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Cooperative PhD Program

Dust mitigation solutions for robotic space exploration

Swinburne University of Technology, Melbourne, Australia

University of Stuttgart – Institute of Space Systems

Motivation:

One of the biggest challenges for lunar rovers and indeed any lunar exploration mission is the presence of lunar regolith dust. The bulk chemical composition of lunar regolith is made up of predominantly varies across the lunar surface, but is about 50% SiO2, 15% Al2O3, 10% CaO, 10% MgO, 5% TiO2 and 5-15% iron. Calcium and other metals from continuous high energy impacts from micrometeorites are also present. Lunar regolith, including the fine fraction of lunar dust, is formed and modified by continuous micrometeorite impacts on the lunar surface. These high velocity impacts induce “shock melting” and cause localized vaporization and recondensation of lunar regolith, resulting in agglutinates with high surface area, complex shapes, and sharp jagged edges. These particles are abrasive in nature can accumulate on to the microrover parts and critically decrease the operational capabilities of any system.
To further complicate the issue, the dust is electrostatically charged due to exposure to solar radiation, can levitate above the surface and this ultimately causes the dust to be electrostatically attracted to nearby surfaces, furthering the contamination issue.
Lunar dust has been recognised by NASA astronauts as “probably one of our greatest inhibitors to a nominal operation on the Moon.” (Eugene Cernan, Apollo 17 Astronaut). Harrison Schmitt, another Apollo 17 astronaut, is quoted as saying “One of the most aggravating, restricting facets of lunar surface exploration is the dust and its adherence to everything no matter what kind of material, whether it be skin, suit material, metal, no matter what it be and its restrictive friction-like action to everything it gets on.”

Figure: Nanokhod Microrover in dust analogue environment (Image courtesy by von Hoerner & Sulger GmbH)

The Nanokhod microrover is a small mobile rover intended to begin lunar exploration in 2024. The Nanokhod is designed to take scientific measurements on the moon around a static landing station. The rover will operate semi-autonomously and will be equipped with an array of sensors. Data connectivity and power will be provided through a 100 m long thin tether from the robot to the static landing station. To enable operational use of the Nanokhod microrover on lunar surface, dust mitigation and sealing solutions against lunar regolith are mandatory. Of focus will be the rover surfaces near or within the tether system of the Nanokhod robot that extends and retracts, which means that it can agitate and collect lunar dust in its expanded form. Trapped dust within the retraction mechanism can cause severe wear to the tether system limiting its useful life and the life of the robot.
It is proposed that the project focuses on finding material solutions and design strategies to prevent lunar dust accumulation on the rover's surfaces within or near the tether unit and critical surfaces. The team will consider coatings or active means to reduce or remove the regolith. This would have relevance also for other parts of the rover, where dust mitigation is an issue. Other proposed parts to co-explore with Stuttgart for dust mitigation could be optical windows of the payload cabin and locomotion unit including the tracks.

Project Scope:
One promising solution to this problem is to create specialised surfaces for the tether, mechanisms and exposed critical surfaces that are dust repellent and/or wear resistant, thus mitigating the effect of the lunar dust. The focus here is to identify mechanically robust lows surface energy materials that are effective in anti-soiling, at the same time compatible with substrate surfaces. Other most appealing method is the use of electrodynamic shields. This facilitates the levitation of particles off shielded surfaces and prevents the deposition of newly settling particulates. Other mechanical, electrical and passive self-cleaning methods will also be explored.
At Swinburne we are ideally situated to address this problem by utilizing both passive and active approaches with key expertise in electrodynamic shielding, surface engineering and advanced characterisation. Enabling us to home on the key surface characteristics of the dust causing the issues surrounding the lunar dust and innovate manufacturable solutions in terms of surface modification. This project can access key Australian research infrastructure such as the Australian Nano Fabrication Facility (ANFF) and Australian Synchrotron for state of the art characterisation.

The cooperative PhD program shall be realized with a large research part at the Institute of Space Systems in Stuttgart with possible attendance at the Swinburn University of Technology in Melbourne. Details and personal emphasis can be discussed individually.

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