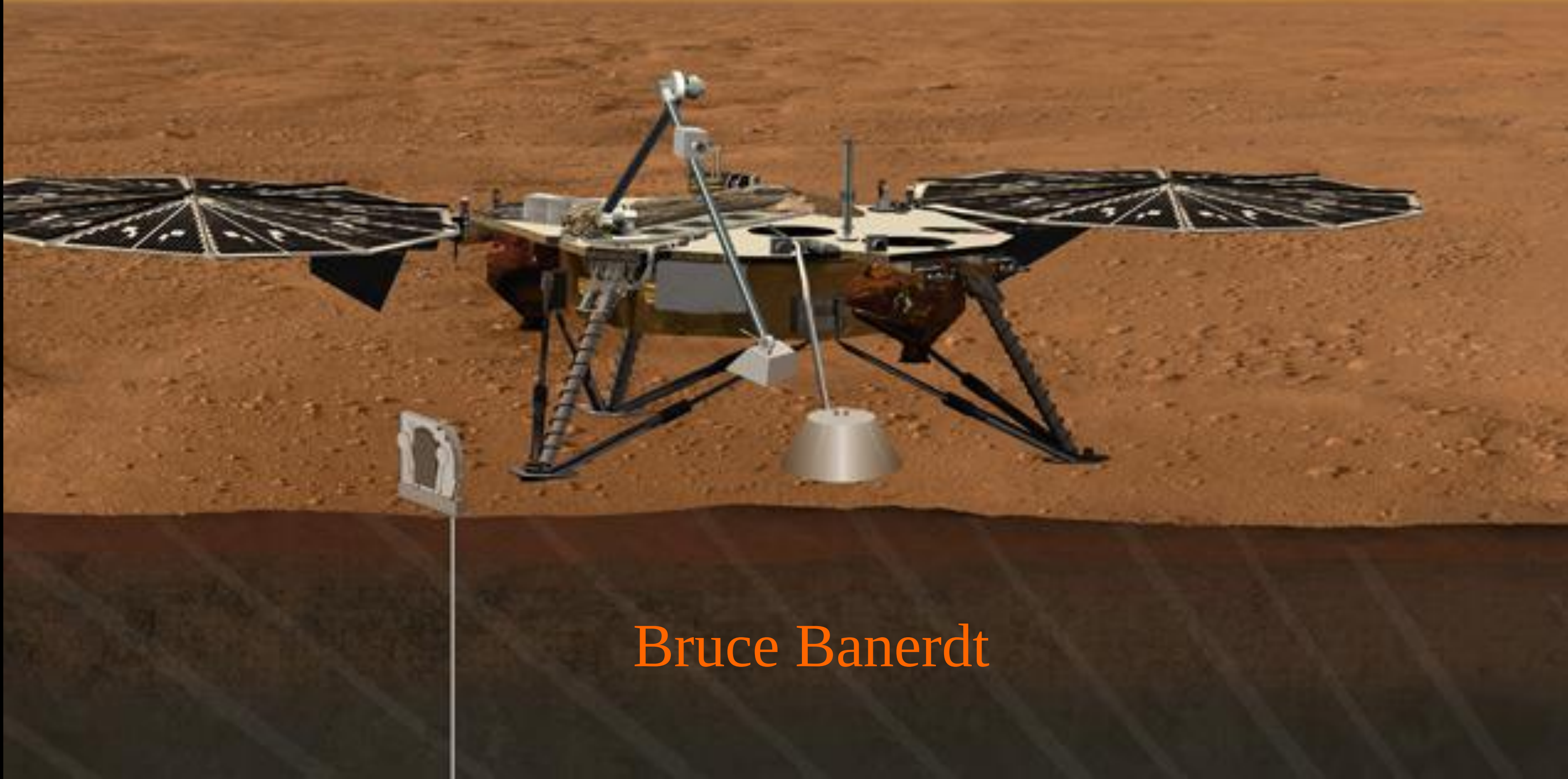
The mission soon to be formerly known as

GEMS (GEophysical Monitoring Station): A Discovery Mission to Understand Terrestrial Planet Evolution



Bruce Banerdt

Introduction

GEMS aims to place a single geophysical (seismology, heat flow, planetary rotation) lander on Mars to study the formation and evolution of terrestrial planets.

Science Goals and Objectives

1. **Understand formation/evolution of terrestrial planets through investigation of the interior structure and processes of Mars**
   - Determine the size, composition, physical state (liquid/solid) 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 meteorite impact rate on Mars**
   - Measure the magnitude, rate and geographical distribution of internal seismic activity.
   - Measure the rate of meteorite impacts on the surface.

Why is Interior Structure Important?

The earliest and most fundamental stages of a planet's evolution can be understood in terms of its basic components: crust, mantle and core.

- The crust of a planet is formed initially through fractionation of accreted material, with later addition through partial melting of the residual mantle (volcanism).

➢Thus the volume (thickness) and vertical structure of the crust (with the composition of the upper mantle) places strong constraints on the depth and evolution of a putative martian magma ocean.

- Crustal thickness is a sensitive indicator of the early thermal and dynamic evolution of a planet.

➢For example, plate tectonics, stagnant lid, and mantle overturn models predict thin, medium, and thick crust, respectively.

- Mantle composition and dynamics/thermal structure play a key role in shaping the geology of the surface through volcanism and tectonics.

➢The dynamics of the mantle, reflected in its thermal structure and any compositional or mineralogical stratification, determines the character of the thermal and magmatic history of a planet.

•Knowledge of the core state and size is crucial for understanding a planet's history, as the thermal evolution of a terrestrial planet is strongly affected by core dynamics.

  ➢ The state of the core depends on the percentage of light elements and temperature, which in turn is related to heat transport in the mantle.

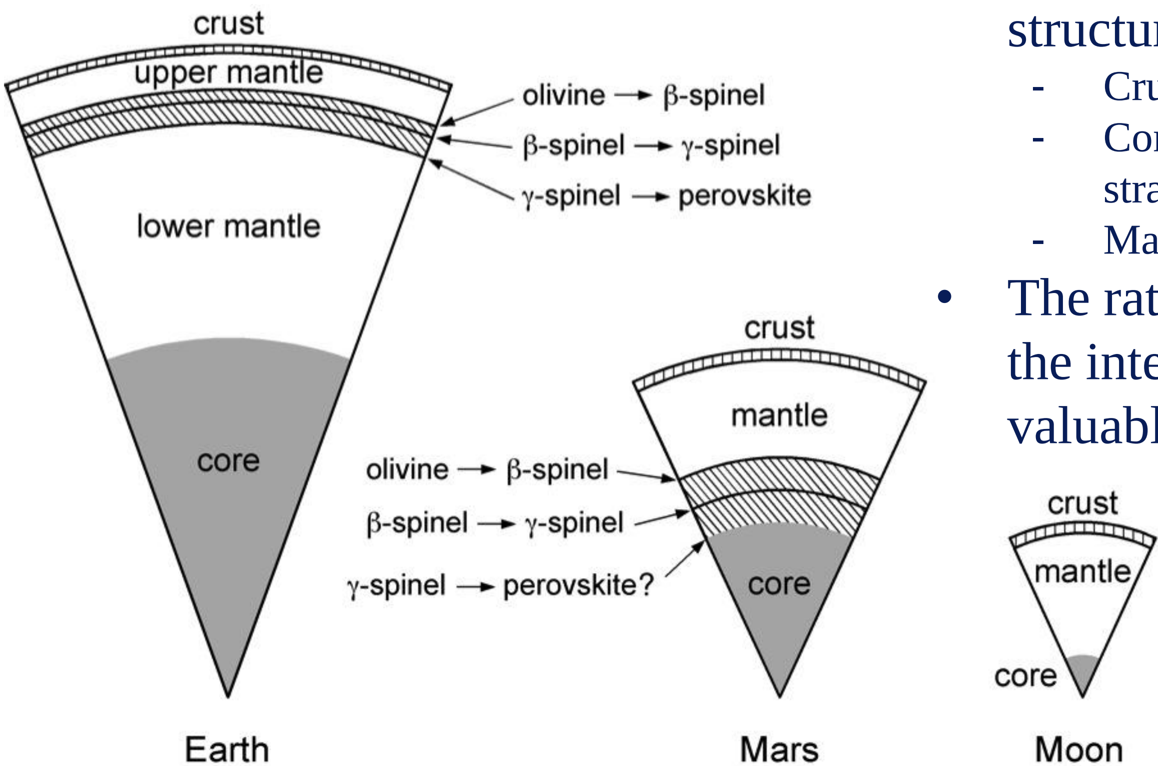
➢In addition, these parameters are crucial in understanding the magnetic history, as a dynamo requires high heat flow into the mantle, a strong gradient in the liquid core, or a growing solid inner core.

Why is the Interior Structure of Mars Important?

- Because of vigorous mantle convection and plate tectonics, the Earth has lost the original structures reflecting differentiation and early evolution.
- But for Mars:
  - SNC compositions indicate isolated melt source regions that have persisted since the earliest evolution of the planet, suggesting that mantle convection has been insufficiently vigorous to homogenize the mantle.
  - Much of the martian crust dates to the first half billion years of its history.
- Thus measurements of the martian interior are likely to reveal structures that still reflect the initial differentiation and early planetary formation processes.

GEMS: A Terrestrial Planets Mission That Just Happens to be Going to Mars …

- **Mars is in the sweet spot:** Big enough to have undergone most of the early (first few hundred million years) processes that fundamentally shaped the terrestrial planets (Earth, Venus, Mars, Mercury), but small enough to have retained the signature of those processes for the next 4 billion years.



- That signature is revealed in the basic structural building blocks of the planet:
  - Crust thickness and global layering
  - Core size, density (= composition), stratification (inner core?), liquid/solid
  - Mantle density/stratification
- The rate at which heat is escaping from the interior provides an additional valuable constraint.

Project Overview

- **JPL-managed mission, Lockheed-Martin-built spacecraft, shared operations**
  - Use Phoenix heritage (both hardware and roles/relationships) to maximum extent possible to control cost and risk
- **Contributed instruments, international team**
  - Major foreign partners: CNES (France), DLR (Germany), each with several European sub-partners.
- **Schedule:**
  - Launch March 2016, arrive September 2016 (L_s~235), direct entry
  - One month intense operations after landing (including deploying two instruments to the ground with robotic arm)
  - One Mars year routine surface operations (non-interactive science ops)

International Science Team

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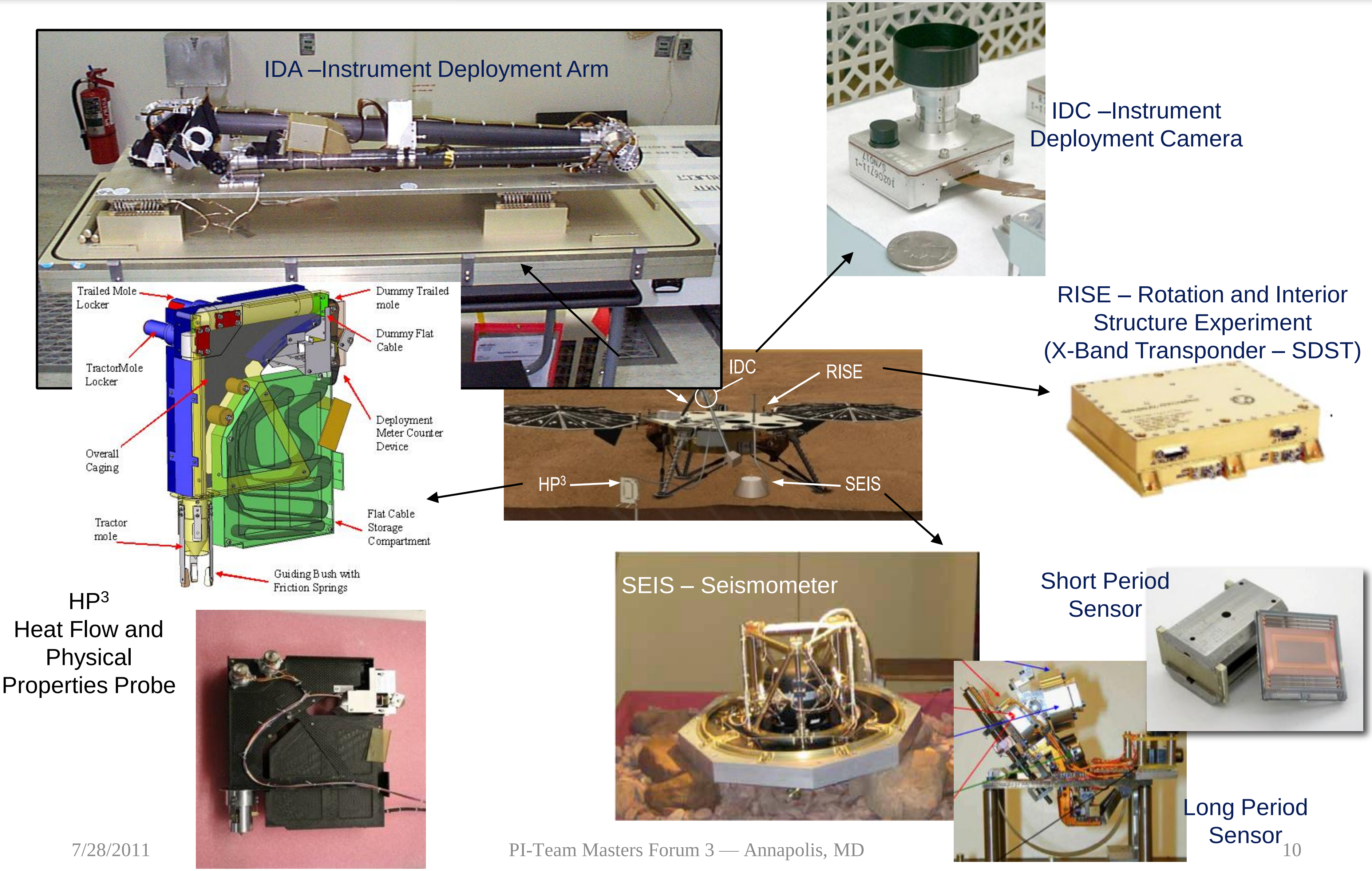
Measurement Strategy

- **The conceptual breakthrough that enables this mission is the application of sophisticated, state-of-the-art, single-station analysis techniques to high-quality broad-band seismic data.**
  - We will take advantage of multiple overlapping and complementary techniques that capitalize on the wealth of information contained in seismic time series.
  - This allows the extraction of planetary parameters from seismic signals acquired by a single lander; a multiple-station network, while providing a stronger data set, is not required for scientifically valuable observations.
- **Although several lines of analysis predict a relatively high level of seismic activity, mission success does not dependent on it.**
  - Results can be derived from “guaranteed” non-traditional signals: Meteorite impacts, Phobos tide, atmospheric interaction with the surface.
- **Precision tracking reveals minute variations in the rotation vector (magnitude and direction) that are relatable to interior structure.**
  - This information is complementary to the seismic measurements.
- **Thermal gradient + conductivity (= heat flux) is a secondary measurement that is valuable, but not absolutely essential.**
  - Heat flow is not in the science floor.

Payload

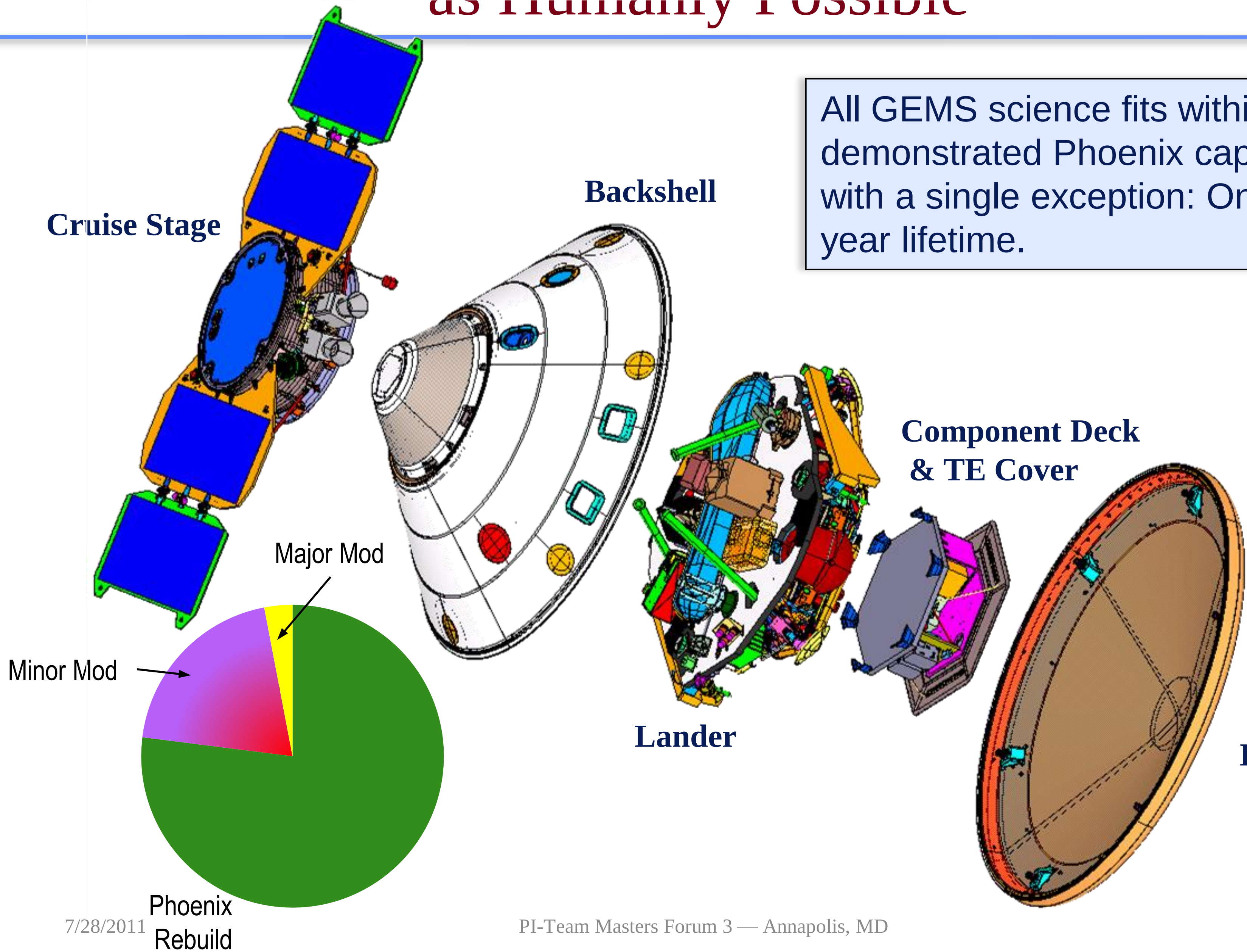
- **2 Instruments**
  - Seismometer
  - Heat Flow Probe
- **3 Investigations**
  - Seismology
  - Heat Flow and Soil Properties
  - Rotation and Interior Structure
- **4 Payload Elements (plus 1 Spacecraft Subsystem)**
  - Seismic Experiment for Interior Structure (**SEIS** – CNES/IPGP, France)
  - Heat Flow & Physical Properties Probe (**HP^3** – DLR, Germany)
  - Instrument Deployment Arm (**IDA** – MSP01 flight hardware, JPL)
  - Instrument Deployment Camera (**IDC** – MER Navcam, JPL)
  - \+ Rotation & Interior Structure Experiment (**RISE** – telecom subsystem)

Payload


IDA –Instrument Deployment Arm
IDC –Instrument Deployment Camera
RISE – Rotation and Interior Structure Experiment (X-Band Transponder – SDST)
Trailed Mole Locker
Dummy Trailed mole
Dummy Flat Cable
TractorMole Locker
Deployment Meter Counter Device
Overall Caging
Tractor mole
Flat Cable Storage Compartment
Guiding Bush with Friction Springs
IDC
RISE
HP3
SEIS
HP3
Heat Flow and Physical Properties Probe
SEIS – Seismometer
Short Period Sensor
Long Period Sensor

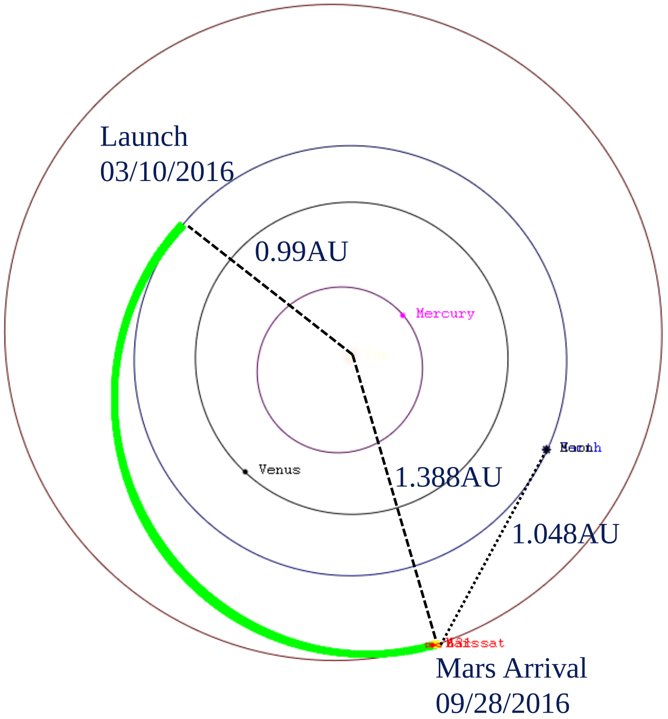
Spacecraft – As Close to Phoenix as Humanly Possible

All GEMS science fits within demonstrated Phoenix capabilities, with a single exception: One Mars year lifetime.

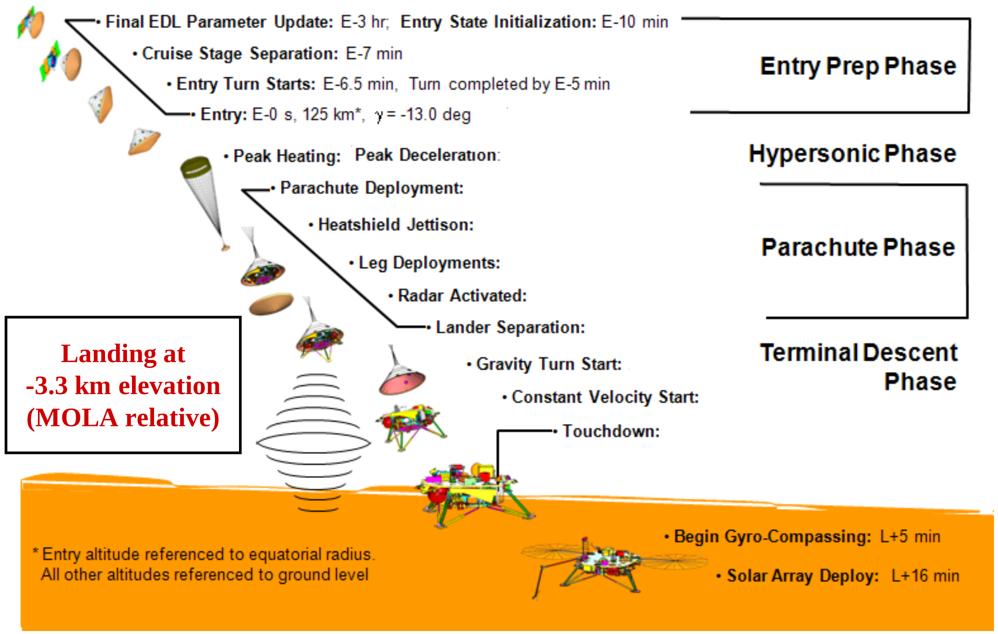


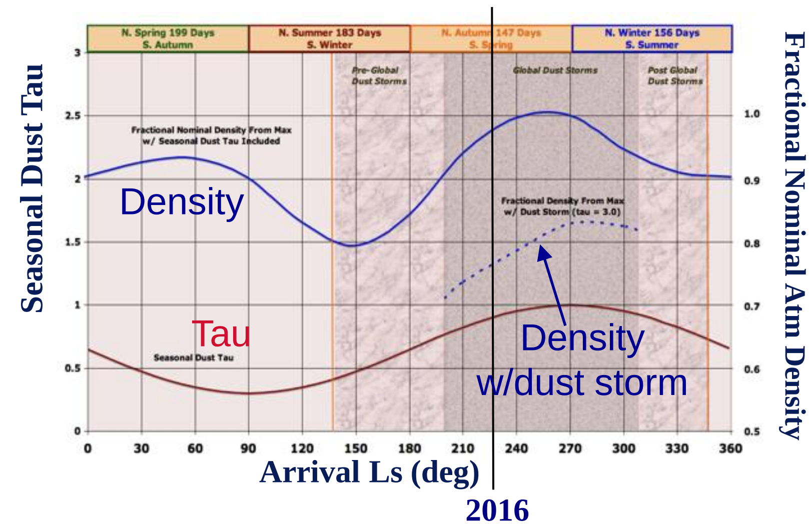
Mission Design Overview

Phase	Timeframe
Launch period Launch Vehicle Max C3, DLA	Mar. 10 – Mar. 30, 2016 Atlas V (401), Delta IV (4040) or Falcon 9 18.1 km^2/sec^2 , -43.7 deg
Cruise Duration Transfer to Mars, Orbit Type Max Earth-Spacecraft Range Spacecraft ΔV Budget	202 days Type I 1.048 AU 56 m/s (TCM-1 to TCM-6)
Mars Arrival L_s Season Entry Speed (Inertial) Example Landing Site Example Site Elevation	Sept. 28 – Oct. 12, 2016 230.5 – 241 Southern Spring 6.19 km/s 18.5° N, 312° E -3.3 km MOLA



Entry, Descent, & Landing

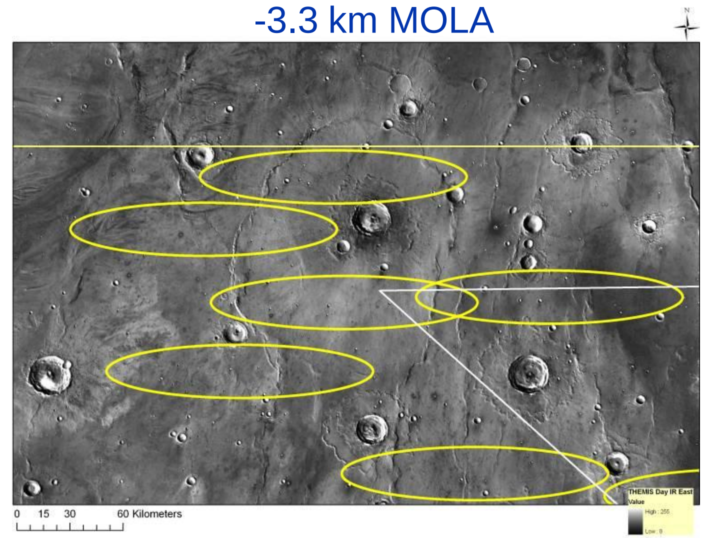




- EDL will be similar to Phoenix 2008
- Example Landing Site: Chryse
  (Multiple target locations in the NW Chryse region within the Phoenix EDL capabilities)

	Phoenix	*GEMS*
Mars Arrival Ls	**76.3 deg**	**231 deg**
Entry Mass	572.7 kg	549 kg
Entry Velocity	5.6 km/s	6.2 km/s
Landing Site Elevation	**-4.1 km**	**-3.3 km**

Lat 18.5° N, Lon 312° E
-3.3 km MOLA



Summary

- Awesome Science
  - **Not just Mars** – applies to fundamental questions relating to the big-picture understanding of the inner solar system.
  - (Plus a lot of cool Mars science, too).
- Low Risk – Technical *and* Cost
  - **JPL+LM have done most of this before** with Phoenix.
  - **Focused payload**; both instruments are at TRL5+ and have over a decade of development (over two decades for SEIS), including up through PDRs for NetLander and ExoMars.
- This will be achieved by **ruthless adherence** to heritage and established capabilities.
  - **No** improvements to S/C capabilities.
  - **No** augmentation to science.
  - **No** science interactivity – Surface operations are turn-key after commissioning phase