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
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
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)
Major Recent Accomplishments FY18-19

- Webb payload completed cryotesting November 2017 and shipped to California January 2018
- XRISM passed Preliminary Design Review / Confirmation Review and entered Phase C January 2018
- TESS launched April 2018, began science operations July 2018 following commissioning
- Hubble detected the most distant, at 9 billion light years, ordinary star ever detected April 2018
- Webb Independent Review Board completed review and NASA announced March 2021 launch date June 2018
- Fermi detected an outburst from a distant supermassive black hole at the same time NSF’s IceCube detects a neutrino, marking the first extragalactic neutrino detection July 2018
- Kepler exhausted its fuel and ceased operations October 2018
- Kepler and Hubble detected the first Exomoon candidate orbiting an exoplanet 8,000 light years away October 2018
- Astrophysics Decadal Survey began November 2018
- IXPE and GUSTO passed their Confirmation Reviews and entered the implementation phase
- Voyager 1 detected no Hawking radiation from primordial black holes, limiting their contribution to the mysterious dark matter January 2019
- ISS-NICER completed its prime mission in January 2019
- First flight hardware electronics packages delivered to ESA for Euclid mission February 2019
- SPHEREx selected as next Astrophysics MIDEX mission February 2019
Planned Accomplishments FY19-20

• Webb began environmental testing of spacecraft/sunshield element in April 2019, will complete in Summer 2019
• Webb will begin observatory integration Fall 2019 followed by observatory testing to be completed by Summer 2020; will be shipped to Kourou Space Center launch site, arriving Fall 2020
• WFIRST will complete four element preliminary design reviews by September 2019
• NASA will release next SMEX and Mission of Opportunity AO April 2019; will select SMEX and Mission of Opportunity proposals for Phase A studies May 2020
• The Astrophysics Senior Review will be completed June 2019; Independent reviews of SOFIA operations and science prospects will be completed May 2019
• IXPE will conduct critical design review May 2019; GUSTO will conduct critical design review July 2019
• XRISM will deliver Resolve instrument hardware to JAXA October 2019; Euclid will deliver final NASA flight hardware to ESA October 2019
• Spitzer will complete mission and be decommissioned January 2020
NASA Astrophysics
Budget Update
FY19 Appropriation

The FY19 appropriation 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
- Spending on starshade technology and life detection technology is required
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.
NASA Astrophysics Budget: FY04-FY19 Appropriated, FY20-FY24 Request

- **WFIRST**
- **Webb**
- **Rest of Astrophysics**

Includes STEM Activation and previous E/PO efforts

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<th>FY08</th>
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FY20 President’s Budget Request for Astrophysics including Webb Telescope

What’s Changed
• Webb budget increased consistent with 2018 re-plan, Webb proceeding toward launch in 2021
• Probe program deferred to fund Webb replan
• SPHEREx begun within Explorers program as next Astrophysics MIDEX
• SOFIA mission funded beyond end of 5-year prime mission in 2019, details pending 2019 independent reviews
• Provides no funding for WFIRST space telescope

What’s the Same
• Cadence of four Explorer and Mission of Opportunity AOs per decade
• Spitzer ends operations January 2020 per 2016 Senior Review
• Phase A studies of Small Explorers (SMEX) and Missions of Opportunity from 2019 AO
• IXPE, GUSTO, XRISM, and Euclid development remains on track and within budget
• Hubble, Chandra, and 6 smaller operating missions continue pending 2019 Senior Review
• CubeSat initiative and four balloon campaigns within healthy research program
• Mission concept studies and technology investments to support Astro2020
NASA Astrophysics Missions Update
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
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
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 will complete environmental testing in Summer 2019
- Science payload and spacecraft integration planned for Fall 2019
- Launch scheduled for 2021
- Webb overrun covered using offsets from Astrophysics Probes
TESS sky survey is more than 25% complete (currently observing sector 10 out of 26)
TESS data is public at MAST
GI program is underway during prime mission (Cycle 1 underway, Cycle 2 proposals received)

http://archive.stsci.edu/tess/
https://heasarc.gsfc.nasa.gov/docs/tess

TESS by the numbers:
- 8 confirmed planets have been published in peer-reviewed journals
- 364 *new* planet candidates have been identified for follow-up ground-based confirmation
- 64 *previously known* planets have been re-detected
- 34 TESS papers have so far been submitted to preprint servers; many of which are focused on astrophysics topics other than exoplanets
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: SMD cost is $3.2B, launch is in late 2025
  • 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
  • Four element Preliminary Design Reviews by September
  • Proceeding during FY19 toward Mission Preliminary Design Review and Confirmation
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 mid-2019
- Mission being prepared for review to enter Implementation phase in ~1yr
Spectro-Photometer for the History of the Universe Epoch of Reionization and Ices Explorer (SPHEREx)

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 (H₂O, CO, CO₂, CH₃OH)

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

- **TESS**: NASA Mission (4/2018)
  - Transiting Exoplanet Survey Satellite
  - Launched!

- **Webb**: NASA Mission (2021)
  - James Webb Space Telescope
  - Replanned SIR in Aug 2019

- **IXPE**: NASA Mission (2021)
  - Imaging X-ray Polarimetry Explorer
  - Passed KDP-C CDR in June 2019

- **GUSTO**: NASA Mission (2021)
  - Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory
  - Passed KDP-C CDR in July 2019

- **XRISM**: JAXA-led Mission (2022)
  - Mission passed PDR
  - Delivering in I&T
  - NASA is supplying the SXS Detectors, ADRs, and SXTs

- **Euclid**: ESA-led Mission (2022)
  - Delivered 7 SCEs
  - Will deliver early

- **SPHEREx**: NASA Mission (2023)
  - Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer
  - Downselected in February 2019

- **WFIRST**: NASA Mission (Mid 2020s)
  - Wide-Field Infrared Survey Telescope
  - Mission PDR in October 2019

- **James Webb**: NASA Mission (2021)
  - NASA is supplying the SXS Detector, ADRs, and SXTs

- **Euclid**: NASA Mission (2022)
  - Replanned SIR in Aug 2019

- **SPHEREx**: NASA Mission (2023)
  - Spectro-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer
  - Downselected in February 2019
# Operating Missions (including GO programs)

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<th>Mission</th>
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<th>Mission Type</th>
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<td>NASA Strategic Mission</td>
<td>Senior Review</td>
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<td>Chandra</td>
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<td>XMM-Newton</td>
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<td>ESA-led Mission</td>
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<td>Spitzer</td>
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<td>NASA Strategic Mission</td>
<td>Began Final Year</td>
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<td>Gehrels Swift</td>
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<td>Fermi</td>
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<tr>
<td>Kepler</td>
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<td>NASA Discovery Mission</td>
<td>Mission Complete!</td>
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<td>NuSTAR</td>
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<td>NuSTAR Stratospheric Observatory for Infrared Astronomy</td>
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<td>TESS Neutron Star Interior Composition Explorer</td>
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NASA Astrophysics
Preparation for 2020 Decadal Survey
Decadal Survey Planning

• NASA’s highest aspiration for the 2020 Decadal Survey is that it be ambitious
  • The important science questions require new and ambitious capabilities
  • Ambitious missions prioritized by previous Decadal Surveys have always led to paradigm shifting discoveries about the universe
• If you plan to a diminishing budget, you get a diminishing program.
  • Great visions inspire great budgets.

Carpe Posterum
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
Medium Missions (Probes)

Probes have had a strong impact on some areas of astrophysics

Ten Probes 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)
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 (NAS, 2017)
Why Flagships

Flagships drive science
Flagships drive US capabilities and contribute to US leadership
Flagships drive NASA budget and create stakeholder support
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 (NAS, 2017)
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
Coronagraph Architecture, Deformable Mirrors, LOWFS/OBWFS, UV & Red-enhanced EMCCDs, Mirror Segment Substrate, Mirror Segment Metrology, Picometer Rigid Body Actuators, Far-UV Broadband Coating, Active Dynamic Isolation, Thermal Sensing & Control, Ultra-stable System Architecture, Large-format CMOS Arrays, GaN Microchannel Plates, Next-generation Microshutter Arrays

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
FY19 Astrophysics Funded Missions
Revised February 21, 2019

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

+ Athena (early 2030s), LISA (early 2030s)
BACKUP