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

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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 HP<sup>3</sup>, was placed on the Martian ground about 1.1 m away from SEIS. HP<sup>3</sup> 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 HP<sup>3</sup> mole operations provide information about the mole attitude and health as well as shed light on the near-surface, despite the fact that the HP<sup>3</sup> mole continues to have difficulty penetrating below 40 cm (one mole length). The seismic investigation of the HP<sup>3</sup> 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, HP<sup>3</sup> 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<sup>3</sup>. Furthermore, the SEIS leveling system resonances, seismic recordings of atmospheric pressure signals, HP<sup>3</sup> housekeeping data, and imagery provide additional constraints to establish a first seismic model of the shallow (topmost meters) subsurface at the landing site.

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