NASA Town Hall
AAS 234th Meeting | June 10, 2019

Paul Hertz
Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

Posted at http://science.nasa.gov/astrophysics/documents
Success criteria are progress in answering fundamental science questions, implementing the decadal survey priorities, and responding to direction from the Executive Branch and Congress.

NASA Strategic Plan (2018)
Astrophysics Strategic Planning

To be updated in 2019 (per GPRAMA)

Astro2020 Decadal Survey underway

2018 update includes:
- Independent reviews of Webb & WFIRST
- Planning for 2020 Decadal Survey

https://science.nasa.gov/astrophysics/documents
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
NASA Events at the 234th AAS Meeting

Monday, June 10
Exploring the Diversity and Habitability of Nearby Planetary Systems with HabEx – 2:30 PM; Midway 1&2
Revealing the Invisible Universe with the Lynx X-ray Observatory – 3:00 PM; Wabash Cannonball Room
NASA Heliophysics Town Hall – 6:30 PM; Regency C
Space Telescope Science Institute Town Hall – 7:30 PM; Grand Ballroom A

Tuesday, June 11
NASA Astrophysics Science SmallSat Studies – 10:40 AM; Grand Ballroom A
Learning to Utilize Kepler’s Unique Dataset for Computing Exoplanet Occurrence Rates – 1:30 PM; Midway 7&8
NASA Living with a Star PAG Town Hall – 1:40 PM; Grand Ballroom B
WFIRST Ultra-deep Fields I - 2:50 PM; Grand Ballroom B
Origins Space Telescope Enables Community Science – 3:30 PM; Jeffersonian/Knickerbocker
The Astronomy and Astrophysics Decadal Survey 2020 Town Hall – 6:30 PM; Grand Ballroom A

Wednesday, June 12
General Astrophysics and Solar System Science with HabEx - 9:30 AM; Midway 7&8
WFIRST Ultra-deep Fields II - 2:50 PM; Grand Ballroom B
Outline

• Community Involvement
  ▪ Building Leaders and Teams for the Future
  ▪ Connecting with NASA

• Program Update
  ▪ Budget Update
  ▪ Project Artemis
  ▪ Research & Analysis

• Missions Update
  ▪ Webb, WFIRST
  ▪ TESS, SPHEREx, Explorers
  ▪ Other missions

• Preparing for Astro2020
  ▪ Large Mission (Flagship) Studies
  ▪ Medium Mission (Probe) Studies
  ▪ Program of the Future
Building Excellent Teams

- Excellent teams require diverse opinions and perspectives
- Teams must foster a community where everyone feels safe
- Encouraging healthy behavior through actions is paramount
- SMD is building excellent teams by:
  - Promoting diversity for both grants and PI-led missions
  - Providing resources to report concerns
  - Partnering with the Office of Diversity and Equal Opportunity
  - Examining barriers to diversity and inclusion within NASA and the broader science community
The NASA Astrophysics Division is actively taking steps to advance diversity, inclusion, and equal opportunity in the NASA workforce and among NASA grantee institutions.

NASA Astrophysics is committed to:
- Setting the expectancy of diversity and inclusion in the composition of: proposal teams, peer review panels, science and technology definition teams, and mission and instrument teams.
- Recruiting diversity on NASA-selected groups (e.g., advisory groups, peer review panels, science teams).
- Recruiting a diverse Astrophysics Division staff.
- Working with the NASA Office of the Chief Scientist and our peer review contractors to address unconscious bias in peer reviews.
- Establishing a Code of Conduct for peer review panel chairs and members
- Sharing best practices in peer reviews with other agencies.
- Observing the demographics of R&A proposers and awardees as an indicator of issues.

The demographics of R&A proposers and awardees – we notice that:
- The inferred gender balance of awardees does reflect that of proposers.
- The inferred gender balance of proposers does not always reflect that of the community.
Inspiring Future Leaders

• Achieve excellence by relying on diverse teams, both within and external to NASA, to most effectively perform SMD’s work
• Attract and retain talent by promoting a culture that actively encourages diversity and inclusion and removes barriers to participation
• Encourage development of future leaders, including the next generation of mission principal investigators, through targeted outreach and hands-on opportunities
• Support early-career scientists to build careers working with NASA
• Engage the general public in NASA Science, including opportunities for citizen scientists
Mission Principal Investigator Development

- Seek to increase the diversity of mission principal investigators and develop the next generation of mission leaders to ensure that new ideas and mission concepts are brought forward
- Based on feedback from November 2018 workshop, NASA Science
  - Developed a consolidated PI resources webpage at https://science.nasa.gov/researchers/new-pi-resources
  - Introduced a pre-reviews of mission peer review panels to ensure diversity and reduce conflicts of interest
  - Added a code of conduct requirement for SMD-funded conferences to ROSES 2019
  - Restarted proposal writing workshops at major science conferences
  - Included career development positions and associated evaluation criteria as part Discovery and New Frontiers AOs
  - Lessons learned presentation by NASA Science AA Thomas Zurbuchen on characteristics and key mistakes associated with proposal success at http://science.nasa.gov/researchers/new-pi-resources
- Upcoming activities include:
  - Information sessions at science conferences and stand-alone workshops to support people developing first proposal
  - Sign up to learn more at https://lists.hq.nasa.gov/mailman/listinfo/hq-smdpi-workshop-outreach
Why Volunteer to Serve on a NASA Peer Review Panel?

• Personal professional development:
  – See how the whole review process works
  – Learn what constitutes excellent proposals
  – Network with your professional colleagues and NASA scientific staff

• Institutional achievement:
  – Improve at competing for NASA money
  – Increase knowledge of NASA’s educational programs and research technology

• Investment in the future:
  – Help select the most transformative science
  – Ensure that all proposals receive a fair and competent review

• Sign up to be a panel reviewer:
  https://science.nasa.gov/researchers/volunteer-review-panels
Keep Informed about NASA

NSPIRES mailing list – information about NASA solicitations
   https://nspires.nasaprs.com/

Cosmic Origins mailing list, Exoplanet Exploration mailing list, Physics of the Cosmos mailing list – information about NASA missions and science
   https://exoplanets.nasa.gov/exep/exopag/announcementList/
   https://pcos.gsfc.nasa.gov/pcosnews-mailing-list.php

NASA Astrophysics Federal Advisory Committees
   Astrophysics Advisory Committee (APAC)
   https://science.nasa.gov/researchers/nac/science-advisory-committees/apac
   NAS Committee on Astronomy and Astrophysics (CAA)
   http://sites.nationalacademies.org/bpa/bpa_048755
   Astronomy and Astrophysics Advisory Committee (AAAC)
   https://www.nsf.gov/mps/ast/aaac.jsp

Sign up to be a panel reviewer:
   https://science.nasa.gov/researchers/volunteer-review-panels
NASA Astrophysics Program Update
NASA’s Astrophysics Program

Large (Flagship) Missions
- Conduct civilization-scale science that only the U.S. has the capability to lead

Medium (Probe) and Small (Explorer) Missions
- Lead missions with more focused or specialized capabilities and objectives

International Partnerships
- Use scientific synergies between NASA and its international partners for a win-win outcome

Supporting Research and Technology
- Lay the foundation of the NASA science program
- Invest in the US scientific community and National capabilities
- Maximize scientific output of missions
- Develop innovative ideas and next generation technology for future missions
NASA Astrophysics Program Summary

**Supporting Research & Technology**
- R&A: ADAP, ATP, XRP, SmallSat Studies, Suborbital & CubeSat Projects
- Technology: APRA, SAT, RTF, Future flagship technologies
- Research support: Balloon project, Astrophysics archives

**Operating Missions**
- Explorers: Gehrels Swift, NuSTAR, NICER, TESS
- International Partnerships: XMM-Newton
- Strategic Missions: Hubble, Chandra, Spitzer, Fermi, Kepler, SOFIA

**Missions in Development or Under Study**
- Explorers: IXPE, GUSTO, SPHEREx
- International Partnerships: Euclid, XRISM, Athena, LISA
- Strategic Missions: Webb, WFIRST
FY19 Budget Appropriation

The FY19 appropriation (Feb 2019) provides an increased level of funding for NASA Astrophysics

- Total appropriated funding for FY19 (Astrophysics including Webb) is ~$1.496B, an increase of $112M (8%) from FY18 appropriation

- Webb funded as requested at $305M, request submitted before 2018 replan
  - Webb is reauthorized at 2018 replan level of $8.8B for development

- WFIRST funded at $312M, proposed termination not supported by Congressional appropriation

- Hubble and SOFIA received appropriations above requested levels
  - NASA is prohibited from including SOFIA in the 2019 Senior Review

- All other programs supported as proposed
FY20 Budget Request

The FY20 President’s Budget Request requests a decreased level of funding for NASA Astrophysics.

Total funding requested for FY20 (Astrophysics including Webb) is ~1.197B, a decrease of $187M (14%) from the FY18 appropriation and a decrease of $299M (20%) from the FY19 appropriation.

https://nasa.gov/budget
FY20 Budget Request

- Accommodates Webb replan to March 2021 LRD
- Given its significant cost within proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST terminated with remaining WFIRST funding redirected towards completing Webb
- Supports formulation of a probe mission as early as 2022, conditional on Decadal Survey recommendations
- Maintains decadal cadence of four AOs per decade for Astrophysics Explorers and Missions of Opportunity
- Funds SOFIA for three years beyond end of prime mission in FY19 at reduced budget; two alternate reviews are underway in 2019 in lieu of inclusion in 2019 Senior Review
- Extends operating missions (other than Hubble and Chandra) at reduced budget beyond FY20 following 2019 Senior Review
- Supports mission concept studies and technology investments starting in 2022 to respond to Astrophysics Decadal Survey priorities
Congressional Markup of FY20 Budget Request

House has marked up NASA’s FY20 budget request

• WFIRST is funded at $510.7M, with $65M for the coronagraph technology demonstration instrument; this is $510.7M above the request

• SOFIA is funded at $85.2M; this is $12.2M above the request

• Webb is funded at $352.6M; this is the request and supports the replan to a 2021 launch

• Astrophysics including Webb is funded at $1,720.3M; this is $522.9M above the request and supports the planned Astrophysics programs

Senate will mark up NASA’s budget later (probably July)
# Congressional Markup of FY20 Budget

<table>
<thead>
<tr>
<th>($M)</th>
<th>Request</th>
<th>House</th>
<th>Senate</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Webb</td>
<td>352.6</td>
<td>352.6</td>
<td></td>
<td>Supports replan</td>
</tr>
<tr>
<td>WFIRST</td>
<td>0</td>
<td>510.7</td>
<td></td>
<td>Includes $65M for CGI</td>
</tr>
<tr>
<td>SOFIA</td>
<td>73.0</td>
<td>85.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest of Astrophysics</td>
<td>772.8</td>
<td>771.8</td>
<td></td>
<td>$1M (0.1%) reduction</td>
</tr>
<tr>
<td>Total</td>
<td>1,197.4</td>
<td>1,720.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
An Agency Budget Increase for the Artemis Program

- The FY2020 budget amendment provides an increase of $1.6 billion above the president’s initial $21 billion budget request with no money taken from existing NASA programs. This is the boost NASA needs.

  - $1 billion to accelerate development of human lunar transportation systems to take astronauts to the surface and back to Gateway*
  - $651 million towards the completion of SLS and Orion to support a 2024 landing.
  - $132 million for new technologies to help astronauts live and work on the lunar surface and in deep space.
  - $90 million for Science to increase robotic exploration at the lunar South Pole in advance of astronauts.

* Focusing Gateway on just the capabilities needed for Phase 1 allowed for a $321M scope reduction and shifts potential development and expanded capabilities for Gateway into Phase 2.
Artemis Phase 1: To the Lunar Surface by 2024

Artemis 1: First human spacecraft to the Moon in the 21st century

Artemis 2: First humans to the Moon in the 21st century

First high power Solar Electric Propulsion (SEP) system

First pressurized module delivered to Gateway

Artemis 3: Crewed mission to Gateway and lunar surface

Commercial Lunar Payload Services
- CLPS delivered science and technology payloads

Early South Pole Mission(s)
- First robotic landing on eventual human lunar return and ISRU site
- First ground truth of polar crater volatiles

Large-Scale Cargo Lander
- Increased capabilities for science and technology payloads

Humans on the Moon - 21st Century
First crew leverages infrastructure left behind by previous missions

LUNAR SOUTH POLE TARGET SITE
Lunar Science by 2024

**Polar Landers and Rovers**
- First direct measurement of polar volatiles, improving understanding of lateral and vertical distribution, physical state, and chemical composition
- Provide geology of the South-Pole Aitken basin, largest impact in the solar system

**Non-Polar Landers and Rovers**
- Explore scientifically valuable terrains not investigated by Apollo, including landing at a lunar swirl and making first surface magnetic measurement
- Using PI-led instruments to generate Discovery-class science, like establishing a geophysical network and visiting a lunar volcanic region to understand volcanic evolution

**Orbital Data**
- Deploy multiple CubeSats with Artemis 1
- Potential to acquire new scientifically valuable datasets through CubeSats delivered by CLPS providers or comm/relay spacecraft
- Global mineral mapping, including resource identification, global elemental maps, and improved volatile mapping

**In-Situ Resource Initial Research**
- Answering questions on composition and ability to use lunar ice for sustainment and fuel
Science After 2024
Human and Robotic Missions Provide Unique Science Opportunities

On Gateway
- Deep space testing of Mars-forward systems
- Hosts groundbreaking science for space weather forecasting, full-disc Earth observation, astrophysics, heliophysics, lunar and planetary science
- Mars transit testbed for reducing risk to humans

Surface Exploration
- Understanding how to use in-situ resources for fuel and life
- Revolutionizing the understanding of the origin and evolution of the Moon and inner solar system by conducting geophysical measurements and returning carefully selected samples to Earth
- Studying lunar impact craters to understand physics of the most prevalent geologic process in the solar system, impact cratering
- Setting up complex surface instrumentation for astrophysics, heliophysics and Earth observation
- Informing and supporting sustained human presence through partial gravity research in physical and life sciences, from combustion to plant growth

Surface Telerobotics to Provide Constant Science
- Sending rovers into areas too difficult for humans to explore; rovers can be teleoperated from Earth to maximize the scientific return
Supporting Research and Technology

Data analysis

Suborbital investigations

(6.9 µm feature)

Wavelength (µm)

5.5  6  6.5  7  7.5

aromatic

Minimally hydrogenated

Fully hydrogenated

Wavenumber (cm⁻¹)

0  600  1200  1800  2400  3000

Theoretical and laboratory studies

Technology development
### Growth in R&A Funding ($M)

<table>
<thead>
<tr>
<th>Program</th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
<th>FY20</th>
<th>FY21</th>
<th>FY22</th>
<th>FY23</th>
<th>FY24</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;A</td>
<td>$74</td>
<td>$73</td>
<td>$74</td>
<td>$85</td>
<td>$83</td>
<td>$80</td>
<td>$88</td>
<td>$87</td>
<td>$91</td>
<td>$92</td>
<td>$103</td>
<td>$107</td>
<td>$112</td>
<td>$115</td>
<td>$118</td>
<td>$118</td>
</tr>
<tr>
<td>CubeSat</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
<td>$5</td>
</tr>
<tr>
<td>Total</td>
<td>$74</td>
<td>$73</td>
<td>$74</td>
<td>$85</td>
<td>$83</td>
<td>$80</td>
<td>$88</td>
<td>$87</td>
<td>$91</td>
<td>$92</td>
<td>$108</td>
<td>$112</td>
<td>$117</td>
<td>$120</td>
<td>$123</td>
<td>$123</td>
</tr>
</tbody>
</table>

- **26% increase in R&A support since Decadal Survey (FY10 – FY18)**
- **Projected 33% increase in R&A support over 6 years (FY19 – FY24)**
- **FY20-FY24 Notional Planning**
- **FY19 Appropriation**
- **CubeSat Initiative**
- **+17%**
## Proposal Status Update

**Status:** May 30, 2019

<table>
<thead>
<tr>
<th>Solicitation5</th>
<th>Proposal Due Date</th>
<th>Notify Date</th>
<th>Days since received</th>
<th>Number received</th>
<th>Number selected</th>
<th>% selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>TESS – Cycle 1</td>
<td>Oct 6, 2017</td>
<td>Feb 3, 2018</td>
<td>132</td>
<td>143</td>
<td>38</td>
<td>27%</td>
</tr>
<tr>
<td>K2 – Cycle 6 (Phase 2)</td>
<td>Apr 19, 2018</td>
<td>June 25, 2018</td>
<td>67</td>
<td>41</td>
<td>23</td>
<td>56%</td>
</tr>
<tr>
<td>NESSF-18</td>
<td>Feb 1, 2018</td>
<td>May 15, 2018</td>
<td>103</td>
<td>176</td>
<td>8</td>
<td>4%</td>
</tr>
<tr>
<td>Chandra GO – Cycle 20</td>
<td>Mar 16, 2018</td>
<td>July 16, 2018</td>
<td>122</td>
<td>526</td>
<td>156</td>
<td>24%</td>
</tr>
<tr>
<td>XARM Participating Scientist</td>
<td>Dec 13, 2017</td>
<td>Feb 21, 2018</td>
<td>64</td>
<td>39</td>
<td>5</td>
<td>13%</td>
</tr>
<tr>
<td>NuSTAR – Cycle 4</td>
<td>Jan 19, 2018</td>
<td>April 17, 2018</td>
<td>88</td>
<td>196</td>
<td>83</td>
<td>42%</td>
</tr>
<tr>
<td>TCAN</td>
<td>Jan 26, 2018</td>
<td>June 21, 2018</td>
<td>146</td>
<td>32</td>
<td>3</td>
<td>9%</td>
</tr>
<tr>
<td>Segmented Telescope Design</td>
<td>Feb 1, 2018</td>
<td>Mar 16, 2018</td>
<td>44</td>
<td>5</td>
<td>2</td>
<td>40%</td>
</tr>
<tr>
<td>Fermi GI – Cycle 11</td>
<td>Feb 23, 2018</td>
<td>May 26, 2018</td>
<td>92</td>
<td>138</td>
<td>42</td>
<td>30%</td>
</tr>
<tr>
<td>Spitzer GI – Cycle 14</td>
<td>Mar 23, 2018</td>
<td>May 29, 2018</td>
<td>67</td>
<td>116</td>
<td>50</td>
<td>43%</td>
</tr>
<tr>
<td>APRA (Basic Research)</td>
<td>Mar 19, 2018</td>
<td>Aug 14, 2018</td>
<td>148</td>
<td>170</td>
<td>49</td>
<td>29%</td>
</tr>
<tr>
<td>SAT (Technology)</td>
<td>Mar 19, 2018</td>
<td>Aug 14, 2018</td>
<td>148</td>
<td>25</td>
<td>11</td>
<td>44%</td>
</tr>
<tr>
<td>SmallSat Studies (AS³)</td>
<td>July 13, 2018</td>
<td>Sep 10, 2018</td>
<td>59</td>
<td>38</td>
<td>9</td>
<td>24%</td>
</tr>
<tr>
<td>ADAP (Data Analysis)</td>
<td>May 17, 2018</td>
<td>Sep 17, 2018</td>
<td>123</td>
<td>242</td>
<td>53</td>
<td>22%</td>
</tr>
<tr>
<td>XRP (Exoplanet Research)</td>
<td>May 30, 2018</td>
<td>Oct 19, 2018</td>
<td>142</td>
<td>67</td>
<td>8</td>
<td>12%</td>
</tr>
<tr>
<td>LISA Preparatory Science</td>
<td>June 14, 2018</td>
<td>Nov 16, 2018</td>
<td>155</td>
<td>30</td>
<td>8</td>
<td>40%</td>
</tr>
<tr>
<td>SOFIA Next Gen Instruments</td>
<td>Aug 1, 2018</td>
<td>Oct 23, 2018</td>
<td>84</td>
<td>6</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Swift GI – Cycle 15</td>
<td>Sep 27, 2018</td>
<td>Feb 12, 2019</td>
<td>153*</td>
<td>141</td>
<td>33</td>
<td>23%</td>
</tr>
<tr>
<td>NICER Cycle 1</td>
<td>Dec 20, 2018</td>
<td>Mar 4, 2019</td>
<td>75</td>
<td>84</td>
<td>49</td>
<td>58%</td>
</tr>
</tbody>
</table>

TESS, Fermi, NuSTAR*  

* affected by partial government shutdown

**GO Selection Rate = 30%**  
**R&A Selection Rate = 23%**

Average: 107 days (44 – 155 days)  
80% PIs notified: 85 days
Submitted Proposals (APRA+ADAP+ATP+TCAN+SAT+XRP)

Total Number of Proposals and Average Success Rate

<table>
<thead>
<tr>
<th>Financial Year</th>
<th>Submitted Proposals</th>
<th>% Selected</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY03</td>
<td>535</td>
<td>28%</td>
</tr>
<tr>
<td>FY04</td>
<td>432</td>
<td>32%</td>
</tr>
<tr>
<td>FY05</td>
<td>381</td>
<td>26%</td>
</tr>
<tr>
<td>FY06</td>
<td>440</td>
<td>31%</td>
</tr>
<tr>
<td>FY07</td>
<td>480</td>
<td>28%</td>
</tr>
<tr>
<td>FY08</td>
<td>441</td>
<td>30%</td>
</tr>
<tr>
<td>FY09</td>
<td>536</td>
<td>55%</td>
</tr>
<tr>
<td>FY10</td>
<td>736</td>
<td>5%</td>
</tr>
<tr>
<td>FY11</td>
<td>736</td>
<td>24%</td>
</tr>
<tr>
<td>FY12</td>
<td>734</td>
<td>19%</td>
</tr>
<tr>
<td>FY13</td>
<td>767</td>
<td>28%</td>
</tr>
<tr>
<td>FY14</td>
<td>793</td>
<td>20%</td>
</tr>
<tr>
<td>FY15</td>
<td>600</td>
<td>24%</td>
</tr>
<tr>
<td>FY16</td>
<td>666</td>
<td>24%</td>
</tr>
<tr>
<td>FY17</td>
<td>712</td>
<td>22%</td>
</tr>
<tr>
<td>FY18</td>
<td>539</td>
<td>20%</td>
</tr>
</tbody>
</table>

No ATP: FY15, FY17, FY18
NESSF name is changing to FINESST (Future Investigators in NASA Earth and Space Science and Technology) in 2019 to more accurately capture the nature of awards.

Historically Astrophysics has funded 24 NESSF / FINESST fellows at any given time.

With 150-200 proposals received annually, the selection rate has been ~6%.

Community input has led to us doubling the Astrophysics NESSF / FINESST program effective in 2019.

Astrophysics will now be funding 45-48 NESSF / FINESST Fellows at any given time.

The selection rate will be ~10%.
Astrophysics Technology Investment FY13-FY19

- More than 200% growth over 6 years in technology development (FY13-FY19); over $600M invested
- Distribution profile among the four sectors is agile even with a robust growth
- The low- and mid-TRL sectors together account for about 70% of technology investment profile
- Investment in future large missions’ technologies is steadily growing
  - Low TRL: APRA (including suborbital-class payloads)
  - Mid TRL: SAT, Athena, LISA, X-ray Mirrors, Detectors, etc.
  - WFIRST: Detectors, Coronagraph
  - Future Large Missions: Ultrastable Telescope, Starshade, Next Gen Coronagraph

$55 M $75 M $168 M
Exoplanet Research Program (XRP)

Within ROSES-19, proposals submitted to the Exoplanet Research Program (XRP, E.3) will be selected jointly by all four divisions of SMD in caucus: Astrophysics, Planetary Sciences, Heliophysics, and Earth Sciences.

- Combines resources across the divisions to make greater strides, more efficiently
- Encourages cross-cutting investigations that approach exoplanet research with fresh, broader perspectives
- Advances our understanding of exoplanetary systems and the Agency’s strategic goals more effectively
NASEM Exoplanet Science Strategy
Extreme Precision Radial Velocity Initiative

Exoplanet Science Strategy Recommendation:

“NASA and NSF should establish a strategic initiative in extremely precise radial velocities (EPRVs) to develop methods and facilities for measuring the masses of temperate terrestrial planets orbiting Sun-like stars”

- Combine efforts in instrumentation, survey execution, and data analysis techniques involving stellar astrophysics and heliophysics
- Undertake the coordinated, sustained effort to tackle the myriad of error terms that currently limit RV precision.
- Assess ultimate goal to control systematics at ~1 cm/s, accounting for stellar variability and tellurics

Response: NASA and NSF have jointly commissioned a community-based “Extreme Precision Radial Velocity (EPRV) Working Group” (EPRV-WG) to develop a blueprint for a strategic EPRV initiative.

- Working Group formed, first in-person workshop June 13-14, 2019
- EPRV-WG to submit a candidate program architecture by Feb 2020 for consideration by Agencies during annual budget formulation process
Multi Messenger Astronomy Coordination and Support

- Multi Messenger Astronomy Science Analysis Group (MMA SAG)
  - Self-organized community group, Co-Chairs J. Conklin, S. Gezari, J. Tomsick
  - Report to APAC in mid-2019 (after coordinating Decadal Survey white papers)

- Gravitational Wave – Electromagnetic Counterpart Task Force (GW-EM TF)
  - NASA ad hoc group with NASA scientists and community consultants
  - Assess the role of NASA in GW-EM astrophysics, in particular in the EM prompt and follow-up observations of LIGO sources
  - Report to NASA in 6-8 months

- Interagency Working Group with NSF
  - Coordinate NASA contributions with NSF’s Big Idea

- Ad Hoc Mission Utilization
  - EM follow-up as TOOs using all NASA space telescopes
  - GRB alerts from Swift and Fermi, enables search for sub-threshold LIGO events

- Development of tools and alerts
  - GCN alerts now, task at GSFC to specify a Next Generation GCN
  - Tools at NASA archives, e.g. NED to automatically search all LIGO event regions
NASA Astrophysics Missions Update
# Astrophysics Missions in Development

<table>
<thead>
<tr>
<th>Mission</th>
<th>Launch Date</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TESS</strong></td>
<td>4/2018</td>
<td>Launched! Transiting Exoplanet Survey Satellite</td>
</tr>
<tr>
<td><strong>Webb</strong></td>
<td>2021</td>
<td>Replanned SIR now in Sep 2019</td>
</tr>
<tr>
<td><strong>IXPE</strong></td>
<td>2021</td>
<td>Passed KDP-C; CDR in June 2019</td>
</tr>
<tr>
<td><strong>GUSTO</strong></td>
<td>2021</td>
<td>Passed KDP-C; CDR in July 2019</td>
</tr>
<tr>
<td><strong>XRISM</strong></td>
<td>2022</td>
<td>Mission passed PDR; Resolve in I&amp;T</td>
</tr>
<tr>
<td><strong>Euclid</strong></td>
<td>2022</td>
<td>Delivered 18 SCEs; Will deliver early</td>
</tr>
<tr>
<td><strong>SPHEREx</strong></td>
<td>2023</td>
<td>Downselected in February 2019</td>
</tr>
<tr>
<td><strong>WFIRST</strong></td>
<td>Mid 2020s</td>
<td>Mission PDR in October 2019</td>
</tr>
</tbody>
</table>

**XRISM**
- JAXA-led Mission
- NASA is supplying the SXS Detectors, ADRs, and SXTs
- Mission passed PDR; Resolve in I&T

**Euclid**
- ESA-led Mission
- NASA is supplying the NISP Sensor Chip System (SCS)
- Delivered 18 SCEs; Will deliver early

**SPHEREx**
- NASA Mission
- Downselected in February 2019
- Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer

**WFIRST**
- NASA Mission
- Wide-Field Infrared Survey Telescope
TESS
Transiting Exoplanet Survey Satellite

Recent Announcements
• TESS spots a system of Super-Earths around the Naked-Eye Star HR 858

• 639 new TESS planet candidates available for follow-up
• 15 confirmed planets
• 130 publications; 77 through peer-review. 56% works relate to exoplanets, 44% pertain to other areas of astrophysics

Hugh Osborn @exohugh
Whoa! @NASA_TESS has detected a triumvirate of small planets around a 6th magnitude (i.e. almost naked-eye) star. That makes this sun-like star one of the brightest in the sky to have ever been found hosting transiting planets! And it’s has three of them! arxiv.org/abs/1905.05193

Observation Sector 11 in progress, 11 of 26 observing sectors complete, 9 sectors publically available ahead of schedule

Updated 2019 May 20
Spectro-Photometer for the History of the Universe Epoch of Reionization and Ices Explorer (SPHEREx)

- Awarded: February 2019
- Launch: 2023
- Prime Mission: 2 Years
- PI: James Bock (Caltech)

Science Highlights include:
- Survey the entire sky every 6 months
- Optical and infrared survey mission (96 bands/pixel)
- Observe hundreds of millions of galaxies
  - Measure redshifts to probe the statistical distribution of inflationary ripples
  - Measure spatial fluctuations in the Extragalactic Background Light to support studies of the origin and history of galaxy formation.
- Survey Galactic Molecular Clouds for water and organic molecules (H$_2$O, CO, CO$_2$, CH$_3$OH)
Webb
The James Webb Space Telescope

An international mission to seek first light of stars and galaxies in the early universe and explore distant planets

- Seeking Light from the First Stars and Galaxies
- Exploring Distant Worlds—Exoplanets & the Outer Solar System

Led by NASA, in partnership with ESA and CSA

Science program defined through peer-review, including future key projects
Observations spanning a wide variety of Astrophysics are already in the works through the Guaranteed Time Observers programs and the Early Release Science program
Webb
The James Webb Space Telescope

- Science payload completed three months cryogenic testing at end of 2017
- Spacecraft and sunshield integration complete January 2018
- Spacecraft element including sunshield completed environmental testing May 2019
- Science payload and spacecraft integration planned for Fall 2019, followed by test deployment of sunshield
- Testing of full observatory begins in 2019 and continues in 2020
- Webb overrun covered using offsets from Astrophysics Probes

The Webb payload (telescope + instruments, left) and spacecraft element (spacecraft + sunshield, right) in the clean room in Redondo Beach, CA before spacecraft element environmental testing and observatory integration.
Webb’s spacecraft being prepared for thermal vacuum testing and being lifted into Northrop Grumman’s thermal vacuum chamber for environmental testing to ensure that its hardware will function in the vacuum of space. **Credits: Northrop Grumman**
Remaining Webb I&T Activities*

Science Payload

• OTIS Deployment at NGAS
  (secondary mirror)

Spacecraft Element

Observatory Integration

• Post SCE-Environmental Sunshield deployment
• Observatory fold and stow
  • Observatory system (electrical) test
  • Observatory vibration, acoustics tests
  • Observatory deployment
• Observatory fold and stow for launch
• Observatory final system test

NOTE: *Top-level tasks to go. Many activities are associated with each of these steps

First-time activity
Wide-Field Infrared Survey Telescope

Science Program includes

- Dark energy and the fate of the universe through surveys measuring the expansion history of the universe and the growth of structure
- The full distribution of planets around stars through a microlensing survey
- Wide-field infrared surveys of the universe through General Observer and Archival Research programs
- Technology development for the characterization of exoplanets through a Coronagraph Technology Demonstration Instrument

Work continues with FY19 funding

2016 – Completed Mission Concept review and began Phase A

2018 – Completed Mission Design review / System requirements Review and began Phase B

2019 – Completing Preliminary Design Reviews

2020 – Complete Confirmation Review and begin Phase C

Mid-2020s – Launch

WFIRST is 100 to 1500 times faster than Hubble for large surveys at equivalent area and depth
Wide-Field Infrared Survey Telescope

• NASA continuing work on WFIRST as planned
  • Work continues under recently approved FY19 appropriation; appropriation enacted in February 2019 includes $312M for WFIRST
  • WFIRST remains on the plan approved at the beginning of Phase B: Lifecycle cost range $3.2B -$3.9B, launch range is in late 2025 - 2026
  • Formal cost and schedule commitments, including Headquarters held reserves to increase confidence level to 70%, will be made at Confirmation in early 2020

• Major milestones in 2018:
  • WFIRST passed System Requirements Review / Mission Design Review
  • Approved in May 2018 to enter Phase B (preliminary design phase)
  • Completed System Requirements Reviews for all primary mission elements (Wide Field Instrument, Coronagraph, Optical Telescope)
  • All major contracts awarded: Telescope (Harris), Wide Field Instrument (Ball), Detectors (Teledyne)

• Work Plan for 2019
  • Significant flight hardware in production
  • Significant engineering work in progress
  • Proceeding during FY19 toward Mission Preliminary Design Review and Confirmation
  • Four element Preliminary Design Reviews by September 2019
WFIRST Progress

- WFIRST included in final FY19 appropriation
- Core survey science teams anticipated to be selected in 2021 by open competition
- All mission elements making excellent technical progress; expecting to go through Preliminary Design Reviews Jun-Oct 2019
- Mission being prepared for review to enter Implementation phase in early 2020
Euclid

Near Infrared Spectrometer and Photometer - fully populated focal plane includes NASA provided 16 (2K x 2K each) Sensor Chip Systems

Science Program Includes
- Dark Energy and Dark Matter
- Initial conditions of the Universe
- Conduct deep NIR survey to explore high redshift
- Relationship between dark matter and baryons

ESA led mission with NASA partnership
- Completed mission CDR in November 2018
- NASA completed all flight hardware Sensor Chip Systems deliveries in June 2019 for the NISP instrument focal plane
- Mission In Assembly, Integration and Test phase
- Mission Launch ~ June 2022

Science Participation
- US Euclid Science teams integrated into Euclid Consortium science planning activities
- General US science participation to be through archival data research after Euclid data products release
XRISM: X-ray Imaging and Spectroscopy Mission

- Passed the Integrated Systems Preliminary Design Review which was held in Japan in March 2019.
- Resolve instrument currently integrated in test Dewar at GSFC, undergoing environmental testing.
- US-built hardware to be delivered to JAXA in stages beginning October 2019.
- XRISM science team meeting held in Tokyo in May 2019. Beginning process of target selection for Performance Verification phase of mission.
- Call for US Performance Verification phase Participating Scientists anticipated in ROSES 2020.
- XRISM launch, by JAXA, currently planned for early 2022.
Astrophysics Explorers Program

**Small and Mid-Size Missions**

**Missions of Opportunity**

**AO includes:**
- Contributions to Partner Mission
- Small Complete Mission on ISS
- SmallSat Secondary Payloads
- Opportunities enabled by Project Artemis

**Announcement of Opportunity**
- **ExPLORer 2011**
- **SMEX 2014**
- **SMEX 2019**
- **SMEX 2021**

**Explorers**
- Swift
- NuSTAR
- NICER
- TESS
- IXPE
- GUSTO
- XRISM
Astrophysics Science SmallSat Studies

- NASA selected 9 Astrophysics Science SmallSat Studies in ROSES 2018. These studies will report out at a special session of the June 2019 AAS meeting in St. Louis
  - Tuesday Session 212: 10:40 am–12:10 pm, Grand Ballroom A

- The 2019 Astrophysics Explorers Mission of Opportunity AO includes SmallSats and CubeSats launched using rideshare on ESPA or ESPA Grande
  - NASA received many Notices of Intent (NOIs) for Astrophysics SmallSat Explorers

- A second Astrophysics Science SmallSat Studies solicitation is planned as an amendment to ROSES 2019 later this year

- NASA has selected 5 Astrophysics CubeSats through ROSES/APRA:

- NASA is convening the 2019 NASA SmallSat Mission Technical Interchange Meeting on Jun 24-16 at NASA Ames research Center
  - Applications for consideration as an attendee are due Jun 14, 2019
    https://science.nasa.gov/technology/smallsat-tim
Imaging X-ray Polarimetry Explorer (IXPE)

Progress

• Rework, which resulted from Nov 2018 vibration test failure, is ongoing for the engineering X-ray Modular Mirror Assembly (MMA)
  o Expect new vibration test results by July 2019

• Development of Italian X-ray detector units (DU) is ongoing, with the delivery of engineering DU expected by July 2019
  o First flight DU expected by December 2019

Milestones

• Mission Critical Design Review planned for June 25-28, 2019

• Delivery of flight hardware expected in Fall 2019, with both instrument and spacecraft integration beginning in Spring 2020

• Launch currently planned for April 2021
GUSTO Suborbital Explorer

GUSTO (Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory) led by PI Chris Walker (University of Arizona), is an Astrophysics Explorer (MO) balloon mission and is an advanced version of the STO-2 balloon payload.

GUSTO uses large-scale surveys & spectral diagnostics of the Interstellar Medium (ISM) to answer key questions about the full Life Cycle of the ISM and massive star formation.

~300 dedicated SOFIA flights would be required to equal the GUSTO survey

**Milestones:**

Mission Preliminary Design Review: Nov 15, 2018

Confirmation Review (KDP-C): Mar 12, 2019


Launch from McMurdo Station, Antarctica: Dec 2021
## Operating Missions

<table>
<thead>
<tr>
<th>Mission Name</th>
<th>Launch Date</th>
<th>Type</th>
<th>Status</th>
<th>Reviewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hubble Space Telescope</td>
<td>4/90</td>
<td>NASA Strategic Mission</td>
<td>Senior Review</td>
<td></td>
</tr>
<tr>
<td>Chandra X-ray Observatory</td>
<td>7/99</td>
<td>NASA Strategic Mission</td>
<td>Senior Review</td>
<td></td>
</tr>
<tr>
<td>X-ray Multi Mirror - Newton</td>
<td>12/99</td>
<td>ESA-led Mission</td>
<td>Senior Review</td>
<td></td>
</tr>
<tr>
<td>Spitzer Space Telescope</td>
<td>8/03</td>
<td>NASA Strategic Mission</td>
<td>Began Final Year</td>
<td></td>
</tr>
<tr>
<td>Neil Gehrels Swift Gamma-ray Burst Explorer</td>
<td>11/04</td>
<td>NASA MIDEX Mission</td>
<td>Senior Review</td>
<td></td>
</tr>
<tr>
<td>Fermi Gamma-ray Space Telescope</td>
<td>6/08</td>
<td>NASA Strategic Mission</td>
<td>Senior Review</td>
<td></td>
</tr>
<tr>
<td>NuSTAR</td>
<td>6/12</td>
<td>NASA SMEX Mission</td>
<td>Senior Review</td>
<td></td>
</tr>
<tr>
<td>Stratospheric Observatory for Infrared Astronomy</td>
<td>5/14</td>
<td>NASA Strategic Mission</td>
<td>Two External Reviews</td>
<td></td>
</tr>
<tr>
<td>ISS-NICER</td>
<td>6/17</td>
<td>NASA Explorers Miss. of Oppty</td>
<td>Senior Review</td>
<td></td>
</tr>
<tr>
<td>Transiting Exoplanet Survey Satellite</td>
<td>4/18</td>
<td>NASA MIDEX Mission</td>
<td>Senior Review</td>
<td></td>
</tr>
</tbody>
</table>
Senior Review 2019

- Chandra X-ray Observatory (Chandra)
- Fermi Gamma-ray Space Telescope (Fermi)
- Hubble Space Telescope (Hubble)
- Neutron star Interior Composition Explorer (NICER)
- Nuclear Spectroscopic Telescope Array (NuSTAR)
- Neil Gehrels Swift Observatory (Swift)
- Transiting Exoplanet Survey Satellite (TESS)
- X-ray Multi-mirror Mission-Newton (XMM-Newton)

Not in Senior Review: Kepler, SOFIA, Spitzer
SOFIA
Stratospheric Observatory for Infrared Astronomy

• SOFIA’s 5-year prime mission will be completed at the end of FY19
• Given that the program has finished 5 years of operations, NASA has conducted two reviews of the SOFIA project to make changes directed at increasing the science productivity of SOFIA in FY20 and beyond
  o Review of SOFIA’s maintenance and operations paradigm
  o Review of SOFIA’s science progress and science prospects
• Based on the reviews, NASA will be making some changes in the SOFIA project to improve SOFIA’s science productivity and responsiveness to community science priorities
  o Complete transition of SOFIA from a development mode to a more productive science operations mode
  o SOFIA will fly more frequently to obtain more science hours
  o SOFIA will primarily fly shorter (~8 hour) flights to immediately get to higher altitudes
• HIRMES, the next SOFIA science instrument, continues development
  o Expected delivery date is Dec 2020
NASA Astrophysics
Preparation for 2020 Decadal Survey
Decadal Survey Planning

• NASA’s highest aspiration for the 2020 Decadal Survey is that it be ambitious
  o The important science questions require new and ambitious capabilities
  o Ambitious missions prioritized by previous Decadal Surveys have always led to paradigm shifting discoveries about the universe
What is a Balanced Program?

Balanced among multiple goals and priorities
- Addresses science (Decadal Survey) goals and priorities
- Addresses National goals and priorities
- Addresses NASA goals and priorities

Balanced through time
- Yields science discoveries today
- Enables science discoveries tomorrow
- Is sustainable: maintains necessary National capabilities

The needs for different mission sizes and/or wavelength diversity are necessary tools for success
- A balanced astrophysics portfolio reduces overall risk with different mission sizes that have different risk/reward postures
- A balanced astrophysics portfolio is capable of addressing multiple science goals and priorities and increases overall productivity with wavelength diversity
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
Why Flagships

Flagships drive science
Flagships drive US capabilities and contribute to US leadership
Flagships drive NASA budget and create stakeholder support

“NASA should continue to plan for large strategic missions as a primary component for all science disciplines as part of a balanced program.” – Powering Science: NASA's Large Strategic Science Missions (NASEM, 2017)
Why Flagships

Large strategic missions have multiple benefits.

• Open new windows of scientific inquiry and answer many of the most compelling scientific questions
• Develop and deepen humanity’s understanding of the universe
• Capture science data that cannot be obtained in any other way
• Provide new technology that can benefit future small, medium, and large missions
• Support the workforce, the industrial base, and technology development
• Maintain U.S. leadership in space
• Maintain U.S. scientific leadership
• Produce discoveries that capture the public’s imagination and encourage science and technical careers
• Receive a high degree of external visibility, often representing NASA’s science program as a whole
• Provide greater opportunities for international participation, cooperation, and collaboration

“NASA should continue to plan for large strategic missions as a primary component for all science disciplines as part of a balanced program.” – Powering Science: NASA's Large Strategic Science Missions (NASEM, 2017)
Large Mission Concepts

“NASA should ensure that robust mission studies that allow for trade-offs (including science, risk, cost, performance, and schedule) on potential large strategic missions are conducted prior to the start of a decadal survey. These trade-offs should inform, but not limit, what the decadal surveys can address.” – Powering Science: NASA's Large Strategic Science Missions (NASEM, 2017)

HabEx
Monday
2:30 pm–4:30 pm
Midway 1&2

LUVOIR
Monday
10:40 am–12:10 pm
Jeffersonian/ Knickerbocker Room

Lynx
Monday
3:00 pm–4:30 pm
Wabash Cannonball Room

Origins
Tuesday
3:30 pm–4:30 pm
Jeffersonian/ Knickerbocker Room

NASA Large Mission Concept Decadal Studies showcased at NASA Booth
Monday, June 10 – Thursday, June 13; Exhibit Hall
Preparing for the 2020 Decadal Survey Technology Development

**HabEx**
- Starshade Petal Deployment
  - Position Accuracy, Starshade Petal Shape and Stability, Large Mirror Fabrication, Large Mirror Coating Uniformity, Coronagraph Architecture, Low-order wavefront Sense/Control, Deformable Mirrors, Starshade Edge Scattering, Starshade Starlight Suppression and Modeling, Starshade Lateral Formation Sensing, Microthrusters, Laser Metrology, electron multiplication CCDs, near-IR avalanche photodiodes

**LUVOIR**

**Lynx X-ray Surveyor**
- High-resolution, lightweight X-ray optics, low-stress X-ray reflecting coatings, megapixel X-ray imaging detectors, large-format, high resolution X-ray detectors, X-ray grating arrays

**Origins Space Telescope**
- Far IR Detectors, Cryogenic Readouts for Far IR Detectors, Warm readout electronics for large format Far IR detectors, Mid IR detectors, Sub-Kelvin Coolers, 4.5 K cryocoolers

- Each study identified technology gaps and developed a technology maturation roadmap
- Most technology gaps are being addressed through NASA astrophysics technology development programs
- A well-planned technology roadmap and aggressive technology development reduces the risk for the next mission
Cost Estimation of Flagships

Why is it hard?

• Flagship missions, due to the unprecedented nature of their science and their significant complexity and, are inherently difficult to estimate.

• NASA mission costs are typically estimated given cost model or analogy cost based on historical cost and technical data. Given that Flagship missions are first of a kind, there are no comparable costs to use as an estimate.

• Design trades and options are numerous through the formulation phase. Establishing a robust, stable technical baseline prior to the start of development, and therefore developing a robust, stable cost estimate, is extremely challenging.

What are best practices?

• Conduct a science assessment and concept feasibility study to determine the value of the science and define technology challenges.

• Fund technology development with defined pass/fail gates for each technology and each technology readiness level.

• Provide a funding profile that allows work to be done at the most efficient time. Include adequate reserves and use them to solve problems at the optimal time.

• Establish stable science and measurement requirements early. Avoid mission creep.
NASA Assessment: Large Mission Concept Studies

• NASA has assembled a Large Mission Concept Independent Assessment Team (LCIT) to conduct a technical, risk, and cost assessment of the four large-scale mission concept studies
  o The LCIT includes experienced technical and cost reviewers with expertise in large space missions and in science, instrumentation, and technology.

• The purpose of the LCIT is twofold:
  o Provide feedback to the STDTs that can be used to improve the Final STDT Reports that will be presented to the Decadal Survey
  o Provide NASA Headquarters confidence in the science, technical, cost, and risk conclusions of the Final STDT Reports that will be presented to the Decadal Survey

• The Terms of Reference for the LCIT are posted at https://science.nasa.gov/astrophysics/2020-decadal-survey-planning
Medium Mission Concepts (Probes)

Probes have had a strong impact on some areas of astrophysics

Ten Probe Concepts are under study as input to 2020 Decadal Survey

Options for 2020 Decadal Survey

- Recommend specific probe(s) as medium-size strategic missions
- Recommend several specific concepts for an AO (New Frontiers)
- Recommend an unconstrained AO (Super-Explorer)
NASA Assessment: Probe Concept Studies

• NASA has requested GSFC and JPL’s costing offices to perform independent cost assessments of the Probe mission concepts that used the resources of their respective Centers

• In order to provide an independent, non-advocate assessment of the costing offices’ results, NASA is assembling an independent Probes Concept Assessment Team (PCAT)
  o The PCAT will validate the cost estimates provided by the costing offices, the design labs, and the PI-led studies
  o The PCAT is composed of scientists and subject matter experts who will work with the costing offices and the study teams

• The purpose of conducting a cost and technical validation of the Probe mission concept studies is to provide NASA Headquarters confidence in the science, technical, cost, and risk conclusions of the Probe Mission Concept Reports that will be presented to the Decadal Survey

• The Terms of Reference for the PCAT are posted at https://science.nasa.gov/astrophysics/2020-decadal-survey-planning
International Partnerships

“Complex and high-cost facilities are essential to major progress in astronomy and astrophysics and typically involve collaboration of multiple nations and/or collaboration of federal and non-federal institutions. These partnerships bring great opportunities for pooling resources and expertise to fulfill scientific goals that are beyond the reach of any single country.” – New Worlds, New Horizons in Astronomy and Astrophysics (NASEM, 2010)

“Since its establishment in 1958, international cooperation has been a significant component of NASA's missions, playing a unique role in U.S. global engagement and diplomacy. This role extends from data sharing agreements to joint science and technology payloads, all the way up to major diplomatic initiatives. Over two-thirds of NASA’s science missions have foreign partners who enhance missions in ways NASA could not achieve on its own.” – NASA FY2020 Budget Estimates

• Scientific synergies between NASA and its international partners yields a win-win outcome
• Continued NASA international collaborations and leadership in unique areas maintains US status as preferred partner
• Good partners must be good leaders and good followers
International Partnerships

**Instrument elements**

- **Hubble**
  - NASA Strategic Mission
  - X-ray microcalorimeter
  - X-ray mirrors

- **Chandra**
  - NASA Strategic Mission
  - NIR sensor chip systems

- **Gehrels Swift**
  - NASA MIDEX Mission
  - X-ray microcalorimeter
  - X-ray calibration facility

- **Fermi**
  - NASA Strategic Mission
  - X-ray microcalorimeter
  - X-ray mirrors

- **NuSTAR**
  - NASA SMEX Mission
  - IR spectroscopic focal plane array

- **SOFIA**
  - NASA Strategic Mission
  - Observatory

**US Lead / Partner Lead / US Contribute**

- **XMM-Newton**
  - ESA-led Mission
  - X-ray Multi Mirror - Newton

- **XRISM**
  - JAVA-led Mission
  - NASA is supplying the SXS Detectors, ACRs, and SXTs

- **Euclid**
  - ESA-led Mission
  - NASA is supplying the NISP Sensor Chip System (SCS)

- **Athena**
  - ESA-led Mission
  - NASA is supplying instrument and mission systems

- **LISA**
  - ESA-led Mission
  - NASA is supplying instrument and mission systems
NASA Astrophysics Budget

- **$2B/decade for strategic initiatives**
- **$5B/decade for strategic initiatives**
- **$7B/decade for strategic initiatives**
- **$1.6B Average of recent appropriations**
- **$1.8B Average of recent appropriations plus inflation**
- **$1.45B Average of recent appropriations**
- **$1.1B Runout of FY20 Budget Proposal**
- **$0.9B Current program including Webb operations and 4 Explorers/decade**

**NASA Astrophysics Budget: FY04-FY19 Appropriations**

- **FY20-FY24 Request**

**Rest of A:** R&A, Technology, Operating Missions, Explorers, Infrastructure

**WFIRST**

Real Year $Million

<table>
<thead>
<tr>
<th>Year</th>
<th>FY04</th>
<th>FY06</th>
<th>FY08</th>
<th>FY10</th>
<th>FY12</th>
<th>FY14</th>
<th>FY16</th>
<th>FY18</th>
<th>FY20</th>
<th>FY22</th>
<th>FY24</th>
<th>FY26</th>
<th>FY28</th>
<th>FY30</th>
<th>FY32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budget Proposal</td>
<td>$1.1B</td>
<td>$0.9B</td>
<td>$1.8B</td>
<td>$1.6B</td>
<td>$1.45B</td>
<td>$1.1B</td>
<td>$0.9B</td>
<td>$1.8B</td>
<td>$1.6B</td>
<td>$1.45B</td>
<td>$1.1B</td>
<td>$0.9B</td>
<td>$1.8B</td>
<td>$1.6B</td>
<td>$1.45B</td>
</tr>
</tbody>
</table>

Includes STEM Activation and previous E/PO efforts.
Decadal Survey Planning

• NASA’s highest aspiration for the 2020 Decadal Survey is that it be ambitious
  o The important science questions require new and ambitious capabilities
  o Ambitious missions prioritized by previous Decadal Surveys have always led to paradigm shifting discoveries about the universe

• If you plan to a shrinking budget, you get a shrinking program.
  o Great visions inspire (and justify) great budgets.

Carpe Posterum
FY19 Astrophysics Funded Missions Revised February 21, 2019

+ SMEX/MO (2025), MIDEX/MO (2028), etc.

- Spitzer 8/25/2003
- Kepler 3/7/2009
- XMM-Newton (ESA) 12/10/1999
- Chandra 7/23/1999
- Swift 6/13/2012
- NuSTAR 11/20/2004
- Fermi 6/11/2008
- IXPE 2021
- XMM-Newton (ESA) 10/30/2018 EOM
- TESS 4/18/2018
- FERMI 6/11/2008
- WFIRST Mid 2020s
- Hubble 4/24/1990
- ISS-CREAM 8/14/2017
- SOFIA Full Ops 5/2014
- XRISM (XARM) (JAXA) 2022
- ISS-NICER 6/3/2017
- GUSTO 2021
- SPHEREx 2023
- Athena (early 2030s)
- LISA (early 2030s)

Revised February 21, 2019
BACKUP
### Astrophysics Program Content (FY20 Request)

<table>
<thead>
<tr>
<th></th>
<th>Actual FY 18</th>
<th>Enacted FY 19</th>
<th>Request FY 20</th>
<th>FY 21</th>
<th>FY 22</th>
<th>FY 23</th>
<th>FY 24</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Astrophysics</strong></td>
<td>850.4</td>
<td>1,191.6</td>
<td>844.8</td>
<td>902.4</td>
<td>965.2</td>
<td>913.5</td>
<td>907.7</td>
</tr>
<tr>
<td><strong>Astrophysics Research</strong></td>
<td>203.1</td>
<td>250.7</td>
<td>309.3</td>
<td>302.5</td>
<td>299.1</td>
<td>298.8</td>
<td></td>
</tr>
<tr>
<td>Astrophysics Research and Analysis</td>
<td>74.1</td>
<td>83.4</td>
<td>86.6</td>
<td>90.2</td>
<td>92.2</td>
<td>94.2</td>
<td>94.2</td>
</tr>
<tr>
<td>Balloon Project</td>
<td>36.6</td>
<td>44.8</td>
<td>44.8</td>
<td>44.8</td>
<td>44.8</td>
<td>44.8</td>
<td>44.8</td>
</tr>
<tr>
<td>Science Activation</td>
<td>44.0</td>
<td>45.0</td>
<td>45.6</td>
<td>45.6</td>
<td>45.6</td>
<td>45.6</td>
<td>45.6</td>
</tr>
<tr>
<td>Other Missions and Data Analysis</td>
<td>48.5</td>
<td>73.7</td>
<td>128.7</td>
<td>119.9</td>
<td>114.5</td>
<td>114.2</td>
<td>114.2</td>
</tr>
<tr>
<td>Astrophysics Data Curation and Archival</td>
<td>18.2</td>
<td>21.2</td>
<td>21.2</td>
<td>21.5</td>
<td>22.0</td>
<td>22.0</td>
<td>22.0</td>
</tr>
<tr>
<td>Astrophysics Data Program</td>
<td>17.6</td>
<td>20.4</td>
<td>21.6</td>
<td>22.6</td>
<td>23.6</td>
<td>23.6</td>
<td>23.6</td>
</tr>
<tr>
<td>Astrophysics Senior Review</td>
<td>33.5</td>
<td>30.5</td>
<td>29.5</td>
<td>30.5</td>
<td>29.5</td>
<td>29.5</td>
<td>29.5</td>
</tr>
<tr>
<td>Contract Administration, Audit &amp; QA Svcs</td>
<td>12.7</td>
<td>12.7</td>
<td>12.7</td>
<td>12.7</td>
<td>12.7</td>
<td>12.7</td>
<td>12.7</td>
</tr>
<tr>
<td>Astrophysics Directed R&amp;T</td>
<td>19.4</td>
<td>39.7</td>
<td>42.7</td>
<td>28.9</td>
<td>24.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cosmic Origins</strong></td>
<td>211.2</td>
<td>185.3</td>
<td>173.9</td>
<td>181.7</td>
<td>121.7</td>
<td>121.7</td>
<td></td>
</tr>
<tr>
<td>Hubble Space Telescope (HST)</td>
<td>98.3</td>
<td>98.3</td>
<td>83.3</td>
<td>93.3</td>
<td>98.3</td>
<td>98.3</td>
<td>98.3</td>
</tr>
<tr>
<td>Stratospheric Observatory for Infrared Astronomy</td>
<td>85.2</td>
<td>85.2</td>
<td>73.0</td>
<td>60.0</td>
<td>60.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Missions and Data Analysis</td>
<td>27.7</td>
<td>29.0</td>
<td>20.6</td>
<td>23.4</td>
<td>23.4</td>
<td>23.4</td>
<td>23.4</td>
</tr>
<tr>
<td>Cosmic Origins SR&amp;T</td>
<td>15.5</td>
<td>17.1</td>
<td>18.4</td>
<td>18.4</td>
<td>18.4</td>
<td>18.4</td>
<td></td>
</tr>
<tr>
<td>SIRTF/Spitzer</td>
<td>11.2</td>
<td>8.5</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cosmic Origins Future Missions</td>
<td>1.0</td>
<td>2.2</td>
<td>0.0</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
</tr>
<tr>
<td>Astrophysics Strategic Mission Prog Mgmt</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>
# Astrophysics Program Content (FY20 Request)

<table>
<thead>
<tr>
<th>Physics of the Cosmos</th>
<th>Actual FY 18</th>
<th>Enacted FY 19</th>
<th>Request FY 20</th>
<th>Out-years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>FY 21</td>
</tr>
<tr>
<td>Euclid</td>
<td>118.0</td>
<td>148.4</td>
<td>128.5</td>
<td>123.3</td>
</tr>
<tr>
<td>Physics of the Cosmos Future Missions</td>
<td>0.2</td>
<td>2.0</td>
<td>1.1</td>
<td>3.8</td>
</tr>
<tr>
<td>Chandra X-Ray Observatory</td>
<td>56.9</td>
<td>58.4</td>
<td>58.4</td>
<td>58.4</td>
</tr>
<tr>
<td>Fermi Gamma-ray Space Telescope</td>
<td>13.0</td>
<td>14.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XMM</td>
<td>2.5</td>
<td>3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Astrophysics Program Content (FY20 Request)</td>
<td>26.4</td>
<td>29.1</td>
<td>30.0</td>
<td>28.9</td>
</tr>
<tr>
<td>Physics of the Cosmos SR&amp;T</td>
<td>20.9</td>
<td>50.9</td>
<td>52.1</td>
<td>46.3</td>
</tr>
<tr>
<td>PCOS/COR Technology Office Management</td>
<td>4.6</td>
<td>5.9</td>
<td>5.9</td>
<td>6.0</td>
</tr>
<tr>
<td>Exoplanet Exploration</td>
<td>200.8</td>
<td>46.4</td>
<td>44.3</td>
<td>45.6</td>
</tr>
<tr>
<td>WFIRST</td>
<td>150.0</td>
<td>312.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kepler</td>
<td>10.0</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keck Operations</td>
<td>6.2</td>
<td>6.7</td>
<td>6.9</td>
<td>7.0</td>
</tr>
<tr>
<td>Large Binocular Telescope Interferometer</td>
<td>1.8</td>
<td>6.7</td>
<td>6.9</td>
<td>7.0</td>
</tr>
<tr>
<td>Exoplanet Exploration SR&amp;T</td>
<td>26.4</td>
<td>29.1</td>
<td>30.0</td>
<td>28.9</td>
</tr>
<tr>
<td>Exoplanet Exploration Tech Office Mgmt</td>
<td>5.3</td>
<td>6.5</td>
<td>6.8</td>
<td>7.3</td>
</tr>
<tr>
<td>Exoplanet Exploration Future Missions</td>
<td>1.0</td>
<td>2.8</td>
<td>0.6</td>
<td>2.4</td>
</tr>
</tbody>
</table>
## Astrophysics Program Content (FY20 Request)

<table>
<thead>
<tr>
<th>Program Name</th>
<th>Actual FY18</th>
<th>Enacted FY19</th>
<th>Request FY20</th>
<th>Out-years FY21</th>
<th>Out-years FY22</th>
<th>Out-years FY23</th>
<th>Out-years FY24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astrophysics Explorer</td>
<td>117.4</td>
<td>214.1</td>
<td>246.4</td>
<td>312.0</td>
<td>328.8</td>
<td>321.4</td>
<td></td>
</tr>
<tr>
<td>Imaging X-Ray Polarimetry Explorer</td>
<td>23.5</td>
<td>70.2</td>
<td>45.3</td>
<td>7.4</td>
<td>4.5</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>X-Ray Imaging and Spectroscopy Mission</td>
<td>22.0</td>
<td>29.7</td>
<td>25.7</td>
<td>22.5</td>
<td>17.6</td>
<td>15.8</td>
<td></td>
</tr>
<tr>
<td>GUSTO</td>
<td>4.7</td>
<td>11.1</td>
<td>7.8</td>
<td>6.3</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear Spectroscopic Telescope Array</td>
<td>4.8</td>
<td>7.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neil Gehrels Swift Observatory</td>
<td>3.9</td>
<td>5.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transiting Exoplanet Survey Satellite</td>
<td>33.5</td>
<td>5.0</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutron Star Interior Composition Explor</td>
<td>2.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Astrophysics Explorer Future Missions</td>
<td>11.8</td>
<td>84.8</td>
<td>154.2</td>
<td>267.0</td>
<td>295.1</td>
<td>299.2</td>
<td></td>
</tr>
<tr>
<td>Astrophysics Explorer Program Management</td>
<td>11.1</td>
<td>13.3</td>
<td>8.8</td>
<td>10.7</td>
<td>5.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>James Webb Space Telescope</td>
<td>533.7</td>
<td>304.6</td>
<td>352.6</td>
<td>415.1</td>
<td>175.4</td>
<td>172.0</td>
<td>172.0</td>
</tr>
</tbody>
</table>