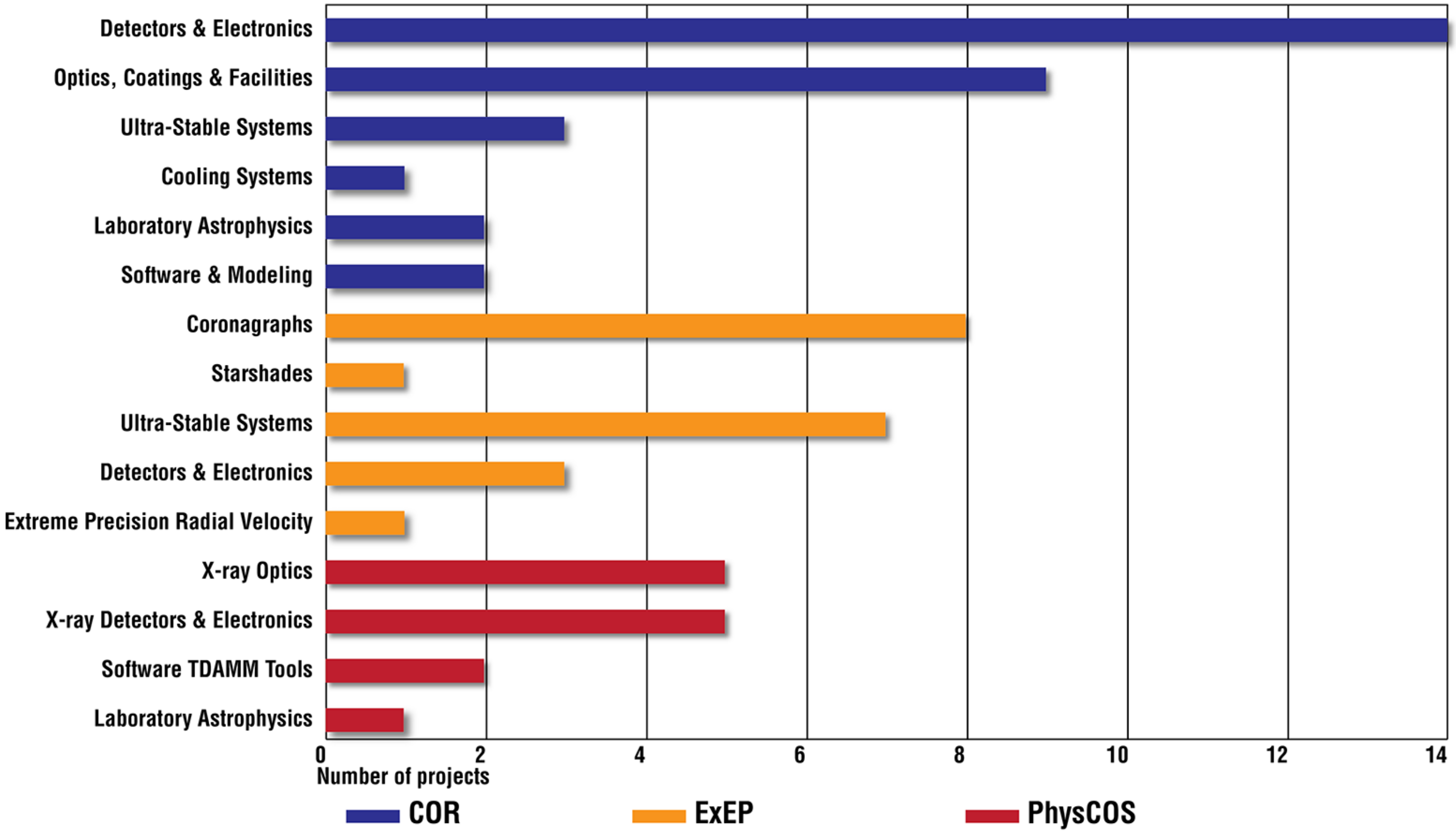
PhysCOS Technology Gaps and Portfolio Highlights

PhysPAG Session of AAS 245

Jason Derleth

PhysCOS/COR Chief Technologist

APD Strategic Technology Portfolio – 2025



The Program Office monitors and manages the PhysCOS and COR Strategic Astrophysics Technology (SAT), Roman Technology Fellowship (RTF), Internal Scientist Funding Model (ISFM) and Critical Technologies for Large Telescopes (CT4LT) technologies portfolio (44 projects)

Current PhysCOS Technology+ Portfolio

PROJECT TITLE	PI	PI ORG	TECH TYPE
Magnetically Coupled Calorimeters	Bandler, S	GSFC	Detector
Extremely Low-noise, High Frame-rate X-ray Image Sensors	Bautz, M	MIT	Detector
Microwave Superconducting QUantum Interference Device (SQUID) Readout Technology for Future X-ray Astrophysics Missions	Bennett, D	NIST	Electronics
Rapid Electron-Beam Lithography Patterning for Customized Reflection Gratings	DeRoo, C	U Iowa	Optics
MSFC Advanced X-Ray Optics: Formulation to Flight	Gaskin, J	MSFC	Optics
Advanced Pixelated Si Sensors for the Next Generation of X-ray Observatories	Kenter, A	SAO	Detector
Optimized Soft X-ray Sensors for Strategic X-ray Astrophysics Missions	Leitz, C	MIT/LL	Detector
Advanced X-Ray Microcalorimeters: Laboratory Astrophysics	Porter, S	GSFC	Lab astro
General Coordinates Network	Racusin, J	GSFC	Software
High-Sensitivity and High-Resolving-Power X-ray Spectrometer	Schattenburg, M	MIT	Optics
Advanced X-Ray Microcalorimeters: Transition Edge Sensors	Smith, S	GSFC	Detector
MSFC Relativistic Astrophysics: Multi-Messenger Astrophysics Community Tools & Support	Wilson-Hodge, C	MSFC	Software
Next-Generation X-ray Optics: High Resolution, Light Weight, and Low Cost	Zhang, W	GSFC	Optics

PhysCOS Technology Development & Test Facilities

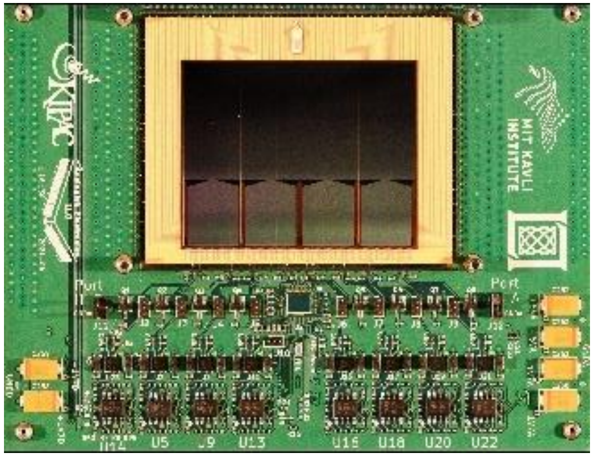
X-ray & Cryogenic Facility (XRCF, MSFC): With a 500-m beam line and 7×23-m vacuum chamber, XRCF is the world's largest X-ray optic calibration facility and NASA's premier thermal optical test facility. A 6,000 sqft clean room facilitates flight mirror integration, and the chamber can test 6-m class mirrors to 20 K. XRCF was built to calibrate the Chandra telescope and contributed to multiple X-ray missions. For JWST, MSFC performed cryogenic primary-mirror and backplane structure testing, life-cycle-tested candidate mirror actuators, characterized flight primary-mirror segments, cryo-cycled structure and acceptance-tested primary-mirror assemblies. Recent enhancements allow calibration of Athena X-ray optics via partial illumination in a diverging beam.

Marshall-100 (MSFC): This highly capable, low-overhead test facility for calibrating X-ray optics, detectors, and telescopes consists of a 97-m-long horizontal beamline that terminates at a 3×12-m thermal vacuum instrument chamber with a -40^{o}C chiller. It provides users with a collimated, 1.3-m-diameter X-ray beam at 0.25-110 keV and a complement of detectors and test stages. An additional vacuum chamber can be attached to the instrument chamber through a gate valve, allowing rapid testing of small optics without re-pressurizing the entire line. The facility allows standard sounding-rocket payload skins to be mounted to the instrument chamber gate valve and aligned to the X-ray beam for end-to-end testing of sounding-rocket payloads.

PhysCOS Technology Development Highlights

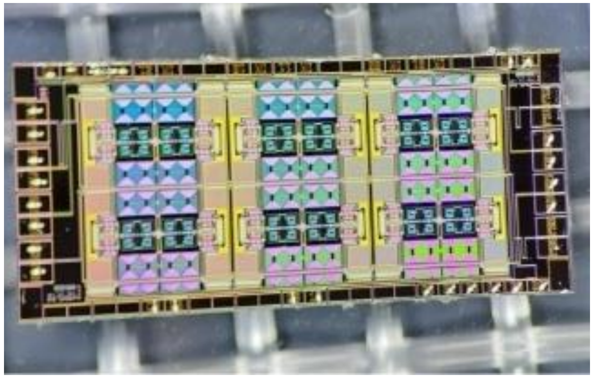
Extremely Low-Noise, High Frame-Rate X-ray Image Sensors (M. Bautz, MIT)

X-ray missions, including an X-ray Great Observatory and X-ray Probe, both recommended by Astro2020, as well as X-ray spectrometer-based Explorers, would all benefit from fast, low-noise, X-ray image sensors. The project is building on an existing MIT Lincoln Laboratory (MIT/LL) advanced-CCD program developing low-noise, low-power, high-frame-rate CCDs. The team, which also includes researchers at Stanford University, recently began fabricating prototype and noise-reduction test sensors significantly exceeding the requirements of the proposed Advanced X-ray Imaging Satellite (AXIS) X-ray Probe.



Microwave SQUID Readout Technology Development for Future X-ray Astrophysics Missions (D. Bennett, NIST)

Robust and scalable integration of microwave SQUID multiplexing with large arrays of X-ray microcalorimeters enables large-format X-ray focal plane arrays needed for a future X-ray Great Observatory and X-ray Probe, such as the Line Emission Mapper (LEM). The team recently designed, fabricated, and delivered TDM chips targeting LEM's baseline parameters. They also designed small-footprint TDMs for the LEM compact focal plane option.

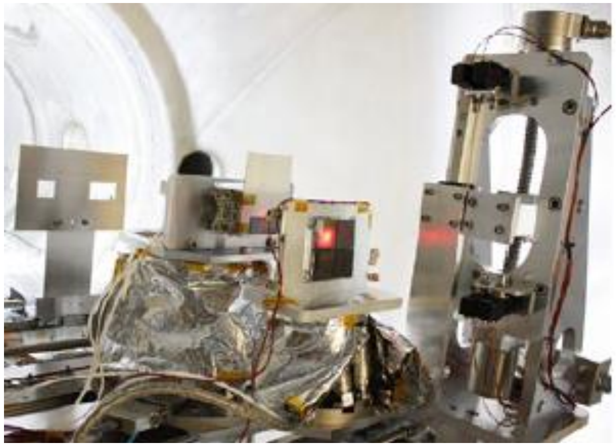


PhysCOS Technology Development Highlights

Next-Generation X-ray Optics: High Angular Resolution, High Throughput, and Low Cost (W. Zhang, GSFC)

Imaging astrophysical X-ray sources is crucial to studying the high-energy processes in the universe. Since X-rays can only be reflected at very shallow angles, X-ray telescopes use grazing-incidence reflections to focus photons on detectors several meters away. The project developed a process that carves sub-mm-thickness slices from commercial blocks of single-crystal silicon, then etches, polishes, trims, and coats them to make 10×10 cm^2 segments. Expecting this technology to reach its target resolution, the Lynx reference design baselined it, with nearly 40,000 segments to be assembled into a 3-m-diameter barrel, offering 30× larger collection area than Chandra, at an expected cost that would fit within a flagship-mission-level budget. The project recently achieved 2.8”-half-power-diameter images, and perfected a new method of polishing mirrors, reducing time and cost, scalable for mass production.

Technology Maturation for a High-Sensitivity and High-Resolving Power X-ray Spectrometer (M. Schattenburg, MIT)



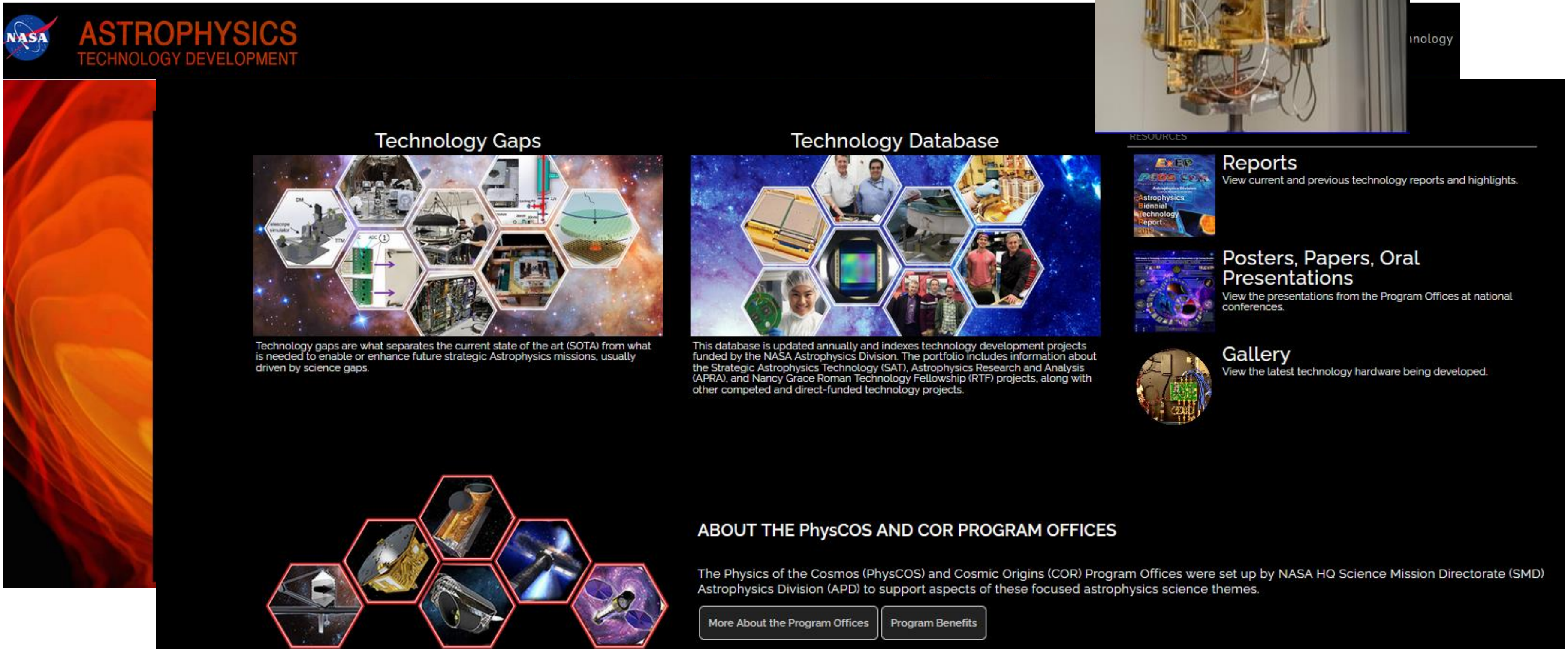
An improved Critical-Angle X-ray Transmission Grating Spectrometer with higher diffraction efficiency and resolving power in combination with grazing-incidence X-ray mirrors and CCD detectors, promise an order-of-magnitude improvement in both efficiency and resolving power over existing spectrographs, enabling absorption- and emission-line spectroscopy needed to study the large-scale structure of the universe, cosmic feedback, the interstellar and intergalactic media, and stellar activity across all stellar types and lifecycles. In collaboration with MIT/LL and Smithsonian Astrophysical Observatory (SAO), the team fabricated multiple 4- and 6-µm-deep flight-like CAT grating facets from 200-mm Silicon-on-Insulator (SOI) wafers using volume production tools; confirmed resolving power of 8,000-13,000 for individual and co-aligned grating facets; patterned new enhanced-SOI wafers with 10× better thickness control; and demonstrated increased diffraction efficiency from chemically thinned grating bars.

Learn more about the Technology Program

PhysPCOS/COR Technology Website

https://apd440.gsfc.nasa.gov/technology.html

- Technology gaps list and tech gaps process
- Links to other Program Office resources
- Published papers and posters
- Annual galleries of hardware developed by SAT projects



Learn more about the Technology Program

AstroTech database– search our portfolio

http://www.AstroStrategicTech.us/

- **Over 900 records of SATs, ISFMs, APRAs, RTFs, and other directed work**
- **Query your search:**
  - PI name
  - Signal Type
  - Technology
  - Institution

Example Query

You have searched for :

Funding Program All

Portfolio Manager PCOS

Project Status: Active

Technology Type: Detector

Signal Type: Sub-mm

Research Area: Detector Development

There are 8 record(s) found.

Results in columns below can be sorted by clicking the column heading.

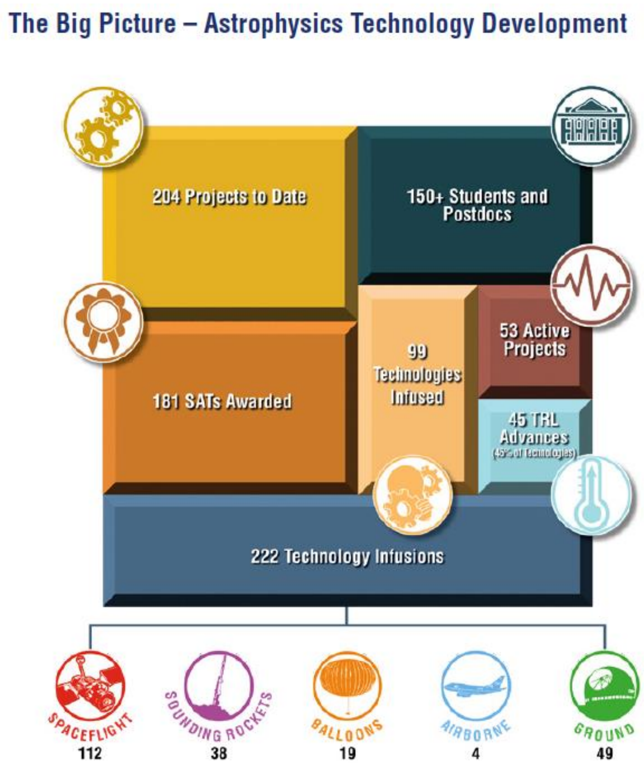
Click here to export search results below into an Excel Spreadsheet.

▲ Portfolio Manager	Funding Program	Project Title	PI Name	PI Org	Research Area	Research Category	Technology Area	Signal Type	Start FY	End FY	Project Status	TRL*	Project Description
HQ	APRA2018	Quantum-limited Amplifiers for Large Array Readout of Superconducting Detectors	Vissers, Michael	National Institute of Standards and Technology	Detector Development	Technology Development	Detector	Sub-mm	2020	2023	Active	N/A	Abstract & Reports
HQ	APRA2020	Quantum limited amplifiers for detector readout and coherent receivers	Day, Peter	Jet Propulsion Laboratory	Detector Development	Technology Development	Detector	Sub-mm	2022	2024	Active	N/A	Abstract & Reports

Learn more about the Technology Program

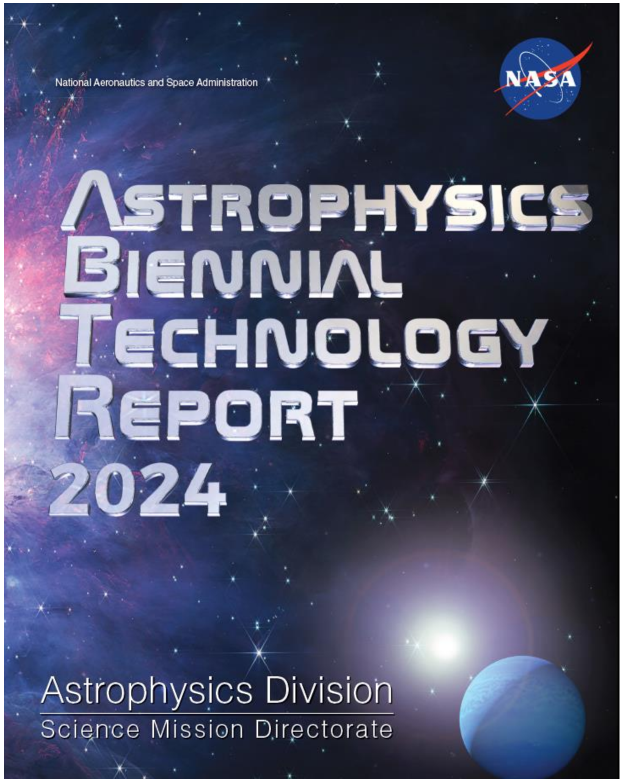
Astrophysics Biennial Technology Report (ABTR)
https://apd440.gsfc.nasa.gov/images/tech/2022_ABTR.pdf

Technology Report published every other year—next ABTR will be in 2026



The 2024 report includes:

- New SAT Awards
- About Astrophysics Technology Program
- Program success metrics and technology infusion information
- Technology development and test facilities
- Technology portfolio summaries and highlights
- Tech Gaps and Prioritization Tiers



Technology Gap Prioritization

- **Gaps next solicitation currently scheduled to have a June 1, 2026 due date for gap entries**
- **The gaps are split among the three Program Offices based on the science most impacted**
- **Three gap lists scrubbed with help of PhysPAG EC, COPAG EC, and ExoTAC by July 1, 2026**
- **Gaps prioritized by Technology Management Boards by August 2026 using four criteria:**
  - Strategic alignment
  - Impacts and benefits
  - Urgency
  - Scope of applicability
- **The three lists (PhysCOS, COR, ExEP) are merged into a unified Astrophysics technology gaps list**
- **List published in Astrophysics Biennial Technology Report (ABTR) and PO website in October**

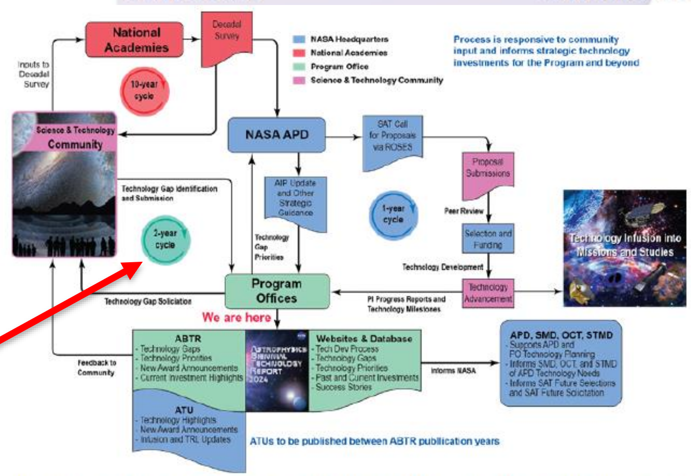
2024 Astrophysics Tech Gaps List
(informed by Astro2020 and HWO START/TAG)

Tier-1 Technology Gaps

Coronagraph Contrast and Efficiency in the Near IR
Coronagraph Contrast and Efficiency in the Near UV
Coronagraph Stability
Cryogenic Readouts for Large-Format Far-IR Detectors
Fast, Low-Noise, Megapixel X-ray Imaging Arrays with Moderate Spectral Resolution
High-Bandwidth Cryogenic Readout Technologies for Compact and Large-Format Calorimeter Arrays
High-Efficiency, Low-Scatter, High- and Low-Ruling-Density, High- and Low-Blazed-Angle UV Gratings
High-Efficiency X-ray Grating Arrays for High-Resolution Spectroscopy
High-Performance Sub-Kelvin Coolers
High-Reflectivity Broadband Far-UV-to-Near-IR Mirror Coatings
High-Resolution, Lightweight X-ray Optics
High-Throughput, Large-Format Object-Selection Technologies for Multi-Object and Integral-Field Spectroscopy
Integrated Modeling for HWO: Multi-Physics Systems Modeling, Uncertainty Quantification, and Model Validation
Large-Format, High-Resolution Far-UV (100 - 200 nm) Detectors
Large-Format, High-Resolution Near-UV (200 - 400 nm) Detectors
Low-Stress, Low-Roughness, High-Stability X-ray Reflective Coatings
Mirror Technologies for High Angular Resolution (UV/Visible/Near IR)
Optical Blocking Filters for X-ray Instruments
Scaling and Metrology for Advanced Broadband Mirror Coatings for HWO
Segmented-Pupil Coronagraph Contrast and Efficiency in the Visible Band
UV Multi-Object Spectrograph Calibration Technologies
UV Single-Photon Detection Sensitivity
Visible/Near-IR Single-Photon Detection Sensitivity

Tier-2 Technology Gaps

Advanced Cryocoolers
Broadband X-ray Detectors
Compact, Integrated Spectrometers for 100 to 1000 μm
Cryogenic Far-IR to mm-Wave Focal-Plane Detectors
Far-IR Imaging Interferometer for High-Resolution Spectroscopy
Far-IR Spatio-Spectral Interferometry
Heterodyne Far-IR Detector Systems
High-Performance Computing for Event Reconstruction
High-Resolution, Direct-Detection Spectrometers for Far-IR Wavelengths
High-Throughput Focusing Optics for 0.1-1 MeV Photons
High-Throughput UV Bandpass Standalone and Detector-Integrated Filters and Bandpass Selection
Improving the Calibration of Far-IR Heterodyne Measurements
Large-Format, High-Spectral-Resolution, Small-Pixel X-ray Focal-Plane Arrays
Large-Format, Low-Noise and Ultralow-Noise, Far-IR Direct Detectors
Low-Power Readout and Multiplexing for CMB Detectors
Millimeter-Wave Focal-Plane Arrays for CMB Polarimetry
Optical Elements for a CMB Space Mission
Starshade Deployment and Shape Stability
Starshade Starlight Suppression and Model Validation
Stellar Reflex Motion Sensitivity: Astrometry
Stellar Reflex Motion Sensitivity: Extreme Precision Radial Velocity
Warm Readout Electronics for Large-Format Far-IR Detectors



The Astrophysics strategic technology development process starts with the National Academies' Decadal Survey recommendations, and APD's programmatic guidance. Based on these, the process matures and enables infusion of key technologies into Astrophysics missions and beyond.

2-year technology gap prioritization cycle

More info at apd440.gsfc.nasa.gov/technology.html

PhysCOS-Specific Technology Gaps

Tier 1 PhysCOS Technology Gaps

1. Fast, Low-noise, Megapixel X-ray Imaging Arrays with Moderate Spectral Resolution
2. High-Bandwidth Cryogenic Readout Technologies for Compact and Large-Format Calorimeter Arrays
3. High-Efficiency X-ray Grating Arrays for High-Resolution Spectroscopy
4. High-Resolution, Lightweight X-ray Optics
5. Low-Stress, Low-Roughness, High-Stability X-ray Reflective Coatings
6. Optical Blocking Filters for X-ray Instruments

Tier 2 PhysCOS Technology Gaps

7. Broadband X-Ray Detectors
8. High-Performance Computing for Event Reconstruction
9. High-Throughput Focusing Optics for 0.1-1 MeV Photons
10. Large-Format, High-Spectral-Resolution, Small-Pixel X-ray Focal-Plane Arrays
11. Low-Power Readout and Multiplexing for CMB Detectors
12. Millimeter-Wave Focal-Plane Arrays for CMB Polarimetry
13. Optical Elements for a CMB Space Mission

Tier 3 PhysCOS Technology Gaps

14. Broadband X-ray Polarimeter
15. Charged-Particle-Discriminating X-ray/Gamma-Ray Detectors
16. Dynamic Switching for Ultra-Low-Power, High-Resolution Charge Readout
17. High-Energy-Resolution Gamma-Ray Detectors
18. Large Field-of-View and Effective Area Gamma-Ray Detectors
19. Low-Power, Low-Cost Semiconductor Detectors
20. Low-Power Readout for Silicon Photomultipliers
21. Radiation-Tolerant, Photon-Counting Light Detectors
22. Sensitive Spectrometer for CMB Spectrum Measurement

Non-Strategic PhysCOS Technology Gap(s)

23. Advancement of X-ray Polarimeter Sensitivity

More info at apd440.gsfc.nasa.gov/technology.html

Back-Up