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NAVIGATION AND COMMUNICATION NETWORK FOR THE MARS VALLES MARINERIS EXPLORER (VAMEX)

Abstract

With the advances in robotics and planetary exploration within our Solar System, innovative mission concepts are designed to further extend our knowledge boundary about these relatively undiscovered worlds. VaMEx, abbreviation for Valles Marineris Explorer, is an example of such an initiative. It aims to survey the canyon of the Valles Marineris valley, which spans approximately 4000 km from East to West and 7 km in depth near the Martian equator, for the duration of one year. VaMEx comprises of a swarm of multiple robotic elements: crawler robots, surface mobility rovers and aerial mobility vehicles. These users are foreseen to disperse along the Valles Marineris independently while pursuing their collaborative exploration tasks. Due to the hazardous environment, it is required that these elements navigate autonomously, broadcast position information and exchange science data during the operational phase of the mission. To support these functions, a Martian space segment is proposed. This space segment is called the VaMEx NavComNet. The NavComNet has the concrete aims of serving as a near real-time positioning system for surface, aerial and potential space-based user missions; serving as a science data, telemetry and telecommand relay between Earth and the in-situ user missions; as well as cross-communication relay between users. In order to develop a suitable concept for the VaMEx NavComNet, three different swarm localization architectures are being investigated: 1) radio positioning, 2) cartographic triangulation of ground features from optical images and 3) cartographic triangulation of radar persistent scatters. The first method, radio positioning, relies on range and Doppler shift observables of an RF signal transmitted between provider-user. A good example of such architecture, requiring no time synchronization between elements, are widely used Global Navigation Satellite Systems (GNSS). The second method involves the detection and tracking of swarm elements by comparing topographic characteristics extracted from optical images. The third concept involves synthetic aperture radar imaging (SAR), whereby interactions with the impinging radar signal can be detected and used to triangulate the user's location. For each of the proposed navigation concepts, an orbit constellation solution is proposed. Each solution is analysed in terms of orbit degradation/stability, control effort and navigation performance using metrics specific to each of the three concepts (resolution, visibility conditions, length of pass, etc.). With the described navigation concept and mission analysis results, a preliminary operational architecture for the VaMEx NavComNet space segment is conceived, taking into account existing technologies, navigation performance, overall mission complexity and feasibility.