Paper ID: 61007
student

23rd IAA SYMPOSIUM ON HUMAN EXPLORATION OF THE SOLAR SYSTEM (A5)
Human and Robotic Partnerships in Exploration - Joint session of the IAF Human Spaceflight and IAF Exploration Symposia (3-B3.6)

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ROBOTIC MARS OPERATIONS USING VERSATILE AND SCALABLE INTELLIGENT PLANETARY SWARM SYSTEMS

Abstract

The inherent risk of future crewed missions to Mars warrants precursor robotic missions to deploy, verify, and maintain infrastructure essential to survival before the arrival of the crew. Precursor robotic missions have complex objectives that can range from preparation of site and leveling of terrain to transportation of heavy payloads and deployment of assets such as power source, habitat, and ISRU plants. However, our experience on Mars is built on uncrewed exploration missions designed to address scientific objectives. So far objectives have been accomplished using rovers with onboard scientific equipment and instruments while traversing harsh terrain, which makes current rovers highly specialized, non-modular, non-adaptive, expensive to engineer and reproduce, and have sufficient redundancy to mitigate predictable environmental challenges and enough resilience for the relatively short-duration missions. Current rovers, therefore, cannot scale up to the needs of future complex missions. This paper explores the design transition from the current state of practice to what is needed for future precursor and crewed missions. This research first examines future Mars design reference architecture missions and plans as proposed by different agencies and entities – in particular NASA – in order to extract needs, expectations, potential limitations as well as detailed surface activities anticipated of robotic systems and mission crew. The research then explores technological constraints, environmental challenges, system engineering aspects, and human factors as important design drivers and extrapolates on current technologies, analogs, and developments to identify existing opportunities. By looking at future missions from a holistic architectural view that encompasses different aspects and integrates various disciplines, this research proposes the main design drivers, parameters and criteria to be considered at the design and planning phase that can address the needs of precursor missions as well as become the basis for a sustainable, efficient and economically feasible space-fairing future. This research culminates with a concept of a planetary size modular, scalable, versatile, and adaptive intelligent swarm systems that demonstrate the application of the process.