A Martian and Lunar Very Broad Band Seismometer

S. Tillier[(1)], S. de Raucourt[(1)], P. Lognonné[(1)], T. Nébut[(1)], O. Robert[(1)], P. Schibler[(1)], T. Gabsi[(1)], B. Lecomte[(1)], O. Pot[(1)], J. Gagnepain-Beyneix[(1)], D. Mimoun[(2)]

[(1)]PRES Paris-Cité, Institut de Physique du Globe de Paris, Planetary and Space Geophysics, Paris – FRANCE, Email: tillier@ipgp.fr
[(2)]DEOS, ISAE, Toulouse – FRANCE

Introduction

The very broad band seismometer (VBB) is a seismic sensor being developed by the Institut de Physique du Globe de Paris (IPGP) in France, under the founding of CNES, the French national space agency.
It is part of a planetary seismometer being developed by an international consortium, which is currently a unit of the core payload for the Martian project GEMS-2 from JPL (Jet Propulsion Laboratory, USA), but also for the SELENE-2 Japanese Lunar project (ISAS–JAXA).
The VBB development relies on a solid technical heritage of a series of aborted Martian projects. But for the Moon's conditions and environment, some design adaptations and performances enhancement have been required, ultimately leading to a new VBB design.

Science

The main goal for planetary seismometers is to study the seismic activity of a planet and the meteorite flux at the planet's surface. The seismometer allows for the characterization of shallow and deep interior of the planet, and especially the deep subsurface layering structure, the crustal thickness of the landing site, the core size and the mantle structure.
The vibrations detected by a seismometer reflect the characteristics of the original source, the geometry of the path taken from the source to the receiver (and thus the structure of the planet) and the physical properties of the material through which it has passed.

Current Mars and Moon Missions Projects Including the VBB

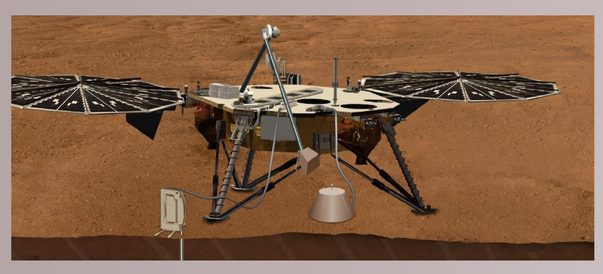


Figure 1 : The Phoenix Lander and its payload in operation. HP3 and SEIS are deployed on the ground. RISE is on the deck.

GEMS-2 is a project proposed by the American JPL (B.Banerdt) for the NASA's DISCOVERY program, which has recently been selected for a phase A study.
The GEMS 2 proposal use a Phoenix bus for the Lander with MRO/GRAIL for the avionics. Launch to Mars is foreseen in 2016. GEMS 2 will operates continuously for 1 Martian year.

A Japanese team from ISAS – JAXA is also working on the development of a geophysical mission including a seismometer (S.Tanaka, N.Kobayashi, H.Shiraisi, R.Yamada), but with the Moon as the subject. This project, which started in 2008, is named SELENE-2, and is currently in phase A.
The mission is scheduled to be launched by 2018.

Figure 2 – SELENE-2 illustration

The SEISmometer Instrument : An International Configuration

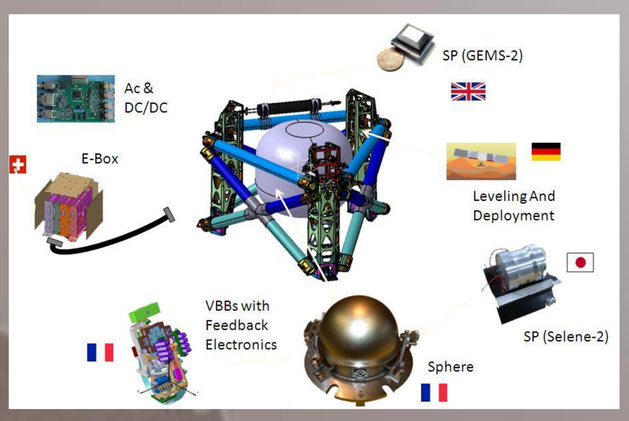


Figure 3: Seismometer international consortium

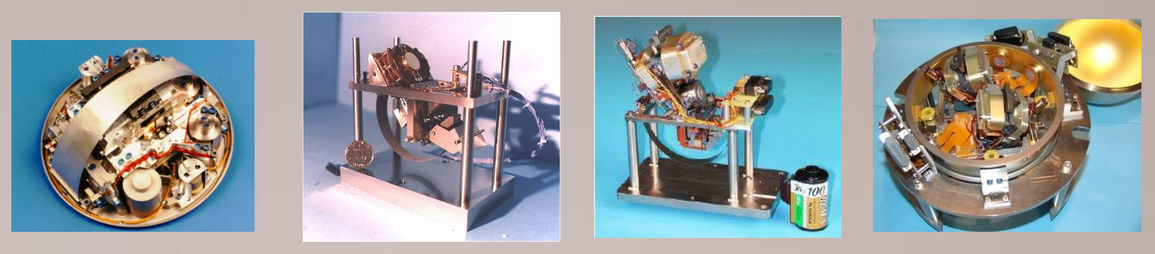
For both the projects, the complete seismometer instrument (**SEIS** for GEMS-2, and **LBBS** for SELENE-2) involve an international consortium. The subsystems configuration is the following (see Figure 3):

- **VBB seismic sensors, VBB feedback electronics, Sphere Housing**: P. Lognonné, S. DeRaucourt, IPGP, France
- **Leveling and Deployment mechanism and electronics**: U.Christensen, R.Roll, M.Bierwirth, Max-Planck-Institut für Sonnensystemforschung, Lindau – GERMANY
- **Acquisition and Control electronics (AC), Power Convertion electronics (DC/DC) and E-Box system design**: D.Giardini, P.Zweifel, D.Mance, Geophysics, ETHZ, Zürich – SWITZERLAND
- **Short Period seismic sensors for SELENE-2**: N.Kobayashi, H.Shiraisi, R.Yamada, ISAS-JAXA, Tokyo – Japan
- **Short Period seismic sensors for GEMS-2**: T.Pike, Imperial College, London – United Kingdom
- **The Sun and thermal shield** which protects the sensors platform on the Moon surface for SELENE-2: ISAS – JAXA.
- **The Sun, thermal and wind shield** which protects the sensors platform on Mars surface for GEMS-2: JPL.

VBB Heritage at IPGP

The Space and Planetary Geophysics (GSP) team from the IPGP (Parisian Earth Sciences Institute) has been working on space seismometers for more than a decade. The first study started in 1993 with a first seismometer named Optimism, which has been on board the Russian Mars96 mission to Mars.

The first VBB prototype was built in 1998, and then engineering models where built during the aborted Netlander (CNES) and the Exomars-Humboldt (ESA) project s.



Optimism 1993 → *IPGP VBB Demonstrator 1998* → *NetLander VBB EM 2004* → *ExoMars Sphere EM 2008*

Figure 4 – Schematic of the VBB development history at IPGP

Improving the Performances and Planetary Compatibility

In order to meet the Moon performance requirements ($2x10^{-11}m/s^2/sqrt(Hz)$ @ 0.1 Hz) and allow the compatibility with both the Moon and Mars' environments and missions constrains, the following improvements were tested on breadboards for implementation:

- Reducing the thermal sensitivity
- Improving the displacement capacitive sensor (DCS)
- Optimizing the mechanical gain
- Adaptability of the VBB's balance to the planets

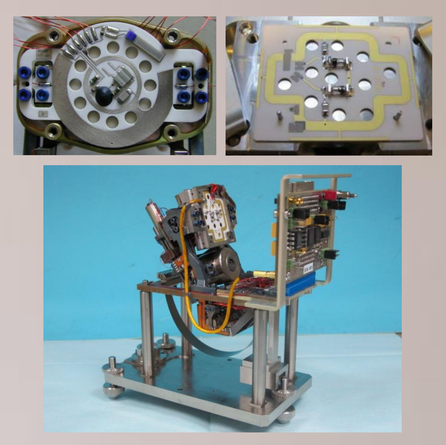
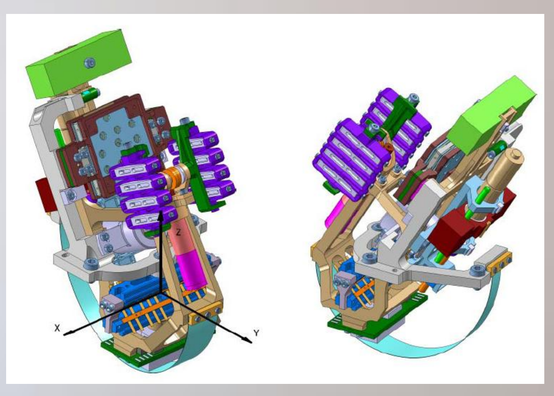


Figure 5 – The old (Top left) and new (Top right) DCS' ceramic electrodes, and one of the two enhanced VBBs' EM integrating the new DCS (bottom) - 2010

The Resulting New Martian/Lunar VBB Design

Figure 6 – Selene-2 / GEMS-2 VBB preliminary design, including the new DCS electrodes (Brown), the Moon counter weight at the top of the pendulum (green part) and the thermal compensation mechanism (Purple). 2011 - EADS - SODERN



This latest development of the IPGP's VBB have been through a preliminary design review process at the beginning of 2011, with an independent review board composed by French experts, and also involving the CNES.
During Gems-2 Phase A, the design will be further validated as the missions' specifications will grow more mature.
A breadboard of the consolidated new design is foreseen for 2012.

Conclusion

To meet the requirements for the new geophysical missions to Mars and the Moon, the Very Broad Band seismometer developed by IPGP has known several recent evolutions.
Those evolutions build upon the solid heritage obtained through the previous developments achieved since 1993, with the Optimism Martian seismometer, NetLander and ExoMars Martian projects, with which the maturity of the IPGP's VBB has reached an end of phase B readiness level (ESA TRL higher than 5).
Enhancements have been tested and approved with breadboards in order to improve further the noise performances, and have now been integrated to the new design.
The IPGP's VBB design has also now evolved toward a version compatible with both Martian and Lunar projects, with only minor adaptations between the two configurations, which is allowing saving costs as well as qualification and building time.
An engineering model breadboard of this last VBB design is to be built by 2012, and tests are also continuing on the existing breadboards in order to have the readiness level progressing, with full SEISmometer instrument integration and environmental tests under preparation and scheduled by the end of 2011, aiming at reaching a TRL level of 6 by then. This is necessary to meet the GEMS-2 schedule which is planned for a launch in 2016, and also for SELENE-2, which may follow on tightly.

Contact : tillier@ipgp.fr