EPSC Abstracts
Vol. 6, EPSC-DPS2011-1507-1, 2011
EPSC-DPS Joint Meeting 2011

The GEMS (GEophysical Monitoring Station) SEISmometer

Ph. Lognonné (1), B. Banerdt (2) (GEMS-PI), D. Giardini (3), U. Christensen (4), T. Pike (5), D. Mimoun (6), S. de Raucourt (1), S. Tillier (1), P. Zweifel (3), D. Mance (3), R. Roll (4), M. Bierwirth (4), L. Boschi (3), R. Garcia (7), W. Goetz (4), C. Johnson (8), N. Kobayashi (9), A. Mocquet (10), M. Panning (11), J. Tromp (12), R. Weber (13), M. Wieczorek (1) and the SEIS technical team.

(1) Institut de Physique du Globe, Paris, France; (2) Jet Propulsion Laboratory, Caltech, Pasadena, USA; (3) ETH, Zurich, Switzerland; (4) MPS, Lindau, Germany; (5) Imperial College, London, UK; (6) ISAE, Toulouse; (7) IRAP, Toulouse; (8) U British Columbia; (9) JAXA, Tokyo; (10) U Nantes; (11) U Florida; (12) Princeton; (13) NASA-MSFC.

Abstract

The seismic monitoring of Mars is the primary science goal of GEMS (GEophysical Monitoring Station), one of three missions undergoing Phase A development for possible selection by NASA's Discovery Program. This monitoring will be performed by a 3-component VBB (Very Broad Band) seismometer [1] (Figure 1), augmented with three Short Period (SP) channels (Figure 2). The VBB components have both velocity and position outputs. The VBB velocity outputs will be recorded at 20 Hz and at 2 Hz. The VBB position output will be sampled at 0.1 Hz. The SP sensors will be sampled at 100 Hz for normal operations and can be sampled at 200 Hz in a campaign mode. Fundamental interior structure information for Mars will be derived for the first time using state-of-the-art, single-station seismic analysis techniques.

Figure 1: Engineering model of the SEIS-VBB.

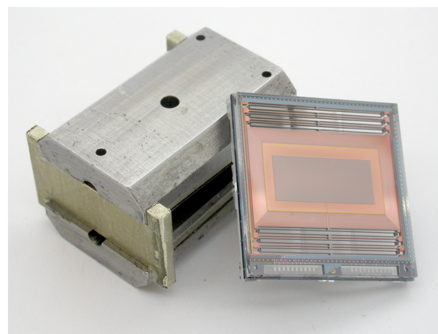

Figure 2: Prototype of the SEIS-SP.

1. Expected Level of Activity

GEMS will be the first mission to attempt the seismic exploration of Mars since Viking [2]. The lack of detection by the Viking seismic experiment is consistent with an upper estimate of the Martian activity comparable to the Earth's intraplate activity [3]. Theoretical estimates from thermoelastic cooling and surface faults predict a level of activity within this bound but still ~100 times greater than the shallow moonquake activity detected on the Moon by the Apollo Passive Seismic Experiment. This level would provide ~50 quakes of seismic moment $\geqslant 10^{15}$ Nm (a globally detectable quake, roughly equivalent to terrestrial magnitude m_b=4; see below) per (Earth) year [4]. There should be ~5 times more quakes for each unit decrease in moment magnitude (or a factor of 30 decrease in seismic moment). Another major source is impacts. We have calculated that the frequency of impacts detectable by a seismic station on Mars, assuming a seismometer with a sensitivity better than the expected seismic noise level (~10^{-9}m/s^2 at 0.05 Hz; see below), should be comparable to the frequency of detection on the Moon, where impact events comprised a major fraction of the seismic catalog [5].

This projected seismic activity is low as compared to the Earth. But with no ocean (the major source of terrestrial noise between 0.07 and 0.14 Hz) nor human activity, we can expect relatively low seismic noise. Estimates for the ground acceleration produced by wind pressure fluctuations have amplitudes of the order of 10^{-9} m/s^2 in the range of 0.1-0.01 Hz for wind speed of the order of 4 m/s. Moreover, terrestrial tests have shown that the direct effects of wind on a seismometer can be decreased to similar levels when protected by a light windshield, a strategy planned on GEMS. When these factors are integrated into standard seismic models, we can conclude that quakes of 10^{15}Nm can be detected globally with SNR>5 for both P and S waves (until cut off by the antipodal core shadow zone) assuming an instrumental sensitivity of 10^{-9}m/s^2.

2. Single-Station Seismic Analysis

Traditional seismic analysis has been based largely on arrival times of body waves acquired by a widely distributed network of stations. However, over the past few decades a wide variety of analysis techniques have been developed for extracting information about the properties of the Earth's interior and about seismic events themselves using the data acquired from a single seismometer. The collection of a high-quality broad-band seismic data set for Mars will provide an invaluable resource for the seismological community to apply various current and future techniques to learn more about Mars. Among the science goals which can be achieved by a single VBB seismometer will be determination of core size through measurement of the amplitude of the solid tide induced by Phobos, determination of the seismicity by the monitoring body waves, a priori location of epicenters with P-S and azimuth determination, identification of internal discontinuities by analysis of seismic secondary phases, determination of the crustal thickness below the landing site by the receiver function analysis method, and, if large quakes are detected or if a low seismic noise threshold is achieved, determination of the upper mantle structure by normal modes, surface waves and noise analysis.

References

[1] Lognonné, P., D. Giardini, B. Banerdt, J. Gagnepain-Beyneix, A. Mocquet, T. Spohn, J.-F. Karczewski, P. Schibler, S. Cacho, W. T. Pike, C. Cavoit, A. Desautez, M. Favède, T. Gabsi, L. Simoulin, N. Striebig, M. Campillo, A. Deschamp, J. Hinderer, J.-J. Lévêque, J.-P. Montagner, L. Rivéra, W. Benz, D. Breuer, P. Defraigne, V. Dehant, A. Fujimura, H. Mizutani, J. Oberst (2000). The NetLander very broad band seismometer, Planet. Space Sci., 48, 1289-1302.

[2] Anderson, D.L., W.F. Miller, G.V. Latham, Y. Nakamura, M.N. Toksöz, A.M. Dainty, F.K. Duennebier, A.R. Lazarewicz, R.L. Kovach, and T.C.D. Knight (1977). Seismology on Mars, J. Geophys. Res., 82:4524–4546.

[3] Goins N.R., and A.R. Lazarewicz (1979). Martian seismicity, Geophys. Res. Lett., 6, 368–370.

[4] Golombek, M.P., W.B. Banerdt, K.L. Tanaka, and D.M. Tralli (1992). A prediction of Mars seismicity from surface faulting. Science, 258, 979–81.

[5] Oberst, J. and Y. Nakamura (1991). A search for clustering among the meteoroid impacts detected by the Apollo lunar seismic network, Icarus, 91, 315-325.