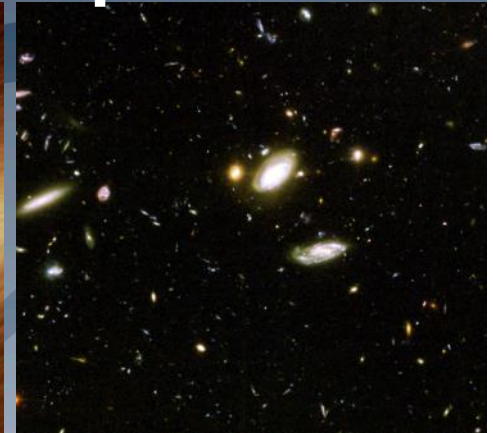




# Astrophysics

# NASA Headquarters Updates



## ExoPAG #16

NASA Ames Research Center  
June 18, 2017

Martin Still

ExoPAG Executive Secretary  
Astrophysics Division  
Science Mission Directorate  
[Martin.Still@nasa.gov](mailto:Martin.Still@nasa.gov)

# Content

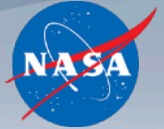


1. ExoPAG Status
2. Budget Status
3. Current Missions Status
4. Future Missions Status
5. Decadal Studies Status



# 1. ExoPAG Status

# Exoplanet Program Analysis Group



- The ExoPAG enables direct regular communication between NASA and the community, and within the community, through public meetings that give the community opportunities to provide its scientific and programmatic input
  - The full ExoPAG consists of all members of the community who participate in these open meetings
  - The ExoPAG Chair and the ExoPAG Executive Committee (EC) are appointed members whose responsibilities include organizing meetings and collecting and summarizing community input with subsequent reporting to the Astrophysics Division Director
  
- The ExoPAG may be tasked to carry out the following:
  - Articulate and prioritize the key scientific drivers for Exoplanet Exploration research;
  - Evaluate the expected capabilities of potential ExEP missions for achieving the science goal of the program
  - Evaluate ExEP goals, objectives, investigations and required measurements on the basis of the widest possible community outreach;
  - Articulate and prioritize focus areas for needed mission technologies; and
  - Provide findings on related activities such as ground-based observing, theory and modeling programs, laboratory astrophysics, suborbital investigations, data archiving and community engagement.



# The ExoPAG Executive Committee (EC)



- The ExoPAG Chair is a member of the NASA Astrophysics Advisory Committee
- EC members are selected to reflect the broad range of scientific disciplines and interests represented in exoplanet exploration
- New EC members are selected by the Astrophysics Division Director annually

# ExoPAG Executive Committee



Name	Home	Year
Alan Boss (chair)	Carnegie Institution	3/3
Daniel Apai	Arizona	3/3
David Ciardi	NExSci	3/3
Shawn Domagal-Goldman	NASA GSFC	3/3
Tiffany Glassman	Northrop Grumman	2/3
Dimitri Mawet	Caltech/JPL	2/3
Tyler Robinson	UC Santa Cruz	2/3
Eliza Kempton	Grinnell College	1/3
Michael Meyer	Michigan	1/3
Johanna Teske	Carnegie Institution	1/3
Chris Stark	STScI	1/3

Members Rus Belikov, Maggie Turnbull, and Lucianne Walkowicz rolled off the EC in 2017

Future Call for Nominations: <https://exoplanets.nasa.gov/exep/exopag>

Deadline: Jan 2018

# Science Analysis Group Status

<https://exoplanets.nasa.gov/exep/exopag/sag>



Delivered	SAG	Title	Lead
2015	8	Requirements and Limits of Future Precision Radial Velocity Measurements	Latham, Plavchan
2015	9	Exoplanet Probe to Medium Scale Direct-Imaging Mission Requirements and Characteristics	Soummer
2015	10	Characterizing the Atmospheres of Transiting Planets with JWST and Beyond	Cowan
2014	11	Preparing for the WFIRST Microlensing Survey	Yee
2017	12	Scientific potential and feasibility of high-precision astrometry for exoplanet detection and characterization	Bendek
--	13	Exoplanet Occurrence Rates and Distributions	Belikov
--	14	Characterization of Stars Targeted for NASA Exoplanet Missions	Stassun
--	15	Exploring Other Worlds: Observational Constraints and Science Questions for Direct Imaging Exoplanet Missions	Apai
--	16	Exoplanet biosignatures	Domagal-Goldman
--	17	Community Resources Needed for K2 and TESS Planetary Candidate Confirmation	Ciardi
--	18	Metrics for Direct-Imaging with Starshades	Glassman, Turnbull
--	19	Exoplanet Imaging Signal Detection Theory and Rigorous Contrast Metrics	Mawet, Jensen-Clem

# Why is the ExoPAG here at the Kepler/K2 Science Meeting?



## Afternoon Exoplanet Occurrence Rates and Direct Imaging Yields Panels

2:30 PM	Occurrence Rate Panel	Rus Belikov (chairing), Chris Burke, BJ Fulton, Susan Thompson, Jessie Christiansen, Erik Petigura, Eric Ford
3:30 PM	<b>Break</b>	
4:00 PM	Large Mission Yield Panel	Rus Belikov (chairing), Chris Stark, Rhonda Morgan, Shawn Domagal-Goldman, Ty Robinson, Mark Marley



## 2. Budget Status

# FY17 Consolidated Appropriations Bill (H.R. 244)



	<b>FY 2017 Request</b>	<b>FY 2017 Omnibus Conference</b>	<b>Change from FY2016 Enacted</b>	<b>Change from FY2017 Request</b>
<b>NASA TOTAL</b>	19,025.1	19,653.3	368.3	628.2
<b>Science</b>	5,600.5	5,764.9	175.5	164.4
Earth Science	2,032.2	1,921.0	0.0	-111.2
Planetary	1,518.7	1,846.0	215.0	327.3
Europa	49.6	275.0	100.0	225.4
Astrophysics	781.5	750.0	-17.6	-31.5
STEM Activation <sup>1</sup>	25.0	37.0	0.0	12.0
JWST	569.4	569.4	-50.6	0.0
Heliophysics	698.7	678.5	28.7	-20.2

Note 1: \$37.0M for STEM Activation is to be derived equally from Planetary Science and Astrophysics, and continue to be administered by Astrophysics.



# FY17 Consolidated Appropriations Bill (H.R. 244)



	FY17 Request	FY17 Approp	Language from Conference Committee Report
<b>Total</b>	1,350.9	1,319.0	
<b>Webb</b>	569.4	569.4	Includes \$569.4M for Webb
<b>WFIRST</b>	90.0	105.0	Includes \$105M for WFIRST; Committee directs NASA to cap WFIRST life cycle costs at no more than \$3,500M through the end of its prime mission
<b>SOFIA</b>	83.8	85.2	Provides \$85.2M for SOFIA
<b>Hubble</b>	97.3	98.3	Provides \$98.3M for Hubble Space Telescope
<b>Mirror Tech</b>	-	5.0	Includes <u>up to</u> \$5M for segmented aperture telescope activities
<b>Starshade</b>	-	-	Supports continued appropriate technology development for a starshade
<b>STEM Activation</b>	25.0	18.5	Includes \$37M for STEM Activation programs, derived from Planetary Science and Astrophysics
<b>Rest of Astrophysics</b>	485.4	438.0	

- Up to \$47.4M reduction to “Rest of Astrophysics” (Astrophysics excluding Webb, WFIRST, SOFIA, Hubble) relative to FY17 request; 11% reduction with 4 months remaining in FY17

# FY18 President's Budget Request

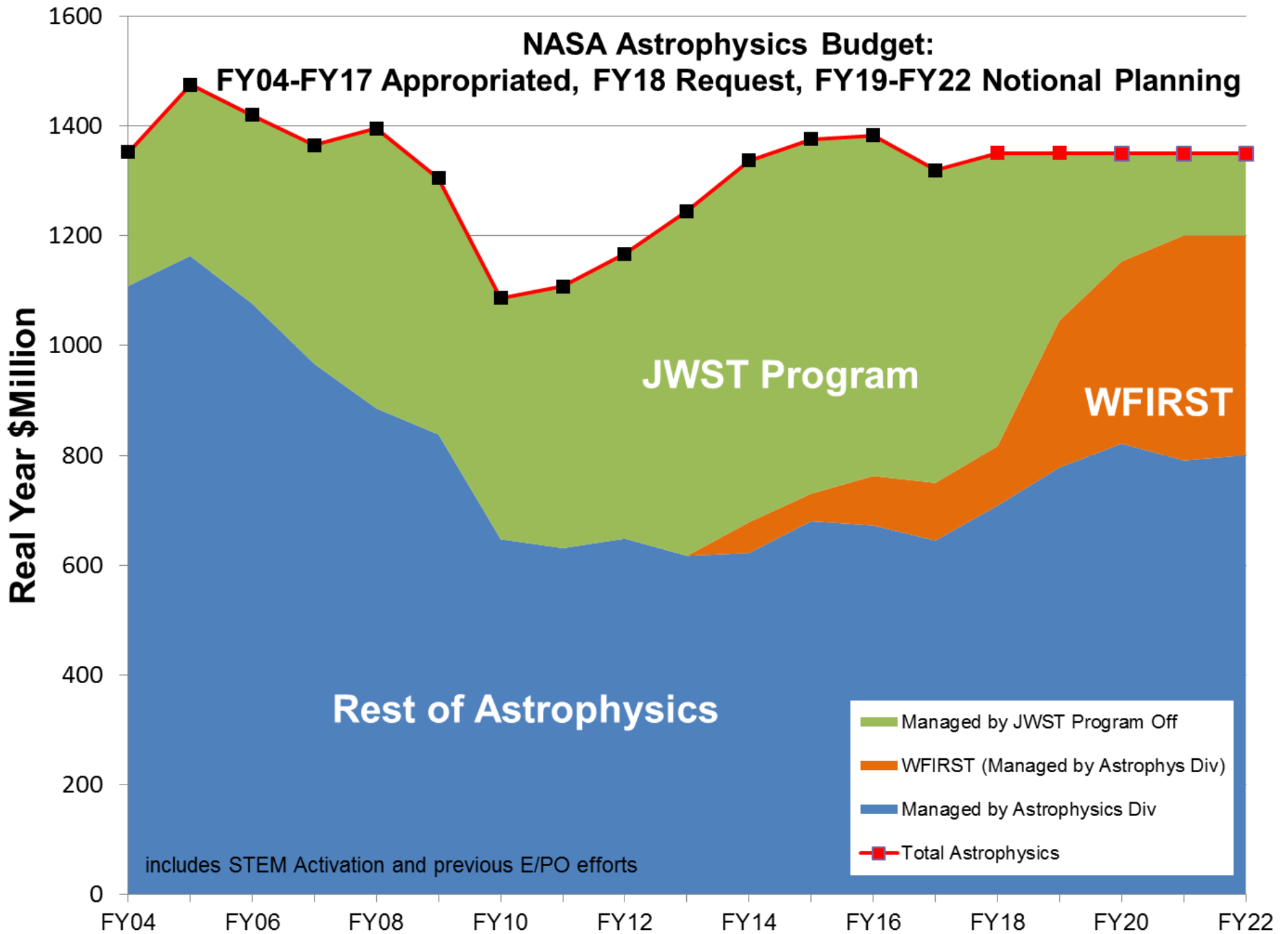


	Actual	Enacted	Request	Notional			
Budget (in \$ millions)	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022
Astrophysics Research	193	--	204	221	225	262	288
Cosmic Origins	196	--	192	190	142	158	156
Physics of the Cosmos	125	--	100	109	111	94	94
Exoplanet Exploration	141	--	176	351	473	476	440
Astrophysics Explorer	108	--	145	175	201	212	222
James Webb Telescope	620	569	534	305	197	150	150
<b>Total Astrophysics</b>	<b>1382</b>	<b>1319</b>	<b>1350</b>	<b>1350</b>	<b>1350</b>	<b>1350</b>	<b>1350</b>

- Supports an SMD-wide CubeSat/SmallSat initiative that uses smaller, less expensive satellites to advance science in a cost-effective manner.
- Reflects more efficient operations of the Hubble Space Telescope, without impact to science.
- Reflects efficiencies realized by the SOFIA in the past few years. SOFIA will participate in the 2019 Astrophysics Senior Review.

# NASA Astrophysics Budget:

FY04-FY17 Appropriated, FY18 Request, FY19-FY22 Notional Planning





## **3. Current Missions Status**

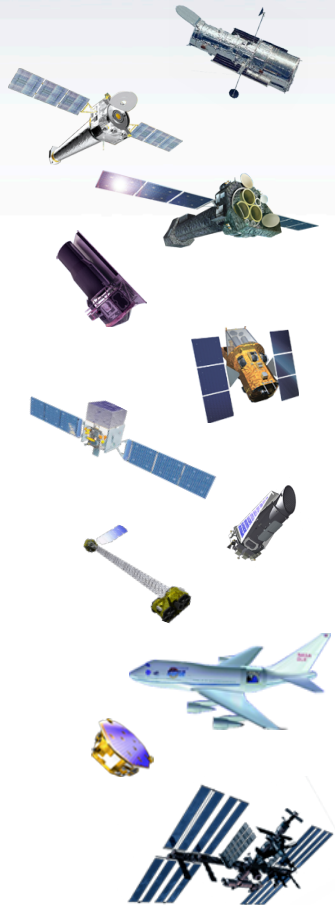




Revised  
June 3, 2017



# Astrophysics Missions in Operation



	Phase	2017 GO	Notes
Hubble	Extended	Yes	
Chandra	Extended	Yes	
XMM-Newton (ESA)	Extended	Yes	
Spitzer	Extended	Yes	EOM in 2019
Swift	Extended	Yes	
Fermi	Extended	Yes	
Kepler	Extended	Yes	EOM in ~2019
NuSTAR	Extended	Yes	
SOFIA	Prime	Yes	
LISA Pathfinder (ESA)	Extended		EOM in 2017
NICER	Checkout		Science in July

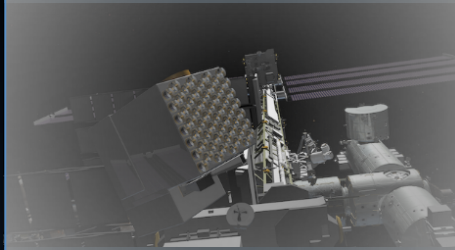




## **4. Future Missions Status**

# Astrophysics Missions in Development

ISS-NICER 6/2017  
NASA Mission



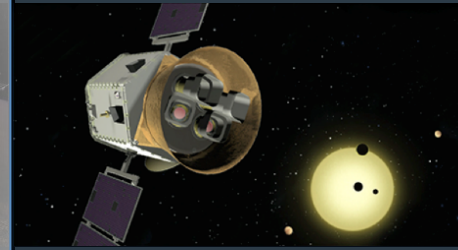
Neutron Star Interior  
Composition Explorer

ISS-CREAM 8/2017  
NASA Mission



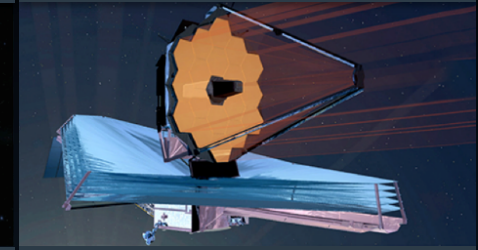
Cosmic Ray Energetics  
And Mass

TESS 3/2018  
NASA Mission



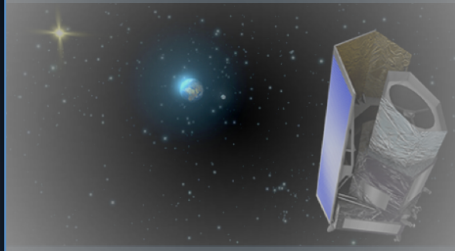
Transiting Exoplanet  
Survey Satellite

Webb 10/2018  
NASA Mission



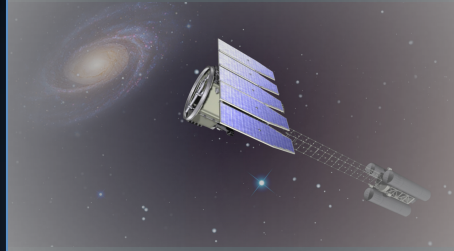
James Webb  
Space Telescope

Euclid 2020  
ESA-led Mission



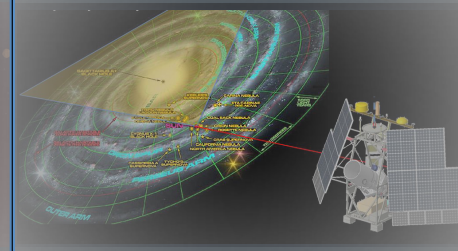
NASA is supplying the NISP  
Sensor Chip System (SCS)

IXPE 2020  
NASA Mission



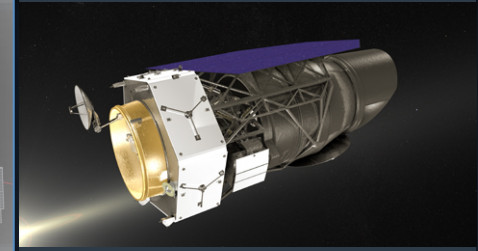
Imaging X-ray  
Polarimetry Explorer

GUSTO 2021  
NASA Mission



Galactic/ Extragalactic ULDB  
Spectroscopic Terahertz Observatory

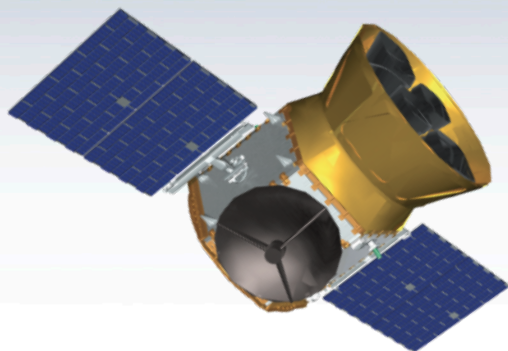
WFIRST Mid 2020s  
NASA Mission



Wide-Field Infrared  
Survey Telescope

# TESS

## Transiting Exoplanet Survey Satellite



### CURRENT STATUS:

- Both instrument and spacecraft bus completion are planned for late-June early July 2017.
- Observatory integration beginning in mid-Summer 2017 with completion by the end of fall 2017.
- All four flight cameras are assembled and now in testing.

### SCHEDULE:

- mid-Summer thru Fall 2017 – Observatory integration and test
- Summer 2017 – SIR & KDP-D
- January 2018 – Delivery to KSC payload processing facility.
- March 2018 – Launch readiness date from Cape Canaveral FL.

### Medium Explorer (MIDEX) Mission

**PI:** G. Ricker (MIT)

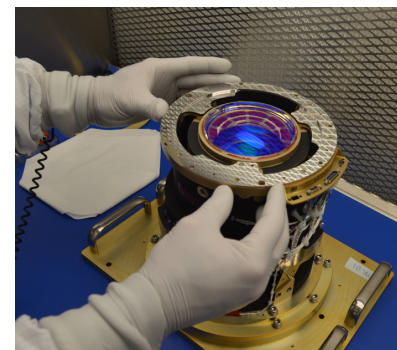
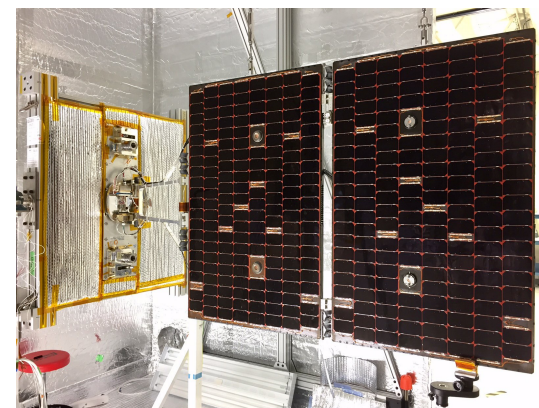
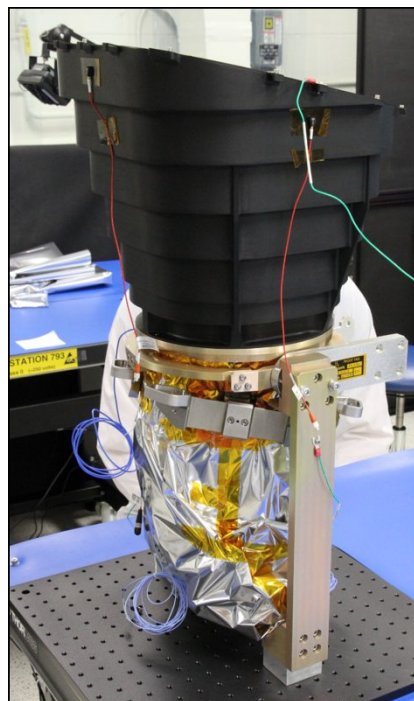
**Mission:** All-Sky photometric exoplanet mapping mission.

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

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

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

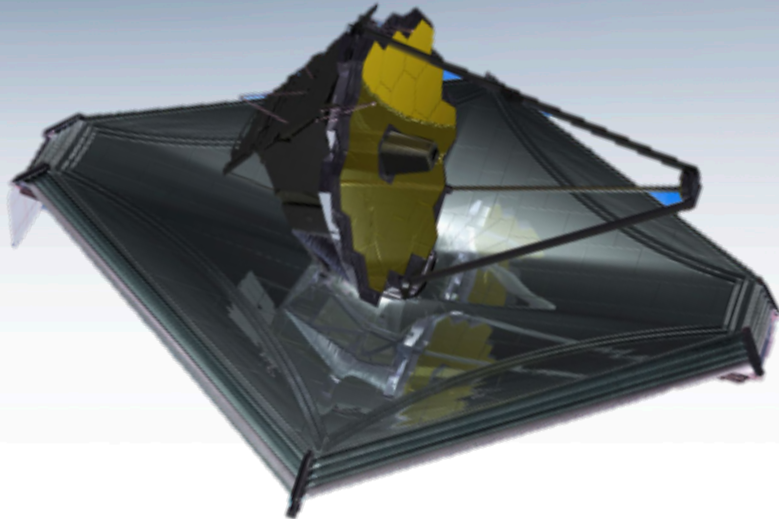
<http://tess.gsfc.nasa.gov/>





# Webb

## James Webb Space Telescope



### Large Infrared Space Observatory

Top priority of 2000 Decadal Survey

**Science themes:** First Light; Assembly of Galaxies; Birth of Stars and Planetary Systems; Planetary Systems and the Origins of Life

**Mission:** 6.5m deployable, segmented telescope at L2, passively cooled to <50K behind a large, deployable sunshield

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

**Operations:** 2018 launch for a 5-year prime mission

**Partners:** ESA, CSA

### RECENT ACCOMPLISHMENTS:

- Completed spacecraft bus assembly
- Completed ambient testing of combined telescope and instruments
- Shipped science payload to JSC for end-to-end testing
- Issued calls for Early Release Science Notices of Intent

### 2017 Plans:

- Integrate spacecraft and sunshield
- Cryo-vacuum testing of the science payload at JSC
- Flight operations rehearsals and training

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

Webb remains on track for an October 2018 launch



# OTIS (Telescope + Instruments)



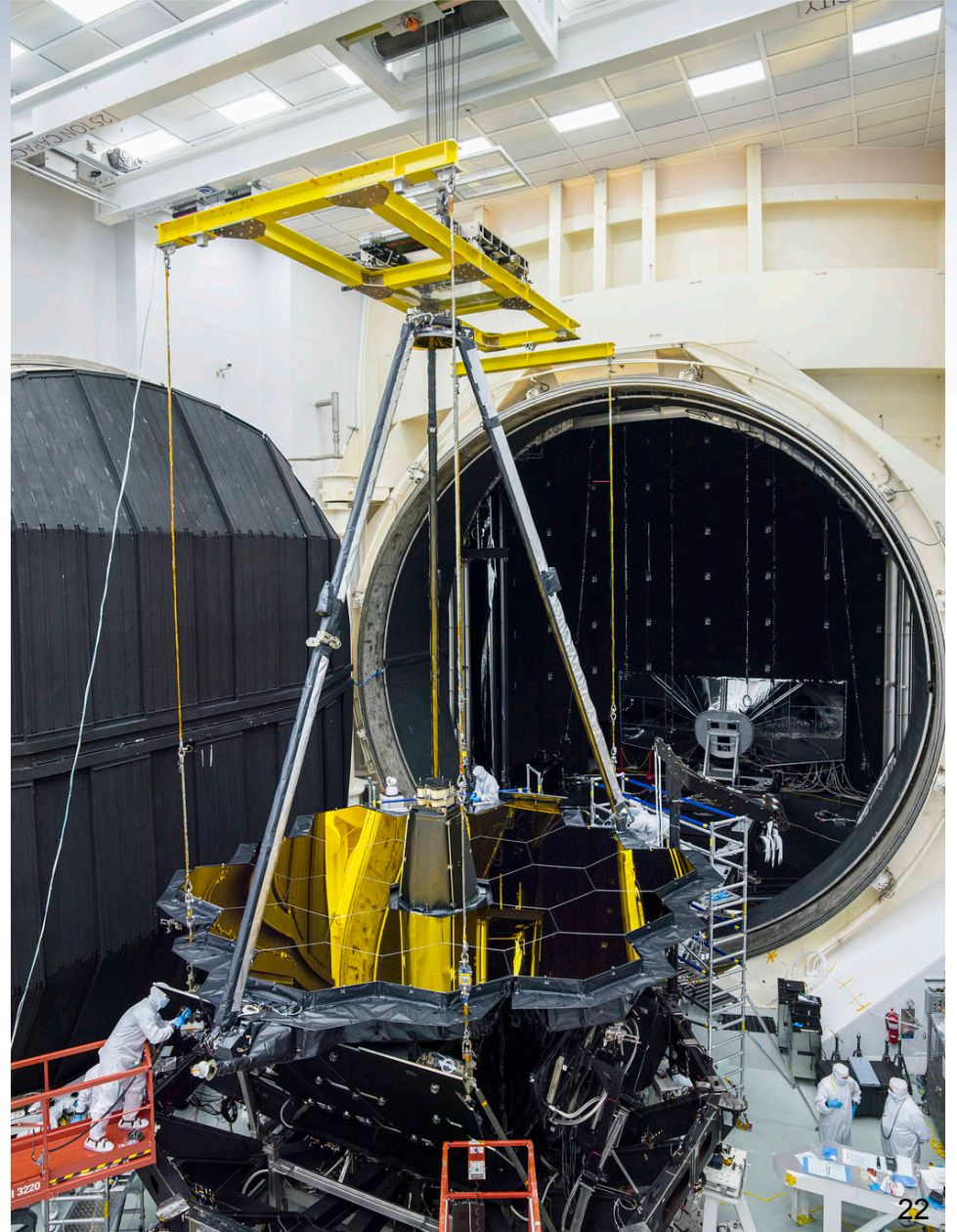
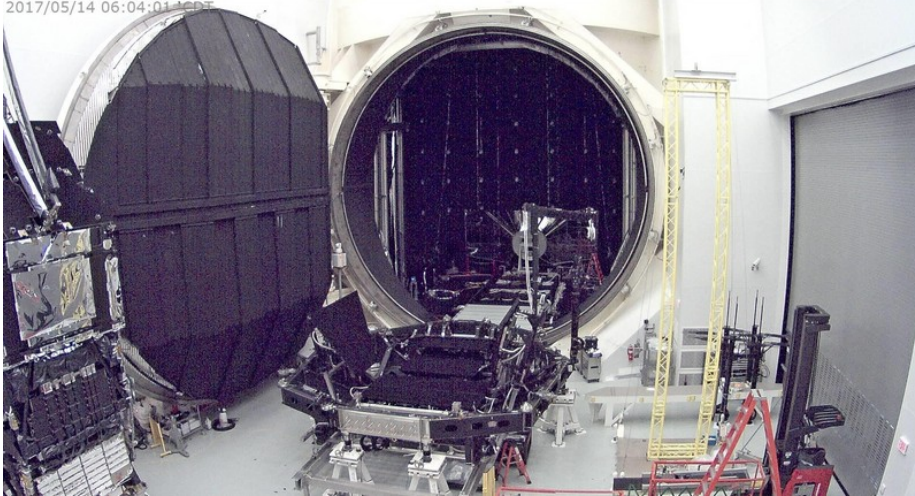


# OTIS @ JSC



2017-05-14 06:04:01

2017/05/14 06:04:01 CDT







# SPACECRAFT

- Spacecraft and sunshield integration underway
- All components delivered except deployable radiator shields and actuators (not planned for delivery yet anyway)



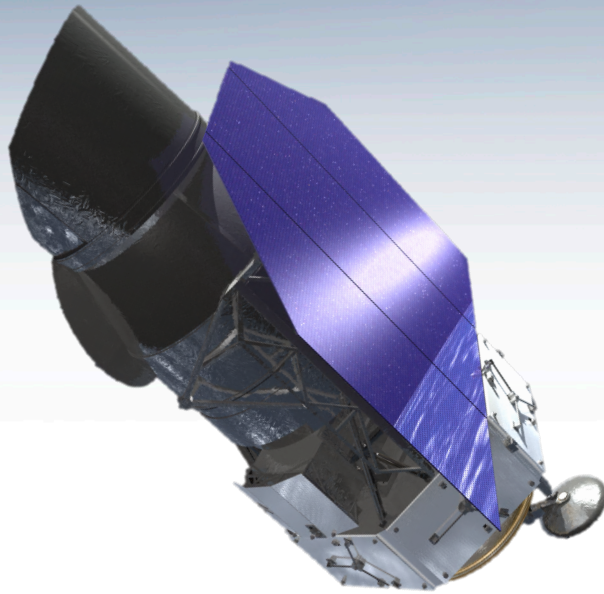
Second sunshield mid-boom installation



UPS ready for installation onto spacecraft

# 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  $0.28\text{deg}^2$  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:

- Successfully completed three-year technology demonstration activities on WFIRST's two critical mission technologies (near infrared detectors and coronagraph technologies)
- Completed industry formulation studies on Wide Field Instrument Optomechanical Assembly
- Conducting WFIRST Independent External Technical/Cost/Management Review (WIETR) in response to findings and recommendations in National Academies' Midterm Assessment
  - NASA is managing WFIRST with major emphasis on cost control
  - WFIRST will proceed to SRR/MDR and KDP-B after responding to WIETR recommendations
- WFIRST does not have a starshade; but NASA is studying a starshade for the next Decadal Survey's consideration.
  - Starshade compatibility is being studied during Phase A; mandated minimum impact on WFIRST.
  - NASA will decide by fall 2017 whether to maintain starshade compatibility.
- Jeff Kruk is new Project Scientist following loss of Neil Gehrels

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



# WFIRST Independent Review

- WFIRST is the highest priority large space mission from the 2010 Decadal Survey in Astronomy and Astrophysics
  - The 2016 Astrophysics Midterm Assessment recognized the continued compelling science value of WFIRST.
  - After several years of mission concept studies and technology investments, NASA began formulation of WFIRST in 2016
- Two National Academies studies have recommended that NASA conduct an independent technical/management/cost (TMC) review of WFIRST before beginning Phase B and before proceeding to the Preliminary Design review
  - Both reports expressed concern that mission cost growth could endanger the balance of NASA's astrophysics program and the alignment of its scientific priorities with those put forward by the Decadal Survey.
  - The studies are the 2014 WFIRST/AFTA study (F. Harrison et al.) and the 2016 Astrophysics Midterm Assessment (J. Hewitt et al.)
- NASA is implementing these recommendations and establishing the WFIRST Independent External TMC Review (WIETR)
- The Review will begin as soon as the panel members are identified
  - Once begun, the review should take ~2 months
  - The WFIRST System Requirements Review (SRR) / Mission Design Review (MDR), planned for Summer 2017, and beginning of Phase B, planned for Fall 2017, will be deferred until after the WIETR so that any findings and recommendations can be incorporated into the WFIRST project plan



# 5. Decadal Studies Status



# Large Mission Concepts - Science



<p><b>Tracing the Signatures of Life and the Ingredients of Habitable Worlds</b></p> <p>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.</p>	<p><b>Unveiling the Growth of Black Holes and Galaxies over Cosmic Time</b></p> <p>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.</p>
<p><b>Charting the Rise of Metals, Dust, and the First Galaxies</b></p> <p>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.</p>	<p><b>Characterizing Small Bodies in the Solar System</b></p> <p>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.</p>

**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?

**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?

<p><b>Astrophysics</b></p> <p>LUVOIR's unprecedented resolution will resolve 1-parsec-sized star-forming regions of galaxies at distances up to 10-25 mega-parsecs, map the distribution of dark matter in the nearby universe, and isolate gravitational wave sources.</p>	<p><b>Exoplanets</b></p> <p>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.</p>
<p><b>Cosmic Origins</b></p> <p>LUVOIR will identify the first starlight in the early universe, uncover the archaeology of early galaxies, and find the first black holes.</p>	<p><b>Solar System</b></p> <p>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.</p>

**SCIENCE**

<p><b>Exoplanets</b></p> <p>The primary goal of HabEx is to image and study habitable exoplanets. However, it will also study the full range of exoplanets within the systems.</p>	<p><b>Astrophysics</b></p> <p>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.</p>	<p><b>Astrobiology</b></p> <p>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.</p>
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# Astrophysics Probes



- In August 2016, NASA issued a solicitation requesting proposals for mission concept studies for medium-size missions (Probes)
  - 27 proposals were received on November 15, 2016, spanning a broad range of science disciplines
- The proposals were evaluated by peer review
  - Reviewers evaluated the proposals based on intrinsic science merit, relevance to NASA, value of the study in the context of other studies, and likelihood that the mission concept is Probe-class (<\$1B).
  - Each panel was requested to provide general guidelines on how to assemble the Probes portfolio.
  - Panels recommended proposal selection spanning a broad range of science disciplines and mission concepts.
- NASA has selected 10 proposals for mission concept studies involving a PI-led science team and NASA mission design labs at JPL and Goddard.
  - An independent cost assessment of the resulting mission concepts will be conducted by NASA
- The results of the mission concept studies will be provided by NASA to the 2020 Decadal Committee for their consideration



# Selected Probe Mission Concept Studies



PI	Affiliation	Short title
Jordan Camp	NASA GSFC	Transient Astrophysics Probe
Asantha Cooray	Univ. California, Irvine	Cosmic Dawn Intensity Mapper
Bill Danchi	NASA GSFC	Cosmic Evolution through UV Spectroscopy Probe
Jason Glenn	Univ. of Colorado	Galaxy Evolution Probe
Shaul Hanany	Univ. of Minnesota	Inflation Probe
Richard Mushotzky	Univ. of Maryland	High Spatial Resolution X-ray Probe
Angela Olinto	Univ. of Chicago	Multi-Messenger Astrophysics Probe
Peter Plavchan *	Missouri State Univ.	Precise Radial Velocity Observatory
Paul Ray	Naval Research Lab	X-ray Timing and Spectroscopy Probe
Sara Seager *	MIT	Starshade Rendezvous Mission

\* Partial Selections

The Selection Document and Probes Implementation Plan are posted at <https://science.nasa.gov/astrophysics/2020-decadal-survey-planning>



# Backup Slides