Autonomous Soil Assessment System: Contextualizing Rocks, Anomalies and Terrains in Exploratory Robotic Science (ASAS-CRATERS). K. R. Raimalwala[1], M. Faragalli[1], J. E. Reid[1], E. P. Smal[1], and M. M. Battler[1], [1]Mission Control Space Services Inc., kaizad@missioncontrolspaceservices.com, 1125 Colonel By Drive, 311 St. Patrick's Building, Ottawa, ON K1S 5B6.

Introduction: In almost every planetary surface scientific investigation, the characterization from a rover camera is a common initial step [1]. Mission Control is developing ASAS-CRATERS, a multi-mission technology, to enable automated surface characterization on planetary rover missions, which can benefit a wide range of science investigations, rover navigation, and activities like resource prospecting. It comprises algorithms for terrain classification and novelty detection using convolutional neural networks, and for data aggregation to produce relevant data products for supporting science operations. Built on cutting-edge algorithms and off-the-shelf computing components, it offers low-cost ways to speed up tactical decision-making in next-generation commercial lunar missions.

Background and Motivation:

Autonomy in Science Operations. Upcoming commercial lunar rover missions will have reduced latency, short lifetimes, and constrained bandwidth. This will result in a need for rapid tactical decision-making processes with limited data, leaving little time to analyze data, identify features of interest, and make decisions. Autonomous onboard terrain classification offers a way to downlink light-weight data products and reduce the bottleneck in scientific terrain assessment. Autonomous classification and novelty detection increase the chances of detecting novel/sparse features (ex: lunar outcrop or pyroclasts) that may otherwise be missed when driving and other mission needs are prioritized.

Application to Lunar Geology. A rover's navigation camera can document the surface morphology, morphometry and composition. High-resolution colour images and 3D data from stereo cameras provide information such as the size-frequency distribution and physical characteristics of craters and rocks, regolith properties, and outcrop features. This makes the technology versatile as a tool in support of many science missions. To provide a practical output as a science support tool in upcoming missions, a classification scheme is being developed. See Figure 1 for an example.

Technology: ASAS-CRATERS consists of three algorithms implemented on an embedded processor: i) a terrain classifier that uses a deep-learning encoder-decoder style network which classifies each pixel into semantic terrain labels; ii) a novelty detector uses a semi-supervised convolutional neural network architecture with an autoencoder module and a binary classifier that work in series; iii) a data aggregator will combine the classification and novel feature outputs on a map that is useable by onboard algorithms and light-weight for more efficient downlink.

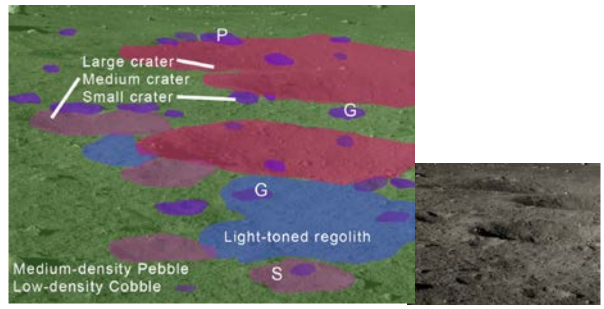

Figure 1: Hand-labelled lunar classification. Letters indicate crater degradation; P: Pristine; S: Semi-Degraded; G: Ghost. Right: original Yutu-1 image.

Field Tests and Demonstrations: The terrain classifier was first developed by Mission Control under the Autonomous Soil Assessment System project [2]. In 2019, it was used to classify eight Mars-relevant terrain types in real-time at ~15 FPS (see Figure 2 for an example). This was a part of tests in Iceland under SAND-E (Semi-Autonomous Navigation for Detrital Environments), a NASA PSTAR funded project led by Dr. Ryan Ewing at Texas A&M University.

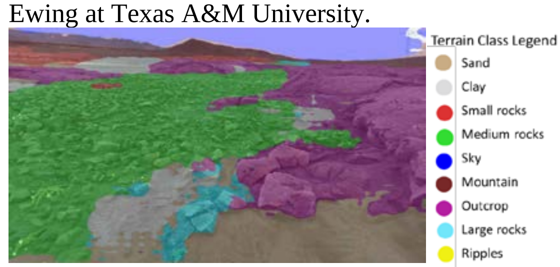

Figure 2: Classifier output overlaid on one camera image during a SAND-E traverse in Iceland field tests.

Field tests to demonstrate its use in a lunar operational context will be conducted in 2020. While ASAS-CRATERS is a mission-agnostic technology, near-term demonstrations are targeted for upcoming lunar rover missions in 2021 and 2022.

Acknowledgements: The authors would like to thank the Canadian Space Agency (CSA) for funding the development of ASAS-CRATERS and previous technology developments.

References: [1] Francis R. et al. (2014) *SpaceOps*. DOI: 10.2514/6.2014-1798. [2] Faragalli M. et al. (2018) *i-SAIRAS*.