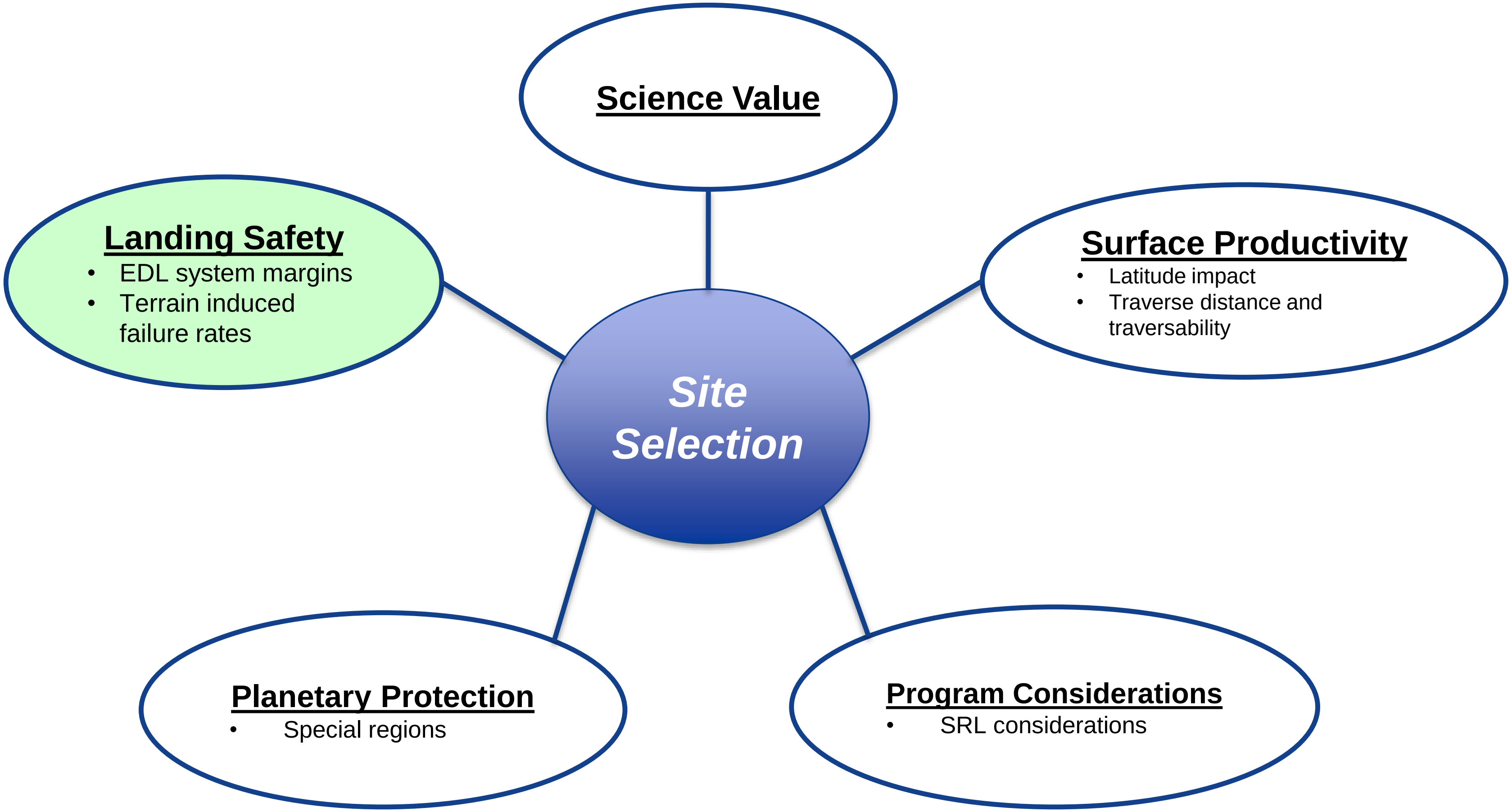
EDL Landing Site Engineering Assessment

Mars 2020 Landing Site Workshop #2

EDL Design Team

August 4-6, 2015

Site Selection 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

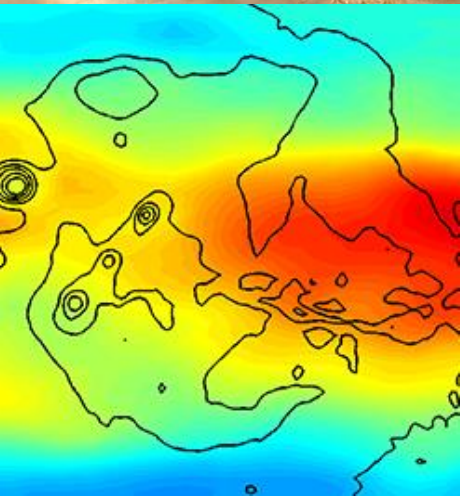
Overview (cont.)

- 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



Jet Propulsion Laboratory
California Institute of Technology

Mars 2020 Project

Atmosphere Characterization

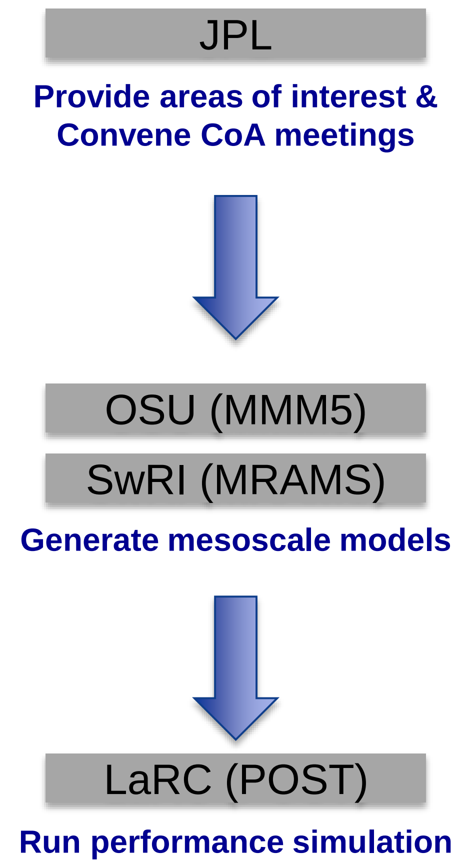
Mars 2020 Landing Site Workshop #2

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



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

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

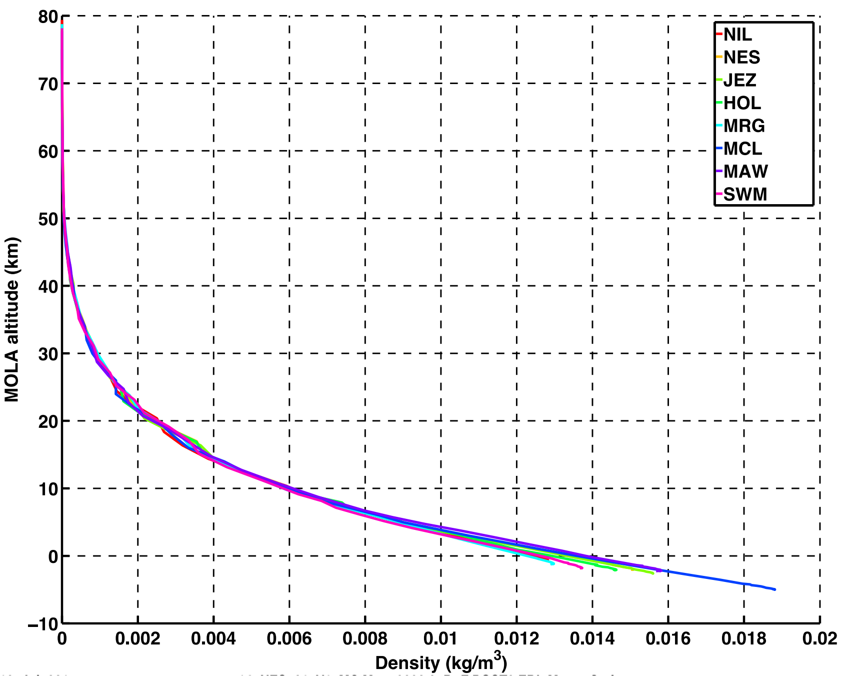
- Key Result
  - As expected, landing ellipses are smaller using mesoscale winds

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

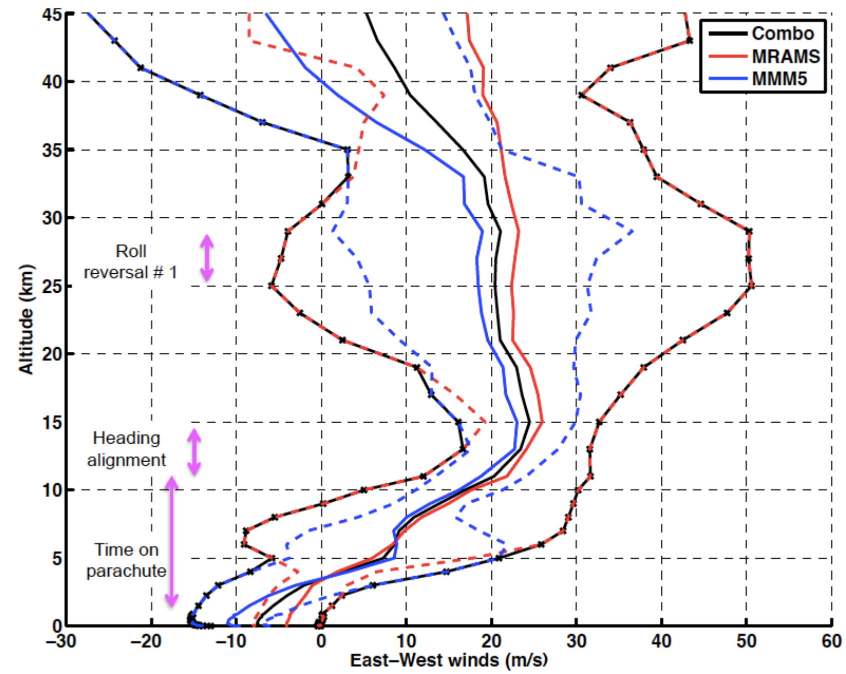
Results are preliminary and several validation steps are ahead of us

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

Pre-Decisional: For Planning and Discussion Purposes Only

CoA Summary

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

Identified issues not expected to significantly impact overall EDL performance

CoA does not expect to encounter issues after further assessment

Jet Propulsion Laboratory
California Institute of Technology

Mars 2020 Project

Terrain Characterization

Mars 2020 Landing Site Workshop #2

Presented by Richard Otero
Council of Terrains

August 4-6, 2015

M2020 Council of Terrains

- 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)

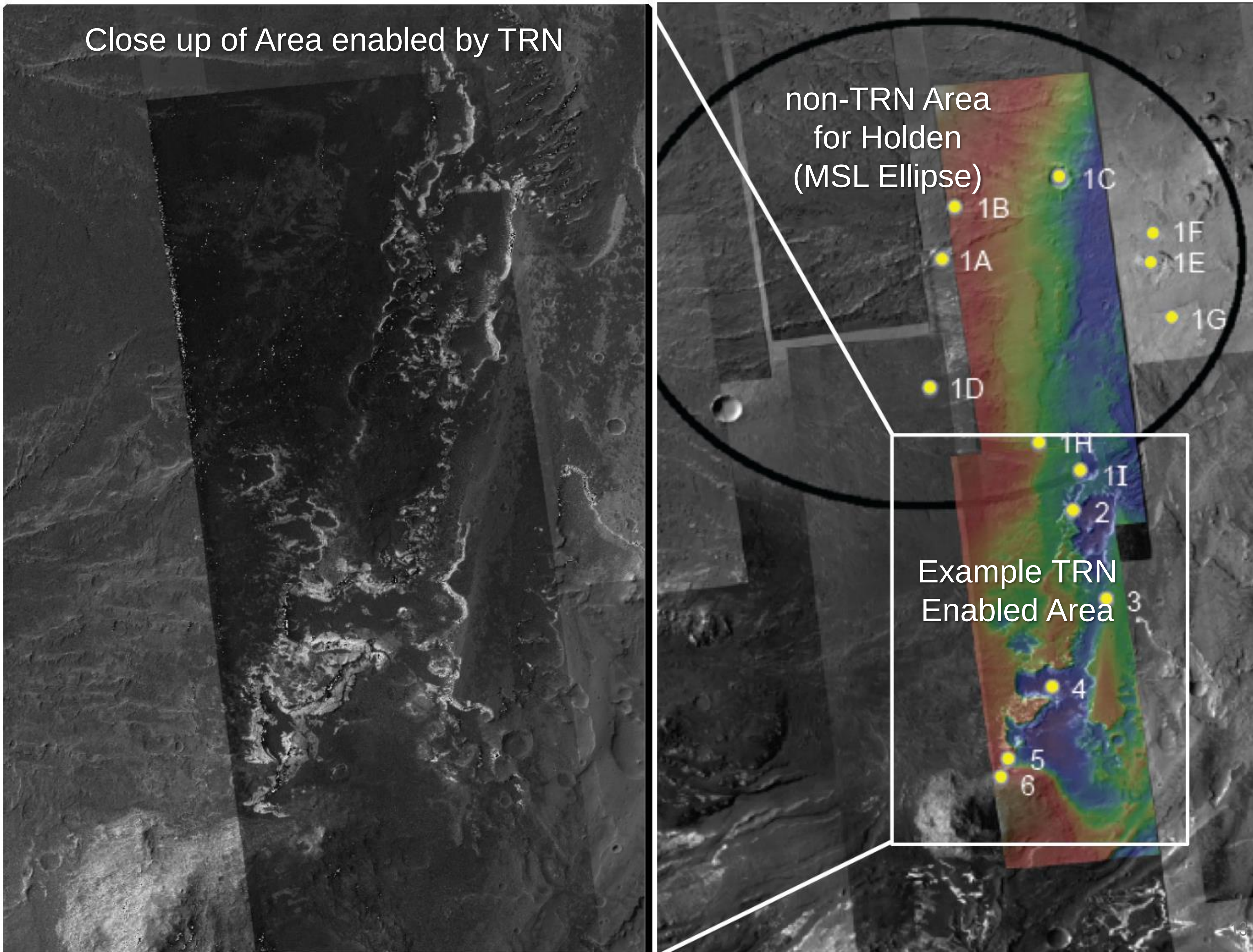
Overview

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

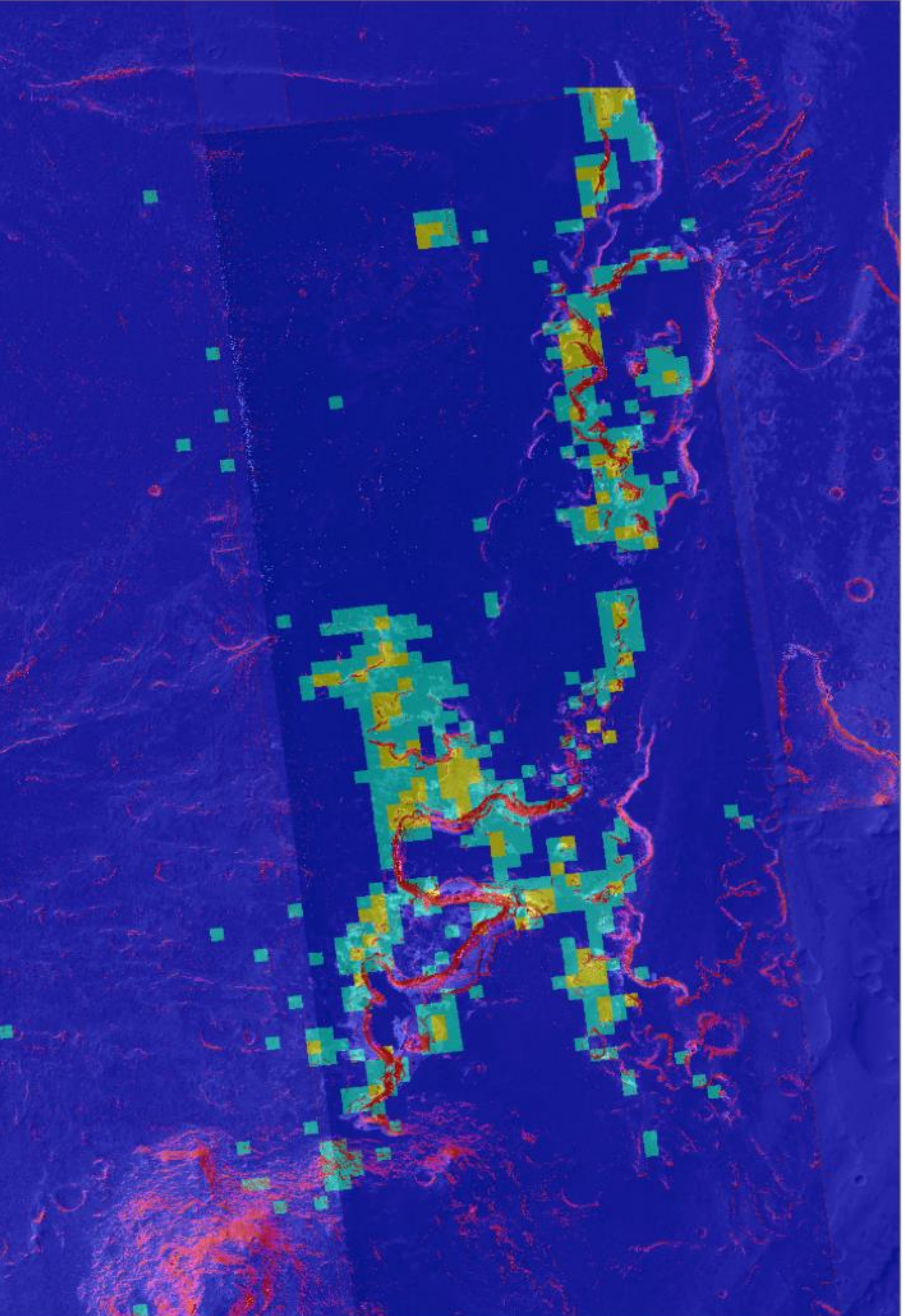
- Key hazards of concern: rover scale slopes, rocks, inescapable hazards
  - Additionally, our understanding of rover capability has changed

- 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



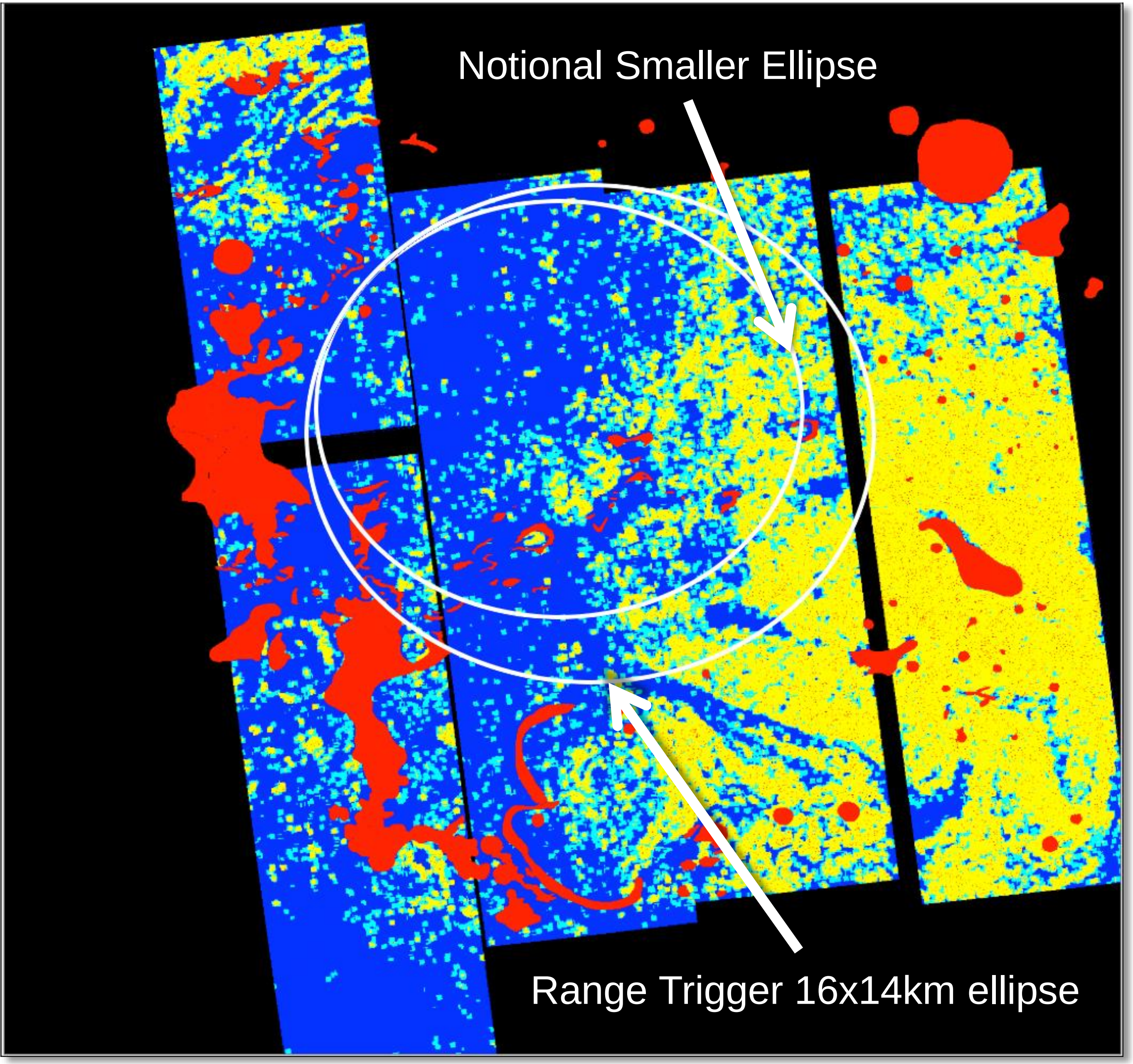
Close up of Area enabled by TRN
non-TRN Area
for Holden
(MSL Ellipse)
1A
1B
1C
1D
1E
1F
1G
1H
1I
2
3
4
5
6
Example TRN
Enabled Area



- 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

Failure Rate	Color Code
0 – 1%	
1 – 2%	
3 – 14%	
14 – 16%	
16 – 100%	

Discussion Purposes Only

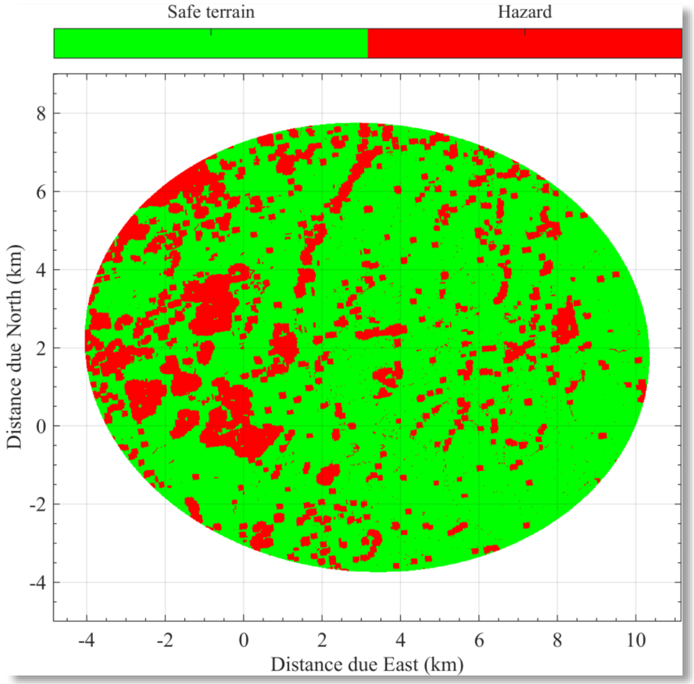


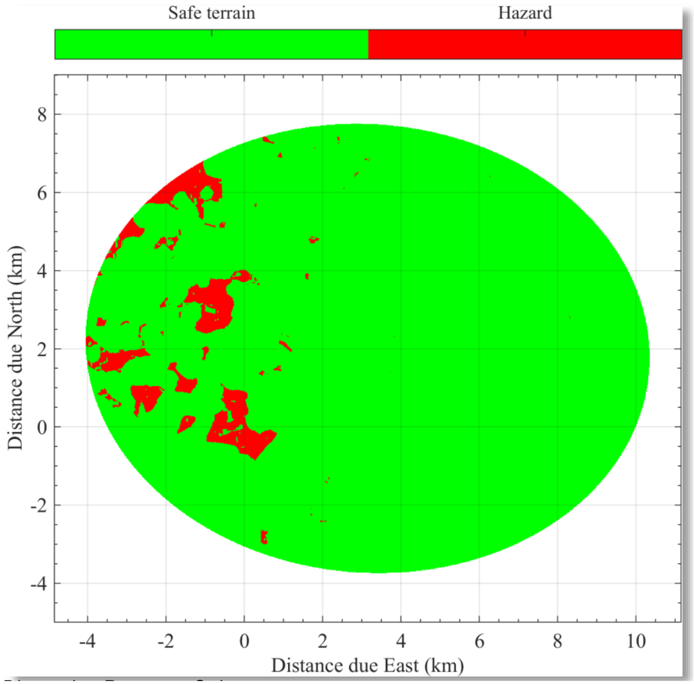
- Example hazard map for Jezero
- Rocks and *potential* inescapable areas identified as first order hazards
- Getting closer to the delta takes us farther from the rock field hazards
- Initial identification of inescapable hazards for TRN to avoid if possible

Failure Rate	Color Code
0 – 1%	
1 – 2%	
3 – 14%	
14 – 16%	
16 – 100%	

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





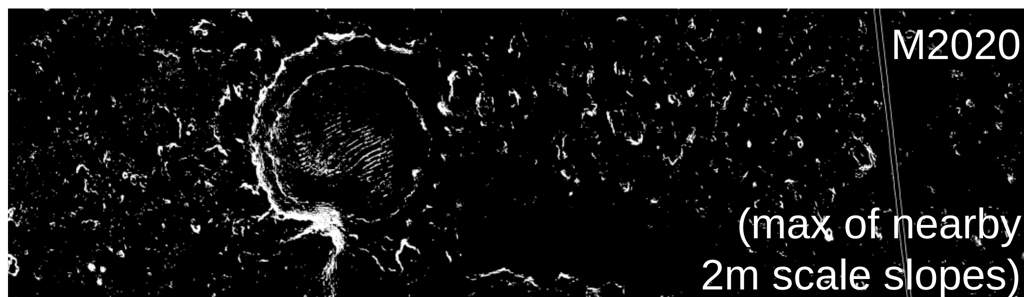
Note: Red color in these two images show areas where failure is >1%

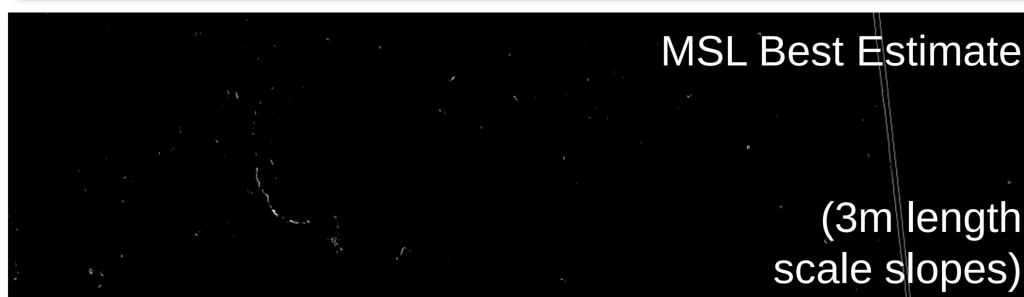
M2020 Hazard Posture is Different from MSL As Flown

- 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

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

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

= in family with MSL risk

= somewhat out of family with MSL risk

= out of family with MSL risk

↑ = likely to improve

↓ = likely to deteriorate

Jet Propulsion Laboratory
California Institute of Technology

Mars 2020 Project

EDL Summary Assessment

Mars 2020 Landing Site Workshop #2

Chen, et al.

August 4-6, 2015

Summary

- 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

- <u>TRN is needed to safely access most of the top sites from LSW1</u>
  - 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