Requirements and Opportunities for Lunar Surface Payload Networks

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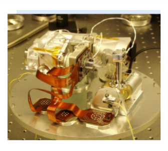
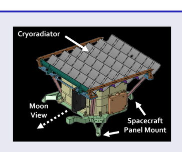
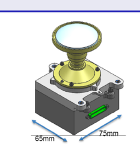
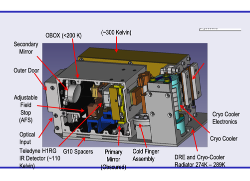
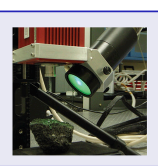
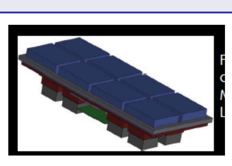
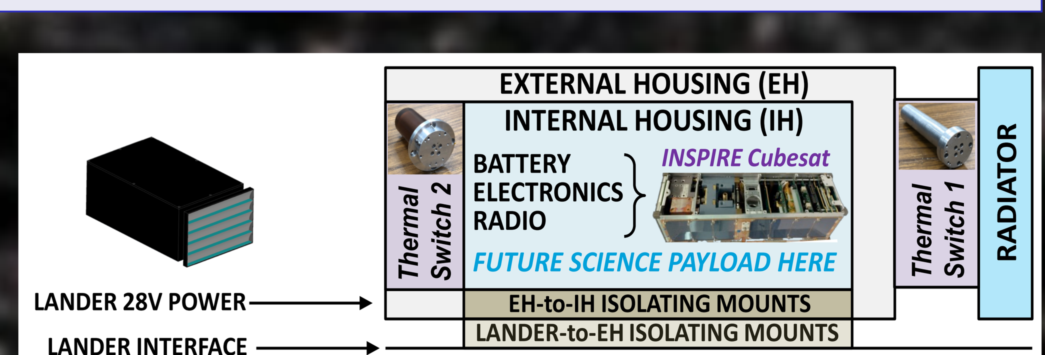
Some Lunar Surface Instrument and Instrument Suite Candidate Characteristics

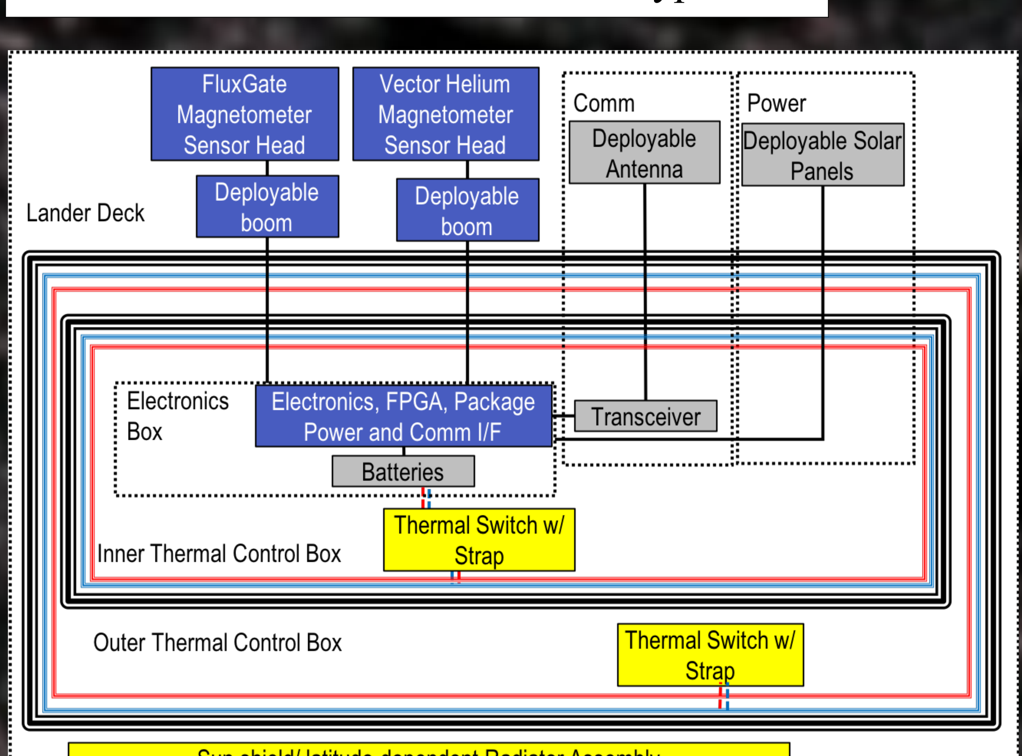
	Instrument	Type	Mass	Power	Volume
	JPL UCIS-Moon [1]	IR Imaging spectrometer 600-3600 nm	4 kg	20 W when operating,	4U
	JPL HVM3 [2]	IR Imaging spectrometer	12 kg	15 W when operating	56 cm3
	JPL EECam [3]	Compact camera	1 kg	5 W	<1U
	GSFC BIRCHES [4]	IR point spectrometer 900-3600 nm	3 kg	15W when operating	2U
	JPL QITMS [5]	Mass Spec	7 kg	24W when operating	8U
	JPL MMI [6]	Microimager (surface)	1 kg	5 W when operating	1U
	JPL miniGPR [7]	Ground penetrating radar (surface)	1.5 kg	1W when operating	2U
	JPL miniSEIS [8]	Interior structure, state, and composition	<1 kg	<1 W	1U
	ASU miniNS [4]	Neutron spectrometer	0.5 kg	5W when operating	1U
	GSFC miniENA, miniESA [9]	Electrostatic analyzer and energetic neutral analyzer	<1 kg each	1W each	1U each
	UCLA/JPL Dual magnetometer [10, 11]	VHM and FGM	0.5 kg FGM, 2 kg VHM + booms	<1W FGM, 2.5 W VHM when operating	<0.5U FGM, 2U VHM
	Mini surface/subsurface water prospectors	Mini IR camera (filter), miniNS, miniGPR	3 kg	8W when operating	6U
	Surface water cycle monitoring stations [[12]	IR imager, miniESA, miniENA, miniNS	5 kg	2 W night, 9W day when operating	5U

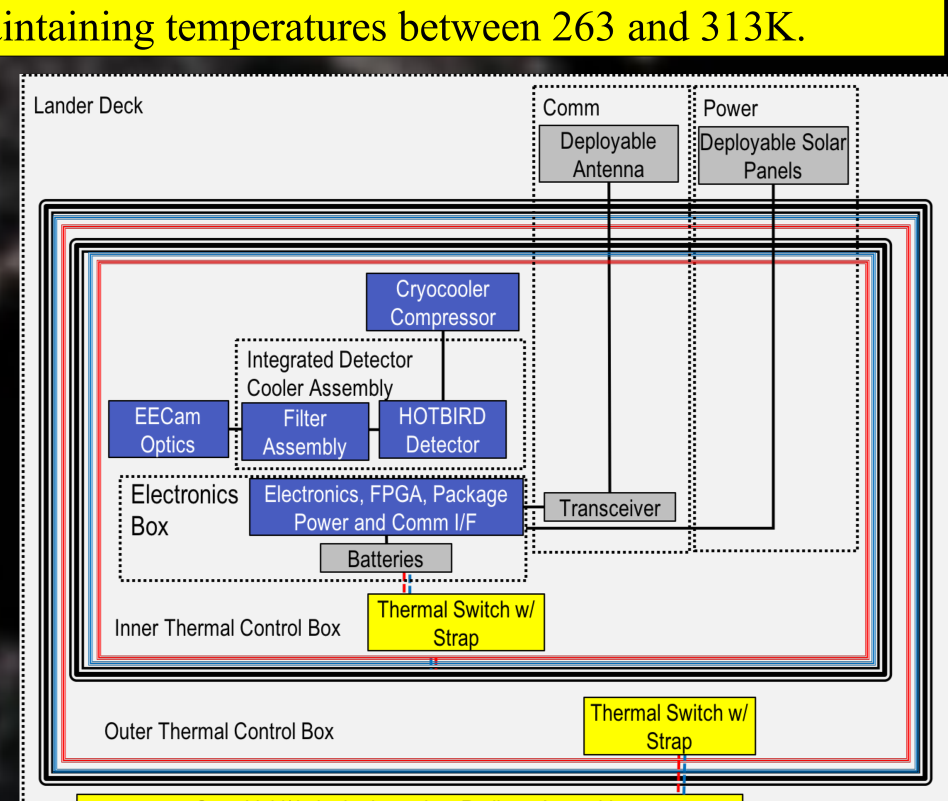
Power when operating. Mass and volume assume high performance packaging but do not include radiators except for HVM3.

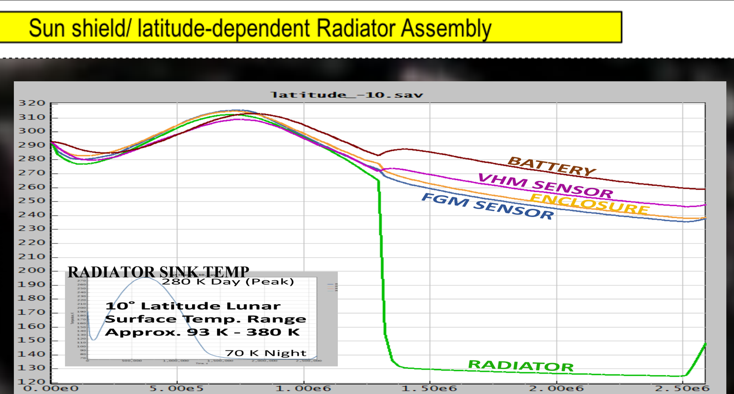
DTE Reverse Thermal Switch Prototypes

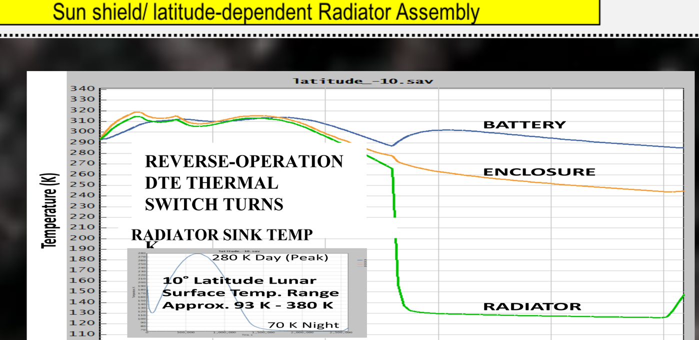


Generic Thermal Package Concept capable of maintaining temperatures between 263 and 313K.









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Science User Requirements: By providing opportunities to fly several small orbital, lander, and/or rover platforms as part of one cislunar or Mars mission/mission suite, ESPA rings launched to GTO equipped with additional stages will greatly facilitate the meeting of high priority science objectives that require distributed (spatially and temporally) measurements to be fully realized. For the Moon, these objectives include

- determining the global distribution and origin as well as resource inventory for water and other volatiles at local-scale resolution;
- monitoring and modeling the nature of the radiation/charged particle/ exosphere/micrometeorite/surface/subsurface interactions constituting the lunar environment;
- monitoring and modeling the lunar interior and constraining the Moon's history and origin; and
- developing potential ISRU resource, including water, inventories.

Potential Payload Instruments: Compact and robust versions of instruments ranging from kilograms to ten kilograms integrated with small orbiter, rover or lander platforms of particular interest are already under development via NASA DALI, CLPS/NPLP, and SIMPLEX programs. These include compact and robust near to IR cameras and imaging spectrometers (e.g., EECam, mini-TES) to characterize surface composition and properties; neutron spectrometers, magnetometers, sub millimeter sounders, and seismometers (e.g., mini-NS, SEIS) to characterize the subsurface, energetic particle analyzers (mini-ESA, mini-ENA) along with mini tunable laser (mini-TLS) or mass spectrometers (mini-QITMS) to measure in situ gaseous species.

Some distributed networks that could be envisioned include: 1) tens of mini-rovers to characterize subsurface water (with IR imagers, mini-neutron spectrometers, and mini-GPRs) to a depth of 1 to 2 meters traveling along traverses at several likely candidates for hundreds of ppm near surface water; 2) 5 to 10 low-altitude orbiters or mini-landers spaced over hundreds of kilometers that characterize the lunar water cycle (with solar wind analyzer, energetic neutral analyzer or mini-QITMS, and IR imager), and 3) several landers spaced over hundreds of kilometers that characterize the lunar interior (with seismometers, heat flow experiments requiring a small drill for deployment, and magnetometers.

Thermal Challenge A major challenge for small packages, particularly on the lunar surface, is thermal packaging to protect the payload from the lengthy temperature extremes without the need for active control systems requiring power and thus significantly increasing mass and volume needed for batteries during lunar night. High performance thermal component based packaging based on passive thermal design that will allow operation on at least limited duty cycle during lunar night is now being developed and tested through the STMD funded PALETTE project [12,13]. An essential part of PALETTE are the high performance thermal switches, which have designed, built and tested in a simulated lunar environment. Their basis of operation is the mating/de-mating of parallel (near mirror finish) flat metal surfaces. The physical mechanism causing the motion is the DTE of mid-CTE, high thermal conductivity (k) metallic end-pieces compared to a low-CTE, low k two-piece metal/polymer support beam. The requirements of operation were to be fully ON above 300 K with 1335 N force and fully OFF below 260 K.

The thermal switches were designed for seamless integration into box-type instrument enclosures. Each prototype easily slides into a small 25-35 mm circular enclosure opening such that most of the 80-120 mm long thermal switch lies within the enclosure, with 6 mm thick disks visible from the outside. In addition to the thermal switches, Ball high performance MLI [14] and kevlar pulley packaging system, both of which have successfully flown in space, would provide even greater performance enhancement in thermal packaging.

Our thermal modeling with the thermal switches alone demonstrates that both dual magnetometer (external sensors on booms) and IR imager (with cryocooler) packages, representing a range of instrument requirements, would be able to meet their requirements for survival and/or operation during lunar night [12,13].

References: [1] Blaney et al, 2012 LPS XLIII #2593; [2] https://www.caltech.edu/about/news/nasa-selects-caltech-led-lunar-mission-finalist; [3] McKinney et al, 2018, LPS CLIX #2857; [4] Clark et al, 2019, Proc SPIE Optics Cubesats and Smallsats, 1113108; [5] Avice G. et al, 2018, JAAS, 34; [6] Nunez et al, 2010, LPS XLI #1581; [7] Kim et al, 2012, Concepts and Approaches for Exploration # 4094; [8] Yu et al, 2019, https://www1.grc.nasa.gov/wp-content/uploads/Atomic-Lunar-Seismometer.pdf; [9] Stubbs et al, 2008, LPS XXXIX #2467; [10] Angelopoulos, 2011, SSR, 165, 3-25; [11] Papalardo et al, 2017, LPS XLVII #2732; [12] Clark et al, 2018, LPS XLVIII #1269; [13] Bugby et al, 2018, Survive Lunar Night #7009; [14] https://www.questthermal.com/sites/default/files/ckfinder/files/QT%20NextGenMLI_flyer_v7.pdf