THE INSIGHT VERY BROAD BAND (VBB) SEISMOMETER PAYLOAD. O.Robert[1], J.Gagnepain-Beyneix[1], T. Nébut[1], S. Tillier[1], S. Deraucourt[1], K.Hurst[2], T. Gabsi[1], P.Lognonné[1], W.B.Banerdt[2], D.Mimoun[3], M. Bierwirth[4], S. Calcutt[5], U.Christenssen[4], D. Giardini[6], L. Kerjean[7], Ph. Laudet[7], D. Mance[6], R. Perez[7], T.Pike[8], R. Roll[4], P. Zweifel[6], and the SEIS Team[1].
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Introduction: The very broad band seismometer is a seismic sensor being developed by the Institut de Physique du Globe de Paris (IPGP) in France, under the funding of CNES, the French national space agency. It is part of the SEIS (SEISmometer) planetary experiment [1] developed by an international consortium under the management of CNES, currently part of the core payload for the Martian project InSight [2] (Interior exploration using Seismic Investigations, Geodesy, and Heat Transfert, formerly known as GEMS) from JPL which has been pre-selected in the frame of the 2012 Discovery mission selection. This paper exposes the latest developments made on the martian VBB sensor and the overall testing activities.

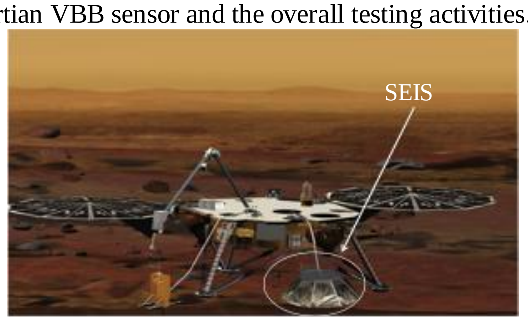

Figure 1 : SEIS deployed on the ground next to the the InSight Lander

VBB principle: The VBB sensor is based on the three single axis seismic sensing heads which are placed on a tetrahedron recovering the 3 dimensions of the seismic waves. The single axis sensor is made with a mechanical inverted pendulum stabilized with a leaf spring. Seismic motion is then sensed with an electronic DCS (Differential Capacitive Sensor).

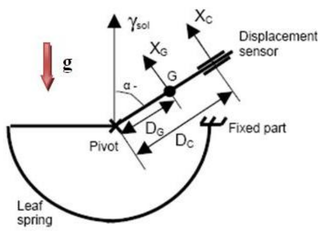

Figure 2 : VBB mechanical principle

VBB heritage: The implementation requires several specific capabilities to reach the sensitivity goals imposed by the science requirements of a Mars mission. All thoses capabilities have been developed at IPGP [3] (Institut de Physique du Globe de Paris, France) starting in 1993 with the Optimism payload (10^{-8} m.s^{-2}/sqrt(Hz) at 1 Hz., [4]) on the Russian Mars96 mission to Mars, followed with the the Netlander [5] CNES program in 2003 which reach 10^{-9} m.s^{-2}/sqrt(Hz) at 1 Hz on a 2 axis seismometer. From 2006 to 2009, the program was funded by the EXOMARS ESA mission and reached a resolution of $3x10^{-10}$ m.s^{-2}/sqrt(Hz) at 1 Hz with a two axis VBB.

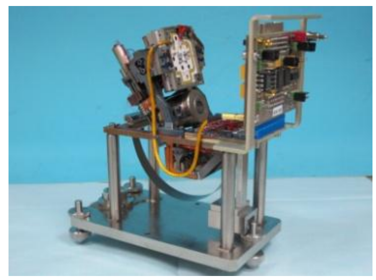

Figure 3 : Last 1 axis-VBB prototype (VBB-41) with its proximity electronic

During those 20 years, not only the expertise on the mechanical pendulum, but also expertise on the high gain capacitive sensor and on the low noise analog front-end and feedback electronic were developed, and the robustness of the seismic sensor to the space mission environment was strongly improved.

Sensor expertise: The DCS, as implemented in the VBB, is a position sensor. It reaches in its last version a precision of several pm/sqrt(Hz) down to the 1/f corner frequency of 2.5Hz with only 30mW power consumption per axis. To guarantee this precision for all the mission and environmental constraints, a thorough verification has been conducted, in order to know the difficulty of temperature, pressure, vibration, planetary protection [6] and radiation requirements on the electronic. Testing up to 15 kRad of cumulated total ionizing dose on the sensitive space parts was conducted recently and demonstrated good robustness of the choosen components regarding the mission needs. Also, thermal characterisation and robustness tests were conducted during the last year to characterize drifts of the overall analog sensitive electronics.

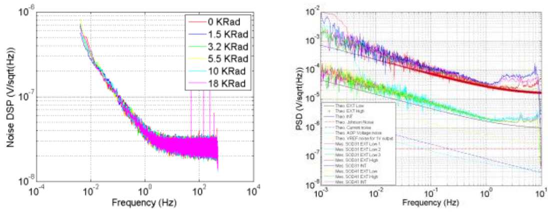

Figure 4 : Sensitive component RH1078 input voltage Noise radiation dependency and different configuration DCS noise.

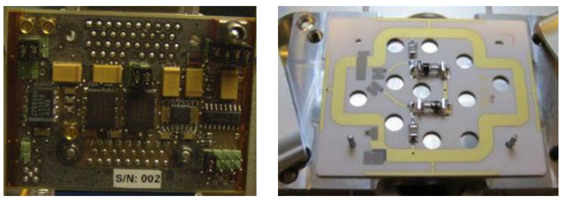

Figure 5 *:* VBB-41 ptotoype sensor head and front-end electronic

Mechanical expertise: A full microtomography analysis was also conducted with the help of CNES on the mechanical parts of the VBB.

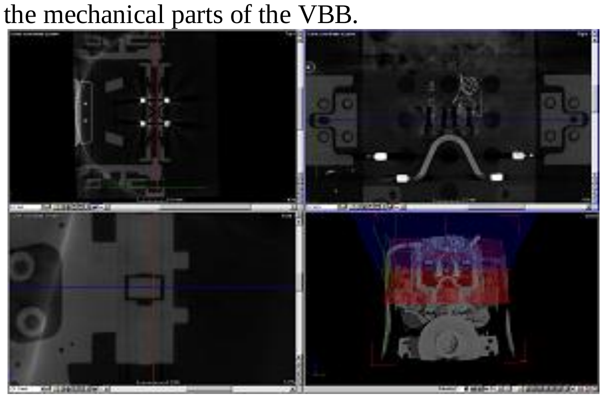

Figure 6 *:* VBB-41 micro-tomography capability at the CNES facility

This micro-tomography shows a final control of the dimensions of the assembled instrument. The measurements proved that the required 100µm DCS gap was achieved with a precision of some 5µm, and similarly all other dimensions were correct. This gives us confidence in the ability of reproducing such a good axis for the incoming InSight mission.

VBB performance: .The development and tests conducted this year on VBB-41, lead to the performance shown in following figure. The performance in the Martian environment can be extrapolated in a straightforward way from the Earth environment with this pendulum design, unsing the gravity ratio (9.81/3.71).

The Earth prototype VBB-41is today marginal to the InSight specification as shown in the following figures.

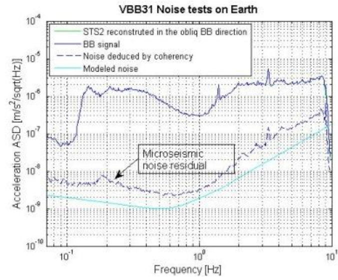

Figure 7 : Earth measured VBB-41 performances around Body Waves frequencies done at IPGP facility. Mars performances will be better by a factor of 2.65 due to the pendulum design.

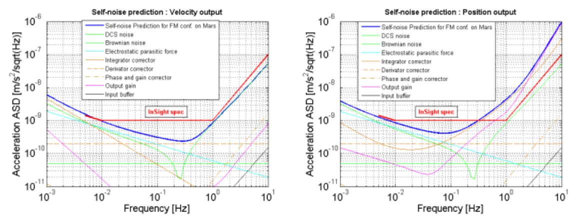

Figure 8 *:* InSight VBB extrapolated sensor performances on Mars (Theoretical noise analysis).

Incoming Flight Models (FM) for the mission will take advantage of a fully Mars adapted design (mechanical gain improvement, better noise distribution in the electronic stages, DCS optimization) that will provide additional margin to the mission specifications.

Conclusion: Performance has been demonstrated with previous prototypes and all the electronical and mechanical aspects of the presented VBB are controlled and reproductible in the many tests performed in the past years of development. The SEIS experiment of the InSight mission, if selected to fly to Mars in 2016, will therefore provide high quality seismic signal acquisition and associated seismic information during one martian year, i.e. the nominal mission duration.

References:

[1] Mimoun and al, The InSight Seis experiment, submission to LPSC 2012. [2] Banerdt, et al., The Rationale for a Long-lived Geophysical Network Mission to Mars, white paper submitted to the National Academy of Sciences Decadal Survey, 2010. [3] Tillier and al, A Martian and Lunar Very Broad Band Seismometer, ESMATS Symposium, 2011. [4] Lognonné et al., *Planetary Space Science*, **46**, *739-747*, 1998 [5] Log- , et al., The NetLander very broad band seismometer, Planet. Space Sci., 48, 1289-1302, 2000.[6] Schibler and al, Planetary Protection Policy applied to Planetary Seismometers development, 41th LPSC conf., Houston, 01-05 March 2010.