Astrophysics Division and Exoplanet Exploration Program Overview

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ExoPAG-9
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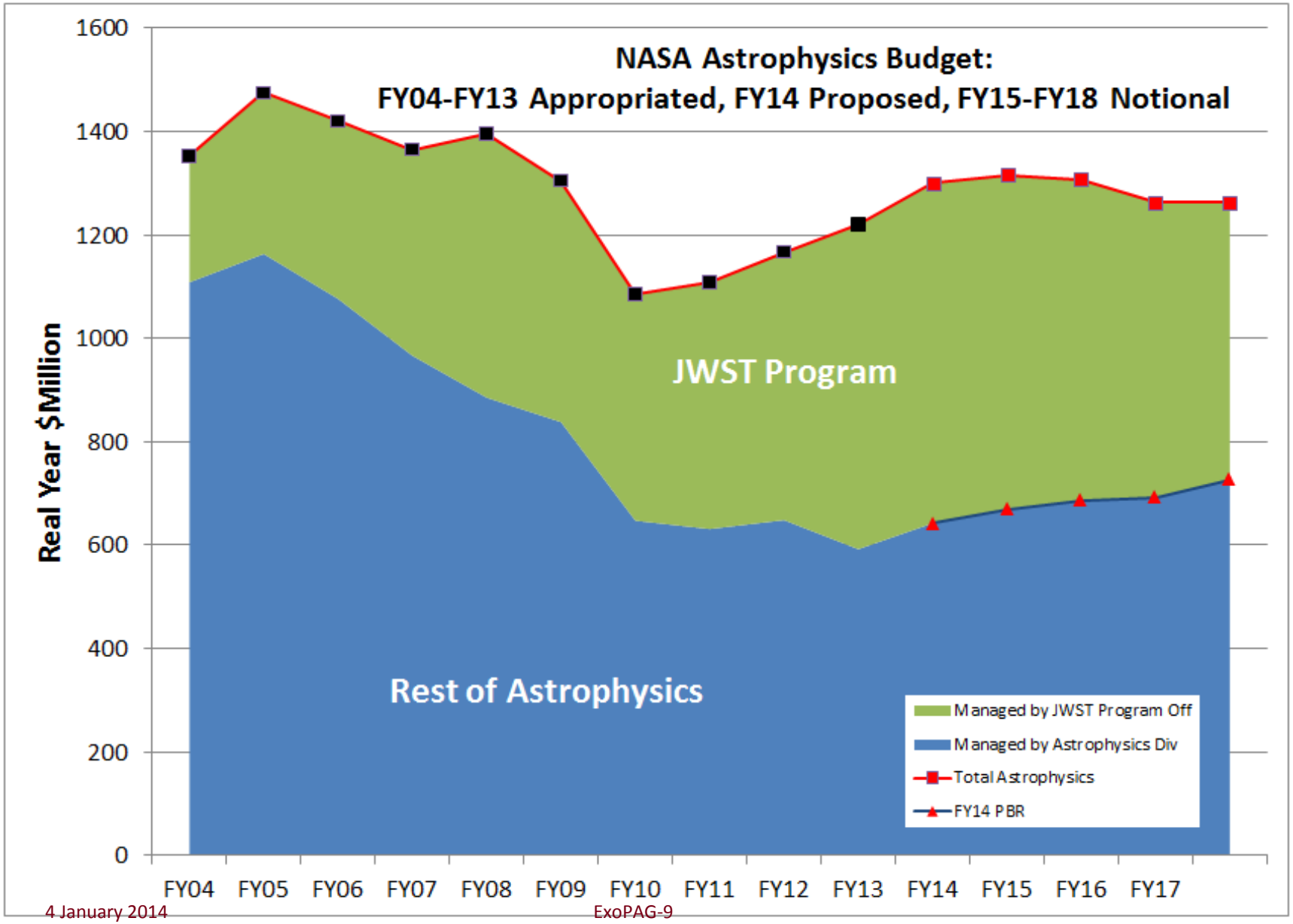

NASA Astrophysics Budget:
FY04-FY13 Appropriated, FY14 Proposed, FY15-FY18 Notional
Real Year $Million
1600
1400
1200
1000
800
600
400
200
0
JWST Program
Rest of Astrophysics
Managed by JWST Program Off
Managed by Astrophysics Div
Total Astrophysics
FY14 PBR
FY04
FY05
FY06
FY07
FY08
FY09
FY10
FY11
FY12
FY13
FY14
FY15
FY16
FY17

FY13 Budget Appropriation

- Congress appropriated $659M for Astrophysics & $628M for JWST.
  - Matched President's budget request before sequestration.
  - Rescission (~1.8%), Sequestration (~5%), and other budget adjustments resulted in an FY13 Astrophysics budget significantly lower.
  - Astrophysics ended at $617M ($42M reduction) & JWST ended at $628M for FY13.
- Astrophysics made reductions totaling $42M (6.4%) in the following areas.
  - Reduced carry-over for operating missions, includes rephasing of GO funds.
  - Rephased unneeded FY13 reserves for developing missions.
  - Rephased R&A funding until FY14 for some PIs, reduced selections.
  - Slowed down development of current and future Explorers.
  - Postponed needed upgrades in infrastructure programs.
  - Downstream impacts include.
    - *Lowered R&A selection rates in 2013 (for FY14 funding).*
    - *Delays in future Explorer AOs.*
    - *Other reductions in FY14 where funding requirements were deferred.*

FY14 Budget Appropriation

- President requested $642M for Astrophysics and $658M for JWST.
  - Request includes full funding required for JWST; new projects for TESS, NICER, Euclid; mission extensions per 2012 Senior Review; core funding for research and suborbital projects; planning budget wedge for strategic mission starting in FY17.
  - Request includes no funding for E/PO.
- Continuing resolution through January 15, 2014, is at FY13 post-sequestration level.
  - JWST is prioritized by NASA and will receive the funding required to maintain progress toward a 2018 LRD per the new baseline plan.
- Budget agreement sets FY14 and FY15 budget levels.
  - Astrophysics budget for FY14 is still TBD, but likely to be between President's Request ($642M) and FY13 post-sequestration ($617M).
  - Our current plans for missions and R&A follow the President's Request, so reductions and deferrals in some programs are expected.

Astrophysics Budget Strategy

- Use the scientific priorities of the 2010 Decadal Survey to guide strategy and inform choices.
- There is inadequate available budget to implement the 2010 Decadal Survey recommendations as written.
- A top goal is to be prepared to start a new strategic NASA Astrophysics mission to follow JWST as soon as funding becomes available, while continuing to advance Decadal Survey science during the interim.
  - WFIRST-AFTA (WFIRST using existing 2.4 m telescopes)
  - Moderate missions ("probes") derived from the science objectives of the prioritized missions and recommendations in the 2010 Decadal Survey are are being studied, in addition to a large mission (WFIRST), to be prepared for a mid-decade decision.
- In the absence of new missions, progress against decadal priorities is maintained through the core program: research and analysis (R&A), supporting and enabling technology development, operation of existing missions and their GO programs, the suborbital programs, and Explorer opportunities.
- As appropriate, collaborate with international partners to realize Decadal Survey priorities and recommendations.
  - Partner on ESA's Euclid mission (complements WFIRST commitment)
  - Partner on ESA's L2 X-ray observatory (responds to IXO recommendation)
  - Partner on ESA's L3 gravitational wave observatory (responds to LISA recommendation)

Implementing the Decadal Survey

FY2012	FY2013	FY2014	FY2015	FY2016	FY2017

Spring 2013: Begin AFTA studies following Administrator's decision

Identified SDT studies:
Versions of WFIRST (2012)
Exoplanet probes (2013)
~~X-ray probe (2013)~~ (halted)

Spring 2014: NRC study of AFTA SDT report

Winter 2015: Final SDT reports to NASA and CAA; CATE on each

Spring 2015: NRC study of all SDT reports resulting in a NRC letter report

Initiate NRC Mid-Decade Review

Complete NRC Mid-Decade Review

Revise plans as necessary in response to Mid-Decade Review report

Formulation new start for strategic mission

Agency Decision Point

Start Pre-formulation for new strategic mission
- Directed/Focused technology development

Agency Decision Point

Astrophysics Implementation Plan (CY2012)	Astrophysics Roadmap (CY2013)

ESA's L2/L3 process

Directed Technology investments for prime candidate

Technology Investments through SAT for prioritization

Technology Investments through SAT for 2020 Decadal Survey

Continuing advice from the Committee on Astronomy and Astrophysics on decadal survey implementation

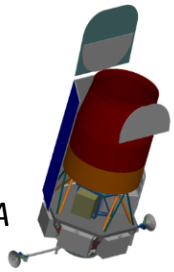
The Exoplanet Exploration Program

Exploring *How the Universe Works*
Discovering *and Characterizing Exoplanets*
Searching *for Signs of Life in the Galaxy*

Space Missions and Mission Studies

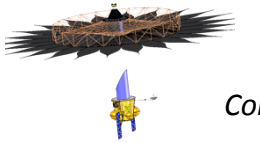
Kepler

AFTA

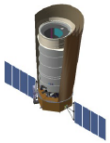


Probe-Scale:

External Occulter (Starshade)



Coronagraph

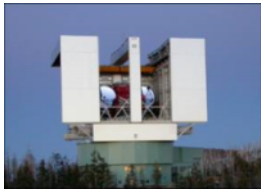


Public Engagement

Supporting Research & Technology

Key Sustaining Research

Keck Single Aperture Imaging and RV



Large Binocular Telescope Interferometer

Technology Development

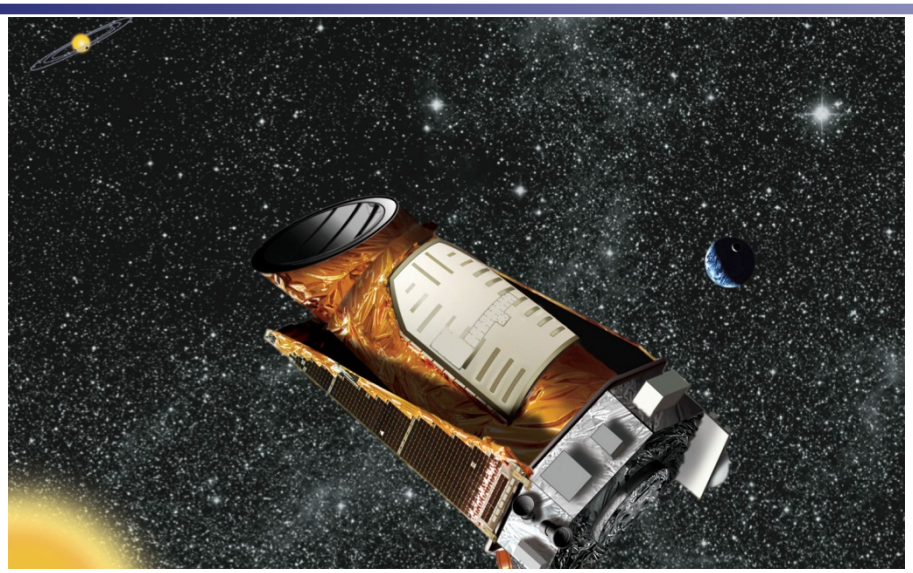
High Contrast Imaging

Deployable Star Shades

Archives, Tools & Professional Education

NASA Exoplanet Science Institute

Kepler
Kepler Space Telescope



- **NASA's first space mission dedicated to the search for extrasolar planets, or exoplanets**
- **PI:** W. Borucki, NASA Ames Research Center
- **Launch Date:** March 6, 2009
- **Payload:** 0.95-meter diameter telescope designed to measure the tiny dimming that occurs when an orbiting planet passes in front of ('transits') a star
- **Scientific objectives:**
  - conduct census of exoplanet systems
  - explore the structure and diversity of extrasolar planetary systems
  - determine the frequency of habitable, Earth-sized planets in our galaxy

Exoplanet Exploration Program

CURRENT STATUS:

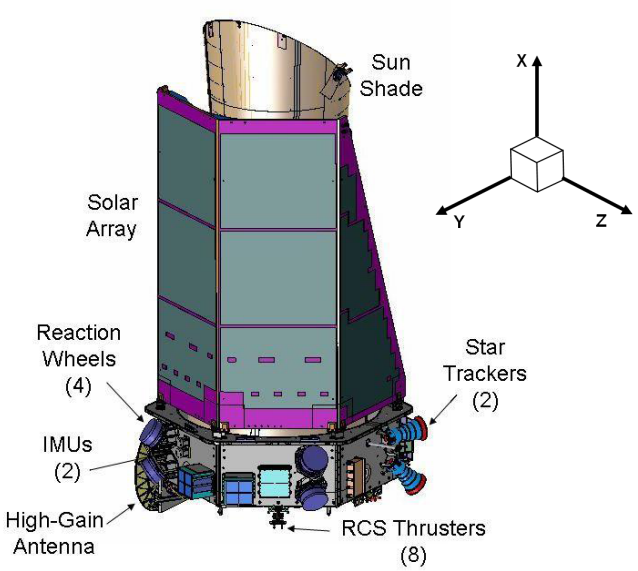
- Continuously monitored 100 sq. deg. field in constellations of Cygnus and Lyra for 4+ years
- Analysis of first 3 years of Kepler data has revealed:
  - 3538 exoplanet candidates orbiting 2658 unique stars
  - 199 candidates confirmed as planets to date
  - More than 100 planets discovered in their star's "habitable zone"—the region in the planetary system where liquid water might exist on the surface of a planet
  - two dozen of the habitable zone planet candidates are less than twice the size of the Earth
- Analysis of the full (4+ year) Kepler data set ongoing
- Spacecraft suffered failure of 2 reaction wheels in July 2012 and May 2013:
  - Only 2 functional reaction wheels remain
  - Not sufficient to maintain precise pointing on the Kepler field
- Project has developed strategy for a new science mission that requires only 2 reaction wheels (see http://www.nasa.gov/kepler/a-sunny-outlook-for-nasa-keplers-second-light)
- New mission concept will be proposed to the 2014 Astrophysics Senior Review

Kepler – Primary Mission Closeout

- After 4+ years of high precision photometry, primary data collection is complete. But…
- Closeout of the primary Kepler mission requires:
  - Data processing/analysis of the full 4+ year data set
  - Finalization of the legacy archive, data products, and tools that will ensure the continued scientific value of the data set.
- Closeout activities will include:
  - Installation of final pipeline capabilities
  - Final uniform processing of complete data set
  - Archiving and documentation of data products including:
    - *Pixel files, light curves, DV reports, final TCE and KOI lists, community tools*
  - Assessment of detection reliability and completeness
  - Final ground-based follow-up observations
- The scope, schedule, and budget profile for Kepler primary mission closeout activities will depend on the outcome of the Senior Review regarding continued spacecraft operations.

Kepler 2-Wheel Operations

- Pointing considerations:
  - Remaining wheels control about Y & Z axes
  - Thruster firings inject momentum about the X axis (the optical axis of telescope)
  - Solar pressure represents a disturbing force
  - Maximum stability occurs when the spacecraft is pointed in its orbital plane, where the sun remains in the XY-plane, i.e. the ecliptic plane.
  - Pointing in the ecliptic plane permits scientific observation of fields for up to ~75 days.
  - Solar torque around the X-axis of the spacecraft would necessitate rolling the spacecraft to compensate on an ~daily basis → costly in terms of fuel usage and science data continuity.

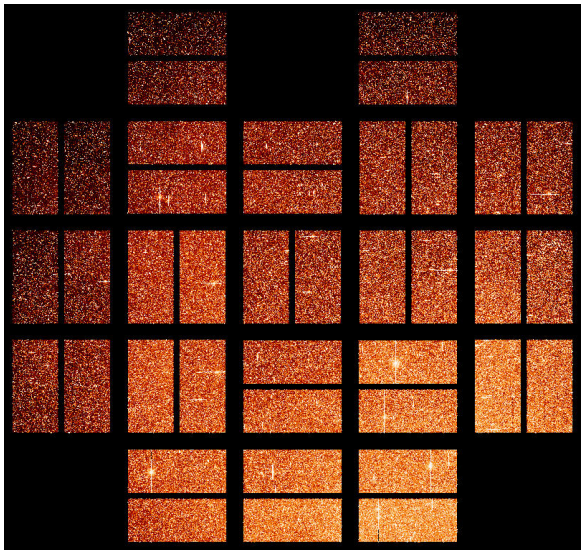


- Ecliptic plane pointings offer the only technically feasible option for continued spacecraft operations.
- **A determination of whether continued operation of the spacecraft is justified within the Division's limited resources for MO&DA will be based on the recommendations of the 2014 Senior Review.**

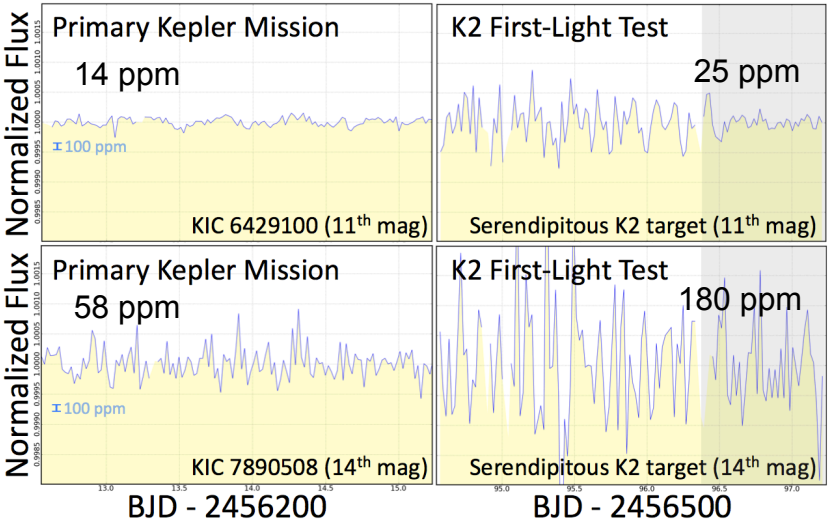
Kepler 2-Wheel Operations

Kepler project's concept for 2-wheel mission ops

- Observe 4-6 different fields per year (campaigns)
- Observe 10,000 to 20,000 targets per field
- Use 30 minute & 1 minute cadence
- Photometric Precision goal <300 ppm
- Observe each field for a minimum of 40 days, 70-80 days preferred
- Deliver data products to public archive

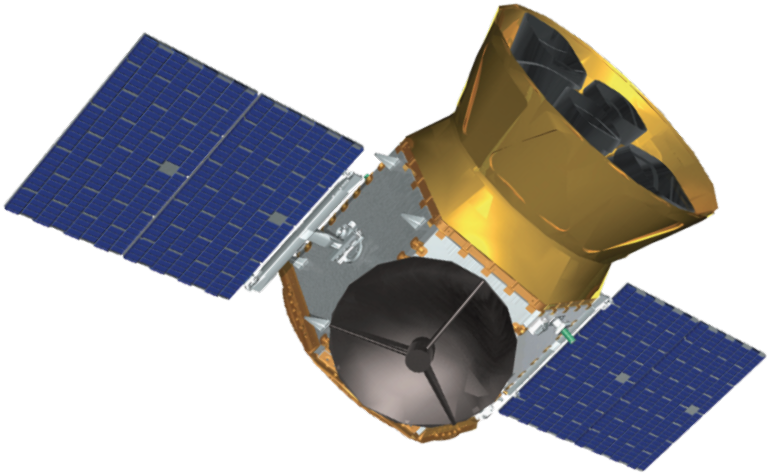


First "K2" Full Frame Image



- **2-Wheel photometric performance.** Comparison of (left) prime mission and (right) uncalibrated, 2-wheel light curves shows the performance of the photometer over this 3-day period came with a factor of 2-3 of the primary mission performance.

TESS
Transiting Exoplanet Survey Satellite



Standard Explorer (EX) Mission

PI: G. Ricker (MIT)

Mission: All-Sky photometric exoplanet mapping mission.

Science goal: Search for transiting exoplanets around the closest and brightest stars in the sky.

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

Operations: 2017 launch with a 2-year prime mission

CURRENT STATUS:

- Downselected April 2013.
- Major partners:
  - PI and science lead: MIT
  - Project management: NASA GSFC
  - Instrument: Lincoln Labs
  - Spacecraft: Orbital Science Corp
- Tentative launch readiness date August 2017.
- High-Earth elliptical orbit (17 x 58.7 Earth radii).
- Development progressing on plan.
  - System Requirements Review planned for February 2014.
  - Confirmation Review, for approval to enter implementation phase, is planned for Fall 2014.

Exoplanet Direct-Imaging STDTs

In Summer 2013, the Exoplanet Exploration Program (ExEP) established two Science and Technology Definition Teams (STDTs) to study concepts for a potential future probe-class (total mission cost <$1B) strategic exoplanet direct imaging mission.

- EXO-C – probe-class mission concept based on an internal coronagraph (Chair: Karl Stapelfeldt, GSFC)
- EXO-S – probe-class mission concept based on an external occulter or starshade (Chair: Sara Seager, MIT)

Engineering and logistical support for the Exoplanet STDTs is provided by the Exoplanet Exploration Program Office at JPL.

The goal of these STDTs will be to establish science requirements and investigation approaches, identify technology development needs, and develop a credible and implementable design reference mission concept.

Status and details of the progress of these STDTs will be provided by ExEP Program Manager Gary Blackwood in next presentation .

Upcoming Exoplanet Exploration R&TD Opportunities

Upcoming solicitations for the support of exoplanet exploration research and technology development include:

- Astrophysics Research & Analysis (APRA) program (ROSES 2013, App. D.3).
  - The supporting technology element of APRA supports basic research into technologies for exoplanet exploration in the TRL 1 - 3 range. Suborbital investigation addressing exoplanet science are also solicited under APRA.
  - Deadline for proposals: **21 March 2014**
- Technology Development for Exoplanet Missions (TDEM) element of the Strategic Astrophysics Technology (SAT) program (ROSES 2013, App. D.8).
  - SAT/TDEM supports the maturation of technologies for Exoplanet Exploration flight missions in the rang from TRL 3 - 6.
  - Areas of emphasis includes starlight suppression technologies, technologies for wavefront sensing and control of scattered light, and system performance modeling and assessment.
  - Proposals for coronagraph technologies that are included in the directed technology development for a potential AFTA-WFIRST coronagraph are specifically excluded from the SAT 2013 solicitation. Excluded technologies are specified in the solicitation.
  - Deadline for proposals: **21 March 2014**
- Origins of Solar Systems (OSS) program.
  - OSS supports ground-based detection and characterization of explanets, and follow-up observations of Kepler exoplanet candidates.
  - Deadline for proposals: **TBA (mid- to late-May 2013**)

Upcoming Exoplanet Exploration R&TD Opportunities (continued)

- Astrophysics Data Analysis Program (ADAP).
  - The ADAP supports research whose primary emphasis is the analysis of data from NASA space astrophysics missions that are archived in the public domain at the time of proposal submission. Of particular interest to the exoplanet community, this includes data from the Kepler mission and data in the Keck Observatory Archive (KOA).
  - Deadline for proposals: **mid-May 2014**
- Future solicitations from NASA's Space Technology Mission Directorate (STMD)
  - The Astrophysics Division (and SMD, in general) has established a solid working relationship with STMD.
  - "Optical components and systems for starlight suppression [and] wavefront control" is specifically identified as an SMD/Astrophysics priority in STMD Roadmap TA08, "Science Instruments, Observatories and Sensor Systems."
  - STMD has demonstrated interest in advancing Astrophysics technology development priorities, having provided funds to support both starshade and coronagraph technology, and partnering with the Astrophysics Division on the the development of a coronagraph for a potential future AFTA-WFIRST mission.
  - STMD has also funded or co-funded technology development programs with the Astrophysics Division in high-energy and gravitational wave astrophysics.
  - Potentially relevant programs solicited under Space Technology Research Opportunities (STRO) include:
    - *Game Changing Developments (GCD)*
    - *Small Business Innovative Research (SBIR)*
    - *Technology Demonstration Missions*
    - *Early Stage Innovation (ESI)*
    - *NASA Innovative Advanced Concepts (NIAC)*

Space Technology Mission Directorate (STMD) & Technology Development Relevant to Astrophysics

Exoplanet Exploration Program

Legend

Total program budget; height scales with $

Technology Program $FY13

TRL range

STMD

NIAC $5.5M — *NASA Innovative Advanced Concepts, $250K Phase I studies*

CIF $16M — *Center Innovation Fund*

STRG $23M — *Space Technology Research Grants: Early Career Fellowships; Early Stage Innovation*

Centennial Challenges $2M

Small Business Innovative Research (SBIR)/ Small Business Technology Transfer (STTR) ~$135M

Four subtopics relevant to Astrophysics:

Topography & Reliability of MEMS Deformable Mirrors Boston Micromachines Corp.

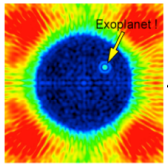
Game Changing Development $145M

under discussion

Flight Ops $10M

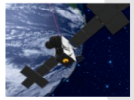
Small Spacecraft ~$20M

AFTA Coronograph



Deep Space Atomic Clock

Laser Comm Relay



Technology Demonstration Missions ~$150M

Green Propellant

APD

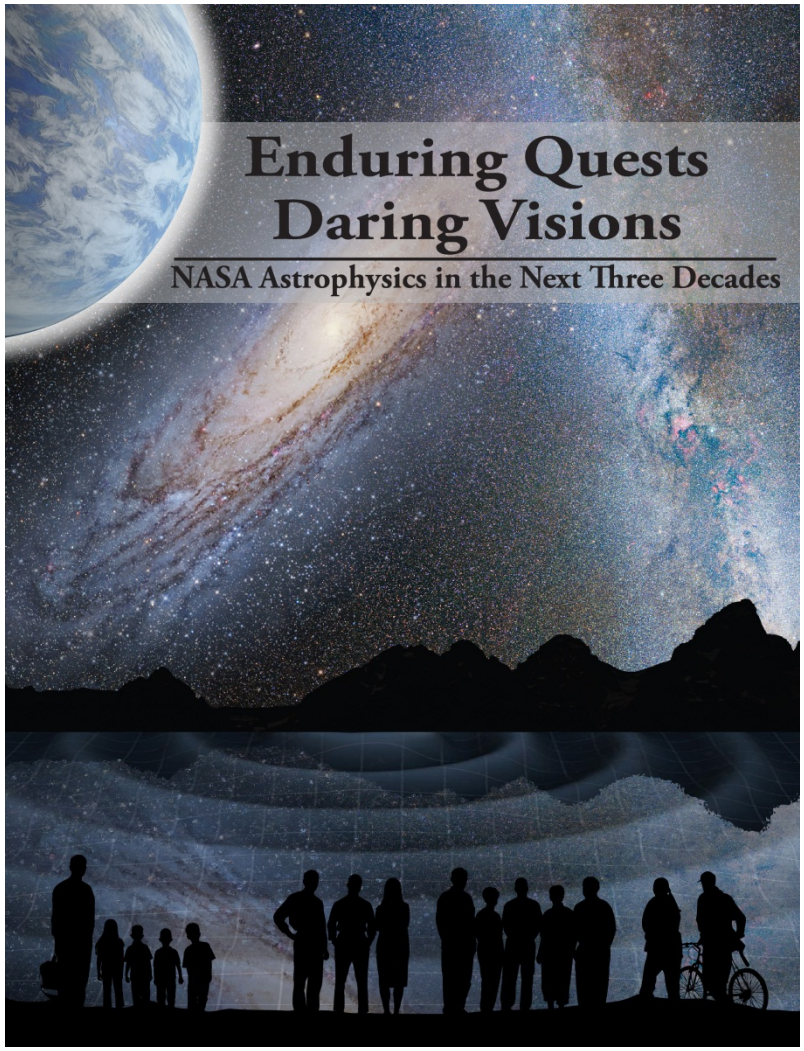
APRA $45M

PCOS-COR-ExEp SR&T $29M

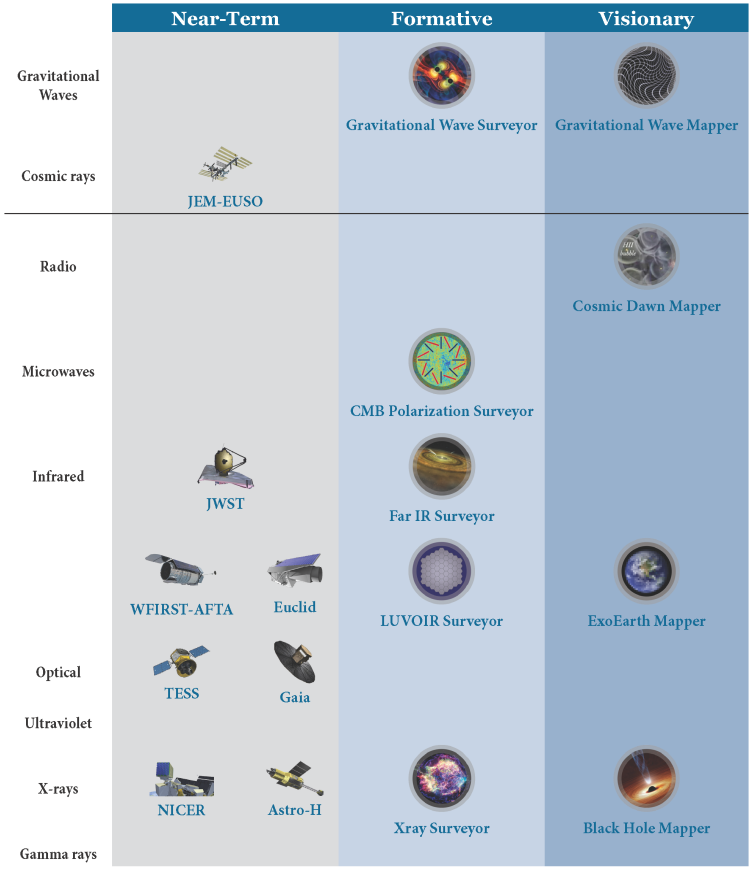
Astrophysics Decadal Priorities

1 2 3 TRL 4 5 6 7

Enduring Quests, Daring Visions



- A 30 year vision to address the enduring questions:
  - Are we alone?
  - How did we get here?
  - How does the universe work?



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