NASA Astrophysics Update

Astrophysics Advisory Committee
April 11-12, 2018
Washington, DC

Paul Hertz
Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA
Why Astrophysics?

How did our universe begin and evolve?

How did galaxies, stars, and planets come to be?

Are we alone?

Enduring National Strategic Drivers

Astrophysics is humankind’s scientific endeavor to understand the universe and our place in it.
Outline

• Program and Budget Update
  - Overview
  - FY18 Omnibus Appropriation
  - FY19 Budget Request
  - TESS
  - James Webb Space Telescope
  - WFIRST

• Missions Update
  - XARM, Explorers, SmallSats
  - Athena, LISA, SOFIA, Kepler/K2
  - Senior Review

• Planning for Astro2020

• Backup
Some NASA Science Stories of 2017
Major Accomplishments: January 2017 - April 2018

- Imaging X-ray Polarimetry Explorer (IXPE) downselected January 2017 as next Astrophysics Small Explorer (SMEX) mission
- Two missions launched to International Space Station (ISS)
  - Neutron Star Interior Composition Explorer (NICER) June 2017
  - Cosmic Ray Energetics and Mass (CREAM) August 2017
- Three Medium-class Explorer (MIDEX) and three Mission of Opportunity (MO) proposals selected August 2017 for competitive Phase A concept studies
- Widefield Infrared Survey Telescope (WFIRST) Independent External Technical/Management/Cost Review (WIETR) completed October 2017; WFIRST directed to reduce cost
- Webb payload completed cryotesting December 2017; Webb sunshield integrated with spacecraft January 2018; Webb payload shipped January 2018
- X-ray Astronomy Recovery Mission (XARM) passed KDP-C January 2018 and began implementation
- Transiting Exoplanet Survey Satellite (TESS) completed testing and delivered to KSC, on track for April 2018 launch
- WFIRST passed SRR/MDR February 2018; on track for April 2018 KDP-B
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.
- Promoting diversity on NASA-selected groups (e.g., advisory groups, peer review panels, science teams, etc.).
- 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.
- 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.
Astrophysics Budget Overview

• The FY18 consolidated appropriation provides funding for NASA astrophysics to continue its planned programs, missions, projects, research, and technology.
  - Total funding provided for FY18 (Astrophysics including Webb) rises from $1.352B in FY17 to 1.384B in FY18, an increase of ~$32M (2.4%) from FY17.
  - The NASA Astrophysics FY18 appropriation funds Webb for progress toward launch, WFIRST formulation into Phase B, Explorers mission development and SMEX AO, increased funding for R&A, continued operating missions, suborbital missions and CubeSats, technology development, and mission studies.
  - $10M (2.2%) reduction in rest of Astrophysics to accommodate directed spending increases for WFIRST, Hubble, and SOFIA.

• The FY19 budget request proposes a reduced level of funding for NASA astrophysics.
  - Total requested funding for FY19 (Astrophysics including Webb) is ~$1.185B, a reduction of $200M (14%) from FY18 appropriation.
  - Webb included as project within Astrophysics budget, integration and testing continues toward launch.
  - Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST is terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research.
FY18 Omnibus Appropriation

• The Consolidated Appropriations Act of 2018 and the explanatory statement provide the following appropriations for Astrophysics (including Webb)
<table>
<thead>
<tr>
<th>FY18 PBR</th>
<th>FY18 Appropriation</th>
<th>Direction (paraphrased)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Astrophysics</td>
<td>$ 1,350.5 M</td>
<td>$ 1,384.1 M</td>
</tr>
<tr>
<td>Webb</td>
<td>$ 533.7 M</td>
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</tr>
<tr>
<td>WFIRST</td>
<td>$ 126.6 M</td>
<td>$ 150.0 M</td>
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<tr>
<td>Hubble</td>
<td>$ 83.3 M</td>
<td>$ 98.3 M</td>
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<tr>
<td>SOFIA</td>
<td>$ 79.9 M</td>
<td>$ 85.2 M</td>
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<tr>
<td>Research &amp; Analysis</td>
<td>$ 74.1 M</td>
<td>$ 74.1 M</td>
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<tr>
<td>Exoplanet technology</td>
<td></td>
<td></td>
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<tr>
<td>Astrophysics observatories</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rest of Astrophysics</td>
<td>$ 452.9 M</td>
<td>$ 442.8 M</td>
</tr>
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</table>
Astrophysics FY2019 Budget Features

• What’s Changed
  - Webb included as project within Astrophysics budget
  - Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research
  - Euclid budget increased to recover from failed sensor electronics design
  - XARM begun within Explorers program
  - Spitzer ops extended until Webb is operational, consistent with 2016 Senior Review

• What’s the Same
  - TESS, IXPE, and GUSTO remain on track and within budget
  - All operating missions continue; next Senior Review in 2019
  - CubeSat initiative and four balloon campaigns within healthy research program
TESS
Transiting Exoplanet Survey Satellite
Launch Readiness Date April 16, 2018

George Ricker presentation on TESS

https://tess.gsfc.nasa.gov/
https://tess.mit.edu/
James Webb Space Telescope

- Included as project within Astrophysics starting in FY2019
- Civilization-scale mission to observe first galaxies formed after Big Bang
- Science payload completed three months cryogenic testing at end of 2017
- Spacecraft and sunshield integration completed January 2018
- Independent schedule review completed March 2018
- Independent Review Board report by June 2018
- Science payload and spacecraft integration planned Summer 2018
Webb OTIS after Thermal Vacuum Testing
Transporting Webb OTIS to NGAS California
Webb Sunshield Deployed
Webb Mission Status - March 23, 2018

Webb Observatory Elements at Northrop Grumman (NGAS) Redondo Beach, CA

Spacecraft Element

Sun-Shield

Spacecraft

Optical Telescope Element (with instruments)
Webb Mission Status - March 23, 2018

- Spacecraft Element (SCE) completed, stowed into launch configuration
  - Performance testing complete and ready for environmental testing
  - Sunshield
    - 7 small tears in the sunshield and sunshield covers have been repaired
    - Lessons learned from first deploy/fold & stow were significant
  - Spacecraft
    - Major impact to schedule due to propulsion valve and transducer rework
    - Dual Thruster Modules removed, valves refurbished, DTM’s reinstalled, pressure check was good

- Optical Telescope Element (Telescope & Instruments)
  - Full performance and environmental testing complete and OTE delivered for Integration and Test

- Launch Readiness Date (LRD) of March - June 2019 not possible due to lessons learned during SCE Integration & Test (I&T) and propulsion system rework

- Standing Review Board (SRB) has reviewed project schedule and their analysis yields an LRD of ~May 2020 at 70% confidence

- Independent Review Board, chaired by Tom Young; final report ~May 2018

- NASA’s final agency decision in June 2018
Webb 18 Month LRD Impact from October 2018 LRD

• 15 months of technical issues *(impacts do not add linearly)*
  - Spacecraft critical path dominated by the propulsion system – 13 months
    - 3 Months - Transducer problem
    - Dual Thruster Module rework slip of 9 months (much of this was worked in parallel with Sunshield issues)
    - 1 Month - Recovery from incorrect voltage applied to the catalyst bed heater
  - Sunshield Complications – 7 months
    - 4 months – Deploy/Fold/Stow (2 months to go)
    - 2 months – Tear repairs (1 month to go)
    - 1 month – Snag guard implementation (0.5 months to go)
  - Observatory I&T Replan – 3 months
    - 3 months – OTE lessons learned and applied to SCE & reduction in parallel task activities

• 3 months additional funded schedule reserve
Remaining I&T Activities

Science Payload
• OTIS Deployments at NGAS (secondary mirror & ISIM radiator)

Spacecraft Element
• *Acoustics, vibe, and thermal vacuum tests*
• Post-Environment deployment and stow

Observatory Integration
• Pre-environmental Observatory deployments
• Observatory fold & stow
• *Observatory system (electrical) test*
• Observatory vibration, acoustics tests
• *Observatory deployment*
• Observatory stow for launch
• Observatory final system test

Blue font indicates “first time” activities
Standing Review Board Schedule Review Summary

Summary of SRB Schedule Risk Assessment

- Summary/Historical view of large, complex NASA SMD program and project schedule overruns
- Analysis of historical JWST I&T schedule margin burn rates since 2011
- SRB Delphi analysis
- SRB Assessment of project’s grassroots schedule analysis and threats
- JWST Project SRA model and parametric analysis
- Comparison of similarly complex NGAS “Project X” to JWST I&T work to go

- Based on the above analyses, the SRB assessment results in a probable JWST LRD range of 1/29/20 to 4/30/20 (increasing probability with latter date)
- Caveats:
  - NGAS schedule performance improves as planned
  - No significant hardware anomalies during remaining I&T
Steps Taken to Improve Performance

• NASA HQ (Program)
  ✓ Additional SMD Front office oversight and direct interaction with NGAS senior management (President/COO)
  ✓ Adding Deputy Associate Administrator of Programs to JWST Program Office
  ✓ Tracking daily & weekly NGAS I&T reports
  ✓ Established IRB

• NASA Goddard (Project)
  ✓ Senior project management resident at NGAS on permanent basis
  ✓ Additional NASA I&T personnel at NGAS planned for specific activities
  ✓ Bi-weekly senior NASA/NGAS (HQ, Center Director, President/COO) schedule reviews
  ✓ JWST Project Manager reporting directly to Deputy Center Director who will actively support the Project Manager

• NGAS (Observatory Contractor)
  ✓ Project Manager to President/COO direct communication path established
  ✓ Reporting channels opened to Project & Program (as mentioned above)
    - I&T personnel and organizational structure changes
    - Reviewing technical processes/procedures
Independent Review Board

• Purpose
  - External team that will evaluate all factors, including
    - Those identified by the SRB
    - Integration and test (I&T) plan
    - Assuming a Ship & Launch Processing window (75 days) and the commissioning (6 months) of the telescope
  - The IRB will
    - Document the results of its review in a presentation and final report
    - The IRB may develop observations, findings, concerns, and recommendations as part of its assessment.

• Final Report to SMD AA ~May 31, 2018
• Chair, Tom Young
# Webb Independent Review Board

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tom Young</td>
<td>NASA, L/M (Ret)</td>
<td>Chair</td>
</tr>
<tr>
<td>Bill Ballhaus</td>
<td>Aerospace</td>
<td>Program</td>
</tr>
<tr>
<td>Steve Battel</td>
<td>Battel Eng</td>
<td>Program</td>
</tr>
<tr>
<td>Orlando Figueroa</td>
<td>Orlando Leadership Enterprise, LLC</td>
<td>Program</td>
</tr>
<tr>
<td>Fiona Harrison</td>
<td>Caltech</td>
<td>Science</td>
</tr>
<tr>
<td>Michele King</td>
<td>NASA/LaRC (SID)</td>
<td>Analyst</td>
</tr>
<tr>
<td>Paul Mcconnaughey</td>
<td>NASA/MSFC JWST SRB Chair</td>
<td>Program</td>
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<tr>
<td>Dolly Perkins</td>
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<tr>
<td>Pete Theisinger</td>
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<tr>
<td>Maria Zuber</td>
<td>MIT</td>
<td>Science</td>
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<tr>
<td>Dan Woods</td>
<td>NASA SMD</td>
<td>Executive Secretary</td>
</tr>
<tr>
<td>John Karcz</td>
<td>NASA SMD</td>
<td>Dep. Exec Sec</td>
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</table>

Eric Smith presentation on Webb
WFIRST status

• Conducted WFIRST Independent External Technical/Cost/Management Review (WIETR) in response to National Academies’ Midterm Assessment

• WFIRST directed by SMD AA to reduce cost and complexity sufficient to have a cost estimate consistent with $3.2B cost target set at the beginning of Phase A.
  - Coronagraph is technology demonstration instrument
  - Independent cost assessment are being conducted to validate the estimated cost of rescoped mission as being consistent with the $3.2B cost target.

• WFIRST moved to (new) Strategic Astrophysics Missions Program

• SRR/MDR completed February 2018.
• KDP-B underway in March/April 2018.
WFIRST cost

- Project estimate of cost to Science Mission Directorate has been reduced from ~$3.6B to <$3.2B.

- Changes include the following:
  - Coronagraph Instrument treated as technology demonstration instrument
  - Contribution to coronagraph technology demonstration instrument by NASA Space Technology Mission Directorate
  - Reduced some Wide Field Instrument capabilities
  - Simplified subsystem designs including C&DH box, high gain antenna, telescope door
  - Contributions to mission by international partners
  - Improved budget profile and accelerated schedule; pulls in launch date 6 months
  - Additional mission risk reduction (sparring, testing, parts, etc.)
# Comparison of Webb and WFIRST Development Risk at KDP-B

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<tr>
<th>Webb @ KDP-B</th>
<th>WFIRST @ KDP-B</th>
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<tr>
<td>Novel, complex segmented Be mirror development</td>
<td>Existing 2.4m monolithic ULE mirror</td>
</tr>
<tr>
<td>Numerous technology developments</td>
<td>High TRL: basis of Decadal selection, recent investments</td>
</tr>
<tr>
<td>Complex cryo-cooler</td>
<td>Passive Al radiator</td>
</tr>
<tr>
<td>ISIM structure materials development (30 K)</td>
<td>Reuse of Webb design in instrument carrier (190K)</td>
</tr>
<tr>
<td>IR detector manufacturing problem uncovered after KDP-C</td>
<td>IR detectors presently at TRL-6, flight growth initiated at start of Phase B; Greater maturity and understanding of Webb-derived detector technologies reduces risk of encountering problems late in the WFIRST program</td>
</tr>
<tr>
<td>Four highly configurable instruments (inherent complexity), major international roles, separate guider</td>
<td>Single primary instrument + tech demo, no separate guider</td>
</tr>
<tr>
<td>Many complex deployments</td>
<td>Standard deployments</td>
</tr>
</tbody>
</table>

**WFIRST risks are lower than those retired on Webb, and typical of high TRL missions. Incorporated numerous Webb lessons learned.**
• NASA is considering changes in the way WFIRST key programs and observing time will be determined
  - The three key science pillars (Dark Energy, Exoplanets, Great Observatory Astrophysics) are all important. There is no expectation that specific amounts of observing time are reserved for any specific science pillar, survey, or observing program.
  - Allocation of WFIRST observing time will be done through open-access, nonproprietary, peer-reviewed competition of programs that address the scientific imperatives of the 2020s, including dark energy and exoplanets. The observing program will be selected as close in time to the observations as possible.
  - Investigate alternate ways of organizing community-based key project teams.
  - Consider openly-competited “Early Release Demonstration Programs” performed at the start of WFIRST operations to inform the peer-reviewed time allocation process during the prime mission.

• WFIRST Formulation Science Working Group (FSWG) is reviewing this proposed change
WFIRST budget

• Given its significant cost within a proposed lower budget for Astrophysics and competing priorities within NASA, WFIRST terminated with remaining WFIRST funding redirected towards competed astrophysics missions and research
• Funds appropriated by Congress in FY18 will allow WFIRST to enter Phase B in April 2018
• If Congress adopts the Administration’s request to terminate WFIRST, the funds made available would enable a competed mission AO in FY19
Astrophysics Program Offices

Astrophysics Division

Flight Programs
- Astrophysics Strategic Missions
- WFIRST
- Webb*
- SOFIA**
- TESS
- IXPE
- GUSTO
- Euclid
- XARM

Supporting Research and Technology Programs
- PCOS/COR
- EXEP

* after commissioning
** after Senior Review
Astrophysics Missions in Development

- **TESS**
  - NASA Mission
  - 4/2018
  - Transiting Exoplanet Survey Satellite

- **Webb**
  - NASA Mission
  - 2020
  - James Webb Space Telescope

- **Euclid**
  - ESA-led Mission
  - 2021
  - NASA is supplying the NISP Sensor Chip System (SCS)

- **IXPE**
  - NASA Mission
  - 2021
  - Imaging X-ray Polarimetry Explorer

- **GUSTO**
  - NASA Mission
  - 2021
  - Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory

- **XARM**
  - JAXA-led Mission
  - 2021
  - NASA is supplying the SXS Detectors, ADRs, and SXTs

- **MIDEX/MO**
  - NASA Mission
  - 2022/2023
  - Arcus, FINESSE, or SPHEREx CASE, COSI-X, or ISS-TAO

- **WFIRST**
  - NASA Mission
  - Mid 2020s
  - Wide-Field Infrared Survey Telescope
X-ray Astronomy Recovery Mission (XARM)

- XARM is the successor to ASTRO-H/Hitomi. Mission will include an X-ray microcalorimeter and an X-ray imager.
- NASA will provide same hardware contribution as for Hitomi: X-ray microcalorimeter and X-ray mirrors.
- Critical Design Review completed in November 2017
- Confirmation Review (KDP-C) completed in January 2018; XARM now in Phase C.
- U.S. Community Involvement
  - Five U.S. Participating Scientists selected to be on XARM Science Team.
  - U.S. Scientists on Guaranteed Time Observing (GTO) Target Teams: to be selected approx. 1 year before launch.
  - General Observing (GO) Program: Open to U.S. scientists starting 6-9 months after launch.
XARM Rebuild Guideline

• The Hitomi Soft X-Ray Spectrometer met or exceeded all of its performance requirements verifiable up through the spacecraft mishap, but not everything was fully demonstrated:
  - The dewar aperture door was never opened (was planned for day 40; mishap occurred on day 38), so aperture system was not verified in-flight.
  - Modulated X-Ray Source not taken to full power (was planned for day 39).

• Carry out lessons learned and review margins, and only make changes as warranted to reduce risk, fix changes made late in the Astro-H program to be more robust, etc.
  - Hundreds generated: adopted changes reviewed as part of Legacy Reviews and PDR/CDR process. Similar process for JAXA.

• Recovery as quickly as possible is the guiding principle. Capability is still very timely, so no need to change science requirements.
XARM High-Level Changes

Agency-Agency

• Establish Joint Executive Steering Group between NASA and JAXA.
  - Meets 1-2 times per year or as needed to discuss progress and resolve issues.

NASA Project

• Establish project management team at Goddard: project manager, mission-level systems engineering (incl. safety & mission assurance and operations engineering) to provide NASA experience and approaches, share risks, participate in reviews.
• Joint Systems Engineering Team with JAXA project.
• Monthly telecons, quarterly face-face meetings, participate in project reviews.

JAXA Project

• Separate Project Manager and Mission PI. Mission Sys Eng. and JSET. Share risks at mission level.
• Creation of detailed plan for JAXA to oversee contractors.
• Mission operations responsibility moved from contractor to JAXA.
• External science advisory process.
Astrophysics Explorers Program

Small and Mid-Size Missions

Missions of Opportunity

Directed 2017

SMEX 2019 (planned)

SMEX 2014

SMEX 2016

MIDEX 2011

MIDEX 2016

Announcement of Opportunity
Astrophysics Explorers Program
2019 Small Explorer (SMEX)

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### Astrophysics Explorers in Competitive Phase A

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<th>PI</th>
<th>Mission</th>
</tr>
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<tbody>
<tr>
<td>Arcus</td>
<td>R. Smith/SAO</td>
<td>High resolution x-ray spectroscopy to explore the origin of galaxies</td>
</tr>
<tr>
<td>CASE</td>
<td>M. Swain/JPL</td>
<td>Contribution of detectors to ESA’s ARIEL</td>
</tr>
<tr>
<td>FINESSE</td>
<td>M. Swain/JPL</td>
<td>NIR transit spectroscopy to explore exoplanet atmospheres</td>
</tr>
<tr>
<td>SPHEREx</td>
<td>J. Bock/Caltech</td>
<td>NIR spectral survey addressing cosmology, galaxy evolution, and origin of ices</td>
</tr>
<tr>
<td>COSI-X</td>
<td>S. Boggs/UCB</td>
<td>ULDB balloon mission to study origin of elements in the galaxy</td>
</tr>
<tr>
<td>ISS-TAO</td>
<td>J. Camp/GSFC</td>
<td>All-sky x-ray survey to study transients and search for GW sources</td>
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Astrophysics SmallSats

- SMD is interested in exploring ways that CubeSats/SmallSats can do highly valued science for lower price points.
- Astrophysics RFI for SmallSats asked for ideas to do high priority Astrophysics science projects at a price point between typical R&A and Explorer MOO projects ($10M-$35M).
- The RFI also asked for advanced mission concepts for which “significant” investments in instrument and/or platform technologies would be required, without budget constraints, in order to inform future STMD solicitations.
- 55 replies were responsive to Astrophysics science and/or technology.

Representative Science Areas: Exoplanets, GRM/EM Counterparts, UV/X-ray Surveys, WHIM, 21cm

Representative Technology Areas: Power systems, antennas, miniaturized cryo-coolers, communication; positioning; on-board processing, and advanced propulsion systems for formation flying.
Astrophysics SmallSats

Step 1: Funded mission concept studies
- NASA will conduct funded SmallSat mission concept studies (via ROSES) in advance of the 2019 SMEX AO

Step 2: NASA is considering adding SmallSats to the 2019 Explorer Mission of Opportunity PEA (Program Element Appendix of the SALMON-3 AO)
- Potential new class of MO: SmallSats ($35M cost cap)
- NASA would offer to find launch for standard CubeSat and ESPA*-ring forms

* EELV Secondary Payload Adapter
Astrophysics Missions in Pre-Formulation

Athena
ESA-led Mission
Late 2020s

NASA is supplying elements for both instruments

LISA
ESA-led Mission
Mid 2030s

NASA is developing technology for both the payload and the mission
Selected Mission Updates

- **Athena**
  - NASA budgeting for a $100M-$150M hardware contribution, plus a U.S. GO program and a U.S. data center.
  - NASA will contribute to both the X-IFU and the WFI instruments.
  - NASA and U.S. community participating in Athena Science Study Team (including its Science Working Groups) and Instrument Teams.

- **LISA**
  - NASA has established a LISA Study Office at GSFC.
  - NASA is funding five US-based technologies with the aim of reaching TRL 5/6 by Adoption.
  - NASA and U.S. community participating in LISA Science Study Team and the LISA Consortium.
  - NASA established a NASA LISA Study Team to interface with NASA LISA Study Office, LISA Consortium, and Decadal Survey.
  - NASA issued call for LISA Preparatory Science proposals in ROSES.
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**Astrophysics Missions in Operation**

- **Hubble Space Telescope**
- **Chandra X-ray Observatory**
- **X-ray Multi Mirror - Newton**
- **Spitzer Space Telescope**
- **Swift Gamma-ray Burst Explorer**
- **Fermi Gamma-ray Space Telescope**
- **Kepler Space Telescope**
- **NuSTAR Nuclear Spectroscopic Telescope Array**
- **Stratospheric Observatory for Infrared Astronomy**
- **Neutron Star Interior Composition Explorer**
- **Cosmic Ray Energetics And Mass**
- **Transiting Exoplanet Survey Satellite**

**COMING SOON**
SOFIA
Stratospheric Observatory for Infrared Astronomy

- Instrument suite being enhanced
  - HAWC+ now in regular usage by GOs
  - HIRMES instrument past CDR
  - Next Gen instrument solicitation issued March 2018

- SOFIA maintenance period extended
  - SOFIA remains in Hamburg, Germany, to address a repair that was discovered during a routine inspection and repair cycle, known as a C-Check.
  - After completion of the inspection and maintenance by technicians at Lufthansa Tecknik AG, a fuel leak was discovered where the outer engine on the left side attaches to the wing.
  - Return of SOFIA to science flights has been delayed since January to address several repairs. SOFIA is currently scheduled to depart Germany in early May, and will resume science flights shortly after its return to NASA Armstrong Flight Research Center’s aircraft operations facility in Palmdale, California.
  - Impacts to the observatory’s science schedule are currently being assessed and will be mitigated through contingency flight dates built into SOFIA’s schedule.

- FY18 Consolidated Appropriations Explanatory Statement excludes SOFIA from 2019 Senior Review
  - Defines prime mission to be 20 years (starting in 2014)
Kepler/K2: Campaign 16 early highlights

• Forward facing campaign to facilitate contemporaneous ground observations.
  - Raw data available March 1. Pipeline data products expected early summer.

• Monitored 9,241 galaxies for supernova.
  - ~20 SN identified
  - ~15 ground telescopes made contemporaneous observations
  - Many types including Ia, Ic, II, IIb, IIP
  - Initial analysis of brightest Ia show signatures of white dwarf / red giant progenitor system

• Observed ~ 20,000 stars
  - ~12 ground telescopes made contemporaneous observations
  - Paper released March 12 (Yu et al) identified 32 planet candidates

K2 lightcurve (yellow) reveals excess flux in the first 2 days, consistent with interaction with red giant companion.
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)
- Stratospheric Observatory for Infrared Astronomy (SOFIA) [pending clarification of Congressional language]
- Neil Gehrels Swift Observatory (Swift)
- Transiting Exoplanet Survey Satellite (TESS)
- X-ray Multi-mirror Mission-Newton (XMM-Newton)
Senior Review 2019

NASA Astrophysics Advisory Committee

Senior Review Subcommittee

- Rest-of-Missions Panel
- Chandra Panel
- Hubble Panel
- SOFIA Panel [TBC]
**Integrated Technology Management**

- **Goal:** One integrated, biennial technology report for Astrophysics' three themes
- **Motivation:**
  - Technology development timescales tend to be of multiyear cadences.
  - Focus should be more on technology development – not just identification of gaps.
  - Integration should lead to consolidation, reduction, and streamlining of the technology efforts across Astrophysics
- **Chief technologists of PCOS/COR and ExEP Program Offices will coordinate and work together to implement this integration.**
  - Independent program annual technology reports (PATRs) will be discontinued and replaced with the integrated Astrophysics Bi-Annual Technology Report (ABATR). PCOS/COR Program Office will lead the publication effort in compiling this biennial technology report.
  - Technology gaps input will continue to be solicited from the community as well as from the associated PAGs (*unchanged from current practice*).
  - Technology gaps prioritization will continue to be maintained separately by the three themes (*unchanged from current practice*). No technology gaps should be duplicated among the POs; the three POs will work together to decide which will carry which technology gaps (*change from current practice*).
  - Technology awards reporting and Technology Management Boards (TMB), including subject matter experts, and other Milestone and TRL Confirmation Reviews, will continue to be held by all three themes (*unchanged from current practice*).
NASA Astrophysics
Planning for Astro2020
Summary

• NASA has initiated studies for large and medium (a.k.a. Probe) size mission concepts to inform the 2020 Decadal Survey Committee in an organized and coherent way
  - Main purpose is to provide the Decadal Survey Committee with several well-defined mission concepts to facilitate their deliberations

• Specifically, NASA is:
  - Sponsoring 4 community-based Science and Technology Definition Teams (STDTs) to partner with a NASA Center-based engineering team and study large (strategic) mission concept studies selected from the NASA Astrophysics 30-year Visionary Roadmap, a community-based report, and the 2010 Decadal Survey
  - Supporting 10 PI-led Study Teams for Probe-size mission concept studies, selected competitively
  - Supporting several other planning activities / studies / white papers

• All material related to NASA’s 2020 Decadal Survey planning activities are posted at https://science.nasa.gov/astrophysics/2020-decadal-survey-planning
## Preparing for the 2020 Decadal Survey
### Large Mission Concepts

<table>
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<th>Mission</th>
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<th>Study Lead Center</th>
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<td>Habitable Exoplanet Imaging Mission</td>
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<td>Martin Still</td>
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<td>Aki Roberge</td>
<td>GSFC</td>
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<td>Jessica Gaskin</td>
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<td>Dan Evans*</td>
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* Dan Evans is on detail to OMB through July 2018

Community STDT CO-Chair(s) presentations
The Decadal Studies Management Plan, page 18, lists the deliverables of the STDTs. In particular:

- A detailed study Plan was delivered to NASA in August 2016
- An Interim Report was delivered to NASA by April 5, 2018
  - The reports are being reviewed by a Large Mission Report Team (LRT) assembled by NASA HQ and including members of the Program Office and community experts in science, technology, engineering, and mission development. The LRT also includes an Aerospace former member. Several of these members have experience with previous Decadal submissions
  - The LRT is chartered by HQ to provide an assessment of the Interim Reports for progress towards a comprehensive Decadal submission
- An Updated Technology Requirements list is due in June 2018
- The Final Report is due to HQ no later than June 2019
  - NASA will submit the reports and the Independent Cost Assessments (ICAs) to the Decadal Survey Committee
Preparing for the 2020 Decadal Survey Technology Development

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<td>• 12 of 12 gaps being addressed</td>
<td>• 7 of 9 gaps being addressed</td>
<td>• 4 of 5 gaps being addressed</td>
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<td>• Mirror coatings, starshade starlight suppression, starshade controlling scattered sunlight, starshade lateral formation sensing, starshade petal position accuracy, starshade petal shape and stability, telescope vibration control, deformable mirrors, visible detectors, large aperture primary mirror, wavefront sensing and control, coronagraph optics and architecture</td>
<td>• Closed-loop segment phasing, vibration isolation, wavefront sensing and control, mirror segments, high-contrast segmented-aperture coronagraphy, deformable mirrors, near infrared detectors, visible detectors, mirror coatings</td>
<td>• Lightweight X-ray optics, non-deforming X-ray reflecting coatings, megapixel X-ray imaging detectors, large-format, high resolution X-ray detectors, X-ray grating arrays</td>
<td>• far-infrared (FIR) detectors, cryogenic readouts for large-format FIR detectors, warm readout electronics for large-format FIR detectors, sub-Kelvin Coolers, cryogenic FIR mirror segments</td>
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- **Purple**: Technologies being advanced through SAT or directed development,
- **Bold**: Technologies being advanced by WFIRST or ATHENA
- **Italics**: Technologies being worked on through the STDT’s design studies
- **Additional gaps being addressed through APRA but not tallied here**
Independent Cost Assessment

• NASA will engage an independent expert/company who specializes in assessing the cost of large space missions

• This task for NASA will be independent of the National Academies CATE process
  - NASA will not conduct a CATE
  - If the same independent expert/company provides CATEs for the NAS, strict firewalls be put in place to ensure independence

• NASA plans to conduct this activity after the final delivery of the report
## Selected Probe Mission Concept Studies

<table>
<thead>
<tr>
<th>PI</th>
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<th>Short title</th>
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<td>Jordan Camp</td>
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<td>Asantha Cooray</td>
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<td>Cosmic Dawn Intensity Mapper</td>
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<td>Bill Danchi</td>
<td>NASA GSFC</td>
<td>Cosmic Evolution through UV Spectroscopy Probe</td>
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<td>Jason Glenn</td>
<td>Univ. of Colorado</td>
<td>Galaxy Evolution Probe</td>
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<td>Shaul Hanany</td>
<td>Univ. of Minnesota</td>
<td>Inflation Probe</td>
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<td>Richard Mushotzky</td>
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<td>High Spatial Resolution X-ray Probe</td>
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<td>Angela Olinto</td>
<td>Univ. of Chicago</td>
<td>Multi-Messenger Astrophysics Probe</td>
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<td>Peter Plavchan *</td>
<td>Missouri State Univ.</td>
<td>Precise Radial Velocity Observatory</td>
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<td>Paul Ray</td>
<td>Naval Research Lab</td>
<td>X-ray Timing and Spectroscopy Probe</td>
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<tr>
<td>Sara Seager *</td>
<td>MIT</td>
<td>Starshade Rendezvous Mission</td>
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</table>

* Partial Selections

Other NASA Planning for Decadal Survey Input

NASA HQ is sponsoring, planning, or contemplating several additional studies as input to the 2020 Decadal Survey

- These are independent of studies being initiated and conducted by NASA scientists at NASA Centers without HQ sponsorship

• Balloon Program Roadmap
  - Conducted by community-based Roadmap team chaired by Peter Gorham (U Hawaii)

• Evolution of NASA Data Centers
  - In planning stage, draws on efforts including STScI study on big data, NASA Big Data Task Force on adapting archives to technology, and IPAC leading on joint data processing from LSST/Euclid/WFIRST

• SmallSats
  - RFI for Astrophysics science and technology concepts

• In-Space Servicing/In-Space Assembly
  - NASA-led study being initiated, joint SMD/STMD/HEOMD

• System-Level Segmented Telescope Technology Program
  - Initial selections announced March 2018 (selected teams led by Ball Aerospace and Lockheed Martin)
Planned Accomplishments FY18-19

• TESS will launch April 2018
• Funds appropriated by Congress in FY18 will allow WFIRST to enter Phase B in April 2018
• IXPE will complete preliminary design review and enter Phase C Fall 2018
• Next MIDEX and Mission of Opportunity missions will be downselected by January 2019
• Decadal Survey will begin January 2019
• Webb will complete observatory integration in 2019
• Senior Review will be conducted Spring 2019
• If Congress approves the Administration’s request to terminate WFIRST, the funds made available would enable a competed mission AO in FY19
+ MIDEX/MO (2023), SMEX/MO (2025), etc.

+ Athena (late 2020s), LISA (mid 2030s)
## Science FY19 Budget Request Summary ($M)

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<th>Enacted FY 18</th>
<th>Request FY 19</th>
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### Notes:
- Actual: FY 17
- Enacted: FY 18
- Request: FY 19, FY 20, FY 21, FY 22, FY 23
- Notional: FY 22, FY 23

### Additional Notes:
- Cosmic Origins SR&T includes Herschel.
## Astrophysics FY19 Budget Request ($M) (cont’d)

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