Ratio
- Collects 24 soundings / sec over a narrow (0.8º) swath
  - 10^6 soundings / day over the sunlit hemisphere

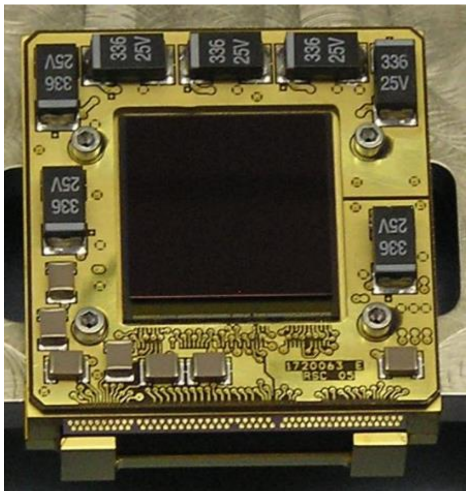


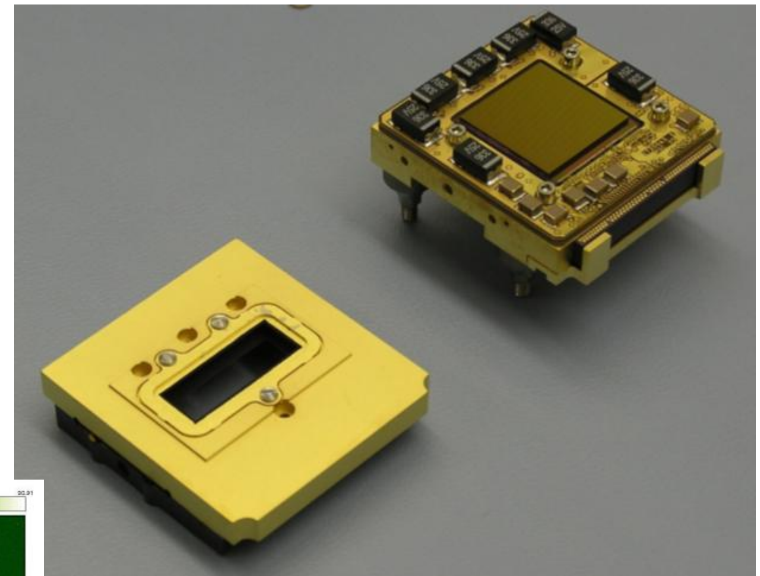




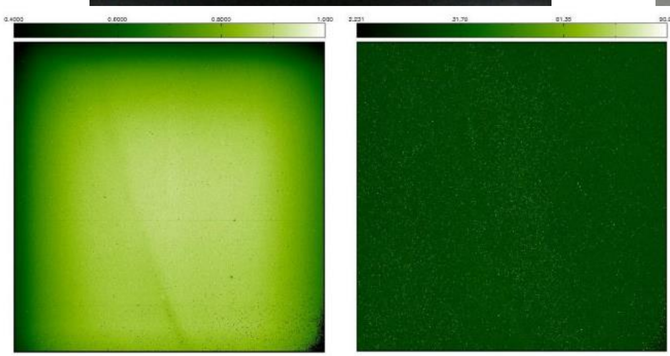


OCO-2 Focal Plane Arrays (Teledyne)



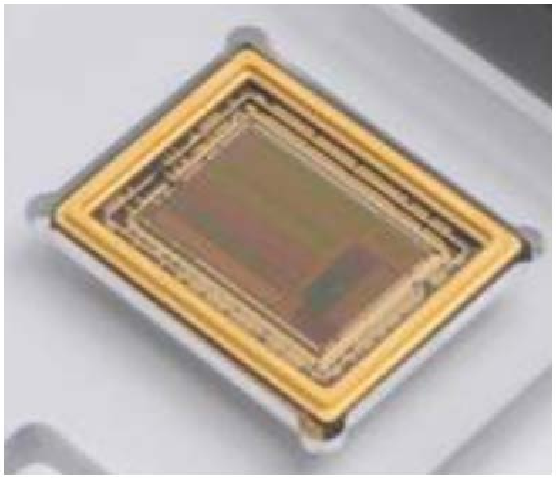


OCO-2 FPA packaging and mask

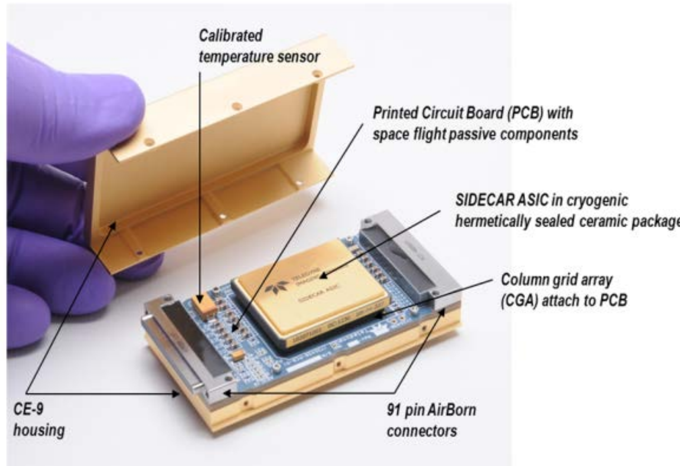


Illumination and Dark response

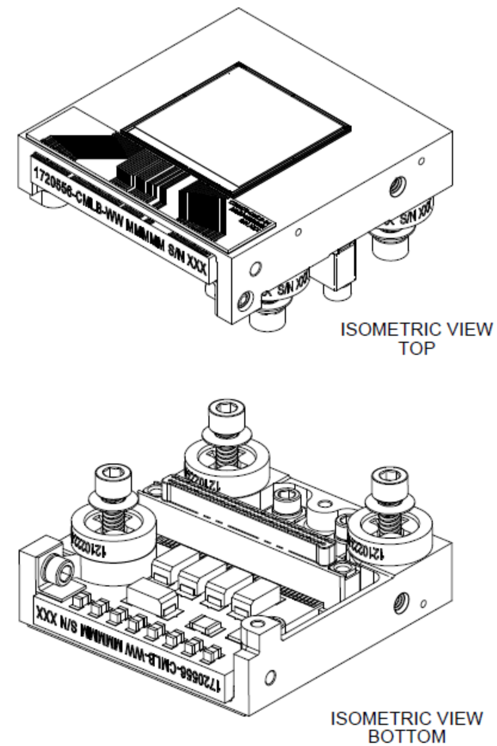
GeoCarb Focal Plane Arrays (Teledyne)



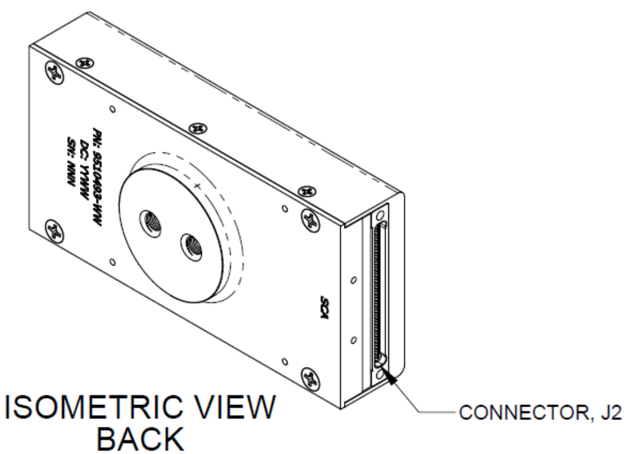
Cryogenic SIDECAR Package



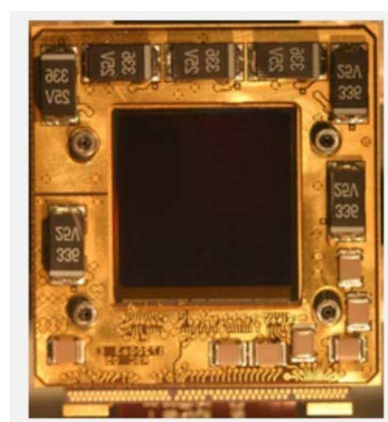
SIDECAR ASIC Module (SMd)



H1RG FRSBE Package



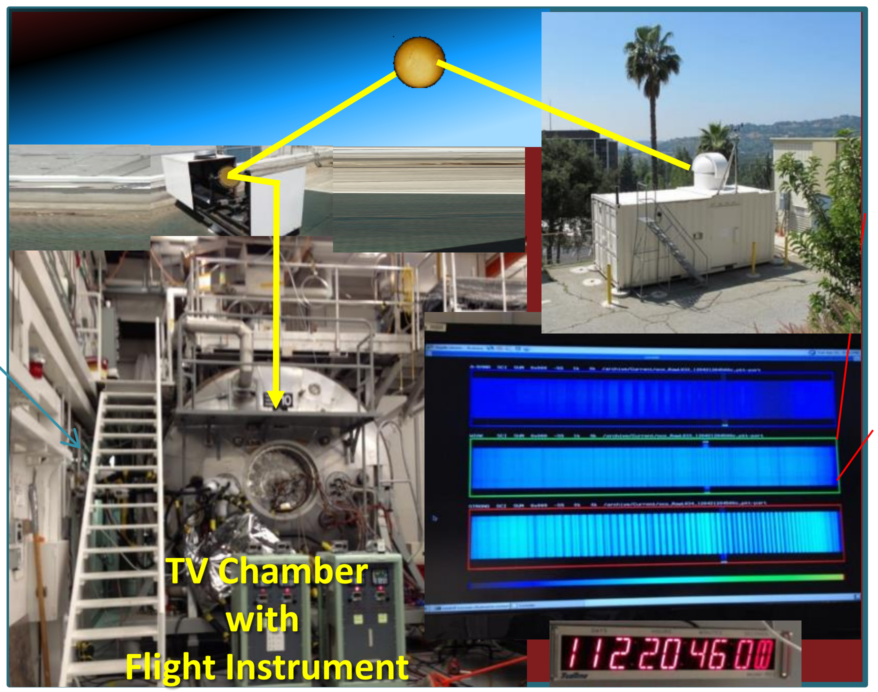
SMd Module (Assembled)

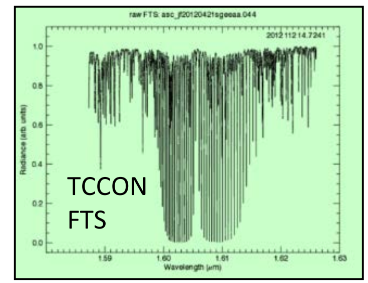


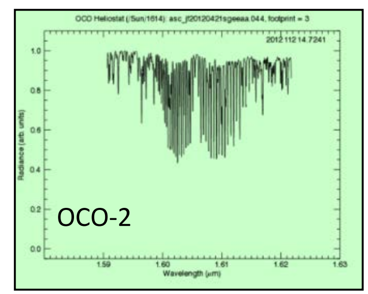
SpaceFlight H1RG

OCO-2 in Chamber with External TCCON

Simultaneous observations of the sun with the flight instrument and a co-located TCCON FTS taken during the thermo-vacuum tests provided an end-to-end test of the instrument performance.





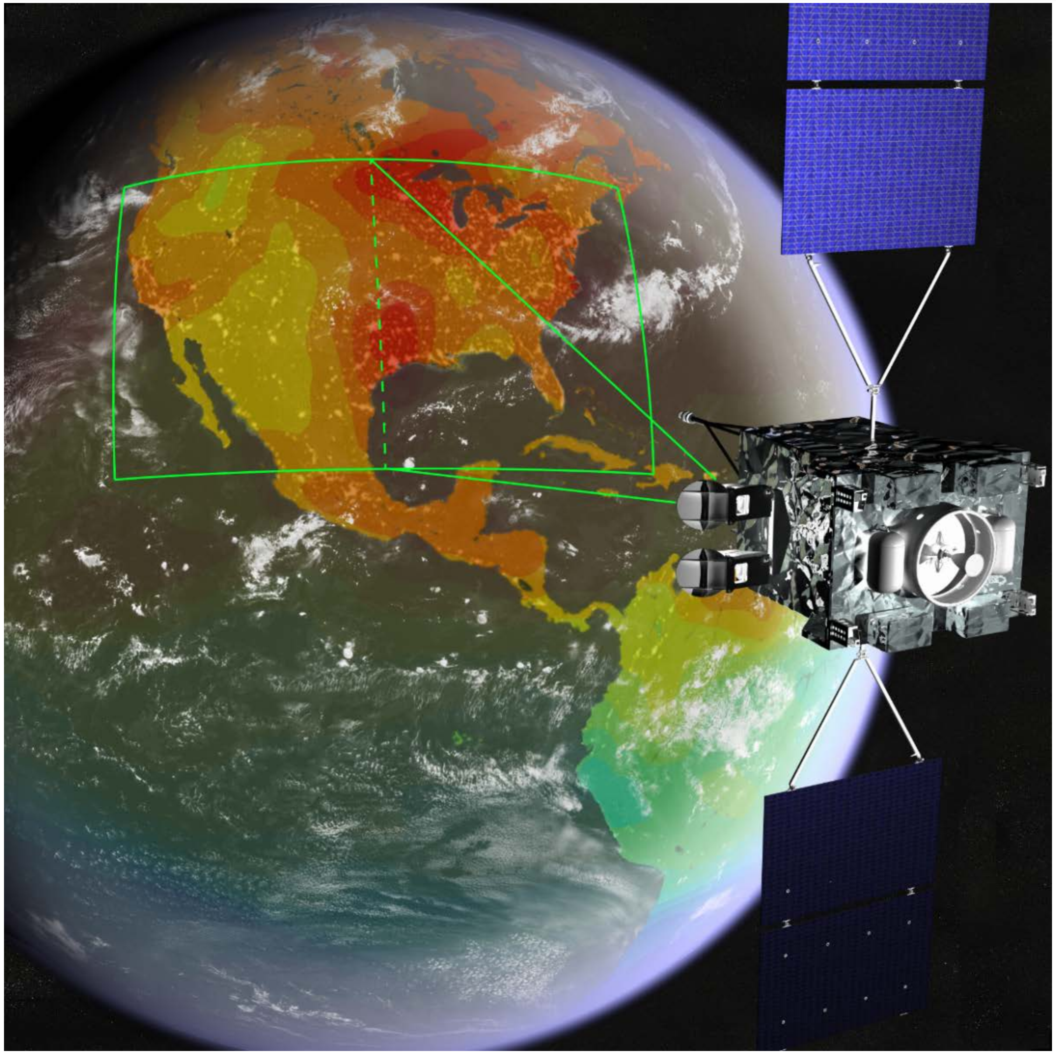


GeoCarb plans to follow this Path

Algorithm Heritage from OCO-2 and GOSAT

- **XCO_2 retrieval developed since ~2004 for OCO, then GOSAT (2009), and OCO-2 (2014).**
- **SIF retrieval developed at JPL for GOSAT (2010) and OCO-2 (2014)**
- **XCO2 have been extensively validated with GOSAT & OCO-2 data.**
- **SIF has been preliminarily validated from OCO-2.**
- **The OCO-2 algorithm serves as the starting point of the GeoCarb retrieval for the gas columns; the Caltech/JPL SIF retrieval will serve as the starting point for GeoCarb SIF algorithm.**
- **Early tests with a modified OCO-2 algorithm to include the XCH_4 and XCO (via band 4) show that GeoCarb promises to meet its requirements for these gases.**

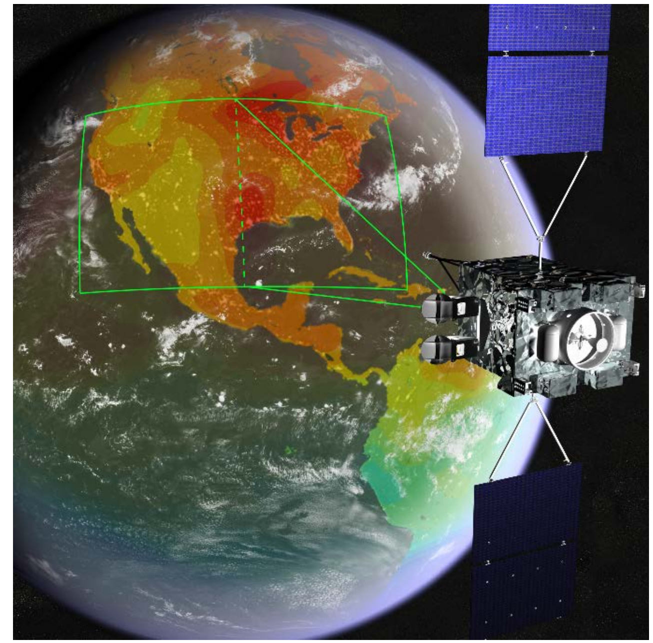
OCO-2: The Foundation for GeoCarb



Without OCO-2, GeoCarb would be a Bridge Too Far

Carbon System: CO_2, CH_4 and CO

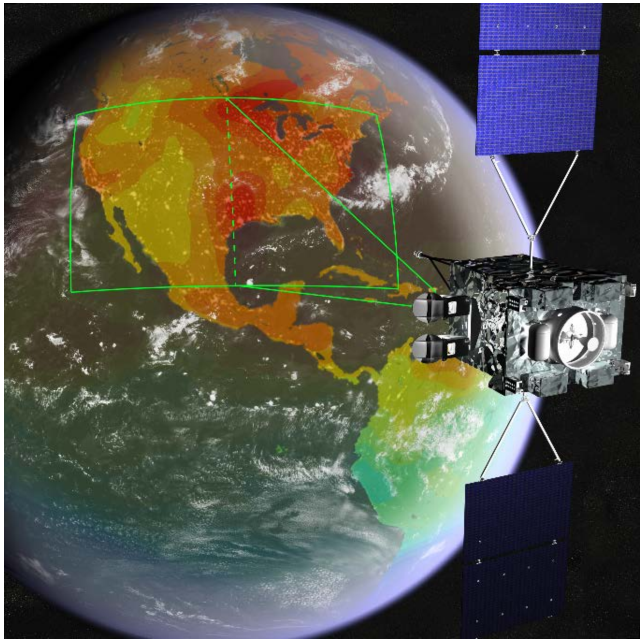
- **Human caused flux of CO_2--45% remains in the atmosphere; 30% is sequestered in the terrestrial biosphere and 25% is taken up by the ocean. *We do not understand the processes that are leading to this dynamic.***
- **The IPCC and CH_4: There are large uncertainties in sources and sinks given the interwoven complexities of human impacts via agriculture and industry and natural sources. *We cannot balance the CH_4 Budget.***
- **Measurements of CO are hugely valuable for health and provide important information for CO_2 and CH_4 *source attribution*.**



Methane Leakage from natural gas production "costs" industry $5-10 Billion dollars annually in the USA

Why GeoCarb???

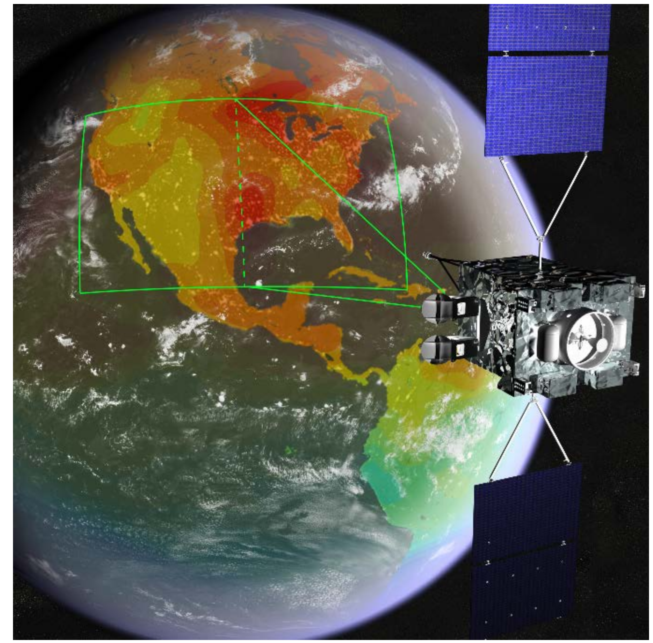
- **Atmospheric Concentrations of Carbon Gases are a combination of fluxes at the surface and the motions of the atmosphere. Resolving terrestrial fluxes *requires observations that are spatially and temporally dense.***
- **Low Earth Orbiting satellites can have long revisit times and large gaps in coverage.**
- **Weather affects ecosystems on the time scale of days to weeks, meaning that polar orbiters may miss ecosystem transitions and hence fail to connect with biogenic processes. Connecting to processes is *essential* for Earth System Model *needed* improvements.**



Anthropogenic sources are concentrated in small areas relative to natural processes, which makes them even harder to detect and differentiate from biogenic emissions with current observing systems.

An "Unexpected" Application via Solar Induced Fluorescence

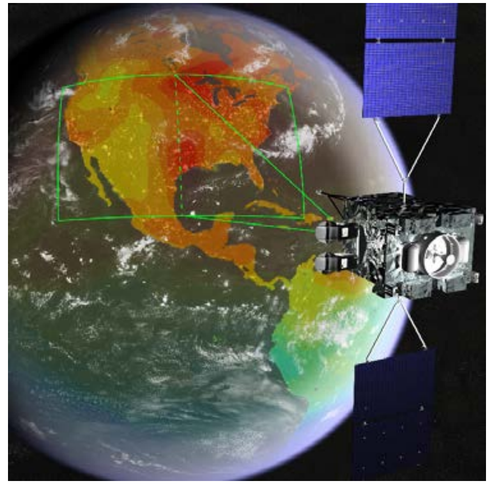
- **Photosynthesis of crops and grasses is sensitive to drought. Agricultural drought can be very costly. SIF data track well the impacts on photosynthesis of drought in croplands.**
- **The pattern of photosynthesis in the croplands of the mid-western US that is projected from *crop models* does not agree with themselves nor with actual yields.**
- **The project will closely collaborate with the USDA National Institute of Food and Agriculture and the Foreign Agricultural Service. The models and workflow developed in the mid-western USA can also be applied to other parts of the world.**



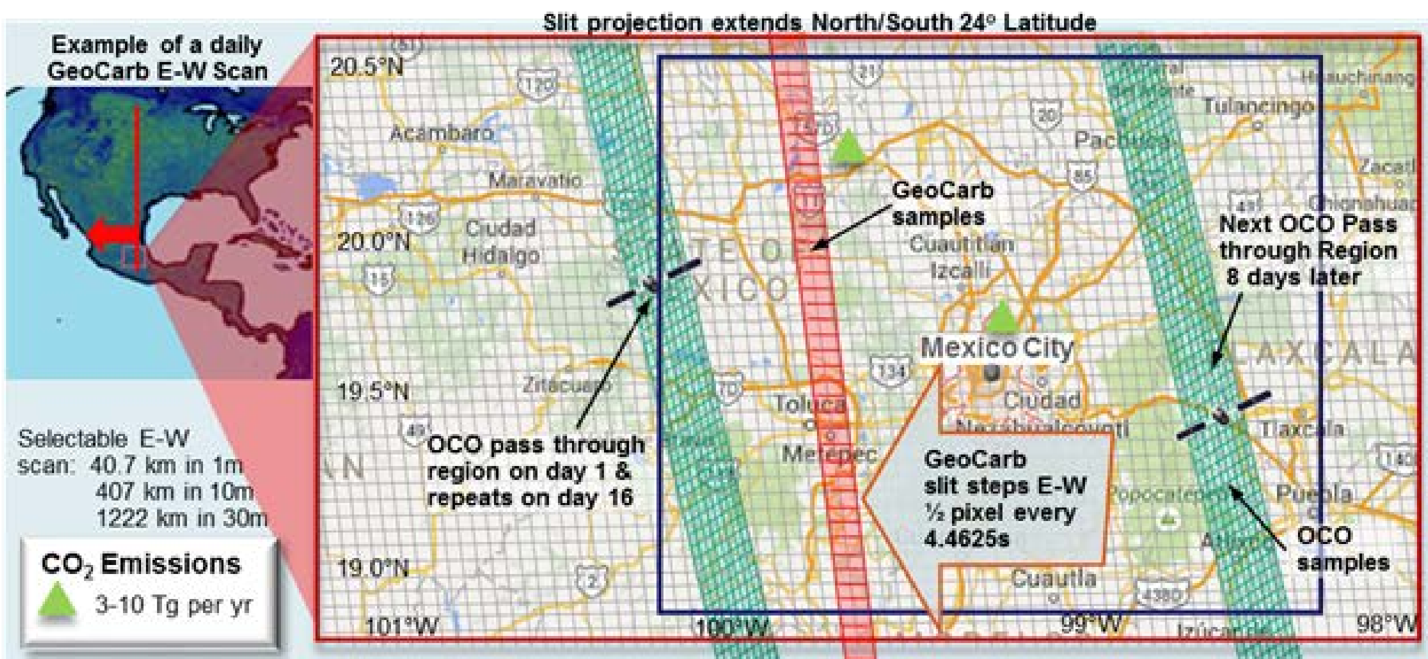
SIF provides the opportunity for direct measurements of Photosynthesis—daily, wall-to-wall, and in cloud cover for the Americans from Southern Canada to the southern tip of South America

GeoCarb: Two Keys for the Observing Strategy

Geostationary Orbit:
***Persistent* Observing**
***Staring* for S/R**
***Scanning* for Coverage**



The Pathfinder
Spectrometer (OCO-Like)
Add CH4 and CO and
A Scanning Slit

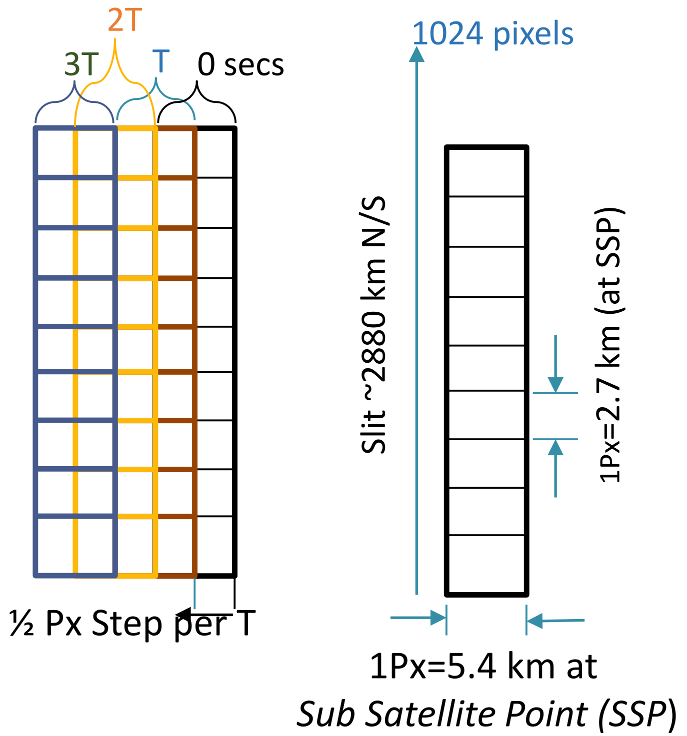


Step and Stare

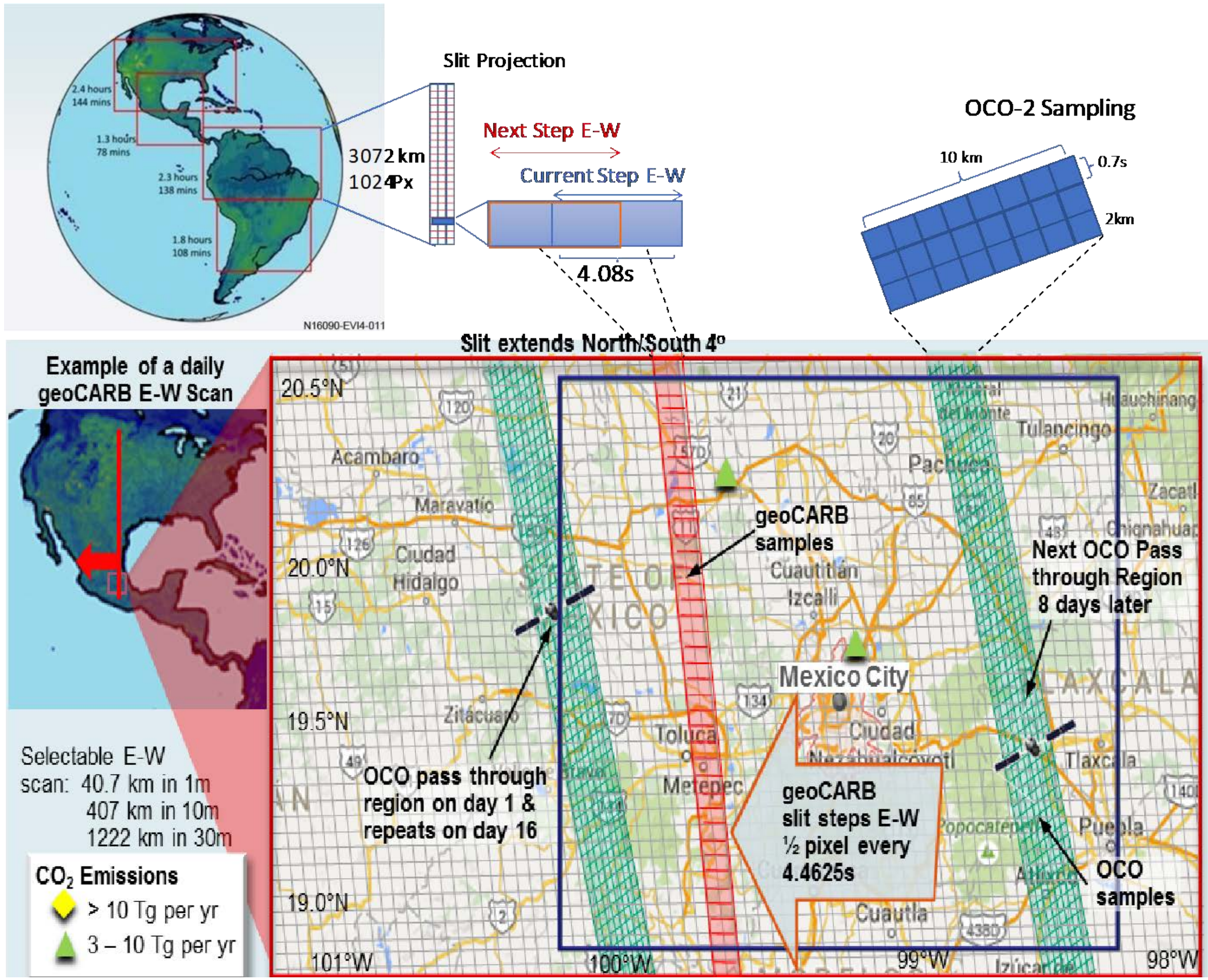
T=4.4625 secs = 0.3825 seconds Step and Settle

+ 4.08sec photon collection (Stare)

- Moving the slit "Half a Slit Width" provides double sampling
- The Continental United States is about 1812 steps across or about 2.25 hours to scan uninterrupted.
- Currently, we plan to "interrupt" the scan every 30mins to perform a 2.5 minute calibration by looking at stars

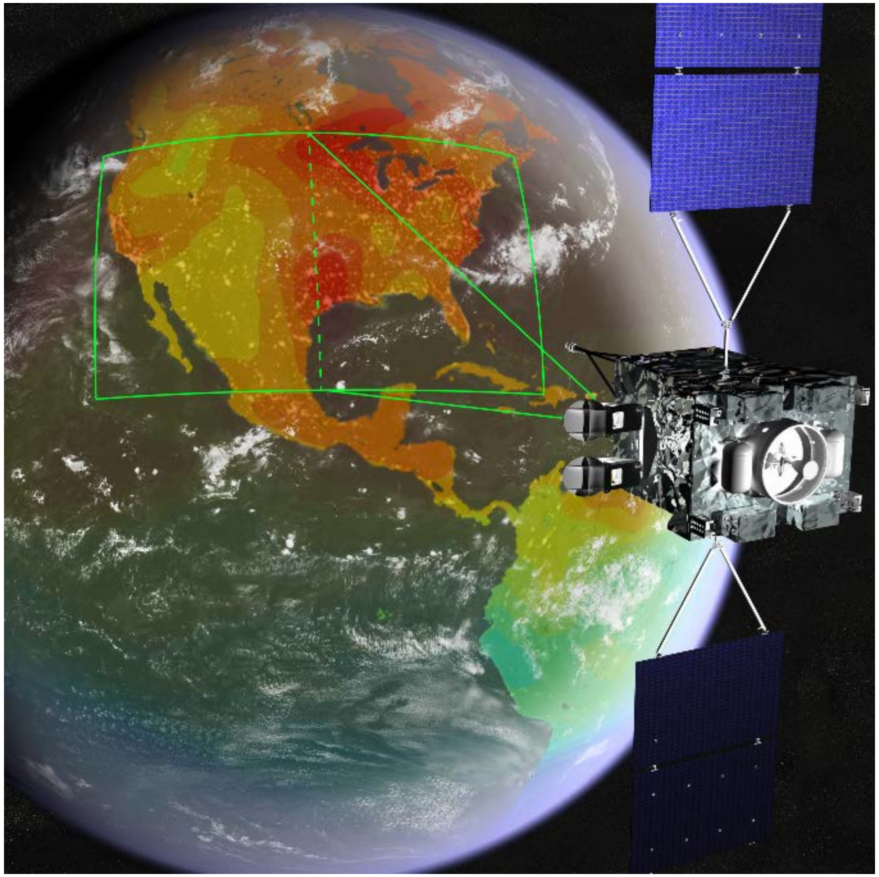


Mexico City: OCO-2 and GeoCarb



A Day in the Life of GeoCarb

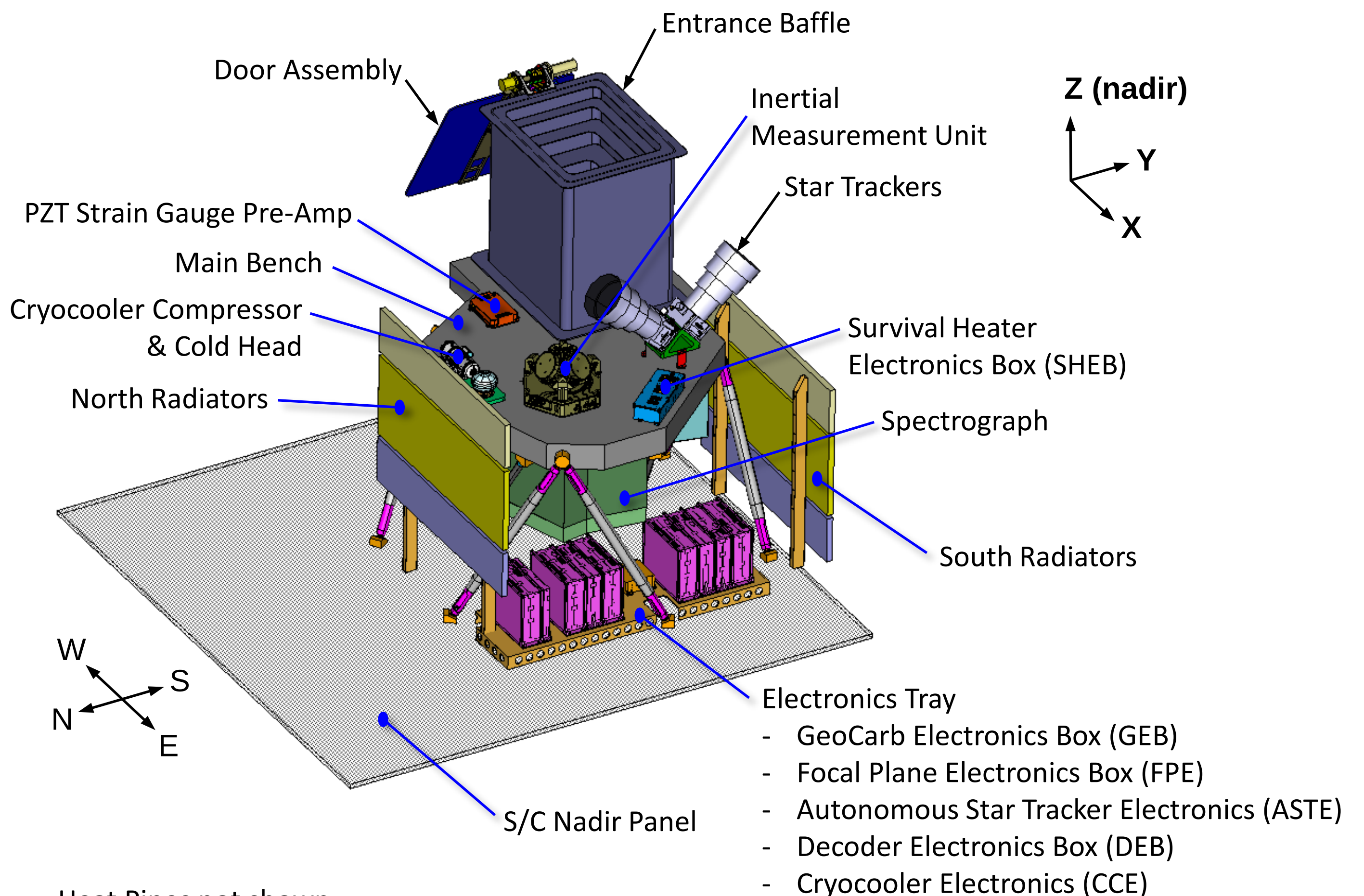
GeoCarb: Host and Payload



Principal Investigator:	**Berrien Moore, University of Oklahoma**
Technology Development:	Lockheed Martin Advanced Technology Center
Host Spacecraft & Mission Ops:	SES

Instrument	**Single slit, 4-Channel IR Scanning Littrow Spectrometer**
Bands	0.76μm, 1.61μm, 2.06μm and 2.32μm
Gases and SIF	O_2, CO_2, CH_4, CO & Solar Induced Fluorescence
Mass	158 kg (CBE)
Dimensions	1.4 m x 1.2 m x 1.2 m
Power (Average)	213 W (CBE)
Data Rates	10 Mbps
Daily Soundings	10 million

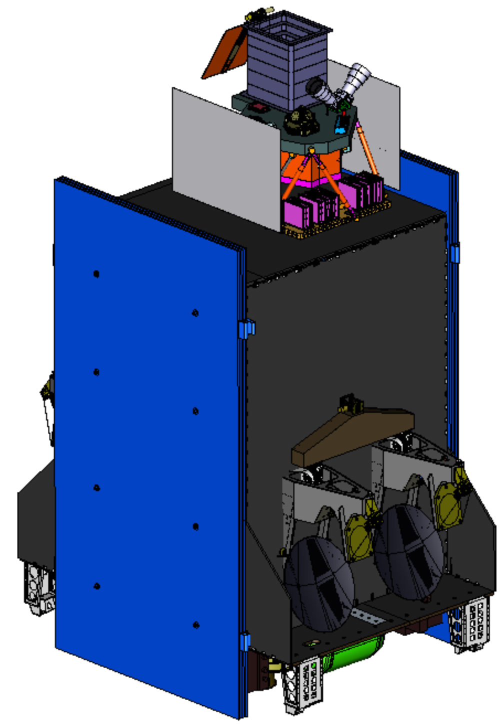
GeoCarb: Baseline Instrument



Heat Pipes not shown

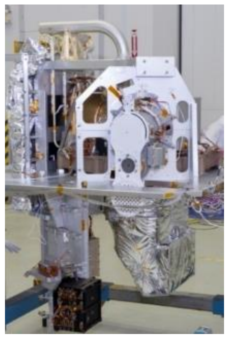
SES Host: Spacecraft, Launch, C^3

- Access to a geostationary platform provides persistent views of the western hemisphere
- Commercial spacecraft provides economical access to GEO
- A communications satellite can easily accommodate the mass, telemetry, and power of an Earth looking science mission
- Benefits from existing infrastructure for command/control and mission data delivery

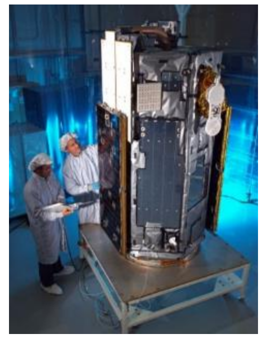


OCO-2 Mission Architecture

3-Channel Grating Spectrometer (JPL)



Dedicated Spacecraft Bus (OSC)

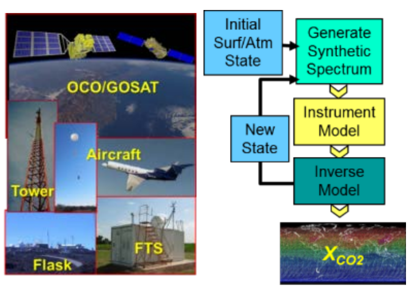


Delta-II Launch Vehicle (ULA)

Formation Flying in the A-Train Constellation

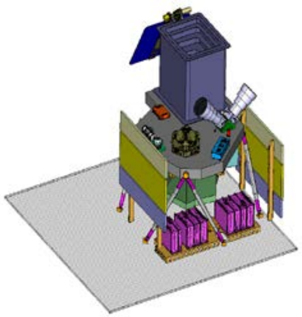
NASA NEN (GSFC) and SN (TDRSS)

Data Product Generation (JPL)

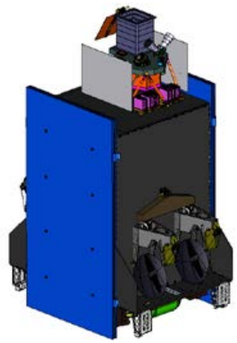


GeoCarb: Mission Architecture

4-Channel Grating Spectrometer (LMCO)

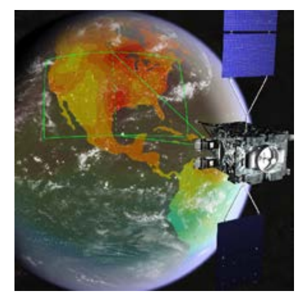


Commercial Communication Bus (TBD)



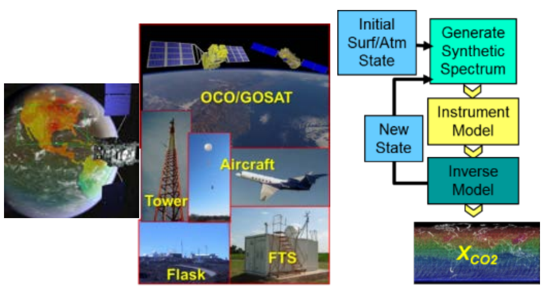
Falcon 9 or Ariane

Flying in GEO over the Americas



SES Teleport and SOC

Data Product Generation (OU/CSU/ARC)



X_{CH4} X_{CO} SIF

GeoCarb: See You June 2022!!