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

<table>
<thead>
<tr>
<th>ESD Total</th>
<th>FY16 (op plan)</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
<th>FY20</th>
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<tr>
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<td>$ 1,966</td>
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<td>$ 1,990</td>
<td>$ 2,001</td>
<td>$ 2,021</td>
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</table>

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

![Budget Graph]
Earth Science Instruments on ISS:
RapidScat, CATS,
LIS, SAGE III, TSIS-1, ECOSTRESS,
GEDI, OCO-3, CLARREO-PF, TSIS-2
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:

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:

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

<table>
<thead>
<tr>
<th>Flight</th>
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<tr>
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<td>FY17 PBS</td>
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<td>$1,432</td>
<td>$1,431</td>
<td>$1,448</td>
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</table>

- 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

Sentinel-6A/B FY20/24
PACE FY22
NI-SAR FY22
OMPS-L FY18/21
RBI FY19/21
SWOT FY20

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

GRACE-FO FY18
ICESat-2 FY18
TEMPO FY17/21
CYGNSS 10/16 – 5/17
### Venture Class Selections/Solicitations

<table>
<thead>
<tr>
<th>Mission</th>
<th>Mission Type</th>
<th>Release Date</th>
<th>Selection Date</th>
<th>Major Milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV-1, aka EVS-1</td>
<td>CARVE, ATTREX, HS3, AirMOSS, DISCOVER-AQ</td>
<td>2009</td>
<td>2010</td>
<td>N/A</td>
</tr>
<tr>
<td>EVM-1, CYGNSS</td>
<td>Smallsat constellation</td>
<td>2011</td>
<td>2012</td>
<td>LRD October 2016</td>
</tr>
<tr>
<td>EVI-1, TEMPO</td>
<td>Geosynchronous hosted payload</td>
<td>2011</td>
<td>2012</td>
<td>Delivery NLT 2017</td>
</tr>
<tr>
<td>EVI-2, ECOSTRESS &amp; GEDI</td>
<td>Class C &amp; Class D ISS-hosted Instruments</td>
<td>2013</td>
<td>2014</td>
<td>Delivery NLT 2019</td>
</tr>
<tr>
<td>EVS-2</td>
<td>OMG, ORACLES, CORAL, NAAMES, ATom, ACT-America</td>
<td>2013</td>
<td>2014</td>
<td>Ended (KDP-F)</td>
</tr>
<tr>
<td>EVI-3</td>
<td>Instrument Only</td>
<td>2015</td>
<td>2016</td>
<td>Delivery NLT 2021</td>
</tr>
<tr>
<td>EVM-2</td>
<td>Full Orbital</td>
<td>2015</td>
<td>2016</td>
<td>Launch ~2021</td>
</tr>
<tr>
<td>EVI-4</td>
<td>Instrument Only</td>
<td>2016</td>
<td>2017</td>
<td>Delivery NLT 2021</td>
</tr>
<tr>
<td>EVS-3</td>
<td>Suborbital Airborne Campaigns</td>
<td>2017</td>
<td>2018</td>
<td>Initiating/Confirmation Rev.</td>
</tr>
<tr>
<td>EVI-5</td>
<td>Instrument Only</td>
<td>2018</td>
<td>2019</td>
<td>Delivery NLT 2023</td>
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<tr>
<td>EVM-3</td>
<td>Full Orbital</td>
<td>2019</td>
<td>2020</td>
<td>Launch ~2025</td>
</tr>
<tr>
<td>EVI-6</td>
<td>Instrument Only</td>
<td>2019</td>
<td>2020</td>
<td>Delivery NLT 2024</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th></th>
<th>FY16 (op plan)</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
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<td>FY17 PBS</td>
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<td>$414</td>
<td>$400</td>
<td>$416</td>
<td>$416</td>
<td>$423</td>
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</tbody>
</table>

## 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
<table>
<thead>
<tr>
<th>Mission</th>
<th>Location(s)</th>
<th>Date(s)</th>
<th>Platform(s)</th>
<th>Summary of Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviris NG India</td>
<td>Hyderabad India</td>
<td>Dec 15 – Spring 16</td>
<td>B200 (ISRO aircraft)</td>
<td>Imaging spectroscopy science and application investigation over Indian territory</td>
</tr>
<tr>
<td>Korus-AQ</td>
<td>Korea</td>
<td>Spring 16</td>
<td>DC8, B200</td>
<td>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</td>
</tr>
<tr>
<td>Atmospheric Carbon and Transport – America</td>
<td>Eastern and Midwestern US</td>
<td>Summer 16, Spring 17, Fall 17, Summer 18</td>
<td>B200, C-130</td>
<td>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</td>
</tr>
<tr>
<td>North Atlantic Aerosols and Marine Ecosystems Study (NAAMES)</td>
<td>Atlantic Ocean, flown from Canada</td>
<td>Sep 17, Mar/Apr 18,</td>
<td>C-130, Ship ((UNOLS) research vessel)</td>
<td>Environmental and ecological controls on plankton communities in the North Atlantic Ocean</td>
</tr>
<tr>
<td>Coral Reef Airborne Laboratory (CORAL)</td>
<td>FL, HI, Mariana Is., Palau, Australia</td>
<td>Apr 16 – Jan 17</td>
<td>Contracted GIV</td>
<td>Provide critical data and new models needed to analyze the status of coral reefs and to predict their future</td>
</tr>
<tr>
<td>ObseRvations of Aerosols Above Clouds and Their InterActionS (ORACLES)</td>
<td>Namibia, Africa</td>
<td>Aug/Sept 16, Jul/Aug 17, Sep/Oct 18</td>
<td>P-3, ER-2</td>
<td>Investigate how smoke particles from massive biomass burning in Africa influences cloud cover over the Atlantic.</td>
</tr>
<tr>
<td>Atmospheric Tomography Experiment (ATom)</td>
<td>Around the Globe</td>
<td>Aug 16, Jan/Feb 17, Sep/Oct 17, Apr/May 18</td>
<td>DC-8</td>
<td>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.</td>
</tr>
<tr>
<td>O2/N2 Ratio and CO2 Airborne Southern Ocean (ORCAS)</td>
<td>Southern Ocean</td>
<td>Jan/Feb 16</td>
<td>GV (NSF)</td>
<td>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</td>
</tr>
<tr>
<td>HyspIRI</td>
<td>Hawaii</td>
<td>Summer 16</td>
<td>ER-2</td>
<td>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</td>
</tr>
<tr>
<td>Operation IceBridge</td>
<td>Alaska, Greenland, Antarctica</td>
<td>Mar – May, Oct/Nov – FY16,17,18,19</td>
<td>P-3, DC-8</td>
<td>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)</td>
</tr>
<tr>
<td>UAVSAR</td>
<td>Various US and South America</td>
<td>Year round</td>
<td>C-20</td>
<td>Study processes that control sea surface salinity in higher salinity region than that sampled in SPURS I (sub-tropical North Atlantic)</td>
</tr>
<tr>
<td>SPURS II</td>
<td>Eastern Sub-Tropical Pacific Ocean</td>
<td>Starting spring 2016, multiple sailings covering 18 month period</td>
<td>Schooner Lady Amber plus in-water observations (e.g., gliders, drifters, buoys)</td>
<td>Study vulnerability and resilience of Arctic ecosystems to environmental change in the Arctic and boreal region of western North America</td>
</tr>
<tr>
<td>ABoVE</td>
<td>Alaska, NW Canada</td>
<td>Beginning 2016, continuing</td>
<td>Surface measurements; airborne to follow</td>
<td>Study vulnerability and resilience of Arctic ecosystems to environmental change in the Arctic and boreal region of western North America</td>
</tr>
</tbody>
</table>
### 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

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**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

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<table>
<thead>
<tr>
<th>Applied</th>
<th>FY16 (op plan)</th>
<th>FY17</th>
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<td>FY16 PBS</td>
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<td>52</td>
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</tbody>
</table>
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)

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)

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
  - “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
    - **NI-SAR**: In Phase B for Dec 2020-Sept 2021 launch; NI-SAR is radar component of DESDynl; GEDI (EVI-2) contributes substantially to DESDynl 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)
    - 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