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# Environmental noise contributors on the InSight seismometers

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## Abstract

The SEIS instrument onboard the InSight mission to Mars is the critical instrument for determining the interior structure of Mars and for determining the current level of tectonic activity and the meteorite flux. Meeting the performance requirements of the SEIS instrument is vital to successfully achieve these mission objectives. However, there has never been a complete study taking into account all of the potential noise sources on seismometers in the Martian environment. Here we attempt to understand and evaluate the noise contributions due to the Martian environment and determine the cumulative effect that these are likely to have on the SEIS instruments.

## 1. Introduction

The upcoming InSight mission, selected under the NASA Discovery programme for launch in 2016, will perform the first comprehensive surface-based geophysical investigation of Mars. InSight, which will land in Elysium Planitia, will help scientists to understand the formation and evolution of terrestrial planets and to determine the current level of tectonic activity and impact flux on Mars. SEIS (*Seismic Experiment for Internal Structures*) is the critical instrument for delineating the deep interior structure of Mars, including the thickness and structure of the crust, the composition and structure of the mantle, and the size of the core.

SEIS consists of two independent, 3-axis seismometers: an ultra-sensitive very broad band (VBB) oblique seismometer; and a miniature, short-period (SP) seismometer that provides partial measurement redundancy and extends the high-frequency measurement capability. This combined VBB+SP instrument architecture was also used for NetLander, ExoMars, and SELENE-2. Both are mounted on the LVL (precision levelling structure) together with their respective signal preamplifier stages. VBB, SP, and LVL are deployed on the ground as an integrated package. They are isolated from the weather by an aerogel thermal blanket and the WTS (wind and thermal shield), and connected by a flexible cable tether to the E-box, a set of electronic cards located inside the Lander thermal enclosure. Simultaneous measurements of pressure, temperature, and wind will support the SEIS analyses. To achieve the mission goals, the VBB seismometer must have a noise on Mars of $\leq 10^{-9}$ m/s$^2$/Hz$^{1/2}$ in the [0.01-1 Hz] frequency range in the vertical direction, and in the [0.1-1 Hz] frequency range in the horizontal direction. The SP seismometer must have a noise on Mars of $\leq 10^{-8}$ m/s$^2$/Hz$^{1/2}$ in the [0.5-25 Hz] frequency range in both the vertical and horizontal directions.

## 2. Noise contributors

There are many potential sources of noise on seismic instruments. Some of these noise sources have been the study of detailed investigation (the pressure noise, for example; see [1,2,3]). However, there has never been a complete study taking into account all of the potential noise sources in the Martian environment. Here, for the first time, we attempt to understand and evaluate the noise contributions due to the Martian environment and determine the cumulative effect that these are likely to have on the SEIS instruments.

### 2.1 Thermal Noise

SEIS thermal protection is performed by the WTS and the SEIS sphere. With respect to performance point of view, their function is to attenuate the external temperature fluctuations. The external Martian temperature profile is derived from Viking Lander and Mars Pathfinder temperature data. The modelling used for the performance computation idealises the behaviour of the WTS and the VBB sphere as thermal filters with thermal time constants of $\tau$ = 5h30 and 2h, respectively. This allows the thermal noise in the [0.01-1 Hz] frequency range to be estimated.

## 2.2 Pressure Noise

The atmospheric pressure fluctuations induce an elastic response in the ground. This effect has been known since the 1970s [1,2] and has been used by [3] to provide the first estimations of the Martian noise. In this theory both the wind and the pressure play a role. Elastic deformations are concentrated in the vertical direction for the body-wave frequency band (0.1–1 Hz), and horizontally for lower frequencies (<0.1 Hz, important for surface waves and normal modes). Analyses were conducted using Mars Pathfinder pressure data and assuming regolith properties to determine the likely level of pressure noise on Mars. Pressure decorrelation, as demonstrated for several Earth seismic data [4], can correct the seismic detected waveforms from this environmental signal.

The atmospheric pressure variations will also induce a buoyancy noise on the SEIS sphere. Using pressure data from Mars Pathfinder, and assuming that the Martian atmosphere is adiabatic, we calculate the atmospheric density variations. Then, assuming that the ground behaves as an elastic half-space, we use Hertzian contact mechanics to calculate the vertical displacement (or indentation depth) of each foot as a function of time and the resulting acceleration noise felt by SEIS.

## 2.3 Thermoelastic Noise

Gravity is usually not seen by the seismometer except when it is tilted, as it is indistinguishable from the acceleration. The LVL temperature signal is derived using the temperature profile and the idealised thermal filters described in Sect. 2.1. The angle of the tilt, and thus the acceleration noise, is calculated assuming the thermoelastic sensitivity of the LVL.

It is also possible that the cable tether will expand and contract due to the temperature variations. This may result in a force being exerted on SEIS causing it to tilt. We also investigate the apparent acceleration that may be induced by such forcing.

## 2.4 Wind Noise

The SEIS instrument is protected from wind variations using a wind and thermal shield (WTS). The wind will exert drag and lift forces onto the WTS and these stresses will be transmitted to the ground though the three WTS feet, and then propagated through the ground to SEIS as an acceleration noise. SEIS will also experience an acceleration noise coming from the wind stresses on the lander and the cable tether that will also be transmitted via the ground. Given the small distances between the locations of the stresses and the SEIS feet compared to the thickness of the regolith layer, we model the ground as an elastic half-space with properties of a Martian regolith. We calculate the acceleration noise felt by SEIS as a result of the ground acceleration and the tilt induced by the ground displacement. The data used for the wind velocities in Elysium Planitia come from Global Circulation Models and Large Eddy Simulations [5] and have been compared with wind data from the Viking Landers.

## 2.5 Magnetic Noise

The radial magnetic field in Elysium Planitia has been measured to be <10 nT at an altitude of 200 km [6]. There are, however, no measurements of the magnetic field variability at the surface of Mars. We, therefore, take some typical data from the surface of the Earth as measured in Kourou [7] as a rough estimate of the Martian magnetic field variability. Assuming the magnetic sensitivity of SEIS we can then estimate the noise induced by the magnetic field. With a magnetometer it will be possible to decorrelate the magnetic field variations and reduce the magnetic noise.

# 3. Summary and Conclusions

The SEIS instrument onboard the InSight mission to Mars is the critical instrument for determining the interior structure of Mars and for determining the current level of tectonic activity and the meteorite flux. Here we have introduced some of the key sources of noise on the seismometers due to the Martian environment. The results of these detailed analyses of these noise contributors will be presented during the conference.

# References

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