DEEP SPACE GATEWAY AS A DEPLOYMENT STAGING PLATFORM AND COMMUNICATION HUB OF LUNAR HEAT FLOW EXPERIMENT. Shaopeng Huang, Department of Earth and Environmental Sciences, University of Michigan, Ann Arbor, MI 48109-1005, USA (shaopeng@umich.edu).

Background: Planetary heat flow density (or heat flow in short) is a measure of the conductive heat flux from the interior of a planet. It is a fundamental parameter in understanding the internal physical state, chemical composition, and near surface thermal environment of a celestial body. The Moon is the only planetary body (except for Earth) from which its heat flow density has ever been measured with instruments emplaced in situ by humans. However, while there are heat flow measurements from tens of thousands of sites on the Earth [1], there are only two on the Moon [2]. Moreover, the two lunar heat flow measurements, respectively from the Apollo 15 and Apollo 17 landing sites, might not be of global representativeness [3,4,5]. Heat flow experiment remains as a high priority task in lunar science and exploration [6].

Apollo Heat Flow Experiment: Lunar Heat Flow Experiment is an integral component of the Apollo Lunar Surface Experiments Package (ALSEP). The Experiment was planned for Apollo 13, 15, 16, and 17 missions. Apollo 13 did not land on the Moon due to a malfunction caused by an explosion and rupture of an oxygen tank in the service module. The experiment on Apollo 16 failed, unfortunately, due to a broken cable connection. So far only two heat flow values have been obtained on the Moon – 21 mW/m^2 from the Apollo 15 landing site in Hadley Rille and 14 mW/m^2 from the Apollo 17 landing site in Taurus Littrow [2]. These two lunar heat flow values are less than a quarter of the global terrestrial mean of 87 mW/m^2 [1]. However, they are significantly higher than the prediction with respect to the small size and commonly accepted chemistry of the Moon [4]. There are concerns that the existing measurements are biased because they are located at geographical/geological boundaries [7]. The Apollo 15 is located within the confines of the Procellarum KREEP Terrane which possesses high abundances of heat producing elements as determined from the Lunar Prospector gamma-ray spectrometer. In contrast, Apollo 17 is located in the Feldspathic Highlands Terrance which possesses much lower crustal abundances of heat producing elements.

Three Deployment Options: Heat flow is measured as the product of the thermal conductivity and vertical temperature gradient in the subsurface. Therefor, a lunar heat flow measurement requires penetration into the regolith layer. There are three possible deployment options [8].

Manned Onsite Drilling. This conventional and most reliable approach was taken by the Apollo 15-17 missions. It involves astronaut operation of drilling at least 1.5 meters into the lunar regolith near the landing site.

*Lander-Attached Deployment***.** This would use either a drill or a telescopic injection system attached to the main lander. The prospective Mars mission InSight would use this approach with a self-penetrating mole to deploy the Heat Flow and Physical Properties Probe (HP^3) down to a depth of 5m [9].

Gravitational Penetration. A lunar heat flow probe can be deployed by gravitational force via free-fall from a high altitude. This approach was designed for the canceled Japanese mission Lunar-A [10]. It would allow the heat flow experiment to be deployed over a greater range without the constraints of a lander.

This Proposal: The idea of this proposal is to use the Deep Space Gateway (DSG) as a staging platform for the deployment of lunar heat flow experiment, and consequentially as a communication hub of the installed heat flow experiment. A mini-spacecraft loaded with multiple instrumented penetrators will be inserted by the DSG into a low lunar orbit. The spacecraft will later release the penetrators to let them freely fall to the lunar surface and penetrate vertically into the regolith at least 1m deep with appropriate impact speeds. The instruments of the penetrators will measure the temperatures and thermal physical properties of the regolith for the determination of lunar heat flow density. The following are some advantages of such an approach for lunar heat flow experiment.

Rich Knowledge Base of Lunar-A. The design and development of the deployment mechanism and instrumentation of such a DSG enabled lunar heat flow experiment can be based on the lessons and rich experimental data of the canceled Lunar-A, from which this concept is derived. The well-tested missile-shaped Lunar-A penetrators are 75 cm in length, 14 cm in diameter, and 13 kg in weight. They were designed to penetrate 1-3m into the regolith [10].

Lower Risk and Cost Effective. The deployment has no dependency on astronaut or robot on the Moon. No landing module is required.

Reduced Artificial Perturbation. Subsurface temperature at shallow depths of the regolith layer is sensitive to the physical properties of the surface [11]. Any changes in the regolith compactness related to human/robot exploration activity, or shading of any artificial object such as a lander will introduce transient perturbation to the subsurface temperature field and, hence, heat flow measurement. Such perturbation can be avoided with astronaut/robot free deployment, although there might be some perturbation due to penetration impact.

Global Coverage. With the DSG as the staging platform and communication hub, in principle there would be no limitation on the target of deployment. Heat flow experiment can be deployed to various geological areas including those on the far side of the Moon. This is of great importance to the characterization of the lunar heat flow distribution and the assessment of its global energy budget.

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