
# PCOS Program's Strategic Technology Gaps - Current and Future

PhysPAG Meeting at AAS

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# NASA Astrophysics Funds Technology Development at All Levels of Maturity

- **The Astrophysics Research and Analysis (APRA) program** funds technology development in the earlier phases, from basic principles through proof-of-concept and beyond **(typically Technology Readiness Level (TRL) 1 through 3)**. APRA also funds suborbital science and/or technology investigations that can be carried out with sounding rockets, balloons, or other platforms (CubeSat, ISS) which can be at TRLs higher than 3.
- **The Strategic Astrophysics Technology (SAT) program** matures key technologies filling the high priority technology gaps to the point at which they can be implemented into space flight missions, taking them from proof-of-concept to a high fidelity demonstration of a design that meets specific performance requirements **(mid-TRLs; 3 to 6)**.
- **Funded flight projects** address the final maturation stages **(TRL 6 through 9)** focusing on proving the technology's flight-worthiness for a specific mission.

# Strategic Technology Development Model

- **Identify** technology gaps based on an annual prioritization of inputs submitted by the science and technology community and on the guidance of the Astrophysics Implementation Plan which is guided by the Decadal Survey.
- **Invest** in technology development through the ROSES SAT peer review process.
- **Monitor** the development and maturity of funded technologies.
- **Support** mission concepts in formulation with the guidance of Technology Development Plans (TDPs)
- **Enable** future flight missions by supporting the infusion of maturing technologies.

# STRATEGIC TECHNOLOGY DEVELOPMENT PROCESS

**Technology gap submissions from the community are central to our strategic technology development process**

NRC

Decadal Survey

Inputs to Decadal Survey

NASA/Astrophysics

SAT Annual Call for Proposals

Strategic Guidance (e.g., AIP)

Proposals

Peer Review

Selection and Funding

Technology Development

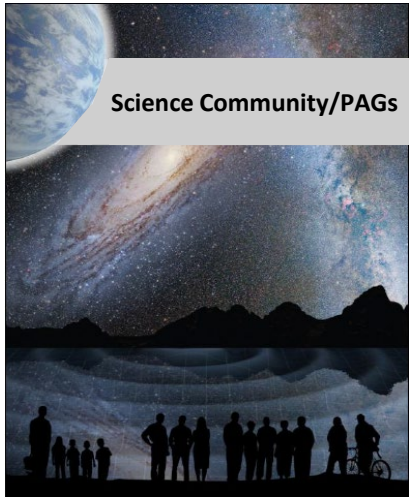
Technology Advancement

Technology Gap Identification

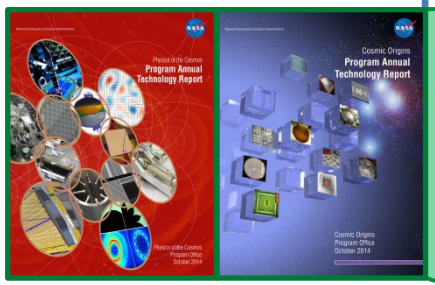
Technology Gap Prioritization

Program Office/TMBs

PI Progress Reports and Technology Milestones








**PATRs:**
- Technology Gaps
- Technology Priorities
- New Award Announcements
- Current Investment Progress Reports

Informs NASA

APD, SMD, OCT, STMD

Feedback to Community

# Program Annual Technology Report (PATR)


The PATR is an annual report that summarizes the Program's technology development activities for the prior year.

- Provides overview of the Program and its technology development activities
- Give status of the Program's strategic and targeted technology development for the prior year and announces the new SAT award selections.
- Summarizes the technology capability gaps obtained from the community.
- Provides a prioritized list of the capability gaps for the coming year to inform the SAT proposal calls and the selection decisions
- Updated annually and released in October to support annual technology development planning.

The PCOS PATR can be downloaded from https://pcos.gsfc.nasa.gov

# Current PCOS SAT Portfolio

| Funding Source | Technology Development Title | PI | Organization | Start Year and Duration | Science Area |
|---|---|---|---|---|---|
| SAT2010 | Directly-Deposited Blocking Filters for Imaging X-ray Detectors | M. Bautz | MIT | FY12, 3 years | X-ray |
| SAT2010 | Development of Moderate Angular Resolution Full Shell Electroplated Metal Grazing Incidence X-ray Optics | P. Reid | SAO | FY12, 3 years | X-ray |
| SAT2011 | Demonstrating Enabling Technologies for the High-Resolution Imaging Spectrometer of the Next NASA X-ray Astronomy Mission | C. Kilbourne | GSFC | FY13, 3 years | X-ray |
| SAT2011 | Colloid Microthruster Propellant Feed System for Gravitational-Wave Astrophysics Missions | J. Ziemer | JPL | FY13, 2 years | GW |
| SAT2011 | Telescope for a Space-based Gravitational-Wave Mission | J. Livas | GSFC | FY13, 2 years | GW |
| SAT2011 | Advanced Laser Frequency Stabilization Using Molecular Gases (co-funded with STMD) | J. Lipa | Stanford | FY13, 2 years | GW |
| SAT2012 | Antenna-Coupled Superconducting Detectors for Cosmic Microwave Background Polarimetry | J. Bock | JPL | FY14, 2 years | Inflation |
| SAT2012 | Demonstration of a TRL 5 Laser System for eLISA | J. Camp | GSFC | FY14, 2 years | GW |
| SAT2012 | Phase Measurement System Development for Interferometric Gravitational-Wave Detectors | W. Klipstein | JPL | FY14, 2 years | GW |
| SAT2010+13 | Advanced Packaging for Critical Angle X-ray Transmission Gratings | M. Schattenburg | MIT | FY15, 2 years | X-ray |
| APRA2011-SAT2013 | Development of 0.5 Arc-second Adjustable Grazing Incidence X-ray Mirrors for the SMART-X Mission Concept | P. Reid | SAO | FY15, 2 years | X-ray |
| SAT2010+13 | Reflection Grating Modules: Alignment and Testing | R. McEntaffer | U. of Iowa | FY15, 2 years | X-ray |
| SAT2011+13 | Affordable and Lightweight High-Resolution Astronomical X-Ray Optics | W. Zhang | GSFC | FY15, 2 years | X-ray |
| SAT2013 | Fast Event Recognition for the ATHENA Wide Field Imager | D. Burrows | PSU | FY15, 2 years | X-ray |

# Objectives and Purposes of Technology Gaps Prioritization

- **Objectives**
  - Identify technology gaps that are applicable and relevant to the Program's strategic objectives as described in the Astrophysics Implementation Plan
  - Rank these technology gaps to represent our recommended investment priorities
- **Purposes**
  - Inform the SAT solicitation and other NASA technology development program planning (APRA, SBIR and other OCT and STMD activities)
  - Inform technology developers of the Program's technology gaps to help focus efforts
  - Guide the selection of technology awards to be aligned with Program goals and science objectives.
  - Improve the transparency and relevance of Program technology investments
  - Inform the community about and engage it in our technology development process
  - Leverage the technology investments of external organizations by defining our capability gaps and NASA as a potential customer

# Summary of Technology Gaps Identification and Prioritization

- The community identifies technology capability gaps each June by working with the Program Analysis Group (PAG) or through direct individual submission to the Program Office's website.
- The Program's Technology Management Board (TMB) reviews and prioritizes the community identified technology gaps in July.
  - TMB membership includes senior members of the Astrophysics Division at NASA HQ and its Program Offices, and as required, independent subject matter expert(s) from the community.
  - Technology gaps prioritization is based on a published set of criteria that addresses **scientific priorities, benefits and impacts, scope of applicability, and timeliness**.
- The technology gaps and the resulting priorities are published each year in the PATR which is released in October.

# 2014 PCOS Technology Gaps List

- New, more focused, PCOS gaps list better reflects technology needs relevant to Program strategic objectives
  - Prior year's list of 90+ gaps included many overlapping entries, and others not applicable to PCOS charter or strategic missions

- Received 21 gap inputs in 2014, consolidated to 14

# PCOS 2014 Technology Gaps Prioritization

| Priority | PCOS Capability Gaps | Science |
|---|---|---|
| 1 | Kilo-Pixel X-ray Focal Plane Array With 2 eV Spectral Resolution at 6 keV | X-ray |
| | Affordable, Lightweight X-Ray Optics with 5 Arcsec Resolution | X-ray |
| | High Power, Narrow Linewidth Laser Sources | Gravitational Wave |
| | Highly Stable, Low Stray Light Telescope | Gravitational Wave |
| | Phase Measurement Subsystem (PMS) | Gravitational Wave |
| | Sub-Kelvin Cooling System Including a High-Efficiency Cryo-Cooler and/or an ADR Stage | General |
| 2 | High-Efficiency X-ray Grating Arrays for High-Resolution Spectroscopy | X-ray |
| | Advanced Millimeter-Wave Focal Plane Arrays for CMB Polarimetry | Inflation |
| | Fast, Low-noise, Megapixel X-ray Imaging Array With Moderate Spectral Resolution | X-ray |
| | Quasi-Optical Millimeter-Wave Polarization Modulators | Inflation |
| | Low Mass, Long-Term Stability Optical Bench | Gravitational Wave |
| | Millimeter-Wave Filters and Coatings | Inflation |
| 3 | Gravitational Reference Sensor (GRS) | Gravitational Wave |
| | High-Performance Gamma-Ray Telescope | Gamma-ray |

# How You Can Contribute and Help Develop Next Year's Prioritization

- Provide feedback on the technology gaps identification and prioritization process
- Propose to the SAT call
  - Notices of Intent due January 23, 2015
  - Proposals due March 20, 2015

| Solicitation Year | PCOS SAT Proposals | | Proposal Success Ratio |
|---|---|---|---|
| | Submitted | Selected | |
| 2010 | 21 | 5 | 24% |
| 2011 | 26 | 5 | 19% |
| 2012 | 10 | 3 | 30% |
| 2013 | 8 | 5 | 63% |
| **Total to Date** | **65** | **18** | **28%** |

***Number of PCOS SAT Proposals and Awards.***

- Identify and consolidate strategic technology gaps by the end of June for our annual prioritization

# Technology Gap Submission

A technology gap can be identified by anyone and provided to the PO for prioritization in either of two ways:

- Provide it to the appropriate SIG of the PhysPAG
- Submit it through the PCOS Program website (http://pcos.gsfc.nasa.gov/technology)
- This year all submissions will be forwarded to the PhysPAG Executive Committee for help with consolidation (combining similar or overlapping gaps) and check for completeness
  - Determining the resulting goals, technical objectives, or timing of the combined entries can be challenging
  - Best if PhysPAG performs this integration to take advantage of community expertise, and not risk leaving out or inaccurately defining any combined gaps

# An "Ideal" Technology Gaps List

- Consists only of technology capability gaps that are consistent with the PCOS program's strategic objectives as articulated by the Astrophysics Implementation Plan or any relevant current programmatic directives
- Inputs received from a broad and diverse community base
- Technology gaps are identified as capability gaps and not specific implementation approaches
- List is concise, non-redundant, and well-defined
- No proprietary or ITAR-sensitive information included

# Conclusions

- A process is in place to identify and prioritize technology gaps to inform the SAT call and selection and to support other NASA programs' technology development activities
- This process improves the transparency and relevance of our strategic technology investments and leverages the technology investments of external organizations
- Community feedback and input to the process is very much appreciated as we continue to evolve the process to best achieve the objectives of the PCOS Program.

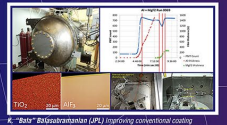
# SAT Poster (#442.02) at AAS Thursday

National Aeronautics and Space Administration

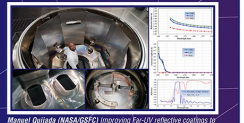
## NASA Funds Strategic Astrophysics Technology (SAT) Development

NASA Astrophysics Division Cosmic Origins (COR) and Physics of the Cosmos (PCOS) SAT Development Program Funds Projects Maturing Strategic Mid-TRL Technologies Addressing these Science Questions

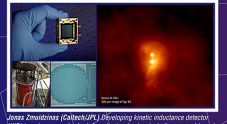
### How Did We Get Here? How Does the Universe Work?



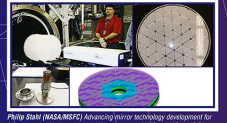
*K. "Eric" Balasubramanian (JPL)* Improving conventional coating techniques and advancing the state of the art for Atomic Layer Deposition (ALD) coatings, materials, and processes, including $MgF_2$-, $AlF_3$-, and $LiF$-protected Al mirrors, to enable and improve fabrication, characterization, and performance measurement of advanced UV telescope optics.



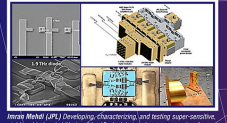
*Manuel Quijada (NASA/GSFC)* Improving far-UV reflective coatings to enhance system throughput for future missions, by depositing high-index lanthanide trifluorides overcoated with other dielectric fluorides through Ion Beam Sputtering (IBS) and High-temperature Physical Vapor Deposition (PVD).



*Jonas Zmuidzinas (Caltech/JPL)* Developing kinetic inductance detector (KID) imaging arrays for far-infrared astrophysics, including ground-based and fly-in-sat system demonstration at the Caltech Submillimeter Observatory (right), and lab demonstrations for balloon-borne, space-borne, and SOFIA-airborne applications.



*Philip Stahl (NASA/MSFC)* Advancing mirror technology development for future, monolithic or segmented, large-aperture UV/Optical/IR (UVOIR) space telescopes, including mechanical-and-thermal modeling, as well as fabrication and prototype testing of 6 deep-core mirror.



*Imran Mehdi (JPL)* Developing, characterizing, and testing super-sensitive, stable, wide-bandwidth, tunable, 16-pixel, heterodyne array receiver for imaging above 1.9 THz. These will enable future missions investigating the structure and properties of the interstellar medium, including as the Stratospheric Observatory for Infrared Astronomy (SOFIA).

**The COR and PCOS Program Objectives are to Answer the Following Fundamental Questions:**

- COR: "How did the universe originate and evolve to produce the galaxies, stars, and planets we see today?"
- PCOS: "How does the universe work, starting with the basic building blocks of our existence – matter, energy, space, and time?"

**Current and Future Strategic Missions and Platforms Pursuing COR and PCOS Objectives:**

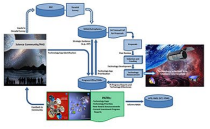
- COR: Hubble Space Telescope, Spitzer Space Telescope, Stratospheric Observatory for Infrared Astronomy (SOFIA), and James Webb Space Telescope.
- PCOS: Planck (data analysis), Chandra X-ray Observatory, Fermi Gamma-ray Space Telescope, X-ray Multi-Mirror – Newton, Space Technology 7/LISA Pathfinder, and Euclid.

**The COR and PCOS Program Offices (POs):**

The COR and PCOS POs reside at the NASA Goddard Space Flight Center (GSFC), serving as the NASA Astrophysics Division's implementation arm for matters relating to the two programs. One aspect of the POs' activities is managing the COR and PCOS SAT program, helping mature technologies to enable and enhance future astrophysics missions.

**COR and PCOS Technology Development Process:**

- Guided by the *New Worlds, New Horizons in Astronomy and Astrophysics* (NWNH) 2010 Decadal Survey, NASA's Astrophysics Division released the NASA *Astrophysics Implementation Plan* (AIP), describing future strategic missions it will implement. Strategic science goals identified by the NWNH or AIP include dark energy; gravitational waves; X-ray observatories, e.g., US participation in ATHENA; Inflation Probe; Cosmic Dawn; highly redshifted universe; first stars; and technology development benefiting a future large UV telescope.
- The Programs solicit technology gap submissions from the community throughout the year, and prioritize from annually; the submitted gaps and priorities are published in the COR and PCOS Program Annual Technology Reports (PATRs); the PATRs also provide an overview and status report of the Programs and their technology development activities for the prior year.



- The SAT Program solicits proposals addressing the highest priority gaps through a Research Opportunities in Space and Earth Sciences (ROSES) announcement of opportunity. SAT projects mature technologies at mid-range Technology Readiness Levels (TRLs 3-5) for eventual injection into instruments, missions, and studies pursuing COR and PCOS science objectives.

**SAT Proposal Statistics to Date:**

- 51 COR and 65 PCOS SAT proposals received
- 11 COR and 18 PCOS projects funded

**Benefits of the COR and PCOS SAT Programs:**

- Maturation of technologies enabling and enhancing future strategic missions;
- Principal Investigators (PIs) leveraging funding from internal and external (NASA and non-NASA) sources;
- PIs hiring students and post-docs, training the future astrophysics workforce; and
- Generating research collaborations and industry partnerships in support of Program goals.

**Notable SAT Development Successes:**

- Maturation of a new far-IR detector, later adopted by the SOFIA HAWC instrument;
- Maturation of the HARG near-IR detector, adopted by WFIRST;
- Development of an antenna-coupled transition-edge superconducting bolometer, a technology deployed by BICEP2;
- REXIS instrument on OSIRIS-REx is incorporating CCDs with directly deposited optical blocking filters developed by an SAT-funded project; and
- CCDs and GOLD Explorer missions to use high-reflectivity UV coating technology matured by an SAT-funded project.

**Technologies Solicited in ROSES-14 SAT:**

- ***COR***
  - Next generation detectors (high-QE, large-format, photon-counting, and ultra-low-noise detectors from extreme UV to far-IR and associated technologies);
  - Optical coatings, gratings, and filters for UV/Vis/NIR (high-performance mirror coatings, AR coatings for gratings and detectors, and wavelength-selective applications such as dichroics or blockers); and
  - Ultra-precise, lightweight, large-aperture optics and technologies for improved thermal and dynamic stability, wavefront sensing, and surface-figure control.
- ***PCOS***
  - X-ray astrophysics technologies (high-resolution detector arrays, lightweight replicated optics, high-resolution gratings, etc.);
  - Gravitational-wave astrophysics technologies (dimensionally stable telescopes, frequency-stabilized metrology lasers, high-resolution phasemeters, low-noise microthrusters, ultra-quiet inertial references, etc.); and
  - CMB polarization measurement technologies (high-throughput, cold, mm-wave telescopes; large, low-background, multiplexed detector arrays, etc.).

***See PATRs for more details.***

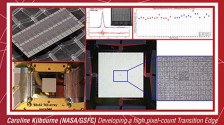
**To Submit Proposals in Response to ROSES-14 SAT:**

- Notice of Intent deadline 1/23/2015
- Proposals due by 3/20/2015
- Full details available from ROSES-14 SAT page (http://bit.ly/1AnI7Ev)

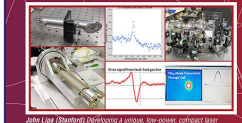
**To Submit Technology Gaps for Consideration in 2015:**

- COR: Visit http://cor.gsfc.nasa.gov/technology/tech-gap.php
- PCOS: Visit http://pcos.gsfc.nasa.gov/technology/tech-gap.php

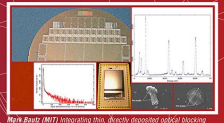
*William Klipstein (JPL)* Developing and testing prototype phase-measurement electronics required by all gravitational-wave laser interferometry missions under consideration to address a 2010 Decadal Survey top priority, tests use an upgraded interferometer-system-level test-bed; work includes maturing analog signal chain, demonstrating wave-front sensing-/-loading options for reduced photo-receiver size, and incorporating low-light signals into system tests.



*Caroline Kilbourne (NASA/GSFC)* Developing a high-pixel-count Transition Edge Sensor (TES) micro-calorimeter spectrometer with simultaneous high resolution in X-ray energy and spectroscopy, using MoAu thermometry and close-packed (8-by) thermally-sensing X-ray absorbers; as well as a time-division-multiplexed readout to enable future X-ray missions intended to study event-near black holes, large-scale structure evolution, and the cosmic feedback between them.

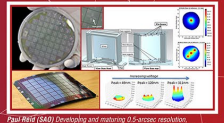


*John Lipa (Stanford)* Developing a unique, low-power, cryogen-free laser frequency stabilization system, enabling improved signal-to-noise ratio needed for gravitational-wave detection experiments similar to LISA; goal is a bench-top demonstration significantly improving oil icotrop-stabilized lasers, the current transportable system gold-standard, achieving an Allan deviation of ~2x10$^{-14}$ in a one-second measurement time.



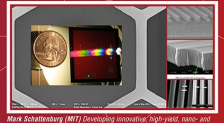
*Mark Bautz (MIT)* Integrating thin, directly deposited optical blocking filters ($OBF_s$) onto CCD X-ray imaging detectors, to reduce UV and optical light background; this technology allows lower-cost, lighter, and more robust sensors with improved quantum efficiency (QE), and enables larger focal planes.

*Jeff Livas (NASA/GSFC)* Developing full-scale design, fabricating, and testing a prototype spectrom for a space-based gravitational-wave mission that meets optical, mechanical, thermal, and manufacturability requirements for a MIE contribution to ESA's eLISA; requirements include pm-/Hz precision over more than 1,000,000 km in the presence of thermal gradients, and sufficient stray-light suppression to accommodate $10^{12}$ received/transmitted laser power ratio.

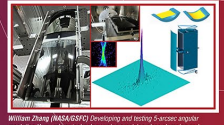


*Paul Reid (SAO)* Developing and maturing 0.5-arcsec resolution, piezoelectric-adjustable, grazing-incidence X-ray optics, in support of future X-ray mission concepts; this includes developing and X-ray testing 0.25-arcsec multiple X-ray shell alignment and mounting.

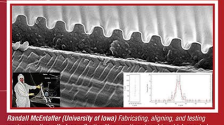
*John Ziemer (JPL)* Define requirements, design, fabricate, and prototype-test a lightweight, fully redundant, high-capacity, low-mass colloid microthruster propellant feed system based on heat microvalves and a stainless steel diaphragm tank, enabling high-precision spacecraft control needed for future gravitational-wave missions.



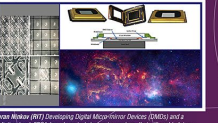
*Mark Schattenburg (MIT)* Developing innovative, high-yield, nano- and micro-fabrication processes and packaging for large-area, compact, robust, high-efficiency, superior-resolution, low-mass critical-angle X-ray transmission (CAT) grating elements, in support of future X-ray missions and concepts, including a possible US contribution to ESA's ATHENA mission.



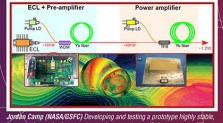
*William Zhang (NASA/GSFC)* Developing and testing 5-arcsec angular resolution X-ray mirror technology using precision glass slumping and magnetron sputter or atomic layer deposition to minimize mass, cost, and development time; the ultimate goal is to achieve Chandra-level angular resolution with Suzaku-level mass and cost, enabling X-ray missions similar to that recommended by the 2010 Decadal Survey.



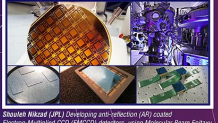
*Randall McEntaffer (University of Iowa)* Fabricating, aligning, and testing next-generation, off-plane reflection X-ray gratings to achieve high spectral resolution and high throughput over the 0.2 – 1.5 keV soft X-ray band, applicable to X-ray missions similar to that recommended by the 2010 Decadal Survey. These aligned gratings are to be tested on the Off-plane Grating Rocket Experiment (OGRE), planned to launch in 2017.



*Zoran Ninkov (RIT)* Developing Digital Micro-Mirror Devices (DMDs) and a custom-built, FPGA-based, control electronics package that will enable future hyper-spectral imaging missions; a Spectroscopic survey with A DMD-based multi-object spectrograph (MOS) could pursue a 2010 Decadal Survey high-priority objective to capture "large and detailed surveys of galaxies as they evolve across … cosmic time. …a myriad of the lives of galaxies rather than a snapshot."

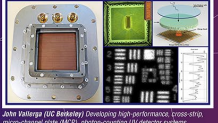



*Jordan Camp (NASA/GSFC)* Developing and testing a prototype highly stable, compact, low-noise laser system, using a master oscillator power amplifier (MOPA) design with a novel diode laser oscillator (external cavity laser, ECL), followed by an Yb fiber amplifier; this system supports future gravitational-wave interferometry missions, a top priority of the 2010 Decadal Survey.

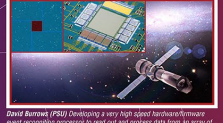


*Shouleh Nikzad (JPL)* Developing anti-reflection (AR) coated Electron-Multiplied CCD (EMCCD) detectors, using Molecular Beam Epitaxy (MBE) for delta doping and Atomic Layer Deposition (ALD); these will be tested on the FIREBall balloon experiment to verify high-efficiency, high-stability imaging, and spectroscopy capability.

*James Bock (CalTech/JPL)* Advancing antenna-coupled superconducting detector technologies, including modular focal plane units for large arrays; MKIDs, transition-edge superconducting (TES) bolometers, extensive frequency antennas, and state-noise readout; BICEP2, at the South Pole, used antenna-coupled TES Bolometer and "polarimeter-on-a-chip" technologies, matured through this project, to look for a Cosmic Gravitational-wave Background signal predicted by cosmic inflation theory.



*John Vallerga (UC Berkeley)* Developing high-performance, 'cross-strip, micro-channel plate (MCP), photon-counting UV detector systems applicable to future UV astrophysics missions; these include fast, low power, mass, and volume readout ASICs; FPGA readout circuit; and the cross-strip MCP detectors themselves.



*David Burrows (PSU)* Developing a very high speed hardware/firmware event recognition processor to read out and process data from an array of Depleted P-channel Field Effect Transistor (DEPFET) detectors; DEPFETs are expected to enable the Wide Field Imager of ESA's planned L2 mission, ATHENA, to conduct sensitive wide-field observations of bright and faint X-ray sources simultaneously.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***COR and PCOS Program Annual Technology Reports (PATRs)***

- *Summarize technology development activities for the prior year*
- *Provide an overview of the programs and their technology development activities*
- *Report the status of the 'pi(ping)' strategic and targeted technology development*
- *Summarize the technology capability gaps obtained from the community*
- *Provide a prioritized list of technology gaps for the coming year to inform program technology planning and SAT proposal call and selection decisions*

To explore possible collaboration or use of these technologies, contact the PIs directly or through the relevant Program Office
For more information, visit the COR Program website at cor.gsfc.nasa.gov and the PCOS website at pcos.gsfc.nasa.gov

# Backup

# Prioritization Criteria Address…

- **Strategic Alignment:** How well does the technology align with the science and/or programmatic priorities of the Astrophysics Implementation Plan (AIP) or current programmatic assessment?
- **Benefits and Impacts:** How much impact does the technology have on notional mission(s)? To what degree does the technology enable and/or enhance achievable science objectives, reduce cost, and/or reduce mission risks?
- **Scope of Applicability:** How crosscutting is the technology? How many Astrophysics programs and/or mission concepts could benefit from this technology?
- **Time to Anticipated Need**: When does the technology need to be at TRL 6? Astrophysics Division requires that critical/enabling technology be at TRL 6 at Key Decision Point (KDP) B, and non-critical/enhancing technology be at TRL 6 at KDP C.

# Prioritization Criteria Scoring Guideline

| PCOS Strategic Technology Gaps Prioritization Criteria | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Score Meaning | | | | |
| # | Criterion | Weight | Max Score | Max Weighted | General Description/Question | 4 | 3 | 2 | 1 | 0 |
| 1 | Strategic Alignment | 10 | 4 | 40 | How well does the technology align with the PCOS science and/or programmatic priorities of the Astrophysics Implementation Plan (AIP) or current programmatic assessment? | Applicable mission concept receives highest AIP consideration. | Applicable mission concept receives medium AIP consideration. | Applicable mission concept receives low AIP consideration. | Applicable mission concept was not considered in the AIP but was positively addressed in the 2010 Decadal Survey. | Not considered by the AIP or the 2010 Decadal Survey. |
| 2 | Benefits and Impacts | 9 | 4 | 36 | How much impact does the technology have on notional mission(s)? To what degree does the technology enable and/or enhance achievable science objectives, reduce cost, and/or reduce mission risks? | Critical and key enabling technology - required to meet mission concept objective(s). Without this technology, notional mission(s) would not be launched. | Highly desirable - not mission-critical, but provides major benefits in enhanced science capability, reduced critical resources need, and/or reduced mission risks. Without this technology, mission(s) may be launched, but science or implementation would be severely degraded. | Desirable - not required for mission success, but offers significant science or implementation benefits. If technology is available, would almost certainly be implemented in mission(s). | Minor science impact or implementation improvements; if technology is available. Would be considered for implementation in mission(s). | No science impact or implementation improvement. Even if available, technology would not be implemented in mission(s). |
| 3 | Scope of Applicability | 3 | 4 | 12 | How cross-cutting is the technology? How many Astrophysics programs and/or mission concepts could benefit from this technology? | The technology applies widely to PCOS mission concepts and both COR and ExoPlanet mission concepts. | The technology applies widely to PCOS mission concepts and either COR or ExoPlanet mission concepts. | The technology applies widely to PCOS mission concepts. | The technology applies to a single PCOS mission concept. | No known applicable PCOS mission concept. |
| 4 | Time To Anticipated Need | 3 | 4 | 12 | When does the technology need to be at TRL 6? Critical/enabling technology - TRL 6 at KDP B Non-critical/enhancing technology - TRL 6 at KDP C | TRL 6 is needed within 5 years (before 2020). | TRL 6 is needed within 6 to 10 years (2020 - 2024). | TRL 6 is needed within 11 to 15 years (2025 - 2029). | TRL 6 is needed within 16 to 20 years (2030 - 2034). | TRL 6 is needed in more than 20 years (2035 or later). |

# Lessons Learned from Previous Technology Gaps List

- **The previous PCOS technology gaps list was unwieldy (>90 inputs) given that we can only afford to invest in a few SATs**

- **The list included some gaps that were not applicable or relevant such as those that are:**
  - Not in the PCOS Program charter (ex. launch vehicle, rover, avionics technologies)
  - Requiring engineering solutions and not technology developments
  - So vaguely defined that it is not possible to evaluate their needs status
  - Subset or duplicate of another technology needs input
  - Already at TRL 6 or higher
  - Specific implementations, solutions or approaches
  - Have a time horizon beyond the strategic goal of the SAT program
  - Not within the scope of the Astrophysics Implementation Plan (AIP)

# Suggestions for Future Technology Capability Gaps List

- **Suggestions to obtain a more effective Technology Capability Gap list for prioritization to inform the SAT program**
  - Focus on technology capability gaps associated with missions prioritized in the Astrophysics Implementation Plan or any relevant programmatic directives
  - Submit technology gaps that are directly applicable to Program objectives. Don't include gaps that are not in our charter such as technologies associated with launch vehicle, rover, avionics, spacecraft systems, etc.
  - Don't include gaps that don't require technology development, that are not well defined, that are redundant (duplicate, similar, or subsets of other needs), or are at TRL 6 or higher
  - Inputs should be submitted as technology capability gaps between the current state-of-the-art and the science objective targeted and not as specific implementations

# SAT Selection Rate

| Solicitation Year | TPCOS Proposals | | Proposal Success Ratio |
|---|---|---|---|
| | Submitted | Selected | |
| 2010 | 21 | 5 | 24% |
| 2011 | 26 | 5 | 19% |
| 2012 | 10 | 3 | 30% |
| 2013 | 8 | 5 | 63% |
| **Total to Date** | **65** | **18** | **28%** |

*Table 2-3. Number of TPCOS SAT Proposals and Awards.*