PhysCOS Technology Development

Francesca Civano and Brian Humensky
On behalf of

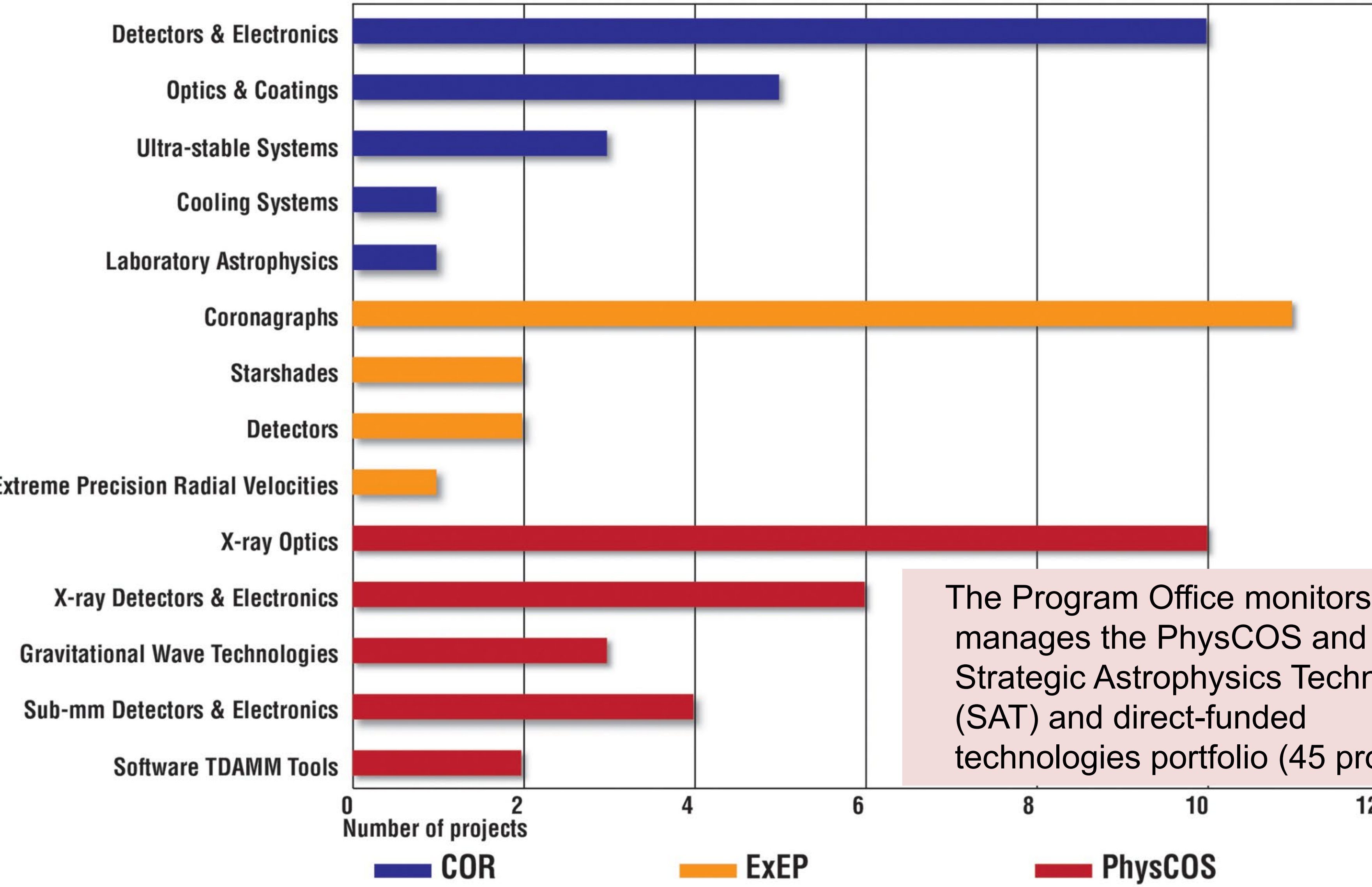
Rachel Rivera – Technology Development Manager

Opher Ganel – Program Technologist / Systems Engineer

NASA – GSFC

APS meeting 2023

APD Strategic Technology Portfolio – 2022



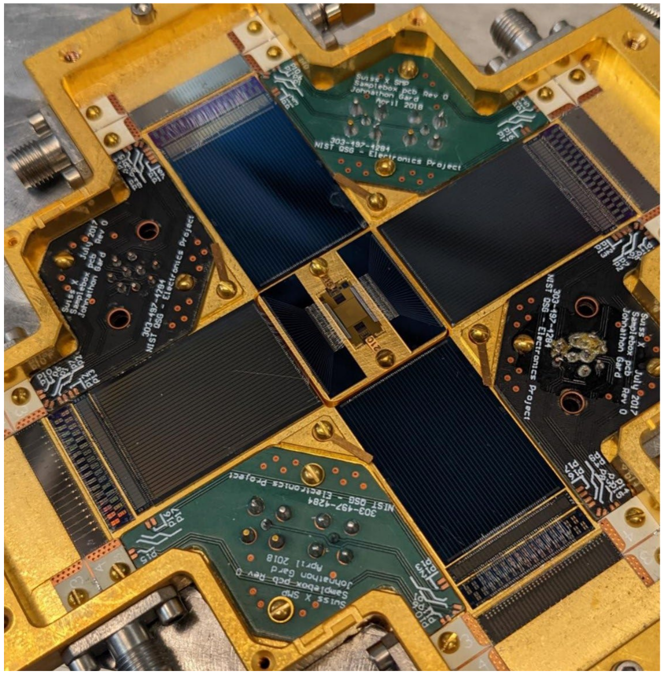
The Program Office monitors and manages the PhysCOS and COR Strategic Astrophysics Technology (SAT) and direct-funded technologies portfolio (45 projects)

Current PhysCOS Technology+ Portfolio

Funding Program	Project Title	PI Name	PI Inst	Technology Area	Signal Type
SAT2017	Development of Adjustable X-ray Optics with 0.5 Arcsecond Resolution for the Lynx Mission Concept	Reid, Paul	SAO	Optics	X Ray
SAT2021	Microwave SQUID readout technology to enable Lynx and other future Great Observatories	Bennett, Douglas	NIST	Electronics	X Ray
SAT2021	High Resolution and High Efficiency X-ray Transmission Grating Spectrometer	Schattenburg, Mark	MIT	Optics	X Ray
Directed2018	Space-based Gravitational Wave Laser Technology Development Project for the LISA Mission	Yu, Anthony	GSFC	Laser	GW
Directed2018	Telescopes for Space-Based Gravitational-Wave Observatories	Livas, Jeffrey	GSFC	Telescope	GW
Directed2018	UV LED-based Charge Management System	Conklin, John	UF	Electronics	GW
Directed2018	Advancing the Focal Plane TRL for LiteBIRD and Other Next Generation CMB Space Missions	Lee, Adrian	UCB	Detector	Sub-mm
ISFM22	Next Generation X-ray Optics	Zhang, William	GSFC	Optics	X Ray
ISFM22	Advanced X-ray Optics Sub-package #1: Differential Deposition for Figure Correction in X-ray Optics	Davis, Jacqueline	MSFC	Optics	X Ray
ISFM22	Advanced X-ray Optics Sub-package #2: Direct Fabrication of Full Shells, Mounting & Alignment	Bongiorno, Stephen	MSFC	Optics	X Ray
ISFM22	Advanced X-ray Optics Sub-package #3: Computer-Controlled Polishing of High-Quality Mandrels	Kolodziejczak, Jeff	MSFC	Optics	X Ray
ISFM22	Advanced X-ray Optics Sub-package #4: Low Stress Mirror Coatings	Gurgew, Danielle	MSFC	Optical Coating	X Ray
ISFM22	Advanced X-ray Optics Sub-package #5: X-ray Testing and Calibration	Thomas, Nick & Kegley, Jeff	MSFC	Optics	X Ray
ISFM22	Advanced X-ray Optics Sub-package #6: Hybrid X-ray Optics by Additive Manufacturing, Replication Studies	Singam, Panini	MSFC	Optics	X Ray
ISFM22	Advanced X-ray Microcalorimeters Sub-package #1:TES Microcalorimeters	Smith, Stephen	GSFC	Detector	X Ray
ISFM22	Advanced X-ray Microcalorimeters Sub-package #2: Laboratory Spectroscopy for Space Atomic Physics	Porter, Scott	GSFC	Detector	X Ray
ISFM22	Advanced X-ray Microcalorimeters Sub-package #3: Magnetically Coupled Calorimeters	Bandler, Simon	GSFC	Detector	X Ray
SAT2021	Toward Fast, Low-Noise, Rad-Tolerant X-ray Imaging Arrays for Lynx: Raising Tech Readiness Further	Bautz, Mark	MIT	Detector	X-ray
SAT2018	Superconducting Antenna-Coupled Detectors and Readouts for CMB Polarimetry in PICO	O'Brient, Roger	JPL	Detector	Sub-mm
SAT2018	Development of Low Power FPGA-based Readout Electronics for Superconducting Detector Arrays	Mauskopf, Philip	ASU	Electronics	Sub-mm, X-ray
SAT2018	Microwave Multiplexing Readout Development	Ruckman, Larry	Stanford	Electronics	X-ray, Sub-mm
Directed2020	Readying X-ray Gratings and Optics for Space Applications; Manufacturability & Alignment	Smith, Randall	SAO	Optics	X Ray
SAT2021	Development of Advanced Pixelated Si Sensors for the Next Generation of X-ray Observatories	Kraft, Ralph	SAO	Detector	X-ray
ISFM22	MSFC Relativistic Astrophysics – Multi-messenger Astrophysics Community Tools and Support	Wilson-Hodge, Colleen	MSFC	Software	TDAMM
ISFM22	General Coordinates Network	Racusin, Judith	GSFC	Software	TDAMM

PhysCOS Technology Development Highlights

A project led by NIST's **Douglas Bennett** is developing microwave Superconducting QUantum Interference Device (SQUID) multiplexers (μMUX) optimized for reading out the sensors proposed for the Lynx X-ray Microcalorimeter (LXM). The LXM is one of three Lynx instruments, with a focal plane of >100,000 pixels. The most promising strategy to achieve the required multiplexing factor is using a combination of thermal and electrical multiplexing. The electrical multiplexing is achieved via μMUXs that transform the baseband signals from the detectors into frequency shifts of superconducting resonators at gigahertz frequencies.



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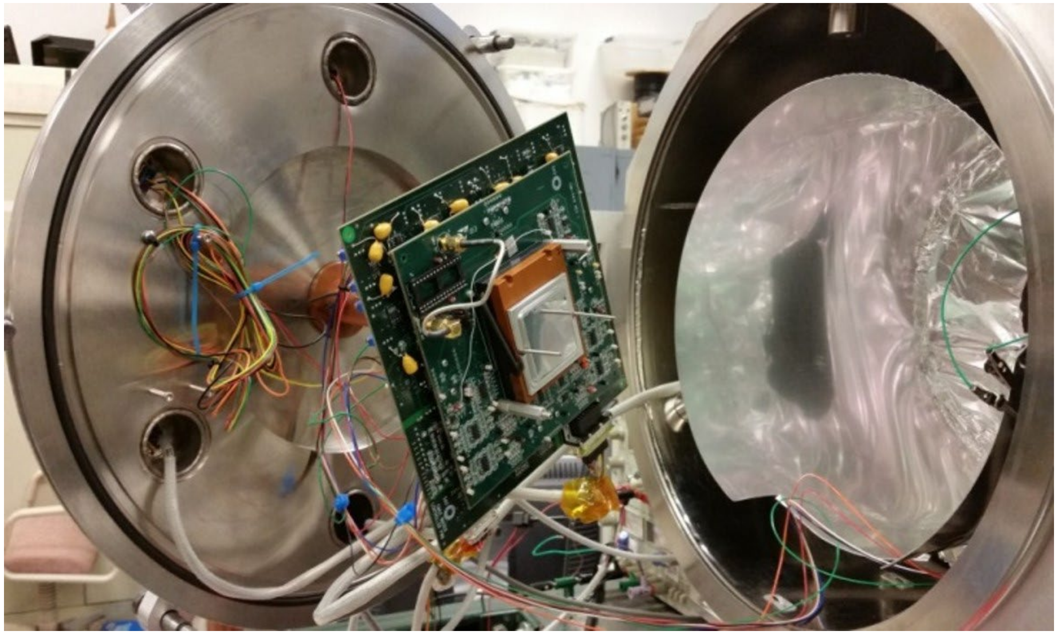

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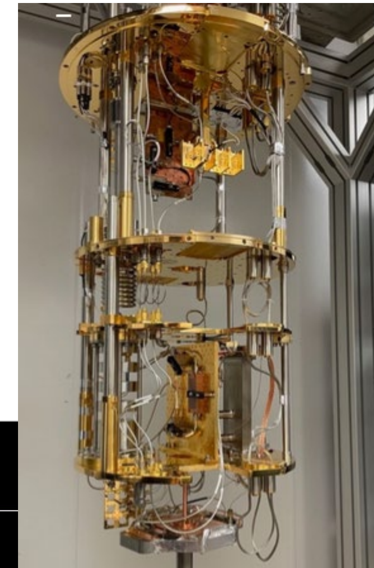
A project led by **William Zhang** at GSFC is developing next-generation thin X-ray optics that will enable an X-ray flagship, as well as Probes, Explorers, and other X-ray missions. This technology was baselined by the Lynx STDT for their reference mission design. The team demonstrated 2.8” half-power-diameter image with five pairs of mirror segments.

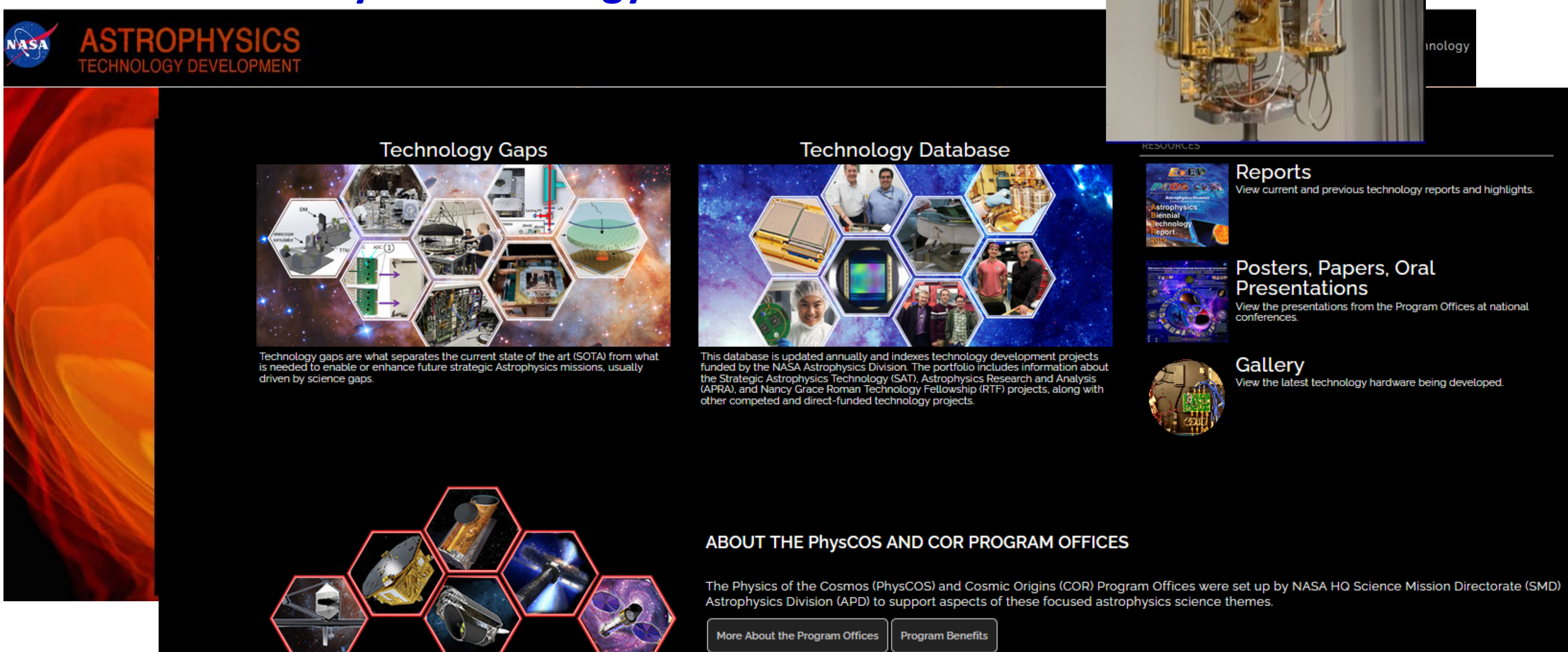
Learn more about the Technology Program

PhysCOS/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
- Visit our Gallery of technology





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

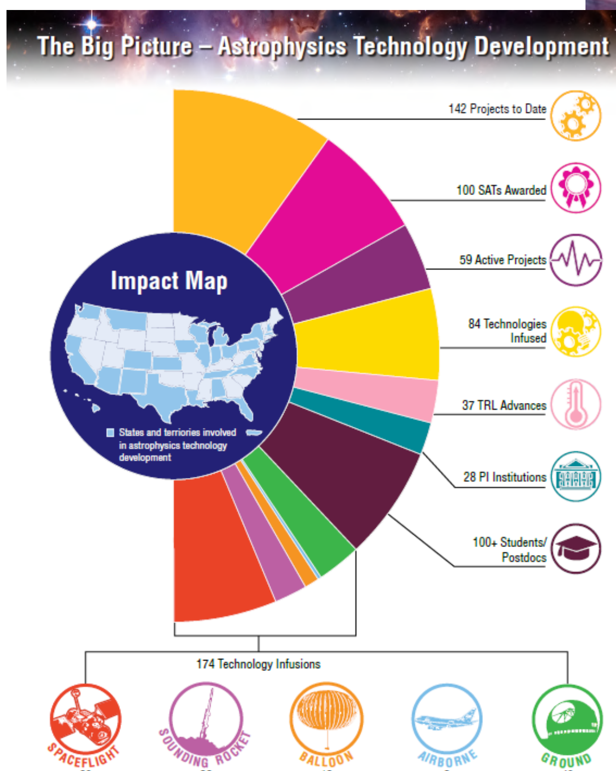
Learn more about the Technology Program

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 2024

The 2022 report includes:

- About Astrophysics Technology Program
- Program success metrics and technology infusion information
- Technology portfolio summaries and highlights
- Tech Gaps and Prioritization Tiers



Technology Gap Prioritization

- Gaps next solicitation currently scheduled to have a June 1, 2024 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, 2024
- Gaps prioritized by Technology Management Boards by August 2024 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

2-year technology gap prioritization cycle

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

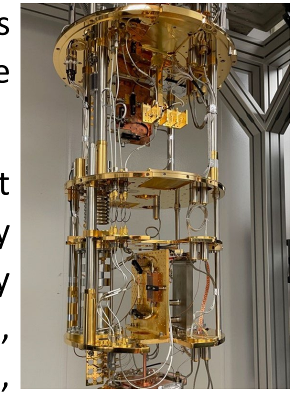
Thank You!

Back-Up

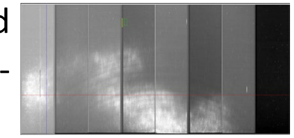
Back-Up Charts with summaries of the PhysCOS Technology Portfolio

PhysCOS Technology Development Projects (1)

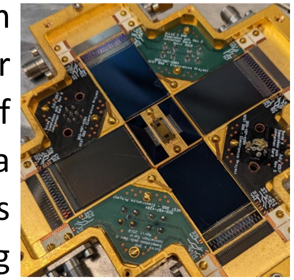
A team led by **GSFC's Simon Bandler** works to develop and mature Magnetically Coupled Calorimeters (MMCs). This technology targets the sensors for the Lynx X-ray Microcalorimeter (LXM), one of three Lynx instruments, with a focal plane of >100k pixels.



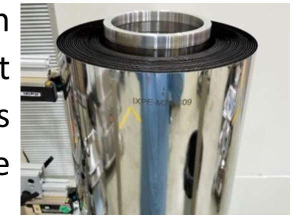
MIT's **Mark Bautz** leads a team working on high-speed, large-format, low-noise, and radiation tolerant X-ray charge-coupled devices (CCD) for use in mega-pixel X-ray imaging for, e.g., the Lynx X-ray observatory. This technology is also directly applicable to future Probe- or Explorer-class X-ray missions. The project's goal is to demonstrate large-format imaging sensors that provide the speed, sensitivity, and spectral resolution required by Lynx. The near-term objectives are to fabricate, test, and characterize a much larger, next-generation detector with multiple outputs and the improved charge transfer efficiency required for a device of this size, and to integrate it with ASICs for low-power signal processing.



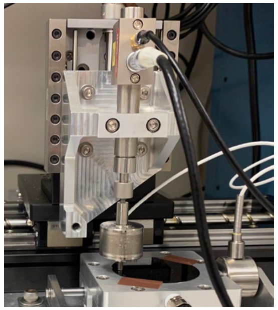
A project led by NIST's **Douglas Bennett** is developing microwave Superconducting QUantum Interference Device (SQUID) multiplexers (μMUX) optimized for reading out the sensors proposed for the Lynx X-ray Microcalorimeter (LXM). The LXM is one of three Lynx instruments, with a focal plane of >100,000 pixels. The most promising strategy to achieve the required multiplexing factor is using a combination of thermal and electrical multiplexing. The electrical multiplexing is achieved via μMUXs that transform the baseband signals from the detectors into frequency shifts of superconducting resonators at gigahertz frequencies.



Stephen Bongiorno's project at MSFC works on X-ray mirror shell alignment and mounting. Since thin optics distort significantly under self-gravity, they must be supported without imparting significant distortion during metrology and while being attached to permanent mounting structures. This is increasingly important as shell thickness decrease and X-ray angular resolution targets improve. The technology was infused into the recently selected APRA REDSoX sounding rocket mission.

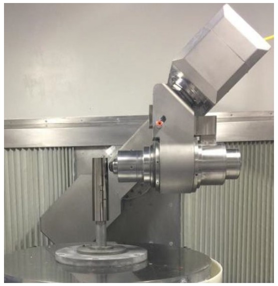


PhysCOS Technology Development Projects (2)

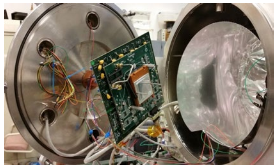


Jacqueline Davis's project at MSFC works on metrology development for full-shell X-ray optics. Approaching sub-arcsec X-ray optics necessitates more accurate measurements of the optical error. Quantifying error sources enables improving the optical surface.

Danielle Gurgew's project at MSFC develops thin-film coatings for X-ray mirrors. This is especially important for thin X-ray mirrors where reflective coatings typically have very high stress and if this stress isn't relaxed or compensated by coating on the opposite side of the mirror, could warp a thin mirror, significantly degrading its angular resolution.



Jeff Kolodziejczak's project at MSFC develops computer-controlled polishing of high-quality mandrels and shells. This will allow faster fabrication of X-ray mirrors.



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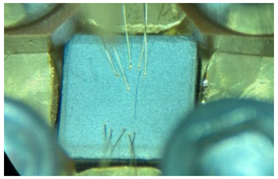
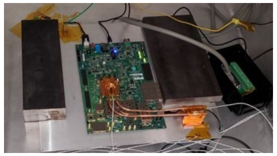


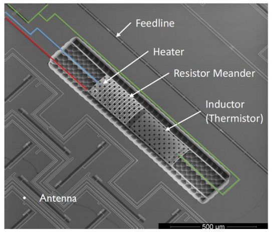
UC Berkeley's **Adrian Lee** leads a project to Advance the Focal Plane TRL for LiteBIRD and Other Next-Generation CMB Space Missions. This technology is crucial for JAXA's LiteBIRD CMB mission, which plans a 13k-pixel detector array across 15 spectral bands, with a 128-fold-multiplexed readout.



A team led by Arizona State University's **Philip Mauskopf** aims to demonstrate high-speed digital signal processing electronics for reading out large arrays of superconducting detectors for future balloon-borne and space-based astronomy missions including the Origins Space Telescope.

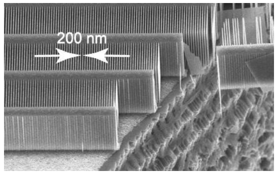
PhysCOS Technology Development Projects (3)

A project led by **Roger O'Brient** of JPL and Caltech develops advanced antenna-coupled superconducting detector-array technology for the Probe of Inflation and Cosmic Origins (PICO). PICO will need a 13-kilopixel array and 128-way time division multiplexing (TDM) readout. These technologies may also be useful for JAXA's LiteBIRD and ESA's CORE. Devices developed by the team were installed in the BICEP/Keck Array, leading the way in state-of-the-art (SOTA) CMB measurements. Detector arrays tuned to 90-, 150-, and 220-GHz optical bands allowed the tightest constraints on inflationary polarization signals to date, exceeding the constraints on temperature alone as well as polarized studies from prior generation satellites. The balloon-borne Suborbital Polarimeter for Inflation Dust and the Epoch of Reionization (SPIDER) conducted a successful 16-day long-duration balloon flight with antenna-coupled TES arrays, with record-setting sensitivities and stabilities for TESs in CMB polarimetry.



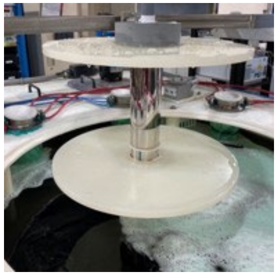
SLAC's **Larry Ruckman** leads a project to increase the Technology Readiness Level (TRL) of high-density-readout μMUX for superconducting sensor arrays. Potential mission applications include, e.g., far-IR and X-ray Flagships and/or Probes recommended by Astro220, and the technology is applicable to a wide range of spacecraft instruments.

A project led by **Mark Schattenburg** of MIT is working on a High Resolution and High Efficiency X-ray Transmission Grating Spectrometer. Such gratings provide extremely important measurement for X-ray observatories such as X-ray flagship and Probe recommended by Astro2020, where they can be used in front of a microcalorimeter-style energy-measuring detector. The X-ray Grating Spectrometer (XGS) instrument in the Lynx reference design baselined this technology, and the current TRL was assessed as 3.

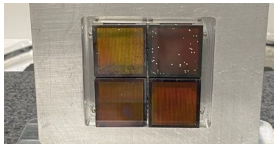


PhysCOS Technology Development Projects (4)

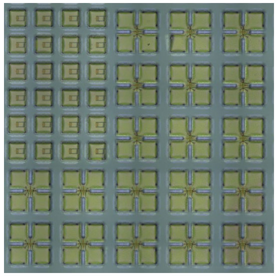
Panini Singam's project at MSFC works on electroforming replication of full-shell X-ray mirrors. These are conceptually similar to Chandra's mirrors but intended to be much thinner (sub-mm) to increase the effective collection area for X-ray photons. Depending on their ultimate performance, these may be useful for a variety of future X-ray missions.



A project led by SAO's **Randall Smith** works to develop manufacturable X-ray Critical-Angle Transmission (CAT) gratings, at a Manufacturing Readiness Level (MRL) of 6. To allow the exquisitely tight geometric nanostructure tolerances typically only available on expensive, modern, large-wafer, semiconductor-processing tools, the team forged an alliance with the Advanced Imager Technology group at MIT Lincoln Laboratory. This work would allow X-ray CAT gratings to be manufactured with the precision required by missions such as the X-ray flagship and Probe recommended by Astro2020, at an acceptable cost within an acceptable schedule.



Steven Smith of GSFC leads project developing technologies for advanced X-ray microcalorimeters using transition-edge sensors (TESs). These can be used, e.g., for the Lynx enhanced main array (EMA).



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