JSC-ROCKNEST: A LARGE-SCALE MOJAVE MARS SIMULANT (MMS) BASED SOIL SIMULANT FOR IN-SITU RESOURCE UTILIZATION WATER-EXTRACTION STUDIES. J.V. Hogancamp[1], P.D. Archer[2], J. Gruener[3], D.W. Ming[3], V. Tu[2]. [1]Geocontrols Systems – Jacobs JETS Contract, NASA Johnson Space Center, Houston, TX 77058, [2]Jacobs, NASA Johnson Space Center, Houston, TX 77058, [3]NASA Johnson Space Center, Houston, TX 77058.

Introduction: The Johnson Space Center Rocknest (JSC-RN) simulant was developed in response to a need by NASA's Advanced Exploration Systems (AES) In Situ Resource Utilization (ISRU) project for a simulant to be used in component and system testing for water extraction from Mars regolith. JSC-RN was designed to be chemically and mineralogically similar to material from the aeolian sand shadow named Rocknest in Gale Crater, particularly the 1-3 wt.% water release as measured by the Sample Analysis at Mars (SAM) instrument [1]. Rocknest material is a proxy for average martian soils, which are unconsolidated and could be easily scooped by rovers or landers in order to extract water. One way in which water can be extracted from aeolian material is through heating, where adsorbed and structural water is thermally removed from minerals. The water can then be condensed and used as drinking water or split and used as propellant for spacecraft or as a source of breathable O_2. As such, it was essential that JSC-RN contained evolved gas profiles, especially low temperature water (<400 ºC), that mimicked what is observed in martian soils. Because many of these ISRU tests require hundreds of kilograms of Mars soil simulant, it was essential that JSC-RN be cost-effective and based on components that could be purchased commercially (i.e., not synthesized in the lab). Here, we describe the JSC-RN martian soil simulant, which is ideal for large-scale production and use in ISRU water extraction studies.

Rocknest (RN) was the first sample scooped by the *Curiosity* rover and sits on top of the Bradbury group, which underlies the Mount Sharp group in northern Gale Crater [1]. RN was sampled from an inactive, dust-covered sand shadow and was interpreted to be deposited by northerly winds on the leeward side of an obstacle [2]. RN is a well characterized bright soil and is an ideal basis for a martian soil simulant.

Chemistry and Mineralogy (CheMin) X-ray diffraction (XRD) analyses of RN revealed that the major mineralogy consists of plagioclase feldspar, olivine, pyroxenes, augite, and pigeonite [3]. RN also contains a large (~35 wt.%) amorphous component consistent with basaltic glass, allophane, poorly crystalline sulfate, and nanophase iron oxides such as ferrihydrite [1,3]. Volatiles in RN were analyzed by the SAM instrument, which contains (among other things) an oven and a quadrupole mass spectrometer (Fig.1). The SAM instrument detects the presence of volatiles in the martian soil and rock from substances that thermally decompose below ~900 ºC [1]. The Alpha Particle X-ray spectrometer (APXS) analyzed the elemental chemistry of RN and found that it consisted of high SiO_2 (44.97 wt.%), followed by FeO, Al_2O_3, MgO, and CaO [3]. The JSC-RN simulant was developed to mimic the evolved gas profile, bulk mineralogy, and elemental chemistry as measured by SAM, CheMin, and APXS.

Materials and methods: *Development of the simulant:* JSC-RN was developed based on publicly available data from CheMin, SAM, and APXS. Multiple iterations of a mixture were made and characterized on a SAM-like instrument at Johnson Space Center until it mimicked the RN SAM data [4]. Components were sourced with the goal of being cost-effective and broadly matching the mineralogy of RN as reported by CheMin. All components were individually characterized for their mineralogy and evolved gas profiles.

Production and characterization of the simulant: Once the final simulant recipe was developed, the components were ordered with the intention of making ~1000 kg of JSC-RN. The components were sent to the United States Geological Survey (USGS), which has specialized facilities to powder minerals and rocks and homogenize large-scale mixtures. JSC-RN was sent back to NASA in 5 gallon buckets. 14 randomly selected buckets were sampled and characterized for their mineralogy and evolved gas profiles using XRD and SAM-like evolved gas analysis to test their homogeneity

Results and Discussion: The final recipe for JSC-RN was developed based on multiple SAM-like laboratory analyses (Table 1). The base of JSC-RN was Mojave Mars Simulant, which is a crushed-basalt simulant composed of Saddleback Basalt [5]. All additives and their weight percentages were chosen based on the mineralogy, evolved gas profiles, and elemental chemistry of RN. $NaClO_4$ was added to match the evolved oxygen and HCl, and was the easiest perchlorate to work with. Ferric sulfate and sulfide (i.e., pyrite) were chosen based on the two SO_2 releases. Goethite dehydroxylates at <400 ºC and was chosen because it contributed to a broad low-temperature water release. The granular ferric oxides (GFO) were added to replicate the Fe-rich amorphous component and because they contribute to the broad, low-temperature water release. XRD analyses of the GFO's at JSC revealed that they are mainly 2-line ferrihydrite. Nature's Footprint foresterite was added to increase the SiO_2 and MgO content and because it was an economical option. The evolved gas profile of the final mixture that was made at JSC is shown in red in Fig. 1. The JSC-RN simulant that was produced at the USGS was subsampled, and 14 of these are shown in black in Fig. 1. The small batch of JSC-RN had similar evolved gas profiles as the subsamples from the USGS produced simulants, with the exception of HCl. All JSC-RN samples had similar evolved gas profiles as RN measured by the SAM instrument on Mars. In particular, the water releases were similar and the amount of water evolved from JSC-RN <400 ºC (~1-3 wt.%) was similar to the water content of RN based on SAM water peak integrations [6].

Conclusion: JSC-RN was developed in response to the need for a martian soil simulant that could be used in large-scale ISRU water-extraction studies. This simulant is mineralogically and chemically similar to the RN sample, which was well-characterized by instruments on the *Curiosity* rover. The focus of JSC-RN was to mimic the broad, low-temperature (<400 ºC) water release in RN. JSC-RN was developed at JSC labs and produced in large amounts by the USGS. Our characterization studies have shown that the large-scale batches of JSC-RN are homogenous and have similar low-temperature evolved gas profiles as RN. Additionally, JSC-RN is cost-effective, relatively easy to make, and is ideal for ISRU studies.

Table 1. 1. Components, source, and weight percentages for JSC-RN soil simulant.

Component	Wt.%	Source
$NaClO_4$	1	Synthetic, Sigma Aldrich
Goethite	1.5	Laguna Clay Company
Pyrite	1	Natural, Ward's
Ferric Sulfate	1	Synthetic, Sigma Aldrich
High Capacity GFO	5	Kolar Filtration
Regular capacity GFO	2.5	Bayoxide
Foresterite	10	Nature's Footprint
Mojave Mars Simulant	78	Jet Propulsion Laboratory

[1] Sutter et al. (2017) *JGR: Planets*, 122. [2] Blake et al. (2013) *Science*, 341. [3] Achilles et al. (2017) *JGR Planets*, 122. [4] Archer et al. (2018) *LPSC*, #2806. [5] Peters et al. (2008) *Icarus*, 197. [6] Archer et al. (2014) *JGR Planets*, 119.

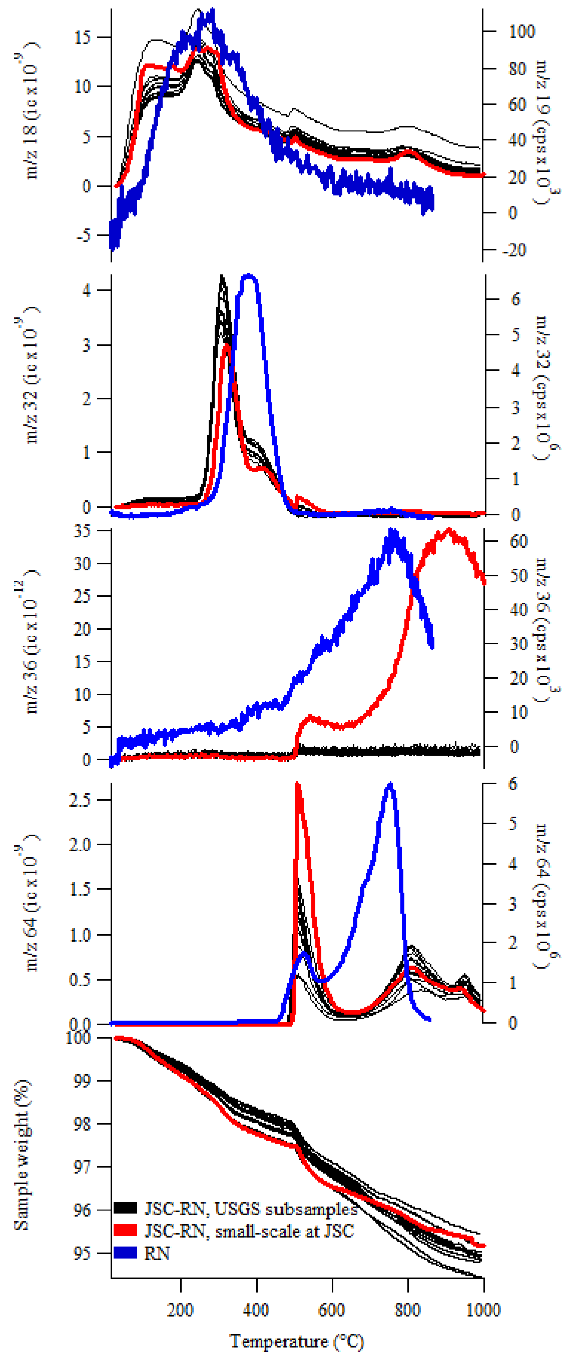

Fig. 1. Water (m/z 18, 19), oxygen (m/z 32), HCl (m/z 36), SO2 (m/z 64) releases and weight loss from JSC-RN compared to the RN samples analyzed by SAM. A small batch of JSC-RN was made at JSC and large-scale mixtures were made at the USGS.