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GEMS (GEophysical Monitoring Station)

Banerdt B.(1) (PI), Smrekar S.(1) (Deputy PI), **Dehant V.**(2), Lognonné Ph.(3), Spohn T.(4), Grott M.(4), and the GEMS team: Asmar S. (JPL), Banfield D. (Cornell), Boschi L. (ETH), Christensen U. (MPS), Folkner W. (JPL), Garcia R. (IRAP), Giardini D. (ETH), Goetz W. (MPS), Golombek M. (JPL), Hudson T. (JPL), Johnson C. (UBC), Kargl G. (IWF), Kobayashi N. (JAXA), Maki J. (JPL), Mimoun D. (ISAE), Mocquet A. (U Nantes), Morgan P. (NAU), Panning M. (U Florida), Pike T. (ICL), Tromp J. (Princeton), van Zoest T. (DLR), Weber R. (USGS), Wieczorek M. (IPGP)
(1) Jet Propulsion Laboratory, Caltech, Pasadena, USA, (2) Royal Observatory of Belgium, Brussels, Belgium, (3) Institut de Physique du Globe, Paris, France, (4) Institute of Planetary Research, DLR, Berlin, Germany
(v.dehant@oma.be / Tel: +32-2-3730266 / Fax: +32-3-3749822)

Abstract

The GEMS (GEophysical Monitoring Station) is one of three missions undergoing Phase A development for possible selection by NASA's Discovery Program [1]. If selected, GEMS will illuminate the fundamental processes of terrestrial planet formation and evolution by performing the first comprehensive surface-based geophysical investigation of Mars. It will provide key information on the composition and structure of an Earth-like planet that has gone through most of the evolutionary stages of the Earth up to, but not including, plate tectonics. Thus the traces of this history are still contained in the basic parameters of the planet: the size, state and composition of the core, the composition and layering of the mantle, the thickness and layering of the crust, and the thermal flux from the interior.

1. Introduction

Historically, our fundamental understanding of the interior of the Earth has come from geophysics, geodesy, geochemistry, geomagnetism, and petrology. The geophysical measurements of seismology, geodesy, magnetic field and surface heat flow have revealed the basic internal layering of the Earth, its thermal structure, its gross compositional stratification, as well as significant lateral variations in these quantities. In addition to geophysics, the mission will provide important constraints for the astrobiology of Mars by constraining the dynamics of magnetic field generation early in Mars' history (with implications for atmospheric retention), by helping to understand the evolution of the atmosphere through volcanic outgassing, and by illuminating the possibilities of a chemoautrophic biosphere through a measurement of the subsurface thermal gradient.

2. Scientific Goals

The scientific goals of GEMS are to understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars and to determine its present level of tectonic activity and impact flux. A straightforward set of scientific objectives address these goals: 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; measure the rate and distribution of internal seismic activity; and measure the rate of impacts on the surface.

4. Instrumentation

GEMS will delineate these parameters for Mars with a focused set of investigations centered on seismology and supported by precision tracking and heat flow measurements. Rather than relying on a multi-station network to provide this information, GEMS will utilize state-of-the-art analysis techniques to derive interior information from a single station on the surface carrying three scientific instruments: SEIS [2], a six-component very-broad-band seismometer, with careful thermal compensation/ control and a sensitivity comparable to the best terrestrial instruments across a frequency range of 1 mHz to 50 Hz; RISE [3] (Rotation and Interior Structure Experiment), which uses the spacecraft X-band communication system to provide precision tracking for planetary dynamical studies; and HP^3 [4] (Heat Flow and Physical Properties Package), an instrumented self-penetrating mole system that trails a string of temperature sensors to measure the planetary heat flux through thermal gradient and conductivity measurements. A robotic arm and camera will be used to deploy the seismometer and heat flow instruments to the ground, and atmospheric sensors will monitor the ambient wind and air temperature in order to separate environmental noise from seismic signals. The instrumentation is represented in Figure 1 and Table 1 summarizes the payload element contributions.

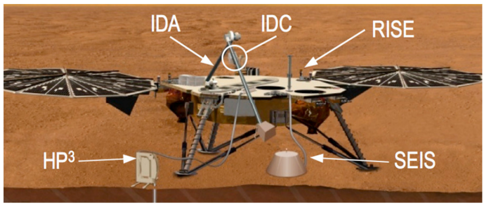

Figure 1: GEMS architecture.

Table 1: Focused Science Payload

Payload	Mission Contribution
SEIS	Measure seismic waves traveling through the interior to determine interior structure and composition
RISE	Determine precession, nutations, and wobble to constrain interior structure
HP^3	Investigate the thermal evolution and mechanisms of heating/cooling
IDA	Deploys the SEIS and HP^3 to surface
IDC	Supports deployment of SEIS and HP^3

It is widely believed that multiple landers making simultaneous measurements (a network) are required to address the objectives for understanding terrestrial planet interiors. However comprehensive measurements from a single geophysical station can be used to determine the first-order divisions of a terrestrial planet interior (crust, mantle, core). GEMS will utilize sophisticated analysis techniques specific to single-station measurements such as first motion analysis, receiver functions, surface wave dispersion, normal modes, tidal deformation, polarization and correlation techniques. These results will be combined with measurements of rotational variations (which are sensitive to radial variations in density and strength) and heat flow (which can be related to such things as the state of the core and the viscosity of the mantle).

6. Summary and Conclusions

The GEMS mission will fill a longstanding gap in the scientific exploration of the solar system by performing an in-situ investigation of the interior of an Earth-like planet other than our own. It will provide unique and critical information about the fundamental processes of terrestrial planet formation and evolution.

These goals will be reached with three instruments (see Figure 1): (1) Seismic Experiment for Interior Structure (SEIS), (2) Rotation and Interior Structure Experiment (RISE), (3) Heat Flow and Physical Properties Package (HP^3), as well as two payload elements that will deploy these instruments: (4) Instrument Deployment Arm (IDA), and (5) Instrument Deployment Camera (IDC).

This investigation has been ranked as a high priority in virtually every set of European, US and international high-level planetary science recommendations for the past 30 years, including the recently released Decadal Survey for Planetary Exploration [5] [6].

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