National Aeronautics and Space Administration

Earth Science

FY17 Budget Overview/Summary

March 10, 2016

ESD Budget/Program Overview

- The FY17-21 budget is executable and balanced, *informed by and consistent with Decadal Survey and national Administration priorities*:
  - **advances Earth system science**
  - **delivers societal benefit through applications development and testing**
  - **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**

- Funds operations and core data production for on-orbit missions in prime and extended phases, in keeping with 2015 Senior Review recommendations/decisions. Funds NASA portal for Copernicus and other international missions, increasing DAAC capability to host added NASA missions
- Completes high priority missions**: SAGE-III/ISS, ICESat-2, CYGNSS, GRACE-FO, SWOT, TEMPO, RBI, OMPS-Limb, TSIS-1 and -2, CLARREO Pathfinder, Jason-CS/Sentinel-6A,Landsat-9, NISAR**
- Develops (for launch beyond budget window)**: PACE, Landsat-10, Jason-CS/Sentinel-6B**
- Continues all originally **planned Venture Class** solicitations/selections on schedule
- Conducts limited Decadal mission studies, pending release of the 2nd ESAS Decadal Survey

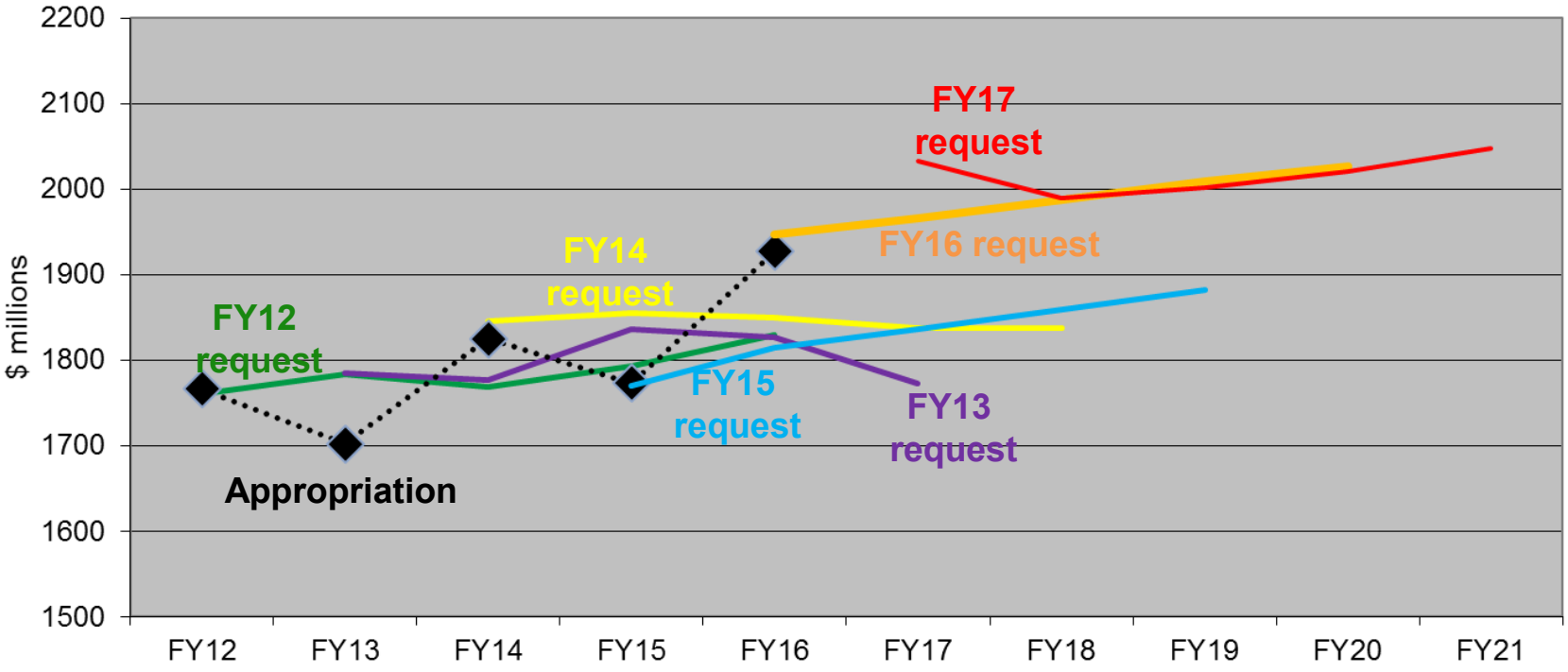
- Supports non-flight elements**: Research, Applied Sciences, and Technology Development**

- Provides support to **National Climate Assessment, USGCRP**, international coordination activities **(CEOS and GEO**), **USGEO, Carbon Monitoring System**, data-related activities (**CDI, BEDI, GCIS**) in support of the Administration's climate initiative, and **GLOBE**

ESD Budget: FY17 Request/Appropriation

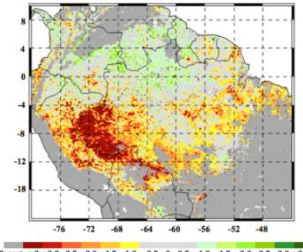
ESD Total						
$M	**FY16 (op plan)**	**FY17**	**FY18**	**FY19**	**FY20**	**FY21**
FY16 PBS	$ 1,927	$ 1,966	$ 1,988	$ 2,009	$ 2,027	
FY17 PBS		$ 2,032	$ 1,990	$ 2,001	$ 2,021	$ 2,048

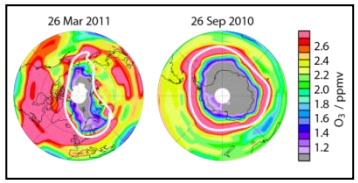
- *ESD budget jumps significantly in FY17 – then becomes consistent with FY16 PBR for the out-years*

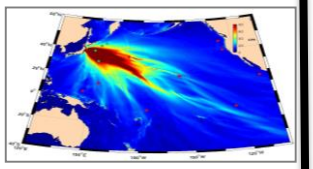


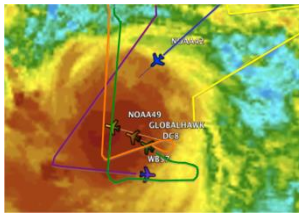
NASA's Earth Science Division

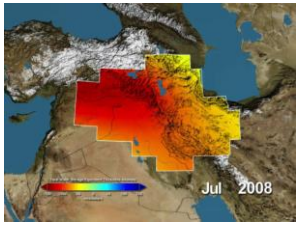
Research

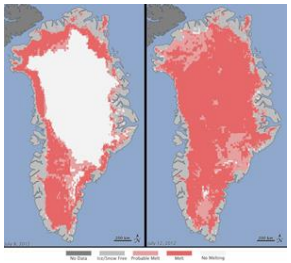




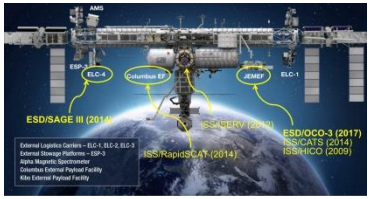




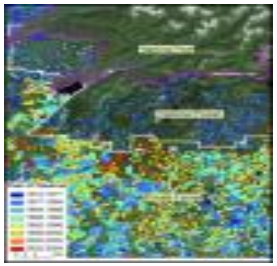


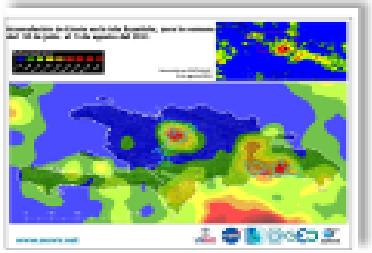


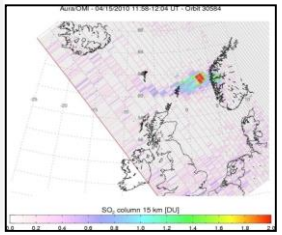
Flight

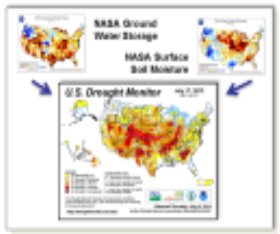


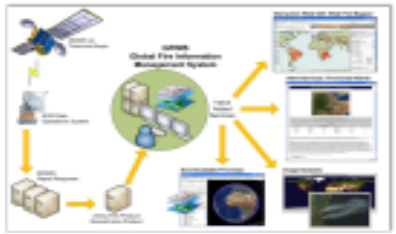
Applied Sciences

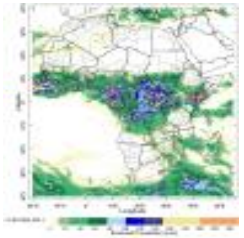




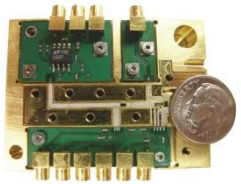


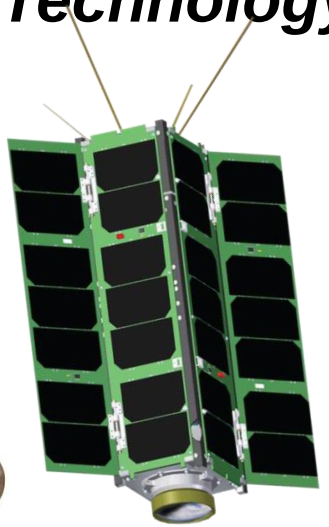


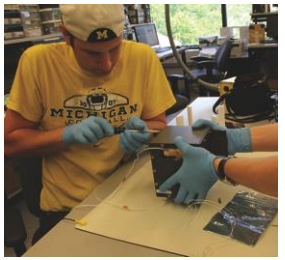




Technology








(Pre)Formulation
Implementation
Primary Ops
Extended Ops
Sentinel-6A/B
Earth Science Instruments on ISS:
RapidScat, CATS,
LIS, SAGE III, TSIS-1, ECOSTRESS,
GEDI, OCO-3, CLARREO-PF, TSIS-2
Landsat 9
PACE
NI-SAR
SWOT
TEMPO
JPSS-2 (NOAA)
RBI, OMPS-Limb
GRACE-FO (2)
ICESat-2
CYGNSS
ISS
SORCE,
TCTE (NOAA)
NISTAR, EPIC
(NOAA'S DSCOVR)
QuikSCAT
EO-1
Landsat 7
(USGS)
SMAP
Terra
Suomi NPP
(NOAA)
Aqua
Landsat 8
(USGS)
CloudSat
CALIPSO
GPM
Aura
GRACE (2)
OSTM/Jason 2
(NOAA)
OCO-2

ESM and ESSP Program Overviews

- The Earth Systematic Missions (ESM) ***development*** missions in this period include:
  - ICESat-2, SAGE III, GRACE-FO, SWOT, Landsat-9, RBI, TSIS-1 and -2, OMPS-Limb, NISAR, PACE, Jason CS/Sentinel 6A and -B, CLARREO Pathfinder
- The Earth Systematic Missions (ESM) ***on-orbit**** missions include:
  - SMAP (>2021), DSCOVR (2019), S-NPP (>2021), GPM (>2021), LDCM (>2021), Terra (>2021), Aqua (>2021), Aura (>2021), OSTM (>2021), QuikScat (2015), SORCE (2017), and EO-1 (2016); also RapidScat (2017) and CATS (>2016)

- The Earth System Science Pathfinder (ESSP) ***development*** missions in this period include:
  - OCO-3, CYGNSS, TEMPO, GEDI, ECOSTRESS
  - EVS-2 and -3 and Venture Technology selections (GrAOWL, Tempest), EVM-2 & 3, EVI-3, 4, 5, and 6
- The Earth System Science Pathfinder (ESSP) ***on-orbit*** missions include:
  - OCO-2 (>2021), GRACE (2018), CALIPSO (>2021), CloudSat (2018), Aquarius (>2021)

**On-orbit dates correspond to end-of-mission assumptions, consistent with 2015 Sr. Review*

ELEMENT SUMMARY: Flight

Flight						
$M	**FY16 (op plan)**	**FY17**	**FY18**	**FY19**	**FY20**	**FY21**
FY16 PBS	$ 1,148	$ 1,385	$ 1,398	$ 1,425	$ 1,445	
FY17 PBS		$ 1,421	$ 1,408	$ 1,432	$ 1,431	$ 1,448

- Continues development and launch of: SAGE-III/ISS, ECOSTRESS/ISS, GEDI/ISS, CYGNSS, TEMPO, RBI, OMPS-Limb, TSIS-1/2, GRACE-FO, ICESat-2, SWOT, NISAR, PACE, CLARREO Pathfinder/ISS, Sentinel-6A **and -6B**
- Sustainable Land Imaging Program (w/USGS; NASA funds flight hardware):
  - *No Thermal Infrared Free-Flyer*
  - Full Class-B Landsat-9 to launch in FY2021
  - Focused technology development to inform designs of Landsat-10+
  - Begins Landsat-10 late in budget window, for launch in 2027-2028
- Continues Venture Class - on schedule with full funding
- Completes OCO-3 delivered 3/2018, launched to ISS ~6/2018
- Initiates Small Satellite Constellation effort (FY17 only! – ESSP-PO)

Earth Science

2010
Climate
Architecture
Plan

CYGNSS
10/16 – 5/17

TEMPO
FY17/21

ICESat-2
FY18

GRACE-FO
FY18

CLARREO PF FY19
ECOSTRESS FY19
GEDI FY18/20
TSIS-1 FY17
TSIS-2 FY20/22
OCO-3 FY18

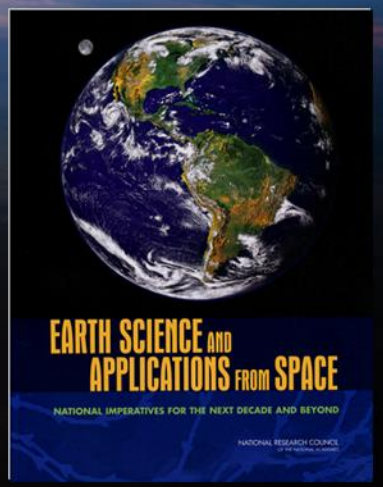
OMPS-L FY18/21
RBI FY19/21

SWOT
FY20

NI-SAR
FY22

PACE
FY22

Sentinel-6A/B
FY20/24



2007
Decadal
Survey

Venture Class Selections/Solicitations

Mission	MissionType	Release Date	Selection Date	Major Milestone
EV-1, aka EVS-1	CARVE, ATTREX, HS3, AirMOSS, DISCOVER-AQ	2009	2010	N/A
EVM-1, CYGNSS	Smallsat constellation	2011	2012	LRD October 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	OMG, ORACLES, CORAL,NAAMES, ATom, ACT-America	2013	2014	Ended (KDP-F)
EVI-3	Instrument Only	2015	2016	Delivery NLT 2021
EVM-2	Full Orbital	2015	2016	Launch ~2021
EVI-4	Instrument Only	2016	2017	Delivery NLT 2021
EVS-3	Suborbital Airborne Campaigns	2017	2018	Initiating/Confirmation Rev.
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

Open solicitation

Completed solicitation

EVS-1: CARVE, ATTREX, DISCOVER-AQ, AirMOSS, HS-3

EVM-1: CYGNSS (10/2016 LRD)

EVI-1: TEMPO (2019-; 2017 instrument delivery)

EVI-2: GEDI (2019; 2018 del.); ECOSTRESS (10/2017; 5/2017 del.)

EVS-2: ATom, NAAMES, OMG, ORACLES, ACT-America, CORAL

EVI-3: *Selection(s) likely by end of Q2 FY2016*

EVM-2: *Selection(s) likely by end of FY2016*

Multi-Mission Operations

- Provide science data receipt, ingest, processing, archive, and distribution to users via 12 Distributed Active Archive Centers (DAACs)
  - ***New*** data sets to be supported in this budget include: DSCOVR (EPIC, NISTAR), SAOCOM, ICESat-2, TEMPO, OCO-3, TSIS-1
  - SWOT and NI-SAR DAAC estimates are anticipated for future budgets

- Includes support for Sentinel-1 (SAR) and -6 (radar altimetry) ingest, archive, and distribution of level 0/1 data products

- EOSDIS includes ~$7M per year (FY16-17) and ~$5M per year (FY18-21) for Climate Data Initiative, Big Earth Data Initiative, and Global Change Information System activities

Earth Science Research

Research						
$K	**FY16 (op plan)**	**FY17**	**FY18**	**FY19**	**FY20**	**FY21**
FY16 PBS	$ 478	$ 417	$ 425	$ 418	$ 414	
FY17 PBS		$ 445	$ 414	$ 400	$ 416	$ 423

Focus Areas

Carbon cycle and Ecosystems

Climate Variability and Change

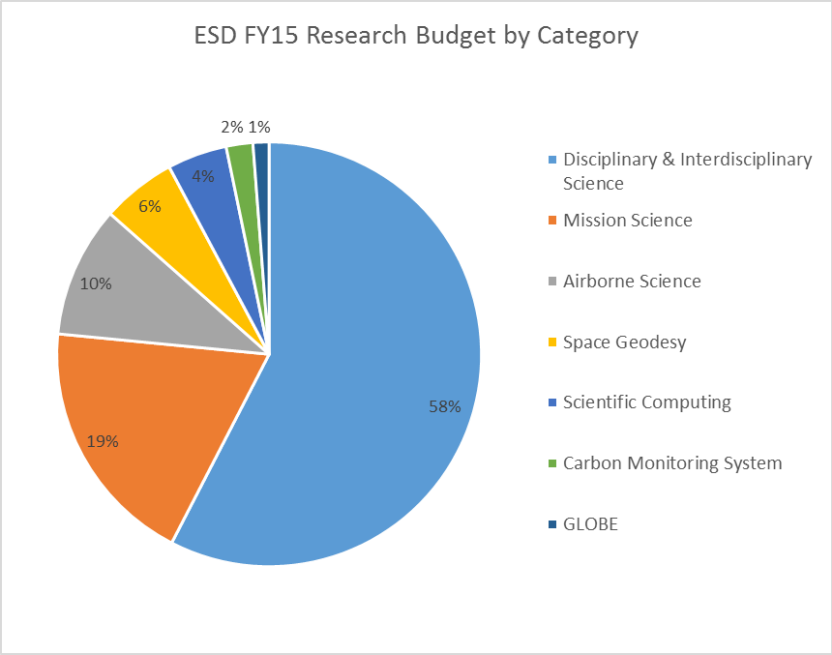
Atmospheric Composition

Global Water and Energy Cycle

Earth Surface and Interior

Weather

- Subtract DR&T and HECC (~$70 M/year)
- Add Flight mission science teams ($108M-128M/yr)
- Note $30M increase in FY17



Mission	Location(s)	Date(s)	Platform(s)	Summary of Mission
Aviris NG India	Hyderabad India	Dec 15 – Spring 16	B200 (ISRO aircraft)	Imaging spectroscopy science and application investigation over Indian territory
AfriSAR/G-TEC	Gabon Africa	Feb – Mar 16	B200, C20A	NASA/ESA collaboration on algorithm development and future mission cal/val activities for above-ground biomass and ecosystem structure and dynamics usint radar and lidar.
Korus-AQ	Korea	Spring 16	DC8, B200	Study sources of pollution in atmosphere over Korea and Western Pacific region using a mix of in situ and remote sensing capability while enhancing understanding of future geostationary atmospheric composition observations
Atmospheric Carbon and Transport – America	Eastern and Midwestern US	Summer 16, Spring 17, Fall 17, Summer 18	B200, C-130	Quantify the sources of regional carbon dioxide, methane and other gases, and document how weather systems transport these gases in the atmosphere; improve identification and predictions of carbon dioxide and methane sources and sinks over the eastern US
North Atlantic Aerosols and Marine Ecosystems Study (NAAMES)	Atlantic Ocean, flown from Canada	Sep 17, Mar/Apr 18,	C-130, Ship ((UNOLS) research vessel)	Environmental and ecological controls on plankton communities in the North Atlantic Ocean
Coral Reef Airborne Laboratory (CORAL)	FL, HI, Mariana Is., Palau, Australia	Apr 16 – Jan 17	Contracted GIV	Provide critical data and new models needed to analyze the status of coral reefs and to predict their future
ObseRvations of Aerosols Above Clouds and Their IntEractionS (ORACLES)	Namibia, Africa	Aug/Sep 16, Jul/Aug 17, Sep/Oct 18	P-3, ER-2	Investigate how smoke particles from massive biomass burning in Africa influences cloud cover over the Atlantic.
Oceans Melting Greenland (OMG)	Greenland	Sep/Oct 16 - + multiple till Sept/Oct 2019	Contracted Twin Otter, GIII, Ship (MV Cape Race)	investigate the role of warmer saltier Atlantic subsurface waters in Greenland glacier melting. The study will help pave the way for improved estimates of future sea level rise.
Atmospheric Tomography Experiment (ATom)	Around the Globe	Aug 16, Jan/Feb 17, Sep/Oct 17, Apr/May 18	DC-8	Study the impact of human-produced air pollution on multiple greenhouse gases, addressing transformation of various air pollutants, especially methane and ozone.
O2/N2 Ratio and CO2 Airborne Southern Ocean (ORCAS)	Southern Ocean	Jan/Feb 16	GV (NSF)	NASA brings remote sensing (PRISM) capability to NSF-led mission to Investigate the large-scale tropospheric distributions, gradients, and fluxes of O2 and CO2 over Southern Ocean.
HyspIRI	Hawaii	Summer 16	ER-2	Study the optical characteristics of coral reef and volcanic systems in and around Hawaii using MASTER and AVIRIS to assess value of HysPIRI-like observations
Operation IceBridge	Alaska, Greenland, Antarctica	Mar – May, Oct/Nov – FY16,17,18,19	P-3, DC-8	Study ice sheet thickness, sea ice distributions, and related parameters over Arctic and Antarctic to bridge gap between ICESat-1 and ICESat-2, complement lidar observations with those using related techniques (e.g., radar) and obtain coincident data with ESA CryoSat-2
UAVSAR	Various US and South America	Year round	C-20	Radar data collected for multiple NASA focus areas (Earth Surface and Interior, Carbon Cycle and Ecosystems, Global Water and Energy Cycle, Climate Variability and Change) and for Applications Uses (e.g., levee monitoring)
SPURS II	Eastern Sub-Tropical Pacific Ocean	Starting spring 2016, multiple sailings covering 18 month period	Schooner Lady Amber plus in-water observations (e.g., gliders, drifters, buoys)	Study processes that control sea surface salinity in higher salinity region than that sampled in SPURS I (sub-tropical North Atlantic)
ABoVE	Alaska, NW Canada	Beginning 2016, continuing	Surface measurements; airborne to follow	Study vulnerability and resilience of Arctic ecosystems to environmental change in the Arctic and boreal region of western North America

Applied Sciences Program

Applied						
$K	**FY16 (op plan)**	**FY17**	**FY18**	**FY19**	**FY20**	**FY21**
FY16 PBS	$ 48	$ 49	$ 48	$ 48	$ 49	
FY17 PBS		$ 48	$ 48	$ 49	$ 51	$ 52

Applications
Health & Air Quality
Ecological Forecasting
Water Resources
Disaster Applications & Response Team
Wildfires (through FY17)

Capacity Building
SERVIR (joint with USAID)
ARSET, Applied Remote Sensing Training
DEVELOP

Satellite Mission Planning
Early Adopters, Apps. Workshops

Program-wide
Socioeconomic Impact Analyses
Community Utilities (ESIP, NEX, etc.)
Communications
GEO and USGEO Support

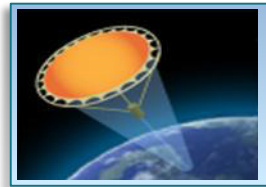
President's FY17 Budget Request

- **Re-establishes funds for full SERVIR Applied Sciences Team FY16-18; expands Team in FY19-21 for increase to 6 SERVIR hubs by 2018**
- **Increases funding for Applications Areas (via internal re-allocation)**
- **Implements Snow & Water Availability focused activity for Western States**
- **Implements Food Security Consortium**
- **Implements Disaster Response Plan for increased preparation-based approach**
- **Continues activities to develop techniques to quantify social and economic benefits from Earth science applications**

Earth Science Technology Office

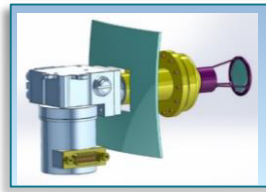
Technology						
$K	**FY16 (op plan)**	**FY17**	**FY18**	**FY19**	**FY20**	**FY21**
FY16 PBS	$ 61	$ 62	$ 62	$ 61	$ 63	
FY17 PBS		$ 61	$ 60	$ 60	$ 63	$ 64

Observation



Instrument Incubator Program (IIP)
robust new instruments and measurement techniques
17 new projects added in FY14 (total funding ~$71M over 3 years)

Advanced Component Technologies (ACT)
critical components and subsystems for instruments and platforms
11 new projects added in FY14 (total funding ~$13M over 3 years)



Sustainable Land Imaging-Technology (SLI-T); *Managed by ESTO, funded from SLI*
new technologies and reduced costs for future land imaging (Landsat) measurements
First solicitation released in FY16 (total funding ~$29M over 5 years from SLI budget – investigations managed by ESTO)

Information

Advanced Information Systems Technology (AIST)
innovative on-orbit and ground capabilities for communication, processing, and management of remotely sensed data and the efficient generation of data products
24 new projects added in FY15 (total funding ~$25M over 2 years)

Validation

In-Space Validation of Earth Science Technologies (InVEST)
on-orbit technology validation and risk reduction for small instruments and instrument systems that could not otherwise be fully tested on the ground or airborne systems
4 new projects added in FY15 (total funding ~$21M over 3 years)

Decadal Survey Status (1)

- 2007 Earth Science and Applications from Space is most recent Decadal Survey (Jan 2007); NRC mid-term assessment May 2012
  - **All Legacy Missions launched**: OSTM (2008), OCO-1 (2009*), Aquarius (2011), Glory (2011*), NPP (2011), LDCM (2013), GPM (2014), *OCO-2 (2014)*
  - "NASA responded favorably and aggressively to the decadal survey, embracing its overall recommendations for Earth observations, missions, technology investments, and priorities for the underlying science. As a consequence, the scientific and applications communities have made significant progress over the past 5 years." (Mid-Term Report overarching Finding)
- 31 July 2017 target completion date for 2nd ESAS Decadal Survey
- Main 2007 Decadal Survey ***New Mission*** recommendations/status
  - Tier I
    - Venture Class: 3 strands, multiple solicitations in each strand, on-schedule, fully funded
      - EV-S 1: all 5 investigations completed data acquisition 2015; EV-S 2: 6 investigations selected 2015
      - EV-Instrument 1: TEMPO in Phase C for Sept 2017 instrument delivery, NLT Dec 2021 launch on GEO host
      - EV-Mission 1 CYGNSS in Phase D for Oct 2016 launch
      - EV-Instrument 2: GEDI in Phase B for May 2018 launch to ISS;
        ECOSTRESS in Phase B (24 Sept KDP-C) for May 2017 delivery, Aug 2017 launch to ISS
      - EV-Instrument 3: Proposals in-hand, under review
    - SMAP: Launched 31 January 2015
    - ICESat-2: In Phase C for June 2018 [Oct 2017 MA] launch
    - NI-SAR: In Phase B for Dec 2020-Sept 2021 launch; NI-SAR is radar component of DESDynI; GEDI (EVI-2) contributes substantially to DESDynI lidar/ecosystem
    - CLARREO-Pathfinder: Initiated in FY16 appropriation, flight to ISS, 9/2019 launch

Decadal Survey Status (2)

- Main 2007 Dec. Survey ***Mission*** recommendations/status (cont.)
  - Tier II, III
    - SWOT: In Phase B for Oct 2020 launch (joint with CNES)
    - *GRACE-FO*: In Phase D for Feb 2018 [~Dec 2017 MA] launch (GFZ partner)
    - Pre-formulation: GEO-CAPE, ASCENDS, ACE, HySpIRI, [CLARREO]
    - *PACE*: In pre-Phase A Design-to-Cost study, for development/launch 2022-2023; PACE substantially covers ocean color component of Decadal ACE mission

- Climate Architecture Missions (not included in Decadal Survey)
  - RBI (JPSS-2), TSIS-1 (ISS) Continuity measurements transferred from TSIS-2 (ISS), OMPS-L (JPSS-2) NOAA to NASA
  - Altimeter Follow-On: **FY16** appropriation funds NASA contribution to Jason-CS/Sentinel-6A (w/ESA/EUMETSAT/EU); (radiometer, GPS, Laser Retroreflector, LV), 2020 LRD
    FY17 budget request includes additional funding to allow efficient development of 2nd copy (Sentinel-6B) consistent with Copernicus program plans (2024 LRD)
  - OCO-3: **FY16** appropriation restarted OCO-3 development;
    FY17 request consistent with 6/2018 launch to ISS