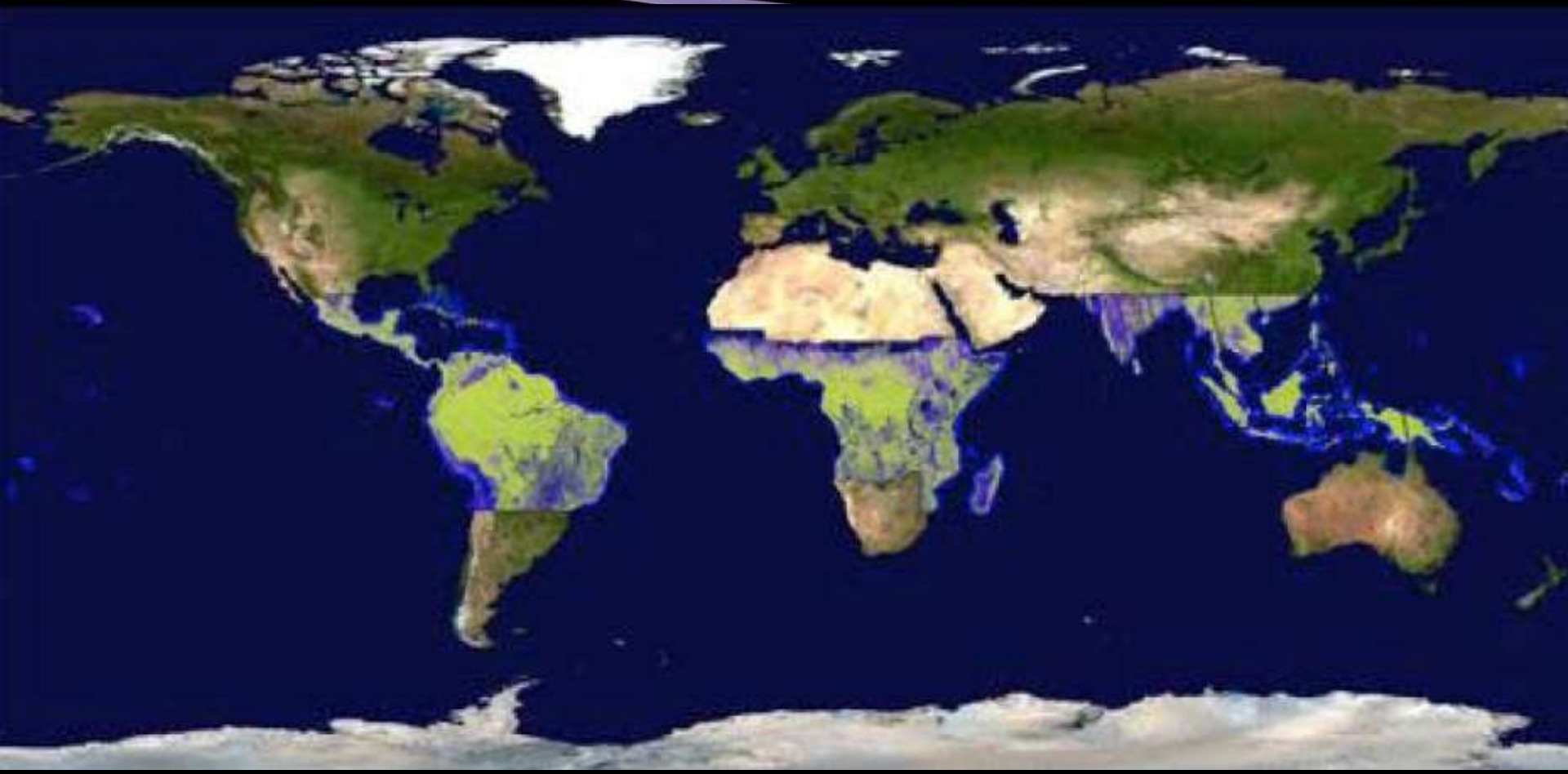
National Aeronautics and Space Administration



NASA Earth Science Division Update

Michael H. Freilich

7 March 2013

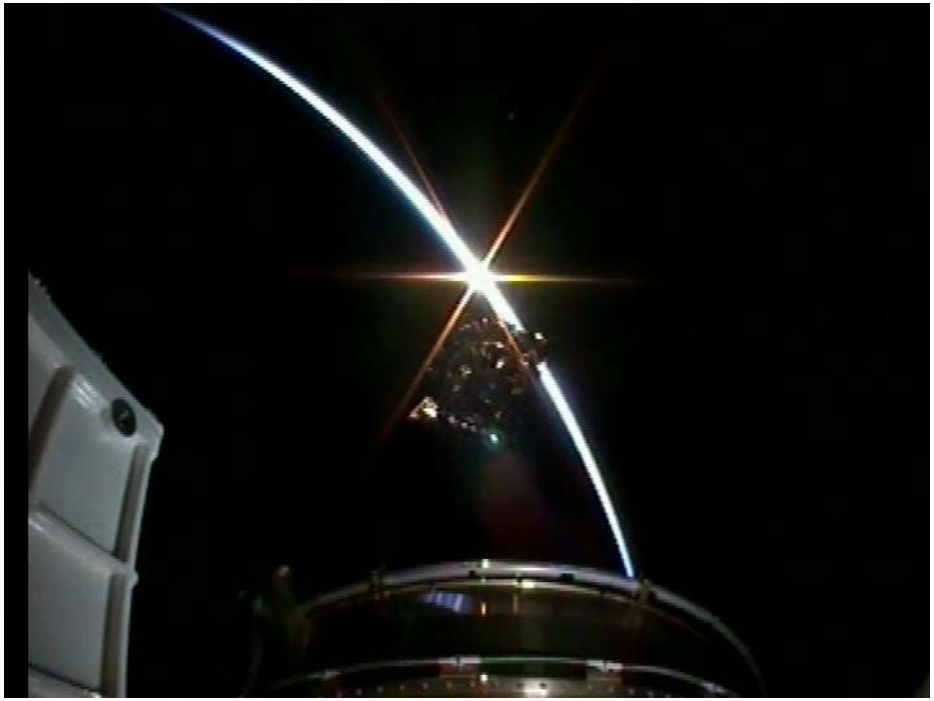
OUTLINE

- Science and launch highlights
- On-orbit constellation overview
- Venture Class status/accomplishments/selections/ plans
- Budget reminder
- Mission development status/plans
- ESD on the ISS
- Issues

LDCM – on orbit and working well

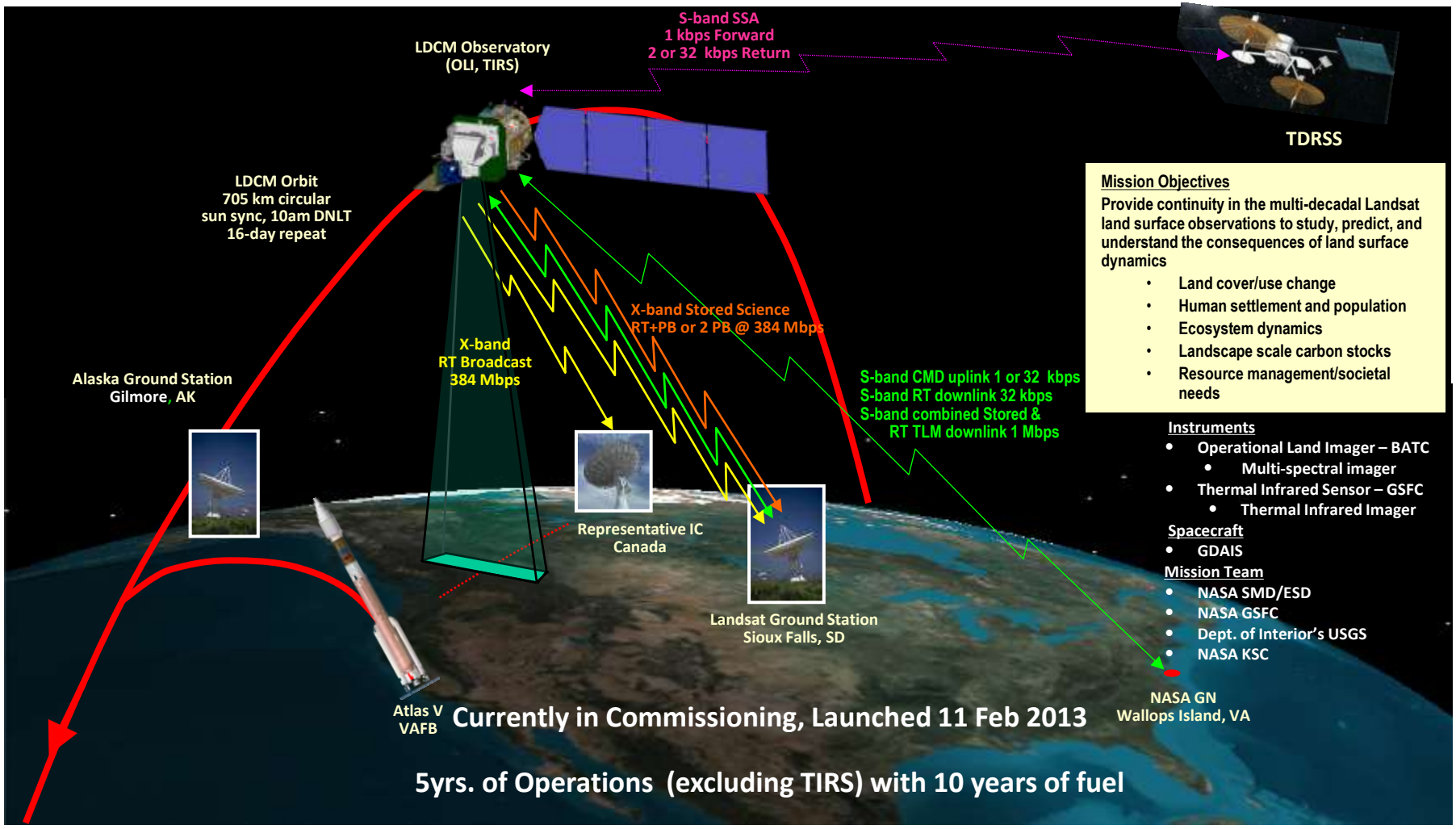
Monday, February 11, 2013 @ 10:02 a.m. (PST)

The LDCM Observatory was lifted to orbit by a United Launch Alliance Atlas V rocket launching from Vandenberg Air Force Base, Calif. The launch capped a flawless countdown.



The Observatory separated from the Centaur upper stage approximately 79 minutes after launch.

LDCM Mission Overview



Mission Objectives

Provide continuity in the multi-decadal Landsat land surface observations to study, predict, and understand the consequences of land surface dynamics

- Land cover/use change
- Human settlement and population
- Ecosystem dynamics
- Landscape scale carbon stocks
- Resource management/societal needs

Instruments

- Operational Land Imager – BATC
  - Multi-spectral imager
- Thermal Infrared Sensor – GSFC
  - Thermal Infrared Imager

Spacecraft

- GDAIS

Mission Team

- NASA SMD/ESD
- NASA GSFC
- Dept. of Interior's USGS
- NASA KSC

LDCM Commissioning Events

(planning dates as of 3/6/13)

ACTIVITY	DATE	STATUS
S/C Sub-system Activation (initialize GPS, SADA , SSR, X band, ACS)	Feb. 11-17	**Complete**
OLI and TIRS power up	Feb. 16	**Complete**
1st Engineering Burn	Feb. 17	**Complete**
Began generating and downlinking OLI and TIRS test pattern data	Feb. 17	**Complete**
Open OLI shutter to begin dryout	Feb. 18	**Complete**
ACS calibration maneuvers	Feb. 20 - Mar. 3	**Complete**
TIRS cryocooler launch lock deployment, uncage, and electronics power on	Feb. 24	**Complete**
Load OLI pixel map	Feb. 26	**Complete**
TIRS earth shield deployment, Passive cooldown begins	Mar. 4	**Complete**
TIRS focal plane electronics (FPE) power up, Scene Select Mirror (SSM) Activation	Mar. 5	**Complete**
TIRS Cryogenic Cooldown begins	Mar. 6	In Progress
ACS calibration maneuvers (post earth shield deploy)	Mar. 6 - 12	In Progress
OLI dryout complete, cooldown begins	Mar. 6	*In Progress?*
First TIRS Preliminary Engineering Data	Mar. 7	
TIRS calibrations begin	Mar. 10	
Ascent Burn 1	Mar. 10	
Ascent Burn 2	Mar. 13	
OLI calibrations begin	Mar. 14	
First OLI Image	Mar. 18	
Goal: Approach 400 scenes / day before Underfly	Mar. 27	
Landsat 7 Underfly	Mar. 28 - Apr. 1	
Ascent Burn 3	Apr. 7	
Ascent Burn 4 - Arrive on WRS-2 Grid	Apr. 11	
WRS-2 16-day cycle demonstration begins	Apr. 26	

AIRBORNE ACTIVITIES:
EV-1 (EV-S) Summary Status

- CARVE
  - Data analysis ongoing
- ATTREX
  - Science flights ongoing (mid Jan – Feb/Mar)
    - 6 flights total planned, completed (2 March 2013)
- HS3
  - Data analysis ongoing
- DISCOVER-AQ
  - California deployment complete
  - Data analysis ongoing
- AirMOSS
  - Data analysis ongoing
  - Science flights ongoing (local from Ellington Field 13 -18 Feb, Costa Rica 19 Feb – 3 Mar; deployment interrupted to fix instrument)

DISCOVER-AQ California

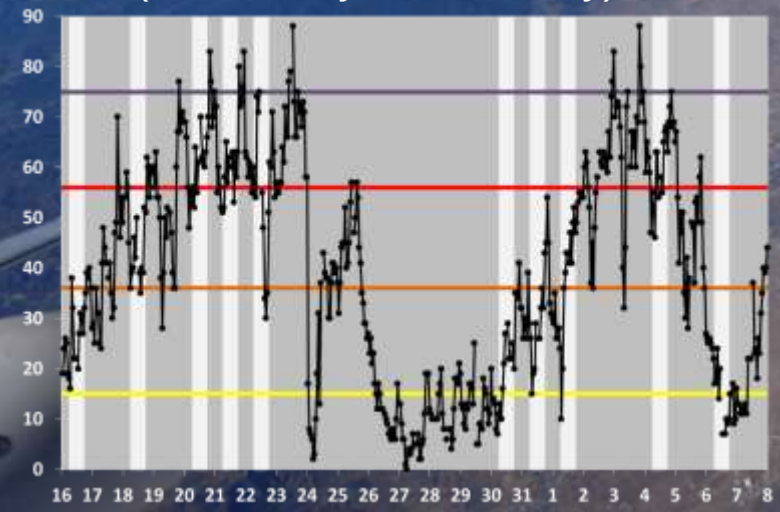
Ten science flights documented the details of two successive PM2.5 episodes in the San Joaquin Valley

- 176 flight hours
- P3B, King Air
- UC Davis Mooney also flew
- PODEX/ER-2 collaboration

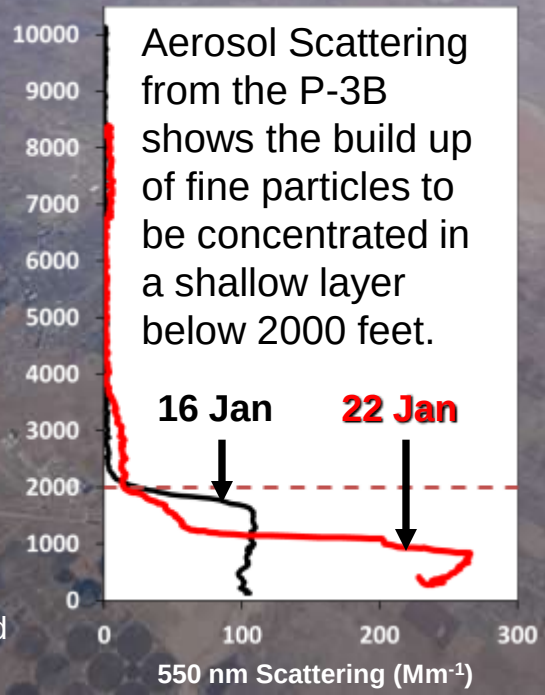
(Photo taken from ER-2 during PODEX flight on 20 January)

HSRL-2 on the King Air Maps the Spatial Distribution of Aerosol between ground monitors across the valley

Bakersfield PM2.5
(16 January - 7 February)



*Orange line (36 ug/m^3) is the 24hr average threshold for violating National Ambient Air Quality Standards



PODEX

Polarimeter Definition Experiment @ NASA Dryden, Jan/Feb 2013

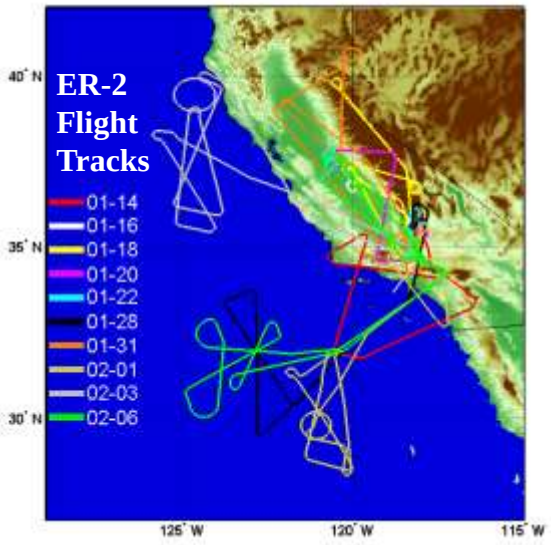
Objective: Airborne field experiment on NASA ER-2 to compare radiometric and **polarimetric** measurements from three instrument designs (alphabetically)

AirMSPI Multiangle SpectroPolarimetric Imager (JPL)

PACS Passive Aerosol and Cloud Suite (UMBC/Goddard)

RSP Research Scanning Polarimeter (GISS)

- Coordinated with DISCOVER-AQ (DAQ) (EV-1)
- Augmented by AMS, CPL, SSFR instruments on ER-2



- 10 flights
- 49 flight hours
- Observations include:
  - Bright (snow) and dark (ocean) targets
  - Aerosols over dark, bright, and urban areas (with DAQ correlative data)
  - Clouds – Fog, Stratus, Stratocumulus, Cirrus

Winter 2013 ASCENDS DC-8 Airborne Campaign

(19 February – 7 March 2013)

JPL/LMCT Lidar

LaRC/Exelis Lidar

GSFC CO2 Lidar Sounder

GSFC Broadband CO2 Lidar

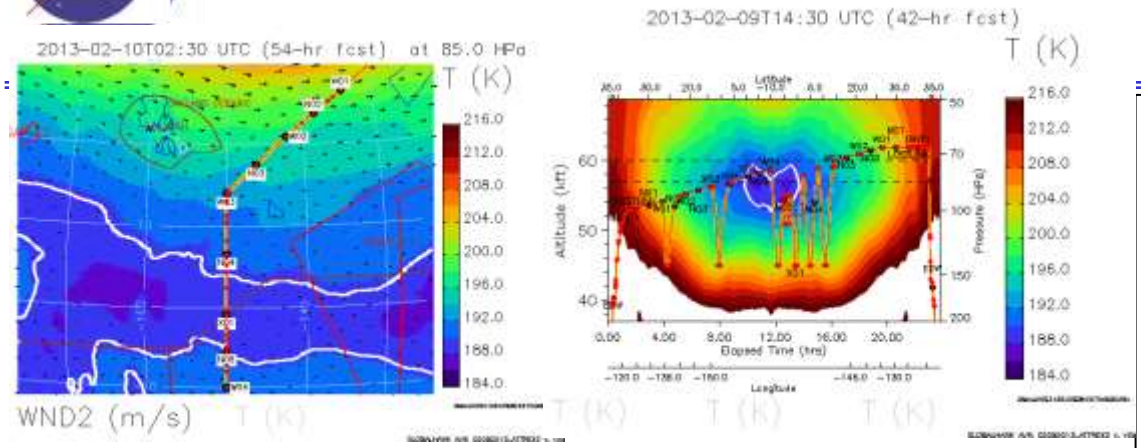
Implementation

- Flight Test Candidate ASCENDS Instruments: LaRC/Exelis IM-CW CO_2 Lidar (MFLL); GSFC CO_2 Lidar Sounder; JPL CO_2 LAS; GSFC Broadband CO_2 Lidar (shown above installed on DC-8)
- Conduct Eight DC-8 Flight Tests from NASA Dryden Palmdale Base:
  - Engineering Flight; CA Central Valley Flights (day & night); RRV Flight
  - Three long-range flights over snow surfaces east of Rocky Mountains
  - Long-range flight over Pacific with sampling over CA/OR coastal forest

Objectives

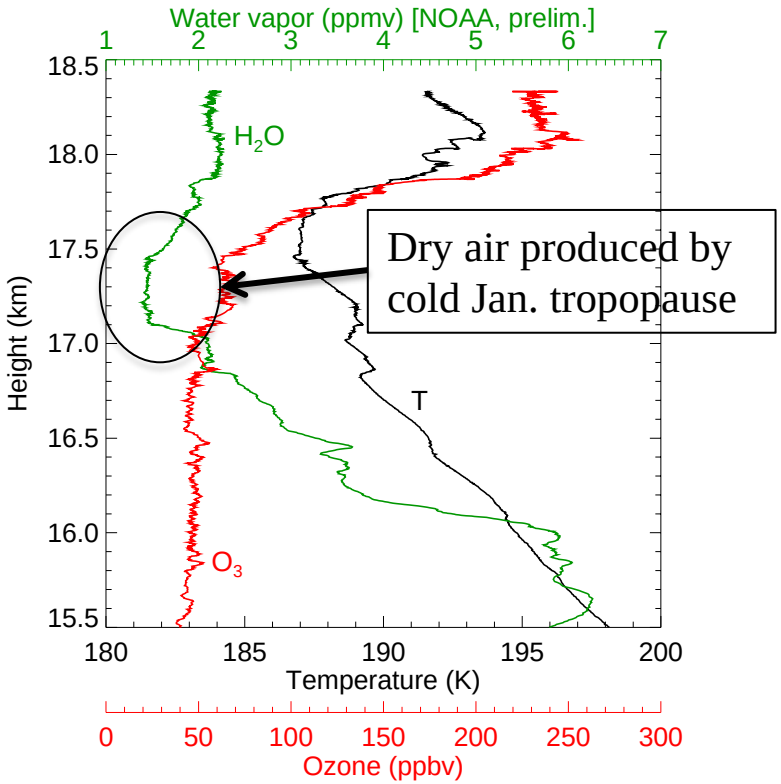
- Advance testing of CO_2 & O_2 measurements under day and night conditions.
- Assess CO_2 & O_2 measurements over Railroad Valley (RRV) with GOSAT overpass.
- Obtain reflectance and CO_2 & O_2 measurements over fresh and aged snow surfaces.
- Evaluate CO_2 & O_2 measurement performance in presence of thin cirrus clouds.
- Obtain reflectance data from ocean surface with high wind speeds (~10 m/s) and assess CO_2 & O_2 performance over tall coastal forest conditions.
- Evaluate derivation of XCO_2 from combination of CO_2 & O_2 measurements.

ATTREX Science Campaign #1
Vertical Profiles through the Tropical Tropopause Layer



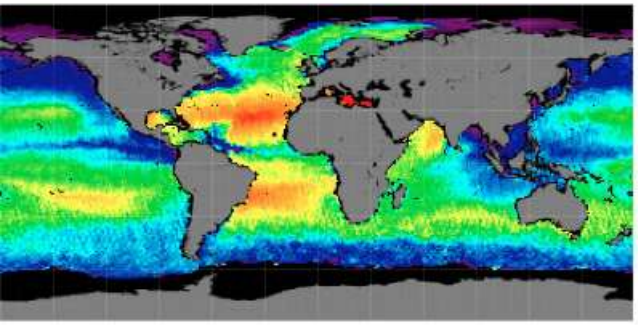
The first science campaign for the EV-1 selected ATTREX investigation is occurring now with a NASA Global Hawk from DFRC.

- 5 science flights of >24 hours have occurred since 2/5/13 (1st was planned for 1/15)
- 1 more flight planned this campaign, with hard end date of 3/15 (including reserve).
- The next 2 campaigns are planned for January 2014 in Guam and July 2014 in either Australia or Okinawa.

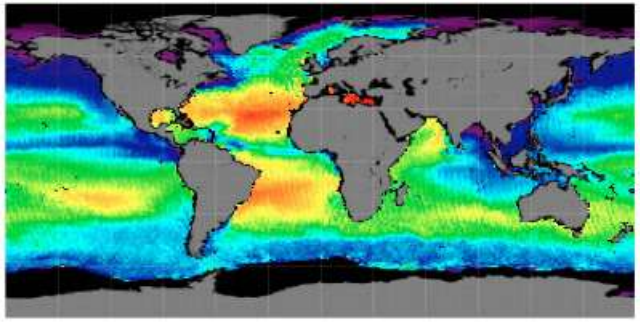


- The Global Hawk is now performing altitude profiles numerous times each flight through air masses colder than the aircraft was test-rated. This required significant discussion with Northrup.
- This year's tropical tropopause is much colder than normal due to the same atmospheric transport processes that warmed this year's Arctic vortex.
- ATTREX measurements are showing the lowest atmospheric water vapor concentrations ever measured.
- This combined set of observations (12 instruments), along with MLS on Aura, should significantly improve our understanding of the control of stratospheric water vapor, cirrus formation, and atmospheric transport.

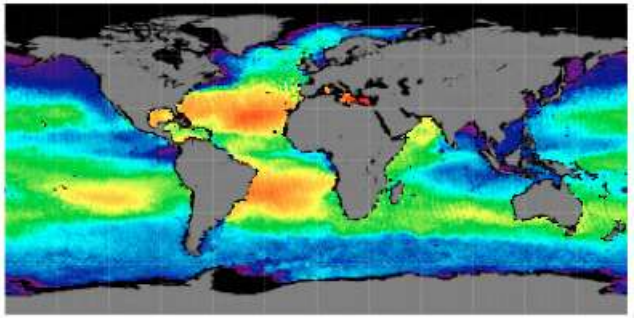
Aquarius Seasonal Salinity



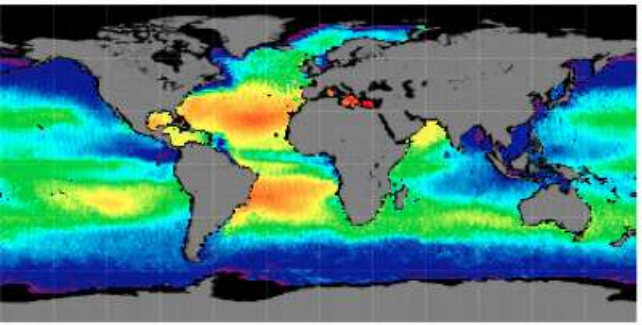
Summer 2011



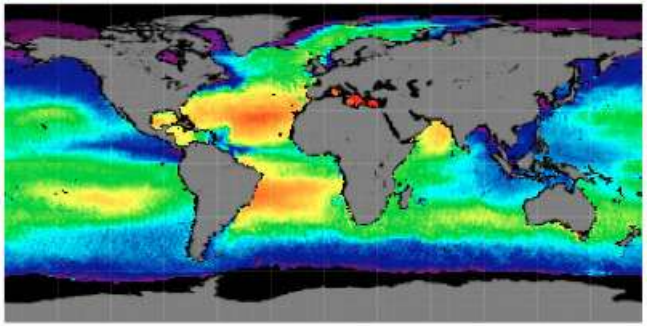
Autumn 2011



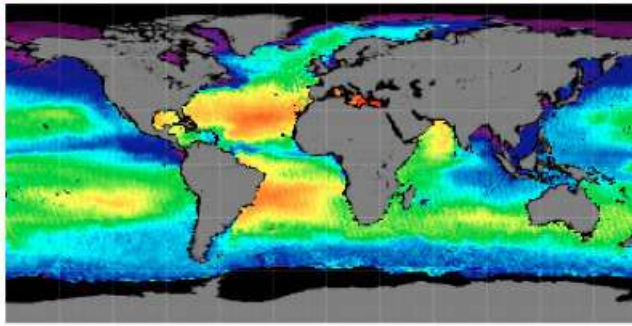
Winter 2011/2012



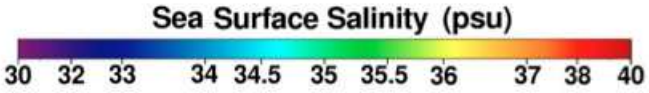
Spring 2012



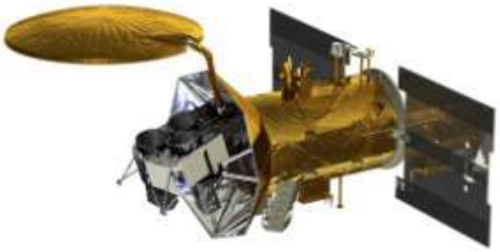
Summer 2012



Autumn 2012



Aquarius Version 2 Data was released 2/25 (available at PODAAC). This version is released for scientific analysis and fully documented for the oceanographic community.



The table below shows the advancement of this product over prior version (1.3). Further advancement toward Level 1 requirements is expected with Version 3 (later in 2013).

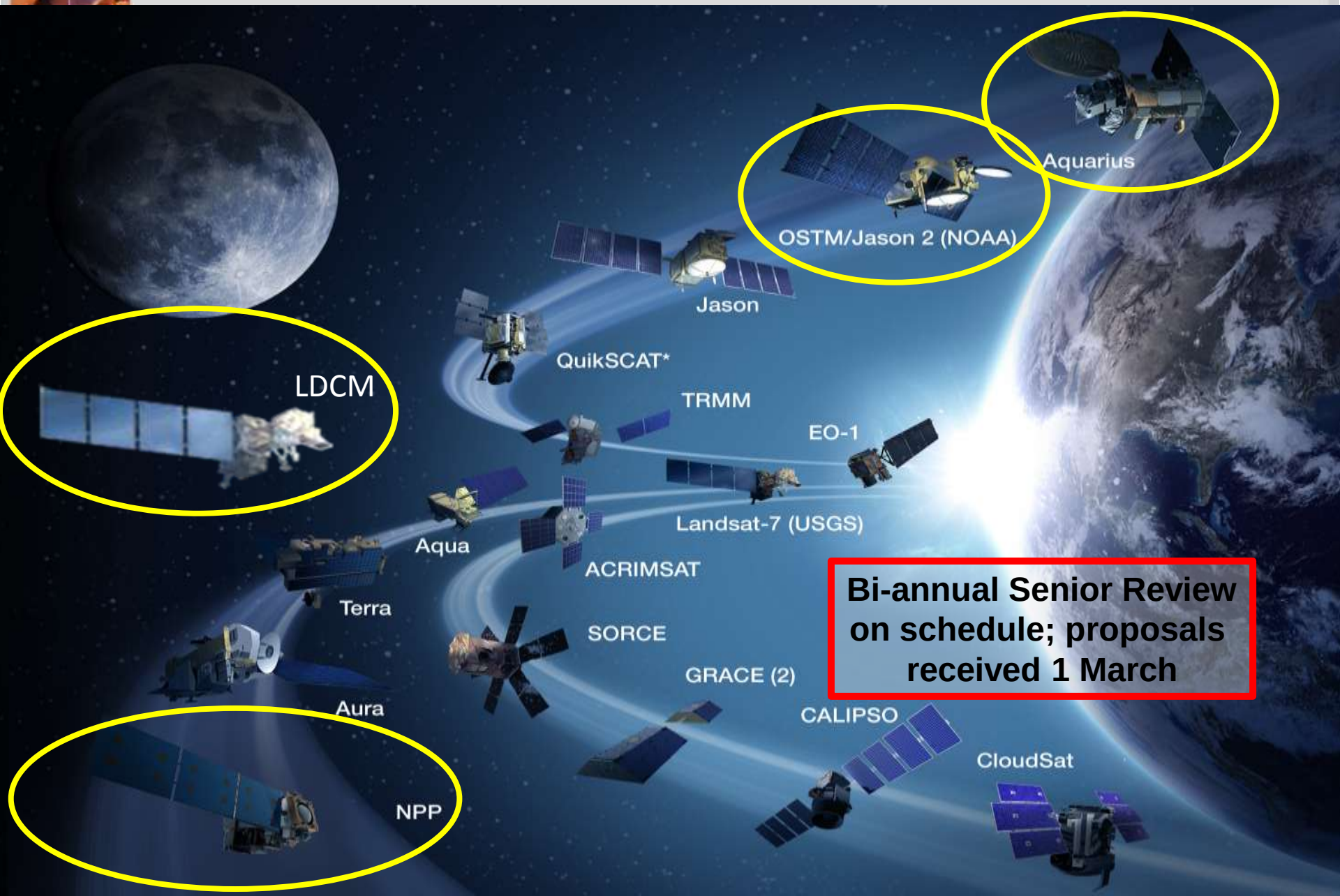
	Level 1 Science Mission Requirement	Baseline Mission	Minimum Mission
1	The Aquarius Mission shall collect the space-based measurements to retrieve Sea Surface Salinity (SSS) with global root-mean-square (rms) random errors and systematic biases no larger than **0.2 psu** on 150 km by 150 km scales over the open ocean.	V1.3: 0.44	V1.3: 0.38
		V2.0 0.30	V2.0 0.27
2	SSS Averaging Interval	1 Month	3 Months
3	Mission Duration	At least 3 Years	At least 1 Year
4	Deliver data products to a NASA Distributed Active Archive Center (DAAC). Level 1a Reconstructed Unprocessed Instrument Data Level 1b Calibrated Sensor Units Level 2 Derived Geolocated SSS Level 3 Time-space averaged SSS on a standard Earth Projection		Yes

Reinvigorate On-Orbit Constellation (1 of 2)

- OSTM/Jason-2 Launched 6/2008
- ~~OCO Launched 2/2009~~ (LV Failure)
- ~~Glory Launched 3/2011~~ (LV Failure)
- Aquarius/SAC-D Launched 6/2011
- NPP Launched 11/2011
- LDCM Launched 2/2013

- GPM On Schedule for 2/15/2014 Launch
- OCO-2 On Schedule for 7/1-7/2014 Launch
- SAGE-III/ISS On Schedule for 8-12/2014 Launch
- SMAP On Schedule for 10/31/2014 Launch

ESD Operating Missions (2013)



Bi-annual Senior Review on schedule; proposals received 1 March

VENTURE-CLASS UPDATE/STATUS

- **Venture-Class is a Tier-I Decadal Survey recommendation**
  - Science-driven, PI-led, competitively selected, cost- and schedule-constrained, regularly solicited, orbital and suborbital
  - Venture-class investigations complement the systematic missions identified in the Decadal Survey, and provide flexibility to accommodate scientific advances and new implementation approaches

- **Venture-Class is fully funded, with 3 "strands"**
  - EV-1: suborbital/airborne investigations (5 years duration)
    - Solicited in May FY09 (selections in FY10) ***and every 4 years***
    - ***5 investigations selected***; flights began in FY11
  - EV-2: small complete missions, Class D (5 years development)
    - Solicited in FY11 ***and every 4 years***
    - Small-sat or stand-alone payload for MoO; $150M total development cost
    - AO released 17 June 2011, ***CYGNSS selected July 2012***
  - EV-Instrument: spaceborne instruments for flight on MoO (5 years dev.)
    - Solicited in FY11 ***and every 18 months thereafter***
    - AO release Feb 7; proposals received May 2012; ***TEMPO selected Nov 2012***
    - ~$90M development costs, accommodation costs budgeted separately

VENTURE-CLASS UPDATE/STATUS (cont)

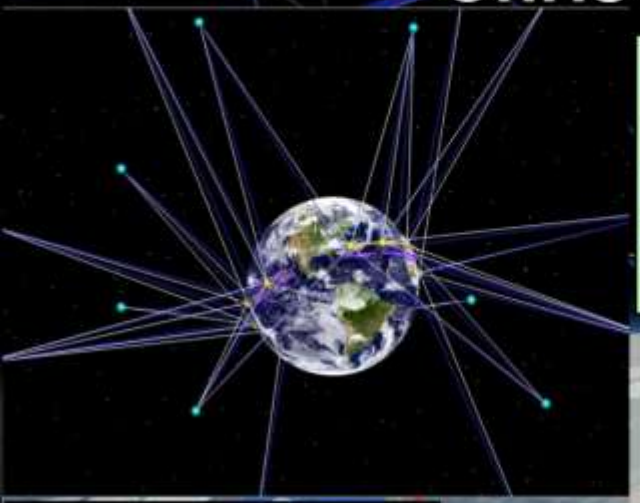
- **EV-1 (Airborne)**
  - All 5 investigations will have completed at least 1 sustained field campaign by early in CY2013
    - All EV-1 investigations will fly during 2013
  - **Second "EV-3" ("EV-Suborbital") solicitation funded, in preparation for release on schedule in mid-2013**

- **EV-2 (Small-sat)**
  - CYGNSS PI team and NASA program office making good progress, should be under contract by late CY2012 (planned 2016-2017 launch)
  - ESD/SMD developing detailed "Class D" management approaches and processes

- **EV-I (Instrument)**
  - TEMPO selected for GEO hosted payload opportunity (2017 launch)
  - ESD initiating formal host selection/negotiation process
  - **Second "EV-Instrument2" solicitation funded, on schedule for release ~August, 2013**

CYclone Global Navigation Satellite System

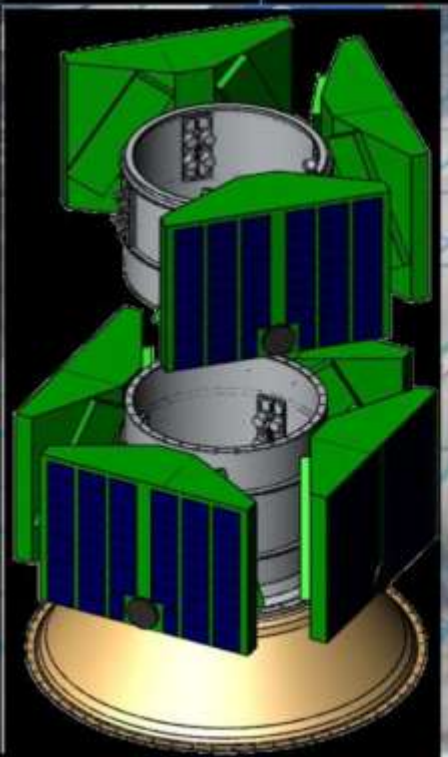
Chris Ruf, PI (U. Michigan)



CYGNSS is a constellation of 8 microsatellites that will use direct and reflected GPS signals to measure ocean surface wind speeds during most precipitation levels. This will increase the understanding of Tropical Cyclone genesis and intensification.

Primary Science Objectives

- **Measure ocean surface wind speed in almost all precipitating conditions including those in the Tropical Cyclone eyewall**
- **Measure ocean surface wind speed in the Tropical Cyclone inner core with sufficient frequency to resolve genesis and rapid intensification.**



Partners	Southwest Research Institute: Primary Observatory development Surrey Satellite Technology, U.S.: Delay Doppler Mapping Instrument NASA Ames Research Center: Deployment Module
Risk	7120.5D Category 3; 8705.4 Payload Risk Class D
LRD	Target date February 2016
Orbit	35 deg inclination, 500 km altitude
Duration	2 year
Payload	Delay Doppler Mapping Instrument
LCC	$151.7M (RY$)

Earth Venture Instrument-1 Selection
Tropospheric Emissions: Monitoring of Pollution

PI: Kelly Chance, Smithsonian Astrophysical Observatory
Instrument Development: Ball Aerospace
Project Management: LARC (Wendy Pennington, PM; Dave Flittner, PS)
Other Institutions: GSFC, NCAR, Harvard, NOAA, UC Berkeley, SLU, UAH, EPA, Nebraska
RY$: 93.2M
Orbit requirements: ***Geostationary Orbit.*** NASA plans to host instrument on a commercial Geostationary communication satellite.

Scientific and Programmatic Characteristics

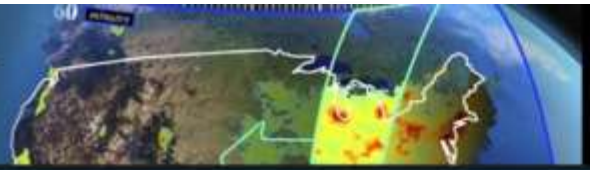
- Tropospheric pollution observations from Geostationary Orbit using a UV and Visible Offner Grating spectrometer
  - Retrieve Ozone, NO_2, SO_2, aerosols, CH_2O, others.
- TEMPO will be simultaneous with, and complements, EU/GEMS Sentinel 4 and Korean GEO AQ observations, forming a global AQ constellation in GEO.
- Operational agencies like EPA and NOAA are part of the science team.
- ***TEMPO will be a pathfinder to using hosted commercial payloads from GEO***

TEMPO Overview

TEMPO

Tropospheric Emissions: Monitoring of Pollution

PI: Dr. Kelly Chance, Smithsonian Astrophysical Observatory

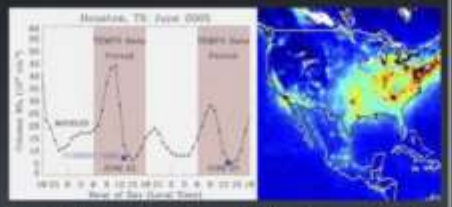


FACTS

TEMPO's concurrent high temporal (hourly) and spatial resolution measurements from geostationary orbit (GEO) of tropospheric ozone, aerosols, their precursors, and clouds create a revolutionary dataset that provides understanding and improves prediction of air quality (AQ) and climate forcing in Greater North America (GNA).

SCIENCE OBJECTIVES

- Collect simultaneous high temporal and spatial resolution measurements of pollutants over GNA.
- Measure the key elements in tropospheric ozone chemistry & aerosol cycles.
- Observe aerosols & gases for quantifying and tracking evolution of pollution.
- Integrate observations from TEMPO and other platforms into models to improve representation of processes.
- Serve as the North American geostationary component of an international constellation for air quality monitoring.
- Determine the diurnal instantaneous radiative forcings associated with pollutants and other climate agents on the continental scale.



TEMPO maps hourly changes in North American air quality.

SCIENCE TEAM captures global expertise in air pollution science, UV-Visible measurements, and image navigation and registration.

Kelly Chance, (PI)	SAO	Xiong Liu, (DPI)	SAO
James Carr	Carr Astro	Ronald Cohen	UC Berkeley
David Edwards	NCAR	Jack Fishman	St. Louis U.
David Fittiner	LaRC	Jay Herman	UMBC
Daniel Jacob	Harvard	Scott Janz	GSFC
Joanna Joiner	GSFC	Nickolay Krotkov	GSFC
James Leitch	Ball	Randall Martin	SAO
Doreen Neil	LaRC	Michael Newchurch	UAH
R. Bradley Pierce	NOAA	Robert Spurr	RT Solutions
Raid Suleiman	SAO	James Szykman	EPA
Omar Torres	GSFC	Jun Wang	U. Nebraska

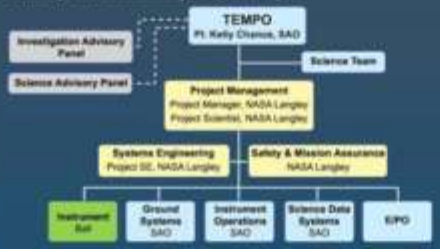
UNIQUE CAPABILITIES

- Demonstrated space-based chemical suite sensitive to key elements of tropospheric air pollution chemistry.
- Hourly daylight observations from geostationary orbit capture diurnal cycle of emissions & chemistry.
- Order of magnitude improvement in spatial sampling to resolve gases at urban scales and improve emissions inventory.
- Multi-spectral observations are sensitive to ozone in the lower-most troposphere, reducing uncertainty in air quality predictions by 50%.
- Geostationary orbit allows multiple observations per day, increasing the probability of viewing a clear-sky scene.

INVESTIGATION OVERVIEW

TEMPO is an innovative use of a well-proven technique, able to produce a ground-breaking dataset. It is led by PI Dr. Kelly Chance, SAO, who for over 30 years has been at the forefront of atmospheric composition and pollution remote sensing. Dr. Chance and the Science Team have extensive expertise in algorithm development for GOME-1 & 2, SCIAMACHY, OMI and OMPS. The PI is supported by the NASA Langley team, which brings project management and space flight instrument development expertise (CALIPSO, CERES, SAGE III) with emphasis on hosting science payloads on a variety of platforms. The TEMPO imaging grating spectrometer is designed and built by Ball (with heritage in building OMPS and SAGE III) to take advantage of a GEO host spacecraft. Image navigation and registration is led by Carr Astronautics (GOES-R). Science data processing capitalizes on operational algorithms used with current LEO instruments. TEMPO will launch at a prime time to be the U.S. component of a global GEO constellation for pollution monitoring.

INVESTIGATION ORGANIZATION provides clear lines of authority with accountability and ownership.



KEY INSTRUMENT CHARACTERISTICS

Requirements		Comment
Field of Regard	GNA	Mexico City to Canada tar sands & Atlantic to Pacific
Imaging Time	1 hr	1250 scan positions with 2.8 sec integration
Footprint N/S	2.0 km	Native pixel achieved by 44 cm telescope effective focal length
Footprint E/W	4.5 km	
Spectral Range	290-690 nm	1,024 spectral channels matched to 2k focal plane
Spectral Resolution	0.6 nm	Achieved by spectrometer design
Spectral Sampling	0.2 nm	

Heritage-based grating spectrometer efficiently achieves the requirements derived directly from the Science Traceability Matrix.

Species	λ Band nm	SNR Reqs	SNR Predict	EOL Margin
SO_2	305-345	1297	1820	40%
H_2CO	327-334	467	2094	330%
NO_2	423-431	1233	1910	55%
$C_2H_2O_2$	433-437	1350	2331	73%
O_3 (UV)	303-345	1122	1635	46%
O_3 (Vis)	540-648	958	1254	31%
AOD	354, 388	1000	1596	60%

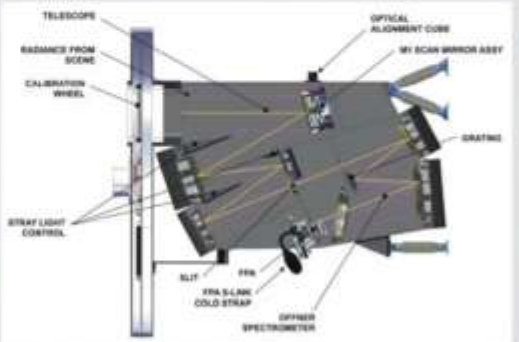
Substantial margins for predicted signal-to-noise ratios are the foundation for a low-risk program.

INSTRUMENT COMPLEMENT

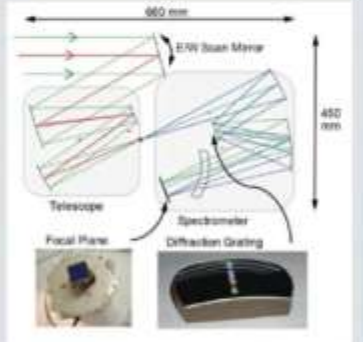
TEMPO moves high heritage LEO hardware to GEO following a low-risk build philosophy. The high design maturity of the TEMPO spectrometer is leveraged from LEO-proven heritage from OMPS, SAGE III, and SBUV, as well as from GEO studies and risk reduction activities. This, coupled with substantial performance margins, results in a low-risk, compact configuration ideally matched to deliver a high value science product.

Requirements	TEMPO		
	Current Best Estimate	Contingency	Maximum Expected Value
Mass (kg)	82	17%	107.9
Average Power (W)	81.6	22%	99.4
Downlink Rate (Mbps)	8.66		
Volume (l x w x h)	1.02m x 1.07m x 0.96m		

The low resource requirements for TEMPO can be accommodated by any of the commercial GEO buses over GNA, ensuring flexibility to selection of a host platform.

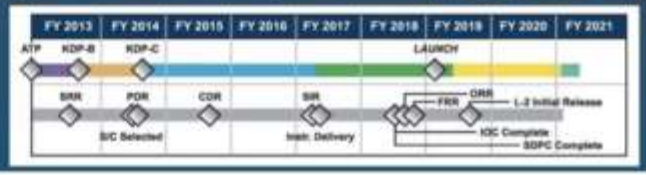


UV-Visible spectrometer: High heritage assemblies deliver innovative science using a low-risk approach.



The optical subsystem leverages Ball's heritage designs. Ball internal efforts have characterized the proposed focal plane and diffraction grating, reducing the implementation risk.

SCHEDULE, with margin, enables U.S. participation in a global GEO constellation to monitor pollution.



Proposed Total Mission Cost:
RY Lifecycle Cost: $93,216,782
FY14 Lifecycle Cost: $90,000,000

Earth Science Program/Budget Strategy

Maintain a **balanced program** that:

- **advances Earth System Science**
- **delivers societal benefit** through Applications Development
- **provides essential global spaceborne measurements** supporting science and operations
- **develops and demonstrates technologies** for next-generation measurements, and
- **complements and is coordinated with activities of other agencies and international partners**

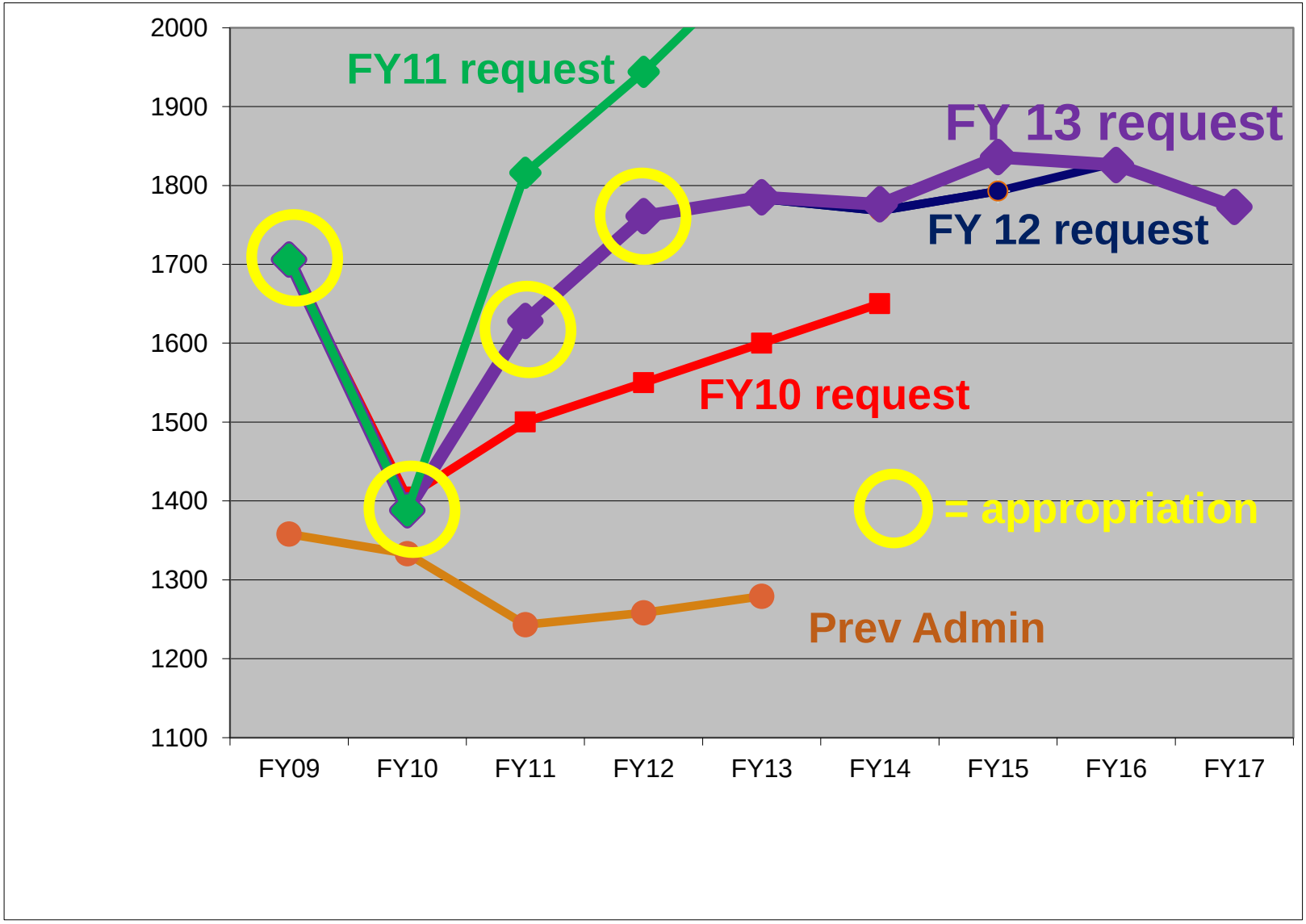
Support **Research, Applied Sciences, Technology Development, and E/PO programs**

- Continue to fund **operations and routine data products for all on-orbit NASA research missions**
- **Develop and launch remaining foundational missions**: LDCM, GPM, OCO-2
- **Advance formulation and development of top-priority Decadal Survey and Continuity missions**: SMAP (10/2014), ICESat-2 (9/2016), SAGE-III/ISS (8/2014) and GRACE-FO (2017) [OCO-3 (2017), PACE (2020), SWOT (2020), ASCENDS, CLARREO, ERM, studies of other missions]
- Continue **execution of the full Venture Class program**

Continue working with NOAA and OSTP to address approaches for **providing sustained, long-term spaceborne measurements**.

Provide significant support to **National Climate Assessment**, **USGCRP**, and **international (CEOS) coordination** activities

Earth Science Budget – FY13 Request

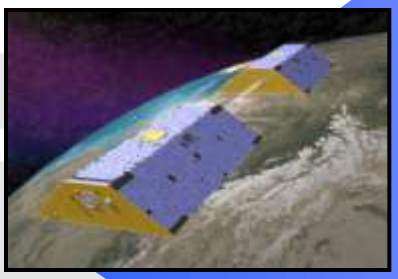


Formulation & Development Mission Plans

GPM
Feb 2014
w/ JAXA; Precip
H-IIA

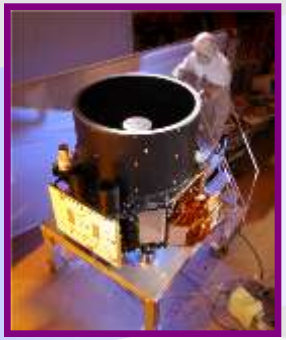
OCO-2
July 2014
Global CO_2
Delta II

SAGE III
Late 2014
Ozone & Trace Gases
Falcon-9



GRACE FO
Aug 2017
w/Germany; Global Mass & Water Variation
German-supplied LV

CYGNSS
2016-2017
Tropical Cyclone Generation, Air-sea Interaction in Extreme Conditions



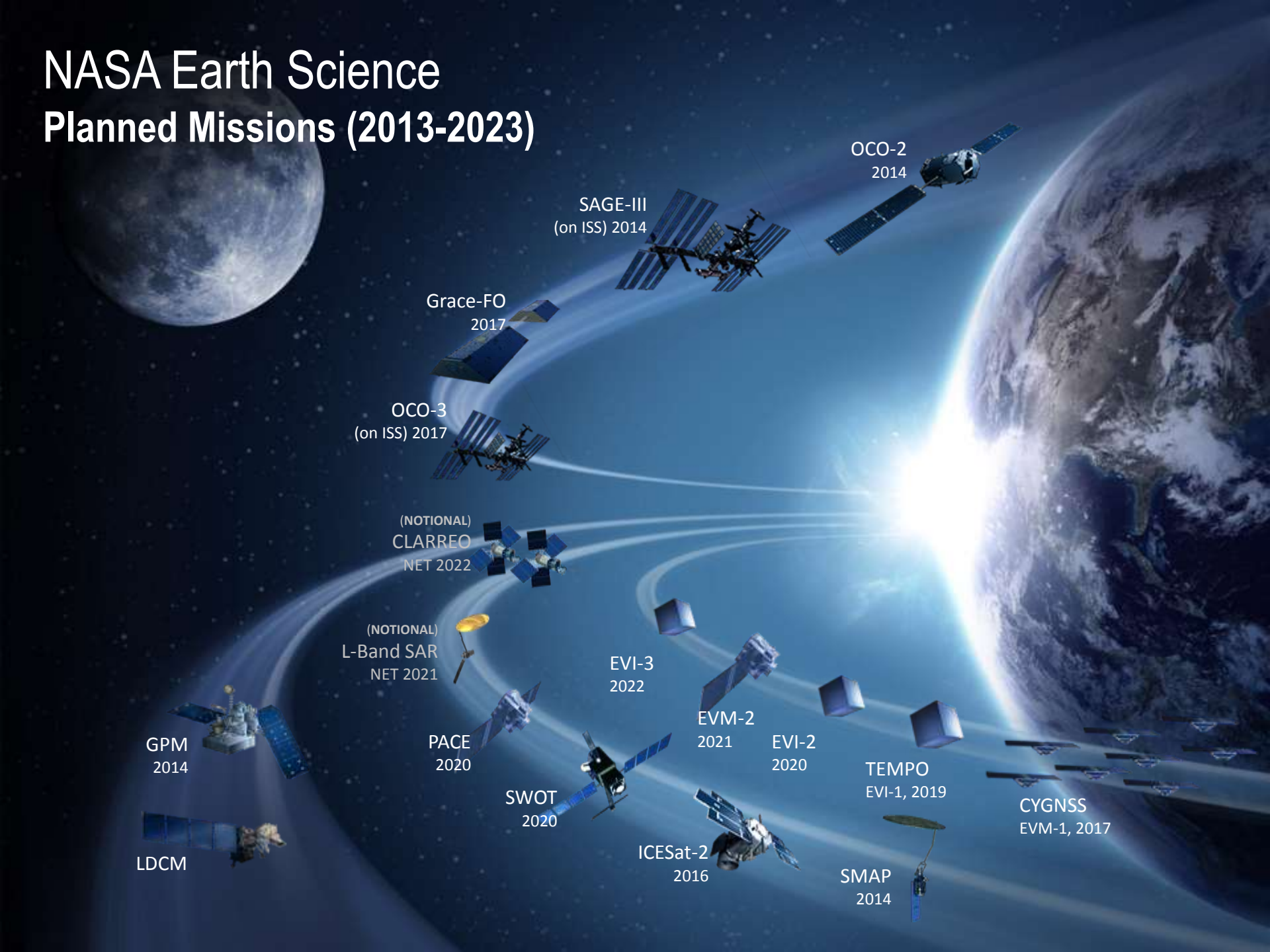
ICESat-2
Jul 2016
Ice Dynamics
Delta II

SMAP
Oct 2014
w/CSA
Soil Moist., Frz/Thaw
Delta II

Reinvigorate On-Orbit Constellation (2 of 2)

• GRACE-FO	Formulation for launch 8/2016
• ICESAT-2	Confirmed for launch 12/2016
• CYGNSS (EVM)	Formulation for launch late 2016
• OCO-3/ISS	Formulation for launch 2017
• TEMPO (EVI)	Formulation for launch 2017
• PACE	Acquisition Strategy under evaluation, launch 2020
• SWOT	Formulation for launch 2020

NASA Earth Science
Planned Missions (2013-2023)

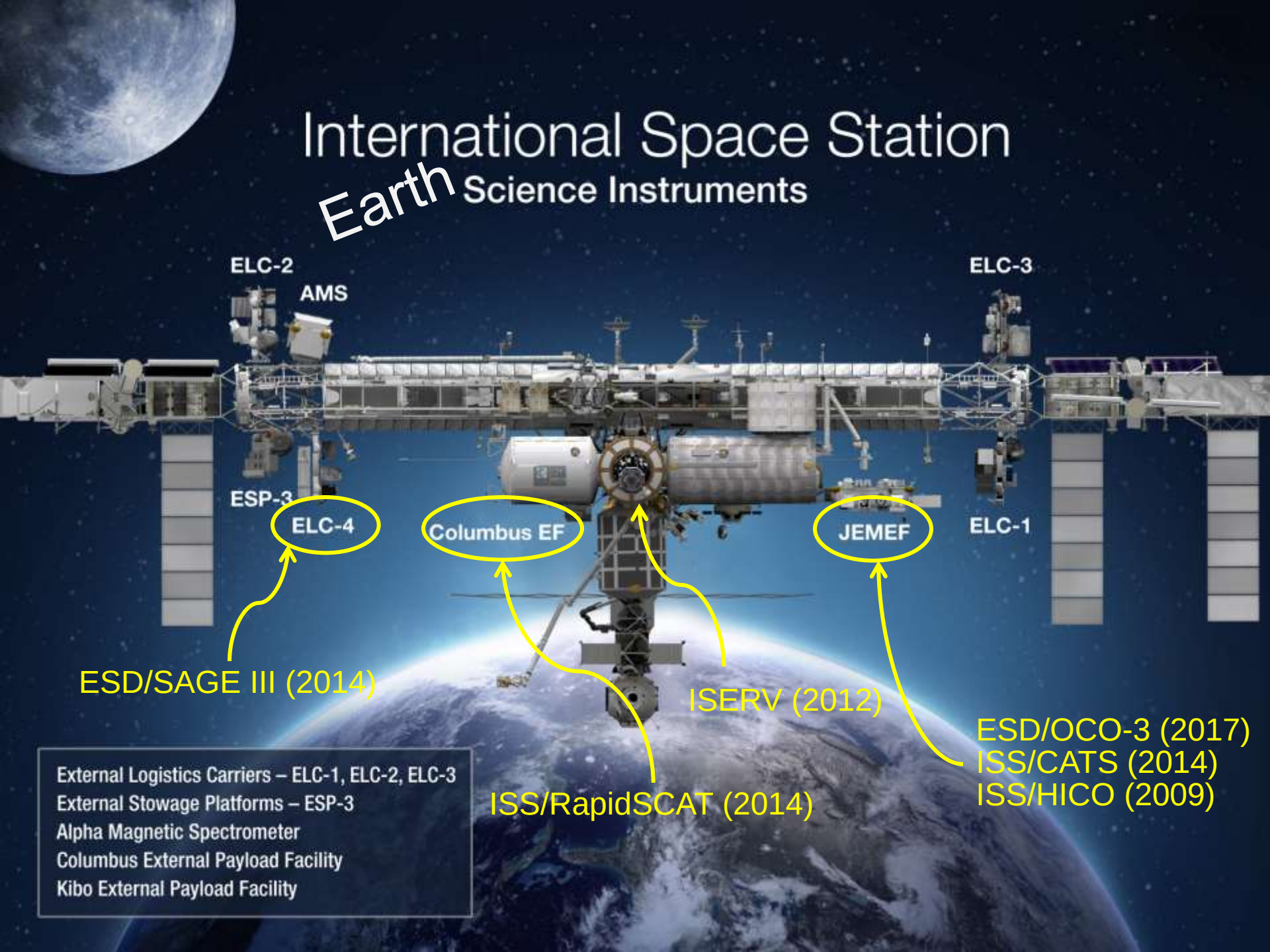


Earth Observations from the ISS: NASA/ESD Status and Plans

- On-orbit instruments funded by non-ESD sources, ESD funding for analysis
  - HICO (Hyperspectral Imager for the Coastal Ocean)
    - Launched September, 2009 on HTV; mounted on JEM-EF
  - ISERV (Digital Camera and Telescope)
    - Launched July, 2012 on HTV-3; mounted internally on WORF

- Planned instruments funded by NASA/HEOMD, ESD funding for analysis
  - CATS (Cloud-Aerosol Transport System for ISS)
    - LIDAR, summer 2013, HTV, JEM-EF
  - Rapid-Scat (Ku-band scatterometer)
    - Launch early CY2014, Falcon/Dragon
  - *Lightning Imaging Sensor (under consideration)*
  - *Hyperspectral Follow-on to HICO (under consideration)*

- Approved instruments funded by ESD
  - SAGE-III (Stratospheric Aerosol and Gas Expt)
    - In Phase-C; 8/2014 Launch on Falcon/Dragon; ESA provides hexapod pointing p'form
  - *OCO-3 (Orbiting Carbon Observatory-3 instrument only)*
    - *Phase-A November 2012; Launch Fall, 2017*


International Space Station
Earth Science Instruments
ELC-2
AMS
ELC-3
ESP-3
ELC-4
Columbus EF
JEMEF
ELC-1
ESD/SAGE III (2014)
ISERV (2012)
ESD/OCO-3 (2017)
ISS/CATS (2014)
ISS/HICO (2009)
ISS/RapidSCAT (2014)
External Logistics Carriers – ELC-1, ELC-2, ELC-3
External Stowage Platforms – ESP-3
Alpha Magnetic Spectrometer
Columbus External Payload Facility
Kibo External Payload Facility

ISERV: The ISS / SERVIR Environmental Research and Visualization System

ISERV *Pathfinder* in WORF

@ 350 km alt.	Angular	Spatial
Resolution	1.65 arc sec	2.8m
FOV	2.38º x 1.59º	14.5km x 9.8km
Spectral	350nm to 800nm	

Applications

- **Primary** – Humanitarian Response/Disaster Analysis (assessment, ground operations support)
- **Secondary** – Deforestation Survey, Space Archaeology, Agriculture Inventory

Current Status

- Fit check and HFIT verification – 11Jan2012
- Payload delivery to CMC @ JSC – 12Jan2012
- Shipment to JAXA – 23Jan2012
- Launch aboard HTV-3 – 21July 2012
- System operations initiation – February 2013

ISERV *Pathfinder* is a COTS-based, visible spectrum instrument designed to provide a low cost path to experience and expertise in data acquisition, and system design and implementation. *Pathfinder* is the first step in an envisioned suite of Earth observing instruments aboard ISS, culminating in a broad spectrum, multipurpose, externally mounted sensor system.

ISERV First Light Image

February 18, 2013: The Rio San Pablo in Veraguas, Panama, as it empties into the Golfo de Montijo

Image dimensions:
~15 km x 13 km.
North is to upper right.

ISERV is in ISS WORF

ESD Programmatic Summary: 2007 - 2013

- 1/2007: Decadal Survey Released
  - Legacy missions under development: Jason-2/OSTM, OCO, Glory, Aquarius/SAC-D, NPP, LDCM, GPM (Core+LIO)
  - ~55%/45% split between Flight, non-Flight
  - ~1000 hours planned flight time for Airborne Science Program
  - No budgeted competitive flight program (no ESSP solicitations)
  - FY2007 ESD budget request - ~1.45B (after $55M for rescission)
- Decadal Survey Recommendations
  - Re-invigorate on-orbit constellation – launch legacy missions
  - Preserve programmatic balance
  - Embark on 15 new missions in 3 tiers
  - Institute competitive flight program (Venture-Class)
  - Increase use of airborne science program
  - Increase ESD budget by 30-40% (to $2B/year [FY07 $$] by 2010
  - Implement missions in a more cost-effective way, while preserving NASA core expertise

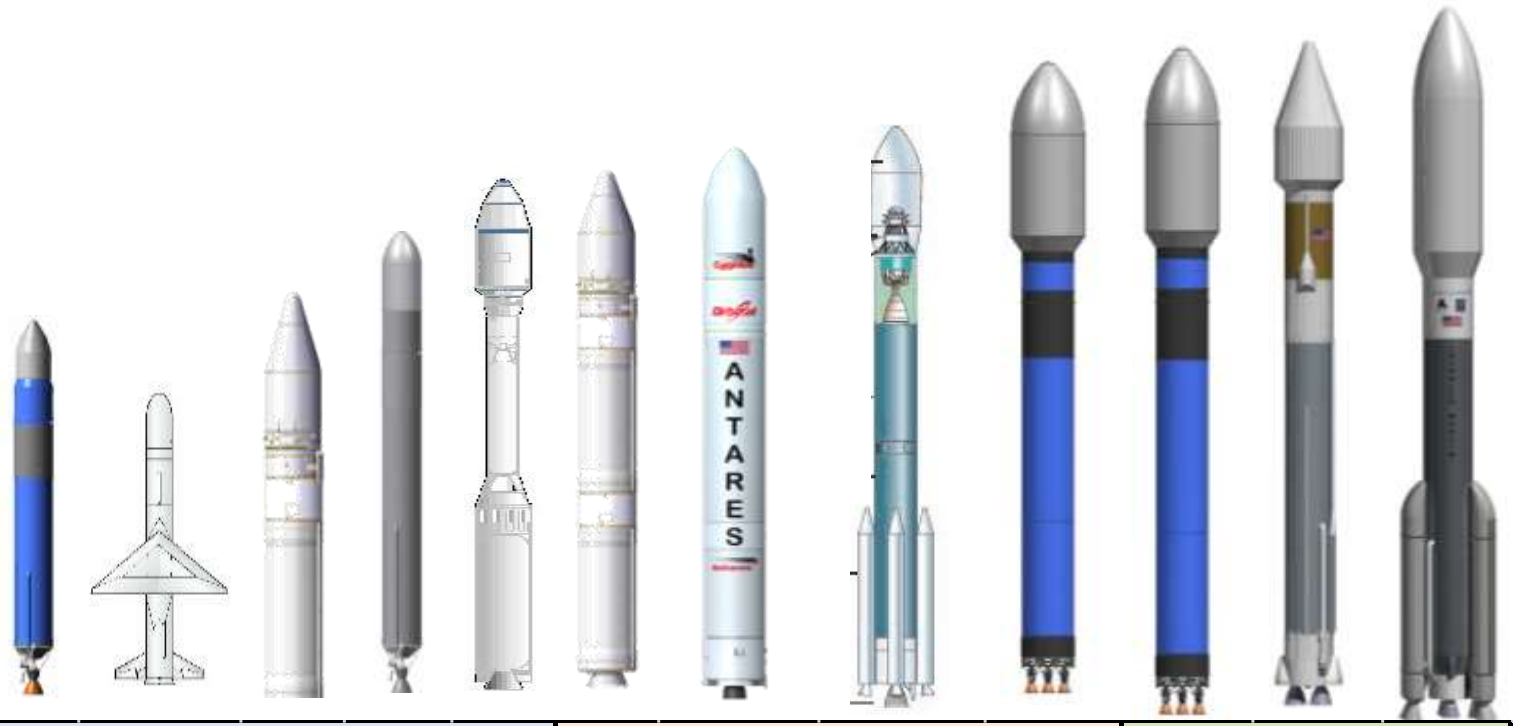
What ESD Did: 2007 – 2013

- **6** Legacy Missions Launched (4 successfully); 1 more to launch before 2/2014
  - OSTM: 6/20/08; ~~OCO: 2/24/09~~; ~~Glory: 3/4/11~~; Aquarius: 6/10/11; NPP: 10/28/11; LDCM: 2/11/2013
  - GPM: 2/15/14
- Climate Initiative developed: OCO-2 (7/14), SMAP (10/14), SAGE-III/ISS (late CY2014) to launch in 2014
- 7 additional missions funded for launch by 2020 (ICESAT-2, CYGNSS, *TEMPO*, GRACE-FO, OCO-3, *PACE*, SWOT)
- Airborne hours increased x 2.5, including ICEBridge, EVS
- Venture-Class funded, selected, next round on schedule (all 3 strands)
- Budget increased to ~$1.8B/year

ISSUES

- Launch Vehicle cost, availability

- Potential significant external budget perturbations from sequestration, FY14-18 budget submit, etc.



Performance shown below rounded down to nearest 50kg in the Small class and nearest 100 kg in the Medium and Intermediate classes. For detailed performance data see http://elvperf.ksc.nasa.gov

Vehicle Class	Small					Medium				Intermediate		
Launch Vehicle	**Falcon 1**	**Pegasus XL**	**Athena Ic**	**Falcon 1e**	**Taurus XL**	**Athena IIc**	**Antares 120/130**	**Delta II 7320/7920**	**Falcon 9 v1.0**	**Falcon 9 v1.1**	**Atlas V 401**	**Atlas V 551**
Offeror	SpaceX	OSC	LMSSC	SpaceX	OSC	LMSSC	OSC	ULS	SpaceX	SpaceX	ULS	ULS
Perf @ 600 km Sun Synch	150kg	200kg	300kg	500kg	800kg	1100kg	1400/*2500kg	1500/2900kg	6400 kg	12200 kg	6600 kg	14200 kg
Perf @ C3 of 10	n/a	n/a	n/a	n/a	n/a	n/a	*600 / n/a	n/a	1300 kg	2600 kg	2400 kg	5000 kg
Certification Cat	n/a	Cat 3	n/a	n/a	Cat 2	n/a	n/a	Cat 3	n/a	n/a	Cat 3	Cat 3
Launch Sites	RTS	CCAFS WFF RTS VAFB	CCAFS KLC WFF	RTS	CCAFS WFF VAFB	CCAFS KLC	WFF	VAFB	CCAFS VAFB	CCAFS VAFB	CCAFS VAFB	CCAFS VAFB

*Antares 120 performance @ C3 of 10 is not available. Data shown is for Antares 122 performance @ C3 of 10 // Antares 130 performance to sun synch not available. Data shown is for Antares 131 performance to 600km sun synch. NOTE: Delta IV is not currently offered on NLS II

NLS II Launch Vehicles

For detailed performance data see http://elvperf.ksc.nasa.gov

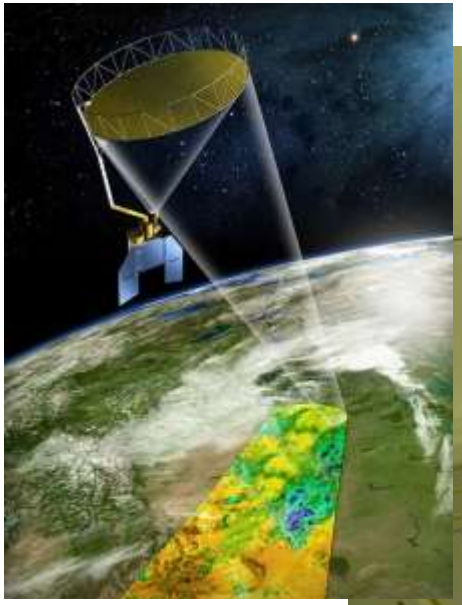
NOTE: Delta IV and Antares are not currently offered on NLS II

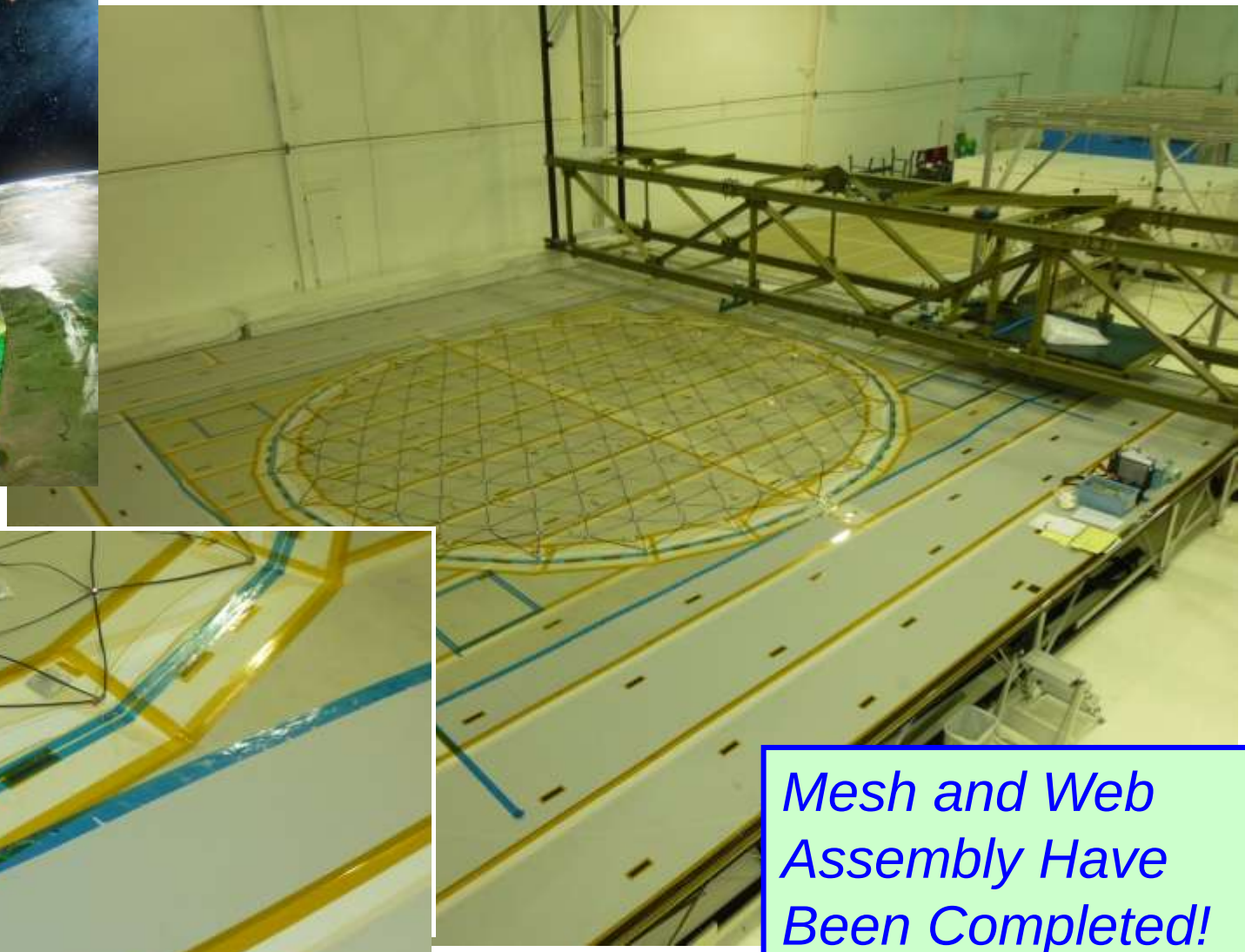
Launch Vehicle	Falcon 1	Pegasus	Athena I	Falcon 1e	Taurus XL	Athena II	Delta II 7320	Falcon 9 Blk1	Falcon 9 Blk2	Atlas V 401
Offeror	SpaceX	OSC	LMSSC	SpaceX	OSC	LMSSC	ULS	SpaceX	SpaceX	ULS
Perf @ 600 km Sun Synch	175 kg	240 kg	320 kg	505 kg	950 kg	1175 kg	1700 kg	6490 kg	7540 kg	6640 kg
Certification Cat	n/a	Cat 3	n/a	n/a	Cat 2	n/a	Cat 3	n/a	n/a	Cat 3
Launch Sites	RTS	CCAFS WFF RTS VAFB	CCAFS KLC WFF	RTS	CCAFS WFF VAFB	CCAFS KLC WFF	VAFB	CCAFS RTS	CCAFS RTS	CCAFS VAFB

GPM Completed TVAC

The GPM Core Observatory was removed from the GSFC SES Chamber on January 27th

SMAP: Reflector Boom Assembly Mesh and Web





Mesh and Web Assembly Have Been Completed!

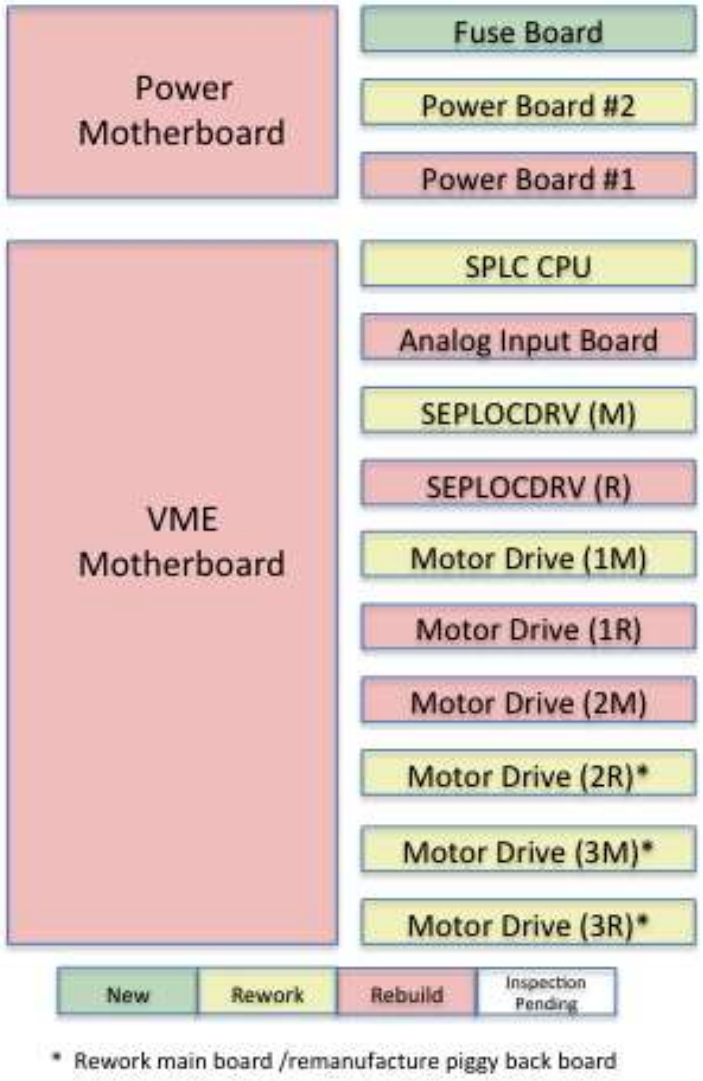
SAGE III:
Hexapod Electronics Unit Status

Hexapod Mechanical Assembly (HMA)

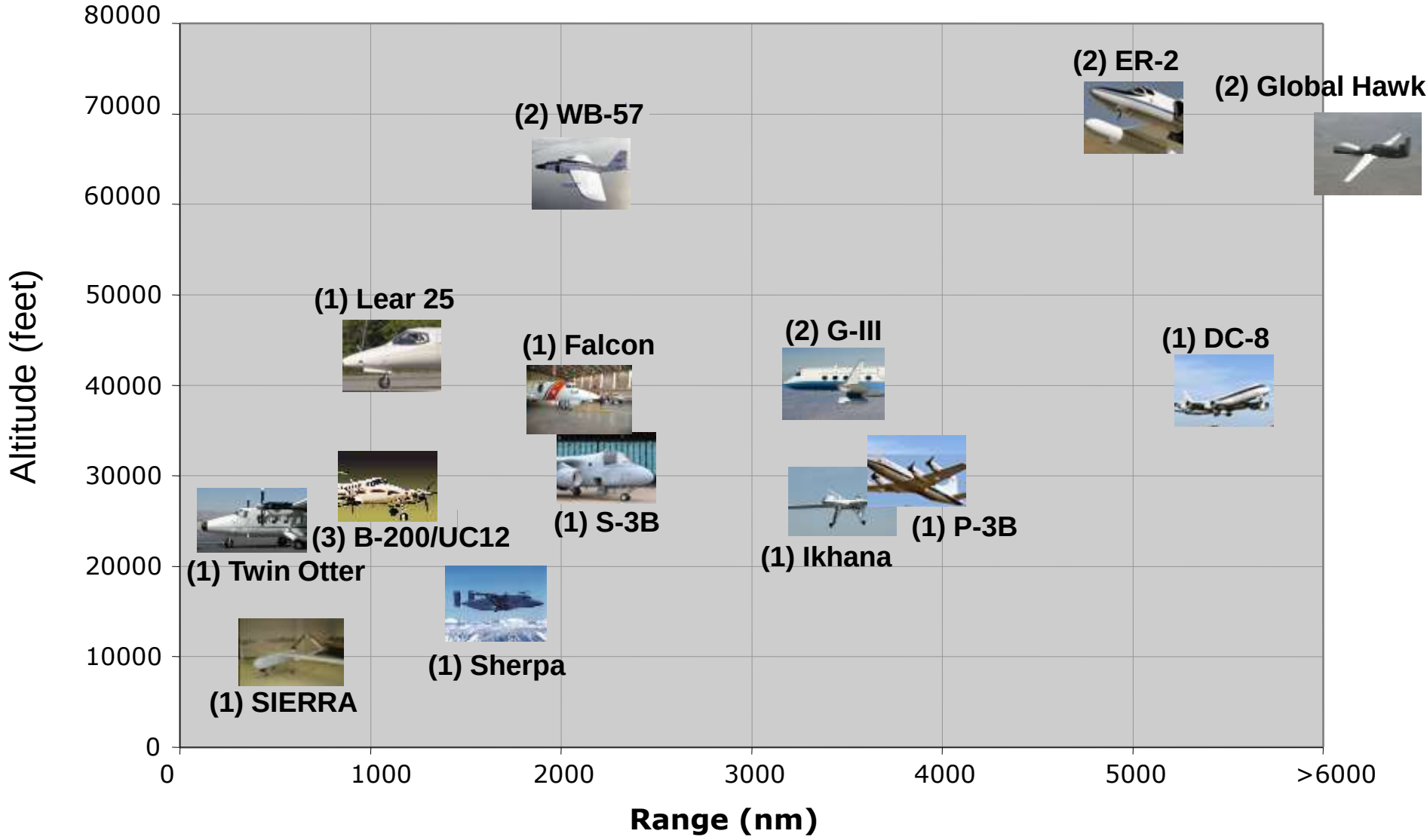
Hexapod Electronics Unit (HEU)

- All boards inspected and **all boards need replacement or rework**!
- Discussing recovery plans with ESA and ISS

HEU Printed Wiring Board Status



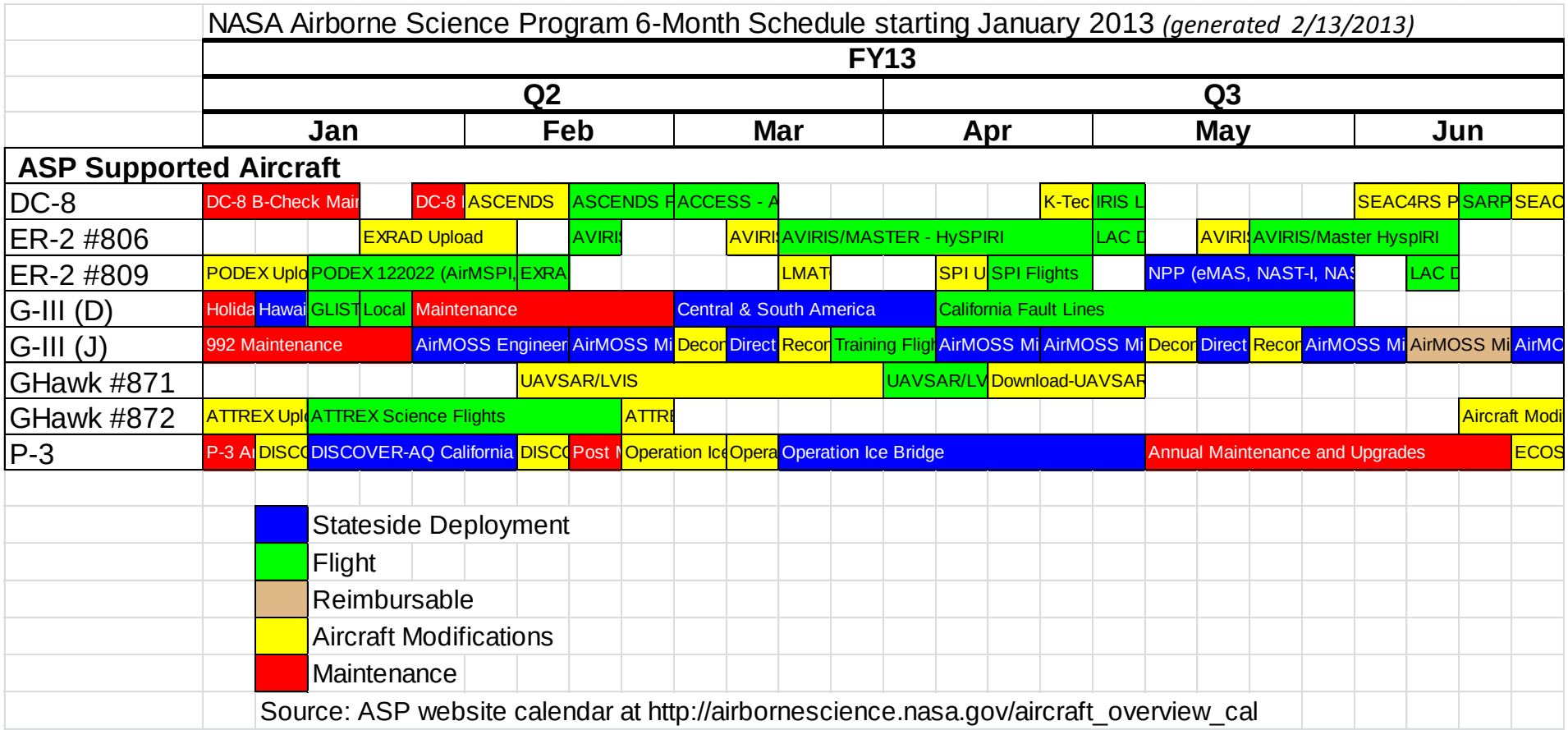
NASA Airborne Science Aircraft



LDCM Commissioning Events
(planning dates)

S/C Sub-system Activation (initialize GPS, SADA , SSR, X band, ACS)	Feb. 11-17	**Complete**
OLI and TIRS power up	Feb. 16	**Complete**
1st Engineering Burn	Feb. 17	**Complete**
Began generating and downlinking OLI and TIRS test pattern data	Feb. 17	**Complete**
Open OLI shutter to begin dryout	Feb. 18	**Complete**
ACS calibration maneuvers	Feb. 20 - Mar. 3	**In Progress**
TIRS cryocooler launch lock deployment, uncage, and electronics power on	Feb. 24	**Complete**
Load OLI pixel map	Feb. 26	**Complete**
TIRS earth shield deployment, Cooldown begins	Mar. 4	
TIRS focal plane electronics (FPE) power up, Cryocooler commissioning	Mar. 5	
ACS calibration maneuvers (post earth shield deploy)	Mar. 6 - 12	
OLI dryout complete, cooldown begins	Mar. 6	
First TIRS Image	Mar. 8	
OLI and TIRS routine calibrations begin	Mar. 10	
First OLI image	Mar. 14	
Ascent Burn 1	Mar. 16	
Ascent Burn 2	Mar. 19	
Goal: Approach 400 scenes / day before Underfly	Mar. 27	
Landsat 7 Underfly	Mar. 28 - Apr. 1	
Inclination Adjust Maneuver	Apr. 3	
Ascent Burn 3	Apr. 9	
Ascent Burn 4 - Arrive on WRS-2 Grid	Apr. 12	
WRS-2 16-day cycle demonstration begins	Apr. 26	

Airborne Science 6-month Schedule

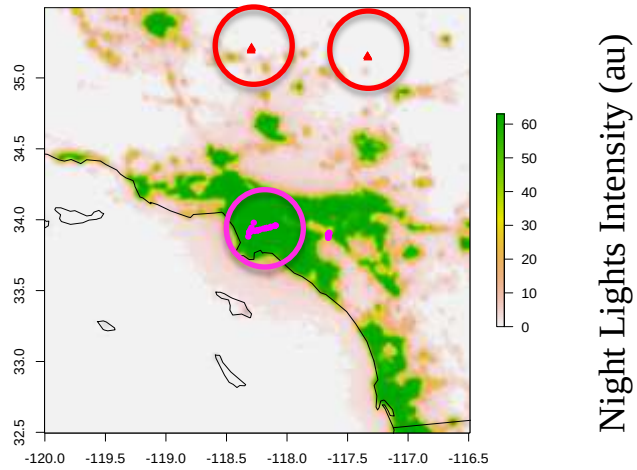


Space-based observations of megacity carbon dioxide

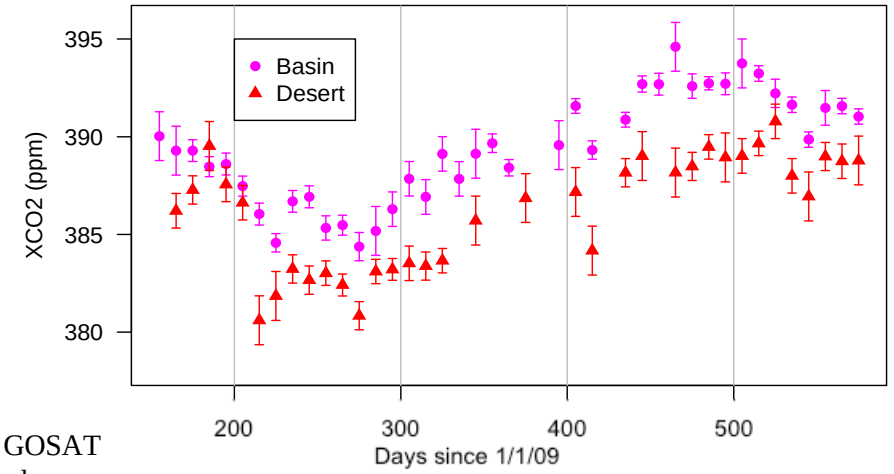
Eric A. Kort, Christian Frankenberg, Charles E. Miller, and Tom Oda, GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L17806, doi:10.1029/2012GL052738, 2012

NASA scientists demonstrated the potential of satellite-borne instruments to provide accurate global monitoring of megacity CO_2 emissions using GOSAT observations of column averaged CO_2 dry air mole fraction (X_{CO2}) collected over Los Angeles and Mumbai. By differencing observations over the megacity with those in nearby background, they observed robust, statistically significant X_{CO2} enhancements of 3.2 ±1.5 ppm for Los Angeles and 2.4 ±1.2 ppm for Mumbai, and found these enhancements can be exploited to track anthropogenic emission trends over time. They estimated that X_{CO2} changes as small as 0.7 ppm in Los Angeles, corresponding to a 22% change in emissions, could be detected with GOSAT at the 95% confidence level. Urban areas now house more than half the world's population, and are estimated to contribute over 70% of global energy-related CO_2 emissions. Many cities have emission reduction policies in place, but lack objective, observation- based methods for verifying their outcomes. The study used data from the Japan Aerospace Exploration Agency's Greenhouse gases Observing Satellite (GOSAT) and algorithms developed for NASA's Orbiting Carbon Observatory-2 (OCO-2) mission. Future observations from OCO-2 will enable significant improvements over GOSAT based on better measurement precision, 100x more observations and spatially-resolved urban CO_2 dome sampling along the OCO-2 flight track.

Figures: Observed X_{CO2} urban dome of Los Angeles from June 2009 to August 2010.



10-day average column CO_2 (LA)



3.2 ± 1.5 ppm in-city

(Top) Nightlights map of the Los Angeles megacity and surroundings. Selected GOSAT observations within the basin (pink circles near 34N, 118W) and in the desert (red triangles near 35N, 117–118W). *(Bottom)* Time-series for basin and desert observations averaged in 10-day bins.

ESD Orbital Flight Portfolio – 2012-2022

- **LDCM** (2/11/2013) – "Landsat-8" including thermal IR, w/USGS ✓ ✓ ✓
- **GPM** (2/2014) – Global Precipitation mapping, w/JAXA
- **OCO-2** (7/2014) – Atmospheric CO2 monitoring, recovery mission
- **SAGE-III/ISS** (8/2014) – Ozone, Temp, Humidity profiles, w/HEOMD, ESA
- **SMAP** (10/2014) – Soil Moisture and Freeze/Thaw cycling, w/CSA (minor)
- **ICESat-2** (late-2016) – Precision Ice Topography, Ecosystem monitoring
- ***CYGNSS [EV-Mission/1]*** *(late 2016)*
- **GRACE-FO** (8/2017) – Gravity/Ice Mass/Ground Water, w/GFZ & DLR
- ***OCO-3/ISS*** *(Fall 2017)* – CO2 continuity, from ISS, OCO-2 spares
- ***TEMPO [EV-Instrument/1]*** *(2017)*
- **SWOT** (2020) – Wide-swath ocean altimetry, land water, w/CNES
- ***PACE*** *(2020)* – Ocean Color, possibly Aerosols
- ***EV-Instrument/2 Venture-Class*** *(NLT 2020)*
- ***L-band SAR*** *(2021)* – Solid Earth, Cryosphere, Ecosystems, w/ISRO
- ***CLARREO*** *(2022?)* – Precise global radiation balance, possibly w/UK
- ***EV-Mission/2*** *(NLT 2022)*
- ***EV-Instrument/3*** *(NLT 2022)*
- Significant studies ongoing for all other Tier-2 Decadal Survey missions