Lunar Ice Cube Mission: Determining Lunar Water Dynamics with a First Generation Deep Space CubeSat.

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Introduction: Lunar Ice Cube, a science requirements-driven deep space exploration 6U cubesat mission was selected for a NASA HEOMD NextSTEP slot on the EM1 launch. We are developing a compact broadband IR instrument for a high priority science application: understanding volatile origin, distribution, and ongoing processes in the inner solar system. Focus on lunar exploration is especially relevant because of the Moon's accessibility as a stepping stone to the rest of the solar system, combined with its suitability as an analog with extreme range of conditions and thus an ideal technology testbed for much of the solar system. The recent announcement of opportunities to propose to fly one of cubesats to be deployed from EM1 generated a plethora of proposals for 'lunar cubes'. JPL's Lunar Flashlight, and Arizona State University's LunaH-Map, both also EM1 lunar orbiters, will provide complimentary observations to be used in understanding volatile dynamics [1,2].

Science Goals: The Lunar Ice Cube mission science focus, led by the JPL Science PI, is on 1) enabling broadband spectral determination of composition and distribution of volatiles in regoliths of the Moon and analogous bodies as a function of time of day, latitude, regolith age and composition; 2) providing geological context by way of spectral determination of major minerals; and 3) thus enabling understanding of current dynamics of volatile sources, sinks, and processes, with implications for evolutionary origin of volatiles. The mission is designed to address NASA HEOMD Strategic Knowledge Gaps related to lunar volatile distribution (abundance, location, and transportation physics of water ice).

Lunar Ice Cube amplifies and extends the findings of previous missions [3,4,5]. While Chandrayaan M3 provided a 'snapshot' mosaic of the lunar nearside, indicating surface coating of OH/H2O near the poles, Lunar Ice Cube will provide coverage of the same swaths as a function of latitude at several times of day. Lunar Ice Cube will extend evidence for diurnal variation in OH absorption provided by Deep Impact and other C-, H-, O-, and S-bearing volatiles provided by LCROSS through geospatial linkage. Lunar Ice Cube measurements will completely encompass the broad 3 micron band resulting from absorption by several forms of water instead of cutting off at 3 microns as previous Near IR spectrometers have done.

Payload: A major challenge for deep space, science requirements-driven cubesats is the development of compact yet sufficiently robust and sensitive versions of successful instruments in a 'funding starved' environment. Lunar Ice Cube responds to both of these challenges through the development of its versatile GSFC-developed payload: BIRCHES, Broadband InfraRed Compact, High-resolution Exploration Spectrometer, a miniaturized version of OVIRS on OSIRIS-REx. BIRCHES is a compact (1.5U, 2 kg, 7W including cryocooler) point spectrometer with a compact cryocooled HgCdTe focal plane array for broadband (1 to 4 micron) measurements, achieving sufficient SNR (>400) and spectral resolution (10 nm) through the use of a Linear Variable Filter to characterize and distinguish important volatiles (water, H_2S, NH_3, CO_2, CH_4, OH, organics) and mineral bands. The instrument has built-in flexibility, using an adjustable 4-sided iris, to maintain the same spot size regardless of variations in altitude (by up to a factor of 5) or to vary spot size at a given altitude, as the application requires. We are also developing compact instrument electronics which can be easily reconfigured to support the instrument in 'imager' mode, once the communication downlink bandwidth becomes available, and the H1RG family of focal plane arrays.

Thermal design is critical for the instrument. The compact and efficient Ricor cryocooler is designed to maintain the detector temperature below 120K. In order to maintain the optical system below 220K, a special radiator is dedicated to optics alone, in addition to a smaller radiator to maintain a nominal environment for spacecraft electronics.

Supporting Subsystems: The Lunar Ice Cube team is led by Morehead State University, who will provide build, integrate and test the spacecraft, provide missions operations and ground communication. Propulsion is provided by the Busek Iodine ion propulsion (BIT-3) engine. Attitude Control will be provided by the Blue Canyon Technology XB1, which also includes a C&DH 'bus'. C&DH will also be supported, redundantly, by the Proton 200k Lite and Honeywell DM microprocessor. Onboard communication will be provided by the X-band JPL Iris Radio and dual patch antennas. Ground communication will be provided by the DSN X-band network, particularly the Morehead State University 21-meter substation. Flight Dynamics support, including trajectory design, is provided by GSFC.

Mission Concept: Lunar Ice Cube will be deployed from EM1. Use of a micropropulsion system in a low energy trajectory will allow the spacecraft to achieve lunar orbital insertion and, through progressive periapsis lowering, the final science orbit over a period of about a year. The high inclination, equatorial periapsis orbit will allow coverage of overlapping swaths, with a 10 km along-track and cross-track footprint, once every lunar cycle at up to six different times of day (from dawn to dusk) as the mission progresses during its nominal six month science mapping period.

References: [1 Cohen B. et al. (2015, Lunar and Planetary Science XLVI, 2020.pdf; [2] Hardgrove C. et al. (2015) 5th International Workshop on Lunar-cubes, http://lunar-cubes.com/images/docs/LCW5-Abstract-C-Hargrove.pdf; [3] Pieters C. et al. (2009) Science, 326, 568-572; [4] Sunshine J. et al. (2009) Science, 326, 565-578; [5] Colaprete A. et al. (2010) Science, 330, 463-468.