National Aeronautics and Space Administration

Astrophysics




NASA Astrophysics Report
Meeting of Astronomy Department Chairs
Chicago, IL
November 5, 2016

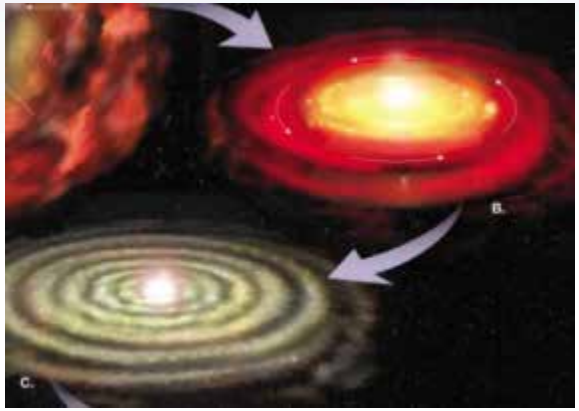
Paul Hertz
Director, Astrophysics Division
Science Mission Directorate
@PHertzNASA

Outline

Why Astrophysics?

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

1. How did our universe begin and evolve?

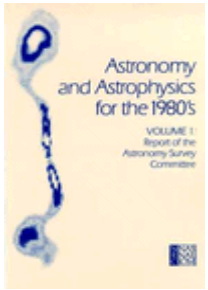


2. How did galaxies, stars, and planets come to be?

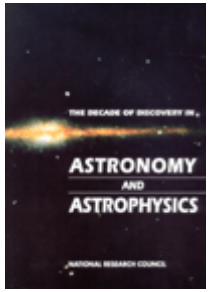
3. Are We Alone?

These national strategic drivers are enduring

1972



1982

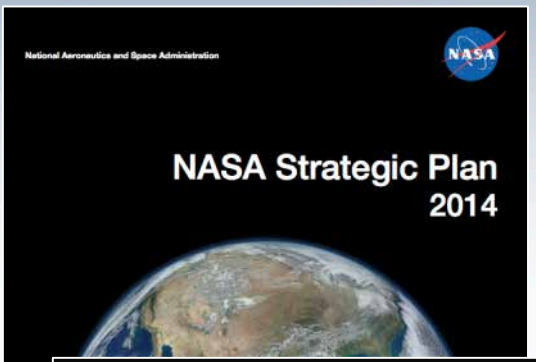


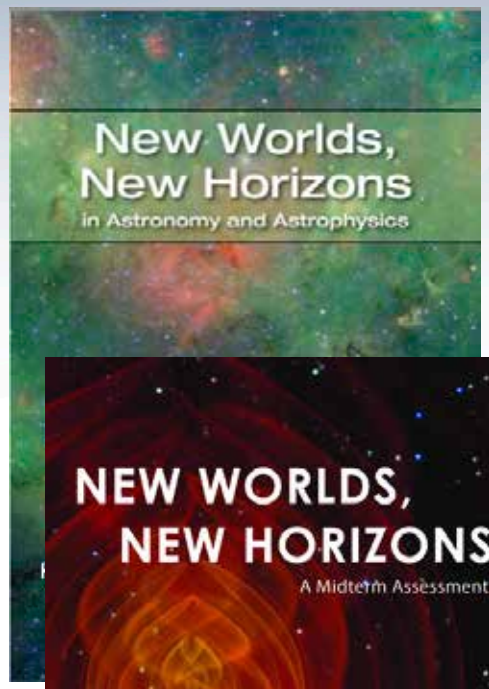
1991

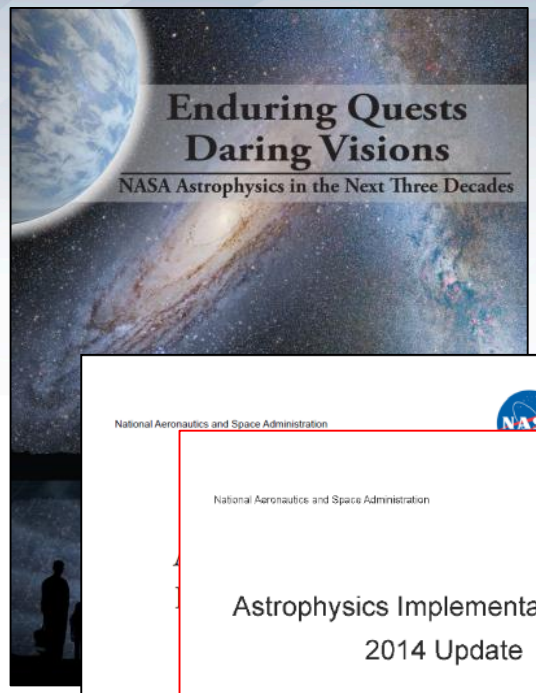
2001

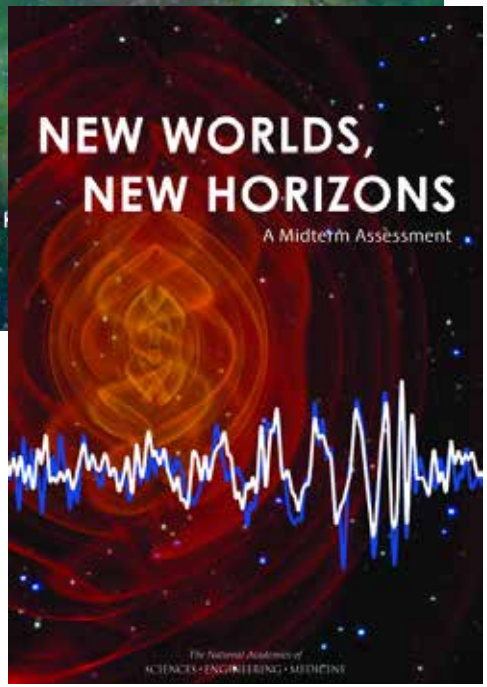
2010

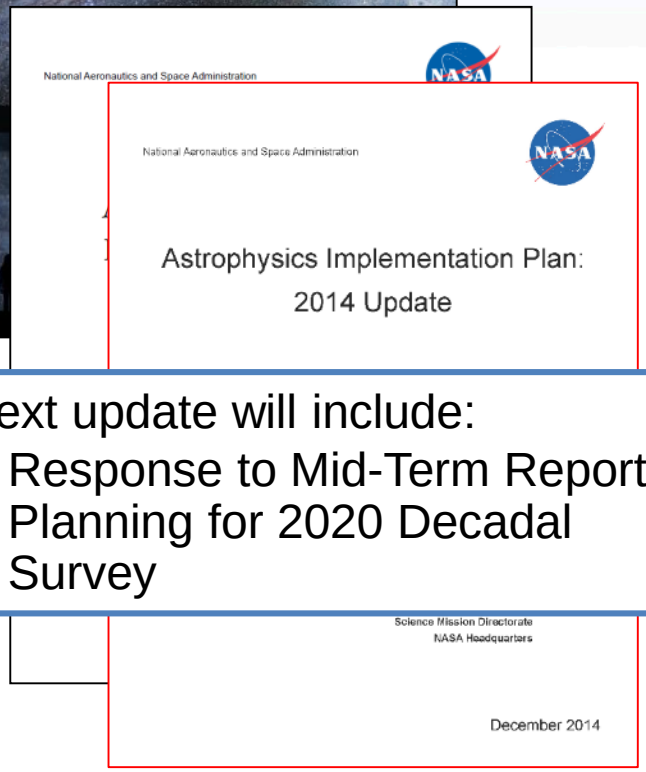
Astrophysics Driving Documents











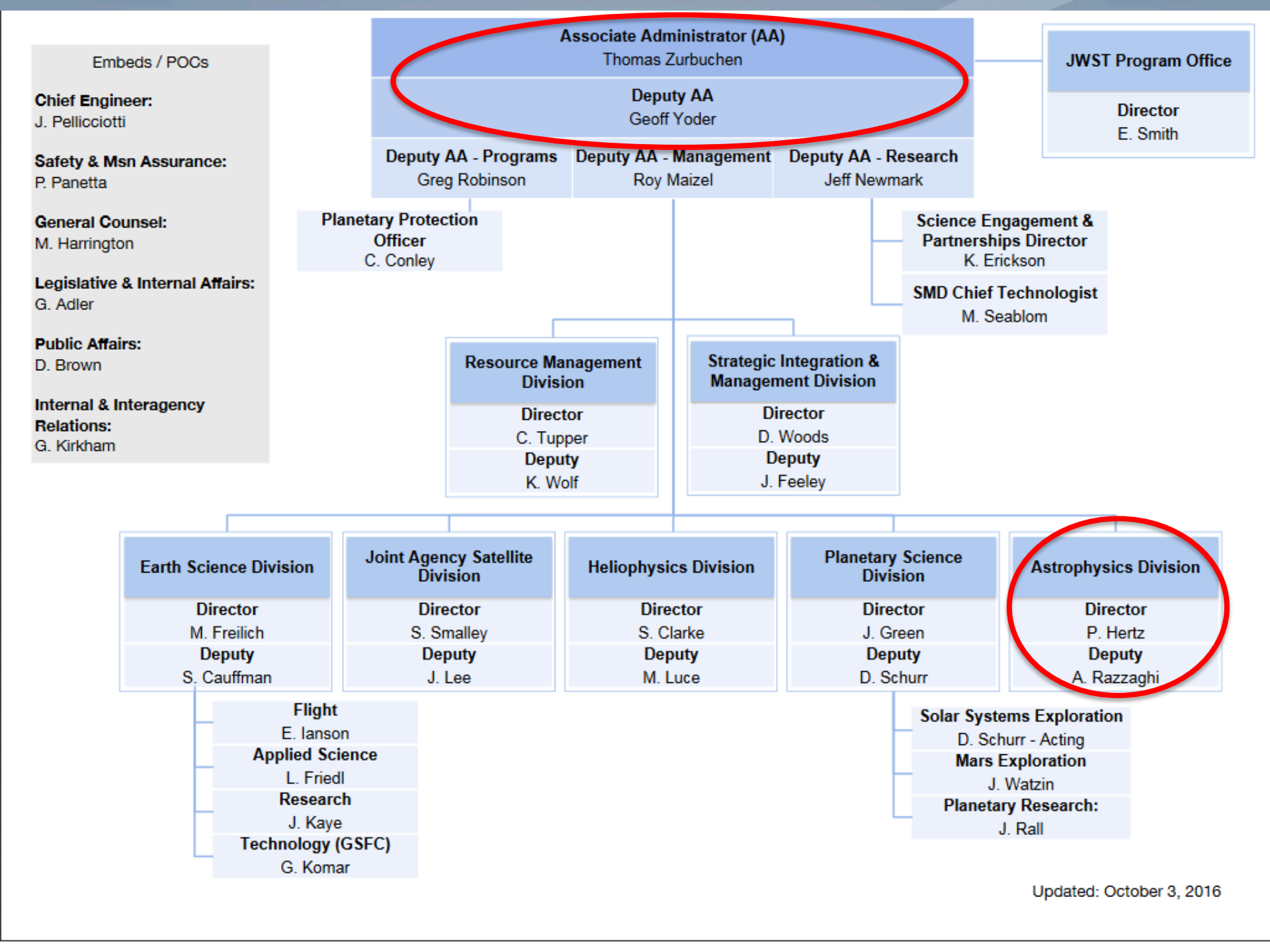
Next update will include:

- Response to Mid-Term Report
- Planning for 2020 Decadal Survey

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

NASA Astrophysics

General Update including Budget


Embeds / POCs
Chief Engineer:
J. Pellicciotti
Safety & Msn Assurance:
P. Panetta
General Counsel:
M. Harrington
Legislative & Internal Affairs:
G. Adler
Public Affairs:
D. Brown
Internal & Interagency Relations:
G. Kirkham
Associate Administrator (AA)
Thomas Zurbuchen
Deputy AA
Geoff Yoder
JWST Program Office
Director
E. Smith
Deputy AA - Programs
Greg Robinson
Deputy AA - Management
Roy Maizel
Deputy AA - Research
Jeff Newmark
Planetary Protection Officer
C. Conley
Science Engagement & Partnerships Director
K. Erickson
SMD Chief Technologist
M. Seablom
Resource Management Division
Director
C. Tupper
Deputy
K. Wolf
Strategic Integration & Management Division
Director
D. Woods
Deputy
J. Feeley
Earth Science Division
Director
M. Freilich
Deputy
S. Cauffman
Joint Agency Satellite Division
Director
S. Smalley
Deputy
J. Lee
Heliophysics Division
Director
S. Clarke
Deputy
M. Luce
Planetary Science Division
Director
J. Green
Deputy
D. Schurr
Astrophysics Division
Director
P. Hertz
Deputy
A. Razzaghi
Flight
E. Ianson
Applied Science
L. Friedl
Research
J. Kaye
Technology (GSFC)
G. Komar
Solar Systems Exploration
D. Schurr - Acting
Mars Exploration
J. Watzin
Planetary Research:
J. Rall
Updated: October 3, 2016

New Associate Administrator for Science Mission Directorate

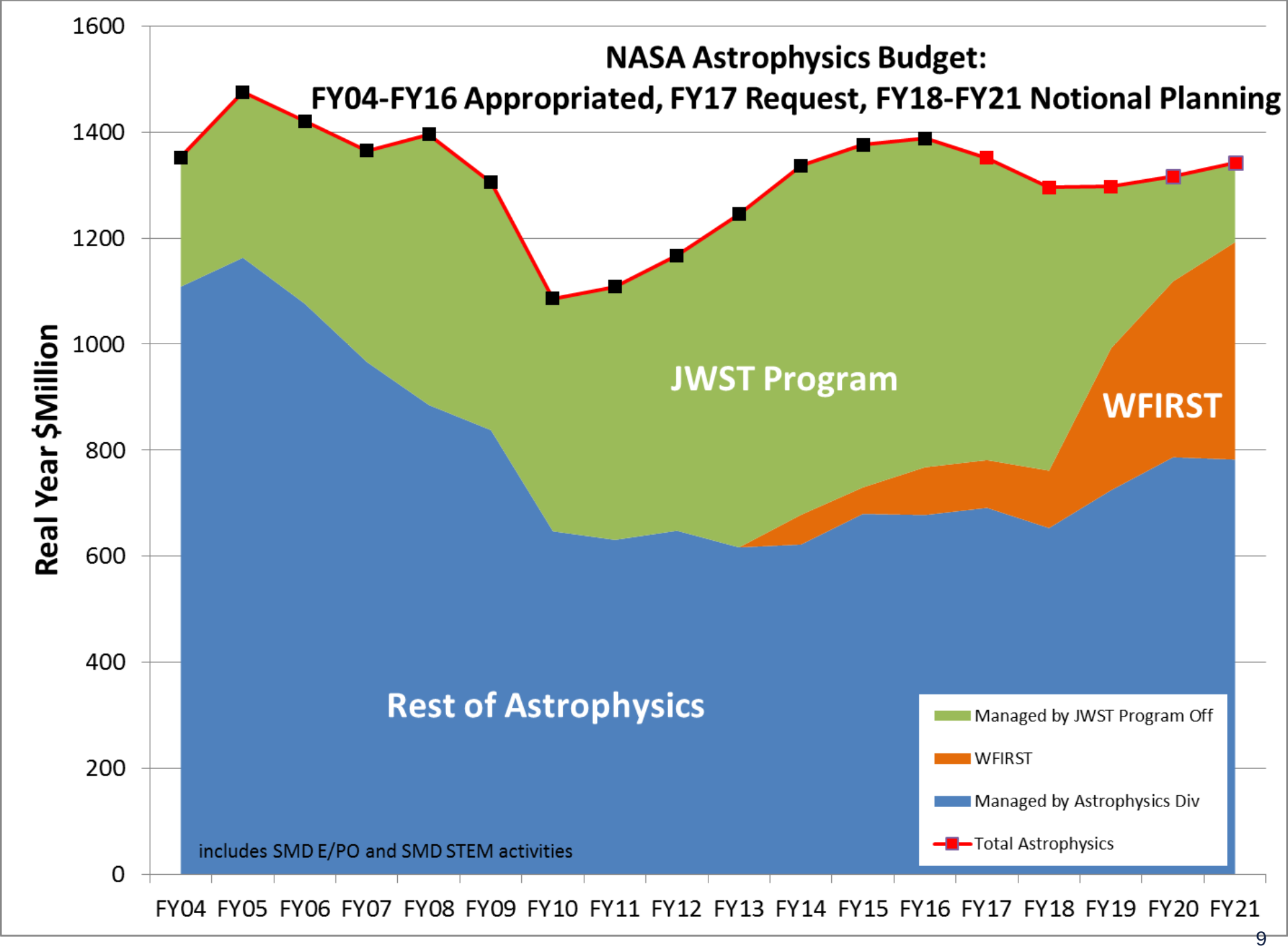
Space Studies Board, Heliophysics Decadal Survey, CubeSat Study

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 physics and master of science degree in physics from the University of Bern in Switzerland.

Astrophysics - Big Picture

- **The FY16 appropriation/FY17 continuing resolution and FY17 President's budget request provide funding for NASA astrophysics to continue its programs, missions, projects, and supporting research and technology.**
  - The total funding (Astrophysics including Webb excluding STEM) remains at ~$1.35B.
  - Fully funds Webb for an October 2018 launch, WFIRST formulation (new start), and increased funding for R&A and new suborbital capabilities.
  - No negative impact from FY17 continuing resolution (through December 9, 2016).
- **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+ 2nd gen instrument being commissioned; HIRMES 3rd gen instrument selected; 4th gen instrument call in 2017.
  - NASA missions under development making progress toward launches: ISS-NICER (2017), ISS-CREAM (2017), TESS (2017), Webb (2018), WFIRST (mid-2020s).
  - Partnerships with ESA and JAXA on their future missions create additional science opportunities: XRRM (JAXA), Athena (ESA), L3 (ESA).
  - Explorer AOs are being released every 2-3 years, soliciting a mission and a mission of opportunity each time.
- **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 Budget:
FY04-FY16 Appropriated, FY17 Request, FY18-FY21 Notional Planning
Real Year $Million
1600
1400
1200
1000
800
600
400
200
0
JWST Program
WFIRST
Rest of Astrophysics
includes SMD E/PO and SMD STEM activities
Managed by JWST Program Off
WFIRST
Managed by Astrophysics Div
Total Astrophysics
FY04 FY05 FY06 FY07 FY08 FY09 FY10 FY11 FY12 FY13 FY14 FY15 FY16 FY17 FY18 FY19 FY20 FY21

FY17 Budget Update

- FY17 budget request sent to Congress in February 2016
- Both House and Senate appropriations committees have marked up the FY17 NASA budget request
  - Senate adds $53M in spending and $25.5M in funding, net general reduction of $27.5M
  - House adds $23.4M in spending and $11.4M in funding, net general reduction of $12.0M
- Neither chamber of Congress has passed a NASA appropriations bill

- As of September 28-29, Congress passed and the President signed a continuing resolution to fund the Government until December 9

- The continuing resolution does not contain any special language regarding NASA
- All NASA astrophysics projects and activities can continue as planned under the continuing resolution

NASA Astrophysics

Research and Analysis Program

Research and Analysis Opportunities

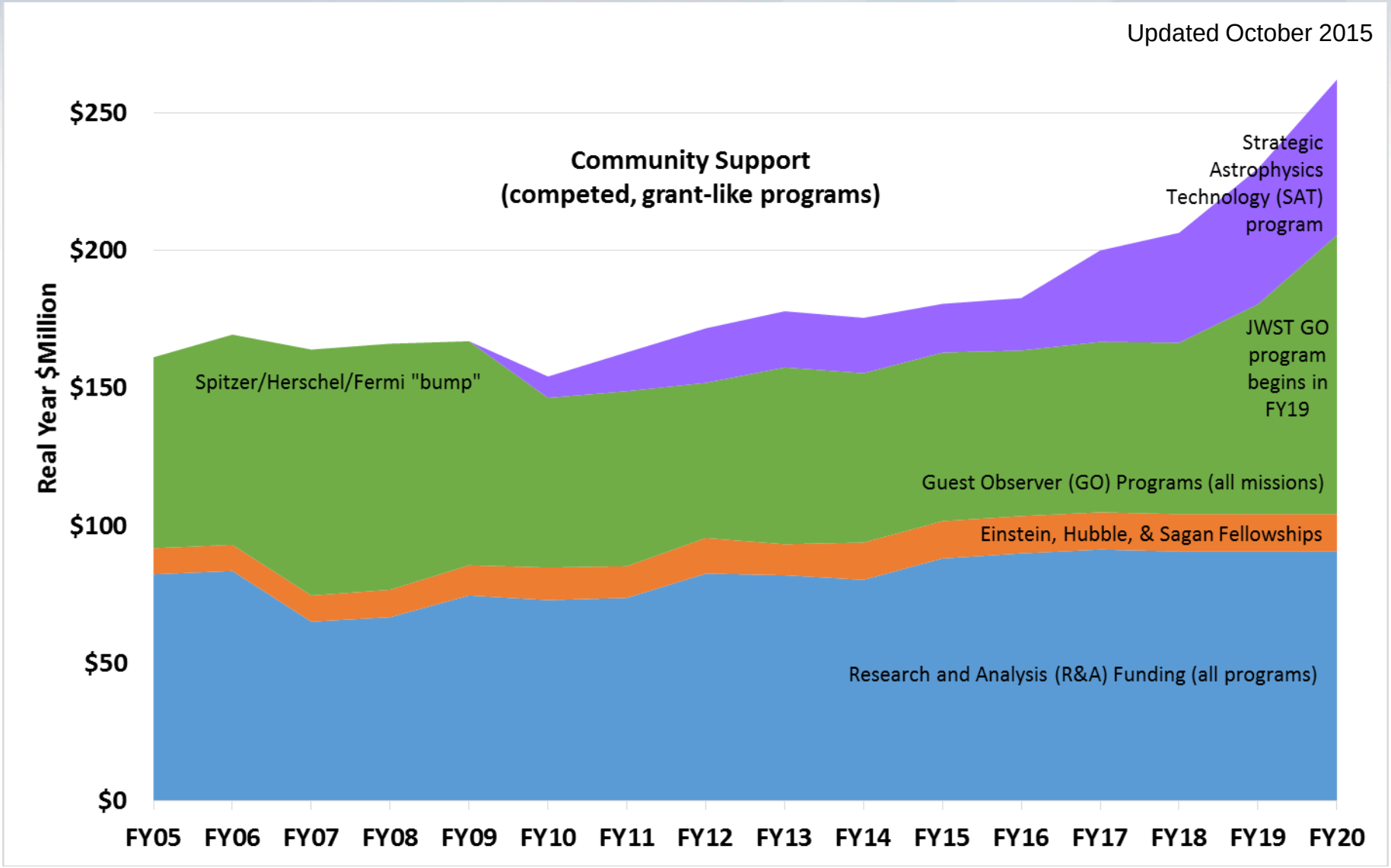
Solicited through ROSES:

- 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)
- Data Analysis
  - Astrophysics Data Analysis (ADAP)
  - Guest Observer and Guest Investigator programs for Fermi, Kepler/K2, NuSTAR, Swift

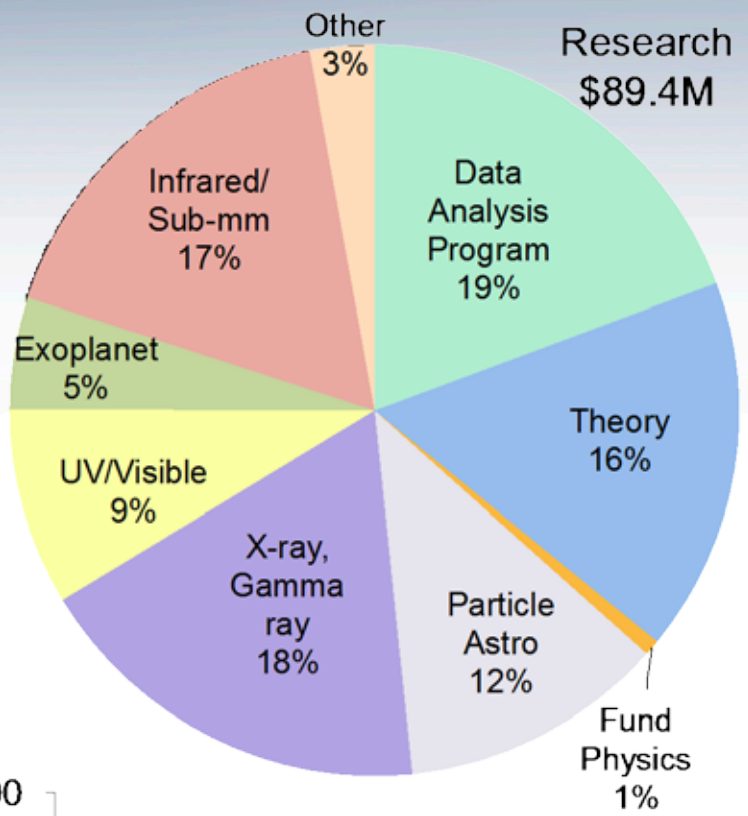
Separately solicited:

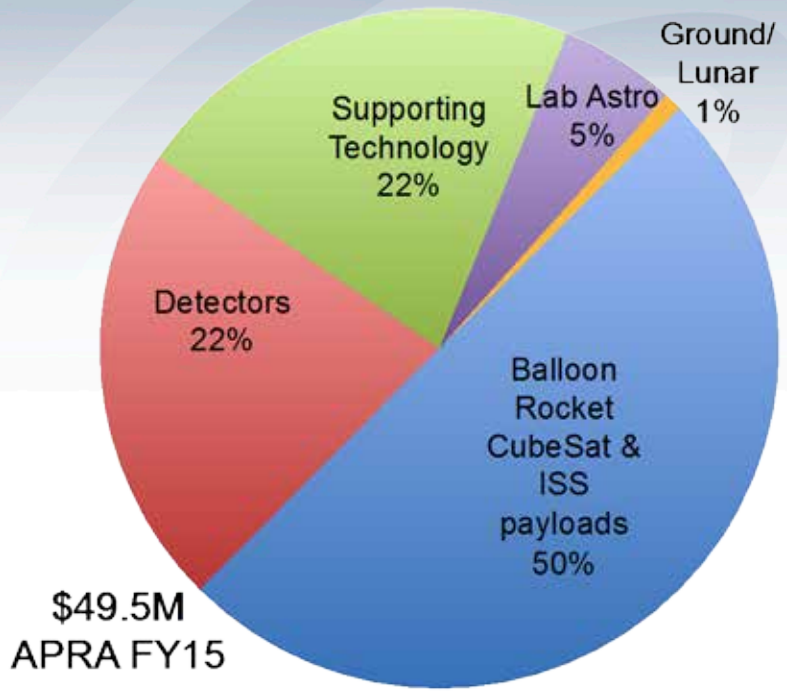
- Proposals for Hubble & Chandra observations and archival research, and for SOFIA and Spitzer observations; XMM (ESA)
- NASA Earth and Space Science Fellowships, for graduate students
- Einstein, Hubble, and Sagan Postdoctoral Fellowships

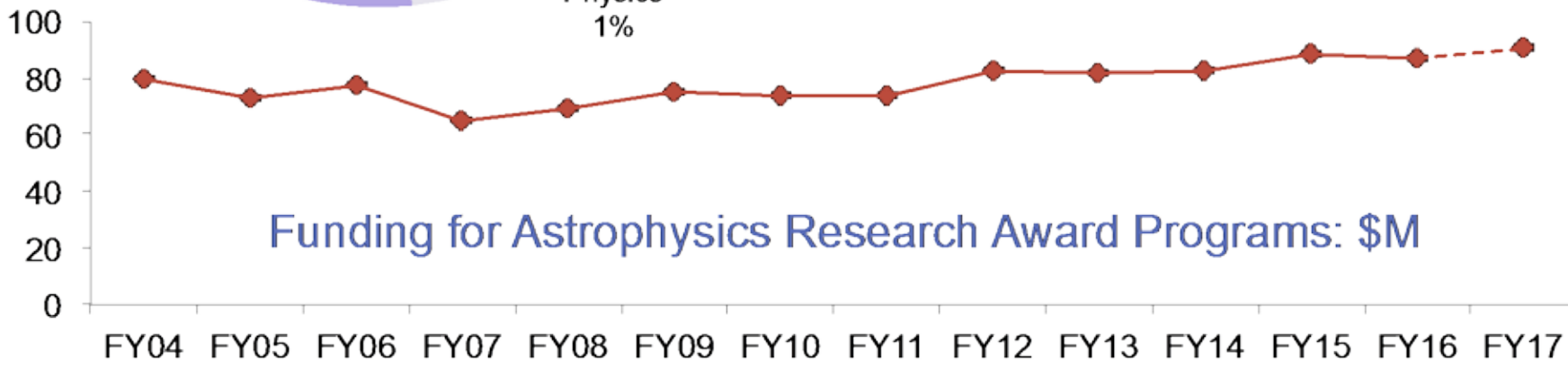
Response to Recommendations: Core Research



FY15 Research Program Budget and Spending







Recent Proposal Selections

Status: October 27, 2016

	Proposal Due Date	Notify Date	Days past received	Number received	Number selected	% selected
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	Jun 1, 2016	114	136	9	7%
Kepler K2 GO – Cycle 4	Mar 4, 2016	Jul 11, 2016	118	109	36	33%
Chandra GO – Cycle 18	Mar 15, 2016	Jul 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	Jun 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	Jun 8, 2016	Aug 5, 2016	58	115	49	43%
SOFIA GI – Cycle 5	Jul 1, 2016	Oct 24, 2016	115	179	72	40%
ATP (Astrophysics Theory)	Jul 8, 2016		111	201		

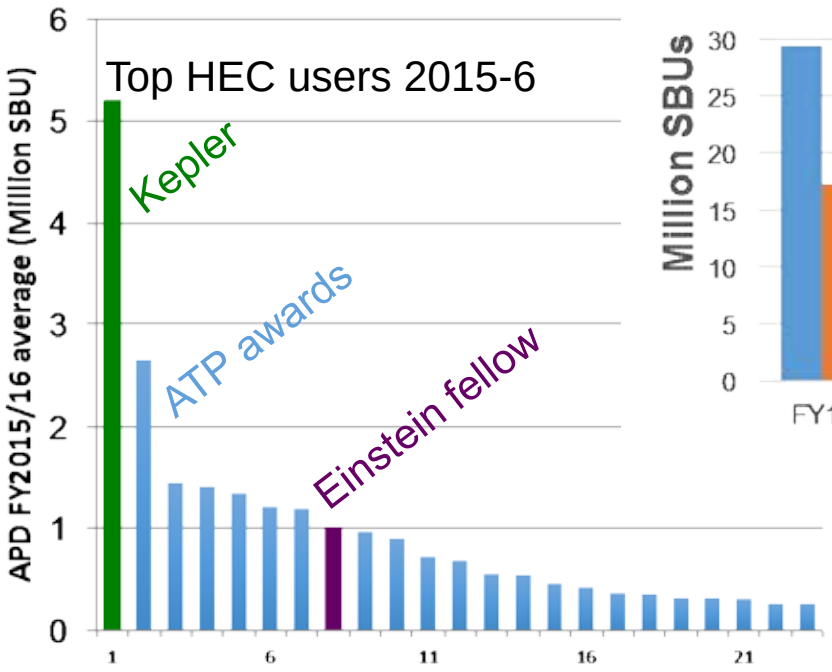
100% of recent announcements within 150 days

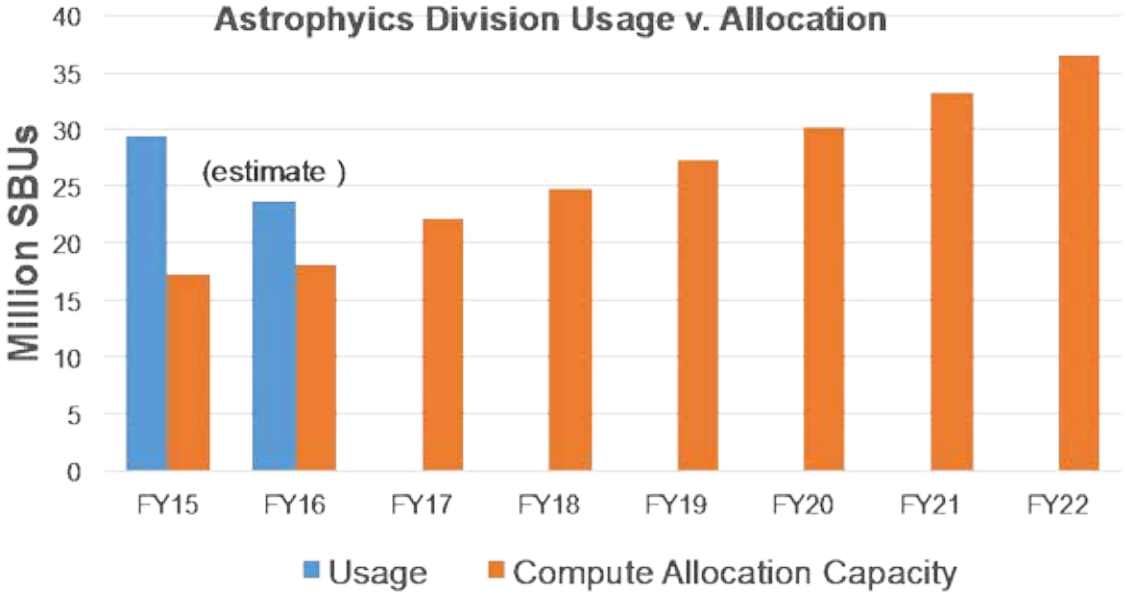
R&A Selection Rate: 22%; GO Selection Rate: 28%

High End Computing

- New for 2016: Proposals needing high-end computing (HEC) must now estimate and justify required resources.
- Proposers request far more HEC cycles than are available; we must plan for the future.
- Astrophysics received extra resources in 2015-6 for Kepler mission processing.

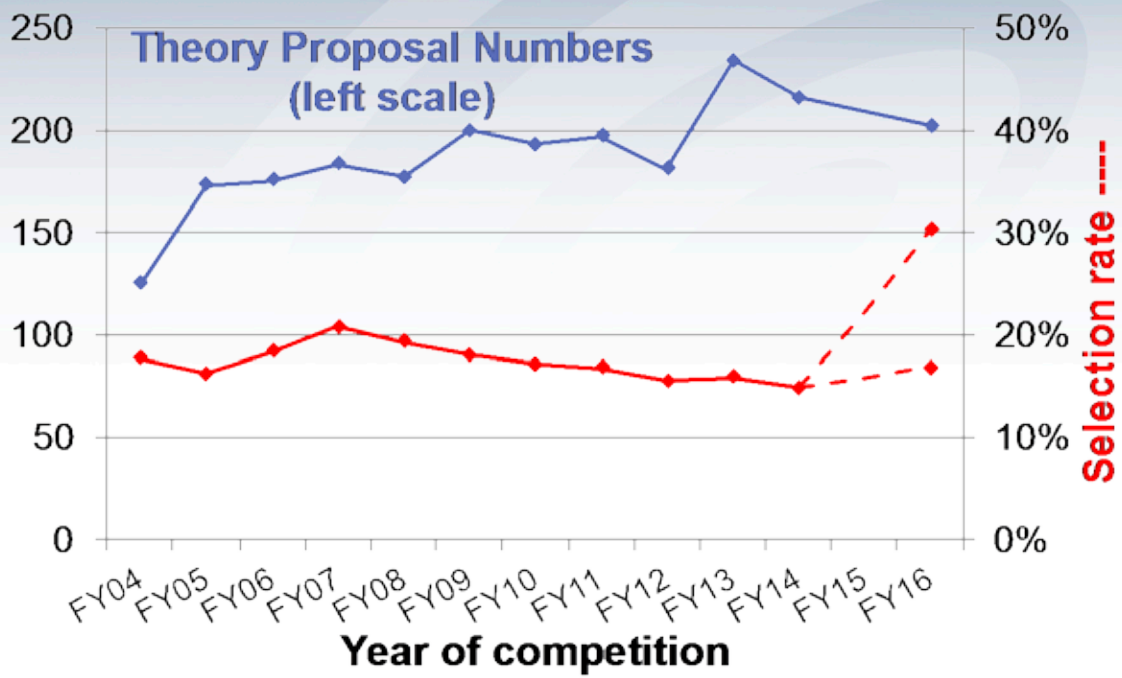
June 2016 estimates of usage in FY15 and FY16





Astrophysics Theory Program (ATP)

- To address the problem of low selection rates, the Astrophysics Division plans to compete ATP in alternate years, without reducing the program budget.
- This change will increase the selection rate close to that recommended in the 2015-6 report of the Astronomy and Astrophysics Advisory Committee.



- Continuing with an annual ATP competition: roughly $5M or 17% of the requested year-1 funding could be awarded for ATP-16. If grades are as in past years, we would have to decline almost half of the E/VG proposals.
- Competing ATP only in odd years: roughly $9M in year-1 funding could be awarded for ATP-16, about 30% of the request. If grades are as in past years, we could fund all the E and E/VG proposals, and some VG proposals.
- This change will reduce the burden on reviewers and proposers alike.

Review of Proposed Changes to NASA Named Fellowships (NNF)

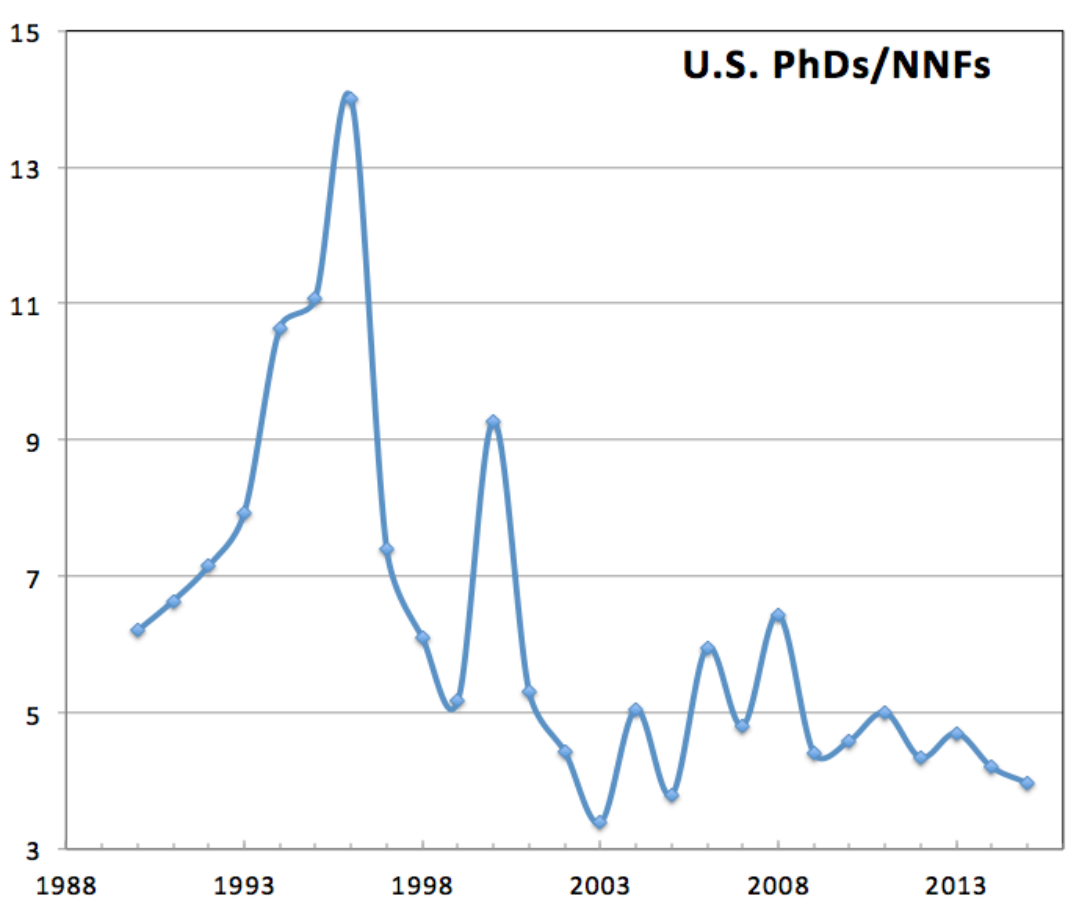
Proposal: Reallocate a fraction of Named Fellowship $$ to core R&A

Why: To restore balance of $$ between research grants & NNF postdoctoral fellowships which has changed from 10:1 to 6:1 over last decade

Current: $14M per year supports 100 Fellows (35 new Fellows each year)

Proposed: $9M per year supports 65 Fellows (24 new Fellows per year)

- It is not NASA's intent to alter the current balance of science topics within the NNF.
- Note : while pressure on grants programs has steadily increased, the US PhDs / NNF ratio has *decreased* from ~10:1 to ~4:1.



NASA Astrophysics

Mission Updates


Formulation
Implementation
Primary Ops
Extended Ops
Spitzer
8/25/2003
Kepler
3/7/2009
WFIRST
Mid 2020s
LISA Pathfinder (ESA)
12/3/2015
Webb
2018
Euclid (ESA)
2020
Chandra
7/23/1999
XMM-Newton (ESA)
12/10/1999
TESS
2017
Swift
11/20/2004
NuSTAR
6/13/2012
Fermi
6/11/2008
Hubble
4/24/1990
CREAM (on ISS)
2017
NICER (on ISS)
2017
SOFIA
Full Ops 5/2014

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 will require some reductions in mission funding in order allow the overarching finding (the continuation of all missions) to be implemented.

Astrophysics Missions in Development

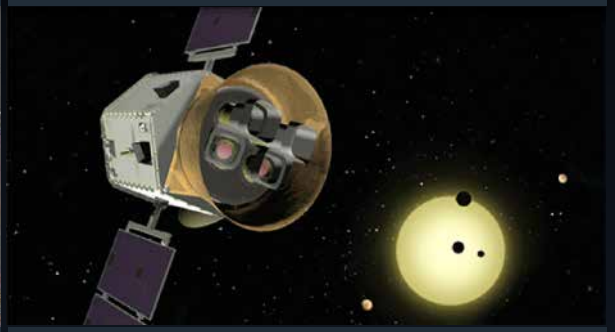
ISS-NICER
3/2017
NASA Mission

Neutron Star Interior Composition Explorer

ISS-CREAM
6/2017
NASA Mission

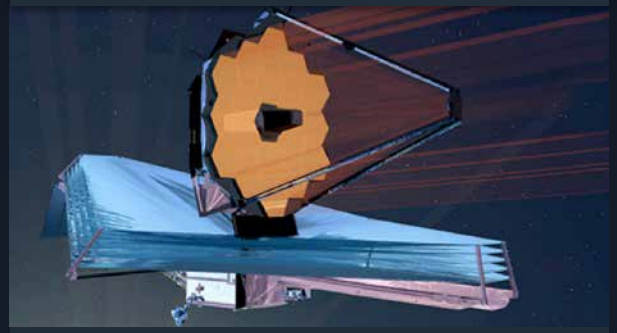
Cosmic Ray Energetics And Mass

TESS
12/2017
NASA Mission



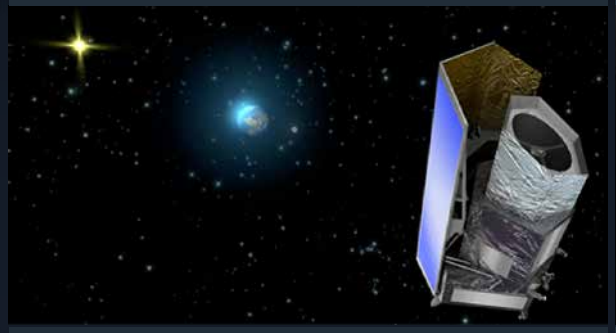
Transiting Exoplanet Survey Satellite

Webb
10/2018
NASA Mission



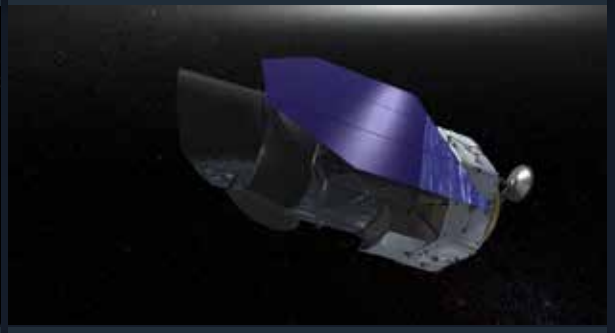
James Webb Space Telescope

Euclid
2020
ESA-led Mission



NASA is supplying the NISP Sensor Chip System (SCS)

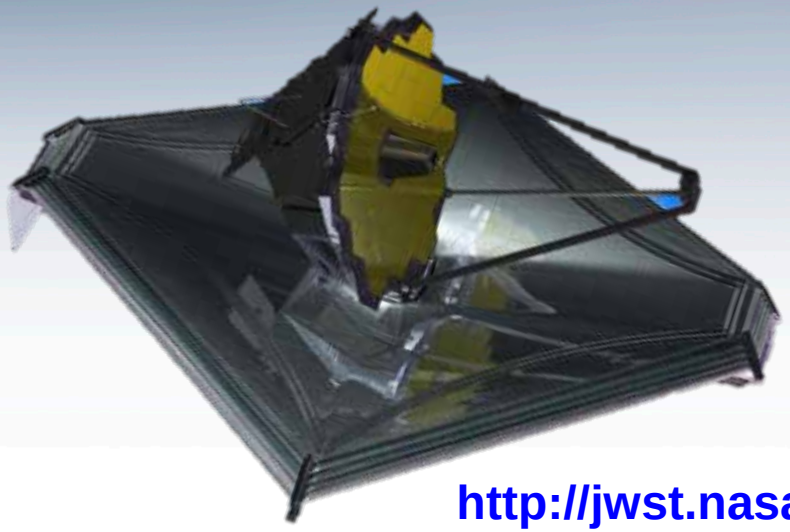
WFIRST
Mid 2020s
NASA Mission



Wide-Field Infrared Survey Telescope

Webb

James Webb Space Telescope



http://jwst.nasa.gov/

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

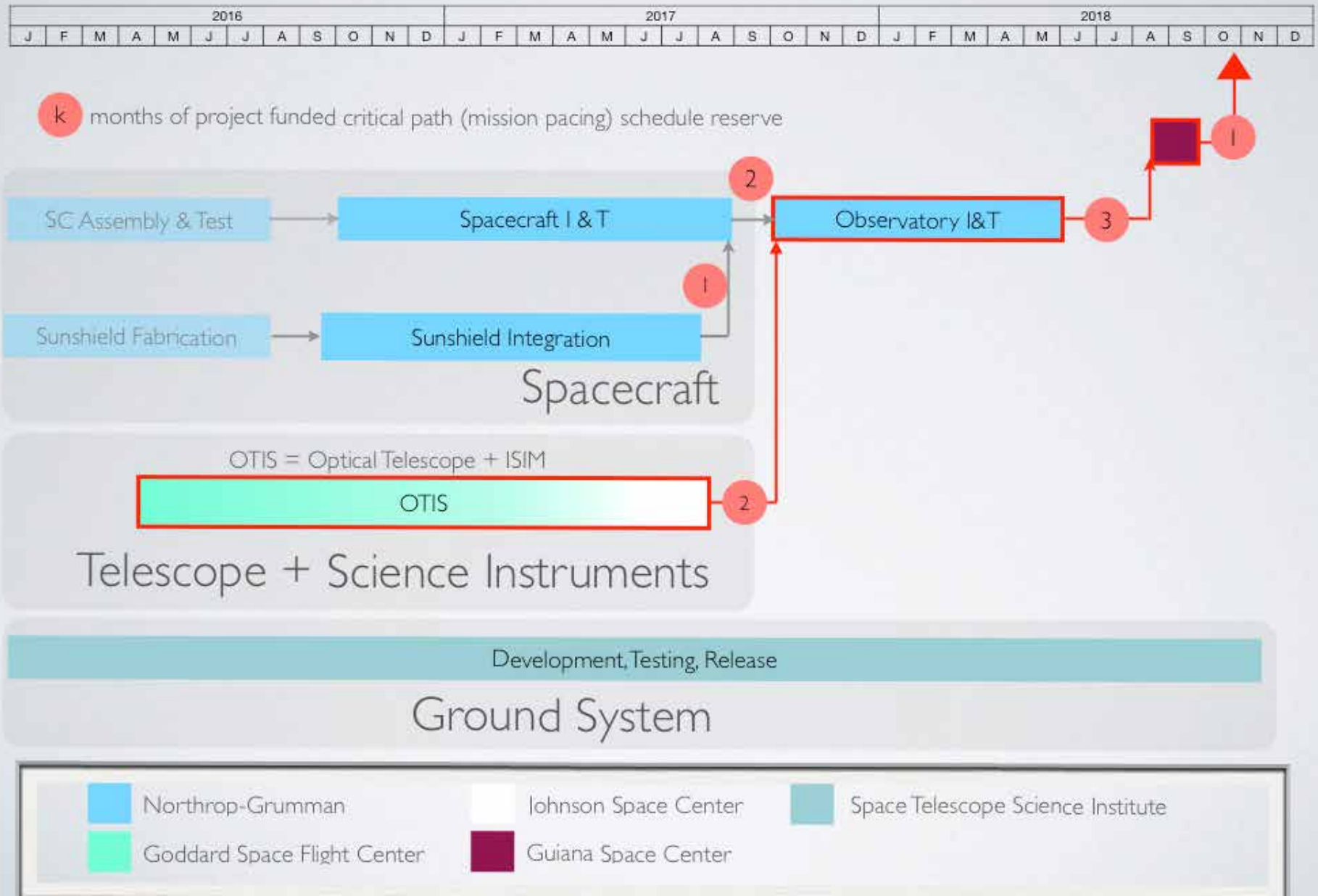
Instruments: Near IR Camera, Near IR Spectrograph, Mid IR Instrument, Near IR Imager and Slitless Spectrograph

Operations: 2018 launch for a 5-year prime mission

Partners: ESA, CSA

JWST remains on track for an October 2018 launch

Webb Simplified Schedule



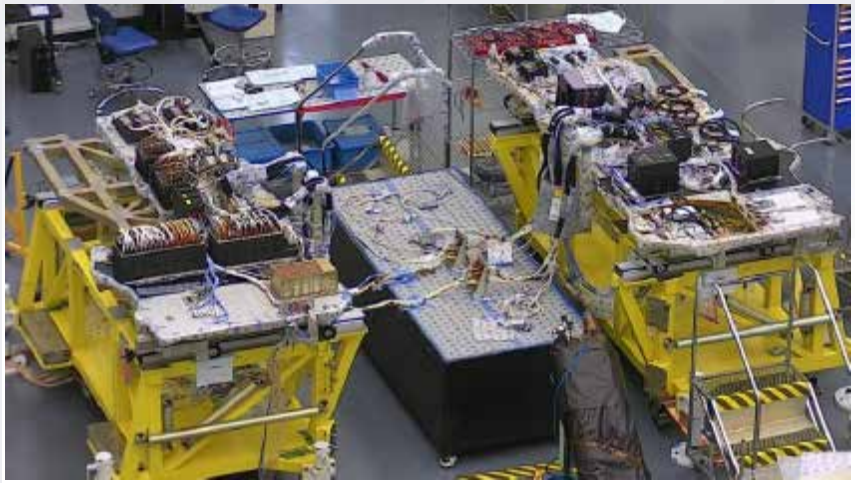
Webb OTIS (@ GSFC)

OTIS = **O**ptical **T**elescope Element and **I**ntegrated **S**cience Instrument Module

Webb Pathfinder Test (@ JSC)

Webb Spacecraft

- All electronics and harnessing installed
- MIRI cryocooler compressor assembly and radiator panels installed
- Sunshield core assembly installation commenced
- Solar Array in test



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.
- Community engagement is less than one year away.

SOFIA

Stratospheric Observatory for Infrared Astronomy

- **World's Largest Airborne Observatory**
- In prime mission operation since May 2014
- 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 US and Two German science instruments commissioned
  - Provide imaging, spectroscopy and photometry ranging from visible to far infrared
  - Advanced science instruments under development for future operation

CURRENT STATUS:

- Received over 200 proposals in response to the Cycle 5 Call for Proposals with selections to be announced in late October 2016; Significant interest in new SOFIA instruments.
- Commissioning of German upGREAT High Frequency Array, operating at 4.7 THz, is planned for November 2016.
- Conducted Part I of HAWC+ 2nd generation science instrument commissioning in April 2016; engineering flights in October 2016 addressed vibration issues; final commissioning series scheduled for December 2016.
- Selected the third generation science instrument High Resolution Mid-InfrarEd Spectrometer (HIRMES) with PI Harvey Moseley (GSFC).
  - Planned to be available for use in 2019.
- Next U.S. instrument call planned for 2017.
- Re-competing contract for science mission operations; RFP closed September 26, 2016.

SOFIA Science Symposium: *"The Local Truth, Star Formation and Feedback in the SOFIA Era"* (Asilomar Conference Center; Oct 17- 20, 2016).

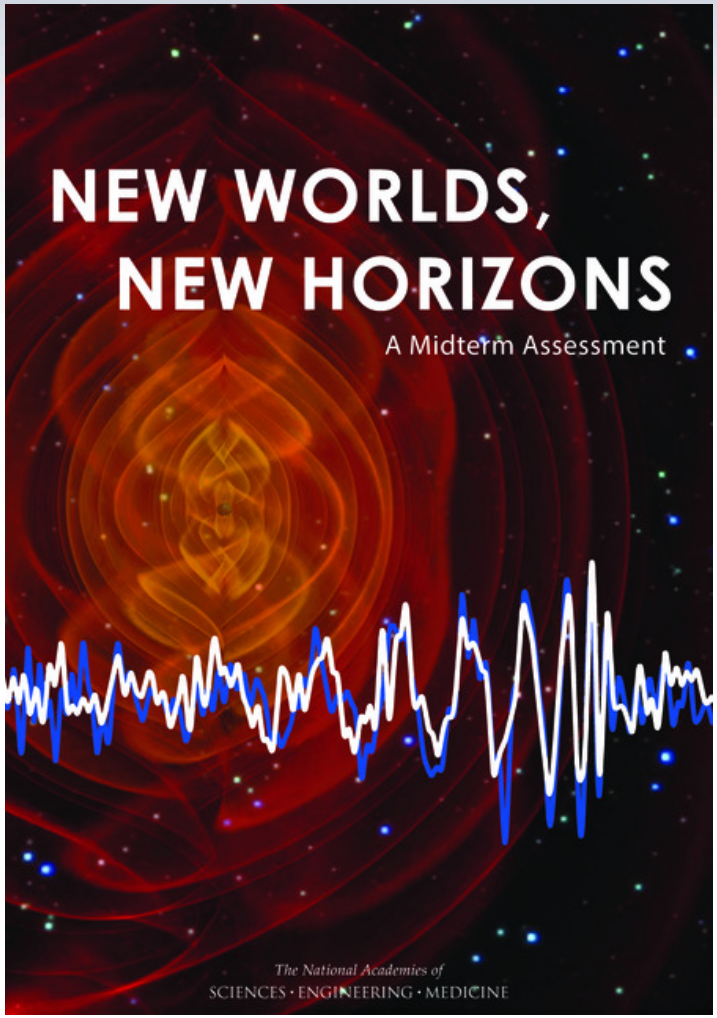
https://www.sofia.usra.edu/

NASA Astrophysics

Response to Midterm Assessment

Midterm Assessment Report

Released August 15, 2016



- 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.
- It will take NASA a while to formulate a complete response to the Report, and it will take NASA an entire budget cycle to make any substantive changes in our program.

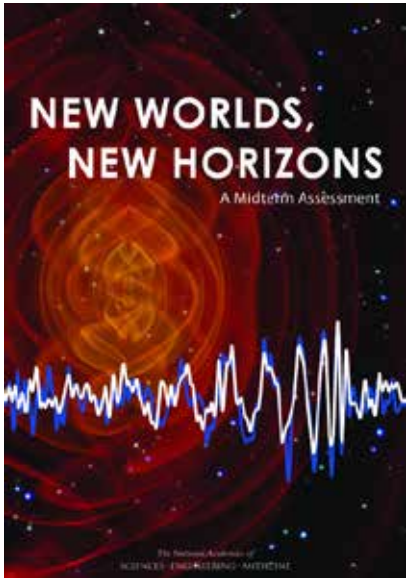
http://www.nap.edu/download/23560

Midterm Assessment Report – Program Balance

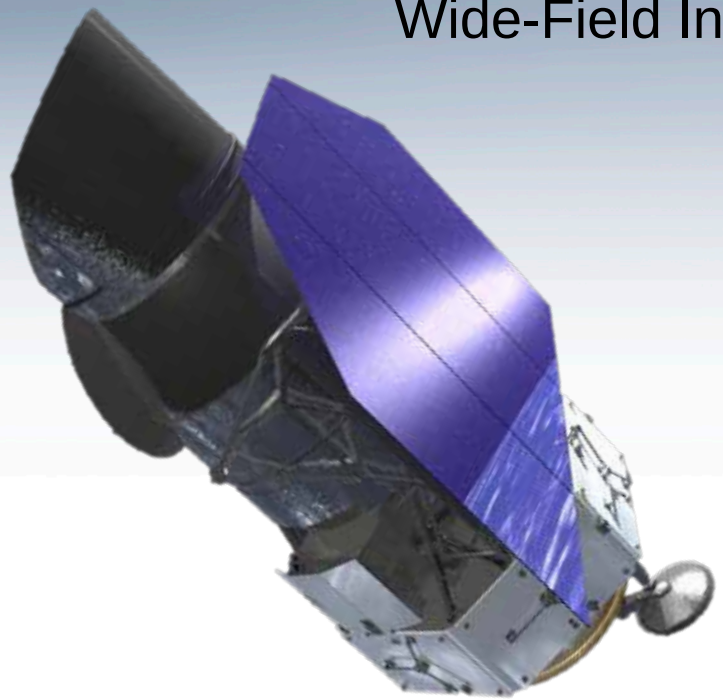
- “Despite a challenging budget environment, NASA-APD has maintained a balanced portfolio through the first half of the decade and, with the assumption of successful completion of an ambitious Explorer schedule, will do so during the second half of the decade as well. This stability, however, has been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

NASA Initial Response:

- Agreed.



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)

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

CURRENT STATUS:

- Acquisition Strategy Meeting (ASM) completed on August 18, 2016.
  - Established approach to development of each element of the mission.
  - Approved Government/Industry approach to Wide Field Instrument (WFI) development.
- Working toward System Requirements Review (SRR) in June 2017 and KDP-B in October 2017.
- Starshade compatibility incorporated into Phase A baseline.
  - NASA will decide before KDP-B whether to maintain starshade compatibility as a requirement.
- National Academies' Mid-Term Report stressed need for cost control on WFIRST.
  - Consistent with current NASA approach to managing design/development of the mission.
- On track for TRL-6 of new technologies in 2017.
  - All technology milestones achieved on time.
- FY17 budget request matches FY16 appropriation of $90M. In-guide budget supports launch in mid-2020s.

Midterm Assessment Report – WFIRST

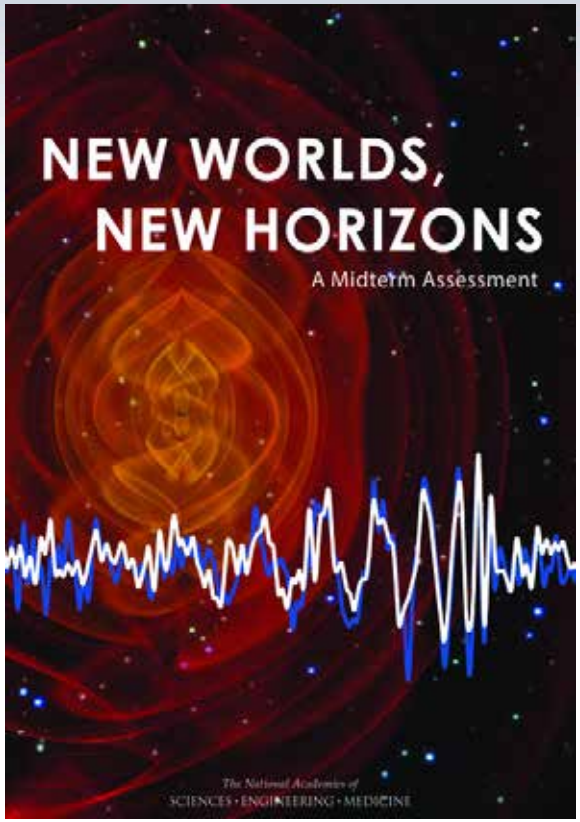
- "At the currently estimated cost, NASA's decision to add a coronagraph to … WFIRST is justifiable within the scientific goals of NWNH. The broader societal interest in the possibility of life beyond Earth is also compelling. However, an increase in cost much beyond the currently estimated $350 million 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 – LISA

Released August 15, 2016



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

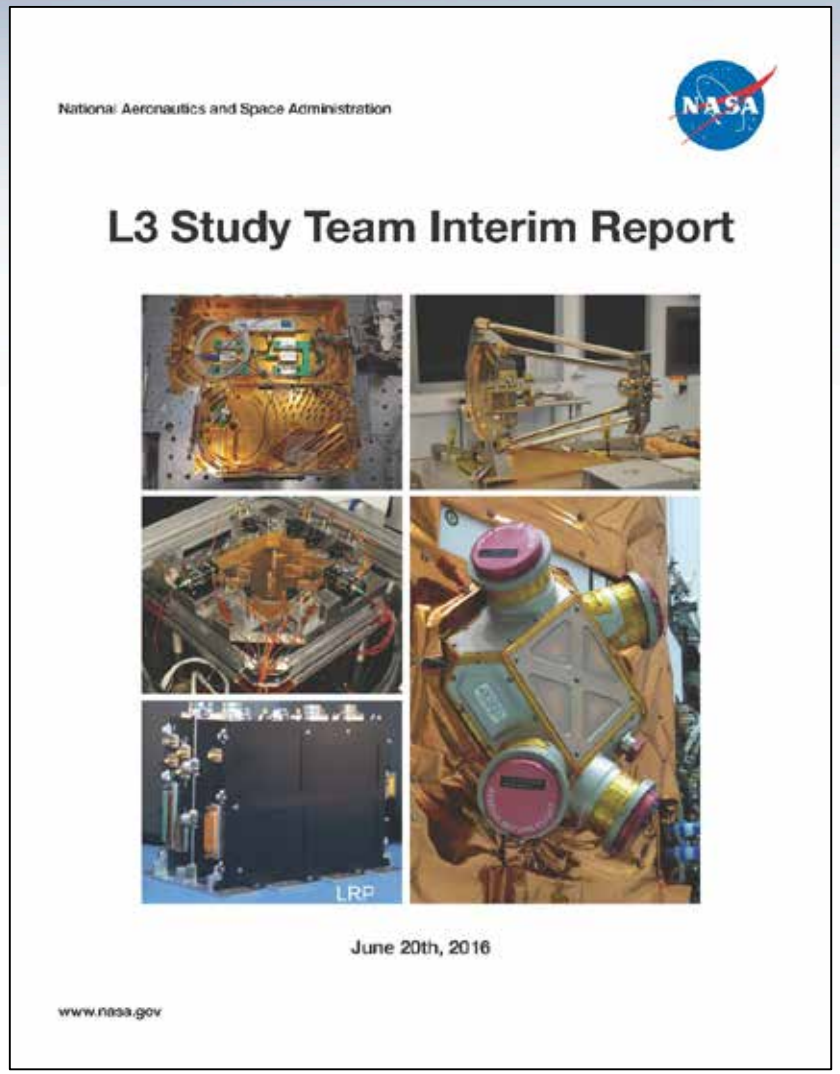
"The science of LISA is even more compelling than in 2010 with the success of Advanced LIGO in making a direct detection of gravitational waves."

"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."

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.

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
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 WFIRST
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

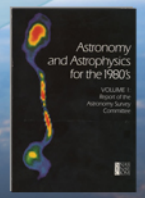
NASA Astrophysics

Planning for the 2020 Decadal Survey

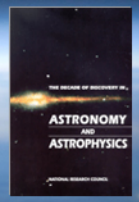
ASTROPHYSICS

Decadal Survey Missions

1972
Decadal Survey
Hubble



1982
Decadal Survey
Chandra



1991
Decadal Survey
Spitzer, SOFIA

2001
Decadal Survey
JWST

2010
Decadal Survey
WFIRST

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.
  - X-ray Surveyor
  - Far Infrared Surveyor (proposed name Origins Space Telescope)
  - Large Ultraviolet/Optical/Infrared Surveyor
  - Habitable Exoplanet Imaging Mission
- 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 face to face meetings twice since early this year.
  - Teams are planning for quarterly face to face meetings in FY17.
- APD held a Pause and Learn October 20-21 for teams to share progress and study approach, how they are engaging external community involvement, what are the lessons learned so far. APD provided guidance on emerging issues, final report content, next steps.

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

Preparing for the 2020 Decadal Survey
Large Mission Concepts

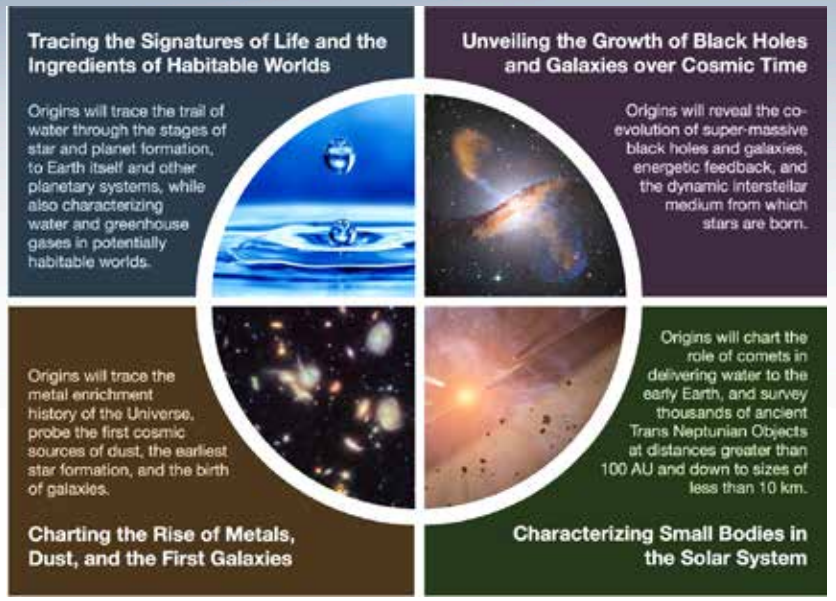
NASA has assembled Science and Technology Definition Teams (STDTs) for each of the four large mission candidates to enable Mission Concept Studies as input to the 2020 Decadal Survey.

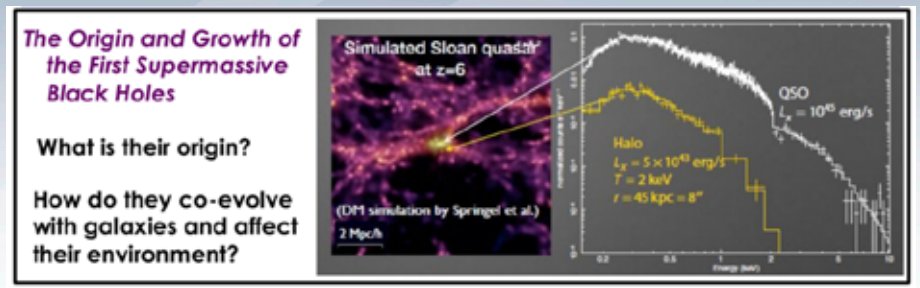
	Community STDT Chairs	Center Study Scientist	Study Lead Center	HQ Program Scientist
Far IR Surveyor asd.gsfc.nasa.gov/firs	Asantha Cooray* Margaret Meixner	David Leisawitz	GSFC	Kartik Sheth
Habitable Exoplanet Imaging Mission www.jpl.nasa.gov/habex	Scott Gaudi* Sara Seager	Bertrand Mennesson	JPL	Martin 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

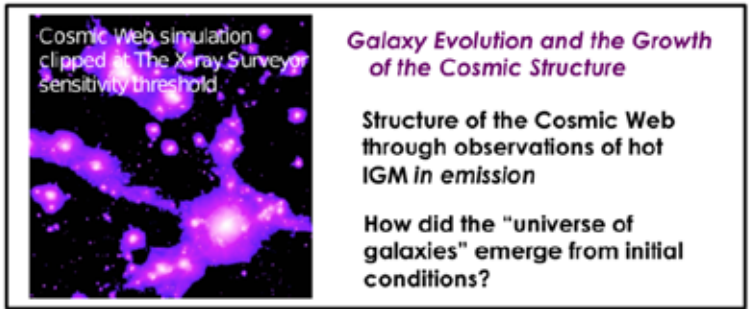
* APS member

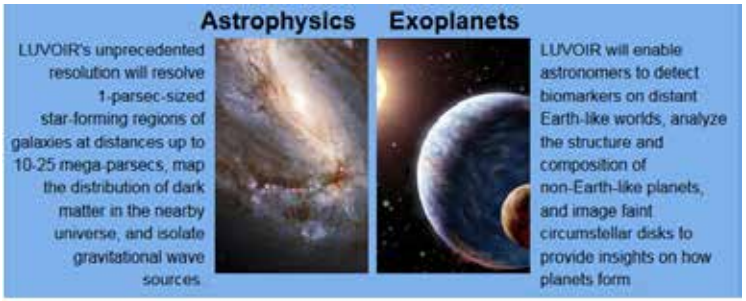
http://science.nasa.gov/astrophysics/2020-decadal-survey-planning/

Large Mission Concepts - Science









Large Mission Concepts - Technology

Far Infrared Surveyor

- FIR detectors
  - FIR Heterodyne Array, Imran Medhi/JPL
  - KID Imaging Arrays, Jonas Zmuidzinas/JPL
  - 4.7-THz Local Oscillators, Qing Hu/MIT
- Cryocoolers
  - High-Efficiency Continuous Cooling for Cryogenic Instruments and sub-Kelvin Detectors, James Tuttle/GSFC

X-ray Surveyor

- Large format microcalorimeters
  - Providing Technologies for the Athena X-IFU, Caroline Kilbourne/GSFC
  - AC-Multiplexed Calorimeter for Athena, Joel Ullom/NIST
- X-ray optics
  - Affordable and Lightweight High-Resolution Astronomical X-Ray Optics, Will Zhang/GSFC
  - Arc-second Adjustable Grazing Incidence X-ray Mirrors, Paul Reid/SAO

Large UV/Optical/IR Surveyor

- Coronagraphy
  - Visible Nulling Coronagraph using a Segmented Aperture, Matthew Bolcar/GSFC
  - Optical Vortex Coronagraph and Broadband Light Rejection, Gene Serabyn/JPL
  - Segmented Aperture Nulling Coronagraphy, Richard Lyon/GSFC
- Ultra stable opto-mechanical
  - Ultra-Stable Structure: Development and Characterization, Babak Saif/GSFC
  - Predictive Thermal Control Technology for Stable Telescope, Phil Stahl/MSFC

Habitable Exoplanet Imaging Mission

- Star shade
  - Starshade Optical Shield, Mark Thomson/JPL
  - Development of Formation Flying Sensors, Webster Cash/Colorado
  - Formation Flying for External Occulters, Jeremy Kasdin/Princeton
- Large aperture monolithic mirror
  - Advanced Mirror Technology Development Phase 2, Phil Stahl/MSFC
  - Predictive Thermal Control Technology for Stable Telescope, Phil Stahl/MSFC

Astrophysics Probes

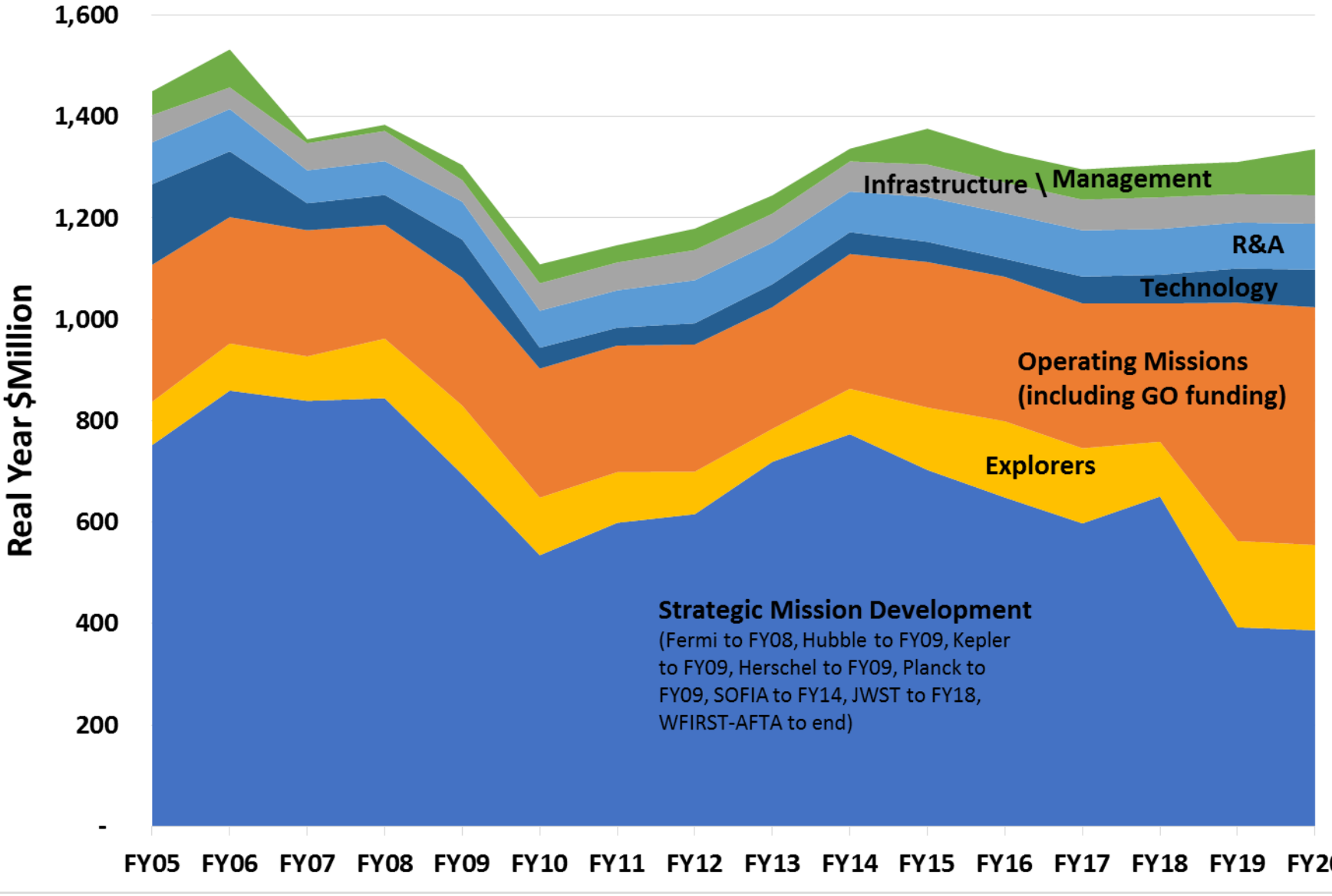
- NASA is soliciting mission concept ideas for medium-size missions as part of community preparations for the 2020 Decadal.
- A solicitation for mission concept proposals was issued on August 15 via NSPIRES as an amendment to ROSES-16.
  - An Astrophysics Probe is defined as a mission with total lifecycle cost (NASA's Phase A through E) in the range $400M to $1B.
  - NASA will provide funding to the PI-led mission concept study team, as well as fund a run with a mission design center at GSFC or JPL, as well as a cost assessment at the end of the study.
- On September 13 a pre-proposal conference was held; the Q&A list has been posted on the Astrophysics Probes NSPIRES website.
- 36 NOIs were received on September 16 in several research areas and from a variety of institutions including NASA Centers, academia, and industry.
- Next Steps:
  - Proposals are due November 15, 2016
  - 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 Decal Survey Committee.


Formulation
Implementation
Primary Ops
Extended Ops
Spitzer
8/25/2003
Kepler
3/7/2009
WFIRST
Mid 2020s
LISA Pathfinder (ESA)
12/3/2015
Webb
2018
Euclid (ESA)
2020
Chandra
7/23/1999
XMM-Newton (ESA)
12/10/1999
TESS
2017
Swift
11/20/2004
NuSTAR
6/13/2012
Fermi
6/11/2008
Hubble
4/24/1990
ISS-CREAM
2017
ISS-NICER
2017
SOFIA
Full Ops 5/2014

NASA Astrophysics

Backup

Astrophysics Budget by Function
FY05-FY14 Actual, FY15 Op Plan, FY16-FY20 Request



FY17 Appropriations

- Both the House and the Senate appropriation committees have marked up the President's budget request for NASA.
- Neither chamber has had a full vote on the NASA appropriation.
- Both chambers made changes to the President's budget request for NASA. The differences must be resolved before the FY17 NASA appropriation can be signed into law.

($M)	FY17 Request	Senate Mark	Senate Delta	House Mark	House Delta
Total Astrophysics	1350.9	1376.4	+25.5	1362.3	+11.4
JWST	569.4	569.4		569.4	
Hubble	97.3	98.3	+1.0		
SOFIA	83.8	83.8		85.2	+1.4
WFIRST	90.0	120.0	+30.0		
Mirror Tech		5.0	+5.0		
Starshade Tech				10.0	+10.0
STEM	25.0	42.0	+17.0	37.0	+12.0
Rest of Astrophysics		457.9	-27.5	660.7	-12.0

Astrophysics R&A Budget is up from FY14

Amounts in $k	FY09 Final	FY10 Final	FY11 Final	FY12 Final	FY13 Final	FY14 Final	FY15 Jul-16	FY16 Op Plan	FY17 request
Particle Astro	$ 8,201	$ 8,260	$ 8,305	$ 9,375	$10,545	$11,125	$ 9,806	$ 9,065	
High Energy	$13,878	$14,110	$13,846	$14,950	$14,270	$13,391	$14,935	$14,595	
UV/Opt/IR/ Sub-mm	$22,389	$21,537	$21,292	$23,385	$21,859	$21,379	$22,731	$25,023	
Fundamental Physics		$ 968	$ 588	$ 860	$ 741	$ 784	$ 618	$ 800	
APRA Total	$44,468	$44,875	$44,030	$48,570	$47,415	$46,680	$48,089	$49,483	
Exoplanet Research	$ 3,000	$ 2,807	$ 2,944	$ 3,244	$ 3,500	$ 3,701	$ 4,350	$ 4,230	
Astro Theory Program	$11,488	$12,262	$12,173	$11,811	$11,560	$12,009	$13,003	$10,373	
TCAN with NSF						$ 1,435	$ 1,563	$1,501	
Tech Fellows				$ 538	$ 975	$ 694	$ 1,555	$1,124	
Other	$ 1,045	$ 670	$ 647	$ 2,008	$ 1,588	$ 1,256	$ 2,512	$2,970	
R&A (399131)	$60,000	$59,646	$59,611	$66,172	$65,038	$63,275	$71,073	$69,681	$72,717
ADAP	$14,384	$13,258	$14,132	$16,365	$16,929	$17,008	$16,983	$17,550	$17,573
399131+ADAP	$74,384	$72,904	$73,743	$82,537	$81,967	$80,283	$88,056	$87,231	$90,290
Other funding					WFIRST support	$ 2,500	$ 522	$ 195	CREAM
					CubeSat (964105)		$ 863	$1,287	$1,180
TOTAL ($M)	**$74.38**	**$73.87**	**$73.74**	**$82.54**	**$81.97**	**$82.78**	**$89.44**	**$88.71**	**$91.47**
	partial recovery	flat	flat	growth!			growth to cover CREAM costs	flat	some growth

Funding for R&A, including Astrophysics Data Analysis (ADAP) is up 25% since the Astro2010 Decadal Survey.

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:

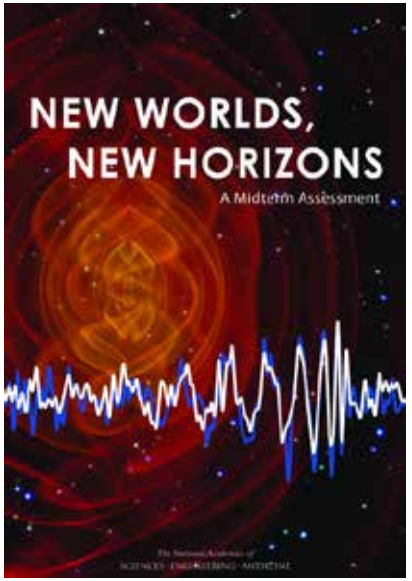
- NASA will treat growth in Euclid elements beyond hardware (US science center, support for US science team) as lower priority.
- NASA will discuss with the CAA whether this means that no funded Euclid GO program can be initiated for the US community.

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.

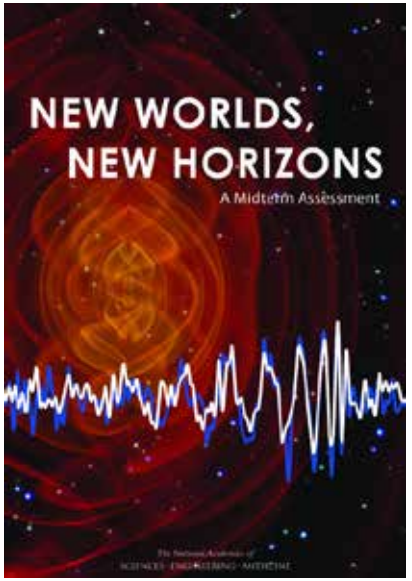


Midterm Assessment Report – Athena

- “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 – 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:

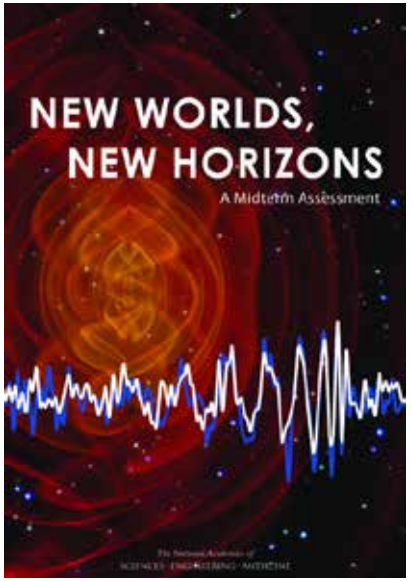
- NASA is reviewing options for reduced funding of exoplanet technology development beyond the WFIRST coronagraph.

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

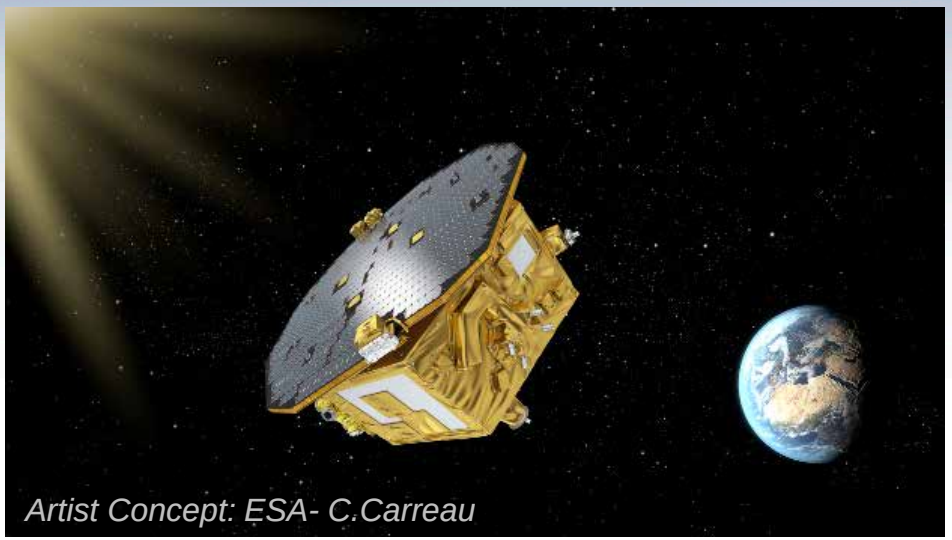
- "NASA's implementation of NWNH's recommended small-scale activities has been mixed. Some recommended augmentations have not occurred and there have been cuts in some programs recommended for augmentation. Other programs, in particular the suborbital and exoplanet areas, have seen increases in excess 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.

X-ray Recovery Mission (update)

- Hitomi (ASTRO-H) was lost on March 26, 2016.
  - On June 8, JAXA released a report on the cause of the mission-ending anomaly.
  - http://global.jaxa.jp/projects/sat/astro_h/topics.html
- JAXA has proposed an X-ray Recovery Mission (XRRM) to recover the science lost with Hitomi.
  - Proposal is part of JFY2017 budget proposal, which requires Government approval as part of the Japanese budget process.
  - JAXA and NASA have had several rounds of talks on (a) whether NASA will participate in XRRM and (b) what changes would be made for XRRM.
- The NASA Advisory Council recommended on July 28, 2016, that NASA participate in XRRM.
  - NASA should rebuild SXS provided problems leading to loss of Hitomi are solved, does not interfere with decadal Survey priorities, and subject to Mid Term Review report findings.
  - Recommendation came from Astrophysics Subcommittee via Science Committee.
- As discussed at July APS meeting, should NASA participate, then
  - NASA's hardware role on XRRM would be same as on Hitomi.
  - Project would be directed to GSFC to reduce cost, schedule, and technical risk by leveraging off Hitomi experience and heritage.
  - US community participants, beyond XRRM team at GSFC, would be selected anew from an open call.

ST-7/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:

- ESA's LISA completed nominal ESA science operation on June 25, 2016.
- On July 7, 2016 experience anomaly in DRS Cluster 2 computer. Workaround implemented using the spacecraft computer.
- NASA's Disturbance Reduction System (DRS) completed commissioning on August 14, 2016
- System operating nominally and have completed over 900 hours of flight operation and over 650 hours since the fault recovery.

- DRS will until continue through December 15, 2016, completing the prime mission.
- Extended operation will begin and continue into early part of 2017.

ISS-NICER

Neutron star Interior Composition Explorer

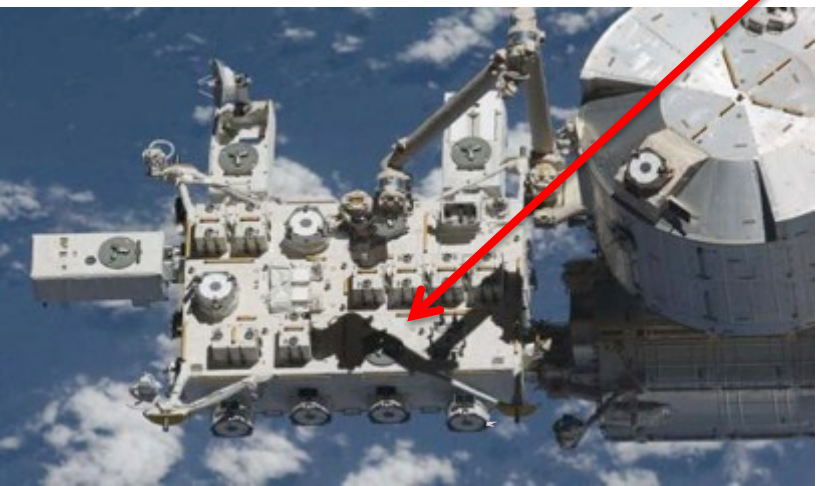
Removal of shipping container cover from NICER payload at Kennedy Space Center

NICER in storage at KSC

- 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 completed ISS interface testing. Now stored at KSC until launch **P**
- March 2017 (TBC): Launch on SpaceX-11 commercial resupply service (CRS) flight to ISS

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

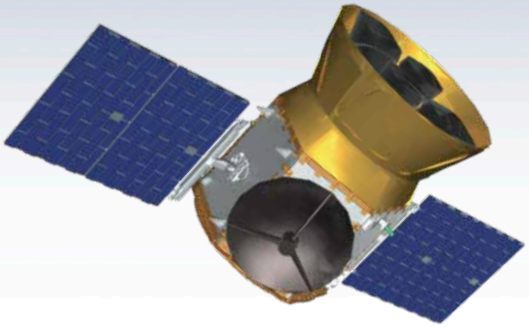
CREAM
Cosmic Ray Energy and Mass



- 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.

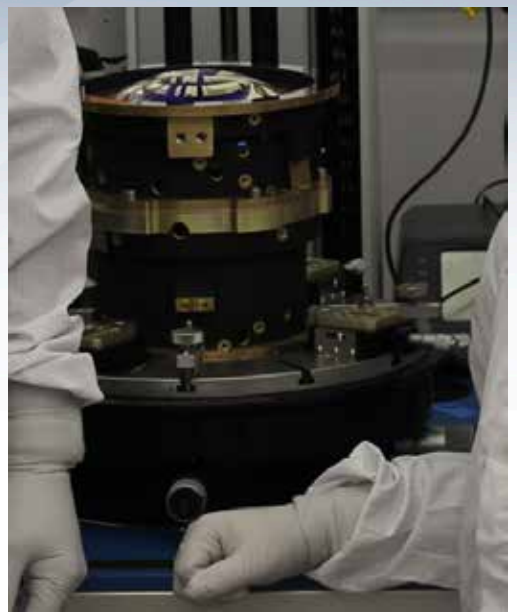
http://cosmicray.umd.edu/iss-cream/

TESS
Transiting Exoplanet Survey Satellite



CURRENT STATUS:

- Most spacecraft bus components have been delivered and s/c bus is being assembled **P**
- Flight instrument build underway; first lots of flight CCDs have been produced **P**
- Flight camera optics in assembly **P**



Completed TESS Flight Camera #1 Lens Assembly

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).

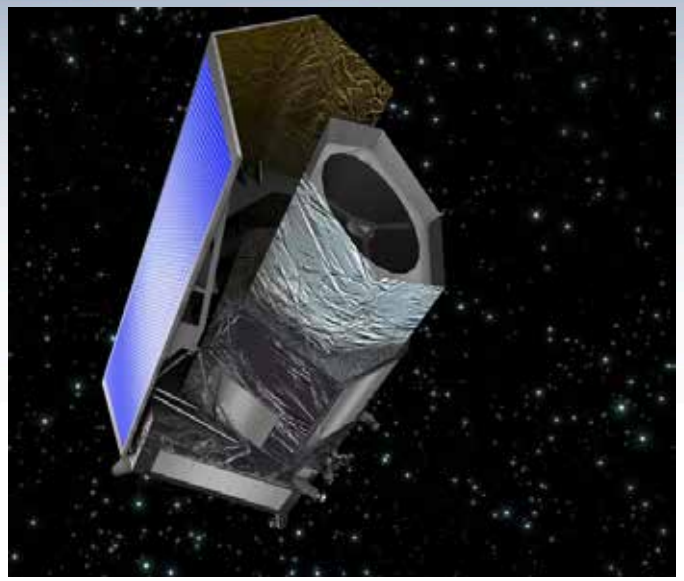
Operations: NLT June 2018 launch with a 3-year prime mission including 2 years of spacecraft operations and an additional 1 year ground-based observations and analysis. High-Earth elliptical orbit (17 x 58.7 Earth radii).

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

UPCOMING EVENTS:

- Fall 2016 - Spring 2017 – TESS 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 launch site.
- Dec 2017 – Launch readiness date from Canaveral FL (pending review of recent SpaceX pad anomaly)

Euclid

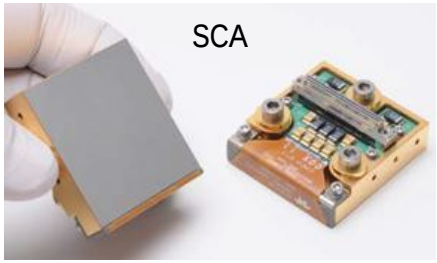


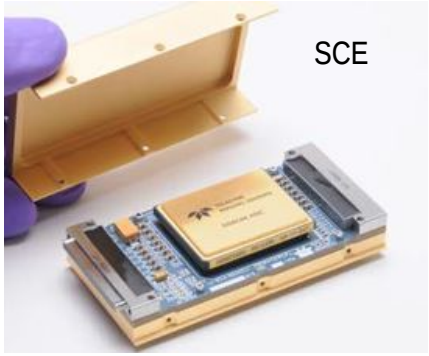
- ESA Mission with NASA Collaborating
- ESA Cosmic Vision 2015-2025 Mission, M-Class
- Category 3 - Risk Class B
- Optical and NIR Observatory with 1.2-m Telescope
- U.S. Providing Characterized NIR Detectors
- Launch Date: Dec 2020
- ~70 U.S. Science Team members selected by NASA HQ
- Euclid NASA Science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

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

CURRENT STATUS:

- In development phase. To date, 20 Sensor Chip Assemblies (SCA) have been delivered, 26 are expected, and 20 are required.
- Six SCAs have been tested and results are very good, some of the best ever seen in this frequency range.
- The Sensor Chip Electronics (SCE) are in process but have had trouble with the printed circuit board fabrication.

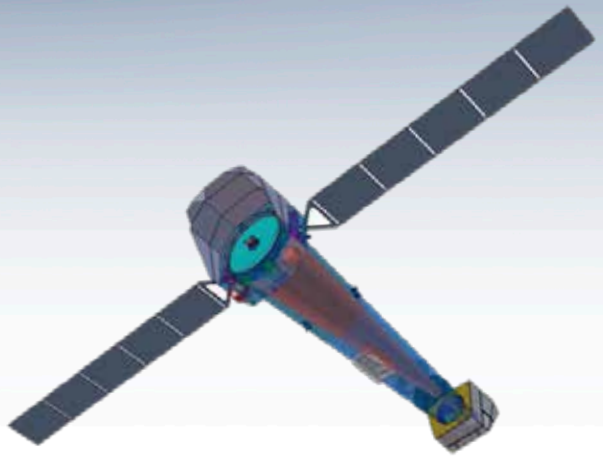




- Initial SCE deliveries are delayed but final deliveries have approximately two months schedule margin
- Cryo Flex Cables, which connect the SCA and SCE, are in progress. Two have been delivered to GSFC with more in test.

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-IFU and WFI instruments

Launch Date: 2028

Breakthrough Technologies:

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

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-ray Integral Field Unit (X-IFU) and the Wide Field Imager (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