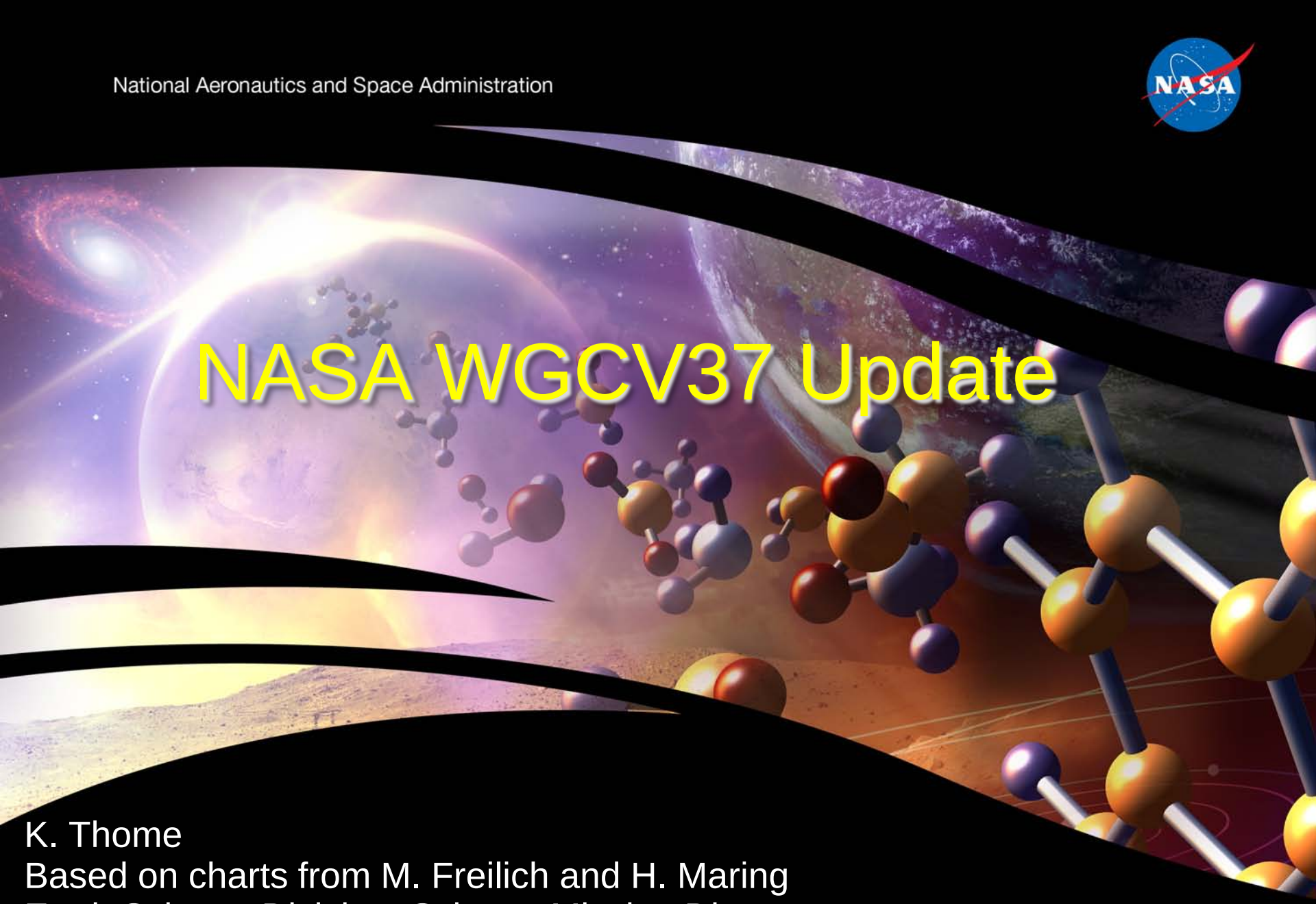
National Aeronautics and Space Administration

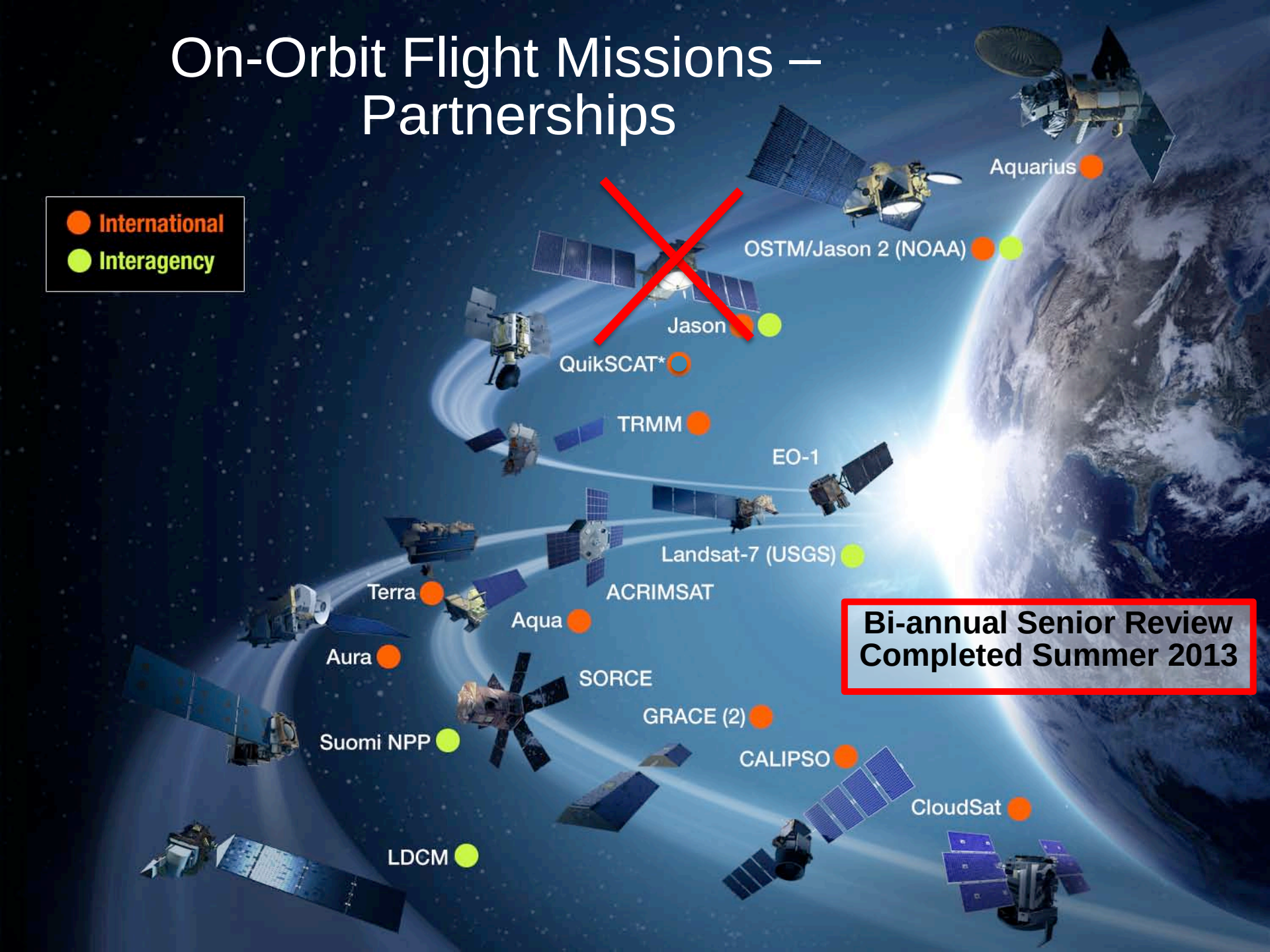


NASA WGCV37 Update

K. Thome
Based on charts from M. Freilich and H. Maring
Earth Science Division, Science Mission Directorate

February 2014

On-Orbit Flight Missions – Partnerships



Bi-annual Senior Review Completed Summer 2013

Operating Satellite Status

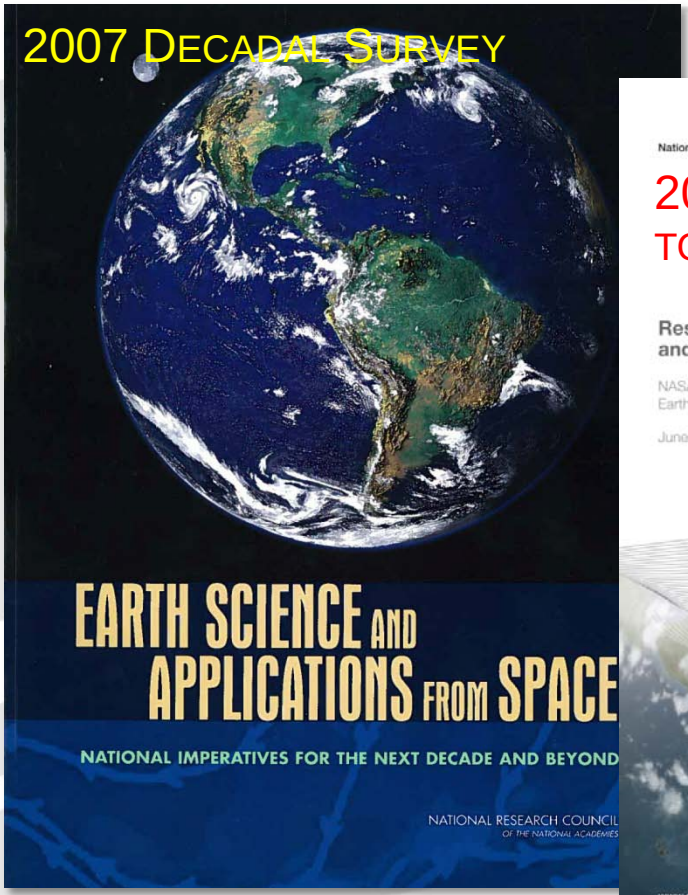
Mission	Launch	Phase	Design Life (yr)	Current Life (yr)	Expected End
Terra	18-Dec-99	Extended	5	14	2017
ACRIMSat	20-Dec-99	Extended	5	14	2020
Aqua	03-May-02	Extended	5	12	2022
SORCE	25-Jan-03	Extended	5	11	2015
Aura	15-Jul-04	Extended	5	9	2018
Cloudsat	28-Apr-06	Extended	3	8	2015
CALIPSO	28-Apr-06	Extended	3	8	2016
OCO - 1	24-Feb-09	Launch Failure	2	N/A	N/A
Glory	04-Mar-11	Launch Failure	3	N/A	N/A
Suomi-NPP	25-Oct-11	Prime till Oct 2016	5	2	not enough data

Operating Instrument Status

INSTRUMENT	INSTRUMENT	MISSION	STATUS
Spectral Irradiance Monitor	SIM	SORCE	Operating in daylight only
Solar-Stellar Irradiance Comparison Experiment	SOLSTICE	SORCE	Operating in daylight only
Total Irradiance Monitor	TIM	SORCE	Operating in daylight only
XUV Photometer System	XPS	SORCE	Operating in daylight only
Clouds and the Earth's Radiation Energy System	CERES	Terra	Operating nominally
Moderate Resolution Imaging Spectroradiometer	MODIS	Terra	Operating nominally
Multi-Angle Imaging Spectrometer	MISR	Terra	Operating nominally
Measuerment of Pollution in the Troposphere	MOPITT	Terra	Operating nominally
Advanced Spaceborne Thermal Emission & Reflection Radiometer	ASTER	Terra	SWIR failed (VNIR & TIR operational)
High Resolution Dynamics Limb Sounder	HIRDLS	Aura	Failed
Ozone Monitoring Instrument	OMI	Aura	Row anomaly
Microwave Limb Sounder	MLS	Aura	Operating nominally with Band 13 powered off & THz channel in standby; on redundant mirror switching mechanism electronics
Troposphere Emission Spectrometer	TES	Aura	Interferometer Control System currently working
Cloud-Aerosol Lidar with orthogonal Polarization	CALIOP	CALIPSO	Operating nominally second laser unit
Imaging Infrared Radiometer	IIR	CALIPSO	Operating nominally
Wide Field Camera	WFC	CALIPSO	Operating nominally
Active Cavity Radiometer Irradiance Monitor-III	ACRIM-III	ACRIMSAT	Battery problems
Atmospheric Infrared Sounder	AIRS	Aqua	Operating nominally
Advanced Microwave Scanning Radiometer for EOS	AMSR-E	Aqua	Operating at 2rpm for cross-calibration with GCOM-W1 AMSR2
Advanced Microwave Sounding Unit-A	AMSU-A	Aqua	10 of 15 channels performing well
Humidity Sounder-Brazil	HSB	Aqua	Failed
Clouds and the Earth's Radiation Energy System	CERES	Aqua	Operating nominally
Moderate Resolution Imaging Spectroradiometer	MODIS	Aqua	Operating nominally
Cloud Profiling Radar	CPR	Cloudsat	Daylight Only operations
Visible Infrared Imaging Radiometer Suite	VIIRS	Suomi-NPP	Operating nominally
Cross-track Infrared Sounder	CrIS	Suomi-NPP	Operating nominally
Clouds and the Earth's Radiation Energy System	CERES	Suomi-NPP	Operating nominally
Advanced Technology Microwave Sounder	ATMS	Suomi-NPP	Operating nominally
Ozone Mapping and Profiler Suite	OMPS	Suomi-NPP	Operating nominally

Science Objectives are Provided through External Recommendations

2007 Decadal Survey

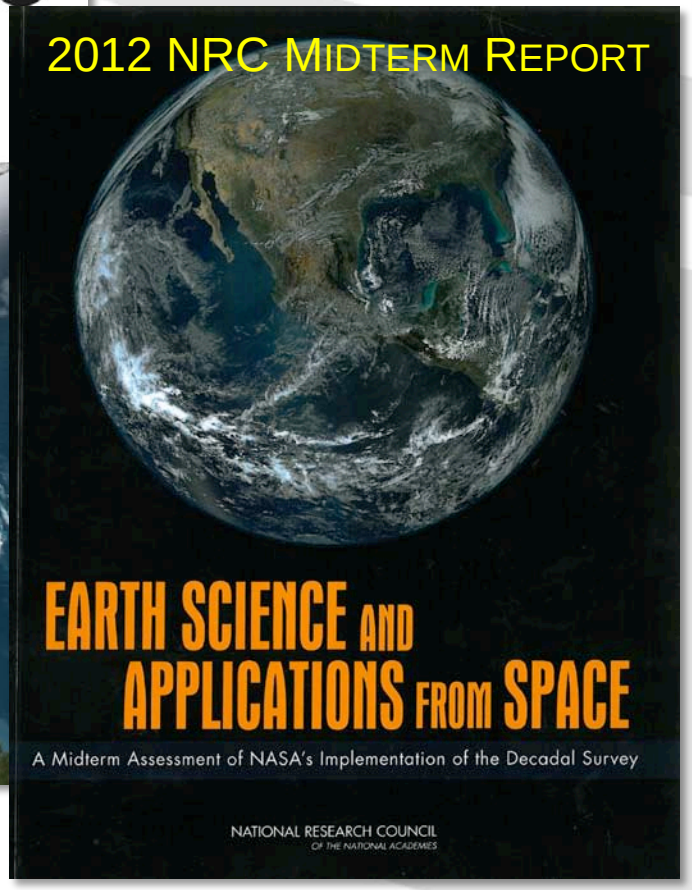


- Research/Applications priorities
- No realistic budget constraint
- Shopping list of missions & activities
- Assumed Legacy missions completed

2010 NASA Response to Climate Plan

- Identified new Climate Measurements
- Matched against President's budget
- Vetted w/OSTP, OMB & Admin

2012 NRC Midterm Report



- Endorsed NASA's implementation
- "Encouraged" more rigorous cost control
- Endorsed additional Venture calls

Common in all guidance is the focus on the long term science objectives

Upcoming Orbital Missions

NASA ESD Flight Portfolio 2013 - 2022

- **GPM** (2/2014) – Global Precipitation mapping, w/JAXA
- **OCO-2** (7/2014) – Atmospheric CO_2 monitoring, recovery mission
- **CATS** (8/2014) – Aerosol and Cloud vertical profile
- **SMAP** (10/2014) – Soil Moisture and Freeze/Thaw cycling, w/CSA (minor)
- **SAGE-III/ISS** (3/2015) – Ozone, Temp, Humidity profiles, w/HEOMD, ESA
- **ICESat-2** (12/2016) – Precision Ice Topography, Ecosystem monitoring
- **CYGNSS [EVM-1]** (late 2016)
- **GRACE-FO** (8/2017) – Gravity/Ice Mass/Ground Water, w/GFZ & DLR
- **OCO-3/ISS** (Fall 2017) – CO_2 continuity, from ISS, OCO-2 spares
- **TEMPO [EVI-1]** (2019) – Tropospheric Emissions from geosynchronous vantage
- **SWOT** (2020) – Wide-swath ocean altimetry, land water, w/CNES
- **EVI-2 Venture-Class** (NLT 2020)
- **PACE** (2020) – Ocean Color, possibly Aerosols
- **L-band SAR** (2021) – Solid Earth, Cryosphere, Ecosystems, w/ISRO
- **CLARREO** (2022?) – Precise global radiation balance, possibly w/UK
- **EVM-2** (NLT 2022)
- **EVI-3** (NLT 2022)
  - Significant studies ongoing for all other Tier-2 Decadal Survey missions
- ***And on the horizon:***
  - ***Sustained Land Imaging program for the U.S. for 2018 – 2038***
  - ***Solar Irradiance, Ozone profiles, and Earth Radiation Budget measurements for beyond 2020***

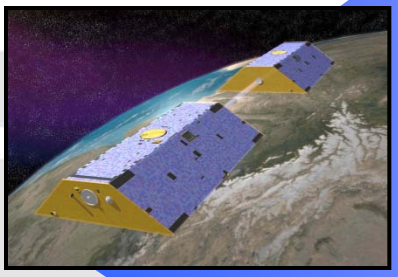
Near-Term Formulation & Development Missions

GPM
Feb. 27, 2014
w/ JAXA; Precip
H-IIA

OCO-2
1 July 2014
Global CO_2
Delta II

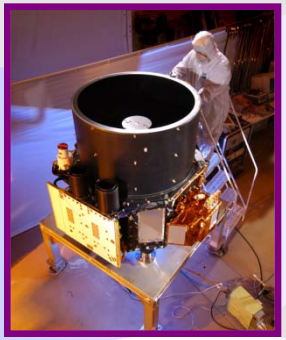
CATS
Aug 2014
w/ ISS
Aerosol & Cloud
Falcon-9

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



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

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



ICESat-2
Dec 2016 (TBR)
Ice Dynamics
Delta II

SAGE III
NET Mar 2015 (TBR)
Ozone & Trace Gases
Falcon-9

Venture Class Activities

- EVS ("EV-1" - Suborbital, Airborne; solicited every 4 years)
  - All 5 investigations are well into their sustained field campaigns
  - All EV-1 investigations flew during 2013
  - ***Second EV-S solicitation proposals received 10 Jan 2014***

- EVM ("EV-2" - Small-sat; solicited every 4 years)
  - CYGNSS successful moved to phase C in July 2013 with planned launch readiness date for October 2016 – April 2017
  - ***FY14 budget proposal includes EV-M/2 solicitation on-schedule in June 2015***

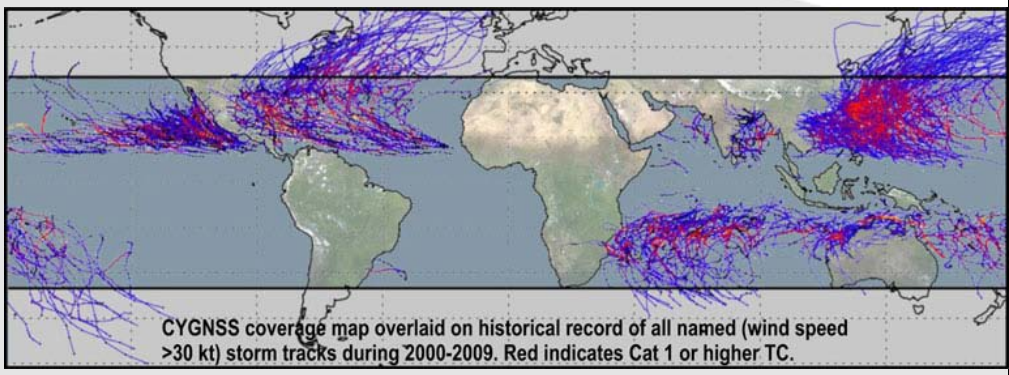
- EVI (Instrument; solicited every 18 months)
  - TEMPO selected for geo-synchronous orbit on hosted payload opportunity (early FY18 launch)
  - ESD making progress on formal host selection
  - **Second "EV-I/2" solicitation released July 2013, proposals received 25 November 2013**
  - ***FY14 budget proposal includes EVI-3 and subsequent solicitations on-schedule***

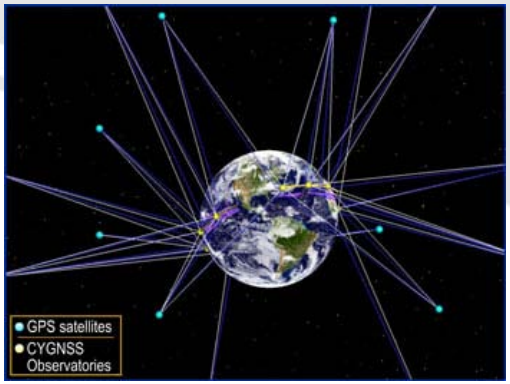
CYGNSS:
Cyclone Global Navigation Satellite System

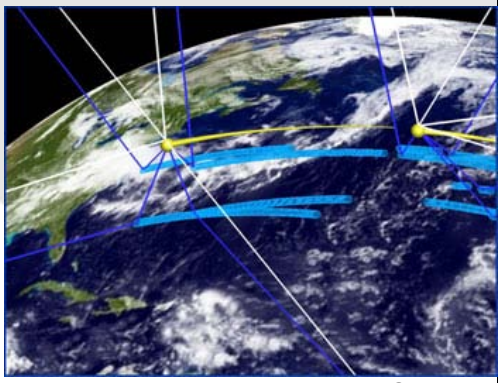
PI: Chris Ruf, University of Michigan
Instrument Development: Surrey Satellite Tech.
Project Management/Science: SW Research Inst.
Other Institutions: NASA Ames, Sierra Nevada Corp.

Features:

- 2016 launch
- Measure ocean surface wind speed in the tropical cyclone inner core with sufficient frequency to resolve genesis and rapid intensification
- Measure ocean surface wind speed in all precipitating conditions, including those experienced in the tropical cyclone eyewall
- Scatterometer approach with GPS receivers of direct and reflected signals from GPS satellites


CYGNSS coverage map overlaid on historical record of all named (wind speed >30 kt) storm tracks during 2000-2009. Red indicates Cat 1 or higher TC.





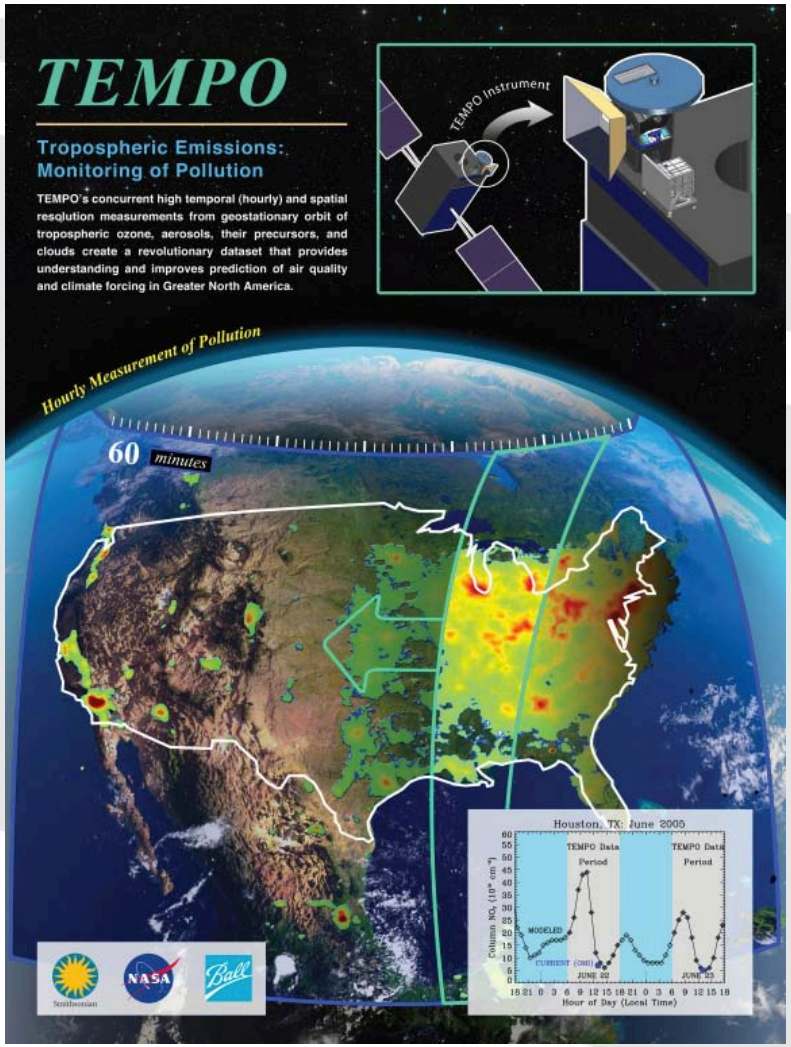
TEMPO Tropospheric Emissions: Monitoring of Pollution

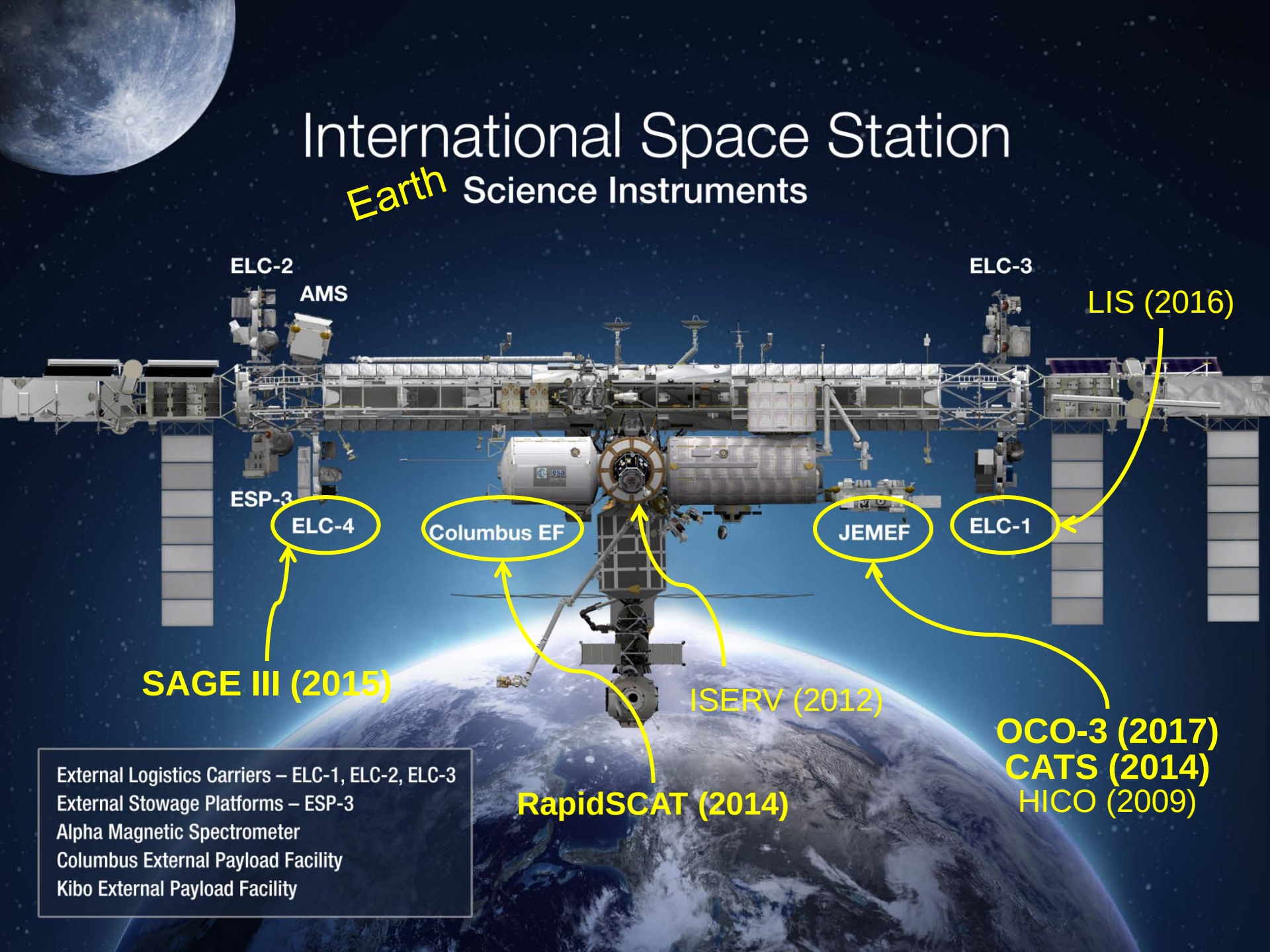
Hourly atmospheric pollution observations from geostationary Earth orbit

PI: Kelly Chance, Smithsonian Astrophysical Observatory
Instrument Development: Ball Aerospace
Project Management/Science: NASA LaRC
Other Institutions: NASA GSFC, NOAA, EPA, NCAR, Harvard, UC Berkeley, SLU, UAH, Nebraska

Features:

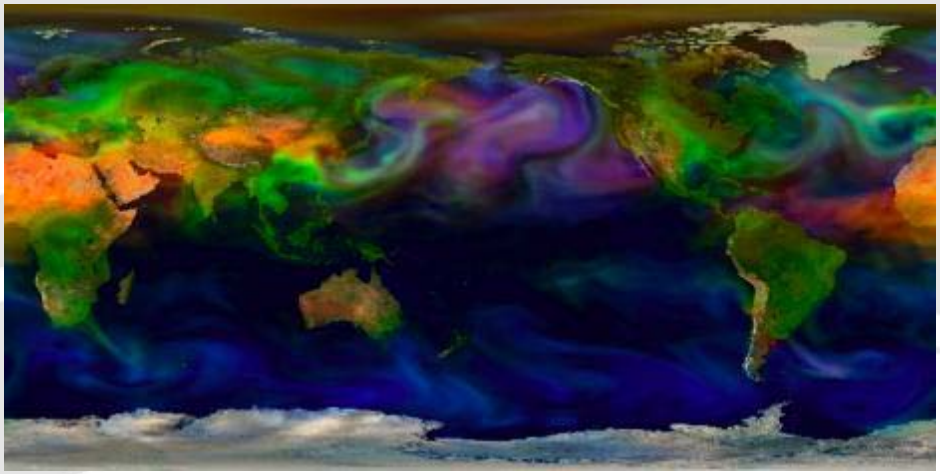
- Delivery 52 months from Authority to Proceed
- NASA will arrange hosting on commercial geostationary communications satellite with expected ~2018 launch
- Provides hourly daylight observations to capture rapidly varying emissions & chemistry
- UV-Vis grating spectrometer to measure key elements in tropospheric ozone & aerosol
- Distinguishes boundary layer from free tropospheric & stratospheric ozone
- North American geostationary component of an international constellation for air quality monitoring



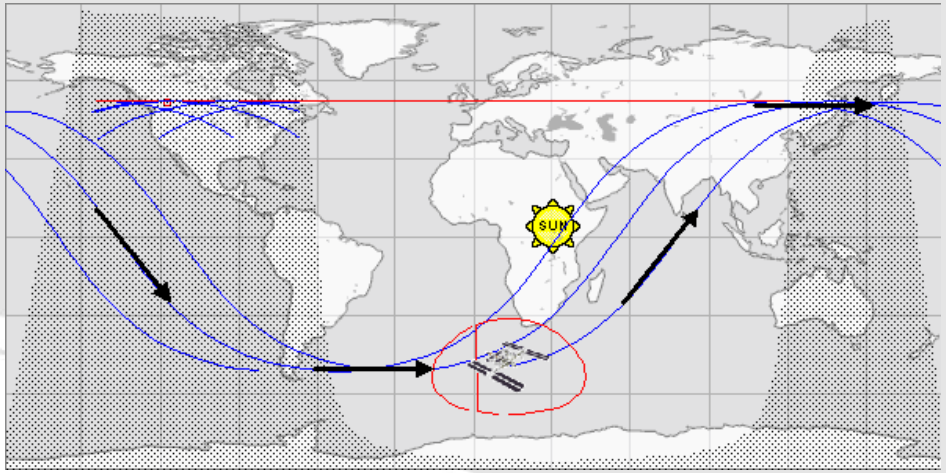

International Space Station
Earth Science Instruments
ELC-2
AMS
ELC-3
LIS (2016)
ESP-3
ELC-4
Columbus EF
JEMEF
ELC-1
SAGE III (2015)
ISERV (2012)
OCO-3 (2017)
CATS (2014)
HICO (2009)
RapidSCAT (2014)
External Logistics Carriers – ELC-1, ELC-2, ELC-3
External Stowage Platforms – ESP-3
Alpha Magnetic Spectrometer
Columbus External Payload Facility
Kibo External Payload Facility

Cloud-Aerosol Transport System (CATS): Key Science Objectives

- Demonstrate multi-wavelength aerosol and cloud retrievals.
- Provide cloud and aerosol data to help bridge the gap between CALIPSO and future missions.
- Enable aerosol transport models with real-time data downlink from ISS
- ISS orbit is intriguing for tracking of plumes and study of diurnal effects (something not possible with A-Train orbit).



Snapshot of GEOS-4 model global aerosol distribution forecast for March 20, 2006
Orange = dust; Blue = sea salt; Green = smoke and sulfate; Saturation ~ species column amount



ISS orbit. The low-inclination orbit permits extensive measurements over aerosol source and aerosol transport regions.

NASA ESD's New Responsibilities

- The responsibility for ***sustained*** measurements of Solar Irradiance, Ozone Profiles, and Earth Radiation Balance beginning in the 2021 ("JPSS-2") timeframe was transferred *from* NOAA *to* NASA/ESD in the FY14 President's Budget Request.

- Additional funding ($40M, FY14) was provided to ESD for this new scope in FY14; no funds were added in FY15 and beyond.

- FY14 President's budget proposal calls for NASA to lead the architecture design and space component implementation of a sustained system for moderate-resolution, global land imaging – with USGS
  - NASA has lead role in system architecture study, design, implementation, launch, and on-orbit commissioning
  - USGS represents user communities in architecture study, and leads post-commissioning operations, downlink, ground data processing, data distribution, archiving
  - Study Parameters from Office of Management and Budget
    - ***Cost is a constraint:*** $120M/year ***NASA*** average cost (and near-flat budget) over system lifetime
    - Examine international and private sector partnerships
    - Specifically examine infusion of hyperspectral technology
    - Balance initial capability, gap risk/continuity, technology infusion over system lifetime, cost
    - Study results due August 2014

NASA Earth science Highlights

- GPM, OCO-2, CATS, and SMAP will launch in 2014
- Development of a national sustained Land Imaging Satellite System (with USGS) architecture study due in August
- Continued Venture-Class competitions and implementing selected missions
- Operation funding for QSCAT, Jason-1, CloudSat, GRACE, SORCE in FY14 – ends all by FY18
- Advanced development of SMAP, SAGE III/ISS, GRACE-FO, SWOT, CYGNSS, OCO-3, TEMPO, and ICESat-2 for launch before 2021
- Pre-formulation studies continued for PACE, L-band SAR, and other US NAS Decadal survey-recommended and climate architecture missions