# Low-Cost Distributed Lunar Surface Networks Enabled by High Performance Thermal Components

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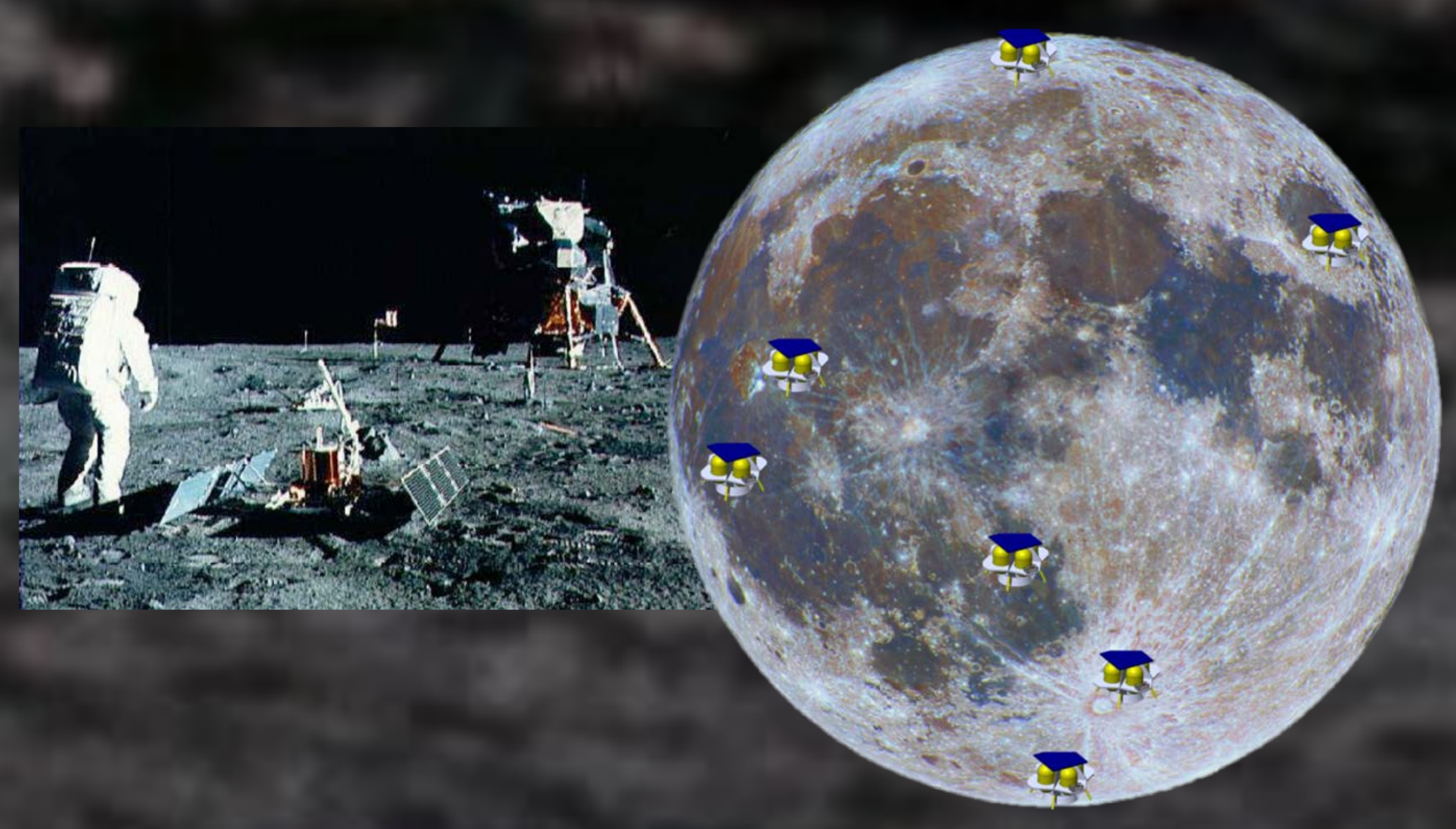
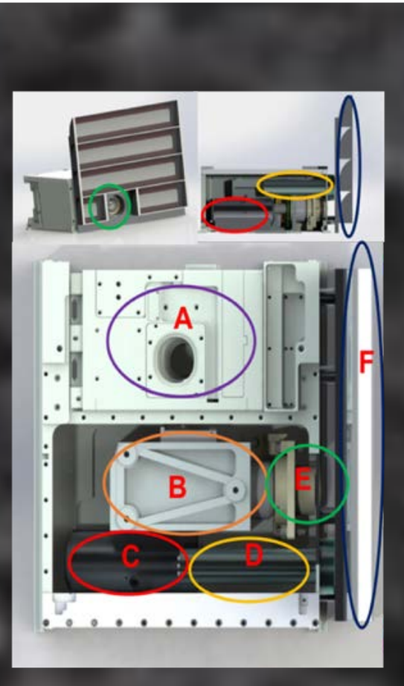
| Lunar Science Instrument | Existing Compact Example | Relevant Science NASA Planetary Science Goal |
|---|---|---|
| **X-Ray Spectrometer** | MIT REXIS | Solar System Formation, Internal processes, Composition: Elemental Abundances |
| **Broadband IR** | GSFC/JPL BIRCHES | Solar System formation, internal 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: Elelctric Fields |
| **Radiation Detectors** | U NH DOSEN | Surface Enviornment, Surface Dynmaics: Radiation |

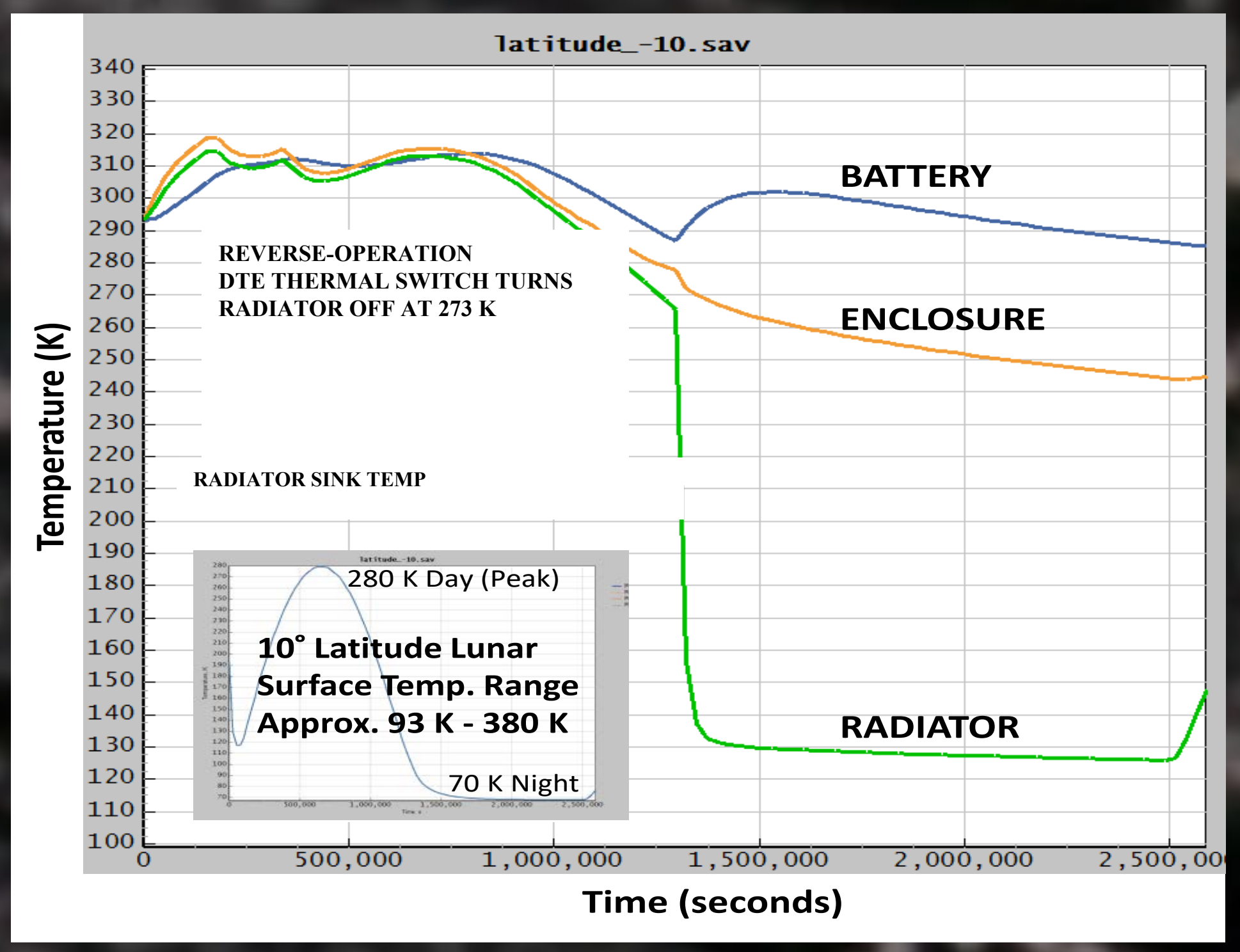


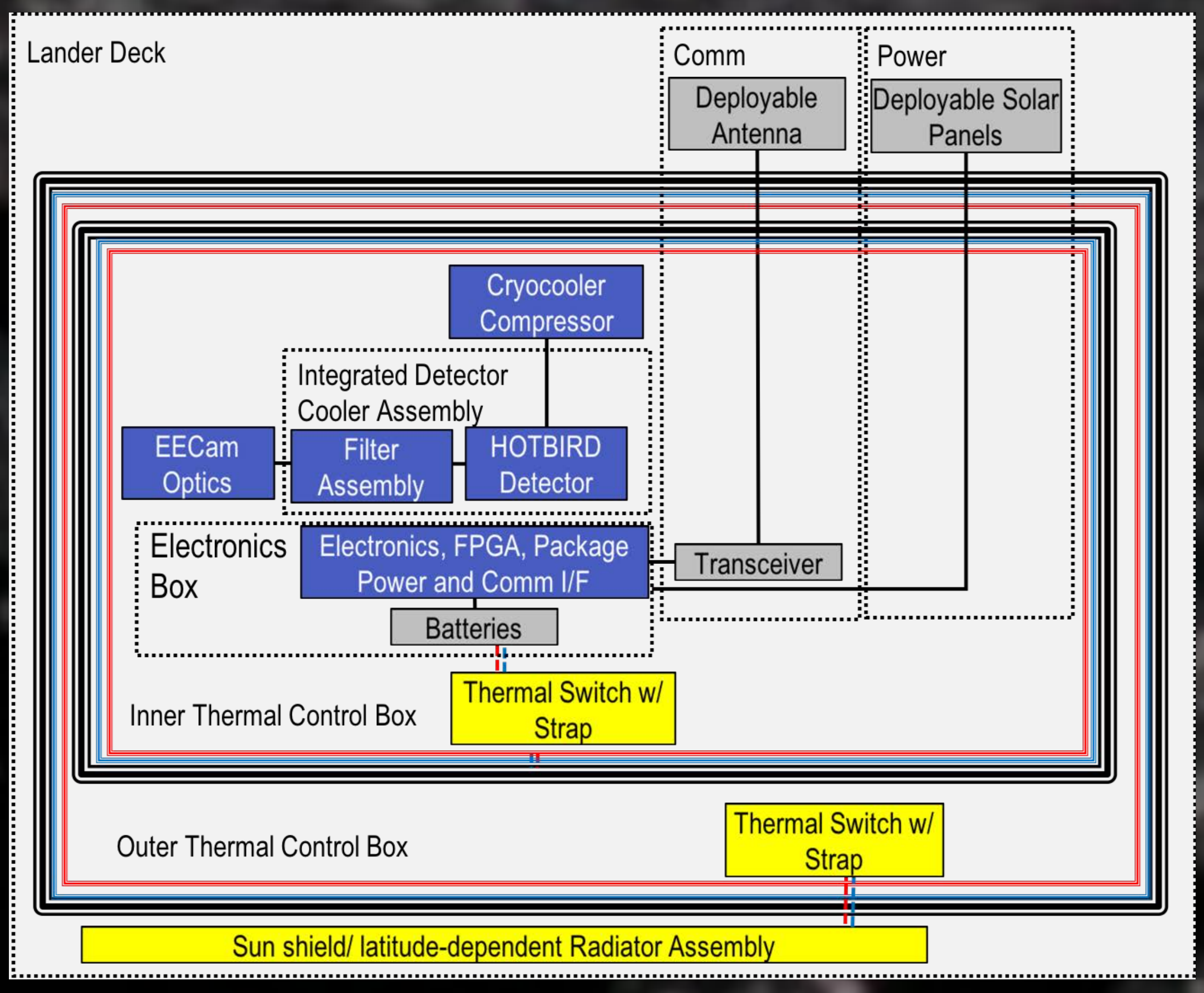
| Instrument Package | Mass kg | Power W | Special Need |
|---|---|---|---|
| Generic | <15 | 8W | range |
| SILVIR | 10 | 4W day (20% duty cycle), 1W night | Cryocooler, window |
| LIMS | 10 | 4W day, 2W night | Two sensors on external booms |

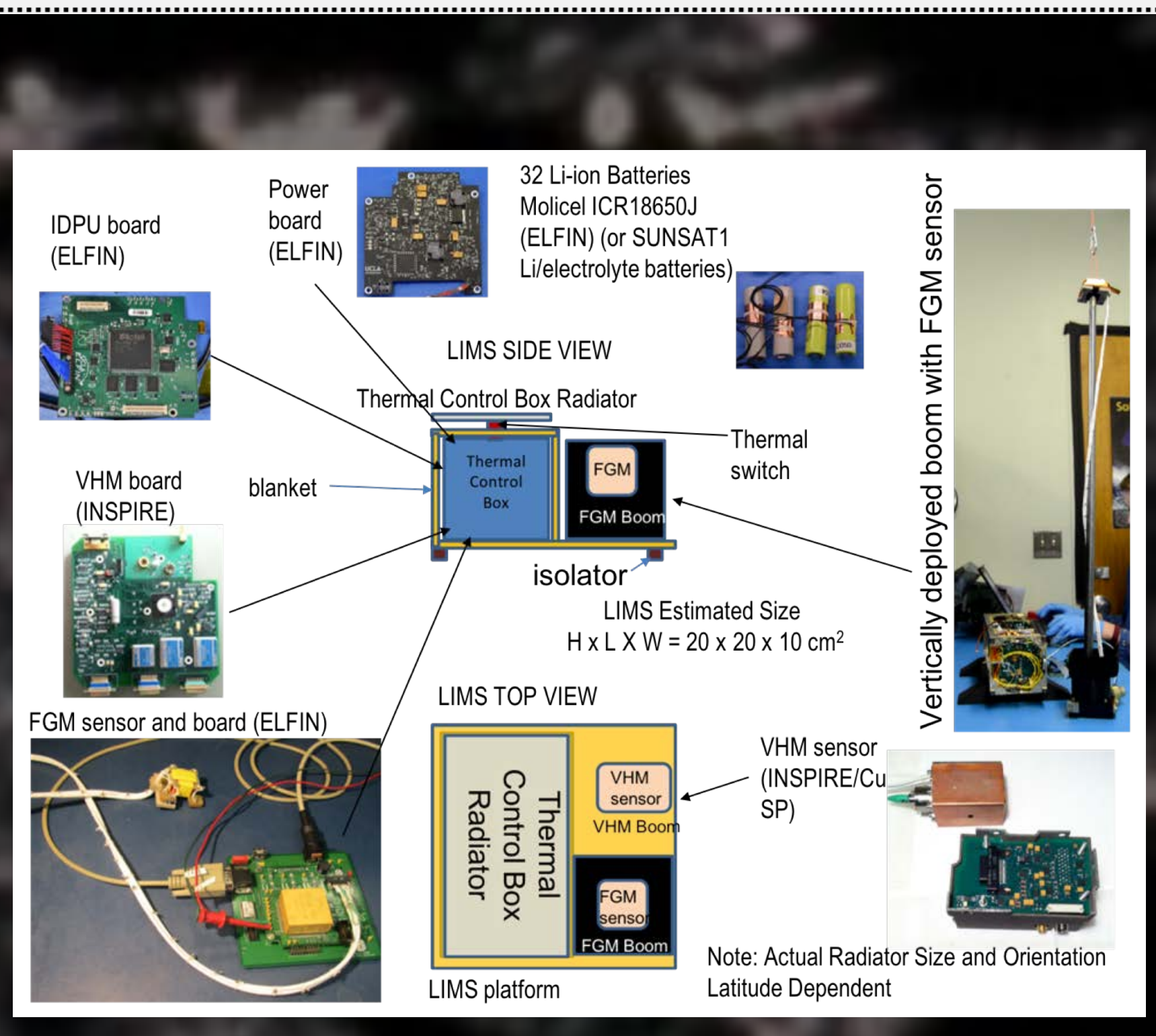
| Science Investigations Requiring Long Duration | Projected Temp. Range |
|---|---|
| X-Ray Spectrometer, Broadband IR | 263 K – 313 K |
| Near IR Imager, Compact Camera, Magnetometer | |
| Seismometer, Particle/Dust Analyzers, Others | |

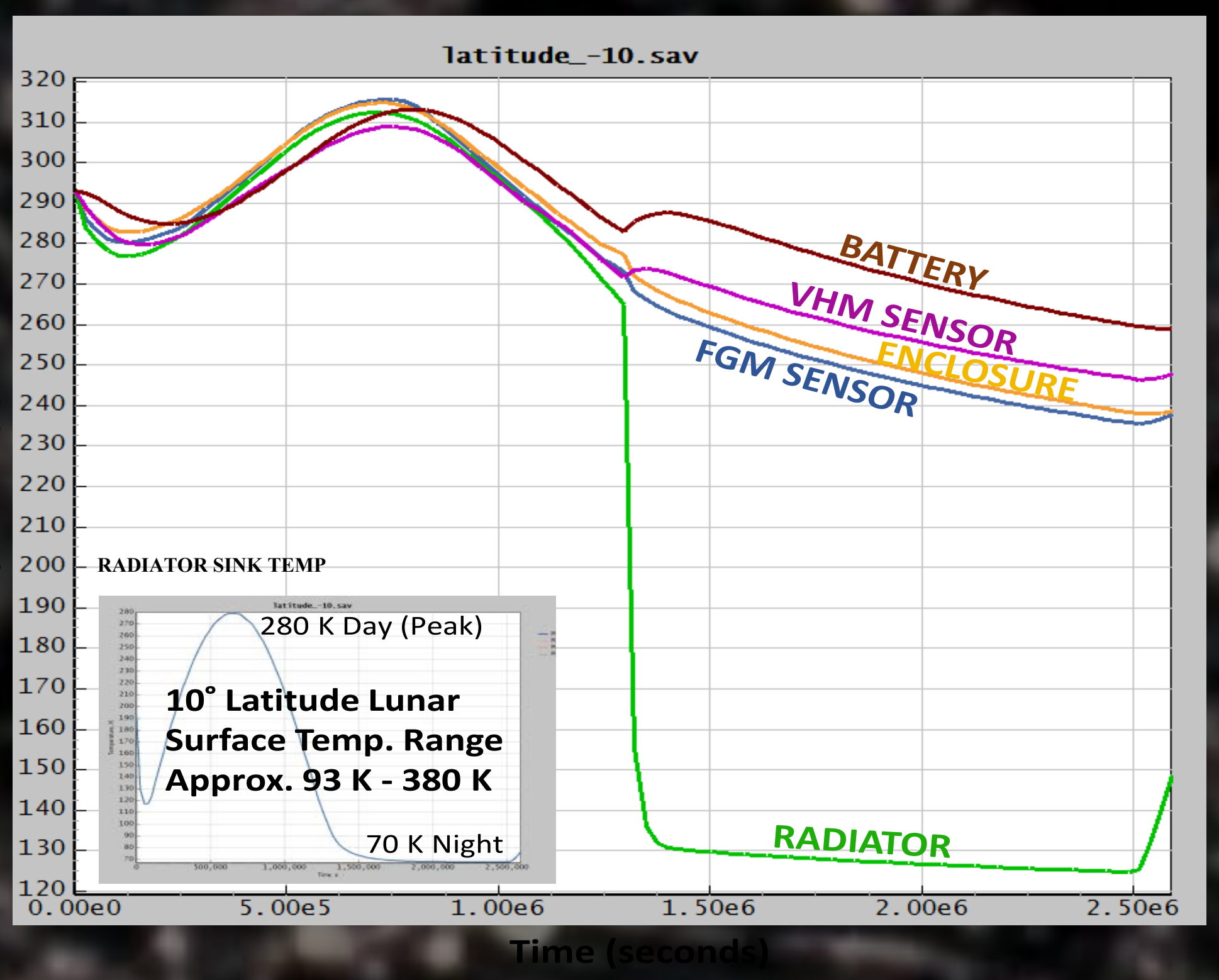


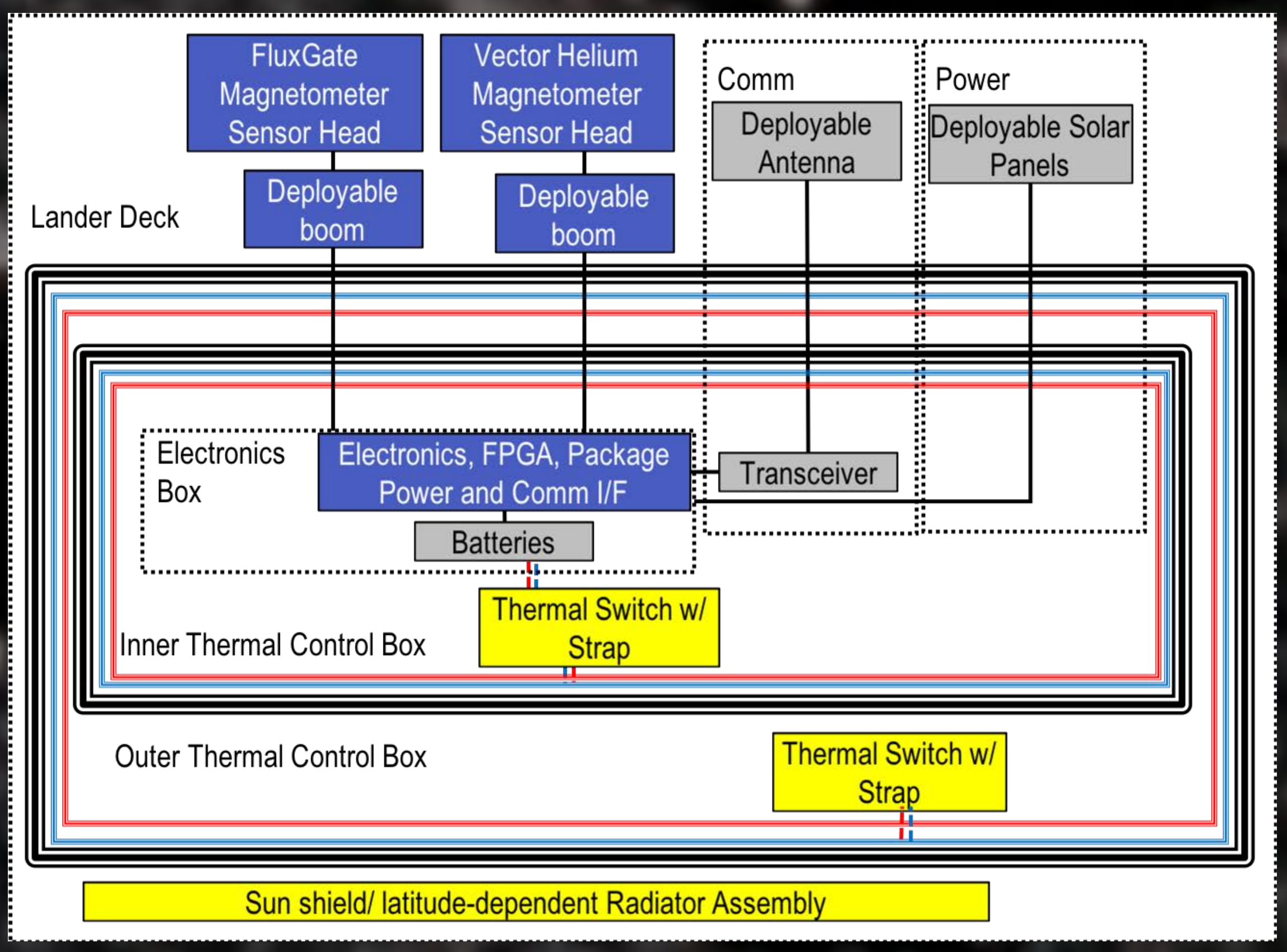
Compact SILVIR.
A Electronics box (space for battery),
B Dewar w/ IDCA (FPA under mount).
C Cryo-cooler compressor.
D Thermal switch bolted to chassis, connected to radiator via strap.
E Camera lens assembly.
F Radiator.











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**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.

**Examples 1:** The Surface Imaging of Lunar Volatiles in the InfraRed (SILVIR), based on a ruggedized version of JPL's EECam (Enhanced Engineering Camera) optics and electronics [2] updated with a JPL cryo-cooled HOTBIRD (High Operating Temperature Barrier InfraRed Detector) focal plane array [3] and filters for selection of water-related absorption bands, would provide snapshots of water-related features as a function of time of day, shadow, and slope, at a given landing site, and thus local 'ground truth' for the orbital observations over many lunar cycles. The SILVIR package would also include instrument electronics, a battery assembly, and the Bugby thermal switch. SILVIR would be most suitable, equipped with a gimbal, for a lander network, but could be used as a water feature 'mapper' on a rover as well. The principal thermal challenge is making sure the battery temperature is within operational limits to operate the cryocooler for at least two hours before the first observation of the day, at dawn.

**Example 2**: The Lunar Interior Magnetic Sounder (LIMS) [4], based on fluxgate and vector helium magnetometers and their associated electronics on short booms, would provide, in conjunction with the orbital ARTEMIS magnetometer, would provide measurements of lunar magnetic induction varying over the course of several lunar cycles (including traverses through the Earth's magnetotail) from which the lunar interior temperature profile could be derived, and models for the origin and formation of the core constrained. The fluxgate magnetometer would be calibrated with the thermally stable vector helium magnetometer. The LIMS package would also include instrument electronics, a battery assembly, and the Bugby thermal switch. LIMS would be most suitable for a lander network. The principal thermal challenges are maintaining the fluxgate magnetometer and battery within operational limits, and vector helium magnetometer within survival limits during lunar night.

- 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].

**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