PRELIMENARY ON-ORBIT RESULTS AND TRL MATURATION OF THE COMPACT INFRARED RADIOMETER IN SPACE (CIRiS): A TESTBED FOR FUTURE LWIR PLANETARY IMAGERS. M. S. Veto[1] (mveto@ball.com), D. P. Osterman[1] (PI: dosterma@ball.com), D. Piqueira[1], R. Rohrschneider[1], R. Schindhelm[1], & R. Warden[1]. [1]Ball Aerospace (1600 Commerce St., Boulder, CO 80302)

Introduction: Compact instruments are of high value for planetary science missions with strict technical constraints (e.g., mass, volume, and power). Furthermore, programmatic constraints (e.g., cost, schedule, risk, complexity, and heritage) are of equal importance to ensure the success of a mission. CIRiS is a compact infrared camera—designed, built, and tested at Ball Aerospace—that incorporates an uncooled microbolometer and carbon nanotube calibration sources to minimize technical and programmatic constraints while providing sufficient performance to meet planetary science requirements. The CIRiS instrument has been successfully integrated into a 6U CubeSat configuration (figure 1). Currently berthed at the *International Space Station*, the upcoming deployment is planned to mature the TRL and establish heritage for future planetary science applications.

Figure 1. A Ball Aerospace technician stows the solar panels on CIRiS to complete the final assembly before shipment on September 25th, 2019.

Preliminary Results:

Ground Testing: A TVAC campaign has provided characterization results in a relevant environment to mature the instrument system to TRL-5 and calibration result with a well-controlled, well-calibrated NIST blackbody (e.g. figure 2) to produce simulated on-orbit performance results (e.g. figure 2) [1,2]. In addition, pre-delivery images verify the qualitative image performance of the completed system (figure 3).

On-orbit Results: CIRiS is planned to be deployed from the *International Space Station* in early 2020. Preliminary results will be discussed, pending successful deployment.

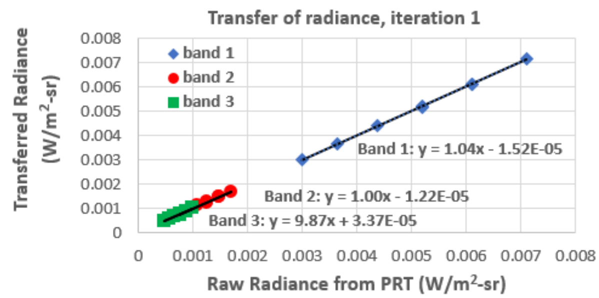

Figure 2. Transfer of raw NIST-traceable radiance.

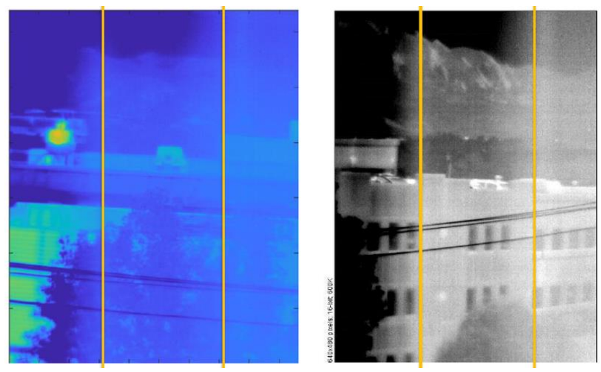

Figure 3. Pre-ship images of Rocky Mountains (background) and hospital parking garage/helipad (foreground) show camera focus, band divisions, and both geologic and anthropogenic thermal feature identification.

Technology Readiness Level (TRL): The primary mission of CIRiS is to raise the readiness of compact, high-performance technology (microbolometer infrared cameras with carbon nanotube blackbody sources) in the space environment from TRL 5 to 7 and to reduce risk to future missions [3]. Without full radiation testing of the system on-ground, we do not claim TRL 6 prior to launch. This TRL maturation provides a system prototype demonstration in-space of the CIRiS baseline system. Planetary science has the unique constraint that the “fly-learn-refly” paradigm does not typically apply; there is usually only one opportunity to complete a mission [4]. Future missions can use the baseline CIRiS instrument (planned to soon be TRL-7).

Planetary Science Applications: The longwave infrared (LWIR: ~7-15 μm) has been used for measuring planetary surface heat flux, deriving surface temperature, thermal inertia, particle size, mapping mineralogy, and detecting atmospheric gases with a number of planetary instruments (e.g., CIRS, Diviner, TES, THEMIS, PFS, etc) [5-9]. These instruments have yielded exceptional results for mid to large scale missions that optimize performance with budget for larger aperture size, advanced thermal control systems, and mass/monetary budget for radiation-hardening of electronics and shielding. High-risk missions, missions to uncharted regions, in-situ measurements, and multi-point measurements have all been identified as conditions for flying CubeSat-class instruments [4]. CIRiS, small, affordable, and reliable, is a candidate for these types of missions.

*Deployable Ride-share***:** Flagship missions have historically carried deployable probes to conduct augmented science objectives. More recently, the *MarCO* CubeSats, launched with the *InSight* to Mars, proved that standardized CubeSats could be deployed as autonomous systems to enhance the scientific/engineering return of the parent mission [10]. Deployable CubeSats offer opportunities to probe environments unobtainable to the host spacecraft-instruments (e.g., expendable probing of plumes, atmospheres, and surfaces; investigation of high-risk, high-reward ancillary targets; and extension of simple, multi-point measurements significantly augment the science return as a network).

Modular Design: Having completed and delivered baseline build, CIRiS can be adapted for unique mission requirement (e.g., see *L-CIRiS*, recently selected for the CLPS program [11]).

Figure 4. Launch of spaceflight *CRS-19* (*Dragon-Falcon 9*) to the *International Space Station* on December 5th, 2019.

Planned Engineering Enhancements for Planetary Science: For unique environmental requirements, Ball is planning engineering enchantments to augment CIRiS for Planetary Science missions.

Radiation Engineering: Radiation engineering is planned to be performed to enhance the radiation hardness and to guarantee performance on-ground for missions to harsher environments to reduce risk.

Planetary Protection: To comply with specific target body mission requirements relating to planetary protection, analysis and protocols are planned to be applied to enhance the contamination safety.

Environmental Testing: TVAC testing both to characterize and to calibrate the instrument system is standard practice and is customizable for the mission environment to quantify performance [1].

Mission Assurance: Mission Assurance capabilities are planned to be applied, as specified, for the relevant mission class to reduce risk.

Acknowledgements: We thank the NASA-ESTO office and review panel for selection and funding for the *CIRiS* instrument/mission and the NASA-CLPS office and review panel for selection of the *L-CIRiS* instrument.

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