

NASA JOHNSON SPACE CENTER'S PLANETARY SAMPLE ANALYSIS AND MISSION SCIENCE (PSAMS) LABORATORY: A NATIONAL FACILITY FOR PLANETARY RESEARCH. D. S. Draper and the Astromaterials Research and Exploration Science Division, NASA Johnson Space Center, 2101 NASA Parkway, Houston TX 77058. david.draper@nasa.gov.

Introduction: NASA Johnson Space Center's (JSC's) Astromaterials Research and Exploration Science (ARES) Division, part of the Exploration Integration and Science Directorate, houses a unique combination of laboratories and other assets for conducting cutting-edge planetary research. These facilities have been accessed for decades by outside scientists, most at no cost and on an informal basis. ARES has thus provided substantial leverage to many past and ongoing science projects at the national and international level. Here we propose to formalize that support via an ARES/JSC *Planetary Sample Analysis and Mission Science Laboratory* (PSAMS Lab). We maintain three major research capabilities: astromaterial sample analysis, planetary process simulation, and robotic-mission analog research. ARES scientists also support planning for eventual human exploration missions, including astronaut geological training. We outline our facility's capabilities and its potential service to the community at large which, taken together with longstanding ARES experience and expertise in curation [1] and in applied mission science, enable multidisciplinary planetary research possible at no other institution. Comprehensive campaigns incorporating sample data, experimental constraints, and mission science data can be conducted under one roof. Table 1 lists PSAMS Lab capabilities and instrumentation.

Intended service to the community: The PSAMS Lab would devote a significant fraction of its available laboratory time to serve the needs of colleagues and collaborators. ARES scientists would work closely with PIs to design and implement the comprehensive research projects that PSAMS facilities make possible. Our integrated technical- and science-support capabilities will maximize efficiency and productivity for NASA PSD-funded planetary and mission science. The latter, in the PSD-declared "Decade of Sample Return," is particularly strengthened by our unique ability to characterize and simulate a wide range of planetary processes and materials.

Astromaterial Sample Analysis: ARES scientists have a decades-long record of accomplishment in astromaterials research, producing hundreds of peer-reviewed publications. Our capabilities include both bulk and

high-resolution (micrometer to nanometer scale) analytical techniques. Specific subsets of PSAMS analytical facilities are used for coordinated analysis; for geochemical, isotopic, and spectroscopic measurements; and for analysis of organic materials.

Coordinated analysis. ARES scientists pioneered the process of performing sequences of related analyses on astromaterial samples judiciously chosen such that early analytical steps do not compromise those later in the sequence. In addition to studying traditional meteoritic materials, this coordinated approach is particularly valuable for work on very small particles, such as those returned by NASA's Stardust and JAXA's Hayabusa missions, as well as on interplanetary dust particles recovered from stratospheric collection flights. For most coordinated analytical studies, the sequence includes the use of field-emission SEM, TEM, FIB, and EPMA; in many cases, isotopic ratios are imaged using a Cameca 50L NanoSIMS; and in some cases, organics are measured using the unique, ARES-designed and -built dual-laser time-of-flight mass spectrometer (L²MS). These techniques can all be applied to the exact same sample, rather than to separate subsets of a sample, enabling unprecedented insights into their formation. Two new minerals, brownleeite [2] and wassonite [3], were discovered in recent years by separate (but overlapping) teams led by ARES scientist K. Nakamura-Messenger using this coordinated approach. In addition, samples returned by the New Frontiers OSIRIS-REx mission will undergo preliminary examination in this facility.

Geochemistry and isotopes. Astromaterials can be studied using a wide array of capabilities in addition to those that form the heart of the coordinated analysis suite. Geochemical data for major, minor, and trace elements are acquired largely by electron-beam and ICPMS techniques. Isotopic compositions are determined for both stable and radiogenic elements in the Light Element Analysis and Thermal Ionization Mass Spectrometry laboratories, respectively. These labs conduct geochronology and isotopic-tracer studies utilizing dedicated mineral separation facilities and an automated microdrilling system. Some isotopic studies use NanoSIMS high-resolution imaging of isotopic ratios, as outlined above.

Table 1. Capabilities of the ARES/JSC Planetary Sample Analysis and Mission Science Laboratory

E-beam	SEM, TEM, EPMA, FIB	EIL	Experimental Impact Laboratory
NanoSIMS	Nano-scale secondary ion mass spectrometry	EXPET	High-P,T petrological experimentation
Isotopes	Triton TIMS, GC + Quadrupole mass spectrom.	Soil chem	Soil formation & modification analyses
Organics	Soluble organics, L ² MS, Raman	Analog &	Flight-like EGA, ChemCam, ChemMin, VNIR,
ICPMS	Inductively-coupled plasma mass spectrom.	Mission inst.	Mössbauer for MER, Phoenix, MRO, MSL
Spectroscopy/CT	XRD, FTIR, Raman, Mössbauer, MicroCT	Sample Library	Samples for remote-sensing ground truth

Spectroscopy and micro-computed tomography: Samples can be characterized spectroscopically using Raman, Mössbauer, high-resolution FTIR, and x-ray diffraction instrumentation. A large geometry microCT scanner will be installed during the summer of 2016 that, in addition to quantitative 3-D imaging studies, will provide the preliminary investigations needed to evaluate sample interiors before more damaging preparation for analyses is done.

Organics. The ARES Soluble Organics in Astro-materials Laboratory houses an ultra-high performance liquid chromatograph with fluorescence and diode array detectors, a liquid chromatograph with fluorescence detector and a quadrupole/Time-of-Flight mass spectrometer, as well as a pair of Thermo Trace Gas Chromatographs with flame-ionization and thermal conductivity detectors. Organics are also analyzed using the L²MS and with Raman spectroscopy.

Planetary Process Simulation: Another important strength of the proposed facility is the complementarity between the sample-based approaches outlined above and our facilities for experimental simulation of planetary processes. These include impact and cratering, high-temperature and -pressure petrological processes, and low-temperature and -pressure processes of (largely martian) soil formation and modification.

Experimental impacts. The Experimental Impact Laboratory contains three different accelerators, which can launch a variety of projectiles at targets intended to simulate materials on the surfaces of the solid bodies of the Solar System. The 5-mm Light-Gas Gun is capable of accelerating projectiles smaller than 5 mm in diameter to speeds up to 8 km/sec. The Flat-Plate Accelerator is used to shock load targets to stresses above ~70 GPa, after which they are recovered for analysis to examine the effects of shock on different planetary materials. With a variety of different barrels, the Vertical Impact Facility can launch projectiles as small as grains of sand and as large as 10 mm in diameter at speeds approaching 3 km/sec. Its impact chamber can be refrigerated, supporting experiments involving icy targets.

High-P, T petrological experimentation. PSAMS experimental petrology laboratories house several DelTech gas-mixing 1-bar furnaces (temperatures to 1500°C), two multi-anvil presses designed to reach pressures between about 3 and 30 GPa, and three piston-cylinder presses, designed to achieve pressures of 0.5 to 4.0 GPa and temperatures >2000°C. These labs enable exploration of conditions of pressure and temperature typical of small asteroids (essentially zero pressure) up to those of terrestrial planetary interiors.

Low-P, T soil science. The Mars, Moon, Meteorite Evolved Gas Analysis (M3EGA) laboratory conducts thermal and evolved gas analyses of volatile bearing minerals (e.g., carbonates, sulfates, perchlorates, oxyhydroxides, phyllosilicates) that are compared to similar data

collected during planetary missions to verify the presence and abundance of such minerals on other planetary bodies. It has three differential scanning calorimeter / thermal gravimetric analyzers (DSC/TGA) that are coupled to mass spectrometers. The DSC/TGA instruments provide thermal data that indicate the reaction enthalpies and weight losses or gains associated with mineral decomposition or formation reactions. Simultaneous mass spectrometer analyses allow determination of evolved gas release during mineral reactions. The M3EGA lab can do analyses from -120 to 1400°C and 0.1 to 1000 mbar, and under flowing CO₂, N₂, or He. Solution chemistry analyses (atomic absorption spectroscopy [AA], ion chromatography [IC], pH, electrical conductivity, etc.) allow determination of ppb and ppm concentrations of cations in dilute acid solutions (AA) and ppm levels of several anions simultaneously in aqueous solutions (IC). PSAMS soil-science labs provide crucial experimental tests of observations made by Mars missions (e.g. Phoenix, MSL).

Robotic Mission Analog Studies: Science return from robotic planetary exploration missions is greatly enhanced with flight-like versions of flown instrumentation housed in the proposed facility, as well as by an extensive analog sample library.

Flight-like instruments. These include components that mimic the operations of the CheMin instrument on MSL and a LIBS system that provides a high-fidelity lab version of the MSL ChemCam instrument. M3EGA instrumentation operates under MSL SAM-like conditions. All have been extensively used to strengthen the science return from MSL but are useful for many other applications. Mössbauer and VNIR spectrometers, the latter in controlled environmental chambers, are used in support of the MER, MRO, and Mars Express missions.

Analog sample library. The ARES Spectroscopy and Magnetics lab hosts the field's largest collection of extensively characterized rock, mineral, and glass samples for validation of mission science data, with over 10,000 samples and counting. This library has been used to validate instruments and data from most Mars missions starting with MER.

Everyone is welcome: Access to the proposed PSAMS facility will be provided to PSD-funded PIs and mission teams. ARES scientists and staff will work with users to maximize science return from both R&A studies and mission operations. Co-location with JSC Curation (which houses all NASA-controlled Astromaterials collections) will allow PIs and mission teams easy access to the samples that they have been approved to study. We believe our outside user base and ability to advance the broader field warrant formal PSD facility support.

References: [1] McCubbin F. M. *et al.* (2016), this meeting. [2] Nakamura-Messenger, K. *et al.* (2010) *Am Min*, 95, 221–228. [3] Nakamura-Messenger, K. *et al.* (2012) *Am Min*, 97, 807–815.