Mars Science Laboratory Overview &
MSL EDL Challenges

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**MSL PROJECT OVERVIEW**

**Salient Features**
- Mobile Science Laboratory
- Hundreds of days of surface operational lifetime
- Discovery Responsive over wide range of latitudes and altitudes
- Controlled Propulsive Landing
- Precision Landing via Guided Entry

**Science**
- Mission science will focus on Mars habitability
- Next generation in-situ science investigations – To be acquired during FY’04 / FY’05
- Remote sensing/contact investigations - To be acquired during FY’04 / FY’05
EDL Challenges

Desires

• Significantly larger landed payload
  – Mass: 550 kg max
• Global access to Mars
  – Up to +2.5 km (MOLA)
  – Broad latitude range
• Smaller landing ellipse
  – ~ 20 km major axis
• EDL communication coverage
• Generalize EDL for future missions

Realities

• Each EDL design is somehow different
  – Different mission design
    • Entry velocity
  – The Martian atmosphere is different at each opportunity
    • Due to atmospheric pressure cycle
  – Different landing site
• Many uncertainties associated with the atmosphere
• EDL design is highly coupled
• EDL communication requirements introduce many constraints and variables
Mars Science Laboratory

MSL Surface System

- Current Mobility Details:
  - Wheels – 393 mm dia
  - Ground clearance – 660 mm static
  - Wheel base – 1720 mm
  - Track – 2100 mm
  - Middle Wheel is located 83 mm outside of front and rear wheels
Mars Rover Wheel Family Tree

MSL: ø400 mm  
MER: ø250 mm  
MPF: ø127 mm
Gusev Comparisons

3 km MOC NA FOV Coverage in 3 swaths
(HiRise=6 km, 2 swaths)
Mars Surface Accessibility

MOLA 1/4° Gridded Topography

Meridian:
- MER Northern Limit
- MSL Proposed Northern Limit
- MSL Proposed Southern Limit
- MSL Elev. Limit
- MER Elev. Limit

Elevation (km):
- <1.5
- 1.5-2.5
- 2.5-5
- >5

Longitude (°W):
- 0° to 360°
Parachute Deployment Altitude Variation with Time of Year and Latitude

- **Northern Winter**: Ls 124 (Sept 7, 2008)
- **Northern Summer**: Ls 171 (Oct 27, 2010)
- **MPL Ls 256**
- **M01 Ls 313**
- **MER Ls 333**
- **60° South in Southern Winter**
- **60° North in Northern Winter**

*MSL '09 arrival intentionally biased late to mitigate this effect*

**Typical progression is 50° Ls per opportunity ('16=250°, '18=300°, etc.)**

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<th>Event</th>
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<td>124</td>
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<thead>
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Dust Storms and Winds

- Increased dust (higher dust tau) reduces landing altitude capability
  - Higher atmospheric temperatures
  - Pushes column of air “up”
  - Results in higher chute deployment floor, reduced capability
  - Dust tau nominal range 0.1 – 0.9, 0.45 assumed to be typical
  - Designing to survive dust storm tau = 2.0

- Winds model based on MarsGRAM 2001 and Chia-Yen Peng dispersed wind model
# Nominal MSL EDL Timeline

## Entry Interface

$r = \text{3522.2 km}$

* $L/D = 0.18$
* Hypersonic Aeromaneuver Guidance

### Deploy Supersonic Chute

- $M = 2.2$
- $V = 491 \text{ m/s}$
- $\gamma = -15.0 \text{ deg}$
- $h = 8.0 \text{ km}$

### Jettison Heatshield, Activate Radar, and Deploy Mobility

- $M = 0.8$
- $V = 179 \text{ m/s}$
- $\gamma = -31.3 \text{ deg}$
- $h = 5.7 \text{ km}$

### Sense Velocity with Radar

$h = 2.0 \text{ km}$

### Jettison Chute and Backshell, Begin Powered Descent

- $V_v = 95 \text{ m/s}$, $V_H = 30 \text{ m/s}$
- $\gamma = -89.7 \text{ deg}$
- $h = 1.0 \text{ km}$

### Begin Sky Crane Maneuver

- $V_v = 3 \text{ m/s}$, $V_H = 0 \text{ m/s}$
- $h = 28 \text{ m/s}$

### Rover Touchdown

- $V_v = 0.75 \text{ m/s}$, $V_H = 0 \text{ m/s}$
- $h = 0 \text{ m/s}$

### Flyaway

2500 m above MOLA areoid
Specific EDL Challenges

• Entry
  – Aerothermological environment definition (i.e. TPS requirements)
  – TPS material selection and risk evaluation
  – Entry guidance reinvigoration, entry guidance last used on Viking

• Descent
  – Parachutes are never off the shelf

• Landing
  – Sky-crane lander is a new landing concept
  – Terminal Descent Sensor (landing radar)
  – Throttle-able propulsion system