A SPACE VERY BROAD BAND (VBB) SEISMOMETER

Insight : The next NASA Discovery 12 Mission to MARS

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.Christensen[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]

[1]IPGP-Sorbonne Paris Cité, Univ Paris Diderot, France, [2] JPL, CalTech, Pasadena, USA , [3]ISAE, Université de Toulouse, France, [4]MPS, Germany, [5]Oxford U, UK, [6]ETHZ, CH, [7]CNES, France, [8]Imperial college, UK.

Poster n° 1156

1. Introduction

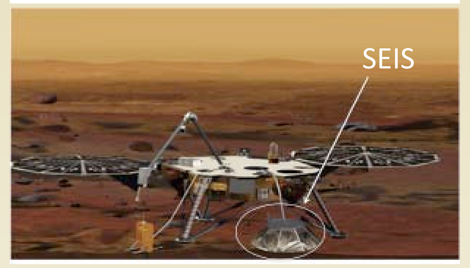


Fig. 1: SEIS instrument (upon deployment)

The very broad band (VBB) 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 Transport) from JPL.

This project has been selected by NASA for the next Discovery mission. Delivery of the payload is planed for end 2014 for a launch in March 2016.

This paper exposes the SEIS VBB Payload and the latest developments made on the Martian VBB sensor and the overall testing activities.

2. VBB Instrument Description

The Instrument consists of three identical **VBB Sensor Heads** measuring the 3D ground acceleration (m/s^2) of seismic waves. It is based on three single axis acceleration sensors placed on a tetrahedron (Chapter 3).

The three identical **VBB Sensor Heads** are placed in an evacuated **SPHERE**, supported by a **LeVeLing System**. All this will be deployed on soil by a robotic arm, and covered by a **Thermal Shield**. A flexible copper –on-kapton Tether will link **the FeedBack** and **ACQuisition Electronics** in the thermal enclosure on the Spacecraft to the deployed sensors.[1].

Fig. 2: Instrumented STM SPHERE (Exomars)

Fig. 3: Instrumented SPHERE on a Leveling (LVL) system prototype (courtesy MPS)

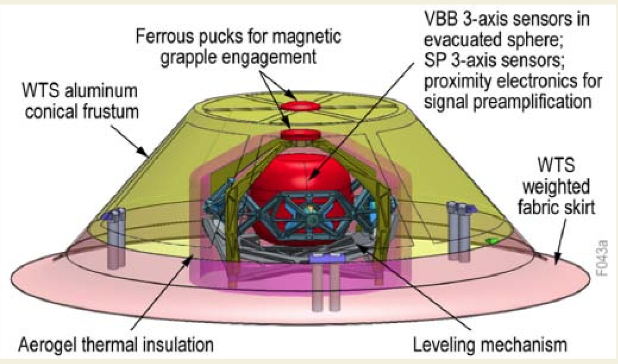


Fig. 4: Overall deployed seismic sensor payload (courtesy JPL).

- **VBB Sensor Head:**
  - Senses the ground acceleration with a pendulum and a Differential Capacitive position Sensor (DCS)
  - Proximity electronics outside the SPHERE condition the analog signal
- **SPHERE:**
  - Maintains an internal vacuum to thermally and mechanically isolate the 3 VBB sensors to improve performance
- **Leveling System:**
  - Levels the SPHERE to allow the VBB pendulums to be in their operating range
- **Thermal Blanket:**
  - Protects the SPHERE and Leveling System from variations in the thermal environment
  - Wind and Thermal Shield
  - Protects the VBB sensors from direct wind forces.

As described in Fig. 4, the VBB Seismometer is the core of the seismic experiment which also includes 3 Short Period (SP) Seismometer provided by Imperial College (UK) and House Keeping sensors.

3. VBB Sensor Head Principle and Heritage

One single axis sensor is made with a mechanical inverted pendulum stabilized with a leaf spring (fig. 2). Accelerations such as Seismic motion are sensed with an electronic Differential Capacitive Sensor(DCS). In order to extend the dynamic of the pendulum, the position of the mobile mass is locked on to zero thanks to a coil and an analog feedback loop.

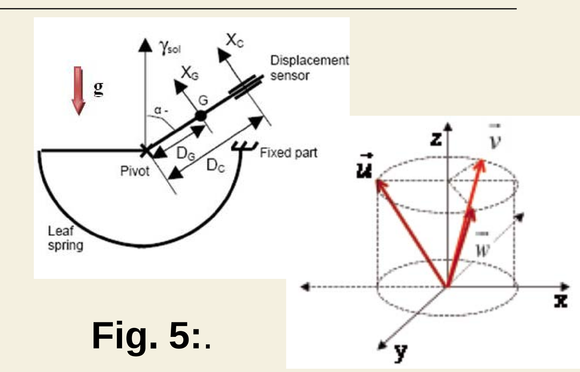


Fig. 5:. SEIS instrument Sensor head principle and (x, y, z) scientific sensing axes recovery.

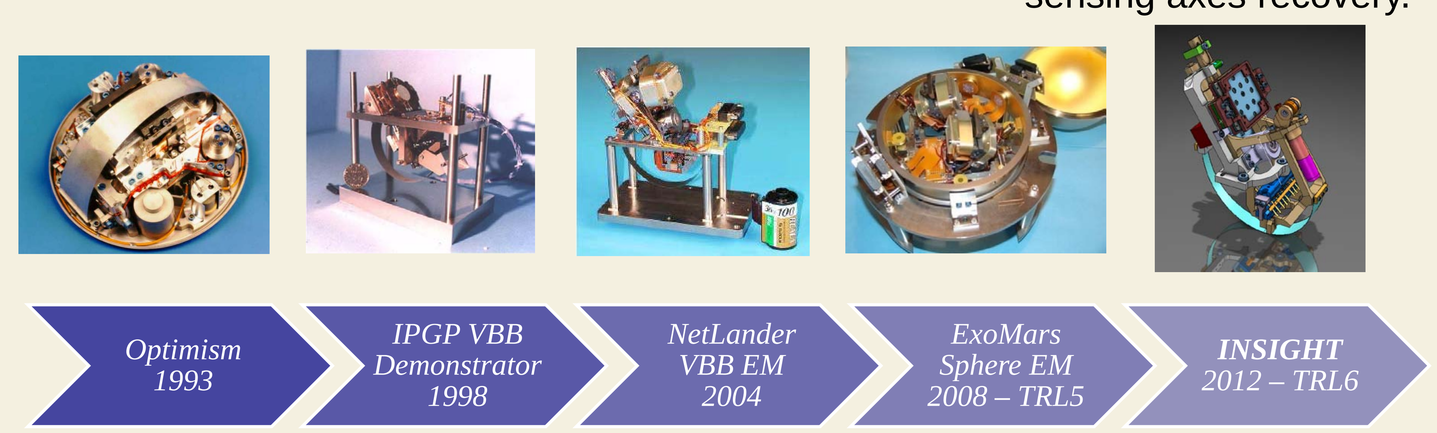


Fig. 6: VBB Heritage at IPGP: Optimism (93), Netlander (04), Exomars (08), Insight (12)

Seismic measurement capabilities developed at IPGP [3] since 90's:

- 1993: **Optimism** payload (10^{-8} m.s^{-2}/sqrt(Hz) at 1 Hz) [4] on the Russian Mars96 mission to Mars
- 2004: **Netlander** CNES program (10^{-9} m.s^{-2}/sqrt(Hz) at 1 Hz) [5] with a 2-axis seismometer
- 2009: **EXOMARS** ESA mission ($3x10^{-10}$ m.s^{-2}/sqrt(Hz) at 1 Hz) with 2-axis VBB

4. Mechanical Engineering

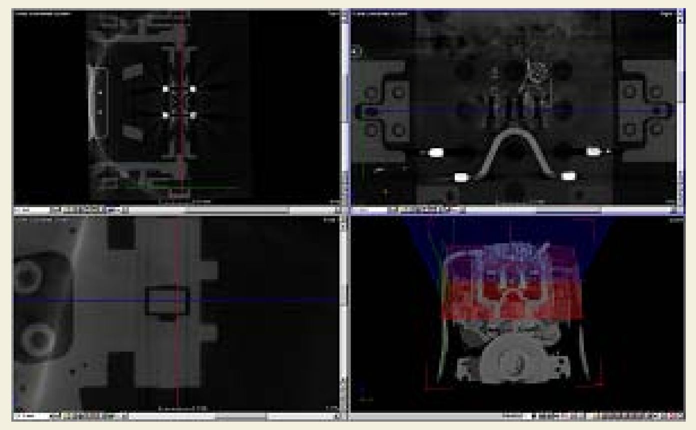


Fig. 7: VBB-31 micro-tomography at CNES facility, inspecting the DCS gap (100µm), final stops and all the key internal assembly

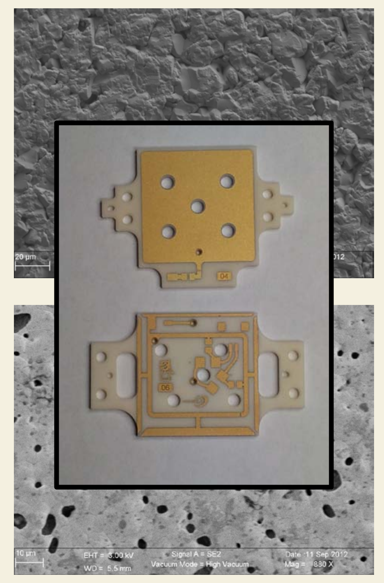
The Mechanical pendulum of the VBB:

- High gain (0,2m/m.s^{-2}), low mass (150g)
- Thermally compensated spring
- High shock and vibration level tolerance
- TRL6 level mechanisms

VBB Mechanical/Thermal/Magnetic behavior validated by tests on 1 demonstrator, 2 engineering breadboards (EM) and 1 STM. New Insight EM model in 2012.

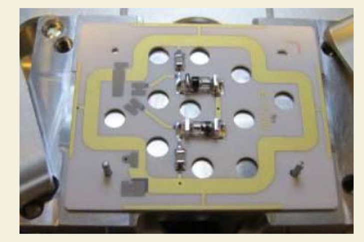
Mature design based on a solid development and tests heritage

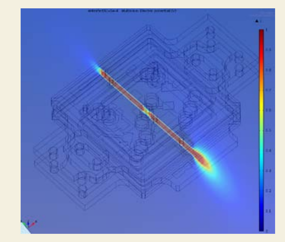
5. Sensor / Magnetic Actuator Engineering



A complete Electromagnetic Model of the VBB sensor has been made and experimentally validated.

Physical characterization of the sensor head has been conducted (DRX, MEB, T°, …)





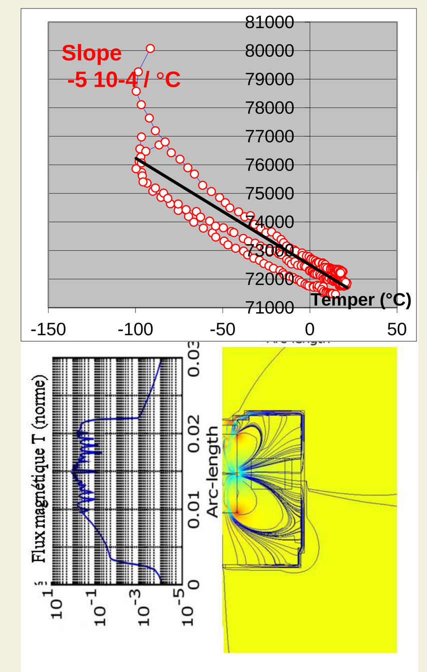


Fig. 8: Electromagnetic model of the VBB (**Left/Middle**: Capacitive Sensor prototypes and model, **Right**: Magnetic Actuators)

References: [1] Mimoun and al, The InSight Seis experiment, 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] Lognonné, 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.

6. Electronics Engineering

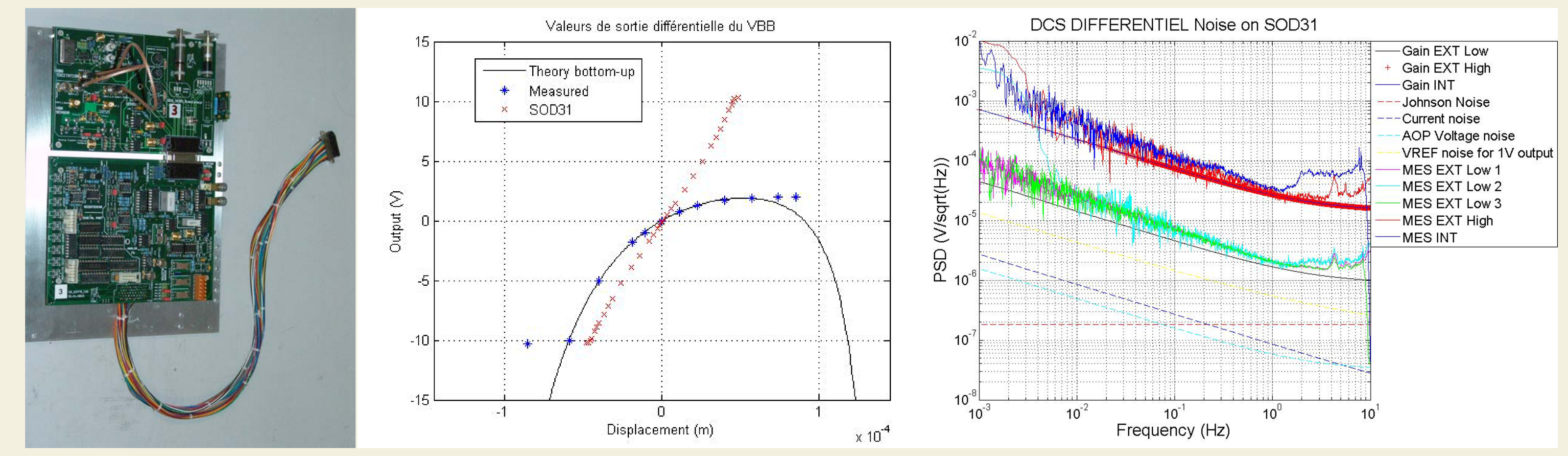


Fig. 9: VBB Electronics : **Left**: FeedBack and Sensor simulator, **Middle**: Gain prediction (nominal, Failure modes), **Right** : Noise prediction and measurement.

Tests and validations

1. Integrated interface validation done with simulators
2. VBB Transfer Function model validated for working and failure modes
3. VBB self noise model validated for all modes
4. Low noise AOP Radiation Validation 18kRad @ low dose rate 36 Rad/h (^{60}Co): parameters drift + noise
5. Electronic thermal sensitivity

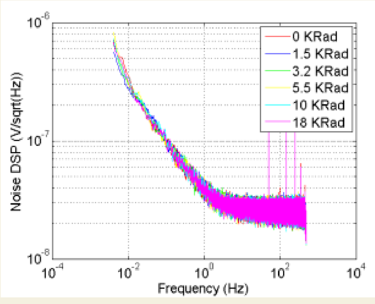


Fig. 10: RH1078 TID Voltage noise drift.

7. Performances, TRL maturation

Performances

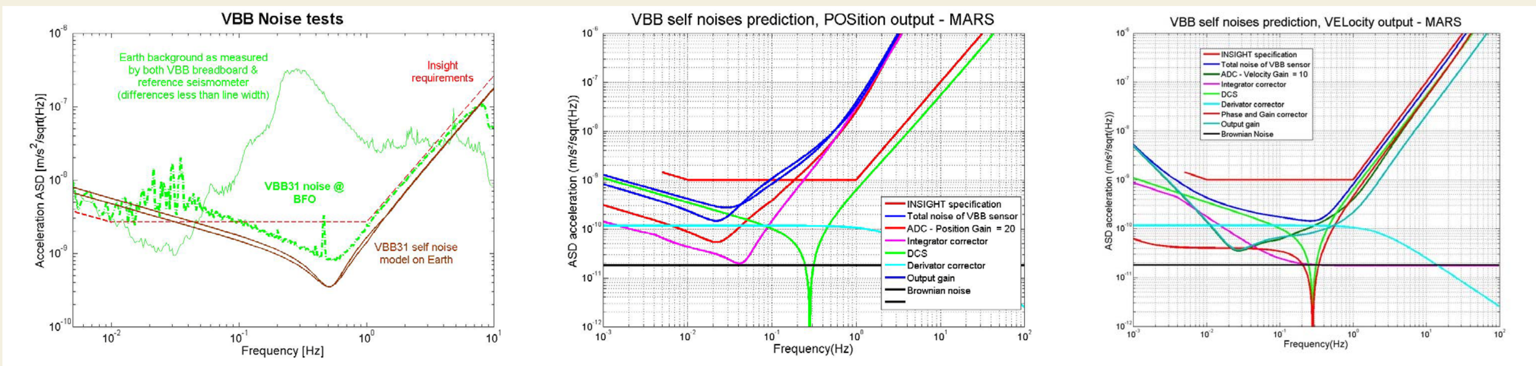


Fig. 11: Left : Earth Performances validation, **Middle**: POSition (tide and very long periods seismic bandwidth) gain prediction on Mars, **Right** : VELocity (seismic bandwidth) gain prediction on Mars.

Technology validation scheduled

1. **TRL 6 @ component level** (mechanisms, DCS electrodes, proximity board, thermal compensator, plus a STM of VBB pendulum) Key technologies and components level qualification scheduled 2012 Extensive test plan: vibration, thermal environment and cycling, TID, lifetime,…
2. **TRL 6 @ VBB level**
   InSight configuration EM under manufacturing (Delivery end 2012) Test campaign end of 2012 / early 2013 : performances and environments.

8. Summary

- Performance Model has been demonstrated with a family of prototypes developed at IPGP
- Mechanical and electronic aspects of the VBB are modeled, controlled and reproducible
- Radiation Tests were performed on sensitive electronic elements
- TRL6 Level scheduled 2012 is ongoing

The SEIS experiment of the InSight mission, selected to fly to Mars in 2016, will provide high quality seismic signal acquisition and associated seismic information during one Martian year, i.e. the nominal mission duration.