2022 APD Technology Gaps: Prioritization Process and Results

Program Office Technologists:
Pin Chen Brendan Crill, Nick Siegler (ExEP);
Jay Falker, Opher Ganel, Rachel Rivera (PCOS/COR)

June 12, 2022

Purposes of Technology Gap List

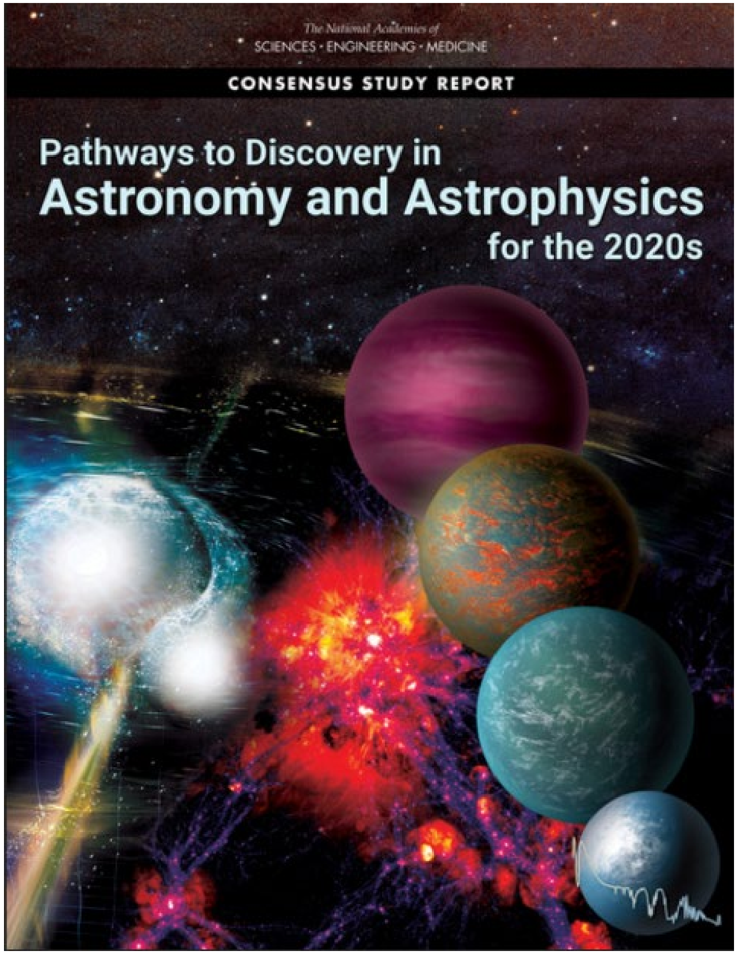
- **A technology gap is the difference between a capability needed to enable (or enhance) a future mission and the current state-of-the-art**
- **The Astrophysics Division maintains a prioritized Technology Gap List**
- **Program Office technologists carry out biennial technology gap prioritizations**
  - **Identify technology gaps** applicable to Astrophysics strategic objectives
  - **Rank technology gaps** to prioritize for investment
  - **Inform the community** of Astrophysics technology needs through Astrophysics Biennial Technology Report (ABTR) https://apd440.gsfc.nasa.gov/images/tech/2022_ABTR.pdf

Technology Gap Solicitation and Prioritization Process

1. **Technology gaps are solicited from the community, informed by the Decadal Survey**
   – Planned to collect by 6/1/2021, delayed to 1/3/2022 due to Astro2020 release schedule
2. **Program Office (PO) staff review the collected gaps and assign each to the Program that would be most impacted by closing it**
3. **Each PO consolidates the inputs for its Program and asks its community to review the gaps for accuracy and completeness before prioritization**
4. **A Technology Management Board (TMB) reviews and prioritizes the resulting gaps**
   – TMB membership is diverse and includes senior members of Astrophysics Division, STMD, and the POs; technologists and scientists from the three POs; and subject matter experts
   – Prioritization is based on a published set of criteria (strategic alignment, benefits and impacts, urgency, and scope of applicability)
5. **The lists from the three Programs is merged into a joint, prioritized Astrophysics technology gap list**

How Did the Astro2020 Affect the 2022 Prioritization?

1. **The strategic missions recommended by Astro2020 replaced the previous set of strategic missions (the TDAMM program was added, despite no missions specified)**
   - IROUV Flagship
   - X-ray Flagship
   - Far-IR Flagship
   - X-ray Probe
   - Far-IR Probe
   - CMB Probe
   - TDAMM
2. **The estimated launch timeline informed gap urgency**



Astrophysics Technology Gap Priorities

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

Tier 1 Technology Gaps

Advanced Cryocoolers
Coronagraph Contrast and Efficiency
Coronagraph Stability
Cryogenic Readouts for Large-Format Far-IR Detectors
Heterodyne Far-IR Detector Systems
High-Performance, Sub-Kelvin Coolers
High-Reflectivity Broadband Far-UV-to-Near-IR Mirror Coatings
High-Resolution, Large-Area, Lightweight X-ray Optics
High-Throughput Bandpass Selection for UV/VIS
High-Throughput, Large-Format Object Selection Technologies for Multi-Object and Integral Field Spectroscopy
Large Cryogenic Optics for the Mid IR to Far IR
Large-Format, High-Resolution Focal Plane Arrays
Large-Format, Low-Darkrate, High-Efficiency, Photon-Counting, Solar-blind, Far- and Near-UV Detectors
Large-Format, Low-Noise and Ultralow-Noise Far-IR Direct Detectors
Long-Wavelength-Blocking Filters for X-ray Micro-Calorimeters
Low-Stress, High-Stability, X-ray Reflective Coatings
Mirror Technologies for High Angular Resolution (UV/Vis/Near IR)
Stellar Reflex Motion Sensitivity – Astrometry
Stellar Reflex Motion Sensitivity – Extreme Precision Radial Velocity
Vis/Near-IR Detection Sensitivity

Tier 2 Technology Gaps

Broadband X-ray Detectors
Compact, Integrated Spectrometers for 100 to 1000 µm
Far-IR Imaging Interferometer for High-Resolution Spectroscopy
Far-IR Spatio-Spectral Interferometry
Fast, Low-Noise, Megapixel X-ray Imaging Arrays with Moderate Spectral Resolution
High-Efficiency X-ray Grating Arrays for High-Resolution Spectroscopy
High-Resolution, Direct-Detection Spectrometers for Far-IR Wavelengths
Improving the Calibration of Far-IR Heterodyne Measurements
Large-Aperture Deployable Antennas for Far-IR/THz/sub-mm Astronomy for Frequencies over 100 GHz
Large-Format, High-Spectral-Resolution, Small-Pixel X-ray Focal-Plane Arrays
Polarization-Preserving Millimeter-Wave Optical Elements
Precision Timing for Space-Based Astrophysics
Rapid Readout Electronics for X-ray Detectors
Starshade Deployment and Shape Stability
Starshade Starlight Suppression and Model Validation
UV Detection Sensitivity

Tier 3 Technology Gaps

Advancement of X-ray Polarimeter Sensitivity
Detection Stability in Mid-IR
Far-UV Imaging Bandpass Filters
High-Efficiency Far-UV Mirror
High-Efficiency, Low-Scatter, High- and Low-Ruling-Density, High- and Low-Blazed-Angle UV Gratings
High-Quantum-Efficiency, Solar-Blind, Broadband Near-UV Detector
Photon-Counting, Large-Format UV Detectors
Short-Wave UV Coatings
Warm Readout Electronics for Large-Format Far-IR Detectors

Tier 4 Technology Gaps

Advanced Millimeter-Wave Focal-Plane Arrays for CMB Polarimetry
Improving the Photometric and Spectro-Photometric Precision of Time-Domain and Time-Series Measurements
UV/Opt/Near-IR Tunable Narrow-Band Imaging Capability
Very-Wide-Field Focusing Instrument for Time-Domain X-ray Astronomy

Tier 5 Technology Gaps

Complex Ultra-Stable Structures for Future Gravitational-Wave Missions
Disturbance Reduction for Gravitational-Wave Missions
Gravitational Reference Sensor
High-Performance Spectral Dispersion Component/Device
High-Power, High-Stability Laser for Gravitational-Wave Missions
Laser Phase Measurement Chain for a Decihertz Gravitational-Wave Mission
Micro-Newton Thrusters for Gravitational Wave-Missions
Stable Telescopes for Gravitational Wave-Missions

You can find this priority list in the ABTR, or at the above URL

Gaps by Program

Program	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5	Total	2019
COR	11	7	7	2	1	**28**	23
ExEP	6	3	1	0	0	**10**	12
PCOS	3	6	1	2	7	**19**	13
Total	**20**	**16**	**9**	**4**	**8**	**57**	**48**

Gaps by Relevant Strategic Mission

Mission	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5	Total
IROUV	11	3	6	1		**21**
Far-IR Flagship	6	8	2			**16**
X-ray Flagship	3	5	1			**9**
Far-IR Probe	6	8	2			**16**
X-ray Probe	3	5	1	1		**10**
CMB Probe				1		**2**
TDAMM				2		**2**
None					8	**8**
Total	**29**	**30**	**12**	**5**	**8**	**84**

What do These Priorities Mean?

- **The technology gap list informs the SAT solicitation and selections; historically the focus has been on the first two priority tiers**
- **However, gaps in lower tiers are not ignored**
  - Technologies that address any gap, whether solicited in SAT or not, may fit in APRA
  - Gaps in lower tiers have at times moved to higher tiers in later cycles (a new Astrophysics Implementation Plan, AIP, is expected to be released by the end of 2022, and will inform the next cycle)
  - Astrophysics Division may decide to direct-fund technologies they deem important enough after considering programmatic aspects, for example through the work of the Technology Strategy Team (TST)

Where to find the 2022 Gap List

https://apd440.gsfc.nasa.gov/tech_gap-descriptions.html

ASTROPHYSICS TECHNOLOGY DEVELOPMENT

Overview | Technology | Outreach

Astrophysics Program Offices

2022 Astrophysics Strategic Technology Gaps

TECHNOLOGY GAPS: OVERVIEW / TECH GAP PRIORITIES / PRIORITIZATION PROCESS / TECH GAP DESCRIPTIONS

Download the Excel Spreadsheet

Gap Name	Description	Current State-of-the-Art	TRL	Performance Goals and Objectives	Scientific, Engineering, and/or Programmatic Benefits	Applications and Potential Relevant Astrophysics Missions	Urgency
Cryogenic Readouts for Large-format Far-IR Detectors	Readout schemes including cryogenic multiplexing for arrays of large-format Far-IR detectors need to be developed.	Readout schemes using HEMT or SiGe amplifiers and frequency-multiplexed resonant circuits are in development. A few hundred channels per 1 mW HEMT amplifier have been demonstrated. Low power dissipation at 4 K is required. For TES-based detectors a microwave SQUID multiplexer using frequency division, time division or code division multiplexing is needed. Frequency division multiplexing is well advanced and can meet the needs of a far-IR flagship when scaled to 2000 pixels (resonators) per 4 GHz channel.	3	Near-term, this scheme should result in 2000 pixels per amplifier channel (enabling), 3000 pixels/channel (enhancing).HEMT amplifiers from Low Noise Factory can achieve 10 dB with 0.38 mW of dissipation at 4 K.	Sensitivity reduces observing times from many hours to a few minutes (≈ 100× faster), while array format increases areal coverage by ×10-100. Overall mapping speed can increase by factors of thousands. Sensitivity enables measurement of low-surface-brightness debris disks and protogalaxies with an interferometer. This is enabling technology. Suborbital and ground-based platforms can be used to validate technologies and advance TRL of new detectors.	Far-IR Flagship Far-IR Probe FIR detector technology is an enabling aspect of all future FIR mission concepts, and is essential for future progress. This technology can improve science capability at a fixed cost much more rapidly than larger telescope sizes. This development serves Astrophysics almost exclusively (with some impact on planetary and Earth studies). Many synergies exist with similar developments for x-ray microcalorimeters	Required TRL 6 by mission PDR. Extreme stretch Single tech

You can download the details of all gaps in Excel from this page

Backup

Gap Submission Guidelines

1. Focus on technology gaps associated with missions prioritized in Astro2020
2. Submit gaps directly applicable to Program objectives (not ones outside our purview (e.g., associated with launch vehicle, rover, avionics, s/c systems, etc.)
3. Don't include gaps that don't require technology development, that are not well defined, that are redundant (duplicate, similar, or subsets of existing gaps), or where solutions are at TRL 6 or higher for the relevant strategic mission(s)
4. Inputs should be submitted as gaps between the current state-of-the-art and what's required to achieve the science objective targeted, not specific solutions
5. Inputs should not endorse or advertise any organization, mission, or person
6. Inputs should not contain proprietary, or EAR/ITAR-restricted information

Full details are provided in the gap submission form instructions

Four Prioritization Criteria

- **Strategic Alignment:** How well does the technology align with astrophysics science and/or programmatic priorities set out in the Decadal Survey?
- **Benefits and Impacts:** How much impact does the technology have on applicable missions? To what degree does it enable and/or enhance achievable science objectives, reduce cost, and/or reduce mission risks?
- **Urgency:** Given the anticipated difficulty of maturing from current TRL of a full solution to TRL 6, assessed against the time available until the need-by year, how urgently does the gap need to be addressed?
- **Scope of Applicability:** How crosscutting is the technology? How many Astrophysics programs and/or mission concepts (strategic or other) would benefit by closing the gap?