Enabling Autonomous Robotics for Lunar Surface Missions and Resource Prospecting. K. Raimalwala[1], M. Battler[1], M. Faragalli[1], Rohaan Ahmed[1], M. Cross[1], E. Reid[1], [1]Mission Control Space Services Inc., 162 Elm St. West, Ottawa, ON Canada, kaizad@missioncontrolspaceservices.com

Introduction: The rise of commercial missions and activities on the Moon necessitates the shift to increasingly self-reliant system architectures to support a growing lunar economy, using on-site computing to enable real-time autonomous robotics with AI applications just as we will increasingly rely upon in-situ resources. This is critical to mitigate Earth-Moon delays, expected or unforeseen network dropouts, and data transfer constraints. Therefore, vehicles and other systems must operate to a high degree of supervised autonomy. Mission Control is developing a suite of flight software applications to allow lunar rovers to autonomously and intelligently understand the lunar surface environment and make key decisions in support of ISRU-relevant activities such as resource prospecting, excavation, and construction.

Identification of Lunar Surface Features: Any intelligent decision-making process onboard will require a semantic representation of the terrain. Mission Control has developed technology to classify known geological features at a macro-level as seen in standard colour images or identify features considered rare or novel on the lunar surface, using deep learning models (convolutional neural networks). Figure 1 shows an example output from our classifier that can detect craters, boulders, and other surface features.

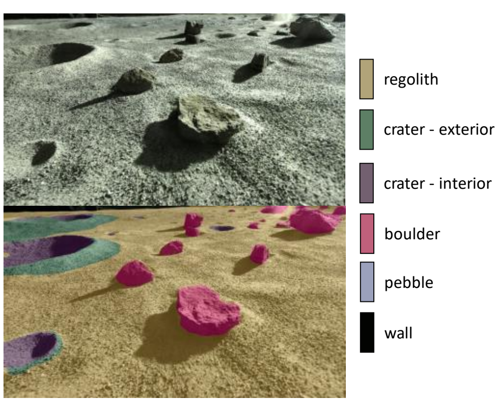

Figure 1. *Example output of our latest terrain classifier, processing an image taken from our lunar analogue testbed.*

Data Aggregation and Mapping: For geological features classified from stereo imagery (or if other correlated depth information is available), they can be projected onto a map frame and aggregated from multiple images to build a rich map-based data product that can be used by the flight software suite to enable tasks such as autonomous instrument targeting and data collection. On the ground segment, this data product can also be more easily integrated into GIS tools for rapid analysis with the context of scale and other information layers derived from *in situ* or orbital sensors. This is key to support comprehensive scientific mapping and resource prospective efforts.

Autonomous Decision-Making: Once an onboard system can infer some knowledge of the surrounding terrain's geological features, it can also be programmed with some decision-making capabilities. For rover navigation, this includes planning and executing safe and efficient trajectories that also maximize key objectives in prospecting and mining scenarios. Based on an understanding of lunar surface features, the rover can also make intelligent decisions to target payloads to collect high-priority data, and rank and prioritize data for immediate downlink to support operator decision cycles [1]. Targeted actuation such as scooping, drilling, and robotic arm operations can also be achieved autonomously using the same methodology. Mission Control can integrate this comprehensive flight software suite on a high-performance and compact processor to enable lunar rovers to autonomously conduct critical activities for resource prospecting, mining, and more. In this presentation, Mission Control will also provide an overview of participation in the ESA-ESRIC Space Resources Challenge.

Flight Demonstration: Mission Control will fly a payload on the first ispace mission M1 in 2022 and conduct the first demonstration of Deep Learning on the lunar surface, a historic milestone for space exploration. It will classify lunar geological features visible in images from the Rashid rover in the Emirates Lunar Mission (ELM). Mission Control will also participate in the international science collaboration of ELM, led by the Mohammed Bin Rashid Space Centre (MBRSC) [2].

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References:

[1] Castano R. et al. (2007) *JFR,* 24, no. 5, pp. 379–397. [2] Faragalli M. et al. (2021) *IAC*.