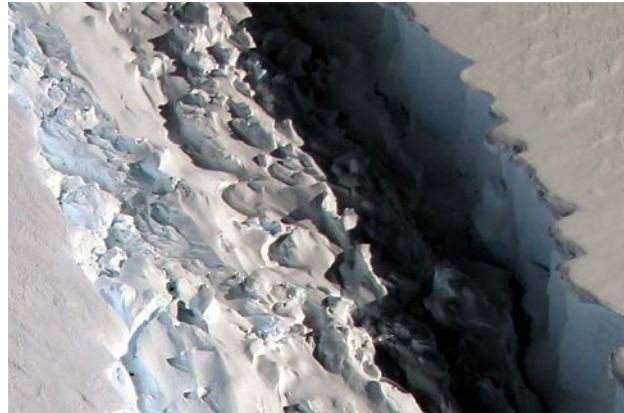


SCIENCE



Briefing to CESAS

Michael Freilich
Division Director
Earth Science Division

March 27, 2018

Outline

- FY18, FY19 Appropriation Status
- 2017 *Earth Science and Applications from Space* Decadal Survey
- ESD Approach Formulation to Decadal Implementation
- ESD Flight-related Partnerships
- Overview of ESD FY18 Program (non-Flight emphasis)

NASA/ESD Appropriation: FY18

- FY18 (1 Oct 2017 – 30 Sept 2018) funding – appropriated via an Omnibus – is at the **FY16/FY17** level (~\$1.92B)
- Continues operations and development of FY17 Program of Record (including DSCOVR EPIC/NISTAR, PACE, CLARREO-PF, OCO-3 (to launch as manifested in late CY2018
- Endorses ESD/SMD discontinuance of RBI (mitigation report due in 180 days)
- Silent on **termination** of Carbon Monitoring System budget line (all ongoing grants will continue) (R&A)

- (Pre)Formulation
- Implementation
- Primary Ops
- Extended Ops

NASA Earth Science

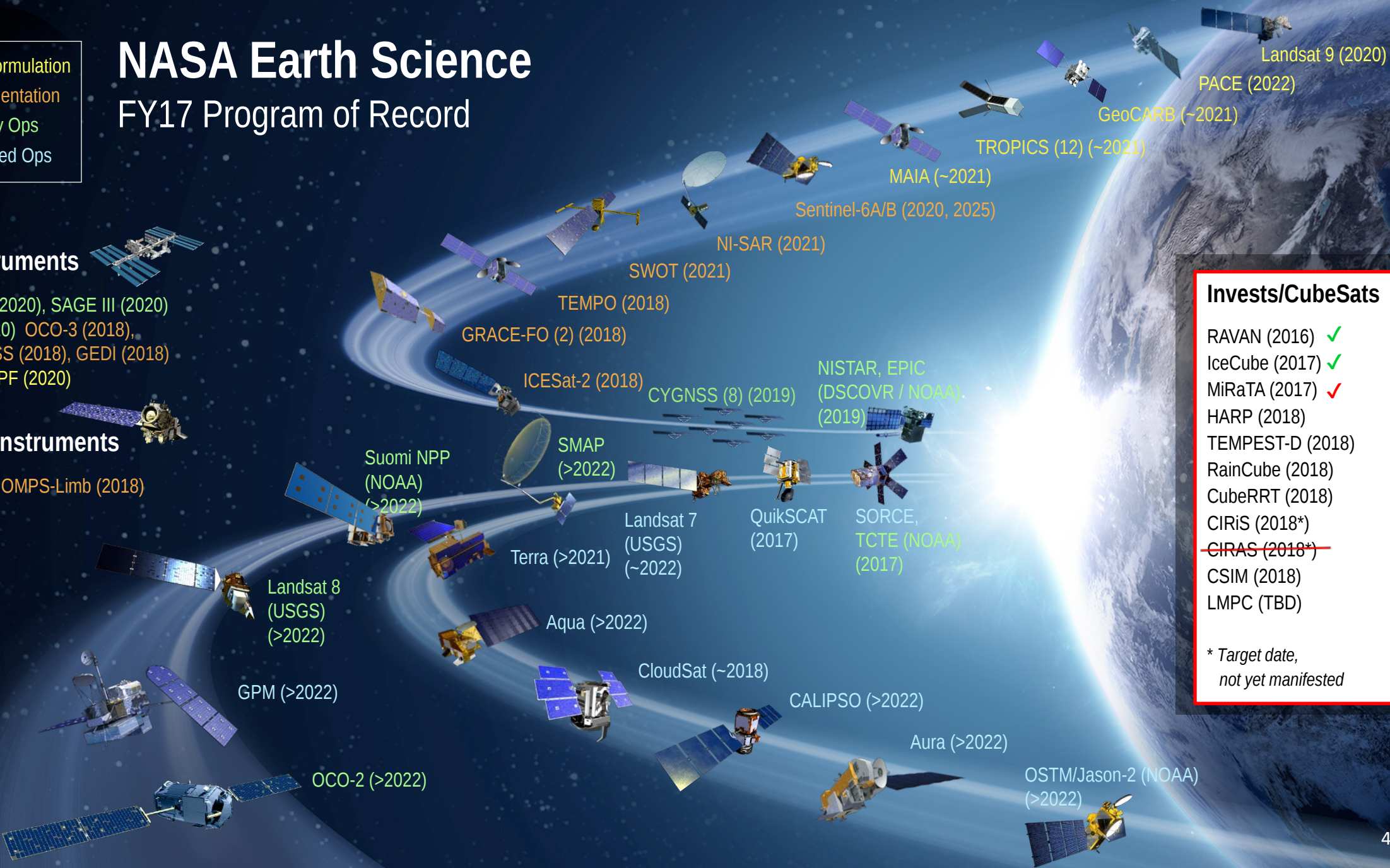
FY17 Program of Record

ISS Instruments

CATS, LIS (2020), SAGE III (2020)
 TSIS-1 (2020) OCO-3 (2018),
 ECOSTRESS (2018), GEDI (2018)
 CLARREO-PF (2020)

JPSS-2 Instruments

RBI (2018), OMPS-Limb (2018)



Invests/CubeSats

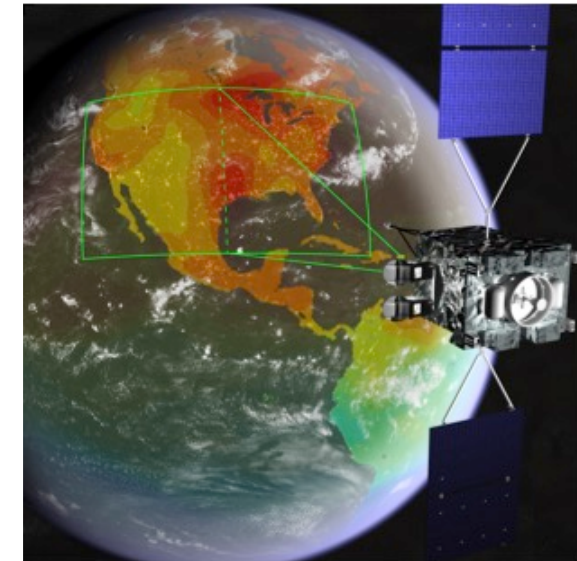
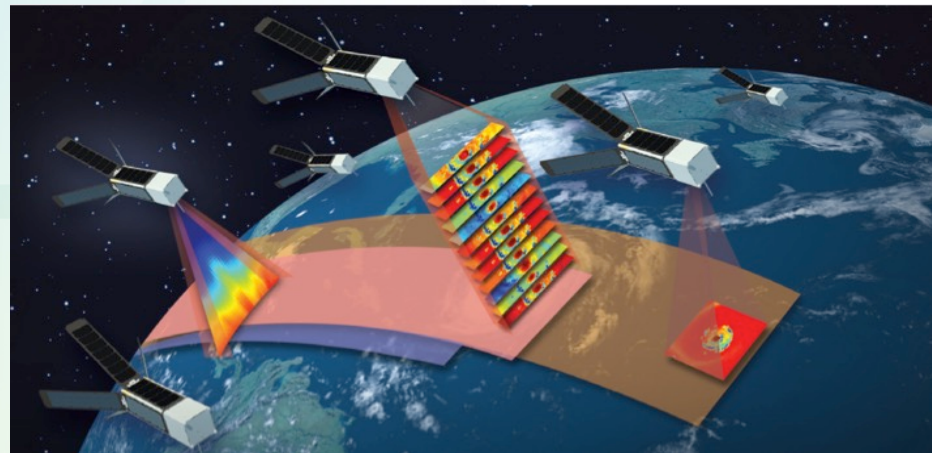
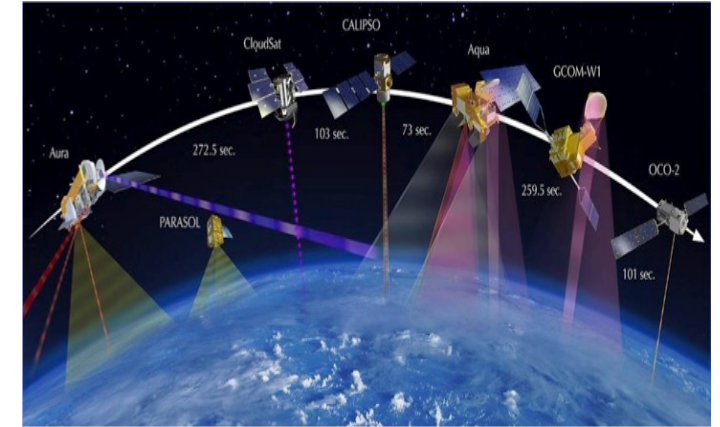
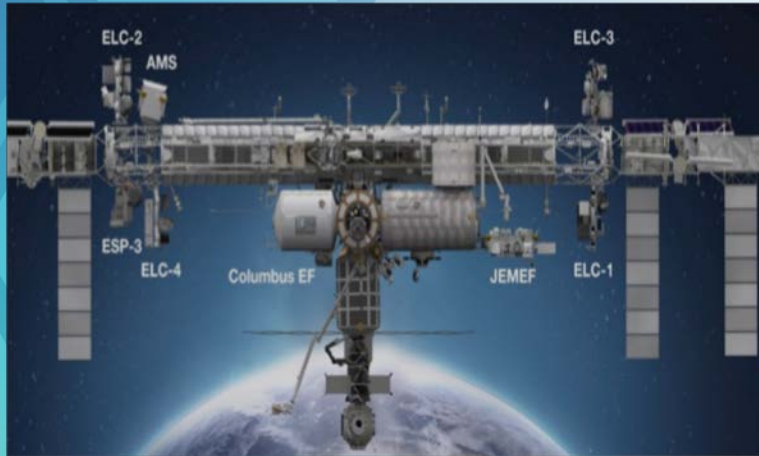
- RAVAN (2016) ✓
- IceCube (2017) ✓
- MiRaTA (2017) ✓
- HARP (2018)
- TEMPEST-D (2018)
- RainCube (2018)
- CubeRRR (2018)
- CIRiS (2018*)
- ~~CIRAS (2018*)~~
- CSIM (2018)
- LMPC (TBD)

* Target date, not yet manifested

NASA/ESD Funding/Appropriation: FY19

- President's **FY19-23** detailed budget proposal released 12 February 2018
 - o Proposes **FY19 ESD funding at \$1.8B**
 - o Continues to propose termination of **DSCOV**R EO instruments **EPIC, NISTAR; OCO-3; PACE; CLARREO-PF; RBI** (discontinued by ESD/SMD in February, 2018 owing to high cost-to-complete and technical issues); **Carbon Monitoring System (R&A)**; modest (undirected) cut to other R&A activities
- FY19-23 President's Budget Proposal ***does allow continuation of a balanced ESD portfolio of activities***
 - o Funding for all remaining elements of the ongoing Flight Program of Record
 - o Landsat-9 remains on-track for 12/2020 launch; NASA portion of Sustainable Land Imaging Program funded
 - o Venture-Class remains fully funded and on-track for planned solicitations and selections
 - o Applied Sciences and Earth Science Technology Office programs flat-funded, including InVEST CubeSat validation program
 - o Small-satellite Constellation Data Buy Pilot funded

NASA Observing System *INNOVATIONS*



RECENT and UPCOMING NOTABLE FLIGHT PROGRAM EVENTS

- o 2017 Senior Review recommended continuation of most on-orbit missions
 - o QuikSCAT to be terminated by October 2018
 - o TES instrument on Aura discontinued (low availability resulting from hardware issues)
 - o GRACE mission ended
 - o CATS (ISS) mission ended owing to instrument failure
 - o Jason-2/OSTM moved to lower orbit (IMU redundancy/temperature issues) – continues to provide near-real-time and geodetic measurements
 - o CloudSat moved to safe orbit 2.7 km below A-Train (loss of hardware redundancy) – continues to provide high-quality science data
 - o RBI discontinued by NASA for technical, cost, schedule issues; work underway to develop an affordable and capable replacement for launch in JPSS-3 timeframe (2026)
 - o TSIS-1 instrument successfully launched to ISS and operating
 - o NOAA's JPSS-1 mission successfully launched and operating
 - o ICECube, MIRATA CubeSats launched (MIRATA failed once on-orbit); MicroMAS-2 CubeSat successful on JPSS-1 launch
-
- o OCO-3 completion and delivery to storage April, 2018
 - o GRACE-FO on-track for launch late April, 2018
 - o ICESat-2 on-track for launch September, 2018
 - o ECOSTRESS on track for launch late FY18
 - o GEDI delivery accelerated to allow launch as early as November, 2018
 - o HARP, TEMPEST-D, RainCube, CubeRRT, CSIM CubeSats/SmallSats manifested for launch in 2018
 - o EVI-4 selections: EMIT (hyperspectral aerosol mineralogy/composition) and PREFIRE (Arctic Far-IR emissions from dual CubeSats)

Earth Science Division's Venture Opportunities

EVS

Sustained Sub-Orbital
Investigations
(~4 years)

EVM

Complete, self-
contained, small
missions
(~4 years)

EVI

Full function, facility-class
instruments Missions of
Opportunity (MoO)
(~18 months)

Mission	Mission Type	Release Date	Selection Date	Major Milestone
EV-1, aka EVS-1	5 Suborbital Airborne Campaigns	2009	2010	N/A
EVM-1, CYGNSS	Smallsat constellation	2011	2012	Launched Dec 2016
EVI-1, TEMPO	Geosynchronous hosted payload	2011	2012	Delivery NLT 2017
EVI-2, ECOSTRESS & GEDI	Class C & Class D ISS-hosted Instruments	2013	2014	Delivery NLT 2019
EVS-2	6 Suborbital Airborne Campaigns	2013	2014	N/A
EVI-3, MAIA & TROPICS	Class C LEO Instrument & Class D Cubesat Constellation	2015	2016	Delivery NLT 2021
EVM-2, GeoCarb	Geostationary hosted payload	2015	2016	Launch ~2021
EVI-4	Instrument Only	2016	2018	Delivery NLT 2021
EVS-3	Suborbital Airborne Campaigns	2017	2018	N/A
EVI-5	Instrument Only	2018	2019	Delivery NLT 2023
EVM-3	Full Orbital	2019	2020	Launch ~2025
EVI-6	Instrument Only	2019	2020	Delivery NLT 2024

EMIT, PREFIRE
selected for
EVI-4

Open solicitation - In
Review
Completed solicitation

Private Sector Small-Satellite Constellation Pilot (1)

ESD is pursuing a rich program of orbital missions using small satellites

- **CYGNSS (Cyclone Global Navigation Satellite System):** homogeneous tropical constellation of 8 *micro-satellites* using reflected GPS to measure surface winds/air-sea interactions, especially valuable/unique in the precipitation-dominated, dynamic, eyewalls of tropical storms and hurricanes – frequent tropical sampling from 1 orbit plane **SCIENCE**
- **TROPICS (Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats):** homogeneous tropical constellation of 6 *CubeSats* to measure atmospheric profiles in storms/hurricanes – frequent sampling from 2-3 orbit planes **SCIENCE**
- **In-Space Validation of Earth Science Technologies (InVEST):** on-orbit *CubeSat-based* technology validation and risk reduction that could not otherwise be fully tested using ground/airborne systems **TECHNOLOGY**
- **Venture Class Launch Services:** Investment in new, low-cost (<\$15M/launch), commercial launch vehicles capable of orbiting small payloads to LEO – science control of launch schedule and orbits **ENABLING**

Private Sector Small-Satellite Constellation Pilot (2)

Present ESD funding opportunities for use of Small-Satellites and resulting data

- **Earth Venture–Mission and –Instrument programs:** Science-driven, PI-led, cost/schedule constrained, competitively selected, frequently solicited (every 4 years for EVM, every 18 months for EVI); proposals using small-sats have been selected for both EVM and EVI
- **InVEST:** Competitively selected spaceborne technology validations that ***must use*** small-sats or cubesats; 3-year solicitation cadence, frequent launch opportunities using NASA CSLI and VCLS
- **R&A and Applications ROSES calls:** R&A and Applied Sciences competitive research calls are data-source agnostic – use of measurements and information from small-satellite systems/constellations is welcomed if their scientific and applications value to the research is justified in the proposal
- **Earth Observations from Private Sector Small Satellite Constellations Pilot:** Data buys of ***existing*** data products related to ECVs, derived from private sector-funded small-satellite ***constellations*** (3-satellite minimum constellation, full longitude coverage); ***for evaluation by NASA researchers to determine value*** for advancing NASA research and applications activities and objectives; ***pilot buys in 2018***

Private Sector Small-Satellite Constellation Pilot (3)

Status:

- **RFIs released 12 August 2016 and 5 Dec 2017** requesting capability statements
 - 5 responses received to 2016 RFI (3 qualifying)
 - 11 responses received to 2017 RFI (4 qualifying)
- **FY18 funding is available** (OMB and Congressional committees support moving forward)
- **Intend to issue JOFOC contracts to all qualifying respondents**
- **Broad set of ESD-funded researchers will be supported to *assess the value of the geophysical information in the products wrt NASA research and applications objectives***
 - 1 year evaluation period
 - Participants primarily chosen from existing ESD-funded community – evaluation support as budget augmentation
 - Written reports to ESD (not scientific papers)

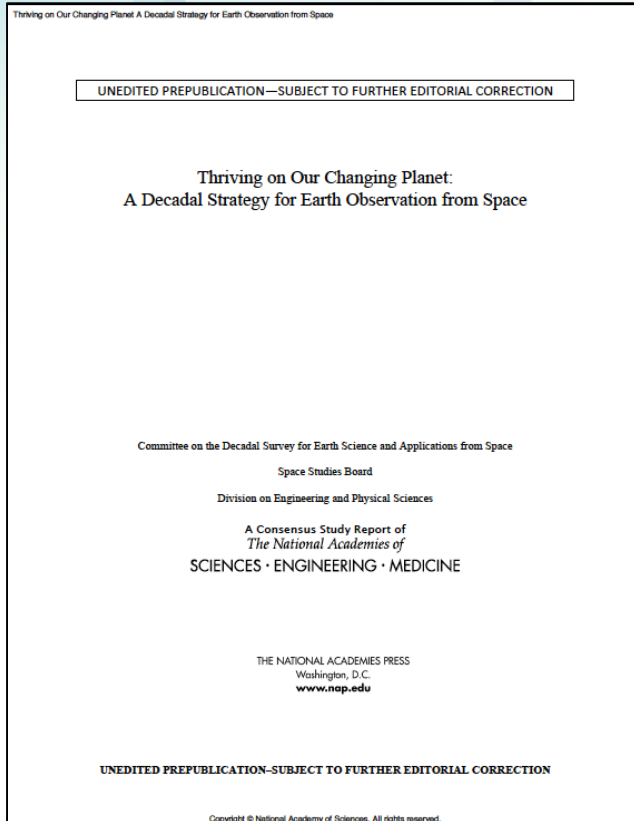
Private Sector Small-Satellite Constellation Pilot (4)

ESD “Value” Elements:

- **Quality of geophysical information**
- **Data availability (latency) and rights (sub-distribution)**
 - Long-term contracts will need to adhere to ESD Data Policy – discussions during pilot evaluation period will help detail cost sensitivities
- **Supplier future plans for constellation(s)**

2017 Decadal Survey Snapshot

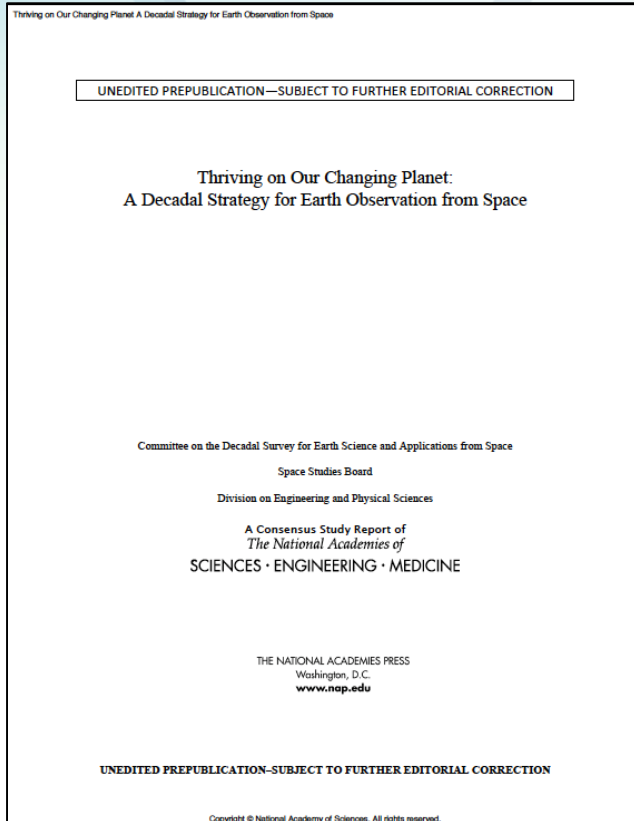
2017 DECADAL SURVEY



- Publicly released January 5, 2018
- Supports the ESD (and international) Program of Record
- Prioritized observations rather than specific missions
- Emphasis on competition
- Explicitly allows implementation flexibility – encourages competition as cost-control method
- Explicitly notes value of, and encourages, international partnerships
- Endorsed existing balances in ESD portfolio

2017 Decadal Survey Snapshot (cont.)

2017 DECADAL SURVEY



- Identified 5 "Designated" observables for mandatory missions (*Aerosols; Clouds, Convection, & Precipitation; Mass Change; Surface Biology & Geology; Surface Deformation & Change*)
- Called for cost-capping on essentially all missions
- Introduced a new competed "Explorer" flight line with \$350M cost constraint, 3 observables to be chosen by ESD from among 6 identified
- Recommended "Continuity Measurement" strand (\$150M full mission cost cap) for existing Venture-class program
- Called for "Incubator Program" between Technology, R&A, and Flight to mature specific technologies for important – but presently immature – measurements (preparation for next Decadal)
- ***ESD will conduct focused community forums for 12-18 months to translate the recommendations into an executable program and, for Flight, a portfolio of specific, realistic, launch-ordered missions and solicitations.***
 - With 15 - 20 missions/instruments now in development for launch before 2023, Decadal budget wedge does not begin to open up until late FY21; if appropriation is constrained to PBR levels, most decadal mission/new program recommendations will be unexecutable after 2023

Quick Summary of Recommendations

2

SCIENCE & APPLICATIONS

Address **35 key science/applications questions**, from among hundreds suggested. Highest priority objectives fell into **six categories**:

- Coupling of the Water and Energy Cycles
- Ecosystem Change
- Extending & Improving Weather and Air Quality Forecasts
- Sea Level Rise
- Reducing Climate Uncertainty & Informing Societal Response
- Surface Dynamics, Geological Hazards and Disasters

1

VISION & STRATEGY

“Thriving on our Changing Planet”

3

OBSERVATIONS

Augment the **Program of Record** with **eight priority observables**:

- **Five** that are specified/designated to be implemented:
 - *Aerosols*
 - *Clouds, Convection, & Precipitation*
 - *Mass Change*
 - *Surface Biology & Geology*
 - *Surface Deformation & Change*
- **Three** others to be selected competitively from among six candidates
- Structure **new mission program elements** to accomplish this

4

PROGRAMMATICS

- CROSS-AGENCY
- NASA
 - Flight
 - Technology
 - Applications
- NOAA
- USGS

Summary of Top Science and Applications Priorities*

* Complete set of Questions and Objectives in Table 3.3

Science & Applications Topic	Science & Applications Questions addressed by MOST IMPORTANT Objectives
Coupling of the Water and Energy Cycles	(H-1) How is the water cycle changing? Are changes in evapotranspiration and precipitation accelerating, with greater rates of evapotranspiration and thereby precipitation, and how are these changes expressed in the space-time distribution of rainfall, snowfall, evapotranspiration, and the frequency and magnitude of extremes such as droughts and floods? (H-2) How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally and globally and what are the short- and long-term consequences?
Ecosystem Change	(E-1) What are the structure, function, and biodiversity of Earth's ecosystems, and how and why are they changing in time and space? (E-2) What are the fluxes (of carbon, water, nutrients, and energy) <i>between</i> ecosystems and the atmosphere, the ocean and the solid Earth, and how and why are they changing? (E-3) What are the fluxes (of carbon, water, nutrients, and energy) <i>within</i> ecosystems, and how and why are they changing?
Extending & Improving Weather and Air Quality Forecasts	(W-1) What planetary boundary layer (PBL) processes are integral to the air-surface (land, ocean and sea ice) exchanges of energy, momentum and mass, and how do these impact weather forecasts and air quality simulations? (W-2) How can environmental predictions of weather and air quality be extended to seamlessly forecast Earth System conditions at lead times of 1 week to 2 months? (W-4) Why do convective storms, heavy precipitation, and clouds occur exactly when and where they do? (W-5) What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?
Reducing Climate Uncertainty & Informing Societal Response	(C-2) How can we reduce the uncertainty in the amount of future warming of the Earth as a function of fossil fuel emissions, improve our ability to predict local and regional climate response to natural and anthropogenic forcings, and reduce the uncertainty in global climate sensitivity that drives uncertainty in future economic impacts and mitigation/adaptation strategies?
Sea Level Rise	(C-1) How much will sea level rise, globally and regionally, over the next decade and beyond, and what will be the role of ice sheets and ocean heat storage? (S-3) How will local sea level change along coastlines around the world in the next decade to century?
Surface Dynamics, Geological Hazards	(S-1) How can large-scale geological hazards be accurately forecasted and eventually predicted in a socially relevant timeframe?

Observing System Priorities

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Aerosols	Aerosol properties, aerosol vertical profiles, and cloud properties to understand their direct and indirect effects on climate and air quality	Backscatter lidar and multi-channel/multi-angle/polarization imaging radiometer flown together on the same platform	X		
Clouds, Convection, & Precipitation	Coupled cloud-precipitation state and dynamics for monitoring global hydrological cycle and understanding contributing processes	Radar(s), with multi-frequency passive microwave and sub-mm radiometer	X		
Mass Change	Large-scale Earth dynamics measured by the changing mass distribution within and between the Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly	X		
Surface Biology & Geology	Earth surface geology and biology, ground/water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass	Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR	X		
Surface Deformation & Change	Earth surface dynamics from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction	X		
Greenhouse Gases	CO ₂ and methane fluxes and trends, global and regional with quantification of point sources and identification of source types	Multispectral short wave IR and thermal IR sounders; or lidar**		X	
Ice Elevation	Global ice characterization including elevation change of land ice to assess sea level contributions and freeboard height of sea ice to assess sea ice/ocean/atmosphere interaction	Lidar**		X	
Ocean Surface Winds & Currents	Coincident high-accuracy currents and vector winds to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift.	Radar scatterometer		X	

Ozone & Trace Gases	Vertical profiles of ozone and trace gases (including water vapor, CO, NO ₂ , methane, and N ₂ O) globally and with high spatial resolution	UV/IR/microwave limb/nadir sounding and UV/IR solar/stellar occultation		X	
Snow Depth & Snow Water Equivalent	Snow depth and snow water equivalent including high spatial resolution in mountain areas	Radar (Ka/Ku band) altimeter; or lidar**		X	
Terrestrial Ecosystem Structure	3D structure of terrestrial ecosystem including forest canopy and above ground biomass and changes in above ground carbon stock from processes such as deforestation & forest degradation	Lidar**		X	
Atmospheric Winds	3D winds in troposphere/PBL for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery or radiometry-based atmos. motion vectors (AMVs) tracking; or lidar**		X	X
Planetary Boundary Layer	Diurnal 3D PBL thermodynamic properties and 2D PBL structure to understand the impact of PBL processes on weather and AQ through high vertical and temporal profiling of PBL temperature, moisture and heights.	Microwave, hyperspectral IR sounder(s) (e.g., in geo or small sat constellation), GPS radio occultation for diurnal PBL temperature and humidity and heights; water vapor profiling DIAL lidar; and lidar** for PBL height			X
Surface Topography & Vegetation	High-resolution global topography including bare surface land topography ice topography, vegetation structure, and shallow water bathymetry	Radar; or lidar**			X
** Could potentially be addressed by a multi-function lidar designed to address two or more of the Targeted Observables					
Other ESAS 2017 Targeted Observables, not Allocated to a Flight Program Element					
Aquatic Biogeochemistry		Radiance Intercalibration			
Magnetic Field Changes		Sea Surface Salinity			
Ocean Ecosystem Structure		Soil Moisture			

On-going Decadal Strategy Activities

- ESD leadership is meeting on a weekly basis.
- Identified and prioritized key elements to be addressed over the next 6 -18 months; starting with:
 - Strategies for Designated observables, Venture Class-Continuity, and Incubator program
 - Community engagement and communication
 - International partner communications

Pre-formulation Efforts

- ESD observable/mission studies will be aligned with the recommendations of the 2017 Decadal Survey; studies will also explore development approaches for future missions.
- Given the updated guidance from the 2017 Decadal, ESD decided to close the pre-formulation activities for HypsIRI, ACE, GEO-CAPE, CLARREO, and ASCENDS by the end of FY18.
- ESD will build on the HypsIRI and ACE teams to advance pre-formulation studies for 3 designated observables – Aerosols; Cloud, Convection and Precipitation; and Surface Biology and Geology.
- By July 2018 ESD will determine how to proceed with similar pre-formulation groups (involving multiple NASA centers and community members) for the other designated observables.
- Significant study funds exist in the FY19 – FY22 budget requests.

Community Forums & Website

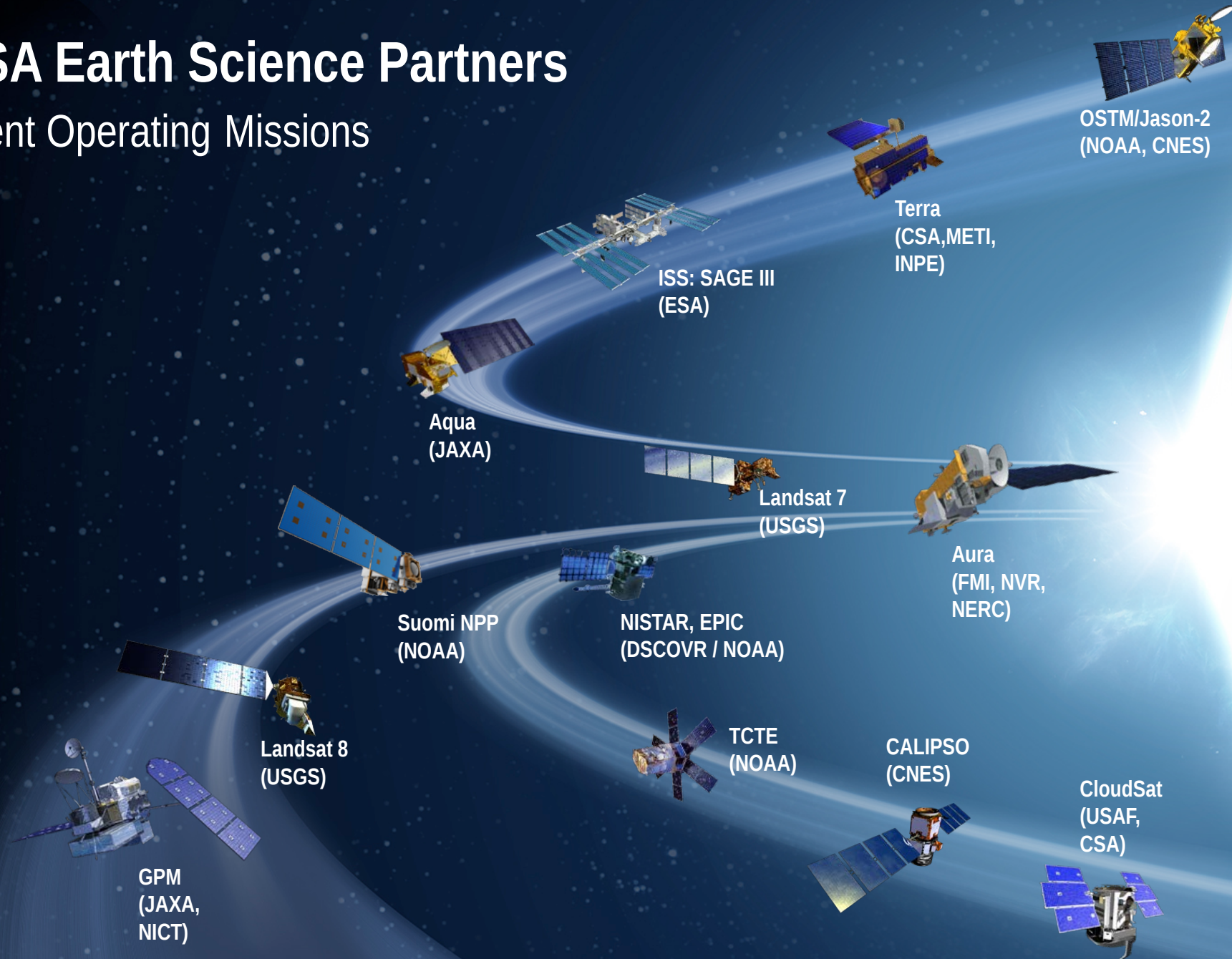
- We are developing mechanisms for communicating progress and for gathering external questions for our further consideration.
- A series of community forums to keep you – and all of us – in the loop as we go forward in implementing the Decadal Survey has been planned.
- Community forums inform/engage the internal HQ ESD Division (weekly), the centers (monthly), the community-at-large, including industry, universities, OGA, etc. (every 4 months) and our international partners.
- We are opening a website to allow the community to provide questions, comments, suggestions, and ideas related to implementation of the 2017 ESAS Decadal Survey.
 - Please submit your questions via this site, to go live by 30 March – specific link will be provided on the top-level ESD web portal <https://science.nasa.gov/earth-science>.

International Engagement

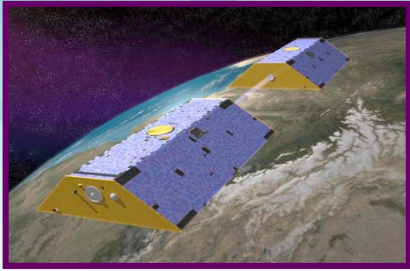
- ESD has conducted focused Decadal Survey telecons/meetings with key international partners
 - CNES, CSA, DLR, ESA, EUMETSAT, ISRO, JAXA
 - Bilateral, HQ-level, face-to-face meetings planned over the next 6 months
 - Some directed international partnerships may originate from ESD/HQ
- Centers are explicitly encouraged to discuss and explore possible observable implementation approaches with international partners
 - Multi-center joint efforts appreciated
 - Keep ESD leadership informed
- ESD will make final partnership determinations and then codify necessary international agreements

NASA Earth Science Partners

Current Operating Missions



ESD Partnership Missions in Development



GRACE FO

LRD: Apr 2018

Global mass & water variation

Partner: GFZ

- ✦ Science & science processing
- ✦ Mission operations
- ✦ Optical
- ✦ components of Laser Ranging Instrument
- ✦ Launch Services



Sentinel 6A/B

ABC: 2021/2026

Ocean Altimetry

Partner: NOAA

- ✦ Science data dissemination
- ✦ Ground stations

Partner: ESA

- ✦ Spacecraft bus
- ✦ Science instruments (Poseidon-4 Altimeter, DORIS, GNSS POD)
- ✦ Satellite control center (during LEOP)

Partner: EUMETSAT

- ✦ Mission/System coordinator,
- ✦ Satellite control center (Ops)
- ✦ Science data processing
- ✦ Science data dissemination
- ✦ Data archiving
- ✦ Ground stations



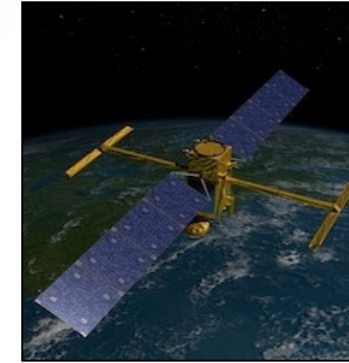
Landsat 9

ABC: 2021

Land Imaging

Partner: USGS

- ✦ Ground system
- ✦ Mission Operations



SWOT

ABC: Apr 2022

Sea surface & fresh water height, slope

Partner: CNES

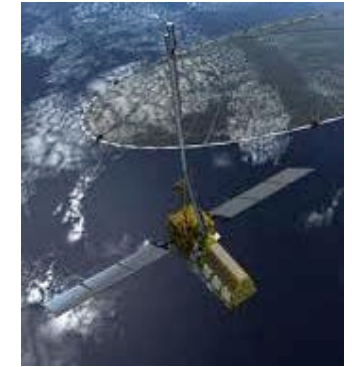
- ✦ Spacecraft bus
- ✦ Science instruments (Nadir Altimeter, DORIS, KaRIn RF Unit subsystem)

Partner: CSA

- ✦ Klystrons for KaRIn

Partner: UKSA

- ✦ Duplexers for KaRIn



NISAR

ABC: Sep 2022

Cryosphere, ecosystems, deformation

Partner: ISRO

- ✦ S-Band SAR
- ✦ Spacecraft bus
- ✦ Spacecraft operations
- ✦ Science Downlink
- ✦ S-Band processing

* Implementation = Phase C/D

**Delivery of payload to host

ABC=Agency Baseline Commitment

NASA ESD International & Interagency Partners



Canada

- CloudSat (CSA)
- SWOT (CSA)
- Terra (CSA)

US – Other Agencies

- CloudSat (DOE/USAF)
- DSCOVR (NOAA)
- Landsat 7, 8, 9 (USGS)
- OMPS-L (NOAA)
- OSTM/Jason-2 (NOAA)
- Sentinel-6A/B (NOAA)
- Suomi-NPP (NOAA)

Brazil

- Terra (INPE)

United Kingdom

- Aura (NERC)
- SWOT (UKSA)

France

- CALIPSO (CNES)
- OSTM/Jason-2 (CNES)
- SWOT (CNES)

Finland

- Aura (FMI)

The Netherlands

- Aura (NVR)

Germany

- GRACE (DLR/GFZ)
- GRACE-FO (GFZ)

Europe

- SAGE-III (ESA)
- Sentinel-6A/B (ESA/EUMETSAT)

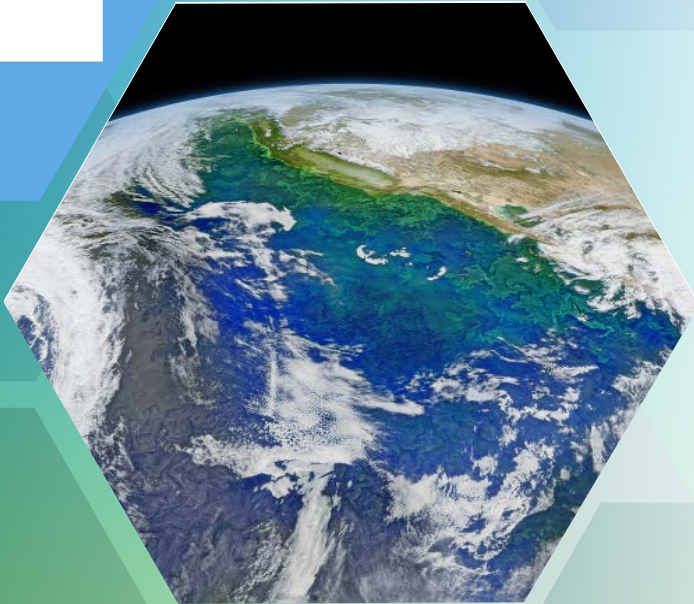
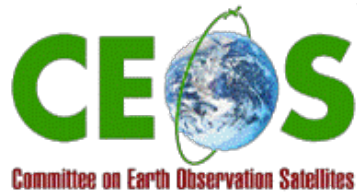
India

- NISAR (ISRO)

Japan

- Aqua (JAXA)
- GPM (JAXA/NICT)
- Terra (METI)

CEOS: Internal Structure



Seven Virtual Constellations

- Atmospheric Composition
- Land Surface Imaging
- Ocean Colour Radiometry
- Ocean Surface Topography
- Ocean Surface Vector Wind
- Precipitation
- Sea Surface Temperature

Working Groups

- Working Group on Capacity Building and Data Democracy
- CEOS/CGMS Working Group on Climate
- Working Group on Calibration and Validation
- Working Group on Disasters
- Working Group on Information Systems and Services

Ad Hoc Teams

- Future Data Architectures
- Group on Earth Observations Global Agricultural Monitoring Initiative
- Space Data Coordination Group for the Global Forest Observations initiative

CEOS is the satellite coordination arm of GEO

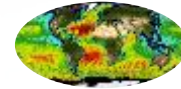
Sustainable Development Goals

NASA Earth Science Division Elements



Flight (incl. Data Systems)

Develops, launches, and operates NASA's fleet of Earth-observing satellites, instruments, and aircraft. Manages data systems to make data and information products freely and openly available.



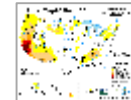
Research & Analysis

Supports integrative research that advances knowledge of the Earth as a system. Six focus areas plus field campaigns, modeling, and scientific computing.



Technology

Develops and demonstrates technologies for future satellite and airborne missions: Instruments, Information Systems, Components, InSpace Validation (cubesat and small-sat form factors).



Applied Sciences

Develops, tests, and supports innovative uses of Earth observations and scientific knowledge to inform private and public sector planning, decisions, and actions. Activities include disaster response support and capacity building.

R&A Selected Highlights

- **Field Work**

- 2018 *Cloud and Aerosol Monsoonal Processes Exp't* (near Phillipines); *EXPORTS* field program (NE Pacific; in coordination with NSF), *FLARE* (Alaska), *HyspIRI* (Hawaii), *ABOVE* (surface only); 2019 *FIREChem* (Kansas; with NOAA)

- **New Competed Science Programs (highlights only – many ROSES calls)**

- Selected new round of Interdisciplinary Science investigators – 28 principal investigators – 5 topics, \$34M over three years
- Solicited for competed science teams for newly launched missions/instruments (CYGNSS, SAGE III), new combined Terra/Aqua/Suomi-NPP science

- **Modeling and Data Assimilation**

- GMAO evolved and transitioned to a “hybrid 4D VAR” data assimilation system

- **Enabling Capabilities**

- Built a modular computing facility at ARC and expanded SMD's supercomputing capacity to 6 pflops; expanded capacity at NCCS to 3.5 pflops.
- Installed antenna at MSFC for real-time receipt of GOES-16 for SPoRT (jointly with NOAA); antenna for GOES-S on order
- Purchased 60 new/improved/reliable sensors for AERONET to replace ~20% of existing sensors in 2018

Earth Science Technology

Advanced Technology Initiatives (ATI)



ACT

Advanced Component Technologies

Development of critical components and subsystems for instruments & platforms

12 projects awarded in 2018. Future solicitations/selections planned in FY 2020 and FY 2023

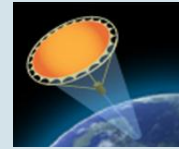


InVEST

In-Space Validation of Earth Science Tech.

On-orbit technology validation and risk reduction for small instruments and instrument systems that could not otherwise be fully tested on the ground or in airborne systems.

Future solicitations/selections planned in FY 2018 & FY 2021



IIP

Instrument Incubator Program

Robust new instrument developments and measurement techniques

17 new projects awarded in FY17. Future solicitations/selections planned in FY 2019 and FY 2022



AIST

Advanced Information Systems Technology

Innovative advances in on-orbit and ground technologies to generate, manage, and exploit data in the 5-20 year horizon

22 new projects awarded in FY17. Future solicitations/selections planned in FY 2018, FY 2020 and FY 2022

Applied Sciences Program: Selected Highlights–2018

Disasters



ROSES call for applications focused on a few disaster types – flood, hurricane, earthquake.

Water Resources

Call to support water resources management. Two-step process planned.

Sustainable Development Goals



Earth science call for applications and research on SDG 14 (oceans) and SDG 15 (life on land).

Food Security and Agriculture Consortium



New effort led by Umd to advance uses of Earth obs for humanitarian pursuits, economic growth, and resilience in food systems in U.S. and globally.

Impact Assessments



VALUABLES Consortium conducting economic studies on Earth science; also arranging venues for Earth scientists wanting to learn about policy and economic terms/methods.

SERVIR



New Amazonia regional hub for South America is planned to open in Spring.

DEVELOP



2018 marks the 20th year for this development, workforce & Earth science applications program.

ARSET Trainings

Over 15 professional-level hands-on and webinar trainings on remote sensing to reach people across all 50 U.S. States again in 2018.

Earth Science Partnerships

Harnessing commercial and NGO partnerships to amplify our work to understand the Earth as an integrated system and enable societal benefit by essentially leveraging the expertise of NASA and the partners to achieve together what neither could alone.

Current Partners



Activities

- Advancing the ability of remote sensing to inform economic valuation of ecosystem services
 - Increasing the public's access to and use of Earth observations to explore our planet
- Integrating Earth observations into humanitarian decision making to strengthen global resilience to environmental shocks and stressors
- Supporting decision making in smart cities by integrating Earth observations into cloud-based services

ESD Airborne Platforms

- ***WB-57F (JSC)*** –ESD core funding eliminated several years ago and the 2 aircraft were converted to reimbursable platforms; request for renewed core support is being considered by ESD as part of FY2020 PPBE process.
- ***Global Hawk (AFRC)*** – ESD core funding eliminated and aircraft were converted to reimbursable platforms following only minimally successful Earth Venture Suborbital-1 campaigns (ATTREX, HS3) and lack of demand for EVS-2.
- ***C-130s (GSFC/WFF)*** – will become reimbursable in May, 2018 after completion of active deployments for EVS-2 campaigns (the reason the planes were acquired)
- ***C-23 (Sherpas, GSFC/WFF)*** – have been available as reimbursable platforms. Recent utilization included CARAFE project at GSFC; Sherpas also used during SARP in 2017 when DC-8 was unavailable.
- ***G-V (JSC)*** – ESD acquired (jointly with HEOMD) a new, long-range aircraft to be focused on remote-sensing; viewing ports to be cut into the fuselage when procurement is complete. Use priorities/principles/agreements complete between HEOMD and SMD/ESD.
- ***G-III (LaRC)*** – a new platform will be available on a reimbursable basis with two downward viewing ports for remote sensing

Questions?



Backup

Panels

I. Global Hydrological Cycles and Water Resources

Co-Chairs: Jeff Dozier, UC Santa Barbara and Ana Barros, Duke University

The movement, distribution, and availability of water and how these are changing over time

II. Weather and Air Quality: Minutes to Subseasonal

Co-Chairs: Steve Ackerman, University of Wisconsin and Nancy Baker, NRL

Atmospheric Dynamics, Thermodynamics, Chemistry, and their interactions at land and ocean interfaces

III. Marine and Terrestrial Ecosystems and Natural Resource Management

Co-Chairs: Compton (Jim) Tucker, NASA GSFC and Jim Yoder, WHOI

Biogeochemical Cycles, Ecosystem Functioning, Biodiversity, and factors that influence health and ecosystem services

IV. Climate Variability and Change: Seasonal to Centennial

Co-Chairs: Carol Anne Clayson, WHOI and Venkatachalam (Ram) Ramaswamy, NOAA GFDL

Forcings and Feedbacks of the Ocean, Atmosphere, Land, and Cryosphere within the Coupled Climate System

V. Earth Surface and Interior: Dynamics and Hazards

Co-Chairs: Dave Sandwell, Scripps and Doug Burbank, UC Santa Barbara

Core, mantle, lithosphere, and surface processes, system interactions, and the hazards they generate

Comparison to ESAS 2007

- **Prioritization Method.** Prioritize science and applications targets instead of missions
- **Budget Resources.** Align with planned budgets instead of aspirational
- **Large Missions.** Avoid having one recommended activity grow at expense of all others
- **Innovation.** Consider “new space” technology and business ideas
- **Policy.** Existence of recent high-level US government policy guidance regarding Earth observations
- **International.** Increased recognition of important role of international partners

Progress Since ESAS 2007

Mission	Geophysical Variables	Status
OSTM/Jason-2**	Ocean Surface Topography	Launched 2008, operating
OCO**	CO ₂	Launch failure
Glory**	Aerosol and cloud particle size and optical thickness	Launch failure
Aquarius**	Sea surface salinity	Mission ended
Suomi NPP**	Multiple variables (ATMS, VIIRS, CrIS, OMPS, CERES)	Launched 2011, operating
LDCM**	Land use and land surface temperature	Launched 2013, operating
GPM**	Precipitation (rain and snow)	Launched 2014, operating
OCO-2	CO ₂	Launched 2014, operating
CYGNSS*	Hurricane Winds	Launched 2016, operating
SMAP*	Soil moisture; freeze/thaw state; surface salinity	Launched 2017, operating
SAGE-III (on ISS)	Stratospheric O ₃ , aerosols	Launched 2017, operating
GRACE-FO	Changes in Gravitational Field	In Development (2017)
ICESat-2*	Ice sheet elevation change, sea ice thickness, vegetation canopy height	In Development (2018)
ECOSTRESS*	Plant temperature and water stress	In Development (2018)
GEDI*	Ecosystem structure and dynamics	In Development (2018)
TEMPO*	Air pollution (O ₃ , NO ₂ , ...)	In Development (2018)
MAIA*	Aerosols	In Development (2021)
TROPICS*	Precipitation and storm intensity	In Development (2021)
GeoCARB*	Carbon exchanges between land and atmosphere	In Development (TBD)
PACE	Phytoplankton communities	In Development (2022)
NISAR*	Surface changes from ice-sheet collapse, earthquakes, tsunamis, volcanoes, and landslides	In Development (late 2021)
SWOT*	Ocean (and freshwater) high resolution elevation, providing water storage and ocean circulation	In Development (2021)
CLARREO-Pathfinder on ISS*	High accuracy spectral reflectance with on-board calibration	In Development (2021 timeframe)
OCO-3 (on ISS)	CO ₂	In Development (2018)

Finding 2A: The NASA ESD program has made important progress during the decade, partially recovering from the underfunded state it was in a decade ago . . .

Finding 2B: NOAA progress during the decade was hampered by major programmatic adjustments . . .

Finding 2C: The USGS has transformed the Landsat program via the Sustainable Land Imaging (SLI) program . . .

Strategic Framework for Leveraging Resources & Advancing

ELEMENTS OF DECADAL STRATEGY

- I. Embrace **Innovative Methodologies** for Integrated Science/Applications
 - II. Commit to **Sustained Science and Applications**
 - III. Amplify the **Cross-Benefit of Science and Applications**
 - IV. Leverage **External Resources and Partnerships**
 - V. Institutionalize **Programmatic Agility and Balance**
 - VI. Exploit **External Trends** in Technology and User Needs
 - VII. Expand Use of **Competition**
 - VIII. Pursue **Ambitious Science**, Despite Constraints
-

Program of Record (example, 1 of 10)

[illegible]

NASA Flight Program Elements

Program of Record. The series of existing or previously planned observations, which should be completed as planned. Execution of the ESAS 2017 recommendation requires that the total cost to NASA of the Program of Record *flight missions from FY18-FY27 be capped at \$3.6B.*

- ***Designated.*** A new program element for ESAS-designated cost-capped medium- and large-size missions to address ***observables essential to the overall program*** and that are outside the scope of other opportunities in many cases. Can be competed, at NASA discretion.
- ***Earth System Explorer.*** A new program element involving competitive opportunities for medium-size instruments and missions serving specified ESAS-priority observations. ***Promotes competition among priorities.***
- ***Incubation.*** A new program element, focused on investment for priority observation opportunities needing advancement prior to cost-effective implementation, including an Innovation Fund to respond to emerging needs. ***Investment in innovation for the future.***
- ***Ventures.*** Earth Ventures program element, as recommended in ESAS 2007 with the addition of a new Ventures-Continuity component to provide ***opportunity for low-cost sustained observations.***

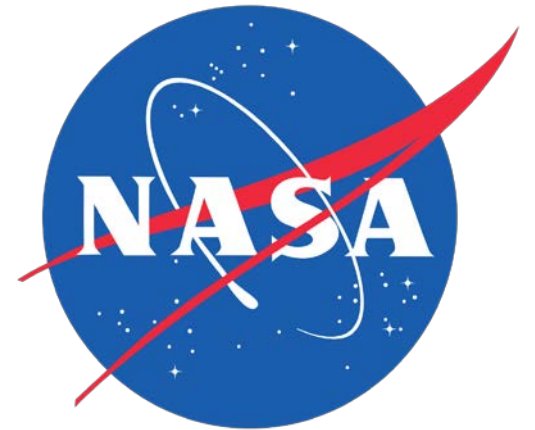
Programmatics – General Considerations

- Rec 4.1 Reduce barriers to **applications**
- Rec 4.2 Improve **modeling and assimilation**
- Rec 4.3 Advance **data science**
- Rec 4.4 Complete **Global Geodetic Observing System**
- Rec 4.5 Build and expand **international partnerships**



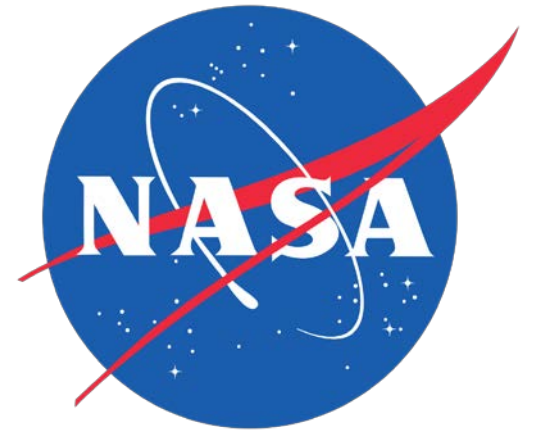
Programmatics - NASA

- Rec 4.6** Apply **decision rules** (included) to maintain programmatic balance (programmatic balance was a high priority)
- Rec 4.7** Small scope changes to **applications & technology programs**
- Rec 4.8** Reevaluate **Ventures structure** at mid-term
- Rec 4.9** **Avoiding cost growth** is critical to program's success (capability and reliability are where the flexibility must be found)

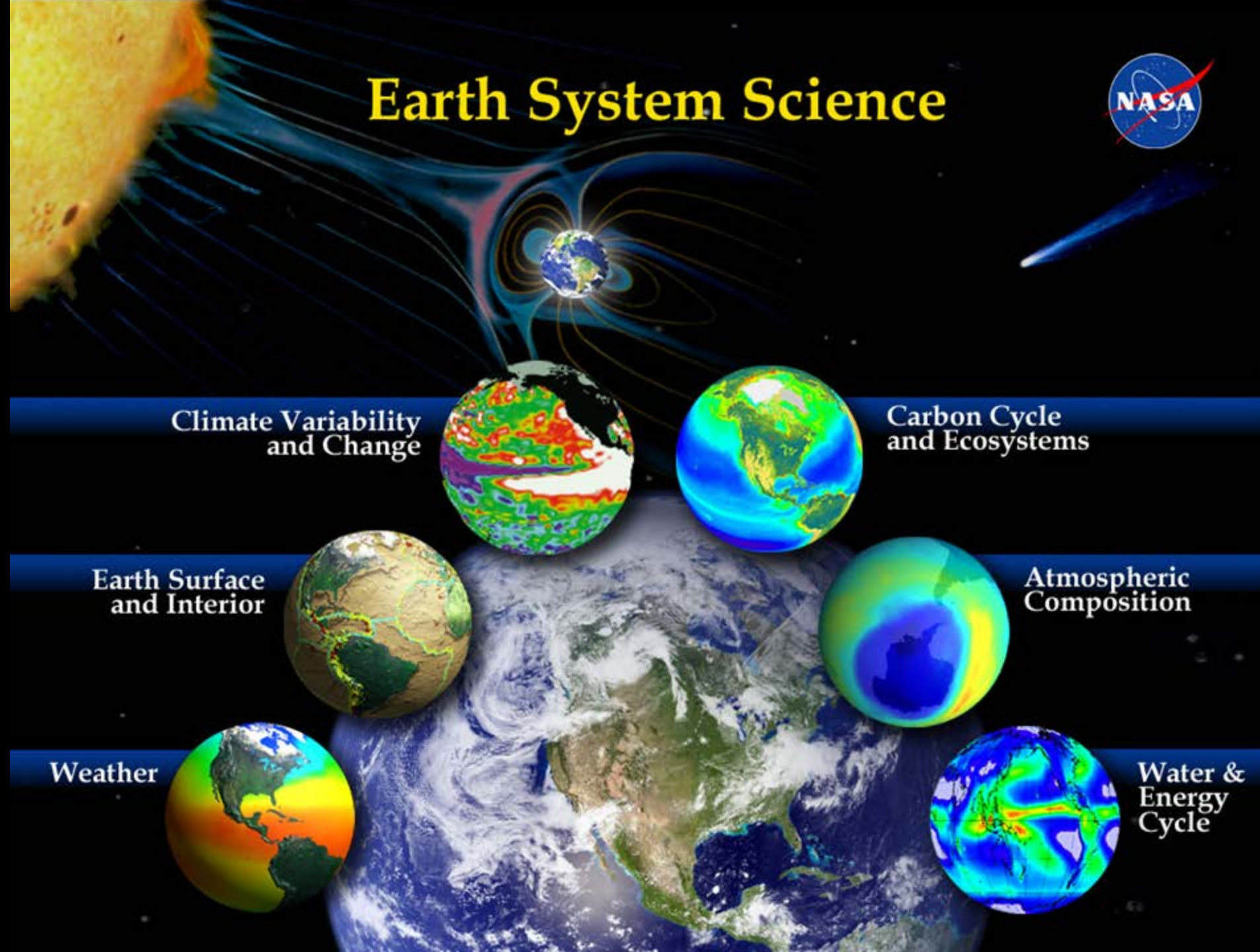


NASA Portfolio Balance

- Earth Science research: *maintain* at approximately 24% of the budget (22-26%)
 - Includes 18% for openly competed research and analysis
 - Includes approximately 3% each for computing and administration
- Applications program: *maintain* at 2-3% of the budget
- Technology program: *increase* from its current 3% to about 5%
- Flight programs, including Venture: *maintain* at 50-60% of the budget
- Mission Operations: *maintain* at 8-12% of the budget



Earth System Science



Climate Variability
and Change

Carbon Cycle
and Ecosystems

Earth Surface
and Interior

Atmospheric
Composition

Weather

Water &
Energy
Cycle