Analog Network with Technology for Dust Quantification, Characterization, and Mitigation.

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Introduction:

In our Solar System, most exploration targets have surfaces that are known to be covered in dust grains and pebbles: the so-called regolith. This regolith is the first element any landed mission is interfacing with, and yet, there is still poor understanding of how it behaves in the environments encountered at the surfaces of the target bodies it covers. As we already know from past and current operations (both human and robotic) on the Moon and Mars, regolith dust is a nuisance that can range from minor hardware difficulties to overall mission failure (Gaier, 2005; Wagner, 2006; Latch et al., 2008; International Agency Working Group, 2016). In addition, Human space exploration is to be performed in dusty environments and we currently do not dispose under a thorough understanding of the impact of regolith pollution and transport on instrument performance and organic contamination. As NASA and commercial companies are planning for several missions to the Moon in the upcoming years, and further on Mars, increased surface activity will exacerbate dust-related hardware issues. We are now at a crucial point in space exploration when human missions to Mars are being planned and ***there is a strong need to address the impact of dusty environments on hardware and science measurement quality.***

Goal of the Project:

The ***goal*** of our investigation is the development of operational procedures to optimize scientific activities on regolith-covered planetary surfaces. Our innovative ***approach*** combines small-scale laboratory experiments with field measurements and computer simulations, working with state-of-the-art regolith simulants. Our goal will be achieved by addressing the following specific ***objectives***:

Objective 1: Quantification of the dust pollution generated by increased activity on planetary surfaces. We will create a better understanding of the quantities of dust generated by various types of activities on regolith-covered planetary surfaces such as the Moon and Mars.

Objective 2: Characterization of the impact of dusty environments on hardware and instrument performance. Once the level of dust pollution is quantified for different surface activities (Objective 1), we will conduct performance measurements for hardware and instruments and test dust mitigation solutions on critical components, thus providing recommendations on optimizing hardware and operational procedures for optimal detections in dusty environments.

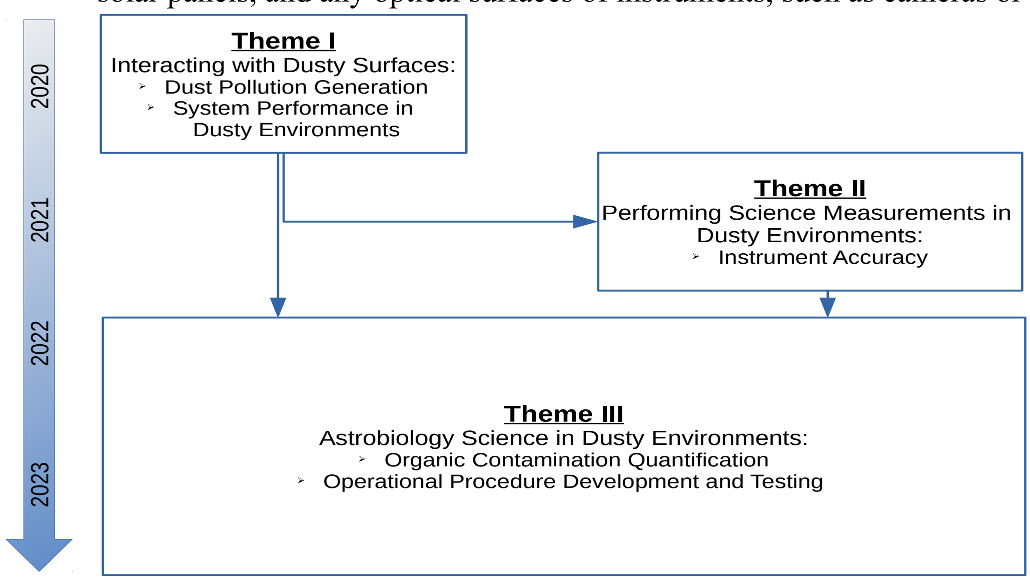
Objective 3: Prevention and mitigation of terrain and sample contamination during astrobiology investigations on planetary surfaces. One of the main goals of near-future missions to Mars is the detection of traces of ancient life. In order to achieve such a detection, false-positives due to Earth contamination will need to be identified and reduced to a minimum. We will run contamination measurements for various operations during field campaigns and measure the associated organic contamination of the terrain. Next, we will implement these measurements into large-scale computer simulations and determine the operational procedures that minimize the contamination of planetary surfaces during operations.

Methods:

Landed missions to the Moon and Mars have collected the first data on how planetary regolith behaves when interfacing with robotic equipment and human space suits. In particular, mission reports from the Apollo program detail the extreme nuisance associated with the fine surface dust in the absence of an atmosphere, when performing exploration and science operations on the surface of the Moon. Gaier (2005) sorts the problems encountered into various categories including false instrument readings, dust coating and contamination, and thermal control problems. Gaier (2005) analyzes each of these problems, detailing the issues encountered by the Apollo astronauts and their equipment, and concludes that dust will be a major issue to deal with during future long-duration activities planned for the Moon.

The Lunar dust problem consists of two parts:

1) The dust is easily levitated both by natural and human-induced processes. This is particularly due to the absence of an atmosphere and the low gravity level at the surface of the Moon. Katzan and Edwards (1991) identify the currently known natural sources of Lunar dust levitation (meteoritic impacts, terminator electrostatic levitation) and find that their production of suspended dust particles is negligible compared to the amounts generated by human-induced activities (rover operations, mining and construction, or even walking).
2) The second part of the dust problem is the tenacious deposition of levitated dust on all types of surfaces. This leads to not only mechanical issues, but also to loss of performance for several hardware and instrument components; these include radiators, solar panels, and any optical surfaces of instruments, such as cameras or spectrometers.



Theme I: **Characterize the interaction between equipment and dusty surfaces.**

- I.1: Quantify the increased dust production levels due to surface operations.
- I.2: Quantify dust-related performance loss for hardware and electronics.
- I.3: Evaluate the performance of dust mitigation solutions for hardware and electronics.

- **Theme II**: **Optimizing science measurements on surfaces covered in regolith.**
  - II.1: Quantify dust-related performance loss for science instruments.
  - II.2: Evaluate the performance of dust mitigation solutions for science instruments.

- **Theme III**: **Prevention and mitigation of organic contamination during science operations on planetary surfaces.**
    - III.1: Quantification of organic contamination due to surface operations.
    - III.2: Procedure development and testing for minimizing organic contamination.

Project Implementation:
Our team will apply an integrated multidisciplinary approach to the Themes described above as a crucial part of the preparation for robotic and human space missions on planetary surfaces. Our approach will test comprehensive technical and scientific methods to perform systematic dust quantification, characterization, and mitigation.

Laboratory Simulations:
Small-scale laboratory simulations of interactions with regolith analogs will allow for the thorough preparation and the optimization of the science return of the field simulations. In addition, the collected experimental data will provide input for scaling field and virtual simulation results to actual planetary environments and full-scale surface operations.

Task L1: Vacuum chamber tests

Task L2: Drop tower tests

Task L3: Regolith bin tests

Task L4: Laboratory Dust and Contamination Simulations

Field Simulations:
Location: We will prepare and execute full-scale simulated and analog operations in the vicinity of the Desert Studies Center (DSC) in Zzyzx (CA), located in the Mojave Desert, which can accommodate our team during field work. The Mojave Desert has been considered an analog to Mars. The Mojave Desert presents perfect opportunities to study locations analog to those on the Moon and Mars with the full suite of mission support in the form of water, electricity, housing, internet access, and emergency supplies. This is a rare combination of remote field access in a Mars-like environment that can support the operational needs of technical support systems.

Task F1: Development of planetary surface operations scenarios for dust-related field testing addressing our project Themes.

Task F2: Field test preparation and execution

Task F3: Formulation of best practice recommendations and protocols for minimizing dust pollution and organic contamination.

Virtual Simulations:
We will perform two types of virtual simulations: (1) After UCF Facilities Downtown Campus laboratory measurements (Task L4), we will use the recorded motion-capture and video data to simulate entire procedures and thus prepare for the field simulations; (2) At the tail end of the project, we will use computer virtual simulations to extrapolate our collected laboratory and field data to possible magnified and compounding effects of repetitive missions, adding robotic and human presence on planetary surfaces. These computerized virtual simulations will provide estimates of the overall dust pollution, impact on equipment and science, and contamination of full-scale missions and surface activities on the surface of the Moon or Mars. They will support a better understanding of the impact of increased human activity on the planetary environment, which will be essential for optimized operations (dealing with the dust) and science return (reduce false detections when searching for life).

Task V1: Procedure simulations using UCF Facilities Downtown Campus laboratory data.

Task V2: Scaling simulations for dust pollution and organic contamination of large operations on dusty planetary surface.

Project Impact:

Our investigation will allow the scientific and regulatory communities to gain knowledge of dust/regolith interactions with biological life and help significantly advance our practical experience in operations procedures on Earth, in order to prepare for space missions to the Moon and Mars. We will gain further understanding of needed capabilities for operations in extreme environments and learn how to create effective scenarios with realistic conditions for human and robotic interfaces. We will accelerate scientific knowledge and experience in operations testing relevant to current NASA's goals, and provide insight in a possible organizational structure for optimum human-robotic surface exploration relative to minimal biological forward and backward contamination. Accomplishing these goals will provide a substantive framework of understanding that can be used for implementing Planetary Protection (PP) protocols, procedures, and policies guiding our future habitation of Lunar and Martian surfaces.

References:

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