



# **NASA Astrophysics Division Update**

**Board of Physics and  
Astronomy**

**April 24, 2015**

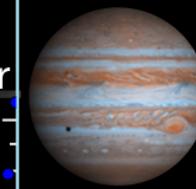
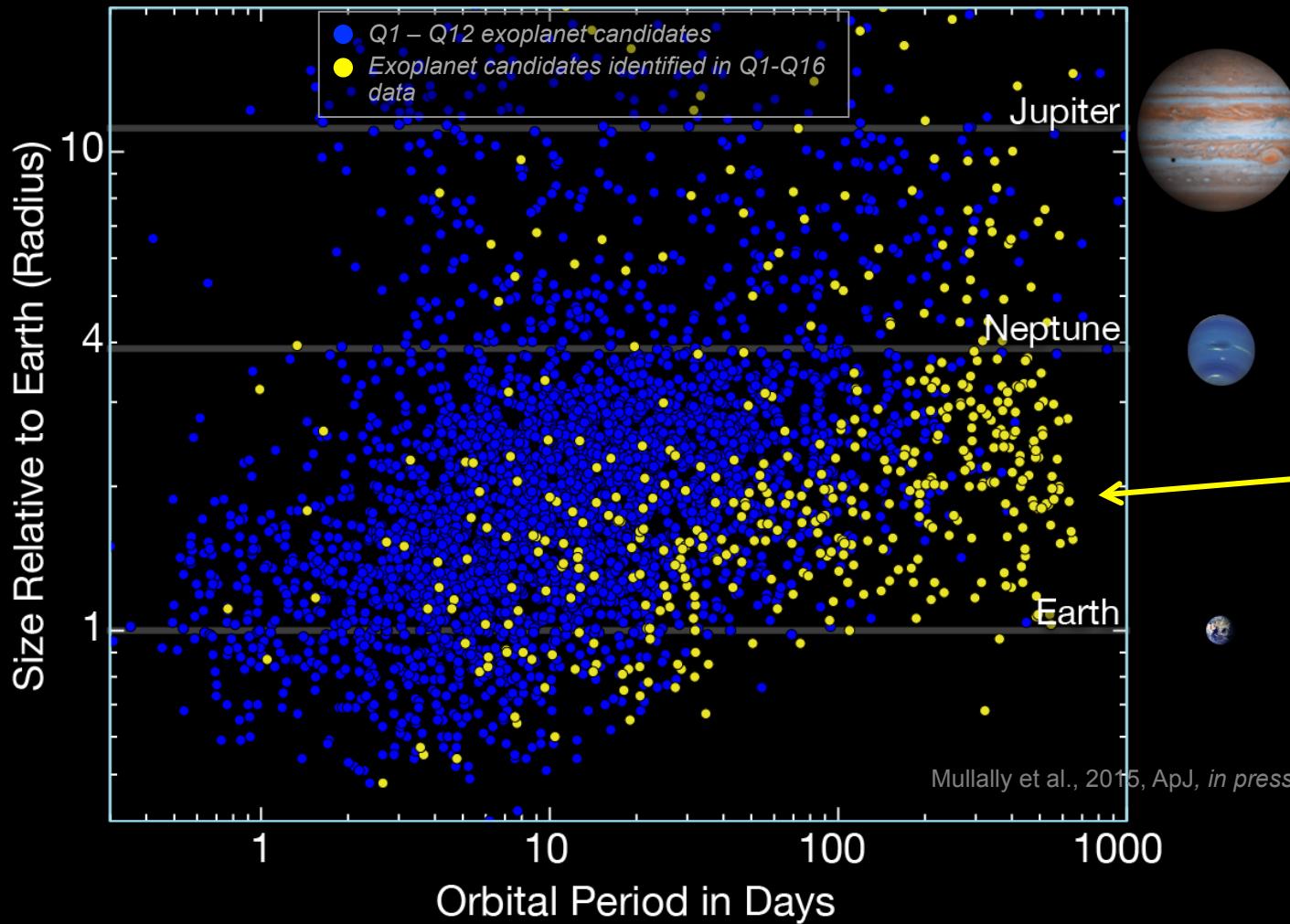
# **Astrophysics**

**Douglas Hudgins**  
Exoplanet Exploration Program Scientist  
Astrophysics Division  
Science Mission Directorate



# NASA's Kepler Marks 1,000th Exoplanet Discovery, Uncovers More Small Worlds in Habitable Zones

Total Exoplanet Candidates = 4175  
Confirmed Exoplanets = 1019



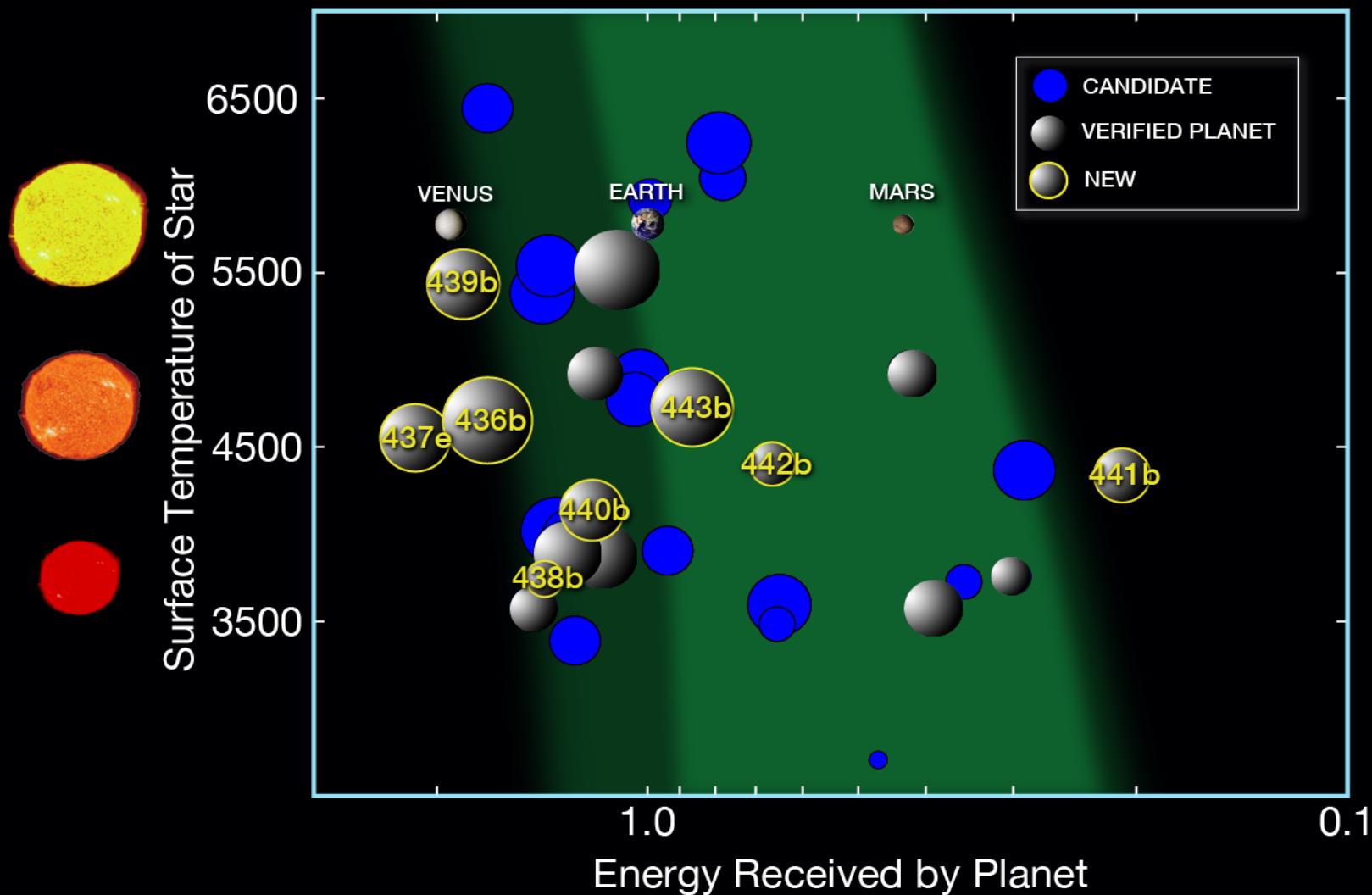
Analysis of  
Q1-Q16 data  
has revealed  
554 new  
exoplanet  
candidates.



# Kepler's Small Habitable Zone Planets/Candidates

As of January 2015

Plot Kepler planets/candidates with radii  $< 4 R_{\text{Earth}}$  as a function of host star type and degree of “instellation” (Earth = 1.0).



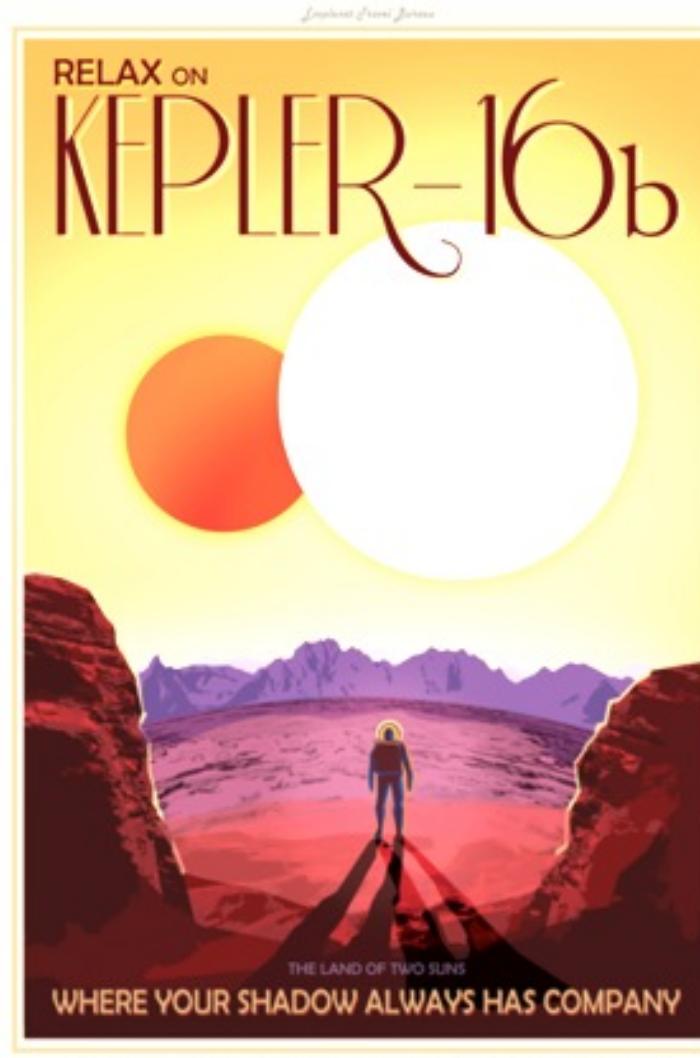


# The Exoplanet Travel Bureau



Kepler-186f is the first Earth-size planet discovered in the potentially habitable zone around another star, where liquid water could exist on the planet's surface. Its star is much cooler and redder than our Sun. If planet-life does exist on a planet like Kepler-186f, its photosynthesis could have been influenced by the star's red-near-infrared photons, making for a color palette that's very different from the greens on Earth.

This discovery was made by Kepler, NASA's planet-hunting space telescope.



Like Luke Skywalker's planet "Tatooine" in "Star Wars," Kepler-16b orbits a pair of stars. Observed here as a terrestrial planet, Kepler-16b might also be a "gas giant" like Saturn. Prospects for life on this unusual double-star system, as it has a temperature similar to that of any star. But this discovery indicates that the planet's double shadow cast by its orbiting star system.

Image: NASA/JPL-Caltech/Space Telescope Science Institute



# Astrophysics Driving Documents

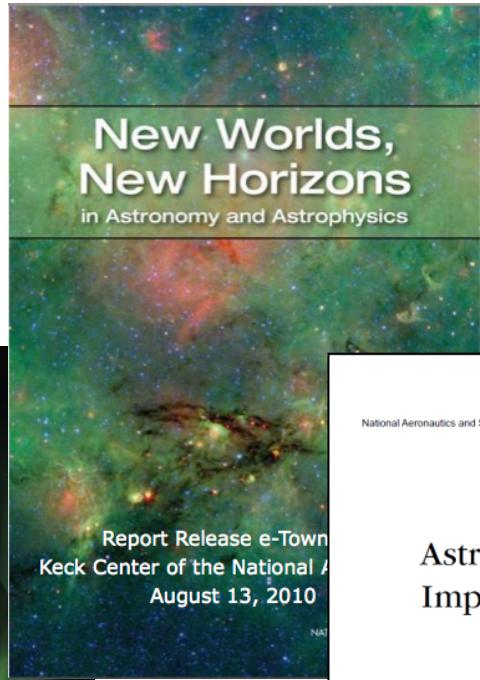
## NASA Strategic Plan 2014



## SCIENCE PLAN 2014



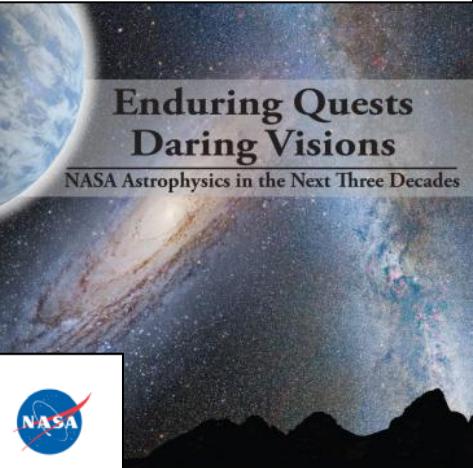
## New Worlds, New Horizons in Astronomy and Astrophysics



Report Release e-Town  
Keck Center of the National A  
August 13, 2010

National Aeronautics and Space Administration

## Astrophys Implemen



National Aeronautics and Space Administration



## Astrophysics Implementation Plan: 2014 Update

This Update provides a summary since the last update of the Astrophysics Implementation Plan in 2010. It highlights developments that affect NASA's Astrophysics Program, including the Astrophysics Decadal Survey, the 2010 Astrophysics Implementation Plan, and the 2010 Decadal Survey of Astronomy and Astrophysics.

This Update also provides an update on the status of the Astrophysics Division's implementation of the 2010 Decadal Survey of Astronomy and Astrophysics.

New

Astrophysics Division  
Science Mission Directorate  
NASA Headquarters

December 2014

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



# Big Picture

- The FY15 appropriation and FY16 budget request provide funding for NASA astrophysics to continue its programs, missions, and projects as planned
  - The total funding (Astrophysics including JWST) is flat at ~\$1.3B through FY20
  - Fully fund JWST to remain on plan for an October 2018 launch
  - Fund continued pre-formulation and technology work leading toward WFIRST
  - Restore SOFIA to the budget with a reduction in FY15 and full funding beyond
- The operating missions continue to generate important and compelling science results, and new missions are under development for the future
  - Chandra, Fermi, Hubble, Kepler/K2, NuSTAR, Spitzer, Suzaku, Swift, XMM-Newton continued following the 2014 Senior Review
  - SOFIA is in prime operations as of May 2014
  - Missions on track for launch include LISA Pathfinder (2015), ASTRO-H (2015), NICER (2016), TESS (2017), JWST (2018), Euclid (2020)
  - New Explorers being selected (SMEX in 2015, MIDEX in 2017), WFIRST being studied, NASA joining ESA's Athena and ESA's L3 gravitational wave observatory
- Update to the Astrophysics Implementation Plan has been released
- Progress being made against recommendations of the 2010 Decadal Survey
  - NRC Mid Decade Review (with NSF, DOE) to begin in early 2015
  - NASA initiating large mission concept studies for 2020 Decadal Survey



# FY15 Appropriation

(\$M)	2013	2014	2015	2016	2017	2018	2019
Astrophysics			\$685				
JWST			\$645				

## Highlights:

- Provides \$77M more than the President's Budget Request for FY15
- Supports the commitment to an October 2018 launch date for JWST
- Includes \$50M for continued preformulation of WFIRST, an increase of \$36M over the Administration request and comparable to FY14
- Includes \$70M for continued SOFIA operations, a reduction of \$14M (17%) from FY14
  - Directs NASA to (a) seek partners to restore SOFIA to its full level, and (b) not terminate missions without a Senior Review
- Includes \$38M for scientific ballooning, an increase of \$5M (15%) from FY14
- For the rest of the Division portfolio, the funding is adequate for Astrophysics to execute its program as planned in FY15.



# FY16 President's Budget Request

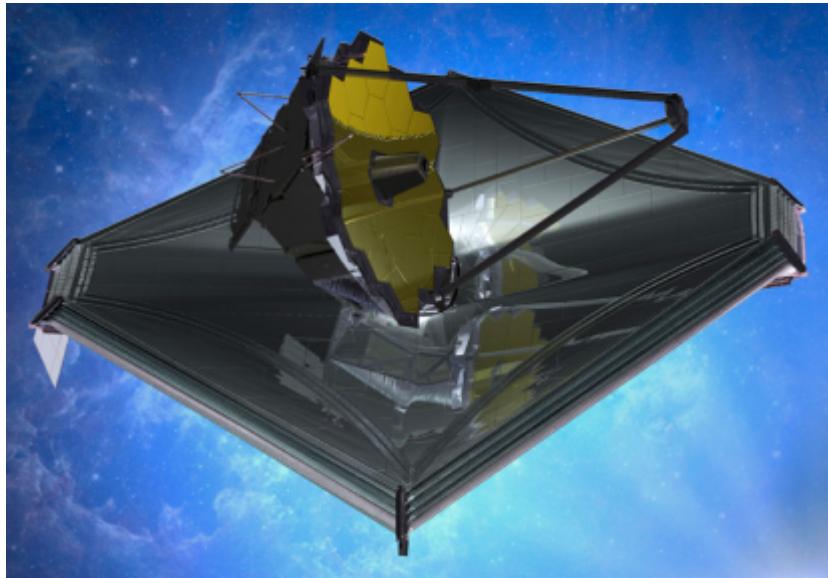
Outyears are notional planning from FY16 President's budget request

(\$M)	2014	2015	2016	2017	2018	2019	2020
Astrophysics*	\$678	\$685	\$689	\$707	\$750	\$986	\$1,118
JWST	\$658	\$645	\$620	\$569	\$535	\$305	\$198

- Supports the commitment of an October 2018 launch date for JWST.
- Continues preformulation of WFIRST/AFTA as the “Astrophysics Decadal Strategic Mission.”
- Grows Astrophysics Research and Analysis (including Astrophysics Data Analysis Program) from ~\$80M/yr to ~\$90M/yr in FY16.
- Supports completion of missions under development, including LPF/ST7, ASTRO-H, NICER, TESS, and Euclid.
- Enables selection of a SMEX mission and an Explorer Mission of Opportunity from the 2014 AO, and notional release of a MIDEX AO in late CY16/early FY17.
- Provides full funding for SOFIA operations and places SOFIA into the 2016 Astrophysics Senior Review.
- Plans for the 2016 Astrophysics Senior Review.
- Plans for continued Hubble ops through FY20, providing overlap with JWST.
- Plans for mission concept studies and technology development (within the three Program SR&T budgets) leading up to the 2020 Decadal Survey.

# JWST

## James Webb Space Telescope



### Large Infrared Space Observatory

Top priority of 2000 Decadal Survey

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

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

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

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

**Partners:** ESA, CSA <http://jwst.nasa.gov/>

### 2015 Accomplishments

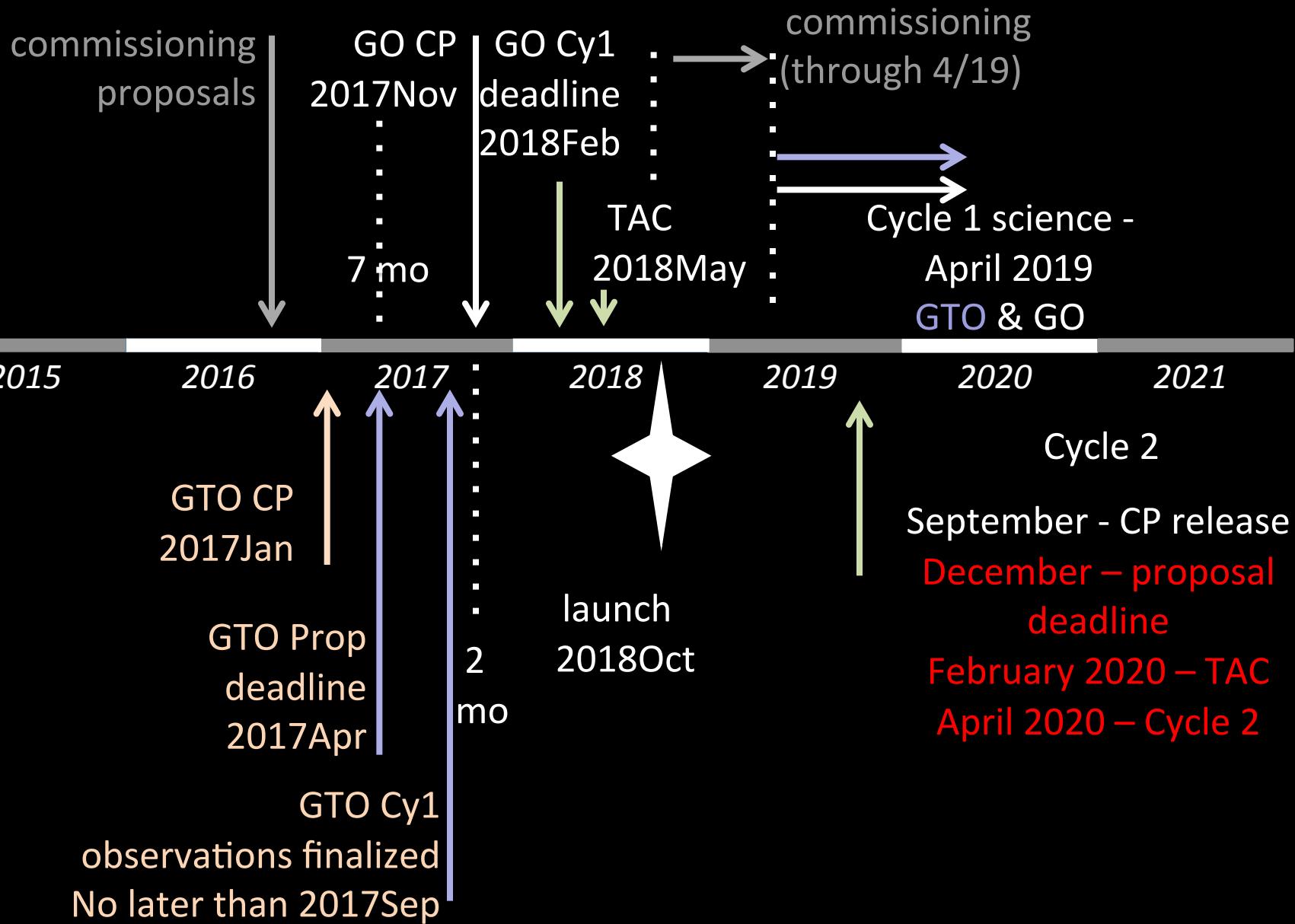
- FGS/NIRISS and NIRSpec detector replacement completed; ISIM ready for final cryo test.
- 4 of 5 flight sunshield membranes in manufacturing (final to start in a couple months)
- Spacecraft manufacturing continues on schedule
- Telescope Pathfinder installed into JSC chamber A for testing
- Telescope Flight Backplane, wings and secondary tower assembled

### 2015 Plans

- Test ISIM for the final time before integration into observatory
- Conduct tests at JSC in preparation for full telescope and instrument tests
- Complete MIRI cryocooler
- Start Assembly of the Primary mirror



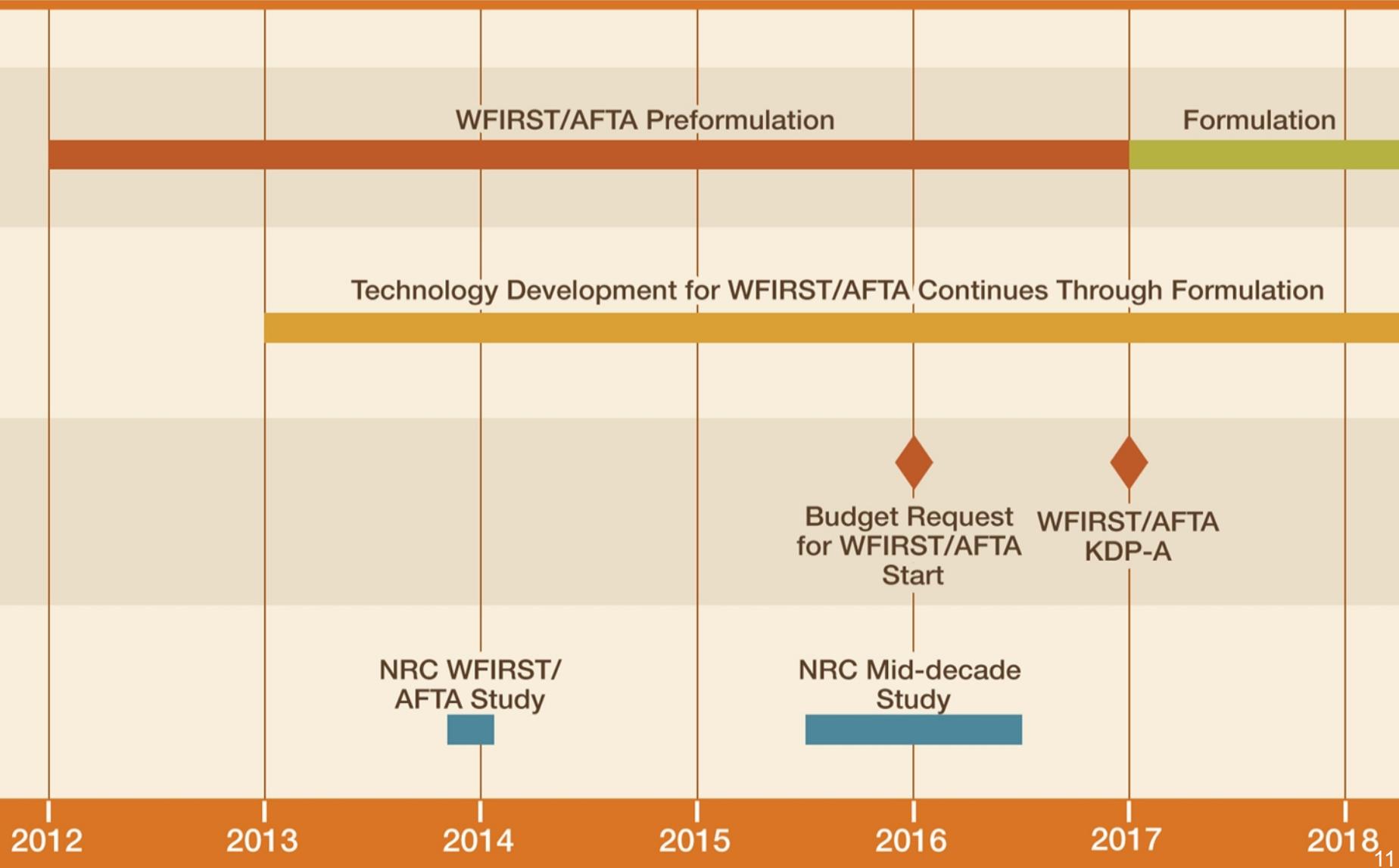
# JWST Science Planning Timeline



# Plan for WFIRST/AFTA Preformulation

## WFIRST mission using Astrophysics Focused Telescope Assets

### WFIRST/AFTA timeline



# WFIRST / AFTA

## Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets



### Widefield Infrared Survey Telescope

Top priority of 2010 Decadal Survey

**Science themes:** Dark Energy, Exoplanet Science, Large Area Near Infrared Surveys

**Mission:** 2.4m widefield telescope at GEO, uses existing AFTA hardware to image 0.28 deg<sup>2</sup> at 0.8-2.0 μm

**Instruments (design reference mission):**  
Wide Field Instrument, Coronagraph Instrument

- Plans support Agency/Administration decision for formulation to begin NET FY 2017, should funding be available.

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

### CURRENT STATUS:

- May 2013, NASA Administrator Bolden directed study of WFIRST/AFTA and preserve option for FY17 new start if budget is available.
  - No decision expected before early CY 2016.
- Currently in pre-formulation phase.
  - Activities include technology development for detectors and coronagraph (with STMD), assessment of the 2.4m telescopes including risk mitigation, mission design trades, payload accommodation studies, and observatory performance simulations.
- Maturing key technologies by FY19.
  - H4RG infrared detectors for widefield imager.
  - Internal coronagraph for exoplanet characterization.
- March 2014 NRC study on WFIRST/AFTA offered positive view of AFTA, expressed concerns about technology and cost risks.
- March 2015 SDT report with design reference mission presents baseline plan for WFIRST/AFTA
- WFIRST Preparatory Science funds 17 ROSES proposals that are relevant to WFIRST's goals and WFIRST-specific simulations and models.



# WFIRST / AFTA

## Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets

### Coronagraph Technology Milestones

1	Shaped Pupil mask fabricated with reflectivity of $10^{-4}$ and $20 \mu m$ pixel size.	7/21/14
2	Shaped Pupil Coronagraph demos $10^{-8}$ raw contrast with narrowband light.	9/30/14
3	PIAACMC mask fabricated with $10^{-8}$ raw contrast with 10% broadband light.	12/15/14
4	Hybrid Lyot Coronagraph demos $10^{-8}$ raw contrast with narrowband light..	2/28/15
5	Occulting Mask Coronagraph demos $10^{-8}$ raw contrast with 10% broadband light.	9/15/15
6	Low Order Wavefront Sensing provides jitter sensing better than 0.4 mas rms.	9/30/15
7	Spectrograph read-out demo to have low dark current and read noise.	8/25/16
8	PIAACMC coronagraph demos $10^{-8}$ raw contrast with 10% broadband light.	9/30/16
9	Occulting Mask Coronagraph demos $10^{-8}$ raw contrast with 10% broadband light.	9/30/16

### Widefield Detector Technology Milestones

1	Produce, test, and analyze 2 candidate passivation techniques in banded arrays.	7/31/14
2	Produce, test, and analyze 1 additional candidate passivation techniques in banded arrays.	12/30/14
3	Produce, test, and analyze full arrays with operability $> 95\%$ .	9/15/15
4	Produce, test, and analyze final selected recipe in full arrays demonstrating a yield $> 20\%$ with operability $> 95\%$ .	9/15/16
5	Complete environmental testing of one sensor chip assembly, as per NASA test standards.	12/1/16



# Planning for the 2015-2016 Mid-Decade Review

- The NASA Authorization Act of 2005 requires assessments of NASA's science programs that include mid-decade reviews.
  - The Astrophysics Mid-Decade Review will be during 2015-2016
  - Study will be co-sponsored by NASA, NSF, and DOE (the Agencies)
- Given the funding circumstances that are substantially below those assumed in the Decadal Survey, the committee's review will describe:
  - The most significant scientific discoveries, technical advances, and relevant programmatic changes in astronomy and astrophysics since the Decadal Survey;
  - How well the Agencies' programs address the strategies, goals, and priorities outlined in the Decadal Survey and other NRC reports;
  - Progress toward realizing these strategies, goals and priorities; and
  - Any actions that could be taken to maximize the science return of the Agencies' programs.
- The Agencies are in the process of charging the NRC, and formation of the Study Committee will begin soon.



# Planning for the 2015-2016 Mid-Decade Review

## Directions in *New Worlds, New Horizons* relevant to NASA (paraphrased)

- LISA: If LISA is not L1, or LISA Pathfinder is not successful, or equal partnership is not possible, then conduct review to reconsider LISA's prioritization. (p.9, p.213)
  - NASA working toward partnership on ESA L3, will invest in enabling technology and LPF; anticipate review by 2020 Decadal Survey regarding priority of strategic partnership on ESA L3.
- IXO: If IXO is L1, conduct review then (maybe) invest immediately in technology. By mid-decade, invest aggressively in technology. (p. 9, p. 214, p. 215)
  - NASA planning on partnership on ESA Athena, investing in technology now, expect details of partnership to be established soon; anticipate partnership well underway by time of 2020 Decadal Survey.
- New Worlds: If precursor science is favorable, conduct review then (maybe) downselect technology and invest to ready a mission for the 2020 decadal survey. (p.20, p.195, p. 216)
  - NASA maturing multiple technologies and studying multiple architectures in advance of 2020 Decadal Survey, not planning to downselect technology prematurely; anticipate review by 2020 Decadal Survey regarding priority – and possibly size and architecture – of strategic mission.
- Inflation Probe: If B-mode detected, conduct review then (maybe) invest in technology for an all-sky mission. (p.198, p.217)
  - NASA maturing multiple detector technologies, considering potential partnerships on ESA and JAXA led missions; anticipate review by 2020 Decadal Survey regarding priority of probe-class mission.
- Mid-Decadal Review: Conduct review to see whether any contingencies have occurred and recommend action. (p.102, p.237)



# Planning for the 2015-2016 Mid-Decade Review

- What kind of input and reporting from NASA would be valuable to the Mid Decade Review Committee?
  - Programmatic update on addressing the recommendations in the Decadal Survey.
    - *Captured in 2014 Implementation Plan Update*
    - *Looking for a definitive list of Decadal Survey recommendations, or at least subjects that the Committee would like addressed*
  - Programmatic and budget update on NASA initiatives and activities which are not recommendations of the Decadal Survey.
  - Spending actuals and budget plan against the major recommendations, all of which came with proposed spending allocations.
  - Spending actuals and budget plan for community support, including R&A, GO, and Fellowships.
  - Plans for the rest of the decade, including expected decision points.
  - Plans for preparing for the 2020 Decadal Survey.



# Preparing for the 2020 Decadal Survey

## Large Mission Concepts

- The 2020 Decadal Survey will prioritize large space missions to follow JWST and WFIRST.
  - To enable this prioritization, NASA needs to provide information on several candidate large space mission concepts for consideration by the 2020 Decadal Survey Committee.
- What information needs to be provided to the Decadal Survey committee to enable prioritization of large missions?
  - Science case
  - Strawman design reference mission with strawman payload
  - Technology development needs
  - Cost requirements assessment
- NASA needs to initiate technology development for candidate large missions so that technology will be ready when needed.
  - Technology needs to be sufficiently mature when it is time to start the highest priority large mission in the 2020 Decadal Survey.
  - The next large mission after WFIRST could be started when funding becomes available as WFIRST approaches launch in the early or mid-2020s.



# Preparing for the 2020 Decadal Survey

## Large Mission Concepts

The initial short list (in alphabetical order):

- **FAR IR Surveyor** – The Astrophysics Visionary Roadmap identifies a Far IR Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.
- **Habitable-Exoplanet Imaging Mission** – The 2010 Decadal Survey recommends that a habitable-exoplanet imaging mission be studied in time for consideration by the 2020 decadal survey.
- **UV/Optical/IR Surveyor** – The Astrophysics Visionary Roadmap identifies a UV/Optical/IR Surveyor as contributing through improvements in sensitivity, spectroscopy, high contrast imaging, astrometry, angular resolution and/or wavelength coverage. The 2010 Decadal Survey recommends that NASA prepare for a UV mission to be considered by the 2020 Decadal Survey.
- **X-ray Surveyor** – The Astrophysics Visionary Roadmap identifies an X-ray Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.



# Preparing for the 2020 Decadal Survey

## Large Mission Concepts

### Part A – 2015

- Identify a small set of candidate large mission concepts to study
  - NASA draws a small set of candidate mission concepts from existing roadmap and strategic documents
  - Incorporate community input through the three Astrophysics Program Analysis Groups (PAGs)

### Part B – 2016-2019

- Initiate studies
  - Includes community-based Science and Technology Definition Teams
- Conduct studies
  - Includes NASA Center-provided engineering teams
- Identify technology requirements to motivate early technology development
  - Enables funding through existing Astrophysics technology programs
- Deliver results to 2020 Decadal Survey committee

*Planning for the 2020 Decadal Survey: An Astrophysics Division White Paper*  
available at <http://science.nasa.gov/astrophysics/documents>