EDL Landing Site Engineering Assessment
Mars 2020 Landing Site Workshop #2

EDL Design Team
August 4-6, 2015
Site Selection Considerations

- **Science Value**
- **Landing Safety**
  - EDL system margins
  - Terrain induced failure rates
- **Surface Productivity**
  - Latitude impact
  - Traverse distance and traversability
- **Planetary Protection**
  - Special regions
- **Program Considerations**
  - SRL considerations
Overview

• Studied the impact of landing sites on EDL system margins and estimated failure rates
  – Key EDL margins: timeline and fuel
  – Failures rates: driven by terrain/ touchdown hazards

• Margins and failure rates driven by three factors:
  – Site elevation
  – Atmosphere characteristics (winds and density profiles)
  – Terrain hazards (slopes, rocks, and inescapable hazards)

• Due to limited resources and time, we’ve focused our work on the top 9 sites from LSW1

• Since LSW1, range trigger has been approved
  – Smaller landing ellipse: 16 km x 14 km (or smaller)
    • Ellipse area shrinks by 40-50%
  – Focused on sites at -0.5 km MOLA or lower

• Evaluated landing safety with and without TRN
  – Color coded normalized to MSL final four risk assessment
  – Intended to inform TRN baseline decision
Overview (cont.)

• Our understanding of our landing capability is a little different than it was for “final four” selection on MSL
  – New inescapable hazard type: ripples
  – Cannot count on all the as-built performance realized on MSL; need to revert to margined performance to account for development uncertainty

• At sites where we’re having trouble, we’ve tried to make small tweaks to improve landing safety
  – Ceded some EDL margins (through smaller ellipses) where reasonable
  – Moved some landing ellipse targets (informed by ROI inputs from site proposers)
  – Applied as consistently as possible across sites, where warranted

• Terrain/touchdown hazards are the dominant concern

• There’s good news and bad news
  – At least one site does not require TRN
  – Most of the top 9 sites do require TRN for safe landing
Atmosphere Characterization
Mars 2020 Landing Site Workshop #2

Council of Atmospheres
Overview

- **Council of Atmospheres (CoA)**
  - Joint engineering and science team
  - Tasked with assessing atmospheric EDL risk
  - Provide mesoscale data to performance simulation

- **Participating Institutions**
  - **Jet Propulsion Laboratory (JPL)**
    - Michael Mischna
    - David Kass
    - Al Chen
    - Gregory Villar
  - **Oregon State University (OSU)**
    - Jeff Barnes
    - Dan Tyler
  - **Southwest Research Institute (SwRI)**
    - Scott Rafkin
    - Jorge Pla-Garcia
  - **Langley Research Center (LaRC)**
    - Som Dutta
    - Dave Way

---

**JPL**
- Provide areas of interest & Convene CoA meetings

**OSU (MMM5)**
- Generate mesoscale models

**SwRI (MRAMS)**
- Run performance simulation

**LaRC (POST)**

MMM5 – Mars Mesoscale Model 5
MRAMS – Mars Regional Atmospheric Modeling System
POST – Program to Optimize Simulation Trajectories

Pre-Decisional: For Planning and Discussion Purposes Only
Process and Status

• Timeline
  – 2014 September  Mars 2020 initiated Council of Atmospheres
  – 2014 November Global Circulation Models completed
  – 2015 April  Mesoscale Models completed
  – 2015 June  EDL Simulations completed

• Work Performed
  – Employed MSL-like process for top 9 sites
  – Preliminary mesoscale results from 2 models integrated in EDL simulations

• Key Result
  – As expected, landing ellipses are smaller using mesoscale winds

• Work To Go
  – Assess off-nominal cases (e.g. dust)
  – Perform surface pressure/total atmospheric mass study

Results are preliminary and several validation steps are ahead of us
Modeled Atmospheric Parameters

- Primary parameters considered in EDL performance
  - Winds – most influential from parachute deploy to touchdown
  - Densities – contributes to experienced loads
- Temperatures and pressures were also modeled
  - EDL performance is not as sensitive to these parameters

**Density at Top Sites**

**Example of Mesoscale Products**

*North East Syrtis – East-West Winds*
## CoA Summary

<table>
<thead>
<tr>
<th>#</th>
<th>Site</th>
<th>Atmosphere</th>
<th>Comments / Further Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NE Syrtis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Nili Fossae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Nili Carbonate</td>
<td></td>
<td>• Mesoscale model results were produced</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Work suspended pending resolution of terrain assessment</td>
</tr>
<tr>
<td>4</td>
<td>Jezero Crater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Holden Crater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>McLaughlin Crater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>SW Melas</td>
<td></td>
<td>• Small variability in winds at lower altitudes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Weaker winds compared to MSL analysis</td>
</tr>
<tr>
<td>8</td>
<td>Mawrth Vallis</td>
<td></td>
<td>• Stronger and more variable winds at lower altitudes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Some disagreement between models</td>
</tr>
<tr>
<td>9</td>
<td>East Margaritifer</td>
<td></td>
<td>• Some disagreement between models</td>
</tr>
</tbody>
</table>

**Identified issues not expected to significantly impact overall EDL performance**

**CoA does not expect to encounter issues after further assessment**
Terrain Characterization
Mars 2020 Landing Site Workshop #2

Presented by Richard Otero
Council of Terrains
August 4-6, 2015
• Current Members
  – Matt Golombek
  – Richard Otero
  – Fred Calef
  – Andres Huertas
  – James Ashley
  – Eduardo Almeida

• Critical Data Product Contributions
  – Randy Kirk (USGS – CTX/HiRISE DEM Generation)
  – Robin Fergason (USGS – CTX/HiRISE DEM Generation)
  – Matt Heverly (Surface Mobility Lead, initial inescapable hazard mapping)
  – Masahiro Ono (Traversibility Analysis Lead)
Overview

• As with MSL, Council of Terrains formed to characterize terrain hazards at candidate landing sites

• Key hazards of concern: rover scale slopes, rocks, inescapable hazards
  – Additionally, our understanding of rover capability has changed

• Focused on top 9 sites from LSW1
  – Identified and focused on hazard types of concern for each site
  – Combination of final and extrapolated data products used to generate preliminary hazard maps

• Evaluated landing safety with and without TRN
  – Color code normalized to the expected risk magnitude used by the MSL Final Four Analysis
  – **Green** (in family), **yellow** (on the edge), **red** (out of family)
  – Intended to inform TRN baseline decision
Close up of Area enabled by TRN

Example TRN Enabled Area

non-TRN Area for Holden (MSL Ellipse)
• Example hazard map for Holden (area requiring TRN)

• Incorporates rock and slope hazards

• Maps used with TRN to examine how well guidance can mitigate the identified hazards

• Initial identification of inescapable hazards for TRN to avoid if possible

<table>
<thead>
<tr>
<th>Failure Rate</th>
<th>Color Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 1%</td>
<td>Blue</td>
</tr>
<tr>
<td>1 – 2%</td>
<td>Green</td>
</tr>
<tr>
<td>3 – 14%</td>
<td>Yellow</td>
</tr>
<tr>
<td>14 – 16%</td>
<td>Orange</td>
</tr>
<tr>
<td>16 – 100%</td>
<td>Red</td>
</tr>
</tbody>
</table>
- Example hazard map for Jezero

- Rocks and *potential* inescapable areas identified as first order hazards

- Getting closer to the delta takes us farther from the rock field hazards

- Initial identification of inescapable hazards for TRN to avoid if possible

<table>
<thead>
<tr>
<th>Failure Rate</th>
<th>Color Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 1%</td>
<td></td>
</tr>
<tr>
<td>1 – 2%</td>
<td></td>
</tr>
<tr>
<td>3 – 14%</td>
<td></td>
</tr>
<tr>
<td>14 – 16%</td>
<td></td>
</tr>
<tr>
<td>16 – 100%</td>
<td></td>
</tr>
</tbody>
</table>
TRN Assessment

- 2020 continues to study the value of TRN for landing site access
  - Not currently in the baseline
- Developed analytical tools to quantify the effectiveness of TRN at candidate landing sites
  - Leverages all generated hazard maps and terrain data products
  - Very conservative assumptions of TRN capability
  - Diverts between 300-600m

Note: Red color in these two images show areas where failure is >1%
M2020 Hazard Posture is Different from MSL As Flown

- Current M2020 hazard posture incorporates new information and uncertainties
  - Pending changes to the rover and mobility system may impact touchdown capability
  - Ripple traverse performance worse than expected on MSL (may not improve for M2020)
- Forced to revert to more conservative hazard definitions for M2020
- Example: slope hazards at Mawrth

Near center of MSL Mawrth ellipse

>35 degree mask (100% slope death)
## Terrain Hazard Summary

<table>
<thead>
<tr>
<th>#</th>
<th>Site</th>
<th>w/o TRN</th>
<th>w/ TRN</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NE Syrtis</td>
<td>Red</td>
<td>Green</td>
<td>TRN not necessary safe landing</td>
</tr>
<tr>
<td>2</td>
<td>Nili Fossae</td>
<td>Green</td>
<td>Green</td>
<td>High percentage of original ellipse covered with inescapable hazards (not workable); investigating a potential alternative ellipse to the NW</td>
</tr>
<tr>
<td>3</td>
<td>Nili Carbonate</td>
<td>Red</td>
<td>Green</td>
<td>Ellipse size reduction will allow the trimming of the highest hazardous areas. TRN improvements and rock tolerance relief are under investigation.</td>
</tr>
<tr>
<td>4</td>
<td>Jezero Crater</td>
<td>Red</td>
<td>Green</td>
<td>Slight relocation of ellipse to the northeast.</td>
</tr>
<tr>
<td>5A</td>
<td>Holden Crater (MSL)</td>
<td>Red</td>
<td>Green</td>
<td>Small ellipse reduction used to remove inescapable hazards to the north. Relocated ellipse between main rock fields.</td>
</tr>
<tr>
<td>5B</td>
<td>Holden Crater (Land-On)</td>
<td>Red</td>
<td>Green</td>
<td>Ripple hazard concerns drove ellipse off original MSL location. Margined slopes increase the hazard relative to the MSL Final Four Analysis.</td>
</tr>
<tr>
<td>6</td>
<td>McLaughlin Crater</td>
<td>Red</td>
<td>Green</td>
<td>Significant slope and inescapable hazards. Situation not likely to improve.</td>
</tr>
</tbody>
</table>

*Color coded normalized to assessed risk of MSL final four landing sites

- **Green**: in family with MSL risk
- **Red**: out of family with MSL risk
- **Yellow**: somewhat out of family with MSL risk

Pre-Decisional: For Planning and Discussion Purposes Only
EDL Summary Assessment
Mars 2020 Landing Site Workshop #2

Chen, et al.
August 4-6, 2015
• Non-terrain related EDL margins are healthy at all top sites
  – Potential rover mass growth may eventually threaten margins at high site elevations for sites where TRN is also required
  – Current highest elevation site in top 9 (Nili Fossae) does not require TRN

• Terrain/touchdown induced failures are the prime discriminator between sites

• **TRN is needed to safely access most of the top sites from LSW1**
  – There is at least one non-TRN site in the top 9: Nili Fossae
  – Three sites may or may not require TRN: Holden, SW Melas, McLaughlin
  – There are two other potential non-TRN sites in the top 15 we could investigate
    • #11 Eberswalde
    • #13 Gusev