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SEIS: FIRST RESULTS FROM THE SEISMIC INVESTIGATION OF MARS P.Lognonné[1], W.B.Banerdt[2],W. T. Pike[3], D.Giardini[4], D.Banfield[5], U.Christensen[6], M.Bierwirth[6], S.Calcutt[7], J.Clinton[4], S.Kedar[2], R.Garcia[8], S.de Raucourt[1], K.Hurst[2], T.Kawamura[1], L.Margerin[12], D.Mimoun[8], M.Panning[2], A.Spiga[9], P.Zweifel[4], E.Beucler[10], N.Verdier[11] and the SEIS Team*.[1]Institut de Physique du Globe de Paris- Sorbonne Paris Cité, Université Paris Diderot (lognonne@ipgp.fr); [2]JPL, CA, USA, [3]IC,UK ; [4]ETH-Zurich, CH ;[5]Cornel, NY, USA ; [6]MPS, Germany ; [7]University of Oxford, UK, [8]ISAE-SUPAERO, France, [9]LMD, France, [10]LPG, Nantes, France. [11]CNES, Toulouse, France, [12]IRAP, Toulouse, France

Introduction: The InSight mission landed on Mars on November, 26, 2018. This is the first planetary mission aimed to deploy a complete geophysical observatory on Mars since the Apollo Lunar Surface Experiments Package (ALSEP) operated on the Moon [1].

The Seismic Experiment for Interior Structure (SEIS), incorporating both VBB (very-broad band) and SP (short-period) sensors [2] is one of the three primary scientific investigations, the two others being the Heat Flow and Physical Properties Package (HP^3) [3] and the Rotation and Interior Structure Experiment (RISE) [4]. SEIS is augmented by the APSS experiment, (Auxiliary Payload Suite, [5]) to monitor atmospheric signals with potential for seismic injection, as well as an imaging system [6]. After a brief description of the SEIS experiment, we report here the deployment process, including the evolution of the SEIS noise, as well as the first scientific observations.

Instrument description, deployment on Mars and first constraints on the Martian microseismic noise: As summarized by D.L. Anderson after the Viking [7]: "*One firm conclusion is that the natural background noise on Mars is low and that the wind is the prime noise source. It will be possible to reduce this noise by a factor of 10^3 on future missions by removing the seismometer from the lander, operation of an extremely sensitive seismometer thus being possible on the surface*". We show how much the SEIS first data confirmed this possibility and present the noise level recorded when SEIS was on the deck, by its SP sensors (*Fig 1*), on the ground by both VBB and SP sensors before and after the tether release (*Fig. 2*), and finally after the mechanical decoupling of the tether and the installation of the wind and thermal shield.

We compare these noise levels not only to those obtained on the Earth and on the Moon [8] but also to those predicted prior the landing [9,10,11,12] as well as to the self-noise of both the VBBs and SPs components of SEIS, as recorded on Earth or expected by their noise model [Figure 2]. These noise records, together with in-situ calibration, including thermal sensitivity, allow us to estimate the fraction of the sensor noise related to instrument and temperature fluctuations for both the VBBs and SPs, and magnetic field fluctuations for the VBBs, providing the first constrains on the micro-seismic noise of Mars and of its diurnal variation. We compare this to the estimation of the lander noise [11,13,14] and discuss the residue in terms of the microseismic background.

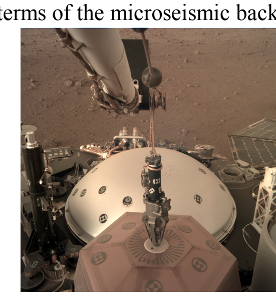

Figure 1: On-deck configuration with the grapple on SEIS with the Wind and Thermal Shield behind.

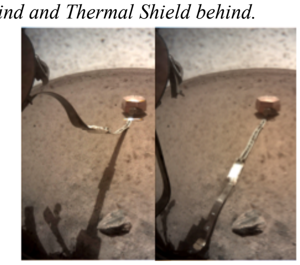

Figure 2: SEIS on the ground before (left) and after (right) tether release.

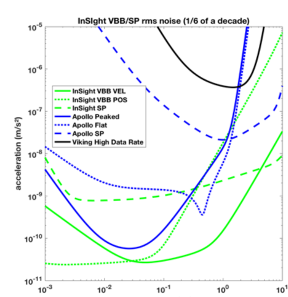

Figure 3: Root-mean-squared self-noise of the three main SEIS outputs (VBB VEL, VBB POS and SP VEL), in acceleration for a 1/6 of decade bandwidth, compared to the Apollo and Viking resolution.

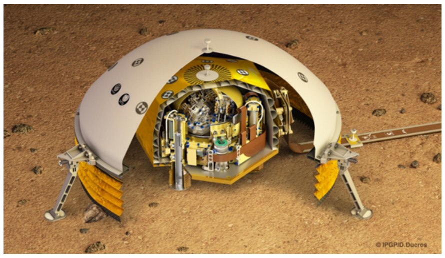

Figure 4: Final configuration of SEIS with the three layers of thermal protection of the VBBs (Sphere, Thermal Blanket and Wind Shield). The two last are shielding SPs.

Post-deployment ambient signal detection: As proposed by several studies made prior the landing, atmospheric seismic signals on the ground are expected from turbulences in the planetary boundary layer and atmospheric events, such as dust devils at both long period and short period [15,16,17]. We expect also diurnal variation of the seismic noise, as a consequence of the variation of the weather activity and wind [2,18] and as already observed on Earth [19].

We compare our observations to these predictions [20] and discuss the possible events identified on the ground, by both the SEIS and APSS data. For that purpose, models made from a priori ground properties [21] will be presented and compared to those obtained from the inversion of SEIS data for the first 5 meters. We also quantify the relationship of the seismic signals to both lander vibrations transmitted to SEIS [22,23] including lander [24] and SEIS-support-structure resonances [25] with the regolith, as well as propagation from pressure [17], short-period surface-wave dispersion [16, 26] and body-wave resonances [27]. We conclude by comparing SEIS on Mars with Apollo on the Moon.

Detection of quakes and impacts: We present the first candidate seismic events, and discuss the constraints on source type and location (e.g. quake [29] or impact [30]), including the relationship to terrestrial and lunar quakes in terms of signal polarisation, profile, and frequency content, and how well existing seismic models explain our observations. In the light of these events we assess the first constraints on the crust and discuss the perspectives of future interior structure inversion [31], including with augmentation from long-period observations such as normal modes [8,9,32,33] and tides [2,8,34,35]. We conclude by providing an estimate of the Mars seismic activity of Mars from operations to date and compare it to predictions.

Conclusions: After its successful landing, deployment and commissioning SEIS will perform the first long term seismic monitoring of Mars, with a nominal mission of one Martian year. First SEIS data have already be released to the community by NASA PSD, SEIS Mars Data Service and IRIS DMC during the 2019 summer. See the SEIS link for more information [36].

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*SEIS Science commissioning team, see update at [37])