The Science Case for a Scanning Electron Microscope on Mars

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Miniaturized Variable Pressure Scanning Electron Microscope (MVP-SEM)

- Funded by the NASA Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) Opportunity.
- Designed to utilize the CO_2-rich atmosphere of Mars as an imaging medium, preventing charging of a sample.
- Developed under a partnership between NASA's Marshall Space Flight Center, the Jet Propulsion Laboratory (JPL), Applied Physics Technologies (AP-Tech), and Creare LLC.
- Capabilities will include a resolution of 100nm or better in both backscattered electron and secondary electron imaging, micron-scale calibrated energy dispersive spectroscopy (EDS) for geochemical analysis.

Instrument Development Status

- LaB_6 and Schottky emitters tested for suitability and lifespan in a CO_2-rich environment; LaB_6 selected.
- Emitter mounts vibration tested to gauge resistance to launch and landing loads; both LaB_6 and Schottky emitters withstood 2 minutes at a maximum 14.11 G-RMS (~20s ramp) on x, y, and z axes with minimal resulting offsets that do not exceed the ability of the electron optics to accommodate.
- Optics modeling resulted in a working design for a field of view of 1mm square at an environmental distance of 2mm.
- Electron gun and column assembly has been built and tested in a vacuum; testing of electronics and software is ongoing (Figures 1-3).
- Sample chamber design uses 3D printed components (Figure 4) and utilizes a custom sample rod to insert samples; pressure inside the chamber is controlled to allow for imaging and EDS under optimum conditions.

Future Work

- Testing of the prototype instrument, with the integrated sample chamber, will be completed in a Mars Environment Chamber at JPL during the late spring/early summer of 2018.
- The MVP-SEM team will respond to the 2018 Maturation of Instruments for Solar System Exploration Call in which the status of the prototype PICASSO instrument will be presented, as well as a plan to increase the MVP-SEM's technology readiness level.
- The Science Team will publish details of the Concept of Operations, Science Requirements, and other information relevant to MVP-SEM science.

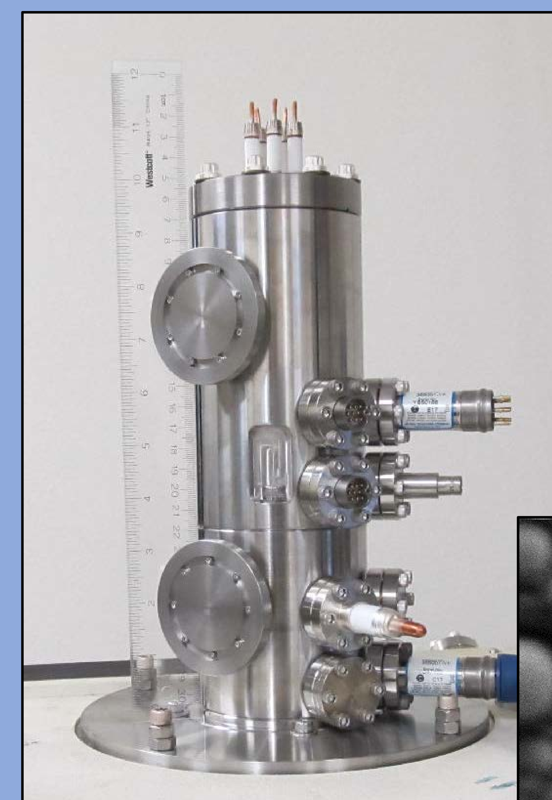
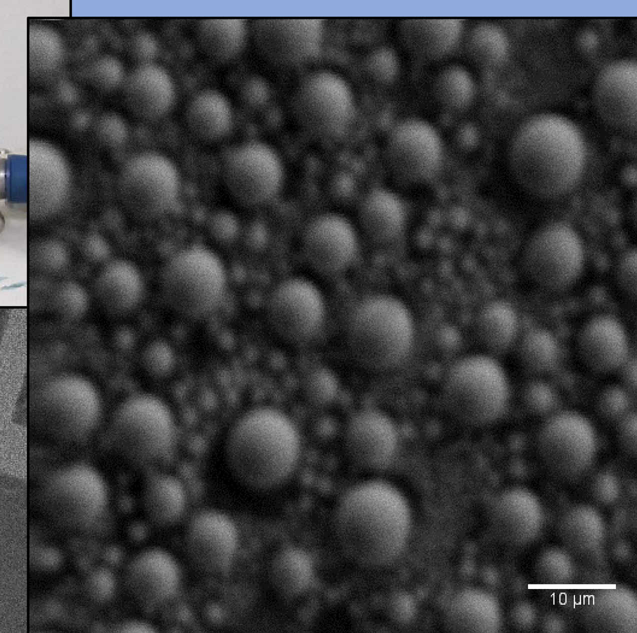


Figure 1: MVP-SEM prototype column housing. Further miniaturization is possible with custom flanges and fittings. Image provided by AP-Tech

Figure 2: Test image of tin spheres without noise reduction and Pressure Limiting Aperture 1. Image provided by AP-Tech



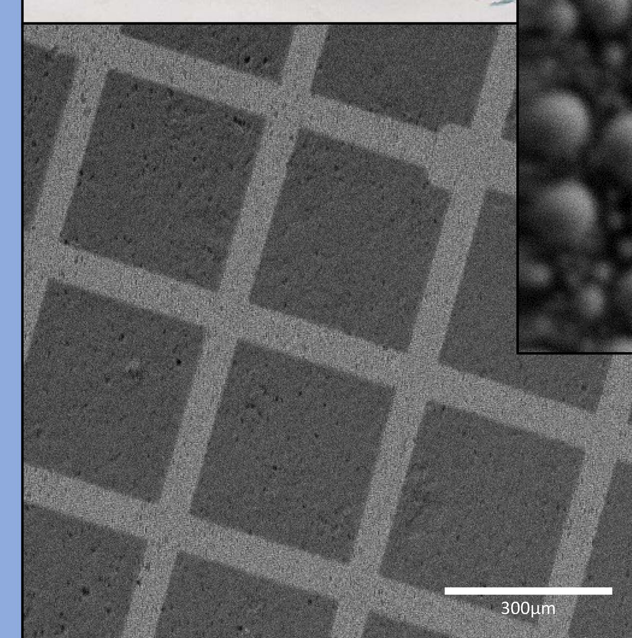


Figure 3: Prototype instrument image of a gold and carbon grid. Image provided by AP-Tech

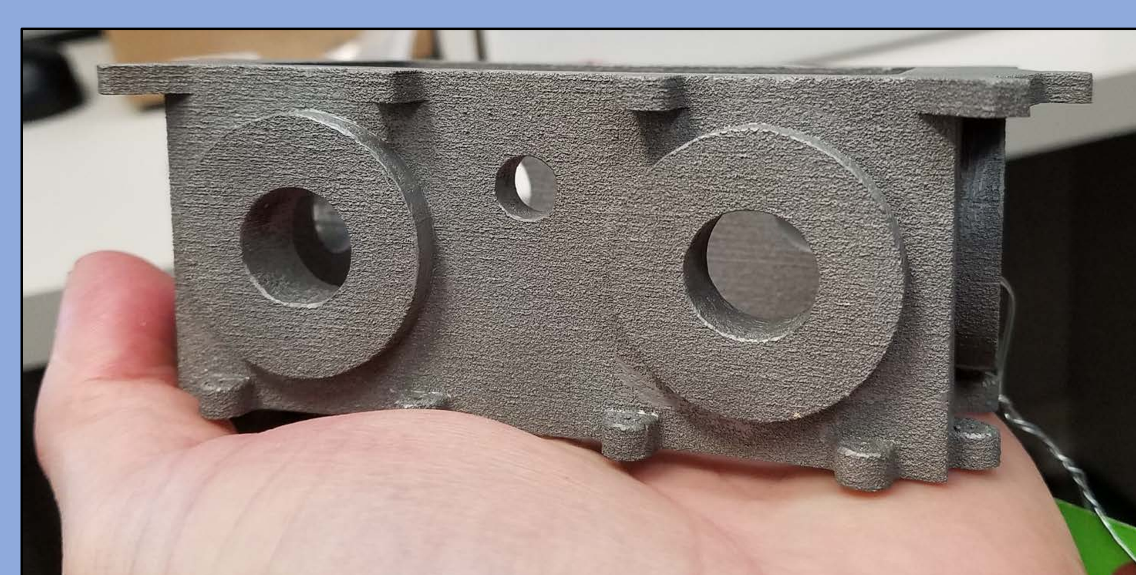


Figure 4: 3D printed base of sample chamber Image provided by JPL

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Understanding of Mars

- Origin and Evolution
- Petrology
- Human Interests
- Habitability
- Astrobiology

Geochronology: Determine the relative petrologic sequence of events on a microscopic scale using imaging and EDS.

Igneous Rocks: Analyze existing phases to calculate magmatic conditions and evaluate microscopic texture, zoning, and resorbed minerals.

Metamorphism: Observe fabrics, textures, and specific minerals indicative of metamorphic processes on a microscopic scale.

Geochemistry: Analyze minerals and amorphous phases using EDS (EDS analysis does not rely on crystal structure), as well as resolve flow banding compositional differences.

Mineralogy: Obtain modal mineralogy via backscattered electron imaging and element mapping via EDS; the mineralogy of small phases such as martian dust will also be determined.

Resource Prospecting and Utilization: Identify water-ice and hydrated minerals, ores, metal/silicate phases, etc. to provide feedstock for applications such as in-space manufacturing, agriculture, life support consumables, propellant, and other in-situ resource utilization needs.

Alteration: Investigate evidence of weathering and metasomatism, and characterize alteration (e.g., surface rinds on individual grains).

Sediments: Detrital mineralogical analysis, characterization of cementitious materials (e.g., salts), and visualization of oxidation/reduction reaction products and depositional fabrics.

Environments Favorable for Life: Positively identify clays and other weathering products that are indicative of conditions favorable for life in the past or present, and assess the habitability of Mars for human life.

Biosignatures: Study small-scale structures and geochemical signatures indicative of life, including fossil morphologies.

Toxicity of the Environment: Identify fine particles that could potentially enter a human habitat, recognize materials that are toxic to humans, and characterize any organisms that could impact human operation on the martian surface.

Potential Existing Life: Resolve micron-scale bacteria or other organisms that could be toxic to humans should they exist on Mars, even in the presence of larger grains as an SEM enjoys a greater depth of field than optical microscopes.