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Seismic near-surface investigations at the InSight landing site using the Heat and Physical Properties (HP3) probe as a seismic source

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The InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission is the first lander to place an ultra-sensitive broadband seismometer on the surface of Mars. About a meter away from the seismometer, a Heat Flow and Physical Properties Probe (HP3) experiment will hammer a probe into the Martian subsurface to measure the heat coming from Mars' interior and to reveal the planet's thermal history The hammering of the HP3 mole into the ground up to 5 m depth will generate thousands of seismic signals that provide a unique opportunity to investigate the shallow Martian subsurface (meters to possibly few tens of meters) using seismic-exploration techniques. It is expected that the mole will require several thousand strikes to reach 3–5 m depth and each strike will generate a seismic signal.

The analysis of the HP3 hammering signals is not included in the InSight mission's level-1 science objectives, which focus on planetary-scale seismic and tectonic processes as well as their implications to rocky planet formation. However, the proximity of a repeating hammer source to a sensitive seismometer presents a unique opportunity to study the physical properties of the shallow subsurface of the landing site. Understanding the elastic properties of the Martian regolith and determining its thickness as well as resolving the internal structure of the shallow subsurface will help reducing InSight's seismic measurement errors. In addition, this experiment provides the unique opportunity to carry out the first geotechnical study of the shallow Martian subsurface.

The implementation of this opportunistic experiment meets several challenges. The InSight seismic-data sampling strategy was designed to record at a maximum of 100 samples-per-seconds which is too coarse to properly capture the expected high-frequency hammering signal. The team therefore developed a series of strategies including changing the anti-aliasing filters in the acquisition chain to recover information above the nominal Nyquist frequency. Then, the processing of the wavefield data required the adaptation of seismic-data analysis techniques to extract the signals of interest to establish an elastic near-surface model. Furthermore, the team is exploring the impact of the seismometer leveling system on the high-frequency seismic recordings as well as the interaction of the leveling system with the ground.

In preparation for the mission, these workflows were intensively tested on synthetic and field data from an analogue experiment in the California Mojave desert. This experiment involved placing a series of seismometers next to a HP3 model. The recorded data were used to test our ability to recover the near-surface P- and S-wave velocities. These analyses techniques will then be applied to the HP3 hammering data recorded on Mars as one of the first InSight experiments.