SMD Leadership Change

• John Grunsfeld has retired from NASA as of May 31.
• Geoffrey Yoder, previously the Deputy Associate Administrator for SMD, is now the Acting Associate Administrator for SMD.

• Mr. Yoder has spent 16 years in industry and 16 years at NASA, and his prior assignments include Deputy Director for Astrophysics, Acting Director for Astrophysics, JWST Program Director, SMD Deputy AA for Programs, and SMD Deputy AA.

• Mr. Yoder’s priorities for SMD are
  – Continuing to advance the SMD missions in formulation, development, and operations.
  – Integrating strategic planning across all Divisions to further advance NASA objectives and Decadal Surveys.
  – Making NASA’s technical and capability management more efficient to free up resources for missions and science.
  – Basing NASA’s decisions firmly on community input and peer review.
Astrophysics is humankind’s scientific endeavor to understand the universe and our place in it.

Why Astrophysics?

1. How did our universe begin and evolve?
2. How did galaxies, stars, and planets come to be?
3. Are We Alone?

These national strategic drivers are enduring

Astrophysics Driving Documents

Next update: December 2016
Will include:
• Response to Mid-Term Report
• Planning for 2020 Decadal Survey

http://science.nasa.gov/astrophysics/documents
**NASA Astrophysics Activities**

**Strategic Missions**
- Hubble Space Telescope
- Chandra X-ray Observatory
- XMM-Newton (ESA mission)
- Spitzer Space Telescope
- Fermi Gamma-ray Space Telescope
- Kepler Space Telescope
- Stratospheric Observatory for Infrared Astronomy (SOFIA)
- LISA Pathfinder (ESA mission)
- James Webb Space Telescope
- Widefield Infrared Survey Telescope (WFIRST)

**Explorers Missions**
- Swift Gamma-ray Burst Explorer
- Nuclear Spectroscopic Telescope Array (NuSTAR)
- Neutron star Interior Composition Explorer (NICER)
- Transiting Exoplanet Survey Satellite (TESS)
- SMEX (AO 2014): IXPE, PRAXYS, or SPHEREX
- MO (AO 2014): LiteBIRD (JAXA mission) or GUSTO
- MIDEX/MO AO in 2016

**Research and Analysis**
- Astrophysics Data Analysis Program (ADAP)
- Astrophysics Research and Analysis (APRA)
- Astrophysics Theory Program (ATP)
- Einstein Fellowships
- Exoplanet Research Program (XRP)
- Hubble Fellowships
- Roman Technology Fellowships (RTF)
- Sagan Fellowships
- Theoretical and Computational Astrophysics Networks (TCAN)

**Other Activities**
- Astrophysics Archives (ADS, HEASARC, IRSA, MAST, NED, NExScI)
- Balloon Program, Cosmic-ray Energy and Mass on the International Space Station (ISS-CREAM)
- Keck Observatory
- Large Binocular Telescope Interferometer (LBTI)
- NASA-NSF Exoplanet Observational Research (NN-EXPLORE)
- SMD STEM Education Activities
NASA Astrophysics Community Groups

• Federal Advisory Committees
  – Committee on Astronomy and Astrophysics (NRC Space Studies Board)
  – Astronomy and Astrophysics Advisory Committee (NSF/NASA/DOE)
  – Astrophysics Subcommittee (NASA Advisory Council)

• Program Analysis Groups
  – Cosmic Origins Program Analysis Group – COPAG
  – Exoplanet Exploration Program Analysis Group – ExoPAG
  – Physics of the Cosmos Program Analysis Group – PhysPAG

• Operating Mission Users Groups (examples)
  – Hubble Space Telescope Users Committee
  – Chandra Users Committee
  – Spitzer Science Users Panel
  – SOFIA Users Group

• Science and Technology Definition Teams
  – Far Infrared Surveyor
  – Habitable Exoplanet Imaging Mission
  – Large UV/Optical/IR Surveyor
  – X-ray Surveyor

• To get involved with a mission users group, contact the Center Project Scientist or Users Group Chair for any mission.
• To volunteer for a Federal Advisory Committee or a Program Analysis Group, sign up for the Astrophysics NSPIRES email list and respond to our annual call for self-nominations.
Astrophysics - Big Picture

• The FY16 appropriation and FY17 President’s budget request provide funding for NASA astrophysics to continue its programs, missions, projects, and supporting research and technology.
  – The total funding (Astrophysics including Webb excluding STEM) remains at ~$1.35B.
  – Fully funds Webb to remain on plan for an October 2018 launch.
  – Funds WFIRST formulation (new start) starting in February 2016.
  – Allows operating missions to continue in FY16 and through FY18 (2016 Senior Review).
  – Funds SMD STEM education activities across astrophysics and other disciplines.

• The operating missions continue to generate important and compelling science results, and new missions are under development for the future.
  – Chandra, Fermi, Hubble, Kepler/K2, NuSTAR, Spitzer, Swift, ESA’s XMM-Newton all operating well; Senior Review in Spring 2016 recommended continued operation.
  – SOFIA is in 5-year prime operations as of May 2014; HAWC+ 2nd generation instrument commissioning in Spring 2016; 3rd generation instrument studies underway.
  – ESA’s LISA Pathfinder successfully launched on December 3, 2015; performing well.
  – JAXA’s Hitomi (née ASTRO-H) launched on February 17, 2016; communication was lost with spacecraft on March 26, 2016, and JAXA has ceased recovery efforts.
  – 5 SMEX and MO concept studies selected in 2015; MIDEX AO in 2016; NASA joining ESA’s Athena X-ray observatory (2028) and ESA’s L3 gravitational wave obs (2034).

• Progress being made toward recommendations of the 2010 Decadal Survey.
  – NASA initiating large and medium mission concept studies as input for 2020 Decadal Survey.
NASA Astrophysics

Program Update

Research and analysis
Missions in extended operation
Missions in prime operation
Suborbital missions
Missions in development
### Growth of Funding

- **FY07:** $65M
- **FY08:** $74M
- **FY09:** $88M
- **FY10:** $90M

### Most Recent Year: Proposals, Success Rate, and Year-1 Funding

<table>
<thead>
<tr>
<th>Program</th>
<th>Proposals</th>
<th>Rec'd</th>
<th>selected</th>
<th>Success Rate</th>
<th>Year-1 $M</th>
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<tbody>
<tr>
<td>RTF-15</td>
<td>5</td>
<td>5</td>
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<td>60%</td>
<td>0.3</td>
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<tr>
<td>APRA-14</td>
<td>149</td>
<td>149</td>
<td>42</td>
<td>28%</td>
<td>12.7</td>
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<tr>
<td>SAT-14</td>
<td>27</td>
<td>27</td>
<td>11</td>
<td>41%</td>
<td>6.6</td>
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<tr>
<td>ADAP-15</td>
<td>249</td>
<td>249</td>
<td>51</td>
<td>20%</td>
<td>6.2</td>
</tr>
<tr>
<td>XRP-15</td>
<td>43</td>
<td>43</td>
<td>7</td>
<td>16%</td>
<td>1.2</td>
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<tr>
<td>ATP-14</td>
<td>214</td>
<td>214</td>
<td>32</td>
<td>15%</td>
<td>4.7</td>
</tr>
</tbody>
</table>

### Funding Breakdown

- **Infrared/Sub-mm:** 17%
- **Data Analysis Program:** 19%
- **Theory:** 16%
- **Fund Physics:** 12%
- **Particle Astro:** 12%
- **X-ray, Gamma ray:** 18%
- **UV/Visible:** 9%
- **Exoplanet:** 5%
- **Other:** 3%

### Split of $88M in FY15

- **Total Funding:** $88M
## Recent Proposal Selections

**Status:** May 18, 2016

<table>
<thead>
<tr>
<th>Proposal</th>
<th>Proposal Due Date</th>
<th>Notify Date</th>
<th>Days past received</th>
<th>Number received</th>
<th>Number selected</th>
<th>% selected</th>
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<tbody>
<tr>
<td>Chandra GO – Cycle 17</td>
<td>Mar 17, 2015</td>
<td>July 17, 2015</td>
<td>122</td>
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<tr>
<td>APRA (Basic Research)</td>
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<td>149</td>
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<tr>
<td>SAT (Technology)</td>
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<td>Aug 12, 2015</td>
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<td>11</td>
<td>41%</td>
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<tr>
<td>Hubble GO – Cycle 23</td>
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<td>June 24, 2015</td>
<td>75</td>
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<td>EPAD (Doppler Spectr)</td>
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<td>ADAP (Data Analysis)</td>
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<tr>
<td>Exoplanet Research</td>
<td>May 22, 2015</td>
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<td>146</td>
<td>43</td>
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<tr>
<td>Kepler K2 GO – Cycle 3</td>
<td>Jul 1, 2015</td>
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<td>105</td>
<td>72</td>
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<tr>
<td>SOFIA GI – Cycle 4</td>
<td>Jul 10, 2015</td>
<td>Oct 22, 2015</td>
<td>104</td>
<td>155</td>
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<tr>
<td>Spitzer GO – Cycle 12</td>
<td>Sep 11, 2015</td>
<td>Oct 26, 2015</td>
<td>45</td>
<td>104</td>
<td>31</td>
<td>30%</td>
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<tr>
<td>SOFIA 3rd Gen Instrument</td>
<td>Oct 7, 2015</td>
<td>Dec 10, 2015</td>
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<tr>
<td>WFIRST Sci. Inv. Teams</td>
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<td>Dec 18, 2015</td>
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<td>13</td>
<td>34%</td>
</tr>
<tr>
<td>Swift GI – Cycle 12</td>
<td>Sep 25, 2015</td>
<td>Jan 19, 2016</td>
<td>116</td>
<td>185</td>
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<tr>
<td>Roman Tech Fellows</td>
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<td>Feb 5, 2016</td>
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<tr>
<td>NuSTAR GO – Cycle 2</td>
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<td>Feb 2, 2016</td>
<td>53</td>
<td>185</td>
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<td>27%</td>
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<tr>
<td>Fermi GI – Cycle 9</td>
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<td>May 5, 2016</td>
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<td>185</td>
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<td>NESSF-16</td>
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<td>Kepler K2 GO – Cycle 4</td>
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<td>Chandra GO – Cycle 18</td>
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<tr>
<td>APRA (Basic Research)</td>
<td>Mar 18, 2016</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>SAT (Technology)</td>
<td>Mar 18, 2016</td>
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<td></td>
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</tr>
<tr>
<td>Hubble GO – Cycle 24</td>
<td>Apr 8, 2016</td>
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<td></td>
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<td></td>
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<tr>
<td>ADAP (Data Analysis)</td>
<td>May 13, 2015</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exoplanet Research</td>
<td>May 23, 2015</td>
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<td></td>
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<tr>
<td>Spitzer GO – Cycle 13</td>
<td>June 8, 2016</td>
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</tr>
</tbody>
</table>

100% of 2015-16 selections announced within 150 days

R&A Selection Rate: 23%
GO Selection Rate: 28%
<table>
<thead>
<tr>
<th>Date</th>
<th>Opportunity Description</th>
<th>Website/Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 1, 2016</td>
<td>SOFIA GO Cycle 5</td>
<td><a href="http://www.sofia.usra.edu">www.sofia.usra.edu</a></td>
</tr>
<tr>
<td>July 8, 2016</td>
<td>Astrophysics Theory</td>
<td>ROSES-16 D.4</td>
</tr>
<tr>
<td>September 23, 2016</td>
<td>Swift GI Cycle 13</td>
<td>ROSES-16 D.5</td>
</tr>
<tr>
<td>September 23, 2016</td>
<td>Kepler K2 GO Cycle 5 (Step 1)</td>
<td>ROSES-16 D.7</td>
</tr>
<tr>
<td>Fall 2016</td>
<td>Explorers MIDEX &amp; MO AO</td>
<td>NSPIRES</td>
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<tr>
<td>October 2016</td>
<td>XMM-Newton GO Cycle 16</td>
<td>heasarc.gsfc.nasa.gov</td>
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<tr>
<td>November 18, 2016</td>
<td>Habitable Worlds (Step 1)</td>
<td>ROSES-16 E.4</td>
</tr>
<tr>
<td>January 13, 2017</td>
<td>NuSTAR GO Cycle 3</td>
<td>ROSES-16 D.10</td>
</tr>
<tr>
<td>January 20, 2017</td>
<td>Fermi GI Cycle 10</td>
<td>ROSES-16 D.6</td>
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<tr>
<td>March 17, 2017</td>
<td>Astrophysics R&amp;A</td>
<td>ROSES-16 D.3</td>
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<td>March 17, 2017</td>
<td>Strategic Astrophysics Technology</td>
<td>ROSES-16 D.8</td>
</tr>
<tr>
<td>March 2017</td>
<td>Exoplanet Research (Step 1)</td>
<td>ROSES-17</td>
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<td>March 2017</td>
<td>Chandra GO Cycle 19</td>
<td>cxc.harvard.edu</td>
</tr>
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<td>April 2017</td>
<td>Hubble Cycle 24</td>
<td><a href="http://www.stsci.edu">www.stsci.edu</a></td>
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<td>May 2017</td>
<td>Astrophysics Data Analysis</td>
<td>ROSES-17</td>
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<tr>
<td>June 2017</td>
<td>Spitzer GO Cycle 14</td>
<td>ssc.spitzer.caltech.edu</td>
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<tr>
<td>Late 2017</td>
<td>Webb GO Cycle 1</td>
<td>TBD</td>
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</table>
Explorers MIDEX and MO AO in 2016

• Target dates: draft AO late Spring 2016, AO release late Summer 2016, proposals due 90 days later, Selection Summer 2017, final downselect late 2018.

• MIDEX: standard launch services on an ELV provided at no charge against the mission cost cap; no MIDEX ISS attached payloads
  – PI-managed Cost Cap for the MIDEX is $250M (FY2017 dollars)
  – MIDEX launch readiness date no later than December 2023

• MO may be Partner MO, Small Complete Missions (SCM) or NMES.
  – SCM that are suborbital class (ULDB, CubeSat, SRLV) or on ISS: access to space provided by NASA at no charge to PI-managed Mission Cost
  – PI-managed Cost Cap for the MO is $70M, $35M for suborbital class MO
  – SCM launch readiness date no later than December 2022
  – PMO or NMES endorsement need date before January 2022

• Selected missions execute a nine-month Phase A study funded at $2M for MIDEX, $500K for MO
  – Science Enhancement Options (SEOs) are allowed
  – Student Collaborations are allowed (incentive of 1% of the PI-Managed Mission Cost Cap)
  – NASA-developed technology infusion may be allowed
Budgets already recognized in the notional run-out of the President’s FY 2016 budget request. Mature and stable missions with no operational changes.
• “The SR2016 panel finds no scientific reason to discontinue or significantly reduce any of the six missions under this review.”
• “We strongly encourage NASA to find a way to continue all of these missions at their full funding level.”
• “The scientific value of the complete Astrophysics Senior Review 2016 portfolio is greater than the sum of its parts.”
## 2016 Astrophysics Senior Review
### NASA Implementation Decisions

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Hubble</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Chandra</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Fermi</td>
<td>Yes</td>
<td>Yes</td>
<td>Reduced budget</td>
</tr>
<tr>
<td>Kepler/K2</td>
<td>Yes</td>
<td>No</td>
<td>End-of-mission plan</td>
</tr>
<tr>
<td>NuSTAR</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Spitzer</td>
<td>Yes</td>
<td>No</td>
<td>Reduced budget; end-of-mission plan</td>
</tr>
<tr>
<td>Swift</td>
<td>Yes</td>
<td>Yes</td>
<td>Augmentation for automation</td>
</tr>
<tr>
<td>XMM</td>
<td>Yes</td>
<td>Yes</td>
<td>Augmentation for GO program</td>
</tr>
</tbody>
</table>

- Maintain all 8 missions in operation, with K2 and Spitzer ending.
  - Spitzer ending in mid-FY19 after providing significant precursor work for JWST and after JWST commissioned.
  - Kepler/K2 ending in FY19 when fuel is exhausted.
- Maintaining all 8 missions will require some reductions in mission funding in order allow the overarching finding (the continuation of all missions) to be implemented.
2016 New Zealand SPB Campaign

As of 10:44:04Z 06/11/16

Launched May 11, 2016

Compton Spectrometer and Imager (COSI)
Pl: Steven Boggs, UC Berkeley

http://www.csbf.nasa.gov/
http://www.csbf.nasa.gov/newzealand/wanaka.htm
Recent & Upcoming Suborbital Missions

Sounding Rockets
• FY16-FY17 Sounding Rocket Launches @ White Sands NM
  o **PICTURE-B** – S. Chakrabarti, U Mass Lowell (Nov 24, 2015)
  o **DXL** – M. Galeazzi, U Miami (Dec 5, 2015)
  o **FORTIS** – S. McCandliss, JHU (Dec 18, 2015)
  o **CHESS** – K. France, Colorado U (Feb 22, 2016)
  o **Micro-X** – E. Figueroa, MIT (~Nov 2016)
  o **CIBER-2** – J. Bock, Caltech (~Dec 2016)

Stratospheric Balloons
• Winter FY16 Conventional Balloon Campaign @ McMurdo Station Antarctica
  o **GRIPS** – P. Saint-Hilaire, UC Berkeley (Jan 19-30, 2016)
• Spring FY16 Super Pressure Balloon Campaign @ Wanaka New Zealand
  o **COSI** – S. Boggs, UC Berkeley (May 16, 2016 ongoing)
• Summer FY16 Conventional Balloon Campaign @ Palestine TX
  o **SuperBIT** – W. Jones, Princeton U (Jun 2016 ready to launch)
• Fall FY16 Conventional Balloon Campaign @ Ft Sumner NM
  o **BETTII** – S. Rinehart, NASA GSFC (Aug/Sep 2016)
  o **FIREBALL-2** – C. Martin, Caltech (Aug/Sep 2016)
  o **PIPER** – A. Kogut, NASA GSFC (Aug/Sep 2016)
  o **X-Calibur** – H. Krawczynski, Washington U (Aug/Sep 2016)
• Winter FY17 Conventional Balloon Campaign @ McMurdo Station Antarctica
  o **ANITA-4** – P. Gorham, U Hawaii (Dec 2016/Jan 2017)
  o **BACCUS** – E.S. Seo, U Maryland (Dec 2016/Jan 2017)
  o **STO-2** – C. Walker, U Arizona (Dec 2016/Jan 2017)
ST-7/LISA Pathfinder
ST-7/Disturbance Reduction System (DRS)

CURRENT STATUS:
• LISA Pathfinder successfully launched on December 3, 2015.
• Satellite reached Earth-Sun L1 on Jan 22 and all systems are nominal.
• Test masses released on Feb 15 (“Elwood”) and Feb 16 (“Jake”) are operating nominally.
• Began science operations on March 1, 2016.
• ESA’s LISA Test Package for 90 days
• LISA test package performance exceeds requirements.
• NASA’s Disturbance Reduction System for 90 days (commissioning starts June 27)
• ESA discussing potential (2-3 months) mission extension if all goes well

• ESA Mission with NASA Collaborating
• Project Category: 3  Risk Class: C
• DRS flies on the ESA LISA Pathfinder spacecraft
• Sun-Earth L1 halo orbit
• Drag-free satellite to offset solar pressure
• Payload delivery: July 2009
• Launched: December 3, 2015 GMT
• LPF prime mission: 7 months
• Data Analysis: 12 months

http://sci.esa.int/lisa-pathfinder/
Hitomi
(formerly ASTRO-H)
Soft X-ray Spectrometer and Soft X-ray Telescope Mirrors

CURRENT STATUS
The U.S. provided key instrument contributions to the JAXA Hitomi mission, including:

- Soft X-ray telescope mirrors (SXT-S and SXT-I)
- X-ray Calorimeter Spectrometer Insert (CSI), including Adiabatic Demagnetization Refrigerator (ADR) and ADR Controller
- Aperture Assembly

- Following successful activation of the observatory and instruments, Hitomi suffered a mission-ending spacecraft anomaly on March 26, 2016
- Prior to mission failure, the SXS demonstrated a spectral resolution of ~4.7 eV, significantly exceeding the pre-launch requirement
- The SXS completed several science observations, including a scientifically important observation of the Perseus Cluster

UPCOMING EVENTS:
- Finalization of JAXA mishap investigation
- PI-led team complete analysis and archiving of available data

• Explorer Mission of Opportunity
• PI: R. Kelley, Goddard Space Flight Center
• Launch Date: Feb 17, 2016 on JAXA H-IIA
• Science Objectives: Study the physics of cosmic sources via high-resolution X-ray spectroscopy. The SXS will enable a wide range of physical measurements of sources ranging from stellar coronae to clusters of galaxies.
SOFIA
Stratospheric Observatory for Infrared Astronomy

• World’s Largest Airborne Observatory
• 2.5-meter telescope
• 80/20 Partnership between NASA and the German Aerospace Center (DLR)
• Science Center and Program Management at NASA-Ames Research Center
• Science Flight Operations at NASA-Armstrong Flight Research Center
• Four US and Two German science instruments commissioned
  – Provide imaging, spectroscopy and photometry ranging from visible to far infrared
  – Advanced science instruments under development for future operation

https://www.sofia.usra.edu/

CURRENT STATUS:
• In prime mission operation since May 2014
• Observing status:
  – Pluto occultation data (July 2015) synergistic with New Horizons
  – Calibrated data from Horsehead nebula released in February 2016 with no proprietary restrictions
  – Cycle 4 started in February 2016
  – 7-week, 3 science instrument deployment to Christchurch, New Zealand planned from June 4 – July 25, 2016
• Second generation instruments:
  – Commissioned upGREAT, multi-pixel heterodyne spectrometer (German instrument)
  – Testing/integrating HAWC+, far infrared imager & polarimeter; 2016 commissioning (U.S. instrument)
• Two Third-generation instrument concepts selected in 2016 for six month study. Down select in August 2016.
• Implemented science community feedback and IG recommendations for improved science productivity
  – Large impact science observation program offerings
  – Increased guest investigator support by a factor of 3 (~$10K per hour of observing)
  – Increased capacity to deploy multiple instruments
  – Increased support for future science instrumentation
• Recompeting contract for science mission operations
### Astrophysics Missions in Development

<table>
<thead>
<tr>
<th>Mission</th>
<th>Start Date</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>NICER</td>
<td>2/2017</td>
<td>Neutron Star Interior Composition Explorer</td>
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<tr>
<td>CREAM</td>
<td>6/2017</td>
<td>Cosmic Ray Energetics And Mass</td>
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<tr>
<td>TESS</td>
<td>12/2017</td>
<td>Transiting Exoplanet Survey Satellite</td>
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<tr>
<td>Webb</td>
<td>10/2018</td>
<td>James Webb Space Telescope</td>
</tr>
<tr>
<td>Euclid</td>
<td>2020</td>
<td>NASA is supplying the NISP Sensor Chip System (SCS)</td>
</tr>
<tr>
<td>WFIRST</td>
<td>Mid 2020s</td>
<td>Wide-Field Infrared Survey Telescope</td>
</tr>
</tbody>
</table>
NICER
Neutron star Interior Composition Explorer

- All subsystems/sub-assemblies have completed fabrication and environmental testing
- The NICER payload completed final integration and test
- December 2015: Pre-environmental Review
- January 2016: Start Phase D
- February 2016: Start of payload environmental testing
- April 2016: Completion of payload environmental testing
- June 2016: Payload delivered to KSC and stored at KSC until launch
- February 2017 (TBC): Launch on SpaceX-11 commercial resupply service (CRS) flight to ISS

https://heasarc.gsfc.nasa.gov/docs/nicer/
CREAM
Cosmic Ray Energy and Mass

- July 2015: CREAM delivered to KSC and stored at KSC until launch ✓
- June 2017 (TBC): Launch on SpaceX-12 commercial resupply service (CRS) flight to ISS

http://cosmicray.umd.edu/iss-cream/
**Medium Explorer (MIDEX) Mission**

**PI**: G. Ricker (MIT)

**Mission**: All-Sky photometric exoplanet mapping mission.

**Science goal**: Search for transiting exoplanets around the nearby, bright stars.

**Instruments**: Four wide field of view (24x24 degrees) CCD cameras with overlapping field of view, operating in the Visible-IR spectrum (0.6-1 micron).

**Operations**: NLT June 2018 launch with a 3-year prime mission including 2 years of spacecraft operations and an additional 1 year ground-based observations and analysis. High-Earth elliptical orbit (17 x 58.7 Earth radii).

**CURRENT STATUS:**
- CDR completed Dec 7, 2015; Mission in fabrication and assembly phase ✓
- Most spacecraft bus components have been delivered and s/c is being assembled ✓
- Flight instrument build underway; first lots of flight CCDs have been produced ✓
- Flight camera optics in assembly ✓

**TESS**

Transiting Exoplanet Survey Satellite

**UPCOMING EVENTS:**
- Spring-Fall 2016 – TESS bus integration and instrument integration ongoing
- Winter-Spring 2017 – TESS Observatory integration and test
- Spring 2017 – System Integration Review (SIR) and KDP-D
- Fall 2017 – TESS delivery to KSC launch site.
- Dec 2017 – Launch readiness date from Canaveral FL

http://tess.gsfc.nasa.gov/
Webb
James Webb Space Telescope

2015-2016 Accomplishments
• Telescope mirrors installed ✓
• Science instruments integrated with Telescope ✓
• MIRI cryocooler completed ✓
• Spacecraft bus powered on for first time ✓
• Completed 2nd test of Pathfinder Telescope and ground support equipment at JSC in support of 2017 test of flight hardware ✓

2016 Plans
• Complete ambient testing of combined Telescope and instruments
• Complete spacecraft bus
• Complete sunshield membrane fabrication
• Cryovacuum testing of combined Telescope and instruments at JSC
• Integrate Sunshield and Spacecraft

http://www.jwst.nasa.gov/

Large Infrared Space Observatory
Top priority of 2000 Decadal Survey
Science themes: First Light; Assembly of Galaxies; Birth of Stars and Planetary Systems; Planetary Systems and the Origins of Life
Mission: 6.5m deployable, segmented telescope at L2, passively cooled to <50K behind a large, deployable sunshield
Instruments: Near IR Camera, Near IR Spectrograph, Mid IR Instrument, Near IR Imager and Slitless Spectrograph
Operations: 2018 launch for a 5-year prime mission
Partners: ESA, CSA
Webb Top Level Schedule

<table>
<thead>
<tr>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
</table>

- **k** months of project funded critical path (mission pacing) schedule reserve

**Spacecraft**

1. SC Assembly & Test
2. Spacecraft I & T
3. Observatory I & T

**Telescope + Science Instruments**

OTIS = Optical Telescope + ISIM

OTIS

Legend:
- Northrop-Grumman
- Goddard Space Flight Center
- Johnson Space Center
- Guiana Space Center
JWST Spacecraft

Spacecraft Bus making good progress at Northrop-Grumman. Currently in propulsion system integration stage.

Powered-On Configuration on the –J2 Panel
### Webb Sunshield

<table>
<thead>
<tr>
<th>Manufacturing Activity</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>L2</th>
<th>L1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut Gores &amp; Coating removal</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Rip stops</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sub-assembly TSB seaming</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Assembly TSB seaming</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ACS off-nominal Bonding</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Bonding &amp; Assembly</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>In-process</td>
</tr>
<tr>
<td>Initial Shape Test (IST)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>N/A</td>
</tr>
<tr>
<td>Hole Tool (-J2 side)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hole Tool (+J2 side)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Vent Holes</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Grounding</td>
<td>✓</td>
<td>✓</td>
<td>In-process</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MDMS</td>
<td>✓</td>
<td>✓</td>
<td>In-process</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acceptance Shape Test (AST)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Epaullets &amp; Closeout</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Verification</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Package &amp; Ship</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Flight Layer 2 Membrane**

**Flight Layer 1 Membrane**

**Flight Layer 5 under 3X load**
Webb Telescope & Instruments

Primary Mirror on a turnover fixture at GSFC

Science Instruments being installed into Telescope Backplane Support Fixture

JWST remains on track for an October 2018 launch within its replan budget guidelines.
WFIRST
Wide-Field Infrared Survey Telescope

WFIRST highest ranked large space mission in 2010 Decadal Survey
- Study Dark Energy, Exoplanet Census, NIR Sky Survey

Use of 2.4m telescope enables
- Hubble quality imaging over 100x more sky
- Imaging of exoplanets with $10^{-9}$ contrast with a coronagraph

http://wfirst.gsfc.nasa.gov/
WFIRST
Wide-Field Infrared Survey Telescope

CURRENT STATUS:
• Completed Mission Concept Review (MCR) held in December 2015
• Formulation Science Investigation Teams selected in December 2015; first meeting held February 2016.
• Ball and Lockheed Martin selected in February 2016 to support Wide-field Instrument Concept Studies
• Passed Key Decision Point A (KDP-A) in Feb 2016
  – Official start of formulation phase
  – Successful KDP-A held February 17, 2016
  – Established management agreement for total mission cost to govern formulation trades
  – Next major milestone is acquisition strategy meeting (ASM) in July 2016
• On track for TRL-6 of new technologies in 2017
• Working toward System Requirements Review (SRR) in June 2017 and KDP-B in October 2017
• FY17 budget request matches FY16 appropriation of $90M. In-guide budget supports launch in mid-2020s.

Wide-Field Infrared Survey Telescope
Top priority of 2010 Decadal Survey
Science themes: Dark Energy, Exoplanets, Large Area Near Infrared Surveys
Mission: 2.4m widefield telescope at L2; using existing hardware, images 0.28deg² at 0.8-2µm
Instruments (design reference mission): Wide Field Instrument (camera plus IFU), Coronagraph Instrument (imaging/IFS)
Phase: Currently in Formulation (Phase A)

http://wfirst.gsfc.nasa.gov/

WFIRST has begun Formulation
NASA Astrophysics

Budget Update
FY16 Appropriation

Outyears are notional planning from FY16 President's budget request

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Astrophysics*</td>
<td>$678</td>
<td>$685</td>
<td>$731</td>
<td>$707</td>
<td>$750</td>
<td>$986</td>
<td>$1118</td>
</tr>
<tr>
<td>JWST</td>
<td>$658</td>
<td>$645</td>
<td>$620</td>
<td>$569</td>
<td>$535</td>
<td>$305</td>
<td>$198</td>
</tr>
<tr>
<td>Total</td>
<td>$1336</td>
<td>$1330</td>
<td>$1351</td>
<td>$1273</td>
<td>$1285</td>
<td>$1291</td>
<td>$1316</td>
</tr>
</tbody>
</table>

* Excludes “SMD STEM Activities” in all years.

- Provides $90M for WFIRST and directs NASA to start Formulation.
- Provides full funding ($85M) for SOFIA operations and places SOFIA into the 2018 Astrophysics Senior Review.
- Provides full funding ($98M) for continued Hubble operations.
- Provides $37M for SMD STEM education activities.
- Requires reduction of $36M in rest of Astrophysics portfolio.

<table>
<thead>
<tr>
<th>($M)</th>
<th>FY16 Request</th>
<th>FY16 Approps</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>JWST</td>
<td>$620</td>
<td>$620</td>
<td>--</td>
</tr>
<tr>
<td>WFIRST</td>
<td>$14</td>
<td>$90</td>
<td>+$76</td>
</tr>
<tr>
<td>SOFIA</td>
<td>$85</td>
<td>$85</td>
<td>--</td>
</tr>
<tr>
<td>Hubble</td>
<td>$97</td>
<td>$98</td>
<td>+$1</td>
</tr>
<tr>
<td>Rest of Astrophysics*</td>
<td>$493</td>
<td>$457</td>
<td>-$36 (-7%)</td>
</tr>
<tr>
<td>Total</td>
<td>$1309</td>
<td>$1351</td>
<td>+$42</td>
</tr>
</tbody>
</table>

* Excludes “SMD STEM Activities.”
FY16 Appropriation

- Addressing the $36M reduction across the rest of Astrophysics

<table>
<thead>
<tr>
<th>Project</th>
<th>$ FY16</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explorers Futures</td>
<td>$11M</td>
<td>Two month delay in development of future Explorers missions</td>
</tr>
<tr>
<td>TESS</td>
<td>$11M</td>
<td>Use of reserves not needed by the TESS project in FY16, with payback to the TESS project in FY17 and FY18 (rephasing of reserves)</td>
</tr>
<tr>
<td>ASTRO-H</td>
<td>$7M</td>
<td>Use of reserves held by the ASTRO-H project in case of problems in I&amp;T or a launch delay; not needed by ASTRO-H project because ASTRO-H launched on time</td>
</tr>
<tr>
<td>R&amp;A</td>
<td>$3M</td>
<td>One year reduction; fewer selections spread over FY16-FY17</td>
</tr>
<tr>
<td>Spitzer</td>
<td>$3M</td>
<td>Additional support from SMD makes up for reduction</td>
</tr>
</tbody>
</table>
This budget request is an excellent budget request for NASA Astrophysics ($1,326M excluding STEM).

It compares well with the FY16 Appropriation ($1,351M excluding STEM) and significantly exceeds the FY17 notional runout in the President’s FY16 request for NASA Astrophysics including JWST ($1,276M excluding STEM).

This budget request and the notional runout allows WFIRST to be executed without additional funding.

This budget request and the notional runout support other Decadal Survey priorities.
- Continued Explorer AOs at the cadence of 4 per decade.
- Partnerships on ESA’s Athena X-ray observatory and L3 gravitational wave observatory.
- Precursor exoplanet science and technology including Large Binocular Telescope Interferometer, Extreme Precision Doppler Spectrometer, and WFIRST Coronagraph.
- Retains prior growth in R&A and suborbital programs.

Senior Review funding is inadequate to continue all currently operating missions in FY17-FY18 without reductions in mission and GO funding.
NASA Astrophysics Budget:
FY04-FY16 Appropriated, FY17 Request, FY18-FY21 Notional Planning

Real Year $Million

includes SMD E/PO and SMD STEM activities

Managed by JWST Program Off
WFIRST
Managed by Astrophysics Div
Total Astrophysics

JWST Program
WFIRST
Rest of Astrophysics
FY17 Appropriations

- Both the House and the Senate appropriation subcommittees for NASA have marked up the President’s budget request for NASA.
- Neither chamber has had a full vote on the NASA appropriation.
- Both chambers made changes to the President’s budget request for NASA. The differences must be resolved before the FY17 NASA appropriation can be signed into law.

<table>
<thead>
<tr>
<th>($M)</th>
<th>FY17 Request</th>
<th>Senate Mark</th>
<th>Senate Delta</th>
<th>House Mark</th>
<th>House Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Astrophysics</td>
<td>1350.9</td>
<td>1376.4</td>
<td>+25.5</td>
<td>1362.3</td>
<td>+11.4</td>
</tr>
<tr>
<td>JWST</td>
<td>569.4</td>
<td>569.4</td>
<td></td>
<td>569.4</td>
<td></td>
</tr>
<tr>
<td>Hubble</td>
<td>97.3</td>
<td>98.3</td>
<td>+1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOFIA</td>
<td>83.8</td>
<td>83.8</td>
<td></td>
<td>85.2</td>
<td>+1.4</td>
</tr>
<tr>
<td>WFIRST</td>
<td>90.0</td>
<td>120.0</td>
<td>+30.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mirror Tech</td>
<td>5.0</td>
<td></td>
<td>+5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starshade Tech</td>
<td></td>
<td></td>
<td></td>
<td>10.0</td>
<td>+10.0</td>
</tr>
<tr>
<td>STEM</td>
<td>25.0</td>
<td>42.0</td>
<td>+17.0</td>
<td>697.7</td>
<td>0</td>
</tr>
<tr>
<td>Rest of Astrophysics</td>
<td>457.9</td>
<td>457.9</td>
<td>-27.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NASA Astrophysics

Planning for the 2020 Decadal Survey
### Responding to the 2010 Decadal Survey

<table>
<thead>
<tr>
<th>Prioritized Recommendation</th>
<th>NASA plans</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LARGE ACTIVITIES</strong></td>
<td></td>
</tr>
<tr>
<td>WFIRST</td>
<td>In Phase A, launch in mid-2020s</td>
</tr>
<tr>
<td>Explorers</td>
<td>Executing 4 AOs per decade</td>
</tr>
<tr>
<td>LISA</td>
<td>Partnering on ESA’s space-based gravitational wave observatory</td>
</tr>
<tr>
<td>IXO</td>
<td>Partnering on ESA’s Athena x-ray observatory</td>
</tr>
<tr>
<td><strong>MEDIUM ACTIVITIES</strong></td>
<td></td>
</tr>
<tr>
<td>Exoplanet technology</td>
<td>WFIRST coronagraph, Starshade and coronagraph technology development</td>
</tr>
<tr>
<td>Inflation Probe technology</td>
<td>3 balloon-borne technology experiments</td>
</tr>
<tr>
<td><strong>SMALL ACTIVITIES</strong></td>
<td></td>
</tr>
<tr>
<td>R&amp;A augmentations</td>
<td>R&amp;A up 20% since FY10</td>
</tr>
<tr>
<td>Mid-TRL technology</td>
<td>Initiated Strategic Astrophysics Technology program</td>
</tr>
<tr>
<td>Suborbital missions</td>
<td>Initiated ultra long duration balloon capability</td>
</tr>
</tbody>
</table>
ASTROPHYSICS

Decadal Survey Missions

1972 Decadal Survey Hubble

1982 Decadal Survey Chandra

1991 Decadal Survey Spitzer, SOFIA

2001 Decadal Survey JWST

2010 Decadal Survey WFIRST
Preparing for the 2020 Astrophysics Decadal Survey

• NASA has begun to study large mission concepts as input to the 2020 Decadal Survey
  – A well informed Decadal Survey makes better recommendations
• NASA has appointed Science and Technology Development Teams and initiated four large mission concept studies
  – X-ray Surveyor
  – Far Infrared Surveyor
  – Large Ultraviolet/Optical/Infrared Surveyor
  – Habitable Exoplanet Imaging Mission
• Science and Technology Definition Teams have a significant role and responsibility
  – Develop science case
  – Flow science case into mission parameters
  – Vet technology gap list
  – Direct trades of science vs cost/capability
• NASA is also planning to issue a call for medium-size mission concept studies (Astrophysics Probes)

http://science.nasa.gov/astrophysics/2020-decadal-survey-planning/
Preparing for the 2020 Decadal Survey  
Large Mission Concepts

NASA has assembled Science and Technology Definition Teams (STDTs) for each of the four large mission candidates to enable Mission Concept Studies as input to the 2020 Decadal Survey.

<table>
<thead>
<tr>
<th>Mission Concept</th>
<th>Community STDT Chairs</th>
<th>Center Study Scientist</th>
<th>Study Lead Center</th>
<th>HQ Program Scientist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Far IR Surveyor</td>
<td>Asantha Cooray Margaret Meixner</td>
<td>David Leisawitz</td>
<td>GSFC</td>
<td>Kartik Sheth</td>
</tr>
<tr>
<td>Habitable Exoplanet Imaging Mission</td>
<td>Scott Gaudi Sara Seager</td>
<td>Bertrand Mennesson</td>
<td>JPL</td>
<td>Martin Still</td>
</tr>
<tr>
<td>Large UV/Optical/IR Surveyor</td>
<td>Debra Fischer Bradley Peterson</td>
<td>Aki Roberge</td>
<td>GSFC</td>
<td>Mario Perez</td>
</tr>
<tr>
<td>X-ray Surveyor</td>
<td>Feryal Ozel Alexey Vikhlinin</td>
<td>Jessica Gaskin</td>
<td>MSFC</td>
<td>Dan Evans</td>
</tr>
</tbody>
</table>

BACKUP
Astrophysics Division, NASA Science Mission Directorate

**Resource Management**
- Omana Cawthon*
- Clemencia Gallegos-Kelly*

**Director**
- Paul Hertz

**Deputy Director**
- Andrea Razzaghi

**Lead Secretary**
- Kelly Johnson

**Secretary**
- Leslie Allen

**Program Support Specialist**
- Jackie Mackall

**Cross Cutting**
- Technology Lead: Billy Lightsey*
  - Education POC: Hashima Hasan (Lead Comm Team)
  - Public Affairs POC: Kartik Sheth
  - Information Manager: Lisa Wainio*

**Astrophysics Research**
- Program Manager: Linda Sparke
- Program Support: Pam Terrell*
- Astrophysics Data Analysis: Doug Hudgins
- Astrophysics Theory: Keith MacGregor*
- Exoplanet Research: Martin Still*
- APRA lead: Michael Garcia*
- Gamma Ray/X-ray: Dan Evans, Michael Garcia*, Stefan Immmler*, Lou Kaluziensi, Rita Sambruna, Wilt Sanders
- Optical/Ultraviolet: Michael Garcia*, Hashima Hasan, Mario Perez*, Martin Still*
- IR/Submillimeter/Radio: Dominic Benford*, Doug Hudgins, Kartik Sheth, Erin Smith*
- Lab Astro: Doug Hudgins
- Theory & Comp Astro Net: Keith MacGregor*
- Roman Tech Fellows: Billy Lightsey*
- Data Archives: Hashima Hasan
- Astrophys Sounding Rockets: Wilt Sanders
- Balloons Program: Vernon Jones(PS), Mark Sistilli (PE)

**Programs / Missions & Projects**

**Exoplanet Exploration (EXEP)**
- Program: Doug Hudgins
- Keck: Hashima Hasan
- Kepler/K2: Mario Perez*
- LBTT: Doug Hudgins
- NN-EXPLORE: Doug Hudgins
- WFIRST: Dominic Benford*

**Cosmic Origins (COR)**
- Program: Mario Perez*
- Herschel: Dominic Benford*
- Hubble: Michael Garcia*
- James Webb*: Hashima Hasan
- SOFIA: Hashima Hasan
- Spitzer: Erin Smith*

**Physics of the Cosmos (PCOS)**
- Program: Rita Sambruna
- Athena: Michael Garcia*
- Chandra: Stefan Immler*
- Euclid: Linda Sparke
- Fermi: Stefan Immler*
- Planck: Rita Sambruna
- ST-7/LPF: Rita Sambruna
- XMM-Newton: Stefan Immler*

**Astrophysics Explorers (APEX)**
- Program: Wilt Sanders
- Hitomi: Lou Kaluziensi
- NICER: Rita Sambruna
- NuSTAR: Lou Kaluziensi
- Suzaku: Stefan Immler*
- Swift: Martin Still*
- TESS: Doug Hudgins

* Member of the Resources Management Division
* Detailee, IPA, or contractor
^ James Webb is part of the JWST Program Office.

April 18, 2016
SMD Education Cooperative Agreements dedicated to astrophysics

Universe of Learning (PI: Denise Smith, STScI; co-I institutions: CXC/SAO, IPAC/JPL, ExEP/JPL, Sonoma State U.; Evaluation: Goodman Research Group, Cornerstone Evaluation Associates.)

- Combines science and technology from across NASA Astrophysics with proven education infrastructure to address audience needs and SMD education objectives.
- Program Status: Start-Up Phase Underway
  Year 1 funded effective 3/21/16; full team kick-off in June; Needs assessments, literature reviews, evaluation plan in progress; User benchmarking of website infrastructure initiating in May; Definition of collaborations with other CAN awardees in progress.

SOFIA Airborne Astronomy Ambassadors (PI: Dana Backman; Evaluation: WestEd)

- Met with Santa Clara County (N. California) school district science coordinators for assessment of needs, aimed at eventual selection of Cycle 5 (2017) teacher cohort and baseline measurements of student performance; Scheduled meetings with Los Angeles county school officials for assessment of needs.

Girl Scouts: Reaching for the Stars (PI: Edna DeVore, SETI)

- Held two Space Science Badge design workshops.
- Drafted Badges for Daisies, Brownies, and Junior Girl Scouts (grades K-5).
- Collaborated with the GS Volunteer Tool Kit team to develop online materials for leaders.
- Supported Bridging Day for 6,500 Junior Girl Scouts at Golden Gate Bridge, San Francisco.
- Held 3-day Volunteer Leader Astronomy Camp at University of Arizona.