FY24 R&TD Innovative Spontaneous Concepts (ISC)

Study of Returnable Data Volume in Mars Proximity Links Affected by Multipath Fading

Principal Investigator: Marc Sanchez Net (332)**; Co-Investigators:** Emily Wiederhold (397), Charles Lee (332), Ryan Mukai (337), Kar-Ming Cheung (332)

Strategic Focus Area: Innovative Spontaneous Concepts

Objectives: We studied the presence of multipath fading on Mars Science Laboratory proximity links and quantified the ability of numerical electromagnetic (EM) tools to predict the effect of multipath. Accuracy of predictions was evaluated against real-life telemetry from the Mars Relay Network. We also considered how multipath predictions could be used for planning of future Mars relay passes at the strategic level (e.g., weeks in advance) and prototyped a new tool called TSLICE.

Background: Mars rover operations work on a tight Sol-by-Sol timeline where downlinked data from a given Sol is used to plan activities on the upcoming Sol. Therefore, unexpected low data volume over a given pass can lead to insufficient data for mission operations to perform rover planning, thus disrupting the vehicle operational timeline. While there may be several factors that contribute to unexpected low data volume, multipath effects have been observed operationally but are poorly understood to date (other than basic geometric line-of-sight occlusion) [1].

Approach and Results:

1) Data collection and statistical analysis: Data on several MSL overflights was collected, including position/orientation of the rover/orbiter, Martian digital elevation map, telemetry from the return link, and link predictions used for relay planning.

2) High-fidelity EM simulations: A handful of overflights with the JPL Fading Model (JFM) [2]. Because data volume predicts are calculated from received signal level (RSL) estimates, and RSL was readily available as an output of the JFM, RSL was selected as the metric for comparison.

3) Prototyping of multipath-aware tactical planning process: We prototyped a tool (TSLICE) to enhance the relay planning process so that it includes terrain-induced effects.

We showed that there is clear evidence of the impact of multipath effect in historical relay telemetry, including higher likelihood of reduced data volume in the return direction, and an increase in unpredictability of the link performance, which leads to generally pessimistic data volume predictions. We also showed that line-of-sight blockage is a poor predictor of data volume loss, and that EM simulation tools cannot predict fading effect deterministically but provide reasonable results from a statistical standpoint, by relating fading loss to elevation angle above the terrain.

Significance/Benefits to JPL and NASA: In the near-term, this work is relevant to the MSL and M2020 projects which are already experiencing multipath effects. In the medium-term, this is synergistic with activities for understanding/mitigating multipath at the lunar South Pole, which affects the NASA's ARTEMIS and CLPS program, as well as JPL's Endurance rover. In the long-term, this is applicable to Mars Sample Return campaign.

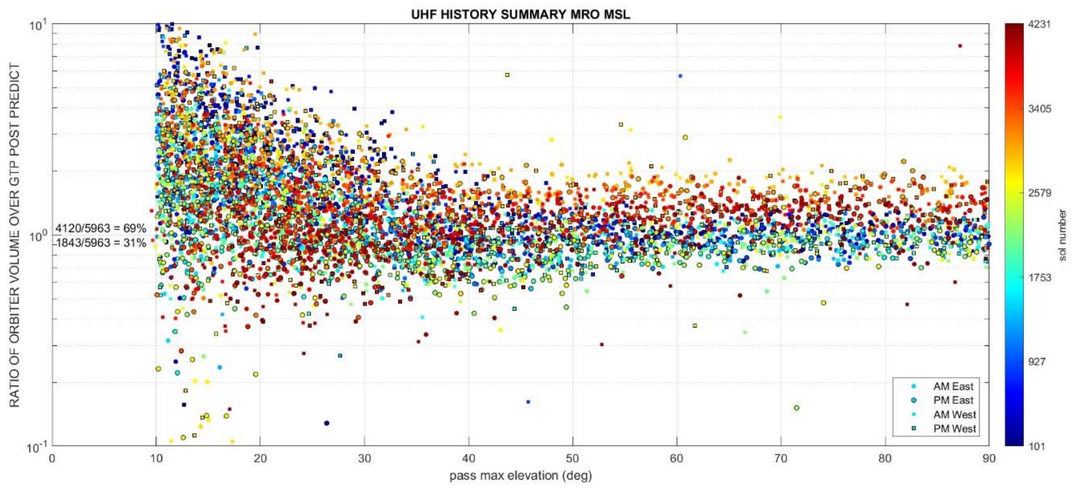

Figure 1:Ratio of actual to predicted data volumes as a function of the overflight maximum elevation angle. Colors indicate sol number. Marker type indicates type of overflight.

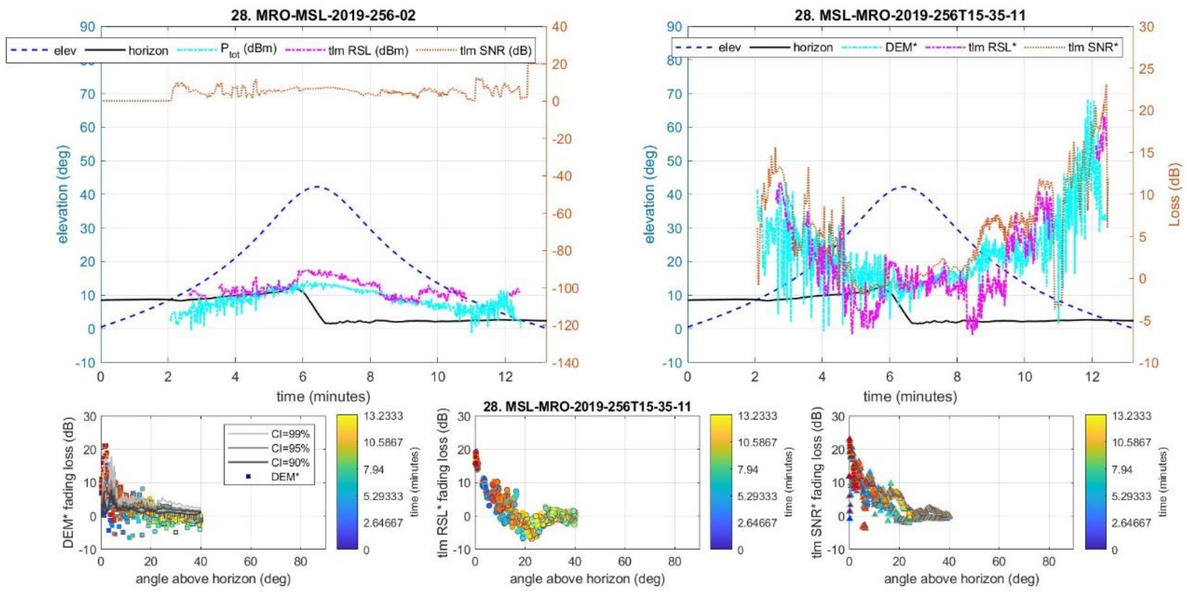

Figure 2:Comparison of RSL and fading loss curves generated by the JFM and telemetry from MRO (top row). Comparison of statistical relationship between fading loss and elevation angle (bottom row)

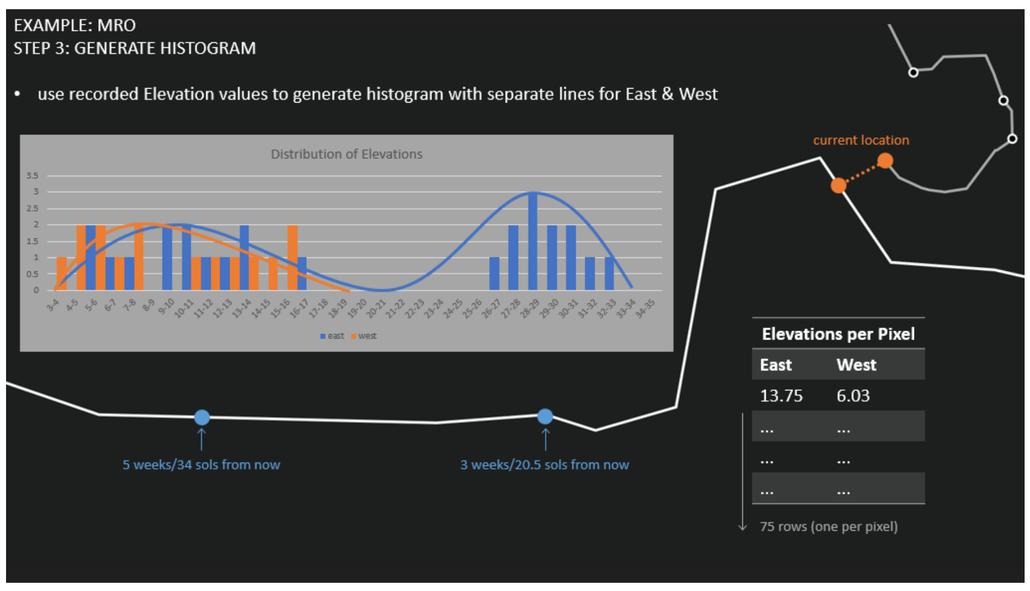

Figure 3:Mock-up of TSLICE, a tool for telecom relay planning considering the terrain effects.

References

[1] Emme V. Wiederhold et al. Playing Telephone Through Martian Rock: Assessing Terrain Occlusions to Enhance Telecom Predictions. 2023 IEEE Aerospace Conference.

[2] Marc Sanchez Net. Simulation of Multipath Reflections from Planetary Bodies: Theory and Application to the Lunar South Pole. The Interplanetary Network Progress Report, Volume 42-226, pp. 1-53, August 15, 2021.

Acknowledgement

We would like to acknowledge Neil Chamberlain and Ricardo Mendoza from Section 337, Andrew Kwok, from Section 333, Aseel Anabtawi, from Section 397, for their support of this task.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

RPD-000 Clearance Number: CL#00-0000

Publications:

Sanchez Net, Marc, Wiederhold, Emme, Lee, Charles, Mukai, Ryan. "Investigation of Multipath Effects on Mars Relay Network Overflights," 2025 IEEE Aerospace Conference (To be published).

PI/Task Mgr. Contact Information:

(818)-354-1650 and marc.sanchez.net@jpl.nasa.gov)