AUTONOMOUS DETECTION AND CLASSIFICATION OF LUNAR MINERALS USING A CONVOLUTIONAL NEURAL NETWORK BASED FRAMEWORK FOR THE SUCR DALI PROJECT.

N. R. Carter[1], E. Z. Tucker[2,*], M. S. Grant[3], M. N. Abedin[2], [1]STEM Takes Flight, NASA Langley Research Center, Hampton, VA 23681, USA, [2]Nondestructive Evaluation Sciences Branch, NASA Langley Research Center, Hampton, VA 23681, USA, [3]NASA Langley Research Center (ret.) *E-mail: Eric.Z.Tucker@nasa.gov.

Introduction: Raman spectroscopy is an important technology for planetary exploration with the potential to detect ice, minerals, and other important materials on various solid planetary bodies. The perseverance rover has demonstrated the detection of minerals on the Martian surface using a Raman spectrometer [1]. The standoff ultracompact Raman (SUCR) instrument is one such technology, which is being developed for operation in a lunar setting through a funded Development and Advancement of Lunar Instrumentation (DALI) proposal, but has not yet become a flight ready instrument [2]. There is a need to implement functionality in such systems that can allow for real-time, autonomous detection of mineral, water, and other materials, depending on the objectives of the mission.

We developed a MATLAB-based convolutional neural network (CNN) algorithm for automatically classifying minerals from Raman spectroscopy data (this product is not officially endorsed by NASA nor the authors of this report). The current prototype version of this algorithm, called the Autonomous Detection Classifier (ADC), is part of the recently funded SUCR DALI proposal and is designed to autonomously classify spectral data from samples containing primarily one type of mineral, but will eventually be extended to classify multiple minerals in mixture samples. Our results showed that this CNN-based algorithm, was able to successfully identify single minerals in spectra of mostly pure samples with a current validation accuracy of 92.86% as shown in Figure 1.

Methods and Capabilities: The ADC system was trained from well-defined datasets, primarily data from a commercial Raman spectroscopy instrument. However, various preprocessing steps were employed to remove background interference and other unwanted signals from the data [3]. Additionally, preprocessing was also done to augment the training data set through the creation of simulated spectral data. Other preprocessing was incorporated to automatically account for differences the spectral ranges and wavenumber resolution between data sets. It was found that these preprocessing efforts are essential for improving classification accuracy and versatility.

Current Limitations: As an initial prototype, the ADC performs optimally when classifying single-source spectra obtained from consistent and uniform datasets, achieving a 92.86% validation accuracy. Further, thus far, the algorithm has been trained on only data from one commercial instrument and under similar conditions, so classification accuracy may decrease when trying to classify data from other instruments or data collected under different conditions, such as elevated or lower temperatures, but expanding and diversifying the training data set should help mitigate some of these issues.

Future Development: The current CNN-based prototype successfully identifies single-mineral spectra using a training database with similar data. Parallel work involves development of an algorithm utilizing a feedforward neural network (FNN) for classification. Later prototypes, whether CNN or FNN-based, will be developed to identify multiple constituent minerals and substances in mixture samples, including lunar simulant samples. It is anticipated that this milestone will require augmentation of the training database with data from more sources and other types of minerals, and possibly spectral data from known mixture samples. Additionally, work is planned to enable the ADC model to detect water states, such as liquid water and ice. Achieving this will require building updated spectral datasets for frozen and hydrated substances.

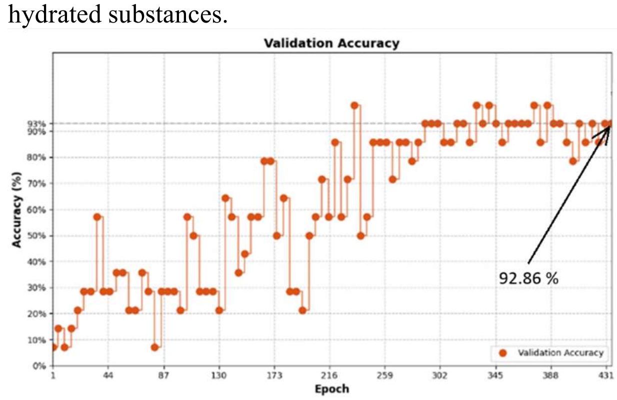

Figure 1. Graph showing the training results for the CNN-based algorithm demonstrating 92.86% accuracy.

Conclusion: The ADC algorithm currently demonstrates the ability to classify minerals from single-source spectra with a high validation rate. These results demonstrate a growing potential for automated spectral classification using CNN algorithms as has been shown previously for other types of samples using other forms of spectroscopy [4].

Acknowledgements: We would like to acknowledge M. Nurul Abedin for some guidance on this project. This work was partially supported by the SUCR DALI project and Virginia Space Grant Consortium STF program.

References: [1] Bhartia R. et al. (2021) Space Sci. Rev., 217, 1-115 [2] Abedin M. N. et al. (2018) Appl. Opt., 57, 62. [3] Gautam R. et al. (2015) EPJ Techn Instrum, **2**, 8. [4] Meza Ramirez C. A. et al. (2021) Appl. Spec. Rev., 56(8-10), 733-763.