LVL TRANSFER FUNCTION AND GROUND/DURICRUST MECHANICAL PROPERTIES PREDICTED FROM INSIGHT SEIS DATA ON THE GROUND.

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Introduction: Both seismic sensors of the SEIS (Seismic Experiment for Interior Structure) instrument [1] of the NASA InSight mission, i.e. the VBBs (Very Broad Band seismometers) and SPs (Short Period seismometers), are mounted on a mechanical leveling system, the LVL. The purpose of the LVL is twofold: provide the mechanical coupling between the instrument and the ground and ensure the sensors' level placement on the Martian ground. We developed a simplified analytical model of the LVL structure in order to reproduce its mechanical behavior by predicting its resonances and transfer function. Before landing on Mars, this model allowed to estimate the effects of the LVL on the data recorded on Mars by the VBBs and SPs. Once on Mars, an inversion study can be performed to characterize the LVL transfer function and to assess the rigidity of the ground directly in contact with the feet.

Model construction: The model is based on a method to detect and compensate for inconsistent coupling conditions during seismic acquisition [2,3]. The LVL tripod is considered as composed of a platform and three feet, which are linked by springs in the 3 directions of space (with two horizontal and one vertical components) as shown in Figure 1, with also a picture of the flight hardware in Figure 2. The eigenmode problem was numerically solved with Matlab.

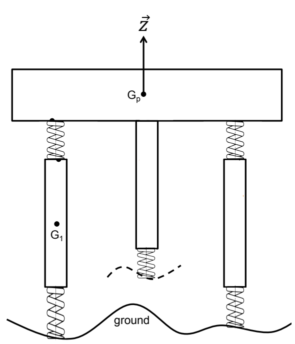

Figure 1: Schematic LVL view in the leg 2 direction.

Figure 2: Picture of the LVL flight unit during SEIS integration.

After calculation of the resulting LVL resonances, the model was validated. Indeed, two resonances were obtained between 35 and 50 Hz in both horizontal components, which is in good agreement with laboratory measurements performed on the LVL flight model (Figure 3). These resonances depend on both the length of the feet and the elastic properties at the 3 contact points of SEIS with the ground. The later depend also on the penetration of the cones, located at the base of each foot [4].

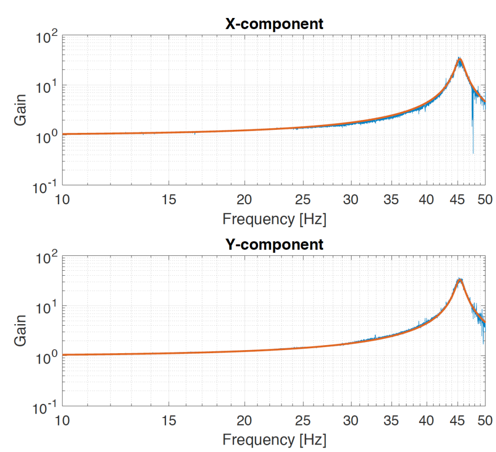

Figure 3: Measured (in blue) and modeled (in red) gain of the horizontal transfer function on x-axis (top curve) and y-axis (bottom curve) for the LVL flight model (leveled low).

Applications: A few parameters are adjustable in the numerical model, and after some simulations we noticed that varying the LVL total mass and leg lengths can strongly change both horizontal resonance frequencies, in agreement with laboratory observations. Once on Mars and after LVL leveling, these parameters are known and an inversion can be made to predict the exact LVL transfer function.

The horizontal ground stiffness and the torque induced by the ground on the LVL are also adjustable parameters which seem to change the horizontal mode frequencies. This means that the LVL resonances also depend on the mechanical coupling between it and the ground. For this reason, the LVL resonances, as well as the relative comparison between SPs and VBBs, can be used to assess both the ground structure just beneath the feet and the quality of the transfer function.

Discussion: Whereas the InSight lander contact with the ground has been imaged by the lander cameras (Figure 4) [5], this has not been possible for the contact of the SEIS feet, which remains to be characterized by indirect methods. DEM analysis indicates for example that out of the 20 mm length of the foot cone, at least 17 mm have penetrated, but the remaining 3 mm are within the error bars of the 3D location of the instrument on the ground.

Figure 4: Picture of the lander penetration on the ground, as taken by the InSight camera system [5].

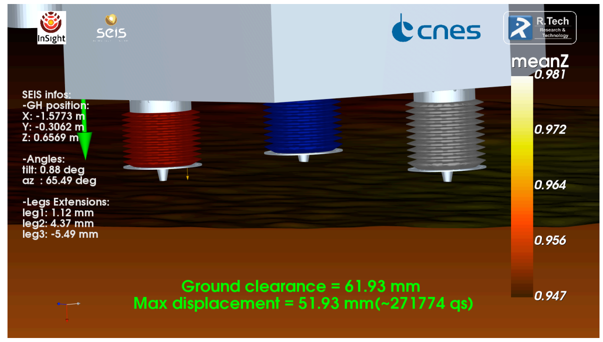

Figure 5: Reconstruction of the LVL contact with the ground, as inferred from the 3D DEM and the SEIS 3D tool developed by CNES.

Conclusion: We show the preliminary analysis of SEIS data on the ground as well as some results from updated SEIS DEM models and discuss constraints on the depth of penetration of the cone on each foot, and on the geometry of feet penetration. We conclude by discussing if the mechanical properties of the surface layer or duricrust can be inferred.

References: [1] Lognonné P. et al., SSR, in press, 2019. [2] Bagaini C. and Barajas-Olalde, C., Geophysical Prospecting, 2007. [3] Fayon L. et al., SSR, 2019. [4] Delage, P. et al, SSR, 2017. [5] Maki, J., SSR, 2019.