

Astrophysics



Astrophysics Division Update

NAC Astrophysics Subcommittee

October 3, 2016

Paul Hertz

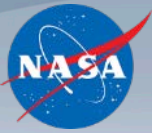
Director, Astrophysics Division

Science Mission Directorate

@PHertzNASA

This presentation will be posted at
[http://science.nasa.gov/science-committee/subcommittees/
nac-astrophysics-subcommittee/](http://science.nasa.gov/science-committee/subcommittees/nac-astrophysics-subcommittee/)

Outline



	All charts	Must do
• Topics for the Subcommittee	p. 3-5	p. 3-5
• Science Highlights	p. 6-11	p. 6-11
• Focused Topics	p. 12-29	p. 12-29
• Mission Updates	p. 30-40	
• Budget Update	p. 41-49	p. 42
• Planning for the 2020 Decadal Survey	p. 50-55	p. 54
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Topics for the Subcommittee



NASA seeking findings or recommendations

- Renewal of Keck agreement (Doris Daou)
- R&A changes including (i) Moving forward with TCAN without NSF, (ii) doubling the Astrophysics Theory Program selection rate with a two year cadence for solicitations, (iii) Revisions to Roman Technology Fellowship process (Linda Sparke)
- Rebalancing NASA Named Fellowships and R&A budgets (Kartik Sheth)

NASA discussing programmatic changes

- Status of X-ray Recovery Mission (Paul Hertz) [addressed here]
- First response to Mid Term Review (Jackie Hewitt, Paul Hertz)
- Changes to High End Computing (Tsengdar Lee)

NASA providing programmatic updates

- James Webb Space Telescope (Eric Smith, Nicole Lewis)
- SMD Education Program (Kristen Erickson)
- L3 Study Team (David Shoemaker)

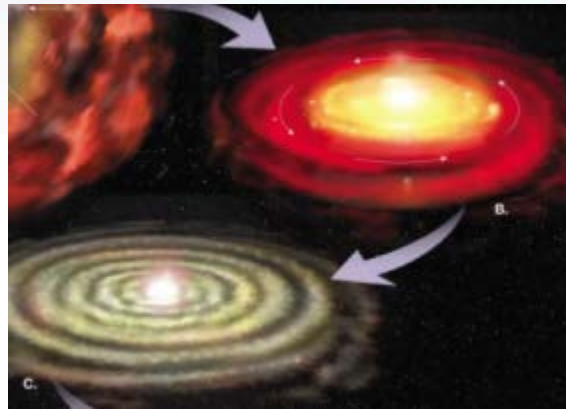
Why Astrophysics?



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



1. How did our universe begin and evolve?

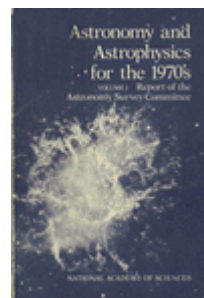


2. How did galaxies, stars, and planets come to be?

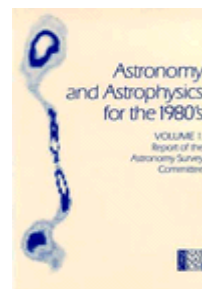


3. Are We Alone?

These national strategic drivers are enduring



1972



1982



1991

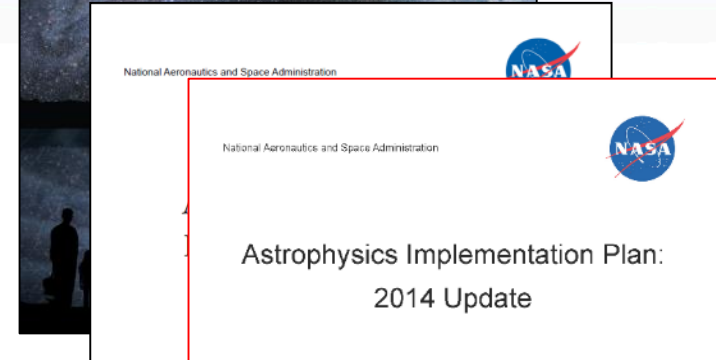
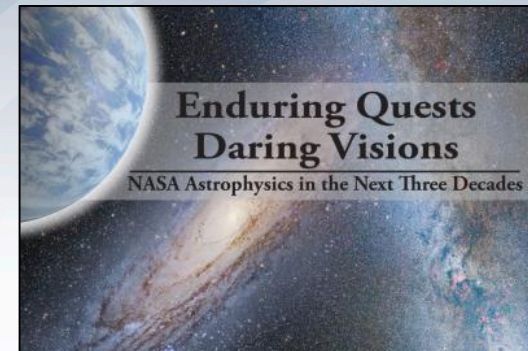


2001



2010

Astrophysics Driving Documents

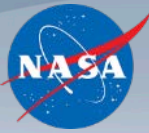


Next update will include:

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

Science Mission Directorate
NASA Headquarters

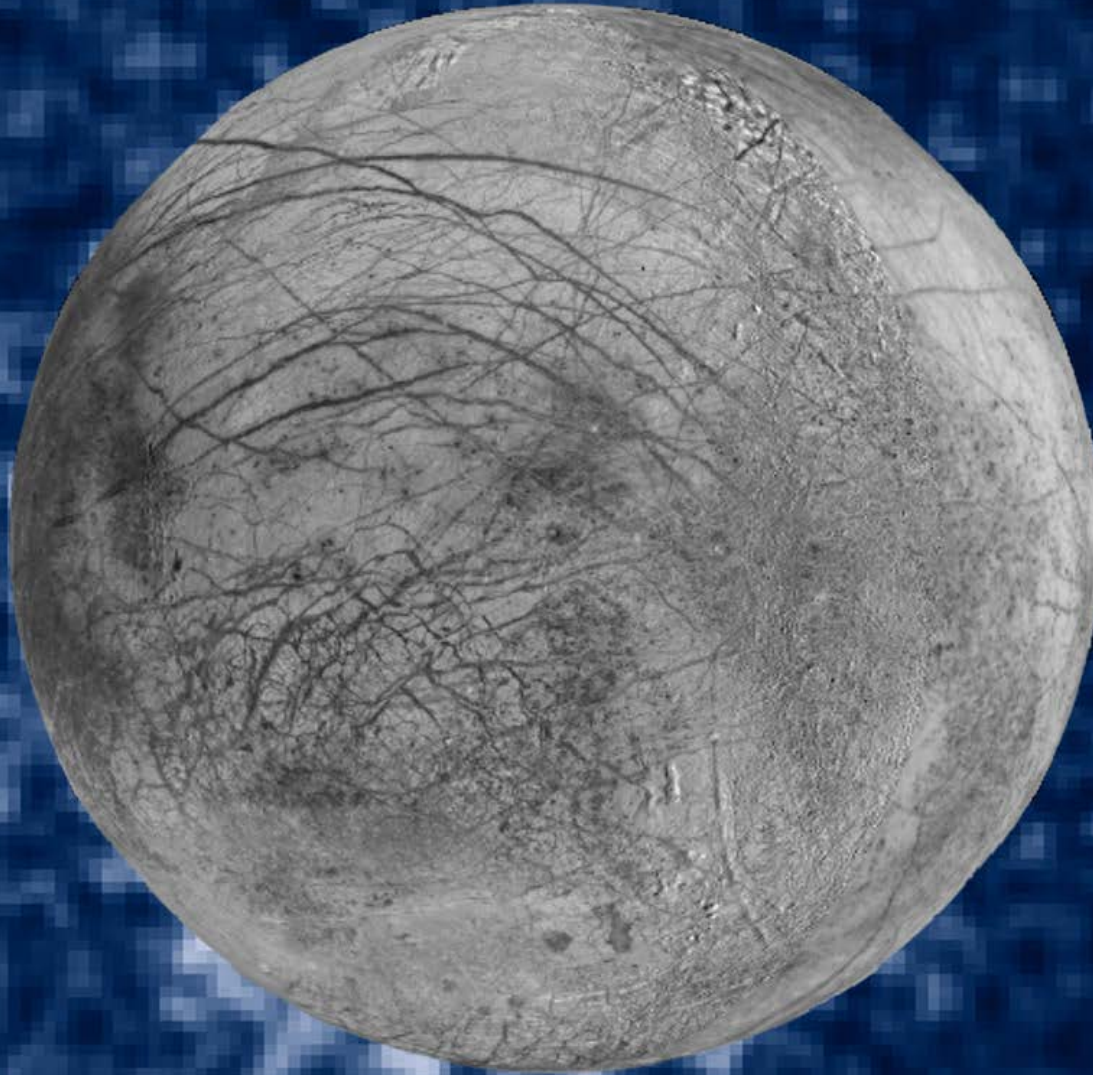
December 2014



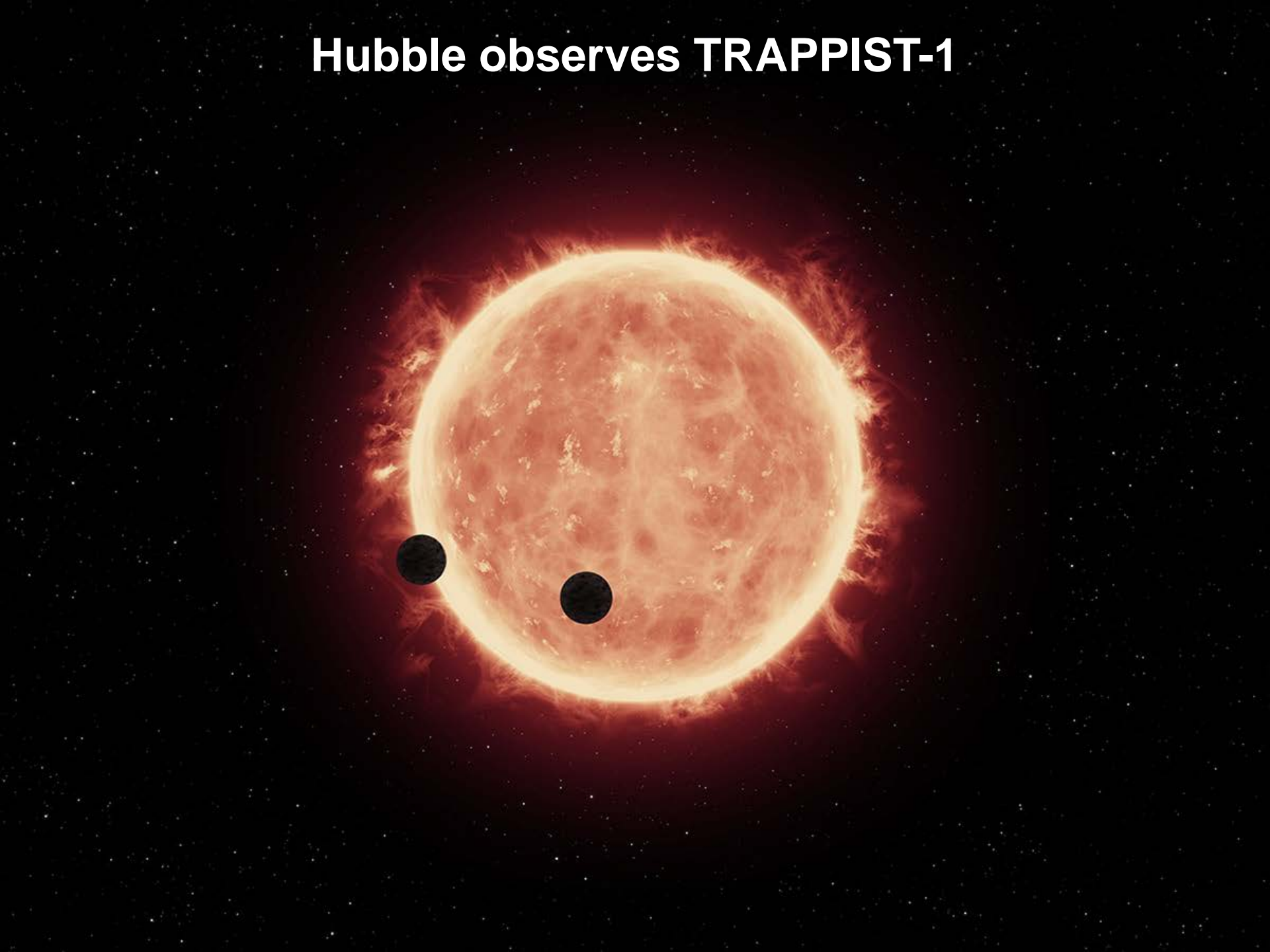
NASA Astrophysics

Science Highlights

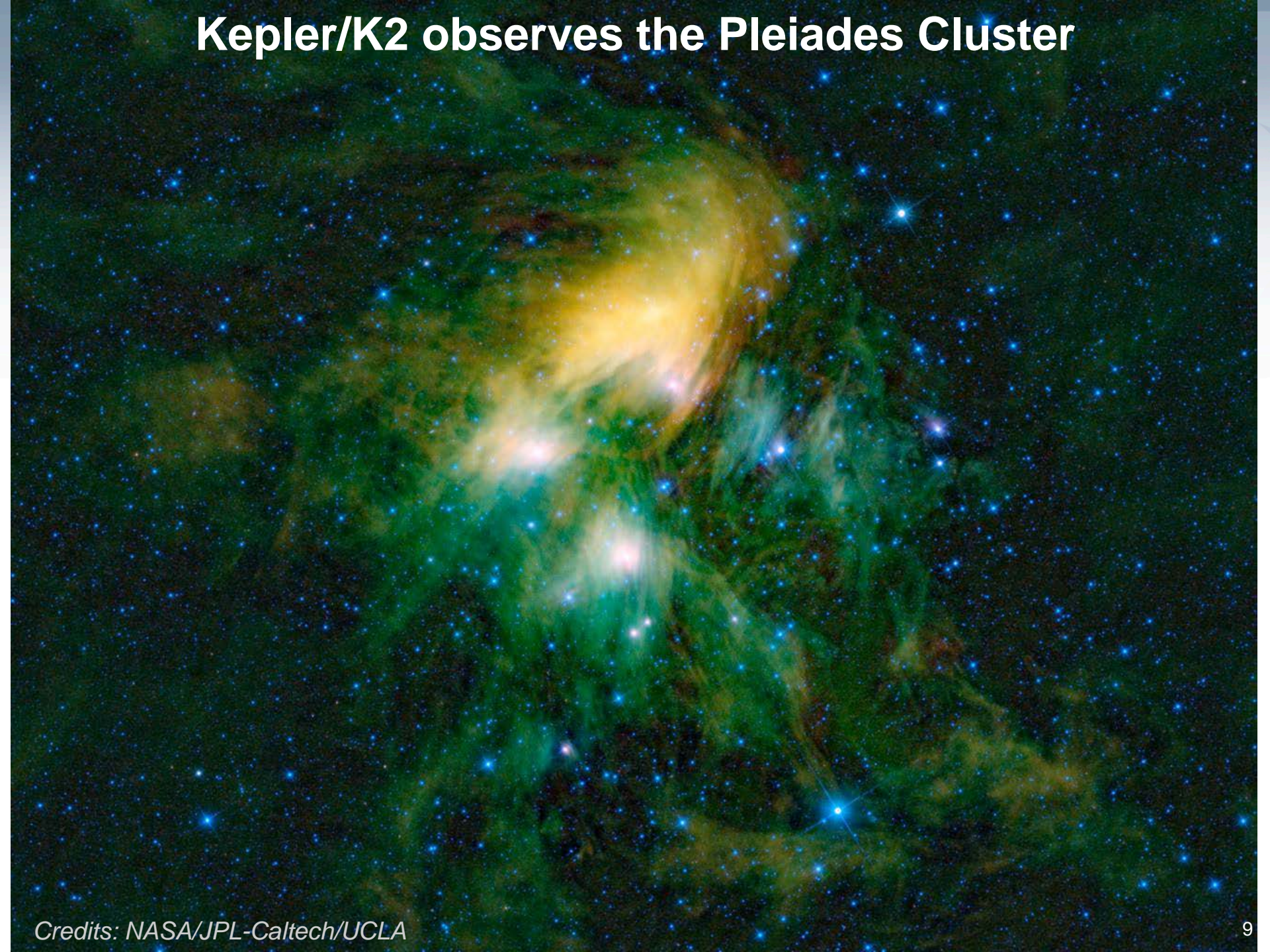
Hubble Observes Europa



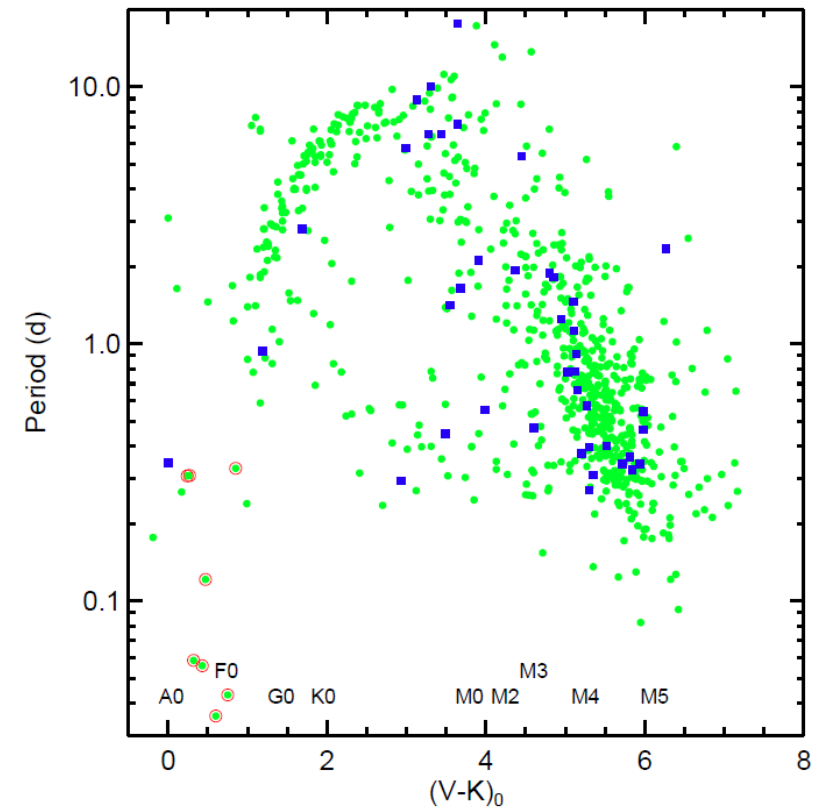
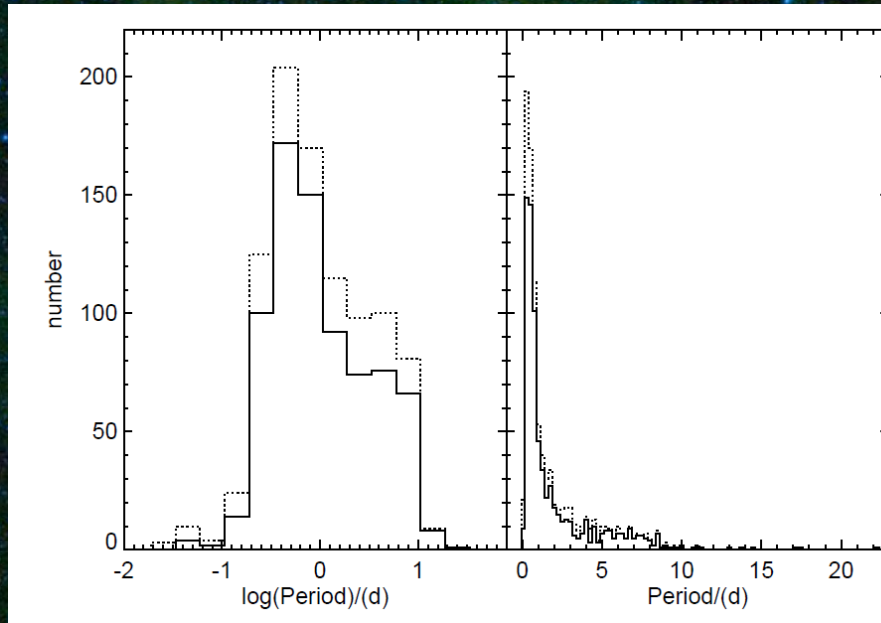
Hubble observes TRAPPIST-1



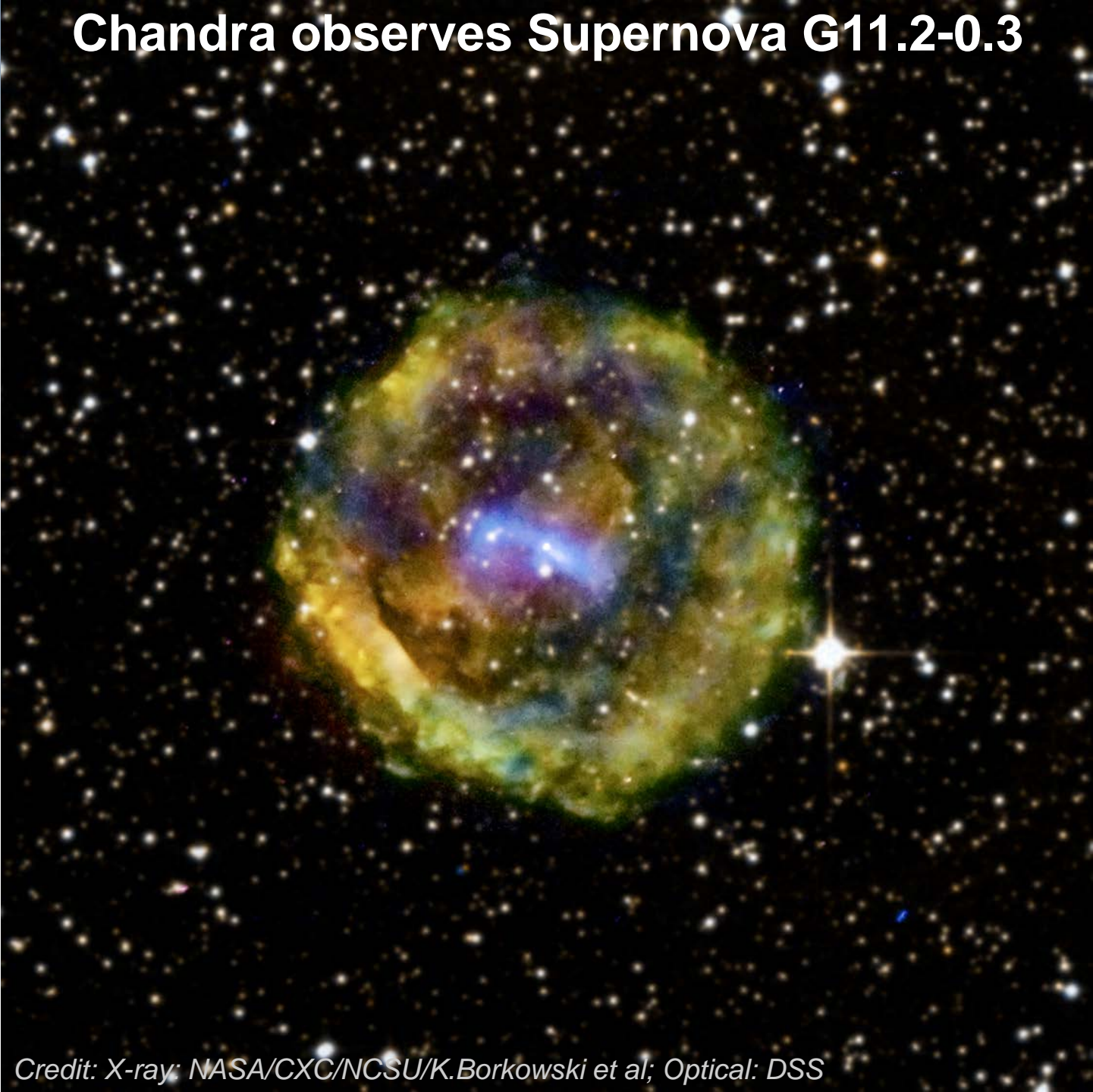
Kepler/K2 observes the Pleiades Cluster



Kepler/K2 observes the Pleiades Cluster



Chandra observes Supernova G11.2-0.3



Credit: X-ray: NASA/CXC/NCSU/K.Borkowski et al; Optical: DSS



NASA Astrophysics

Focused Topics

Astrophysics - Big Picture



- **The FY16 appropriation 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.
- **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 is 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 as input for 2020 Decadal Survey.

Evolution of the Astrophysics Subcommittee



- NASA has decided to apply for FACA charters for the four science advisory subcommittees, including the Astrophysics Subcommittee.
 - Many community-based studies (e.g., Senior Reviews, Science and Technology Definition Teams) will now have a chartered Federal Advisory Committee to report to.
- Once chartered, this Astrophysics Subcommittee (APS) will be replaced by the Astrophysics Advisory Committee (APAC).
 - All current APS members will be appointed to the APAC.
 - Meeting schedule and member expectations will be unchanged.
- The Astrophysics Advisory Committee will report to the Director of the Astrophysics Division.
 - The APAC Chair will continue to serve as a member of the NAC Science Committee.
- Once the Astrophysics Advisory Committee is chartered, then the Director of the Astrophysics Division will establish subordinate groups.
 - Four STDs for large mission studies (FIRS, HabEx, LUVOIR, XRS)
 - L3 Study Team
- **October Update: Charters have been submitted to the GSA for approval.**

Renewal of Keck Observatory Agreement



- NASA participates in the Keck Observatory through a Cooperative Agreement with CARA
 - NASA provides 1/6 of the Keck operating cost in exchange for 1/6 of the observing time for both 10m telescopes
 - NASA also funds GOs using NASA time and, by agreement with CARA, archives all Keck data (not just data from NASA-time) in the Keck Observatory Archive
 - NASA uses its observing time in three ways
 - Directed key projects for strategic support (e.g., Kepler for exoplanet confirmation; none current)
 - Competed key projects for strategic support – three current: K2 small exoplanet composition, Europa plume monitoring, Euclid/WFIRST galaxy color/redshift calibrations
 - Competed for individual GOs, but required to support NASA missions and strategic goals
- NASA seeks APS findings on renewal of the Keck CA
 - Current CA expires in early 2018; NASA must initiate new CA process this fall
 - NASA HQ is conducting a two-step process
 - (i) A mixed NASA/community panel compiled a report of pros and cons
 - (ii) The APS provides findings and advice for NASA regarding the CA renewal
 - Doris Daou (panel co-chair) will present panel report to APS

Keck ops	Keck archive	Keck GO awards	NExSci	FY16 Total (\$M)
\$3.9 M	\$1.2 M	\$0.9 M	\$0.1 M	\$6.2 M

WMKO Panel Members



Joel Bregman – U. Michigan

Doris Daou – Planetary Science Division, NASA HQ --- Chair

Kathryn Flanagan – Space Telescope Science Institute

John Gagosian – Astrophysics Division, NASA HQ

Michael Garcia – Astrophysics Division, NASA HQ

Ken Johnston – U.S. Naval Observatory (Retired) --- Co-Chair

Susan Lederer – NASA Johnson Space Center

Thomas Statler – Planetary Science Division, NASA HQ

Ex-officio

Hashima Hasan – Keck Program Scientist, NASA HQ

Mario Perez – Keck Program Executive, NASA HQ

Charge to WMKO Panel



Review Objective

The current five-year cooperative agreement ends on February 28, 2018. The objective of the review is to develop findings that reflect the pros and cons of continuing this partnership for another five years.

Charge to Panel

- Evaluate the contribution/productivity of Keck to support NASA missions and achieve NASA strategic goals.
- Estimate the promise of Keck in the next 5 years towards support of NASA missions.
- Prepare a list of findings, representing the pros and cons of continuing a partnership with Keck, to present to NASA's Astrophysics Subcommittee on Oct. 3-4, 2016.

Deliverables

- Panel Chair and co-Chair will provide list of findings to APD Division Director NLT September 29, 2016.
- Panel Chair and co-Chair will present findings to NASA's Astrophysics Subcommittee on Oct. 3-4, 2016.

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.

X-ray Recovery Mission (timeline)



- On June 14, JAXA President Okumura announced JAXA's intent to study an X-ray Recovery Mission to recover the science lost due to the untimely loss of Hitomi.
- On July 14, JAXA VP Tsuneta presented JAXA's proposal to develop an X-ray Recovery Mission centered on the SXS instrument.
- On July 26, the NASA Advisory Council recommended that "NASA proceed with the plan to rebuild the SXS instrument, provided that efforts were made to ensure that risks of another catastrophic failure will be mitigated, that doing so will not affect the other priorities of the decadal surveys, and subject to the conclusions of the mid-decadal report."
- On August 5, JAXA VP Tsuneta met with NASA AA Yoder and Astrophysics DD Hertz to discuss proven best practices on international partnerships.
- On September 22, JAXA President Okumura met with Administrator Bolden and requested NASA's participation in the proposed X-ray Recovery Mission.
- On September 22-23, JAXA VP Tsuneta et al visited GSFC for a Lessons Learned Summit and to discuss the proposed X-ray Recovery Mission with Astrophysics DD Hertz, GSFC mission experts, and the XRRM proto-study team.
- In late October, NASA AA Yoder and Astrophysics DD Hertz will visit JAXA to discuss the proposed X-ray Recovery Mission.

2016 Astrophysics Explorers MIDEX AO & MO SALMON-2 PEA



- MIDEX (Standard) AO, MO SALMON-2 PEA, & ROSES-2016 USPI.
- AO Cost Cap is \$250M for MIDEX, not including ELV launch provided by NASA.
- Three categories of MO: Partner Mission of Opportunity, Small Complete Mission (SCM) including ISS & suborbital-class (ULDB, sRLV, CubeSats), & New Missions using Existing Spacecraft.
- Cost Cap is \$70M for MOs, except suborbital-class MOs are capped at \$35M.
- Access to space provided by NASA for ISS or suborbital-class SCM MOs at no charge; SCM access to space may be provided by NASA for a charge (\$3M - \$15M, see Catalog in Program Library).
- AOs released September 15, 2016; PPC on Oct 6; NOIs required by Oct 13.
- Proposals due December 15, 2016.
- Step 1: select 2 or 3 MIDEX missions and 2 or 3 MOs for 9-month Phase A Concept Studies, funded at \$2M for MIDEX and \$500K for MOs.
- Step 2: review Phase A Concept Study Reports; in early 2019 downselect 1 MIDEX and 1 or 2 MOs for Phase B and subsequent phases.
- MIDEX launch readiness date no later than December 2023.
- More information at <https://explorers.larc.nasa.gov/APMIDEX2016>

Recent & Upcoming Suborbital Missions



Stratospheric Balloons

- Fall FY16 Conventional Balloon Campaign @ Ft. Sumner NM (Aug/Sep 2016)
 - **HASP** – T.G. Guzik, Louisiana State U – student payloads ✓ (successfully flown Sep 1-2)
 - **X-Calibur** – H. Krawczynski, Washington U – X-ray polarimetry of high energy compact objects ✓ (successfully flown Sep 17-18)
 - **REMOTE** – G. Toon, JPL – Earth Sciences – Study photochemical stratospheric ozone processes ✓ (successfully flown Sep 27-28)
 - **Engineering test flight** – D. Fairbrother, NASA WFF ✓ (successfully flown Sep 28)
 - **BETTII** – S. Rinehart, NASA GSFC – Understand how stars form within dense clusters (deferred until next year)
 - **PIPER** – A. Kogut, NASA GSFC – Measure polarization of CMB & look for GW imprint in early universe (awaiting launch, depends on weather)
- Winter FY17 Conventional Balloon Campaign @ McMurdo Station (Dec 2016/Jan 2017)
 - **ANITA-4** – P. Gorham, U Hawaii – Search for ultra-high energy neutrinos (4th flight)
 - **BACCUS** – E.S. Seo, U MD – Study boron and carbon cosmic rays in upper stratosphere
 - **STO-2** – C. Walker, U Arizona – Determine life cycle of galactic interstellar gas & study star formation parameters.

Sounding Rockets

- FY16-FY17 Sounding Rocket Launches @ White Sands NM
 - **CIBER-2** – J. Bock, Caltech (~May 2017) – Cosmic Infrared Background from galaxies
 - **CHESS** – K. France, U Colorado (~June 2017) – High resolution UV spectra tech development
 - **Micro-X** – E. Figueroa, MIT (~July 2017) – High resolution microcalorimeter X-ray imaging
 - **ACCESS1** – M. Kaiser, JHU (~Aug 2017) – 1% photometry needed for dark energy measurements

SOFIA

Stratospheric Observatory for Infrared Astronomy



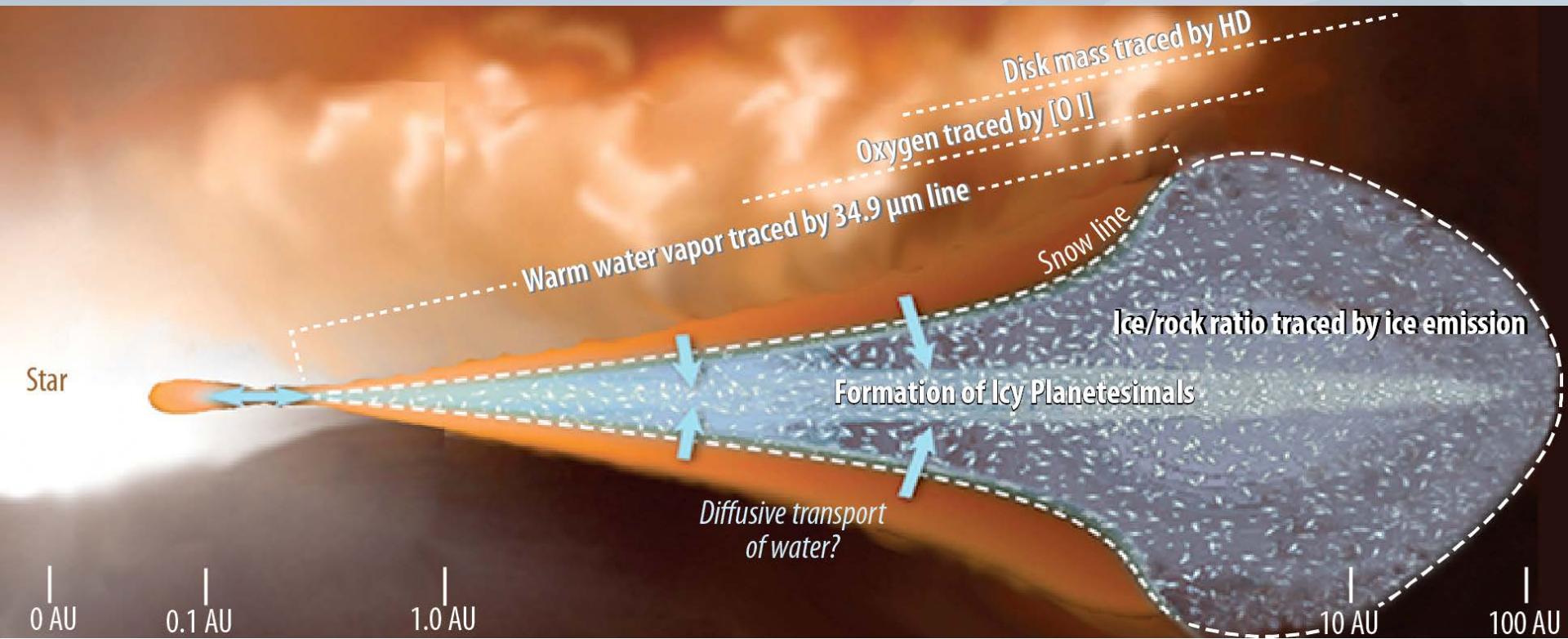
- **World's Largest Airborne Observatory**
- In prime mission operation since May 2014
- 2.5-meter telescope
- 80/20 Partnership between NASA and the German Aerospace Center (DLR)
- Science Center and Program Management at NASA-Ames Research Center
- Science Flight Operations at NASA-Armstrong Flight 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 early 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 to address vibration issues; Part II commissioning series is 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).

SOFIA 3rd Generation Instrument - HIRMES



High Resolution Mid-Infrared Spectrometer (HIRMES)

- PI S. Harvey Moseley (GSFC) and his team will construct HIRMES over the next two and one-half years with flights on board SOFIA slated for spring 2019.
- HIRMES is optimized to detect neutral atomic oxygen, water, as well as normal and deuterated hydrogen molecules at infrared wavelengths between 28 and 112 μm .

L3 Gravitational Wave (GW) Observatory



- What went before
 - In 2013, ESA selected the GW theme for its L3 mission in 2034.
 - ESA's LISA Pathfinder launched in December 2015. LISA Test Package exceeds requirements; results published in June 2016. NASA's ST7/Disturbance Reduction System experiment is ongoing.
 - Gravitational Observatory Assessment Team (GOAT) report in March 2016 confirms laser interferometry as appropriate architecture for L3 mission.
 - NASA forms L3 Study Team (L3ST) in January 2016 to (i) analyze options for US participation in L3 mission and (ii) to prepare a report for the 2020 Decadal Survey.
- Recent updates
 - In June 2016, the L3ST released an interim report on options for NASA participation in ESA's L3 mission.
 - In August 2016, the Midterm Assessment Committee released its report. Among its recommendations is one to “restore support this decade for gravitational wave research that enables the U.S. community to be a strong technical and scientific partner in the European Space Agency (ESA)-led L3 mission.”
 - In September 2016, at the 11th International LISA Symposium, ESA announced that the call for L3 mission concepts was being advanced to ~October 2016.
 - In September 2016, at the same symposium, NASA announced that it would be a strong partner in the L3 mission.
- More details provided in the presentation, “First Response to Midterm Assessment”

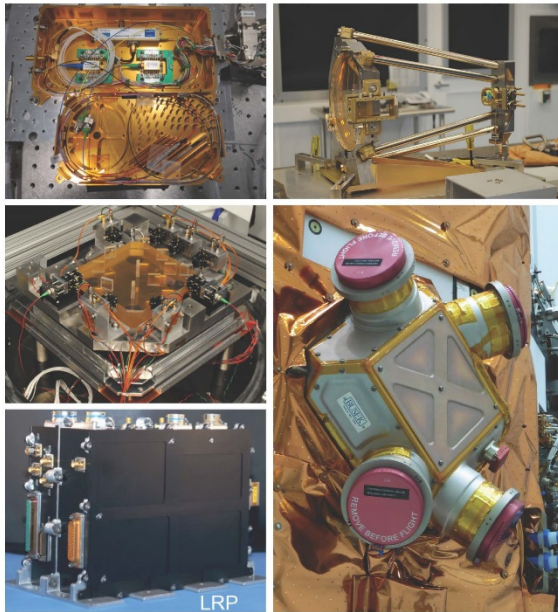
L3ST Interim Report



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/>

L3ST Interim Report

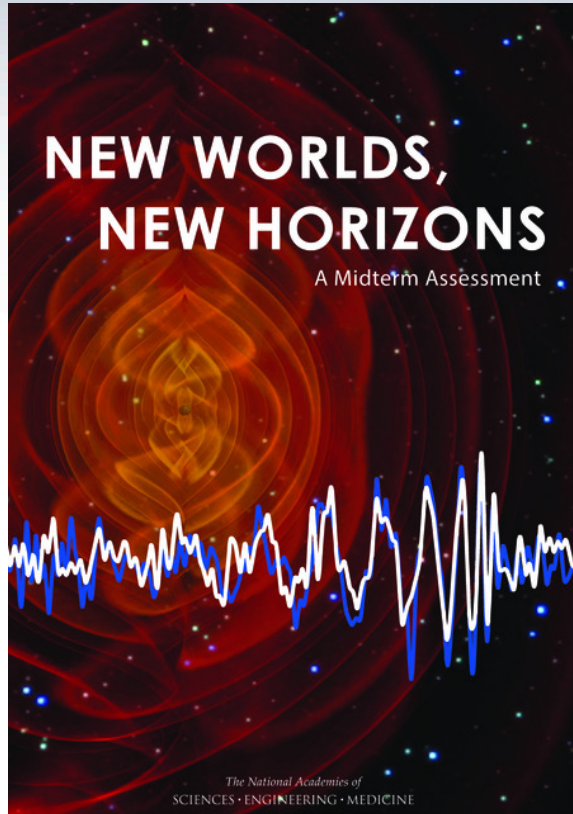


Major Instrument System	Impact and Insight	US Capabilities & Heritage	Implementation Simplicity	Rough Delivery Cost Estimate (FY16 M\$)
Laser	Moderate coupling to science performance	Novel seed laser; transparent design	Simple instrument interfaces. Requirements moderately stable.	~60
Micropropulsion	Limited coupling to science performance	Flight demo on LPF No equivalent European system	Minimal interfaces with instrument. Additional interfaces with flight system	~90
Optical Bench	Core of physical measurement. Insight into other systems	Limited investment to date.	Many optical, mechanical, and thermal interfaces. Design less mature. Close coupling with telescope	~100
Phase Measurement	Core of instrument control & operation	Extensive LISA development Flight demo on GRACE-FO	Many electrical and control system interfaces	~70
Telescope	Significant impact on science performance	Moderate grant-funded development. Aligns well with core competencies	Several optical, mechanical, and thermal interfaces. Close coupling with optical bench	~90

2016 Midterm Assessment Report



Released August 15, 2016



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

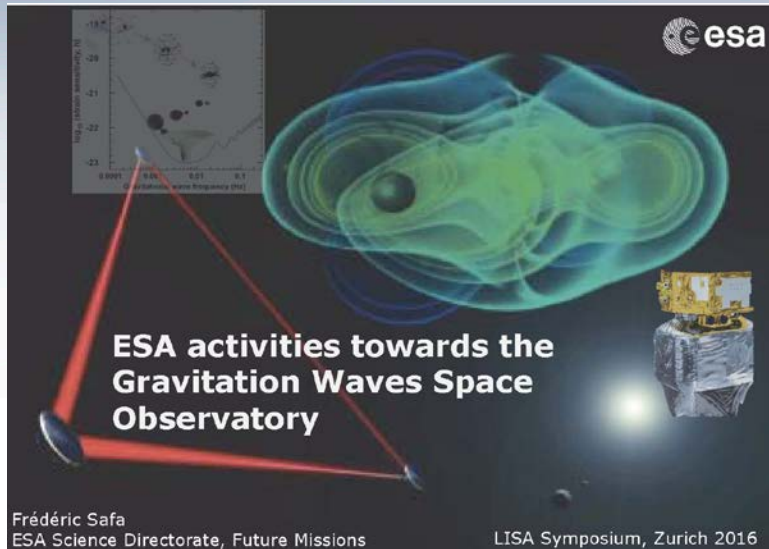
“The science of LISA is even more compelling than in 2010 with the success of Advanced LIGO in making a direct detection of gravitational waves.”

“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.”

ESA's Plans for L3 Mission



http://www.physik.uzh.ch/events/lisa2016/uploads/230/Zurich%202016%20F_Sifa.pdf

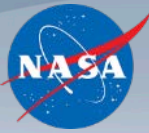
- Technology development activities resumed in 2016
- Mission definition studies and Phase A industrial study initiated in 2017
- Industrial Phase A completed, including payload definition, in 2020
- Technology maturation, and Science Programme Committee decision to proceed to Phase B1 industrial study, in 2022
- Phase B1 industrial study completed, and mission adoption by the Science Programme Committee, in 2024
- Launch in late 2033/early 2034

What is NASA doing for GW?



- ✓ **Searching for EM counterparts** to LIGO sources
- ✓ **Supporting DRS operations on LISA Pathfinder**
- ✓ **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)
- ✓ **Funding data analysis, simulations, and modeling** relevant for a future space-based GW observatory thru competitive programs (Astrophysics Research and Analysis Program, Astrophysics Theory Program, Theoretical and Computational Astrophysics Networks Program)
- ✓ **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
- ✓ **Establishing a U.S. L3 Study Office** at GSFC to coordinate technology development and mission contribution planning
- ✓ **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>



NASA Astrophysics

Mission Updates

(no “must do” slides)

Astrophysics Missions in Development

ISS-NICER

2/2017

NASA Mission

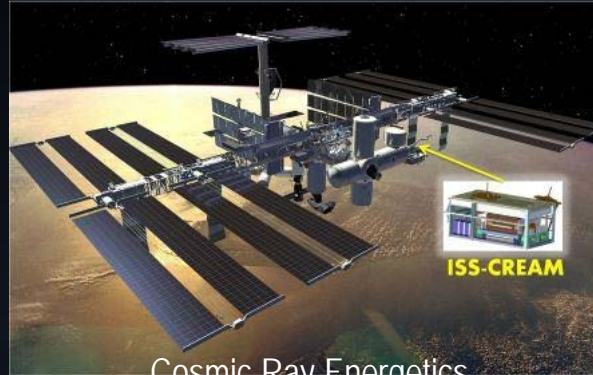


Neutron Star Interior
Composition Explorer

ISS-CREAM

6/2017

NASA Mission

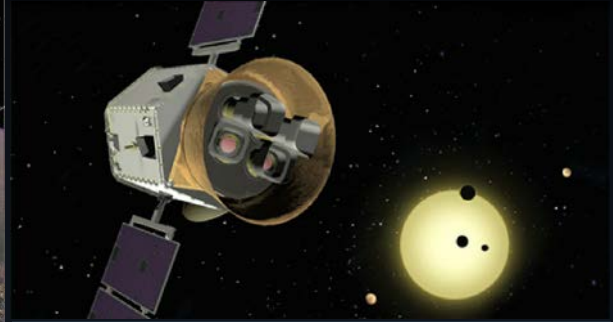


Cosmic Ray Energetics
And Mass

TESS

12/2017

NASA Mission

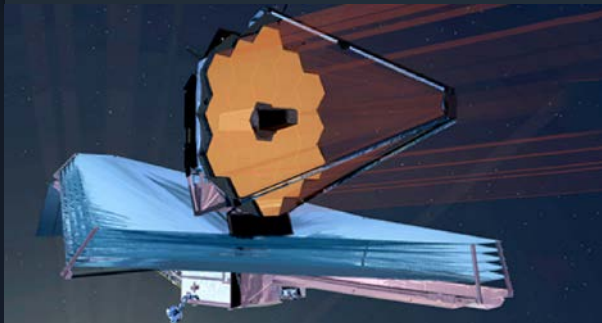


Transiting Exoplanet
Survey Satellite

Webb

10/2018

NASA Mission

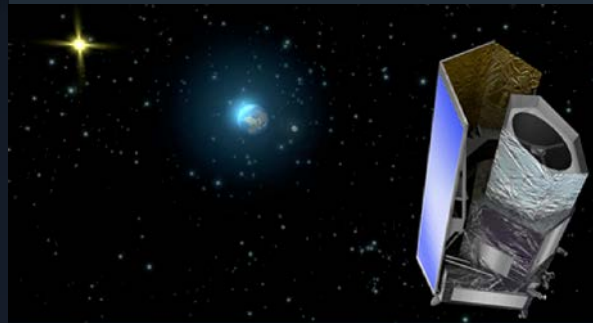


James Webb
Space Telescope

Euclid

2020

ESA-led Mission



NASA is supplying the NISP
Sensor Chip System (SCS)

WFIRST

Mid 2020s

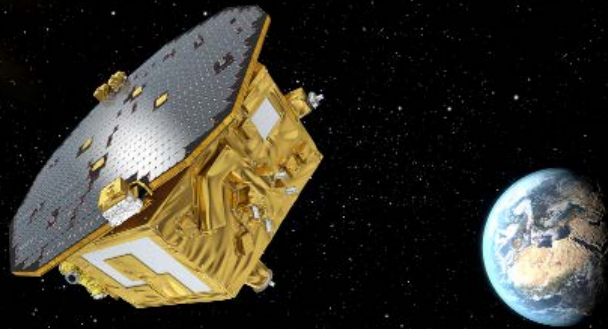
NASA Mission



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

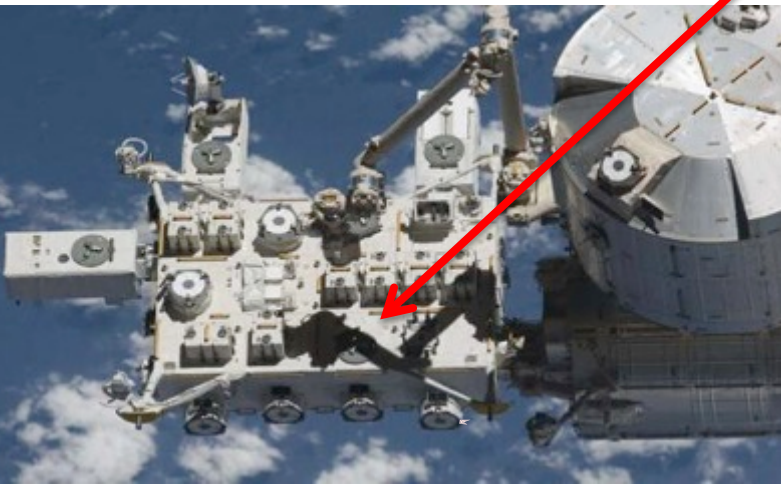


- All subsystems/sub-assemblies have completed fabrication and environmental testing ✓
- The NICER payload completed final integration and test ✓
- December 2015: Pre-environmental Review ✓
- January 2016: Start Phase D ✓
- February 2016: Start of payload environmental testing ✓
- April 2016: Completion of payload environmental testing ✓
- June 2016: Payload delivered to KSC and completed ISS interface testing. Now stored at KSC until launch ✓
- February 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

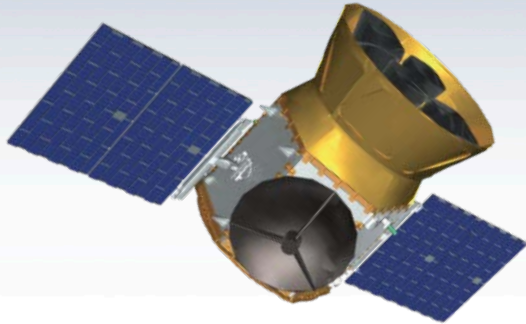


- July 2015: CREAM delivered to KSC and stored at KSC until launch ✓
- June 2017 (TBC): Launch on SpaceX-12 commercial resupply service (CRS) flight to ISS pending review of recent SpaceX pad anomaly.

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

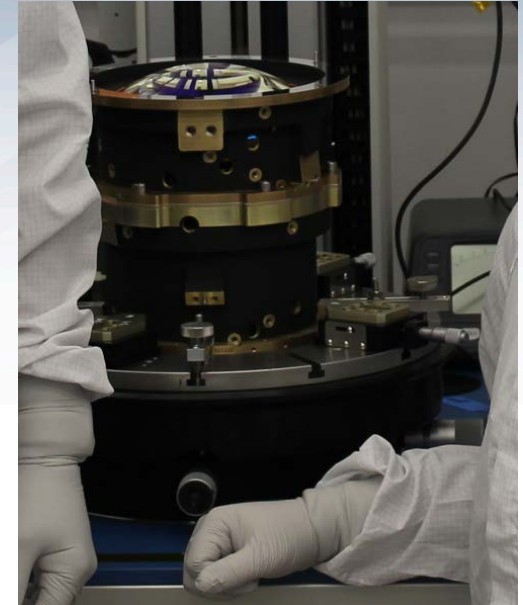
TESS

Transiting Exoplanet Survey Satellite



CURRENT STATUS:

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



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).

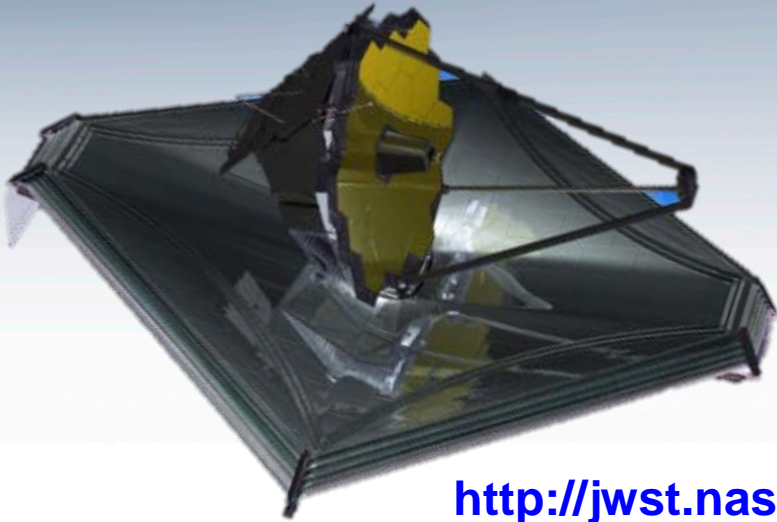
Operations: NLT June 2018 launch with a 3-year prime mission including 2 years of spacecraft operations and an additional 1 year ground-based observations and analysis. High-Earth elliptical orbit (17 x 58.7 Earth radii).

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)

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

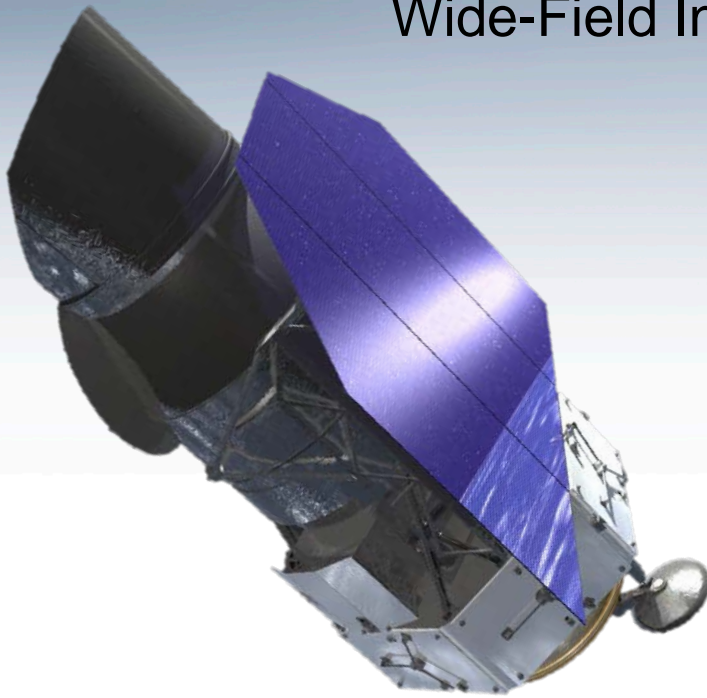
Partners: ESA, CSA



JWST remains on track for an October 2018 launch

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):

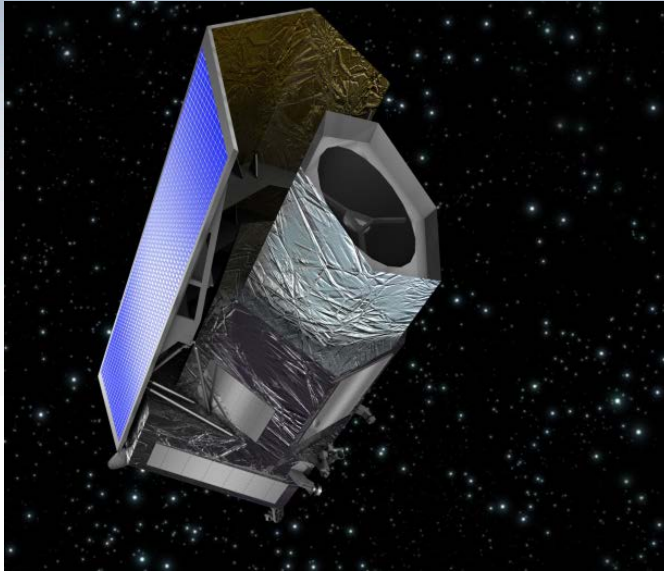
Wide Field Instrument (camera plus IFU),
Coronagraph Instrument (imaging/IFS)

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.

Euclid

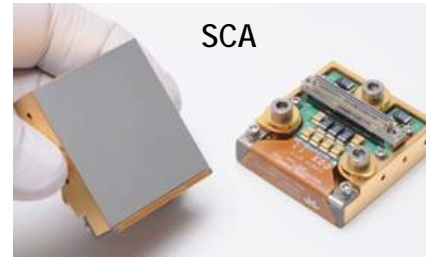


- ESA Mission with NASA Collaborating
- ESA Cosmic Vision 2015-2025 Mission, M-Class
- Category 3 - Risk Class B
- Optical and NIR Observatory with 1.2-m Telescope
- U.S. Providing Characterized NIR Detectors
- Launch Date: Dec 2020
- ~70 U.S. Science Team members selected by NASA HQ
- Euclid NASA Science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

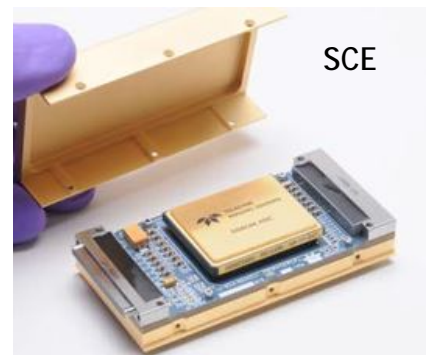
<http://sci.esa.int/euclid/>

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.



SCA

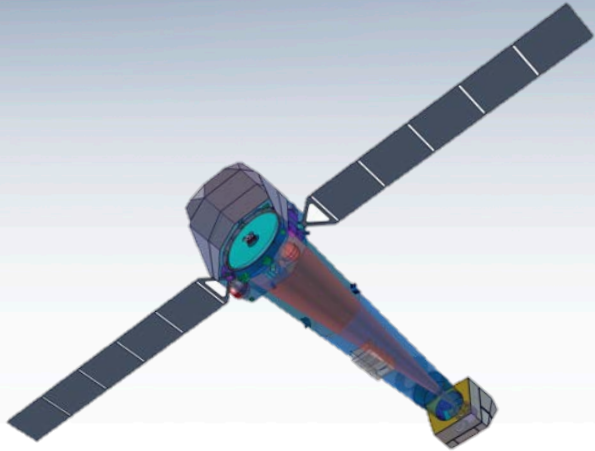


SCE

- 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

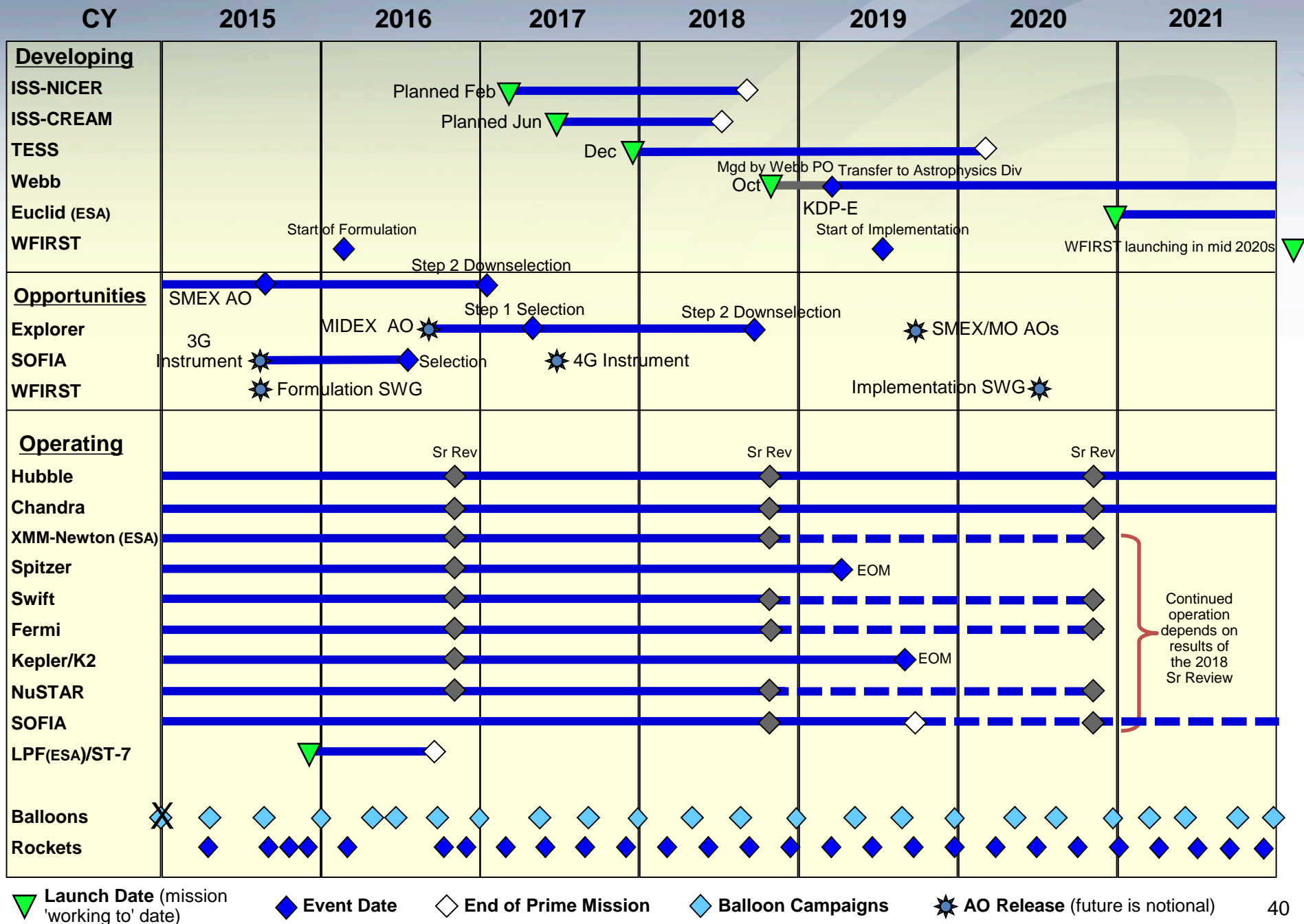
Breakthrough Technologies:

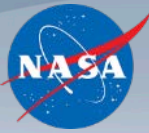
- High Throughput, Wide FOV, High spectral resolution X-ray Astronomy
- 10x Chandra area, 100x improved non-dispersive spectral resolution, 5x FOV.

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?

Astrophysics Science Mission Events

Last updated: August 23, 2016





NASA Astrophysics

Budget Update

("must do" slide 42)

FY17 Budget Update



- FY17 budget request sent to Congress in February 2016
 - Both House and Senate space subcommittees of appropriation committees have marked up the FY17 NASA budget request
 - Neither chamber of Congress has passed a NASA appropriations bill
-
- As of September 29, Congress has passed and the President has 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

FY16 Appropriation



Outyears are notional planning from FY16 President's budget request

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

* Excludes "SMD STEM Activities" in all years.

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

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

* Excludes "SMD STEM Activities."

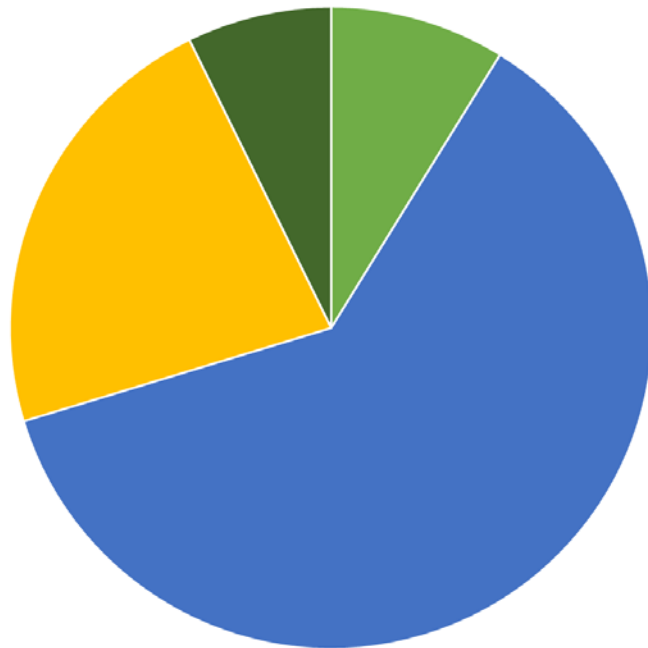
FY16 Appropriation



- Addressing the \$36M reduction across the rest of Astrophysics

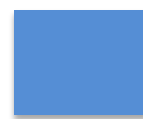
Project	\$ FY16	Impact
Explorers Futures	\$11M	Two month delay in development of future Explorers missions
TESS	\$11M	Use of reserves not needed by the TESS project in FY16, with payback to the TESS project in FY17 and FY18 (rephasing of reserves)
ASTRO-H	\$7M	Use of reserves held by the ASTRO-H project in case of problems in I&T or a launch delay; not needed by ASTRO-H project because ASTRO-H launched on time
R&A	\$3M	One year reduction; fewer selections spread over FY16-FY17
Spitzer	\$3M	Additional support from SMD makes up for reduction

NASA Astrophysics



■ Research & Technology ■ Missions in Development
■ Missions in Operation ■ Infrastructure & Other

FY 2016
Total US\$ 1,333 M



Missions in Development

includes James Webb, ISS-NICER, ISS-CREAM, TESS, Euclid, WFIRST



Missions in Operation includes Hubble, Chandra, XMM-Newton, Spitzer, Swift, Fermi, Kepler, NuSTAR, SOFIA, LISA Pathfinder



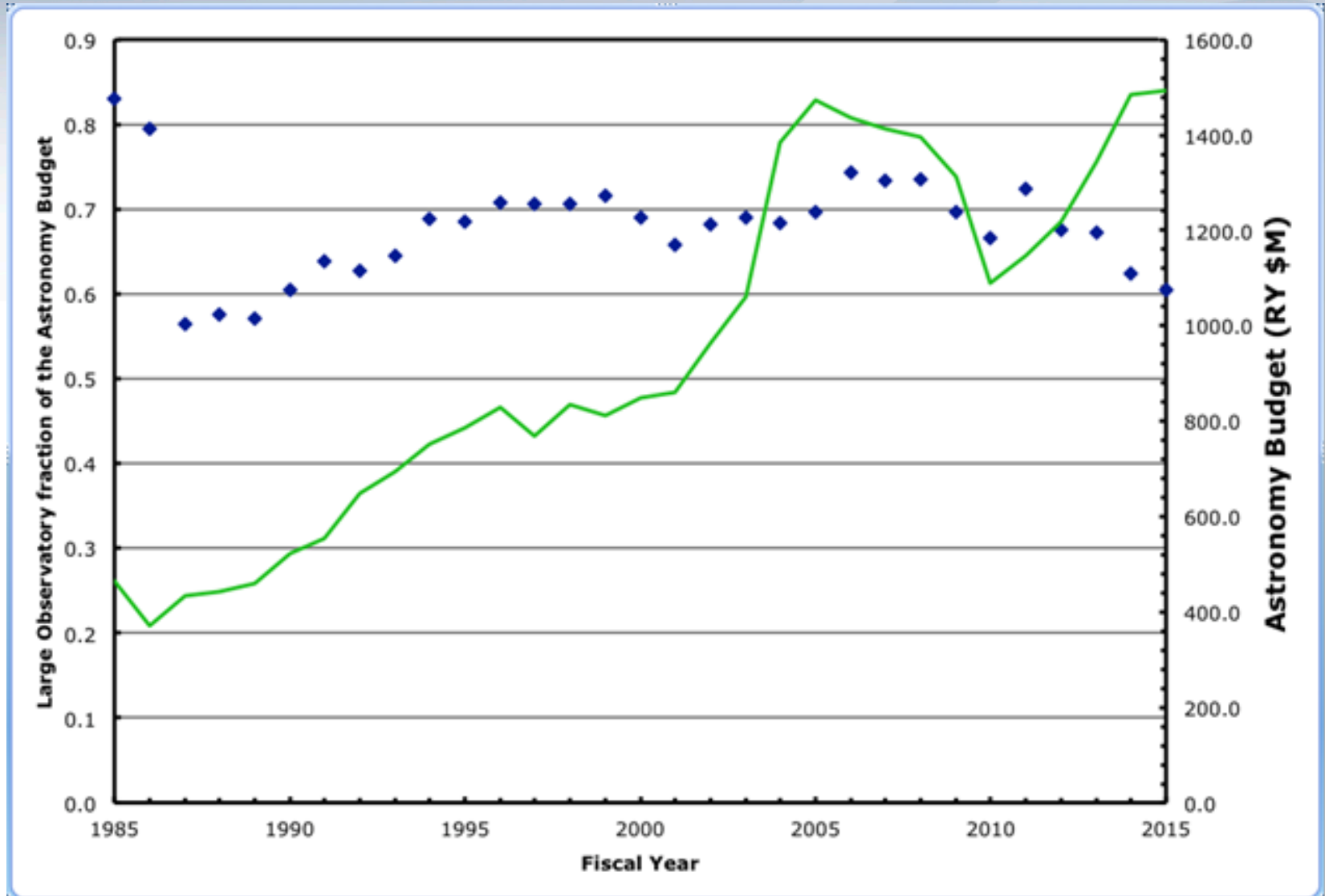
Infrastructure & Other includes data archives, suborbital balloons, ground-based telescopes, management



Research & Technology

includes basic technology, strategic technology, theory, data analysis, fellowships

Fraction of budget on Large Observatories



FY17 Budget Request

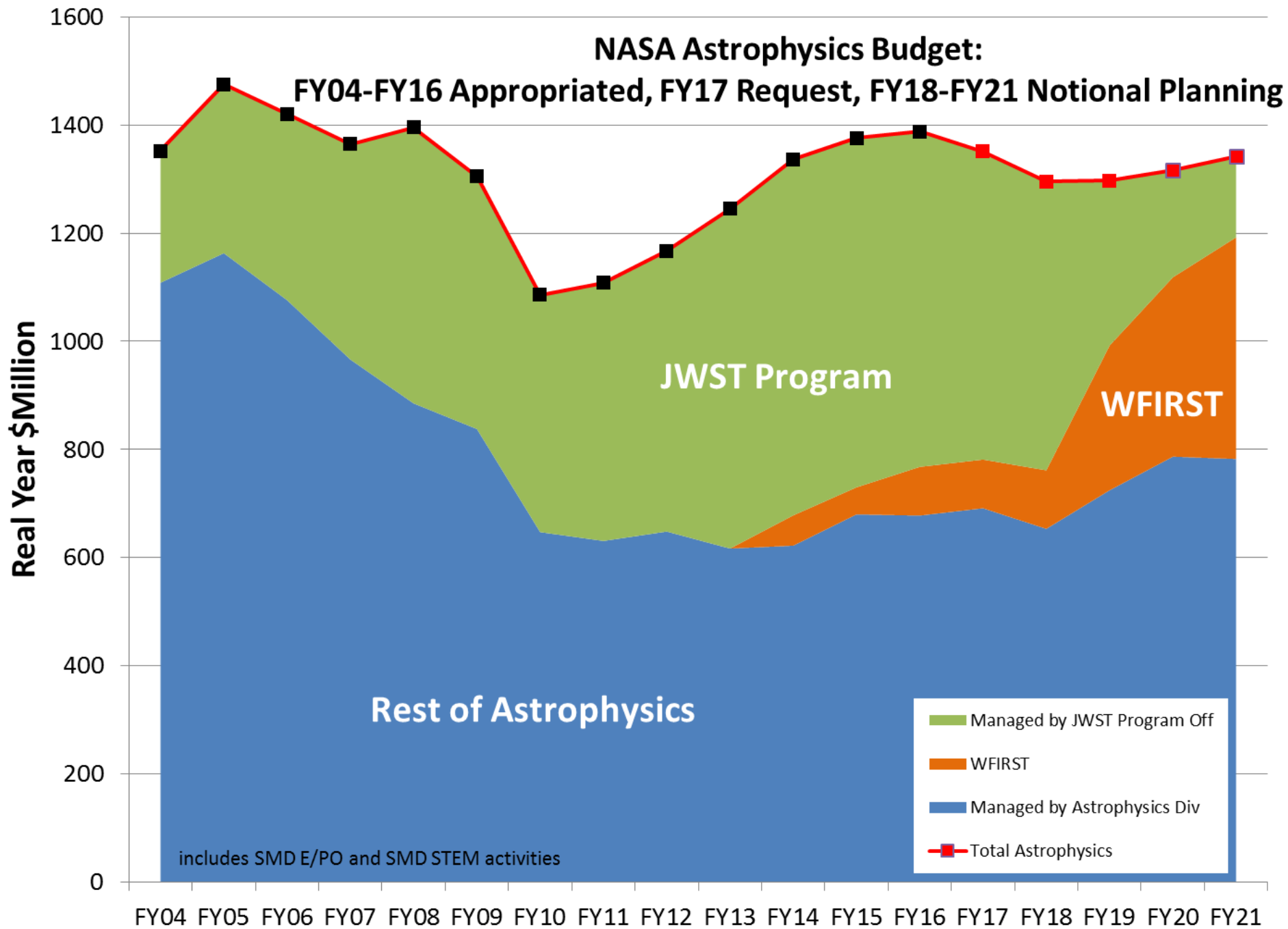


Outyears are notional planning from FY17 budget request

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

* Excludes “SMD STEM Activities” in all years.

- This budget request is an excellent budget request for NASA Astrophysics (\$1,326M excluding STEM).
- It compares well with the FY16 Appropriation (\$1,351M excluding STEM) and significantly exceeds the FY17 notional runout in the President’s FY16 request for NASA Astrophysics including JWST (\$1,276M excluding STEM).
- This budget request and the notional runout allows WFIRST to be executed without additional funding.
- This budget request and the notional runout support other Decadal Survey priorities.
 - Continued Explorer AOs at the cadence of 4 per decade.
 - Partnerships on ESA’s Athena X-ray observatory and L3 gravitational wave observatory.
 - Precursor exoplanet science and technology including Large Binocular Telescope Interferometer, Extreme Precision Doppler Spectrometer, and WFIRST Coronagraph.
 - Retains prior growth in R&A and suborbital programs.
- Senior Review funding is inadequate to continue all currently operating missions in FY17-FY18 without reductions in mission and GO funding.

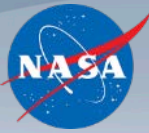


FY17 Appropriations



- Both the House and the Senate appropriation subcommittees for NASA 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

Planning for the 2020 Decadal Survey

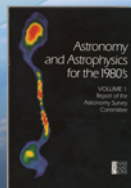
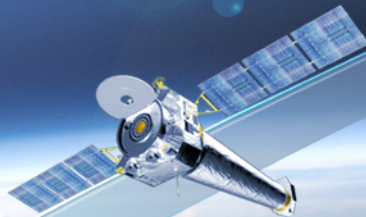
“must do” slide 54

ASTROPHYSICS

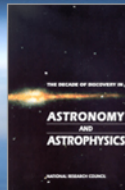
Decadal Survey Missions



1972
Decadal Survey
Hubble



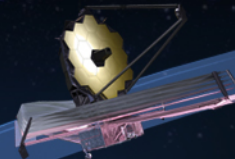
1982
Decadal Survey
Chandra



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 is hosting 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 will provide 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/>

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

XMM-Newton (ESA)
12/10/1999

TESS
2017

Chandra
7/23/1999

Swift
11/20/2004

NuSTAR
6/13/2012

Hubble
4/24/1990

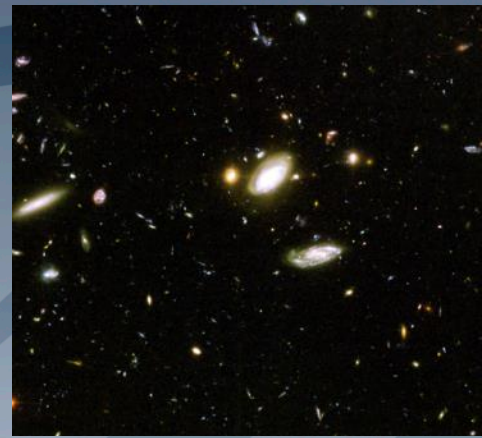
Fermi
6/11/2008

ISS-CREAM
2017

ISS-NICER
2017

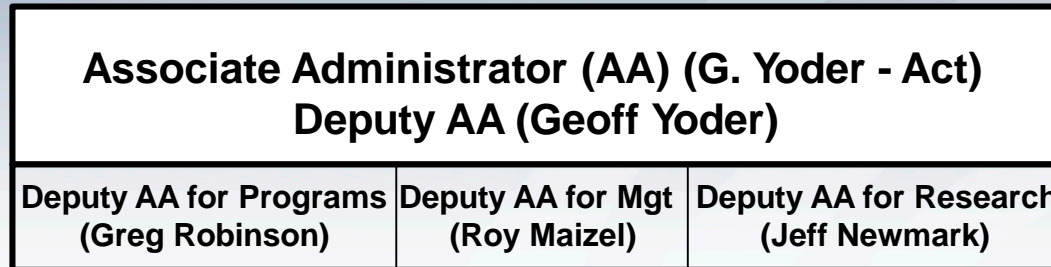
SOFIA
Full Ops 5/2014

Astrophysics



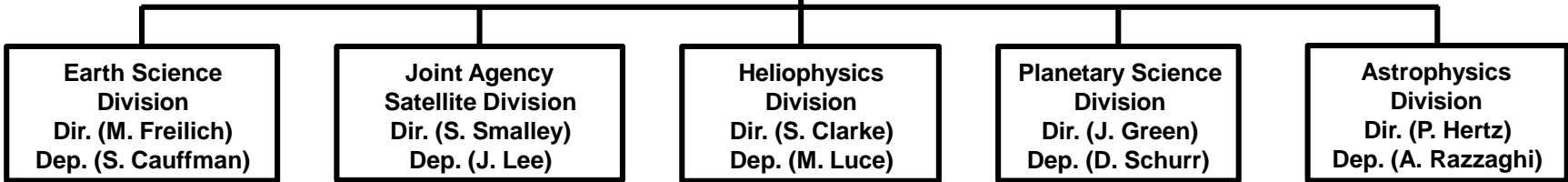
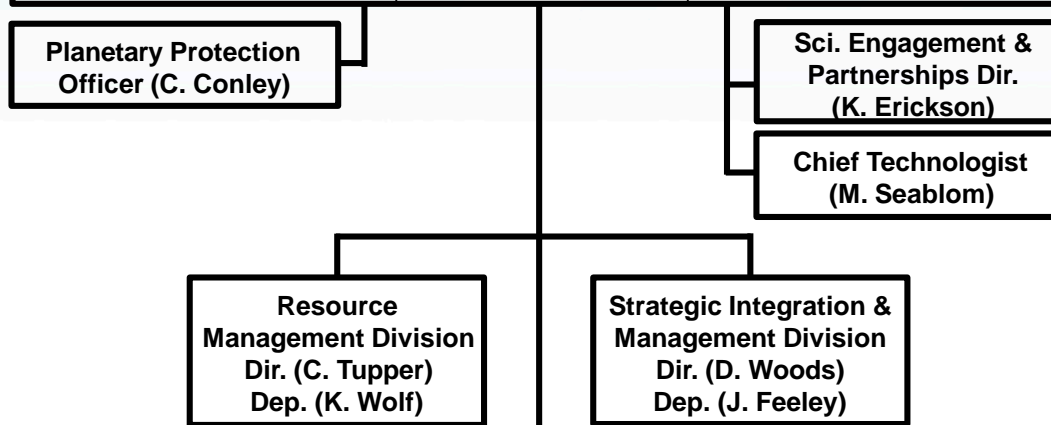
BACKUP

SMD Organization



JWST Program Office
 Dir. (E. Smith)

Embeds/POCs
 Chief Engineer
 (J. Pellicciotti)
 Safety & Msn Assurance
 (P. Panetta)
 General Counsel
 (M. Harrington)
 Legislative & Intergvtl Affairs
 (G. Adler)
 Public Affairs
 (D. Brown)
 Intl & Interagency Relations
 (D. McSweeney)



— Flight
 (E. Ianson)
 — Applied Sciences
 (L. Friedl)
 — Research
 (J. Kaye)
 — Technology (GSFC)
 (G. Komar)

— Solar System Expl
 (D. Schurr - Act)
 — Mars Exploration
 (J. Watzin)
 — Research
 (J. Rall)

Astrophysics Division, NASA Science Mission Directorate

Resource Management

Omana Cawthon+
Clemencia Gallegos-Kelly+

Director

Paul Hertz

Deputy Director

Andrea Razzaghi

Lead Secretary: Kelly Johnson

Secretary: Leslie Allen

Program Support Specialist: Jackie Mackall

Cross Cutting

Technology Lead: Billy Lightsey*

Education POC: Hashima Hasan (Lead Comm Team)

Public Affairs Lead: Kartik Sheth

Information Manager: Lisa Wainio*

Astrophysics Research

Program Manager: Linda Sparke

Program Support: Pam Terrell*

Astrophysics Data Analysis: Doug Hudgins

Astrophysics Theory: Keith MacGregor*, Theresa Brandt*

Exoplanet Research: Martin Still*

APRA lead: Michael Garcia*

Cosmic Ray, Fund Physics: Thomas Hams*, Vernon Jones,

Keith MacGregor*, Rita Sambruna

Gamma Ray/X-ray: Dan Evans, Michael Garcia*, Stefan

Immler*, Lou Kaluzienski, Rita

Sambruna, Wilt Sanders

Optical/Ultraviolet: Michael Garcia*, Hashima Hasan,

Mario Perez*, Martin Still*

IR/Submillimeter/Radio: Dominic Benford*, Doug Hudgins,

Kartik Sheth, Erin Smith*

Lab Astro: Doug Hudgins

Theory & Comp Astro Net: Keith MacGregor*

Roman Tech Fellows: Billy Lightsey*

Data Archives: Hashima Hasan

Astrophys Sounding Rockets: Wilt Sanders

Balloons Program: Vernon Jones(PS), Mark Sistilli (PE)

Programs / Missions & Projects

Program Scientist

Program Executive

Exoplanet Exploration (EXEP)

Program

Doug Hudgins

John Gagosian

Keck

Hashima Hasan

Mario Perez*

Kepler/K2

Mario Perez*

K. Chamberlin*/Jeff Hayes

LBTI

Doug Hudgins

Mario Perez*

NN-EXPLORE

Doug Hudgins

John Gagosian

WFIRST

Dominic Benford*

John Gagosian

Cosmic Origins (COR)

Program

Mario Perez*

Shahid Habib*

Herschel

Dominic Benford*

Jeff Hayes

Hubble

Michael Garcia*

Jeff Hayes

James Webb^

Hashima Hasan

Ray Taylor^

SOFIA

Hashima Hasan

Shahid Habib*

Spitzer

Erin Smith*

Jeff Hayes

Physics of the Cosmos (PCOS)

Program

Rita Sambruna

Shahid Habib*

Athena

Michael Garcia*

Jeanne Davis

Chandra

Stefan Immler*

Jeff Hayes

Euclid

Linda Sparke

Keith Chamberlin*

Fermi

Stefan Immler*

Jeff Hayes

Planck

Rita Sambruna

Jeff Hayes

ST-7/LPF

Rita Sambruna

Keith Chamberlin*

XMM-Newton

Stefan Immler*

Jeff Hayes

Astrophysics Explorers (APEX)

Program

Wilt Sanders

Jeanne Davis

Hitomi

Lou Kaluzienski

Jeanne Davis

NICER

Rita Sambruna

Jeanne Davis

NuSTAR

Lou Kaluzienski

Jeff Hayes

Suzaku

Stefan Immler*

Jeff Hayes

Swift

Martin Still*

Jeff Hayes

TESS

Doug Hudgins

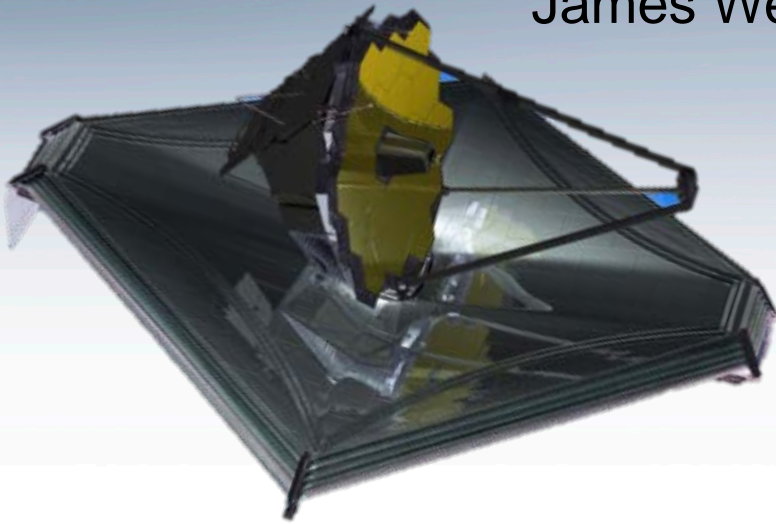
Mark Sistilli

+ Member of the Resources Management Division

* Detailee, IPA, or contractor

^ James Webb is part of the JWST Program Office.

July 13, 2016



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

2015-2016 Accomplishments

- Telescope mirrors installed ✓
- Science instruments integrated with Telescope ✓
- MIRI cryocooler completed ✓
- Spacecraft bus powered on for first time ✓
- Completed 2nd test of Pathfinder Telescope and ground support equipment at JSC in support of 2017 test of flight hardware ✓

2016 Plans

- Complete ambient testing of combined Telescope and instruments
- Complete spacecraft bus structure ✓
- Complete sunshield membrane fabrication ✓
- Cryovacuum testing of combined Telescope and instruments at JSC
- Integrate Sunshield and Spacecraft

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

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