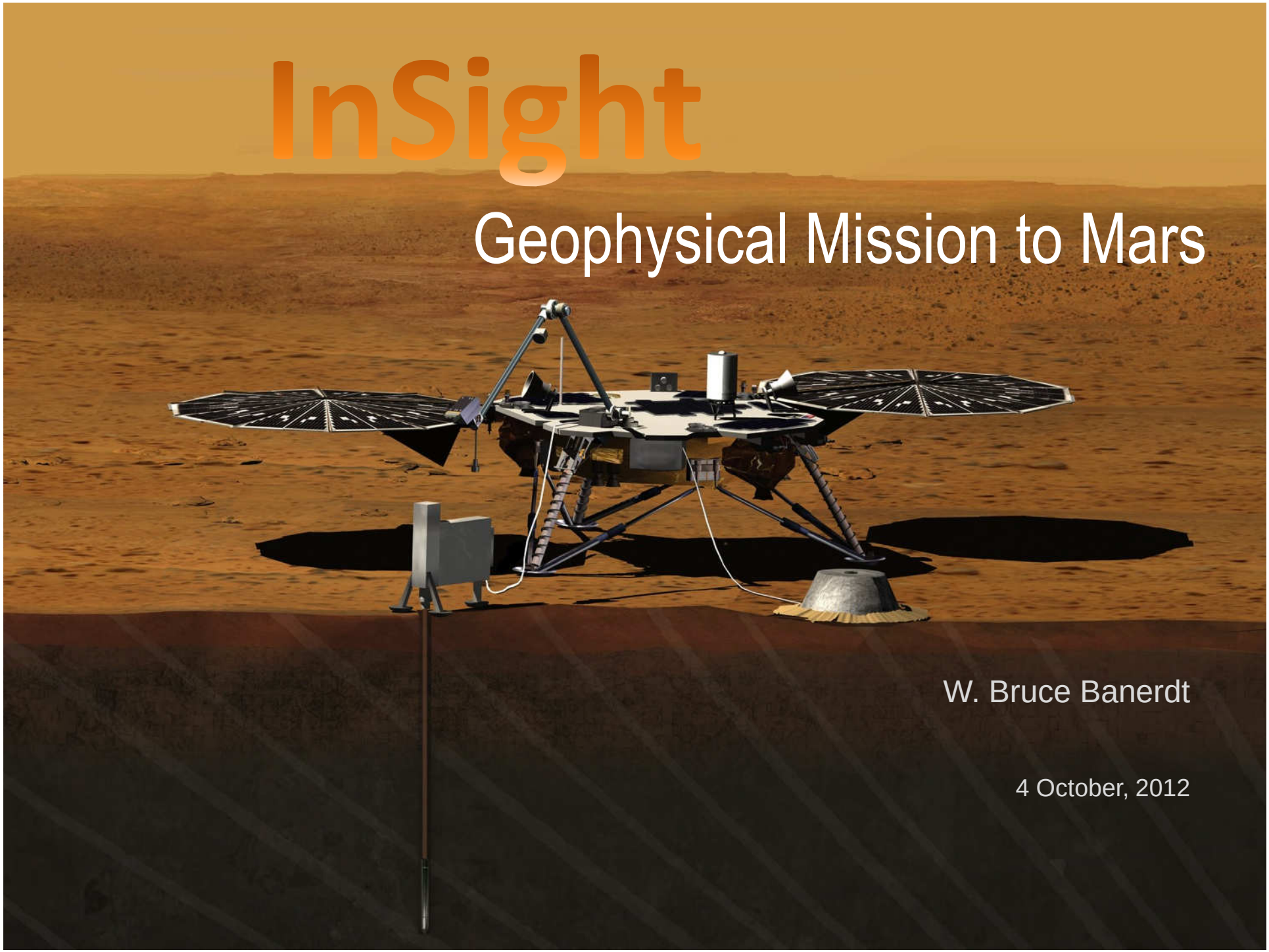
# InSight

## Geophysical Mission to Mars



W. Bruce Banerdt

4 October, 2012

# InSight Science Team

**PI: Bruce Banerdt, JPL**
Sami Asmar, JPL
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Lapo Boschi, ETH
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**RISE PI: Bill Folkner, JPL**
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Catherine Johnson, UBC
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**Dep. PI: Sue Smrekar, JPL**
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Justin Maki, JPL
David Mimoun, SUPAERO
Antoine Mocquet, Univ. Nantes
Paul Morgan, Colo. Geol. Surv.
Mark Panning, Univ. Florida
Tom Pike, Imperial College
**HP$^3$ PI: Tilman Spohn, DLR**
Jeroen Tromp, Princeton
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Mark Wieczorek, IPGP

# InSight Partner Organizations

JPL
Jet Propulsion Laboratory
California Institute of Technology

NASA ARC

NASA LaRC

LOCKHEED MARTIN

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Institut Supérieur de l'Aéronautique et de l'Espace

ETH
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Swiss Federal institute of Technology Zurich

cnes
CENTRE NATIONAL D'ÉTUDES SPATIALES

MPS

UNIVERSITY OF OXFORD

DLR

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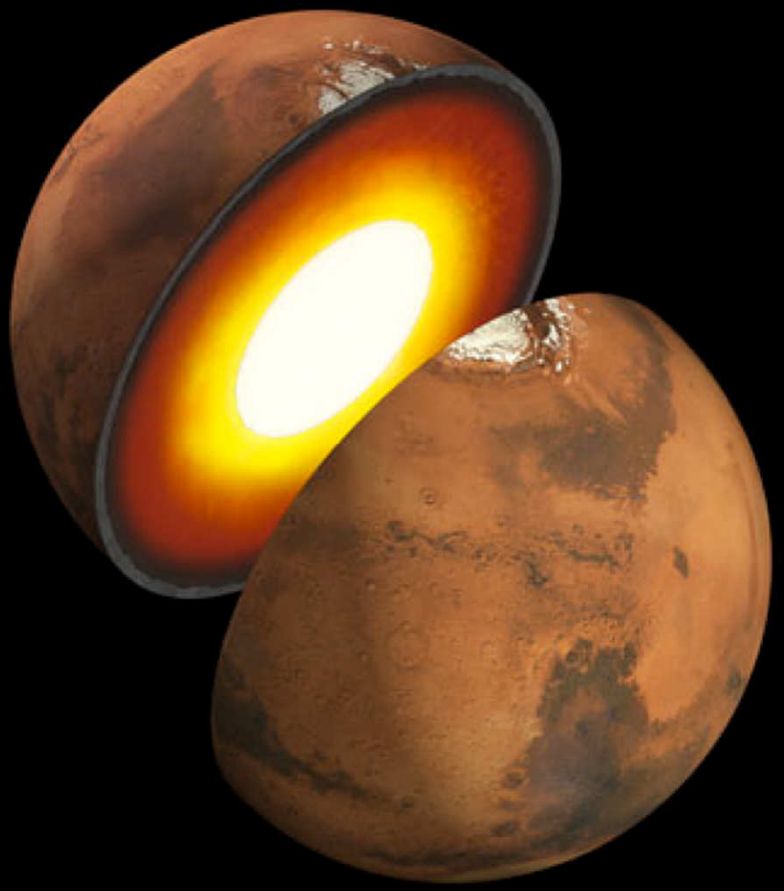
UK SPACE AGENCY

# InSight Science Goal

***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".

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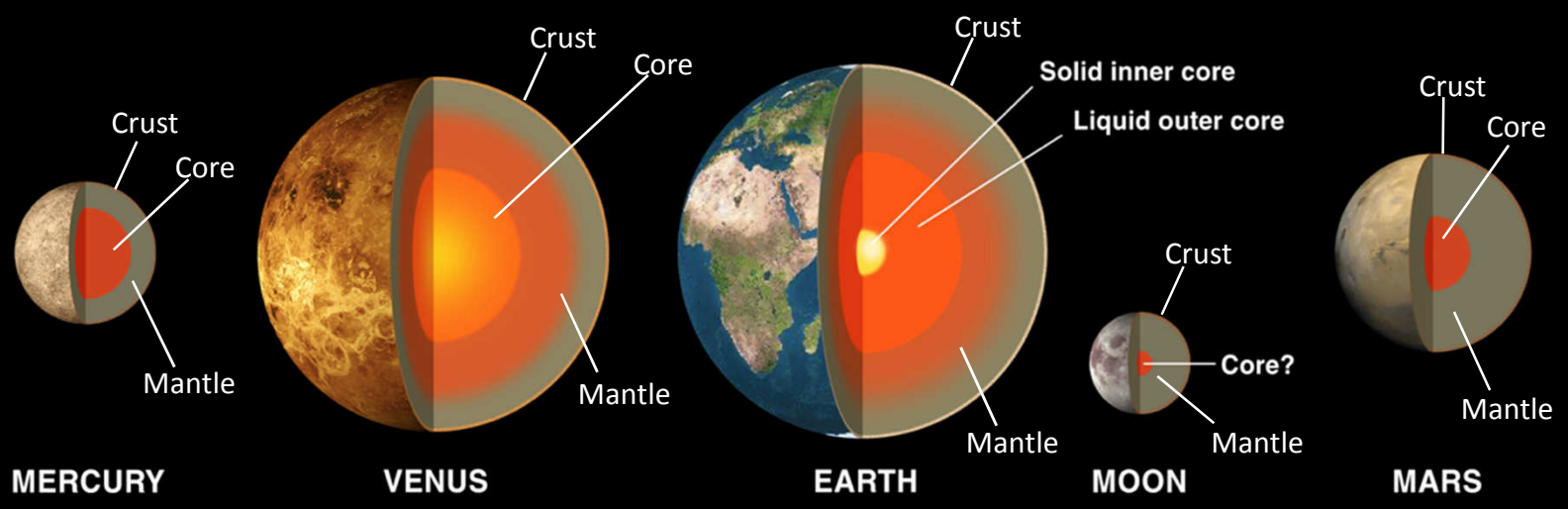
# Mars is Key to Understanding Early Formation of Terrestrial Planets, Including Rocky Exoplanets

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.

# What's So Special About Mars?

- 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.

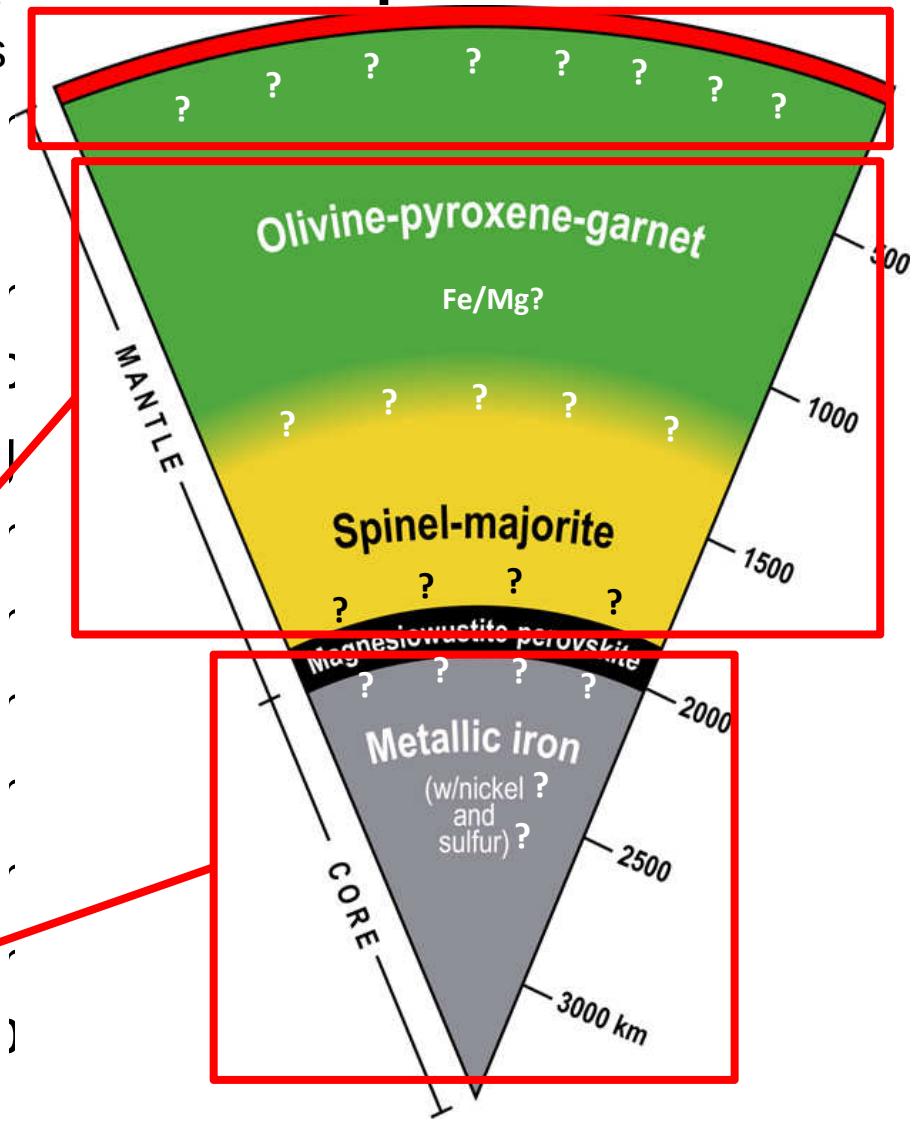
# Direct Linkage Between Science Objectives and Requirements

## Level 1 Requirements

- **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**.

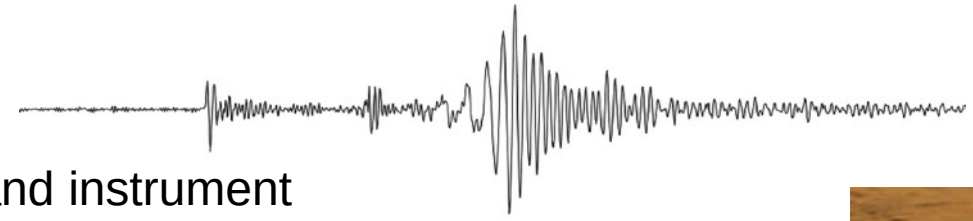
- **Core:** Its **size** and composition (**density**) reflect conditions of accretion and early differentiation; its **state** (liquid vs. solid) reflects its composition and the thermal history of the planet.



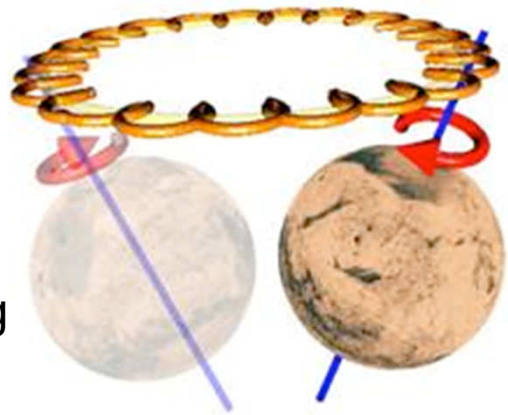
# Focused Set of Measurements

- 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

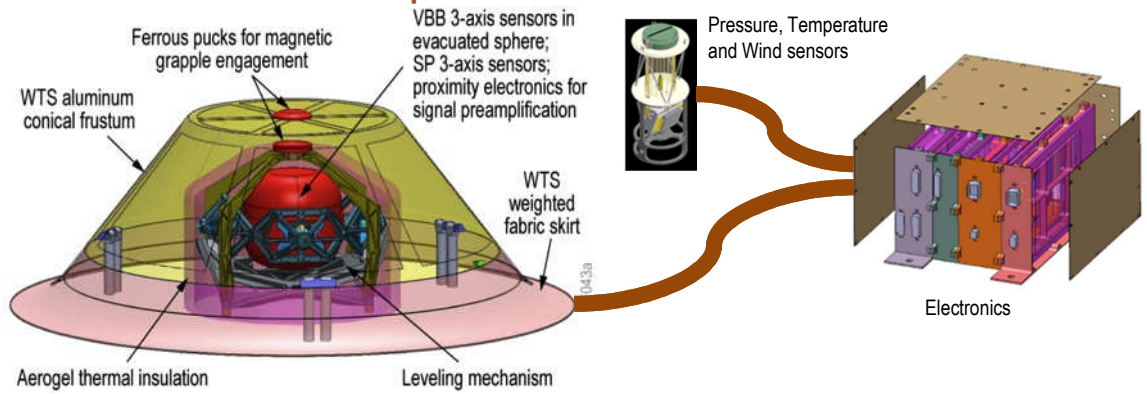
Small Deep Space Transponder

## RISE (S/C Telecom)

**Rotation and Interior Structure Experiment**

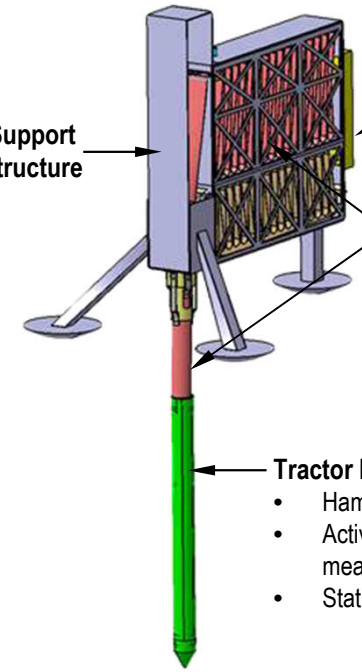
## SEIS (CNES) (also ETH/ESA, MPS/DLR, IC/Oxford/UKSA, JPL)

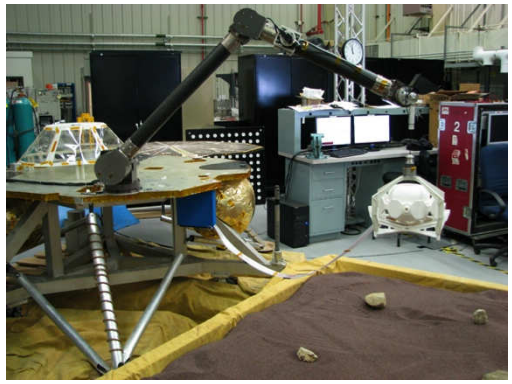
**Seismic Experiment for Interior Structure**




## HP$^3$ (DLR)

**Heat Flow and Physical Properties Probe**



**Surface Deployment Test Bed**

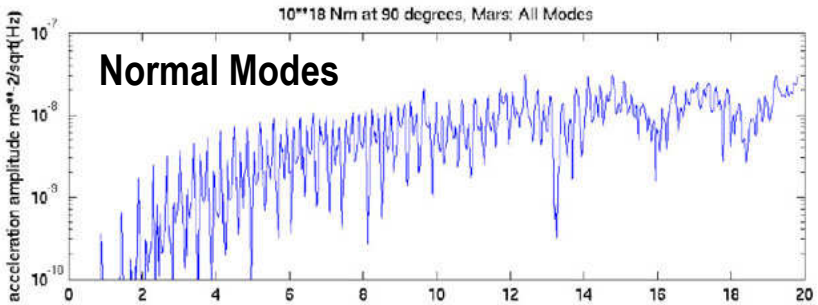
**IDA (JPL) – Instrument Deployment Arm)**

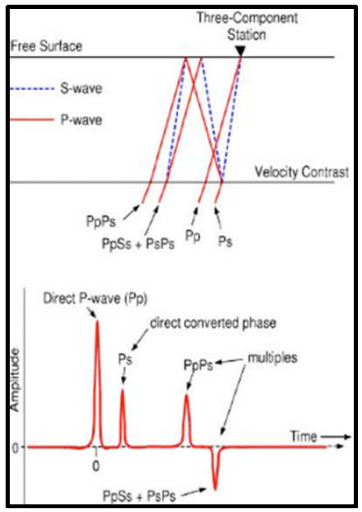
**IDC (JPL) – Instrument Deployment Camera)**

**ICC (JPL) – Instrument Context Camera)**

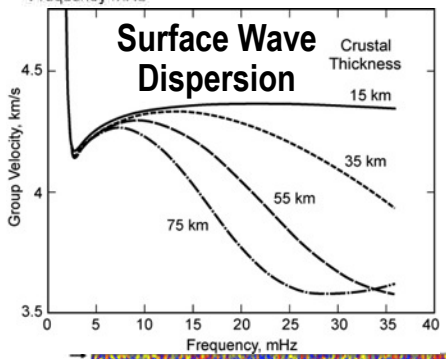
# Martian Seismology – SEIS

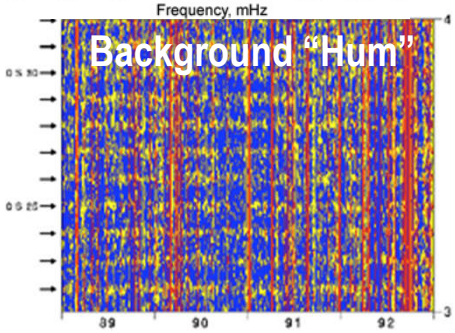
## Multiple Analysis Techniques

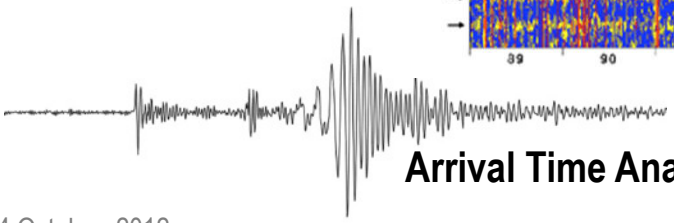



Receiver Function

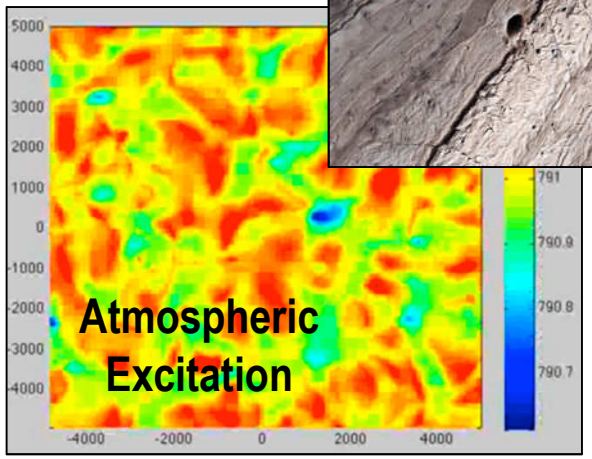


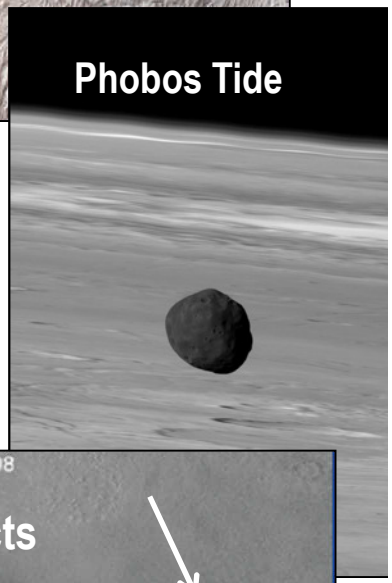



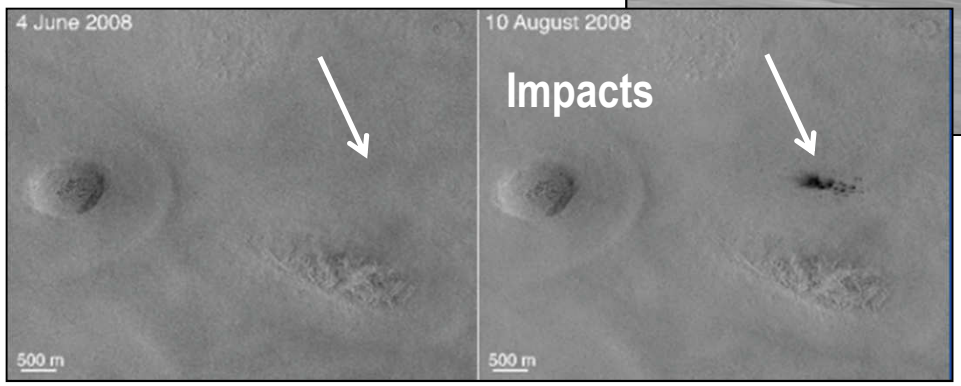



Arrival Time Analysis

## Multiple Signal Sources

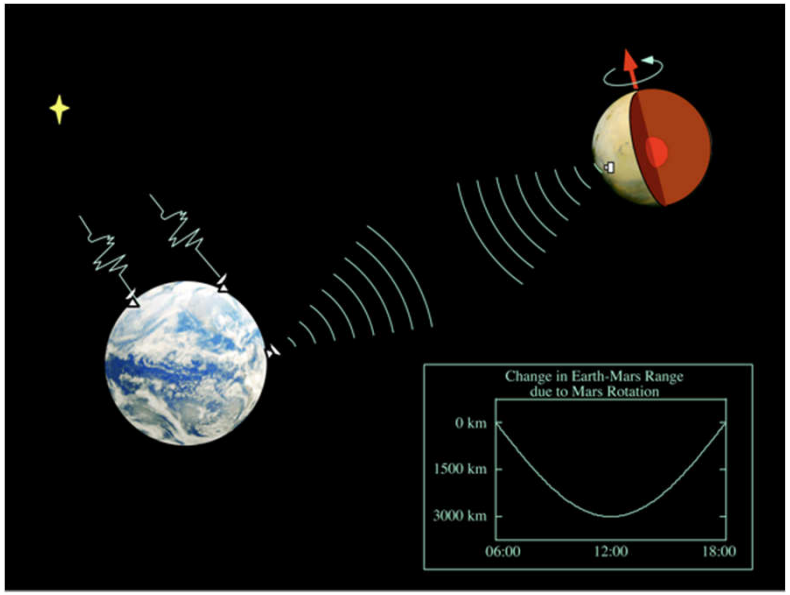


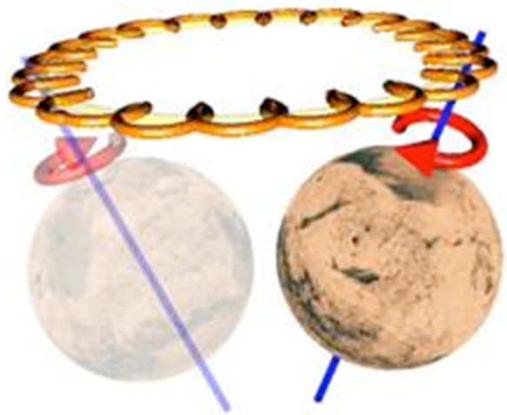



# Precision Radio Tracking – RISE

- 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.



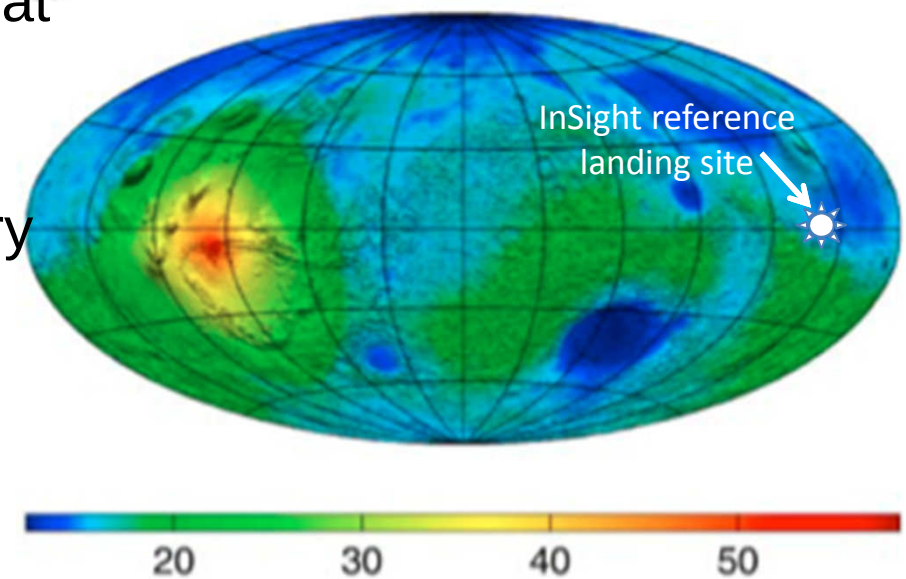

precession/nutation



# Heat Flow Measurement – HP$^3$

- HP$^3$ (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.

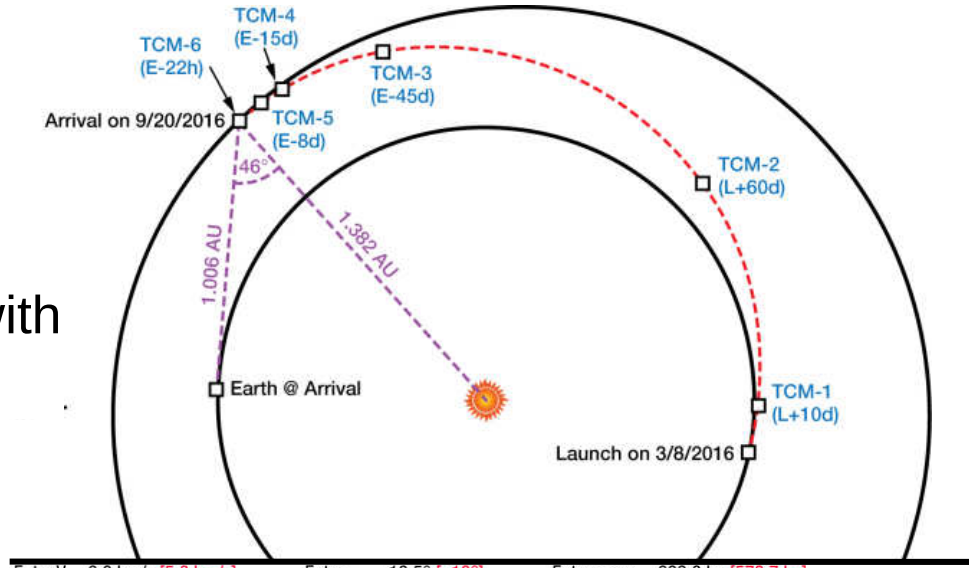
- Together, these yield the rate of heat flowing from the interior.
- Present-day heat flow at a given location provides a critical boundary condition on models of planetary thermal history.

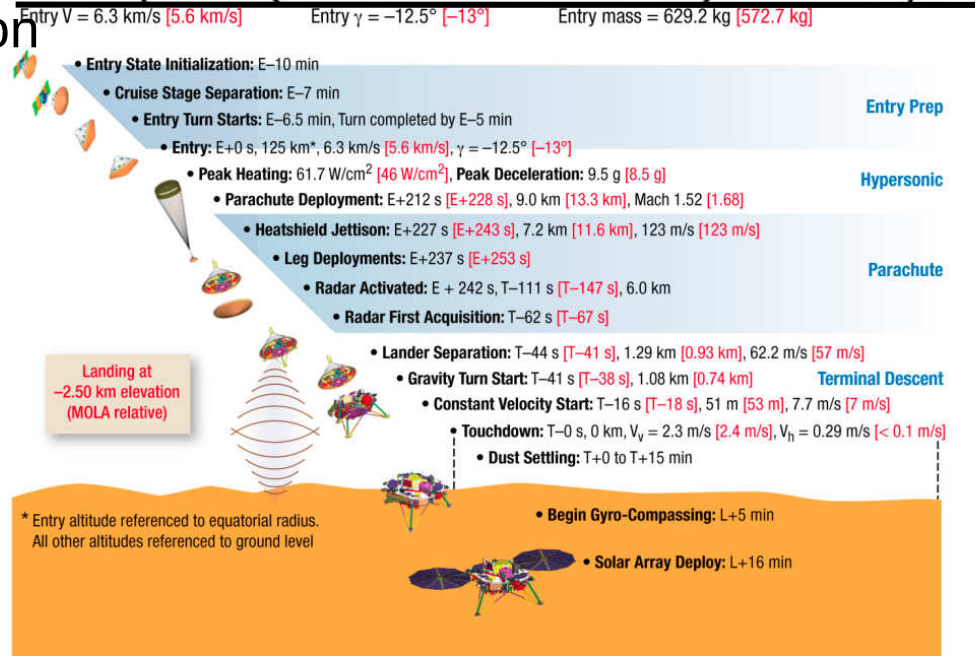



Surface Heat Flow Model (mW/m$^2$)

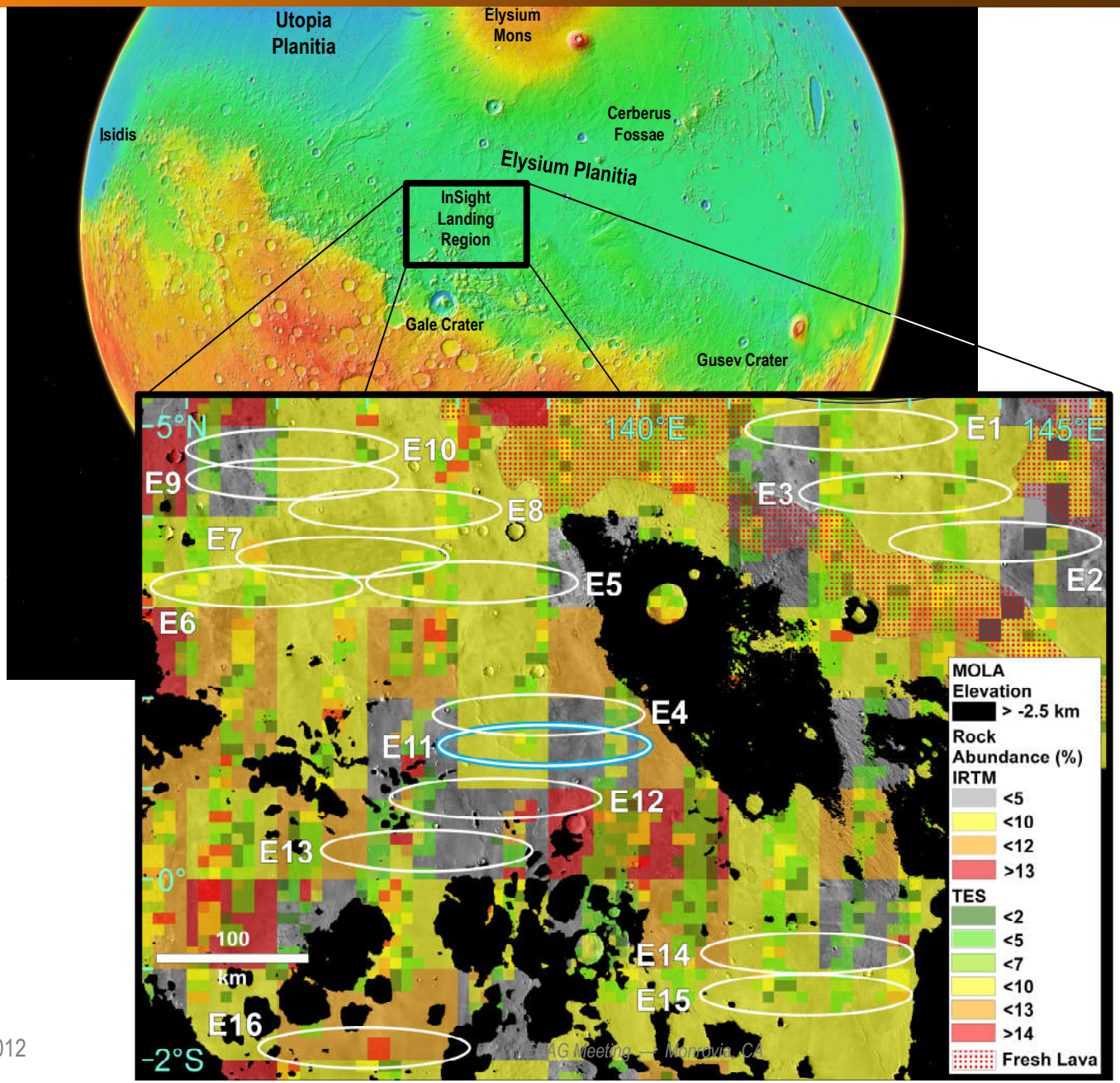
# Mission Overview

- 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



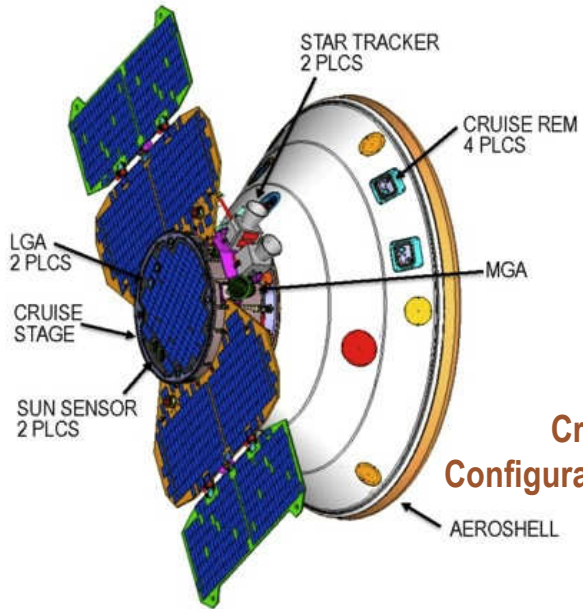



# InSight Landing Region – Western Elysium Planitia

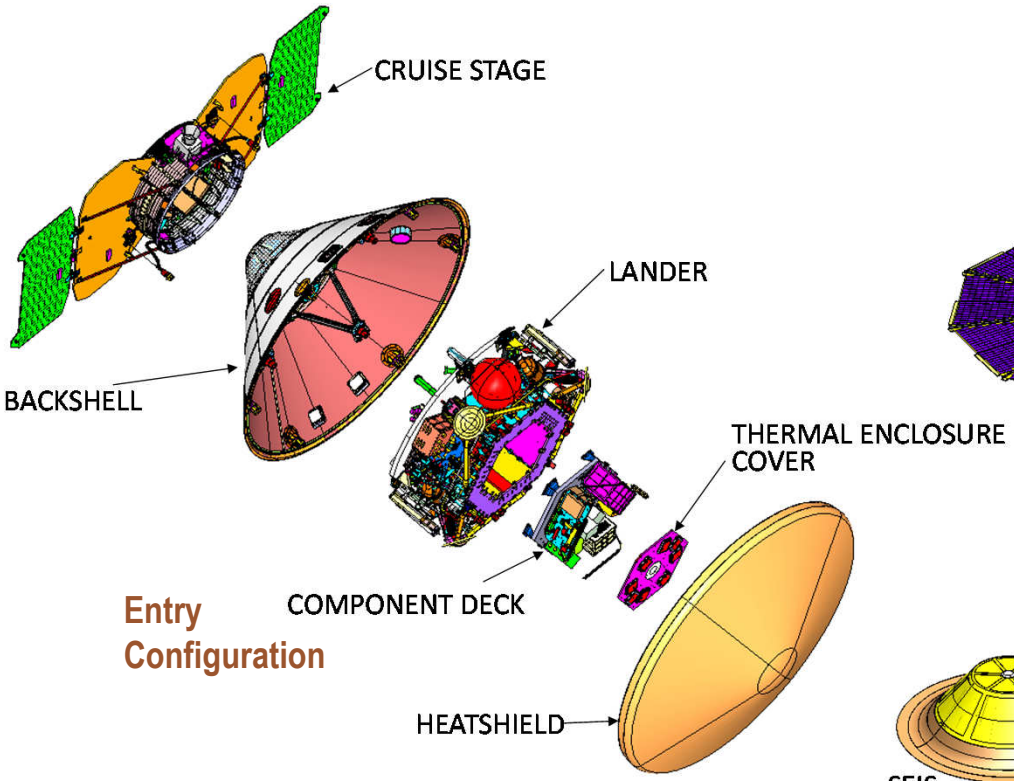


# Spacecraft

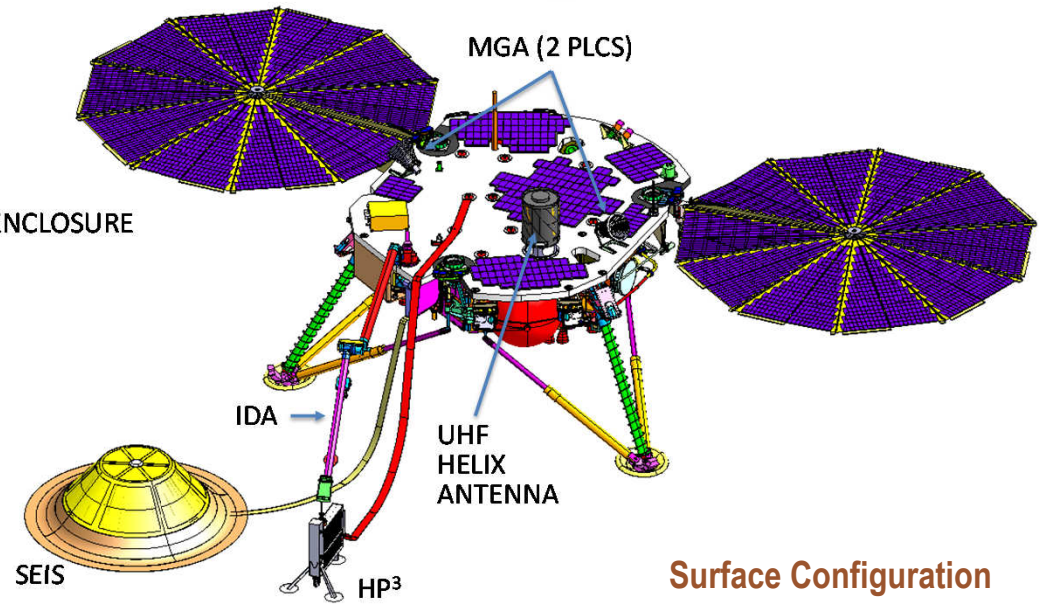
- InSight will fly a near-copy of the successful Phoenix Flight System
  - System (including hardware, procedures, and personnel) has already operated on Mars
  - Only minor changes required for InSight




Cruise Configuration



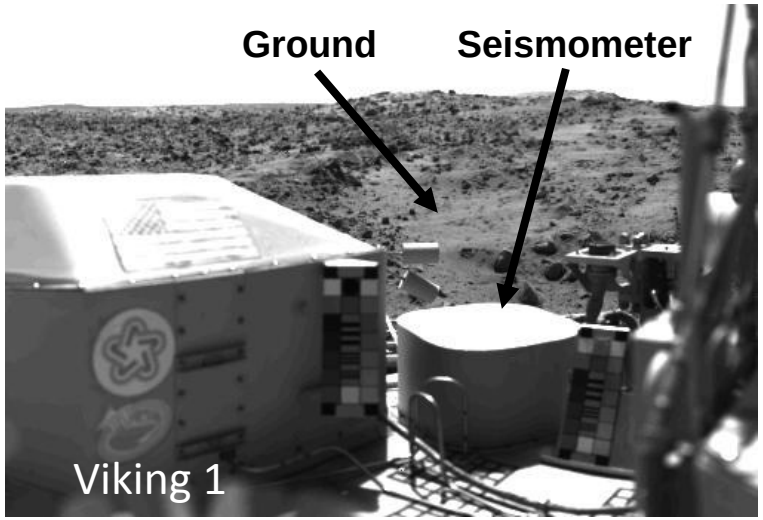

Entry Configuration

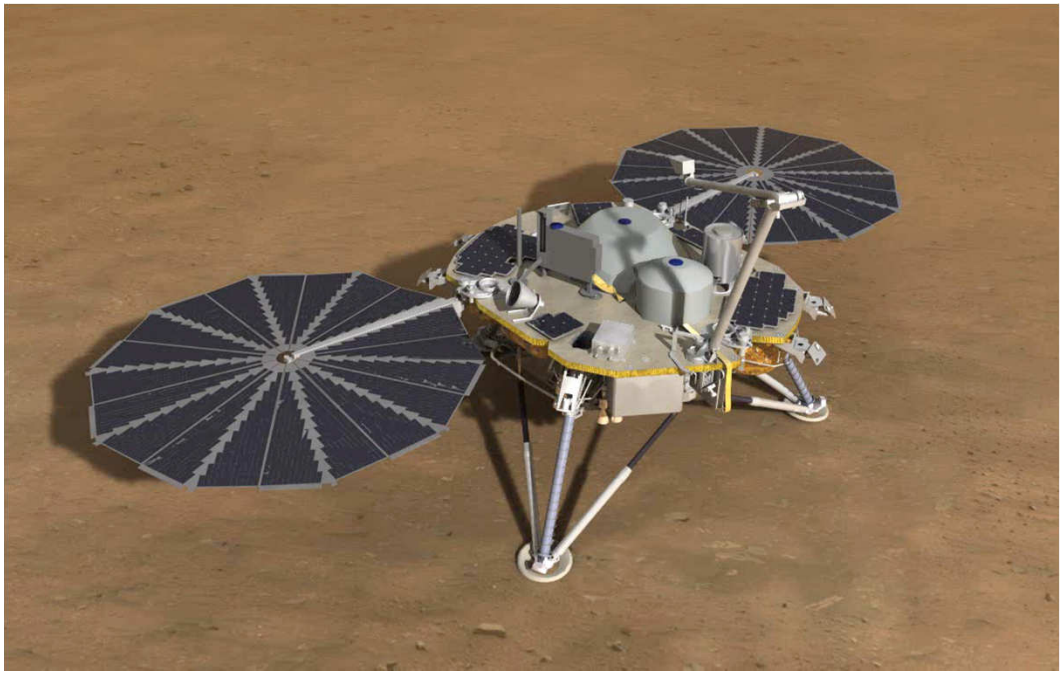



Surface Configuration

# 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.
- $HP^3$ 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

Earth, seen from Mars

**Look deep into nature, and then you will understand everything better. – Albert Einstein**

Gusev Crater

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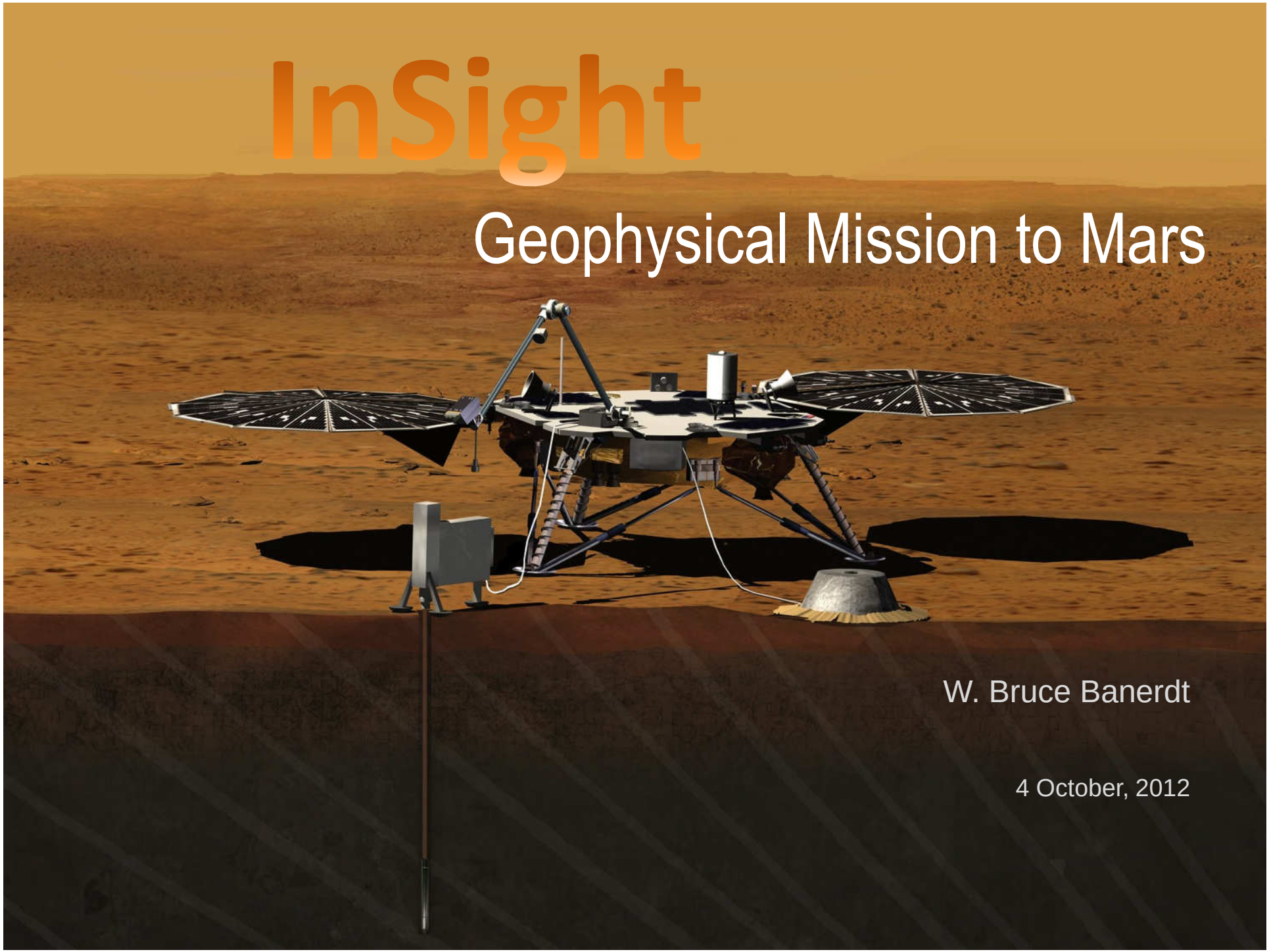

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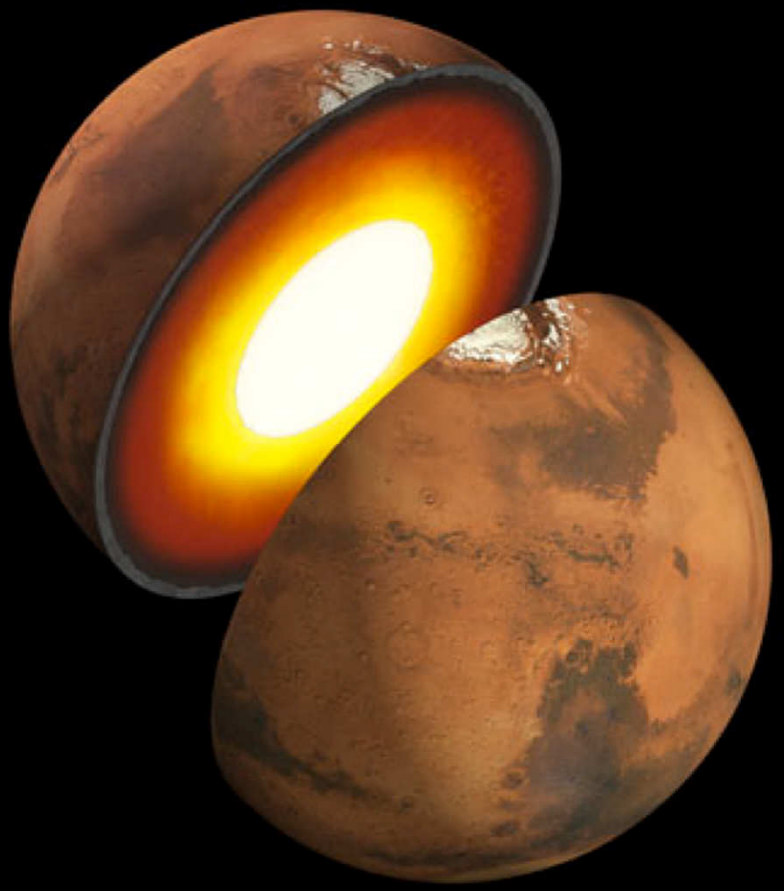

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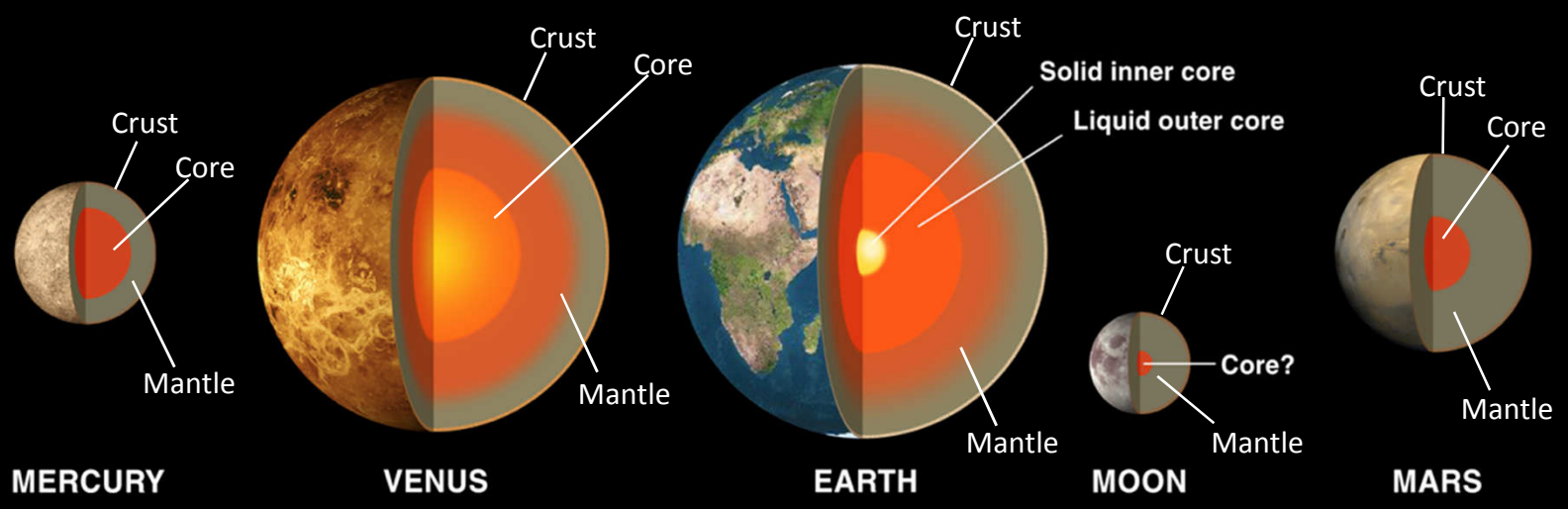


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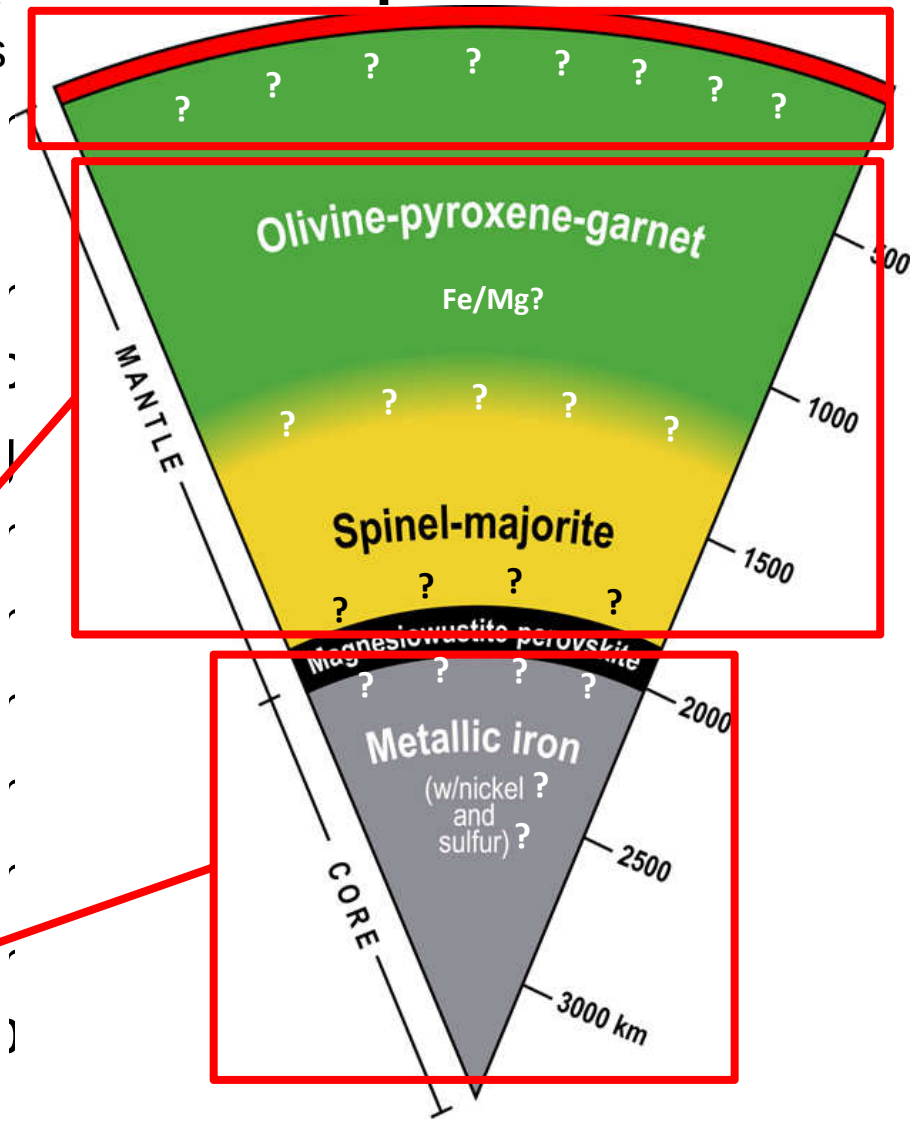

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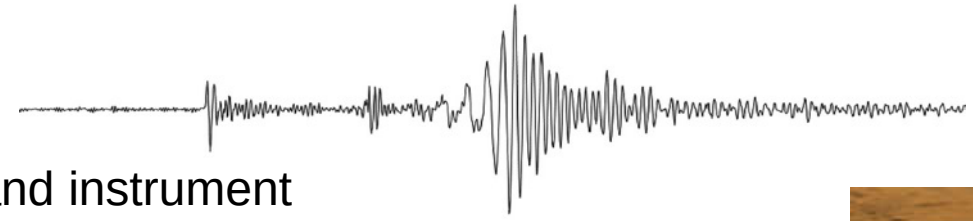

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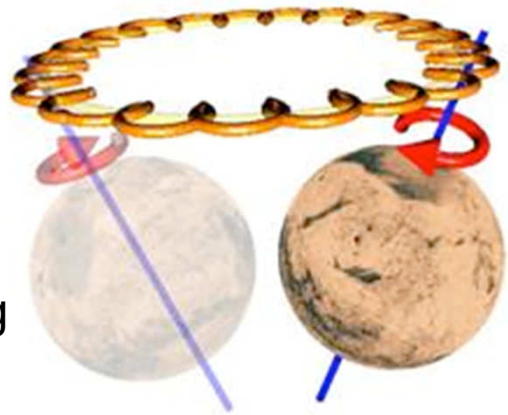

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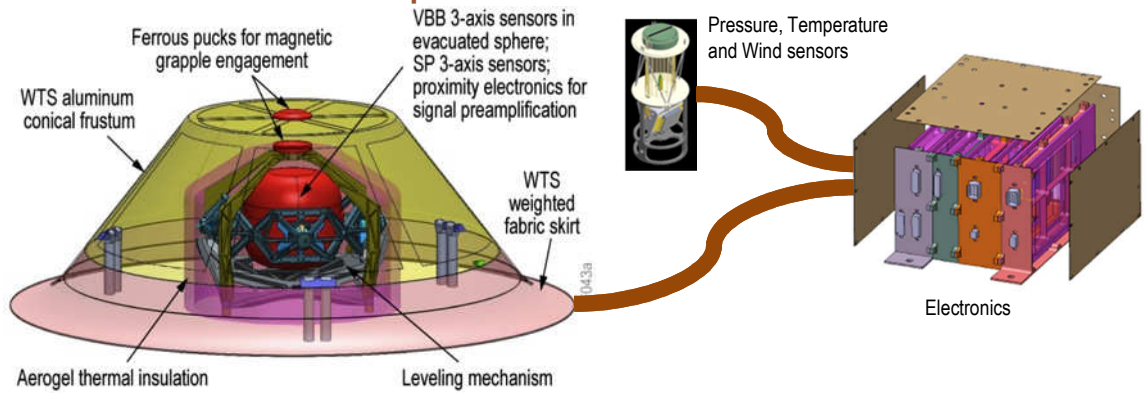


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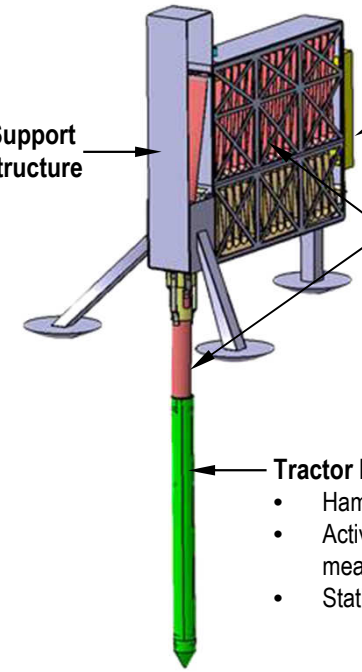
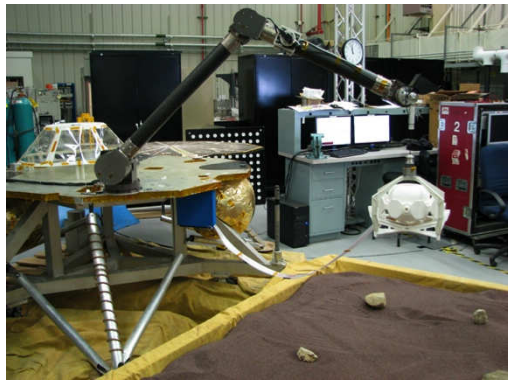
**Heat Flow and Physical Properties Probe**



**Surface Deployment Test Bed**

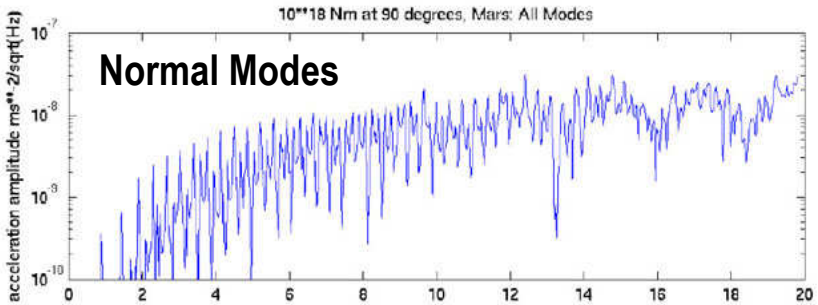
**IDA (JPL) – Instrument Deployment Arm)**

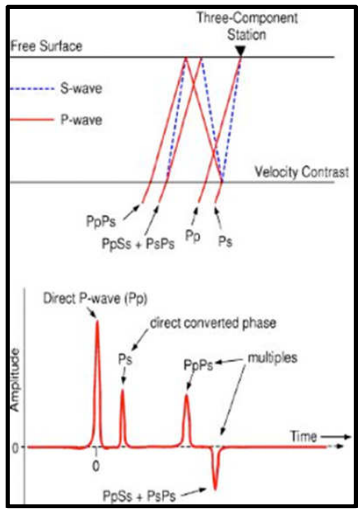
**IDC (JPL) – Instrument Deployment Camera)**

**ICC (JPL) – Instrument Context Camera)**

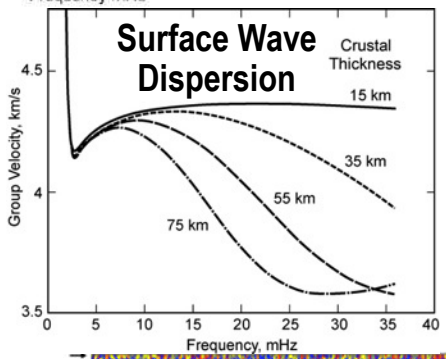
# Martian Seismology – SEIS

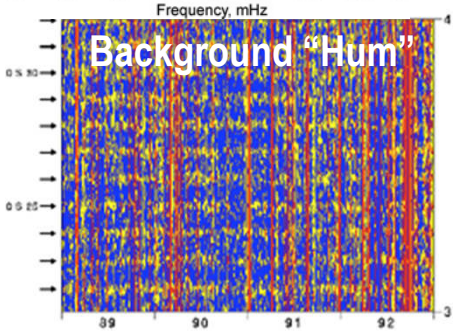
## Multiple Analysis Techniques

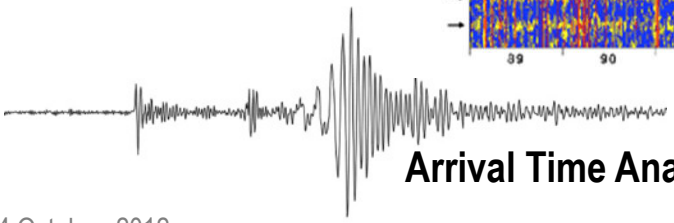



Receiver Function

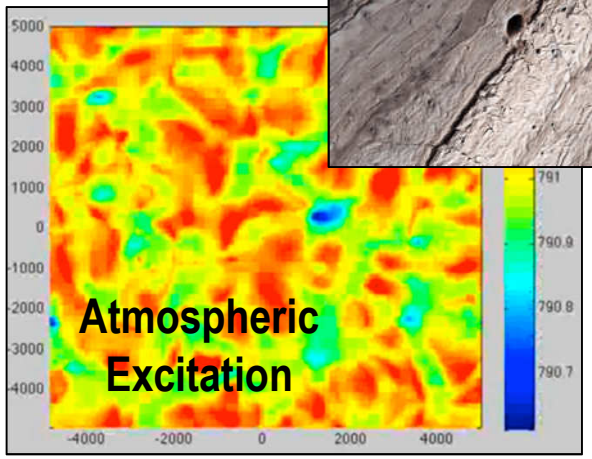


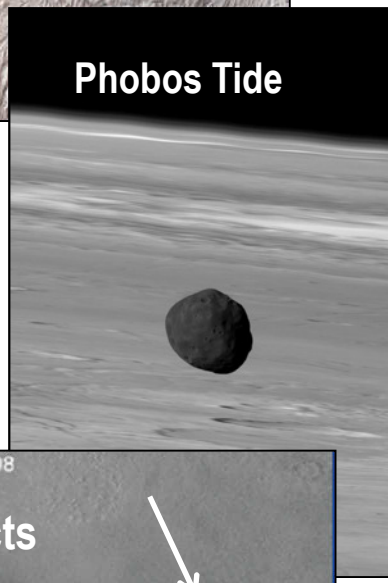



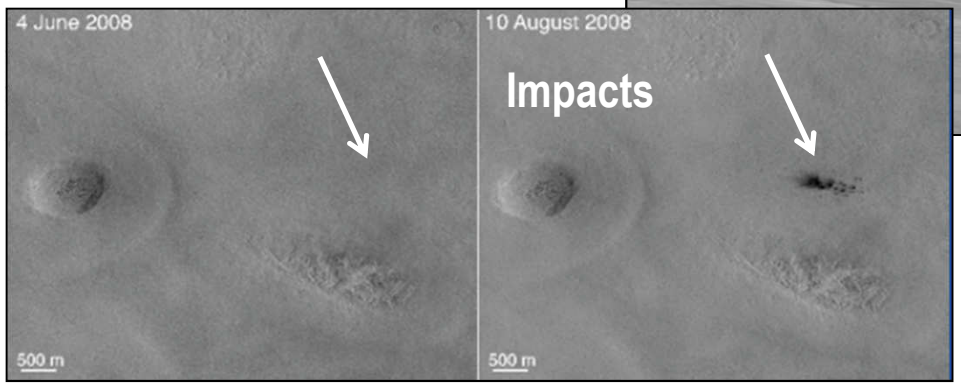



Arrival Time Analysis

## Multiple Signal Sources

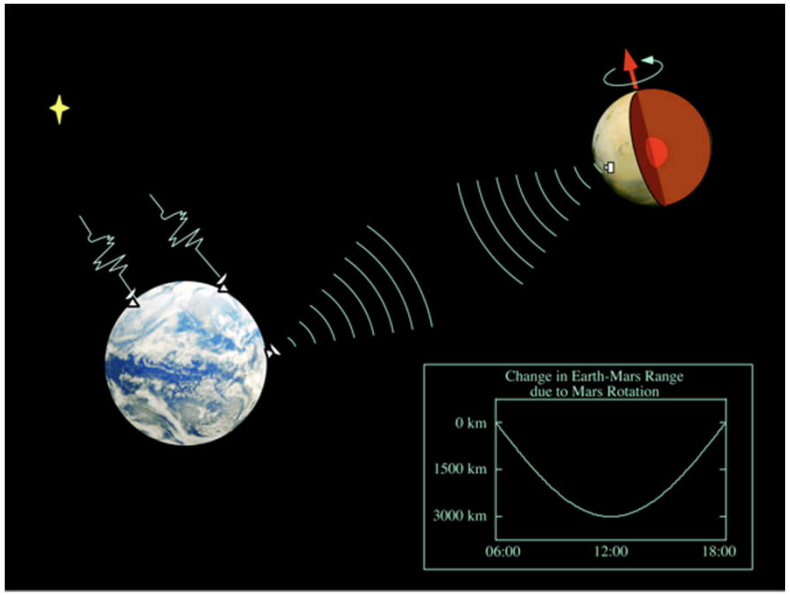


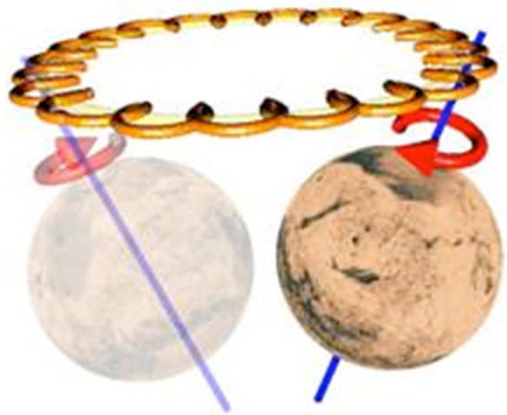



# Precision Radio Tracking – RISE

- 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.



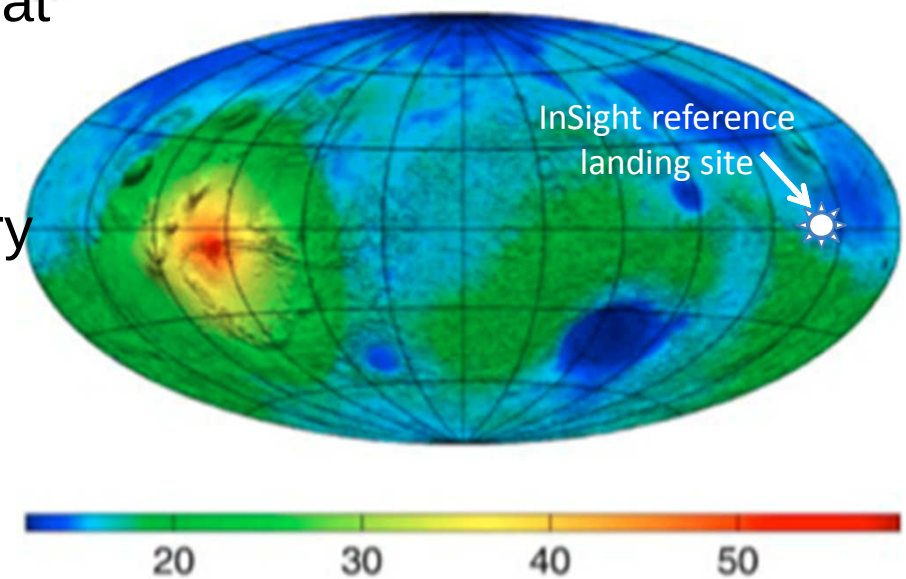

precession/nutation



# Heat Flow Measurement – HP$^3$

- HP$^3$ (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.

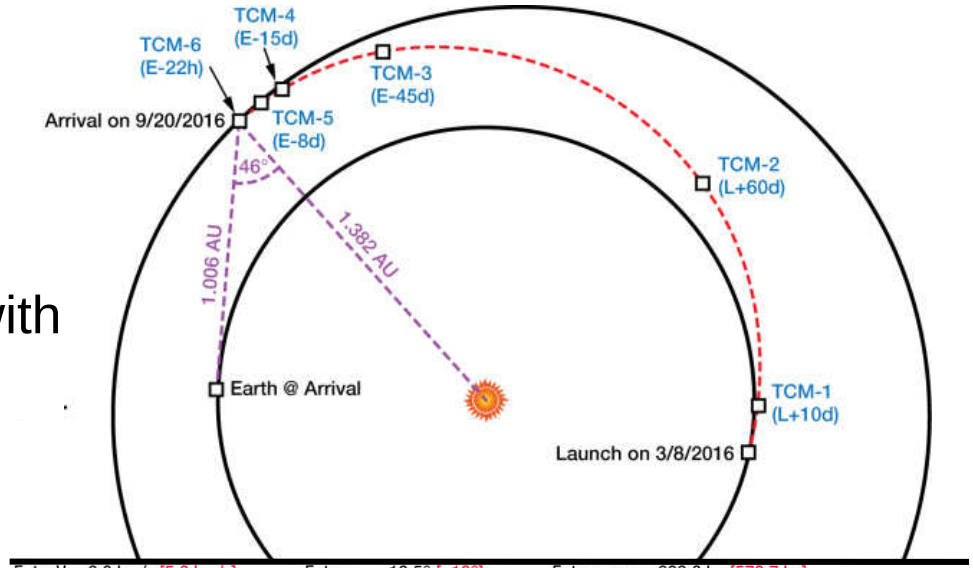
- Together, these yield the rate of heat flowing from the interior.
- Present-day heat flow at a given location provides a critical boundary condition on models of planetary thermal history.

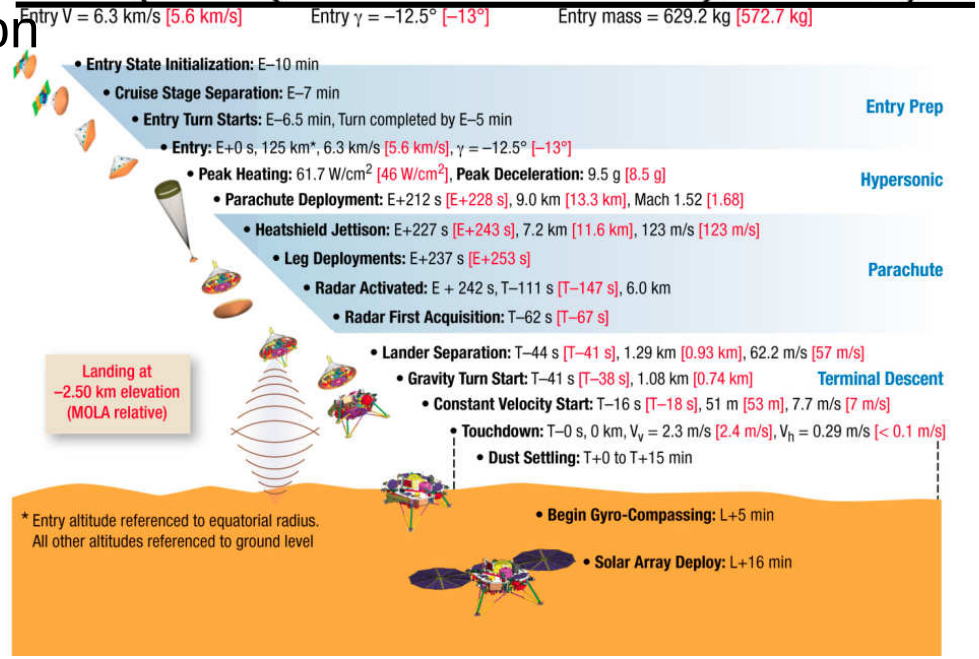



Surface Heat Flow Model (mW/m$^2$)

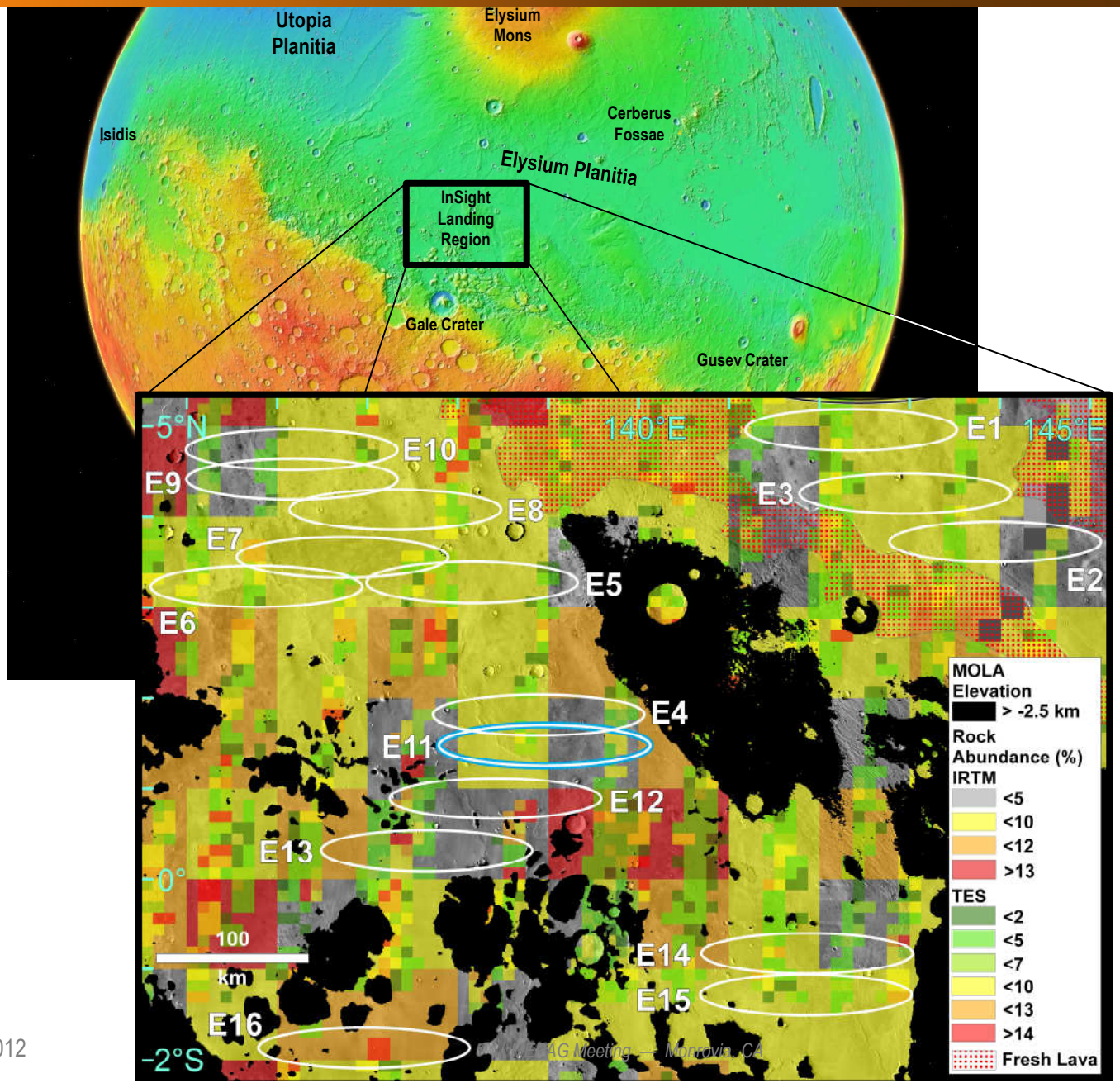
# Mission Overview

- 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



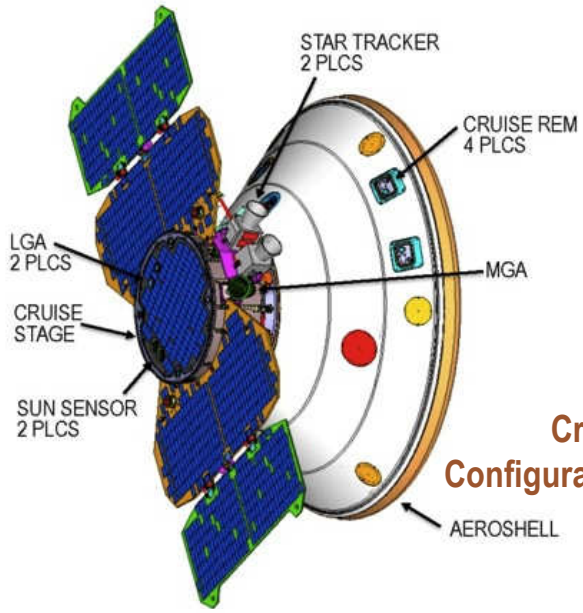



# InSight Landing Region – Western Elysium Planitia

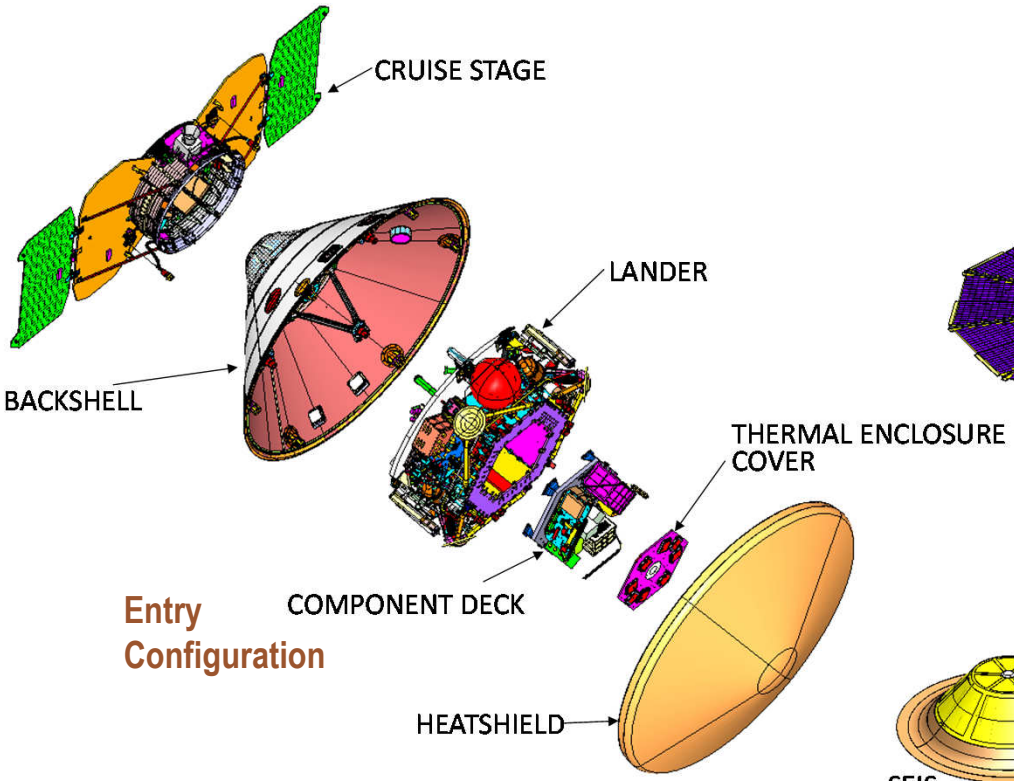


# Spacecraft

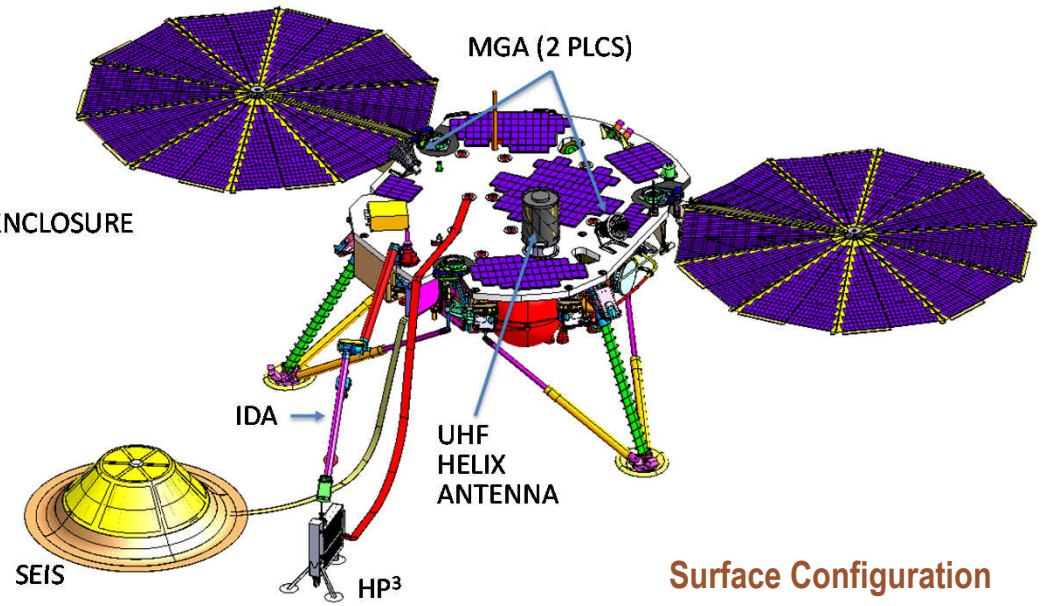
- InSight will fly a near-copy of the successful Phoenix Flight System
  - System (including hardware, procedures, and personnel) has already operated on Mars
  - Only minor changes required for InSight




Cruise Configuration



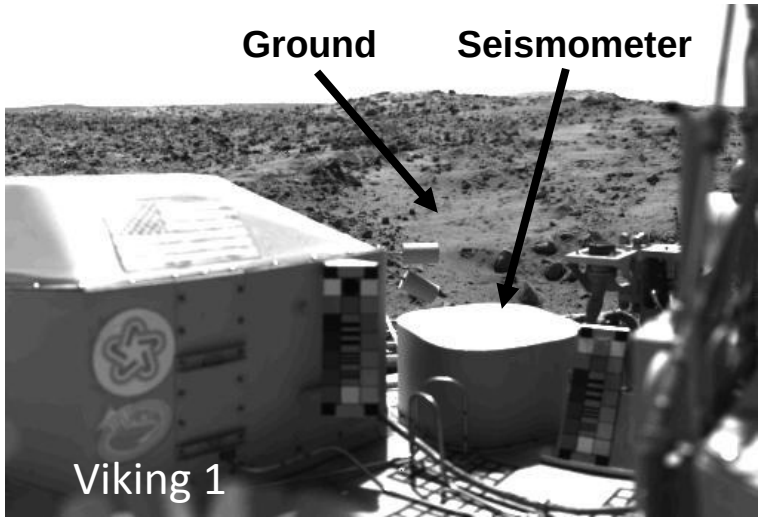

Entry Configuration

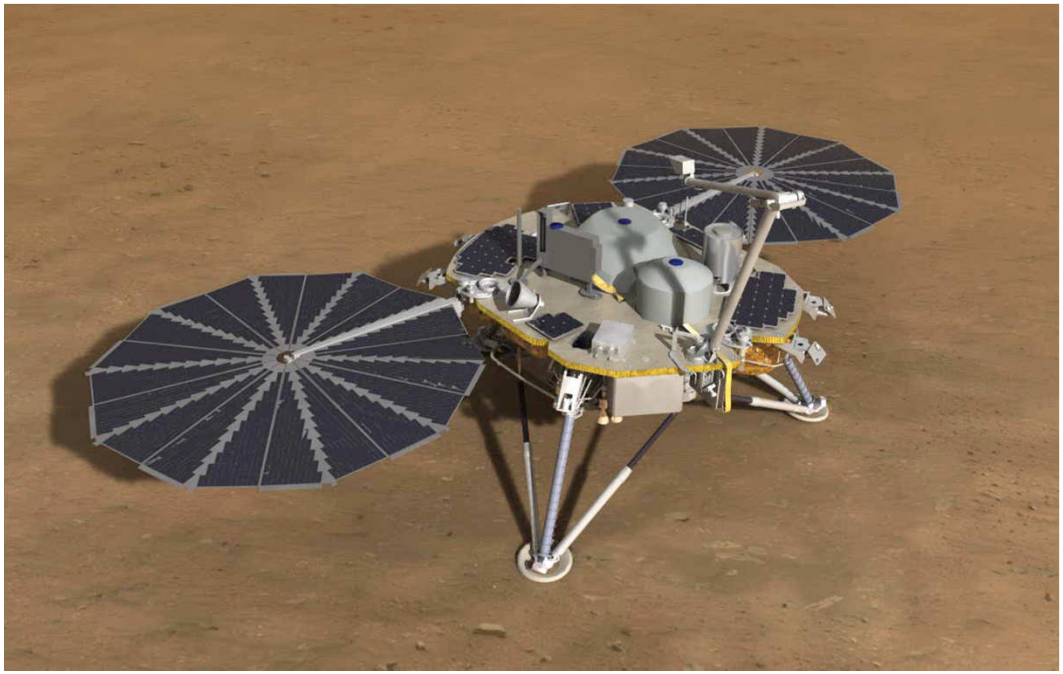



Surface Configuration

# 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.
- $HP^3$ 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

Earth, seen from Mars

**Look deep into nature, and then you will understand everything better. – Albert Einstein**

Gusev Crater