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Author: Ms. Stefania Cornara
Deimos Space S.L., Spain

Mr. Pablo Hermosin
Deimos Space SLU, Spain
Dr. Stefania Tonetti
Deimos Space SLU, Spain
Mr. Sergio Sanchez Esteve
Deimos Space SLU, Spain
Mr. Marcello Sciarra
Deimos Space SLU, Spain
Mrs. Valentina Marchese
Argotec, Italy
Mr. Federico Miglioretti
Argotec, Italy

THE MARS COMMUNICATIONS AND NAVIGATION CONSTELLATION MISSION DESIGN: SMALL SATELLITES AROUND MARS

Abstract

The Mars Communications and Navigation (MCN) mission addresses a small-satellite constellation to prototype key technologies and provide services to Mars missions by enabling Earth-Mars data relay communications and localisation services reducing the complexity and cost of the payloads and outsourcing the operations and logistics. The key challenges consist in communicating with multiple users and relaying high data volumes (few GB per day), as well as providing accurate positioning (few metres) to users during 15 years.

A Walker constellation is selected to provide the navigation and communication service around Mars: it is composed of 18 satellites distributed in 6 orbital planes. To embed robustness in the constellation, one active spare satellite per orbital plane is envisaged, thus leading to 24 satellites to be launched, transferred to Mars and deployed around the planet. One of the main requirements of the autonomous navigation system at Mars is the need to fulfil 98% coverage from Earth outside the periods of solar conjunctions. Different combinations of Earth ground stations have been considered to maintain the Earth-Mars link active for the required amount of time. However, due to power limitations on the small satellites in the MCN constellation, even if an Earth ground station is always in view, a Relay Satellite is required to collect data and transmit it to Earth. The Relay Satellite is placed in an orbit around the L1 Lagrangian Point of the Mars-Sun system, since this orbit enables a stable geometry with respect to Mars and, thus, with respect to the satellites in the constellation.

The selected navigation strategy is the autonomous GNSS, which does not foresee any ground equipment deployed on the Martian surface, except from pseudolites. The main advantage of an autonomous GNSS is the local generation of the ephemerides and clock biases and a large degree of autonomy from Earth support. Ephemerides estimation complexity could benefit significantly from availability of pseudolites on the Mars surface or in low orbit. This paper focuses on the end-to-end mission architecture design, paying special attention at the performance of the MCN constellation, both in terms of coverage and navigation.