Overview

• Mission highlights
• PP requirements
• Implementation approach
• Special analyses
• Improvements (lessons learned) since MSL
• Foreign payload handling
• Effective, continuing communication with the PP Officer
• InSight schedule
Salient Features

- Category: 2; Risk Class: B
- Mars Lander based on Phoenix heritage
- Science instruments contributed from CNES (SEIS) and DLR (HP3)
- Launch Period March 4-26, 2016, on ATLAS V 401
- 6.5-month cruise, type 1 trajectory, direct entry
- Landing on Sept. 28, 2016, followed by one Martian year of science measurements on the surface

Science

1. Understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars by determining:
   - The size, composition and physical state (liquid/solid) of the core
   - The thickness and structure of the crust
   - The composition and structure of the mantle.
   - The thermal state of the interior
2. Determine the present level of tectonic activity and meteorite impact rate on Mars by measuring:
   - The magnitude, rate and geographical distribution of internal seismic activity
   - The rate of meteorite impacts on the surface

Payload

- SEIS – Broad-band seismometer: Measures seismic waves from 0.01 mHz to 50 Hz to determine the planet’s interior structure
- HP3 – Heat Flow and Physical Properties Package: Measures subsurface thermal gradient and conductivity to determine planetary heat flow
- RISE – Rotation and Interior Structure Experiment: Uses S/C communication system to measure rotational variations of Mars
- IDS – Instrument Deployment System: Robotic arm and cameras to deploy SEIS and HP3 to the surface
- APSS – Auxiliary Payload Sensor Subsystem: Environmental sensors (wind, pressure, and magnetic field) to support the SEIS experiment
Launch, Cruise, and EDL Phases

• 23-day launch period opening on 4 March 2016
  – Launch vehicle will be Atlas V 501
  – Constant arrival date of 28 September 2016
  – Assumes MRO node move to 2:30 PM for robust EDL Comm

• Type 1 transfer from Earth to Mars with 6.5-month Cruise Phase
  – EDL delivery accuracy is dependent on ESA (or JAXA) DDORs

• InSight EDL design is within the heritage capabilities
  – Higher entry speed and elevation
  – Landing region already selected—Elysium Planitia
InSight Payload

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

HP³ (DLR)
Heat Flow and Physical Properties Package

SEIS (CNES)
Seismic Experiment for Interior Structure

IDS (JPL)
Instrument Deployment System

APSS (JPL)
Auxiliary Payload Sensor Suite

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Surface Deployment and Science Monitoring

- 67-sol instrument deployment period
  - 22 days of built in margin
  - Science starts on sol 7 (RISE)
  - No strict time constraint for deployment

- Operational support
  - Full-team tactical operations during deployment
  - Using heritage MOS/GDS tools and processes

- One full martian year of science monitoring
  - Only minimal support team needed during science operations
  - Technical margins for operations are in good shape
Landing Site Constraints

- **Latitude**: 15°S to 5°N: Sufficient Solar Power Margins
  - 3°N to 5°N Elysium Planitia (takes advantage of the northern latitudes)
- **Elevation**: <-2.5 km MOLA: Sufficient Atmosphere for EDL
- **Ellipse Size**: 139 km x 27 km [99.5% ellipse]
- **Thermal Inertia**: >100–140 J m⁻² K⁻¹ s⁻¹/²
  - Avoid surfaces with thick dust that is not loading bearing
  - Prefer ~200 J m⁻² K⁻¹ s⁻¹/² for uncemented or poorly cemented soil
  - Radar reflective surface
- **Rock Abundance**: <10%
  - 99% Safe Landing and Opening Solar Panels
- **Smooth Flat Surface**: No large relief features
  - Slopes <15° for Safe Touchdown and Radar Tracking (1-5 m & 84 m)
- **Deploy Instruments**: [<10% Rock Abundance, <15° Slope]
- **Broken up regolith >5 m thick**: Hesperian Cratered Surface
  - Penetration of the Mole

*No Other Science Requirements: Just Land Safely*
• Prior to down-selection
• Second Landing Site Workshop 2014
• Landing Site Downselection – Late Summer/Fall – 2 ellipses
• Landing Site Selection PPO Review – ~10/15
PP Requirements

• As a Mars lander mission without life detection instruments, the InSight mission has been designated **PP Category IVa** by the NASA PPO.

• In accordance with the requirements stated in NPR 8020.12D for this category and type of mission, the InSight Project will comply with:
  – Bioburden requirements, *i.e.*, \( \leq 5 \times 10^6 \) total spores at launch, \( 3 \times 10^6 \) total spores on planned landing hardware, a mean exposed surface density of \( 300 \) spores/m\(^2\)
  – Assembly and testing in ISO 8 (or better) cleanroom environments
  – Launch environment cleanliness and recontamination avoidance – hardware cleanliness and launch recontamination not to exceed bioburden requirements
  – Organic inventory – bulk inventory of at least 50 grams of each organic material type for which more than 25 kg is transported to Mars and documentation of organic materials for which are present in quantities of 1kg
  – Probability of Impact – Launch vehicle Mars avoidance of less than \( 10^{-4} \) for 50 years after launch, and probability of a non-nominal impact of Mars by the spacecraft due to cruise phase failure shall not exceed a \( 10^{-2} \)
PP Requirements

• Additional Project requirements to include:
  – Average internal (behind HEPA or tortuous path) bioburden $\leq 1,000$ spores/m$^2$
  – Mole shall be unpowered and cease operations immediately if tether breaks
  – Ice shall not be present within reach of HP$^3$ instrument’s mole
  – Mole shall not generate a thin liquid film as a result of operations sufficient enough to transport a 50 nm particle.
  – Planetary Protection Landing Site Review Required

• Utilizing NASA PPO provided “new” heat microbial reduction specifications which provide expanded implementation options (e.g., no humidity constraints, credit for manufacturing credit)

• All PP requirements have been captured into the Level 2 Project System Requirement Document [first Project to capture all PP requirements into Dynamic Object Oriented Requirements (DOORS) V&V tool].

• All Level 2 and 3 requirements are under Project Change Control Board management.
The general approach to implementing PP for the InSight mission consists of:

1. microbial burden reduction (e.g., heat microbial reduction, manufacturing credit, IPA cleaning)
2. sampling and bioassays
3. re-contamination prevention (bagging, draping, etc.)
4. exemption of accountable bioburden via HEPA filters and/or tortuous paths
5. special cases (Backshell TPS destructive assays, French Press technique, cryogenic grinding, etc.)

Campaign flexible and able to be tailored to specific hardware
– the requirements of PP, particularly microbial bioburden requirements
– implementation feasibility
– assembly and integration details
– minimization of hardware manipulation and operations

Use of Flight spare(s) treated as flight units for proxy sampling

Phoenix PP implementation approach = baseline for InSight!
### Bioburden Allocation

- **Total Bioburden – 500,000 spores**

<table>
<thead>
<tr>
<th>Category</th>
<th>Spores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lander</td>
<td></td>
</tr>
<tr>
<td>PHX Landed Hardware (minus parachute)</td>
<td>32,000</td>
</tr>
<tr>
<td>Parachute</td>
<td>32,000</td>
</tr>
<tr>
<td>New External Lander Hardware and LM Reserves</td>
<td>35,000</td>
</tr>
<tr>
<td><strong>Payload</strong></td>
<td></td>
</tr>
<tr>
<td>SEIS</td>
<td>20,000</td>
</tr>
<tr>
<td>HP3</td>
<td>25,000</td>
</tr>
<tr>
<td>IDS</td>
<td>25,000</td>
</tr>
<tr>
<td>APSS</td>
<td>25,000</td>
</tr>
<tr>
<td>Impacting Hardware (PHX actuals)</td>
<td>100,000</td>
</tr>
<tr>
<td>Launch Recontamination (MSL heritage value from Atlas V)</td>
<td>22,000</td>
</tr>
<tr>
<td>Project Held Reserves</td>
<td>160,000 (32%)</td>
</tr>
</tbody>
</table>
• Landing Site Characterization
  
  – **Landing Site is NOT a Special Region**
    
    • Modeling shows the bounding sub-surface temperatures over the full Mars year on specific sols if the InSight Mission. HP3 penetration phase expected ~sol 67 -100. Thermal model verification being conducted.
    
    • The short-lived temperature elevation of the subsurface above ambient due to HP$^3$ hammering and thermal conductivity measurement activities is on the order of 10 – 50°C. Mean subsurface temperatures at this site are -55°C, producing thermal elevations to ~0°C. The regolith in the Elysium region is dry and ice-free, preventing HP$^3$ heating from generating water activities in pore spaces from exceeding 0.5, the threshold for microbial activity. The maximum possible water activity ($a_w = rh/100$) of 0.09.

  – **Thin Film Analysis**
    
    • Background - A) hydrous mineral composition in martian soil capable of dehydration in the -55°C – 0°C, conservative as it accounts for MgSO$_4$ minerals not likely at equatorial sites and B) factors in the maximum quantities of water lost from dehydration of those minerals
    
    • A pulse of a small quantity of water due to the mole would generate 8 to 10 monolayer equivalents in the immediate mole vicinity. This would return to its equilibrium value of 2 monolayers within hours.
    
    • Liberated water would flow in under capillary action, spreading out in all directions. But, the maximum film thickness is too small to entrain a 50 nm particle and is both a short-lived and small-distance phenomenon.
• L2-PSRD-113: The InSight project injection aimpoint for launch shall be biased away from Mars such that the probability of the launch vehicle upper stage impacting Mars is less than $1.0 \times 10^{-4}$ for 50 years after launch.

• Directed to consider Centaur anomalies in the assessment
  – Anomalies include: Failure to separate, failure to perform CCAM, failure to blowdown

• Approved PPO Plan Forward
  1. Design the biased aimpoints and CCAM attitude to ensure a minimum first-pass probability of impact less than $0.5e^{-4}$ for all anomalous scenarios.
  2. Design the blowdown attitude to ensure that the Mars encounter is sufficiently far away that the $\Delta V$ from the gravity assist is insufficient to place the Centaur on a 50-year resonant trajectory in the nominal scenario.
  3. Perform 5,000-case, 50-year Monte Carlo propagations of the three anomalous scenarios to determine the Beta distribution shape parameters for the 50-year probabilities of impact.
  4. Generate one million samples of each of the six Beta distributions representing the probability of an anomaly and the resulting 50-year probability of impact.
  5. Combine the six million-sample sets and analytical probabilities to determine the distribution of the estimate of the total probability of impact.

• Approved NASA PPO methodology being written up and submitted to a peer-reviewed journal.
• Furnished here are bacterial colony forming unit (CFU) indices germane to meaningful real-time prescreening/monitoring of colony counts resulting from Planetary Protection (PP) bioassays of InSight flight hardware.

• These tables provide all personnel conducting PP bioassays with an “early warning” system with respect to CFU observed in real-time. The tables clearly present the ramifications, with respect to hardware being assembled/tested, of varying levels of tallied CFU counts, i.e., PROCEED, CONSULT the PPE, or STOP, RECLEAN, and RESAMPLE.

**Table 1. Real-time CFU Monitoring Scheme for General Flight Hardware (slightly more stringent)**

<table>
<thead>
<tr>
<th>InSight Flight System</th>
<th>CFU Resulting From Assay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Device</td>
<td># of Devices</td>
</tr>
<tr>
<td>Cotton Swab</td>
<td>1 to 4</td>
</tr>
<tr>
<td>Cotton Swab</td>
<td>5</td>
</tr>
<tr>
<td>Cotton Swab</td>
<td>10</td>
</tr>
<tr>
<td>Cotton Swab</td>
<td>15</td>
</tr>
<tr>
<td>Cotton Swab</td>
<td>20</td>
</tr>
<tr>
<td>Flocked Nylon Swab</td>
<td>1 to 4</td>
</tr>
<tr>
<td>Flocked Nylon Swab</td>
<td>5</td>
</tr>
<tr>
<td>Flocked Nylon Swab</td>
<td>10</td>
</tr>
<tr>
<td>Flocked Nylon Swab</td>
<td>15</td>
</tr>
<tr>
<td>Flocked Nylon Swab</td>
<td>20</td>
</tr>
<tr>
<td>Polyester Wipe</td>
<td>1</td>
</tr>
<tr>
<td>Polyester Wipe</td>
<td>2</td>
</tr>
<tr>
<td>Polyester Wipe</td>
<td>3</td>
</tr>
<tr>
<td>Polyester Wipe</td>
<td>4</td>
</tr>
<tr>
<td>Polyester Wipe</td>
<td>5</td>
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<tr>
<td>Polyester Wipe</td>
<td>10</td>
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<tr>
<td>Polyester Wipe</td>
<td>15</td>
</tr>
<tr>
<td>Polyester Wipe</td>
<td>20</td>
</tr>
</tbody>
</table>

*#equates to between zero and 30 spores/m², proceed
*#equates to between 31 and 299 spores/m², consult PPE for necessary rectification/resampling
*#equates to >299 spores/m², reclean and resample
Improvements (lessons learned) since MSL

- Systems engineering approach for requirements flow down. All PP requirements have been captured in the Level 2 Project System Requirement Document [(first Project to capture all PP requirements into Verification & Validation (V&V) tool]. PP requirements flow down to Level 5, and V&V confirmation is planned.

- PP Equipment Implementation List – one-stop excel spreadsheet for engineers to reference planned PP implementation approach & bioburden reduction/cleaning regimen for their hardware. This includes drawing impacts, captures bioassays, cleaning steps, heat microbial reduction time and temperatures, etc.

- PP inclusion during PDR and CDR subsystem and system level reviews.

- Involvement of PPO early on in the Project for Launch operation PP implementation approach
  - Launch pad operations walk down and implementation options briefed 4-17-14
  - Payload processing facility walk down and implementation options ~Late Fall 2014/Early 2015
Foreign Payload Handling

- Specific InSight Project PP Payload Implementation Plans
- Instrument Providers then generated own Institutional (i.e. CNES and DLR) PP Plans
- Flow down of PP requirements to L4 payloads
- Frequent telecons and email exchanges (effective & efficient communication)
  - Implementation approach questions
  - Assay updates
- PP participation / topic area of discussion for HP³ and SEIS weekly telecons
- Planned
  - PP assay interfaces and hardware certification process and status bio-assays planned on site at CNES and DLR with InSight planetary protection engineer.
Effective, continuing communication with the PP Officer

- Quarterly Insight / PPO meetings
- Subsystem CDR PP specific briefing
- Vandenberg Air Force Base launch complex PP / CC working group
  - SLC-3E walk down
  - West Coast PP Implementation approach presented
  - Planned: payload processing facility walk down and implementation approach overview
- Verification Assays
  - Instrument Deployment Arm Hardware
  - Proactively working bioassay schedule to identify PPO verification assays for tracking
- Frequent email and phone exchanges (open, effective, efficient communication)
  - Including multiple informal meetings, tag-ups and review with not only the PPO, but with the PPO’s designee / advisor
Looking ahead…

• PP Compliance Review – ~9/15/14
• System Integration Review (SIR) – 10/7/14
• Start of ATLO – 11/4/14
• Instrument Deliveries to ATLO – 1/15
• Spacecraft ship to VAFB -12/15
• Launch – 3/16
InSight Planetary Protection Team

- JPL
  - Myron La Duc, Deputy PP Lead
  - Gayane Kazarians
  - Moogega Cooper
- LM
  - Joe Witte, LM PP Lead
  - Amy Baker
  - Dennis Vaughn
  - Ray (Jamie) Woodzell
- CNES
  - Christian Martin
  - Delphine Faye
- DLR
  - Matt Dalton
  - Petra Rettberg
1. The planet starts forming through accretion of meteoritic material.

2. As it grows, the interior begins to heat up and melt.

3. Stuff happens! InSight!

4. The planet ends up with a crust, mantle, and core with distinct, non-meteoritic compositions.
Our understanding of planetary differentiation is largely based on the lunar magma ocean model, which was developed in response to Apollo geochemical and geophysical data. But...

- This is a complex process; the physics is not well understood and present constraints are limited.
- Lunar P-T conditions are not particularly representative of other terrestrial planets.
Terrestrial planets all share a common structural framework (crust, mantle, core), which is developed very shortly after formation and which determines subsequent evolution. We seek to understanding the processes by which this structure is formed.

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

- There is strong 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.