Seismic investigations of the Martian near-surface at the InSight landing site

Cedric Schmelzbach1, Nienke Brinkman1, David Sollberger1, Sharon Kedar2, Matthias Grott3, Fredrik Andersson1, Johan Robertsson1, Martin van Driel1, Simon Stähler1, Jan ten Pierick1, Troy Hudson2, Kenneth Hurst2, Mellanie Drilleau4, Balthasar Kenda4, Raphael Garcia5, Naomi Murdoch5, Domenico Giardini1, Philippe Lognonne4, W. Tom Pike6, Tilman Spohn3, and the InSight SEIS and Near Surface Team1

1ETH Zurich, Institute of Geophysics, D-ERDW, Zurich, Switzerland (cedric.schmelzbach@erdw.ethz.ch)
2Jet Propulsion Laboratory, California Institute of Technology, USA
3Deutsches Zentrum für Luft und Raumfahrt, Germany
4Institut de Physique du Globe de Paris, France
5Institut Supérieur de l’Aéronautique et de l’Espace (ISAE), France
6Imperial College, London, UK

* A full list of authors appears at the end of the abstract

The InSight ultra-sensitive broadband seismometer package (SEIS) was installed on the Martian surface with the goal to study the seismicity on Mars and the deep interior of the Planet. A second surface-based instrument, the heat flow and physical properties package HP3, was placed on the Martian ground about 1.1 m away from SEIS. HP3 includes a self-hammering probe called the ‘mole’ to measure the heat coming from Mars’ interior at shallow depth to reveal the planet’s thermal history. While SEIS was designed to study the deep structure of Mars, seismic signals such as the hammering ‘noise’ as well as ambient and other instrument-generated vibrations allow us to investigate the shallow subsurface. The resultant near-surface elastic property models provide additional information to interpret the SEIS data and allow extracting unique geotechnical information on the Martian regolith.

The seismic signals recorded during HP3 mole operations provide information about the mole attitude and health as well as shed light on the near-surface, despite the fact that the HP3 mole continues to have difficulty penetrating below 40 cm (one mole length). The seismic investigation of the HP3 hammering signals, however, was not originally planned during mission design and hence faced several technical challenges. For example, the anti-aliasing filters of the seismic-data acquisition chain were adapted when recording the mole hammering to allow recovering information above the nominal Nyquist frequency. In addition, the independently operating SEIS, HP3 and lander clocks had to be correlated more frequently than in normal operation to enable high-precision timing.

To date, the analysis of the hammering signals allowed us to constrain the bulk P-wave velocity of the volume between the mole tip and SEIS (top 30 cm) to around 120 m/s. This low velocity value is
compatible with laboratory tests performed on Martian regolith analogs with a density of around 1500 kg/m$^3$. Furthermore, the SEIS leveling system resonances, seismic recordings of atmospheric pressure signals, HP$^3$ housekeeping data, and imagery provide additional constraints to establish a first seismic model of the shallow (topmost meters) subsurface at the landing site.

**InSight SEIS and Near Surface Team:** Cedric Schmelzbach, Nienke Brinkman, David Sollberger, Sharon Kedar, Matthias Grott, Fredrik Andersson, Johan Robertsson, Martin van Driel, Simon Stähler, Jan ten Pierick, Troy L. Hudson, Kenneth Hurst, Melanie Drilleau, Balthasar Kenda, Raphael Garcia, Naomi Murdoch, Domenico Giardini, Philippe Lognonné, W. Tom Pike, Tilman Spohn, W. Bruce Banerdt, Lucie Fayon, Anna Horleston, Aaron Kiely, Brigitte Knapmeyer-Endrun, Christian Krause, Nicholas C. Schmerr, Pierre Delage, Nick Teanby, Christos Vrettos