Distributed Autonomy for Lunar Micro-rovers – A Case Study for the Emirates Lunar Mission M. Battler[1,4], M. Faragalli[1,5], M. Cross[1], K. Raimalwala[1], M. Cole[1], E. Smal[1], E. Reid[1], E. Cloutis[2], J. Newman[2], K. Skoniecnzy[3], [1]Mission Control Space Services Inc., 162 Elm St. West, Ottawa, ON Canada, melissa@missioncontrolspaceservices.com, [2]University of Winnipeg, [3]Concordia University, [4]Western University, [5]Carleton University

Introduction: Early lunar micro-rover missions will face several constraints such as limited onboard power, computational and downlink capacity, mobility performance, and will be short-lived without lunar night survival technology. In a traditional mission architecture, rover imagery and telemetry are downlinked to Earth at a constrained data transfer rate, where ground-based operators must make decisions after a series of steps in data processing and analysis. Without onboard autonomy for navigation, it may take several minutes to move a couple meters, resulting in high idle-time, slow mission speeds, and ultimately limited scientific return for instruments onboard.

Autonomy-Enabling Technologies: To maximize scientific return and value of constrained micro-rover missions, Mission Control has developed a suite of novel autonomy-enabling technologies in Artificial Intelligence and robotics that can effectively help increase mission speed, including surface characterization, trafficability & power modeling, mapping, and path planning. With a deep learning model, Mission Control's ASAS-CRATERS (Autonomous Soil Assessment System: Contextualizing Rocks, Anomalies and Terrains in Exploratory Robotic Science) technology can classify surface features as seen by the rover's navigation camera [1]. This provides a high-fidelity semantic map of the surrounding terrain. Our path planning tool can then generate trajectories to an operator-specified waypoint, optimizing for metrics like energy consumption and wheel slip based on the rover's own data-driven models. The terrain representation can also provide rich geologic context for autonomous decisions for instruments to target specific features. To demonstrate autonomous targeting capabilities for scientific instruments, Mission Control is leading the development of the I-SPI (Intelligent Sensing and Perception in Infrared) instrument [2].

Emirates Lunar Mission: To demonstrate these technologies for a lunar micro-rover mission, Mission Control will participate in the international science team of the Emirates Lunar Mission (ELM). ELM is led by the Mohammed Bin Rashid Space Centre (MBRSC) and constitutes a small rover called Rashid. In ELM, Mission Control will demonstrate its advanced computing technologies for AI-based perception and distributed team operations through several investigations.

The primary investigation will demonstrate the feasibility and usefulness of automated terrain classification for science and navigation operations using deep learning models. This will be embedded on a compact and high-performance flight-ready processor, to be integrated on the mission's lander, demonstrating an Edge AI computing architecture for lunar exploration. The classifier will identify high-level geological features in images from the rover's navigation camera and downlink the outputs to science teams, to be used in rapid terrain assessment for science and navigation decision-making. This is targeted to be the first demonstration of Deep Learning on a lunar mission, unlocking potential applications for autonomous decision-making in future missions.

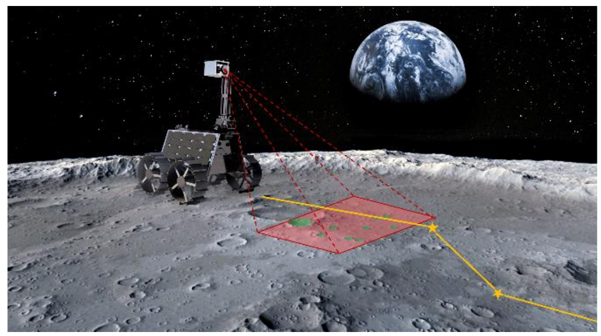

Figure 1. Depiction of the MBRSC Rashid micro-rover and technologies by Mission Control for lunar terrain classification and path planning.

These and other data products will be distributed to our extended Canadian science team in near-real-time using our web-based Mission Control Software platform, to support additional science and robotics investigations. In addition to AI-based terrain classification, Mission Control will lead investigations in trafficability estimation, path planning, and power modeling for skid steer vehicles, to mature our suite of advanced rover navigation applications. The data from Rashid will be used to train the terrain classifier, whose outputs can then be used to intelligently estimate rover wheel slip hazards and power consumption.

The results will be used directly to support path planning decisions for Rashid's navigation framework, and this will be an important demonstration of capabilities for future lunar rover missions.

In addition to technology demonstrations, Mission Control will also aim to test novel strategies for educational outreach and public engagement for lunar missions such as live mission tracking and data hackathons.

Acknowledgments: This project is undertaken with financial support of the Canadian Space Agency.

References: [1] Raimalwala K. et al. (2020) Lunar Surface Science Workshop, LPI Co 2241, p5124. [2] Battler M. M. et al. (2021) *LPSC* no. 2548.