# PCOS Program Technology Capability Gap Input Form

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| Technology Capability Gap Name: Large-format, high-spectral-resolution, small-pixel X-ray focal plane arrays | Date Submitted: |
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**PATR Prioritization Information (instructions on next page)**

Brief Description of the Technology Capability Needed (100 – 150 words):

X-ray microcalorimeters are needed to allow spatially-resolved spectroscopy with the X-ray Surveyor. The arrays need to cover a wide field (>5 arcmin) and with spatial resolution matching future X-ray optics (<~ 1 arcsec). The X-ray microcalorimeter pixels need to provide excellent spectral resolution (<~ 4 eV FWHM in the 0.2 – 10 keV band).

Current X-ray microcalorimeter focal-plane arrays are not yet able to meet these minimum requirements. Fabrication of arrays of sufficiently small pixels, with large enough pixel counts, with an efficient multiplexed read-out capable of simultaneously reading out all X-ray events across the entire array while maintaining high energy resolution, is challenging.

Much of the science for X-ray Surveyor emphasizes soft X-ray band, so detector arrays (and supporting instrumentation including optical blocking filters) should allow a detector with high efficiency down to E~0.2 keV.

| Assessment of the Current State-of-the-Art (SOTA) (100 – 150 words): | Current TRL of SOTA: | |
|---|---|---|
| Fabrication of arrays with 1024 transition-edge sensors (TES) each connected to 9 absorbers on a 75 micron pitch has been demonstrated (9216 pixels). Smaller arrays have been fabricated with a 50 micron pitch. Small arrays with 9 absorbers attached to a singe TES have demonstrated < 3 eV energy resolution (FWHM). Much larger arrays, with more absorbers per sensor are needed. In the context of the required array size, the array fabrication is currently TRL-3. Small arrays (36 pixels) of much larger microcalorimeter pixels, is at TRL-9 (Hitomi).<br><br>Multiplexing of TES microcalorimeters with time-division multiplexing has been demonstrated with 32 pixels in a single read-out channel with less than 3 eV resolution. This read-out option is at TRL- 4 / 5.<br><br>Multiplexing with microwave SQUIDs in resonator circuits at GHz frequencies has the potential to read out hundreds or maybe a thousand sensors per read-out channel, and thus provides a path to the read out of much larger arrays. This has been demonstrated reading out 4 pixels. TRL-3. TESs and magnetically coupled microcalorimeters (MCC) are two of the leading thermal sensor technologies with potential to meet the X-Ray surveyor requirements, and both can be read out using microwave SQUIDs in GHz resonators. | Current TRL of Full Solution: | |

Target Goals and Objectives to Fill the Capability Gap:

• The primary objective for X-ray Surveyor is large-format arrays with pixel count > 100k and spectral resolution < 4eV FWHM in the 0.2 – 10 keV. This likely requires a high degree of multiplexing both thermal and electrical:

• Thermal multiplexing: Sensors attached through varying thermal conductances to multiple absorbers, allowing pixel identification across the entire energy band, up to a multiplexing factor of 25:1, with energy resolution < 4 eV and pixel pitch < 50 μm.

• Electrical multiplexing:

- Readout using conventional multiplexing techniques (< 20 MHz). Desired multiplexing factor is 64:1.
- Readout using microwave resonators, such as with microwave SQUIDs. Desired multiplexing factor is 1000:1.

• A separate objective is the development of optical and IR blocking filters for the calorimeter instrument with higher X-ray throughput in the 0.2-10 keV range.

Scientific, Engineering, and/or Programmatic Benefits (100 – 150 words):

Science benefits identified for IXO in NWNH and for X-ray Surveyor in the 2014 Astrophysics Roadmap.

The more advanced the multiplexed read-out becomes the more engineering benefits there are. These benefits include having less-demanding cryogenic requirements; and also lower instrument mass, power, and cost for the cryogenics and read-out.

Applications and Potential Relevant Missions for PCOS, COR, and ExEP:

X-ray Surveyor. The technology is also synergistic with the enabling technology for US contribution to ATHENA.

Time to Anticipated Need (time to anticipated or estimated launch date for enabled/enhanced missions):

2020 Decadal Survey

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