Entry Descent and Landing on Mars

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Facts About Mars

Earth and Mars How Different are they?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mars</th>
<th>Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from Sun (AU)</td>
<td>1.4</td>
<td>1</td>
</tr>
<tr>
<td>Mass (Earth)</td>
<td>1/10</td>
<td>1</td>
</tr>
<tr>
<td>Radius (km)</td>
<td>1/2</td>
<td>1</td>
</tr>
<tr>
<td>Gravity (Earth)</td>
<td>1/3</td>
<td>1</td>
</tr>
<tr>
<td>Pressure (Earth)</td>
<td>1/100</td>
<td>1</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>CO2</td>
<td>N2/O2</td>
</tr>
<tr>
<td>Temp (F)</td>
<td>-120</td>
<td>60</td>
</tr>
<tr>
<td>Day (hrs)</td>
<td>24.6</td>
<td>24</td>
</tr>
</tbody>
</table>
Facts About Mars

• **Olympus Mons**
  – Largest Mountain in the Solar System: 21,000 km high
  – 3 times Mount Everest

• **Valles Marineres**
  – Largest Valley in the Solar System
  – 4,000 km long, 200 km wide and up to 7 km deep
  – 6 times as deep as Grand Canyon?
Mars Water

- Once oceans flowed on the surface
- Polar Caps have water ice
- Phoenix Lander Found Water

Have We Found Water on Mars?
Visiting Mars

- How many times have we landed on Mars?
  7 times!
  - Viking Landers 1 and 2
  - Pathfinder Sojourner
  - MER: Spirit and Opportunity
  - Phoenix Lander
  - Mars Science Laboratory
Mars Science Laboratory

- Was Mars a habitat for life?
- Largest Rover Mission to date to be Launched in Fall 2011
- Advanced suite of instruments for organic molecule detection
- Advanced EDL
  - 20 km to surface target
  - Up to 1 km above MOLA, 45 deg from equator
  - 4.5 m entry vehicle, 950 kg payload
  - Powered descent vehicle with 8 MLE’s
  - Sky-crane tethered landing of rover
Mars Science Laboratory

[Diagram of Mars Science Laboratory with labels and components like Mastcam, ChemCam, REMS, RAD, MAHLI, APXS, Brush, Drill/Sieves Scoop, MARDI, MSL Science Payload, CheMin, SAM inside the rover, DAN]
How we get down to the surface
Mars Science Laboratory EDL

Entry

E+0, r = 3522.2 km

Supersonic Parachute Descent

Deploy Supersonic Parachute
Heatshield Separation
Entry Balance Mass Jettison
Radar Activation and Mobility
MLE Warm-Up

h = ~10 km MSL
M = 2.0

h = ~8 km MSL
M = 0.7

Backshell Separation

Powered Descent

Sky Crane

Cut to Four Engines
Rover Separation
Rover Touchdown

Flyaway

h = ~800 m AGL

2000 m above MOLA areoid
Parachute Descent Function

- Mass/Volume efficient deceleration
- Provides difference in ballistic coefficient for the heat shield separation
- Prepares vehicle for powered descent
  - Attitude and velocity

Parachute Decelerator System

- 21.5 m Viking-type Disk-Gap-Band
- Mach 2.2 and 700 Pa deployment
- Viking Heritage deployment approach and conditions
- Kevlar / Nylon construction

Parachute Testing: Sometimes Things Don’t Go Right
Try and Try Again!
Try and Try Again!
Team Work!
What happens on Mars?
Hypothesis: Wake effect
Designing a Test Program
Subscale Constrained Parachutes
Non-Intrusive Optical Diagnostics

• Minimize Aerodynamic Interference
• Physical insight into the flow-field
• Quantitative measurement of flow-field

We Selected
High Speed Video, Flow Visualization, Particle Image Velocimetry
Wind Tunnel Camera Layout

Top View (Ceiling Removed)

Side View

End View
Without High Speed Video (30 fps)
With High Speed Video (3 kfps)
Photogrammetric Reconstruction

- Track and Compute “xyz” location of targeted points on the parachute for the purpose of computing inflated shape (i.e. Diameter, Height) and position in air-flow.

Low Density

High Density
Photogrammetry: Mach 2.5

1 Frame

50 Frame Sample
PIV Transient Measurement
PIV Flow Field Results
Wake Effect

Major Discovery

No Wake

Wake Present
Wake Effect of Flexible Parachute
What We Learned!

- Canopy in a high-pressure state.
- Shock moves upstream and becomes conical; streamlines are diverted and canopy depressurizes.
- Shock collapses and becomes flatter; streamlines enter canopy resulting in excessive mass ingestion and overpressurization.

Cycle repeats.
Touchdown

Playing in the sandbox
Plume Impingement Environment

1) Plume-gas thermal / contamination environment
2) Ground/plume soil erosion and contamination environment
3) Plume-gas Radar interference
4) Saltation induced radar interference environment
5) Landing site alteration / Descent stability

Sengupta et. al, 2009.
Phoenix Landing

Mehta et al., 2010.
Quarter-Scale Test Bed

Test bed Aerial View

Impingement Site
Landing Site Alteration

1000 μm media, 100%, 0 deg g-slope, 6.9 m, 1 s duration
Landing Site Alteration

100 um media, 100%, 0 deg g-slope, 6.9 m, 1 s duration
Launch Day: Nov 26th 2011
August 5th Curiosity has Landed
Post Landing EDL Assessment
Post Landing EDL Assessment
Post Landing EDL Assessment
Scooping the soil
Sampling the Rocks

ChemCam 1st Spectrum: 'Coronation'

[Chart showing spectral analysis of rocks, including elements and wavelengths.]
Mars Weather

PRESSURE SENSOR

[Graph showing pressure trends over time]

[Diagram of pressure sensor components and their labels: Wind sensors, Relative humidity sensor, Ground temperature sensor]
and so the Journey Begins
Questions?