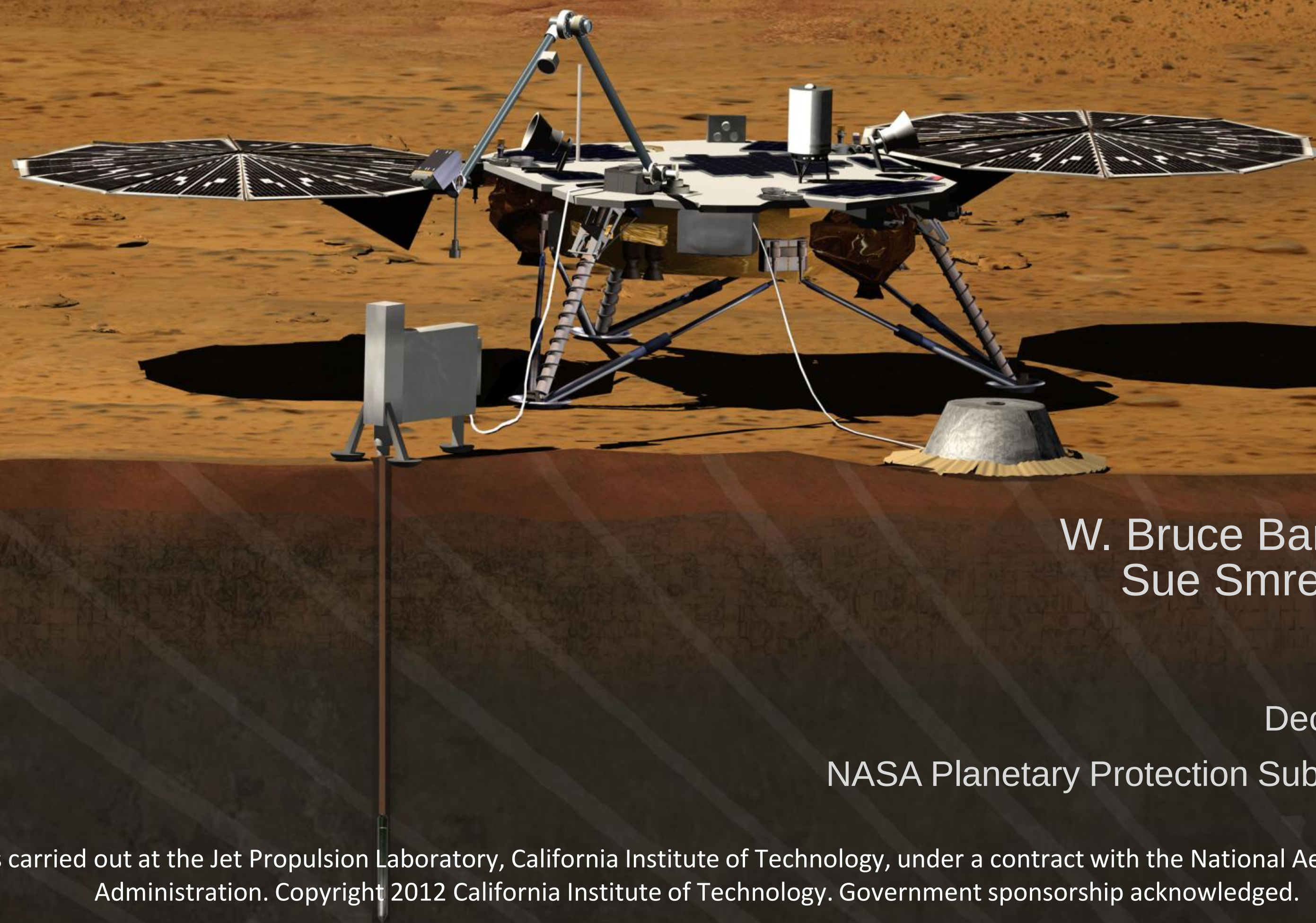
InSight: Science and Mission Overview



W. Bruce Banerdt, PI
Sue Smrekar, DPI

Dec. 19, 2012

NASA Planetary Protection Subcommittee

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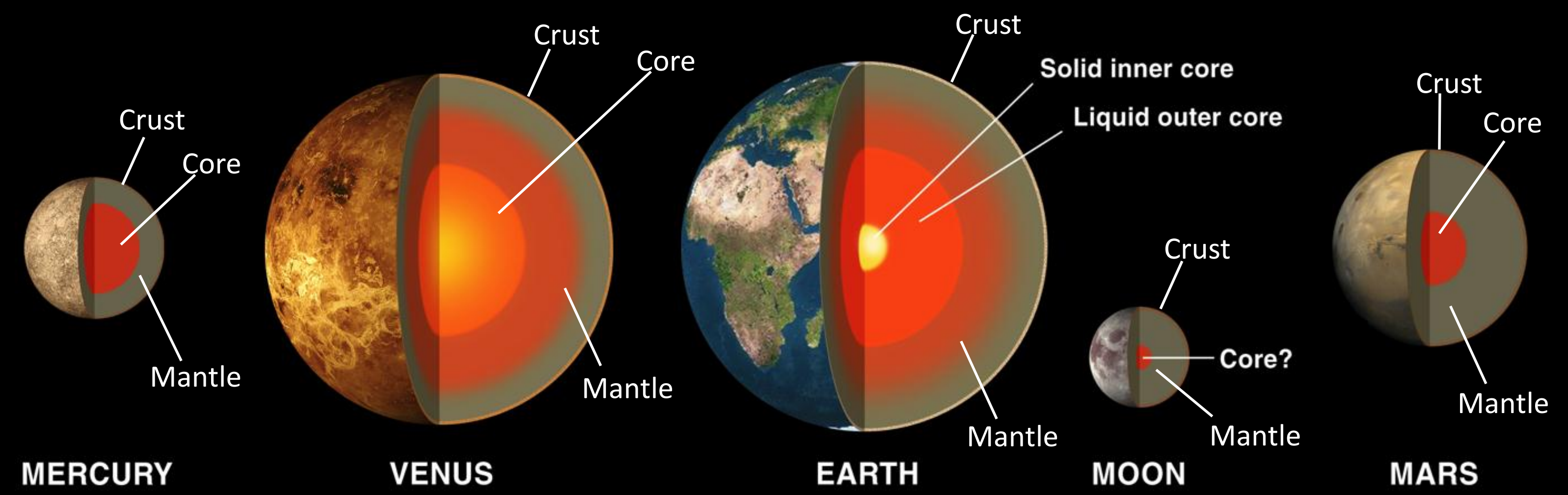
Mars is Key to Understanding Early Formation of the Earth

Terrestrial planets all share a common structural framework …



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

InSight would contribute to the fundamental question of "how we got here"— How did the Earth become the planet we live on today?

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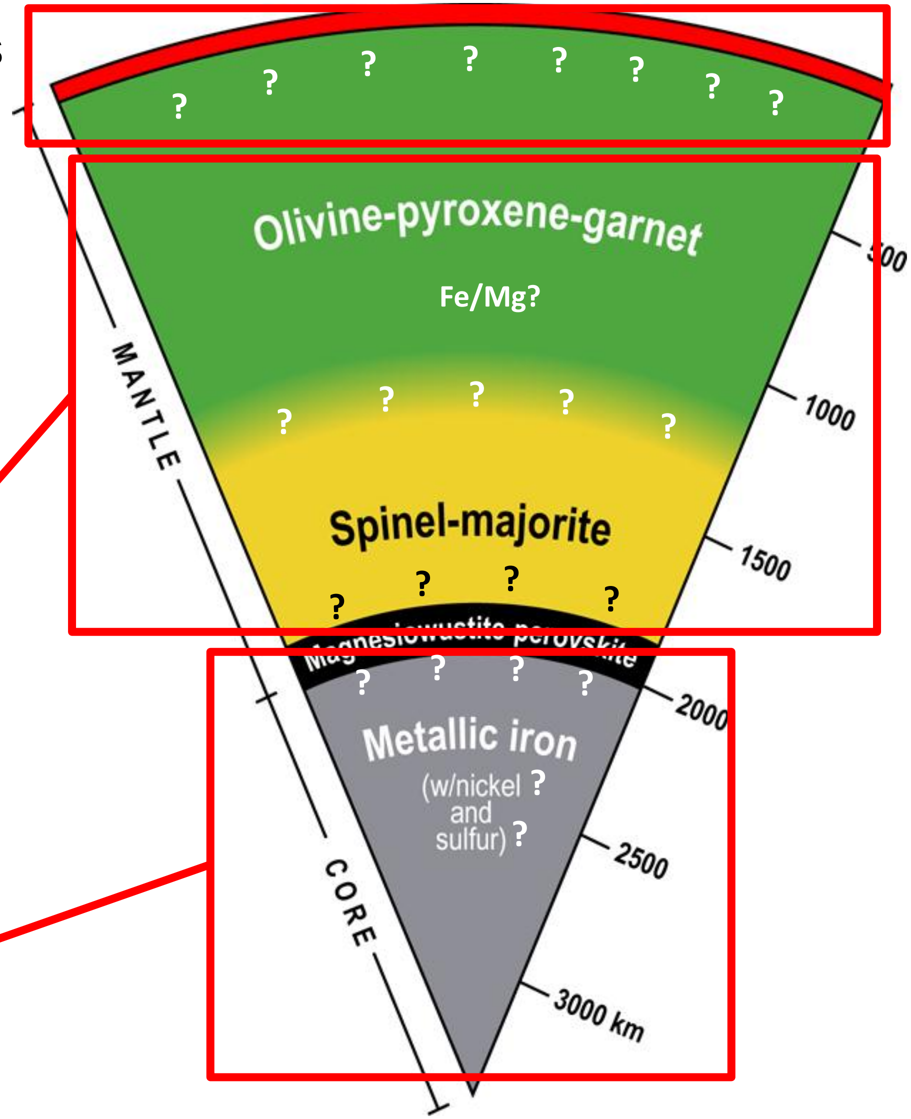
Science Objectives and Measurements Requirements

- **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.



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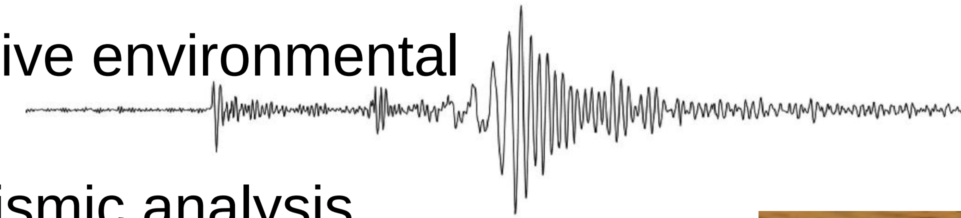
Focused Set of Measurements

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



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

- **Heat Flow**
  - Innovative, self-penetrating mole would penetrate to a depth of 3–5 meters

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All Instruments Have More Than 10 Years of Development

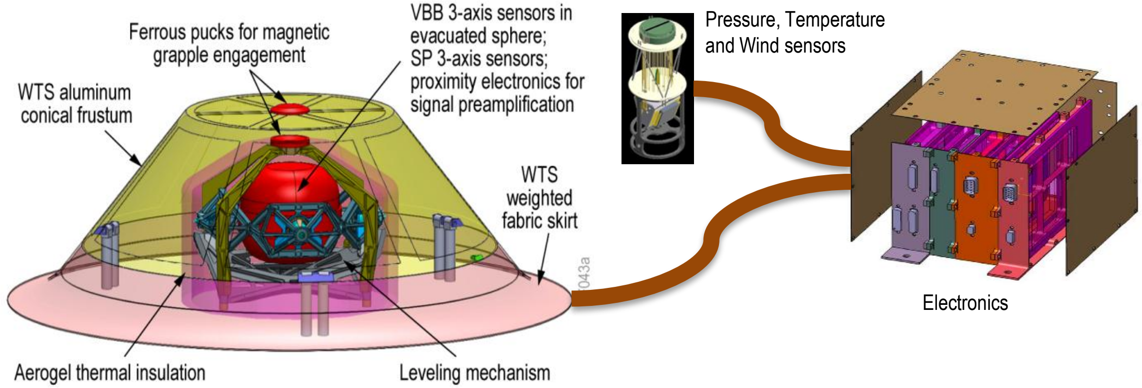
Small Deep Space Transponder

RISE (S/C)

Rotation and Interior Structure Experiment

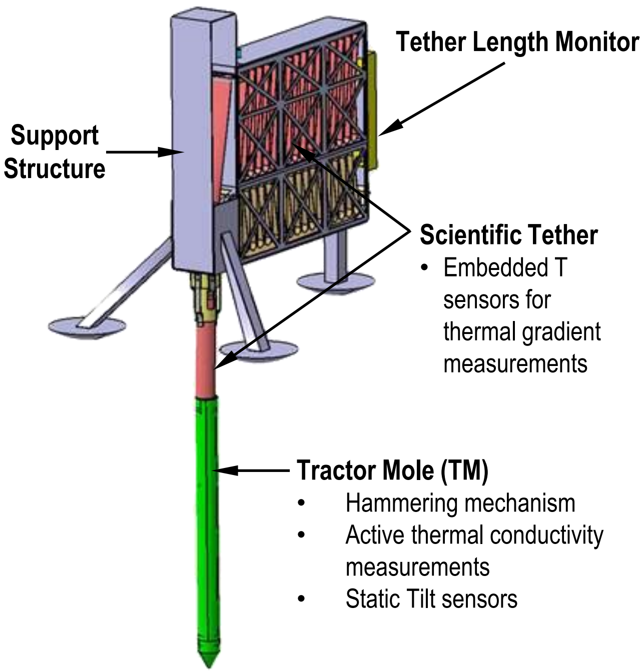
SEIS (CNES)

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)

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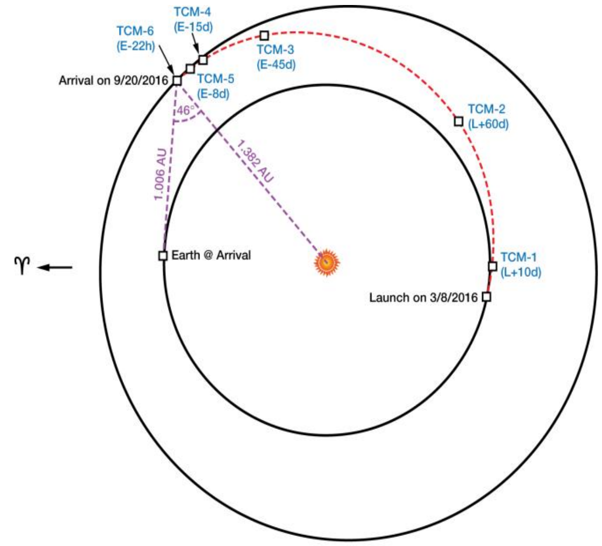
InSight is Delivered to Mars like Phoenix

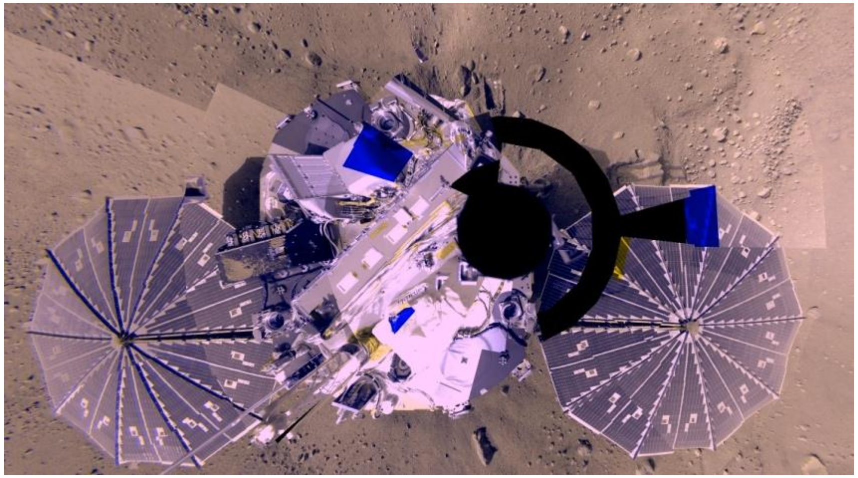
- 20-day Launch Period opening on 8-Mar-2016
  - Could launch any of the three vehicles (Atlas V, Delta 4, Falcon 9)
  - Constant arrival on 20-Sept-2016

- Type 1 transfer with 6.5-month cruise

- InSight EDL would be comfortably within the heritage Phoenix design capabilities
  - Known JPL/LaRC/ARC/LM partnership
  - Science is not a driver for site selection
  - Landing region in western Elysium Planitia with very mature site selection
  - Well characterized environment for landing and Science operations



View from Ecliptic North looking down on Ecliptic



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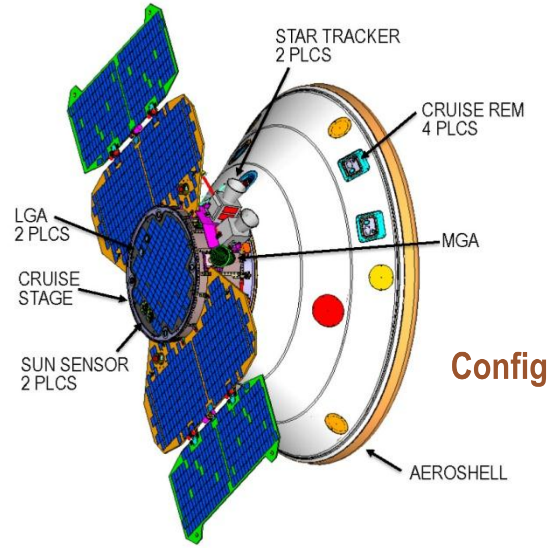
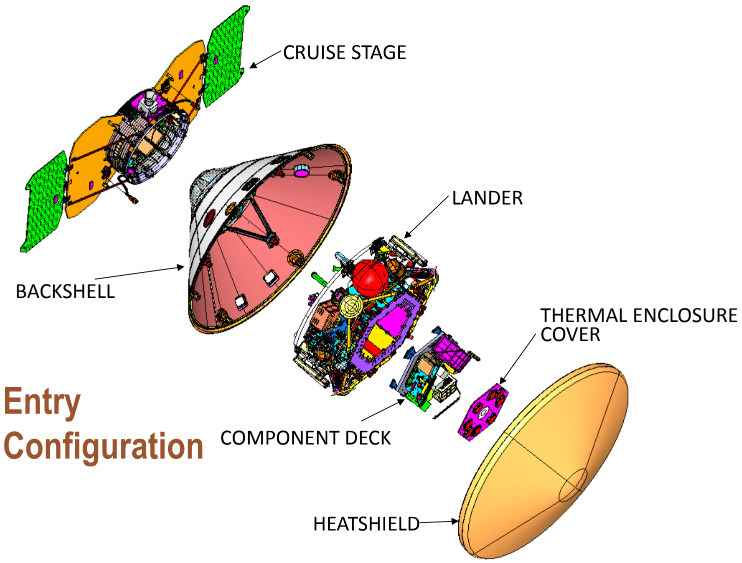
Flight System's Phoenix Heritage

- InSight would 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
  - Proven procedures and personnel available
  - Much fewer instruments with a simpler Science mission

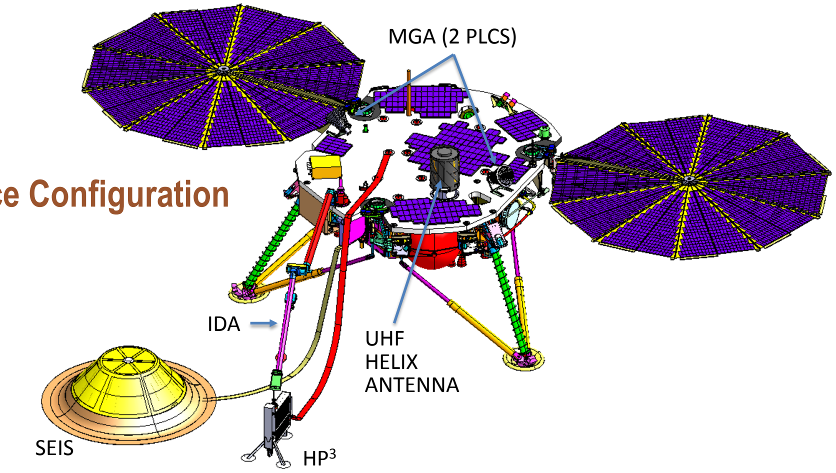


Cruise Configuration



Entry Configuration

Surface Configuration



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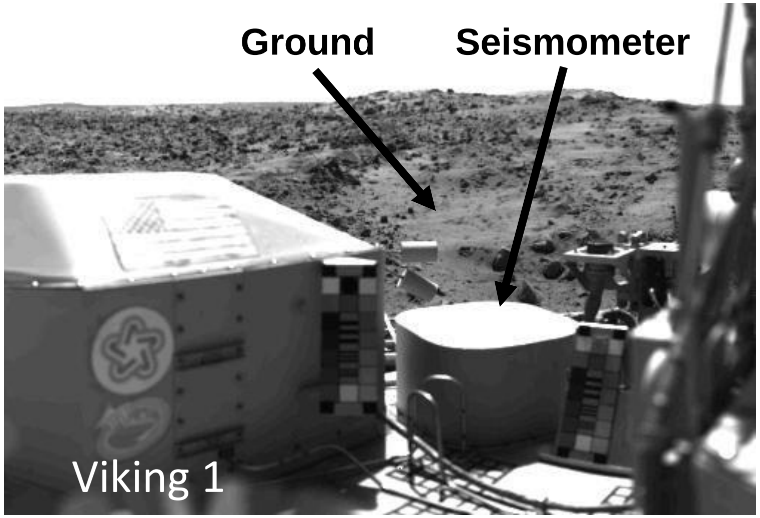
Surface Deployment and Operations

- After landing the instruments would still be ~1 m from the ground
- InSight takes advantage of the large payload mass capability of the Phoenix lander
- Would place the seismometer on the surface and cover it with an effective wind and thermal shield
  – This would allow the seismometer sensitivity to reach the micro-seismic noise level of the planet.



- Robust deployment phase includes 20 margin Sols
- Routine Science operations last one Martian year
  - Science would start on Sol 8 (RISE)
  - SEIS would start acquiring data on sol 36
  - HP3 would be fully deployed by sol 82

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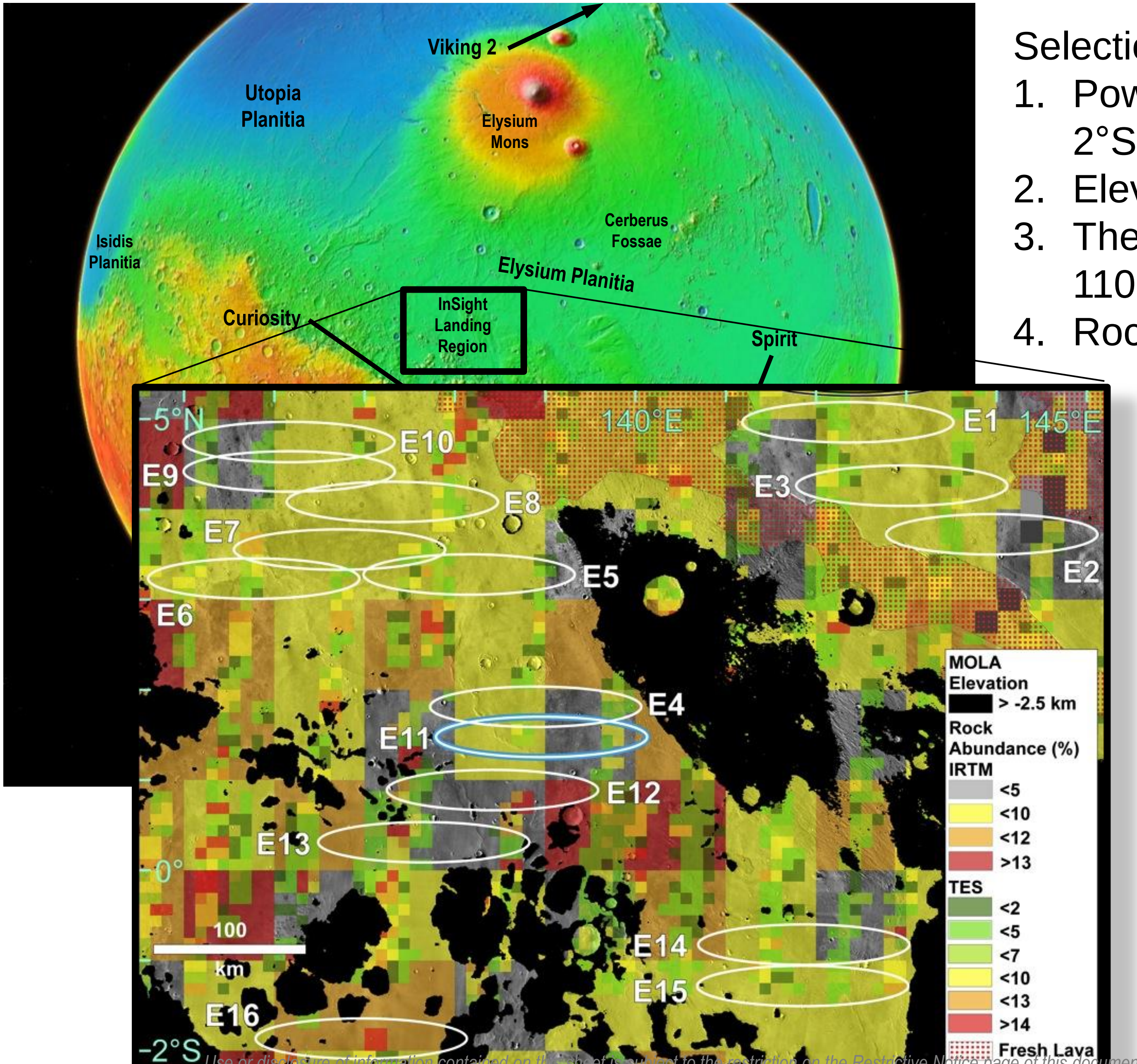
InSight Landing Region: Elysium Planitia



Selection drivers:

1. Power limits latitude to 2°S-5°N
2. Elevation <-2.5 km
3. Thermal inertia range: 110-300 $Jm^{-2}K^{-1}s^{-1/2}$
4. Rock abundance < 10%

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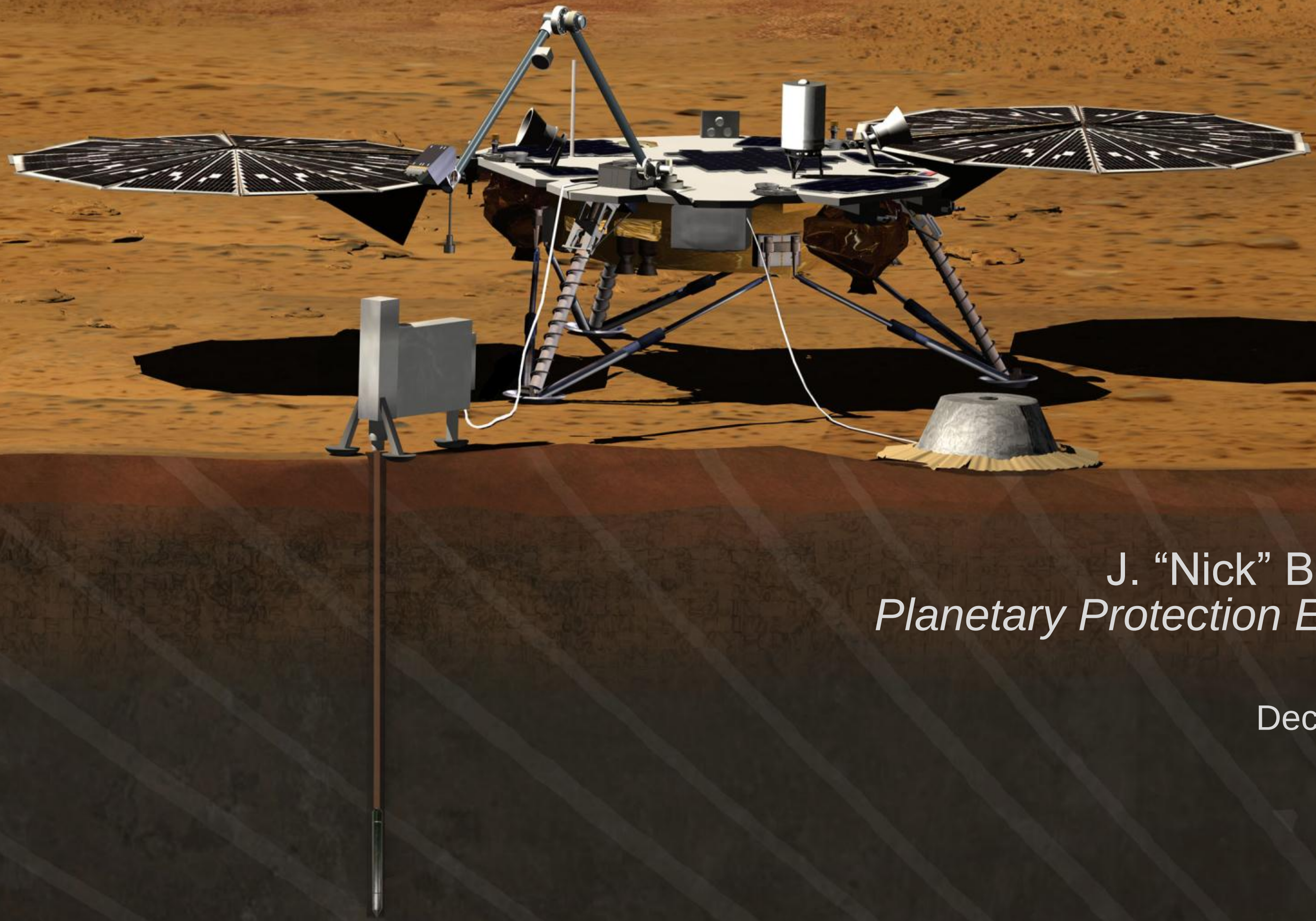
InSight: Planetary Protection Overview



J. “Nick” Benardini
Planetary Protection Engineer

Dec 19., 2012

Preliminary Mission Category and Justification

- **Outbound:** This is a Category IVa mission according to the official NASA Planetary Protection guidelines, "NPR 8020.12D Planetary Protection Provisions for Robotic Extraterrestrial Missions." Category IVa includes lander and/or probe missions to targets of significant interest relative to the process of chemical evolution and/or the origin of life or for which scientific opinion provides a significant chance of contamination, which would jeopardize biological experiment or exploration program(s). Category IVa missions are not permitted to include life detection experiments or to target "special regions".

- **Inbound:** Not Applicable

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Preliminary PP Requirements

- Biological Contamination Control:
  - Total exposed surface bioburden of the landed hardware shall not exceed 3 x 10^5 viable spores at launch
  - Total (all surfaces, including mated, and in the bulk of non-metals) bioburden at launch of hardware for which a hard impact is planned shall not exceed 5 x 10^5 viable spores minus bioburden allocated to landed H/W
  - Average exposed surface bioburden of the landed hardware shall not exceed 300 viable spores/m^2 at launch
  - Bioassays to establish the microbial bioburden levels
  - Independent verification bioassays by NASA Planetary Protection Officer
  - Bioassayed and/or microbially reduced spacecraft surfaces must be protected from recontamination
- Organic materials:
  - Organic Inventory: An itemized list of bulk organic materials and masses used in launched hardware
  - Organic Archive: A stored collection of 50 g samples of organic bulk materials of which 25 kg or more is used in launched hardware

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PP Implementation Procedures

- Preparation of the required PP documentation
- Periodic formal and informal reviews with the NASA PPO
- Trajectory biasing
- Analyses (*i.e. Probability of impact, probability of accidental impact, prob of failure during EDL, bioburden at launch, entry heating, and final landing sire location and disposition of hardware.)*
- Spacecraft assembly performed in Class 100,000 / ISO Class 8 (or better) clean facilities, with appropriate controls and procedures
- Microbial burden Reduction:
  - Alcohol-wipe cleaning
  - Precision cleaning
  - Heat Sterilization (dry, ambient or uncontrolled parameters)
  - Vapor H_2O_2 microbial reduction
- Venting of electronic modules through HEPA filters

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PP Planning

- Heritage Hardware:
  – Utilization of PHX flight system
  – Aeroshell TPS will be similar to MSL
  – Parachute manufacturers same as for PHX
- Payload Hardware
  - Payload assembly at DLR and CNES for HP^3 and SEIS, respectively, are ahead of the flight system buildup.
  - The standard PP Project documentation schedule is therefore misaligned with the Payload assembly and an expedited need for PP guidance is required. This is being mitigated with payload specific PP Plans that are currently in draft with specific bioburden allocations defined based on PHX heritage.
- Launch Vehicle
  - Could utilize a Atlas V, Delta IV, or Falcon 9
  - PP Input has been incorporated into the "InSight Launch Vehicle Interface Requirements Document" based on heritage requirements and lessons learned from MER, PHX, and MSL.

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PP Planning and Implementation

- Manufacturing process is adequate or easily modified to provide needed microbial reduction
  - Aeroshell structure
  - Parachute in canister
- DHMR credit taken for high-temp manufacturing/processes whenever possible
- Backshell outboard surface would not be sterilized on entry similar to that of MER, PHX, and MSL.
- No spacecraft hardware (excluding payload) would penetrate surface during landing
- Trajectory must be biased to meet probability of impact requirements
- It's assumed that the Phoenix PEB design would used, so venting is through a tortuous path provided by batting

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Driving PP Factors for Creation of A Special Region

- **Temperature**
  - MEPAG Finding - Based on current knowledge, terrestrial microorganisms are not known to be able to reproduce at a temperature below about -15°C. For this reason, with margin added, a **temperature threshold of -20°C** is proposed for use when considering special regions.
  - Although reported levels of metabolic activity at temperatures down to -15°C might support growth, no one has demonstrated cell replication to occur at or below -15°C.
  - Cell replication and doubling times range from 10 – 120 days at <-10°C.
- **Water Activity Threshold.**
  - MEPAG Finding. FINDING. Based on current knowledge, terrestrial organisms are not known to be able to reproduce at a water activity below 0.62; with margin, an activity threshold of 0.5 is proposed for use when considering special regions.
  - Water activity (aw) (that is, the activity of liquid water) is related to percent relative humidity (rh) as follows:a_w = rh/100. For pure water, aw = 1.0.
  - Water activity decreases with increasing concentrations of solutes and as increasing proportions of the water in a system are sorbed to surfaces, e.g., during desiccation in a porous medium such as the martian regolith.

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PP Concern: Driving PP Factors for Creation of A Special Region

- Temperature
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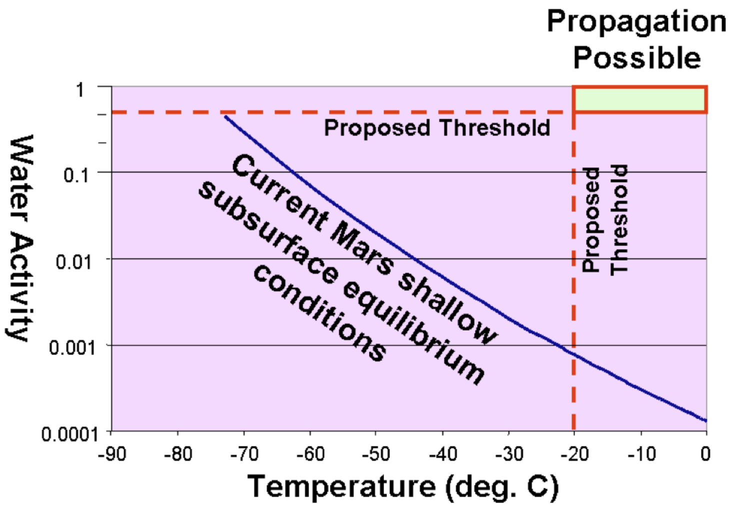

Figure from MEPAG-SR-SA). *Water activity of present-day Mars vs. temperature in equilibrium with the present-day atmosphere, assumed to have a water partial pressure of 0.8 mbar.* MEPAG SR-SAG (2006). Findings of the Mars Special Regions Science Analysis Group, Unpublished white paper, 76 p, posted June 2006 by the Mars Exploration Program Analysis Group (MEPAG) at http://mepag.jpl.nasa.gov/reports/index.html.

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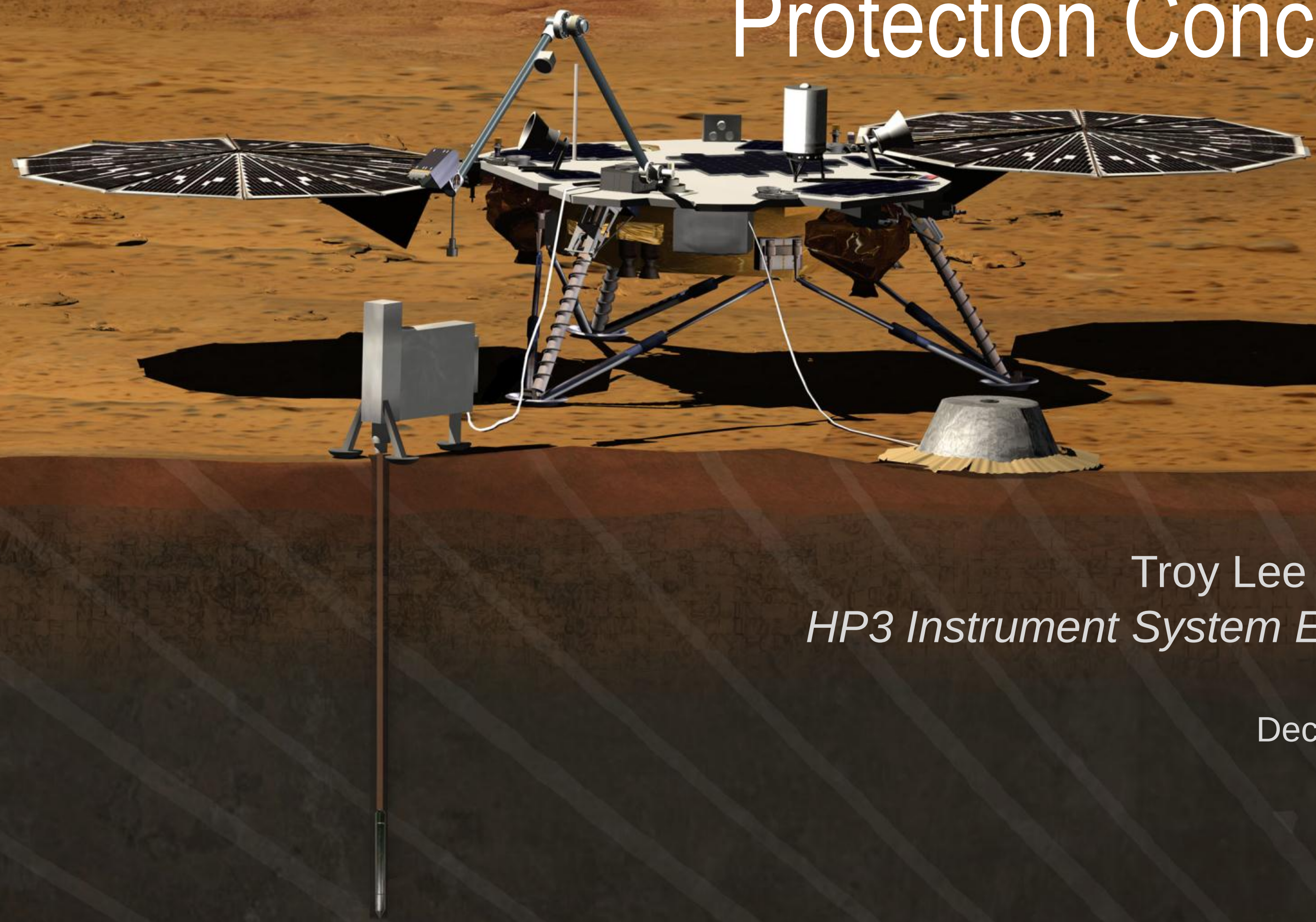
HP^3 Planetary Protection Concerns



Troy Lee Hudson
HP3 Instrument System Engineer

Dec. 19, 2012

Summary

The temperatures generated by HP^3 in the cold, dry environment of the InSight landing site would preclude the creation of a special planetary protection region.

- HP^3 Instrument Operation: Temperature Sources
  - Hammering: 10° increase
  - Thermal Conductivity: 20° increase
  - Internal HP^3 logic would prevent excessive temperature
  - Temperature increase would be short-lived
- Low Temperatures Anticipated in Subsurface
  - Temperatures mostly below -20°C threshold for microbial activity
- Dryness of Elysium Region
  - Water activity < 0.5 for liberated H_2O

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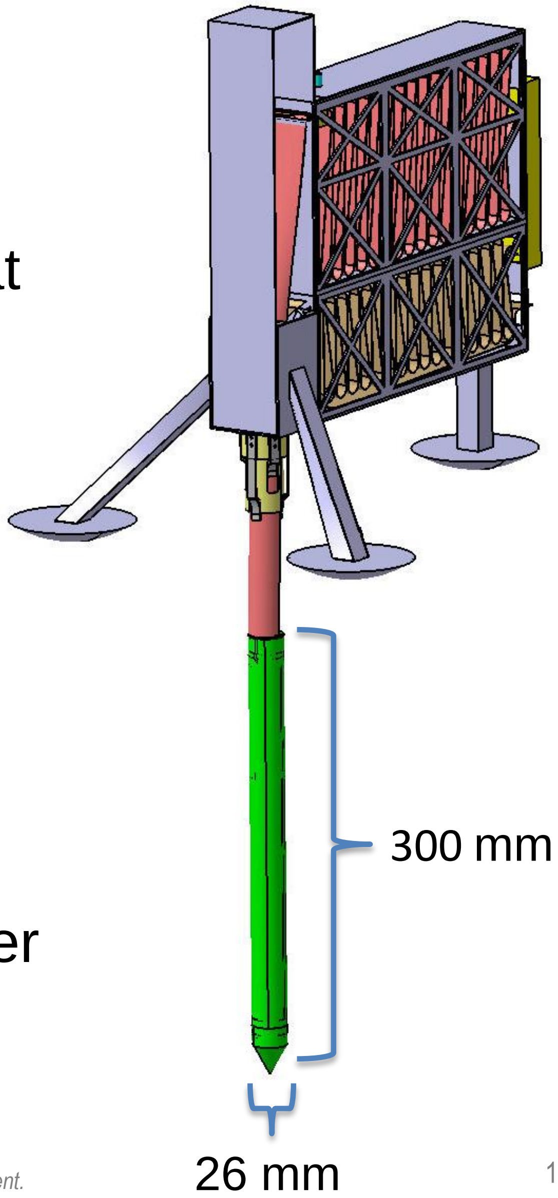
HP3 Proposed Operations

Penetration Cycle

- Mole would penetrate for ~2.5 hours
- 48 hour pause: dissipate hammering heat
- 24 hours active heating TC (Thermal Conductivity) Measurement

- Repeat above cycle 10-20 times
- Achieve maximum depth of 5 meters

- Passive monitoring for ~660 sols
  – TC measurement at final depth once per month



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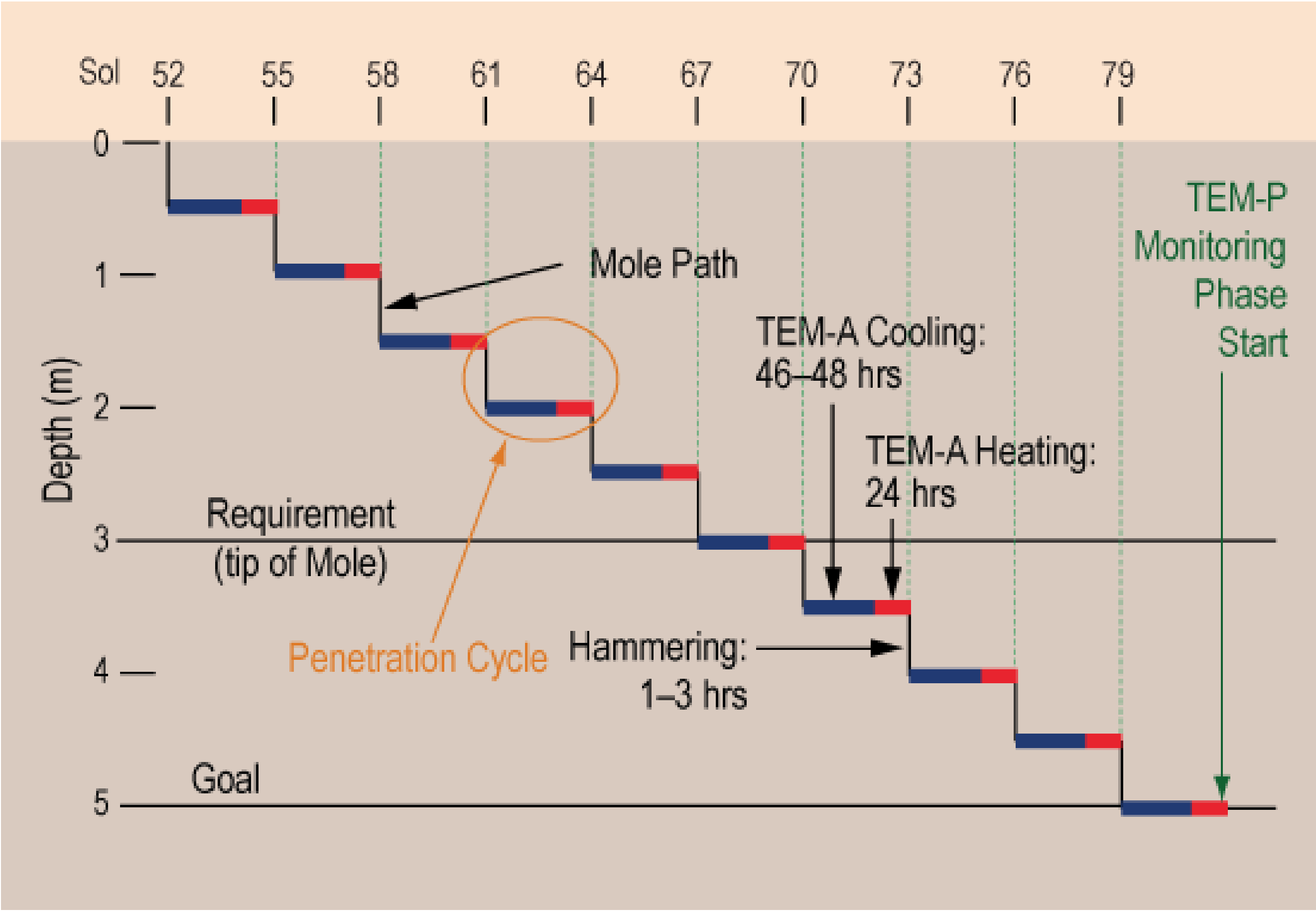
Operations Options / Constraints



HP³ has fault-protection logic that can stop hammering or TC measurements.

- **Mole Body Temperature Too High (> -20°C)**
- Downward Progress = 50 cm
- Forward Motion < 0.1mm/hr
- Mole Tip Depth = 4.95 cm
- Incipient Tether Rupture Detected
- Telemetry Out of Bounds

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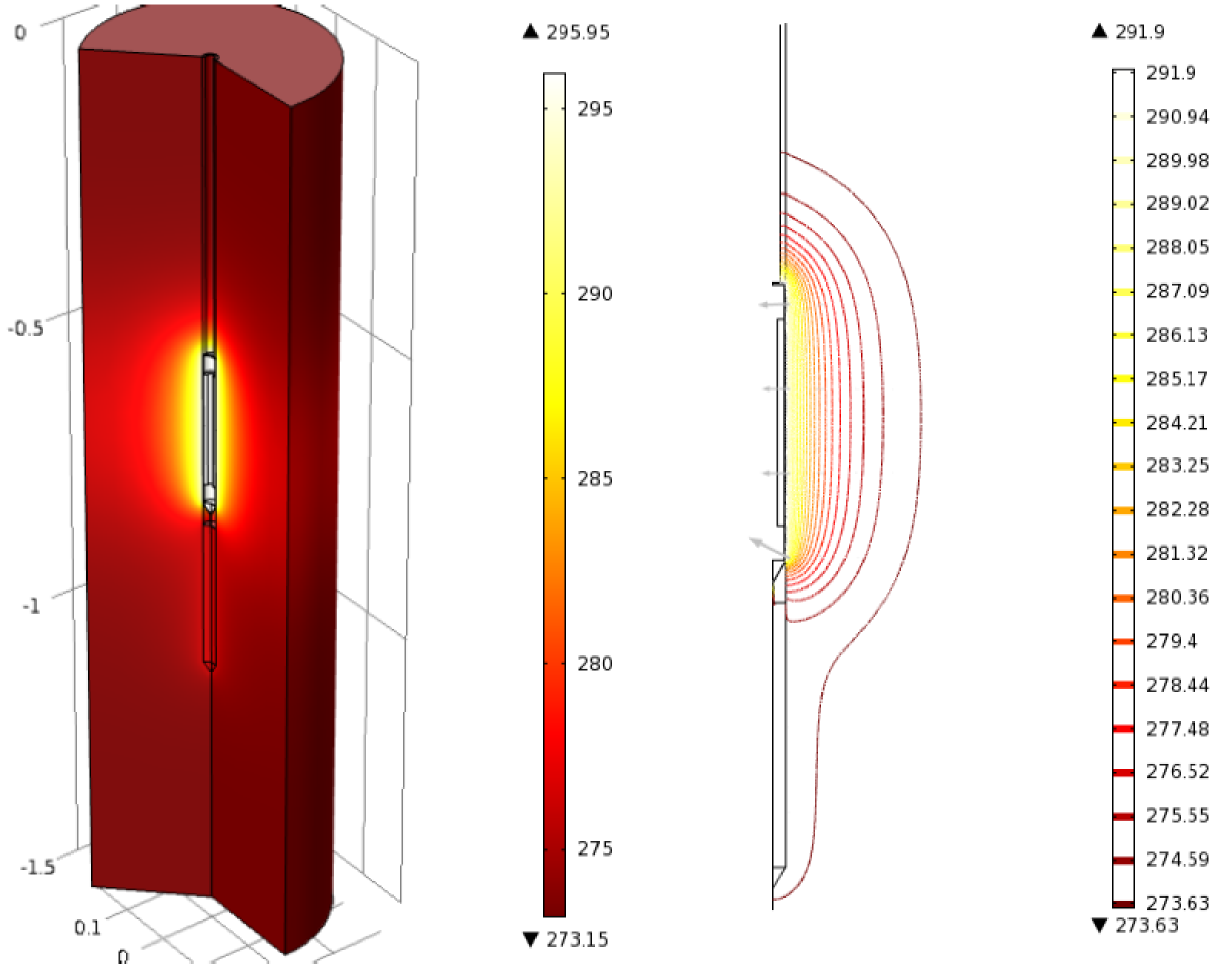
Maximum HP^3 Temperature Elevations



- Detailed numerical modeling and testing in low thermal conductivity regoliths indicate temperature rises of ≤10 K for hammering and ≤20 K for thermal conductivity heating.

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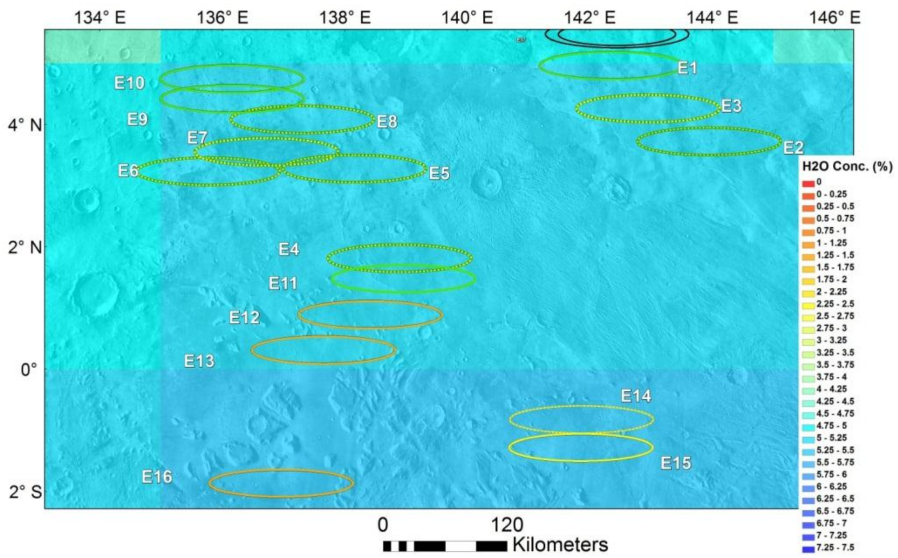
InSight Potential Landing Site has Low Concentrations of Potential H_2O Sources

- No stable subsurface ice at equatorial latitudes.
- GRS data show 4-5% mass fraction water equivalent hydrogen in upper ~1 m.
- Broken up igneous (basaltic) regolith; no geomorphic or mineralogic evidence for sedimentary rocks or fluvial processes



Odyssey GRS data from Boynton, et al., 2008

- Hydrogen signal may come from adsorbed water (~0.5-1%); structural (i.e., non-dehydratable) '–OH' groups in minerals; dehydratable clays, hydrous salts, and zeolites.
- Conservative calculation: No more than 50 mg H_2O / g soil could be liberated.

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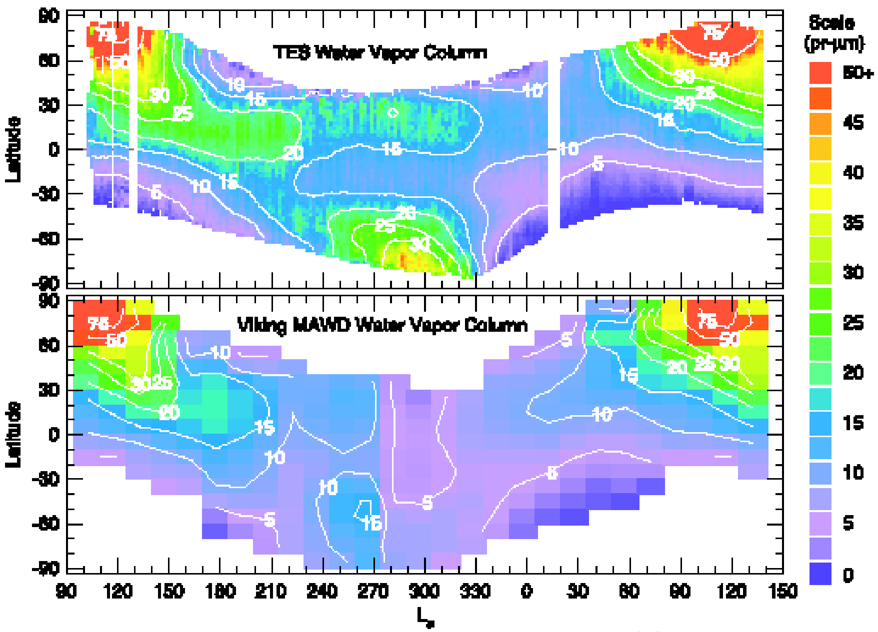
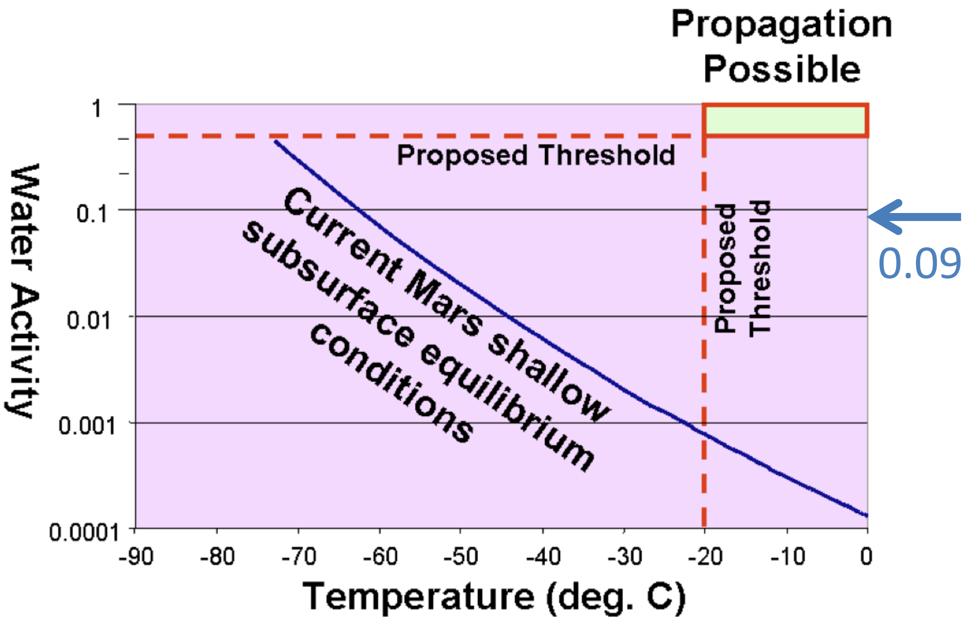
Water activity << 0.5



Smith, 2002



- Atmospheric water content in equatorial regions: 10-20 pr mm.
- Corresponds to water activities w.r.t. pure ice of 0.09 at −55°C, or 0.02 at −20°C.
- Will be even lower over salts, hydratable minerals, or adsobred water films
- **Far below microbial viability threshold.**

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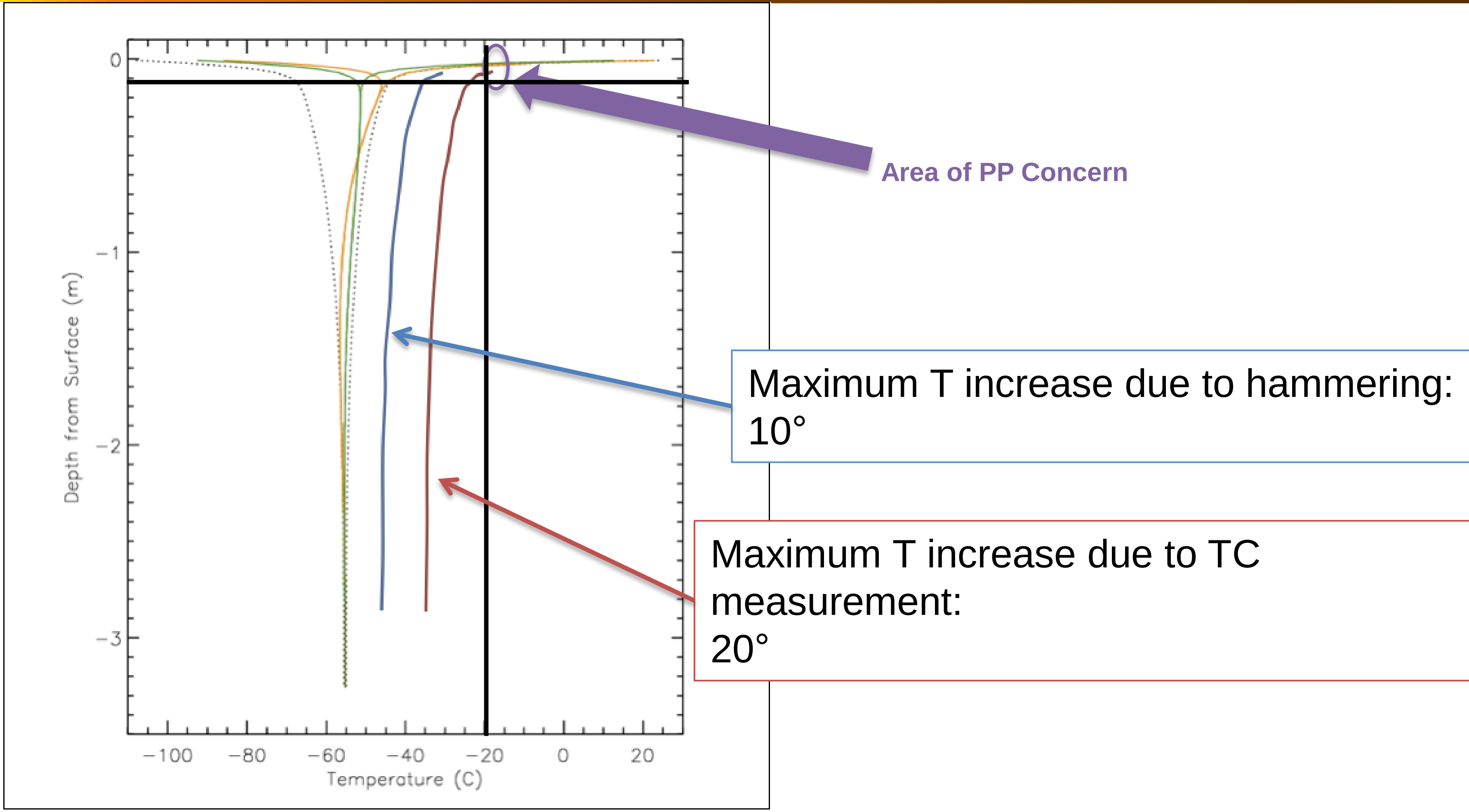
Maximum Subsurface Temperatures Generated by HP^3



- Only thermal conductivity measurements conducted shallower than 10 cm could produce regolith temperature greater than −20°C.
- Top of mole would be at 15 cm or deeper for shallowest TC measurement.

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Mole would not create Special Region

- **InSight potential landing region is dry**
  - Water-equivalent hydrogen is only 4-5%.
  - Greatest potential water activity at −20°C is 0.02, far below microbial activity threshold of 0.5.
- **InSight potential anding region is cold**
  - Mole would only approach −20°C during the final hours of a thermal conductivity measurement *if performed in the top 10 cm*.
- **Operational constraints prevent mole T rising above −20°C**
  - Shallowest TC measurement would be performed when middle of mole body is at 30 cm depth (i.e., top of mole is at 15 cm depth).
  - Internal logic can prevent mole from exceeding -20°C.
  - If necessary, shallowest TC measurement could be performed at colder times of day.

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Backup and/or Evidence Slides

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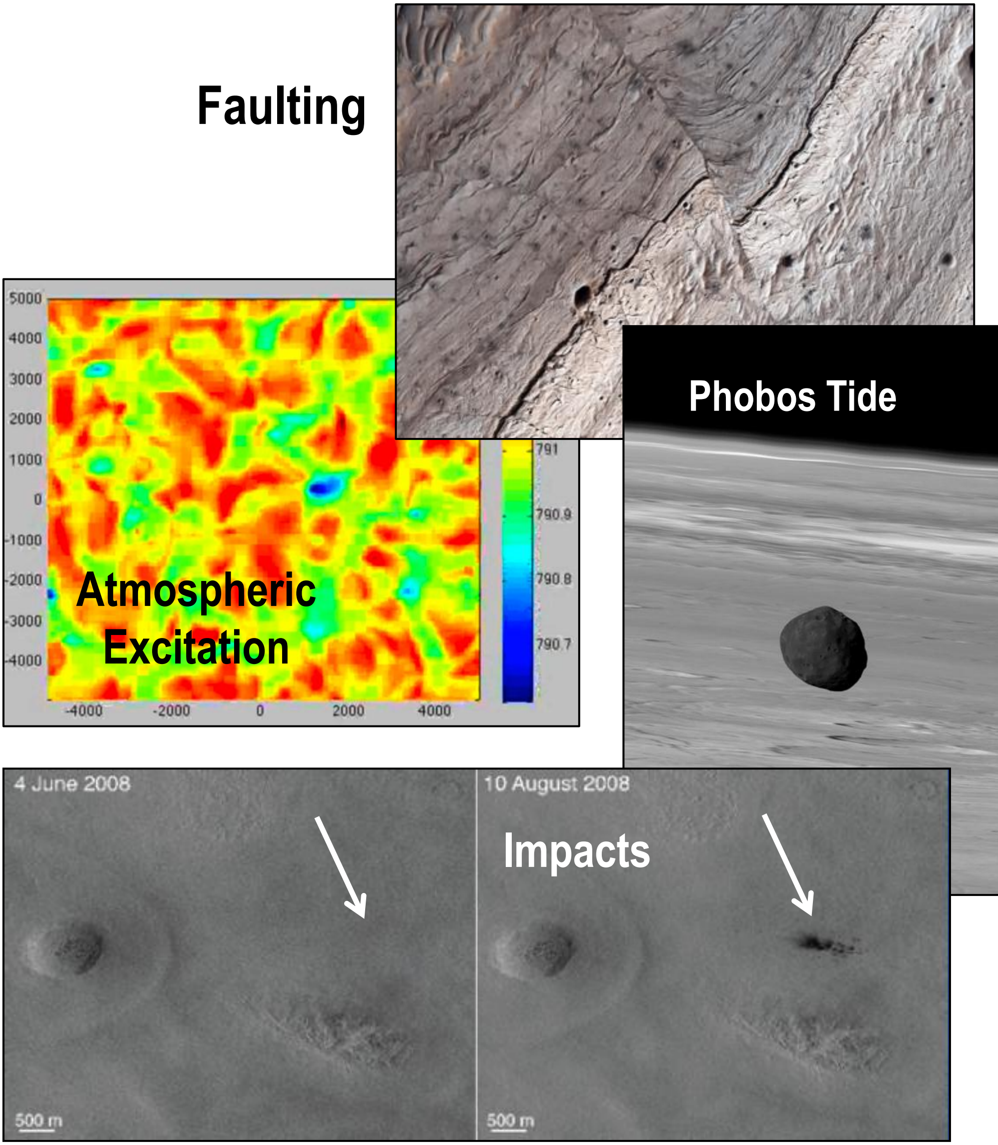
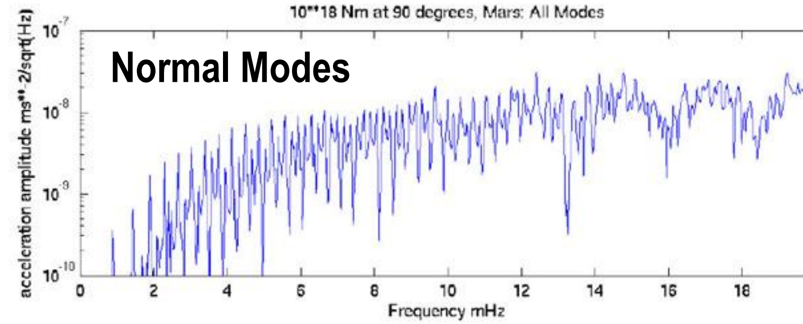
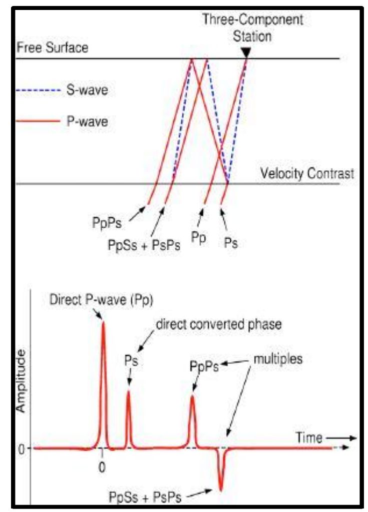
InSight Would Mine an Incredibly Rich Seismic Data Set

Multiple Signal Sources

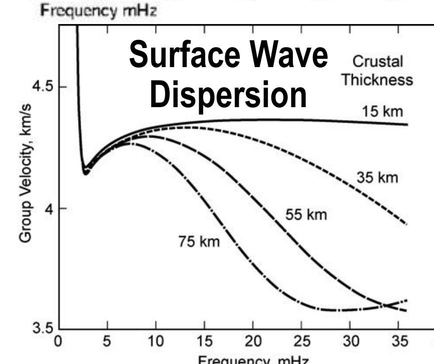


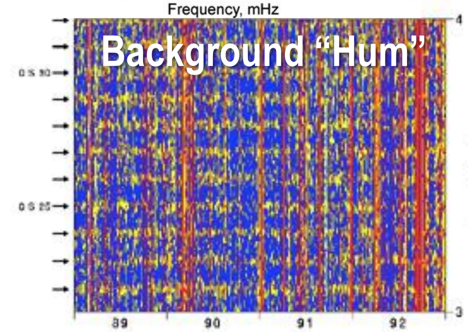
Multiple Analysis Techniques

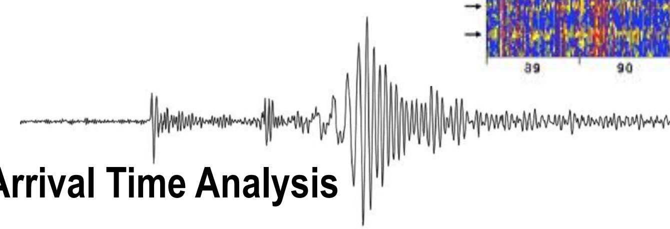




Receiver Function







Arrival Time Analysis

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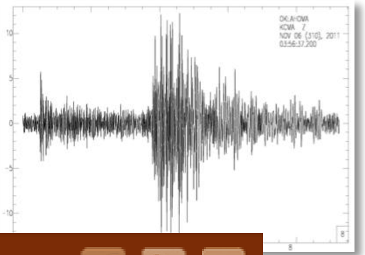
InSight Would Excite and Engage the Public

- Accessible science
  - Understanding the way planets (including the Earth) formed
  - Marsquakes/Earthquakes are visceral, dynamic events
  - Drilling 3–5 meters beneath the Martian surface opens an exciting new dimension
- Humans interacting directly with Mars
  - Robotic operations would engage people with the excitement of working on the surface of Mars
  - Our Twitter followers and mobile app would receive a notice whenever a Marsquake occurs!
- Planetary science data in the classroom
  - Kids would have rapid access to Martian seismic data, leveraging the existing successful “Seismometers in the Classroom” program, plugging directly into the Earth science curriculum

Mars “Shake Rattle and Roll” App



InSight already has a growing following on Facebook and Twitter.

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PP Planning and Implementation (cont…)

- Payload Hardware
  - A majority of the payload hardware is planned to be compatible with heat sterilization or vapor hydrogen peroxide.
  - Both HP^3 and SEIS will be contracting out PP bioburden assay sampling.
  - PP compliance will be monitored with the International Partners by a combination of paperwork, site visits, and NASA PPO verification sampling events
- Impact Avoidance:
  - Probability of impact of Mars by the launch vehicle (or any stage thereof) shall not exceed 10^{-4}
  - Probability of accidental impact of Mars due to failure during cruise phase shall not exceed 10^{-2}
  - Provide an estimate of the Entry, Descent, and Landing Reliability
- Spacecraft would be assembled in Class 100,000 / ISO Class 8 (or better) clean facilities, with appropriate controls and procedures

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