THE PERFORMANCE OF INSIGHT'S SHORT-PERIOD SEISMOMETER ON MARS W.T. Pike[1], C. Charalambous[1], S. Calcutt[2], I.M. Standley[3], A. E. Stott[4], P. H. Lognonné[5], W. B. Banerdt[6], M. P. Panning[6], K. Hurst[6], [1]Electrical and Electronic Eng. Dept, Imperial College London, UK (w.t.pike@imperial.ac.uk) [2]AOPP, Oxford, UK [3]Kinematrics, Pasadena CA, USA [4]ISAE-SUPAERO, Toulouse, France [5]IPGP, Paris, France [6]JPL, Caltech, Pasadena, CA, USA

Introduction: The prime payload of the InSight mission is the seismic instrument suite, SEIS. This comprises of two independent three-axis seismometers: the oblique Very Broad Band (VBB) and Short Period (SP) seismometers [1]. Here we summarise the performance of the SP seismometers during the course of the InSight mission. In particular, during mission operations the SP was able to observe the dynamics of the interplanetary cruise, the wind-induced motion of the lander before deployment and the internal dynamics of Mars, including the teleseismic detection of meteorite impacts.

Background and Methods: The SP instrument consists of three micromachined silicon sensors (fig. 1) and their associated electronics. The sensors are fabricated as a monolithic structure from a single-crystal silicon giving a resonant structure with a frequency of 6 Hz, a capacitive displacement transducer and coils for electromagnetic feedback. The proof mass in uncaged and protected from internal impacts with solder balls incorporated into the frame and proof mass. Each sensor is inserted into a magnetic circuit and enclosed in a sealed container attached to the outside of the instrument assembly frame, LVL.

One of the SP sensors, SP1, is configured for vertical operation under Mars gravity with a range of 3.74±0.5 m/s^2 while two, SP2 and SP3, are configured for a horizontal operation with arrange of ±1 m/s^2. This allows the SP to operate within a tilt range of ±15° on Mars. In addition, the two horizontal SPs can operate under the cruise conditions of zero gravity.

After launch, the SPs were operational for five epochs:

1. During cruise the horizontal SPs were operated for three periods of 10,000 s each, station codes CRU1, CRU2 and CRU3. During these epochs the signals were used to quantify the noise floor of the two horizontal sensors as well as search for possible impacts with interplanetary dust.
2. After landing of InSight, the SPs were operated from sol 4 to 18 prior to deployment of SEIS assembly from the deck to the martian, station code ELYS0. Dur
3. After placement of SEIS to the surface the SPs were operated during subsequent deployment activities, including levelling, deployment of the wind and Thermal Shield (WTS) and the intialisation of the VBBs. The SPs continued to operate up to sol 1210, with station code ELYSE.

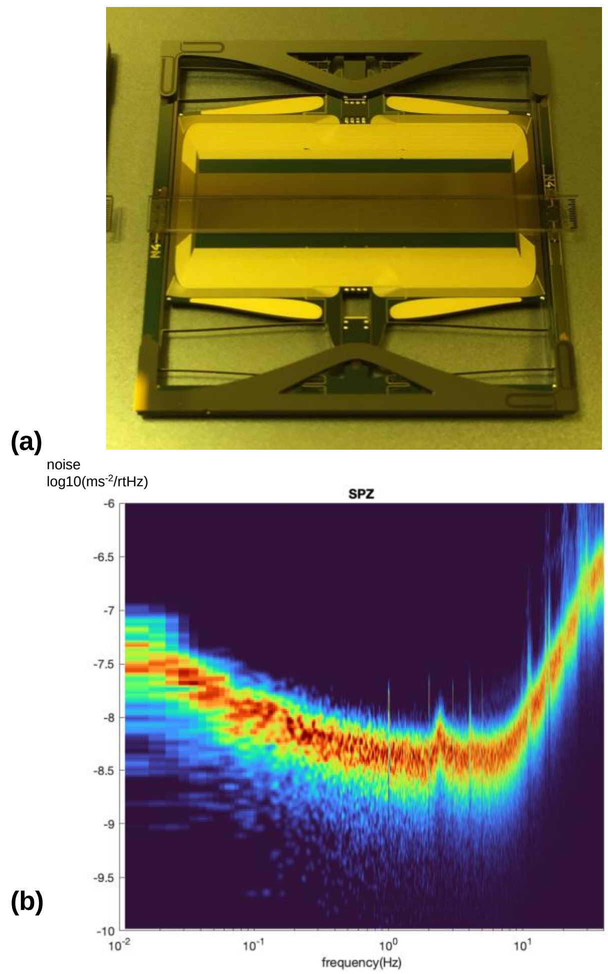

Fig. 1(a). The vertical sensor of InSight's SP seismometer. The die is 25 mm on the side with (b) the noise floor distribution from the same sensor on sol 99 after landing

Results. During cruise operations, the main goal of the SP observations was to determine the noise floor of the sensors under conditions of a minimum external the signal. In testing prior to launch on Earth background seismicity was considerably larger than the self noise of the sensors, and it was necessary to use coherence techniques between the SP outputs and a lower-noise reference seismometer to quantify the noise floor. The power spectral density of the signal had a minimum value of 2.5 m/s^2/rtHz at 1 Hz. No signal above the

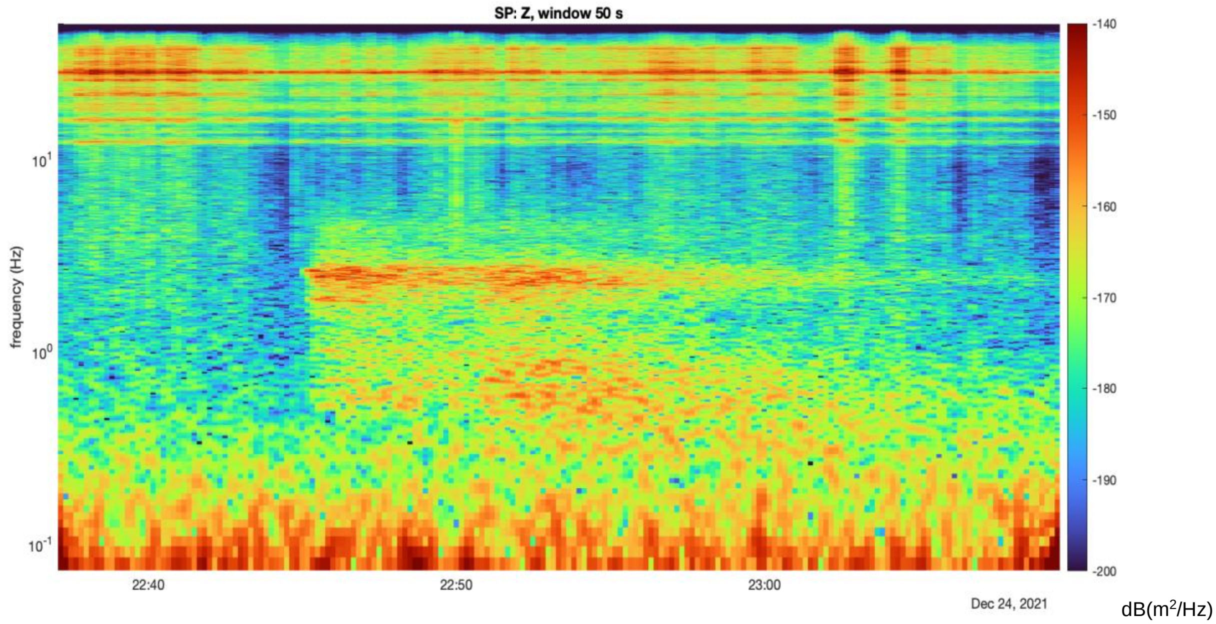

Fig. 2. A spectrogram of the meteorite impact detected on sol 1094. The event occurred during a windy period of the sol giving continuous broadband injection [6]. A very long coda is also apparent for this event, extending beyond the time period of the spectrogram.

statistics of the noise indicative of an interplanetary dust impact was detected, and this is consistent with estimates of dust fluxes on the cruise trajectory of InSight, given the detectivity limit of the sensors [2]. However, the firing of the trajectory trim thrusters was detected, as well as the induced resonances of the spacecraft in its cruise configuration.

After landing, the SPs started operation on Sol 4, collecting more than 50 hours of data between 11:16 LMST to 22:45 LMST. The seismic record is dominated by the wind-induced motion of the lander during this period [3]. This excited the resonances of the lander and the thermal response of these resonances could be followed through a partial diurnal cycle.

After deployment to the surface, the SPs seismic signal was immediately reduced by an order of magnitude as direct injection from the lander was now only possible though the regolith [4]. Only after the WTS was deployed was the noise floor of the SP achieved during the periods of lowest wind seen during the evening. Figure 2 shows the noise distribution of the vertical SP component with a sample rate of 100 sps up the antialias filter limit of 40 Hz.

During the science phase of the mission the SP operated nearly continuously up to Sol 800, and for selected periods up to sol 1210 until power restrictions due to the accumulation of dust on the solar array prevented further observations. During that period when both were operating it detected simultaneously with the VBB all events with significant energy above ~1 Hz, above which both sensors had a comparable noise floor. Figure 2 shows a spectrogram of SP vertical signal for the meteorite impact detected on sol 1094 [5]. The SP is able to distinguish excess energy above 0.5 Hz and identify the P and S phases of the arrival of the seismic energy on all axes, allowing estimation of the arrival azimuth. With the knowledge of the impact location and the P-S arrivals the differential body-wave velocities can be determined and an azimuth of 51° confirmed.

Conclusions. InSight's SP seismometer has demonstrated operation and achievement of its designed sensitity both during the cruise and science phase of the InSight mission. It was able to detect a range of seismic events with energies mostly above 1 Hz, and operated successfully until power restrictions curtailed operations, from sol 4 to sol 1210 of the mission.

References: [1] Lognonné et al., (2019) Space Science Reviews, 215(1) [2] McClean et al., (2019) LPSC 50 #2777 [3] Panning et al., (2020) JGR Planets 125 e2019JE006353 [4] Stott et al. (2021), BSSA 111: 2889–2908 [5] Posiolova et al., (2022) Science 378(6618) [6] Charalambous et al., (2021) JGR Planets 126(4) e2020JE006538