Overview of the Phoenix Entry, Descent and Landing System

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Jet Propulsion Lab
Phoenix Mission Goals

Rebirth of the Mars 2001 Lander

- Study the history of water in Mars’ arctic region.
- Search for habitable zones in Mars’ arctic.
- Develop a robotic system to explore Mars.
Payload

Surface Stereo Imager (SSI)
University of Arizona

Robotic Arm (RA)
JPL

Robotic Arm Camera (RAC)
Max Plank Aeronomie

Microscopy, Electrochemistry & Conductivity Analyzer (MECA)
JPL

Thermal Evolved Gas Analyzer (TEGA)
University of Arizona

Mars Descent Imager (MARDI)
MSSS

Meteorological Package with scanning LIDAR
Canadian Space Agency

2nd IPPW
August 23rd, 2004
# Aeroshell/Entry Comparison

**Entry Vehicles**

<table>
<thead>
<tr>
<th></th>
<th>Viking I, II</th>
<th>MSL</th>
<th>’01 Lander</th>
<th>MPF/MER</th>
<th>Phoenix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter, m</td>
<td>3.505</td>
<td>4.572</td>
<td>2.65</td>
<td>2.65</td>
<td>2.65</td>
</tr>
<tr>
<td>Rel. Entry Velocity, km/s</td>
<td>4.5, 4.42</td>
<td>5.2 to 6.8</td>
<td>6.5</td>
<td>7.6/5.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Rel. Entry FPA, deg</td>
<td>-17.6</td>
<td>-15.63 to -13.68</td>
<td>-12</td>
<td>-13.8/-11.5</td>
<td>-12.5</td>
</tr>
<tr>
<td>Entry Mass, kg</td>
<td>930</td>
<td>2400</td>
<td>588</td>
<td>585/840</td>
<td>602</td>
</tr>
<tr>
<td>m/(C_d A), kg/m²</td>
<td>63.7</td>
<td>94</td>
<td>62.9</td>
<td>62.3/89.8</td>
<td>69.3</td>
</tr>
<tr>
<td>X_{CG}/D reference</td>
<td>0.221</td>
<td>0.27, TBD</td>
<td>0.25</td>
<td>0.27/0.26</td>
<td>0.25</td>
</tr>
<tr>
<td>Nominal α, deg</td>
<td>-11.1</td>
<td>-11</td>
<td>-3.5</td>
<td>0</td>
<td>-3.5</td>
</tr>
<tr>
<td>Nominal L/D</td>
<td>0.18</td>
<td>0.18</td>
<td>0.06</td>
<td>0</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Entry Trajectory Comparison

Altitude, km

Relative velocity, km/s

MER-A

MER-B

Phoenix

MSL

Viking 1 + 2

MPF
Phoenix EDL Timeline

- Entry Turn Starts: E-6.3 min. Turn completed by E-5min.
- Cruise Stage Separation: E-5min
  - Entry: E-0s, L-470s, **125 km***, 5.7 km/s, $\gamma = -12.5^\circ$
  - Peak Heating: E+99s, L-301s, **45 km**, Peak Deceleration: E+117s, L-353s, 7g
  - Parachute Deployment: E+250s, L-150s, **10 km**, < 350 m/s (Mach 1.45)
  - Heat Shield Jettison: E+260s, L-140s, **9 km**
  - Radar Activated: E+263s, L-137s, **8 km**
  - Leg Deployments: E+293s, L-107s, **6.5 km**

- Lander Separation: E+371s, L-29s, **0.74 km**
- Throttle Up: E+374s, L-26s, **0.57 km**
  - Constant Velocity Achieved: E+393s, L-7s, **0.012 km**, 1.6 m/s
  - Radar cutoff: E+395s, L-5s, **0.010 km**, 1.6 m/s

- Touchdown: E+400s, L-0s, **0 km**, 1.6 m/s
  - Dust Settling: L+0 to L+15 min
  - Fire Pyros for Deployments: L+7sec
  - Solar Array Deploy: L+25min
  - Begin Gyro-Compassing: L+100min

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* Altitude referenced to equatorial radius

X-band DTE Closed / Open Loop
UHF-band to Orbiter

X-band DTE Open-Loop
UHF-band to Orbiter

X-band DTE
to Orbiter

* Altitude referenced to equatorial radius

Landing at
-3.5 km
elevation above
MOLA

Lockheed Martin

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RG 6
Hypersonic Phase

- Hypersonic Guidance will be Demonstrated by Using a Modified Version of the Apollo Earth-entry Guidance
  - Terminal Point Range Control with Gain Matrix From Trajectory Perturbations
  - Nominal Vehicle L/D = 0.06 (Alpha=3.5 deg)
  - Utilizes Bank Control to Steer to Target at Chute Deploy
  - Operates at 10 Hz

- No Requirement on Guidance Accuracy
- Performance will be Characterized by End-to-End Monte Carlos
- “Break-it” Testing Will Help Define Capability Limits
- Full “Lift Up”/“Lift Down” Does Not Impact Landed Success, Just Accuracy
Hypersonic Phase

- Begins with Entry Interface at 125 km Reference Altitude
- Dominated by Entry Heating
- All Key Parameters Within Mars 2001 Design Envelope

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<tr>
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<th>Mars ’01 Requirement</th>
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<tr>
<td>Entry Velocity</td>
<td>5.76 kps</td>
<td>~6.5 kps</td>
</tr>
<tr>
<td>Entry Errors, Delivery</td>
<td>0.20 deg</td>
<td>0.27 deg</td>
</tr>
<tr>
<td>Entry Errors, Nav</td>
<td>0.15 deg</td>
<td>0.15 deg</td>
</tr>
<tr>
<td>Max Heating</td>
<td>62 W/cm²</td>
<td>72 W/cm²</td>
</tr>
<tr>
<td>Max Loads</td>
<td>9.5 g’s</td>
<td>16 g’s</td>
</tr>
<tr>
<td>Max Bondline Temp</td>
<td>150 °C</td>
<td>250 °C</td>
</tr>
</tbody>
</table>

- Exist Hardware: Heatshield / Backshell Structure & TPS
- New Hardware: EDL Antennas & Assoc. TPS

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Parachute Phase

Phoenix Parachute

• Viking Design Disc Gap Band (DGB)

• Mars 2001 Parachute: 13.4m Viking disc gap band
• Phoenix Currently 12.4m Viking Disc Gap Band
• Phase Begins with Parachute Mortar Firing
• Mars-01 Deploy Pushed to Viking Limit for Site Performance
• Current Lander Loads Capability Requires a Deploy Below 500 Pa

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<td>Max Deploy Mach</td>
<td>1.7</td>
</tr>
<tr>
<td>Max Deploy Qbar</td>
<td>485 Pa</td>
</tr>
</tbody>
</table>
Terminal Descent Phase

Doppler Radar
- Altitude
  - Op. Range: 40-2400 m
  - Error: ≤5%
- Velocity
  - Op. Range: 40-1400 m
  - Error: ≤4% (> 1m/s)
  - Quantization: 0.82 m/s
- Phoenix Upgrade
  - Mitigates horizontal vel. error due to slopes
  - Extra set of antennas (8 total)
  - Alt. Range: 1-3700 m
  - Vel. Range: 10-2150 m
  - Quantization.: 0.40 m/s
  - Same error specs

Descent Engines
- 12 descent engines, ~300N each.
- Pulse-width modulated at 10Hz.
- Current baseline 3 full on.
- In addition to descent breaking, provides 3-axis attitude control.
EDL Communications

Data Return

- **UHF Comm during all of EDL**
  - Direct link to Odyssey or MRO
  - 8 Kb/s Data Rate
  - Concern about Plasma blackout in Hypersonic
- **X-Band Semaphores during all of EDL**
  - Confirmation of Key Events
  - Capability to produce “fault” semaphores
  - Some level of performance data
- Link analyses to be refined as Mission Design matures
Summary

• Phoenix is a rebirth of the 2001 Lander using the same hardware and many of the same team members.
• Continuation of follow water strategy targeting subsurface ice in the northern polar region.
• First use of hypersonic guidance at Mars.
• Launching in 2007 and landing in 2008, it returns to propulsive soft landing with strong similarity to the Viking landings.