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A Thermal Imaging Instrument with Uncooled Detectors

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The National Research Council's Committee on Implementation of a Sustained Land Imaging Program has identified the inclusion of a thermal imager as critical for both current and future land imaging missions. Such an imaging instrument operating in two bands located at approximately 11 and 12 microns (for example, in Landsat 8, and also Landsat 9 when launched) will provide essential information for furthering our hydrologic understanding at scales of human influence, and produce field-scale moisture information through accurate retrievals of evapotranspiration (ET). Landsat 9 is slated to recycle the TIRS-2 instrument launched with Landsat 8 that uses cooled quantum well infrared photodetectors (QWIPs) operating at about 43-65 K temperature, hence requiring expensive and massive cryocooler technology to achieve its required spectral and spatial accuracies.

Our goal is to conceptualize and develop a thermal imaging instrument which leverages recent and imminent technology advances in uncooled detectors. Such detector technology will offer the benefit of greatly reduced instrument cost, mass, and power at the expense of some acceptable loss in detector sensitivity. It would also allow a thermal imaging instrument to be fielded on board a low-cost platform, e.g., a CubeSat. This would enable capitalizing on the greater number of launch opportunities available for launch vehicles.

Sustained and enhanced land imaging is crucial for providing high-quality science data on change in land use, forest health, crop status, environment, and climate. Accurate satellite mapping of ET at the agricultural field scale (the finest spatial scale of the environmental processes of interest) requires high-quality thermal data to produce the corresponding accurate land surface temperature (LST) retrievals used to drive an ET model. Such an imaging instrument would provide important information on the following: 1) the relationship between land-use and land/water management practices and water use dynamics; 2) the interconnections between anthropogenic water management and changes in hydrologic budget at scales of human influence; and 3) complimentary field-scale moisture values for interpreting coarser resolution datasets.

There is clear need for continuing innovation in thermal remote sensing detector technology. By 2023, scheduled launch year for Landsat 9, its thermal detector technology will be fifteen years old, and Landsat 8 will be approaching the end of its useful life. In the near term, ESA's launch of Sentinel-2, a constellation of two satellites with multi-spectral imagers, will provide high-resolution imaging in the 443-2190 nm spectral range, but with no thermal coverage.

Recent advances in uncooled detector technology, by developing novel types of ultrasensitive thermopiles like doped-silicon thermopiles, offer the prospect of realizing a viable thermal instrument.

We reviewed low-TRL technologies: Vanadium oxide bolometers, Bi-Te thermopile technologies, and doped-Si thermopiles, a new detector concept developed by our team, then compared them and their potential for improvement to the current leading cooled detector technology for land imaging, QWIPs. We modified our doped-Si design to meet TIRs instrument requirements including pixel size and speed. Based on the results of these studies we decided to pursue doped-Si thermopile technology for development efforts.