InSight
Geophysical Mission to Mars

W. Bruce Banerdt

4 October, 2012
InSight Science Team

**PI: Bruce Banerdt, JPL**
- Sami Asmar, JPL
- Don Banfield, Cornell
- Lapo Boschi, ETH
- Ulrich Christensen, MPS
- Véronique Dehant, ROB

**RISE PI: Bill Folkner, JPL**
- Domenico Giardini, ETH
- Walter Goetz, MPS
- Matt Golombek, JPL
- Matthias Grott, DLR
- Troy Hudson, JPL
- Catherine Johnson, UBC
- Günter Kargl, IWF

**Dep. PI: Sue Smrekar, JPL**
- Naoki Kobayashi, JAXA

**SEIS PI: Philippe Lognonné, IPGP**
- Justin Maki, JPL
- David Mimoun, SUPAERO
- Antoine Mocquet, Univ. Nantes
- Paul Morgan, Colo. Geol. Surv.
- Mark Panning, Univ. Florida
- Tom Pike, Imperial College

**HP³ PI: Tilman Spohn, DLR**
- Jeroen Tromp, Princeton
- Tim van Zoest, DLR
- Renée Weber, MSFC
- Mark Wieczorek, IPGP
To understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars.

Directly addresses the 2011 Decadal Survey objective to “understand the origin and diversity of terrestrial planets”.

InSight is a terrestrial planets explorer that just happens to be going to Mars…
Mars is Key to Understanding Early Formation of Terrestrial Planets, Including Rocky Exoplanets

Terrestrial planets all share a common structural framework …

But Mars is uniquely well-suited to study the common processes that early-on shaped all rocky planets and govern their basic habitability.

- There is evidence that its basic crust and mantle structure have survived little changed from the first few hundred Myr of formation.
- Its surface is much more accessible than Mercury, Venus.
- Our knowledge of its geology, chemistry, climate history provides a rich scientific context for using interior information to increase our understanding of the solar system.

4 October, 2012 MEPAG Meeting — Monrovia, CA
• Because of vigorous mantle convection and plate tectonics, the Earth has lost virtually all structural evidence reflecting its differentiation and early evolution.

• Mars likely retains such evidence in its lateral and radial compositional variations.
  – SNC isotopic analyses indicate that isolated melt source regions have persisted since early in Mars’ history, suggesting that mantle convection has been insufficiently vigorous to homogenize the mantle.
  – Noble gas measurements indicate that only ~3% of Ar produced from $^{40}$K has been degassed from Mars’ mantle, compared to >50% for the Earth.
  – Much of the martian crust dates to the first half billion years of solar system history (or earlier).

• Therefore, investigations of the martian interior are likely to find structures that still reflect differentiation and early planetary formation processes.
• **Crust:** Its **thickness** and vertical structure (layering of different compositions) reflects the depth and crystallization processes of the magma ocean and the early post-differentiation evolution of the planet (plate tectonics vs. crustal overturn vs. immobile crust vs. ...).

• **Mantle:** Its behavior (e.g., convection, partial melt generation) determines the manifestation of the thermal history on a planet’s surface; depends directly on its **thermal structure** and **stratification**.

• **Core:** Its **size** and composition (density) reflect conditions of accretion and early differentiation; its **state** (liquid vs. solid) reflects its composition and the thermal history of the planet.
Focused Set of Measurements

- InSight capitalizes on advances in technology and analysis to enable results that previously required 4 stations and >$1B.

  - **Single-Station Seismology**
    - Extremely sensitive, broad-band instrument
    - Surface installation and effective environmental isolation
    - Single-station seismic analysis techniques
    - Multiple signal sources

  - **Precision Tracking**
    - Sub-decimeter (~2 cm) X-band tracking

  - **Heat Flow**
    - Innovative, self-penetrating mole penetrates to a depth of 3–5 meters
Science Payload

RISE (S/C Telecom)
Rotation and Interior Structure Experiment

HP³ (DLR)
Heat Flow and Physical Properties Probe

SEIS (CNES)
Seismic Experiment for Interior Structure

IDA (JPL) – Instrument Deployment Arm
IDC (JPL) – Instrument Deployment Camera
ICC (JPL) – Instrument Context Camera

MEPAG Meeting — Monrovia, CA
Martian Seismology – SEIS

Multiple Analysis Techniques

Normal Modes

Surface Wave Dispersion

Crustal Thickness

15 km

35 km

75 km

55 km

Frequency, mHz

Group velocity, km/s

Background ‘Hum’

Arrival Time Analysis

Faulting

Atmospheric Excitation

Phobos Tide

Receiver Function

Multiple Signal Sources

Multiple Analysis Techniques

Emergent analysis

Permeated by global processes

Arrival Time Analysis

Phobos Tide

Impact Crater

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• First measured constraint on Mars core size came from combining radio Doppler measurements from Viking and Mars Pathfinder
  – Viking (1977) and Pathfinder (1997) tracking determined the directions of the spin axis 20 years apart
  – Difference of spin axis direction gave precession rate and hence planet’s moment of inertia (constrains mean mantle density, core radius and density)

• InSight will provide another snapshot of the axis another 20 years later

• With 2 years of tracking data, it will be possible to determine nutation amplitudes
  – Free core nutation constrains core MOI directly, allowing separation of radius and density.
Heat Flow Measurement – HP³

- HP³ (Heat Flow and Physical Properties Probe) has a self-penetrating “mole” that burrows up to 5 meters below the surface.
  - It trails a tether containing precise temperature sensors every ~30 cm to measure the temperature profile of the subsurface.
  - The mole contains a heater to determine thermal conductivity during descent.

- Together, these yield the rate of heat flowing from the interior.
- Present-day heat flow at a given location provides a critical boundary condition on models of planetary thermal history.

Surface Heat Flow Model (mW/m²)
Mission Overview

- 20-day launch period opens on 8 March 2016
  - Constant Arrival Date of 20-Sep-2016

- Type 1 transfer from Earth-to-Mars with 6.5-month Cruise Phase

- Direct entry, deceleration using heat shield and parachute, final descent on thrusters

- Landing in western Elysium Planitia

- Surface deployment of instruments during first 60 sols.

- Full Mars year of surface science operations
InSight Landing Region – Western Elysium Planitia
• InSight will fly a near-copy of the successful Phoenix Flight System
  – System (including hardware, procedures, and personnel) has already operated on Mars
  – Only minor changes required for InSight
Surface Deployment and Operations

- Surface installation is critical for achieving InSight’s science.
- After landing the instruments are still ~1 m from the ground.
- The 60-sol Surface Deployment Phase completes this process.

- Seismometer installation achieves direct ground contact and environmental isolation.
- HP³ deployment positions the mole for penetration 3-5 meters beneath the surface of Mars.
InSight Timeline

• Aug. 20, 2012    Selection
• Aug. 29, 2012    Begin Phase B
• Aug. 13, 2013    PDR
• May 6, 2014      CDR
• Nov. 4, 2014     Start ATLO
• Jan. 9, 2015     Deliver Instruments
• Dec. 7, 2015     Ship to Cape
• Mar. 8-28, 2016  Launch (3 years, 5 months, 4 days!)
• Sept. 20, 2016   Mars Landing
• Sept. 12, 2018   End of Nominal Mission
Look deep into nature, and then you will understand everything better. – Albert Einstein

Gusev Crater
InSight
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Multiple Analysis Techniques

- Normal Modes
- Receiver Function
- Surface Wave Dispersion
- Background ‘Hum’
- Arrival Time Analysis

Multiple Signal Sources

- Faulting
- Phobos Tide
- Atmospheric Excitation
- Impacts

4 October, 2012
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InSight Landing Region – Western Elysium Planitia

Gale Crater
Cerberus Fossae
Elysium Mons
Utopia Planitia
Isidis
Gusev Crater

InSight Landing Region

Elevation
- > -2.5 km
Rock
Abundance (%)
IRT
< 5
< 10
< 10
< 12
< 13
< 14
TE8
< 2
< 5
< 7
< 10
< 13
< 14
Fresh Lava

4 October, 2012
Spacecraft

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