INSIGHT: MEASURING THE MARTIAN HEAT FLOW USING THE HEAT FLOW AND PHYSICAL PROPERTIES PACKAGE (HP^3). T. Spohn[1], M. Grott[1], J. Knollenberg[1], T.v. Zoest[2], G. Kargl[3], S.E. Smrekar[4], W.B. Banerdt[4], T.L. Hudson[4], and the HP^3 instrument team, [1]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany (tilman.spohn@dlr.de, matthias.grott@dlr.de, joerg.knollenberg@dlr.de), [2]Institute of Space Systems, German Aerospace Center (DLR), Bremen, Germany, [3]Institut für Weltraumforschung, Österreichische Akademie der Wissenschaften, Graz, Austria (guenter.kargl@oeaw.ac.at), [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena (Suzanne.E.Smrekar@jpl.nasa.gov)

Introduction: *InSight* is a proposed Discovery-class mission to study the martian interior. The focused *InSight* payload consists of a seismometer, a radio tracking experiment, and a heat flow probe, and will address fundamental questions of martian geophysics. Main mission goals are the determination of the size, physical state, and composition of the core, the thickness of the crust, and the thermal state of the martian interior.

To constrain the thermal state of the interior, *InSight* will measure the planetary heat flow at the landing site using the Heat Flow and Physical Properties Package (HP^3) [1]. Heat flow is expected to vary with location on the surface of Mars [2], and a first measurement will provide an important baseline to constrain mantle potential temperatures and the bulk abundance of heat producing elements in the martian interior.

Candidate landing sites are located in the Elysium region of Mars, with a baseline landing at 139^{o}E 1^{o}N, and the *InSight* station will operate for a full martian year. This general framework is ideal for heat flow measurements, as temperature signals due to the seasonal variation can be removed from long measurements [3]. Furthermore, the influence of periodic signals due to, e.g., the martian obliquity variations, are minimized for a near equatorial landing site [4].

Instrument description: HP^3 [a] consists of a suite of sensors that will be emplaced into the martian subsurface by means of an electro-mechanical hammering mechanism. Sensors include temperature sensors and heaters to measure the thermal gradient and thermal conductivity of the regolith as well as tilt sensors to determine the position of the instrument in the ground. The instrument is foreseen to penetrate up to 5 m into the martian regolith and perform depth resolved measurements, from which the surface planetary heat flow can be directly deduced.

The instrument consists of three functional subsystems as shown in Fig. 1: The mole houses the electro-mechanical hammering mechanism to provide capability for penetration into the regolith, the heating foils employed for thermal conductivity measurements, and the tilt sensors. The instrumented tether provides the power and data link to the surface and acts as a carrier for the temperature sensors for the thermal gradient determination. The support system stays on the surface after deployment and provides secure storage of Mole and Tether during all flight phases. It also houses the engineering tether, which will connect the instrument to the electronics box in the warm compartment of the lander. As no drilling is required to achieve soil penetration, HP^3 is a relatively lightweight heat flow probe, weighting less than 2 kg.

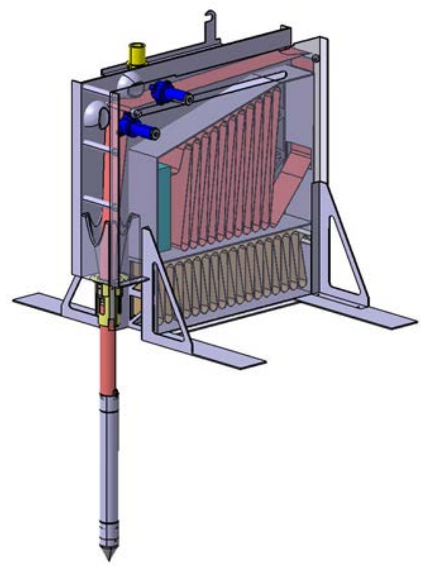

Figure 1: Schematics of the HP^3 instrument showing the functional subsystems.

Instrument Redesign: The HP^3 instrument has been redesigned with respect to previous applications for Mars [5] and the Moon [6], and the Payload Compartment (PC) has been descoped. This configuration change positively influences the penetration performance of the instrument, and preliminary tests indicate a 20% increased performance for highly cohesive soils. This performance gain is due to the reduced wall friction of the instrument.

Further improvements are expected for cohesionless soil, for which the borehole created by the passage of the HP^3 instrument is likely to collapse. Tests including a PC have shown that in this case regolith can accumulate in between Mole and PC, and the PC then acts as an anchor impeding further progress. This weakness of the design has now been removed.

Due to the redesign, the tiltmeter and heating foils were moved from the PC to the Mole, and this configuration change is currently carried out. To accommodate the heating foils, the Mole diameter needs to be slightly increased, and special care is taken to mitigate the shock environment for the tiltmeter.

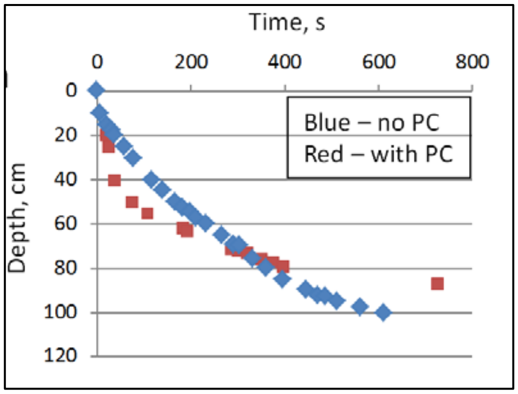

Figure 3: Penetration performance of HP^3 in the highly cohesive martian soil simulant MSSD with and without Payload Compartment (PC). The final penetration depth was limited by the height of the employed test cylinder.

Measurement principle: HP^3 will measure temperatures using platinum resistance temperature detectors, which are mounted on the tether and will allow for a determination of the column temperature profile with a depth resolution of 35 cm. The thermal gradient in the regolith is then obtained from the combination of temperature and position measurements, i.e., the deviation of the mole path from the vertical and the amount of paid out tether.

The basic principle applied to determine the thermal conductivity is the controlled injection of a specified amount of heat into the medium and a measurement of the subsequent temperature increase of the heater, the self-heating curve [7]. We will use the Mole as a line heat source and determine thermal conductivity form a detailed numerical thermal model of Mole and regolith. An additional independent measurement of the regolith's thermophysical properties will be obtained from a measurement of the attenuation of the diurnal temperature wave amplitude.

Instrument Operations: After landing, the seismometer and HP^3 will be deployed onto the martian surface by means of a 2.4 m long robotic arm within a time period of 30 sol. Deployment away from the lander will minimize the effects of lander shadows, which might otherwise alter the thermal structure of the regolith and affect the measurement [8].

After deployment, HP^3 will execute hammering cycles, penetrating 50 cm into the subsurface. Thereafter, heat built up during hammering will be allowed to dissipate for 48 h, before a thermal conductivity measurement is executed for 24 h. This cycle is then repeated until the final penetration depth of 5 m is reached or further progress becomes impossible.

In this way, a target depth of 5 m can be reached within 30 days, after which the long-term monitoring phase starts. This phase consists of tether temperature measurements on the hour and lasts to the end of the mission.

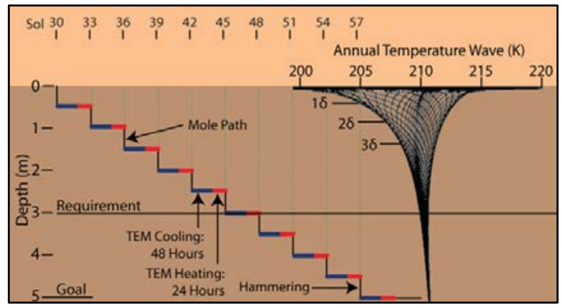

Figure 2: Operational scenario for HP^3 after deployment onto the ground by the robotic arm.

Conclusions: The HP^3 instrument is a light-weight heat flow probe which is being developed for an application on the *InSight* mission to Mars. The HP^3 design is currently changed to accomodate the descope of the payload compartment, thus increasing the penetration performance of the instrument. If the mission is selected, HP^3 will conduct the first planetary heat flow measurement since Apollo, providing the first direct measurement to constrain the thermal state of the planet.

References: [1] Spohn et al., *Plan. Space Sci.*, 49, 1571–1577, 2001. [2] Grott and Breuer *JGR*, 115, E3, E03005, 2010. [3] Grott et al., *JGR*, 112, E9, E09004, 2007. [4] Mellon and Jakosky, *JGR*, 98(E2), 3345-3364., 1993. [5] Grott et al., *EPSC-DPS Joint Meeting 2011*, 379, 2011. [6] Spohn et al., *Ground-Based Geophysics on the Moon*, LPI Contribution No. 1530, p.3016, 2010. [7] Hammerschmidt and Sabuga, *Intern. J. Thermophys*., 21, 6, 2000. [8] Grott, *PSS*, 57, 1, 7177, 2009.