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# DESIGN AND VALIDATION OF AN AUTONOMOUS ORBIT DETERMINATION SYSTEM FOR A SMALLSAT CONSTELLATION

**Abstract**

Various infrastructures, including small satellite constellations, are under development to sustain future space missions towards Moon and Mars. They rely on ground-based and space-based radiometric tracking, laser ranging, and optical navigation techniques for Position, Navigation and Timing (PNT) service. The achievable accuracy depends on the PNT refresh period and so on the availability of the communication link with Earth. More autonomy of the constellations is required to reduce the burden on the ground network.

This work presents a novel mission concept based on an autonomous orbit determination system for a smallsat constellation, a navigation system having the purpose of generating relative and absolute position information (with reference to a planetary body) for a constellation of small satellites beyond Earth orbit. The usage of Inter-Satellite Links (ISL) instead of traditional radiometric tracking from Earth is proposed, which can provide improvement of the measurement accuracy, continuity of acquisition, and autonomy of the satellite constellation.

The study proposes a five spacecraft star-like constellation to cover Mars polar regions. The main spacecraft has the purpose to collect observables data (i.e. two-way range and Doppler measurements from the other nodes of the constellation) to calculate the orbit state vector of the constellation. It can also communicate with Earth to ensure the periodic synchronization of the constellation clocks with a terrestrial time scale, and to periodically check the consistency of the orbital solution. Each constellation's node simultaneously communicates with the main spacecraft using a Code Division Multiple Access (CDMA) scheme.

The proposed configuration will be presented, including the system platform configuration with an overview of the payload. The configuration includes the usage of only one Ultra-Stable Oscillator (USO) onboard the main spacecraft, allowing to contain complexity and costs of the constellation: the limited spatial separation between the satellites guarantees a strong suppression of the noise of the USO since the same reference is used both for uplink and downlink.

The navigation architecture and the critical functions have been validated in a technology demonstrator, carrying out tests in laboratory environment, bringing the system to a final Technology Readiness Level of 4. A laboratory demonstrator has been designed and validated, proving the clock noise suppression, implementing and testing the radio link configuration, and emulating the main communication channel impairments. The demonstrator extracts the radiometric measurements that will be used as input of a developed orbit determination software for the estimation of the navigation performances of the constellation.