The Miniaturized Variable Pressure Scanning Electron Microscope (MVP-SEM) project, funded by the NASA Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) Research Opportunities in Space and Earth Science (ROSES), will build upon previous miniaturized SEM designs for lunar and International Space Station (ISS) applications [1, 2] and recent advancements in variable pressure SEM's [e.g., 3] to design and build a SEM to complete analyses of samples on the surface of Mars using the atmosphere as an imaging medium. By the end of the PICASSO work, a prototype of the primary proof-of-concept components (i.e., the electron gun, focusing optics and scanning system) will be assembled and preliminary testing in a Mars analog chamber at the Jet Propulsion Laboratory will be completed to partially fulfill Technology Readiness Level 5 requirements for those components. The team plans to have Secondary Electron Imaging (SEI), Backscattered Electron (BSE) detection, and Energy Dispersive Spectroscopy (EDS) capabilities with the MVP-SEM.

**SCIENCE GOALS & REQUIREMENTS**

It is the desire of the MVP-SEM team to engage the planetary science community in setting the science goals and requirements of the instrument. The original defined science requirements were presented in [4], were fairly general, and focused primarily on petrology. Refined requirements are expected to yield greater constraints on the instrument and its capabilities. For example, data needs for the calculation of stoichiometry and the identification of reduced or oxidized forms of minerals will require greater precision for EDS for specific elements. The team is looking for inputs from the planetary science community to define a data set that will be useful to the majority of the community. Therefore, all contributions are welcome. A refined set of requirements for the instrument will be produced from the gathered information.

A Science Traceability Matrix (table below) shows the flow-down of the NASA Strategic Goals to the functional requirements of the instrument. Many of the Mars Exploration Program Analysis Group (MEPAG) investigations require both geomorphology and geochemistry of the samples. Remaining testing to define the capabilities of the instrument include EDS sensitivity in the CO₂-rich atmosphere and the amount of beam current needed at the sample for precise results.

**TESTING & MODELING**

This phase in the development of the MVP-SEM involves testing and modeling for the proof-of-concept design. The current focus of the team has been on the following testing and modeling efforts:

- Determining the applicable operating conditions and parameters for imaging using a SEM with the martian atmosphere as the sample chamber gas. For this study, a FEI Quanta 600 Field Emission Gun SEM at NASA's Marshall Space Flight Center is used. This involved systematically changing operating parameters such as beam accelerating voltages, beam current, environmental distance, sample chamber pressure, and magnification. Results are summarized in [4].
- Determining the appropriate electron gun for the environment with sufficient lifetime for mission success. Some types of electron guns are better suited for operation on Mars than others. Emitter lifetime can be cut short by evaporation caused by oxidation. Testing was completed, in which a CO₂ atmosphere was slowly leaked into the electron gun chamber, mimicking the variable pressure aspect of an environmental SEM. No difference was found in the lifetime of the electron gun in a CO₂-rich atmosphere compared to an N₂-rich (common terrestrial) atmosphere.
- Modeling the electron optics. The electron optics need to be able to achieve better than 100 nm resolution (20 nm is predicted) and accommodate the required magnifications and field-of-view (FOV) necessary to satisfy the science requirements. This mini-column will need to be fairly compact and will mate to the electron gun and sample chambers.
- Modeling the overall instrument geometry, as it will be affected by the size of the electron gun, the focusing optics, vacuum system, and sample system. The sample region will need to accommodate three detectors (for SEI, BSE, and EDS) and integrate to a sample wheel (or other delivery mechanism). Ideal characteristics for this delivery mechanism include allowing for samples to be translated under the electron beam, unlimited sample number, and accommodating sample caching and pass-offs to other instruments. A current concept of the MVP-SEM detector geometry is presented in Figure 3.

**FUTURE WORK**

At the end of this PICASSO effort, the team will continue development of the instrument through the Maturation of Instruments for Solar System Exploration (MatISSE) ROSES opportunity.

The team would like to thank the PICASSO program and reviewers for supporting our project!

**REFERENCES**