National Aeronautics and Space Administration

Division Update to Astrophysics Subcommittee

March 26, 2014

Astrophysics

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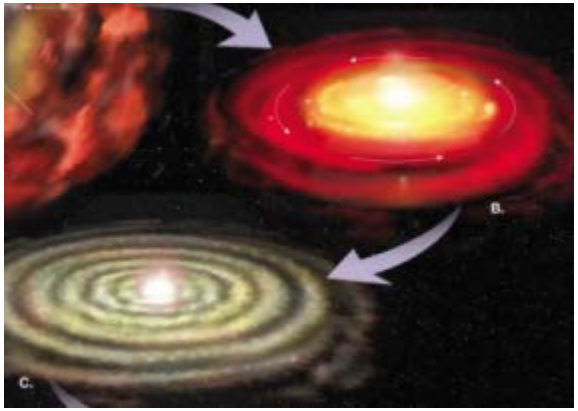
www.nasa.gov

Why Astrophysics?

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

1. How did our universe begin and evolve?

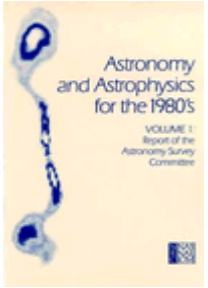


2. How did galaxies, stars, and planets come to be?

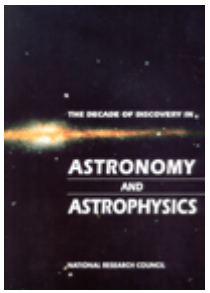
3. Are We Alone?

These national strategic drivers are enduring

1972



1982



1991

2001

2010

ASTROPHYSICS

Decadal Survey Missions

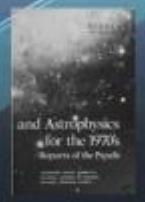
LRD: 2018

LRD: 2020s

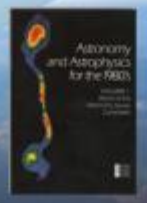
2003

1999

1990



1972 Decadal Survey *Hubble*



1982 Decadal Survey *Chandra*

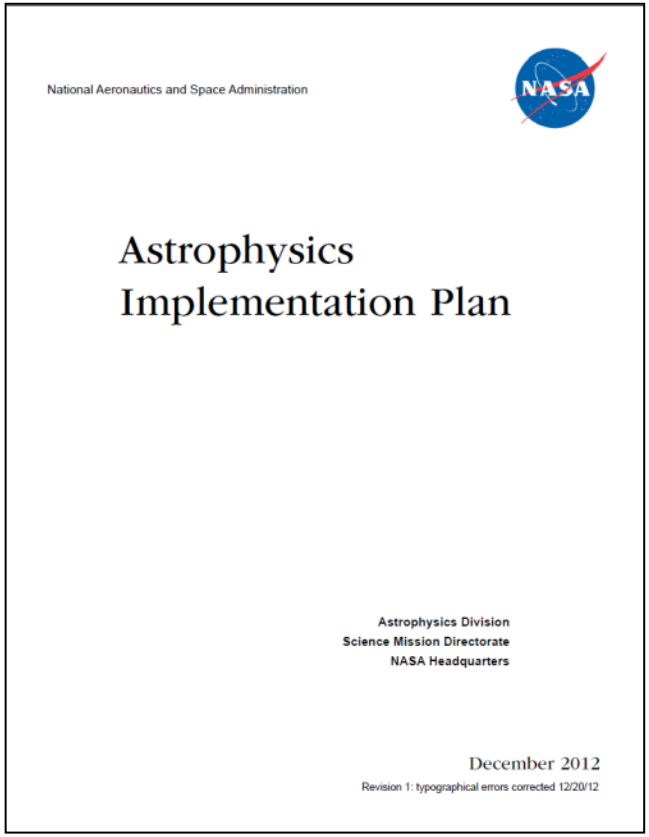
1991 Decadal Survey *Spitzer*

2001 Decadal Survey *JWST*

2010 Decadal Survey *WFIRST*

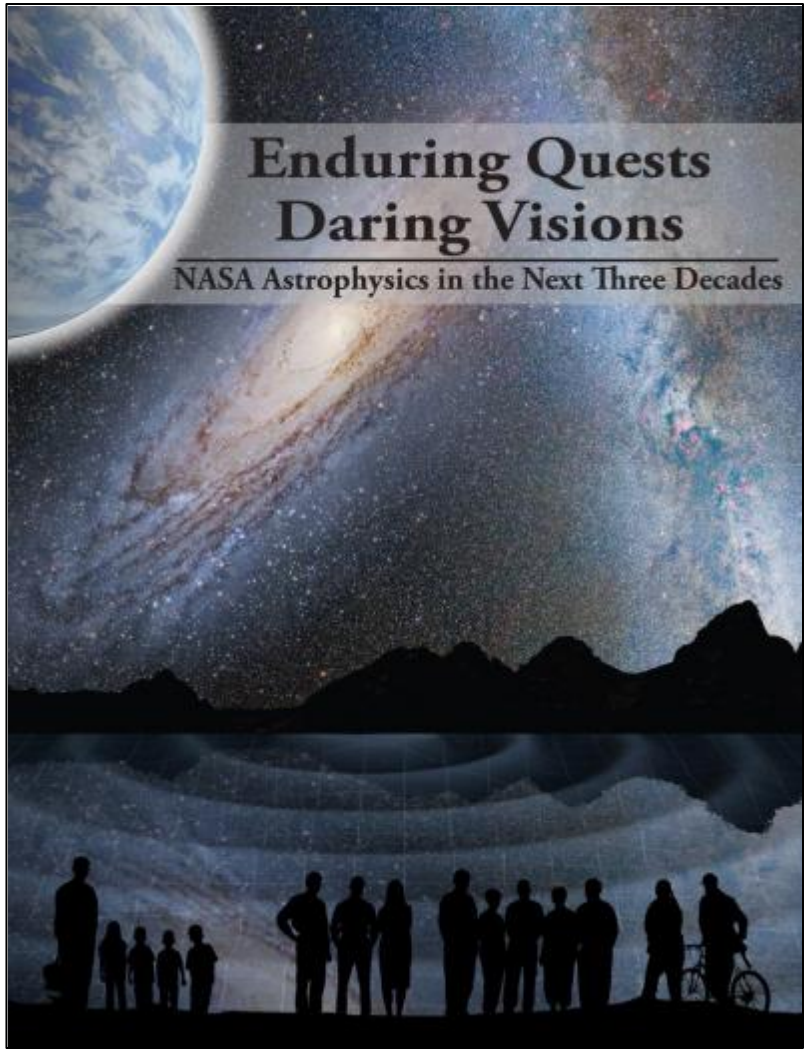
Astrophysics Implementation Plan

- **Astrophysics Implementation Plan**
  - White paper developed by Astrophysics Division
  - Was discussed with the Committee on Astronomy and Astrophysics (CAA) and the NAC Astrophysics Subcommittee (APS) prior to finalization
  - Describes Astrophysics Division strategy in response to the Decadal Survey recommendations
  - Developed in 2012 and consistent with FY13 budget guidance
  - To be updated in 2014 to incorporate recent events and accomplishments and to be consistent with FY15 budget guidance

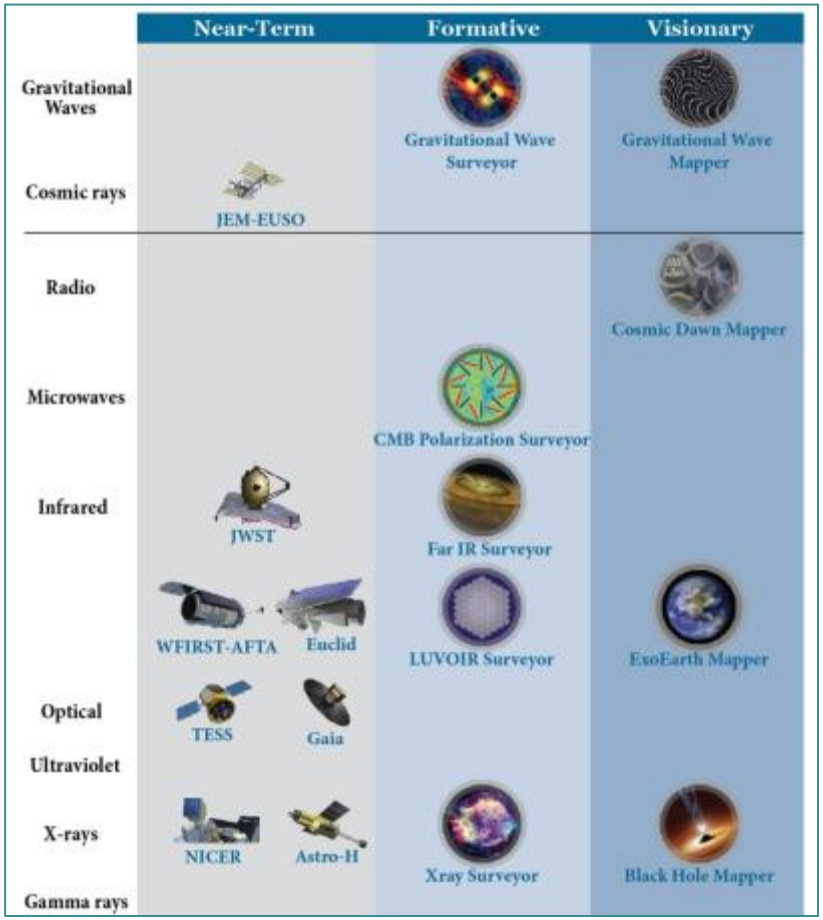


The Astrophysics Implementation Plan is available for download at http://science.nasa.gov/astrophysics/documents/

Enduring Quests, Daring Visions



- A 30 year vision to address the enduring questions:
  - Are we alone?
  - How did we get here?
  - How does the universe work?



http://science.nasa.gov/astrophysics/documents

The Big Picture

- This remains a time of scientific opportunity for NASA Astrophysics.
  - We are poised to answer the most compelling science questions.
  - The budget for NASA astrophysics, which includes JWST, continues at $1.33B in FY14; the President has requested $1.25B in FY15.
  - NASA continues to operate large and small space-based observatories spanning the electromagnetic spectrum, including multiple Great Observatories.
  - The James Webb Space Telescope, the highest priority of the community, is on schedule and fully funded for an October 2018 launch.
  - NASA continues to develop Explorer missions and contributions to international missions for launch this decade, and a Small Explorer AO is planned for late 2014 to select two more Explorer projects.
  - NASA continues to support individual investigators for data analysis, theory, and technology investigations through open, competitive, peer reviews.
  - NASA is preparing for a new strategic Astrophysics mission to follow JWST as soon as funding becomes available; the preparation includes preformulation studies of WFIRST-AFTA.
- The budgetary future remains uncertain.
  - Priorities must be used to guide difficult budget choices.
  - The President has requested a ~10% decrease for the Astrophysics Division in FY15; the cost of operating SOFIA can not be accommodated within this reduced budget.

Progress Toward Decadal Survey Priorities

The NASA FY14 Appropriation, the President's FY15 Budget Request, and its notional out years support	
L1. WFIRST	Preformulation and focused technology development for WFIRST/AFTA (a 2.4m version of WFIRST with a coronagraph) are underway to enable a new start NET FY17
L2. Augmentation to Explorer Program	Increased from ~$90M in FY07 and ~$115M/yr in FY10 to ~$140M/yr in FY16 and beyond; supports decadal cadence of AOs including 2014
L3. LISA	Strategic technology investments including LISA Pathfinder plus discussing partnership in ESA's L3 gravitational wave observatory
L4. IXO	Strategic technology investments plus discussing partnership in ESA's L2 X-ray observatory
M1. New Worlds Technology Development Program	Focused technology development for a coronagraph on WFIRST; mission concept studies and strategic technology investments
M2. Inflation Probe Technology Development Program	Three balloon-borne investigations plus strategic technology investments
Small. Research Program Augmentations	Increased from $65M (FY07) to $74M (FY10) to $82M (FY12 and beyond)

Astrophysics Decadal Survey - Summary

Program Scale	Recommendation	Response supported by FY15 President's Budget Request
Large	**WFIRST**	DRM1 and DRM2 completed in FY12; AFTA "proof of concept" DRM completed in FY13; pre-formulation and technology development (detector and coronagraph) in FY14-FY19; prepared for decision regarding FY17 new start; participating in ESA's Euclid
Large	**Explorer** Augmentation	Impacted by sequestration and budget reductions including cancellation of selections from FY12 MO AO; EX AO in FY11; SMEX AO 2014; EX AO 2016/2017; budget supports 4 AOs per decade; each AO has a mission and a MO
Large	**LISA** Technology	CST completed in FY12; technology supported through SAT; ST-7/LPF supported; partnership discussed with ESA on the L3 gravitational wave observatory selected as L3 mission
Large	**IXO** Technology	CST completed in FY12; technology supported through SAT; partnership planned with ESA including hardware contribution on the advanced X-ray observatory selected as L2 mission
Medium	**New Worlds Technology**	Technology supported through APRA and SAT(TDEM) including multiple architectures and testbeds; exoplanet probe STDTs started in FY13; AFTA coronagraph study completed in FY13; AFTA coronagraph technology starting in FY14 and supported by STMD
Medium	**Inflation Probe Technology**	Technology supported through APRA and SAT including multiple suborbital payloads and ground-based applications
Small	**Astrophysics Theory Program** Augmentation	Funding level impacted by sequestration and budget reductions
Small	(Definition of) a **future UV-optical space capability**	RFI in FY12; follow-on workshops FY14-FY16; technology supported through APRA, SAT, and working with STMD
Small	**Intermediate Technology Development** Augmentation	SAT program initiated in FY11 and funded for prioritized investments; funding directed toward decadal survey priorities including AFTA, probes, New Worlds, ESA L2/L3 technologies; and Inflation Probe; funding level impacted by sequestration and budget reductions
Small	**Laboratory Astrophysics** Augmentation	Augmentation started in FY12 including selection of large consortium; future selections impacted by sequestration and budget reductions
Small	**SPICA** mission (U.S. contributions to JAXA-led)	Candidate for future Explorer Mission of Opportunity
Small	**Suborbital Program** Augmentation	Technology augmentation for balloon program; continued development of ULDB balloon platforms; ISS payload selections; impacted by sequestration and budget reductions
Small	**Theory and Computation Networks** (NASA, NSF, DOE)	Six networks competitively selected in 2013 and funded by NSF and NASA in FY14-FY16
N/A	**Additional core program augmentations**	Includes basic research and technology development, mission extensions, data analysis, N.G. Roman Technology Fellowships; impacted by sequestration and budget reductions

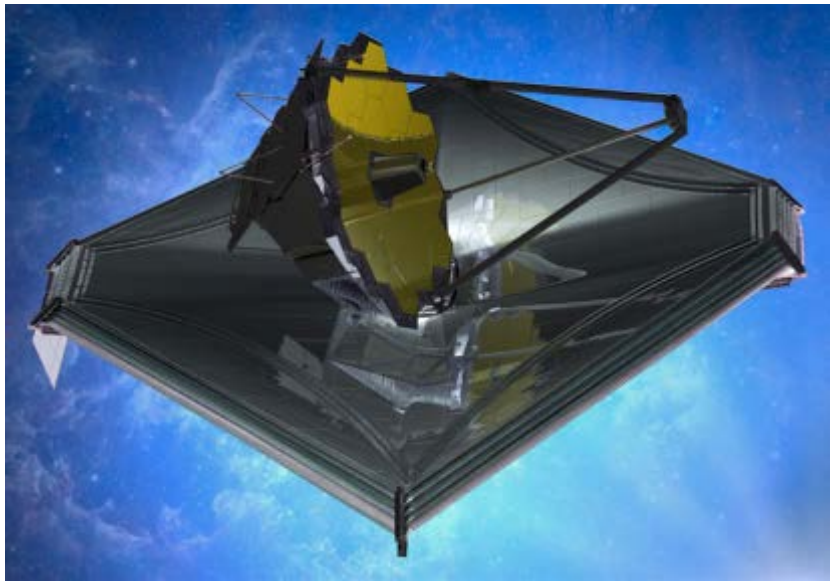
Astrophysics Budget Strategy

- Use the scientific priorities of the 2010 Decadal Survey to guide strategy and inform choices.
- There is inadequate available budget to implement the 2010 Decadal Survey recommendations as written.
- A goal is to be prepared to start a new strategic NASA Astrophysics mission to follow JWST as soon as funding becomes available, while continuing to advance Decadal Survey science during the interim.
  - WFIRST/AFTA (WFIRST using existing 2.4 m telescopes including coronagraph)
  - Moderate missions (“probes”) derived from the science objectives of the prioritized missions and recommendations in the 2010 Decadal Survey are being studied, in addition to a large mission (WFIRST), to be prepared for a mid-decade decision.
- As appropriate, collaborate with international partners to realize Decadal Survey priorities and recommendations.
  - Partner on ESA’s Euclid mission (complements WFIRST commitment)
  - Partner on ESA’s L2 x-ray observatory (responds to IXO recommendation)
  - Partner on ESA’s L3 gravitational wave observatory (responds to LISA recommendation)

FY14 Budget Appropriation

- FY14 President's budget requested $642M for Astrophysics and $658M for JWST.
  - Request includes full funding required for JWST; new projects for TESS, NICER, Euclid; mission extensions per 2012 Senior Review; core funding for research and suborbital projects; planning budget wedge for strategic mission starting in FY17.
  - Request includes no funding for education.
- Final FY14 Appropriation is $668M for Astrophysics and $658M for JWST.
  - JWST plan for 2018 launch is fully funded.
  - Budget is $26M higher for Astrophysics than requested, including $56M directed funding for WFIRST/AFTA studies (compared with $13M planned).
  - Remainder of Astrophysics (other than JWST and WFIRST/AFTA) must be adjusted to accommodate the ~$20M difference. This will be determined through development of the NASA FY14 operating plan.
  - SMD to continue conducting education activities in FY14 and to consider consolidation at the Division level.
- FY15 President's budget request was released on March 4 (top level only) and March 10 (full details)

JWST
James Webb Space Telescope



Large Infrared Space Observatory

Top priority of 2000 Decadal Survey

Science themes: First Light; Assembly of Galaxies; Birth of Stars and Planetary Systems; Planetary Systems and the Origins of Life

Mission: 6.5m deployable, segmented telescope at L2, passively cooled to <50K behind a large, deployable sunshield

Instruments: Near IR Camera, Near IR Spectrograph, Mid IR Instrument, Near IR Imager and Slitless Spectrograph

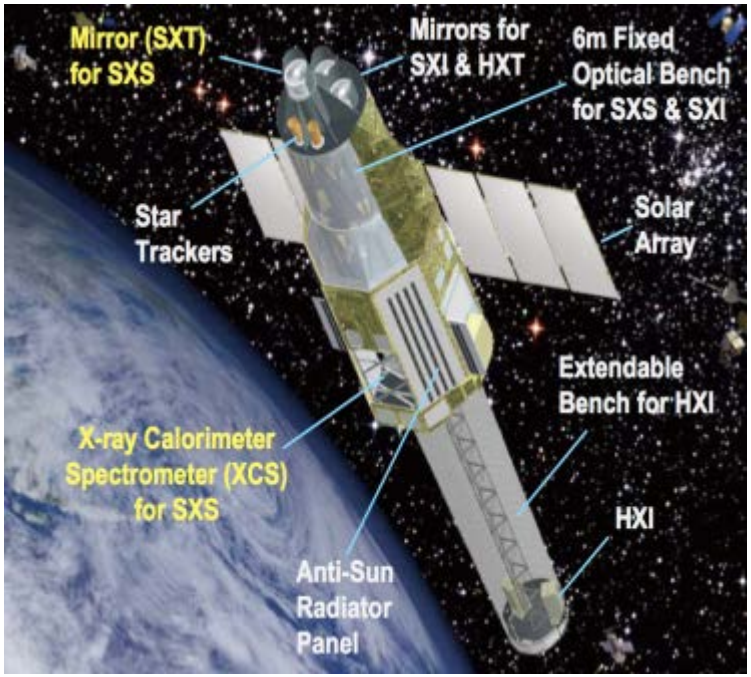
Operations: 2018 launch for a 5-year prime mission

Partners: ESA, CSA

CURRENT STATUS:

- Project has entered its long and challenging Integration and Test activities.
- Technical progress continues to be significant.
  - Instruments are delivered and in integration & test phase.
  - All optics are complete (primary segments, secondary, tertiary and fine steering mirrors) and delivered to GSFC.
  - Telescope wings are complete; backplane support fixture and center section are complete.
  - Spacecraft completed Critical Design Review (Jan 2014).
- Project is performing within the budget, to schedule.
  - Government shutdown did not impact October 2018 launch date.
- FY14 is the peak funding year with many critical activities.

ASTRO-H
Soft X-ray Spectrometer and Soft X-ray Telescope Mirrors



- **Explorer Mission of Opportunity**
- **PI**: R. Kelley, Goddard Space Flight Center
- **Launch Date**: Nov 2015 on JAXA H-IIA
- **Science Objectives**: Study the physics of cosmic sources via high-resolution X-ray spectroscopy. The SXS will enable a wide range of physical measurements of sources ranging from stellar coronae to clusters of galaxies.
- **Operations**: Prime Mission is 3 years

CURRENT STATUS

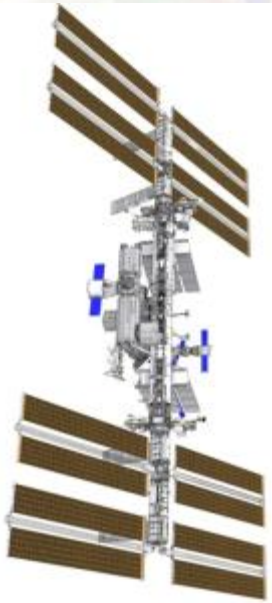
The U.S. is providing instrument contributions to the JAXA ASTRO-H mission.

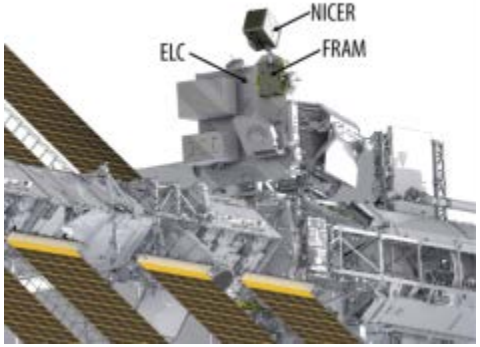
- Soft X-ray telescope mirrors (SXT-S and SXT-I) – Both delivered.
- ADR controller (ADRC) – Delivery Feb 2015
- X-ray Calorimeter Spectrometer Insert (CSI), including the 3-stage adiabatic demagnetization refrigerator and detectors, and Aperture Assembly - Delivery April 2014.
- SXS Electronics Box – Delivery May 2014
- ASTRO-H project rebaselined in November 2013 to account for JAXA schedule changes and impact of U.S. government shutdown in October 2013.
- March 2014 Update: All U.S. elements are on track for delivery as scheduled.

NICER

Neutron Star Interior Composition Explorer

Intl Space Station (ISS)



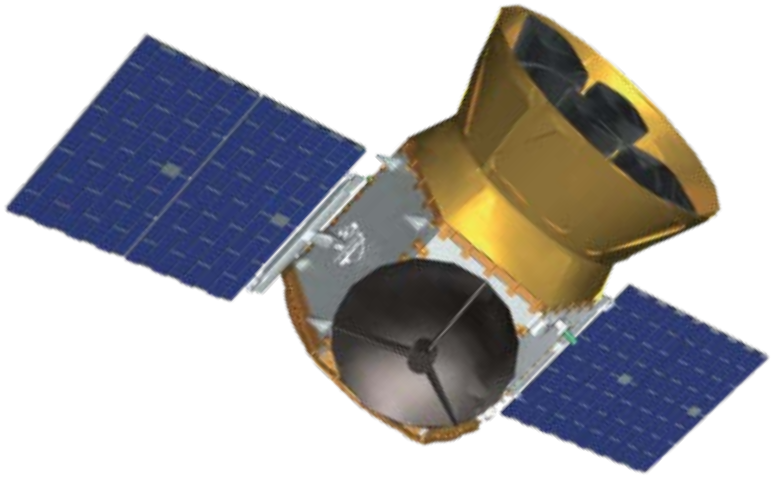


- **Explorer Mission of Opportunity**
- **PI:** Keith Gendreau, GSFC
- **Launch:** August 2016 on Space-X Falcon 9
- **Science Objectives:** Perform high-time-resolution and spectroscopic observations of neutron stars in the .2-12 keV energy range to study the physics of ultra-dense matter in the core of neutron stars.
- **Instrument:** X-ray Timing Instrument uses X-ray concentrators and detectors to detect X-ray photons and return energy and time of arrival.
- **Platform:** Located externally on the ISS, ExPRESS Logistics Carrier 2, Starboard 3 site
- **Operations:** Operated on a non-interference basis for 18 months
- **SEXTANT** for Pulsar navigation demo funded by NASA's Space Technology Mission Directorate

CURRENT STATUS:

- Downselected April 2013.
- Science team and project management both led by NASA GSFC.
- Development progressing on plan.
- The Preliminary Design Review successfully completed in December 2013.
- NICER passed Confirmation (KDP-C), for approval to enter implementation phase, on February 24, 2014.
- Contracts for subsystems being put in place.
- Critical design review (CDR) planned for September 2014

TESS
Transiting Exoplanet Survey Satellite



Standard Explorer (EX) Mission

PI: G. Ricker (MIT)

Mission: All-Sky photometric exoplanet mapping mission.

Science goal: Search for transiting exoplanets around the closest and brightest stars in the sky.

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

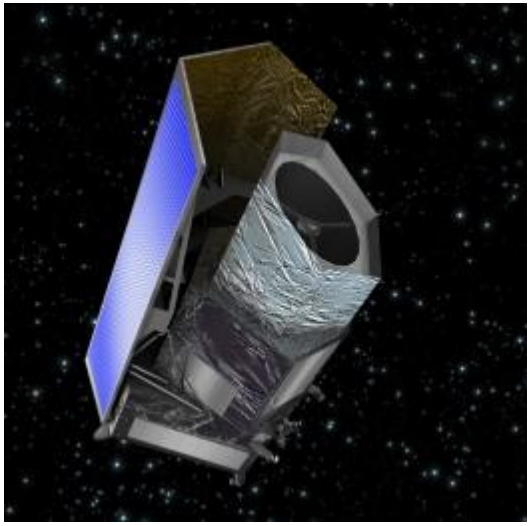
Operations: 2017 launch with a 2-year prime mission

CURRENT STATUS:

- Downselected April 2013.
- Major partners:
  - PI and science lead: MIT
  - Project management: NASA GSFC
  - Instrument: Lincoln Lab
  - Spacecraft: Orbital Science Corp
- Tentative launch readiness date August 2017.
- High-Earth elliptical orbit (17 x 58.7 Earth radii).
- Development progressing on plan.
  - Systems Requirement Review successfully completed on February 12-13, 2014.
  - Confirmation Review, for approval to enter implementation phase, is planned for Fall 2014.

Euclid

A visible and near-infrared telescope to explore cosmic evolution



- **ESA Cosmic Vision 2015-2025 Mission**, M-Class with NASA participation.
- 1.2-m mirror, visible & near-IR images, spectra
- **Launch Date**: Mar 2020
- **Science Objectives**:
  - Euclid will look back 10 billion years into cosmic history.
  - Probe the history of cosmic expansion (influenced by dark energy and dark matter) and how gravity pulls galaxies together to form the largest structures.
  - The shapes of distant galaxies appear distorted because the gravity of dark matter bends their light (gravitational lensing). Measuring this distortion tells us how the largest structures were built up over cosmic time.
  - Measuring how strongly galaxies are clumped together tells us how gravity influences their motions, and how dark energy has affected the cosmic expansion.

CURRENT STATUS:

- NASA Euclid Project passed Confirmation (KDP-C), for approval to enter implementation phase, on September 13, 2013.
- ~50 U.S. scientists are members of the Euclid Science Team that will analyze the data, and make maps of the sky.
- First experimental manufacturing run for the Euclid near-infrared detectors to complete in FY 2014 (ESA).
- NASA will initiate the buy for the flight infrared detectors in FY 2014.
- NASA will test and characterize the near-IR flight detectors.
- NASA developing ground system node and U.S. science center.

Kepler
Kepler Space Telescope

- **NASA's first space mission dedicated to the search for extrasolar planets, or exoplanets**
- **PI:** W. Borucki, NASA Ames Research Center
- **Launch Date:** March 6, 2009
- **Payload:** 0.95-meter diameter telescope designed to measure the tiny dimming that occurs when an orbiting planet passes in front of ('transits') a star
- **Scientific objectives:**
  - conduct census of exoplanet systems
  - explore the structure and diversity of extrasolar planetary systems
  - determine the frequency of habitable, Earth-sized planets in our galaxy

CURRENT STATUS:

- Continuously monitored 100 sq. deg. field in constellations of Cygnus and Lyra for 4+ years
- Analysis of first 3 years of Kepler data has revealed:
  - 3845 exoplanet candidates orbiting 2658 unique stars
  - 961 candidates confirmed as planets to date
  - More than 100 planets discovered in their star's "habitable zone"
  - two dozen of the habitable zone planet candidates are less than twice the size of the Earth
- Analysis of the full (4+ year) Kepler data set ongoing
- Spacecraft suffered failure of 2 reaction wheels in July 2012 and May 2013:
  - Only 2 functional reaction wheels remain
  - Not sufficient to maintain precise pointing on the Kepler field
- Project has developed strategy for a new science mission that requires only 2 reaction wheels
  - Engineering test of 2 reaction wheel mission concept started March 2014
- New mission concept (K2) proposed to the 2014 Astrophysics Senior Review

SOFIA
Stratospheric Observatory for Infrared Astronomy

- **World's Largest Airborne Observatory**
- 2.5-meter telescope
- Capable of observing from the visible to the far infrared
- 80/20 Partnership between NASA and the German Aerospace Center (DLR)
- Mission Ops based at NASA-Armstrong
- Science Ops based at NASA-Ames
- Six First-Generation instruments
  - Four U.S., two German
  - Imaging, Spectroscopy, and Photometry
- Limited Science Ops began 2010
- Full Operational Capability in February 2014

CURRENT STATUS:

- Completed 45 successful flights during Cycle 1
  - 25 science (153 research hours)
  - 9 instrument commissioning
  - 11 engineering/test and ferry for deployment
- Completed Inaugural Southern Hemisphere Deployment, July 2013, Christchurch NZ
  - 9 science flights in 14 nights
  - 100% of objectives achieved
- Completed all technical requirements for Full Operational Capability (FOC) in February 2014
  - FOC will be confirmed following independent review of FLITECAM commissioning data
  - EXES & FIFI-LS begin commissioning in 2014
- Cycle 2 science investigations chosen
  - Initiated February 2014
- Second generation instruments under development (1 U.S., 1 German)
  - HAWC+: far infrared imager and polarimeter
  - upGREAT: multi-pixel heterodyne spectrometer
- President's FY15 budget request proposes to end funding and place SOFIA in storage
  - NASA-DLR working group established to determine path forward

SOFIA to be put into Storage

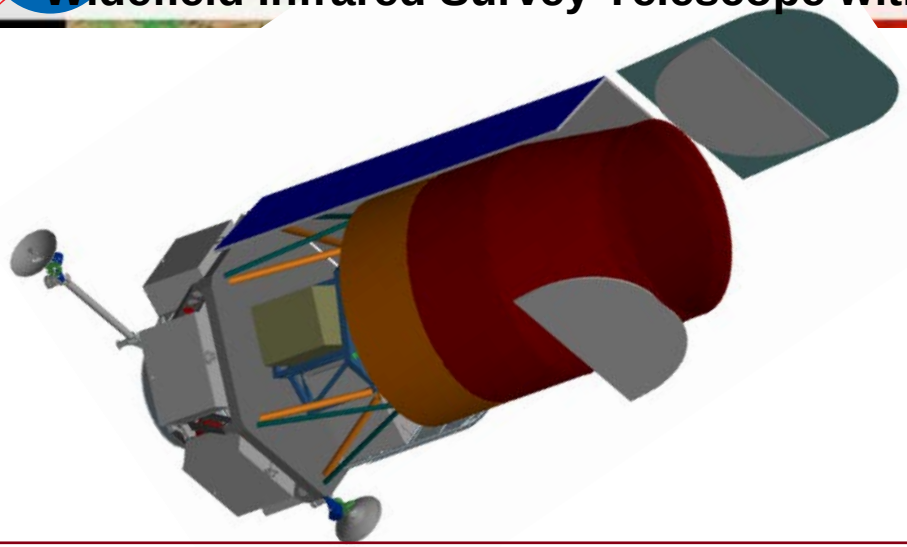
- SOFIA's high operating costs cannot be accommodated within the reduced Astrophysics budget request.
- NASA’s FY 2015 budget request to Congress proposes to place SOFIA into storage by FY 2015.
- NASA has informed our German partner DLR of this proposal. NASA is working with DLR to identify a path forward for SOFIA.

SOFIA Working Group

- NASA and DLR have formed a working group to develop a go forward plan for SOFIA. The WG is to conduct analysis under the following primary assumptions:
  - That the FY2015 budget request will be enacted without further change;
  - That the DLR contribution to SOFIA will not be increased;
  - That DLR does not desire to take over primary program management responsibility for SOFIA;
  - That transition of the Program Office from Armstrong Flight Research Center to Ames Research Center will not occur if the FY2015 budget request is enacted;
  - That, in the absence of additional partnerships, the deadline for SOFIA to enter storage is the end of FY2015, i.e. funding (not the calendar) drives entry into storage; and
  - That any plan must be consistent with available NASA FY2015 funding.
- Overall objectives will include maximizing scientific return within U.S. budget constraints; supporting critical near-term decisions; and identification of long-term options for continued operations or for storage until such time that additional funds are made available for resumption of SOFIA operations.
  - April 4 - Presentation of Findings on Near Term Items
  - April 25 - Final Presentation of Findings on SOFIA Transition Options

WFIRST / AFTA

Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets



- **Top priority in 2010 Decadal Survey**
  - #1 Large Priority: Widefield IR survey telescope
  - #1 Medium Priority: Technology for direct imaging and characterization of exoplanets
- **Study Baseline Payload:**
  - 2.4m existing telescope assets
  - Widefield imager
  - Coronagraph
- **Science objectives:**
  - Determine the history of cosmic expansion and growth of structure
  - Complete statistical census of planetary systems
  - Produce deep sky map at NIR wavelengths
  - Directly image giant planets and debris disks
  - General observer program

CURRENT STATUS:

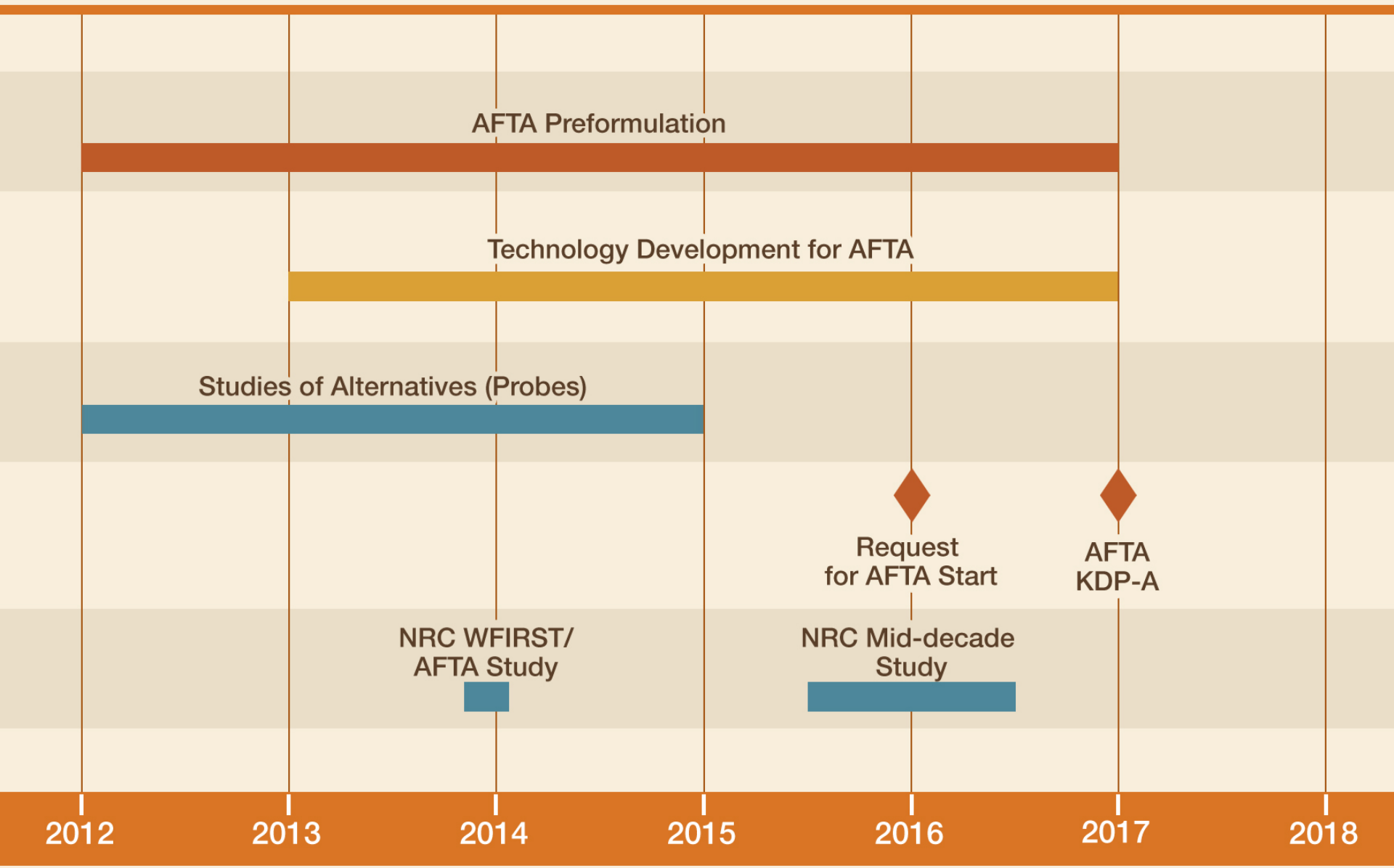
- May 2013, NASA Administrator Bolden directed study of WFIRST/AFTA and preserve option for FY17 new start if budget is available
  - No decision expected before early 2016
- Currently in pre-formulation phase
  - AFTA endorsed by NRC study report released March 2014.
  - SDT final report due Jan 2015
- Maturing key technologies to TRL 5 by FY17 and TRL 6 by FY19
  - H4RG infrared detectors for widefield imager
  - Internal coronagraph for exoplanet characterization (two architectures identified December 2013; occulting mask coronagraph and phased induced amplitude apodization complex mask coronagraph)
- FY14 Appropriation and FY15 Request support
  - Assessment of the 2.4m telescopes, mission design trades, payload accommodation studies, and observatory performance simulations

WFIRST/AFTA to continue Pre-Formulation

- Supports pre-formulation of WFIRST/AFTA, including technology development for detectors and coronagraph.
- Continues efforts from FY14 such as:
  - The WFIRST/AFTA Science Definition Team (SDT) report in early 2015 including a design reference mission and draft science requirements.
  - The WFIRST/AFTA Study Office including continued assessment of the 2.4m telescopes, mission design trades, payload accommodation studies, and observatory performance simulations.
  - Technology development for H4RG detectors for the wide field camera.
  - Technology development for the primary coronagraph architecture (occulting mask coronagraph) and the backup coronagraph architecture (phased induced amplitude apodization complex mask coronagraph).
- Supports Agency/Administration decision for formulation to begin NET FY 2017, should funding be available.

Plan for WFIRST-AFTA Preformulation

Widefield Infrared Survey Telescope using Astrophysics Focused Telescope Assets



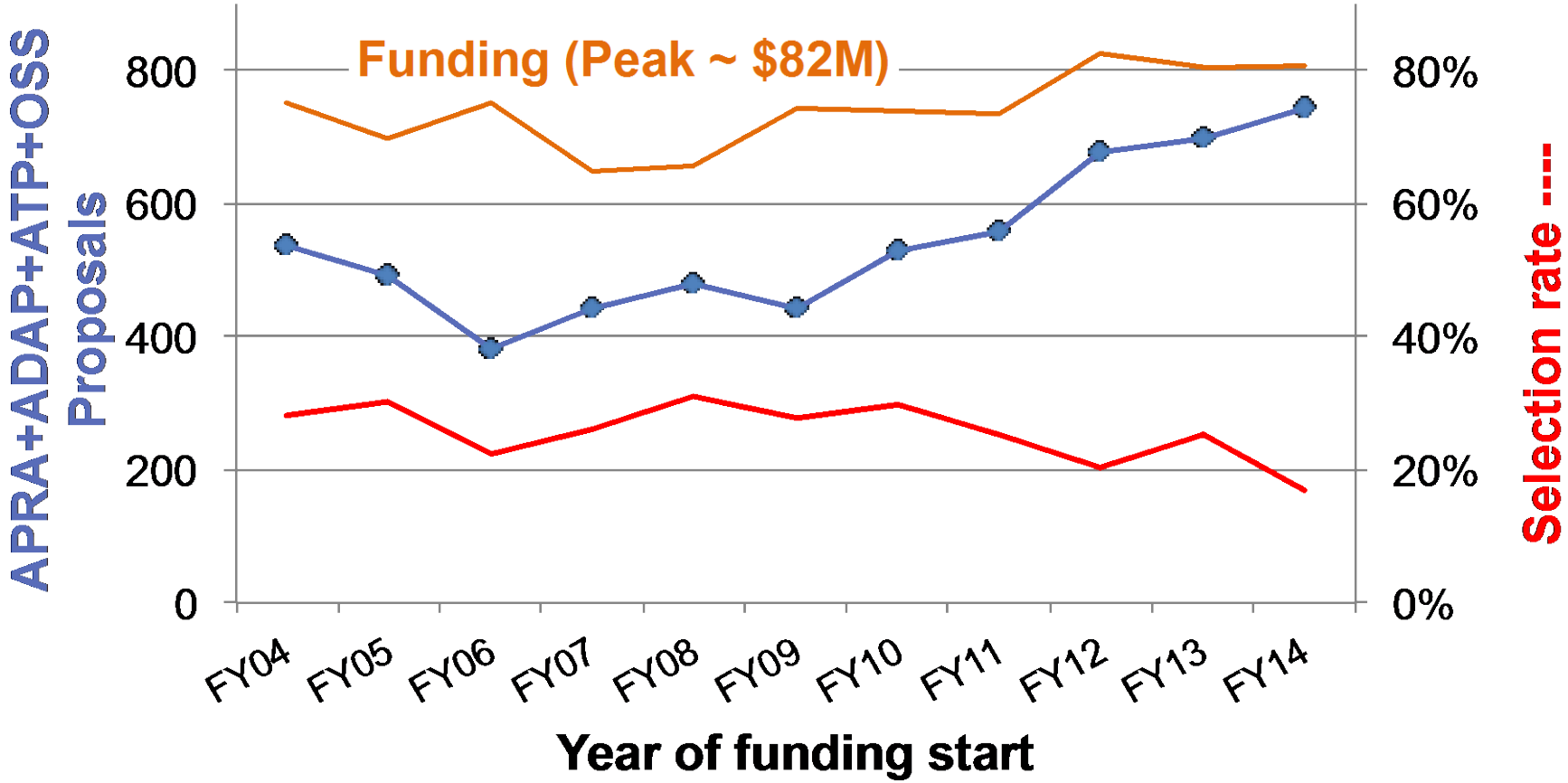
NRC study on WFIRST/AFTA

- NRC study on WFIRST/AFTA offers positive view of AFTA
  - (F3-2) AFTA significantly enhances WFIRST science in NWNH
  - (F1-7) Coronagraph satisfies some aspects of exoplanet technology
  - (F3-3) If AFTA costs compromise program balance, then it is inconsistent with rationale for #1 ranking
  - (F2-4) Risk of cost growth is significantly higher for AFTA than IDRM
  - (F2-6) Adding technology development to flagship creates risks
  - (F2-7) WFIRST's low risk was part of rationale; adding coronagraph compromises rationale
  - (F2-8) Adding coronagraph is not first tier priority for constrained budget; first tier priorities are: WFIRST, Explorers augmentation, core program augmentation; if higher priorities not addressed, adding coronagraph is inconsistent with NWNH priorities
  - (R2-1) Aggressively mature coronagraph design and plans; have independent review to determine whether to descope coronagraph
  - (R3-1) Have external technical and cost review of WFIRST/AFTA mission early enough to rescope mission to see if cost/risk consistent with NWNH

ESA's L2 Advanced X-ray Observatory

- The science theme "the hot and energetic Universe" was selected for L2, and expected to be pursued with an advanced X-ray observatory.
  - Launch date ~2028
- NASA and ESA are discussing a potential NASA contribution.
  - NASA is interested in contributing to this mission because it is responsive to the U.S. Decadal Survey. The U.S. Decadal Survey recommended an international partnership for an advanced X-ray observatory.
- NASA's FY15 budget request supports a potential L2 partnership
  - US scientists are participating in proposal(s) in response to the ESA mission concept call for proposals; proposals due April 15, 2014
  - NASA will provide input to ESA on appropriate US members of the L2 Science Study Team
  - NASA will continue investing in technologies likely to be appropriate for an L2 contribution; investments include both directed and competed SAT investigations
  - NASA is budgeting for development of contributed flight hardware, US participation in the L2 science team, and a US data center and GO program

Research and Analysis (R&A)



Proposal numbers (up 75% from 2007 to 2014) grow faster than funding (up 20% from 2007 to 2014). Overall selection rate at 19% for FY14.

Astrophysics Senior Review in 2014

- Astrophysics is conducting a Senior Review for Operating Missions (in conformity with PL 109-155, § 304(a)).
  - Coordinated reviews for Hubble, Chandra, and the remainder of the MO&DA portfolio.
  - Missions required to submit self-identified mission objectives as well as budgets, FTE/WYE levels, and assessment against prior SR proposal.
  - All missions comparatively assessed by a single Senior Review Panel with the exception of Hubble and Chandra. Hubble and Chandra reviewed in self-contained reviews by individualized Senior Review Panels.
- Senior Review Timeline.
  - Final Call for Proposals issued: November 15, 2013
  - Senior Review Proposals received: January 31, 2014
  - Hubble Senior Review panel meets: March 10-13, 2014
  - Chandra Senior Review panel meets: March 24-27, 2014
  - Comparative Senior Review panel meets: March 31 – April 3, 2014
  - Panel's report & APD response: June 2014
- Missions invited.
  - Hubble, Chandra
  - Fermi, NuSTAR, Spitzer, Suzaku, Swift, XMM-Newton, Kepler (K2), Planck, WISE (MaxWISE)

2014 Astrophysics Explorer AO

- Community Announcement released on November 12, 2013, indicating NASA will solicit proposals for SMEX missions and Missions of Opportunity.
- Draft AO targeted for spring 2014, with Explorer Workshop ~ 2 weeks later.
- Final AO targeted for late summer/early fall 2014, with Pre-Proposal Conference ~ 3 weeks after final AO release. Proposals due 90 days after AO release.
- PI-managed cost cap at $125M (FY2015$) for SMEX, does not include cost of ELV or transportation to the ISS.
  - CAA discussion on February 11 did not result in any change to AO cost cap.
- Missions of Opportunity allowed in all three categories: Partner Mission of Opportunity, New Missions using Existing Spacecraft, or Small Complete Mission, including those requiring flight on the ISS.
- PI-managed cost cap $35M for sub-orbital class MOs, which include ultra-long duration balloons, suborbital reusable launch vehicles, and CubeSats. Other MOs (not suborbital-class) have a $65M PI-managed cost cap.
- Two-step process. Step 1 selects 2-3 SMEX missions and 1-3 MOs for 1-year Phase A concept studies, Step 2 down-selects 1 SMEX and 1 MO for Phase B and subsequent phases.

Education and Public Outreach

- The FY14 appropriated budget does not included any restoration of funding for education, but it does direct SMD to continue conducting education activities and to consider consolidation at the Division level.
- For FY15 SMD will assess its portfolio of education activities and competitively allocate funding to the highest priority education projects within NASA Science.
- FY14 is a bridge year between old and new education practices. SMD has adopted some unifying principles.
  - Each Division would preserve its mission education funding at an appropriate level
  - Investments would be focused on content
  - Education funding can be consolidated, with one mission supporting other missions
  - Education would no longer “be part of everything we do,” and some missions, projects, and programs might have no edcation activities
- For FY14, Astrophysics is consolidating as follows.
  - STScI will consolidate education activities for COR missions including Hubble, JWST, and other COR activities, but excluding SOFIA and JPL/IPAC missions.
  - Chandra will consolidate education activities for PCOS missions including Chandra, Fermi, and other PCOS activities, but excluding JPL/IPAC missions.
  - ExEP Program Office at JPL will consolidate education activities for ExEP missions including Kepler, NExScI, other ExEP activities, as well as JPL/IPAC missions.
  - SOFIA –SOFIA will continue the Airborne Astronomy Ambassadors program for FY14 that was previously approved.

Major Activities for CY 2014

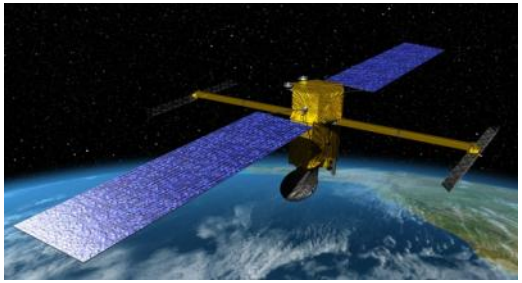
- ✓ Confirm **NICER** Explorer Mission of Opportunity (launch in 2016) (February 2014)
- ✓ Achieve **SOFIA** Full Operational Capability (FOC) milestone (March 2014)
- **Senior Review** for Operating Missions (March 2014)
- Deliver **ASTRO-**H soft X-ray spectrometer to JAXA (launch in 2015) (April 2014)
- Begin Euclid detector flight build (launch in 2020) (mid 2014)
- Complete and test **JWST** instrument suite (launch in 2018) (Summer 2014)
- AO for Small **Explorer** (SMEX) and Mission of Opportunity (Fall 2014)
- Complete **NuSTAR** prime mission (August 2014)
- Deliver **ISS-CREAM** for launch to Space Station (launch in 2014) (Fall 2014)
- Confirm **TESS** Explorer Mission (launch in 2017) (Fall 2014)
- Participate in ESA's **L2** (X-ray observatory) Mission Study (launch in 2028) (throughout 2014)
- Three **Balloon** campaigns in FY14
- Three **Sounding Rocket** launches in FY14

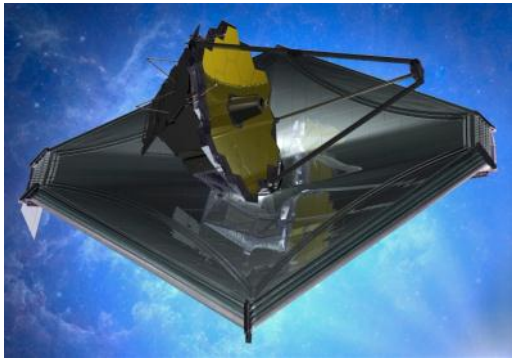
Science Mission Directorate

Outyears are notional

($M)	2013	2014	2015	2016	2017	2018	2019
Science	$4,782	$5,151	$4,972	$5,022	$5,072	$5,123	$5,174

- Supports the 2018 launch of the James Webb Space Telescope and pre-formulation of WFIRST/AFTA, including technology development for detectors and coronagraph.
- Continues formulation and development of Solar Probe Plus, the InSight, Mars Rover 2020, and MOMA/ExoMars missions to Mars, and the development of the robotic OSIRIS-REx mission to retrieve and return samples from an asteroid, as well as pre-formulation work for a potential mission to Jupiter's moon, Europa.
- Develops and implements plans for measurements of solar irradiance, ozone profiles, and Earth radiation budget, and maintains weather and climate change modeling capabilities to enhance forecast accuracy.
- Proposes placing SOFIA into storage due to its high operating cost and budget constraints, but funds about 35 missions currently preparing for launch, and sustains nearly 60 operating missions.





Astrophysics

Outyears are notional

($M)	2013	2014	2015	2016	2017	2018	2019
Astrophysics	$617	$668	$607	$634	$651	$697	$993
JWST	$627	$658	$645	$620	$569	$535	$305

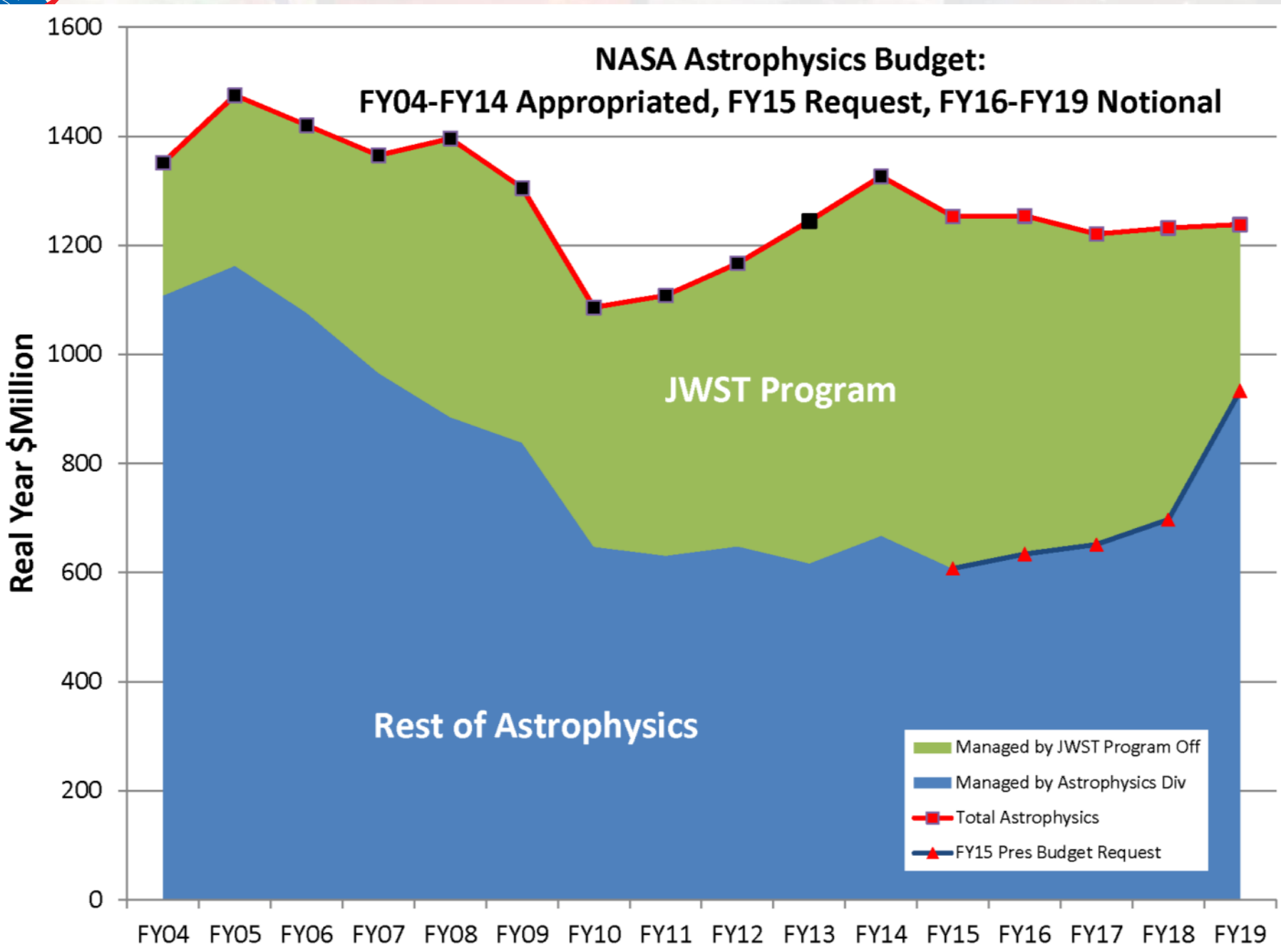
- Supports pre-formulation of WFIRST/AFTA, including technology development for detectors and coronagraph.
- Supports a growing Astrophysics Explorer program with continued development of ASTRO-H, NICER, and TESS, and initiation of the next Small Explorer mission.
- Supports operating missions: Hubble, Chandra, and other missions rated highly by the 2014 Senior Review.
- Continues a competed astrophysics research program and support of the balloon program.
- Seeks to work with current partner Germany and potential partners to identify a path forward for SOFIA with greatly reduced NASA funding. Unless partners are able to support the U.S. portion of SOFIA costs, NASA will place the aircraft into storage by FY 2015.
- Supports the commitment to an October 2018 launch date for JWST. Continues manufacturing of the flight sunshield structure and membranes. Completes and delivers the flight cryogenic cooler tower assembly. Delivers the Optical Telescope Element flight structure. Initiates integration of the 18 flight primary mirror segments. Conducts the final Integrated Science Instrument Module level cryo-vacuum test.

FY15 Planned Accomplishments

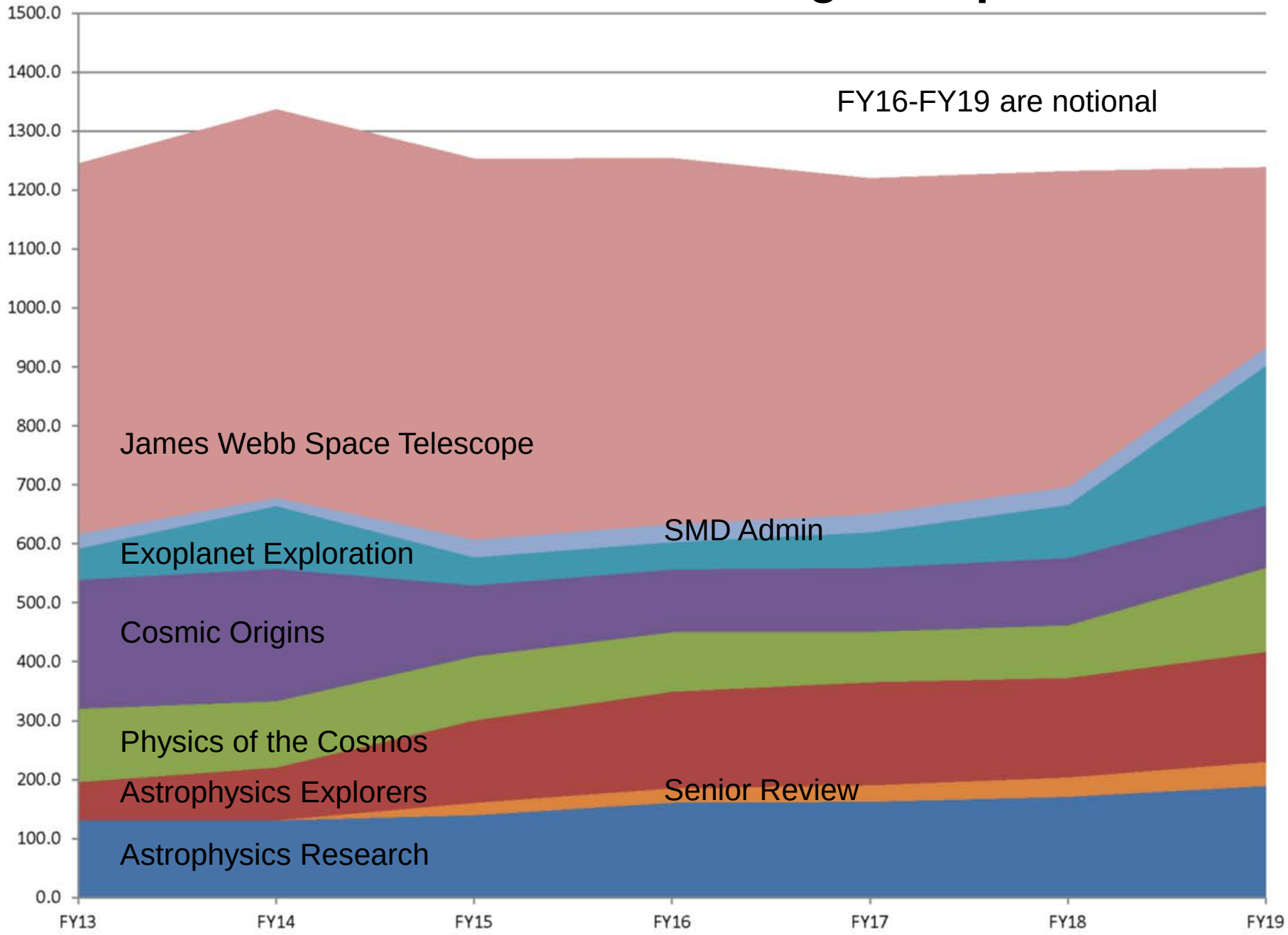
- The **TESS** Explorer Mission will be confirmed to begin implementation (KDP-C) in FY15
- The **ISS-CREAM** experiment will be launched to the International Space Station (KDP-E) in FY15
- The Step 1 selection (KDP-A) will be made for the next Small Astrophysics **Explorer** and Explorer Mission of Opportunity in FY15
- ESA's **LISA Pathfinder** with NASA's ST-7 experiment will launch (KDP-E) in FY15
- The **WFIRST/AFTA** science definition team report will be completed in FY15
- Manufacture, assembly, and test of the **Euclid** flight detectors will continue in FY15
- JAXA's **ASTRO-H** mission spacecraft system level test will take place in FY15
- The Astrophysics **Archives Senior Review** will be held in FY15
- **Hubble** will achieve 25 years of operation in FY15
- The NRC **Mid-Decade Review** will begin in FY15
- Four **Balloon** campaigns in FY15
- Five **Sounding Rocket** launches in FY15

Astrophysics FY 2015 Budget Request

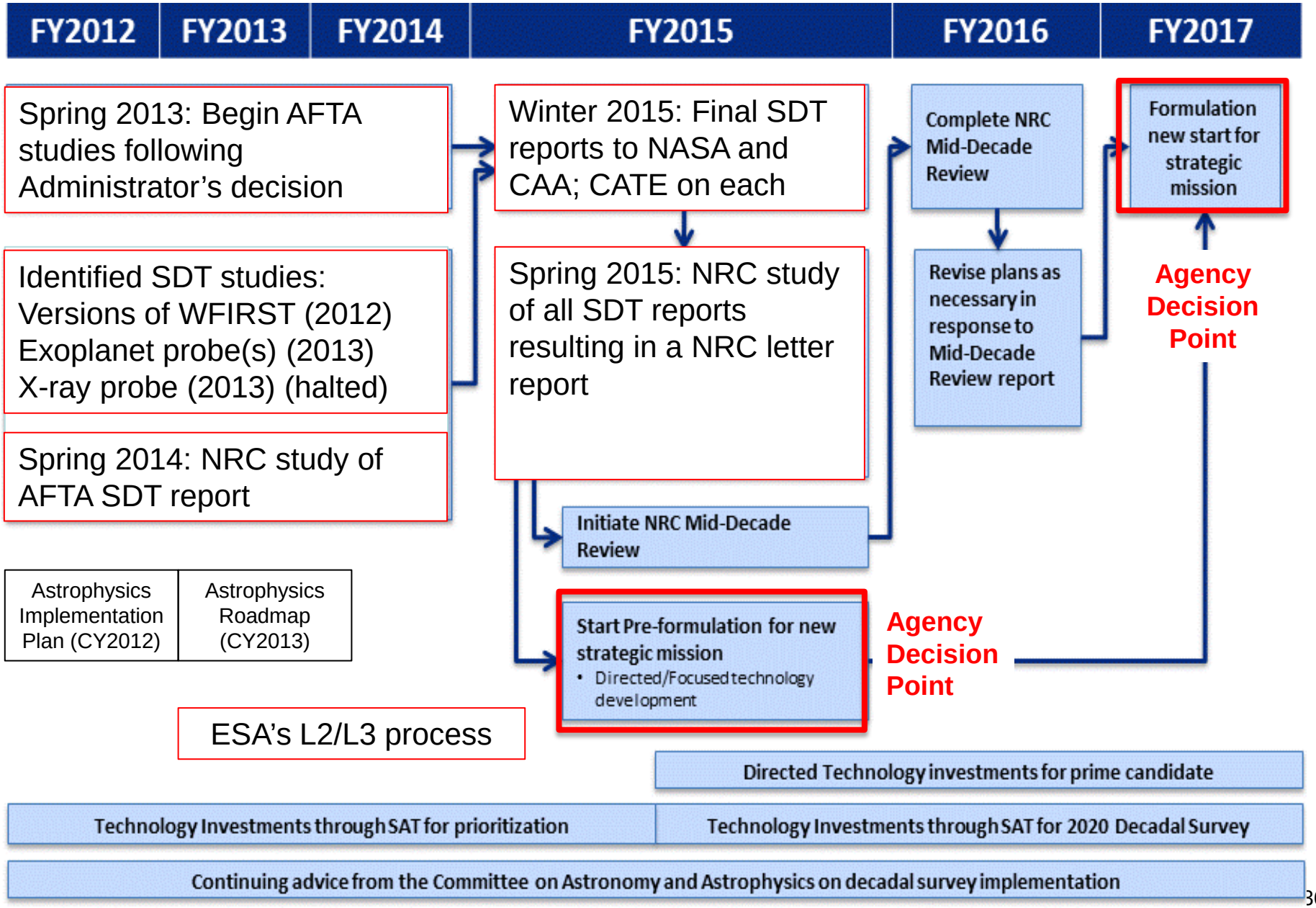
				Notional			
	FY 2013 Op Plan	FY 2014 Op Plan	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Astrophysics	617.0	668.0	607.3	633.7	651.2	696.8	993.0
Astrophysics Research	155.8	134.9	191.0	216.2	221.2	234.6	261.2
Cosmic Origins	218.9	224.2	120.3	106.4	108.2	114.2	105.8
Physics of the Cosmos	124.5	112.6	108.8	100.9	86.6	89.4	142.4
Exoplanet Exploration	52.8	106.7	47.5	46.4	60.4	89.8	237.3
Astrophysics Explorers	65.1	89.6	139.7	163.7	174.9	168.7	186.4
James Webb Space Telescope	627.6	658.2	645.4	620.0	569.4	534.9	305.0
Astrophysics + JWST	1,244.6	1,326.2	1,252.7	1,253.7	1,220.6	1,231.7	1,298.0


NASA Astrophysics Budget:
FY04-FY14 Appropriated, FY15 Request, FY16-FY19 Notional
Real Year $Million
1600
1400
1200
1000
800
600
400
200
0
JWST Program
Rest of Astrophysics
Managed by JWST Program Off
Managed by Astrophysics Div
Total Astrophysics
FY15 Pres Budget Request
FY04
FY05
FY06
FY07
FY08
FY09
FY10
FY11
FY12
FY13
FY14
FY15
FY16
FY17
FY18
FY19

President's FY15 Budget Request



Implementing the Decadal Survey



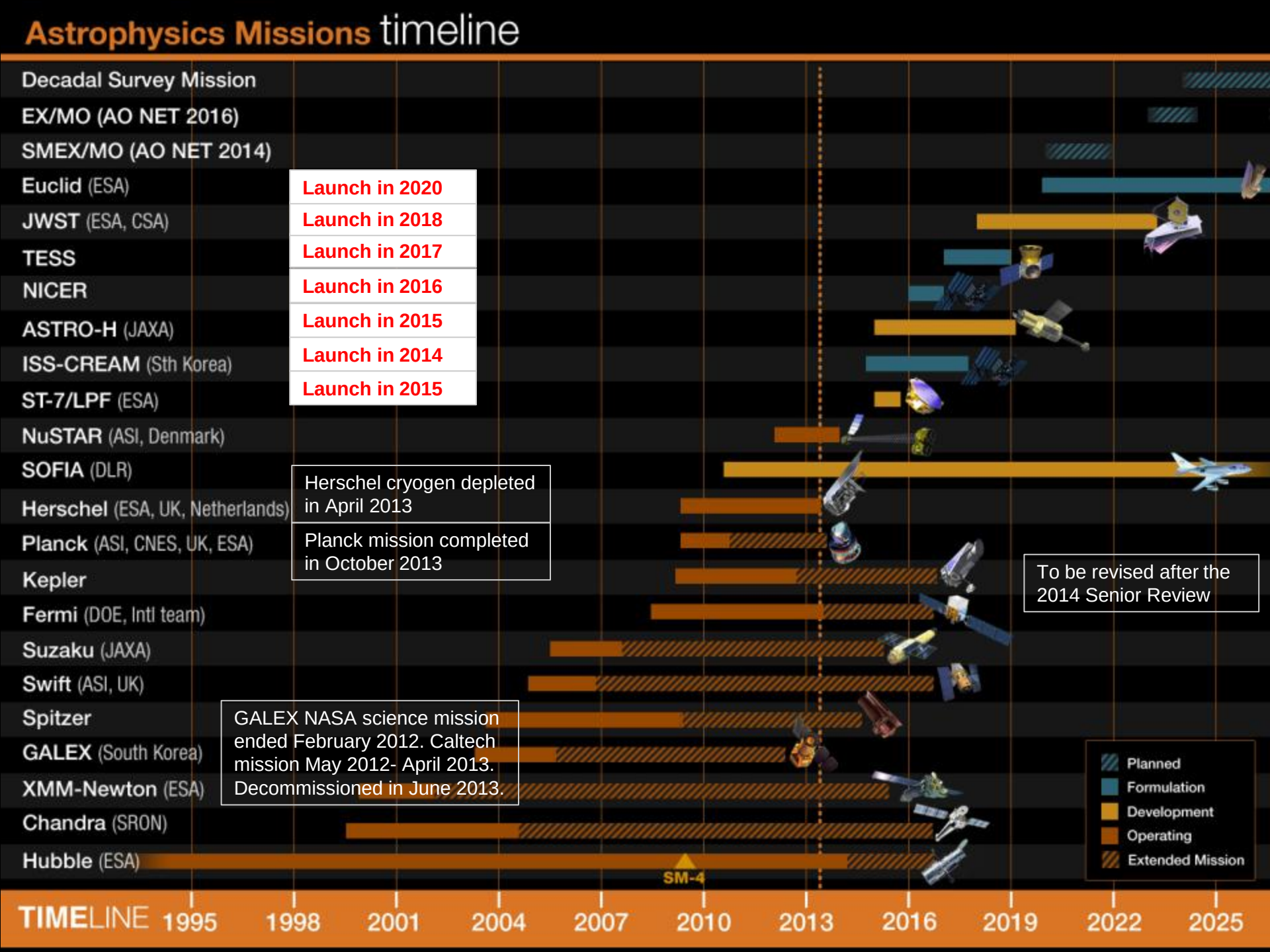
Looking toward the 2020 Decadal Survey

- Although it is too early to start getting ready for the next decadal survey, it is not too early for planning the budget necessary to get ready for the next decadal survey.
- What should NASA be budgeting for in FY17-FY20 that will help make the next decadal survey successful?
  - Mission concept studies for candidate large missions?
    - How identify? How assign the work?
  - Mission concept studies for candidate probe-class missions?
    - How identify? How assign the work?
  - Competed PI-led mission concept studies (as for the 2010 Astrophysics decadal survey) or directed mission concept studies with community based science definition teams (as for the 2011 Planetary Science decadal survey)?
  - Technology development investment strategy that is different from the one outlined in the 2010 decadal survey and currently being implemented?
  - Other activities?

2010 Process: Astrophysics Strategic Mission Concepts

- Solicitation part of ROSES-2007 (NNH07ZDA001N) – Appendix: D.12
  - Proposals due: November 20, 2007
  - Proposals received: 42
  - Selection: 19 selected for funding
  - Funding was $13.4M in FY08-FY09 (average grant was $ 700K)
- Outcome: Most of these ASMC grants were presented as White Paper responses to the 2010 Decadal Survey panels.
- Lessons Learned:
  - The ASMC produced useful products by delivering more matured and refined concepts with better science foundations and more sophisticated architectures.
  - The ASMC funding ($13M) demonstrated to industry that NASA was really interested in investing in future concepts. A ratio of 6:1 is often quoted as the ratio of industry investment and NASA's for new technologies.
  - The concepts generated in the ASMC 2010 solicitation will be around for a long time and will be the basis of new concepts and architectures (e.g., ATLAST, New Worlds -> Exo-S, EPIC -> Exo-C, etc). In that sense, it is too early to measure its impact.
  - The costs of some ASMC proposals were not adequately mature or credible.

Astrophysics Missions timeline



Backup


Formulation
Implementation
Primary Ops
Extended Ops
XMM-Newton (ESA)
12/10/1999
Swift
11/20/2004
Suzaku (JAXA)
7/10/2005
Fermi
6/11/2008
Euclid (ESA)
2020
JWST
2018
Hubble
4/24/1990
Kepler
3/6/2009
Spitzer
8/25/2003
ASTRO-H (JAXA)
2015
Chandra
7/23/1999
NICER (on ISS)
2016
NuSTAR
6/13/2012
TESS
2017
LISA Pathfinder (ESA)
2015
SOFIA
Full Ops 2014
Recently Completed
Planck 2013
Herschel 2013
GALEX 2013

FY 2015 Budget Request

	FY 2013 Op Plan*	FY 2014 Enacted**	Notional FY2015	FY2016	FY2017	FY2018	FY2019
Science	4,781.6	5,151.2	4,972.0	5,021.7	5,071.9	5,122.6	5,173.9
Earth Science	1,659.2	1,826.0	1,770.3	1,815.5	1,837.6	1,861.9	1,886.3
Planetary Science	1,274.6	1,345.0	1,280.3	1,304.9	1,337.1	1,355.7	1,374.1
Astrophysics	617.0	668.0	607.3	633.7	651.2	696.8	993.0
James Webb Space Telescope	627.6	658.2	645.4	620.0	569.4	534.9	305.0
Heliophysics	603.2	654.0	668.9	647.6	676.6	673.3	675.5
Aeronautics	529.5	566.0	551.1	556.6	562.2	567.8	573.5
Space Technology	614.5	576.0	705.5	712.6	719.7	726.9	734.2
Exploration	3,705.5	4,113.2	3,976.0	4,079.9	4,061.2	4,119.5	3,673.4
Exploration Systems Development	2,883.8	3,115.2	2,784.4	2,863.3	2,917.7	2,993.9	3,106.6
Commercial Spaceflight	525.0	696.0	848.3	872.3	791.7	730.9	172.0
Exploration Research and Development	296.7	302.0	343.4	344.3	351.8	394.7	394.7
Space Operations	3,724.9	3,778.0	3,905.4	3,951.9	4,051.0	4,073.8	4,601.8
Space Shuttle	38.8		0.0	0.0	0.0	0.0	0.0
International Space Station	2,775.9		3,050.8	3,126.5	3,266.9	3,290.3	3,818.6
Space and Flight Support (SFS)	910.2		854.6	825.4	784.1	783.5	783.2
Education	116.3	116.6	88.9	89.8	90.7	91.6	92.6
Cross Agency Support	2,711.0	2,793.0	2,778.6	2,806.4	2,834.4	2,862.8	2,891.4
Center Management and Operations	1,991.6		2,038.8	2,059.2	2,079.7	2,100.5	2,121.6
Agency Management and Operations	719.4		739.8	747.2	754.7	762.3	769.8
Construction & Envrmtl Compl Restoration	646.6	515.0	446.1	379.0	382.7	386.6	390.4
Construction of Facilities	589.5		370.6	302.7	305.7	308.7	311.8
Environmental Compliance and Restoration	57.0		75.5	76.3	77.0	77.8	78.6
Inspector General	35.3	37.5	37.0	37.4	37.7	38.1	38.5
Grand Total	**16,865.2**	**17,646.5**	**17,460.6**	**17,635.3**	**17,811.5**	**17,989.7**	**18,169.7**

FY 2013 includes rescissions per P.L.113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1); it also includes sequester per BBEDCA Section 215A, and August 2013 Operating Plan.

****FY 2014 reflects funding levels provided in P.L.113-76, Consolidated Appropriations Act, 2014.***

Note: Funds associated with out-year estimates for programmatic construction remain in programmatic accounts.

Astrophysics Program Content

	Op Plan	Enacted		Notional			
	FY13	FY14	FY15	FY16	FY17	FY18	FY19
Astrophysics	**617.0**	**668.0**	**607.3**	**633.7**	**651.2**	**696.8**	**933.0**
Astrophysics Research	155.8		191.0	216.2	221.2	234.6	261.2
Astrophysics Research and Analysis	65.0		66.0	70.2	71.5	71.5	71.5
Balloon Project	33.0	32.9	38.3	34.2	34.3	37.3	37.4
Other Missions and Data Analysis	57.8		86.6	111.8	115.3	125.8	152.2
Astrophysics Data Program	16.9		17.0	17.6	17.6	17.6	17.6
Astrophysics Data Curation and Archival	16.0		18.6	19.1	19.1	19.1	19.1
Astrophysics Senior Review			21.0	24.4	28.0	32.9	41.0
Education and Public Outreach	10.1		15.0	15.0	15.0	15.0	15.0
Contract Administration, Audit & QA Svcs	14.7		15.0	15.5	15.5	15.5	15.5
Astrophysics Directed R&T				20.3	20.1	25.8	44.1
Cosmic Origins	218.9		120.3	106.4	108.2	114.2	105.8
Hubble Space Telescope (HST)	93.3	98.3	75.3	91.8	88.2	92.3	83.9
SOFIA	77.5		12.3				
Other Missions and Data Analysis	48.1		32.7	14.6	20.0	21.9	21.9
SIRTF/Spitzer	15.3		14.2				
Herschel	21.1		5.5	2.7	1.0		
Cosmic Origins SR&T	8.6		8.8	8.2	15.2	17.0	17.0
Cosmic Origins Future Missions	0.3		1.6	1.0	1.0	2.0	2.0
Cosmic Origins Program Management	2.7		2.6	2.7	2.8	2.9	2.9

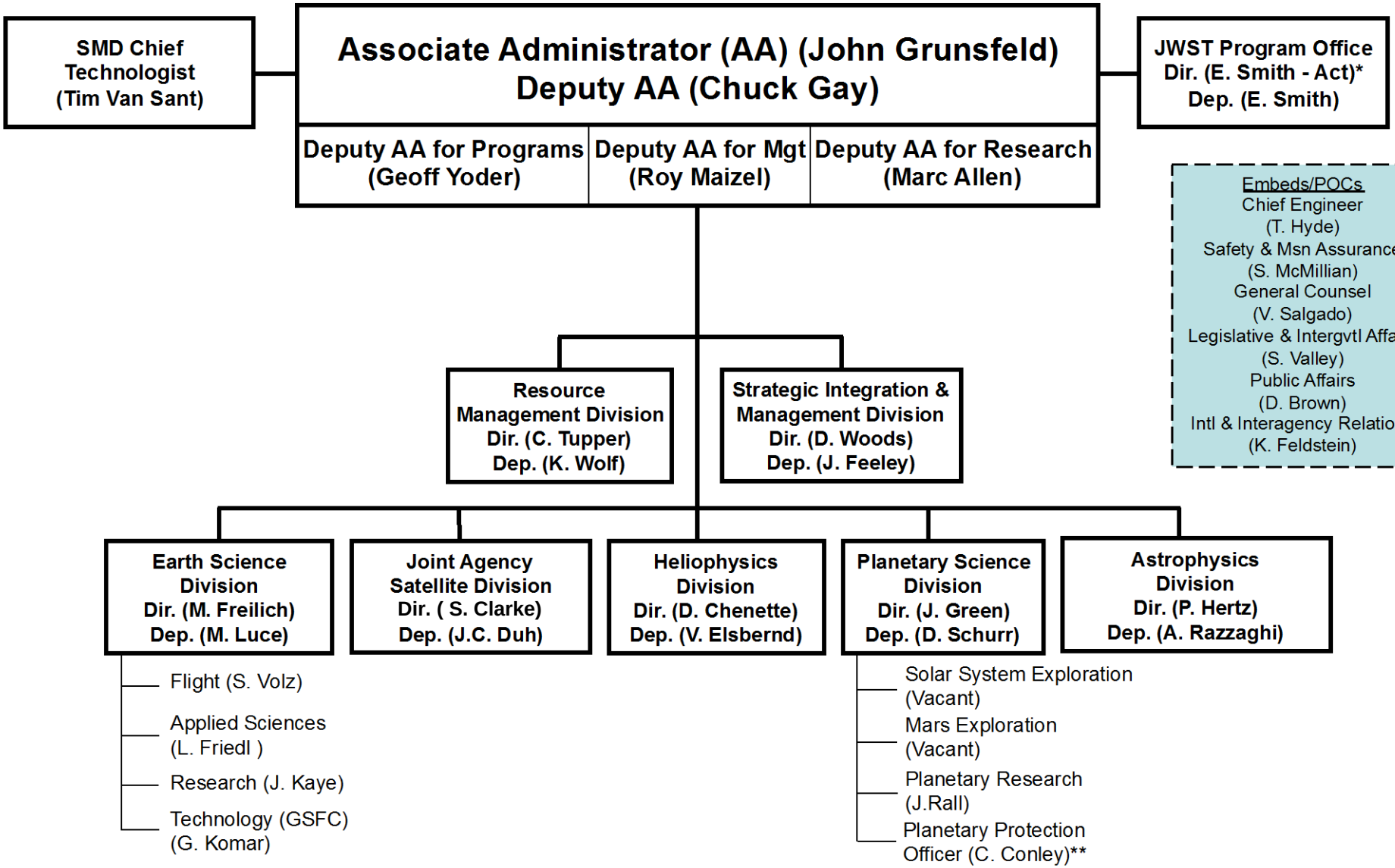
Astrophysics Program Content (cont'd)

	Op Plan	Enacted		Notional			
	FY13	FY14	FY15	FY16	FY17	FY18	FY19
Physics of the Cosmos	124.5		108.8	100.9	86.6	89.4	142.4
Euclid	13.8		15.0	7.3	5.9	5.9	6.0
Chandra X-Ray Observatory	57.3		55.8	55.4	55.6	55.6	55.6
Fermi Gamma-ray Space Telescope	24.9		18.6	18.6			
Planck	7.3		4.1				
XMM	1.9		1.0				
Physics of the Cosmos SR&T	15.9		10.6	15.8	21.1	22.8	34.7
Physics of the Cosmos Program Mgmt	2.9		2.8	2.8	2.9	3.0	3.0
Physics of the Cosmos Future Missions	0.4		1.0	1.0	1.1	2.1	43.0
Exoplanet Exploration	52.8		47.5	46.4	60.4	89.8	237.3
Kepler	19.1						
Keck Operations	5.7		6.0	6.1	6.1	6.2	6.2
Large Binocular Telescope Interferometer	2.6		2.0	1.1	1.3		
Astrophyics Decadal Strategic Mission		56.0	14.0	14.0	21.1	51.4	198.0
Exoplanet Exploration SR&T	20.5		17.8	18.2	24.9	25.1	25.2
Exoplanet Exploration Program Mgmt	4.2		5.8	5.8	5.8	6.0	5.9
Exoplanet Exploration Future Missions	0.7		2.0	1.2	1.1	1.0	2.0

Astrophysics Program Content (cont'd)

	Op Plan	Enacted		Notional			
	FY13	FY14	FY15	FY16	FY17	FY18	FY19
Astrophysics Explorer	65.1		139.7	163.7	174.9	168.7	186.4
Transiting Exoplanet Survey Satellite (TESS)	34.8		98.8	100.8	102.7	13.9	9.1
Other Missions and Data Analysis	30.3		40.9	63.0	72.2	154.7	177.2
Neutron Star Interior Composition Explorer	6.4		11.1	11.6	3.6	1.4	
Astro-H (SXS)	8.9		14.4	11.0	12.0	11.4	9.5
SWIFT	4.9		5.0	5.1			
Suzaku (ASTRO-E II)	0.3		0.3				
Nuclear Spectroscopic Telescope Array	1.9		0.4				
Gravity and Extreme Magnetism	2.0						
Wide-Field Infrared Survey Explorer	0.6						
Astrophysics Explorer Future Missions	0.6		5.6	28.0	49.1	134.9	163.3
Astrophysics Explorer Program Mgmt	4.8		4.0	7.2	7.6	7.1	4.4
James Webb Space Telescope	**627.6**	**658.2**	**645.4**	**620.0**	**569.4**	**534.9**	**305.0**
Astrophysics/JWST Total	**1244.6**	**1326.2**	**1252.6**	**1253.7**	**1220.6**	**1231.7**	**1238.0**

SMD Organization



* Direct report to NASA Associate Administrator
** Co-located from the Front Office

March 2014

Astrophysics Division - Science Mission Directorate

March 05, 2014

Resource Management
Omana Cawthon +
Clemencia Gallegos-Kelly +

Director
Paul Hertz
Deputy Director
Andrea Razzaghi

Lead Secretary: Kelly Johnson
Secretary: Leslie Allen
Program Support Specialist: Vacant

Cross Cutting

Technology Lead: William (Billy) Lightsey *
Division E/PO POC: Hashima Hasan (Lead Comm Team)
Division Public Affairs POC: Lisa Wainio *
Information Manager: Lisa Wainio *

Astrophysics Research

Program Manager: Linda Sparke
Program Support: Janet Larson *
Astrophysics Data Analysis: Debra Wallace *
Astrophysics Theory: Keith MacGregor *
Origins of Solar Systems: Larry Petro *
APRA lead: Michael Garcia *
Cosmic Rays, Fundamental Physics: Vernon Jones, Keith MacGregor *
Gamma Ray/X-ray: Michael Garcia *, Stefan Immler Lou Kaluzienski, Rita Sambruna, Wilt Sanders*
Optical/Ultraviolet: Michael Garcia *, Hashima Hasan, Mario Perez *
IR/Submillimeter/Radio: Dominic Benford *, Doug Hudgins, Larry Petro *, Eric Tollestrup *, Glenn Wahlgren*
Lab Astro: Glenn Wahlgren*
Data Archives: Hashima Hasan
Astrophysics POC for Sounding Rockets: Wilt Sanders *
Balloons Program: Vernon Jones (PS), Mark Sistilli (PE)

Programs / Missions

	Program Scientist	*Program Executive*
Exoplanet Exploration (EXEP)		
Program	**Doug Hudgins**	**John Gagosian**
Keck	Hashima Hasan	Mario Perez *
Kepler	Doug Hudgins	John Gagosian
LBTI	Hashima Hasan	Mario Perez *
NExScI	Hashima Hasan	Mario Perez *
Cosmic Origins (COR)		
Program	**Mario Perez ***	**Lia Lapiana**
Herschel	Glenn Wahlgren *	John Gagosian
Hubble	Michael Garcia *	John Gagosian
JWST	Hashima Hasan	N/A
SOFIA	Glenn Wahlgren *	John Gagosian
Spitzer	Glenn Wahlgren *	Jeff Hayes *
Physics of the Cosmos (PCOS)		
Program	**Rita Sambruna**	**Lia LaPiana**
Chandra	Wilt Sanders *	Jeff Hayes
Euclid	Linda Sparke	Jeff Hayes
Fermi	Keith MacGregor *	Jeff Hayes
Planck	Rita Sambruna	Jeff Hayes
ST-7/LPF	Wilt Sanders *	Jeff Hayes
XMM-Newton	Lou Kaluzienski	Jeff Hayes
Astrophysics Explorers (APEX)		
Program	**Wilt Sanders ***	**Mark Sistilli**
ASTRO-H	Lou Kaluzienski	Jeanne Davis*
NICER	Rita Sambruna	Jeanne Davis *
NuSTAR	Lou Kaluzienski	Jeff Hayes *
Suzaku	Lou Kaluzienski	Jeff Hayes *
Swift	Michael Garcia *	Jeff Hayes *
TESS	Doug Hudgins	Mark Sistilli
WISE	Hashima Hasan	N/A
AFTA Study	Dominic Benford *	Lia LaPiana

+ Member of the Resources Mgmt Division
** Detailee, IPA, or contractor*
JWST now part of the JWST Program Office.

Anne-Marie Novo-Gradac on detail to the SMD Front Office.