A LUNAR GEOPHYSICAL INSTRUMENT PACKAGE (L-GIP) AS A CANDIDATE FOR THE INTERNATIONAL LUNAR NETWORK (ILN) - PART II : ARCHITECTURE

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Summary: This paper examines preliminary results from a recently awarded NASA Planetary Instrument Design and Development Program (PIDDP) study to develop a small self-contained lunar Geophysical Instrument Package (LGIP), which may be used in a long lived lunar geophysical network. The goal of the architectural design portion of the PIDDP study is to develop an integrated package that is flexible enough to accommodate a variety of existing instruments and robust enough to operate under the harsh and diverse conditions on the Lunar surface. This poster presents preliminary results from some of the key trade studies associated with probe design for a lunar geophysical network mission such as the International Lunar Network (ILN), currently under study by NASA. Key considerations for LGIP probe design include a dynamic thermal environment, long lived power source, data storage and communications schemes and instrument accommodation.

Background: As with the Apollo Lunar Science Experiment Packages (ALSEP), it is likely that the next Lunar geophysical network will be incrementally built up in a variety of locations, using a number of missions over a long period of time. In fact, the goal of the ILN is to "… provide an organizing theme for all [*domestic and international*] landed science missions in the 2010s by involving each landed station as a node in a geophysical network. … each node would include some number of 'core' capabilities (e.g., seismic, heat flow, laser retro-reflectors) that would be extant on each station, reflecting the prioritized lunar science goals articulated in the National Research Council's study, '*The Scientific Context for Exploration of the Moon*'."[1]

This time-staggered deployment necessitates the use of a reliable, long-lived power supply, that will allow the initially deployed packages to still be operational when subsequent packages arrive on the lunar surface so that they can all operate as an integrated network. Science goals also dictate that measurements be made over an extended period of time, and that the LGIP be deployed globally across the lunar surface in strategic locations so as to maximize science return and environmental characterization [2].

Probe Design Considerations: System Engineering and development goals traditionally attempt to minimize cost and complexity by designing a single LGIP that can be fabricated multiple times and function at all desired locations and conditions with minimal or no modifications. The difficulty in making a "universal" package, however, lies in the large variability of deployment schemes, locations, operating environments, etc. Some environments, such as radiation, are governed by statistical processes. Others, such as the dust environment are more predictable.

Thermal Environment. Perhaps the most influential environmental design parameter for any Lunar surface hardware is temperature. The Moon has a wide variability of surface temperatures [3]. The combined spatial and temporal variability ranges from 40K in shadowed polar craters to nearly 400K at the solar illuminated equator. Even staying in one mid-latitude spot, the day-night temperature variation is on the order of 280K. However, at depths as shallow as 30 cm beneath the lunar regolith, Apollo probes found temperatures close to average (220 to 255 K), with almost no day-night variation (~ ±3 K).

A variety of temperature mitigation strategies will be investigated in this study including insulation, radiators and heat pipes, electric heaters, radioactive power waste heat or burrowing the entire package into the lunar regolith. An examination of viable options is presented in this poster.

Long Lived Power Options. Traditional power systems for space missions use either a Thermal Electric Generator (RTG's or Stirling engines) to convert heat to electricity, or photo-voltaic cells in conjunction with rechargeable batteries. Smaller Radioisotope Power Sources (RPS) are also an attractive long life low mass option for smaller load demands [4,5]. Mass constraints, long mission duration, large temperature swings, and long intervals (up to 14 days or more) without sunlight make power system design for an LGIP challenging. This paper presents preliminary trade analysis results of the various different types of power systems suitable for the LGIP probe.

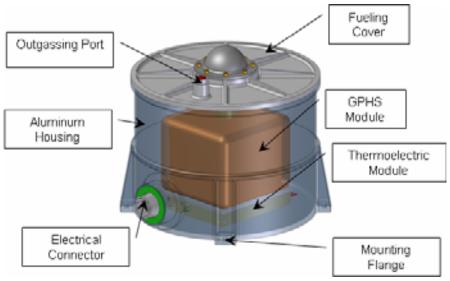

***Figure 1** – Multi-watt RPS design using a single full GPHS block [4,5]*

Data Storage and Communications. The probe deployment technique, communications scheme and power source options all are largely dependent upon whether the LGIP will be used as a payload (attached to a robotic or crewed lander), or as a stand-alone probe (***Fig. 2***). If the package is merely an instrument suite, then power and communications can be provided by a host spacecraft, or via an umbilical to a landed crewed vehicle. In this case, the lifetime of the package is limited by the lifetime of the lander. If the package is designed as a stand-alone probe, it will require it's own power source and communication module.

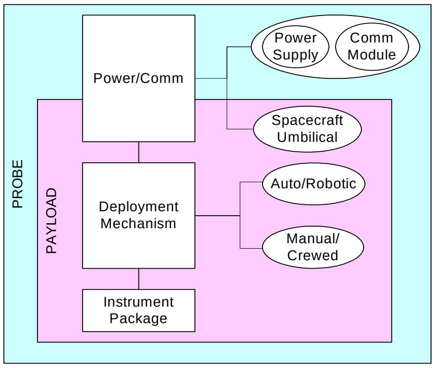

***Figure 2** –LGIP ConOps Approach*

Lunar far side probe deployments will require an orbital communications relay to exchange commands and telemetry with Earth. Near side probes can either use an orbital relay or direct to Earth (DTE) transmission. Other options include the use of a Lunar surface relay station or network. DTE probes may require more power and different antennae than those which rely upon a telecom relay. In either case, considerations need to be made for storing then rapidly down linking data due to limited communication geometries.

Instrument Accommodation. To allow for multiple operational possibilities using a single architectural solution, the LGIP can be designed with high modularity, so that the instrument package design can be separated from the deployment mechanism and power/comm module. The modules may then be joined together with standard, well-defined connections that provide a thermal, mechanical and electrical (power and command/telemetry) interface. This also allows for separability of instrument modules from core probe functions, which allows for "mixing and matching" of instruments in the payload, without disrupting the overall system architecture. The approach is similar to the object oriented philosophy of modeling, simulation and advanced software design. A sample architecture is outlined in ***Figure 3***.

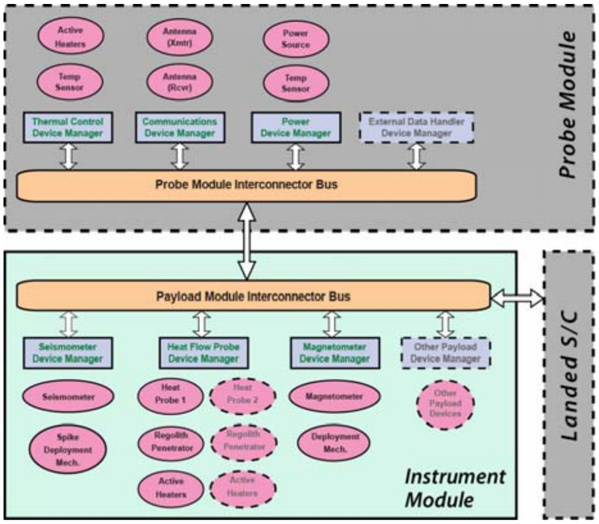

***Figure 3** – Highly ModularLGIP Architecture*

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