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THERMAL IN SITU MEASUREMENTS IN THE LUNAR REGOLITH USING THE LUNAR–A PENETRATORS: AN OUTLINE OF DATA REDUCTION METHODS.
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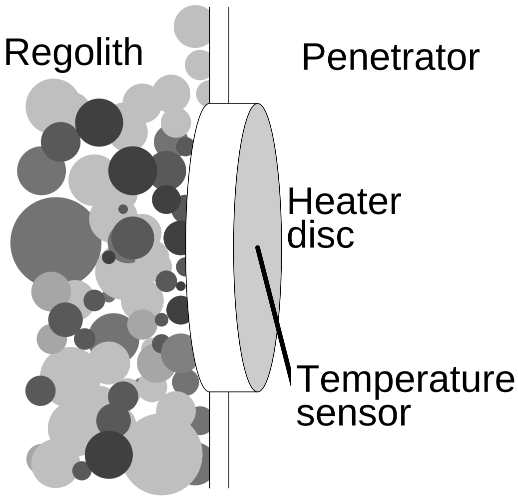

Figure 1: Schematic design of the LUNAR–A thermal property sensors. For details refer to Tanaka et al.[1].

The two penetrators to be launched in the LUNAR–A mission in 2003 by the Institute of Space and Astronautical Science, aim at investigating the internal structure of the Moon. Each penetrator is designed to conduct seismic and heat–flow experiments [2].

For determining the lunar heat–flow two parameters need to be measured: one is the thermal gradient $\partial T/\partial z$, the other is the thermal conductivity λ of the lunar regolith. However, the precise measurement of both quantities using a penetrator is not a trivial task.

As for the measurement of the thermal gradient, a number of factors needs to be taken into consideration: The thermal gradient in the regolith varies with time due varying insolation. This effect can be minimized by emplacing the penetrators deeper than 1 m in the lunar regolith. Upon penetration into the regolith the kinetic energy of the penetrator is dissipated resulting in an unknown temperature distribution in the penetrator and its surroundings. The penetrator itself influences the ambient temperature field considerably because of its high thermal conductance, resulting in a smoothed temperature gradient. A numerical data reduction scheme to find the undisturbed temperature field around a highly heat–conducting penetrator within a half–space with a low thermal conductivity applicable to both unknown initial conditions and temporally varying temperature has been presented by Hagermann and Spohn [3] for the MUPUS penetrator, an experiment used in the Rosetta mission. The algorithm is based on a modified solution of the Inverse Heat Conduction Problem by Kurpisz [4] and remains stable even in the presence of measurement errors, as numerical simulations have shown.

The determination of the thermal conductivity of the material surrounding the penetrator can be determined by observing the thermal response upon thermal excitation: For measuring the thermal conductivity of the lunar regolith, each of the LUNAR–A penetrators will carry five heaters: Upon supplying energy at a constant rate to a small disc on the surface of the penetrator a sensor in the center of the disc measures the increase in temperature. The measured thermal response of the disc serves as the data for the subsequent data interpretation, which is an Identification Heat Conduction Problem (IDHCP). This problem belongs to the class of ill–posed inverse problems because the uniqueness of the solution is not warranted. Horai et al. [5] found a forward analytical solution to the problem of determining the thermal inertia of the regolith. This solution assumes a simplified geometry and constant thermal properties of the regolith and the penetrator components.

In this work we aim to determine the thermal conductivity inversely as a function of both location (i.e. distance from the heater) and time. From these parameter a solution for a space–and temperature–dependent thermal conductivity of the regolith can be developed.

References: [1] Tanaka, S., S. Yoshida, A. Hagermann, M. Hayakawa, A. Fujimura and H. Mizutani (this volume). [2] Mizutani, H. (1995) *J. Phys. Earth* **43**, 657–670. [3] Hagermann, A. and T. Spohn (1999) *Adv. Space Res.* **23**(7), 1333–1336. [4] Kurpisz, K. (1991) *J. Heat Transf.* **113**, 280–286. [5] Horai, K., A. Fujimura, S. Tanaka and H. Mizutani (1990) *Proc. 23rd ISAS Lunar Planet. Symp.*, 277–282.