Viking Seismometer Record : Data Restoration and Dust Devil Search R. D. Lorenz[1] and Y. Nakamura[2].
[1]Space Department, JHU Applied Physics Laboratory, Laurel, MD 20723, USA. (Ralph.lorenz@jhuapl.edu)
[2]Institute for Geophysics, University of Texas at Austin, Austin, TX 78758, USA (yosio@ig.utexas.edu)

Introduction: The Viking landers each carried a sophisticated seismometer, and that of Viking 2 operated for over 500 sols. Although the data are usually dismissed as of limited value due to the susceptibility of the lander-mounted instrument to wind noise, they were able to exclude high global seismicity on Mars, with only one candidate local seismic event being identified. The data may merit closer attention from modern geophysical data analysis methods, and are in fact of interest in atmospheric science since the instrument was sampled better than the meteorology package. . However, the Viking mission predates the emergence of standard formats for digital seismic data, and predates the PDS. The deep public archive at NSSDC is in an unfriendly format, driven by the limited data handling capabilities of the mid-1970s. Here we report an effort to make the Viking data more readily available to the community, and an investigation whether the passage of dust devils (as opposed to wind gusts more generally) can be identified in the seismometer data. Such a re-examination is all the more pertinent given the forthcoming InSight mission : even a ground-emplaced and shielded seismometer will sense wind energy coupled into the ground, and possible surface deformation in response to pressure fields.

Viking Seismometer: The Viking landers had the principal goal of detecting life on the Martian surface, and geophysical and meteorological instrumentation suffered a number of compromises in accommodation [1]. Most notably, the seismometer was mounted on the lander deck. Although for seismic periods of interest the coupling of the instrument with the ground was adequate (contrary to what is often asserted), this arrangement did cause the noise floor of the instrument to be often rather high due to wind-induced motion of the lander body on its compliant legs. For extended periods (especially at night) when wind was low, the instrument was useful.

The instrument was a 3-axis velocity sensing instrument (essentialy similar to a magnet-coil geophone with an appropriate spring arrangement to give a resonant frequency of about 3 Hz). The 2.2kg, 3.5W instrument included variable gains and filters and (for the time) elaborate data handling.

To protect from launch, separation shocks and landing loads, the armature of the seismometer was secured by a caging mechanism during flight. The instrument was uncaged after landing by applying a current to a release wire which was weakened by ohmic heating. While this worked first time on Viking 2, repeated attempts on Viking 1 failed to uncage the instrument and no data were returned [2,3].

Seismometer Data : The instrument [1] had a sensitivity corresponding to about 2nm of displacement at 3Hz, and 10nm at 1Hz. The instrument recorded in 3 modes, Normal, Event and High Data Rate, with rates of ~6, 145, and 1800 kbits/hr respectively. The Normal mode simply records the background amplitude 4.04 times per minute. The High Data Rate mode samples each axis directly at 20.2 Hz, but its data rate precluded extensive operation. Much of the data are in Event mode, which records the envelope in each axis at 1.01Hz, as well as the number of zero crossings (thus a measure of frequency) in the same interval.

Measurement packets are typically 50 or so samples long. The data in hand comprise about 250,000 such packets – in all the Viking 2 seismic record corresponded to about 2100 hours of measurement (89 days) spread over the 560 sols of lander operation.

Lander Noise : Various lander mechanical activities are detectable in the seismometer data [1], including sampling arm operations, X-ray sample dumps, tape-recorder and camera operations and S-band antenna movements. At least some of these are documented, e.g. some sampling arm activities [4] and X-ray fluorescence dump operations [5] : we will assemble these into a catalog, although it must be recognized that there are some uncertainties in spacecraft clock reconstruction among the different instruments.

Interpretation : Despite the wind noise (which in any case was not limiting when wind speeds were less than 2-3 m/s) the Viking data were adequate to pose an upper limit of activity at the Chryse landing site as having a 67% chance of being less than typical intraplate seismicity on Earth. Only one event (on Sol 80) was considered to be a possible seismic event. However, no contemporary wind data were acquired, so a gust (or dust devil) cannot be excluded as the cause, and of course no second seismometer was available to confirm the event or constrain its location (a challenge that will remain for InSight).

The amplitude of lander motion measured in 40-minute bins could be interpreted [6], however, as an indication of windiness. In particular, there are seasonally-varying spectral peaks with periods of 1-3 sols which are likely correspond to baroclinic waves also identified in meteorology data.

Since both lander motion amplitude and frequency relate to the windspeed [2,7], further examination of the raw seismometer data may be able to recover a more detailed wind record.

Dust Devil Signatures : It was noted [1] that while the average wind speed tended to be higher in the morning, the 'gusty' seismic background tended to be highest in the afternoon, between 1300 and 1700hrs. It may be no coincidence that this period is usually when atmospheric convection and dust devil activity tends to be highest. While Transient phenomena such as dust devils require higher sampling rates for their detection than is usual for terrestrial meteorological recording and for most of the Viking record. However, some in-situ detections were made in the first 60 sols of the Viking Lander 2 mission. [8] We are examining the seismic data acquired during these vortex encounters to determine whether a distinctive signature is present (e.g. a change in dominant axis). The gross amplitude of one axis at least (figure 1) does not have a 1:1 correspondence with the passage of Class 1b dust devils (see figure 1)

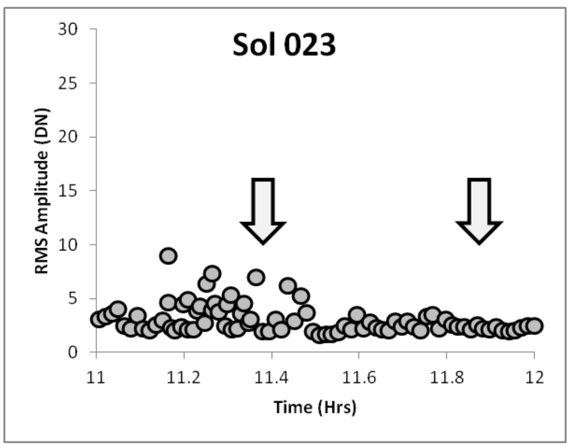

Figure 1. RMS X-axis variations on the VL2 seismometer on part of Sol 23. The passage of two dust devils [8] are noted . Strong signals are present, presumably due to gustiness, but are not uniquely associated with dust devil passage. Higher-fidelity metrics may show a better correlation, however.

Clearly (figure 1) the most simplistic measure (an RMS measure of the seismometer reading in 1 axis) does not appear to be correlated (assuming our reconstruction of the data acquisition time is correct) with dust devil passage. We will be examining the 3-axis data more closely to see if more subtle signatures can be discovered.

Depending on the results of this investigation, it may be possible to exploit the seismometer record to perform a census of dust devil activity over the full mission duration, which would exceed the Phoenix and Pathfinder surveys by a factor of several.

Data Products : Most of the data has been recovered into usable ASCII files, with only occasional manual surgery required to fix transcription errors. We will develop, and deliver to the PDS, data products that we consider will be useful, at least for atmospheric science (for example, long-term records of the amplitudes as in [6]) and at least selected segments (e.g. high rate mode) of data at its native resolution where it is of good quality. The catalog of known disturbance events will also be archived. We will consider the possibility of additional archival on IRIS for terrestrial seismology using their SEED format, and welcome suggestions from colleagues on what products may be most useful. As prospects for new seismic observations at Mars are at hand, it is important that the hard-won first seismometer measurements of 36 years ago be available for renewed investigation.

Acknowledgement: This work is supported by the NASA Mars Data Analysis (MDAP) program, Grant NNX12AJ47G.

References: [1] Anderson, D. L. et al., The Viking Seismic Experiment, Science, 194, 1318-1321, 1976 [2] Anderson, D. L. et al., Seismology on Mars, Journal of Geophysical Research, 82, 4524-4546, 1977 [3] Lazarewicz, A. R. et al., The Viking Seismometry Final Report, NASA Contractor Report 3408, 1981 [4] Moore, H. J. 1987. Physical Properties of the Surface Materials at the Viking Lander Sites on Mars, USGS Professional Paper 1389 [5] Baird, A. et al., 1977. The Viking X-Ray Fluorescence Experiment: Sampling Strategies and Laboratory Simiulations, Journal of Geophysical Research, 82, 4595-4624 [6] Nakamura, Y. and D. L. Anderson, Martian Wind Activity Detected by a Seismometer at Viking Lander 2 Site, Geophysical Research Letters, 6, 499-502, 1979 [7] Lorenz, R. D., Planetary Seismology - Expectations for Lander and Wind Noise with Application to Venus, Planetary and Space Science, 62, 86–96, 2012 [8] Ringrose, T.J. et al. 2003. Convective vortices on Mars: a reanalysis of Viking Lander 2 meteorological data, sols 1-60. Icarus 163, 78-87.