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# MULTIPHYSICS SIMULATION ENVIRONMENT WITH MATERIAL PERFORMANCE STUDIES FOR MARTIAN STEM PROJECTS

**Abstract**

A critical component of any device, especially one designed to best the harsh environments beyond Earth, is the very material used in its structures. The Martian environment is foreign to mankind, still being explored by spacecraft such as Curiosity and Perseverance, built by advanced state-of-the-art facilities. To truly democratize development and access to Mars, research and innovation need to be facilitated at grassroot level.

This student-driven project involves the development of a digital sandbox simulating the Martian environment, to facilitate simulation validation for a plethora of experiments. The performance and results of the experiments in this virtual environment significantly decrease the number of hardware development and test iterations to increase the Technology Readiness Level of a mission to Mars. A controlled Martian environment has been simulated using the COMSOL Multi-physics software, complete with atmosphere, lithosphere, and hydrosphere, based on available literature on the Martian environment. Even at student level accuracy, this significantly raises the TRL of iterative innovation-driven design to lower costs in accessing Mars. The Martian environment simulates and addresses most factors recorded in literature like radiation, atmospheric composition, terrain or surface composition, solar exposure, microgravity, chemical interactions, thermal and wind phenomena, etc. to their optimum parameters over a constrained volume assumed. The sandbox is also a precursor for a student-developed miniature environment tunnel to perform student-budget experiments at a university level, whose design has been successfully validated to prevent failure while maintaining the Martian conditions.

A specific computational scenario considered is material performance and degradation. Al6061, Kevlar, PTFE, and Silver are four materials considered for most space applications ranging from structures to electronics, especially at student-friendly prices. In the developed sandbox environment, these materials are tested in a variety of scenarios ranging from fully airborne to frozen in the acidic ice to underground and on the Martian surface, in different sunlight conditions, to study the performance and degradation of these materials, which in turn has defined the mission life for low-cost payloads to Mars, much similar to the advent of risk-tolerant CubeSats in the 2010s. The time-dependent parametric data after comparative analysis, contrasted with the material behavior on Earth, will also help judge the behavior of these materials when an experimental Earth-based Martian sandbox will be developed to test future payloads

experimentally, aiming to catalyze the new scientific and economic boom internationally towards Martian exploration missions and technology by making its accessibility more universal.