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ON-BOARD SOFTWARE FOR THE AUTONOMOUS ORBIT DETERMINATION OF MARS NAVIGATION SATELLITES TRACKED BY SURFACE BEACONS

Abstract

With the ever-increasing number of space missions venturing beyond Earth, the operational burden on radio-tracking networks such as DSN or ESTRACK is approaching a saturation point: as a consequence, most large dish antennas must adhere to a tight and crowded schedule, leaving little room for regular maintenance or contingency scenarios. While several countermeasures are already being developed, such as NASA's Near Space Network for the management of missions within the Earth and cislunar environments, missions that target further destinations still have no other option than relying on this kind of infrastructure on Earth. A second factor equally important to be considered is the operational cost of the ground stations: orbit determination requires long communication windows which impact in a major manner the costs of the operation phase. A possible solution would be to minimize Earth's contribution to the provision of tracking data to deep-space satellites, making the latter able to autonomously determine their position and velocity with other means of observation.

One possible application for such a system has been identified in an ESA-funded study, carried out by Argotec, called Mars COMMS/NAV, aimed at designing a satellite constellation orbiting Mars to provide communication and navigation to the surface and orbiting users. The space segment of this system is composed of 24 satellites distributed on 6 orbital planes at a 59-degree equatorial inclination. The constellation design made use of small satellite platforms targeting a 60 kg mass to allow for the launch of large batches at a time, thus reducing the constellation deployment cost.

While the communication part of the operations of Mars COMMS/NAV must rely on the Earth ground segment, spacecraft positioning can be estimated exploiting beacons on the surface of Mars, also called pseudolites. The use of this kind of assets on other planets has already been the object of several studies; in this case, it has been established that as few as three pseudolites evenly distributed on the surface

would provide sufficiently frequent tracking data to the entire constellation.

Measurement data (one-way range and Doppler) from the surface beacons will be processed by each spacecraft autonomously via a dedicated on-board software developed alongside the space and ground segment design. The purpose of this work is to report the development, verification, and validation of the on-board software in detail, including high-fidelity orbit propagation and precise estimation: consequently, the resulting navigation service capabilities toward surface users are determined and illustrated. Finally, simulation results and system implications are summarized, along with the identification of the project's future steps and improvements towards the realization of the proposed architecture.