National Aeronautics and Space Administration

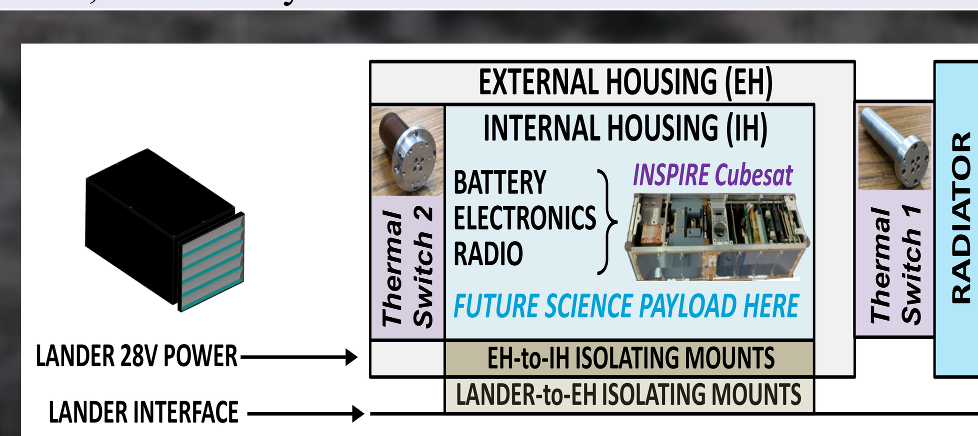
Wide Range of Low Cost Day and Night Operational Lunar Surface Payloads enabled by High Performance Thermal Components based Packaging

Pamela E. Clark and David Bugby

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

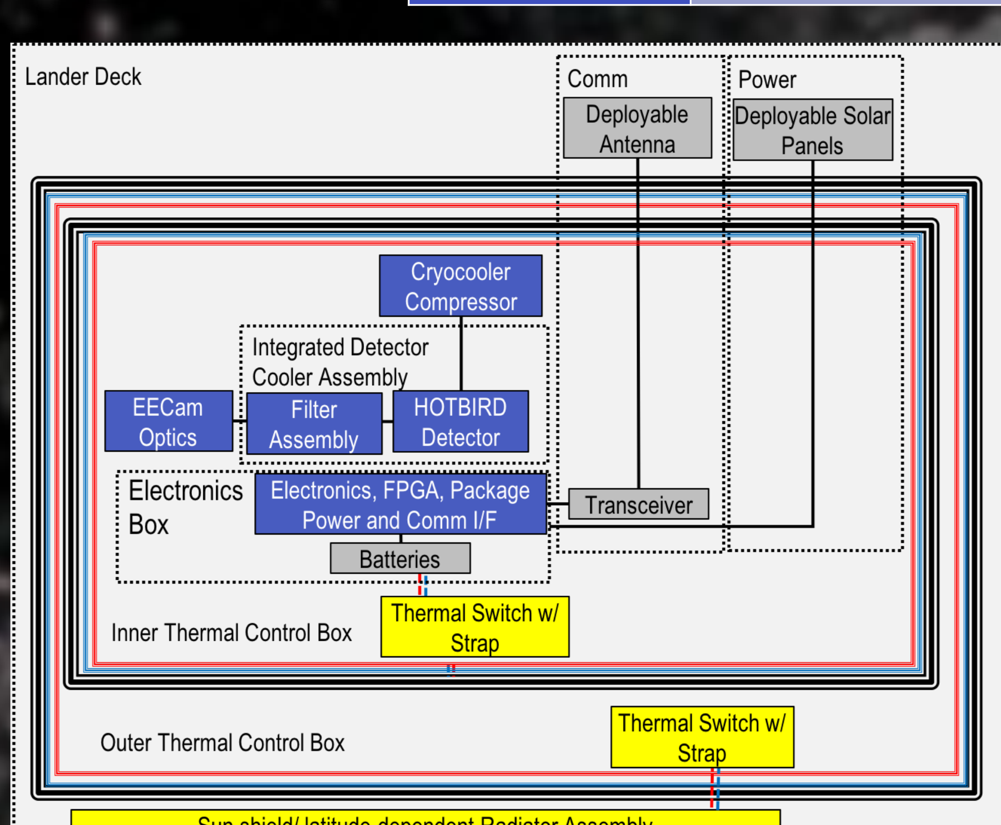
Lunar Science Instrument	Existing Compact Example	Relevant Science NASA Planetary Science Goal
X-Ray Spectrometer	MIT REXIS	Solar System Formation, Internal processes, Composition: Elemental Abundances
Broadband IR	GSFC/JPL BIRCHES	Solar System formation, internal processes, Composition: Volatiles, Mineralogy
Near IR Imager	JPL UCIS, M3	Solar System formation, internal processes, composition: Volatiles, Mineralogy
Compact Camera	JPL EECAM	Site Structure and History, Nature of Regolith and Rocks: Photogeology
Magnetometer	UCLA/FGM, JPL/VHM	Interior structure, materials, processes: Induced magnetic fields
Short Period Seismometer	JPL SP SEIS	Interior structure, materials, processes: seismic activity
Particle Analyzers	GSFC HALO, SIMS	Environmental Processes, Space Weathering: Energetic Particles
Electrostatic Dust Analyzers	U Colorado CEDA	Environmental Processes, Micrometeorite Bombardment: Dust
Electric Field Instrument	GSFC EPIC	Surface Environment, Surface Dynamics: Electric Fields
Radiation Detectors	U NH DOSEN	Surface Environment, Surface Dynamics: Radiation

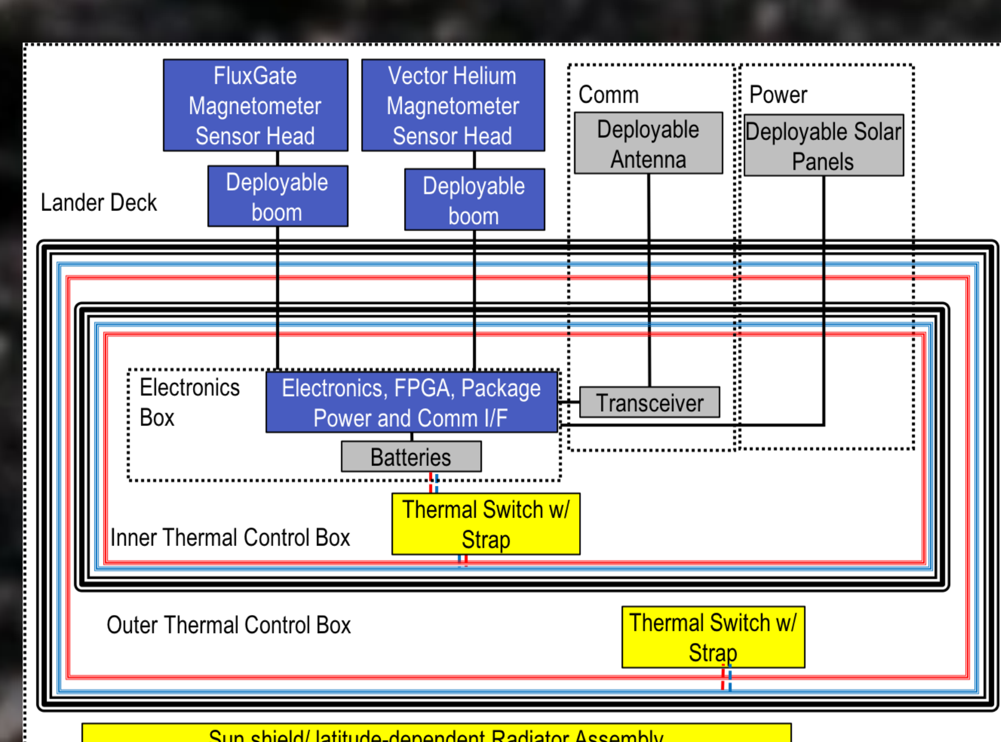
DTE Reverse Thermal Switch Prototypes

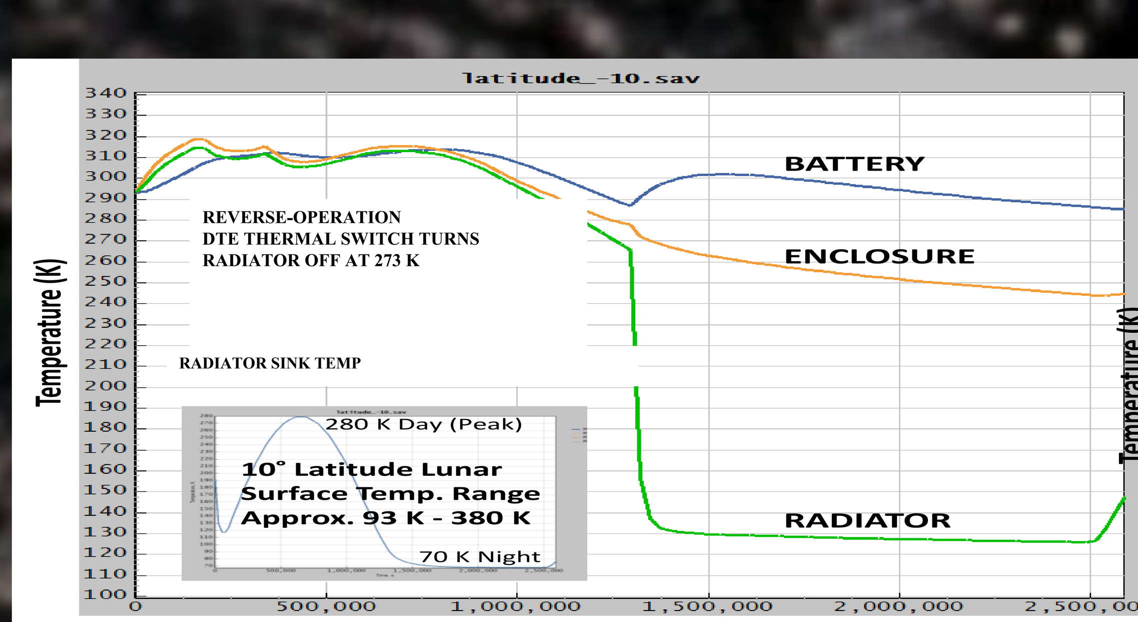


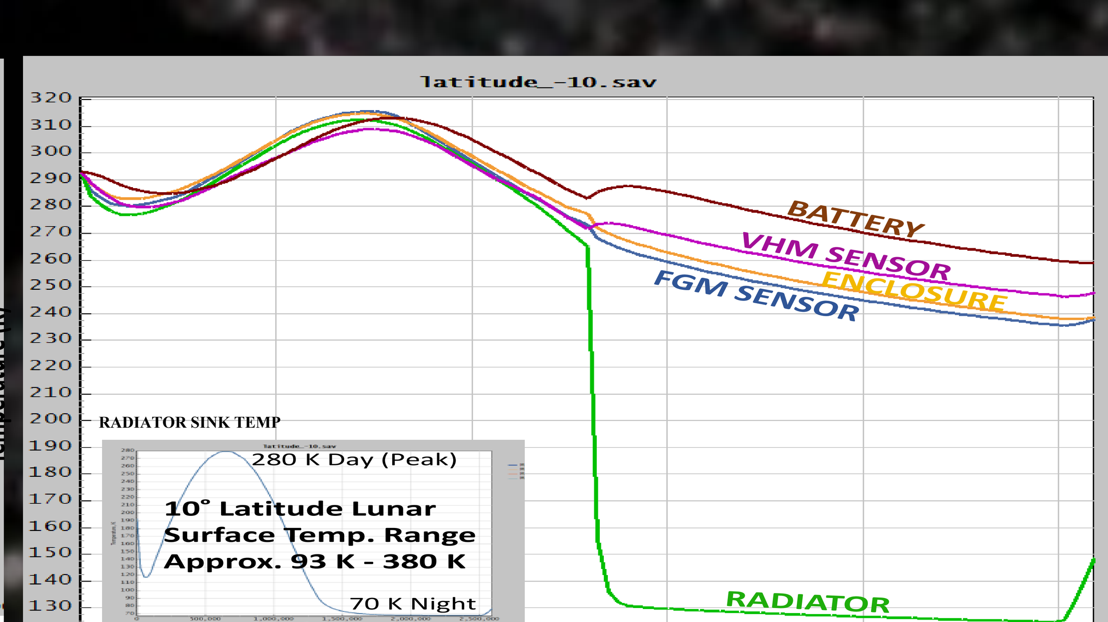
Generic Thermal Package Concept capable of maintaining temperatures between 263 and 313K.

Accommodation from Lander	
Parameter	Value
Mass	15 kg
Power	8 W (28 V)
Volume	12U
Data Volume	N/A Has own Comm system
Orientation	N-S radiator pointing +/- TBD
Thermal	None from lander, maintain 263-313K for payload









National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Purpose: Credible opportunities for delivery of compact payloads to the lunar surface via commercial landers are emerging in the coming decade. Characterization of the highly interactive environment of the lunar surface and subsurface, requires continuous operation. Due to the uniquely extreme lunar surface conditions (high radiation, 2-week <100 K night, 2-week up to 400 K day), radioisotopes have been required for either full day and night operation (Apollo Lunar Surface Experiment Package using RTGs) or day operation and night survival only (all others including Lunakhod, Yutu, proposed commercial designs using RHUs). Compact in situ measurement packages capable of sustaining stand-alone day/night lunar operation could enable science investigations that heretofore required unaffordable dedicated landers with radioisotopes. Successfully demonstrating the feasibility of such a concept would represent a major breakthrough by enabling studies of the dynamic activities on lunar and other extreme environment solar system surfaces via distributed, lower cost platforms. Such packages, deployed on or from landers or rovers, could address high priority science goals and strategic knowledge gaps by providing dynamic measurements of the Moon's environment or interior.

Background: The most challenging problem is creating a thermal design to allow a low-cost, compact (cubesat-scale) package without radioisotopes to, at minimum, survive lunar night, and preferably operate on limited duty cycle during lunar night. Preliminary environmental modeling indicates that the availability of a reverse thermal switch (to maintain a thermal control box) with 1000:1 switching ratio, 10 times better than state of the art MER ratio of 100:1, would be required to allow cubesat-scale package (<20 kg, <2W during lunar night) to survive lunar night. The special parabolic radiator/reflectors required to survive the solar and lunar surface thermal emissions during lunar day have already been demonstrated on the Apollo Lunar Surface Experiment Packages (ALSEPs). Recently, Bugby and coworkers [1] have demonstrated the capability of a reverse thermal switch with a 2500:1 switching ratio.

Thermal/Mechanical Concept: Two prototype of the crucial thermal switch components were designed, built, and tested. 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.

Testing to raise the TRL of the switches to 6 will be completed by January 2019. In the first test, aerosol freeze-spray was sprayed onto each prototype and measured temperature. Electrically non-conductive polymers in the OFF condition flow path allowed electrical resistance to indicate the ON/OFF transition, which verified the pre-test predictions. The second test (in thermal vacuum) was conducted with a calibrated Q-meter, which demonstrated performance that doubled pre-test ON conductance and was in-line with pre-test OFF conductance predictions. Shock and vibration tests were passed with no degradation in performance. High fidelity environmental testing, involving the simulation of lunar cycles, will be completed in January of 2018. The two prototypes are illustrated here.

In addition to the thermal switches, Ball high performance MLI [2] 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 demonstrates that both packages, representing a range of instrument requirements and incorporating the new thermal switch, should be able to meet their requirements for survival and/or operation during lunar night [1].

Examples: Two instruments with very different requirements, an imaging camera requiring a cryocooler and window and a dual magnetometer with external sensors on booms, provided the basis for requirements and thermal modeling of the generic package concept (Figures 2 and 3) to confirm that all instrument components would remain within acceptable temperature limits (Table).

References: [1] Bugby, Clark, and Hofmann (2018), these proceedings; [2] McKinney, C. et al (2018) LPSC 2018, 2857.pdf; [3] Ting, D. et al (2011) NASA Tech Briefs, NPO-46477, 16; [4] Clark, Bugby, and Chin (2018) LPSC 2018, 1269.pdf