COMBINED INERTIAL AND STRAIN SENSORS FOR SEISMOLOGY K. J. Hurst[1], B. Banerdt[1], and M. Hecht[1], [1]Jet Propulsion Laboratory / California Institute of Technology, 4800 Oak Grove Drive Pasadena CA 91109. Ken.Hurst@jpl.nasa.gov.

An ideal placement for both inertial and strain seismometers that would be accessible to a landed Mars mission would be frozen into the bottom of a borehole in the north polar ice cap. The combination of inertial and strain seismic data could enable investigations not possible with only inertial sensors.

A tri-axial strainmeter operating near the free surface could yield the full 9-component strain tensor. The addition of 2 components of tilt could allow determination of the 9 components without recourse to the assumption of a nearby free surface. This tilt signal could be provided by the inertial sensors.

The combination of inertial (time derivative) and strain (spatial derivative) data from a single instrument could yield the local 3D seismic phase velocity directly for the frequency band of overlap. This could enable single-station seismic phase identification (P, S, SS, SP, PS, L, R, etc) and investigation of bulk physical properties of the surrounding material including estimates of anisotropy, which in turn could be interpreted in terms of preferred crystallographic orientations and possible deformation mechanisms.

On Earth, phase identification can be and often is based on time of arrival and source distance. In the Mars environment wherein the seismic velocity profile is poorly known, there are few seismic stations, and the event locations are poorly known apriori, the ability to identify the individual phases and back-azimuth with data from a single station could greatly aid in interpretation of the seismic data..

Space qualified seismometers with sensitivity of 1-30x10^{-9} m/s^2/√Hz exist. Borehole strainmeters exist that are capable of measuring 10^{-9} strain from above 20 Hz to DC[1]. A thermal ice drill capable of reaching depths of 10-200 m has been tested. A borehole diameter of 10-20 cm could provide an ideal environment.

A combination of an inertial sensor with a strain-based sensor can cover the spectrum from more than 200 Hz to DC. The low-frequency response of the strainmeter would permit direct estimation of the strain offsets and moment of Marsquakes given adequate signal-to-noise-ratios, and inference of the stress redistributions caused by them. It would also permit exploration of any steady state strain accumulation that may be present.

The study of low-frequency normal modes of the Earth have contributed to our knowledge of the internal structure [eg Derr 1969, Dziewonski and Gilbert 1971, Ishii and Tromp 2001, Deuss 2008].

The very broad-band response of the combination of the inertial and strain seismometers discussed here would permit addressing a wide variety of phenomena including the flux of micrometeorites, the locations and mechanisms and hence causes of Marquakes, the state of stress and stress redistributions that the Marsquakes are responding to, and several prongs of attack (reflection and refraction of body waves, dispersion of surface waves, and normal modes) to study the internal structure of the Mars.

The Martian tides offer a calibration signal for strain, or the higher harmonics can be used to constrain large scale radial structure.

The performance of a seismometer is often limited by the quality of the mechanical coupling to the surrounding material, not by the instrument itself. Freezing the instrument into ice at the bottom of a borehole in the north polare icecap of Mars would be an ideal placement.

References:

[1] M.T. Gladwin, High-precision multicomponent borehole deformation monitoring, *Review of Scientific Instruments*, 55, 2101-2016, 1984.

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