Astrophysics Program Analysis Groups
AAS 223rd Meeting
Washington, DC
January 5, 2014

Paul Hertz
Director, Astrophysics Division
Science Mission Directorate

This presentation is posted at
http://science.nasa.gov/astrophysics/documents/
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

ASTROPHYSICS

Decadal Survey Missions

1990
1999
2003
2001
2010

LRD: 2018
Decadal Survey JWST

LRD: 2020s
Decadal Survey WFIRST

1982 Decadal Survey Spitzer
1991 Decadal Survey Chandra
1999
1972 Decadal Survey Hubble
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
## Community Participation

### COPAG
- Chair: Ken Sembach
- Executive Cmte: 10 members
- SAGs: 6 Active
- Website: [http://cor.gsfc.nasa.gov/copag](http://cor.gsfc.nasa.gov/copag)

### ExoPAG
- Chair: Scott Gaudi
- Executive Cmte: 11 members
- SAGs: 3 Active
- Website: [http://exep.jpl.nasa.gov/exopag](http://exep.jpl.nasa.gov/exopag)

### PhysPAG
- Chair: John Nousek
- Executive Cmte: 13 members
- SAGs: 5 Active
- Website: [http://pcos.gsfc.nasa.gov/physpag](http://pcos.gsfc.nasa.gov/physpag)

## Science and Technology Definition Teams (STDTs):
- AFTA use of telescope assets: 20 members
- Exoplanet Probe with Internal Coronagraph: 10 members
- Exoplanet Probe with External Occulter: 10 members
- X-ray Astrophysics Probe: 14 members [disbanded 12/12/13]

Preliminary reports from the studies are due Spring 2014.
Final reports from the studies are due in January 2015.

## Advisory Committees:
- NRC Space Studies Board (SSB)
- NRC Committee on Astronomy and Astrophysics (CAA)
- Astronomy and Astrophysics Advisory Committee (AAAC)
- NASA Advisory Council’s Science Committee (NAC SC)
- NASA Advisory Council’s Astrophysics Subcommittee (APS)
## PAG Structure

<table>
<thead>
<tr>
<th>COPAG</th>
<th>ExoPAG</th>
<th>PhysPAG</th>
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</thead>
</table>
| **Chair:** Ken Sembach  
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http://pcos.gsfc.nasa.gov/physpag |

**COPAG SAGs/SIGs include:**
- Science objectives for a 4m–8m UV/optical mission (closed)
- Technologies for a 4m-class monolithic telescope UV/optical mission w/internal coronagraph (closed)
- Technologies for an 8m-class segmented telescope UV/optical mission w/external occulter (closed)
- Technologies for a future far-IR mission
- Science objectives & technology requirements for a series of Cosmic Origins Probes
- Cosmic origins science enabled by the WFIRST-AFTA coronagraph
- Science enabled by operations overlap of HST and JWST
- Science enabled by the WFIRST-AFTA data archive
- Far infrared science and technology Science Interest Group

**ExoPAG SAGs include:**
- Debris Disks & Exozodiacal Dust (closed)
- Potential for Exoplanet Science Measurements from Solar System Probes (closed)
- Planetary Measurements Needed for Exoplanet Characterization
- Exoplanet Flagship Requirements and Characteristics (closed)
- Requirements and Limits of Future Precision Radial Velocity Measurements
- Exoplanet Probe to Medium Scale Direct-Imaging Mission Requirements and Characteristics
- Characterizing the Atmospheres of Transiting Planets with JWST and Beyond
- Preparing for the WFIRST Microlensing Survey

**PhysPAG SAGs/SIGs include:**
- Technology SAG (closed)
- Inflation Probe Science Interest Group
- Gravitational Wave Science Interest Group
- X-ray Science Interest Group
- Gamma-ray Science Interest Group
- Cosmic Ray Science Interest Group
### Present

<table>
<thead>
<tr>
<th>Missions</th>
<th>Science Roadmap</th>
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<tbody>
<tr>
<td>Fermi</td>
<td>Origin &amp; Fate</td>
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<tr>
<td>NICER</td>
<td>Cosmic Extremes</td>
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<tr>
<td>Gravitational Wave Surveyor</td>
<td>Cosmic Dawn</td>
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<td>X-ray Surveyor</td>
<td>Cosmic Dawn</td>
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<tr>
<td>ERS</td>
<td>Cosmic Dawn</td>
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<tr>
<td>WFIRST-AFTA</td>
<td>Cosmic Dawn</td>
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</tbody>
</table>

### Near Term

<table>
<thead>
<tr>
<th>Missions</th>
<th>Science Roadmap</th>
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<tbody>
<tr>
<td>Chandra &amp; XMM-Newton</td>
<td>Local Galaxies</td>
</tr>
<tr>
<td>LSST</td>
<td>Nearby Galaxies</td>
</tr>
<tr>
<td>X-ray Surveyor</td>
<td>Map the Cosmos</td>
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<tr>
<td>James Webb Space Telescope</td>
<td>Map the Cosmos</td>
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<tr>
<td>Far Infrared Surveyor</td>
<td>Map the Cosmos</td>
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<tr>
<td>CMB Polarization Surveyor</td>
<td>Map the Cosmos</td>
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</tbody>
</table>

### Formative

<table>
<thead>
<tr>
<th>Missions</th>
<th>Science Roadmap</th>
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<tbody>
<tr>
<td>Hubble</td>
<td>The Exoplanet Zoo</td>
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<td>Spitzer</td>
<td>The Exoplanet Zoo</td>
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<td>Herschel</td>
<td>The Exoplanet Zoo</td>
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<td>ALMA</td>
<td>The Exoplanet Zoo</td>
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<tr>
<td>WFIRST-AFTA</td>
<td>The Exoplanet Zoo</td>
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### Visionary

<table>
<thead>
<tr>
<th>Missions</th>
<th>Science Roadmap</th>
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<tbody>
<tr>
<td>Kepler</td>
<td>The Exoplanet Zoo</td>
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<tr>
<td>TESS</td>
<td>The Exoplanet Zoo</td>
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<tr>
<td>James Webb Space Telescope</td>
<td>The Exoplanet Zoo</td>
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<tr>
<td>LUVOIR Surveyor</td>
<td>The Exoplanet Zoo</td>
</tr>
<tr>
<td>ExoEarth Mapper</td>
<td>The Exoplanet Zoo</td>
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</table>

**Role of PAGs**

- **Present:**
  - Measure dark energy & history of cosmic growth
  - Probe the epoch of inflation
  - Completely characterize the CMB
  - Constrain neutron star equation of state
  - Understand black-hole-powered engines
  - Image sources detected by aLIGO

- **Near Term:**
  - Map black holes using gravitational waves
  - Measure black hole masses & spins
  - Image the shadows of black hole event horizons

- **Formative:**
  - Chart supermassive black hole mergers
  - Search for eletroweak-era gravitational waves

- **Visionary:**
  - Measure structure at reionization
  - Measure cosmic expansion history with standard sirens
  - Image the shadows of black hole event horizons

**Missions**

- Fermi
- NICER
- Gravitational Wave Surveyor
- X-ray Surveyor
- ERS
- WFIRST-AFTA
- Hubble
- Chandra & XMM-Newton
- LSST
- James Webb Space Telescope
- Far Infrared Surveyor
- CMB Polarization Surveyor
- Spitzer
- Herschel
- ALMA
- Kepler
- TESS
- James Webb Space Telescope
- LUVOIR Surveyor
- ExoEarth Mapper
Role of PAGs

• A PAG enables direct regular communication with the community through public meetings that give the community opportunities to provide its scientific and programmatic input.
  - A PAG provides findings of analyses to NASA through the NASA Advisory Council within which the PAG Chair is a member of the Astrophysics Subcommittee.

• A PAG is responsible for soliciting and coordinating community input into the development and execution of a NASA Program.
  - The PAG Chair and the PAG Executive Committee are appointed members whose responsibilities include collecting and summarizing community input with subsequent reporting to NASA SMD via the NAC.
  - The full PAG consists of all members of the community who participate in the PAG’s open meetings.

• The PAG may choose to organize sub-groups (e.g., Science Analysis Groups - SAGs and/or Science Interest Groups - SIGs) to deal with specific issues and report their findings to the full group.
  - A SAG is typically tasked with reporting on a specific issue, and when the analysis of that issue is complete the SAG is disbanded.
  - A SIG is typically tasked with collecting community input from a specific community on a longer-term basis.

Tuesday 2:00 – 3:30
Session 234: Reports from NASA's Astrophysics Program Analysis Groups (Potomac Ballroom A)
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 probe(s) (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

**Agency Decision Point**

Complete NRC Mid-Decade Review

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

**Agency Decision Point**

Formulation new start for strategic mission

**Directed Technology investments for prime candidate**

**Technology Investments through SAT for 2020 Decadal Survey**

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

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**ESA’s L2/L3 process**

Astrophysics Implementation Plan (CY2012)

Astrophysics Roadmap (CY2013)
### Progress Toward Decadal Survey Priorities

<table>
<thead>
<tr>
<th>The President’s Budget Request for FY14 supports</th>
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<tbody>
<tr>
<td><strong>L1. WFIRST</strong></td>
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<tr>
<td><strong>L2. Augmentation to Explorer Program</strong></td>
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<tr>
<td><strong>L3. LISA</strong></td>
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<tr>
<td><strong>L4. IXO</strong></td>
</tr>
<tr>
<td><strong>M1. New Worlds Technology Development Program</strong></td>
</tr>
<tr>
<td><strong>M2. Inflation Probe Technology Development Program</strong></td>
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</tbody>
</table>
NASA Astrophysics Programs

Recently Completed
Planck 2013
Herschel 2013
GALEX 2013

XMM-Newton (ESA) 12/10/1999
Swift 11/20/2004
Suzaku (JAXA) 7/10/2005
Euclid (ESA) 2020
Spitzer 8/25/2003
Astro-H (JAXA) 2015
Fermi 6/11/2008
Hubble 4/24/1990
Kepler 3/6/2009
JWST 2018
NicER (on ISS) 2016
Chandra 7/23/1999
NuSTAR 6/13/2012
TESS 2017
LISA Pathfinder (ESA) 2015
SOFIA Full Ops 2014
**JWST**
James Webb Space Telescope

**CURRENT STATUS:**
- Project has entered its long and challenging Integration and Test activities.
- Technical progress continues to be significant.
  - Instruments are delivered and in integration & test phase.
  - All optics are complete (primary segments, secondary, tertiary and fine steering mirrors) and delivered to GSFC.
  - Telescope wings are complete; backplane support fixture and center section are complete.
  - Spacecraft completing reviews leading to spacecraft Critical Design Review (Jan 2014).
- Project is performing within the budget, to schedule.
  - Government shutdown did not impact October 2018 launch date.
- FY14 is the peak funding year with many critical activities.

**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
JWST
James Webb Space Telescope

- JWST remains on schedule for its October 2018 launch
- JWST Town Hall: Wednesday 12:45 pm in Potomac Ballroom A

NIRCam
MIRI
FGS/NIRISS
NIRSpec
Euclid
A visible and near-infrared telescope to explore cosmic evolution

CURRENT STATUS:
• Currently in implementation phase.
• ~50 U.S. scientists are members of the Euclid Science Team that will analyze the data, and make maps of the sky.
• First experimental manufacturing run for the Euclid near-infrared detectors to complete in FY 2014 (ESA).
• NASA will initiate the buy for the flight infrared detectors in FY 2014.
• NASA will test and characterize the near-IR flight detectors.

• ESA Cosmic Vision 2015-2025 Mission, M-Class with NASA participation.
• 1.2-m mirror, visible & near-IR images, spectra
• Launch Date: Mar 2020, 5 year prime mission
• Science Objectives:
  - Euclid will look back 10 billion years into cosmic history.
  - Probe the history of cosmic expansion (influenced by dark energy and dark matter) and how gravity pulls galaxies together to form the largest structures.
  - The shapes of distant galaxies appear distorted because the gravity of dark matter bends their light (gravitational lensing). Measuring this distortion tells us how the largest structures were built up over cosmic time.
  - Measuring how strongly galaxies are clumped together tells us how gravity influences their motions, and how dark energy has affected the cosmic expansion.
WFIRST – AFTA
Widefield Infrared Survey Telescope with Astrophysics Focused Telescope Assets

CURRENT STATUS:
• May 2013, NASA Administrator Bolden directed Astrophysics Division to study WFIRST-AFTA and preserve option for FY17 new start if budget is available
  - No decision expected before early 2016
• Currently in pre-formulation phase
  - NRC study in early 2014
  - SDT final report due Jan 2015
• Maturing key technologies to TRL 5 by FY17 and TRL 6 by FY19
  - Infrared detectors
  - Internal coronagraph for exoplanet characterization

Mission description:
• #1 Large-Scale Priority: Widefield infrared survey telescope for Dark Energy, Exoplanets, IR Surveys
• #1 Medium-Scale Priority: Development and demonstration of technology for direct imaging and characterization of exoplanets

Top priority in 2010 Decadal Survey
Study Baseline Payload:
- 2.4m existing telescope assets
- Widefield imager
- Coronagraph
Science objectives:
- Hubble-quality imaging over 200x the field
- Comprehensive study of dark energy
- Systematic census of outer planets
- Coronagraphic imaging of exoplanets
- 25% time for community competitive selected GO program
- Enhancing JWST science

WFIRST Town Hall: Wednesday 6:30 pm in National Harbor 3
Plan for WFIRST-AFTA Preformulation
Widefield Infrared Survey Telescope using Astrophysics Focused Telescope Assets
WFIRST – AFTA Coronagraph

• Community AFTA coronagraph working group (ACWG) conducted an open, technical evaluation using public evaluation criteria in a series of workshops and telecons since July 2013, reaching a broad consensus on the basis for the decision
• Three strong technologies emerged, spanning the risk/performance continuum
• The independent Technical Analysis Committee (TAC) concurred with the basis and with findings of ACWG

Decision:
• **Primary Architecture:** Occulting Mask Coronagraph (OMC) that includes masks for Shaped Pupil Coronagraph (SPC) and Hybrid Lyot Coronagraph (HLC)
• **Backup Architecture:** Phase-Induced Amplitude Apodization Complex Mask Coronagraph (PIAACMC)
• Combination best minimizes risk, preserves options to protect the project schedule, advances technologies, and preserves possibilities of increased science yield
• Plan for Recommendation to reach TRL 5 is feasible (technically) and credible within existing resources (schedule, cost)
ESA’s New Vision to Study the Invisible Universe

• The hot energetic Universe and the search for elusive gravity waves will be the focus of ESA’s next two large science missions.

• The science theme “the hot and energetic Universe” was selected for L2, and expected to be pursued with an advanced X-ray observatory.
  - Launch date ~2028

• The L3 mission will study the gravitational Universe, searching for ripples in the very fabric of space-time created by celestial objects with very strong gravity, such as pairs of merging black holes.
  - Launch date ~2034
  - Will require development of a spaceborne gravitational wave observatory or extreme precision ‘gravitometer’.

• NASA has expressed a strong interest to ESA in contributing to ESA’s next large astrophysics missions if they are responsive to the U.S. Decadal Survey
  - The U.S. Decadal Survey recommended an international partnership for a gravitational wave observatory and an X-ray observatory.

• NASA and ESA will have a bilateral meeting, on January 8-10, 2014 in D.C., to discuss a potential NASA contribution.
Space Technology Mission Directorate Contributes to Astrophysics

Space Technology Mission Directorate

- Innovative Adv Concepts
- Center Innovation Fund
- Space Tech Res Grants
  - ~$45M

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

- Game Changing Development
  - ~$145M

- Small Spacecraft
- Tech Demo Missions
  - ~$20M
  - ~$150M

SMD Astrophysics Division

- APRA
- SAT

Technology Readiness Level (TRL)

1  2  3  4  5  6  7

Station Explorer for X-ray Timing and Navigation Technology
- STMD/GCD funded tech enhancement: SEXTANT development and NICER cost share
- Excellent opportunity for combined Science and Technology return

Primary goals
- Demo GPS-like navigation anywhere in the Solar System using X-ray observations of millisecond pulsars (MSPs)
- Provide 1st real-time, on-orbit demo of X-ray pulsar-based navigation (XNAV)
- Determine practical limitations of XNAV

Additional goals include cataloging/characterizing additional "beacon" MSPs and assessing feasibility of pulsar-based time transfer.
Strategic Astrophysics Technology

- Decadal Survey recommended funding for medium-term technology development be augmented.
- The SAT Program is designed to support the maturation of technologies from demonstrated feasibility (i.e., TRL 3) to where they can be incorporated into NASA flight missions (TRL 6-7).
- SAT has several components
  - Directed technology development (e.g. high contrast imaging testbeds)
  - Focused technology development (e.g. AFTA coronagraph technology)
  - Competed technology development (e.g. ROSES calls)
- SAT first offered in ROSES-09
  - Started at $8M/yr, increased to $20M now
  - More than 35 selected technology investigations to date
  - Some years impacted by changes in the astrophysics planning budget or sequestration
  - Balance between competed and directed has evolved with commitment to having AFTA ready for a formal start by FY2017
- Priorities given to technologies required for future strategic missions
  - WFIRST, GW observatory, X-ray observatory, exoplanet characterization, CMB polarization, …
- SAT will be fully offered in ROSES-14 with ~$6M in new awards
Herschel cryogen depleted in April 2013

Planck mission completed in October 2013


Launch in 2020
Launch in 2018
Launch in 2017
Launch in 2016
Launch in 2015
Launch in 2014
Launch in 2015
Launch in 2016
Launch in 2017
Launch in 2018
Launch in 2020
**Monday**

12:45 – 1:45  Session 122: Kepler Mission Town Hall (Potomac Ballroom C)
6:30 – 8:00  SOFIA Mission Update (Maryland Ballroom A)

**Tuesday**

12:45 – 1:45  Session 222: NASA Town Hall (Potomac Ballroom A)
2:00 – 3:30  Session 234: Reports from NASA's Astrophysics Program Analysis Groups (Potomac Ballroom A)
6:30 – 8:00  Exoplanet Exploration Program Town Hall (National Harbor 3)

**Wednesday**

12:45 – 1:45  Session 319: Hubble and James Webb Space Telescope Town Hall (Potomac Ballroom A)
6:30 – 8:00  Session 339: Preparing for Future NASA Missions: The Strategic Astrophysics Technology Program (National Harbor 2)
6:30 – 8:00  Session 341: Wide Field Infrared Survey Telescope (WFIRST) Town Hall (National Harbor 3)

**Thursday**

10:00 – 11:30  Session 414: Science Highlights from NASA’s Astrophysics Data Analysis Program (Potomac Ballroom A)
Backup
The Big Picture

• This remains a time of scientific opportunity for NASA Astrophysics.
  - We are poised to answer the most compelling science questions.
  - The budget for NASA astrophysics, which includes JWST, is at ~$1.25B, a high level.
  - NASA continues to operate large and small space-based observatories spanning the electromagnetic spectrum, including multiple Great Observatories.
  - The James Webb Space Telescope, the highest priority of the community, is on schedule and fully funded for an October 2018 launch.
  - NASA continues to develop contributions to international missions for launch this decade.
  - NASA has downselected two new Explorer projects to begin development for launch this decade, and an Explorer AO is planned for late 2014 to select two more Explorer projects.
  - NASA continues to support individual investigators for data analysis, theory, and technology investigations through open, competitive, peer reviewed processes.
  - NASA is preparing for the strategic mission that will follow JWST.

• The budgetary future remains uncertain.
  - Priorities must be used to guide difficult budget choices.
<table>
<thead>
<tr>
<th>Program Scale</th>
<th>Recommendation</th>
<th>Response supported by FY14 President’s Budget Request</th>
</tr>
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<tbody>
<tr>
<td>Large</td>
<td><strong>WFIRST</strong></td>
<td>DRM1 and DRM2 completed in FY12; AFTA “proof of concept” DRM completed in FY13; pre-formulation and technology development (detector and coronagraph) in FY14-FY19; prepared for decision regarding new start in FY15; participating in ESA’s Euclid</td>
</tr>
<tr>
<td>Large</td>
<td><strong>Explorer</strong> Augmentation</td>
<td>Impacted by sequestration and budget reductions including cancellation of selections from FY12 MO AO; EX AO in FY11; SMEX AO NET 2014; EX AO NET 2016; each AO has a mission and a MO</td>
</tr>
<tr>
<td>Large</td>
<td><strong>LISA</strong> Technology</td>
<td>CST completed in FY12; technology supported through SAT; ST-7/LPF supported; will pursue partnership with ESA if a GW mission is selected for L2/L3 mission</td>
</tr>
<tr>
<td>Large</td>
<td><strong>IXO</strong> Technology</td>
<td>CST completed in FY12; technology supported through SAT; X-ray probe STDT starting in FY14; will pursue partnership with ESA if an X-ray mission is selected for L2/L3 mission</td>
</tr>
<tr>
<td>Medium</td>
<td><strong>New Worlds Technology</strong></td>
<td>Technology supported through APRA and SAT(TDEM); exoplanet probe STDTs started in FY13; AFTA coronagraph study completed in FY13; AFTA coronagraph technology starting in FY14; will consider partnership with ESA if an exoplanet mission is selected for L2/L3 mission</td>
</tr>
<tr>
<td>Medium</td>
<td><strong>Inflation Probe Technology</strong></td>
<td>Technology supported through APRA and SAT including multiple suborbital payloads; will consider partnership with ESA if a CMB mission is selected for L2/L3 mission</td>
</tr>
<tr>
<td>Small</td>
<td><strong>Astrophysics Theory Program Augmentation</strong></td>
<td>Impacted by sequestration and budget reductions</td>
</tr>
<tr>
<td>Small</td>
<td><strong>(Definition of) a future UV-optical space capability</strong></td>
<td>RFI in FY12; follow-on workshops FY14-FY16; technology supported through APRA, SAT, and working with STMD</td>
</tr>
<tr>
<td>Small</td>
<td><strong>Intermediate Technology Development Augmentation</strong></td>
<td>SAT program initiated in FY11 and funded for prioritized investments; funding directed toward decadal survey priorities including AFTA, probes, New Worlds, and ESA L2/L3 technologies; impacted by sequestration and budget reductions</td>
</tr>
<tr>
<td>Small</td>
<td><strong>Laboratory Astrophysics Augmentation</strong></td>
<td>Augmentation started in FY12 including selection of large consortium; future selections impacted by sequestration and budget reductions</td>
</tr>
<tr>
<td>Small</td>
<td><strong>SPICA mission (U.S. contributions to JAXA-led)</strong></td>
<td>Candidate for future Explorer Mission of Opportunity</td>
</tr>
<tr>
<td>Small</td>
<td><strong>Suborbital Program Augmentation</strong></td>
<td>Technology augmentation for balloon program; continued development of ULDB balloon platforms; ISS payload selections; impacted by sequestration and budget reductions</td>
</tr>
<tr>
<td>Small</td>
<td><strong>Theory and Computation Networks (NASA, NSF, DOE)</strong></td>
<td>Six networks competitively selected in 2013 and funded by NSF and NASA in FY14-FY16</td>
</tr>
<tr>
<td>N/A</td>
<td><strong>Additional core program augmentations</strong></td>
<td>Includes basic research and technology development, mission extensions, data analysis, N.G. Roman Technology Fellowships; impacted by sequestration and budget reductions</td>
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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 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 being studied, in addition to a large mission (WFIRST), to be prepared for a mid-decade decision.
• 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)
## Distribution of FY14 Budget Request

<table>
<thead>
<tr>
<th>Category</th>
<th>% of FY14 PBR</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>R&amp;A program elements</td>
<td>13.2%</td>
<td>includes APRA, OSS, ATP, ADAP, RTF, TCAN</td>
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<tr>
<td>Research infrastructure</td>
<td>10.2%</td>
<td>includes balloon program, Keck, LBTI, archives, astrobiology</td>
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<tr>
<td>Einstein, Hubble, Sagan Fellowships</td>
<td>2.2%</td>
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<tr>
<td>Operating missions (including GO programs)</td>
<td>Total 36.2%</td>
<td>prioritized by Senior Review</td>
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<tr>
<td></td>
<td>Hubble 15.3%</td>
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<td></td>
<td>Chandra 8.7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kepler 3.0%</td>
<td></td>
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<tr>
<td></td>
<td>Spitzer 2.6%</td>
<td></td>
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<tr>
<td></td>
<td>Fermi 2.3%</td>
<td></td>
</tr>
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<td></td>
<td>Others 4.4%</td>
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<td>SOFIA</td>
<td>13.9%</td>
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<tr>
<td>Explorer missions in development</td>
<td>12.8%</td>
<td>includes ASTRO-H, NICER, TESS</td>
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<tr>
<td>Strategic missions in development</td>
<td>2.9%</td>
<td>includes Euclid, ST-7</td>
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<td>Future Explorer missions</td>
<td>0.0%</td>
<td>no funding until next AO selection</td>
</tr>
<tr>
<td>Pre-formulation of WFIRST/AFTA</td>
<td>2.1%</td>
<td>including technology development for detectors and coronagraph</td>
</tr>
<tr>
<td>Strategic Astrophysics Technology</td>
<td>3.3%</td>
<td>directed, competed, and testbeds</td>
</tr>
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<td>Other strategic studies</td>
<td>0.7%</td>
<td>includes exoplanet probes, X-ray probe</td>
</tr>
<tr>
<td>Program management</td>
<td>2.6%</td>
<td></td>
</tr>
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</table>
2.4m Telescope with wide field-of-view

Wide-Field Instrument
- Imaging & spectroscopy over 1000s sq deg.
- Monitoring of SNe and microlensing fields
- 0.7 – 2.0 micron bandpass
- 0.28 sq deg FoV (100x JWST FoV)
- 4 filter imaging, grism + IFU spectroscopy
- 18 H4RG detectors (288 Mpixels)

Requires focused tech. development

Coronagraph (study option)
- Imaging of ice & gas giant exoplanets
- Imaging of debris disks
- 400 – 1000 nm bandpass
- $10^{-9}$ contrast
- 100 milliarcsec inner working angle at 400 nm

Requires focused tech. development

Findings of SDT
- AFTA carries out the WFIRST science program (the top ranked decadal priority).
- AFTA’s larger aperture enables astronomers to make important contributions towards many of the enduring questions listed in the decadal survey through both surveys and peer-reviewed observing programs.
- Equipped with a coronagraph, AFTA can image Jupiter and Saturn-like planets around the nearest stars. AFTA will be an essential stepping stone towards finding signs of life around nearby stars.