REFLECTION SEISMOLOGY SYSTEMS FOR PLANETARY GEOLOGY: FIRST TESTS AT ESTEC EXOGEOLAB AND MDRS, UTAH. P.A.W. Batenburg[1,2], B.H. Foing[1], G.G. Drijkoningen[3], E.K.A. Gill[2], P. Poulakis[4], G. Visentin[4], J. Page[1,4], V. Pletser[5], S. Peters[1,6], A. Borst[1,6], P. Mahapatra[1] and ExoGeoLab team[1], EuroGeoMars team[1,5]

[1]c/o ExoGeoLab, B.Foing ESTEC/SRE-S Postbus 299, 2200 AG Noordwijk, NL, [2]TU Delft Aerospace Engineering, [3]TU Delft Civil Engineering and Geosciences, [4]ESTEC TEC Technology Dir., [5]ESTEC HSF Human Spaceflight, [6]VU Amsterdam

Introduction: Currently, ESA (European Space Agency) is conducting the ExoGeoLab pilot project [3] at ESTEC in which scientific instruments for exobiology, geology and meteorology are to be developed. Within this project the first author is working on his master thesis project to investigate the suitability and design of a reflection seismic system for planetary geology.

We have tested various sets of seismic systems at ESTEC ExoGeoLab to study functional operational aspects, and performances of various seismic sensors and analysis systems. One of the activities within the ExoGeoLab project is the EuroGeoMars expedition to the Mars Society's Mars Desert Research Station (MDRS) in the Utah desert as a precursor for future tests and developments within the project. The authors have performed some preliminary tests during the technical mission of the EuroGeoMars mission to empirically test the influences of surface composition and surface coupling on the data gathered by the sensors.

Background information: In the quest to know more of the contents of the Earth's surface without having to drill, many techniques and methods have been created to map the subsurface structure. Among these methods is the reflection seismology, a method which uses the propagation of sound to measure subsurface layering and its composition. Different types of rocks and soils have different sound velocities; this difference causes reflections and refractions of the sound waves. By measuring the vibrations along a line or network of sensors, one can determine depths and compositions of underground layers. The used sensors for reflection seismology are geophones or hydrophones, respectively for land or underwater seismology. This type of seismology has become a well known method to determine local geology up to several hundred meters of depth. Especially the oil industry favours the method for 3D mapping of oil fields. [1,2]

Tests of seismic systems at ESTEC ExoGeoLab: We have integrated various geophones systems within the ESTEC ExoGeoLab project [4] to study the technical, functional, operational and performance aspects and prepare for scientific measurements.

Fig. 1: System of 8 geophones (with 3 axis) deployed and tested inside ESTEC planetary robotic testbed.

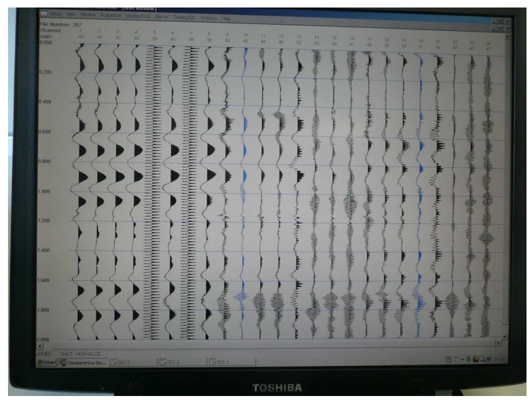

Fig. 2: Quick Look of seismic signal (signal from 8 geophones: vertical, horizontal x, horizontal y)

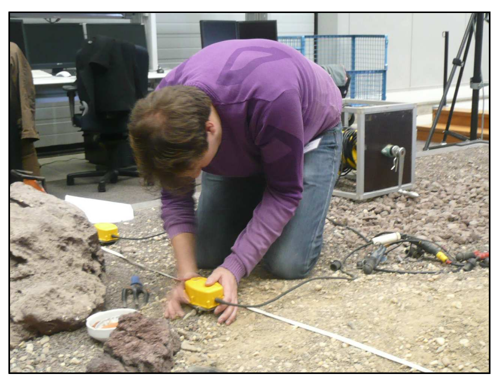

Fig. 3: Tests performed by first author to study the geophone sensitivity according to mechanical coupling to the surface

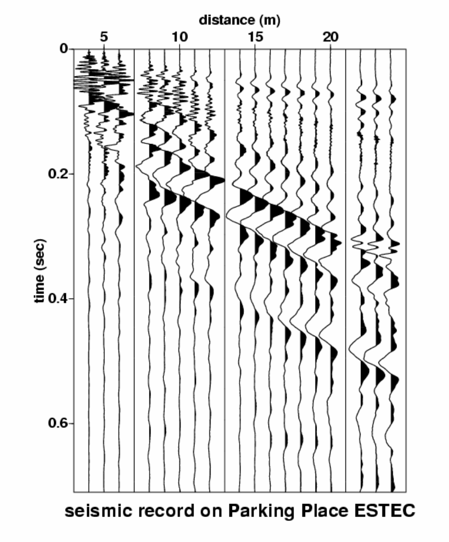

Fig. 4: Test performed with 21 geophones (1-axis) with a hammer trigger in outdoor conditions at ESTEC ExoGeoLab. One can distinguish the air sound wave envelope with a slope consistent with 340 m/s, a refracted wave and a shear wave.

Seismic project for EuroGeoMars expedition: The objective of this research project is to access the problems and requirements of using a reflection seismic network for celestial body geology. The project will focus on modelling the ground coupling of a planetary surface with a geophone or seismometer to determine whether and what type of problems could be expected when a seismic network is deployed on a surface within the constraints of a space mission and the effect of a different (lower) gravitational acceleration. [2] Furthermore the design of the seismic network as a system will be investigated to determine problems and solutions.

Within the EuroGeoMars expedition [4] of the European Space Agency some tests will be run with a geophones monitoring system. The goal is to perform empirical tests regarding ground coupling. The environment of the MDRS (Mars Desert Research Station) in the Utah desert is interesting, because it shows similarities with what can be expected on Lunar or Martian surfaces.

Surface contact and surface composition will be varied to simulate different deployed conditions. The data from the different settings will afterwards be compared to determine the degradation of the data for each setting. The tests are a precursor for further tests after the model of surface coupling has been developed. The results of the EuroGeoMars tests will be used in the modelling of the surface coupling.

Reflection seismology on planetary bodies: Based on models and other remote sensing data, geologists have been able to predict the composition of planetary bodies, at small scale to planet or body size. Remote sensing and data from a small set of seismometers can however only provide rough data on the actual composition of the subsurface or entire object. An exception would be the Moon where several seismometers operated on the surface and where actual geologists have performed surface research.

Reflection seismology would be able to provide more detailed information on subsurface structures and layering from small to large areas or entire planets, depending on the number of sensors and the network dimensions. Reflective seismology can be used to map areas which are hard or impossible to map or to verify model's predictions and would therefore provide valuable data for planetary geologists.

Qualifying reflection seismology for space: Before a seismic network could be deployed on a celestial body, several problems have to be solved to make the system suitable for space applications.

The first problem is the mass of the seismic system. Seismic systems used on Earth are robust systems to survive bare conditions and rough handling. For a space applications, the system mass has to be reduced considerately. Mass reduction can be achieved in the following fields:

1. Miniaturization, recently developed MEMS seismometers have a much lower mass than common used geophones or hydrophones. [3]
2. Wireless communication. The cabling between the sensors takes the largest part of the systems mass. By using wireless communication the system mass can be reduced up to 80-90%

These changes and the remote location of a network on distant objects induce problems and severe requirements on the communication of the measure data between the sensors and back to Earth.

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References:[1] Telford W.M. (1990) *Applied Geophysics*, Cambridge University Press [2] Drijkoningen G. G. (1999) *The usefulness of Geophone ground coupling experiments to seismic data. Geophysics, 65,* n. 6 1780-1787. [3] Gibson J. (2005 *MEMS sensors: Some issues for consideration. The Leading Edge,* August 2005 786-790. [4] Foing B. et al (2009) *ExoGeoLab pilot project & EuroGeoMars*, LPSC abstract (this issue)..