759: Seismic Characteristics of the Shallow (0–1 m) Soils on the Moon and Mars: Ice in Soils

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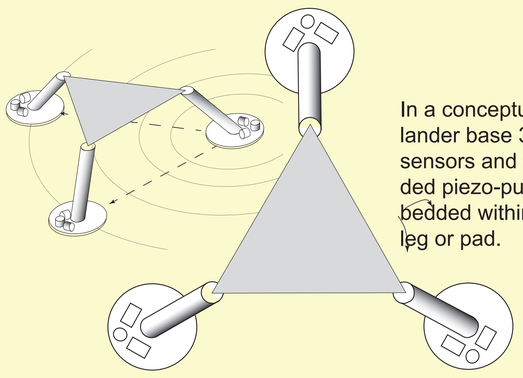
Introduction

We propose a payload concept where **piezo-sensors** are used to characterize the shallow subsurface (0-1 m) regolith of planetary bodies.

Piezo-technology is widely used in the defense, aerospace and structural engineering fields.Our group's long-term goal is to design a seismological instrument to permit non-invasive, high-resolution characterization of the regolith profile.

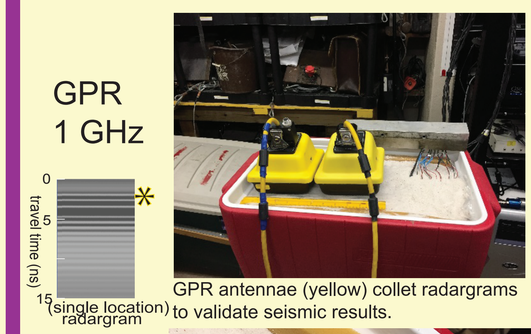
Water is key for to support future human missions on the Moon as well as Mars, and **high-frequency** (kHz) seismic sounding tools can provide a minimally invasive characterization of the volume and distribution of ice.



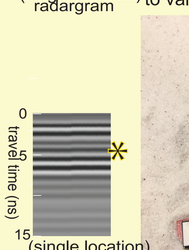
In a conceptual planetary lander base 3 piezo-sensors and one embedded piezo-pulser are embedded within each landing leg or pad.

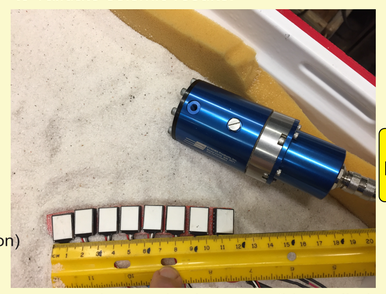
Top view; ~ 1m between landing pads

Physical Seismic Models

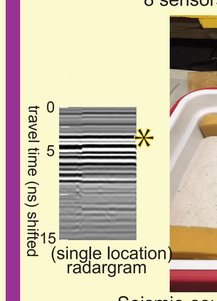


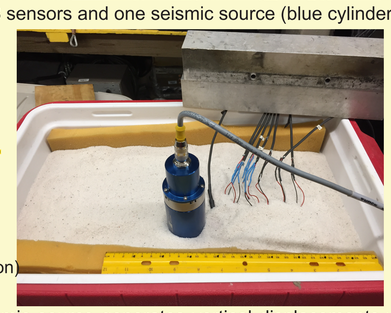
GPR antennae (yellow) collet radargrams to validate seismic results.



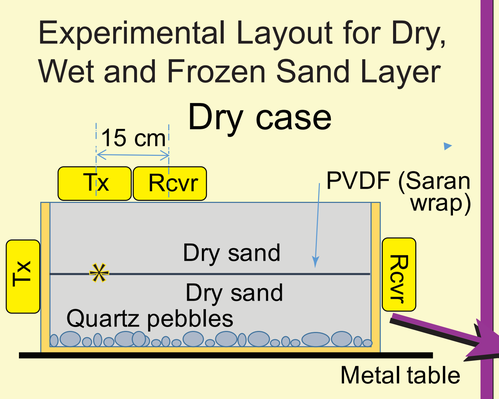


8 sensors and one seismic source (blue cylinder)





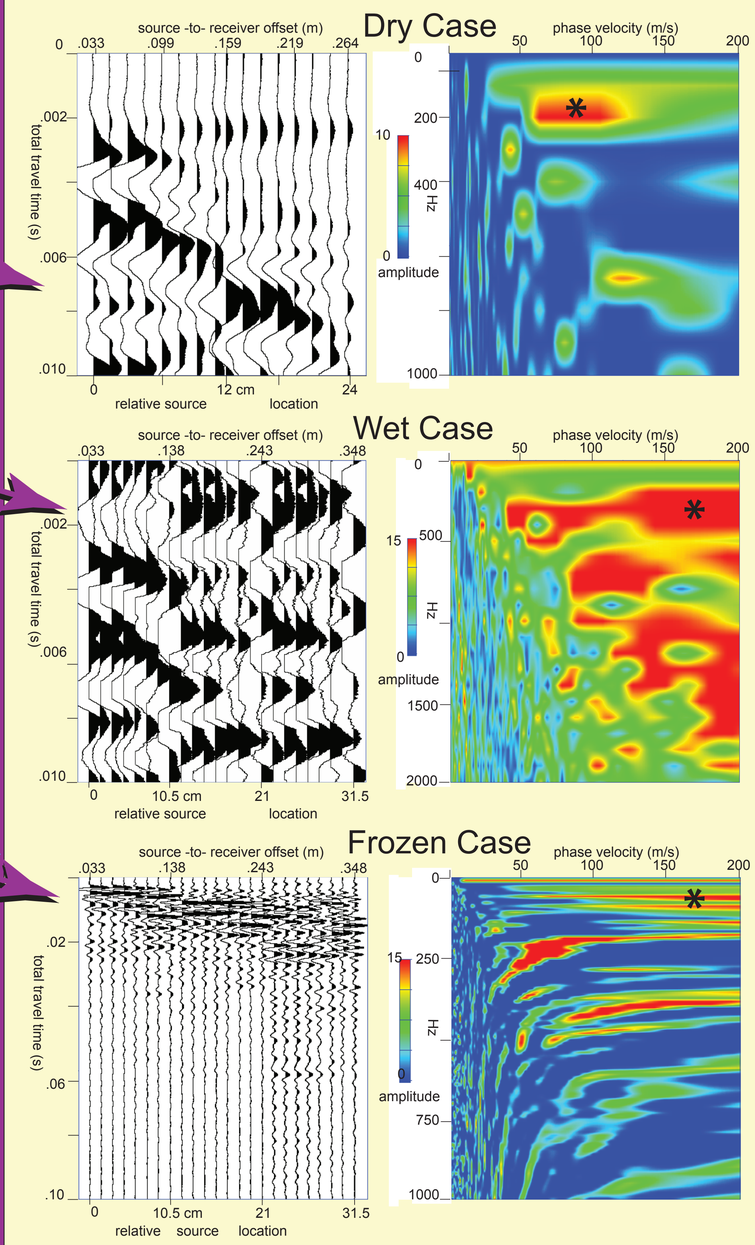
Seismic source generates vertical displacements with a 1-4 kHz bandwidth and sensors measure vertical accelerations



Eight PVDF piezosensors sensors are deployed in a plastic cooler. A magnetostrictive seismic source (blue cylinder) generates a digitally constructed seismic pulse. A linear array of small piezo-accelerometers has bandwidth of 20 - 20 kHz.

Additional GPR radargrams confirm expected changes to permittivity for a totall y dry case, a wet-sand case and a case where the pore water is all frozen (at -20 deg. C)

Seismic Wave Data

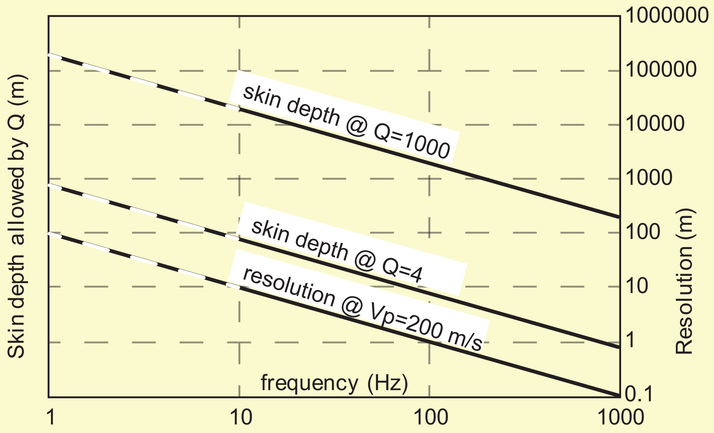


Surface waves dominate the seismograms (left column). Seismic velocity versus frequency (dispersion images in the right column) can be used to determine the dominant shear wave velocity with depth in the three cases.

Dry Case: Average shear-wave velocities of ~ 75 m/s ✱
Wet Case: Higher velocity detected (> 150 m/s) but data are **less coherent**✱
Frozen Case: Higher velocities at greatest depths **and data are coherent**✱

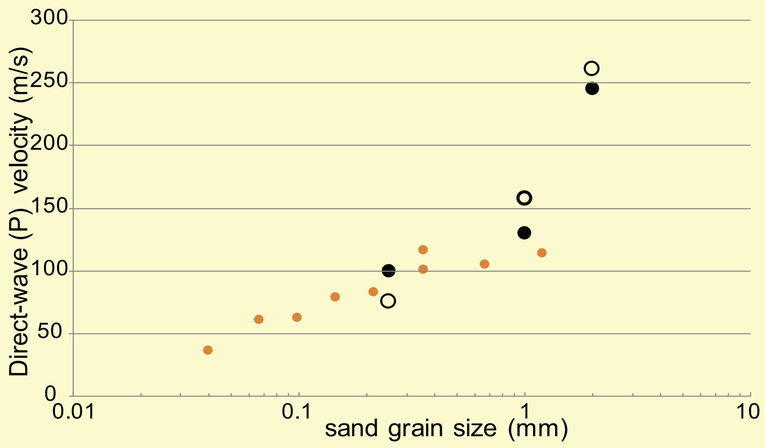
Investigation Depths of Surface Waves

High-amplitude surface waves (cf. P and S body waves) are advantageous BUT are also limited by resolution and attenuation.



Estimates of the effective seismic penetration of surface waves (skin depth), resolution (~wavelength/2) versus frequency content for a 'soft' (=4) and 'hard' (=1000) Quality factor Q (1/intrinsic attenuation). Only 10-1000 Hz cases (NOT dashed) are expected to match piezo-sensor responses. Both axes plotted show log10 scales.

Grain Size Versus Seismic Velocity



In dry sand (phi=1) direct transit times indicate a logarithmic change in seismic propagation velocity with grain size.

In Progress

--Development of elastic contact models: If ice is considered to bond grains together, then cemented contact theory [1] in combination with effective medium theory [2] can be used to predict seismic velocities for the full range of ice saturation in the pore spaces.

--Validation of seismic physical model experiments: old (repeat) and new grain sizes.

Acknowledgements

A Research Enahancement Award suppors this project through a Louisiana Space Consortium/National Aeronautics and Space Agency (NASA) Gran Number NNX15AH82H. George Tsoflias (University of Kansas, Lawrence) kindly provided GPR equipment.

References

[1] Lorenz, R .D. (1994) Measurement Science Technology 5, 1003-1041. [2] Crane, J et al. (2018) Near Surface Geophysics, 16/2, 1-16 . Lett., v. 35, no. 9, p. L09301.