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Supporting Information for

**Overview and Results from the Mars 2020 Perseverance Rover’s First Science Campaign on the Jezero Crater Floor**

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**Introduction**

This supplemental file contains additional information on the Mars 2020 Perseverance rover payload and how they support science observations **(Text S1; Figure SF1)**, details on the sampling sol path **(Text S2)**, and details on SHERLOC detections of potential organics in observed targets **(Text S3)**.

Text S1. Rover Payload Details

To accomplish its objectives, the Perseverance rover is equipped with seven science instruments, as well as engineering instruments, designed to make scientific observations at various spatial scales (**Table 1**; Farley et al., 2020 Fig. 1).

**Remote Sensing (RS)** instruments, most of which are on the Remote Sensing Mast (RSM) are intended to be used on an almost daily basis for operations and science observations. These instruments can be pointed towards targets of interest by pointing the RSM. The remote sensing instruments are also routinely used to support atmospheric observations of atmospheric opacity and to search for clouds and dust devils (Newman et al. 2020).

* **Engineering cameras:** Engineering cameras provide spatially extensive views of the rover surroundings and are used to guide rover navigation, Robotic Arm operation, and the identification and selection of science targets for observation with the science instruments. There are 16 Engineering cameras (Maki et al., 2020), but those most commonly used to support science activities are: the Navigation cameras (Navcams) on the Remote Sensing Mast, the Hazard Avoidance Cameras (Hazcams) located at the front and rear of the rover body, and the Cachecam located inside the rover body to image and document acquired samples.
* **Mastcam-Z:** The Mastcam-Z cameras are used for higher resolution imaging of selected targets at relatively broad spatial scales, employing varying zoom levels that can resolve ~0.7 mm features at 2 meters distance and ~3.3 cm features at 100 meters distance (Bell et al., 2021). Stereo images from both the left and right cameras also allow for three-dimensional models to be generated (Paar et al., 2023). Mastcam-Z can also operate in a multispectral mode (Hayes et al. 2021) which can give scientists insight into compositional variations in the landscape at a broad scale.
* **Supercam:** The SuperCam instrument operates in multiple modes that enable the study of texture, chemistry, and mineralogy of selected targets (Maurice et al., 2021, Wiens et al., 2021). Elemental composition is derived from Laser-Induced Breakdown spectroscopy (LIBS) observations, and mineralogy from Raman, Time-Resolved Luminescence spectroscopy (TRLS), and Visible and Near-Infrared Reflectance spectroscopy (VIS, IR). The Remote Micro-Imager (RMI) also provides the highest-resolution imaging available from the RSM and can resolve ~0.1 mm features at 2 meters distance and ~5 mm features at 100 meters distance, albeit in a smaller spatial footprint than Mastcam-Z images. A Microphone (Mic) also can provide acoustic data as LIBS shots impact selected targets. LIBS, Raman, TRLS, and Mic observations are typically acquired within the rover workspace at distances ranging from 2 to 6.5 meters from the RSM to preserve quality of data, whereas VISIR and RMI observations can be acquired at longer distances.

**Proximity Science (PS)** instruments are mounted on the turret at the end of the Robotic Arm (RA) and can therefore be placed as close as a few cm from a natural or abraded rock surface for the highest-resolution observations possible from the rover payload. However, these instruments are also more power-intensive to operate, and are thus typically used to follow up on interesting results from remote sensing observations or to document characteristics of a rock that will be sampled.

* **SHERLOC:** The Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC; Bhartia et al., 2021) instrument uses fluorescence and Raman spectroscopy to map organics and mineralogy on targets imaged by the Autofocus Context Imager (ACI; < 100 microns per mapping pixel)). SHERLOC resolves the spatial distribution and correlation between organics and minerals with visible grains or crystals, which is key for assessing possible biosignatures. SHERLOC is also accompanied by the Wide Angle Topographic Sensor for Operations and eNgineering (WATSON) which, when placed close to target surfaces, provides the highest resolution imaging possible from Perseverance’s payload, at 13 microns per pixel.
* **PIXL:** The Planetary Instrument for X-Ray Lithochemistry (PIXL; Allwood et al., 2020) is a X-ray fluorescence spectrometer that maps detailed elemental chemistry of targets at 70 microns per pixel. Major and minor rock-forming elements and trace elements are detected and correlated to grains or crystals that can be identified in PIXL’s camera. This allows the science team to determine the composition of individual grains or the elemental maps may be summed to yield the bulk rock composition. Such analyses are critical to determining the lithology of rocks that Perseverance encounters.

Other science instruments are distributed in other parts of, or throughout, the rover body:

* **RIMFAX:** The Radar Imager for Mars’ Subsurface Experiment (RIMFAX; Hamran et al., 2020) is located at the rear of the rover and is a ground penetrating radar (GPR) that yields information about the structure and stratigraphy of the subsurface beneath the rover wheels. Observations from RIMFAX may potentially be extrapolated and related to surface stratigraphy, depending on the depth resolution which relies on the composition and dielectric properties of the subsurface materials.
* **MEDA:** The Mars Environmental Dynamics Analyzer (MEDA; Rodriguez-Manfredi et al., 2021) measures air pressure, surface and air temperature, wind speed and direction, and relative humidity via a suite of elements that are distributed around the rover body. MEDA and its upward-looking Skycam is operated almost daily to monitor atmospheric conditions and activity.
* **MOXIE:** The Mars Oxygen ISRU (In-Situ Resource Utilization) Experiment (MOXIE; Hecht et al., 2021) is located within the rover body and is a technology demonstration intended to prepare for future human exploration. MOXIE generates oxygen (O2) from dissociation of atmospheric CO2, with future applications towards producing O2 for ascent vehicle propellant on a future human mission.

Though not scientific instruments, the following subsystems are used to support scientific investigations and operations:

* **SCS:** TheSampling and Caching Subsystem (SCS; Moeller et al., 2020) provides the mechanisms used to abrade rock surfaces and collect rock core and regolith samples and is composed of several elements distributed throughout the rover. The turret at the end of the Robotic Arm holds the Corer, a drill used to abrade and core and the Gas Dust Removal Tool (gDRT), in addition to PIXL and SHERLOC. Inside the rover body is the Adaptive Caching Assembly (ACA) which houses the 42 sample tubes (with the 43th tube in the bit carousel). The ACA is aided by a Sample Handling Arm (SHA) and a Bit Carousel (BC) that maneuvers bits (e.g., abrading, coring) and sample tubes between the ACA and the Corer. During abrasion, an abrasion bit is exchanged onto the Corer and then placed in contact with the rock surface to produce an abrasion patch that is between 2 to 16 mm deep and 45 mm in diameter, with 40 mm diameter of dust-cleared surface after the gDRT puffs. During coring, the SHA extracts a sample tube and inserts it into a coring drill bit, which is picked up from the Bit Carousel by the turret. The turret is placed onto the rock surface and rotary-percussive motion drills into the rock to produce core samples up to 76 mm long. The full sample tube is then exchanged back into the Bit Carousel within the ACA, where the sample is imaged with Cachecam, measured with a volume probe, and sealed with a hermetic seal.
* **Ingenuity Helicopter:** The Ingenuity Helicopter (Balaram et al., 2021) was deployed for a 30-sol technology demonstration after rover landing and commissioning. Ingenuity is intended to demonstrate the first powered, controlled flight on another planet and will inform future helicopter missions to Mars and other planets. Prior to its deployment, Ingenuity was housed in the belly of the rover. After its deployment, Ingenuity communicated with Perseverance to execute a series of flights during the 30-sol demonstration period. After the period of technology demonstration, Ingenuity was used to fly ahead of the rover and scout, providing Rover Planners with insights on terrain quality to evaluate ease or difficulty in driving and providing the science team with initial images of upcoming outcrops to help determine the most scientifically compelling outcrops to drive to. Ingenuity’s helicopters consist of a black-and-white navigation camera facing down to the martian surface, and a color forward-facing camera, both of which are commercially sourced.

**S1.1 Payload for Atmospheric Observations**

As described in Rodriguez-Manfredi et al. (2021), MEDA measures pressure, surface temperature, air temperature at three heights (0.84, 1.45, and ~40 m), wind speed and direction, and relative humidity, as well as downward and upward longwave and shortwave radiative fluxes. These measurements are typically made at 1 Hz frequency for at least 13 Mars hours per sol, and capture both the radiative forcing of the atmosphere and the complete surface energy budget (including radiative fluxes and surface sensible heat flux) for the first time at the martian surface, as described in Rodriguez-Manfredi et al. (2023) (henceforth RM23) and in Savijärvi et al. and Martínez et al. (this special issue). MEDA measurements of the surface energy budget allow the direct calculation of thermal inertia and albedo at spatial scales of a few meters, providing ground truth for orbital retrievals (Martinez et al., this special issue). In addition, direct and diffuse shortwave fluxes from the atmosphere are measured by MEDA’s novel Radiation and Dust Sensor (RDS), enabling the tracking of dust clouds, water ice clouds, and dusty convective vortices (‘dust devils’) past the rover, as described in Newman et al. (2022) (henceforth N22) and in Apestigue et al., Toledo et al., and Hueso et al. (this special issue). The measurement of both the incident and reflected shortwave surface flux has also been used to measure changes in surface albedo and to pinpoint the timing of local dust lifting by passing dust devils. The combination of this knowledge with other MEDA timeseries - most notably wind speed and pressure - has provided quantitative information on the atmospheric conditions required to raise dust from the surface, as described in N22 and Vicente-Retortillo et al. (this special issue). MEDA pressure data, in combination with other timeseries, have further been used to assess the spatiotemporal variation of convective vortex activity and to infer the physical characteristics of vortices and convection cells (N22; Hueso et al., Richardson et al., this issue). Investigations of wave activity in primarily pressure data reveal seasonal changes in thermal tides, baroclinic waves, and gravity waves, and the turbulent power spectrum (RM23; Sanchez-Lavega et al., Harri et al., this special issue). MEDA wind and temperature data have been used to confirm pre-landing predictions (Pla-Garcia et al., 2019; Newman et al., 2021) of regional and local slope-controlled wind patterns, to study the variability in wind speed linked to daytime convection cells and nighttime turbulence (N22; Navarro et al., Viudez-Moreiras et al., Pla-Garcia et al., this issue), and to explore the vertical structure of the near-surface atmospheric layer with unprecedented temporal coverage (RM23 and Munguira et al., this issue). Last, MEDA relative humidity data have been used to identify temporal variations in water vapor abundance, which may be linked to either variations in transport or surface-atmosphere exchange of water vapor (RM23; Polkko et al., this issue).

Mastcam-Z, Navcam, and MEDA Skycam sky images provide information on aerosol abundances and properties (Wolff et al., Lemmon et al., 2023), including the first unambiguous detection of halos (implying highly developed water ice particles) in an atmosphere other than Earth’s (Lemmon et al., 2023). MEDA’s RDS-Skycam, an upward-looking camera with a fisheye lens, further measures the optical depth of the atmosphere. In addition, MEDA downward longwave fluxes provide the first estimation for Mars of high-frequency opacity variations throughout the diurnal cycle (Smith et al., this issue). MEDA RDS data also reveal episodes of dust lifting and the passage and properties, including in some cases altitude, of dust and water ice clouds (Apestigue et al., Toledo et al., this issue). SuperCam ‘passive sky’ observations provides information on the abundance of CO2 and trace gases such as CO and H2O (Montmessin et al., this issue). SuperCam also has the ability to characterize aerosol abundance and properties from the visible to the near-infrared, as well as to produce O2 abundances.

SuperCam’s microphone has been used to study atmospheric dynamics in an unprecedented frequency range (> 20 Hz; Maurice et al., 2022). This includes characterizing rapid wind fluctuations(Stott et al., this issue), making the first observation of the dissipative turbulence regime (Maurice et al., 2022) and observing convective vortices and saltation impacts (Murdoch et al., this issue). Rapid temperature fluctuations signaling strong daytime turbulence have also been investigated using both MEDA and microphone data (Munguira et al., Chavez and de la Torre et al., Chide et al., this issue), while the weaker night-time turbulence has been investigated with MEDA data (Pla-García et al., this issue).

Text S2. Sampling Sol Path

* When the decision is made to sample at a location, the rover performs a precision drive approach to the rock to be sampled on sol S-6, where “S” is the first Sampling event. Post-drive imaging of the workspace is acquired by MastCam-Z, NavCam, and HazCam, and provides the decisional data needed to assess arm and drill placement on the surface.
* On sol S-5, the operations team plans target assessment and refinement, including WATSON images on candidate abrasion and coring targets in the workspace.
* On sol S-4, abrasion occurs, followed by dust removal with the gDRT and post-abrasion WATSON imaging.
* During S-3 the STOP list activities proceed to key science data products, such as SHERLOC and PIXL spectroscopic analyses of regions within the abrasion patch. To increase signal-to-noise, both in terms of duration of scan and operating at lower temperatures, the PIXL scan typically runs overnight between S-3 and S-2. WATSON images of the intended coring targets are also imaged on S-3.
* The S-2 sequence of activities includes remote science (SuperCam RMI, LIBS, VISIR, Raman and Mastcam-Z multispectral) of the abrasion patch. The SuperCam LIBS measurements can leave small divots (from the laser) and potentially alter the surface chemistry, hence the requirement that these observations occur after the proximity science measurements of SHERLOC and PIXL.
* For the final sol prior to sampling, S-1, engineering constraints necessitate that much of that sol be utilized for recharging the batteries. This sol has also served as an opportunity for opportunistic science activities, i.e. those that are not required by the STOP List, that are typically lower in power usage.
* Finally, on Sol S - the first sampling sol - the first core is collected, after which the arm inverts and performs a percuss to ingest (PTI) activity to cause the core to slide further back into the collection tube. The drill then mates with the bit carousel and the core is transferred to the adaptive caching assembly, where imaging, volume measurements, and sealing of the tube are conducted (Moeller et al., 2020). Post-coring HazCam and NavCam images of the workspace are collected as well. Initially, no images were collected pre- or post-PTI, but after the failure to collect a core at the Roubion site near the southern end of the Séítah region (**Section 4.3**), post-coring imaging of the drill was deemed to be important for core capture assessment.
* On S+1, upon successful collection of the first core, post-coring imaging and remote science (SuperCam LIBS, RMI and Mastcam-Z multispectral) is conducted on the hole from which the core was extracted. WATSON imaging of the borehole is also obtained on this sol, though this step was later added to the sol path midway through the crater floor campaign.
* On S+2, the rover recharges in preparation for the second sampling event, and this sol is again an opportunity for opportunistic science activities as long as the rover sufficiently recharges.
* Sampling of the second core occurs on S+3 in the same manner as performed on sol S.
* On S+4, the rover exchanges the coring bit for the abrading bit.
* On S+5, the rover drives away from the sampling site.

Text S3. Potential Organic Materials in Jezero Crater Floor Rocks

The search for biosignatures is a primary goal of the Perseverance mission, and within that context, the search for organic materials is of critical importance (Farley et al., 2020). The SHERLOC instrument utilizes complementary deep UV Raman and fluorescence spectroscopy to detect minerals and organic matter at a close distance from the rock surface. Fluorescence is a more sensitive, though less diagnostic, technique and can be used to optically detect aromatic organic molecules at low concentrations (ppb), though it cannot identify the specific molecules present. By contrast, Raman spectroscopy capitalizes on a weak scattering phenomenon that can reveal information about vibrational bonds within an organic molecule, thereby providing specific information useful for molecular assignment, but requiring a significantly larger amount of organic matter. Previous Raman examination of martian organic material in martian meteorites shows this material is characterized by a D and G band distribution similar to that seen in carbonaceous chondrites and kerogen-like material on Earth. This material is labeled macromolecular carbon (e.g., Steele et al., 2022). In the crater floor targets observed by SHERLOC, no Raman signatures were found on any of the targets; however, fluorescence measurements revealed strong indications for aromatic compounds. Abraded targets within the Máaz formation revealed the strongest fluorescence signal, while natural surface Máaz and abraded Séítah targets were comparable in signal strength (Sharma and Roppel, in revision). Below we provide an overview of the results from each target.

**Naa’táanii (Máaz formation, Naa’táanii member, natural surface):** No organic compounds were detected with Raman scattering from the Naa’táanii target. Overall, there were few fluorescence detections indicative of organics across the four scans on this target. Two distinct groups of fluorescence signals were observed: 1) a ~345-350 nm single band with variable intensity and not correlated to texture. This band either indicates the presence of two-ring aromatic molecules or mineral luminescence due to the presence of rare earth elements (REEs). 2) A ~270-285 nm single band of relatively low intensity was also observed and was not correlated to texture. This band may be due to the presence of single ring aromatic molecules, though luminescence due to mineral defects is also possible. Aside from low to no concentration of organics, further interpretation of these observations may have been limited by, 1) the low power (pulses per point) used on scans, since it was the first use of the instrument on a target, 2) dust on target surface, and 3) the natural surface of the Naa’táanii target had significant topography, meaning some points were out of focus, leading to somewhat attenuated signal.

**Foux (Máaz formation, Roubion member, natural surface):** There were no organics detected with Raman on the Foux target. However, Foux did reveal the most fluorescence detections of the three natural targets observed in the crater floor campaign. Both the single fluorescence band at ~338-350 nm and at ~270-288 nm were observed at Foux.

**Guillaumes (Máaz formation, Roubion member, abraded surface)**: Observations of potential organics include spatially distributed ~275 and ~340 nm fluorescence features, where again the fluorescence at 275 nm may be attributed to minerals. No correlation with texture was observed, however some association with dust was noted.

**Bellegarde (Máaz formation, Rochette member, abraded surface)**: Spatially distributed ~275 and ~340 nm fluorescence features support the detection of organics, though mineral fluorescence may account for the 340 nm feature. The putative organic bands were found in association with dust and along crystal boundaries. Interestingly, features at ~303 nm and 325 nm were observed and found to be strongly correlated with an area of high sulfate concentration. This two-band feature was observed in multiple large grains, and unlike the previous fluorescence was found within the grains, not along their boundaries. Although these bands could be consistent with organics such as aromatic heterocycles, this is not confirmed with Raman.

**Montpezat (Máaz formation, Artuby member, abraded surface)**: The fluorescence signals were dominated by emissions at ~343 nm, though ~275 nm fluorescence was also observed at a few points. As on previous targets, these features could be due to organic molecules, though mineral defects or REE luminescence may also contribute in these ranges. A single point exhibited a Raman signal that may be consistent with an organic G band that closely aligns with the known G band on the SaU008 meteorite SHERLOC calibration target (Sharma and Roppel, in revision; Fries et al., 2022); 340 nm fluorescence was co-located with this Raman detection.

**Alfalfa (Máaz formation, Ch’ał member, abraded surface):** Fluorescence bands were detected at ~273-284 nm as well as at ~344-349 nm, which may be due to one and two ring organic molecules. However, a mineral contribution in subsets of these ranges cannot be ruled out.

**Dourbes (Séítah formation, Bastide member, abraded surface):** The fluorescence signatures at ~338-350 nm and at ~270-288 nm, consistent with organics, were spatially distributed across Dourbes with no apparent correlation with texture or mineralogy. The fluorescence measurements were associated with dust and were located along crystal boundaries. Interestingly, when Dourbes was analyzed with a second scan (sol 269)after 13 sols of exposure to the environment, the fluorescence bands associated with organics were still detected.

**Garde (Séítah formation, Bastide member, abraded surface)**: Grains were predominantly 1.4-2.0 mm olivine grains. The ~338-350 nm fluorescence feature was found to be spatially distributed, with some positive association with dust and crystal boundaries. The fluorescence band at ~270-288 nm was found to be well correlated with the ~338-350 nm band.

**Quartier (Séítah formation, Bastide member, abraded surface)**: SHERLOC detected fluorescence features at ~343 nm and a doublet at ~303 & 325 nm, which may be due to the presence of one or two-ringed aromatic molecules. Mineral luminescence may possibly contribute to the longer wavelength of fluorescence. The doublet fluorescence feature was frequently spatially correlated to the sulfate mineral detections, which also showed a Raman signal consistent with hydration at many points. Finally, multiple points within Quartier exhibited Raman peaks at ~1330-1410 cm-1 and ~1650 cm-1 that may or may not be due to an organic molecule vibrational mode.

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**Figure S1. Summary of atmospheric science activities.**  
Summary of weekly and less frequency atmospheric / aeolian science activities during the nominal