NASA Strategic Astrophysics Technology Investments: A Decade of Benefits, Outlook Informed by the 2020 Decadal Survey

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Strategic Astrophysics missions as recommended by the 2020 Decadal Survey on Astronomy and Astrophysics

- IR/O/UV Flagship to be launched in the first half of the 2040s
- X-ray Flagship to be launched in a later decade than IR/O/UV Flagship
- Far-IR Flagship to be launched in a later decade than IR/O/UV Flagship
- X-ray Probe to compete for 2030s launch
- Far-IR Probe to compete for 2030s launch
- CMB Probe to compete for 2040s launch vs. above Probe that hasn’t launched
- TDAMM (program recommendation at this point, but missions may be added)
The three Program Offices serve the critical function of developing concepts and technologies for strategic missions and facilitating science investigations derived from them, specifically:

- Assess and prioritize technology gaps, collecting inputs from the community and technology activities.
- Manage projects maturing technologies for strategic missions from TRLs of 3, 4, or 5.
- Promote infusion of technologies into missions and projects.
- Conduct mission studies and develop mission concepts enabling future scientific discoveries.
- Communicate progress to and coordinate with the scientific community.
- Inform the general public about progress achieved by the Programs.

Astrophysics Program Office technology maturation process comprises three cycles

- A 10-year Decadal Survey cycle to recommend the highest-priority missions and activities for the coming decade.
- A biennial technology gap prioritization and Program Office reporting cycle.
- An annual process of soliciting, reviewing, and funding SAT proposals.
Note that this does not include APRA and RTF projects, which are not strategic.
Technology Development Projects’ Length

Number of funding cycles per project, with 30 projects extending 1–4 additional cycles.

Distribution of projects by total length in years, including any follow-on cycles.
Technology Development Projects by Program and Org Type

Technology development by Program since 2009: number of projects (left), and total investment (right).

Distribution institutional types receiving awards for strategic technology developments.
Technology Development Projects by Technology Area and Signal Type

Distribution of the 82 projects in the strategic technology portfolio by topic.

- Micropropulsion, 2
- Laser, 2
- Telescope, 4
- Starshade, 5
- Optical Coating, 6
- Electronics, 8
- Optics, 12
- Coronagraph, 17
- Metrology/Structure, 1
- EPRV, 1
- Detector, 23

Distribution of the 82 projects in the strategic technology portfolio by signal type

- UV, 9
- UV/Vis, 3
- X Ray, 18
- Near IR, 2
- Vis/Near IR, 2
- Mid IR, 1
- Far IR/Sub-mm, 8
- GW, 8
- UVOIR, 30
- Microwave/RF, 4
Distribution of the 82 projects in the strategic technology portfolio by strategic mission(s) supported. Note that many projects support multiple missions, so the total is greater than 82.
Technology Readiness Level (TRL) Advancements

Distribution of TRL advancement (while in the program) for strategic technology development projects. Some continue advancing in TRL after project completion, especially those infused into spaceflight projects.

Percentage of technology development projects achieving TRL advancement vs. TRL_in. Not shown in the graph, nine of 31 projects advancing from TRL_in of 3 advanced by two levels, to 5.
### Technology Infusions

<table>
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<tr>
<th>Disciplines</th>
<th>Space</th>
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</table>

**Summary of infusions, already implemented/upcoming/conceptual by mission/project type.**

(Implemented = in existing/past mission/project; Upcoming = selected by mission/project in development; Concepts = baselined by reference design of strategic mission)

**Summary of missions/projects infused into, by discipline and type.**
Technology gaps are what separates the current state of the art (SOTA) from what's needed to enable and/or enhance future strategic missions.

Technology gap entries need to:
- Focus on strategic Astrophysics missions
- Be directly applicable to Program objectives
- Require technology development (i.e., TRL < 6 for stated requirements)
- Describe gap between SOTA and what’s required for targeted science objective

Technology gaps entries should not:
- Be outside our purview (e.g., for launch vehicles, spacecraft systems, etc.)
- Be a specific solution, or advocate for one
1. Advanced Cryocoolers
2. Coronagraph Contrast and Efficiency
3. Coronagraph Stability
4. Cryogenic Readouts for Large-Format Far-IR Detectors
5. Heterodyne Far-IR Detector Systems
6. High-Performance, Sub-Kelvin Coolers
7. High-Reflectivity Broadband Far-UV-to-Near-IR Mirror Coatings
8. High-Resolution, Large-Area, Lightweight X-ray Optics
9. High-Throughput Bandpass Selection for UV/VIS
10. High-Throughput, Large-Format Object Selection Technologies for Multi-Object and Integral Field Spectroscopy
11. Large Cryogenic Optics for the Mid IR to Far IR
12. Large-Format, High-Resolution Focal Plane Arrays
14. Large-Format, Low-Noise and Ultralow-Noise Far-IR Direct Detectors
15. Long-Wavelength-Blocking Filters for X-ray Micro-Calorimeters
16. Low-Stress, High-Stability, X-ray Reflective Coatings
17. Mirror Technologies for High Angular Resolution (UV/Vis/Near IR)
18. Stellar Reflex Motion Sensitivity – Astrometry
19. Stellar Reflex Motion Sensitivity – Extreme Precision Radial Velocity
20. Vis/Near-IR Detection Sensitivity
1. Broadband X-ray Detectors
2. Compact, Integrated Spectrometers for 100 to 1000 μm
3. Far-IR Imaging Interferometer for High-Resolution Spectroscopy
4. Far-IR Spatio-Spectral Interferometry
5. Fast, Low-Noise, Megapixel X-ray Imaging Arrays with Moderate Spectral Resolution
6. High-Efficiency X-ray Grating Arrays for High-Resolution Spectroscopy
7. High-Resolution, Direct-Detection Spectrometers for Far-IR Wavelengths
8. Improving the Calibration of Far-IR Heterodyne Measurements
9. Large-Aperture Deployable Antennas for Far-IR/THz/sub-mm Astronomy for Frequencies over 100 GHz
10. Large-Format, High-Spectral-Resolution, Small-Pixel X-ray Focal-Plane Arrays
11. Polarization-Preserving Millimeter-Wave Optical Elements
12. Precision Timing for Space-Based Astrophysics
13. Rapid Readout Electronics for X-ray Detectors
14. Starshade Deployment and Shape Stability
15. Starshade Starlight Suppression and Model Validation
16. UV Detection Sensitivity
Strategic Technology Gap Priorities – Tiers 3 to 5

Tier 3:
1. Advancement of X-ray Polarimeter Sensitivity
2. Detection Stability in Mid-IR
3. Far-UV Imaging Bandpass Filters
4. High-Efficiency Far-UV Mirror
5. High-Efficiency, Low-Scatter, High- and Low-Ruling-Density, High- and Low-Blazed-Angle UV Gratings
6. High-Quantum-Efficiency, Solar-Blind, Broadband Near-UV Detector
7. Photon-Counting, Large-Format UV Detectors
8. Short-Wave UV Coatings
9. Warm Readout Electronics for Large-Format Far-IR Detectors

Tier 4:
1. Advanced Millimeter-Wave Focal-Plane Arrays for CMB Polarimetry
2. Improving Photometric and Spectro-Photometric Precision of Time-Domain and Time-Series Measurements
3. UV/Opt/Near-IR Tunable Narrow-Band Imaging Capability
4. Very-Wide-Field Focusing Instrument for Time-Domain X-ray Astronomy

Tier 5:
1. Complex Ultra-Stable Structures for Future Gravitational-Wave Missions
2. Disturbance Reduction for Gravitational-Wave Missions
3. Gravitational Reference Sensor
4. High-Performance Spectral Dispersion Component/Device
5. High-Power, High-Stability Laser for Gravitational-Wave Missions
6. Laser Phase Measurement Chain for a Decihertz Gravitational-Wave Mission
7. Micro-Newton Thrusters for Gravitational Wave-Missions
8. Stable Telescopes for Gravitational Wave-Missions
What do These Priorities Mean?

- The technology gap list informs 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 and technology strategy for the future great observatories.
Gaps by Program & Mission Supported

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<th>Program</th>
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Many gaps affect multiple missions, so the total is greater than 57.
How Can You Participate?

- If you’re from a US institution, you can propose to any of the following opportunities:
  - RTF (https://nspires.nasaprs.com/external/solicitations/summary.do?solId=1EF0CA93-73C0-F40B-CE95-96647D403CA6)&path=&method=init

- Important Due Dates for APRA and SAT
  - Mandatory Notice of Intent (NOI) is due by October 21, 2022
  - Proposals are due by December 15, 2022


• Tech gap list: [https://apd440.gsfc.nasa.gov/tech_gap_priorities.html](https://apd440.gsfc.nasa.gov/tech_gap_priorities.html)

• Tech gaps details: [https://apd440.gsfc.nasa.gov/tech_gap-descriptions.html](https://apd440.gsfc.nasa.gov/tech_gap-descriptions.html)