THE SEIS InSight VBB EXPERIMENT

Insight : The next NASA Discovery 12 Mission to MARS

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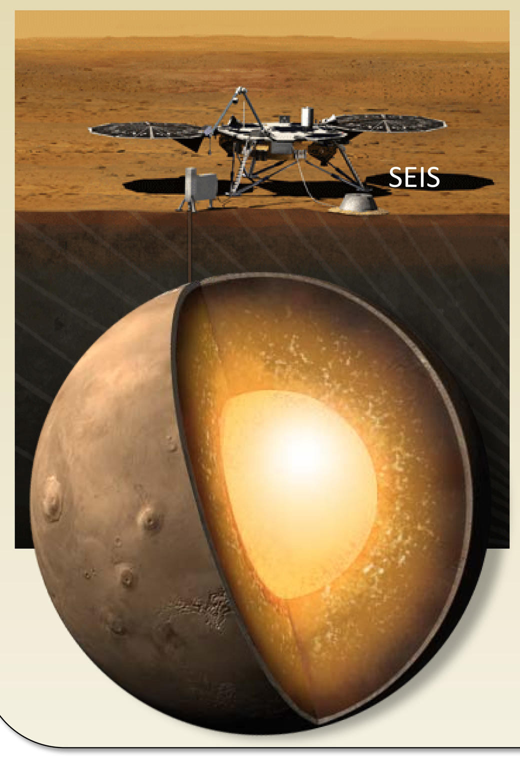
1. Introduction



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.

InSight has been **selected by NASA in August 2012 for the next Discovery 12 mission**. Delivery of the payload is planed for end 2014 for a launch in March 2016.

2. The InSight Mission

INSIGHT science goals :

1. Understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars

• Determine the size, composition and physical state of the core
• Determine the thickness and structure of the crust
• Determine the composition and structure of the mantle
• Determine the thermal state of the interior

2. Determine the present level of tectonic activity and impact flux on Mars

• Measure the rate and distribution of internal seismic activity
• Measure the rate of impacts on the surface

INSIGHT Payload :

To accomplish these objectives, a tightly focused payload has been assembled consisting of three experiments:

1.Seismic Experiment for Interior Structure (SEIS)
Measure seismic waves traveling through the interior to determine interior structure and composition

2. Rotation and Interior Structure Experiment (RISE)
Determine the precession, nutations, and wobble to constrain interior structure

3. Heat Flow and Physical Properties Package (HP3)
Investigate the thermal evolution and mechanisms of heating/cooling

The INSIGHT project use the proven Phoenix landing system.
It is to operate continuously for 1 Martian year.

3. VBB Instrument

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

One single axis sensor is made with a mechanical inverted pendulum stabilized with a leaf spring (fig. 1). 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.

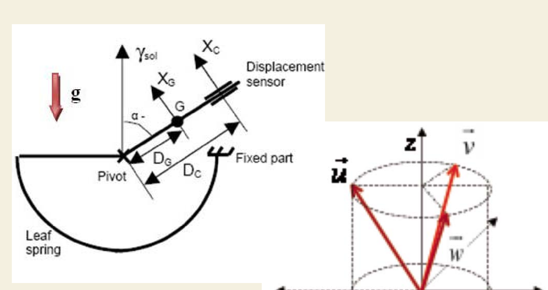


Fig. 1:. SEIS instrument Sensor head principle and (x, y, z) scientific sensing axes recovery.

4. VBB Sensor Head Heritage

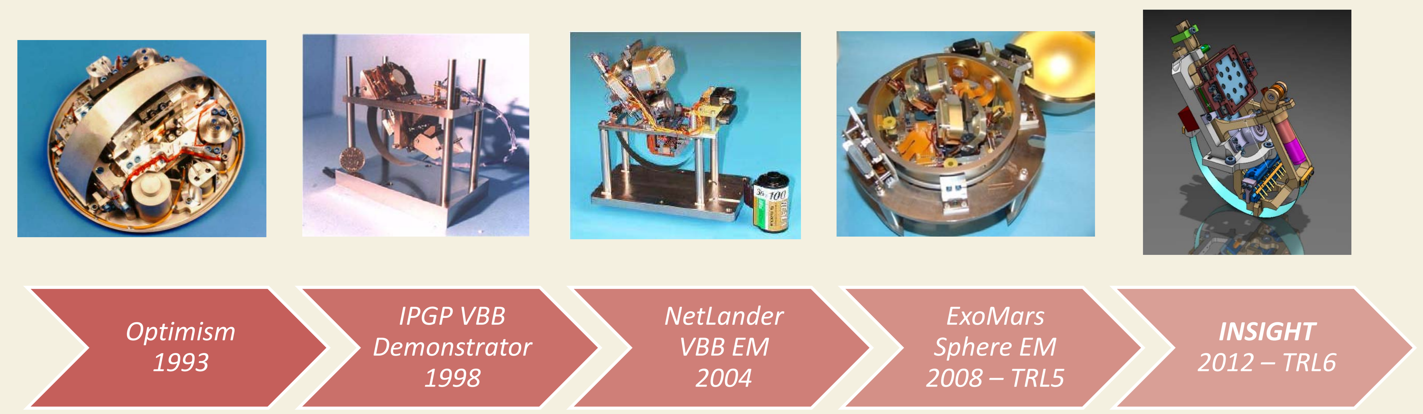


Fig. 2: VBB Heritage at IPGP: Optimism (93), Netlander (04), Exomars (08), Insight (12)

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

Fig. 3: Instrumented STM SPHERE (Exomars)

Fig. 4: Instrumented SPHERE on a ExoMars Leveling (LVL) system prototype (courtesy MPS)

Waves	Frequency bandwidth	*Optimism*	*NetLander / ExoMars VBB*	*Modified ExoMars VBB*	*Insight VBB*
Volume waves	0.1 – 2.5 Hz	10^{-8} $m.s^{-2}.Hz^{-1/2}$	✓	✓	✓
Surfaces waves	0.1 – 0.02 Hz	X	> 0.08Hz *7@0.01 Hz	✓	✓
Phobos Tide	0.05 mHz	X	~	~	✓

Table 1 – Evolution of the Seismometer capability along its development with respect to the predicted seismic levels on Mars

5. InSight VBB Engineering

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

VBB Mechanical/Thermal/Magnetic behavior validated by tests on 1 demonstrator, 2 engineering breadboards (EM) and 1 STM. New Insight EM model in March 2013.

Mature design based on a solid development and tests heritage

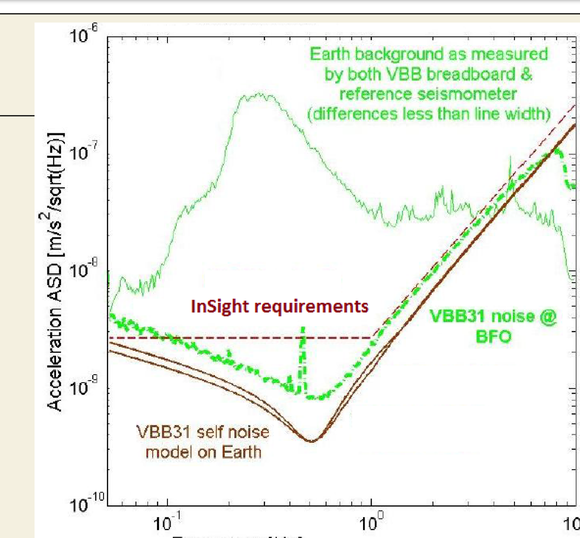


Fig. 5: Earth performance validation at Black Forest Observatory (low noise site in Germany).

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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] Lognonné, et al., The NetLander very broad band seismometer, Planet. Space Sci., 48, 1289-1302, 2000.

6. Current experimental activities

DCS : Six electrodes are tested since the beginning of January.

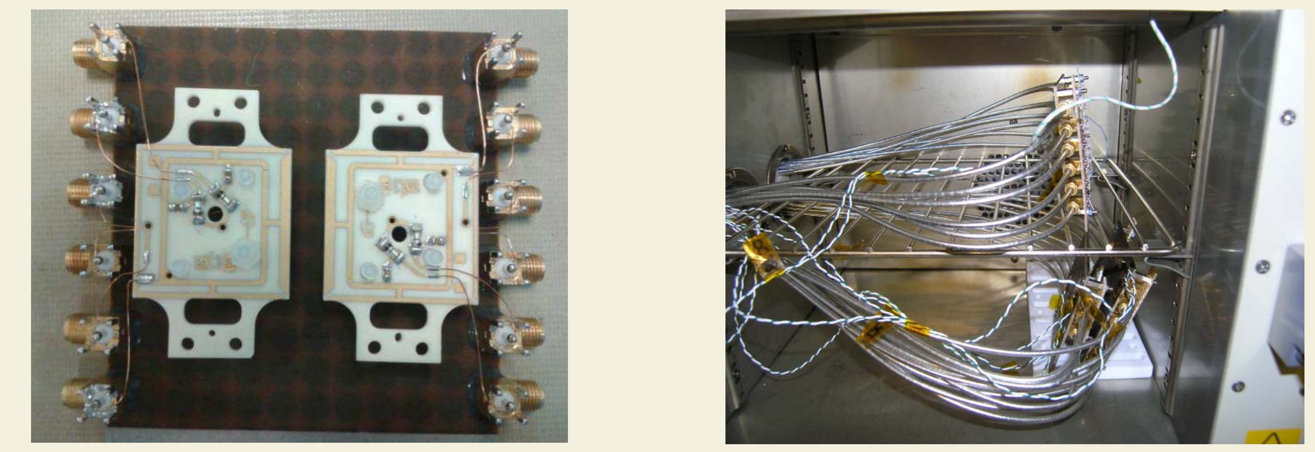

Fig. 6: Two InSight VBB DCS Electrodes on the left
The six DCS Electrodes in the steam room on the right.

Mechanisms : One recentering mechanism and one thermal compensation mechanism are tested since the beginning of March.

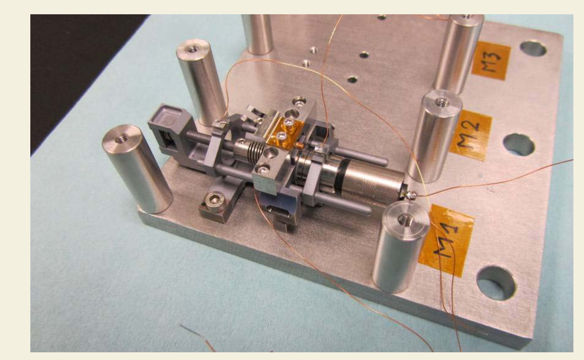

Fig. 7: InSight VBB Recentering mechanism on the left
InSight VBB thermal compensation mechanism on the right

These subsystems are under going Thermal Cycling tests and operating lifetime tests under representative environment, in order to reach the TRL n°6

EM model : The new EM model is going to be delivered in the next days

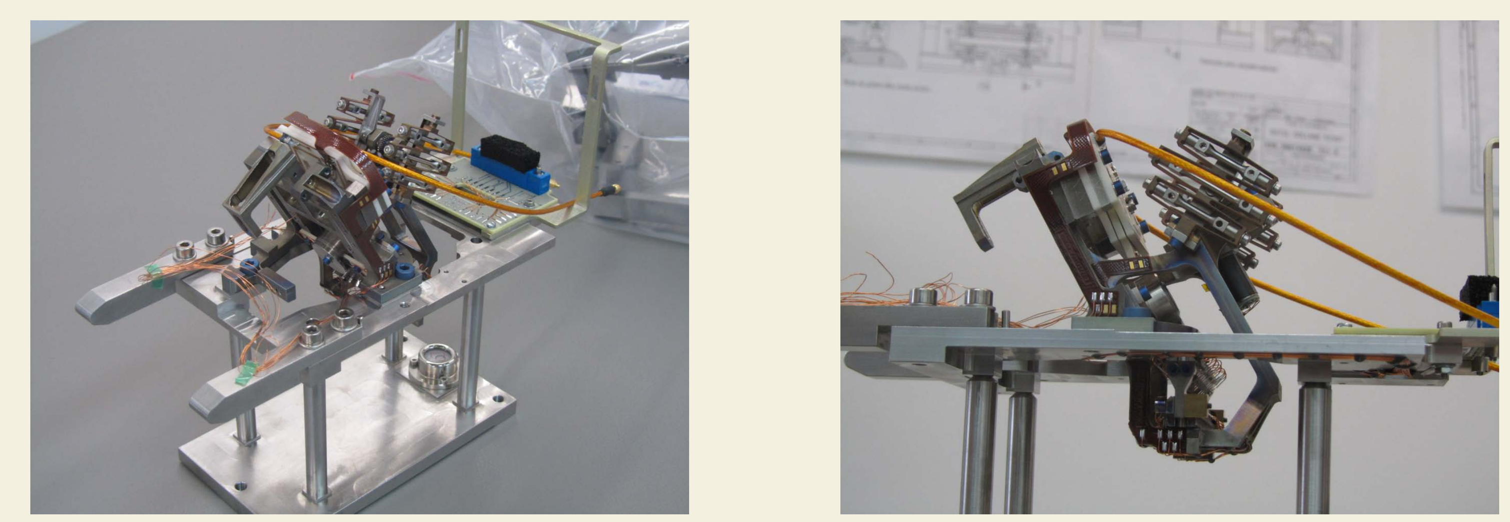

Fig. 8: InSight VBB EM under assembly

7. 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
- TRL6 Level scheduled early 2013 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.