A Miniaturized Seismometer For Subsurface Probing On Mars. W. B. Banerdt and W. T. Pike, M.S. 183-501, Jet Propulsion Laboratory, Pasadena, CA 91109, bruce.banerdt@jpl.nasa.gov.

Introduction: Seismology is one of the most powerful tools for investigating the subsurface structure of a planet. The mechanical structure information derived from seismic measurements is complementary to other methods of probing the subsurface (such as gravity and electromagnetics), both in terms of spatial and depth resolution and the relevant types of material properties being sensed. In the near-surface, the propagation of seismic waves is especially sensitive to density and degree of compaction. In addition, interfaces between layer with contrasting properties can be relatively easily delineated.

The subsurface of Mars provides an obvious target for seismic investigations. Searching for the presence of water is among the highest priority goals of the Mars Exploration Program, but there are many other important science questions that could be addressed by a seismic profile of the upper layers of the crust.

We have developed an extremely small, lightweight, low-power seismometer for planetary applications [see 1-4] which is ideally suited for use on Mars. This instrument has previously been proposed and selected for use on a comet (on the Rosetta Lander [2], subsequently deselected for programmatic reasons) and Mars (on the NetLander mission [4], with an emphasis on global structure determination).

Seismometer Description: The seismometer, which is being developed by the Microdevices Laboratory of JPL, is designed to meet the constraints of extraterrestrial applications, in particular having very low mass, volume and power requirements (~200 gm, 2x2x3 cm, and 100 mW, respectively, for a 3-axis sensor), while delivering performance comparable to that of a conventional terrestrial seismometer ($5x10^{-9}$ $m/sec^2/\sqrt{Hz}$ over a 0.05 to 100-Hz bandwidth). The design uses a micromachined mechanical structure consisting of the suspension mechanism, proof mass and capacitor plates, and a highly sensitive capacitive displacement transducer that employs a force-rebalance feedback system. The current design has been optimized for relatively low frequencies and continuous operation in order to study ambient seismic activity on the NetLander mission. For a active seismic experiment a higher frequency band would be used, with a higher sampling rate, lower mass, and less concern about power (due to the short duty cycle).

The suspension is of a symmetric design, incorporating three wafers bonded together (Fig. 1). The central wafer incorporates a set of flexures allowing motion of the proof mass in the plane of the wafer (Fig. 2). The flexure geometry is designed to maximize the robustness of the suspension; end-stops prevent any motion induced by accelerations greater than about 1 g. The proof mass is free to move under gravity (≤ Earth gravity) to an equilibrium position. Capping wafers carry the metallized fixed electrodes. The displacement signal and feedback actuation result from the changing overlap between electrodes on the fixed plates and the patterned surface of the silicon proof mass. The use of a lateral detection scheme reduces damping effects and hence the fundamental noise floor by two orders of magnitude compared to the more conventional parallel opposed-plate approach.

The small volume available for the microseismometers limits the resonant frequency of the suspension to 10 Hz. This relatively stiff suspension requires a correspondingly sensitive position transducer to measure the deflection of the proof mass. A low-noise switched-capacitance transducer determines the lateral movement between the moving proof mass and fixed electrodes above and below the proof mass to a precision of about 10^{-14}m. The seismic signal from each axis is anti-alias filtered before being digitized with a multiplexed 16-bit analog-digital converter.

The low mass and volume of this device is well-suited for use in seismic arrays that are necessary for active seismic profiling. This, along with the high intrinsic sensitivity of the instrument and the expected low-noise environment on Mars, should allow greater depths of penetration than on the Earth for conventional seismic profiling.

This device provides a high-quality seismic measurement which should be capable of elucidating many of the fundamental questions concerning the subsurface of Mars.

References: [1] Banerdt W. B. et al. (1996) *Planetary Surface Instrument Workshop*, LPI Tech. Rept. 95-05; [2] Banerdt W. B. et al. (1996) *LPS XXVII.*, 59-60; [3] Pike W. T. et al. (1996) *Ann. Geophys.*, **14**, C828; [4] Lognonné Ph. et al. (2000) *Planet Space Sci.*, **48**, 1289-1302;

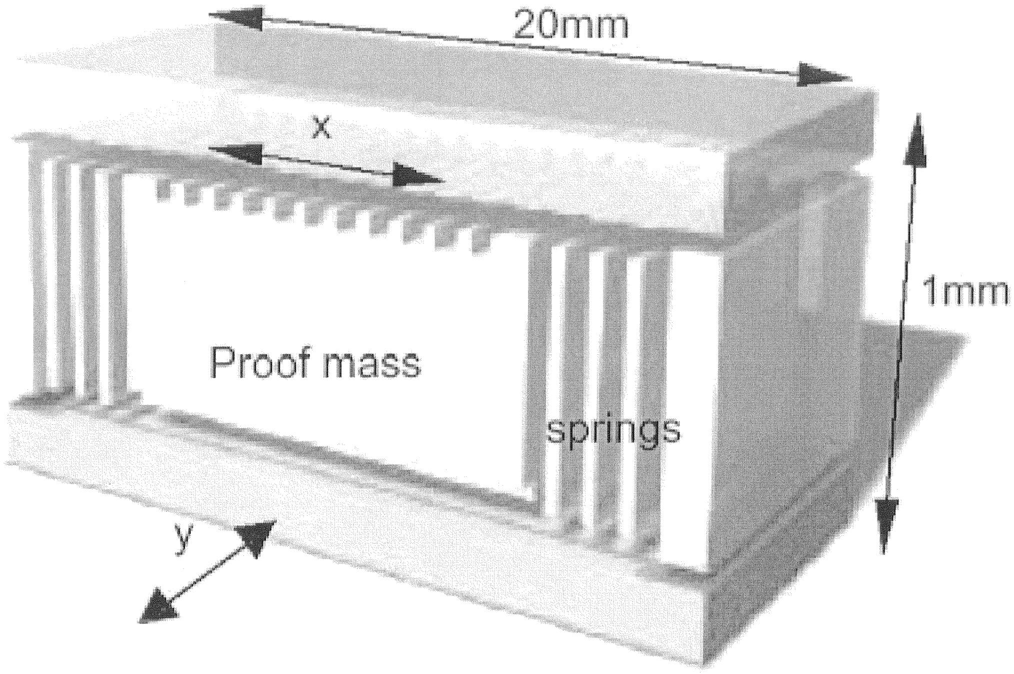

Fig.1: Cutaway drawing showing the geometry of the sensor.

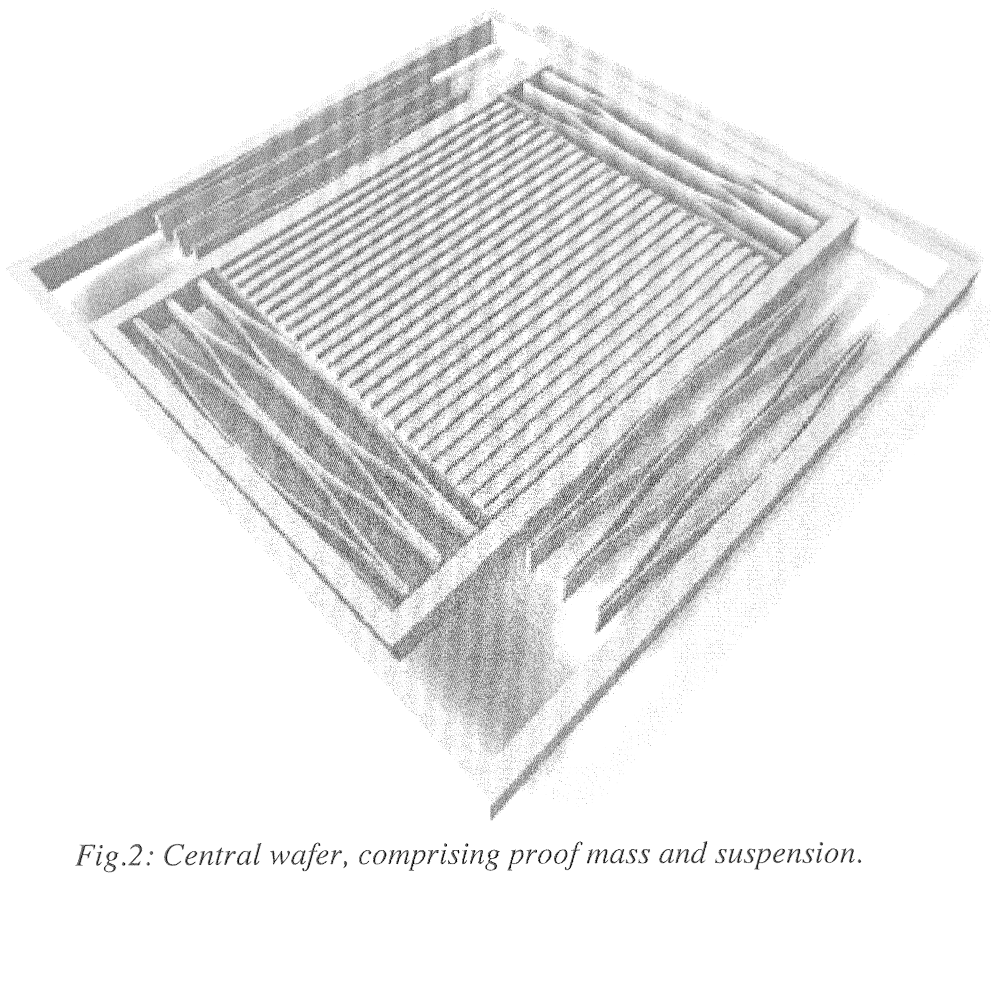

Fig.2: Central wafer, comprising proof mass and suspension.