Potential Atmospheric Hazards

EDL “Council of Atmospheres”

October 23, 2007
EDL System Sensitivities

- Closed-loop, guided entry based on inertial measurements
- Below 30 km MOLA, variations in density/wind/speed of sound from predicted values may cause the internally computed velocity and acceleration with respect to Mars to diverge from the true values
- Both parachute deploy and heatshield separation are critical events that must occur within Mach number and dynamic pressure constraints

- After Powered Descent start (2.0 km AGL)
  - MSL is robust to atmospheric variation
    - But: vertical winds at initiation of powered descent affect fuel usage assumptions
    - Not sensitive to horizontal winds, density perturbations during powered descent

Region of interest:
~2 km AGL - 30 km MOLA

Region of robustness:
0 km - 2 km AGL
## Engineering Safety Constraints

(Within 100 km of the Site)

<table>
<thead>
<tr>
<th>Density</th>
<th>Entry</th>
<th>Parachute Trigger</th>
<th>Heatshield Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;15% unc. from 20 km MOLA to 30 km MOLA</td>
<td>&lt; 10% unc. from 6.5 km MOLA to 20 km MOLA</td>
<td>&lt; 10% unc. from 6.5 km MOLA to 20 km MOLA</td>
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</tr>
</tbody>
</table>

### Thresholds for landing elevations > -1 km MOLA

- **u,v**:
  - < 25 m/s unc. from 6.5 km MOLA to 20 km MOLA
  - < 20 m/s unc. from 3 km MOLA to 6.5 km MOLA
- **W**:
  - < 20 m/s unc. from 3 km MOLA to 6.5 km MOLA
- **C Sound**:
  - < 7% unc. from 6.5 km MOLA to 15 km MOLA
  - < 7% unc. from 3 km MOLA to 6.5 km MOLA

### All Landing Altitudes
- **Sky Crane**
  - max. < 30 m/s
    - From 0 to 10 m AGL
  - max. < 20 m/s
    - From 1 to 5 km AGL
- **Backshell**
Atmospheric Working Group

- Held workshops in 2005 and 2006 to bring the EDL team and atmospheric scientists together; reviewed EDL simulations and scientific models; discussed approaches of MER and PHX.

- In October 2006 we formed a “Council of Atmospheres” to perform analyses and advise the project:
  - MSL Project: EDL team, Mission Manager, Project Science
  - External scientists: Scot Rafkin (SwRI), Jeff Barnes and Dan Tyler (OSU)
  - MarsGRAM and EDL Simulations: Jere Justus, Hilary Justh, Alicia Cianciolo, David Way
  - Additional help from Rich Zurek, Michael Mischna, David Kass, Bruce Cantor

- Goals:
  - Identify potential hazards (regions, phenomena, etc.)
  - Generate simulations, analysis tools, and interfaces
  - Certify safety of candidate sites
Atmospheric Working Group

- Two major workshops and biweekly telecons
- Identified “challenge sites” based on candidate landing sites and a survey of the entire MSL-accessible region.
- Simulated nominal conditions at these sites using MarsGRAM database and state-of-the-art GCM, mesoscale, and LES models.
  - Terby, Melas Chasma, Meridiani, Nili Fossae Trough, Gale
- Extracted relevant results and statistics and assessed them against EDL engineering safety constraints.
- Successfully demonstrated an end-to-end simulation of the MSL spacecraft flying through a model-generated atmosphere.
Atmospheric Hazards

- Season is near the maximum extent of the southern CO₂ cap; deep southern winter
- Descent through SH jet stream is a challenge unique to MSL
- Jet stream has variability in latitude, magnitude
- Also associated with cyclonic winter storms (like Earth)
- Other hazards include vertical winds due to large-scale convergences, orographic and slope winds, planetary boundary layer convection (amplified in NH summer)
Multiple profiles of horizontal wind (\( v \)) and variability envelopes for three challenge sites from MRAMS:
Atmospheric Hazards

SH jet stream mean velocity and afternoon mixed layer depth from OSU Mars-MM5:
Example of mesoscale model topography and vertical winds in Melas Chasma:
Atmospheric Assessment

- For this workshop, our team has provided a “stoplight” ranking of each candidate site based on what we’ve learned through the preliminary assessment of our challenge sites.
  - Proximity to regional topographic or albedo/TI gradients; active PBL
  - Local topography that may induce orographic or slope-driven winds
- After the workshop, we will perform a detailed and comprehensive assessment of each candidate site against the engineering constraints as part of the final selection & certification process.
  - Planetary and regional circulations
  - Topographic and convectively driven winds at the highest spatial resolution possible
  - Sub-grid turbulence; waves
  - Validation against observations
  - Non-nominal conditions including local / regional dust storms