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Introduction: The lunar surface is the next frontier for science beyond Earth. The last several years have brought a renewed focus to the Moon and landed science will greatly expand our understanding of our nearest neighbour. Ball's extensive heritage with imagers and detectors offers multiple opportunities for missions and measurements. Examples are: thermal infrared radiometric measurements for compositional and thermophysical studies, high dynamic range visible imager, and advanced processing and algorithms.

Science and Measurement Opportunities: Ball has developed several miniaturized technologies which would allow detailed scientific measurements of lunar composition, thermal variations, visible imaging, and data processing.

Thermal Infrared Radiometric Measurements for Compositional and Thermophysical Studies: L-CIRiS (Lunar Compact Infrared Imaging System), is a multispectral thermal-infrared imaging radiometer [1] being built by Ball Aerospace for the University of Colorado. L-CIRiS will acquire panoramic infrared images of the lunar surface, enabling the generation of maps of mineral composition and surface temperature on spatial scales to < 1 cm in 4 infrared bands between 7 um and 14 µm. The results will provide insight into the evolution of the Moon's crust, including large- and small-scale impact events, volcanism, and space weathering. Geotechnical information derived from L-CIRiS measurements, including rock abundance and regolith porosity, will support future surface exploration activities by landers and rovers. The latter are identified as science needs in the 2016 NASA study "Lunar Exploration Study Strategic Knowledge Gap" within Theme 1, Understand the Lunar Resource Potential.

L-CIRiS has a mass of < 7 kg and average power between 5 and 15 W, depending on the biasing of heaters in the actively controlled thermal zones. Crew interaction would be valuable in determining areas for L-CIRiS to image and ensuring it has a clear view to the greatest azimuthal field of regard. CIRiS (Figure 1), a prototype for L-CIRiS, is integrated into a 6U CubeSat that is planned to be deployed from the International Space Station on February 1st, 2020, establishing TRL-7 [2-4].

Figure 1. CIRiS, a prototype for L-CIRiS

High Dynamic Range Visible Imager. Ball has developed a high dynamic range, high frame rate, low volume, weight, and power visible imager around the BAE Fairchild CIS2521 CMOS sensor (Figure 2). This device can image the terminator and resolve both the high light and very dark areas. This will enable humans and human scale rovers to safely navigate near the terminator and permanently shadowed regions (PSR). It is a small format imager with an average power of 6 W and can easily be accommodated on an Artemis mission. The sensor features 5 transistor pixels on a 6.5 um pitch with an active imaging area of 2560 x 2160 pixels. Crew required interaction is minimal, as the camera can be easily deployed upon landing. The camera can be used in a variety of locations, such as areas around the lander, rover, and/or carried by the crew.

Figure 2: High dynamic range visible imager.

Advanced Processing and Algorithms. Processing and quickly evaluating lunar scientific data collected will be key to maximizing the science collected by the crew. With the limited processing resources available on the Moon, autonomy and selective data collection become important for minimizing data storage and data downlink volume. Ball has demonstrated a variety of enhanced spacecraft and instrument capabilities in both the laboratory and in-flight to advance autonomy and control for spaceflight hardware. One example of this is the use of Model Predictive Control Algorithms (PCAs). Ball has developed PCAs to provide autonomous instrument operations and spacecraft control to maximize observing opportunities. Using a LIDAR instrument as a sample application, a PCA was developed to autonomously and dynamically steer laser beams to maximize observations of desired features – e.g., waterways or clouds on Earth (Figure 3). [5]

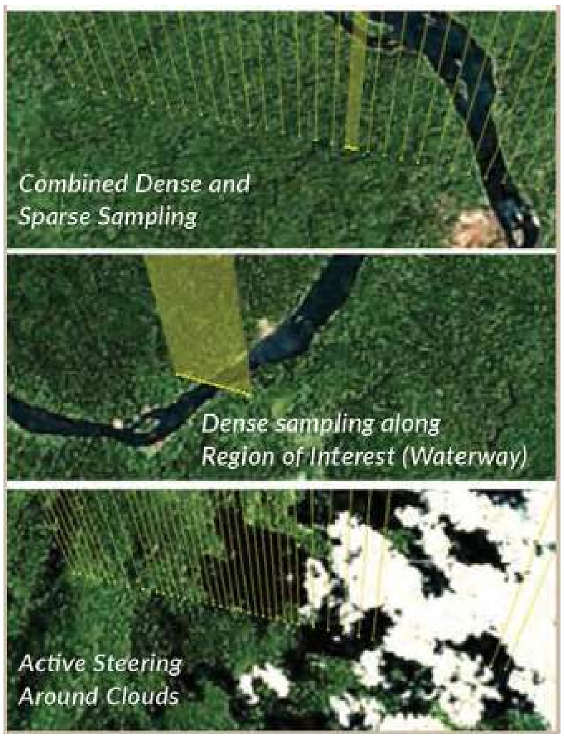

Figure 3: Predictive Control Algorithms enable intelligent instrument operations to optimize power distribution and downlinked data volume.

Conclusion: This is a sampling of Ball's capabilities for lunar landed science missions. These instruments will facilitate a broad range of scientific measurements on the lunar surface. They can operate in a variety of environments and are agnostic to landing location. The Artemis missions will inspire many generations to come. Scientists and engineers will use this landed science data as a foundation for understanding our Moon and our history. Building on Ball's extensive imaging and sensing flight heritage, Ball is pleased share these enabling scientific and measurement technologies.

References:

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