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Radiation Fields, Effects and Risks in Human Space Missions (5)

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IN-SITU INVESTIGATION OF MARS ATMOSPHERE AND IONIZING RADIATION ENVIRONMENT THROUGH A DISTRIBUTED NETWORK OF TUMBLEWEED MEASUREMENT STATIONS

Abstract

Mars' atmospheric historical evolution is integral to forming a complete understanding of the planet, including the possible emergence of biological life. Investigating the characteristics of the Martian atmosphere at various scales is essential to enabling an effective, holistic understanding of the Martian climate, surface environment, and habitability. Additionally, the ionizing radiation environment is one of the main factors impacting surface habitability and atmospheric loss. Long-term exposure to ionizing radiation poses concerns for future human exploration.

However, given the sparse and incomplete nature of present environmental datasets, creating sufficiently detailed and complete models of atmospheric phenomena and interactions is not feasible. Current sampling devices and investigations have been limited to orbiters and singular landers or rovers, which leaves a considerable gap in the ability to acquire datasets with satisfactory surface coverage, as well as spatiotemporal resolution. This paper describes a novel exploration mission equipped with payloads aimed at the acquisition of these much-needed datasets.

We discuss how a swarm of wind-driven mobile impactors exploring the Martian surface can be used to collect measurements of near-surface meteorological parameters, which influence various atmospheric phenomena such as the interaction between water, dust, and carbon dioxide cycles. Using a preliminary mission concept and spacecraft architecture to provide context, we describe scientific experiments and measurements that can be performed during the proposed Tumbleweed Science Mission.

Through direct measurements of flux, dose exposure, spectral distribution, and angular distribution of various high-energy particles and their secondaries, we elaborate on how the swarm would help investigate the ionizing radiation environment on Mars. Datasets from a network of Tumbleweed Measurement Stations enable the refinement of the Martian climate and weather models. The nature and propagation

of dust devils and storms can be investigated using direct physical measurements and perturbation of individual nodes in the network. Atmospheric modulation of incident GCR and SEP particles, the nature and presence of secondary particles, dose exposures for electronics and biology, and the shielding properties of the Martian regolith can be modeled effectively using data from radiation monitors. In conjunction with observations from orbital instruments, the correlation between atmospheric escape rates and solar activity can also be studied further.

Based on the mission concept and architecture, we conclude that a network of ionizing radiation monitors and meteorological stations - Tumbleweed Measurement Stations - can be used to perform a holistic in-situ characterization of various atmospheric phenomena and the ionizing radiation environment on the Martian surface.