### Astrophysics Technology Development PhysCOS/COR Programs

Jason Derleth, PhysCOS/COR Chief Technologist Opher Ganel, PhysCOS/COR Technologist



### **Astrophysics Technology Enables (and Limits) Science**

- NASA
- Current technologies enable great science (e.g., Hubble, Webb, etc.)
- However, our SOTA technologies also limit us science we can do with existing technologies has already been done (or will be "soon");
- Next-level science requires us to push the technological envelope
- To have a chance of going beyond that next level will require new ways of thinking, new approaches, and new synergies

Let's start with a look at our current plans...



### Strategic Astrophysics Missions: Habitable Worlds Observatory (HWO)



### **Capabilities needed**

- Large telescope optics
- Broadband coatings (down to Lyman α)
- Large-format detector arrays
- High-contrast imaging (for exoplanet science)
- Extreme stability (for exoplanet science)



An initial HWO architecture under study



### Strategic Astrophysics Missions: X-Ray Flagship





### **Capabilities needed**

- Low-density, high-precision X-ray optics
- Cryogenics
- Large-format, low-noise X-ray detector arrays

An X-ray Probe may fly in the coming decade that could also benefit from these capabilities



### **Strategic Astrophysics Missions: Far-IR Flagship**



### **Capabilities needed**

- Cryogenic optics
- Large-format cryogenic detector arrays
- Cryogenic coolers

A far-IR Probe may fly in the coming decade and a CMB Probe may fly in the following decade; each could also benefit from some of these capabilities



### Strategic Astrophysics Activities: Time-Domain and Multi-Messenger (TDAMM) Science

## **Capabilities** needed

- Precision timing and advanced onboard computing
- Gamma-ray optics
- Low-noise high-energy detector arrays & electronics
- Cryogenics
- AI/ML for coordinating observations and reviewing existing datasets



### From Capabilities to Gaps: HWO General Astrophysics



#### Large telescope optics

- High-Efficiency, Low-Scatter, High- and Low-Ruling-Density, High- and Low-Blazed-Angle UV Gratings
- High-Throughput, Large-Format Object-Selection Tech for Multi-Object and Integral-Field Spectroscopy
- Mirror Technologies for High Angular Resolution (UV/Visible/Near IR)
- High-Throughput UV Bandpass Standalone and Detector-Integrated Filters and Bandpass Selection



### Broadband coatings (down to Lyman α)

- High-Reflectivity Broadband Far-UV-to-Near-IR Mirror Coatings
- Scaling and Metrology for Advanced Broadband Mirror Coatings for HWO



### Large-format detector arrays

- Large-Format, High-Resolution Far-UV (100 200 nm) Detectors
- Large-Format, High-Resolution Near-UV (200 400 nm) Detectors
- UV Multi-Object Spectrograph Calibration Technologies
- UV Single-Photon Detection Sensitivity
- Visible/Near-IR Single-Photon Detection Sensitivity
- UV/Optical/Near-IR Tunable Narrowband Imaging Capability







Key: Strategic Technology Gaps

- Priority Tier 1 gaps
- Priority Tier 2 gaps
- Priority Tier 3 gaps



### From Capabilities to Gaps: X-Ray Flagship\*



#### Low-density, high-precision X-ray optics

- High-Resolution, Lightweight X-ray Optics
- High-Efficiency X-ray Grating Arrays for High-Resolution Spectroscopy
- Low-Stress, Low-Roughness, High-Stability X-ray Reflective Coatings
- Optical Blocking Filters for X-ray Instruments





#### Cryogenics

Advanced Cryocoolers



#### Large-format, low-noise X-ray detector arrays

- Fast, Low-Noise, Megapixel X-ray Imaging Arrays with Moderate Spectral Resolution
- High-Bandwidth Cryogenic Readout Technologies for Compact and Large-Format Calorimeter Arrays
- Broadband X-ray Detectors
- Imaging Capability Broadband X-ray Polarimeter

\* Flagship: NASA Astrophysics term for a multi-billion-dollar space observatory such as Hubble or James Webb



### From Capabilities to Gaps: Far-IR Flagship



#### Large-format cryogenic detector arrays

- Compact, Integrated Spectrometers for 100 to 1000 μm
- Cryogenic Far-IR to mm-Wave Focal-Plane Detectors
- Cryogenic Readouts for Large-Format Far-IR Detectors
- Far-IR Imaging Interferometer for High-Resolution Spectroscopy
- Far-IR Spatio-Spectral Interferometry
- Heterodyne Far-IR Detector Systems
- High-Resolution, Direct-Detection Spectrometers for Far-IR Wavelengths
- Improving the Calibration of Far-IR Heterodyne Measurements
- 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
- Warm Readout Electronics for Large-Format Far-IR Detectors
- Sensitive Spectrometer for CMB Spectrum Measurement

#### **Cryogenic optics**

- Optical Elements for a CMB Space Mission
- Large-Aperture Deployable Antennas for Far-IR/THz/sub-mm Astronomy for Frequencies Above 100 GHz
- Large Cryogenic Optics for the Mid IR to Far IR

#### **Cryogenic coolers**

- High-Performance Sub-Kelvin Coolers
- Advanced Cryocoolers



### From Capabilities to Gaps: TDAMM

#### Precision timing and advanced onboard computing

- High-Performance Computing for Event Reconstruction
- Precision Timing Measurement Technology

### Gamma-ray optics

High-Throughput Focusing Optics for 0.1-1 MeV Photons

#### Low-noise high-energy detector arrays & electronics

- Charged-Particle-Discriminating X-ray/Gamma-Ray Detectors
- High-Energy-Resolution Gamma-Ray Detectors
- Large Field-of-View and Effective-Area Gamma-Ray Detectors
- Low-Power, Low-Cost Semiconductor Detectors
- Radiation-Tolerant, Photon-Counting Light Detectors
- Low-Power Readout for Silicon Photomultipliers
- Photometric and Spectro-Photometric Precision of Time-Domain and Time-Series Measurements
- Dynamic Switching for Ultra-Low-Power, High-Resolution Charge Readout

#### Cryogenics

Advanced Cryocoolers



### From Gaps to Investments: Current Tech Project Portfolio

	Project Title		Tech Area	Signal Type		100					
Development of a 30 mK ultra-low temperature Continu	ous ADR with a continuous 700 mK intermediates	stage for heat intercept	Cooling	X Ray, Far IR, Sub-mm	Cale -						
Ultrasensitive Far-IR Kinetic Inductance Detector Arrays: Maturation for Flight			Detector	FarlR							
Demonstrating Large Low Noise Transition Edge Sensor Arrays for Future FIR Space Missions				FarlR	11 C					14 A	
Ultra-stable Telescope Metrology Development for Hi	gh-contrast Exoplanet Detection		Metrology	UVOIR							18.
Ultraviolet Spectroscopy for the Next Decade Enable		Project Title	<b>0</b> -4i			TechArea	Signal T	(De	1		
Scalable Microshutter Systems for Multi-object Spec						Detector	Signari	ype			
Advanced AI mirrors with passivated LiF for environ	Far-IR Detector Solutions for Low Noise, Large	Format, Direct Absorption	A otrophysic	ductance Detector Al	rays	Detector	Farik	- 15			
UV/Optical to Far-IR Mirror & Telescope Technology	The Advanced Astronousics Spectroscony Lab	at LASP	Astrophysic	SIMISSIONS		Eacilities & Optics					
Four megapixel sensor for ultra-low-background shc	Advanced Astrophysics Specificscopy Lab	8 Instrumentation				Lab					
High Performance FUV, NUV, and UV/Optical CMOS I	Advancing & Qualitying OV Space Technology a	amstrumentation				Characterization	0.	_	det		
Large Format, High Efficiency, UV/Optical/NIR Photo	Single-photon counting with SiSeRO to search	for Earth-like planets				Electronics	UVOI	2			100
Advancing Readout of Large-Format Far-IR Transitic	Large-area ALD-protected aluminum mirror coa	atings for HWO				Coatings	UV				
Characterizing Single-photon Sensing CMOS Image	Development of space-qualified signal-processing			Project Tit	la			-			Signal Type
NASA Ames Laboratory Astrophysics Directed Work	New techniques toward the nanofabrication of (			Project In					Tech Alea		Signal Type
, , ,	PHANTOM: Precision High-strain composites (	A duran a a d V way Mian									
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	r nation posicion recipiente (	Advanced X-ray Micr	ocalorimet	ers Sub-package#	3: Magnetically Cou	ipled Calorimete	ers		Detector		X Ray
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rac	Extremely Low-noise, I	High Frame	ers Sub-package# -rate X-ray Image Se	3: Magnetically Cou msors for Strategic A	strophysics Mise	ers sions		Detector Detector		X Ray X-ray
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rac Development of a Low EMI and Acoustic Backgrou	Extremely Low-noise, I Microwave SQUID rea	ocalorimet High Frame adout techi	ers Sub-package# -rate X-ray Image Se nology developme	3: Magnetically Cou Insors for Strategic A Int for future X-ray as	ipled Calorimete strophysics Miss	sions	E	Detector Detector		X Ray X-ray X Ray
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rad Development of a Low EMI and Acoustic Backgrou Supporting technologies for large-scale kinetic	Advanced X-ray Micr Extremely Low-noise, I Microwave SQUID rea	ocalorimet High Frame adouttechi	ers Sub-package# -rate X-ray Image Se nology developme	3: Magnetically Cou Insors for Strategic A Int for future X-ray as	ipled Calorimete strophysics Miss strophysics mis	ers sions sions	E Opto-me	Detector Detector Electronics	00005005	X Ray X-ray X Ray
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rac Development of a Low EMI and Acoustic Backgrou Supporting technologies for large-scale kinetic Build and Commission a new Space Optics Lab	Extremely Low-noise, I Microwave SQUID rea Flex Modules for mar	ocalorimet High Frame adout techi nufacturab	ers Sub-package# -rate X-ray Image Se nology developme le high-resolution ) mized Beflection C	3: Magnetically Cou insors for Strategic A nt for future X-ray as (-ray telescope opti ratings	ipled Calorimeta strophysics Miss strophysics mis cs	sions sions	E Opto-me	Detector Detector Electronics chanical Pro	ocesses	X Ray X-ray X Ray X Ray
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rad Development of a Low EMI and Acoustic Backgrou Supporting technologies for large-scale kinetic Build and Commission a new Space Optics Lat STABLE: Systems Technologies for Architectu	Extremely Low-noise, I Microwave SQUID rea Flex Modules for mar Rapid EBL Patterning MSEC Advanced X-R	ocalorimet High Frame adouttechi nufacturab g for Custo av Optics:	ers Sub-package# -rate X-ray Image Se nology developme le high-resolution ) mized Reflection G Formulation to Flic	3: Magnetically Cou Insors for Strategic A Int for future X-ray as K-ray telescope opti Inatings	ipled Calorimeto strophysics Miss strophysics mis cs	sions sions	E Opto-me	Detector Detector Electronics chanical Pro Optics	ocesses	X Ray X-ray X Ray X Ray X Ray, UV
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rac Development of a Low EMI and Acoustic Backgrou Supporting technologies for large-scale kinetic Build and Commission a new Space Optics Lab STABLE: Systems Technologies for Architectu TechMAST: Technology Maturation for Astroph	Extremely Low-noise, I Microwave SQUID rea Flex Modules for mar Rapid EBL Patterning MSFC Advanced X-Ra Optimized Soft X-ray	ocalorimet High Frame adout techi nufacturab g for Custo ay Optics: Sensors fo	ers Sub-package# -rate X-ray Image Se nology developme le high-resolution ) mized Reflection G Formulation to Flig or Strategic X-ray A	3: Magnetically Cou insors for Strategic A nt for future X-ray as (-ray telescope opti iratings ht strophysics Missio	ipled Calorimeta strophysics Miss strophysics mis cs ns: Achieving	sions sions sions O TRL 5	E Opto-me ptics, coati	Detector Detector Electronics chanical Pro Optics ngs, metrolo Detector	ocesses ogy, facilities	X Ray X-ray X Ray X Ray X Ray, UV X-ray X-ray
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rad Development of a Low EMI and Acoustic Backgrou Supporting technologies for large-scale kinetic Build and Commission a new Space Optics Lat STABLE: Systems Technologies for Architectu TechMAST: Technology Maturation for Astroph ULTRA-CT: Ultra-stable Telescope Research ar	Advanced X-ray Micr Extremely Low-noise, I Microwave SQUID rea Flex Modules for mar Rapid EBL Patterning MSFC Advanced X-Ray Optimized Soft X-ray Advanced X-ray Micr	ocalorimet High Frame adout techi nufacturab g for Custo ay Optics: Sensors for ocalorimet	ers Sub-package# -rate X-ray Image Se nology developme le high-resolution ) mized Reflection G Formulation to Flig or Strategic X-ray A ers Sub-package#	3: Magnetically Cou Insors for Strategic A Int for future X-ray as K-ray telescope opti Iratings Int Strophysics Missio 2: Laboratory Spec	ipled Calorimete strophysics Miss strophysics mis cs ins: Achieving	sions sions sions O TRL 5	E Opto-med ptics, coati	Detector Detector Electronics chanical Pro Optics ngs, metrolo Detector	ocesses ogy, facilities	X Ray X-ray X Ray X Ray X Ray, UV X-ray X-ray X Ray
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rad Development of a Low EMI and Acoustic Backgrou Supporting technologies for large-scale kinetic Build and Commission a new Space Optics Lab STABLE: Systems Technologies for Architectu TechMAST: Technology Maturation for Astroph ULTRA-CT: Ultra-stable Telescope Research ar	Extremely Low-noise, I Microwave SQUID rea Flex Modules for mar Rapid EBL Patterning MSFC Advanced X-Ra Optimized Soft X-ray Advanced X-ray Micr	ocalorimet High Frame adout techi nufacturab g for Custo ay Optics: Sensors for ocalorimet	ers Sub-package# -rate X-ray Image Se nology developme le high-resolution ) mized Reflection G Formulation to Flig or Strategic X-ray A ers Sub-package#	3: Magnetically Cou insors for Strategic A nt for future X-ray as (-ray telescope opti iratings ht strophysics Missio 2: Laboratory Spec	ipled Calorimeta strophysics Miss strophysics mis cs ns: Achieving troscopy	sions sions sions of the second secon	E Opto-mer ptics, coatin Labora	Detector Detector Electronics chanical Pro Optics ngs, metrolo Detector tory Astroph	ocesses ogy, facilities hysics	X Ray X-ray X Ray X Ray X Ray, UV X-ray X-ray X Ray
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rad Development of a Low EMI and Acoustic Backgrou Supporting technologies for large-scale kinetic Build and Commission a new Space Optics Lat STABLE: Systems Technologies for Architectu TechMAST: Technology Maturation for Astroph ULTRA-CT: Ultra-stable Telescope Research ar	Extremely Low-noise, I Microwave SQUID rea Flex Modules for mar Rapid EBL Patterning MSFC Advanced X-Ra Optimized Soft X-ray Advanced X-ray Micr General Coordinates	ocalorimet High Frame adout tech nufacturab g for Custo ay Optics: Sensors fo ocalorimet Network	ers Sub-package# -rate X-ray Image Se nology development le high-resolution 2 mized Reflection G Formulation to Flig or Strategic X-ray A ers Sub-package#	3: Magnetically Cou insors for Strategic A nt for future X-ray as K-ray telescope opti ratings ht strophysics Missio 2: Laboratory Spec	ipled Calorimeta strophysics Miss strophysics mis cs ns: Achieving <sup>-</sup> troscopy	ers sions sions sions 0 TRL 5	E Opto-med ptics, coatin Labora	Detector Detector Electronics chanical Pro Optics ngs, metrolo Detector tory Astroph Software	ocesses ogy, facilities hysics	X Ray X-ray X Ray X Ray X Ray, UV X-ray X-ray X Ray TDAMM
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rad Development of a Low EMI and Acoustic Backgrou Supporting technologies for large-scale kinetic Build and Commission a new Space Optics Lat STABLE: Systems Technologies for Architectu TechMAST: Technology Maturation for Astroph ULTRA-CT: Ultra-stable Telescope Research an	Advanced X-ray Micr Extremely Low-noise, I Microwave SQUID rea Flex Modules for mar Rapid EBL Patterning MSFC Advanced X-Ray Optimized Soft X-ray Advanced X-ray Micr General Coordinates Technology develop	A calorimet High Frame adout tech nufacturab g for Custo ay Optics: Sensors for ocalorimet Network ment for a h	ers Sub-package# -rate X-ray Image Se nology developme le high-resolution ) mized Reflection G Formulation to Flig or Strategic X-ray A ers Sub-package#	3: Magnetically Cou ensors for Strategic A nt for future X-ray as (-ray telescope opti ratings ht strophysics Missio 2: Laboratory Spec ver X-ray spectrome	ipled Calorimete strophysics Miss strophysics mis cs ins: Achieving troscopy	sions sions sions 0 TRL 5	E Opto-mer ptics, coatin Labora	Detector Detector Electronics chanical Pro Optics ngs, metrolo Detector tory Astrop Software Optics	ocesses ogy, facilities hysics	X Ray X-ray X Ray X Ray X Ray, UV X-ray X-ray X Ray TDAMM X-ray
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rad Development of a Low EMI and Acoustic Backgrou Supporting technologies for large-scale kinetic Build and Commission a new Space Optics Lat STABLE: Systems Technologies for Architectu TechMAST: Technology Maturation for Astroph ULTRA-CT: Ultra-stable Telescope Research ar	Advanced X-ray Micr Extremely Low-noise, I Microwave SQUID rea Flex Modules for mar Rapid EBL Patterning MSFC Advanced X-Ra Optimized Soft X-ray Advanced X-ray Micr General Coordinates Technology develop Advanced X-Ray Micr	A colorimet High Frame adout techi nufacturab g for Custo ay Optics: Sensors for cocalorimet Network ment for a h	ers Sub-package# -rate X-ray Image Se nology development le high-resolution ) mized Reflection G Formulation to Flig or Strategic X-ray A ers Sub-package # high-resolving-pow ters Sub-package #	3: Magnetically Cou ensors for Strategic A nt for future X-ray as (-ray telescope opti ratings pht strophysics Missio 2: Laboratory Spec ver X-ray spectrome #1: Transition-Edge	ipled Calorimeta strophysics Miss strophysics mis cs ns: Achieving <sup>-</sup> troscopy eter Sensor (TES)	ers sions sions Sions O TRL 5	E Opto-mee ptics, coatin Labora	Detector Detector Electronics chanical Pro Optics ngs, metrolo Detector tory Astroph Software Optics Detector	ocesses ogy, facilities hysics	X Ray X-ray X Ray X Ray X Ray, UV X-ray X-ray X Ray TDAMM X-ray X Ray
Ultrasensitive Far-IR Kinetic Inductance Detector Arr	Building the Foundations for Huge-N Lunar Rad Development of a Low EMI and Acoustic Backgrou Supporting technologies for large-scale kinetic Build and Commission a new Space Optics Lat STABLE: Systems Technologies for Architectu TechMAST: Technology Maturation for Astroph ULTRA-CT: Ultra-stable Telescope Research an	Advanced X-ray Micr Extremely Low-noise, I Microwave SQUID rea Flex Modules for mar Rapid EBL Patterning MSFC Advanced X-Ra Optimized Soft X-ray Advanced X-ray Micr General Coordinates Technology develop Advanced X-Ray Mic MSFC Relativistic Astro	ocalorimet High Frame adout tech nufacturab g for Custo ay Optics: Sensors fo ocalorimet Network ment for a h rocalorime ophysics –	ers Sub-package # -rate X-ray Image Se nology developme le high-resolution 3 mized Reflection G Formulation to Flig or Strategic X-ray A ers Sub-package # high-resolving-pow ters Sub-package #	3: Magnetically Cou Insors for Strategic A Int for future X-ray as K-ray telescope opti Iratings Iht Strophysics Missio 2: Laboratory Spec Ver X-ray spectrome #1: Transition-Edge trophysics Commun	ipled Calorimeta strophysics Miss strophysics mis cs ins: Achieving troscopy eter Sensor (TES) ity Tools and Sup	ers sions sions sions 0 TRL 5 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	E Opto-med ptics, coatii Labora	Detector Detector Electronics chanical Pro Optics ngs, metrolo Detector tory Astroph Software Optics Detector Software	ocesses ogy, facilities hysics	X Ray X-ray X Ray X Ray, UV X-ray X-ray X Ray TDAMM X-ray X Ray TDAMM



### **Additional Material**



# The Physics of the Cosmos (PhysCOS)/Cosmic Origins (COR) technology website (<a href="https://apd440.gsfc.nasa.gov/technology.html">https://apd440.gsfc.nasa.gov/technology.html</a>) provides more details, including:

- Description of our technology development process
- Full details of the current technology gaps and their priority ranking
- AstroTech database (in process of move to NASA URL) with abstracts, PI reports, quad charts, etc. of PhysCOS, COR, and Exoplanet Exploration Program (ExEP) past and current strategic tech investments



ASTROPHYSICS

#### About the PCOS and COR Program Offices

The Physics of the Cosmos (PCOS) and Cosmic Origins (COR) Program Offices were set up by NASA HQ Science Mission Directo Division (APD) to support aspects of these focused astrophysics science themes.

More About the Program Offices

Technology Gaps







#### **Astrophysics Technology Development**

Toos, oon a Exer Trogram onioes

#### Welcome to the Astrophysics Technology Development Portfolio

This database is updated annually and indexes technology development projects funded by the NASA Astrophysics Division. The portfolio includes information about the Strategic Astrophysics Technology (SAT), Astrophysics Research and Analysis (APRA), and Nancy Grace Roman Technology Fellowship (RTF) projects, along with other competed and direct-funded technology projects.

Astrophysics is the science that studies the universe. The Astrophysics Division funds and manages missions and studies that seek to broaden our understanding of our place in the universe. This work addresses three big questions: How does the universe work? How did we get here? Are we alone? These three themes are managed by the Physics of the Cosmos (PCOS), Cosmic Origins (COR), and Exoplanet Exploration (ExEP) Programs, respectively. The breadth and scope of astrophysics can be summed up by simply saying that if it is located outside our Solar System, we are interested in studying it. Astrophysics is humankind's scientific endeavor to understand the universe and our place it it.

Scope of Searc	h						
Funding Program Portfolio Manager	✓ SAT ✓ COR	✓ Directed ✓ ExEP	✓ Other ✓ PCOS			APRA VARA APRA APRA and RTF Portfolios are managed by HQ	
			Project Status	<b>~</b> A	ctive	Completed	
					Clear All		



### Final Words (for Now...)



- We've seen our currently planned path to enable breakthrough science
- The challenges are extreme, as in "Miracles we provide immediately; the impossible takes a little longer"
- Sometimes, impossible-seeming problems become easy when you look at them differently
- Our invitation to you: Where you can, disrupt our assumptions, approaches, and plans, if it enables even more inspiring science – in short, help us find better paths...

Contact information for questions and comments:

- Jason Derleth, PhysCOS/COR Chief Technologist: jason.e.derleth@nasa.gov
- Opher Ganel, PhysCOS/COR Technologist: <u>opher.ganel@nasa.gov</u>

# Backup



## From Missions to Gaps (Tier 1 Gaps)



TECHNOLOGY GAP	OWH	X-RAY GO/PROBE	FAR-IR GO/PROBE	CMB PROBE	TDAMM
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 (from HWO START/TAG)	×				
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 (from HWO START/TAG)	×				
High-Resolution, Lightweight X-ray Optics		×			
High-Throughput, Large-Format Object-Selection Technologies for Multi-Object and Integral Field Spectroscopy (from HWO START/TAG)	×				
Integrated Modeling for HWO: Multi-Physics Systems Modeling, Uncertainty Quantification, and Model Validation	×				
Large-Format, High-Resolution Far-UV (100-200 nm) Detectors (from HWO START/TAG)	×				
Large-Format, High-Resolution Near-UV (200 - 400 nm) Detectors (from HWO START/TAG)	×				
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 (from HWO START/TAG)	×				
Segmented-Pupil Coronagraph Contrast and Efficiency in the Visible Band	×				
UV Multi-Object Spectrograph Calibration Technologies (from HWO START/TAG)	×				
UV Single-Photon Detection Sensitivity	×				
Visible/Near-IR Single-Photon Detection Sensitivity	×				



### From Missions to Gaps (Tier 2 Gaps)







### From Missions to Gaps (Tier 3 Gaps etc.)



TIER	TECHNOLOGY GAP	OWH	X-RAY GO/PROBE	FAR-IR GO/ PROBE	CMB PROBE	TDAMM
	Broadband X-ray Polarimeter		×			
	Charged-Particle-Discriminating X-ray/Gamma-Ray Detectors					×
	Dynamic Switching for Ultra-Low-Power, High-Resolution Charge Readout					×
	High-Energy-Resolution Gamma-Ray Detectors					×
	Large-Aperture Deployable Antennas for Far-IR/THz/sub-mm Astronomy for Frequencies Above 100 GHz			×		
	Large Cryogenic Optics for the Mid IR to Far IR			×		
2	Large Field-of-View and Effective Area Gamma-Ray Detectors					×
3	Low-Power, Low-Cost Semiconductor Detectors					×
	Low-Power Readout for Silicon Photomultipliers					×
	Photometric and Spectro-Photometric Precision of Time-Domain and Time-Series Measurements					×
	Precision Timing Measurement Technology			×		
	Radiation-Tolerant, Photon-Counting Light Detectors		×			
	Sensitive Spectrometer for CMB Spectrum Measurement				×	
	UV/Optical/Near-IR Tunable Narrowband Imaging Capability	×				
4	Advancement of X-ray Polarimeter Sensitivity		None			
4	Detection Stability in Mid-IR	None				

Program	Project Title	Current COR Technology Portfolio	PI Name	PI Inst	Technology Area	Signal Type
SAT2021	Development of a 30 mK ultra-low temperature Continuous ADR with a co	ntinuous 700 mK intermediate stage for heat intercept	Kimball, M	GSFC	Cooling System	X Ray, Far IR, Sub-mm
SAT2021	Ultrasensitive Far-IR Kinetic Inductance Detector Arrays: Maturation fo	r Flight	Bradford, C	JPL	Detector	Far IR
SAT2021	Demonstrating Large Low Noise Transition Edge Sensor Arrays for Fu	ture FIR Space Missions	Staguhn, J	JHU	Detector	Far IR
SAT2021	Ultra-stable Telescope Metrology Development for High-contrast Exop	lanet Detection	Saif, B	GSFC	Metrology	UVOIR
SAT2021	Ultraviolet Spectroscopy for the Next Decade Enabled Through Nanofa	brication Techniques	McEntaffer, R	PSU	Optics	UVOIR
SAT2022	Scalable Microshutter Systems for Multi-object Spectroscopy		Scowen, P	GSFC	Optics	UVOIR
SAT2021	Advanced AI mirrors with passivated LiF for environmentally stable 1-r	neter class UV space telescopes	Quijada, M	GSFC	Optical Coating	UVOIR
ISFM22	UV/Optical to Far-IR Mirror & Telescope Technology Development		Stahl, H P	MSFC	Optics	UVOIR
SAT2022	Four megapixel sensor for ultra-low-background shortwave infrared as	stronomy	Bottom, M	UH	Detector	Near-IR
SAT2021	High Performance FUV, NUV, and UV/Optical CMOS Imagers		Hoenk, M	JPL	Detector	UV
SAT2021	Large Format, High Efficiency, UV/Optical/NIR Photon Counting Detect	ors	Nikzad, S	JPL	Detector	UVOIR
SAT2021	Advancing Readout of Large-Format Far-IR Transition-Edge Sensor Ar	rays	Rostem, K	GSFC	Electronics	Far IR
SAT22	Characterizing Single-photon Sensing CMOS Image Sensors for NASA	Missions	Figer, D	RIT	Detector	VIS
ISFM22	NASA Ames Laboratory Astrophysics Directed Work Package (LADWP	) Round 2 ISFM	Sciamma-O'Brien, E	Ames	Lab Astrophysics	UV, IR, VIS
SAT22	Ultrasensitive Far-IR Kinetic Inductance Detector Arrays for Space		Hailey-Dunsheath, S	Caltech	Detector	Far IR
SAT22	Far-IR Detector Solutions for Low Noise, Large Format, Direct Absorpt	ion Kinetic Inductance Detector Arrays	Austermann, J	NIST	Detector	Far IR
SAT22	A High-Performance Ultraviolet Photon Counting Detector for Strategic	Astrophysics Missions	Nikzad, S	JPL	Detector	UV
RTF23	The Advanced Astrophysics Spectroscopy Lab at LASP		Vorobiev, D	LASP	Facilities & Optics	UV
RTF23	Advancing & Qualifying UV Space Technology & Instrumentation		Hoadley, K	Univ of Iowa	Lab Characterization	UV
SAT23	Single-photon counting with SiSeRO to search for Earth-like planets		Estrada, J	U. of Chicago	Electronics	UVOIR
SAT23	Large-area ALD-protected aluminum mirror coatings for HWO		Hennessy, J	JPL	Coatings	UV
SAT23	Development of space-qualified signal-processing readout electronics for H	WO and Origins Space Telescope detector arrays	Jamison-Hooks, T	ASU	Electronics	UVOIR and Far-IR
SAT23	New techniques toward the nanofabrication of custom, blazed UV grati	ngs to enable next-generation spectroscopy	Miles, D	Caltech	Optics	UV
SAT23	PHANTOM: Precision High-strain composites (HSCs) for AstroNomical	Telescope OptoMechanics	Silver, M	MIT/LL	Structures	UVOIR
RTF24	Building the Foundations for Huge-N Lunar Radio Interferometry		Pober, J	Brown	Software	СМВ
RTF24	Development of a Low EMI and Acoustic Background Characterization Testbe	ed for Ultra-low Noise Transition Edge Sensor Bolometers	Connors, J	GSFC	Detectors	Far-IR
RTF24	Supporting technologies for large-scale kinetic inductance current sen	sor readouts	Szypryt, P	Colorado	Electronics	Visible, Near IR
RTF24	Build and Commission a new Space Optics Laboratory (SOL) at UMass	Lowell	Mendillo, C	Umass Lowell	Facilities	UVOIR
CT4LT	STABLE: Systems Technologies for Architecture Baseline		Glassman, T	NG	Structures	UVOIR
CT4LT	TechMAST: Technology Maturation for Astrophysics Space Telescope	S	Carrier, A	LM	Modeling	UVOIR

Funding Program	Project Title	Current PhysCOS Technology Portfolio	PI Name	PI Inst	Technology Area	Signal Type
ISFM22	Advanced X-ray Microcalorimeters Sub	-package #3: Magnetically Coupled Calorimeters	Bandler, Simon	GSFC	Detector	X Ray
SAT2021	Extremely Low-noise, High Frame-rate	X-ray Image Sensors for Strategic Astrophysics Missions	Bautz, Mark	МІТ	Detector	X-ray
SAT2021	Microwave SQUID readout technology	development for future X-ray astrophysics missions	Bennett, Douglas	NIST	Electronics	X Ray
RTF24	Flex Modules for manufacturable high-	resolution X-ray telescope optics	Chalifoux, Brandon	ASU	Opto-mechanical Processes	X Ray
RTF23	Rapid EBL Patterning for Customized R	eflection Gratings	DeRoo, Casey	Univ of Iowa	Optics	X Ray, UV
ISFM22	MSFC Advanced X-Ray Optics: Formula	ation to Flight	Gaskins, Jessica	MSFC	Optics, coatings, metrology, facilities	X-ray
SAT22	Optimized Soft X-ray Sensors for Strate	gic X-ray Astrophysics Missions: Achieving TRL 5	Leitz, Christopher	MIT/LL	Detector	X-ray
ISFM22	Advanced X-ray Microcalorimeters Sub	-package #2: Laboratory Spectroscopy	Porter, Scott	GSFC	Laboratory Astrophysics	X Ray
ISFM22	General Coordinates Network		Racusin, Judith	GSFC	Software	TDAMM
SAT23	Technology development for a high-res	olving-power X-ray spectrometer	Schattenburg, Mark	МІТ	Optics	X-ray
ISFM22	Advanced X-Ray Microcalorimeters Sul	o-package #1: Transition-Edge Sensor (TES)	Smith, Stephen	GSFC	Detector	X Ray
ISFM22	MSFC Relativistic Astrophysics – Multi	messenger Astrophysics Community Tools and Support	Wilson-Hodge, Colleen	MSFC	Software	TDAMM
ISFM22	Next-Generation X-ray Optics: High Res	solution, Light Weight, and Low Cost	Zhang, William	GSFC	Optics	X Ray