



NASA Astrophysics Division Update

Committee on Astronomy and
Astrophysics

April 1, 2015

Astrophysics

Paul Hertz

Director, Astrophysics Division
Science Mission Directorate

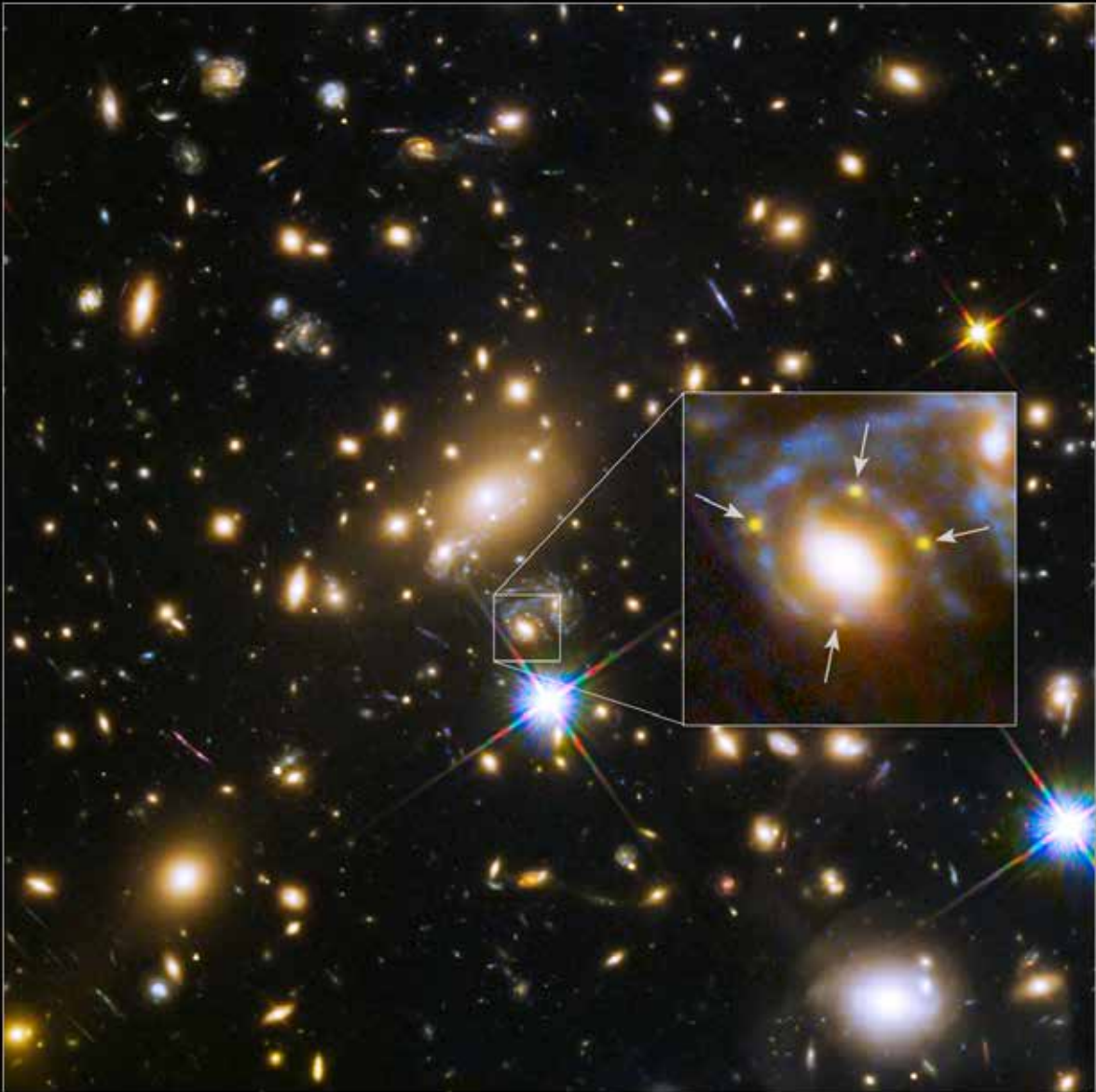
[@PHertzNASA](#)

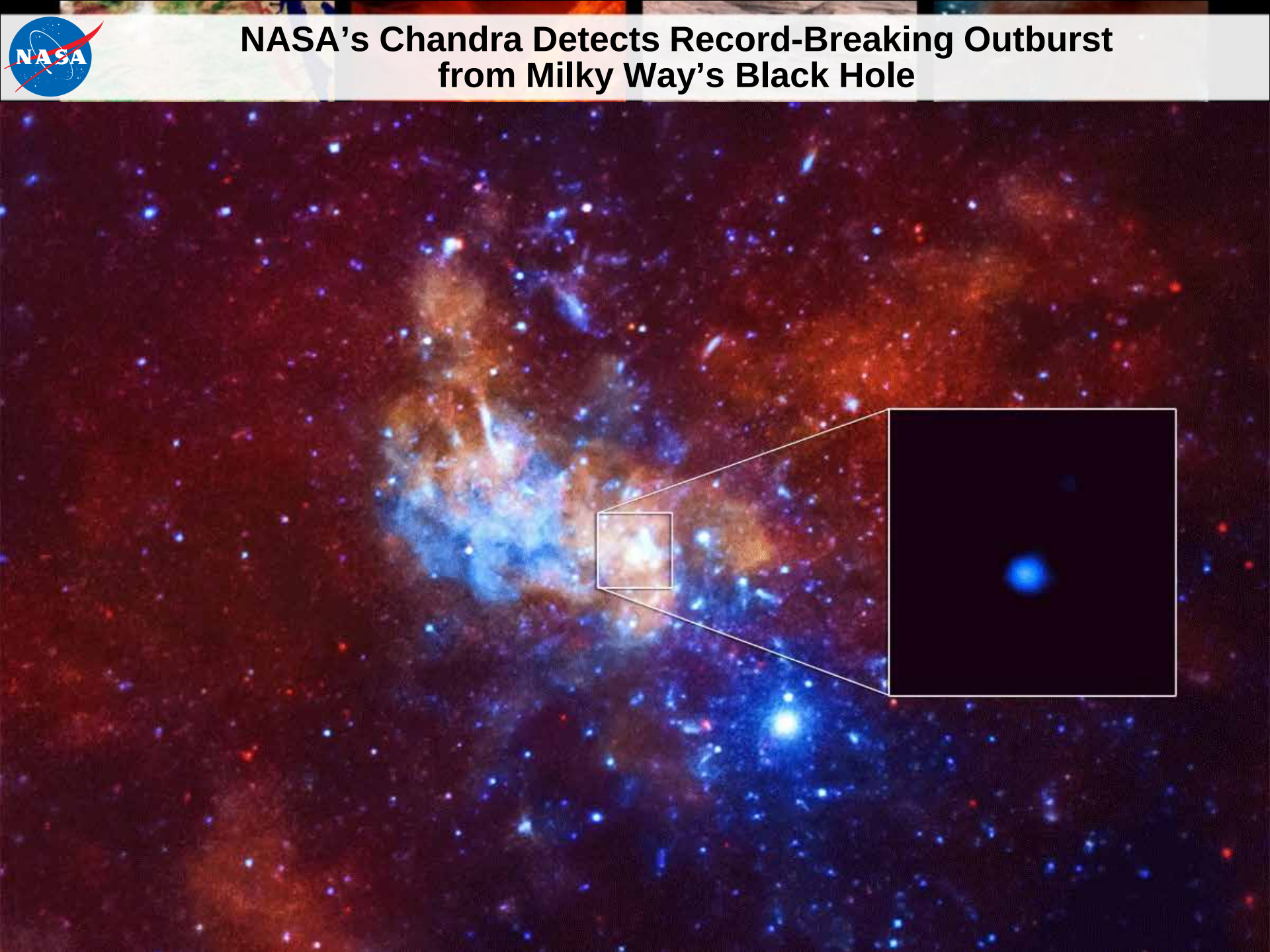


Hubble Sees Supernova Split into Four Images by Cosmic Lens

Supernova Refsdal
Galaxy Cluster MACS J1149.6+2223

Hubble Space Telescope
ACS/WFC ■ WFC3/IR



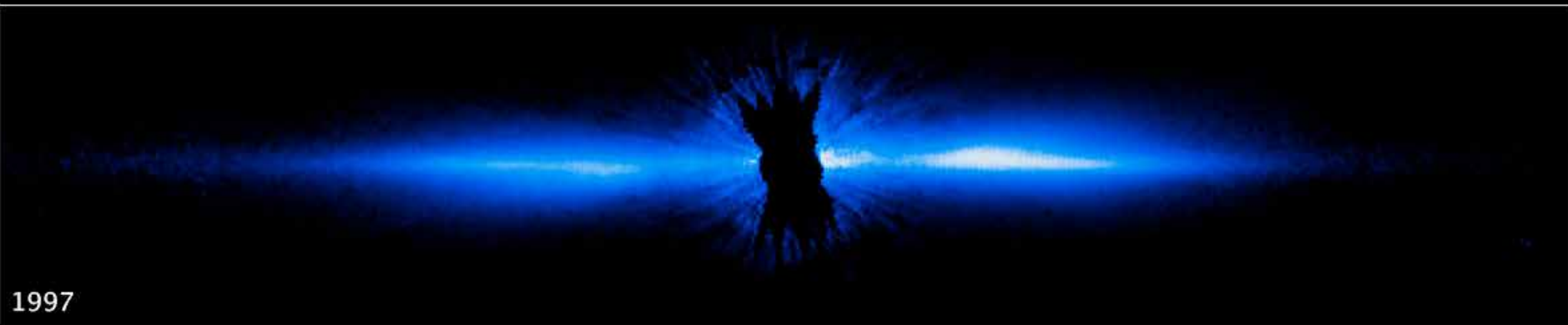


NASA's Chandra Detects Record-Breaking Outburst from Milky Way's Black Hole



NASA's Hubble detects Distortion of Circumstellar Disk by a Planet

Beta Pictoris ■ *Hubble Space Telescope* ■ STIS

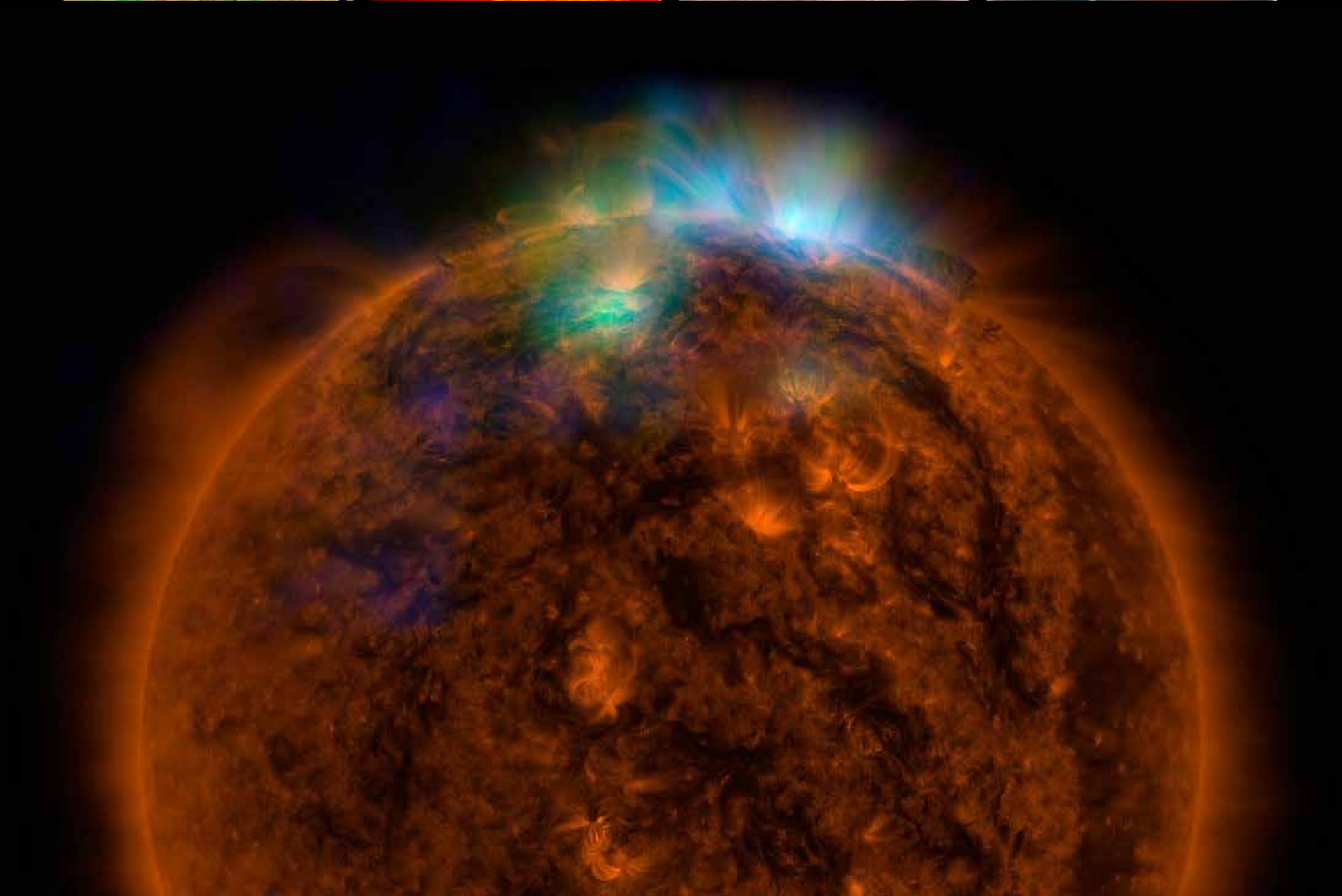


NASA and ESA

STScI-PRC15-06a



Sun Dazzles In First-Ever NuSTAR High-Energy X-Ray Portrait



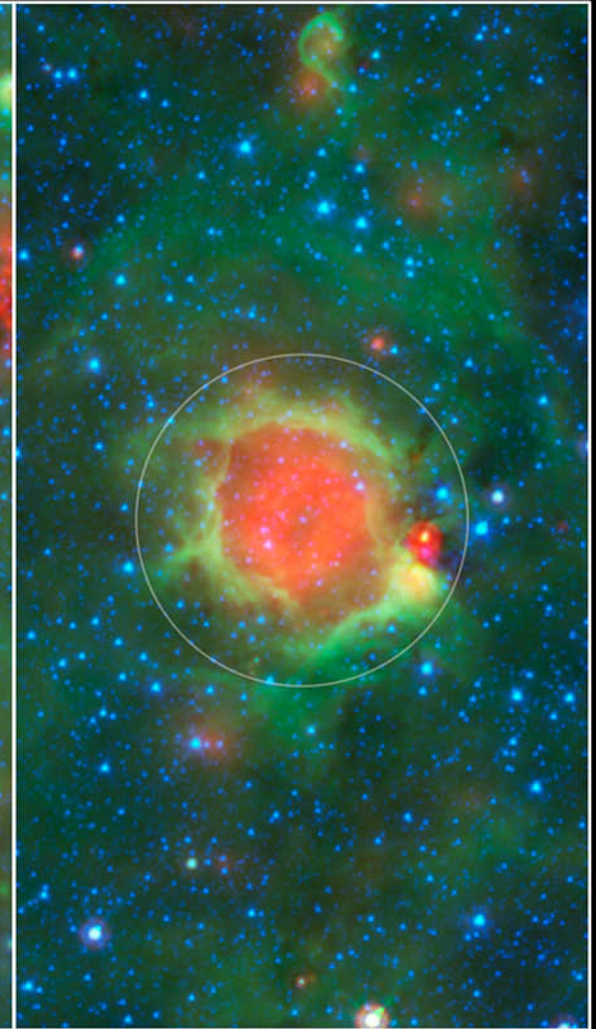
Protostar



"Yellowball"



Bubble



"Yellowballs" in Star Formation Sequence

NASA / JPL-Caltech

Spitzer Space Telescope • IRAC • MIPS

sig15-001

Sagittarius A East Supernova Remnant

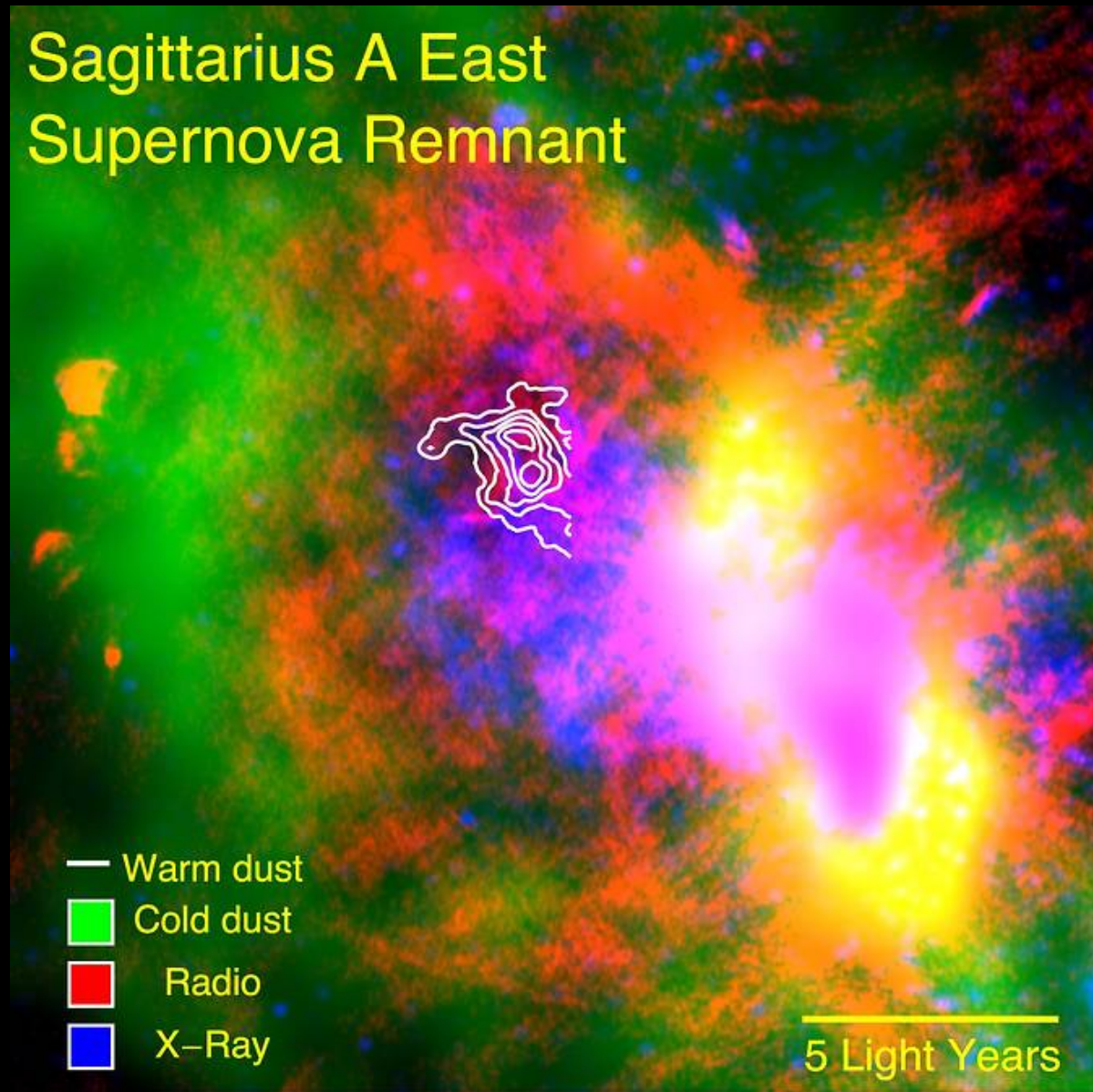
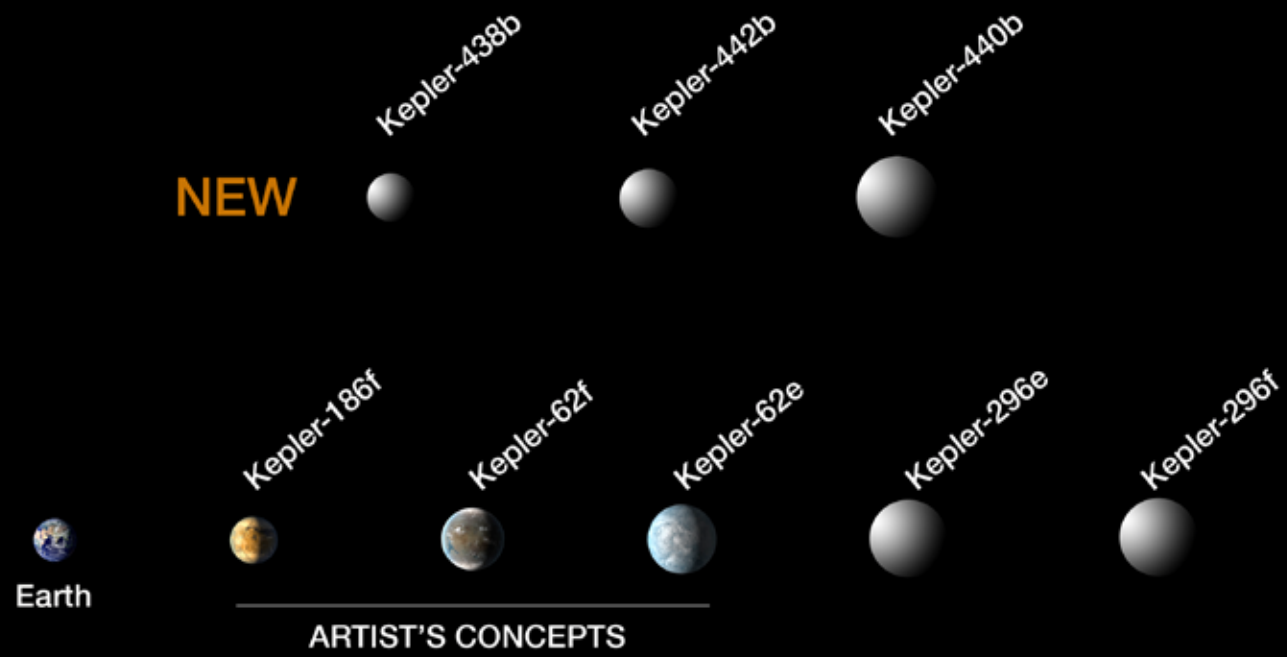


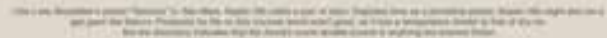
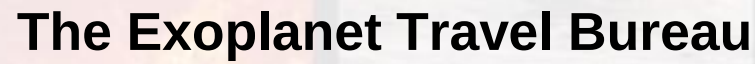
Image Credit: NASA/CXO/Herschel/VLA/Lau et al

NASA Kepler's Hall of Fame:

Small Habitable Zone Planets

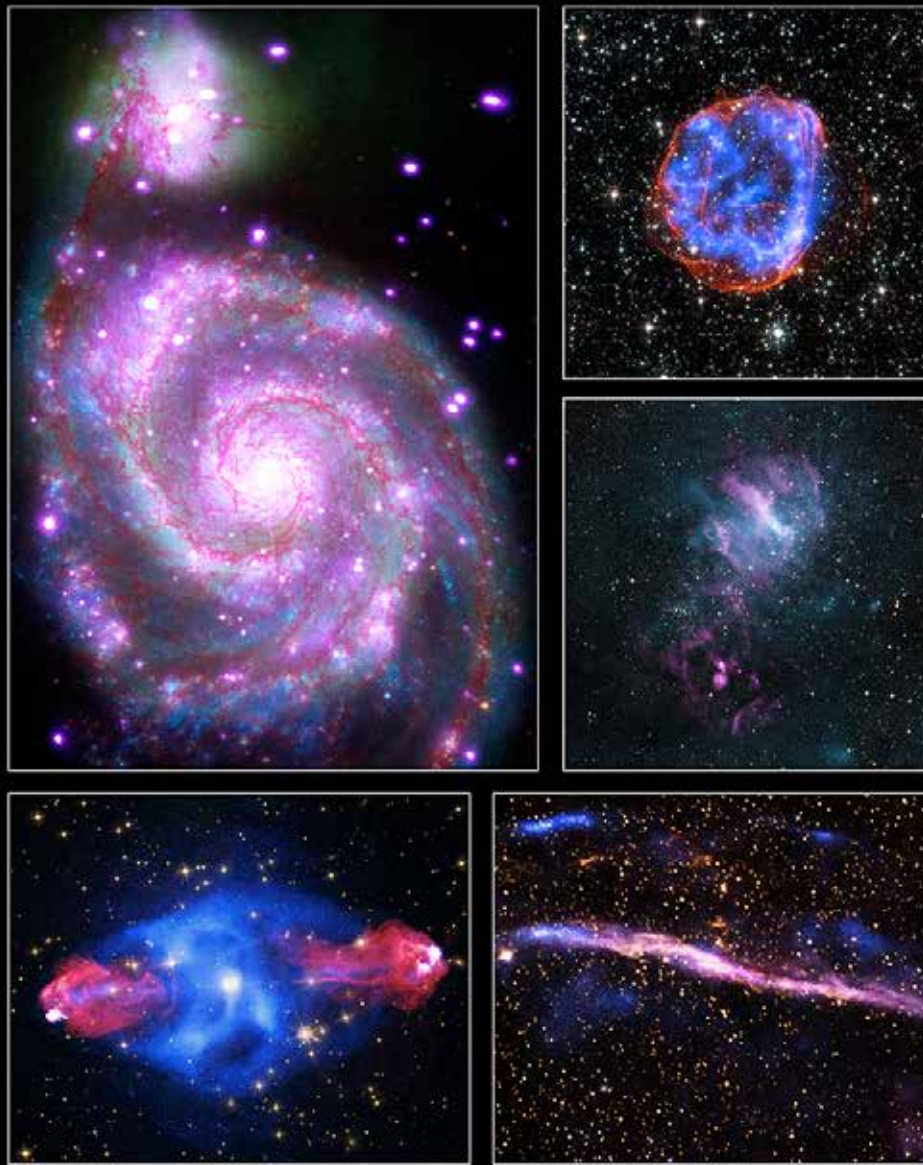
As of January 2015







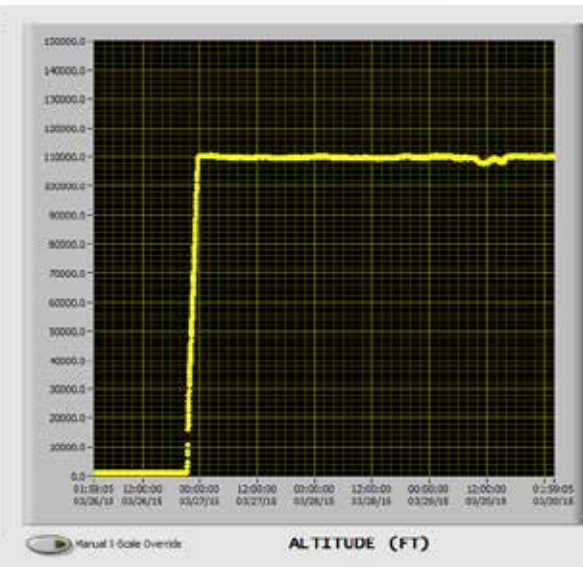
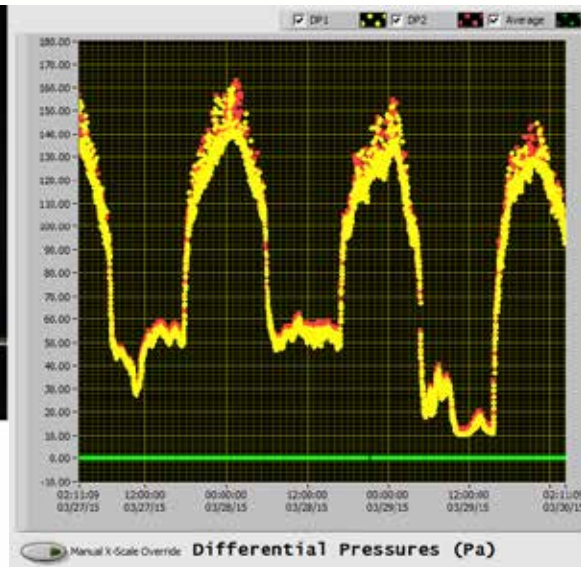
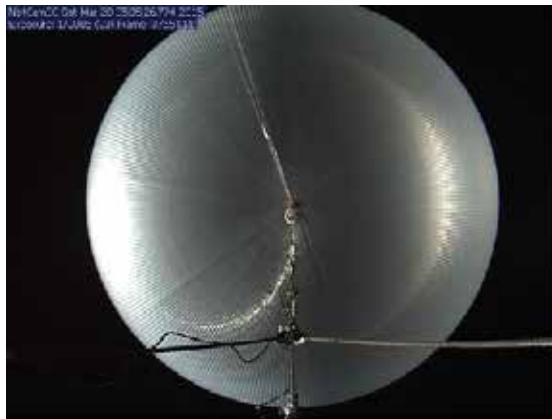
Chandra Celebrates the International Year of Light





ULDB Test Flight – March 30

3/23/2015





ULDB Test Flight – April 1

Balloon Overflight Assessment –
March 31 18 Z UTC

Overflight Distance (nm) 435

Float Speed (knts) 60.8





Astrophysics Driving Documents



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



Big Picture

- The FY15 appropriation and FY16 budget request provide funding for NASA astrophysics to continue its programs, missions, and projects as planned
 - The total funding (Astrophysics including JWST) is flat at ~\$1.3B through FY20
 - Fully fund JWST to remain on plan for an October 2018 launch
 - Fund continued pre-formulation and technology work leading toward WFIRST
 - Restore SOFIA to the budget with a reduction in FY15 and full funding beyond
 - Provide funding for SMD's education programs
- The operating missions continue to generate important and compelling science results, and new missions are under development for the future
 - Chandra, Fermi, Hubble, Kepler/K2, NuSTAR, Spitzer, Suzaku, Swift, XMM-Newton continued following the 2014 Senior Review
 - SOFIA is in prime operations as of May 2014
 - Missions on track for launch include LISA Pathfinder (2015), ASTRO-H (2015), NICER (2016), TESS (2017), JWST (2018), Euclid (2020)
 - New Explorers being selected (SMEX in 2015, MIDEX in 2017), WFIRST being studied, NASA joining ESA's Athena and ESA's L3 gravitational wave observatory
- Update to the Astrophysics Implementation Plan has been released
- Progress being made against recommendations of the 2010 Decadal Survey
 - NRC Mid Decade Review (with NSF, DOE) to begin in early 2015
 - NASA initiating large mission concept studies for 2020 Decadal Survey



FY15 Appropriation

(\$M)	2013	2014	2015	2016	2017	2018	2019
Astrophysics			\$685				
JWST			\$645				

- Provides \$77M more than the President's Budget Request for FY15
- Supports the commitment to an October 2018 launch date for JWST
- Includes \$50M for continued preformulation of WFIRST, an increase of \$36M over the Administration request and comparable to FY14
- Includes \$70M for continued SOFIA operations, a reduction of \$14M (17%) from FY14
 - Directs NASA to (a) seek partners to restore SOFIA to its full level, and (b) not terminate missions without a Senior Review
- Includes \$98M for Hubble operations, the same as FY14
- Includes \$38M for scientific ballooning, an increase of \$5M (15%) from FY14
- Does not specify the distribution of funding for the rest of Astrophysics, but the funding is adequate for Astrophysics to execute its program as planned in FY15.
 - Includes support as planned in FY15 for missions under development, operating missions, SMEX AO, R&A, etc.
 - Final budget numbers available when NASA operating plan approved



FY16 President's Budget Request

Outyears are notional planning from FY16 President's budget request

(\$M)	2014	2015	2016	2017	2018	2019	2020
Astrophysics*	\$678	\$685	\$689	\$707	\$750	\$986	\$1,118
JWST	\$658	\$645	\$620	\$569	\$535	\$305	\$198

- Supports operating missions: Chandra, Fermi, Hubble, Kepler, NuSTAR, SOFIA, Spitzer, and Swift.
- Funds development of Explorer missions TESS and NICER. TESS will continue the search for exoplanets, scanning all of the sky for Exoplanets closer to Earth than those found by Kepler.
- Supports pre-formulation studies for WFIRST/AFTA.
- Maintains a competed astrophysics research program and support of the balloon program.
- Supports the commitment of an October 2018 launch date for JWST.
 - o Will deliver the Integrated Science Instrument Module for integration;
 - o Completes integration of flight primary mirror subassemblies onto the flight primary mirror backplane;
 - o Completes acceptance testing of the cryocooler compressor assembly;
 - o Completes spacecraft bus structure; and
 - o Completes the sunshield structure manufacture and test.

* Excludes "SMD STEM Activities" in all years.



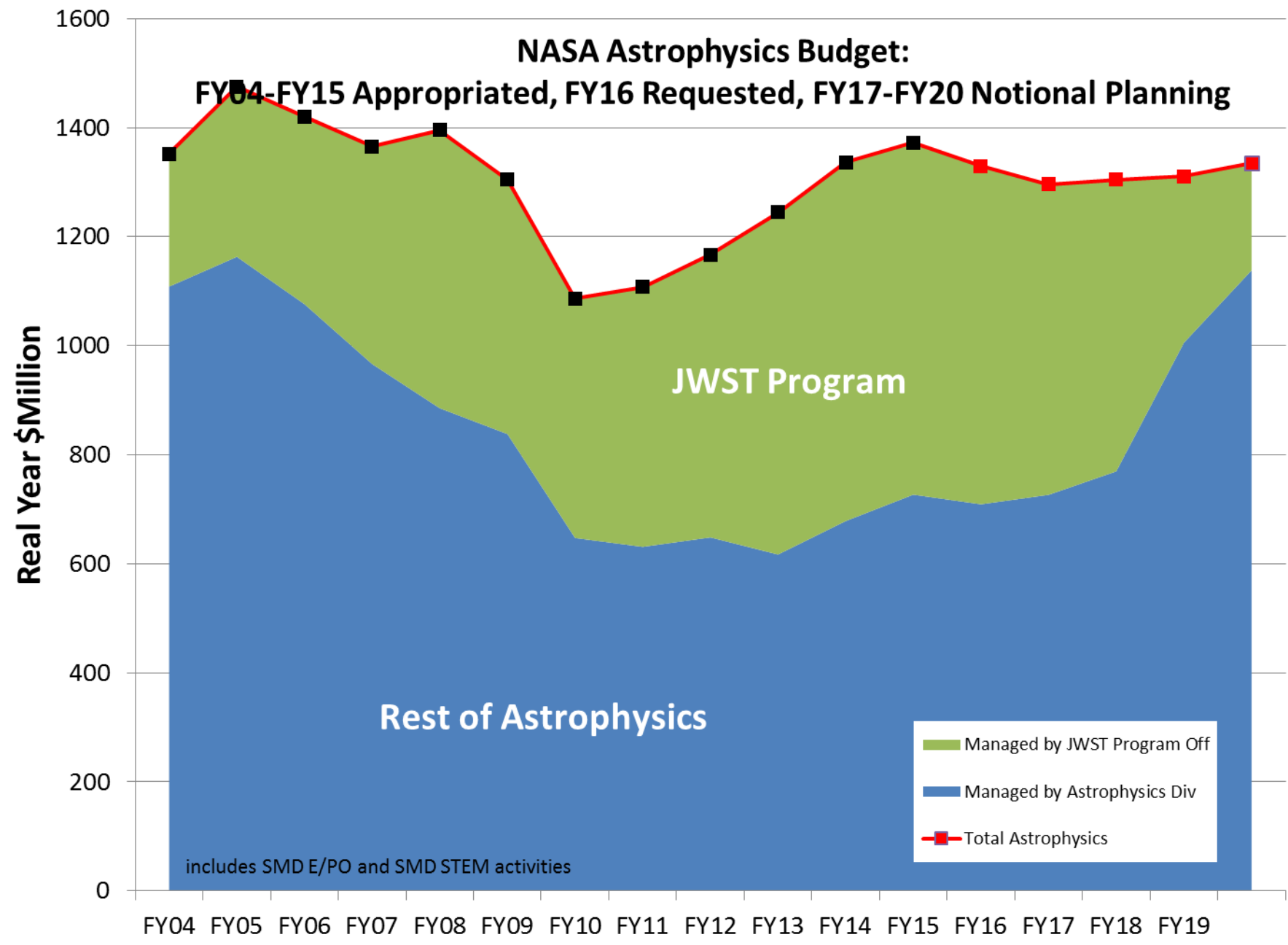
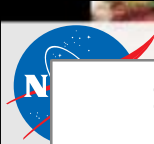
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- Continues preformulation of WFIRST/AFTA as the “Astrophysics Decadal Strategic Mission.”
- Grows Astrophysics Research and Analysis (including Astrophysics Data Analysis Program) from ~\$80M/yr to ~\$90M/yr in FY16.
- Supports completion of missions under development, including LPF/ST7, ASTRO-H, NICER, TESS, and Euclid.
- Enables selection of a SMEX mission and an Explorer Mission of Opportunity from the 2014 AO, and notional release of a MIDEX AO in late CY16/early FY17.
- Provides full funding for SOFIA operations and places SOFIA into the 2016 Astrophysics Senior Review.
- Plans for the 2016 Astrophysics Senior Review.
- Plans for continued Hubble operations through FY20 providing overlap with JWST.
- Plans for mission concept studies and technology development (within the three Program SR&T budgets) leading up to the 2020 Decadal Survey.

* Excludes “SMD STEM Activities” in all years.





Hubble Space Telescope 25th Anniversary

Sample of Events & Programs:

- Webcast event at National Air & Space Museum April 24
- Coordinated events worldwide April 24
- Family Day at Udvar-Hazy April 25
- Hubble 2020 STScI symposium
- Exhibits at museums around the world
- Exhibits at multiple airports
- Nationwide University lecture series
- Education programs in all 50 states
- Comprehensive traditional & social media outreach plans
- 'Ode to Hubble' video contest
- New Planetaria clips
- Re-release of IMAX 'Hubble 3D'



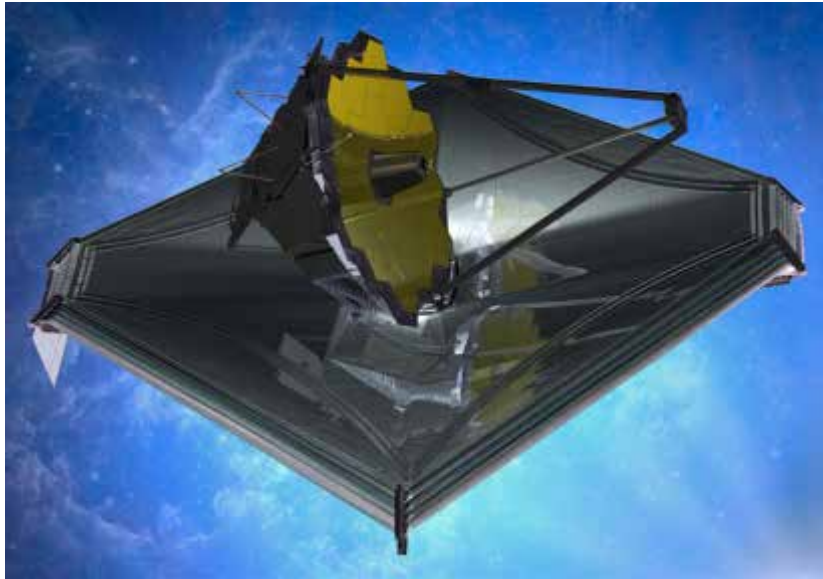
Find out more: hubble25th.org

Join the celebration: [#Hubble25](https://twitter.com/Hubble25)



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 <http://jwst.nasa.gov/>

2015 Accomplishments

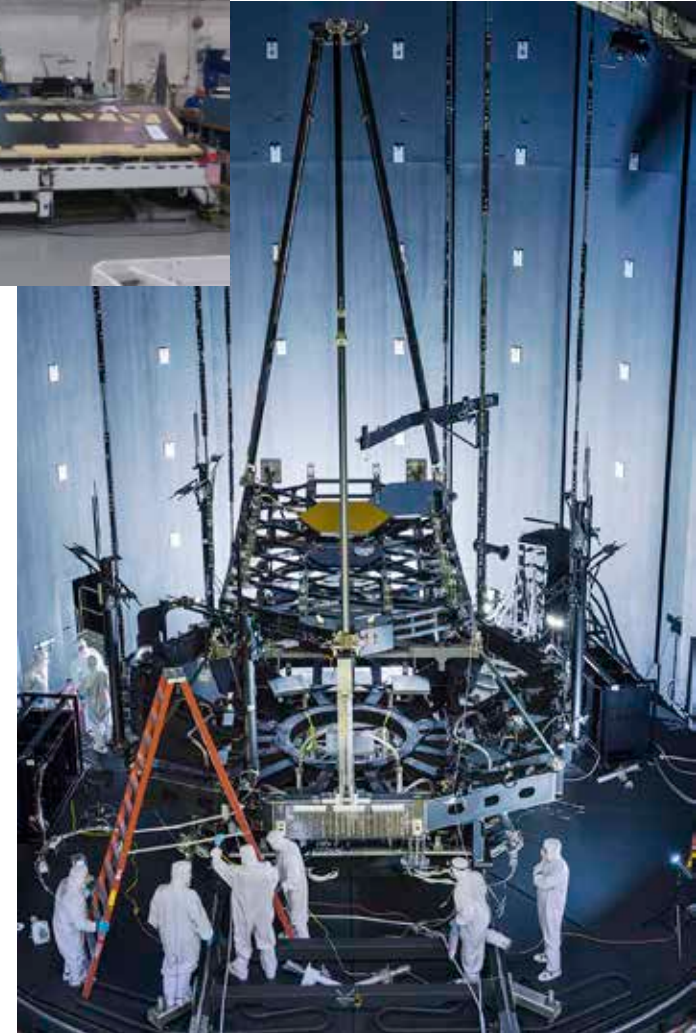
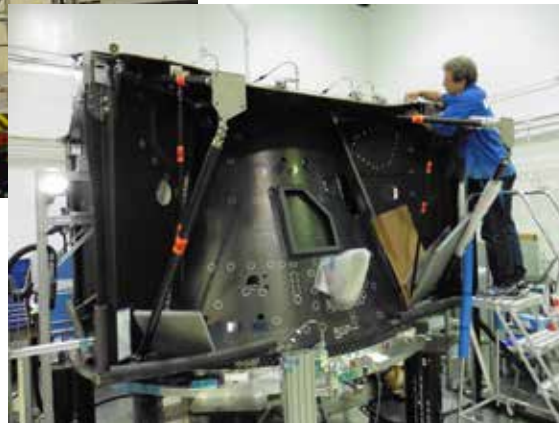
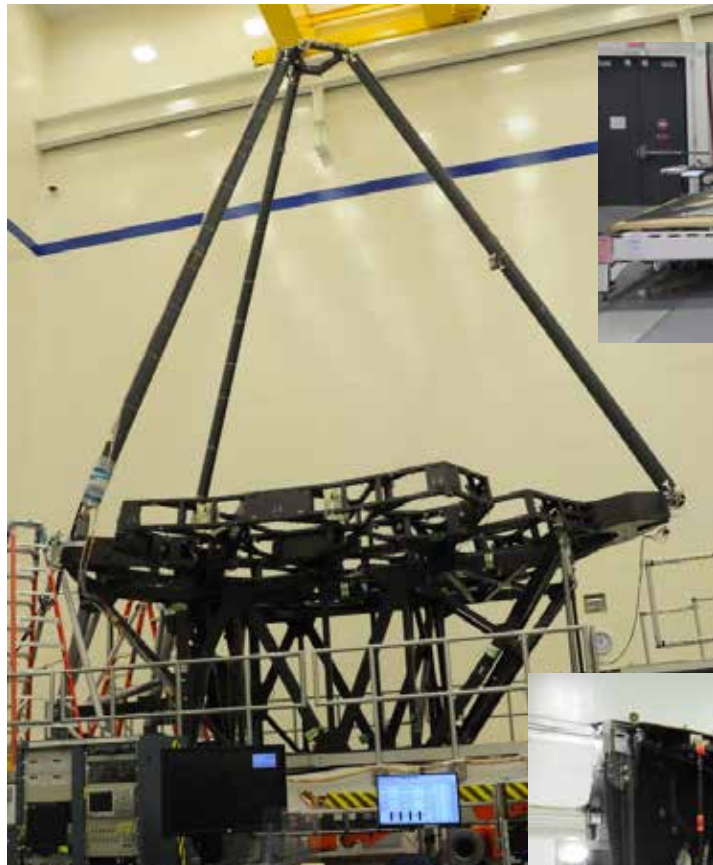
- FGS/NIRISS and NIRSpec detector and parts replacement completed,
- 4 of 5 flight sunshield membranes in manufacturing (final to start in a couple months)
- Spacecraft manufacturing continues on schedule
- Telescope Pathfinder installed into JSC chamber A for testing
- Telescope Flight Backplane, wings and secondary tower assembled

2015 Plans

- Test ISIM for the final time before integration into observatory
- Conduct tests at JSC in preparation for full telescope and instrument tests
- Complete MIRI cryocooler
- Start Assembly of the Primary mirror



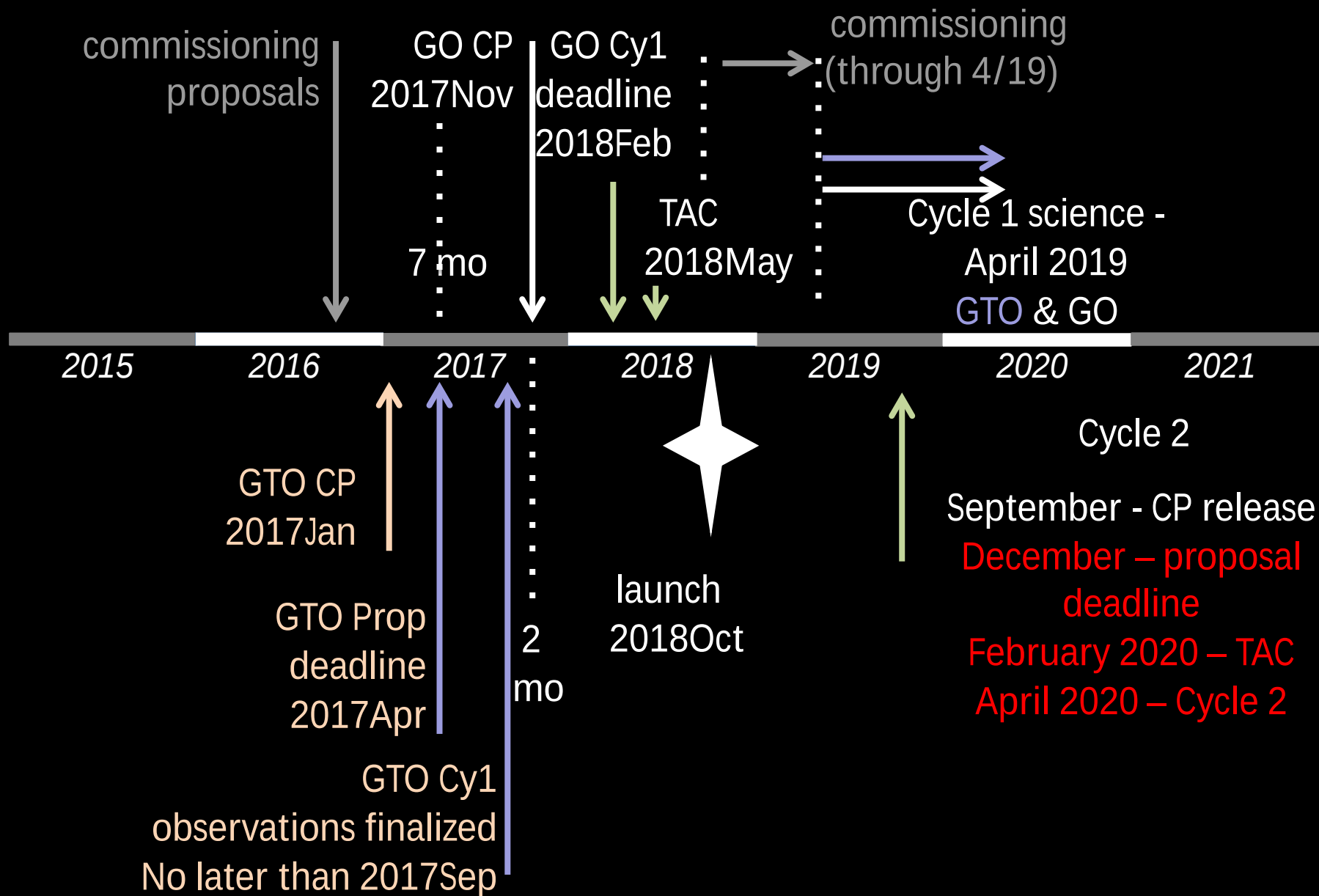
JWST Hardware Progress



JWST remains on track for an October 2018 launch within its replan budget guidelines



JWST Science Planning Timeline

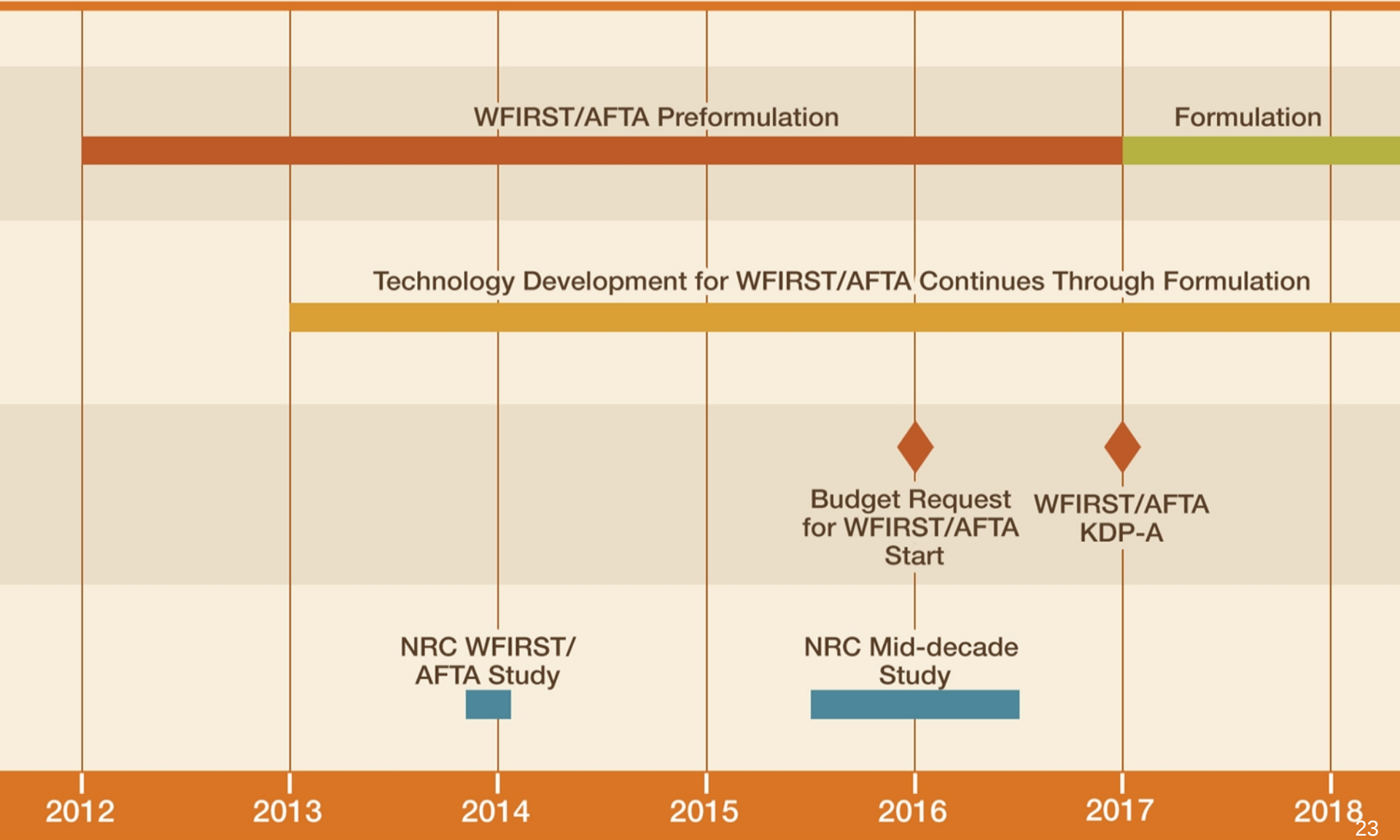




Plan for WFIRST/AFTA Preformulation

Widefield Infrared Survey Telescope using
Astrophysics Focused Telescope Assets

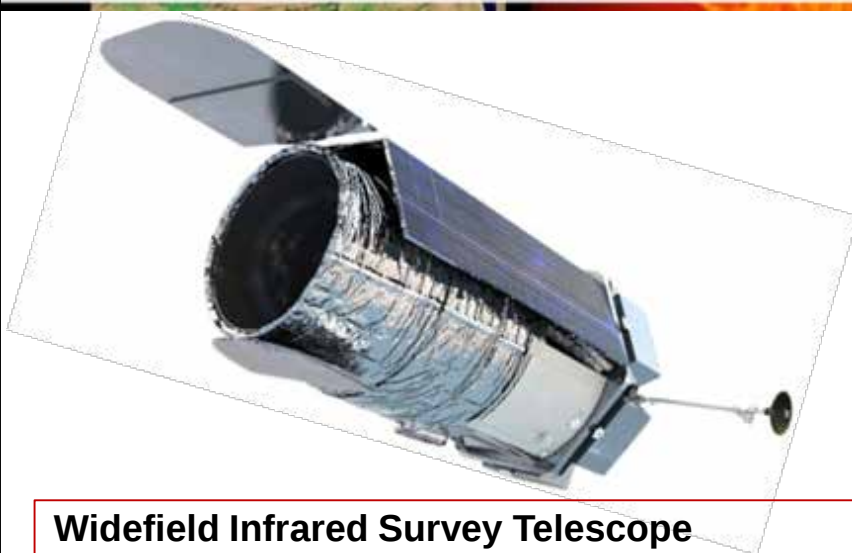
WFIRST/AFTA timeline





WFIRST / AFTA

Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets



Widefield 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 GEO, uses existing AFTA hardware to image 0.28 deg^2 at $0.8\text{--}2.0 \mu\text{m}$

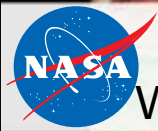
Instruments (design reference mission):
Wide Field Instrument, Coronagraph Instrument

- FY15 Appropriation and FY16 Budget Request support pre-formulation of WFIRST/AFTA
- Plans support Agency/Administration decision for formulation to begin NET FY 2017, should funding be available.

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

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 CY 2016.
- Currently in pre-formulation phase.
 - Activities include technology development for detectors and coronagraph (with STMD), assessment of the 2.4m telescopes including risk mitigation, mission design trades, payload accommodation studies, and observatory performance simulations.
- Maturing key technologies 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).
- March 2014 NRC study on WFIRST/AFTA offers positive view of AFTA, with concerns about technology and cost risks.
- March 2015 SDT report with design reference mission presents baseline plan for WFIRST/AFTA
- WFIRST Preparatory Science funds 17 ROSES proposals that are relevant to WFIRST's goals and WFIRST-specific simulations and models.



WFIRST / AFTA

Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets

Coronagraph Technology Milestones

1	Shaped Pupil mask fabricated with reflectivity of 10^{-4} and 20 μm pixel size.	7/21/14 ü
2	Shaped Pupil Coronagraph demos 10^{-8} raw contrast with narrowband light.	9/30/14 ü
3	PIAACMC mask fabricated with 10^{-8} raw contrast with 10% broadband light.	12/15/14 ü
4	Hybrid Lyot Coronagraph demos 10^{-8} raw contrast with narrowband light..	2/28/15 ü
5	Occulting Mask Coronagraph demos 10^{-8} raw contrast with 10% broadband light.	9/15/15
6	Low Order Wavefront Sensing provides jitter sensing better than 0.4 mas rms.	9/30/15
7	Spectrograph read-out demo to have low dark current and read noise.	8/25/16
8	PIAACMC coronagraph demos 10^{-8} raw contrast with 10% broadband light.	9/30/16
9	Occulting Mask Coronagraph demos 10^{-8} raw contrast with 10% broadband light.	9/30/16

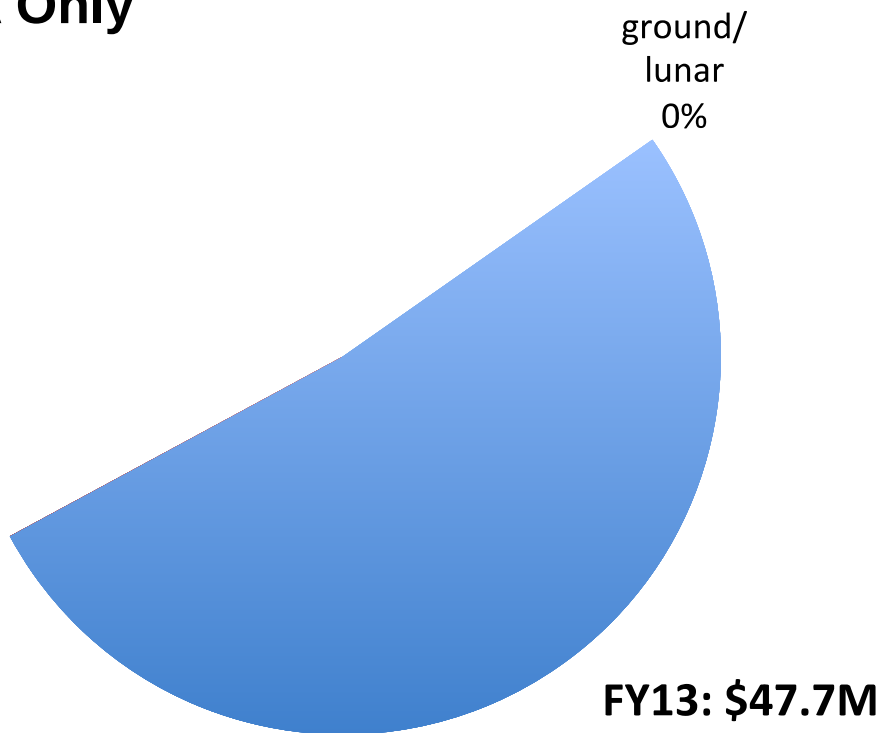
Widefield Detector Technology Milestones

1	Produce, test, and analyze 2 candidate passivation techniques in banded arrays.	7/31/14 ü
2	Produce, test, and analyze 1 additional candidate passivation techniques in banded arrays.	12/30/14 ü
3	Produce, test, and analyze full arrays with operability > 95%.	9/15/15
4	Produce, test, and analyze final selected recipe in full arrays demonstrating a yield > 20% with operability > 95%.	9/15/16
5	Complete environmental testing of one sensor chip assembly, as per NASA test standards.	12/1/16

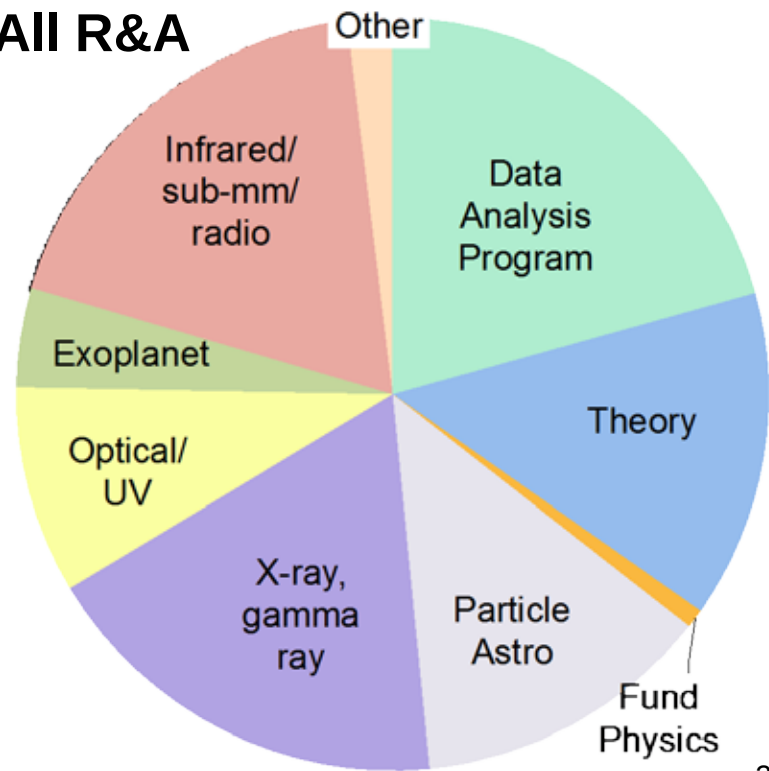
	Proposals Rec'd	Year-1 \$M	Proposals selected	Success Rate	Proposals Rec'd 2015
APRA-13	179	10.0	43	24%	151
SAT-13	18	5.4	10	56%	28
ADAP-14	300	7.5	62	21%	
XRP-14	62	1.3	11	18%	
ATP-14	214	4.7	31	14%	
TOTAL	773	28.9	157	20%	

Does not include
RTF, TCAN, WPS,
GO programs

APRA Only

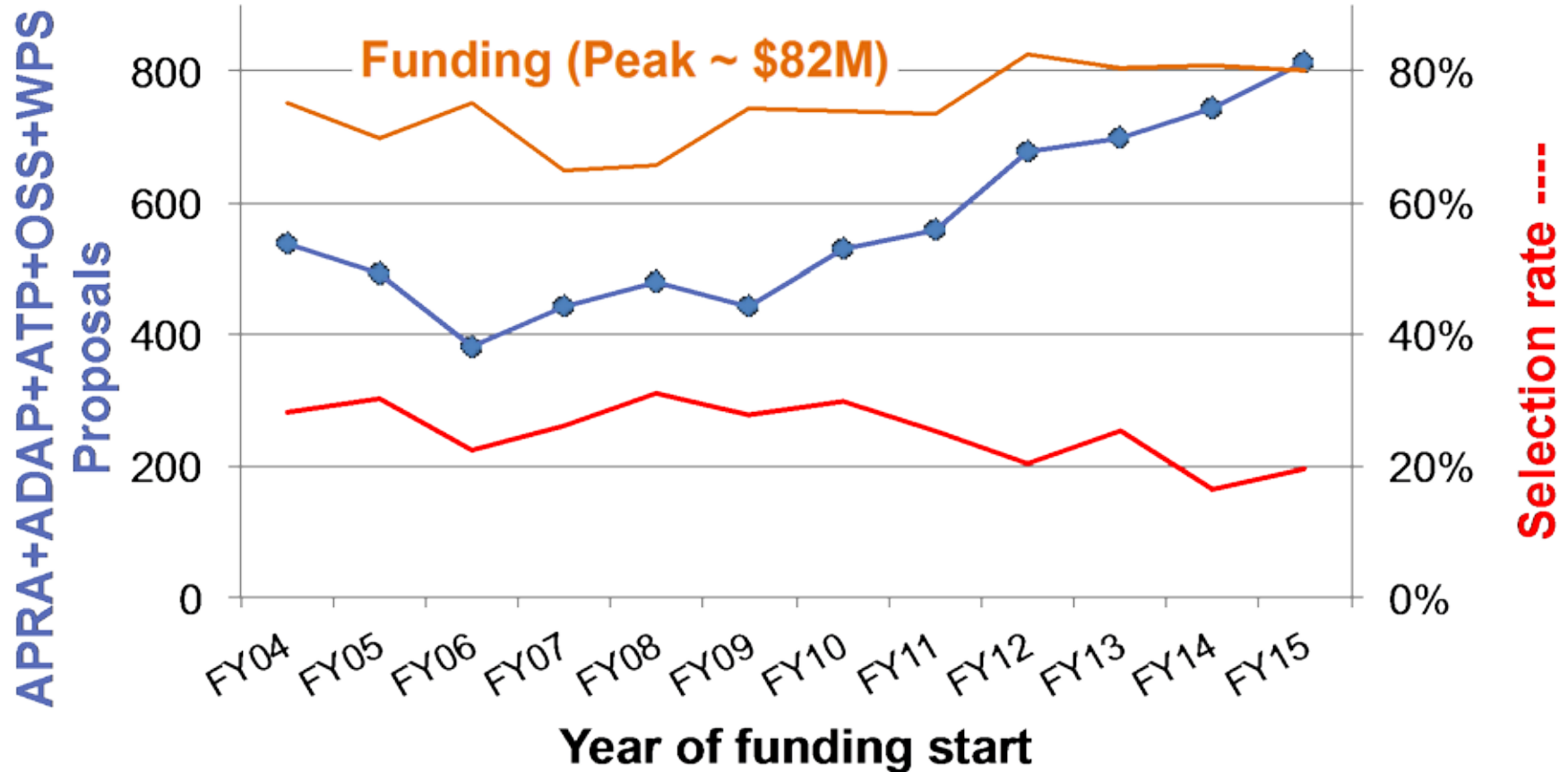


All R&A





Astrophysics ROSES selection rates



AAAC task force on R&A and demographics being led by Prisca Cushman (U. Minn)



SMD Science Education

- Education is funded in the FY15 NASA Appropriation Act at \$42M SMD-wide as a separate budget line (so E/PO is no longer budgeted as 1% of every mission).
- SMD will compete and consolidate education activities for FY16.
- SMD has released a Cooperative Agreement Notice (CAN) soliciting team-based proposals for science education.
- The goal of the NASA SMD Science Education CAN is to meet the following objectives: Enabling STEM education; Improving U.S. science literacy; Advancing National education goals; and Leveraging science education through partnership.
- The schedule is as follows:

CAN Release Date	February 4, 2015
Preproposal Conference	February 27, 2015
Notice of Intent to Propose Deadline	March 9, 2015
Electronic Proposal Submittal Deadline	May 4, 2015
Selections Announced (target)	≤ 120 days after receipt of proposals, with initial awards distributed in FY 2015



Planning for the 2015-2016 Mid-Decade Review

- The NASA Authorization Act of 2005 requires assessments of NASA's science programs that include mid-decade reviews.
 - The Astrophysics Mid-Decade Review will be during 2015-2016
 - Study will be co-sponsored by NASA, NSF, and DOE (the Agencies)
- Given the funding circumstances that are substantially below those assumed in the Decadal Survey, the committee's review will describe:
 - The most significant scientific discoveries, technical advances, and relevant programmatic changes in astronomy and astrophysics since the Decadal Survey;
 - How well the Agencies' programs address the strategies, goals, and priorities outlined in the Decadal Survey and other NRC reports;
 - Progress toward realizing these strategies, goals and priorities; and
 - Any actions that could be taken to maximize the science return of the Agencies' programs.
- The Agencies are in the process of charging the NRC, and formation of the Study Committee will begin soon.



Planning for the 2015-2016 Mid-Decade Review

Directions in *New Worlds*, *New Horizons* relevant to NASA (paraphrased)

- LISA: If LISA is not L1, or LISA Pathfinder is not successful, or equal partnership is not possible, then conduct review to reconsider LISA's prioritization. (p.9, p.213)
 - NASA working toward partnership on ESA L3, will invest in enabling technology and LPF; anticipate review by 2020 Decadal Survey regarding priority of strategic partnership on ESA L3.
- IXO: If IXO is L1, conduct review then (maybe) invest immediately in technology. By mid-decade, invest aggressively in technology. (p. 9, p. 214, p. 215)
 - NASA planning on partnership on ESA Athena, investing in technology now, expect details of partnership to be established soon; anticipate partnership well underway by time of 2020 Decadal Survey.
- New Worlds: If precursor science is favorable, conduct review then (maybe) downselect technology and invest to ready a mission for the 2020 decadal survey. (p.20, p.195, p.216)
 - NASA maturing multiple technologies and studying multiple architectures in advance of 2020 Decadal Survey, not planning to downselect technology prematurely; anticipate review by 2020 Decadal Survey regarding priority – and possibly size and architecture – of strategic mission.
- Inflation Probe: If B-mode detected, conduct review then (maybe) invest in technology for an all-sky mission. (p.198, p.217)
 - NASA maturing multiple detector technologies, considering potential partnerships on ESA and JAXA led missions; anticipate review by 2020 Decadal Survey regarding priority of probe-class mission.
- DSIAC: Conduct review to see whether any contingencies have occurred and recommend action. (p.102, p.237)



Planning for the 2015-2016 Mid-Decade Review

- What kind of input and reporting from NASA would be valuable to the Mid Decade Review Committee?
 - Programmatic update on addressing the recommendations in the Decadal Survey.
 - Captured in 2014 Implementation Plan Update
 - Looking for a definitive list of Decadal Survey recommendations, or at least subjects that the Committee would like addressed
 - Programmatic and budget update on NASA initiatives and activities which are not recommendations of the Decadal Survey.
 - Spending actuals and budget plan against the major recommendations, all of which came with proposed spending allocations.
 - Spending actuals and budget plan for community support, including R&A, GO, and Fellowships.
 - Plans for the rest of the decade, including expected decision points.
 - Plans for preparing for the 2020 Decadal Survey.



Progress Toward Decadal Survey Priorities

The NASA FY15 Appropriation, the President's FY16 Budget Request, and the notional out year budget planning guidance in the President's FY16 Budget Request, support:

Large-scale 1. 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 FY2017. Budget line established for an Astrophysics Decadal Strategic Mission.
Large-scale 2. Augmentation to Explorer Program	Astrophysics Explorers planned budget increased to support decadal cadence of AOs including SMEX AO in Fall 2014 and MIDEX AO in late 2016/early 2017.
Large-scale 3. LISA	Discussing partnership on ESA's L3 gravitational wave observatory and participating in ESA-led assessments in 2014-2015. Strategic astrophysics technology (SAT) investments plus support of LISA Pathfinder.
Large-scale 4. IXO	NASA is pursuing a partnership on ESA's L2 Athena X-ray observatory; the Athena study phase, with U.S. participation, is underway. Strategic astrophysics technology (SAT) investments.
Medium-scale 1. New Worlds Technology Development Program	Focused technology development for a coronagraph on WFIRST, strategic astrophysics technology (SAT) investments, and exoplanet probe mission concept studies. Established partnership with NSF to develop extreme precision Doppler spectrometer as facility instrument. Exozodi survey using LBTI.



Progress Toward Decadal Survey Priorities

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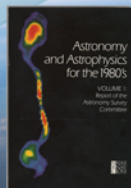
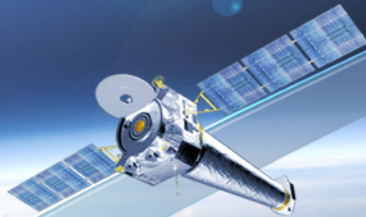
Medium-scale 2. Inflation Probe Technology Development Program	Balloon-borne investigations plus strategic astrophysics technology (SAT) investments.
Small-scale. Research Program Augmentations	Increased annual R&A budget by 10% from FY10 to FY12 and another 10% from FY14 to FY16. Within R&A: established Theoretical and Computational Astrophysics Networks (TCAN) program with NSF; funding available for astrophysics theory; funding available for lab astrophysics; funding available for suborbital payloads.
Small-scale. Intermediate Technology development Augmentation	Established competed Strategic Astrophysics Technology (SAT) program element; directed technology funding for WFIRST and other large-scale decadal priorities.
Small-scale. Future Ultraviolet-Visible Space Capability	Strategic Astrophysics Technology (SAT) investments.
Small-scale. SPICA (U.S. contribution to JAXA-led)	Not supported as a strategic contribution; candidate for Explorer Mission of Opportunity.

ASTROPHYSICS

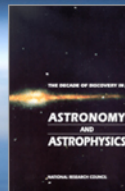
Decadal Survey Missions



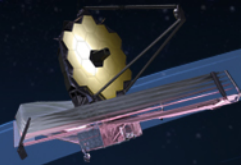
1972
Decadal Survey
Hubble



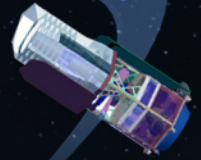
1982
Decadal Survey
Chandra



1991
Decadal Survey
Spitzer, SOFIA



2001
Decadal Survey
JWST



2010
Decadal Survey
WFIRST



Preparing for the 2020 Decadal Survey Large Mission Concepts

- The 2020 Decadal Survey will prioritize large space missions to follow JWST and WFIRST.
 - To enable this prioritization, NASA needs to provide information on several candidate large space mission concepts for consideration by the 2020 Decadal Survey Committee.
- What information needs to be provided to the Decadal Survey committee to enable prioritization of large missions
 - Science case
 - Strawman design reference mission with strawman payload
 - Technology development needs
 - Cost requirements assessment
- NASA needs to initiate technology development for candidate large missions so that technology will be ready when needed.
 - Technology needs to be sufficiently mature when it is time to start the highest priority large mission in the 2020 Decadal Survey.
 - The next large mission after WFIRST could be started when funding becomes available as WFIRST approaches launch in the early or mid-2020s.



Preparing for the 2020 Decadal Survey Large Mission Concepts

Part A – 2015

- Identify a small set of candidate large mission concepts to study
 - NASA draws a small set of candidate mission concepts from existing roadmap and strategic documents
 - Incorporate community input through the three Astrophysics Program Analysis Groups (PAGs)

Part B – 2016-2019

- Initiate studies
 - Includes community-based Science and Technology Definition Teams
- Conduct studies
 - Includes NASA Center-provided engineering teams
- Identify technology requirements to motivate early technology development
 - Enables funding through existing Astrophysics technology programs
- Deliver results to 2020 Decadal Survey committee

Planning for the 2020 Decadal Survey: An Astrophysics Division White Paper
available at <http://science.nasa.gov/astrophysics/documents>



Preparing for the 2020 Decadal Survey Large Mission Concepts

The initial short list (in alphabetical order):

- **FAR IR Surveyor** – The Astrophysics Visionary Roadmap identifies a Far IR Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.
- **Habitable-Exoplanet Imaging Mission** – The 2010 Decadal Survey recommends that a habitable-exoplanet imaging mission be studied in time for consideration by the 2020 decadal survey.
- **UV/Optical/IR Surveyor** – The Astrophysics Visionary Roadmap identifies a UV/Optical/IR Surveyor as contributing through improvements in sensitivity, spectroscopy, high contrast imaging, astrometry, angular resolution and/or wavelength coverage. The 2010 Decadal Survey recommends that NASA prepare for a UV mission to be considered by the 2020 Decadal Survey.
- **X-ray Surveyor** – The Astrophysics Visionary Roadmap identifies an X-ray Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.

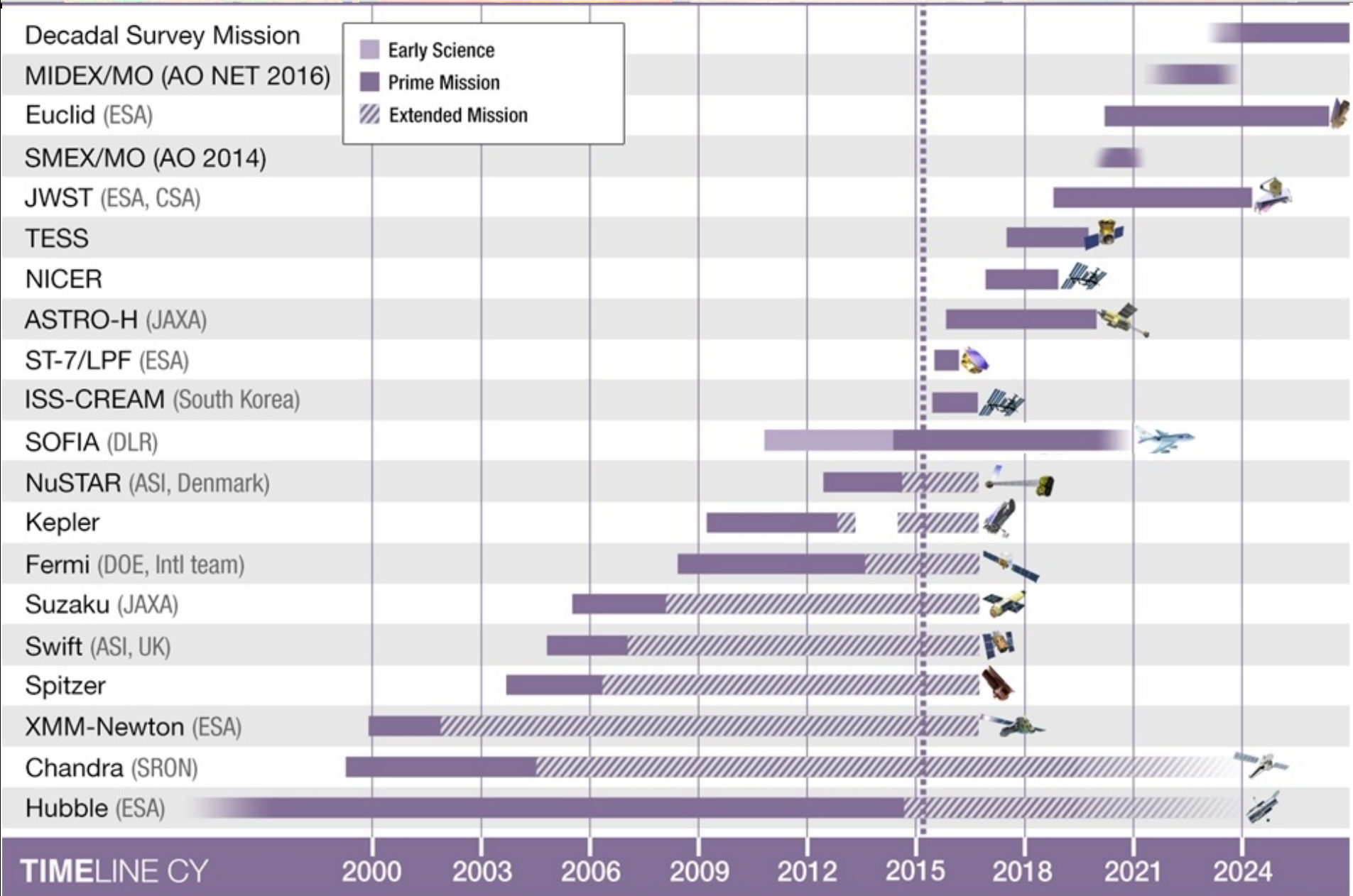


Preparing for the 2020 Decadal Survey Thinking about Probes

- What was done 10 years ago?
 - Origins Probes Mission Concepts (2004)
 - ROSES call for quick (~9 month) paper concept studies
 - ~9 concepts selected in 2004; total funding ~\$1M (\$100K average)
 - Astrophysics Mission Concepts Study (AMCS; 2007)
 - ROSES call for ~1 year paper concept studies
 - Nineteen (+1) ASMC concepts selected in 2007; total funding \$13M (\$700K average)
 - Was this effective? Efficient? Appropriately impactful?
- Possibilities this time
 - Real mission concept studies
 - Just like we are doing for large mission concepts
 - How would we select them? Where does funding come from?
 - Paper mission concept studies
 - Just like AMCS, but limited to Probes
 - Self selected, self funded
 - Anybody can submit a white paper to the 2020 Decadal Survey
- Awaiting input from the PAG reports



Astrophysics Timeline



Dates beyond 2016 are contingent upon the results of the 2016 Senior Review