

Astrophysics



Astrophysics Division Report

Committee on Astronomy and Astrophysics
October 31, 2016

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Science Mission Directorate

[@PHertzNASA](https://twitter.com/PHertzNASA)

Outline



Outline

- | | |
|--|--------------|
| • General Update including Budget | Charts 5-19 |
| • Midterm Assessment & Committee Questions | Charts 20-37 |
| • Planning for the 2020 Decadal Survey | Charts 38-44 |
| • Mission Updates (optional) | Charts 45-53 |

Committee Questions

- What is NASA's response to the findings and recommendations of the mid-decadal review?
- What are NASA's plans for funding gravitational wave research for the rest of the decade? Is there a realistic path (given the current WFIRST budget and schedule) for NASA involvement in LISA or other gravitational wave space missions?
- What is your view on participation by university groups in future mission hardware development?

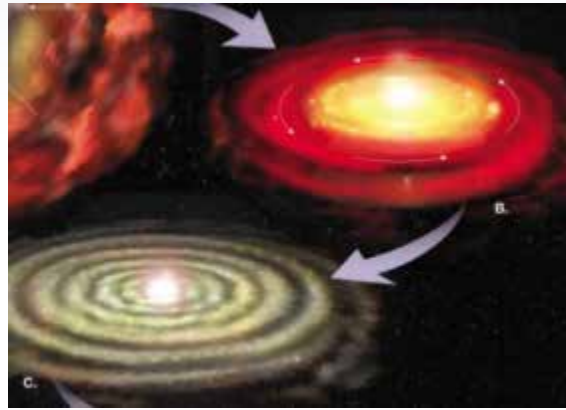
Why Astrophysics?



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



1. How did our universe begin and evolve?

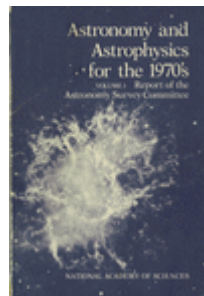


2. How did galaxies, stars, and planets come to be?

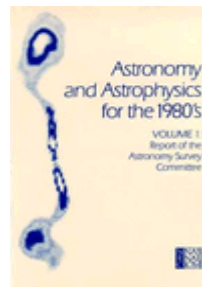


3. Are We Alone?

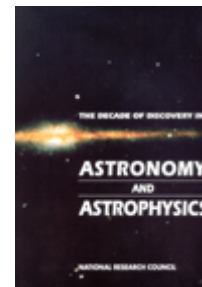
These national strategic drivers are enduring



1972



1982



1991

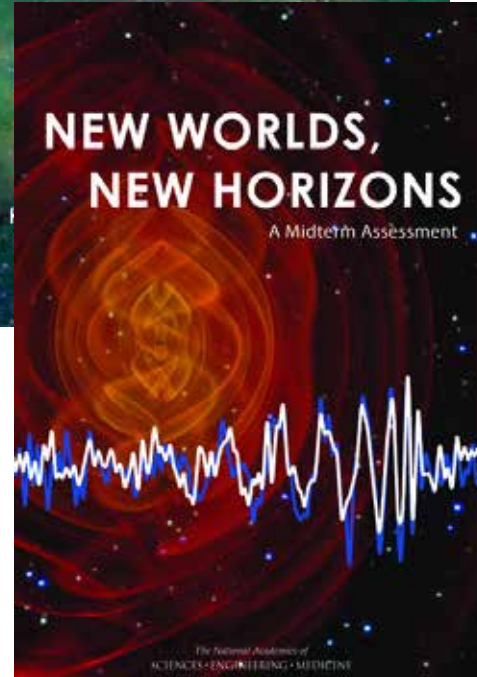
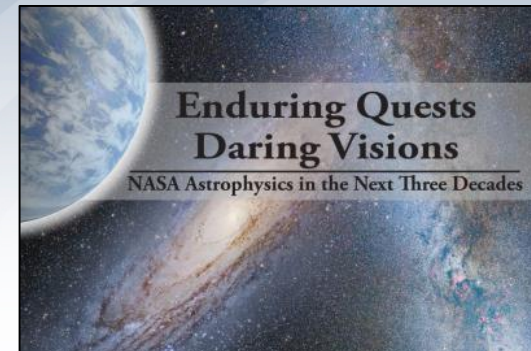
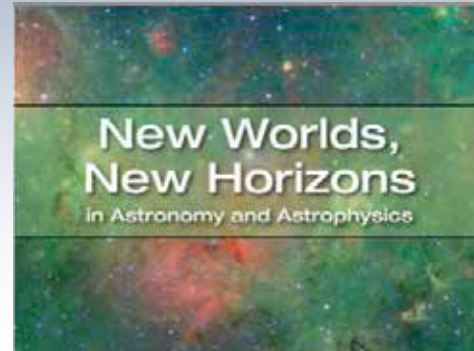


2001



2010

Astrophysics Driving Documents



Next update will include:

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

Science Mission Directorate
NASA Headquarters

December 2014



NASA Astrophysics

Brief General Update

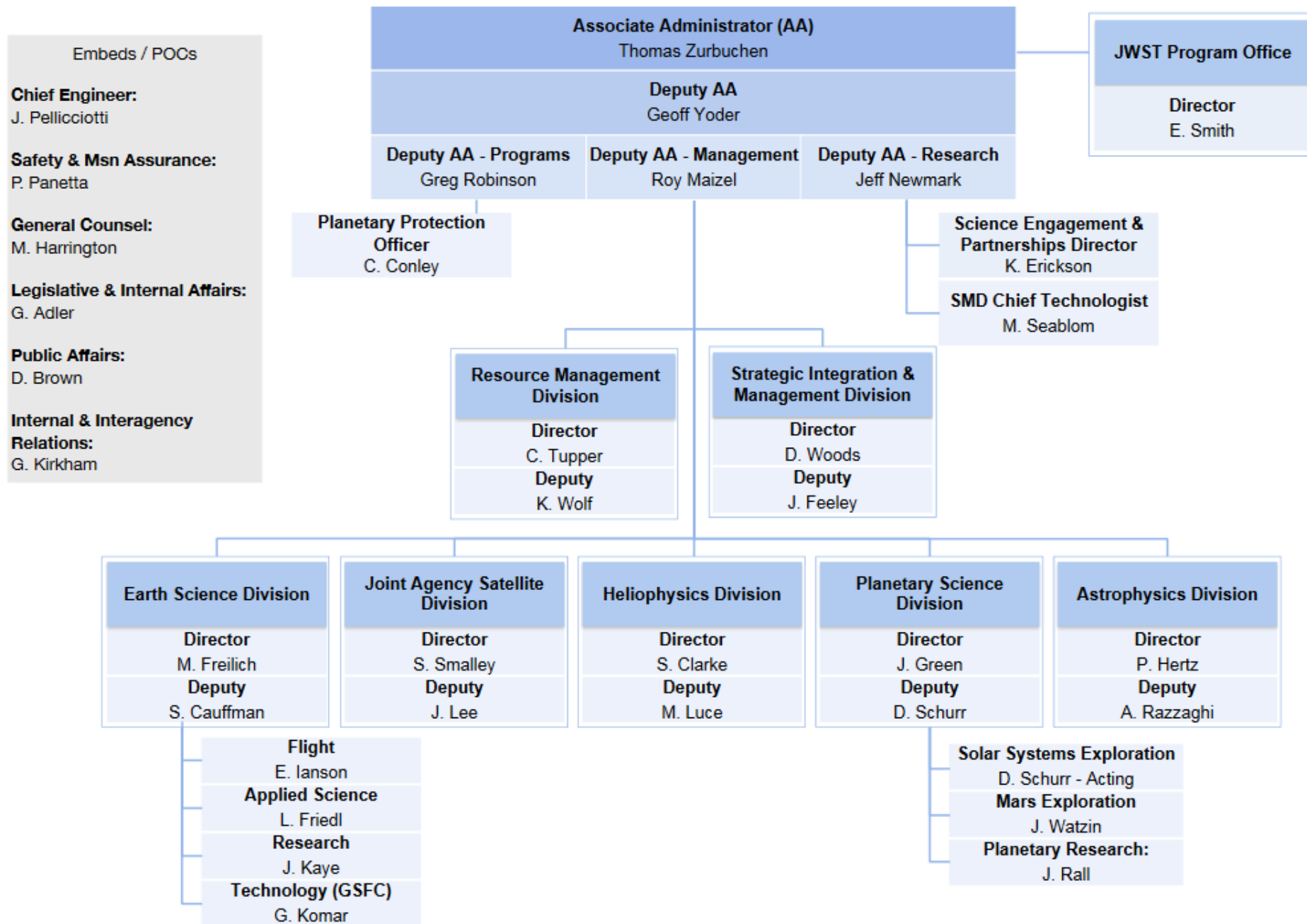
New Associate Administrator for Science Mission Directorate



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.

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.

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

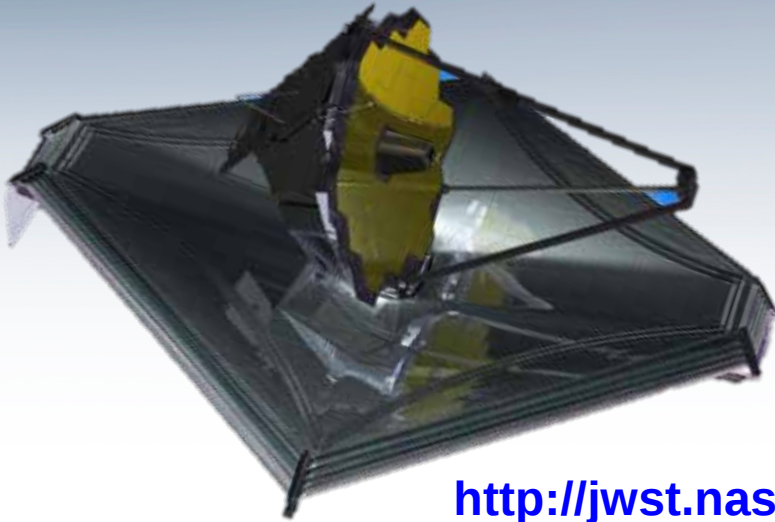
CURRENT STATUS:

- 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).

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 $<50\text{K}$ 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



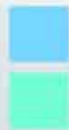
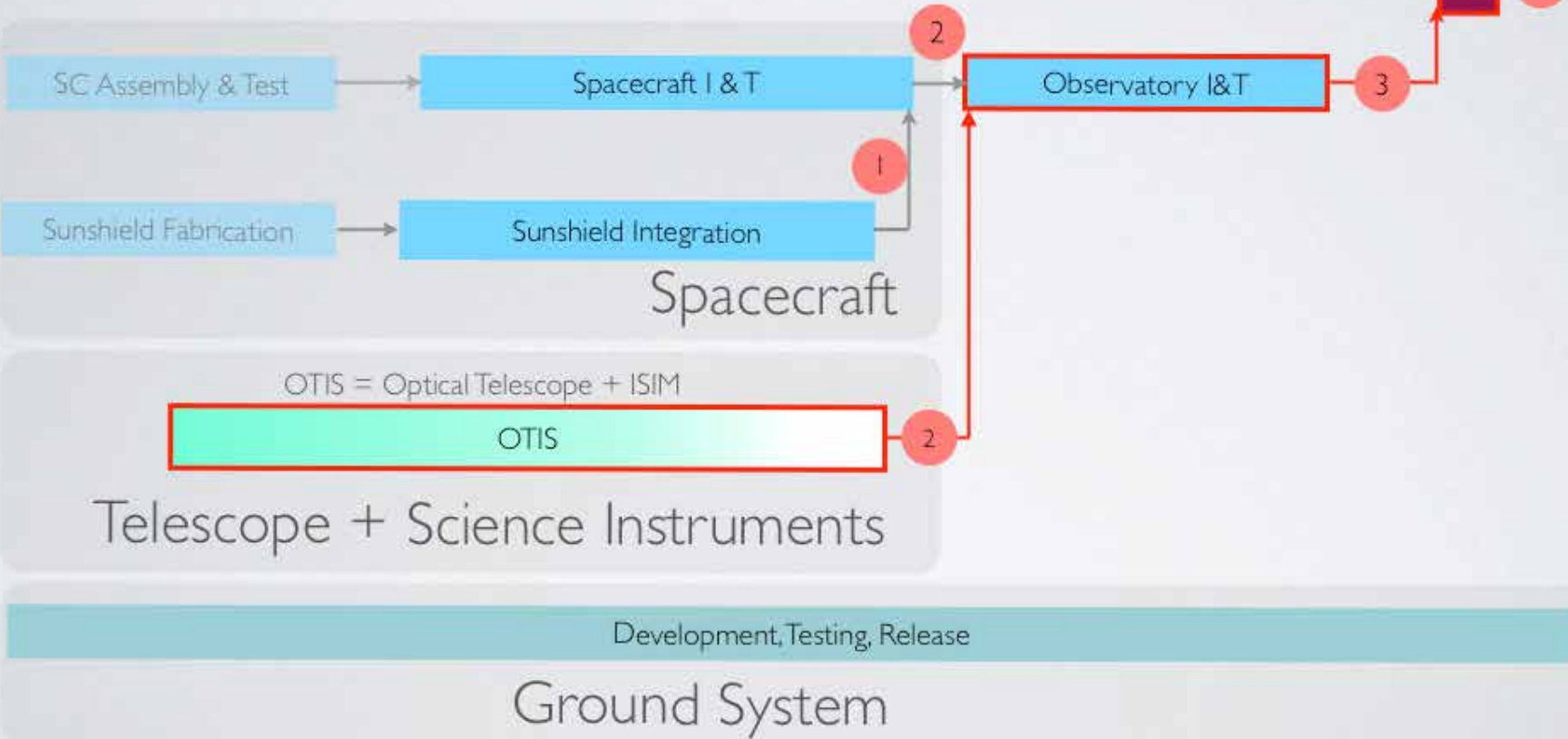
JWST remains on track for an October 2018 launch

Webb Simplified Schedule



2016												2017												2018											
J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D

k months of project funded critical path (mission pacing) schedule reserve



Northrop-Grumman



Johnson Space Center



Space Telescope Science Institute



Goddard Space Flight Center



Guiana Space Center

Webb OTIS (@ GSFC)



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

Webb Pathfinder Test (@ JSC)



Pathfinder
Telescope

Space Vehicle
Thermal Simulator



Webb Spacecraft



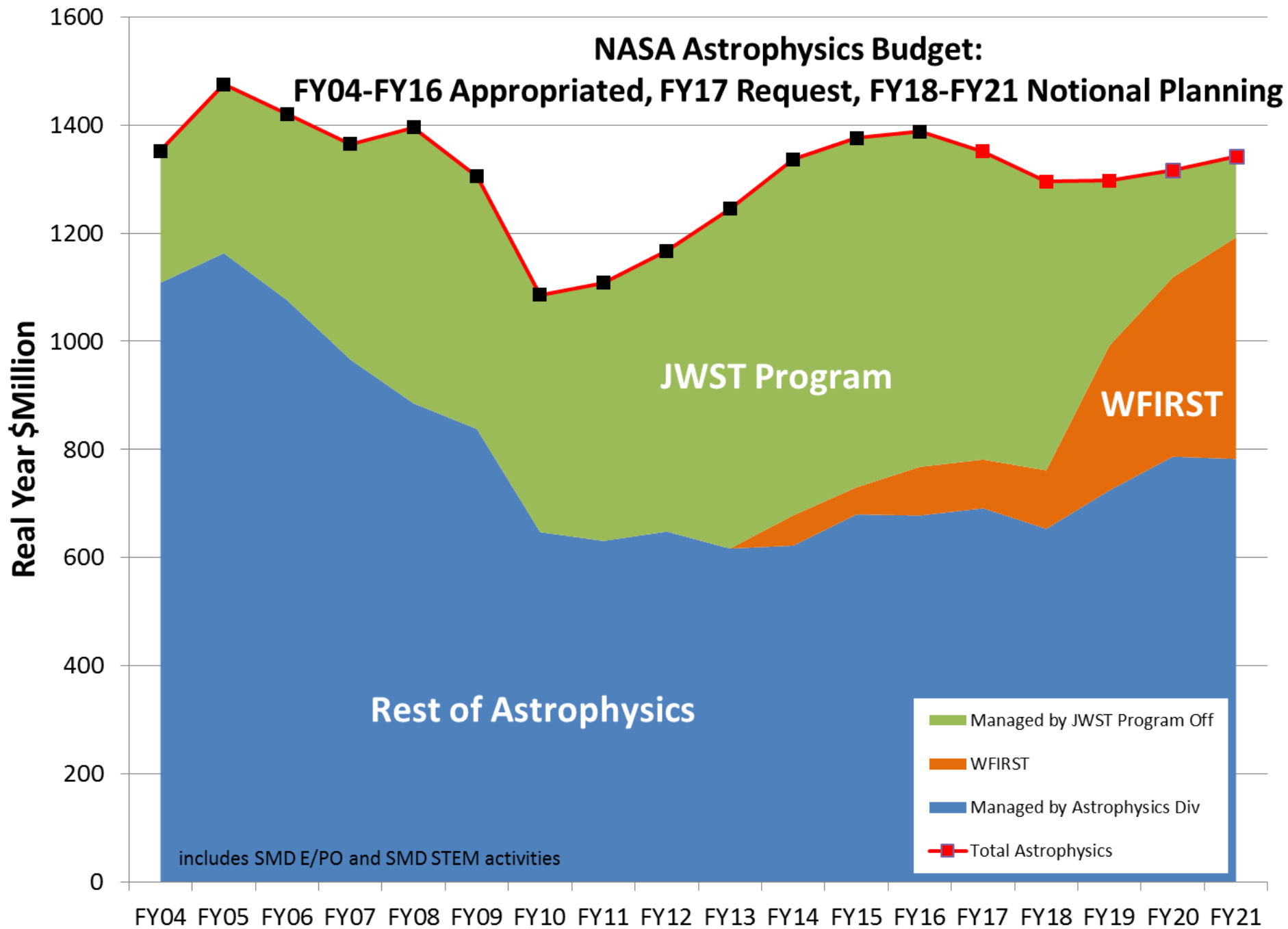
- All electronics and harnessing installed
- MIRI cryocooler compressor assembly and radiator panels installed
- Sunshield core assembly installation commenced
- Solar Array in test



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.



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
- 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

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



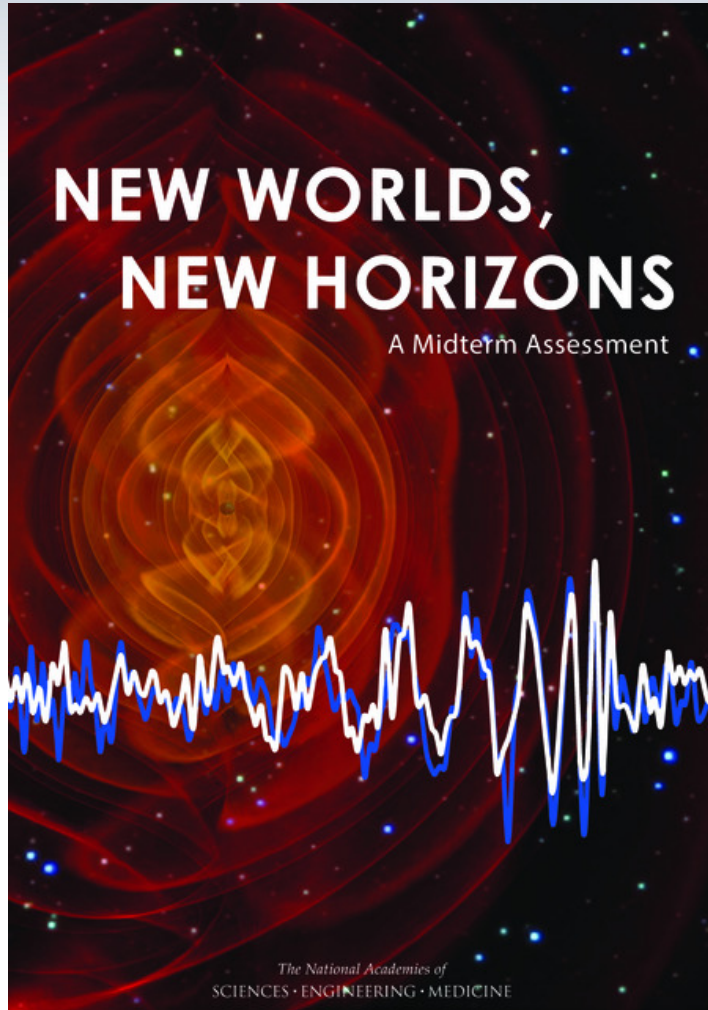
NASA Astrophysics

Response to Midterm Assessment and other Committee Questions

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.

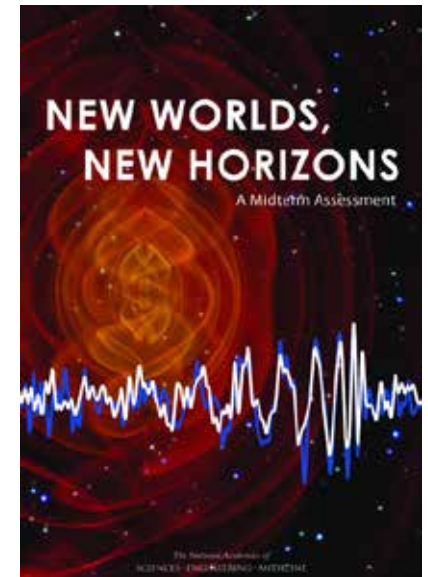
<http://www.nap.edu/download/23560>

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.



Midterm Assessment Report – WFIRST



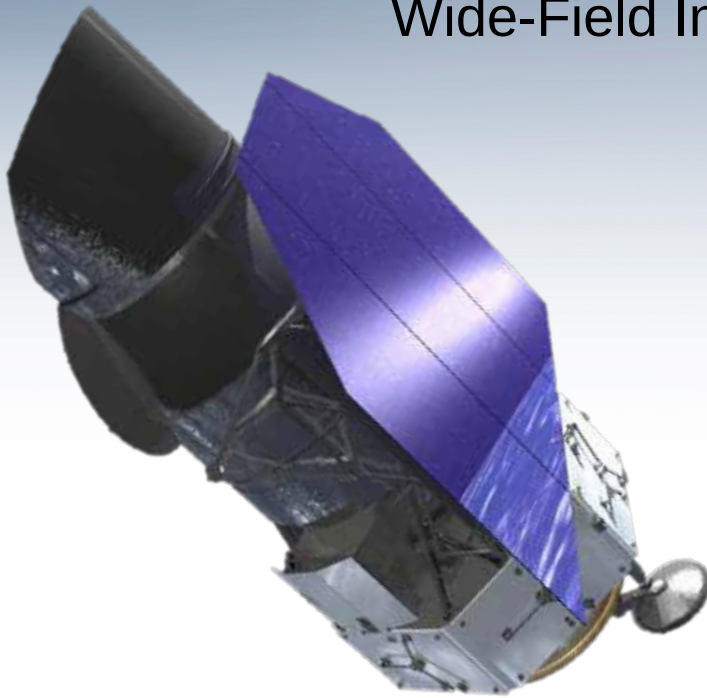
- “At the currently estimated cost, NASA’s decision to add a coronagraph to ... WFIRST is justifiable within the scientific goals of NWNH. The broader societal interest in the possibility of life beyond Earth is also compelling. However, an increase in cost much beyond the currently estimated \$350 million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

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 $0.8\text{-}2\mu\text{m}$

Instruments (design reference mission):

Wide Field Instrument (camera plus IFU), Coronagraph Instrument (imaging/IFS)

Phase: Currently in Formulation (Phase A)

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 – 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.

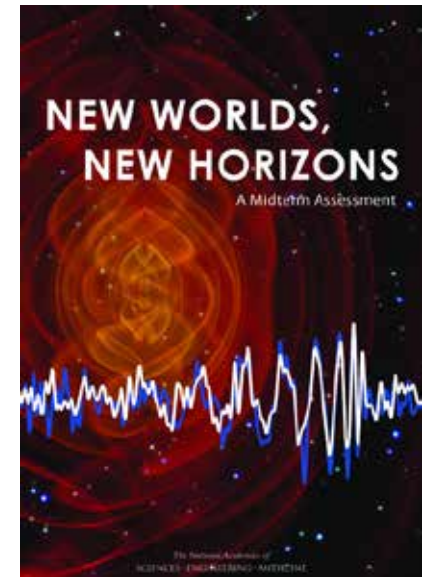
Midterm Assessment Report – Explorers



- “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.



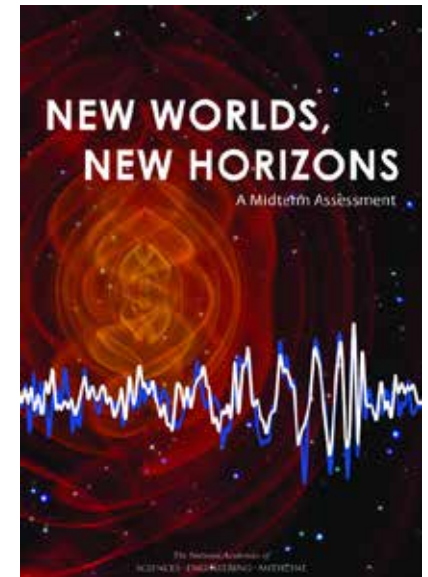
Midterm Assessment Report – Athena



- “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:

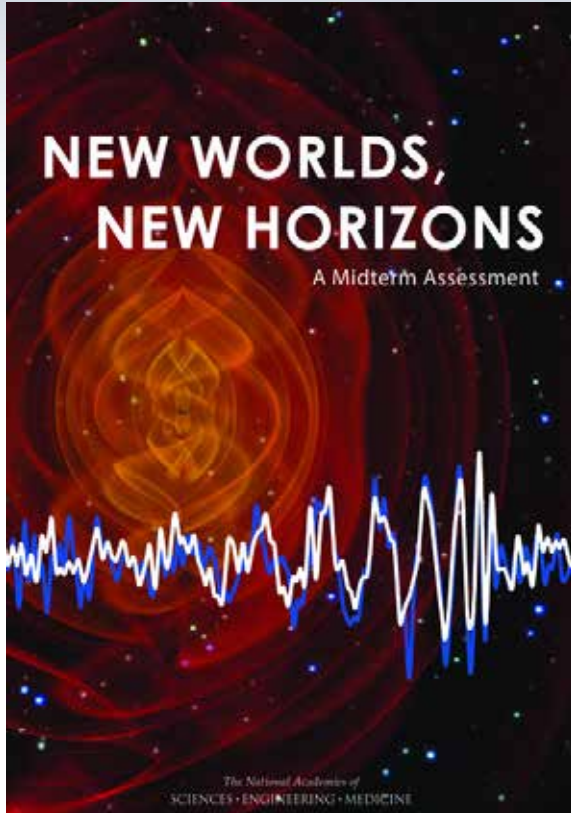
- Agreed.



Midterm Assessment Report – LISA



Released August 15, 2016



<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.”

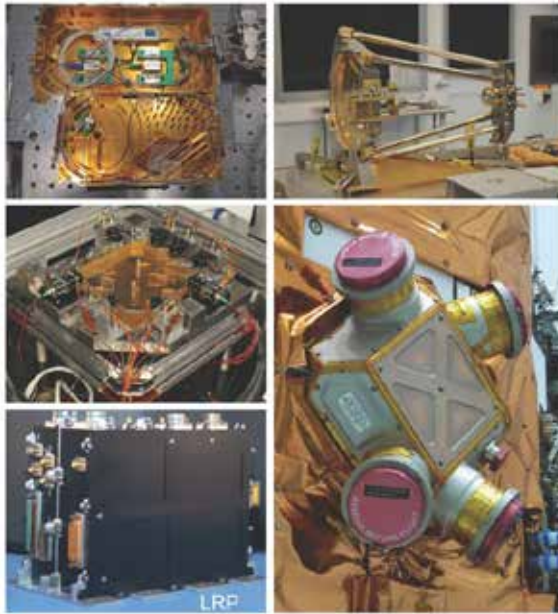
L3ST Interim Report



National Aeronautics and Space Administration



L3 Study Team Interim Report



June 20th, 2016

www.nasa.gov

- 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/>

What is NASA doing for Gravitational Wave Research?



- ü **Searching for EM counterparts** to LIGO sources
- ü **Supporting DRS operations on LISA Pathfinder**
- ü **Investing in 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 **Funding 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 **Establishing 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 **Establishing 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

<http://www.physik.uzh.ch/events/lisa2016/uploads/229/Hertz%20LISA%20Symposium%20FINAL.pdf>

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.

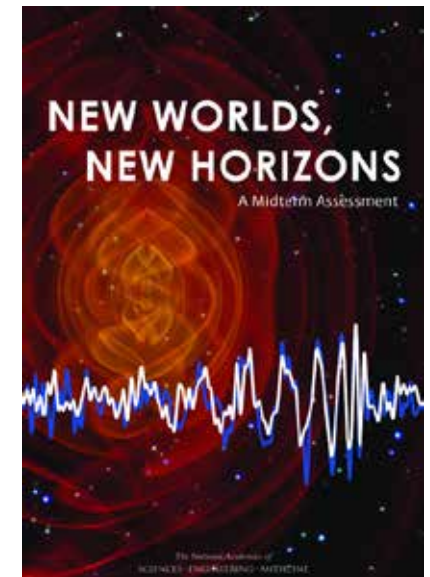
Midterm Assessment Report – Inflation Probe Technology



- “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
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

Committee Question to NASA



What is your view on participation by university groups in future mission hardware development?

- Explorers AOs (missions, and missions of opportunity) are fully open to universities. There are no restrictions against the development of mission hardware by university groups.
 - Examples: TESS, NuSTAR, Swift
- Strategic missions generally have instrument AOs that are fully open to universities. There are no restrictions against the development of mission hardware by university groups.
 - Examples: Hubble, Chandra, Spitzer, Fermi, JWST
 - WFIRST is an exception, though university groups are part of the CGI team.
- Probes might be directed or PI-led through a fully open AO
 - Even if directed, there would be a fully open AO for instruments, payloads, and/or science teams.
- Suborbital missions, and SOFIA instruments, are selected through ROSES, which is fully open to universities.
 - Examples: CREAM (ISS), X-Calibur, ANITA, STO (balloons), CIBER, CHESS, Micro-X, ACCESS (sounding rockets)
- Technology development necessary for future mission hardware is selected through ROSES/APRA and ROSES/SAT, which are fully open to universities.

Committee Question to NASA



What is your view on participation by university groups in future mission hardware development?

- However
 - Missions are larger, more complex (even Explorers), and less frequent. This is a natural consequence of the success of astrophysics and the difficulty of addressing the most compelling science questions, such as those in the Decadal Survey.
 - There are fewer universities with the capability and facilities required to build complex mission hardware. Partnering with industry or Government labs has become more common over the decades.
 - The mission cadence is lower so fewer hardware providers can be maintained with the available and planned opportunities.
 - The capability required for future strategic missions often exists only in NASA Centers, other Government labs, and industry.



NASA Astrophysics

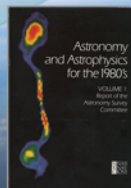
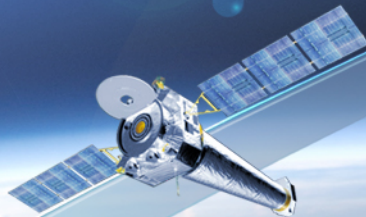
Planning for the 2020 Decadal Survey

ASTROPHYSICS

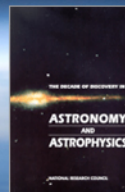
Decadal Survey Missions



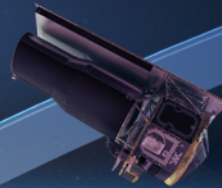
1972
Decadal Survey
Hubble



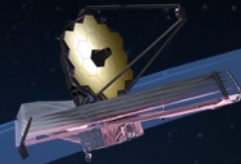
1982
Decadal Survey
Chandra



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.

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



Tracing the Signatures of Life and the Ingredients of Habitable Worlds

Origins will trace the trail of water through the stages of star and planet formation, to Earth itself and other planetary systems, while also characterizing water and greenhouse gases in potentially habitable worlds.



Unveiling the Growth of Black Holes and Galaxies over Cosmic Time

Origins will reveal the co-evolution of super-massive black holes and galaxies, energetic feedback, and the dynamic interstellar medium from which stars are born.



Origins will trace the metal enrichment history of the Universe, probe the first cosmic sources of dust, the earliest star formation, and the birth of galaxies.



Charting the Rise of Metals, Dust, and the First Galaxies



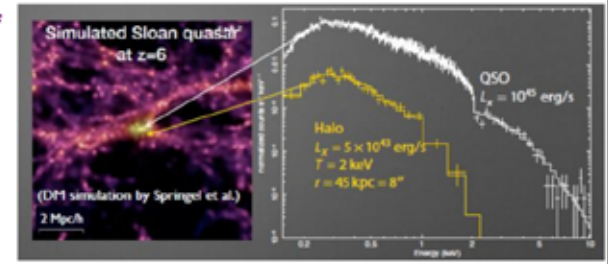
Origins will chart the role of comets in delivering water to the early Earth, and survey thousands of ancient Trans-Neptunian Objects at distances greater than 100 AU and down to sizes of less than 10 km.

Characterizing Small Bodies in the Solar System

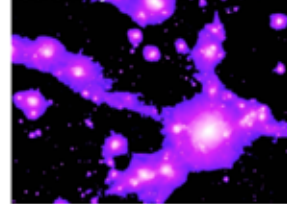
The Origin and Growth of the First Supermassive Black Holes

What is their origin?

How do they co-evolve with galaxies and affect their environment?



Cosmic Web simulation clipped at the X-ray Surveyor sensitivity threshold.



Galaxy Evolution and the Growth of the Cosmic Structure

Structure of the Cosmic Web through observations of hot IGM in emission

How did the "universe of galaxies" emerge from initial conditions?

Astrophysics

LUVOIR's unprecedented resolution will resolve 1-parsec-sized star-forming regions of galaxies at distances up to 10-25 mega-parsec, map the distribution of dark matter in the nearby universe, and isolate gravitational wave sources.



Exoplanets

LUVOIR will enable astronomers to detect biomarkers on distant Earth-like worlds, analyze the structure and composition of non-Earth-like planets, and image faint circumstellar disks to provide insights on how planets form.



Cosmic Origins

LUVOIR will identify the first starlight in the early universe, uncover the archaeology of early galaxies, and find the first black holes.



Solar System

LUVOIR will be able to resolve surface and cloud features as small as 50 km for outer planets and 200 km on Kuiper belt objects, and will image the icy plumes from giant planet moons.



SCIENCE

Exoplanets



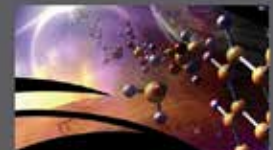
The primary goal of HabEx is to image and study habitable exoplanets. However, it will also study the full range of exoplanets within the system.

Astrophysics



With a large aperture optical/infrared space-based telescope, it will be possible for HabEx to study a broad range of Galactic and extragalactic astrophysics.

Astrobiology



HabEx will search for potential signs of habitability in the atmospheres of exoplanets by seeking signs of water and other biosignature gases, including oxygen and ozone.



Large Mission Concepts - Technology



Far Infrared Surveyor

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

X-ray Surveyor

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

Large UV/Optical/IR Surveyor

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

Habitable Exoplanet Imaging Mission

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



NASA Astrophysics

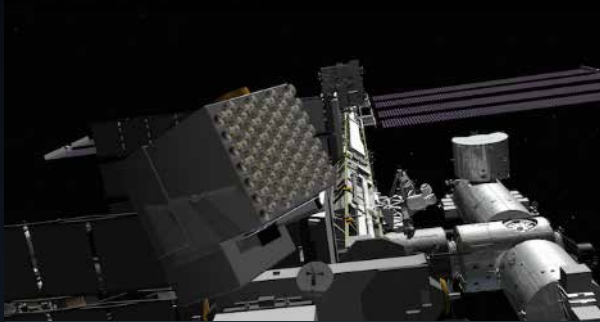
Mission Updates

Astrophysics Missions in Development

ISS-NICER

3/2017

NASA Mission

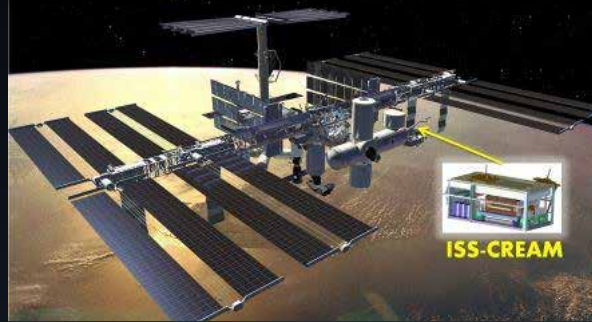


Neutron Star Interior
Composition Explorer

ISS-CREAM

6/2017

NASA Mission



Cosmic Ray Energetics
And Mass

TESS

12/2017

NASA Mission

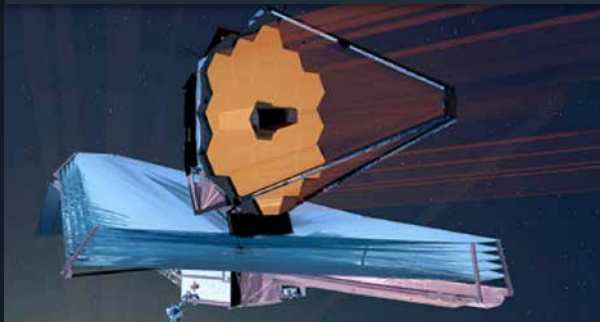


Transiting Exoplanet
Survey Satellite

Webb

10/2018

NASA Mission

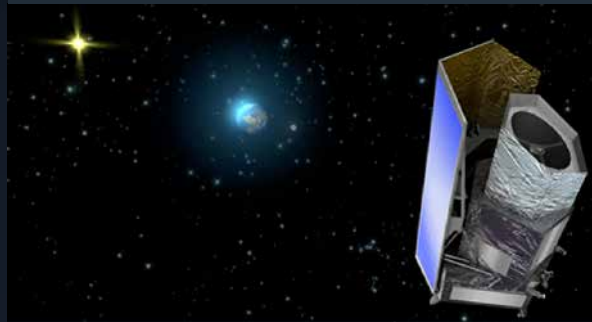


James Webb
Space Telescope

Euclid

2020

ESA-led Mission

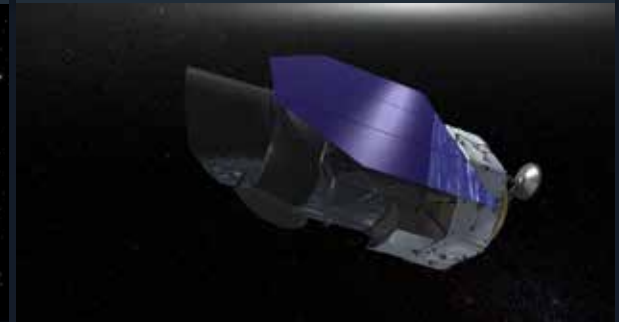


NASA is supplying the NISP
Sensor Chip System (SCS)

WFIRST

Mid 2020s

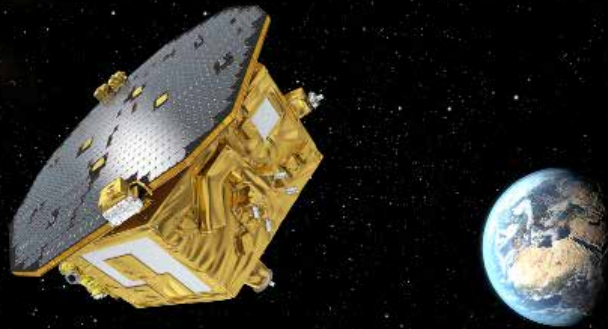
NASA Mission



Wide-Field Infrared
Survey Telescope

ST-7/LISA Pathfinder

ST-7/Disturbance Reduction System (DRS)



Artist Concept: ESA- C.Carreau

- 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

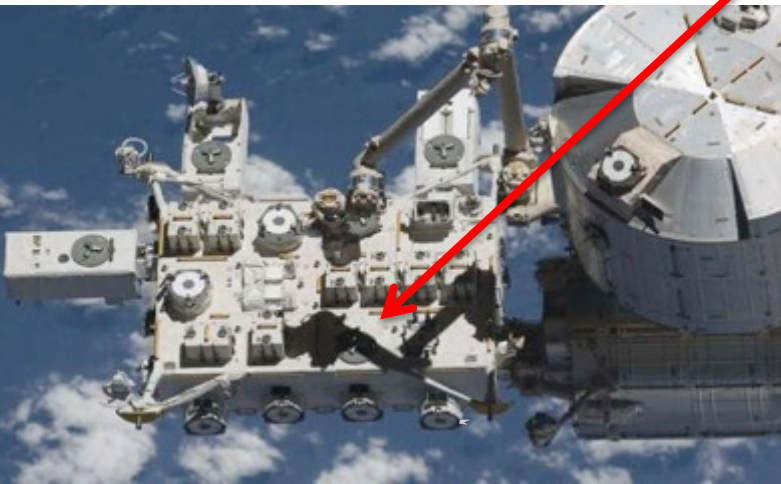


- All subsystems/sub-assemblies have completed fabrication and environmental testing **P**
- The NICER payload completed final integration and test **P**
- December 2015: Pre-environmental Review **P**
- January 2016: Start Phase D **P**
- February 2016: Start of payload environmental testing **P**
- 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

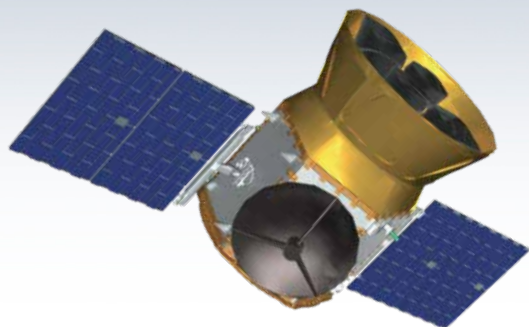


- July 2015: CREAM delivered to KSC and stored at KSC until launch **P**
- June 2017 (TBC): Launch on SpaceX-12 commercial resupply service (CRS) flight to ISS pending review of recent SpaceX pad anomaly.

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

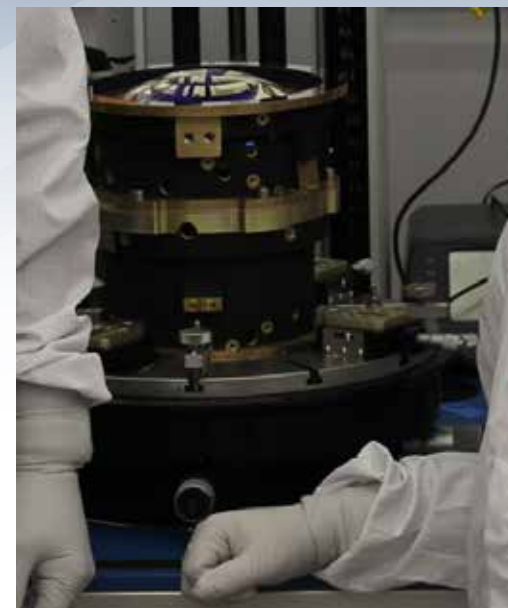
TESS

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.

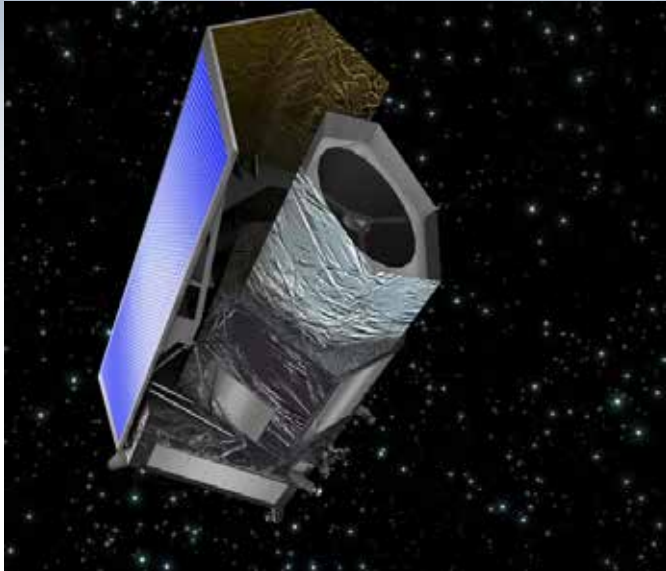
Instruments: Four wide field of view (24x24 degrees) CCD cameras with overlapping field of view, operating in the Visible-IR spectrum (0.6-1 micron).

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).

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

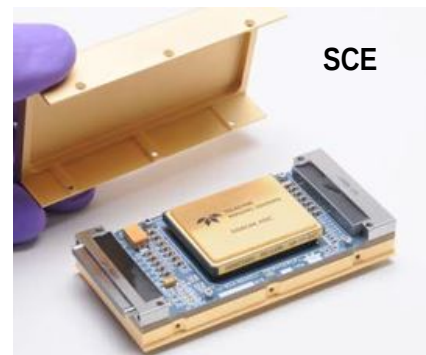
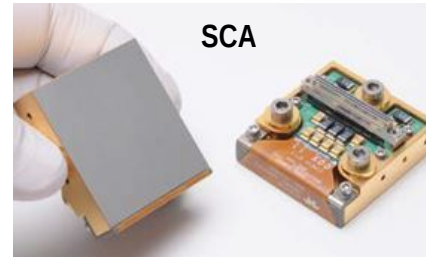


- ESA Mission with NASA Collaborating
- ESA Cosmic Vision 2015-2025 Mission, M-Class
- Category 3 - Risk Class B
- Optical and NIR Observatory with 1.2-m Telescope
- U.S. Providing Characterized NIR Detectors
- Launch Date: Dec 2020
- ~70 U.S. Science Team members selected by NASA HQ
- Euclid NASA Science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

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

CURRENT STATUS:

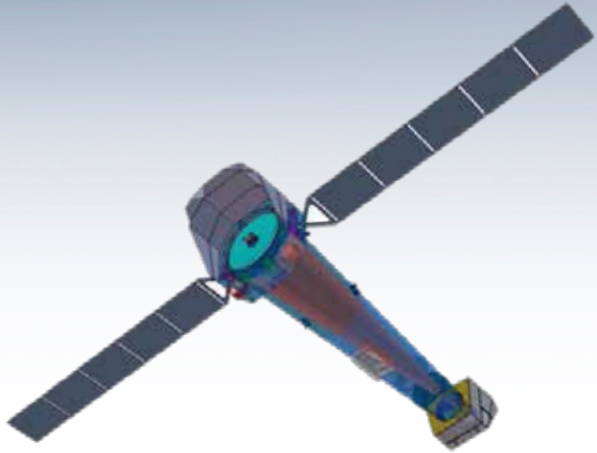
- In development phase. To date, 20 Sensor Chip Assemblies (SCA) have been delivered, 26 are expected, and 20 are required.
- Six SCAs have been tested and results are very good, some of the best ever seen in this frequency range.
- The Sensor Chip Electronics (SCE) are in process but have had trouble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



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.

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?



- 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

XMM-Newton (ESA)
12/10/1999

TESS
2017

Chandra
7/23/1999

Swift
11/20/2004

NuSTAR
6/13/2012

Hubble
4/24/1990

Fermi
6/11/2008

ISS-CREAM
2017

ISS-NICER
2017

SOFIA
Full Ops 5/2014