Paper ID: 89174
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IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

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EXPLORATION OF MARTIAN DUST PATTERNS USING A ROBOTIC SWARM OF TUMBLEWEED ROVERS

Abstract

Mars' climate is dominated by dust events. Despite the deployment of several Martian missions aiming to solidify our understanding of the planet's climate, questions remain regarding the mechanisms for lifting, lofting, and deposition of dust particles. A robust Martian lander program relies on managing the risks that dust poses. Without a reliable understanding of dust processes, appropriate protection for robotic hardware and power systems is not possible. Refining our knowledge of dust shape and size can improve our shielding designs, increasing robotic lifetimes and ensuring the health of future Martian astronauts. Thus, the development of better dust modeling through theory, instrumentation, and robotics is key.

This paper proposes a novel robotic solution, through the design of a biomimetic rover system, to achieve scientific data collection with minimal environmental interference. The proposed mission aims to implement a swarm of tumbleweed-like robots, each carrying a photon sensor as a payload. As the tumbleweeds are pushed by natural wind patterns on Mars, they will follow dust migration patterns, ideally tracking clouds and storms as they evolve. In addition, as they depend on passive locomotion, they are minimally invasive to the surface. Compared to traditional rovers, the tumbleweeds will kick up substantially less dust during movement, resulting in less disturbance during traverses. Finally, as they are smaller and carry simpler payloads, their operational thermal range is more forgiving and hence do not require an RTG.

To develop a robotic proposal, the dynamical modeling and swarm behavior of a tumbleweed rover is explored. High-level requirements, including preliminary calculations and simulations for load, power, and thermal needs, are derived to justify the swarm's capability to deploy such an instrument feasibly, with minimal interference during scientific collection. A probabilistic roadmap of the swarms position is then derived using Weibull distributions of Martian wind patterns, gathered from the Martian Climate Database. This work aims to contribute to a growing interest in unconventional robotic solutions for Martian exploration. This project has been facilitated by the Division of Engineering Science, under the supervision of the University of Toronto Institute for Aerospace Studies.