National Aeronautics and Space Administration

Astrophysics




NRC Midterm Review Committee
Fourth Meeting
Washington DC
February 26, 2016

Paul Hertz
Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

What's New?

- LISA Pathfinder launched on December 3, 2015
- NASA's FY16 budget appropriation signed on December 18, 2015
- NASA's FY17 budget requested submitted on February 9, 2016
- Hitomi (neé ASTRO-H) launched on February 17, 2016
- WFIRST began formulation on February 17, 2016
- ROSES-16 released on February 19, 2016

LISA Pathfinder
ST-7/Disturbance Reduction System (DRS)

Dec 3	Launch ✓
Dec 11	On way to L1 ✓
Jan 22	Arrive at L1 ✓
Feb 3	Uncage test masses ✓
Feb 15	Test mass 1 “Elwood” release ✓
Feb 16	Test mass 2 “Jake” release ✓
Mar 1	Begin LTP operations (90 days)
Jun 20	Begin DRS operations (90 days)
Sep 20	ESA mission extension review

http://sci.esa.int/lisa-pathfinder/
https://lisapathfinder.org/

NASA's Plans for a GW Observatory

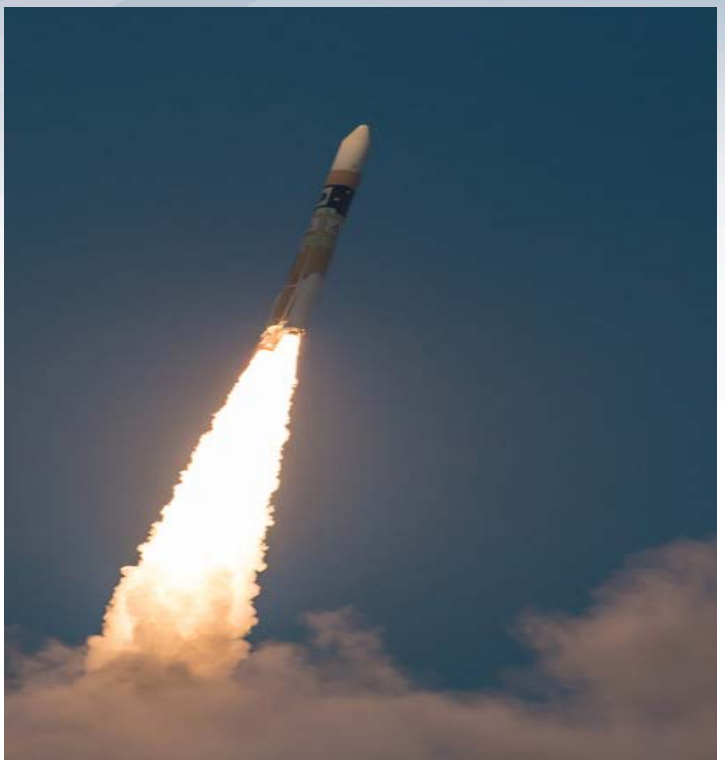
Implications of the LIGO detection and announcement: it is about funding and priorities and timing.

- Either we do a US-led LISA, or we participate in ESA's L3 gravitational wave observatory. If we do a US-led LISA, then we do it either before or after WFIRST.
  - We are not doing it before WFIRST, because the Decadal Survey said WFIRST was the higher priority.
  - We could consider a US-led LISA after WFIRST if the 2020 Decadal Survey makes it the top priority for the large mission to follow WFIRST.
  - ESA plans to launch L3 in 2034.
- Possible outcomes from the 2020 Decadal Survey regarding a space based GW observatory
  - Continue on the path we are on for a 10% share of L3 in 2034.
  - Increase our share to ensure that the third arm is reinstated and that more US technology is included, subject to ESA approval. This would require the Decadal Survey to allocate a medium-size mission priority to a US share in L3. This gets a better L3 at the expense of not doing something else in the NASA portfolio.
- By the time of the 2020 Decadal Survey, we will have
  - Outcome of LISA Pathfinder (so far so good but not successful yet).
  - Another 4 years of LIGO results to inform our priorities for GW observatories beyond LIGO.

NASA's L3 Study

- NASA intends to partner with ESA on the ESA-led L3 gravitational wave mission with launch in 2034. This responds to the recommendations of the 2010 Astrophysics Decadal for a space-based gravitational wave observatory.
- Following the successful launch of the LISA Pathfinder, NASA has formed an L3 Study Team (L3ST) drawing membership from members of the US astrophysics community.
- The goals of the L3ST are:
  1. Analyze the options for NASA participation in the L3 mission and work with the European L3 consortium on proposals to ESA; and
  2. Prepare a report to the 2020 Decadal Survey on NASA's participation, including possible options, in the L3 mission as a minority partner.
- 15 members (plus 6 member technology analysis group). David Shoemaker (MIT) is Chair. ESA has appointed an observer.
- The L3ST Charter and list of selected members can be found at **http://pcos.gsfc.nasa.gov/studies/L3**.

Hitomi (ASTRO-H)
Soft X-ray Spectrometer (SXS)

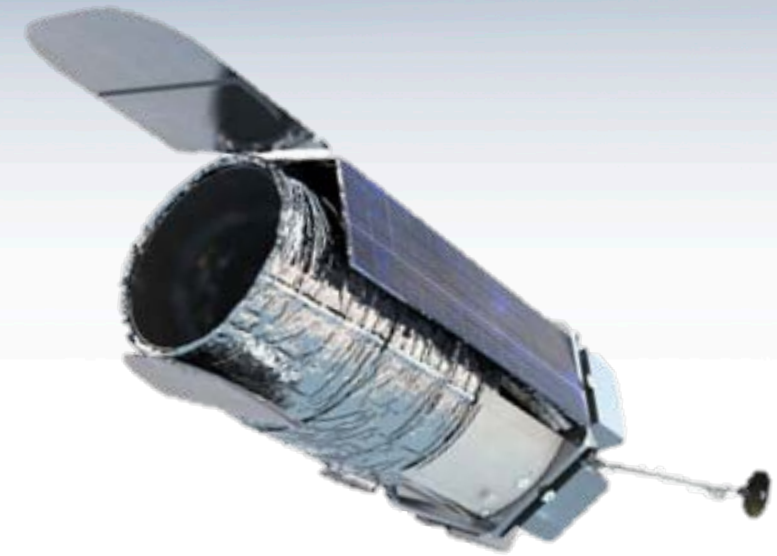


- ASTRO-H successfully launched on Feb 17, 2016 from Tanegashima Space Center on a H-IIA launch vehicle.
- The word Hitomi translates into "eye" or "pupil" hence the spacecraft has become the aperture with which to see the secrets of the universe.
  - o Feb 25 SXS first light
  - o Feb 28 Deployment of extensible optical bench
  - o Apr 1 Release of Cycle 1 GO call-for-proposals in ROSES (target)

https://heasarc.gsfc.nasa.gov/docs/astroh/

WFIRST

Wide-Field Infrared Survey Telescope



Wide-Field Infrared Survey Telescope

Top priority of 2010 Decadal Survey

Science themes: Dark Energy, Exoplanets, Large Area Near Infrared Surveys

Mission: 2.4m widefield telescope at L2; using existing hardware, images 0.28deg^2 at 0.8-2μm

Instruments (design reference mission): Wide Field Instrument (camera plus IFU), Coronagraph Instrument (imaging/IFS)

Phase: Currently in Formulation (Phase A)

CURRENT STATUS:

- Completed Mission Concept Review (MCR) held in December 2015
- Formulation Science Investigation Teams selected in December 2015
- Industry RFI released July 2015; RFP for industry studies released in January 2016; Proposals received from industry in February 2016 to support Wide-field Instrument Concept Study.
- Passed Key Decision Point A (KDP-A) in Feb 2016
  - Official start of formulation phase
  - Supported by FY16 appropriation and FY17 request
  - Developed and signed Formulation Authorization Document (FAD), Project Formulation Agreement (PFA), and preliminary Program Level Requirements Appendix (PLRA).
  - Successful KDP-A DPMC held January 26, 2016.
  - Successful KDP-A APMC held February 17, 2016.
- Schedule under revision to account for FY16 appropriation of $90M and FY17 budget request of $90M.

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

WFIRST has begun Formulation

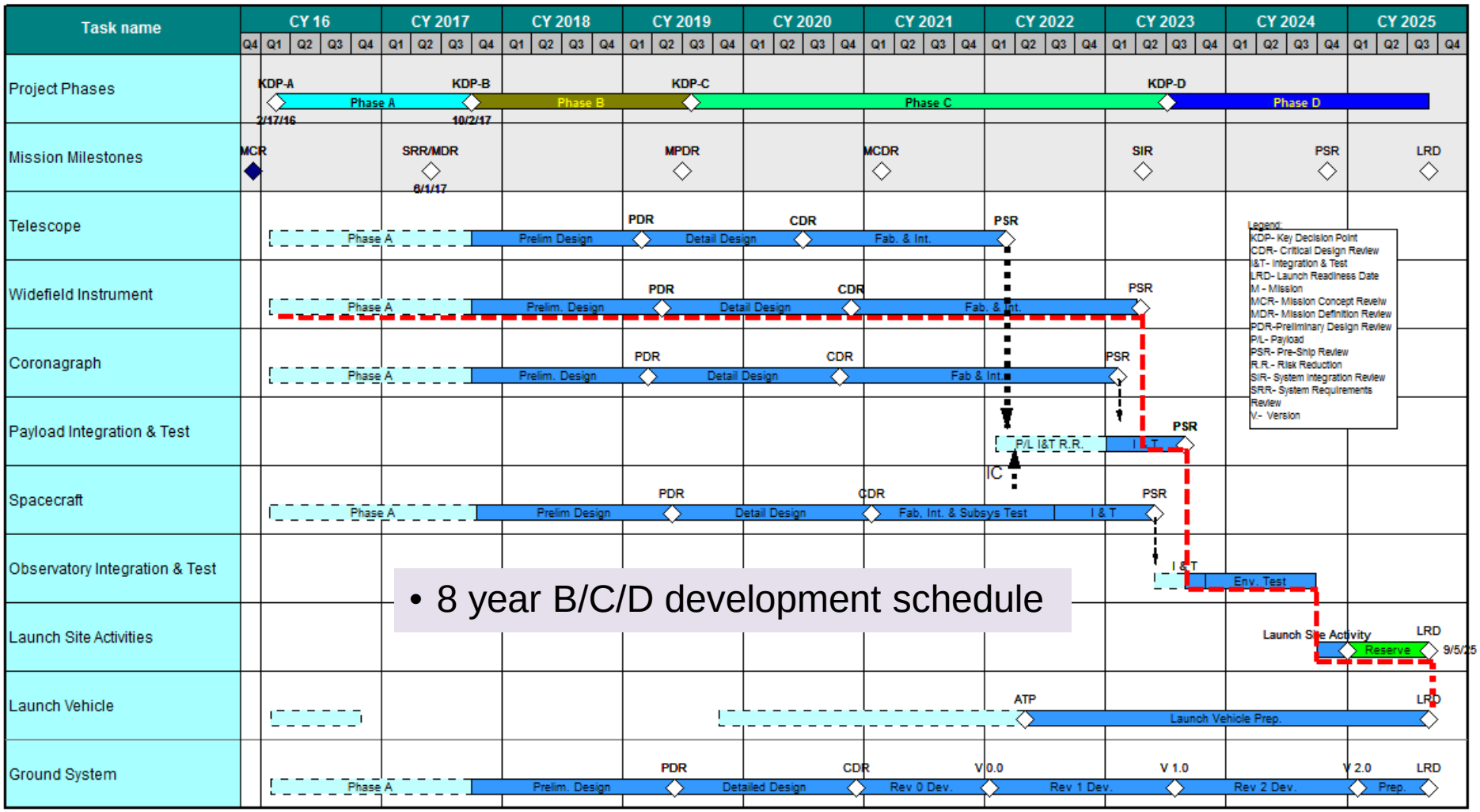
WFIRST KDP-A Budget Estimates (1 of 2)

- WFIRST mission life-cycle cost was updated for MCR design configuration and the Key Decision Point A (KDP-A) process.
- Cost growth was realized for the following changes:
  - Increased estimated launch vehicle costs
  - Increased science team funding – 5 year profile increased prior to ROSES call; additional awards made in SNe, coronagraph, and GO
  - Wide Field instrument changes: aux guider, Relative Calibration System, IFU detector redundancy, structural mass
  - Telescope outer barrel assembly design refinement
  - L2 changes: 4 large propellant tanks, associated structure, solid state recorder, Travelling Wave Tube Amplifier, larger antenna, associated thermal hardware, blankets, heat pipes
  - Phase A extended due to earlier KDP-A and increased formulation time to award and execute Wide Field competitive study contracts
  - Funding for Wide Field industry studies
  - Reserve on the above
- Total cost of changes approximately $300M.
  - The changes associated with the orbit change to L2 are ~$45M of the increase.

WFIRST KDP-A Budget Estimates (2 of 2)

- The current WFIRST budget guideline is constrained in FY18-20. As a result, the Project is working two development profiles.
- The life-cycle estimate for the 2024 launch date (an over-guide budget profile) is $2.3B to $2.5B in FY15$.
- The life-cycle estimate for the 2025 launch date in-guide scenario is $2.6B to $2.8B in FY15$.
- In real year dollars, the total mission cost range is $2.7B to $3.2B for the range of launch dates and launch vehicles.
- Budget includes STMD funding in FY16-FY17 for the coronagraph technology. STMD considering funding portion of coronagraph flight development.
- International contributions – discussions in process for potential contributions Europe/ESA, Canada, and Japan. Contributions include elements of wide field instrument, coronagraph instrument, and ground system.

Mission Schedule – 2025 LRD In-Guide Schedule



- 8 year B/C/D development schedule

FY16 Appropriation

Outyears are notional planning from FY16 President's budget request

($M)	2014	2015	2016	2017	2018	2019	2020
Astrophysics*	$678	$685	$731	$707	$750	$986	$1118
JWST	$658	$645	$620	$569	$535	$305	$198
Total	$1336	$1330	$1351	$1273	$1285	$1291	$1316

*** Excludes "SMD STEM Activities" in all years.**

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

($M)	FY16 Request	FY16 Approps	Delta
JWST	$620	$620	--
WFIRST	$14	$90	+$76
SOFIA	$85	$85	--
Hubble	$97	$98	+$1
Rest of Astrophys*	$493	$457	-$36 (-7%)
Total	$1309	$1351	+$42

* Excludes "SMD STEM Activities."

FY17 Budget Request

Outyears are notional planning from FY17 budget request

($M)	2015	2016	2017	2018	2019	2020	2021
Astrophysics*	$685	$731	$757	$737	$967	$1094	$1168
JWST	$645	$620	$569	$534	$305	$197	$150
Total*	$1330	$1351	$1326	$1271	$1272	$1291	$1318

*** Excludes "SMD STEM Activities" in all years.**

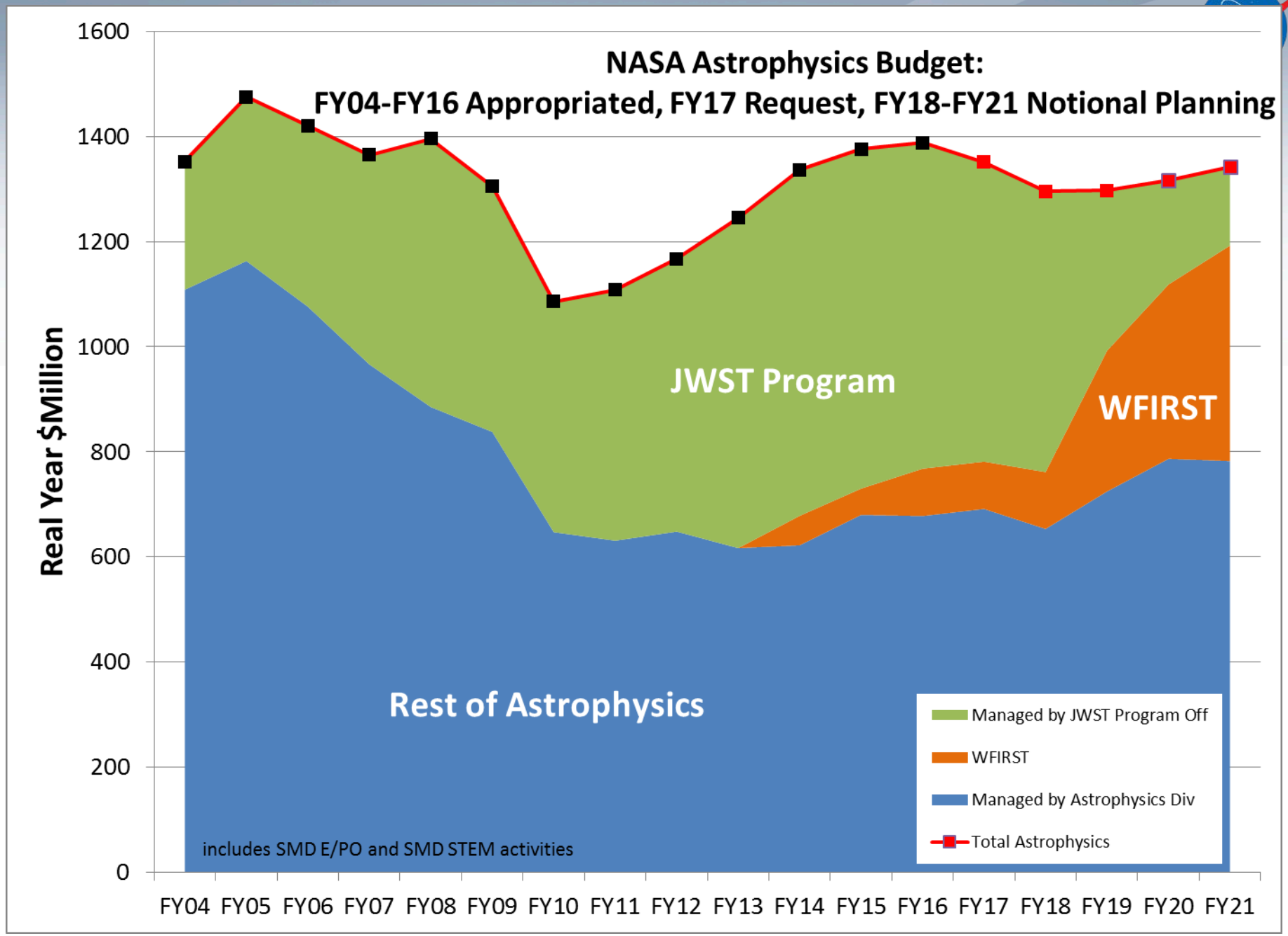
- Supports the commitment of an October 2018 launch date for JWST.
  - Delivers the Optical Telescope element/Integrated Science (OTIS) instrument module to Johnson Space Center for testing.
  - Conducts OTIS cryovacuum testing;
  - Integrates the cryocooler compressor assembly into the spacecraft bus.
  - Delivers the flight solar array to the observatory for integration.
- Formulates the WFIRST/AFTA mission.
- Continues development of the TESS exoplanet mission for launch by FY18.
- Supports operating mission extensions, subject to the results of the 2018 Senior review.
- Enables down selection of next Astrophysics Small Explorer mission, and selection of next Astrophysics Medium Explorer mission concepts for competitive study.
- Increases support for research and analysis.

FY17 Budget Request

	Astrophysics	JWST	STEM	Astrophysics including JWST excluding STEM	Astrophysics including JWST including STEM
FY16 appropriation	$731M excluding STEM	$620M	$37M	$1351M	$1388M
FY17 notional runout of FY16 request	$727M including STEM	$569M	$20M	$1276M	$1296M
FY17 request	$782M including STEM	$569M	$25M	$1326M	$1351M

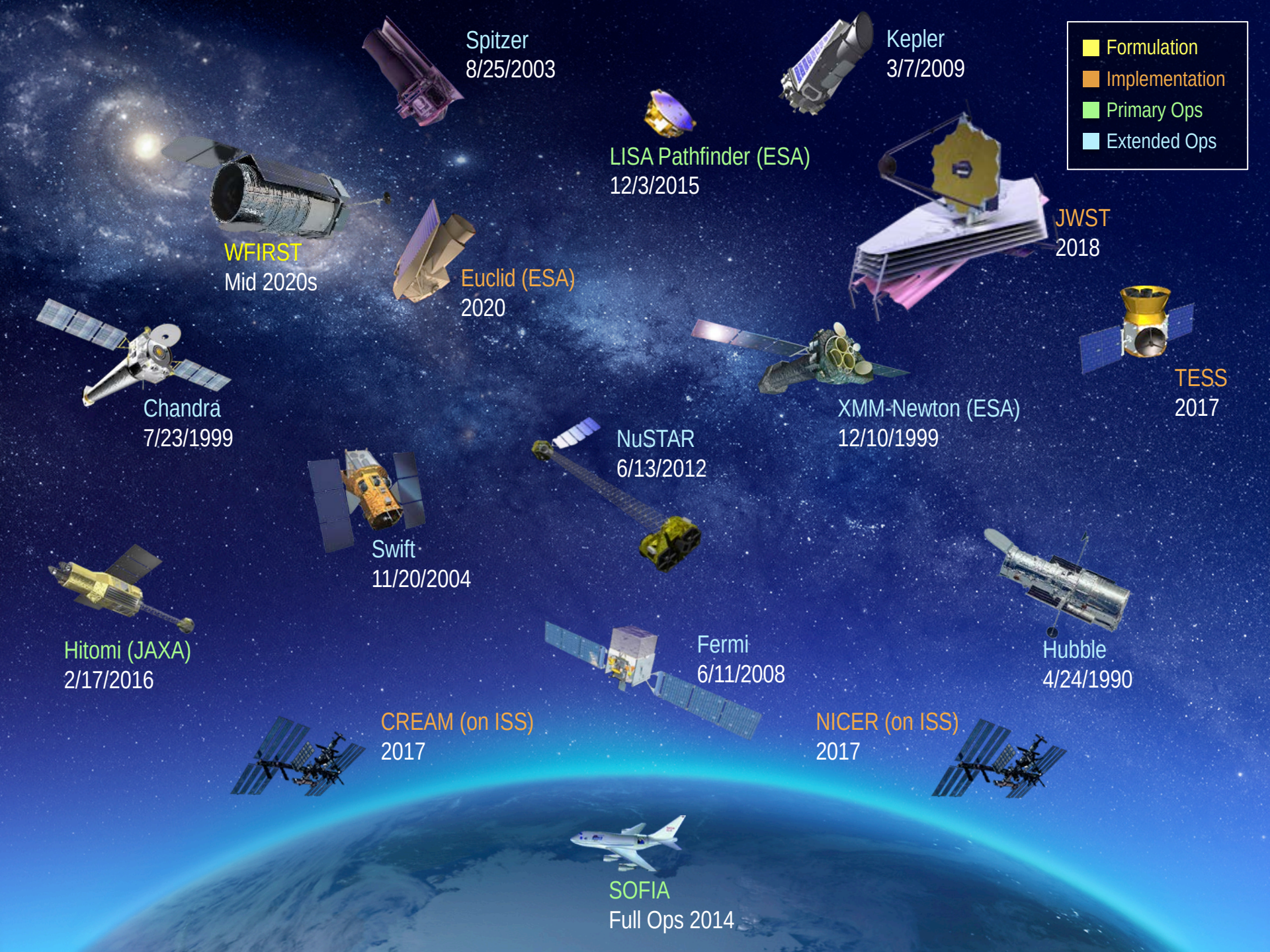
Astrophysics Budget Details

- This budget request is an excellent budget request for NASA Astrophysics ($1,326M excluding STEM).
  - It compares well with the FY16 Appropriation ($1,351M excluding STEM) and significantly exceeds the FY17 notional runout in the President's FY16 request for NASA Astrophysics including JWST ($1,276M excluding STEM).
- This budget request and the notional runout allows WFIRST to be executed without additional funding.
  - At NASA, we would say that WFIRST can be executed within the guidelines.
- This budget request and the notional runout support other Decadal Survey priorities
  - Continued Explorer AOs at the Decadal Survey cadence of 4 per decade
  - Partnerships on ESA's Athena X-ray observatory and L3 gravitational wave observatory
  - Precursor exoplanet science and technology including Large Binocular Telescope Interferometer, Extreme Precision Doppler Spectrometer, and WFIRST Coronagraph
  - Retains prior growth in R&A and suborbital programs
- Senior Review funding may be inadequate to continue all currently operating missions.
  - FY16 budget for Six Senior Review missions is $62M. FY17 Senior Review budget is $37M.


NASA Astrophysics Budget:
FY04-FY16 Appropriated, FY17 Request, FY18-FY21 Notional Planning
Real Year $Million
1600
1400
1200
1000
800
600
400
200
0
JWST Program
WFIRST
Rest of Astrophysics
includes SMD E/PO and SMD STEM activities
Managed by JWST Program Off
WFIRST
Managed by Astrophysics Div
Total Astrophysics
FY04 FY05 FY06 FY07 FY08 FY09 FY10 FY11 FY12 FY13 FY14 FY15 FY16 FY17 FY18 FY19 FY20 FY21

CY16 and FY17 Planned Accomplishments

- JAXA's **Hitomi** (nee ASTRO-H**)** mission launched (KDP-E) on February 17, 2016.
- **WFIRST** entered formulation (KDP-A) on February 17, 2016.
- The main panel of the **Astrophysics Senior Review** was held in February 2016. The **Fermi Gamma-ray Space Telescope, Nuclear Spectroscopic Telescope Array (NuSTAR), Spitzer Space Telescope, Swift Explorer,** and **XMM-Newton** being reviewed.
- The **Astrophysics Senior Review** for the **Hubble Space Telescope** and **Chandra X-ray Observatory** will be held in March 2016.
- **NICER** will be delivered to Kennedy Space Center by August 2016 and launched to the International Space Station (KDP-E) on CRS SpaceX-11 in FY17.
- Commissioning flights for the second-generation High-resolution Airborne Wideband Camera (HAWC+) instrument will be completed aboard **SOFIA** by August 2016.
- An Announcement of Opportunity (AO) for the next **Astrophysics Medium-Class Explorer (MIDEX)** and **Mission of Opportunity** will be released in FY16 [NET September 2016]
- The payload for **TESS** will be integrated and tested (KDP-D) by September 2016.
- The Step 2 downselect will be made for the next **Astrophysics Small Explorer (SMEX)** and **Explorer Mission of Opportunity** in FY17 [NET December 2016].
- The **ISS-CREAM** experiment will be launched to the International Space Station (KDP-E) on CRS SpaceX-12 in FY17.
- A critical design review for **SOFIA**'s third-generation instrument will be conducted in FY17.
- Spacecraft integration and testing will be completed for **TESS** in FY17.
- WFIRST will have its system readiness review (KDP-B) in FY17.
- Four **Balloon** campaigns are planned in FY16, and three campaigns are planned in FY17
- Three Astrophysics **Sounding Rocket** payloads are planned in FY16, and two are planned in FY17.


Formulation
Implementation
Primary Ops
Extended Ops
Spitzer
8/25/2003
Kepler
3/7/2009
LISA Pathfinder (ESA)
12/3/2015
JWST
2018
WFIRST
Mid 2020s
Euclid (ESA)
2020
TESS
2017
Chandra
7/23/1999
XMM-Newton (ESA)
12/10/1999
NuSTAR
6/13/2012
Swift
11/20/2004
Hitomi (JAXA)
2/17/2016
Fermi
6/11/2008
Hubble
4/24/1990
CREAM (on ISS)
2017
NICER (on ISS)
2017
SOFIA
Full Ops 2014

Astrophysics




BACKUP

Astrophysics Program Content

	Actual FY 2015	Enacted FY 2016	Request FY 2017	Notional FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021
Astrophysics	**730.7**		**781.5**	**761.6**	**992.4**	**1,118.6**	**1,192.5**
Astrophysics Research	201.7		226.1	236.3	235.7	248.5	252.0
Science Education	42.0		25.0	25.0	25.0	25.0	25.0
Astrophysics Research and Analysis	71.1		72.7	73.0	73.0	73.0	73.0
Balloon Project	38.0		37.0	37.3	37.4	38.9	40.4
Other Missions and Data Analysis	50.6		91.4	101.0	100.3	111.6	113.6
Astrophysics Data Curation and Archival	18.6		17.8	18.8	18.9	18.9	18.9
Astrophysics Data Program	17.0		17.6	17.6	17.6	17.6	17.6
Astrophysics Senior Review	-		37.4	49.3	40.5	33.6	34.0
Contract Administration, Audit & QA Svcs	15.0		14.9	15.0	15.0	15.1	15.1
Astrophysics Directed R&T	-		3.7	0.2	8.4	26.4	28.1
Cosmic Origins	201.0		198.5	198.4	197.3	195.5	209.5
Hubble Space Telescope (HST)	98.6		97.3	98.3	98.3	98.3	98.3
Stratospheric Observatory for Infrared Astronon	70.0		83.8	84.8	84.8	84.8	84.8
Other Missions and Data Analysis	32.4		17.4	15.3	14.2	12.4	26.4
Cosmic Origins Future Missions	1.2		1.1	1.5	1.5	1.5	1.5
Spitzer	14.6		3.5	-	-	-	-
Herschel	5.1		1.0	-	-	-	-
Cosmic Origins SR&T	8.8		9.3	10.9	9.8	8.0	22.0
Cosmic Origins Program Management	2.6		2.5	2.9	2.9	2.9	2.9

Astrophysics Program Content (cont'd)

	Actual FY 2015	Enacted FY 2016	Request FY 2017	Notional FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021
Physics of the Cosmos	104.1		94.1	88.0	94.1	97.7	94.0
Physics of the Cosmos Future Missions	0.1		0.5	2.1	2.1	2.5	2.5
Euclid	7.5		12.9	7.5	7.7	9.9	6.1
Chandra X-Ray Observatory	55.6		52.4	56.7	57.4	58.4	58.4
Fermi Gamma-ray Space Telescope	16.9		-	-	-	-	-
XMM	2.9		-	-	-	-	-
Planck	6.0		-	-	-	-	-
Physics of the Cosmos SR&T	12.0		25.4	18.5	23.7	23.8	23.9
Physics of the Cosmos Program Management	3.0		2.9	3.2	3.2	3.2	3.2
Exoplanet Exploration	100.6		133.8	148.0	309.3	373.3	450.8
Decadal Strategic Mission (WFIRST)	50.0		90.0	108.2	267.7	331.8	409.9
Exoplanet Exploration Future Missions	0.9		0.5	1.1	8.2	8.3	8.3
Kepler	17.2		2.8	-	-	-	-
Keck Operations	6.0		6.1	6.2	-	-	-
Large Binocular Telescope Interferometer	2.0		1.3	-	-	-	-
Exoplanet Exploration SR&T	19.4		28.0	26.5	27.6	26.9	26.2
Exoplanet Exploration Program Management	5.1		5.1	6.0	5.9	6.3	6.4

Astrophysics Program Content (cont'd)

	Actual FY 2015	Enacted FY 2016	Request FY 2017	Notional FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021
Astrophysics Explorer	123.3		129.0	91.0	156.0	203.5	186.2
Transiting Exoplanet Survey Satellite (TESS)	80.1	73.5	87.0	27.9	9.1	2.5	0.0
Other Missions and Data Analysis	43.2		42.0	63.1	146.9	201.1	186.2
Astrophysics Explorer Future Missions	1.1		16.8	42.7	132.2	192.6	178.5
ASTRO-H (SXS)	11.3		12.0	11.4	9.5	-	-
NICER	11.7		3.5	1.3	-	-	-
Nuclear Spectroscopic Telescope Array	7.4		-	-	-	-	-
Swift	4.9		-	-	-	-	-
Suzaku (ASTRO-E II)	0.6		-	-	-	-	-
Astrophysics Explorer Program Management	6.2		9.8	7.7	5.1	8.5	7.7
James Webb Space Telescope	**645.4**	**620.0**	**569.4**	**533.7**	**304.6**	**197.2**	**149.8**
Astrophysics + Webb Total	**1,376.1**		**1,350.9**	**1,295.3**	**1,297.0**	**1,315.8**	**1,342.3**