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THE HEAT FLOW AND PHYSICAL PROPERTIES PACKAGE HP^3 ON INSIGHT – STATUS AND FIRST RESULTS.

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Abstract

We will present an update on the status and the first results of the HP^3 instrument on InSight

1. Introduction

On Feb 11, InSight [1] deployed the HP^3 instrument package to the surface of Mars at Homestead Hollow. The primary goal of the Heat Flow and Physical Properties Package HP^3 [2] is to measure Mars' geothermal heat flow.

2. Instrument Overview

The HP^3 - shown in Figure 1 - consists of a mechanical hammering device called the "Mole" for penetrating into the regolith, an instrumented tether which the Mole pulls into the ground, an infrared radiometer mounted below the lander deck to determine the surface brightness temperature, and an electronics box. The Mole and the tether are housed in a support structure assembly (SSA) before being deployed. The tether is equipped with 14 platinum resistance temperature sensors (TEM-P) to measure temperature differences with a 1-σ uncertainty of 6.5 mK. Depth is determined by a tether length measurement device (TLM) that monitors the amount of tether extracted from the support structure and a tiltmeter (STATIL) that measures the angle of the Mole axis to the local gravity vector. The Mole includes temperature sensors and heaters (TEM-A) to measure the regolith thermal

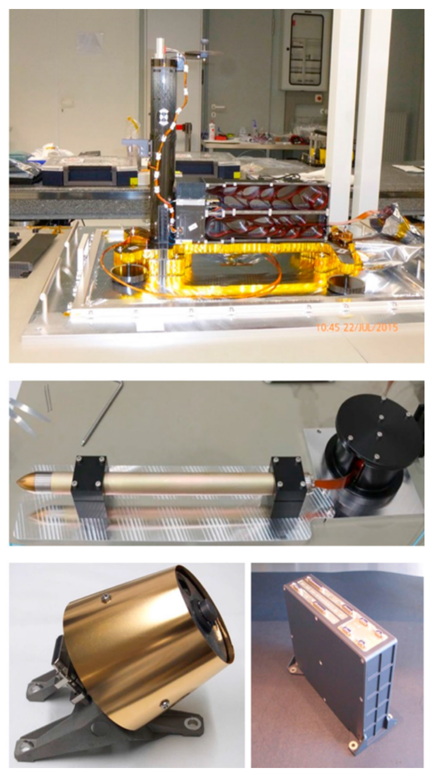

Figure 1: Components of HP^3. The top panel shows the instrument in its support structure but with side wall covers removed. The vertical tube houses the Mole – shown in the panel below. The tether boxes housing the tether equipped with temperature sensors (top) and the tether connecting the instrument to the electronics box on the lander (bottom) are located to the right of the tube. The lower two panels show the radiometer and the electronics box.

conductivity to better than 3.5% (1-σ) using the Mole as a modified line heat source.

The surface heat flow is calculated by multiplying the geothermal gradient and the thermal conductivity of the regolith. The heat flow is expected to vary across the surface of a terrestrial planet. On Mars, model calculations suggest that the surface heat flow mostly maps variations of crustal thickness (enriched in heat producing elements), moderately modified by signals from the mantle convection pattern underneath [7]. For Elysium Planitia, the surface heat flow is expected to be close to the average value for Mars.

The Mole is planned to penetrate to a depth of at least 3 m. The requirement of a minimum depth of 3 m will help to significantly reduce errors introduced by the annual surface temperature variation. Depending on the value of the thermal conductivity, the annual wave thermal skin depth has been estimated to be about 1 m [4].

3. Landing, Deployment, and First Hammering

InSight landed at Homestead Hollow at 4.5°N, 135.6°E (for more accurate coordinates and detailed geological descriptions of the landing site see [8,9]). The properties of the landing site are favourable for HP^3 as significant slopes are absent from the deployment area as well as rocks (on the surface) of sizes that could hamper both deployment and Mole advancement to depth. In addition, HP^3 could be placed far enough away from both the lander and SEIS such that the thermal effects of shadowing are reduced. All the mission requirements for HP^3 placement have been satisfied.

HP^3 was deployed on Feb 11, 2019 and started hammering on March 3rd. Unfortunately, after rapid progress to an estimated depth of about 30 cm, the Mole made little or no measurable progress during the remainder of two hammering sessions. Moreover, the Mole egressed at an angle of 15°-20° with respect to the gravity vector.

The leading hypotheses for the Mole not penetrating further are

1. The Mole is snagged in its support structure
2. The Mole hit a sufficiently large rock
3. The Mole does not have sufficient friction on the hull in the regolith to balance recoil

To test the hypotheses, an extensive test program was started at both DLR and JPL. The test program includes a set of short diagnostic hammerings (~13 min.) on Mars. The first was done on March 26th and was focused on measuring the time between the major hammer stroke and the first sub stroke with the short period seismometer (there is a total of two measurable sub-strokes that follow the main stroke. These are caused by movements of the hammer and counter masses inside the Mole [1]). Model calculations suggest that the length of the time interval should be indicative of the Mole having hull friction or not. In addition, the arm camera took a movie of the support structure. The results show that the latter pitched forward suggesting a small movement of the Mole into the regolith. The seismic data also suggested that the Mole had some friction although most likely not enough for regular penetration. Additional observations with the arm camera showed that the tether in the support structure and its markings could be imaged under suitable lighting conditions through a window in the support structure providing the most direct observation of Mole progress. A second and third short diagnostic hammering session have therefore been planned focused on observing the tether and the second has already been commanded.

At the time of writing, the friction-on-the-hull hypotheses seems to be most likely, although the other hypotheses have not been completely ruled out. Studies are occurring to increase the hull friction by loading the surface with the robotic arm.

First Results: The radiometer RAD is observing as planned. Results are being reported [10] at this meeting. In addition, the thermal conductivity of the near surface layer has been measured to 0.045 W/m/K using the TEM-A sensors on the Mole. Because the Mole is only partly buried, this estimate has considerable uncertainty but is consistent with the thermal inertia measured by the radiometer.

References: [1] Banerdt, W.B., Russell, C.T., *Space Sci. Rev.*, 211, 1–3 (2017). [2] Golombek, M. et al., *Space Sci. Rev.*, 211, 5–95 (2017). [3] Lognonne, P. et al., *Space Sci Rev., submitted.* [4] Spohn, T. et al., *Space Sci. Rev.*, 214:96 (2018). [5] Folkner, W.M. et al., *Space Sci. Rev.*, 214:100 (2018). [6] Banfield, D., Rodriguez-Manfredi, J. A., Russell, C.T. et al., *Space Sci. Rev.*, 215:4 (2018). [7] Plesa, A.C. et al., *J. Geophys., Res.,* 121,1-10 (2016). [8] Golombek et al., Lth LPSC. (2019). [9] Warren et al., Lth LPSC (2019). [10] Müller et al. (2019) EPSC-DPS Abstract.