THE HEAT-FLOW PROBE HARDWARE COMPONENT (HPHC) OF THE LGIP PACKAGE. Roman Wawrzaszek[1], Karol Seweryn[1], Jerzy Grygorczuk[1], Marek Banaszkiewicz[1], Joanna Gurgurewicz[1], Clive R. Neal[2], Shaopeng Huang[3], Norbert Kömle[4].
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Introduction: The objectives of the Heat Flow Probe, one of the instrument in the Lunar Geophysical Instrument Package (LGIP) [1] is to make direct measurements of the steady-state thermal energy flux flowing from the interior of the planet to its surface, and carries rich information about its deep thermal structure, bulk chemical composition, and evolution history. To accomplish these science objectives, the SRC PAS design and developed the Heat Flow Probe Hardware Component (HPHC) which comprises three subsystems: (i) mole penetrating device (sensors carrier), (ii) deployment – manipulator based on tubular boom technology and, (iii) thermal and optic sensors for temperature and heat-flow experiments (mole's payl.).

The work presented in this paper is focused on intagration of the subsystems mentioned above to achive horizontal and vertical mobility of the heat flow probe on the Moon surface.

Mole Penetrator: Mole device (Fig. 1) is a low velocity, high energy (2J in one stroke), self-driven penetrator designed as a carrier of different sensors for *in situ* investigations of subsurface layers of planetary bodies [2]. The principle of operation of the mole is based on the interaction between three masses: the penetrator tube, the hammer and the countermass.

This approach takes advantage of the MUPUS penetrator design (SRC PAS) [3], a payload of the Philae lander on Rosetta mission [4]. It has been proved that the device works well if the penetrated medium consists of porous or granulated matter with a grain size of several μm to several mm. This condition should be fulfilled on the Moon, since the surface layer there is highly comminuted regolith. The maximum penetration depth of the SRC-designed mole has been estimated as 5-6m for dry sand in Earth conditions. Test-proven depth of operating is 2m (limited by test-bed size). The details of the mole penetrator design was presented in [5] while the main properties of prototype are summarized in the table below.

Parameter	Value
Mass	500 g
Diameter	20 mm
Length	330 mm
Average/Peak Power	~0.28 W/~0.7 W
Accumulated energy per stroke	2 J
Maximum Penetration Depth*⁾	2m (tested), 5-6m (estimated)
Average Penetration Speed	8.5 mm/strokes
Science payload	2 Thermal sensors

Fig 1. The laboratory model of the mole penetrator: the outer tube with the tip (bottom) and the hammer with the countermass (top).

Manipulator: Proposed manipulator is evaluation of the deployment built for MUPUS instrument [3] and improves the distance of extention. The main task of the manipulator is to deliver the scientific instruments (heat flow probe and eventually other scientific instrument) from the package body on the lander to measurements position on the Moon surface.

One of the main feature of the manipulator is connected with tubular boom material. This solution provides two important advantages: either minimizing mass of the system and volume of the stoved configuration. The deployment action is performed in four steps (Fig. 2).

Step 1. The stowed Support System is deployed to a length of 1 – 1.5m and tilted up 10 -15 deg in order to guarantee free working space for the Mole rotation.

Step 2. Deployment of the Support System is realized by rotating the Mole housing tube. This can be done during travel or when the deployment stops for a while.

Step 3. Continuation of the deployment to reach the proper extension. The system is still tilted up to minimize the risk of contact with obstacles.

Step 4. TBs stop and the extension of the guy strips only will lower the Support System to the ground.

The main properties of prototype are summarized in the table below.

Parameter	Value
Extension	3 – 3.5 m
Mass	2.2 kg
Stowed size	(L x W x H) 350x350x450 mm

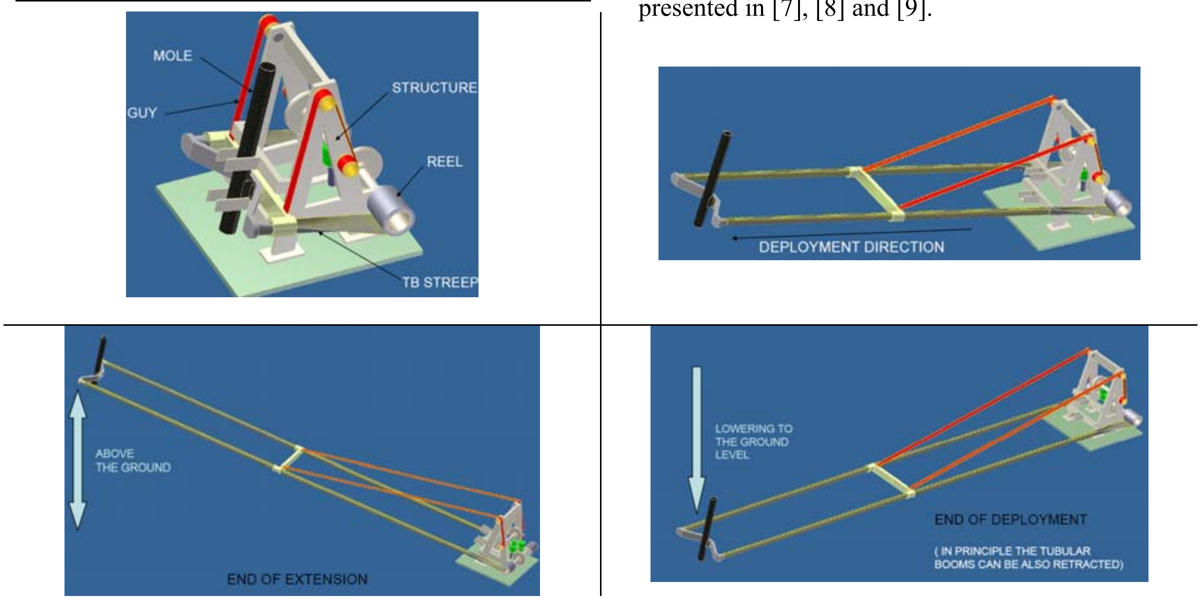

Fig 2. Four steps describing the deployment scenario.

Sensors: The temperature sensors carried by the mole are resistance thermometers. In a 'hot rod' method, thermal conductivity is measured by inserting into the medium a metal cylinder that at the same time is a heat source and a temperature sensor [6]. When heated by the cylinder, a medium with higher conductivity absorbs thermal energy faster than a less conductive material, hence its temperature increase is lower. The mole's payload might comprise:

- ITP-PT sensors for temperature and local heat conductivity measurements (Fig. 3) developed in SRC PAS and described in details in [7],
- camera for observing structure of the penetrated medium (currently in developing phase),
- tilt meter,

Thermal sensors are build based on a thin (75 μm in dia.) platinum wire with well known dependence of the resistance on the temperature. The heating element consists of a isotan wire (200 μm in dia.) with flat resistance v.s. temperature dependence.

Fig. 3 Thermal sensor in granular material.

The accuracy of the sensor is 0.005K while the power 0.1W. The thermal sensors together with active thermal conductivity determination method are presented in [7], [8] and [9].

Results: The main results of the integration of the subsystems presented in the previous paragraphs are connected with the mobility of the heat flow probe. On the one hand the ultra light manipulator allow to horizontal movement above moon surface whereas the mole penetrator "deliver" the sensors vertically under the surface. All of them improve significantly capability of the mole payload and give them a 3D mobility.

References: [1] Weinberg, J.D. et al. (2008), *LPSC XXXIX*. [2] Gromov, V.V. et al. (1997), *7th European Space Mechanisms & Tribology Symposium*, ESTEC. [3] Grygorczuk, J. et al. (2007), *J. Tel. Inf. Techn.* 1/2007. [4] Spohn, T. et al. (2007), Space Sci. Rev, 128. [5] Grygorczuk, J. et al. (2008), *LPSC XXXIX*. [6] Healy, J.J. et al (1976), *Physica C 82*, 392–468. [7] Banaszkiewicz, M. et al. (2007), *Adv. Space Res. 40(2)* 226-237. [8] Seweryn, K. et al. (2008), *LPSC XXXIX*. [9] Wawrzaszek, R. et al. (2008), *EGU*.