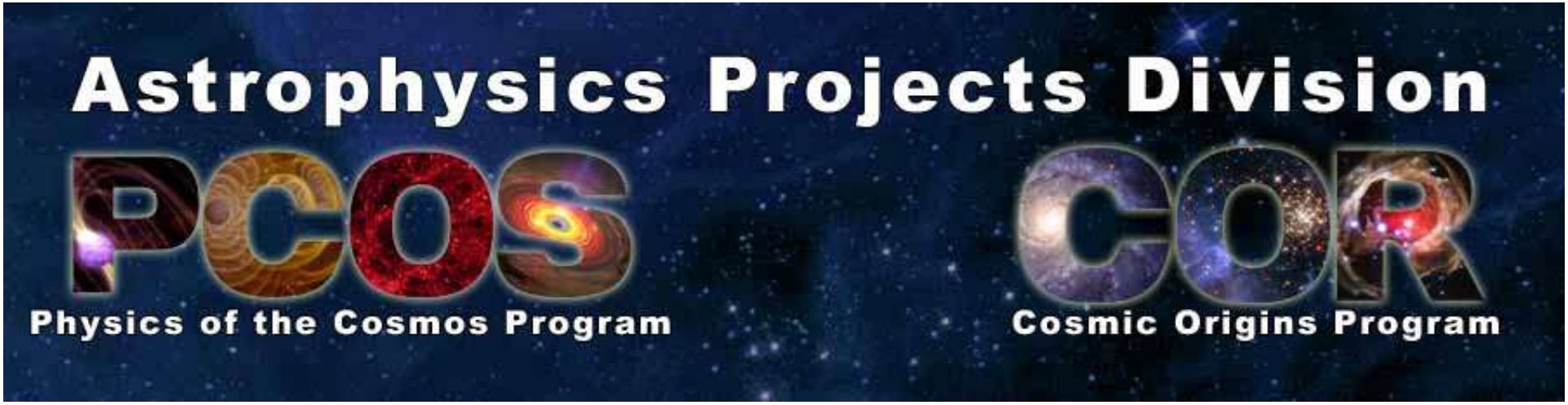


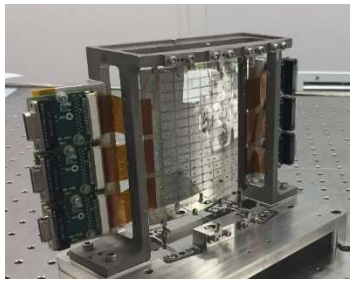
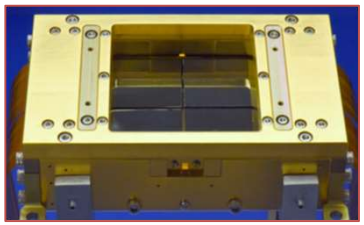
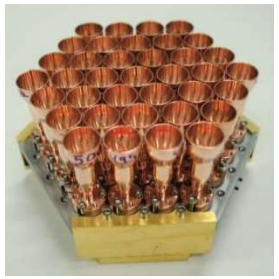
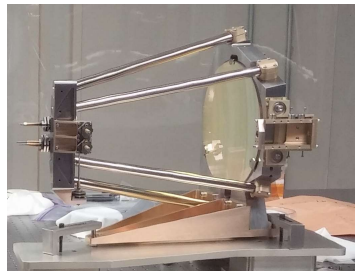
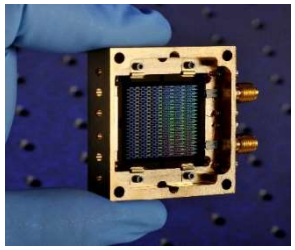
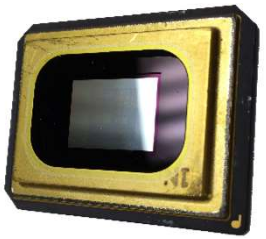
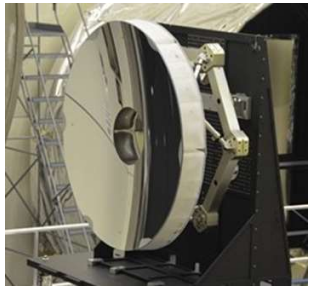
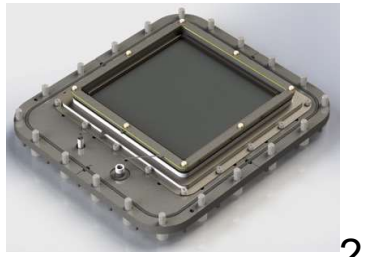
PCOS and COR Programs Technology Gaps, Prioritization, and Development

SBIR/STTR Mirror Tech Days
November 14, 2017

Program Technologists:
Harley Thronson
Thai Pham
Opher Ganel

PCOS and COR Programs Technology Focus

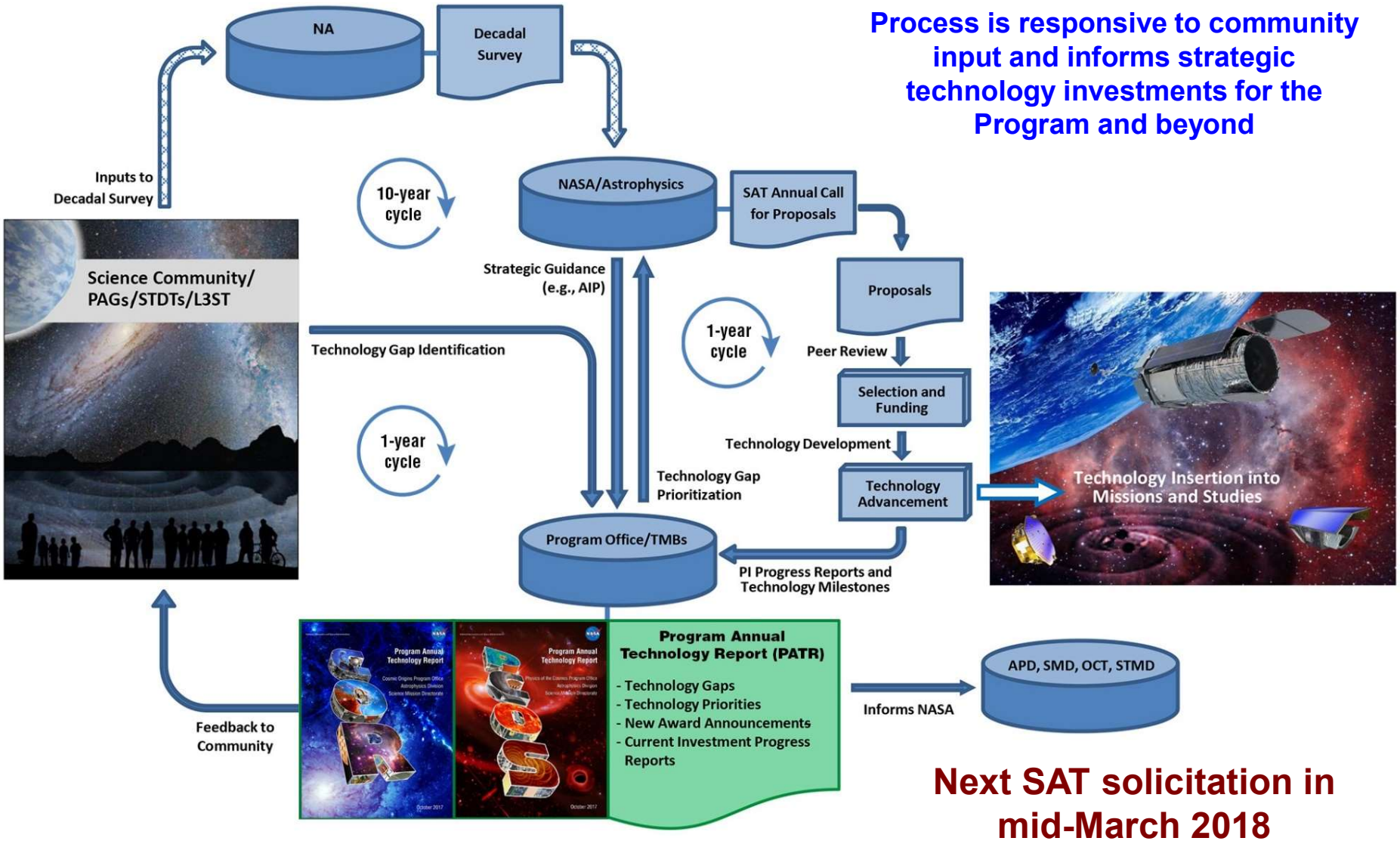
- **PCOS Technology Focus**
  - Technologies for X-ray astrophysics
  - Technologies for gravitational wave astrophysics
  - Technologies for Cosmic Microwave Background (CMB) polarization measurement
- **COR Technology Focus**
  - Next-generation detectors
  - Optical devices and coatings
  - Precision large mirror systems

Technology Gap Prioritization Objectives

- **Identify technology gaps** applicable and relevant to Program strategic objectives as described in the Astrophysics Implementation Plan (AIP), the Roadmap, and the Decadal Survey
- **Rank technology gaps** to inform Program strategic technology development planning and investments (Strategic Astrophysics Technology (SAT) and directed-funding)
- **Inform SAT solicitation** and other NASA technology development programs (APRA, SBIR, and other OCT and STMD activities) of our technology gaps
- Results inform technology developers of Program needs to help **focus technology development efforts and leverage existing technologies** when possible and not duplicate development efforts
- Process **improves transparency and relevance** of Program technology investments
- Process **informs and engage the community** to optimize Program technology development process
- **Leverage technology investments** of other organizations by defining Program strategic technology gaps and identifying NASA as a potential customer

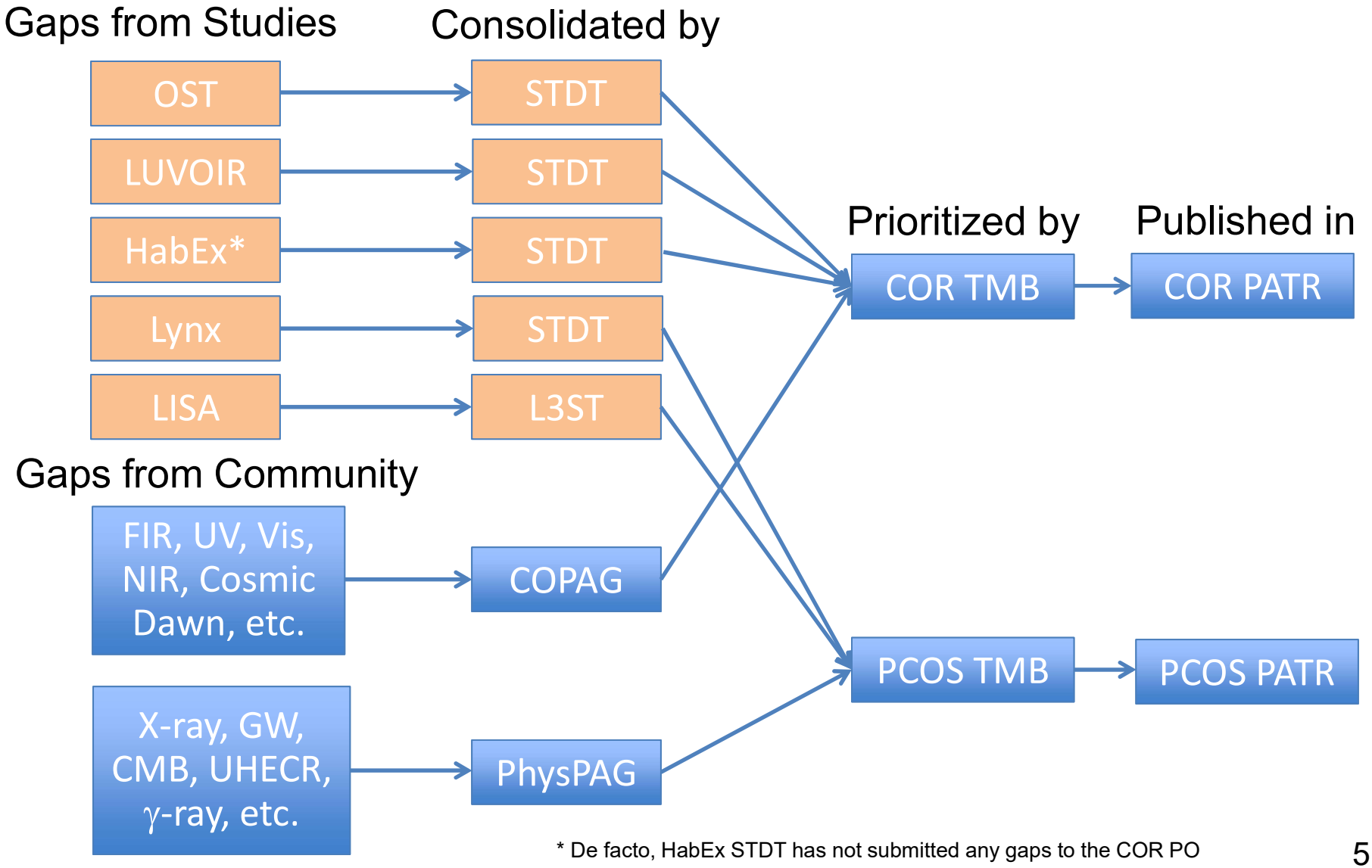
Strategic Technology Development Process



Process is responsive to community input and informs strategic technology investments for the Program and beyond

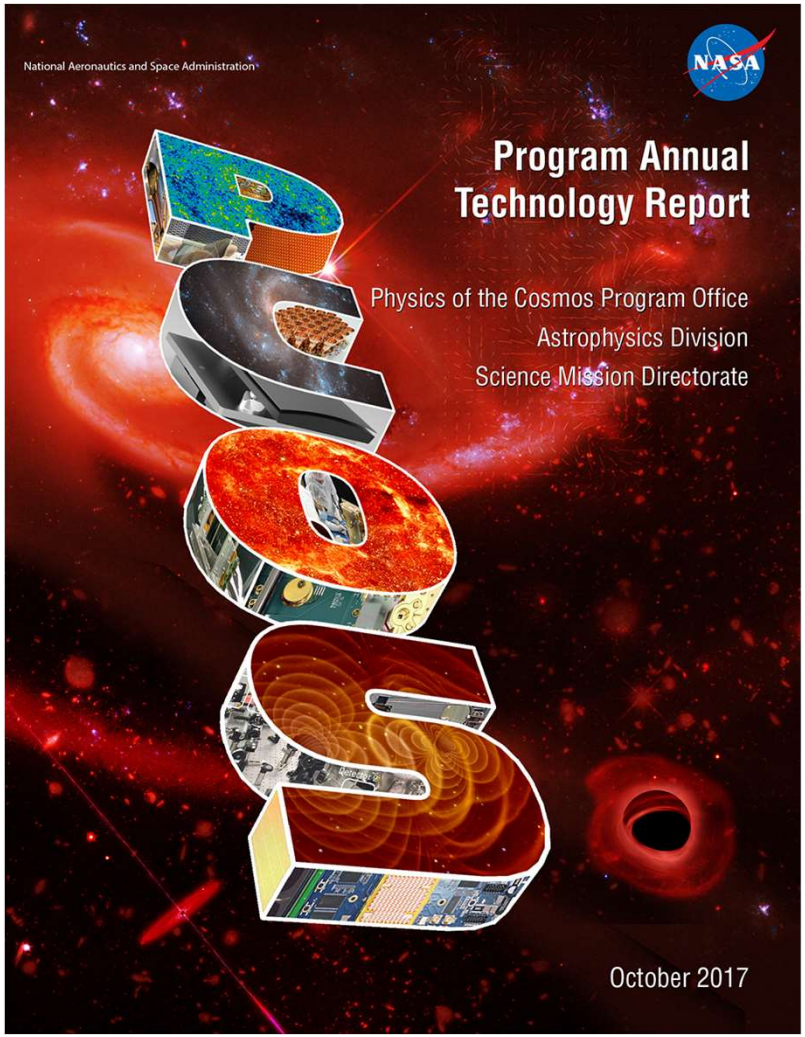
Next SAT solicitation in mid-March 2018

Origin of Gaps



* De facto, HabEx STDT has not submitted any gaps to the COR PO

2017 PCOS and COR PATRs



Available at Program websites (pcos.gsfc.nasa.gov and cor.gsfc.nasa.gov)

Prioritization and Coordination Among Program Offices

- Technology gap **prioritization is Program science-centric** (*not* mission-centric)
- We prioritize technology gaps according to community inputs based on **strategic alignment with the Program science goals, benefits and impacts to Program objectives, scope of applicability, and urgency**
- PCOS/COR/ExEP technologists coordinate during the prioritization cycle by participating in each other's prioritization process
- The POs work together to determine for each gap whether it addresses a science goal within their Program
  - If a gap provides benefits for science to more than one Program, it would be prioritized by each of the Programs, but would likely end up with different priorities due to differences in impacts, urgency, etc. for the different Programs.

2017 PCOS Technology Gaps Prioritization

	2017 PCOS Technology Capability Gaps	Science	Tech	SAT or Directed
1	Highly stable low-stray-light telescope	GW	Telescope	✓
	Low-mass, long-term-stability optical bench	GW	Optical Bench	
	Precision Microthrusters	GW	Propulsion	✓
	High-power, narrow-line-width laser sources	GW	Laser	✓
	Phase measurement subsystem (PMS)	GW	Electronics	✓
	Large-format, high-spectral-resolution, small-pixel X-ray focal plane arrays	X ray	Detector	✓
	Fast, low-noise, megapixel X-ray imaging arrays with moderate spectral resolution	X ray	Detector	✓
	High-efficiency X-ray grating arrays for high-resolution spectroscopy	X ray	Optics	✓
	High-resolution, large-area, lightweight X-ray optics	X ray	Optics	✓
	Non-deforming X-ray reflective coatings	X ray	Coating	New gap
	Long-wavelength-blocking filters for X-ray micro-calorimeters	X ray	Optics	New gap
2	Non-contact charge control for Gravitational Reference Sensors (GRS)	GW	Electronics	✓
	Advanced millimeter-wave focal plane arrays for CMB polarimetry	IP	Detector	✓
	Polarization-preserving millimeter-wave optical elements	IP	Optics	
	High-efficiency, low cost cooling systems for temperatures near 100 mK	IP, X ray	Cooler	✓
	Rapid readout electronics for X-ray detectors	X ray	Electronics	✓
	Optical-blocking filters (OBF)	X ray	Optics	✓
3	Gravitational reference sensor (GRS)	GW	Detector	
	Very-wide-field focusing instrument for time-domain X-ray astronomy	X ray	Optics	
	Ultra-high-resolution focusing X-ray observatory telescope	X ray	Telescope	
	Advancement of X-ray polarimeter sensitivity using negative ion gas	X ray	Detector	
4	Low-power, low-resolution continuous GSa/s direct RF digitizer	CR	Detector	
	Tileable, 2-D Proportional Counter Arrays	Gamma ray	Detector	
	High-performance gamma-ray telescope	Gamma ray	Telescope	
	Lattice optical clock for Solar Time Delay mission and other applications	STD	Electronics	
	Fast, few-photon UV detectors	UHECR	Detector	
	Lightweight, large-area reflective optics	UHECR	Optics	
	Low-power time-sampling readout	UHECR	Electronics	
	Low-power comparators and logic arrays	UHECR	Detector	

Gaps within a specific tier have equal priority. ✓is PCOS funding. ✓ is COR funding.

2017 COR Technology Gaps Prioritization

	2017 COR Technology Capability Gaps	Science	Tech	SAT or Directed
1	Heterodyne FIR detector arrays and related technologies	Far IR	Detector	✓
	Cryogenic readouts for large-format Far-IR detectors	Far IR	Electronics	**New gap**
	Warm readout electronics for large-format Far-IR detectors	Far IR	Electronics	**New gap**
	Large Cryogenic Optics for the Far IR	Far IR	Optics	✓
	Large-format, low-noise and ultralow noise far-infrared (FIR) direct detectors	Far IR	Detector	✓
	High-performance, sub-Kelvin coolers	Far IR, X-ray	Cooler	✓
	Large-format, High-Dynamic-Range UV Detectors	UV, FUV	Detector	✓
	High-Reflectivity Broadband FUV-to-NIR Mirror Coatings	UVOIR	Coating	✓
2	**Lightweight, large-aperture, high-performance telescope mirror systems for Far-IR**	Far IR	Optics	✓
	Compact, Integrated Spectrometers for 100 to 1000 μm	Far IR	Detector	
	Advanced Cryocoolers	Far IR, X-ray	Cooler	
	Mid-IR detectors	Mid IR	Detector	**New gap**
	Cryogenic deformable mirror	Mid IR	Optics	**New gap**
	High-efficiency UV multi-object spectrometers	UV	Detector	✓
	Lightweight, large-aperture, high-performance telescope mirror systems for UVOIR	UVOIR	Optics	✓
	High-performance spectral dispersion component/device	UVOIR, Far IR	Optics	
	Advanced Adaptive Optics	UVOIR, HabEx	Optics	✓
	Band-shaping and dichroic filters for the UV/Vis	UV, VIS	Optics	
3	Wide-bandwidth, high-spectral-dynamic-range receiving system	Cosmic Dawn	Detector	
	High-precision low-frequency radio spectrometers and interferometers	Cosmic Dawn	Detector	
	FIR interferometry	Far IR	Detector	
	Mid-IR coronagraph optics and architecture	Mid IR	Optics	
	UV/Opt/NIR Tunable Narrow-Band Filters	UVOIR	Optics	
	Ultra-Stable Opto-Mechanical Systems Architecture	UVOIR, HabEx	Telescope	✓
	Segment Phasing and Control	UVOIR, HabEx	Telescope	✓
	Dynamic Isolation Systems	UVOIR, HabEx	Telescope	✓
	Segmented-Aperture Coronagraph Architecture	UVOIR, HabEx	Optics	✓
	High-contrast Imaging Post-Processing	UVOIR, HabEx	Electronics	✓
	Mirror Segments Systems	UVOIR, HabEx	Optics	✓

Gaps within a specific tier have equal priority. ✓is COR funding. ✓ is Exoplanet funding.

Current PCOS Strategic Technology Investment

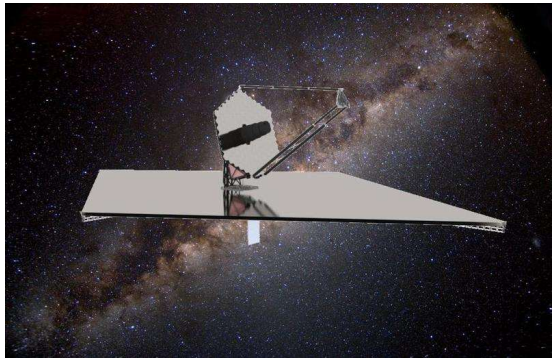
Funding Source	Technology Development Title	Principal Investigator	Org	Science Area	Tech Area
SAT2010	Directly-Deposited Blocking Filters for Imaging X-ray Detectors: Technology Development for the International X-ray Observatory	Mark Bautz	MIT	X Ray	Detector
SAT2013 APRA2011	**Development of 0.5 Arc-second Adjustable Grazing Incidence X-ray Mirrors for the SMART-X Mission Concept**	Paul Reid	SAO	X Ray	Optics
SAT2013	Fast Event Recognition for the ATHENA Wide Field Imager	David Burrows	PSU	X Ray	Electronics
SAT2014	High Efficiency Feedhorn-Coupled TES-based Detectors for CMB Polarization Measurements	Edward Wollack	GSFC	CMB	Detector
SAT2015, 2013, 2010	Development of a Critical Angle Transmission Grating Spectrometer	Mark Schattenburg	MIT	X Ray	Optics
SAT2015, 2013, 2011	**High-Resolution and Lightweight X-ray Optics for the X-Ray Surveyor**	William Zhang	GSFC	X Ray	Optics
SAT2015	**Hybrid lightweight X-ray optics for half arcsecond imaging**	Paul Reid	SAO	X Ray	Optics
Directed2016 Directed2012 SAT2011	Providing Enabling and Enhancing Technologies for a Demonstration Model of the Athena X-IFU	Caroline Kilbourne	GSFC	X Ray	Detector
SAT2016	High-Speed, Low-Noise, Radiation-Tolerant CCD Image Sensors for Strategic High-Energy Astrophysics Missions	Mark Bautz	MIT	X Ray	Detector
SAT2016, 2014, 2012, 2010	Superconducting Antenna-Coupled Detectors for CMB Polarimetry with the Inflation Probe	James Bock	JPL	CMB	Detector
Directed2017 SAT2014, 2011	**Telescope Dimensional Stability Study for a Space-based Gravitational Wave Mission**	Jeffrey Livas	GSFC	GW	Telescope
Directed2017 SAT2015, 2012	Phase Measurement System for Gravitational Wave Detection	Bill Klipstein	JPL	GW	Electronics
Directed2017 SAT2011	Colloid Microthruster Propellant Feed System for Gravity Wave Astrophysics Missions	John Ziemer	JPL	GW	Micro-propulsion
Directed2017 SAT2012	Demonstration of a TRL 5 Laser System for eLISA	Tony Yu	GSFC	GW	Laser
Directed2017	UV LED-based Charge Management System	John Conklin	UF	GW	Electronics

Current COR Strategic Technology Investment

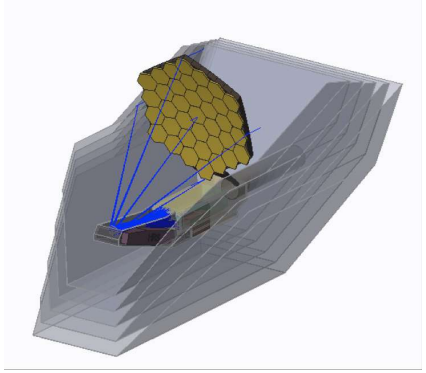
Funding Source	Technology Development Title	Principal Investigator	Org	Science Area	Tech Area
SAT2012 SAT2010	**Advanced UVOIR Mirror Technology Development for Very Large Space Telescopes**	Phil Stahl	MSFC	UVOIR	Optics
SAT2014	**Ultra-Stable Structures: Development and Characterization Using Spatial Dynamic Metrology**	Babak Saif	GSFC	UVOIR	Metrology/ Structure
SAT2014	Raising the Technology Readiness Level of 4.7-THz local oscillators	Qing Hu	MIT	Far IR	Detector
SAT2014 SAT2010	Cross-Strip Micro-Channel-Plate Detector Systems for Spaceflight	John Vallerga	UCB	UV	Detector
SAT2014	**Improving UV Coatings and Filters using Innovative Materials Deposited by ALD**	Paul Scowen	ASU	UV	Optical Coating
SAT2014 SAT2011	Advanced FUVUV/Visible Photon Counting and Ultralow Noise Detectors	Shouleh Nikzad	JPL	UVOIR	Detector
SAT2015	High-Efficiency Continuous Cooling for Cryogenic Instruments and sub-Kelvin Detectors	James Tuttle	GSFC	Far IR, Sub-mm, X Ray	Cooling System
SAT2015	**Predictive Thermal Control Technology for Stable Telescope**	Phil Stahl	MSFC	UVOIR	Optics
SAT2016	Ultrasensitive Bolometers for Far-IR Spectroscopy at the Background Limit	Charles Bradford	JPL	Far IR	Detector
SAT2016	High Performance Sealed Tube Cross Strip Photon Counting Sensors for UV-Vis Astrophysics Instruments	Oswald Siegmund	UCB	UV	Detector
SAT2016 SAT2012	**Development of Digital Micromirror Devices for Far-UV Applications**	Zoran Ninkov	RIT	UV	Optics
SAT2016	Development of a Robust, Efficient Process to Produce Scalable, Superconducting kilopixel Far-IR Detector Arrays	Johannes Staguhn	JHU	Far IR	Detector

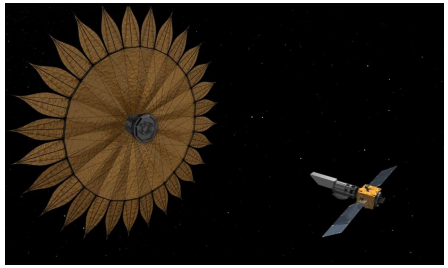
HQ SMD APD Planning for the Future

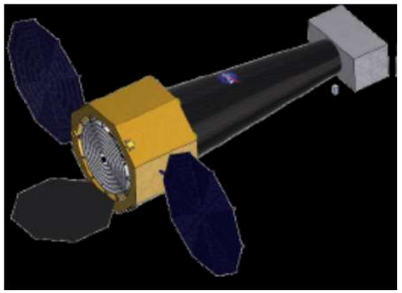
- **Strategic Mission Concept Studies**



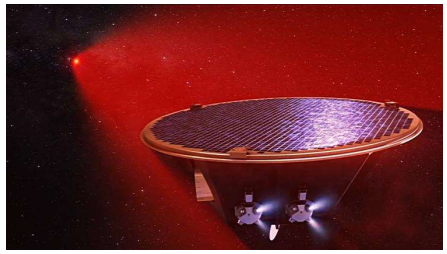
HabEx
LUVOIR
Lynx
OST
ATHENA
LISA
SOFIA







- **Medium (Probe) Concept Studies**
  - Cosmic Dawn Intensity Mapper (A. Cooray)
  - Cosmic Evolution through UV Spectroscopy Probe (W. Danchi)
  - Galaxy Evolution Probe (J. Glenn)
  - High Spatial Resolution X-ray Probe (R. Mushotzky)
  - Inflation Probe (S. Hanany)
  - Multi-Messenger Astrophysics Probe (A. Olinto)
  - Precise Radial Velocity Observatory (P. Plavchan)
  - Starshade Rendezvous Mission (S. Seager)
  - Transient Astrophysics Probe (J. Camp)
  - X-ray Timing and Spectroscopy Probe (P. Ray)



Impediments to Closing Gaps

- **Limited technology development funding**
  - Multiple compelling mission concept studies dilute available funding
  - Uncertainty as to which large mission concepts will be recommended by the Decadal Survey and its schedule
  - Directed funding will likely take effect after Decadal Survey to focus and expedite developments
- **Limited time before 2020 Decadal Survey begins**
  - Final STDT reports due spring CY19, desire is to demonstrate credibility by then
- **Limited technology solutions**
  - Can always use more new and viable ideas
    - **Some high ranking gaps did not receive SAT proposals to close**
    - Some current solution ideas are incremental instead of game changing or revolutionary
    - Developing only one solution path or only an aspect of a gap is risky