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

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Introduction: On Nov 26th, 2018, the NASA InSight mission [1] landed on Mars at Elysium Planum [2] as the first geophysical observatory on another terrestrial planet. The payload includes as main instruments a seismometer SEIS [3] and the Heat Flow and Physical Properties Package HP^3 [4] whose primary goal is to measure Mars' geothermal heat flow. In addition, InSight uses the communication hardware to measure the time variation of the Martian rotation axis RISE [5] and includes an auxiliary sensor package APSS with a magnetometer, an atmospheric pressure sensor, and a pair of wind and air temperature sensors [6].

Instrument Overview: The Heat Flow and Physical Properties Package - 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 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 (see Figure 2). 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 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 Earth, the surface heat flow pattern is known to approximately

Figure 1: *Components of HP^3. The top panel shows the instrument in its support structure but with some 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.*

trace the features of plate tectonics. On Mars, modeling suggests that the surface heat flow mostly maps variations of crustal thickness (assumed 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 but at most to 5 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 3 m.

Penetration to the targeted depth of 5 m is planned to occur in ten steps, each taking about 4 sols. The first step is planned to reach 70 cm depth. Then the Mole will pause for at least 2 sols, to allow Mole motor heat to dissipate. Subsequently, the thermal conductivity of the regolith will be measured using TEM-A as described in [4]. A ground-in-the-loop is foreseen during this step, in case the heating power for the measurement needs to be adjusted. The second step will be 30 cm and from there on the Mole is planned to advance in steps of 50 cm pausing to take thermal conductivity measurements at each depth interval.

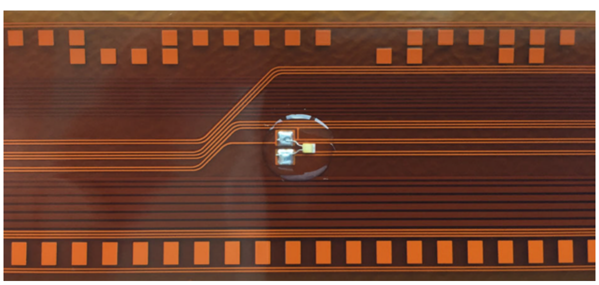

Figure 2: *Segment of the science tether showing a temperature sensor in the center. The sensor is located to the right of the two soldering points. Also visible are various electrical lines running to the sensor and to deeper sensors and the Mole. At the top, Gray code markings are visible that allow the length of tether expelled to be measured. The regular spaced markings at the bottom provide higher-resolution relative position data.*

Landing and Deployment Site Selection: 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 favorable 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 is reduced. All the mission requirements for HP^3 placement have been satisfied.

First Results: By the time of writing, HP^3 is still on the deck of the lander waiting for deployment by the end of January 2019. The radiometer RAD successfully deployed its dust cover and performed in-flight calibrations. The initial assessment shows that the expected noise equivalent temperature difference of less than one K is achieved. The primary sensor observing in 1.5 m distance from the lander center shows only small deviations from the ground calibration. The radiometer has been taking hourly measurements with some interruptions since sol 14; the diurnal temperature near the lander varies between 180 K and 286K, using ground calibration coefficients. The first measurements of the temperature sensors on the tether (TEM-P) and on the Mole (TEM-A) are consistent with these data. By the time of the LPSC conference it is expected that the measurements of the brightness temperature have been complemented by more observation of shadows of the lander passing through the field of view of the instrument, which might provide some additional information on the thermophysical properties of the uppermost surface layers.

Assuming deployment by the end of January and HP^3 Mole advancement as planned taking 44 sols, the instrument should be fully emplaced by the time of the LPSC conference and should have started to monitor the temperature depth profile. We expect to have measured the variation of the thermal conductivity with depth up to 5 m at the time and have the first data on the temperature gradient below the thermal skin depth of the annual surface temperature variation. Through long-term monitoring, we plan to derive the geothermal heat from the geothermal gradient. By combining observations from HP_3 and APSS we also plan to characterize the effects of the atmospheric temperature and pressure on the shallow regolith thermal properties.

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