SEISMIC MEASUREMENTS ON THE MOON: OBJECTIVES AND NETWORK ARCHITECTURES

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Rationale: The international effort for returning on the Moon will allow to adress several scientific objectives with seismic instruments, as well as information important for future crew safety issues, such as the meteoroid rates (meteoroid could damage any Moon base or vehicle) or evaluating the seismic hazards linked to moonquakes, especially near the South Pole where permanent Lunar bases are planned.

Meteoroitic hazards : The frequency and the size law of meteoroids impacting the Moon are still not known precisely (and therefore of the associated probability for affecting a future permanent basis on the Moon). Figure 1 provides such estimates for different models published in the literature, and shows that impacts of 10 mg @ 20 km/s are expected to occur at a rate approximately inversely proportional to the mass and with a flux of 10 to 300 impacts in 10 years per km^2 : this is therefore significant for future long term Lunar basis.

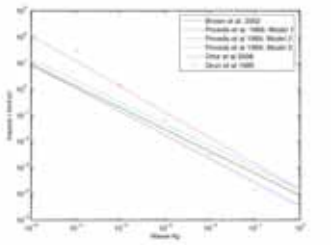

Figure 1 Frequency of the micro-impacts. Note the very large dispersion between the proposed models.

Very large uncertainties remains therefore in the estimation of these hazards, as most of the small impacts are not observed on the Earth, due to the shielding of the atmosphere and the lack of observable signals. A monitoring of these impacts can be done in the future by using a local network of short period micro-seismometers. Such seismometers with an instrument noise of 1-10 ng/$Hz^{1/2}$ will be efficient in detecting small impacts.

Moon internal structure and VBBs global network

The internal structure of the Moon remains unknown and solely the deployment of Very Broad Band seismometers will allow to solve key questions, such as the actual size of the Moon core, and the detailled structure of the mantle. In addition to this, the deployment of a VBB (Very Broadband) seismometer network will allow to have a quantitative evaluation of the seismic risk in the zones where to permament outpost are planned. It will in particular allow to monitor the risk linked to shallow Moonquakes.

Instrument : On the instrument point of view, IPGP in collaboration with CNES, the French Space Agency and ETHZ, is developping a Moon version of the Very Broadband seismic sensor (VBB) now selected to fly on the ESA ExoMars mission. The current specifications of SEIS seismometer allow, with a certain number of non-critical modifications, to make it operational on the Moon with even improved performance, as the mobile mass has been increased.

The maturity of the proposed instrument is good, with a TRL5 to be reached in November 2008 at the instrument PDR. We are currently funded by CNES on the track to increase the performances of the instrument in Moon configuration to level 10-20 times lower than Apollo's background noise, which might be close to the level of micro-seismic noise associated to the permament impacts on the Moon. In addition to this increase in signal to noise ratio, the use of a 24 bit acquisition electronics (we are also studying a 32 bit converter) will also considerably increase the signal dynamics with respect to Apollo data.

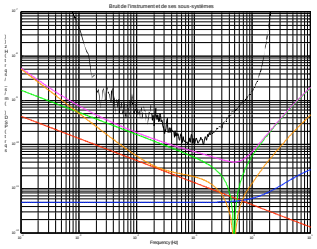

Figure 2 SEIS Moon Noise figure vs Apollo vertical Moon noise

As a result of this, this instrument has been proposed as baseline for the on-going PIDDP study for a LGIP (Lunar Geophysic Instrument package) , as well as for the ISAS/JAXA Selene 2 mission.

Fig 3. Two possible seismometer configurations (IPGP/MPS)

Possible network architectures and associated rationale.

The following table proposes some preliminary architecturesfor the deployment of seismometer network on the Moon.

Network Scale	Instrument	Rationale	Deployment type
Global	**VBB**	**Lunar structure and evolution Global seismic risk**	**Unmaned – Autonomous package deployed by Lander**
Regional	**VBB + SP network**	**Geologic Local structure (regolith depth …) Regional seismic risk - Meteorites rate (++)**	**Manned/Unmaned – Autonomous package**
Local scale	**SP network (3-4)**	**Local seismic risk Subsurface sounding Meteorites rate monitoring (+)**	**Manned (preferred) Small network**

Commonality with Mars exploration

The deployment of such networks on the Moon paves the way for future planetary networks, especially on Mars, which is expected to be the next step for human outpost in the Solar System. Most of the described technologies developed in the frame of the Moon exploration will therefore be re-usable "as is" for future Mars networks.

References

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