National Aeronautics and Space Administration

Astrophysics




Astronomy and Astrophysics Advisory Committee
Washington, DC
January 26, 2017

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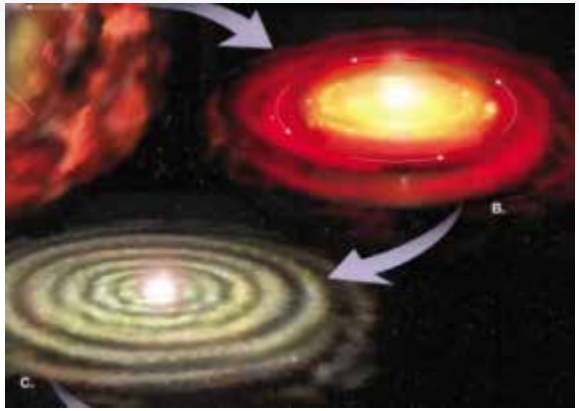
Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

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?

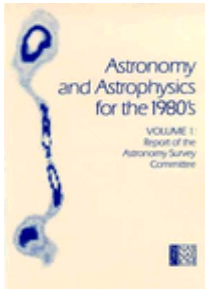


2. How did galaxies, stars, and planets come to be?

3. Are We Alone?

These national strategic drivers are enduring

1972



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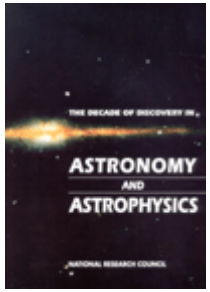
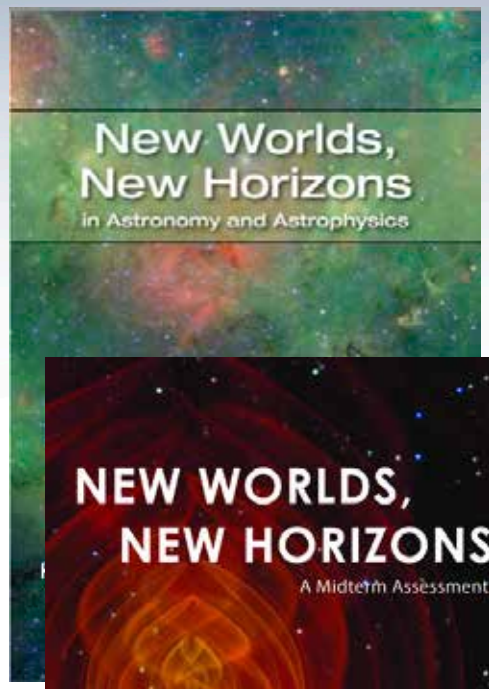


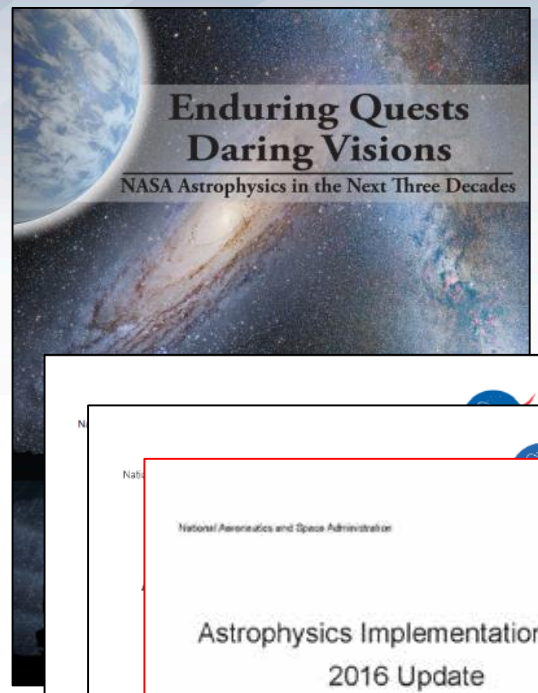
1991

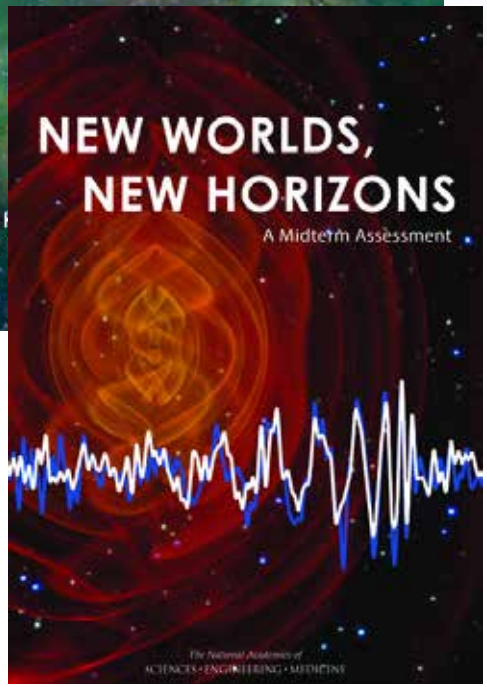
2001

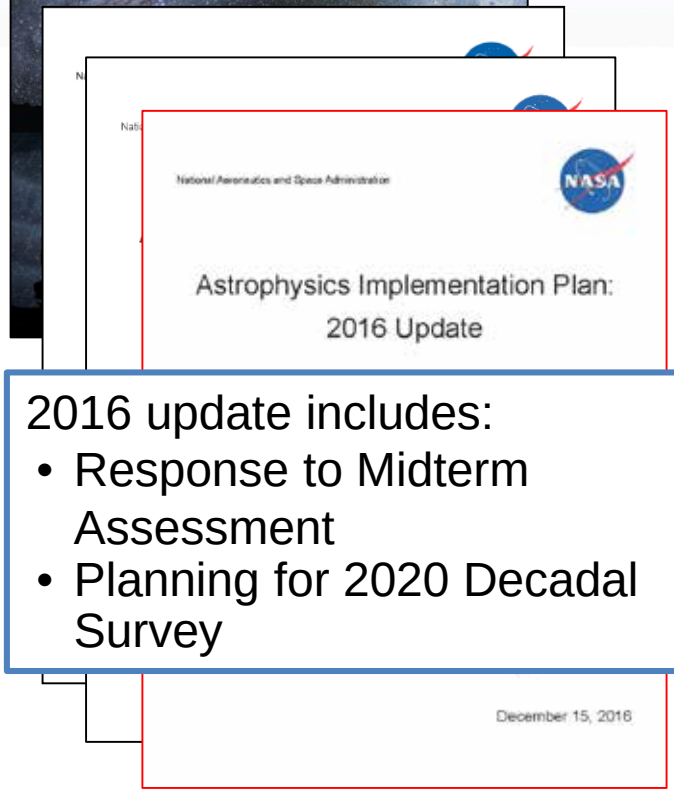
2010

Astrophysics Driving Documents









2016 update includes:

- Response to Midterm Assessment
- Planning for 2020 Decadal Survey

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

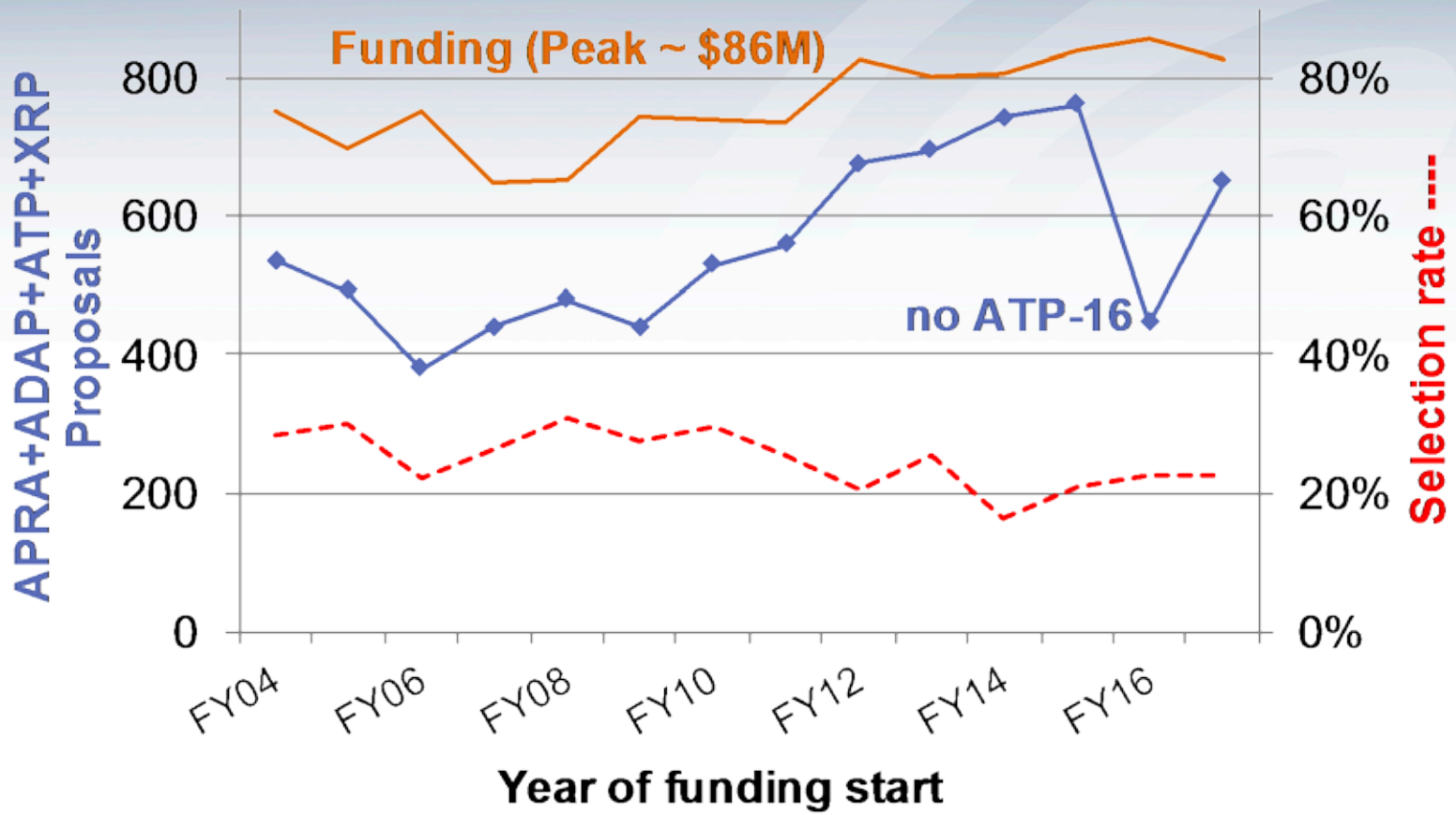
Astrophysics - Big Picture

- **The FY16 appropriation/FY17 continuing resolution and FY17 President's budget request provide funding for NASA astrophysics to continue its planned programs, missions, projects, research, and technology.**
  - The total funding (Astrophysics including Webb) remains at ~$1.35B.
  - Fully funds Webb for an October 2018 launch, WFIRST formulation (new start), Explorers mission development, increased funding for R&A, new suborbital capabilities.
  - No negative impact from FY17 continuing resolution (through April 28, 2017).
  - Awaiting FY18 budget guidance from new Administration.
- **The operating missions continue to generate important and compelling science results, and new missions are under development for the future.**
  - Senior Review in Spring 2016 recommended continued operation of all missions.
  - SOFIA is adding new instruments: HAWC+ instrument being commissioned; HIRMES instrument in development; next gen instrument call in 2017.
  - NASA missions under development making progress toward launches: ISS-NICER (2017), ISS-CREAM (2017), TESS (2018), Webb (2018), IXPE (2020), WFIRST (mid-2020s).
  - Partnerships with ESA and JAXA on their future missions create additional science opportunities: Euclid (ESA), X-ray Astronomy Recovery Mission (JAXA), Athena (ESA), L3/LISA (ESA).
  - Explorer AOs are being released every 2-3 years: MIDEX proposals received in December 2016, IXPE downselected in January 2017
- **Progress being made toward recommendations of the 2010 Decadal Survey.**
  - National Academies Midterm Assessment Report validates that progress.
  - NASA is initiating large and medium mission concept studies for 2020 Decadal Survey.

NASA Astrophysics

Research and Analysis Update

Research Program Trends



- Since 2010, proposal numbers have grown faster than funding, so selection rates have fallen.
- We received fewer proposals for 2016 funding because there was no ATP-15 competition. 2017 funding data is incomplete (APRA proposals due March).

Updated Dec 2016

Recent Proposal Selections

Status: January 3, 2017

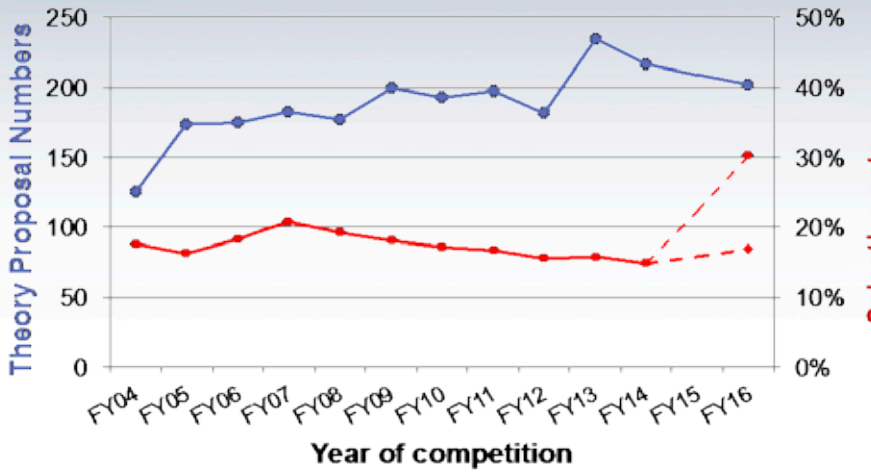
	Proposal Due Date	Notify Date	Days past received	Number received	Number selected	% selected
Spitzer GO – Cycle 12	Sep 11, 2015	Oct 26, 2015	45	104	31	30%
SOFIA 3rd Gen Instrument	Oct 7, 2015	Dec 10, 2015	64	3	2	67%
WFIRST Sci. Inv. Teams	Oct 15, 2015	Dec 18, 2015	64	38	12	32%
Swift GI – Cycle 12	Sep 25, 2015	Jan 19, 2016	116	185	43	23%
Roman Tech Fellows	Nov 6, 2015	Feb 5, 2016	91	5	3	60%
NuSTAR GO – Cycle 2	Dec 11, 2015	Feb 2, 2016	53	185	50	27%
Fermi GI – Cycle 9	Jan 22, 2016	May 5, 2016	104	184	36	20%
NESSF-16	Feb 8, 2016	June 1, 2016	114	136	9	7%
Kepler K2 GO – Cycle 4	Mar 4, 2016	July 11, 2016	118	109	36	33%
Chandra GO – Cycle 18	Mar 15, 2016	July 18, 2016	125	556	168	30%
APRA (Basic Research)	Mar 18, 2016	Aug 13, 2016	148	157	54	34%
SAT (Technology)	Mar 18, 2016	Aug 15, 2016	150	29	7	24%
Hubble GO – Cycle 24	Apr 8, 2016	June 24, 2016	77	1094	245	22%
ADAP (Data Analysis)	May 13, 2015	Sep 22, 2016	132	238	45	19%
Exoplanet Research	May 23, 2015	Oct 7, 2016	134	47	9	19%
Spitzer GO – Cycle 13	June 8, 2016	Aug 5, 2016	58	115	49	43%
SOFIA GI – Cycle 5	July 1, 2016	Oct 25, 2016	116	179	71	40%
ATP (Astrophysics Theory)	July 8, 2016	Dec 9, 2016	154	201	31	15%

100% of announcements within 154 days

R&A Selection Rate: 22%
GO Selection Rate: 27%

ROSES-2017 Changes

Astrophysics Theory Program (ATP)



- ATP selection rates have been <20% for the past decade
  - Increases burden on proposers and reviewers
  - Most proposals rated VG do not receive funding
- Beginning in ROSES-2017, ATP proposals will be solicited every other year
- No reduction to ATP budget, twice as many selections, half as often
- Success rates likely to increase to ~30%

Theoretical and Computational Astrophysics Networks (TCAN)

- TCAN supports coordinated efforts in fundamental theory and computational techniques.
- TCAN aims to unite researchers in collaborative networks that cross institutional and geographical divides.
- NASA expects to issue a call for proposals for TCAN with its deadline late in the ROSES-2017 cycle (early CY 2018).

New Process for Nancy Grace Roman Technology Fellowship

RTF gives early career researchers the opportunity to develop the skills necessary to lead astrophysics flight instrument development projects, including suborbital investigations; to develop innovative technologies for space astrophysics; and to foster new talent by putting early career instrument builders on a trajectory towards long-term positions. NASA is committed to supporting deserving early career researchers by selecting one or more Roman Technology Fellows every year.

1 For early-career applicants:

- **Submit APRA proposal**
- **Tick RTF box, include one-page application**
- **Undergo successful review, APRA proposal selected**
- **Receive the title "Roman Technology Fellow"**

2 When a previously selected RTF gains a permanent or permanent-track position:

- **Submit proposal for up to $300k in Fellowship Funds**
- **Undergo successful review**
- **Use Fellowship Funds to start lab or research group**

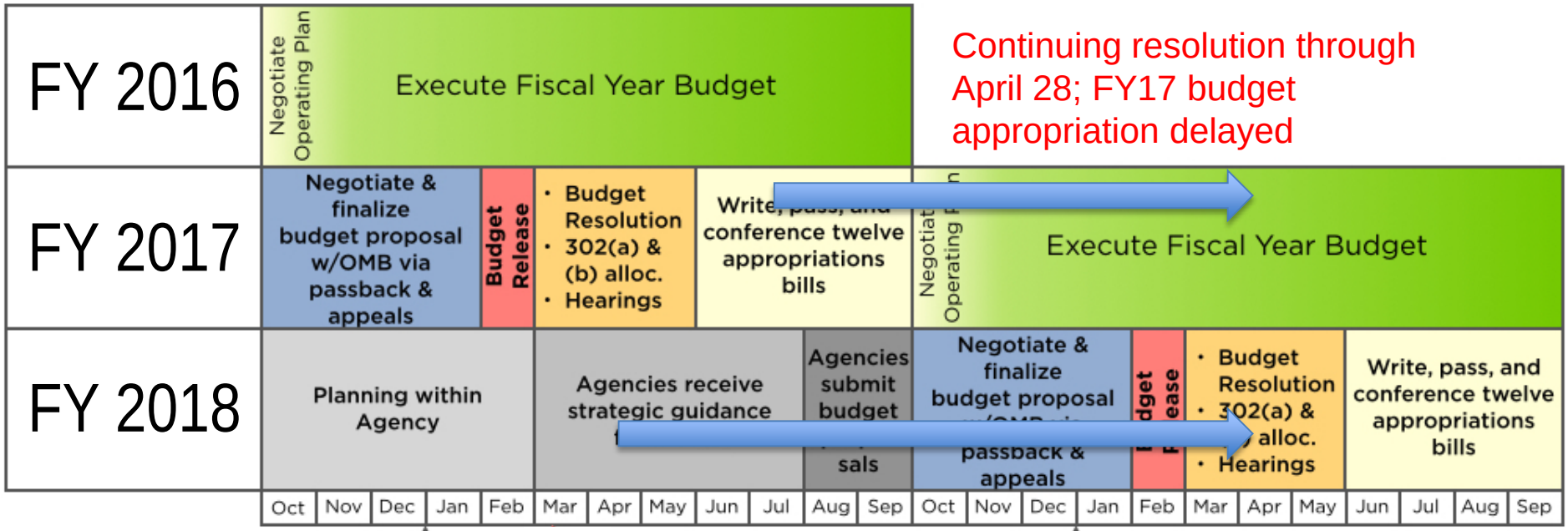
NASA Astrophysics Postdoctoral Fellowships
Einstein, Hubble, and Sagan Fellowships

- **Starting FY18 (fellows selected in early 2017), a fraction** of Postdoc Fellowship budget is re-allocated to community grants (Astrophysics R&A programs)
- **Why**: To restore balance of $$ between research grants & postdoc fellowships, which has changed from 10:1 to 6:1 over the last decade.
- **Rebalance of $$ à Reduction in total number of fellowships.**
  - Current $$ supports ~100 Fellowships – will be reducing to ~75 Fellowships (~25 new Fellows per year)
  - Frees up additional ~$6M for R&A after fully implemented.
- **Large overlap in applications to Hubble/Einstein/Sagan à combine application & review process into a single application & review**
  - Reduces work for applicants, letter writers, reviewers
  - Hubble/Einstein/Sagan symposia to continue
- **The changes will not alter the current balance or the mix of science topics within the overall Postdoc Fellowship program.**

NASA Astrophysics

Budget Update

Federal Budget Cycle



Continuing resolution through April 28; FY17 budget appropriation delayed

Start of Calendar Year 2016

Skipped (which is normal for an Administration change)

Start of Calendar Year 2017

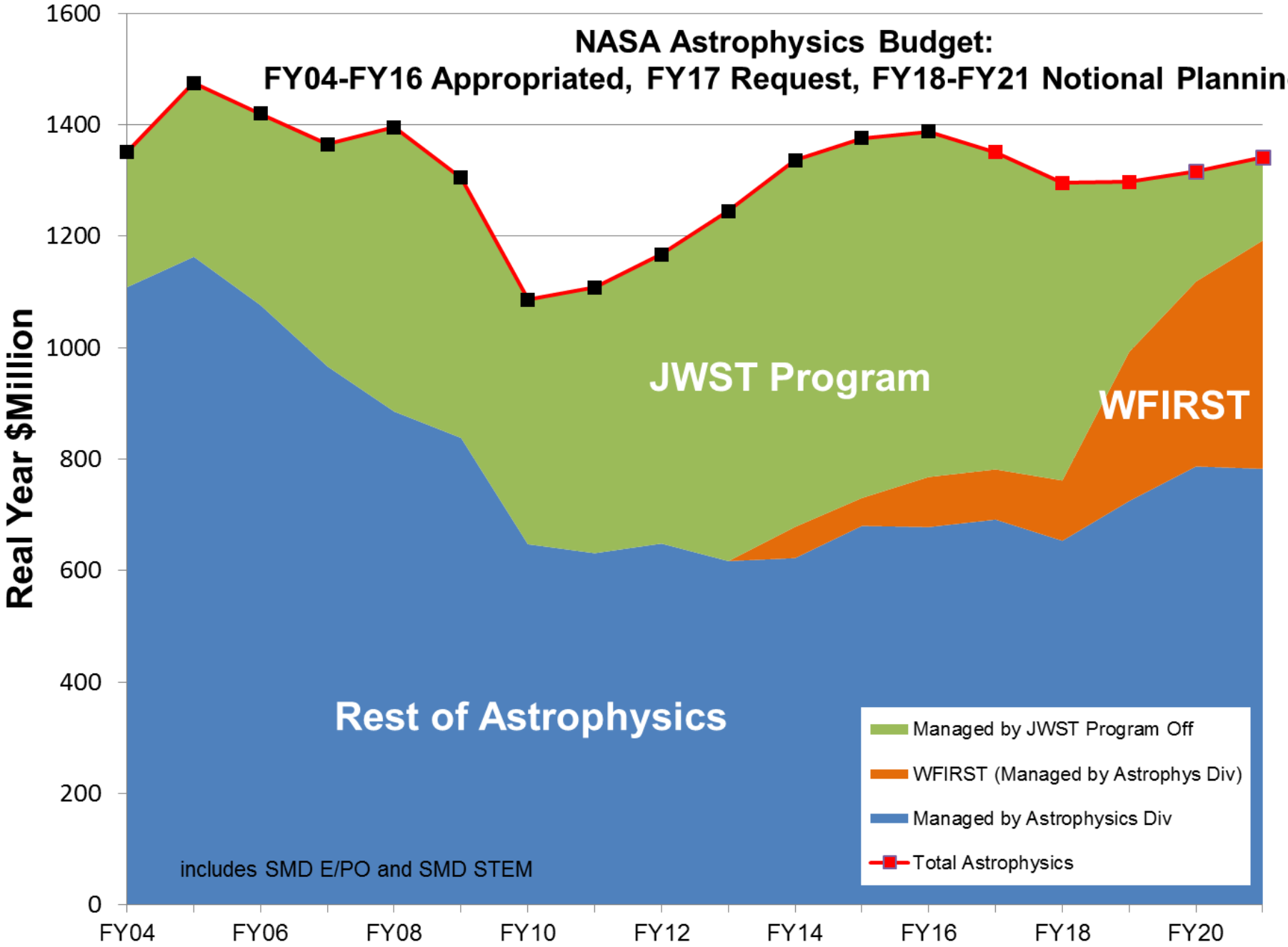
FY18 budget formulation delayed

Adapted by Kevin Marvel (AAS)
https://aas.org/files/budgetprocess_adaptedfromaaas.jpg
from budget presentation by Matt Hourihan (AAAS)
http://www.aaas.org/page/presentations

FY 2017 Budget Update

- FY17 budget request sent to Congress in February 2016
  - The FY17 budget request fully supports NASA astrophysics plans including Webb Telescope, WFIRST, Explorers, R&A, etc.
- Both House and Senate appropriations committees have marked up the FY17 NASA budget request
  - Each chamber directed specific – but different – changes in spending from the FY17 budget request (NASA planning budget)
- Neither chamber of Congress has passed a NASA appropriations bill

- Before October 1, Congress passed and the President signed a continuing resolution to fund the Government until December 9.
- On December 9, Congress passed and the President signed a continuing resolution to fund the Government until April 28.
- Neither continuing resolution contained any special language regarding NASA astrophysics.
- The continuing resolution keeps the Government operating at the FY16 appropriated budget level. All NASA astrophysics projects and activities can continue as planned under the continuing resolution.



Unchanged since February 2016

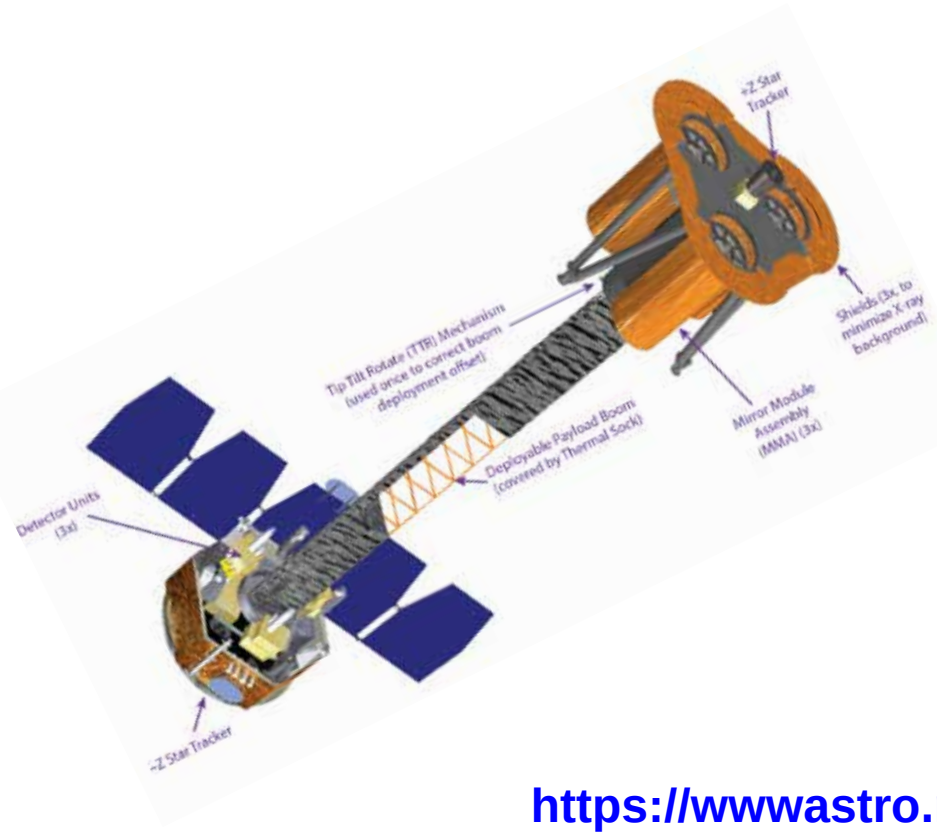
NASA Astrophysics

Program Update

New Small Explorer (SMEX) Selected: IXPE

Imaging X-ray Polarimetry Explorer

- PI: Martin Weisskopf (NASA Marshall Space Flight Center)
- Team members: NASA Marshall Space Flight Center (MSFC), Italian Partners (ASI, IAPS/INAF, INFN), Ball Aerospace, Laboratory for Atmospherics and Space Physics (LASP)



- **Opens a new window on the universe — imaging (≤ 30″) X-ray polarimetry**
- **Addresses key science questions**
  - Spin of a black hole
  - Geometry and magnetic-field in magnetars
  - Magnetic field in synchrotron X-ray sources
  - Geometries of pulsars (isolated & accreting)
- **Provides powerful and unique capabilities**
  - Sensitivity 100 times OSO-8 experiment
  - Simultaneously provides imaging, energy, timing, and polarization data
  - Instrument systematic effects less than 1%
- **Proposed Launch: November 2020**

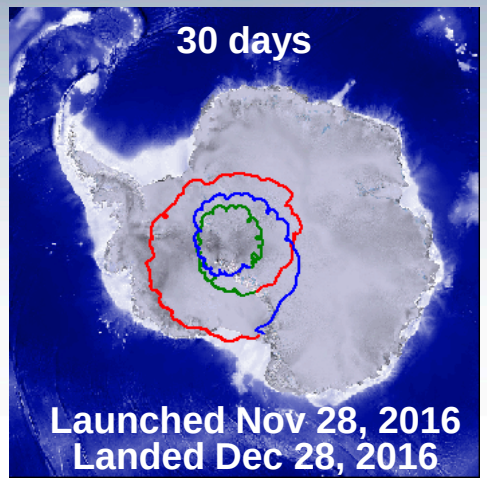
https://wwwastro.msfc.nasa.gov/ixpe/

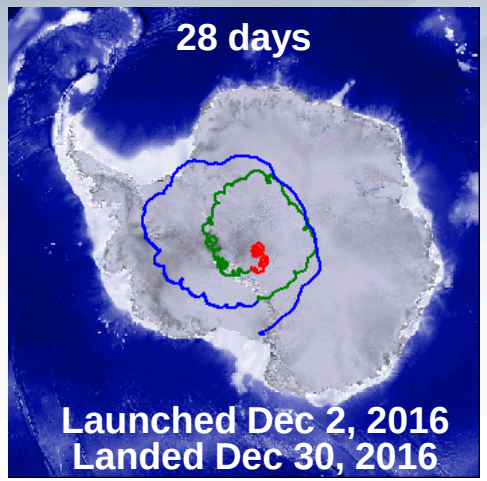
X-ray Astronomy Recovery Mission

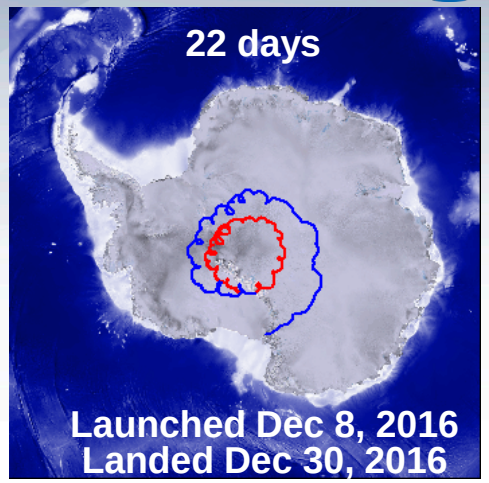
- **JAXA has proposed an X-ray Astronomy Recovery Mission (XARM) to recover the science lost with Hitomi**
  - Ministry has submitted JAXA funding request to Diet for approval
  - JAXA has invited NASA's participation as a key partner in XARM
- **XARM recommended by NASA Astrophysics Subcommittee, NASA Science Committee, and NASA Advisory Council**
  - NASA developing plan for funding NASA contribution from existing budget with minimal impact to other planned activities
  - NASA project to be directed to GSFC following a "build-to-print" approach; only the GSFC team can execute a build-to-print project, on a rapid schedule and at the lowest cost
  - Participation by U.S. science community will be openly solicited at an appropriate time
- **NASA and JAXA are developing a notional joint implementation plan for NASA participation in XARM**
  - Multiple agency and project level meetings have occurred since July 2016, including extensive lessons learned meetings and bilateral discussions
  - Japan decision expected in January 2017; NASA project start expected in Spring 2017; JAXA target launch date is end of JFY2020 (Mar 31, 2021)

2016-2017 Antarctica Balloon Campaign

https://www.csbf.nasa.gov/antarctica/payloads.htm







BACCUS – E.-S. Seo, U Maryland – Study boron and carbon cosmic rays in upper stratosphere

ANITA-4 – P. Gorham, U Hawaii – Search for ultra-high energy neutrinos (4th flight)

STO-2 – C. Walker, U Arizona – Study life cycle of galactic interstellar gas & star formation

2016-2017 Antarctica Balloon Campaign

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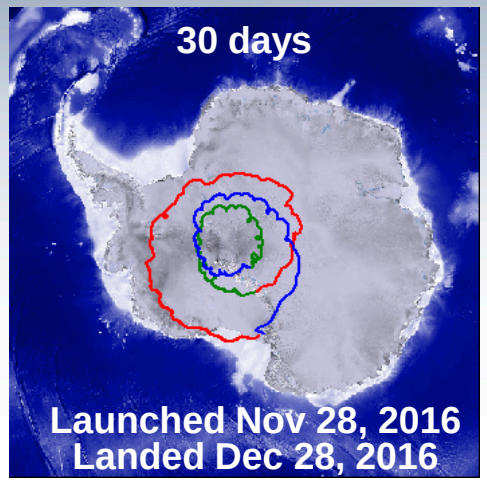

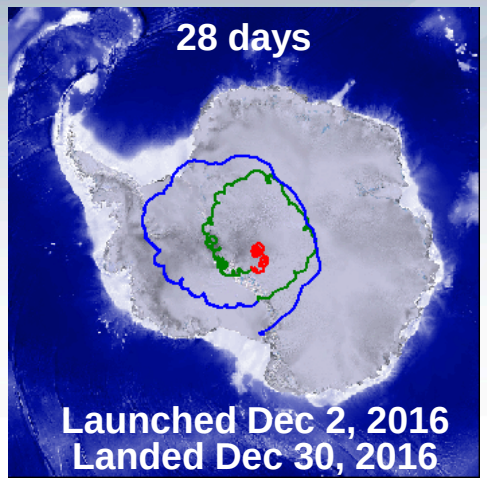

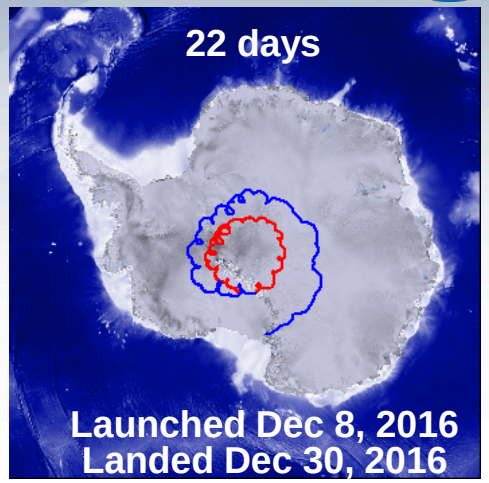

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Astrophysics Missions in Development

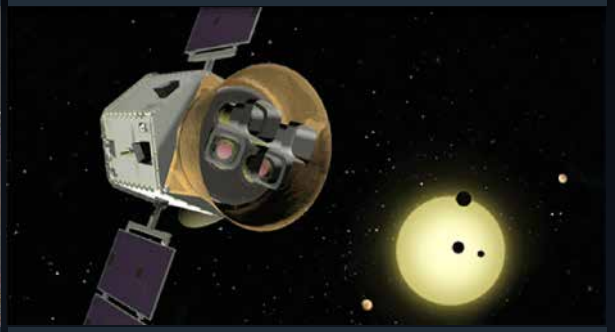
ISS-NICER
4/2017
NASA Mission

Neutron Star Interior Composition Explorer

ISS-CREAM
6/2017
NASA Mission

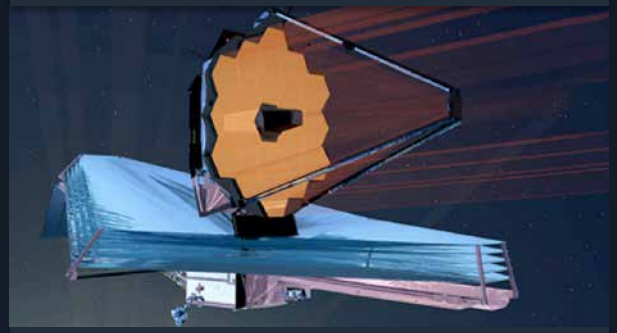
Cosmic Ray Energetics And Mass

TESS
3/2018
NASA Mission



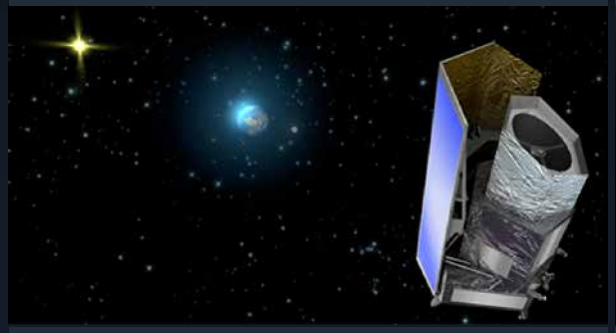
Transiting Exoplanet Survey Satellite

Webb
10/2018
NASA Mission



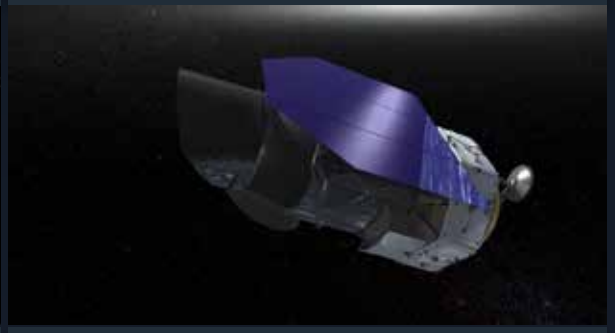
James Webb Space Telescope

Euclid
2020
ESA-led Mission



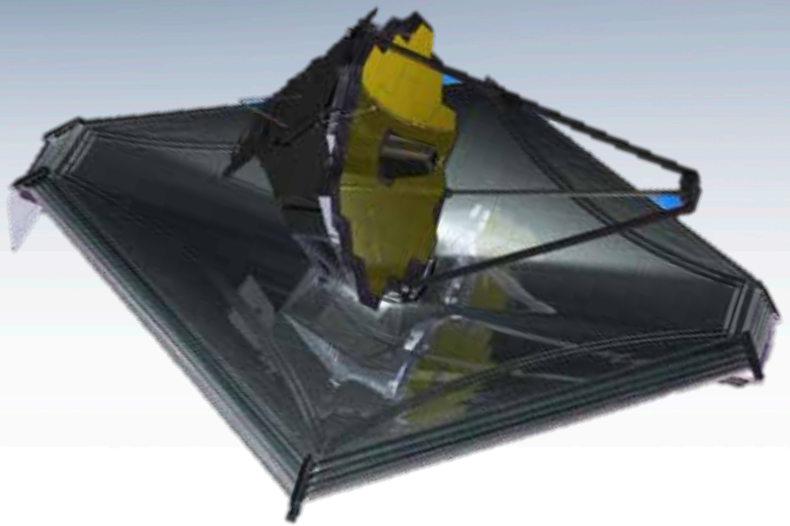
NASA is supplying the NISP Sensor Chip System (SCS)

WFIRST
Mid 2020s
NASA Mission



Wide-Field Infrared Survey Telescope

Webb
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/

James Webb Space Telescope

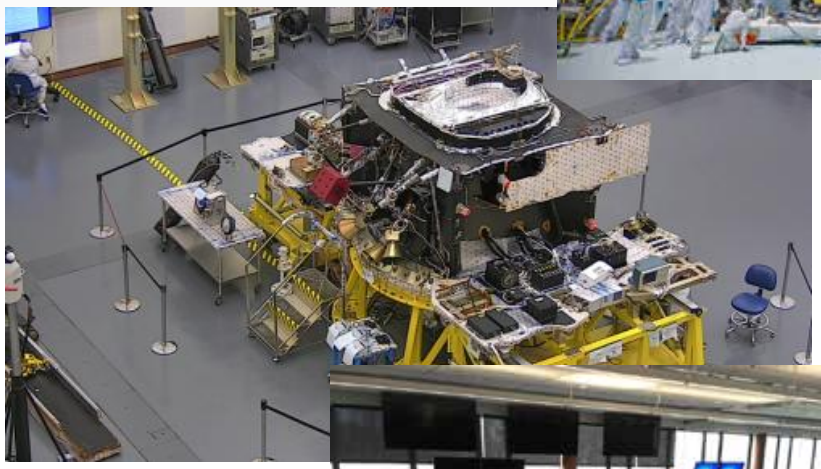
2016 Accomplishments

- Science payload, telescope + instruments completed
- Ambient environmental testing of science payload started
- Spacecraft assembly nearly completed
- Completed 3rd and final test of Pathfinder Telescope and ground support equipment at JSC in support of 2017 test of flight hardware

2017 plans

- Complete ambient testing of combined Telescope and instruments
- Cryo-vacuum testing of the science payload at JSC
- Complete spacecraft bus
- Integrate spacecraft and sunshield
- Issue calls for Early Release Science and Cycle 1 proposals
- Flight operations rehearsals and training

Webb Hardware Progress

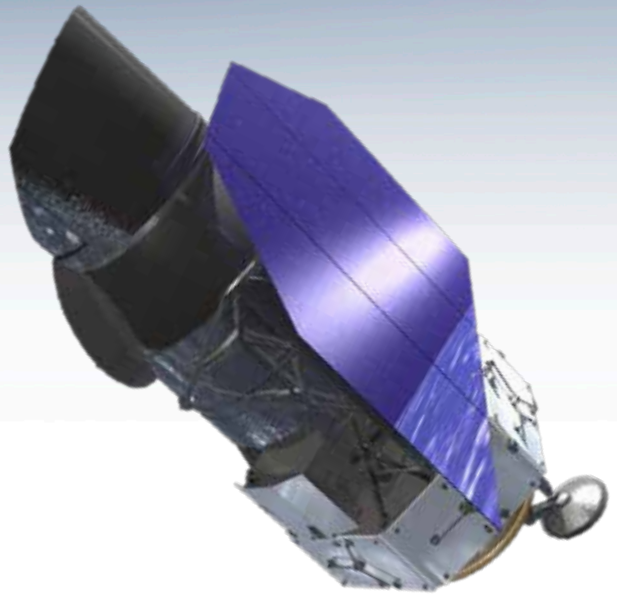


Webb Summary

- Program remains within replan budget and on time for October 2018 launch readiness date.
- Project is concluding manufacturing phase and is transitioning into integration and test. There are new, first time challenges associated with this phase.
- First proposal opportunities are this year.
  - v Early release science proposals due August 18
  - v Call for GO Cycle 1 proposals will be released in November 2017, proposals will be due in March 2018

JWST remains on track for an October 2018 launch

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:

- Mission new start on February 17, 2016, when the NASA Associate Administrator approved WFIRST to begin Phase A
- Working toward System Requirements Review in June 2017 and start of Phase B in October 2017.
- WFIRST does not have a starshade; but NASA is studying a starshade for the next Decadal Survey's consideration.
  - Starshade compatibility is being studied during Phase A; mandated minimum impact on WFIRST.
  - NASA will decide by fall 2017 whether to maintain starshade compatibility.
- National Academies' Midterm Assessment stressed need for cost control on WFIRST.
  - Consistent with current NASA approach to managing design/development of the mission.
- On track for completing maturation of new technologies in 2017.
- In-guide budget supports launch in mid-2020s.

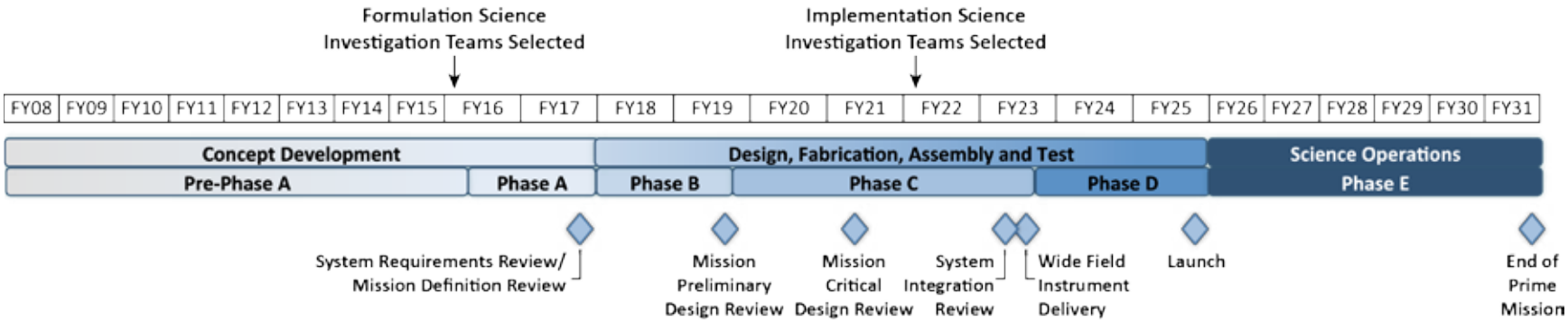
http://wfirst.gsfc.nasa.gov/

WFIRST Development


Flight Primary Mirror Assembly


Primary Mirror Instrumentation and Thermal Control


Spacecraft Mockup

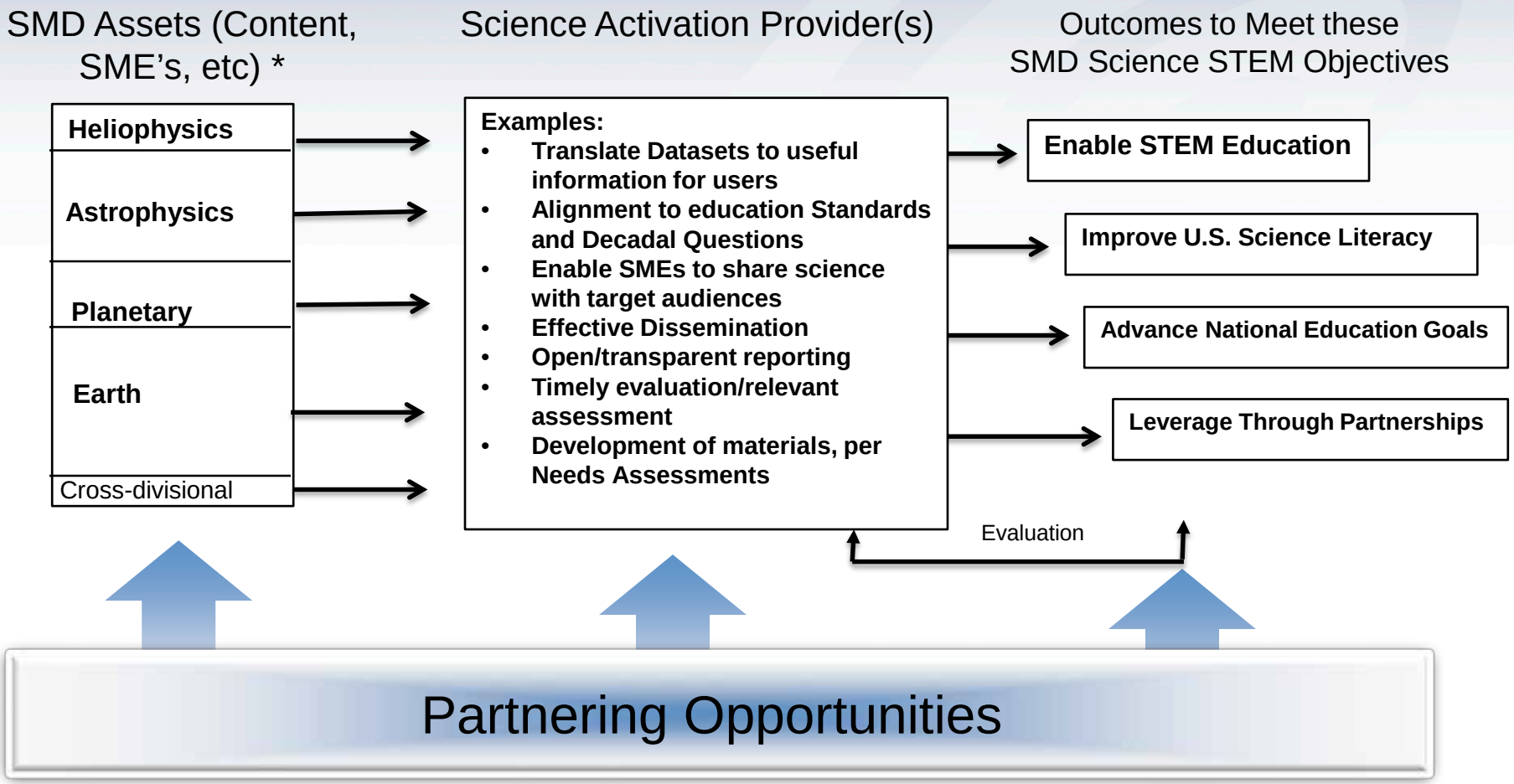


Timeline for WFIRST with major events; dates are for illustration purposes only

NASA Science Mission Directorate

STEM Activation Overview

SMD Science STEM Activation Model



* Divisions responsible for science content datasets, Infrastructure/Tools (e.g. Eyes, GSFC Visualizations), SME selection, and enabling flight opportunities

Key Features of the SMD STEM Science Activation Effort

- The SMD STEM Science Activation emphasizes NASA's unique assets to meet evidence-based audience needs in an active-learning way (not internally focused to meet NASA needs)
- Awardees cooperate with SMD *and each other* to promote understanding by major Science discipline in support of SMD's Science Education objectives/priorities

- Model relies on multiplication effect of partnerships
- Approach responds to technical and social evolution in science education environment

Desired Outcome - To further enable NASA science experts and content into the learning environment more effectively and efficiently with learners of all ages

Map of NASA Science Mission Directorate Science Activation Selections, including Co-Is

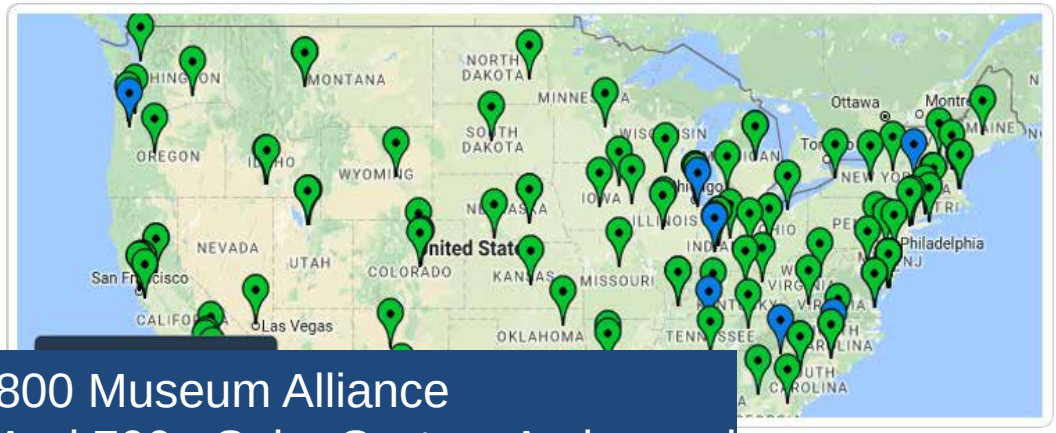
https://www.nasa.gov/feature/list-of-science-education-partners-for-nasa-stem-agreements

Top Level

- 30 Challenger Centers
- 400K+ Girl Scouts
- Open-source products to All US Planetariums
- 2000+ Eclipse events

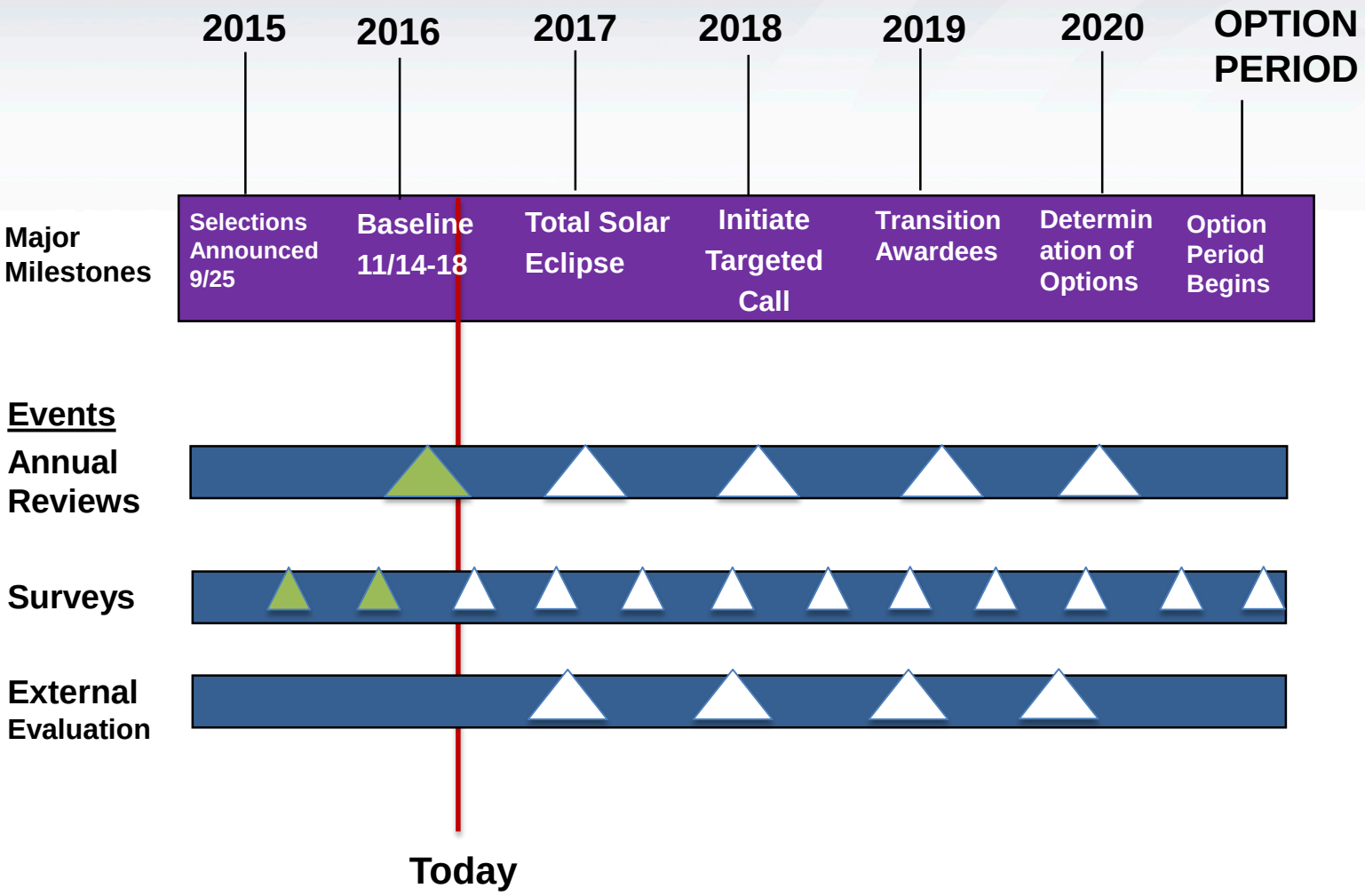
1200 Libraries

250 Museums and Science Centers



800 Museum Alliance
And 700+ Solar System Ambassad

SMD STEM Science Activation Schedule
2017 and Beyond



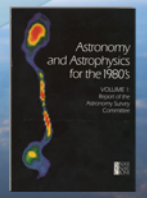
NASA Astrophysics

Planning for the 2020 Decadal Survey

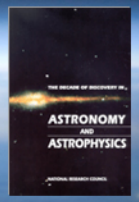
ASTROPHYSICS

Decadal Survey Missions

1972
Decadal Survey
Hubble



1982
Decadal Survey
Chandra



1991
Decadal Survey
Spitzer, SOFIA

2001
Decadal Survey
Webb

2010
Decadal Survey
WFIRST

2020 Decadal Survey

Notional Schedule

2018 March	Astro 2020 proposal submitted to Agencies
2018 December	Chair nominated
2019 January	AAS Town Hall
2019 Feb/March	Committee begins meeting
2019 May/June	Panels begin meeting
2020 May	Panels complete reports and deliver to Committee
2020 August	Review of survey and panel reports begins
2020 December	Astro 2020 completed and report released to Agencies and public

Preparing for the 2020 Astrophysics Decadal Survey

- NASA has begun to study large mission concepts as input to the 2020 Decadal Survey.
  - A well informed Decadal Survey makes better recommendations.
- NASA appointed Science and Technology Development Teams and initiated four large mission concept studies.
  - Far Infrared Surveyor / Origins Space Telescope
  - Habitable Exoplanet Imaging Mission
  - Large Ultraviolet/Optical/Infrared (LUVOIR) Surveyor
  - X-ray Surveyor / Lynx
- Science and Technology Definition Teams have a significant role and responsibility.
  - Develop science case
  - Flow science case into mission parameters
  - Assess technology gap list
  - Direct trades of science vs cost/capability
- All teams have met in several face-to-face meetings since early this year.
  - Teams are planning for additional face-to-face meetings in FY17

http://science.nasa.gov/astrophysics/2020-decadal-survey-planning/

Preparing for the 2020 Decadal Survey
Large Mission Concepts

NASA has assembled Science and Technology Definition Teams (STDTs) for each of the four large mission candidates to enable Mission Concept Studies as input to the 2020 Decadal Survey.

	Community STDT Chairs	Center Study Scientist	Study Lead Center	HQ Program Scientist
Far IR Surveyor asd.gsfc.nasa.gov/firs	Asantha Cooray* Margaret Meixner	David Leisawitz	GSFC	Kartik Sheth
Habitable Exoplanet Imaging Mission www.jpl.nasa.gov/habex	Scott Gaudi* Sara Seager	Bertrand Mennesson	JPL	Martin Still
Large UV/Optical/IR Surveyor asd.gsfc.nasa.gov/luvoir	Debra Fischer* Bradley Peterson	Aki Roberge	GSFC	Mario Perez
X-ray Surveyor wwwastro.msfc.nasa.gov/xrs	Feryal Ozel* Alexey Vikhlinin	Jessica Gaskin	MSFC	Dan Evans

* Astrophysics Subcommittee member

http://science.nasa.gov/astrophysics/2020-decadal-survey-planning/

Astrophysics Probes

- NASA is soliciting mission concept ideas for medium-size missions as part of community preparations for the 2020 Decadal.
  - An Astrophysics Probe is defined as a mission with total lifecycle cost (NASA's Phase A through E) in the range $400M to $1B
  - NASA will provide funding to selected PI-led mission concept study teams, as well as fund a run with a mission design center at GSFC (IDC) or JPL (Team X), as well as a cost assessment at the end of the study
  - Proposals for Astrophysics Probe mission concept studies were received on November 15
- NASA received 27 compliant proposals spanning all areas of astrophysics, and expects to select 5-8 proposals for Astrophysics Probe mission concept studies
- Next Steps:
  - Selection targeted for February 2017
  - Award initiation targeted for March 2017
  - Community workshop at the Winter 2018 AAS meeting at National Harbor
  - Final reports due to NASA in September 2018
- NASA will submit the final reports and the results of the NASA cost assessment to the 2020 Decadal Survey Committee

Revised
December 17, 2016

BACKUP

New Associate Administrator for Science Mission Directorate

Space Studies Board, Heliophysics Decadal Survey, CubeSat Study

Dr. Thomas Zurbuchen

- Professor of space science and aerospace engineering, and founding director of the Center for Entrepreneurship, at the University of Michigan in Ann Arbor.
- Experience includes research in solar and heliospheric physics, experimental space research, space systems, and innovation and entrepreneurship.
- Authored or coauthored more than 200 articles in refereed journals on solar and heliospheric phenomena.
- Involved with several NASA science missions including Ulysses, MESSENGER, and ACE.
- Ph.D. in and M.S. degrees in physics from the University of Bern in Switzerland.

New Deputy Associate Administrator for Science Mission Directorate

Dennis Andrucyk

- Deputy Associate Administrator for Space Technology Mission Directorate at NASA Headquarters
- Director of the Applied Engineering & Technology Directorate, Director of Engineering, and Chief Technologist at NASA Goddard Space Flight Center.
- Prior to NASA, worked at Department of Defense, National Security Agency, Naval Research Laboratory, Westinghouse Electric, General Electric, and Northrop Grumman Corporation.
- Awarded Meritorious Presidential Rank Award, NASA Outstanding Leadership Medal, and NASA Exceptional Service Medal.
- B.S. in engineering from U. Maryland.

NASA Astrophysics Activities

Strategic Missions

Hubble Space Telescope, Chandra X-ray Observatory, XMM-Newton (ESA mission), Spitzer Space Telescope, Fermi Gamma-ray Space Telescope, Kepler Space Telescope, Stratospheric Observatory for Infrared Astronomy (SOFIA), LISA Pathfinder (ESA mission), James Webb Space Telescope, Widefield Infrared Survey Telescope (WFIRST)

Explorers Missions

Swift Gamma-ray Burst Explorer, Nuclear Spectroscopic Telescope Array (NuSTAR), Neutron star Interior Composition Explorer (NICER), Transiting Exoplanet Survey Satellite (TESS), SMEX (AO 2014): IXPE, PRAXYS, or SPHEREX, MO (AO 2014): LiteBIRD (JAXA mission) or GUSTO, MIDEX/MO AO in 2016

Research and Analysis

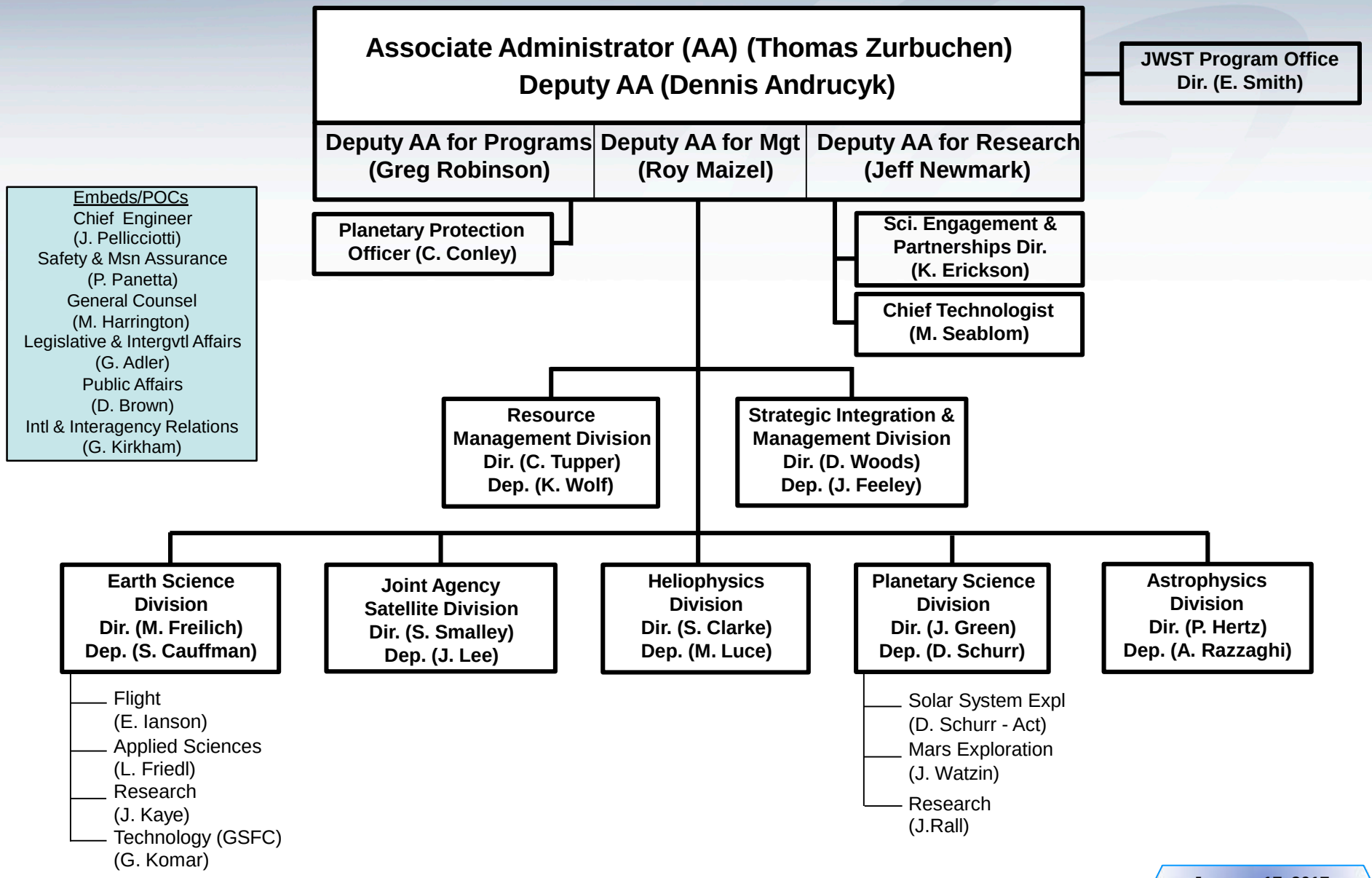
Astrophysics Data Analysis Program (ADAP), Astrophysics Research and Analysis (APRA), Astrophysics Theory Program (ATP), Einstein Fellowships, Exoplanet Research Program (XRP), Hubble Fellowships, Roman Technology Fellowships (RTF), Sagan Fellowships, Theoretical and Computational Astrophysics Networks (TCAN)

Other Activities

Astrophysics Archives (ADS, HEASARC, IRSA, MAST, NED, NExScI), Balloon Program, Cosmic-ray Energy and Mass on the International Space Station (ISS-CREAM), Keck Observatory, Large Binocular Telescope Interferometer (LBTI), NASA-NSF Exoplanet Observational Research (NN-EXPLORE)

SMD STEM Education Activities

SMD Organization



January 17, 2017

Astrophysics Division, NASA Science Mission Directorate

Resource Management
Omana Cawthon+
Clemencia Gallegos-Kelly+

Director
Paul Hertz
Deputy Director
Andrea Razzaghi

Lead Secretary: Kelly Johnson
Secretary: Kyle Nero
Program Support Specialist: Jackie Mackall

Cross Cutting
Technology Lead: Billy Lightsey*
Education POC: Hashima Hasan (Lead Comm Team)
Public Affairs Lead: Kartik Sheth
Information Manager: Lisa Wainio*
Strategic Planning: Rita Sambruna

Astrophysics Research

Program Manager: Linda Sparke
Program Support: Ingrid Farrell*
Astrophysics Data Analysis: Doug Hudgins
Astrophysics Theory: Keith MacGregor*, Theresa Brandt*
Exoplanet Research: Martin Still*
APRA lead: Michael Garcia*
Cosmic Ray, Fund Physics: Thomas Hams*, Vernon Jones, Keith MacGregor*, Rita Sambruna
Gamma Ray/X-ray: Dan Evans, Michael Garcia*, Stefan Immler*, Lou Kaluzienski, Rita Sambruna, Wilt Sanders
Optical/Ultraviolet: Michael Garcia*, Hashima Hasan, Mario Perez*, Martin Still*
IR/Submillimeter/Radio: Dominic Benford*, Doug Hudgins, Kartik Sheth, Eric Tollestrup*
Lab Astro: Doug Hudgins
Theory & Comp Astro Net: Keith MacGregor*
Roman Tech Fellows: Billy Lightsey*
Data Archives: Hashima Hasan
Astrophysics Sounding Rockets: Wilt Sanders
Balloons Program: Vernon Jones(PS), Mark Sistilli (PE)

Programs / Missions & Projects

Exoplanet Exploration (EXEP)

Program	Program Scientist: Doug Hudgins	Program Executive: John Gagosian
Keck	Hashima Hasan	Mario Perez*
Kepler/K2	Mario Perez*	Jeff Hayes
LBTI	Doug Hudgins	Mario Perez*
NN-EXPLORE	Doug Hudgins	John Gagosian
WFIRST	Dominic Benford*	John Gagosian

Cosmic Origins (COR)

Program	Mario Perez*	Shahid Habib*
Herschel	Dominic Benford*	Jeff Hayes
Hubble	Michael Garcia*	Jeff Hayes
James Webb^	Hashima Hasan	Ray Taylor^
SOFIA	Hashima Hasan	Shahid Habib*
Spitzer	Kartik Sheth*	Jeff Hayes

Physics of the Cosmos (PCOS)

Program	Rita Sambruna	Shahid Habib*
Athena	Michael Garcia*	Jeanne Davis
Chandra	Stefan Immler*	Jeff Hayes
Euclid	Linda Sparke	Shahid Habib*
Fermi	Stefan Immler*	Jeff Hayes
Planck	Rita Sambruna	Jeff Hayes
ST-7/LPF	Rita Sambruna	Shahid Habib*
XMM-Newton	Stefan Immler*	Jeff Hayes

Astrophysics Explorers (APEX)

Program	Wilt Sanders	Jeanne Davis
Hitomi	Lou Kaluzienski	Jeanne Davis
NICER	Rita Sambruna	Jeanne Davis
NuSTAR	Lou Kaluzienski	Jeff Hayes
Swift	Martin Still*	Jeff Hayes
TESS	Doug Hudgins	Mark Sistilli

\+ *Member of the Resources Management Division*
* *Detailee, IPA, or contractor*
^ *James Webb is part of the JWST Program Office.*

Research and Analysis Opportunities

Solicited through ROSES:

- Supporting Research & Technology
  - Astrophysics Research & Analysis (APRA)
  - Strategic Astrophysics Technology (SAT)
  - Astrophysics Theory Program (ATP)
  - Theory and Computational Astrophysics Networks (TCAN)
  - Exoplanet Research Program (XRP) & Habitable Worlds (with Planetary Science Division)
  - Nancy Grace Roman Technology Fellowship (Early Career)
  - SOFIA next-generation instrumentation
- Observations & Data Analysis
  - Astrophysics Data Analysis (ADAP)
  - Guest Observer and Guest Investigator programs for Fermi, Kepler/K2, NuSTAR, Swift, TESS

Separately solicited:

- Proposals for Hubble, Chandra, and Webb observations and archival research, SOFIA & Spitzer observations; Keck observations; XMM-Newton observations (ESA)
- Einstein, Hubble, and Sagan Postdoctoral Fellowships
- NASA Earth and Space Science Fellowships, for graduate students

Proposal Opportunities Planned for 2017

	Proposal Due Date	
Habitable Worlds	January 20, 2017 [CLOSED]	ROSES-16 E.4
NuSTAR General Observer - Cycle 3	January 27, 2017	ROSES-16 D.10
NESSF	February 1, 2017	NSPIRES
Fermi Guest Investigator - Cycle 10	February 24, 2017	ROSES-16 D.6
Spitzer DDT	Feb 28, 2017 & Sep 12, 2017	ssc.spitzer.caltech.edu
Chandra General Observer - Cycle 19	March 15, 2017	cxc.harvard.edu
Nancy Grace Roman Technology Fellowship	March 17, 2017	ROSES-16 D.9
Strategic Astrophysics Technology (SAT)	March 17, 2017	ROSES-16 D.8
Astrophysics Research and Analysis (APRA)	March 17, 2017	ROSES-16 D.3
Hubble General Observer - Cycle 25	April 7, 2017	www.stsci.edu
Astrophysics Data Analysis (ADAP)	May 16, 2017	ROSES-17 D.2
Exoplanet Research Program (XRP)	May 25, 2017 (Step 2)	ROSES-17 E.3
SOFIA Cycle 6	Approx early July	www.sofia.usra.edu
Astrophysics Theory Program (ATP)	July 27, 2017	ROSES-17 D.4
SOFIA next-generation instrumentation	Approx August	ROSES-17 D.13
JWST Early Release Science	August 18, 2017	jwst.stsci.edu
Swift Guest Investigator – Cycle 14	September 21, 2017	ROSES-17 D.5
Keck Observing	Approx October	nexsci.caltech.edu/missions/KSA/
XMM-Newton - Cycle 17	October 2017	heasarc.gsfc.nasa.gov
K2 Guest Investigator – Cycle 6	December 14, 2017 (Step 2)	ROSES-17 D.7
TESS Guest Investigator – Cycle 1	9 months before launch	ROSES-17 D.11

Update on STEM Education Cooperative Agreements dedicated to astrophysics

Universe of Learning (PI: Denise Smith, STScI; co-I institutions: CXC/SAO, IPAC/JPL, ExEP/JPL, Sonoma State U.; Evaluation: Goodman Research, Cornerstone Associates.)

- Combines science and technology from across NASA Astrophysics with proven education infrastructure to address audience needs and SMD education objectives.
- Year 1 Focus: Establishing internal team infrastructure & partnerships; needs assessment; integration & dissemination of existing content; prototypes
- Sample Highlights:
  - Developed initial prototypes of multi-wavelength data analysis activity, exoplanet spectroscopy lab, scaffolding framework.
  - Developed prototypes of two “In a Different Light” ViewSpace segments, ViewSpace browser-based app, Orion Nebula visualization.
  - Disseminated existing exhibits to 9 venues; held 10 coding workshops
  - Held 3 Science Briefings for Museum Alliance; initiated partnerships with ASTC, Smithsonian Affiliations, Center for Astronomy Education

Girl Scouts: Reaching for the Stars (PI: Edna DeVore, SETI)

- 6 space science badges are in broad use across the USA—all ages of Girl Scouts
- Volunteers trained at U.AZ and GSFC comprise a network of Girl Scout astronomy volunteers in councils across the USA to communicate and train other volunteers
- Volunteer Tool Kit (online) for astronomy badges serves both girls and volunteer leaders
- Astronomy badge development becomes a model for future STEM badge sequence development with external SMEs
- NASA and GSUSA establish a long-term relationship (MOU).
- Many Girl Scouts will participate in the 2017 Solar Eclipse

Update on STEM Education Cooperative Agreements dedicated to astrophysics

SOFIA Airborne Astronomy Ambassadors (PI: Dana Backman; Evaluation: WestEd)

- Spring 2016 visits to school districts in N. & S. California, followed by convening focus groups to assess 'customer' needs from Offices of Education STEM/STEAM coordinators and district science leaders.
- Received 8 signed Memoranda of Understanding from school districts (4 in N. Cal, 4 in S. Cal) for AAA participation during SOFIA Cycles 5 & 6 (2017 & 2018).
- Applications opened Sept. 15 through Dec. 18 for teachers to participate in Cycles 5 & 6.
- SOFIA flights with first Cycle 4 Ambassadors: 2016 Oct. 18 & 19 (MA & CA), Nov. 7 & 9 (MO & OH); remaining Cycle 4 flights scheduled for January, February, and March 2017.
- NASA AFRC Palmdale B703 (SOFIA home base) location footage filming & testing of in-flight downlink by team from San Francisco Exploratorium (Oct. 18 & 19); tested live feed from B703 to Boston Museum of Science (Oct. 21).
- Planned EM spectrum / multi-wavelength astronomy curriculum to be used by Cycles 5 & 6 AAAs that will be pilot-tested by Cycle 4 AAAs.

BACKUP

Additional Program Updates

2016 Astrophysics Senior Review
NASA Implementation Decisions

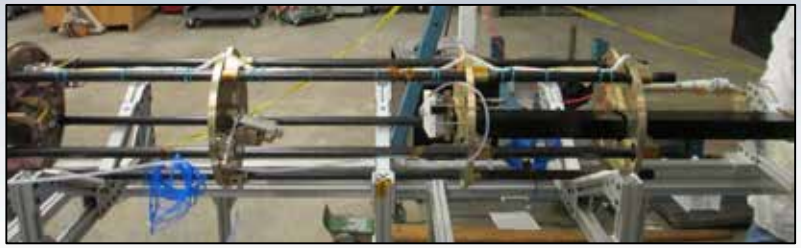
Mission	Extend?	SR2018?	Comments
Hubble	Yes	Yes	
Chandra	Yes	Yes	
Fermi	Yes	Yes	Reduced budget
Kepler/K2	Yes	No	End-of-mission plan
NuSTAR	Yes	Yes	
Spitzer	Yes	No	Reduced budget; end-of-mission plan
Swift	Yes	Yes	Augmentation for automation
XMM	Yes	Yes	Augmentation for GO program

- Maintain all 8 missions in operation, with K2 and Spitzer ending.
  - Spitzer ending in mid-FY19 after providing significant precursor work for JWST and after JWST commissioned.
  - Kepler/K2 ending in FY19 when fuel is exhausted.
- Maintaining all 8 missions requires some reductions in mission funding in order allow the overarching finding (continuation of all missions) to be implemented.
- Other SR2018 missions include SOFIA, NICER*, TESS*. (* depends on launch date)

2017 Sounding Rocket Launches

CHESS 3
(Colorado High-resolution Echelle Stellar Spectrograph)

PI - **K. France** / Univ. of Colorado **~June 2017**
Technology development for future UV missions, characterizing ISM towards nearby stars.

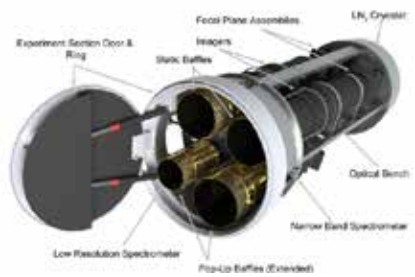


Micro-X

PI - **E. Figueroa** / Northwestern Univ. **~Jul 2017**
Characterize plasma conditions in Puppis A SNR using Transition-Edge Sensors.

CIBER II
(Cosmic Infrared Background Experiment)

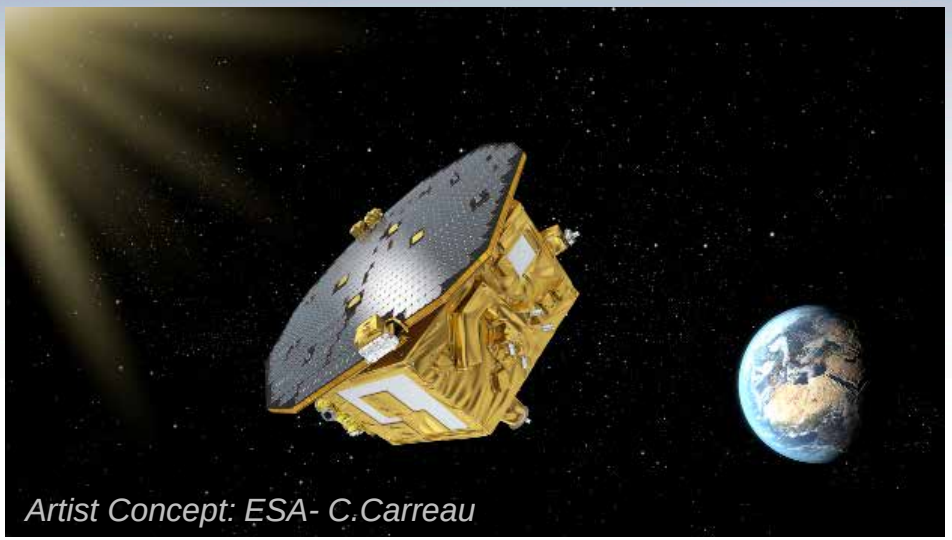
PI - **J. Bock** / Caltech **~Aug 2017**
Characterize the extragalactic near-infrared background light.



DEUCE
(Dual-channel Extreme Ultraviolet Continuum Experiment)

PI - **J. Green** / Univ. of Colorado **~Oct 2017**
Technology development for future UV missions, physics of re-ionization from B stars at extreme UV.

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

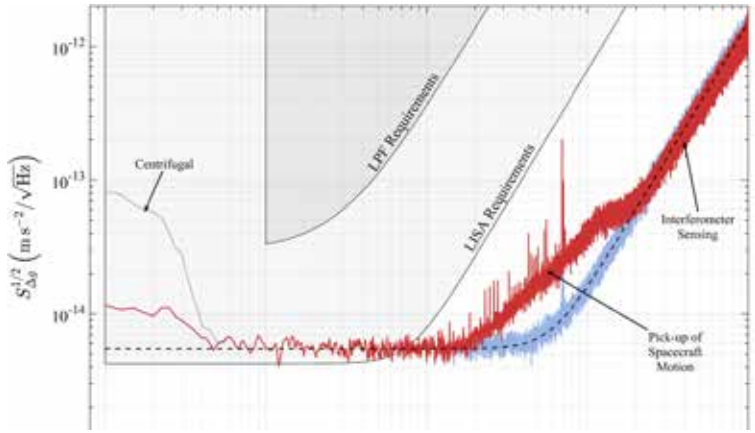


- ESA Mission with NASA Collaborating
- Project Category: 3 Risk Class: C
- DRS flies on the ESA LISA Pathfinder spacecraft
- Sun-Earth L1 halo orbit
- Drag-free satellite to offset solar pressure
- Payload delivery: July 2009
- Launched: December 3, 2015 GMT
- LPF prime mission: 7 months
- Data Analysis: 12 months

http://sci.esa.int/lisa-pathfinder/

CURRENT STATUS:

- LISA Pathfinder completed nominal ESA science operation on June 25, 2016
- NASA's DRS successfully completed its planned experiments and technology demonstration on December 7, 2016, ending the prime mission.
- Extended mission started December 8, 2016 and will continue into early 2017.
- LISA Pathfinder exceeded requirements and demonstrated critical technologies and systemic controls needed for a LISA-like gravitational wave observatory.



M. Armano et al., *Phys. Rev. Lett.* 116, 231101

Hitomi

(formerly 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**: Feb 17, 2016 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.

CURRENT STATUS

- The U.S. provided key instrument contributions to the JAXA Hitomi mission, including Soft X-ray Telescope mirrors and Soft X-ray Spectrometer
- Following successful activation of the observatory and instruments, Hitomi suffered a mission-ending spacecraft anomaly on March 26, 2016
- Completed the JAXA mishap investigation; PI-led team completed analysis and archiving of available data; mission close-out by March 2017
- "First-Light" SXS observation of Perseus cluster reveals unexpectedly low level of plasma turbulence in central region

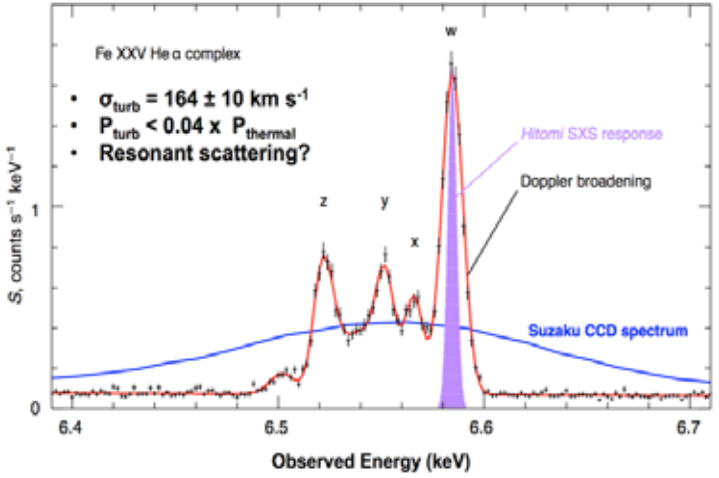


Figure: Hitomi SXS spectrum of Perseus cluster (Hitomi Collaboration, Nature, 2016, 535, 7610)

SOFIA
Stratospheric Observatory for Infrared Astronomy

- **World's Largest Airborne Observatory**
- 2.5-meter telescope
- 80/20 Partnership between NASA and the German Aerospace Center (DLR)
- Science Center and Program Management at NASA-Ames Research Center
- Science Flight Operations at NASA-Armstrong Flight Research Center
- Four U.S. and two German science instruments commissioned
  - Provide imaging, spectroscopy, photometry and polarization-mapping with emphasis across mid- and far-infrared wavelengths
  - Advanced science instruments under development for future operation

CURRENT STATUS:

- In prime mission operation since May 2014
- Observing status:
  - 535 observing hours awarded for Cycle 5 which will start in February 2017.
  - Commissioned new Upgraded German REceiver for Astronomy at Terahertz (upGREAT) High Frequency Array (HFA) in October 2016.
  - High-resolution Airborne Wideband Camera-plus (HAWC+) commissioning completed in December 2016.
  - High Resolution Mid Infrared Spectrometer (HIRMES) instrument under development.
  - Next Gen instrument solicitation planned for mid-2017

https://www.sofia.usra.edu/

NICER
Neutron star Interior Composition Explorer

NICER in storage at KSC

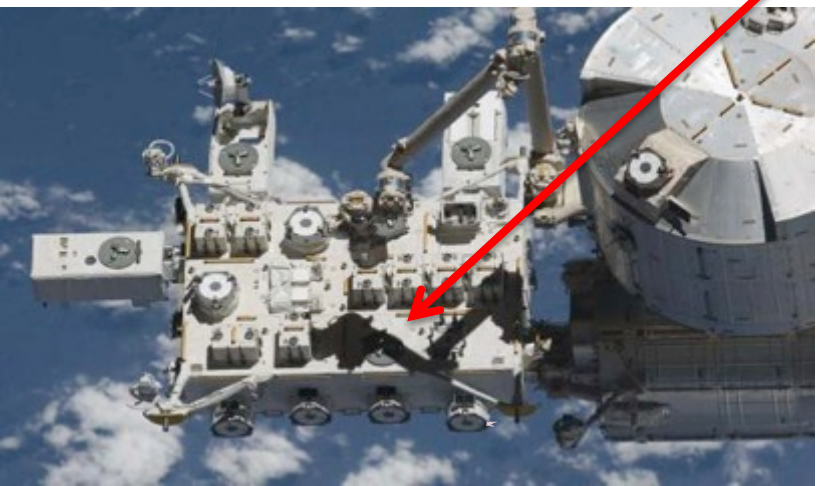
- **Explorer Mission of Opportunity**
- **PI:** Keith Gendreau, GSFC
- **Launch:** April 2017 on Space-X Falcon 9
- **Science Objectives:** Perform high-time-resolution and spectroscopic observations of neutron stars in the .2-12 keV energy range to study the physics of ultra-dense matter in the core 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:

- All subsystems/sub-assemblies have completed fabrication and environmental testing P
- The NICER payload completed final integration and test P
- December 2015: Pre-environmental Review P
- January 2016: Start Phase D P
- February 2016: Start of payload environmental testing P
- April 2016: Completion of payload environmental testing P
- June 2016: Payload delivered to KSC and stored at KSC until launch P
- April 2017 (TBC): Launch on SpaceX-11 commercial resupply service (CRS) flight to ISS

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

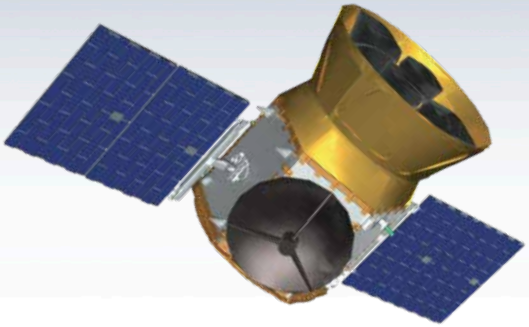
CREAM
Cosmic Ray Energy and Mass



- July 2015: CREAM delivered to KSC and stored at KSC until launch P
- June 2017 (TBC): Launch on SpaceX-12 commercial resupply service (CRS) flight to ISS pending review of recent SpaceX pad anomaly.

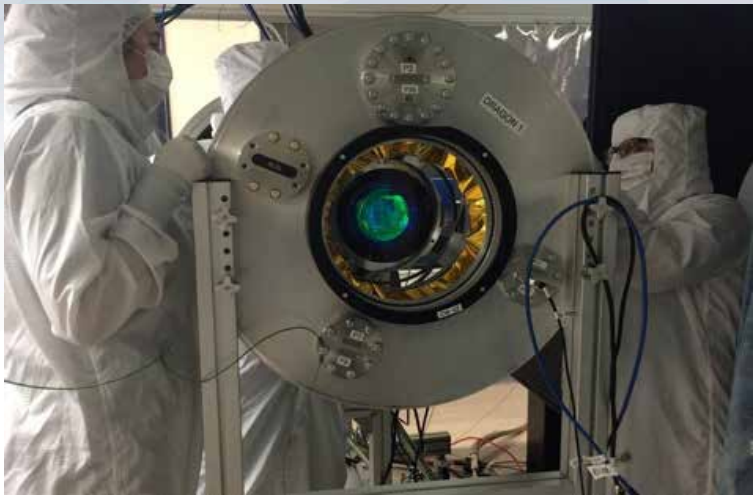
http://cosmicray.umd.edu/iss-cream/

TESS
Transiting Exoplanet Survey Satellite



CURRENT STATUS:

- Both instrument and spacecraft bus are currently on schedule to be delivered in ~March 2017 to begin Observatory Integration.



Flight Camera #1 Cold Optical Testing at MIT/Kavli

Medium Explorer (MIDEX) Mission

PI: G. Ricker (MIT)

Mission: All-Sky photometric exoplanet mapping mission.

Science goal: Search for transiting exoplanets around the nearby, bright stars.

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).

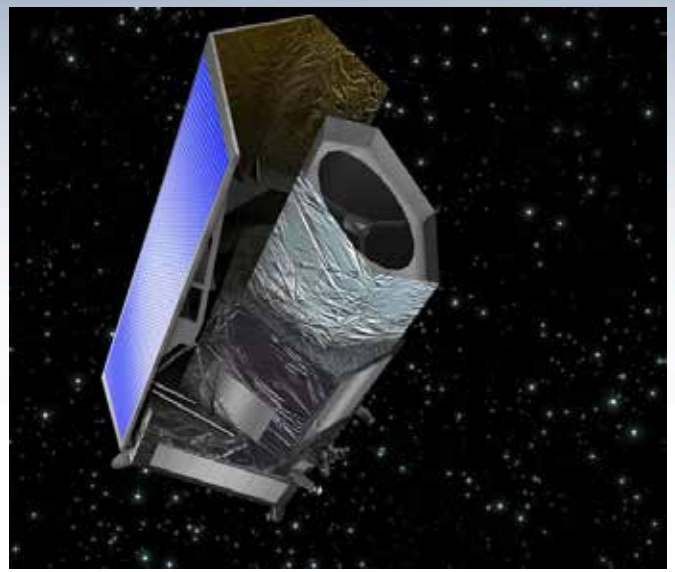
Operations: NLT June 2018 launch with a 3-year prime mission including 2 years of spacecraft operations and an additional 1 year ground-based observations and analysis. High-Earth elliptical orbit (17 x 58.7 Earth radii).

http://tess.gsfc.nasa.gov/

UPCOMING EVENTS:

- Fall 2016 - Spring 2017 – TESS spacecraft bus integration and instrument integration ongoing.
- Spring - Fall 2017 – TESS Observatory integration and test
- Spring 2017 – System Integration Review (SIR) and KDP-D
- Fall 2017 – TESS delivery to KSC payload processing facility.
- Mar 2018 – Launch readiness date from Cape Canaveral FL (pending review of recent SpaceX pad anomaly)

Euclid



- ESA Mission with NASA Collaborating
- ESA Cosmic Vision 2015-2025 Mission, M-Class
- Category 3 - Risk Class B
- Optical and NIR Observatory with 1.2-m Telescope
- U.S. Providing Characterized NIR Detectors
- Launch Date: Dec 2020
- ~70 U.S. Science Team members selected by NASA HQ
- Euclid NASA Science Center at IPAC

http://sci.esa.int/euclid/

BACKGROUND:

- Use two independent probes (weak lensing and galaxy clustering) to examine the nature of dark energy and dark matter, the initial conditions of the Universe, and the growth of large-scale structure.
- Examine expansion and star formation history of the Universe, investigate galaxy formation and evolution, conduct a deep NIR survey to explore the high-redshift Universe.

NASA CONTRIBUTION:

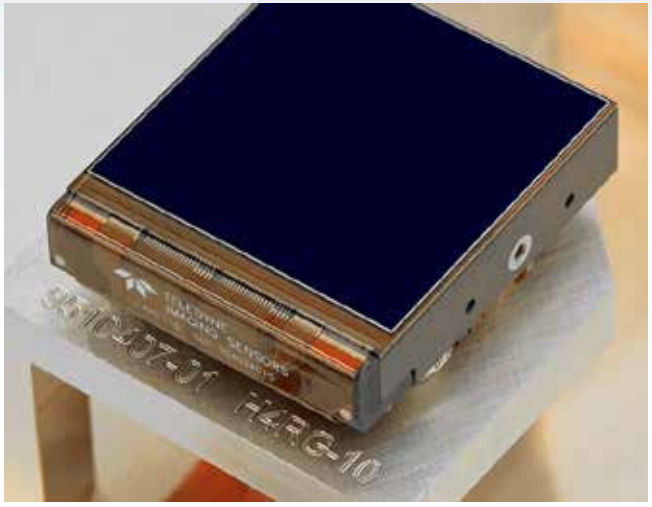
- Flight detectors for the NISP instrument: Multiple number of Sensor Chip Systems (SCS) where each chip consists of 2k x 2k HgCdTe array
- NASA funded US Science Team
- Ground system node and U.S. science center

CURRENT STATUS:

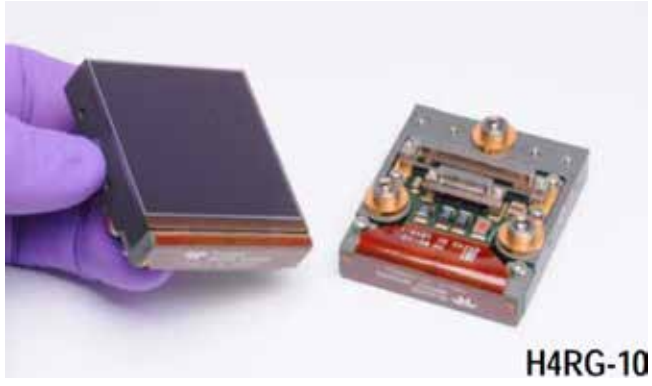
- Flight hardware is being fabricated.
- First NASA flight units will be delivered to ESA in early 2017
- ESA working toward a Dec 2020 launch date

WFIRST Detector Technology Milestones

MS #	Milestone	Milestone Date
1	Produce, test, and analyze 2 candidate passivation techniques (PV1 and PV2) in banded arrays to document baseline performance, inter-pixel capacitance, and shall meet the following derived requirements: dark current less than 0.1 e-/pixel/sec, CDS noise less than 20 e-, and QE greater than 60% (over the bandpass of the WFI channel) at nominal operating temperature.	7/31/14 ✓
2	Produce, test, and analyze 1 additional candidate passivation technique (PV3) in banded arrays to document baseline performance, inter-pixel capacitance, and shall meet the following derived requirements: dark current less than 0.1 e-/pixel/sec, CDS noise less than 20 e-, and QE greater than 60% (over the bandpass of the WFI channel) at nominal operating temperature.	12/30/14 ✓
3	Produce, test, and analyze full arrays with operability > 95% and shall meet the following derived requirements: dark current less than 0.1 e-/pixel/sec, CDS noise less than 20 e-, QE greater than 60% (over the bandpass of the WFI channel) , inter-pixel capacitance ≤3% in nearest-neighbor pixels at nominal operating temperature.	9/15/15 ✓
4	Produce, test, and analyze final selected recipe in full arrays demonstrating a yield of >20% with operability > 95% and shall meet the following derived requirements: dark current less than 0.1 e-/pixel/sec, CDS noise less than 20 e-, QE greater than 60% (over the bandpass of the WFI channel) , inter-pixel capacitance ≤3% in nearest-neighbor pixels, persistence less than 0.1% of full well illumination after 150 sec at nominal operating temperature.	9/15/16 ✓
5	Complete environmental testing (vibration, radiation, thermal cycling) of one SCA sample part, as per NASA test standards.	12/1/16



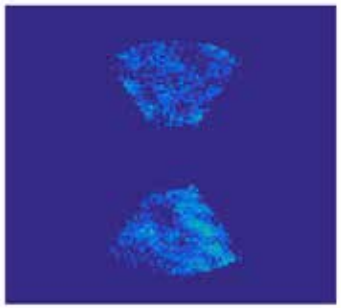
Detector Characterization Lab, GSFC



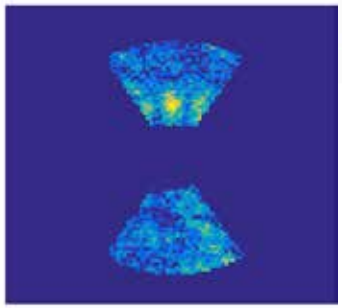
WFIRST Coronagraph Technology Milestones

MS #	Milestone	Milestone Date
1	First-generation reflective Shaped Pupil apodizing mask has been fabricated with black silicon specular reflectivity of less than 10^{-3} and 20 µm pixel size.	7/21/14 ✓
2	Shaped Pupil Coronagraph in the High Contrast Imaging Testbed demonstrates 10^{-8} raw contrast with narrowband light at 550 nm in a static environment.	9/30/14 ✓
3	First-generation PIAACMC focal plane phase mask with at least 12 concentric rings has been fabricated and characterized; results are consistent with model predictions of 10^{-8} raw contrast with 10% broadband light centered at 550 nm.	12/15/14 ✓
4	Hybrid Lyot Coronagraph in the High Contrast Imaging Testbed demonstrates 10^{-8} raw contrast with narrowband light at 550 nm in a static environment.	2/28/15 ✓
5	Occulting Mask Coronagraph in the High Contrast Imaging Testbed demonstrates 10^{-8} raw contrast with 10% broadband light centered at 550 nm in a static environment.	9/15/15 ✓
6	Low Order Wavefront Sensing and Control subsystem provides pointing jitter sensing better than 0.4 mas rms per axis and meets pointing and low order wavefront drift control requirements.	9/30/15 ✓
7	Spectrograph detector and read-out electronics are demonstrated to have dark current less than 0.001 e/pix/s and read noise less than 1 e/pix/frame.	8/25/16 ✓
8	PIAACMC coronagraph in the High Contrast Imaging Testbed demonstrates 10^{-8} raw contrast with 10% broadband light centered at 550 nm in a static environment; contrast sensitivity to pointing and focus is characterized.	9/30/16
9	Occulting Mask Coronagraph in the High Contrast Imaging Testbed demonstrates 10^{-8} raw contrast with 10% broadband light centered at 550 nm in a simulated dynamic environment.	9/30/16

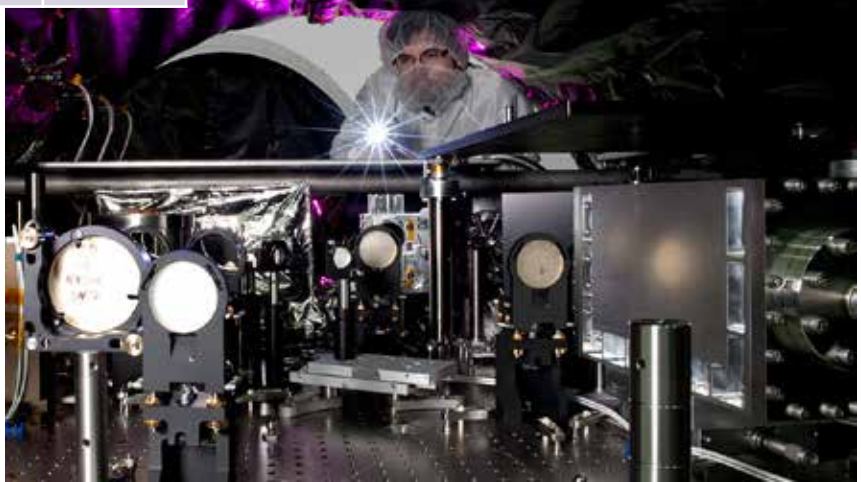
No planet



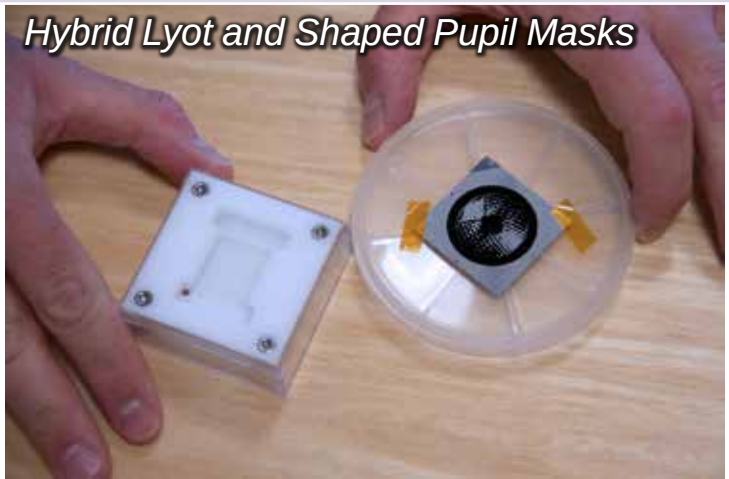
Planet at 4 λ/D



Occulting Mask Coronagraph in High Contrast Imaging Testbed at JPL

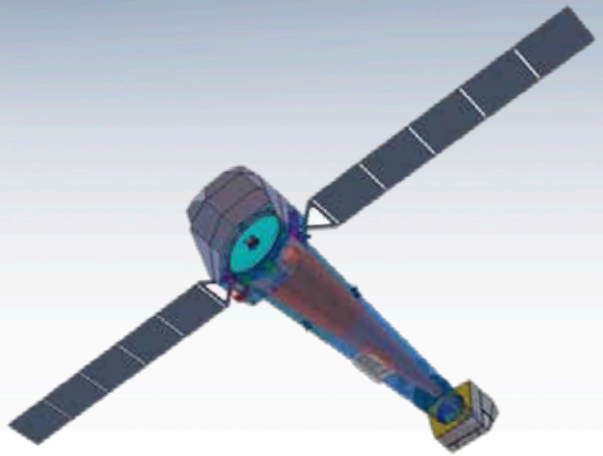


Hybrid Lyot and Shaped Pupil Masks



Athena

Advanced **T**elescope for **H**igh **En**ergy **A**strophysics



Second ESA Cosmic Vision Large mission

- L-class with NASA/JAXA participation
- Decadal Survey recommendation
- Large X-ray mirror, X-ray Integral Field Unit (XIFU) and Wide Field Imager (WFI) instruments

Launch Date: 2028

Breakthrough Capabilities:

- High Throughput, High spectral resolution X-ray Astronomy, Wide FOV
- 10x Chandra area, 100x improved non-dispersive spectral resolution, 5x FOV.

Enabling Technologies: Silicon pore optics, 3000+ pixel microcalorimeter (XIFU), large DEPFET array (WFI)

Science Objectives: The Hot and Energetic Universe: How does ordinary matter assemble into the large scale structures that we see today? How do black holes grow and shape the Universe?

CURRENT STATUS:

- Selected as second Large mission in ESA Cosmic Visions Program.
- Currently in 2-year Study Phase.
- NASA budgeting for a $100M-$150M hardware contribution, plus a U.S. GO program and a U.S. data center.
- NASA will contribute to both the X-IFU and the WFI.
- NASA and ESA are discussing other possible NASA contributions to the observatory.
- NASA and U.S. community involvement in Athena Science Study Team (including its SWG) and Instruments facilitated via series of RFI and CAs.
- Athena team will expand at Adoption in 2020; NASA anticipates this will provide an opportunity to expand U.S. community involvement.

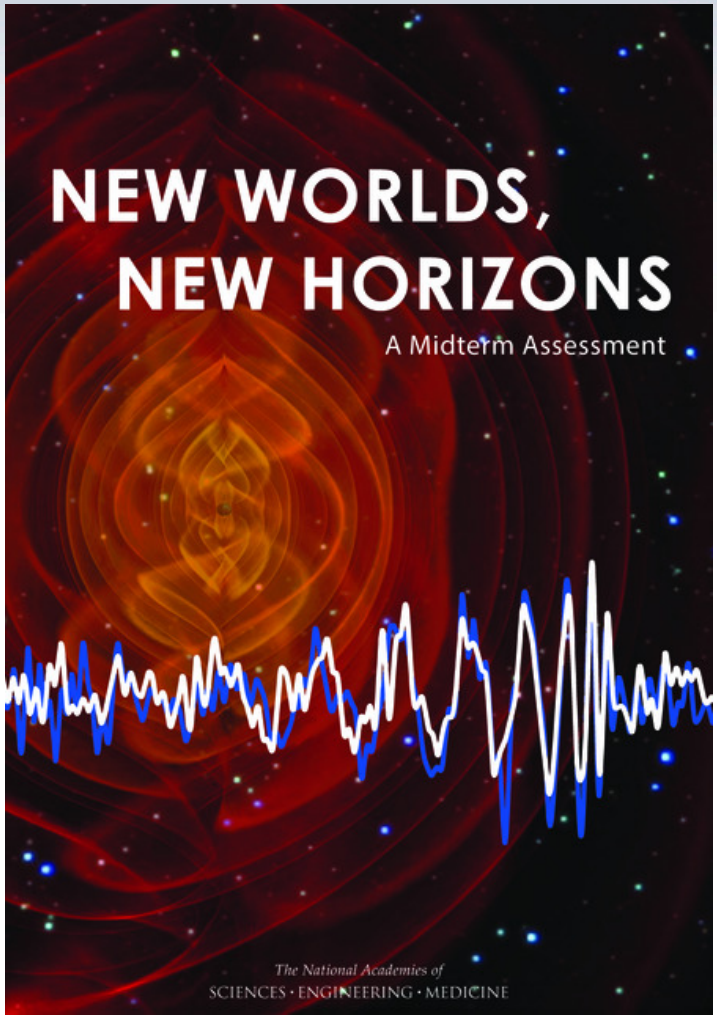
www.the-athena-x-ray-observatory.eu

BACKUP

Complete Response to the National Academies' Midterm Assessment

Midterm Assessment Report

Released August 15, 2016



http://www.nap.edu/download/23560

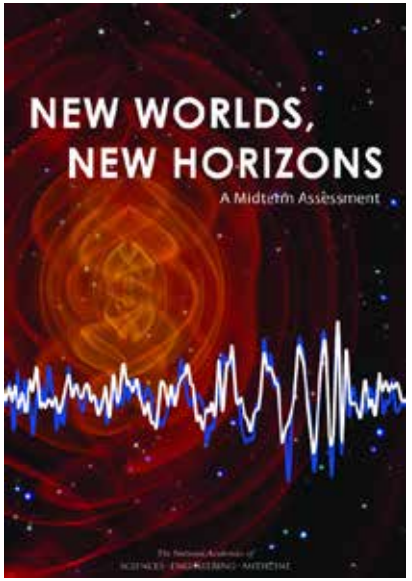
- NASA recognizes and appreciates the excellent job that was done by the Committee for the Review of Progress Toward the Decadal Survey Vision in New Worlds, New Horizons in Astronomy and Astrophysics
  - It is clear that the Committee understood the NASA issues and the planned NASA program.
  - In all cases where the Committee states a finding, a recommendation, or just an opinion, the Committee clearly articulates its rationale and references.
  - This is a very clear report, and the Committee's meaning is unambiguous.
- NASA's full response may be found in the NASA Astrophysics Implementation Plan: Update 2016, and it will take NASA an entire budget cycle to make any substantive changes in the program.

Midterm Assessment Report – Program Balance

- “Despite a challenging budget environment, NASA-APD has maintained a balanced portfolio through the first half of the decade and, with the assumption of successful completion of an ambitious Explorer schedule, will do so during the second half of the decade as well. This stability, however, has been preceded by a decline in individual investigator funding during the last part of the previous decade.” (Finding 4-14)

NASA Initial Response:

- Agreed.



Midterm Assessment Report – WFIRST

- "At the currently estimated cost, NASA's decision to add a coronagraph to … WFIRST is justifiable within the scientific goals of NWNH. The broader societal interest in the possibility of life beyond Earth is also compelling. However, an increase in cost much beyond the currently estimated $350 million would significantly distort the science priorities set forth by NWNH." (Finding 4-4)
- "Prior to KDP-B, NASA should commission an independent technical, management, and cost assessment of WFIRST, including a quantitative assessment of the incremental cost of the coronagraph. If the mission cost estimate exceeds the point at which executing the mission would compromise the scientific priorities and the balanced astrophysics program recommended by [NWNH], then NASA should descope the mission to restore the scientific priorities and program balance by reducing the mission cost." (Recommendation 4-1)

NASA Initial Response:

- NASA plans to conduct an independent TMC assessment of WFIRST prior to KDP-B.
- NASA will manage WFIRST and the overall astrophysics portfolio to maintain program balance.

Midterm Assessment Report – Euclid

- “NASA’s investment in Euclid … is a significant augmentation of the dark energy science program budget beyond the level envisioned by NWNH and by the [NRC Euclid Report].” (Finding 4-7)
- “In the remainder of the decade, NASA should treat support of Euclid participation beyond the existing commitments to ESA as lower priority than support of the Explorer program, gravity wave technology development, and X-ray technology development.” (Recommendation 4-2)

NASA Initial Response:

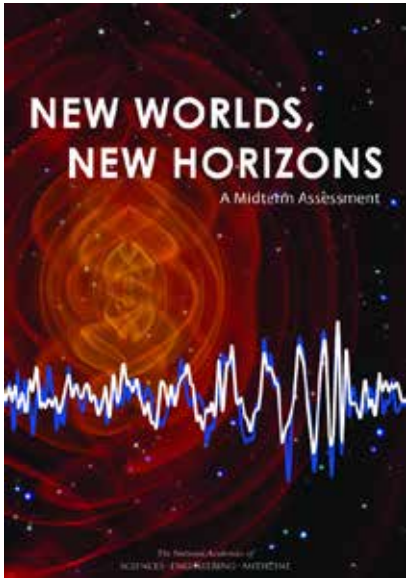
- NASA will treat growth in Euclid elements beyond hardware (US science center, support for US science team) as lower priority.
- NASA will discuss with the CAA whether this means that no funded Euclid GO program can be initiated for the US community.

Midterm Assessment Report – Explorers

- “NASA’s Astrophysics Division should execute its current plan, as presented to the committee, of at least four Explorer Announcements of Opportunity during the 2012-2021 decade, each with a Mission of Opportunity call, and each followed by mission selection.” (Recommendation 4-3)

NASA Initial Response:

- Agreed.

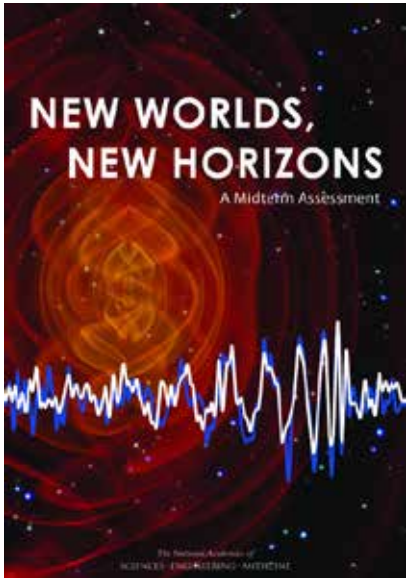


Midterm Assessment Report – Athena

- “NASA should proceed with its current plan to participate in Athena, with primary contributions directed toward enhancing the scientific capabilities of the mission.” (Recommendation 4-5)

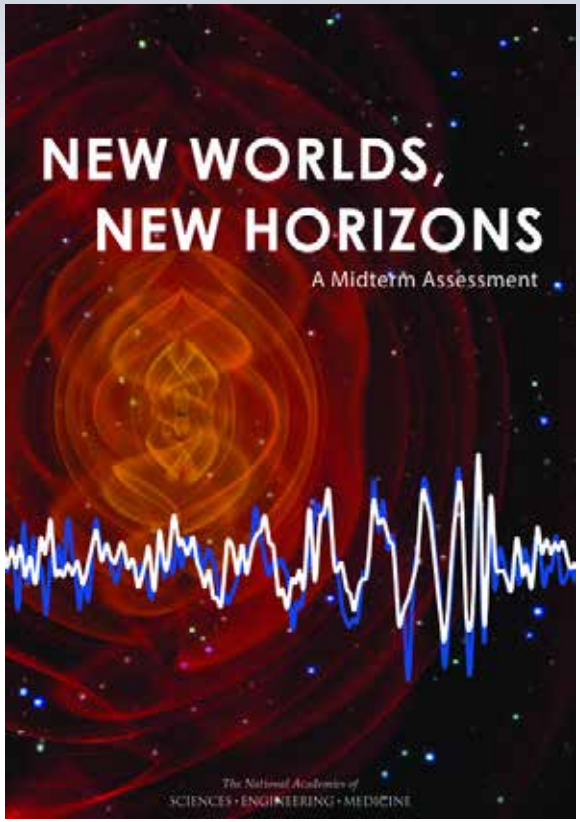
NASA Initial Response:

- Agreed.



Midterm Assessment Report – LISA

Released August 15, 2016



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"The science of LISA is even more compelling than in 2010 with the success of Advanced LIGO in making a direct detection of gravitational waves."

"Results of the LPF mission have demonstrated the feasibility of many of the key technologies needed to carry out a space gravitational wave mission, and ESA has selected a gravitational wave theme for the L3 large mission opportunity. These developments address two of the main conditions identified in NWNH for U.S. participation in a gravitational wave mission."

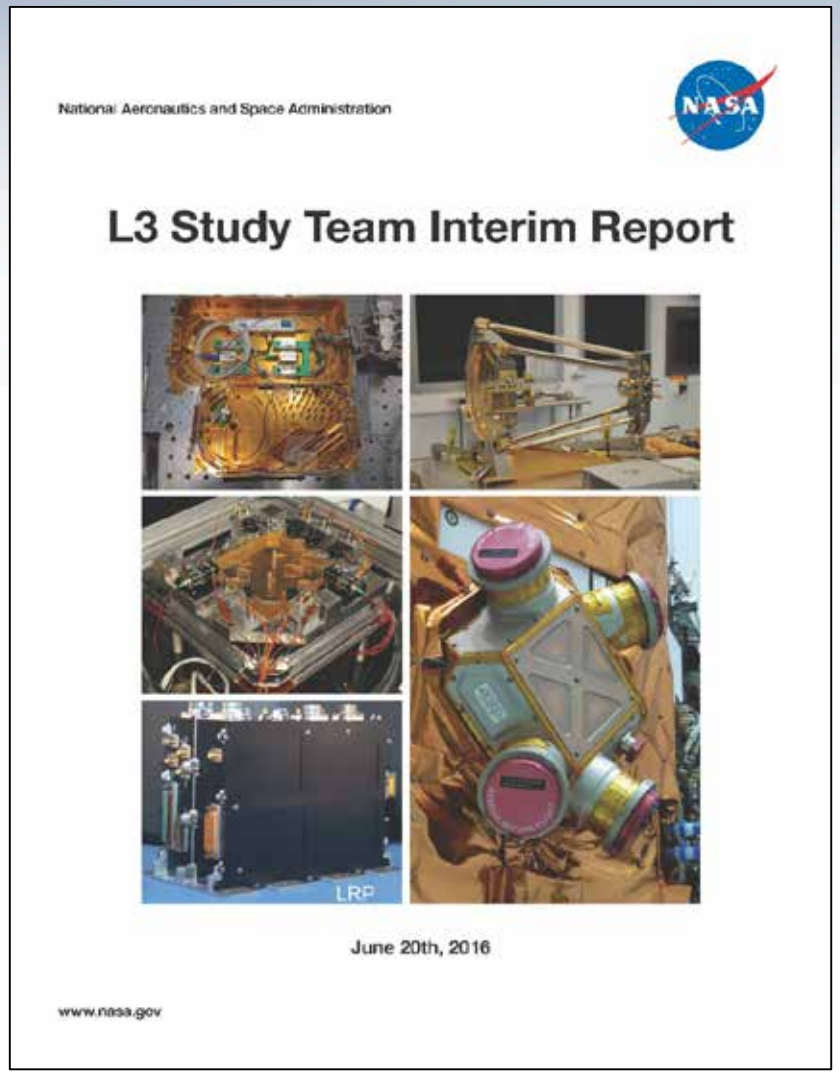
"The newly formed NASA L3 study team would best serve its function by participating in the planning and organization with ESA scientists and by identifying a range of options for U.S. participation in the L3 mission."

RECOMMENDATION 4-4: "NASA should restore support this decade for gravitational wave research that enables the U.S. community to be a strong technical and scientific partner in the ESA-led L3 mission … . One goal of U.S. participation should be the restoration of the full scientific capability of the mission as envisioned by NWNH."

What is NASA doing for Gravitational Wave Research?

- ü **Supporting search for EM counterparts** to LIGO sources
- ü **Supporting DRS operations on LISA Pathfinder**
- ü **Supporting development of GW technologies** relevant for a future space-based GW Observatory through directed and competitive programs (Strategic Astrophysics Technology Program, Astrophysics Research and Analysis Program)
- ü **Supporting data analysis, simulations, and modeling** relevant for a future space-based GW observatory through competitive programs (Astrophysics Research and Analysis Program, Astrophysics Theory Program, Theoretical and Computational Astrophysics Networks Program)
- ü **Established the U.S. L3 Study Team** to analyze the options for NASA participation in the L3 mission, work with the European L3 consortium on proposals to ESA, and prepare a report to the 2020 U.S. Decadal Survey on NASA's participation in the L3 mission as a partner
- ü **Established a U.S. L3 Study Office** at GSFC to coordinate technology development and mission contribution planning
- ü **Discussing with ESA** the U.S. role on the L3 mission; ESA is open to a larger role for the U.S., subject to their established constraints on international partnerships (international contributions limited to 20%, all international contributions require a European backup)

L3ST Interim Report



- An Interim report on options for NASA participation in ESA's L3 mission was delivered to Astrophysics Director on June 20, 2016.
- The report identifies the major areas of interest for the US for gravitational wave technology development and provides an analysis of their respective benefits and limitations.
- The report will assist NASA in its discussions with ESA and will guide future NASA strategic investments in gravitational wave technology.

http://pcos.gsfc.nasa.gov/studies/L3/

Midterm Assessment Report – LISA

- "NASA should restore support this decade for gravitational wave research that enables the U.S. community to be a strong technical and scientific partner in the ESA-led L3 mission, consistent with LISA's high priority in NWNH. One goal of U.S. participation should be the restoration of the full scientific capability of the mission as envisioned by NWNH." (Recommendation 4-4)

NASA Initial Response:

- NASA has begun discussions with ESA about a larger role for the U.S. in the L3 mission. ESA is open to a larger role for the U.S., subject to their established constraints on international partnerships (international contributions limited to 20%, all international contributions require a European backup).
- NASA has begun discussions within the Administration on committing to a larger role for the U.S. in the L3 mission. Any changes in out-year planning are subject to the limitations of the out-year planning budget, i.e., no new money.
- NASA is reviewing options for L3-relevant technology investments through the SAT and other programs.
- NASA is reviewing options for reduced funding of exoplanet technology development beyond the WFIRST coronagraph.

Midterm Assessment Report – New Worlds Technology

- "The current planned decadal investment in NWNH-recommended technology development and precursor science exceeds the level envisioned in NWNH." (Finding 4-11)
- "NASA's support of an Extreme Precision Doppler Spectrograph capability helps address a key need identified in NWNH for exoplanet science and precursor investigations in advance of a large exoplanet mission." (Page 4-17)
- "The committee believes that NASA's continued development of coronagraph and starshade technology at a modest level for mission design, scope, and capability is a positive step and that this activity would be profitably evaluated by the next decadal survey. However, given the substantial advances already enabled by WFIRST coronagraph development, the committee assigns higher priority to supporting adequate gravitational wave technology development than to further exoplanet technology development beyond WFIRST." (Page 4-18)

NASA Initial Response:

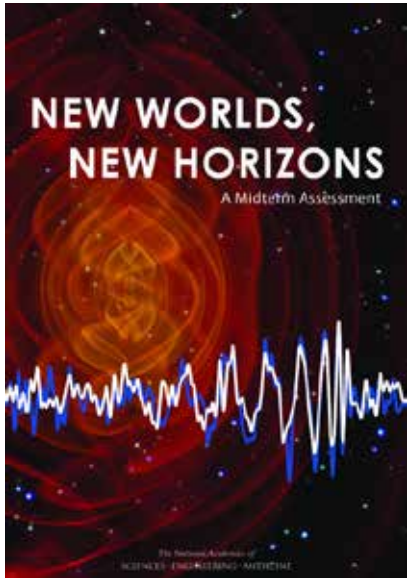
- NASA is reviewing options for reduced funding of exoplanet technology development beyond the WFIRST coronagraph.

Midterm Assessment Report – Inflation Probe Technology

- “The Inflation Probe Technology Development program is well aligned with the recommendations of NWNH, with NASA, NSF, and DOE supporting technology development and precursor science. Third-generation ground-based efforts and a suborbital program are taking place, targeting CMB B-mode polarization. The proposed CMB-S4 program would push the limits of what can be achieved from the ground and advance understanding of the technology and science requirements for a possible future space mission.” (Finding 4-12)

NASA Initial Response:

- Agreed.



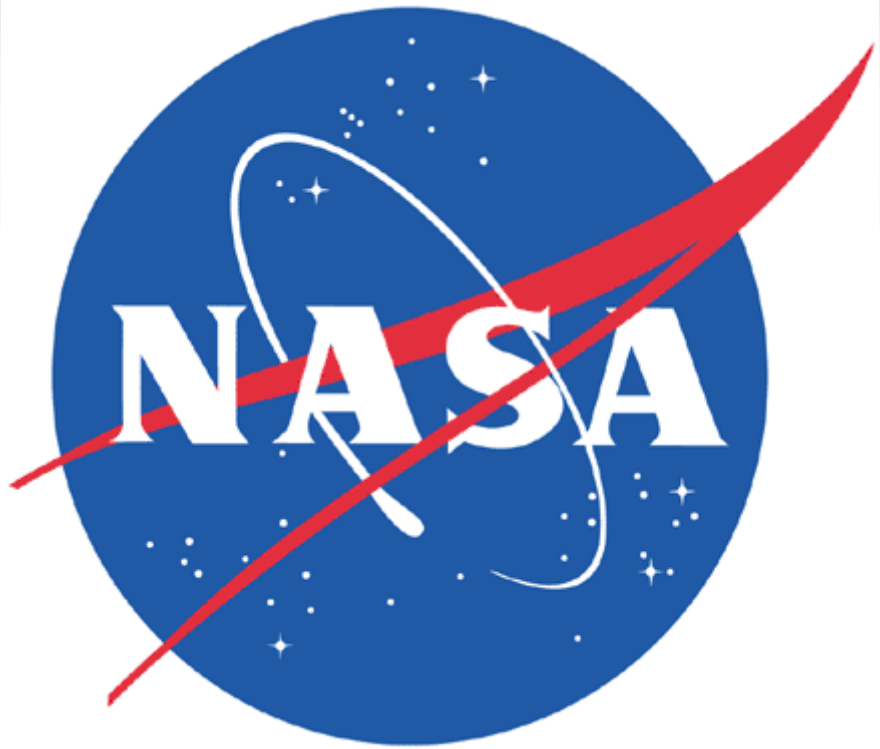
Midterm Assessment Report – Small Activities

- "NASA's implementation of NWNH's recommended small-scale activities has been mixed. Some recommended augmentations have not occurred and there have been cuts in some programs recommended for augmentation. Other programs, in particular the suborbital and exoplanet areas, have seen increases in excess of what was recommended by NWNH." (Finding 4-13)
  - The committee could not identify funding for non-exoplanet UV/O technical developments as recommended for a future ultraviolet space telescope. [p.4-20]
  - The $2 million per year augmentation of laboratory astrophysics augmentation has not occurred, and funding in this area is flat or slightly down. [p.4-20]
  - The current NASA contribution [to TCAN] is $1.5 million per year, while the recommended level was $5 million per year. [p.4-20]
  - This drop of 26 percent [in GO programs] in inflation-adjusted dollars has had a major impact on the support of the community and is likely a major contributor to a sharp drop in proposal success. [p.4-21]
  - A constant level of funding in the ADAP program has not kept pace with the growth in the volume of archival data available. [p.4-21]
  - NASA has used the SAT program to support technology development directed at future strategic missions. Specific initiatives have focused on exoplanet, CMB, gravitational wave, and X-ray science, in addition to optics and detector development. Total funding over the first half of the decade has exceeded $64 million. …Funding for Suborbital program has also been well supported. [p.4-21]

NASA Initial Response: Increases in R&A have not been targeted.

Responding to the 2010 Decadal Survey
Responding to the Midterm Assessment

Prioritized Recommendation	NASA plans (partial list)
LARGE ACTIVITIES	
WFIRST	In Phase A, launch in mid-2020s, control costs
Explorers	Executing 4 AOs per decade
LISA	Partnering on ESA's space-based gravitational wave observatory; increased contribution
IXO	Partnering on ESA's Athena x-ray observatory
MEDIUM ACTIVITIES	
Exoplanet technology	WFIRST coronagraph, reductions being considered for starshade and coronagraph technology development beyond the WFIRST coronagraph
Inflation Probe technology	3 balloon-borne technology experiments
SMALL ACTIVITIES	
R&A augmentations	R&A up 20% since FY10; not targeted except TCAN
Mid-TRL technology	Initiated Strategic Astrophysics Technology program; focused on identified missions
Suborbital missions	Initiated super pressure balloon capability



Astrophysics Division
Science Mission Directorate
National Aeronautics and Space Administration