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NAVIGATION SYSTEM ARCHITECTURE IN SPACECRAFT SWARMS

Abstract

Advances in space technology indicate multiple spacecraft concept as a viable solution for observation, environmental (ground and in-situ) characterization and even solar system exploration missions. The partition of the mission goal(s) among multiple spacecraft offers easily assessable advantages in reliability and payload return. The concept is also related to the efforts in miniaturization, at their turn providing significant advantages in the mass at launch.

In this frame, several projects involve a possibly large number of simple spacecraft, which will be partially able, building on their own limited capabilities, to act as independent platforms, as well as to cooperate, working as a global system (swarm). The step forward from large monolithic spacecraft architecture to a multiple spacecraft one involves different issues about the design of the swarm's spacecraft and of their subsystems. Specifically the swarm concept introduces important issues about autonomous guidance, navigation and control, also in order to save on tracking and command segments (it is certainly more complicated and expensive to monitor many spacecraft instead of a single one).

This paper will focus on possible solutions for the swarm navigation subsystem, presenting both qualitative and quantitative findings and moving from the basic requirement that each member of the swarm should be aware of its kinematic state (position and velocity). The analysis includes a trade-off among possible architectures, within the range of different possibilities between a hierarchic structure, where a leader knows – and even possibly measures and then communicates - the state of each single platform, and a peer structure where each platform has its own navigation system. The requirements in terms of inter-links and the variations in performance depending on possible outages are considered. Even more interestingly, the analysis discusses different possible orbital scenarios, namely terrestrial, lunar and planetary exploration missions. In the first case (Earth orbits), the solution is clearly represented by GNSS receivers, powerful while characterized by low requirements in terms of power and volume, and therefore certainly fitting swarm architecture: performance in orbits from LEO to supersynchronous are analysed. In the second case (Moon), possible combination of onboard sensors are considered, together with a design where some leader has a richer sensors'suite while other swarm members implement simpler systems having limited accuracy. Finally, the mother-slave architecture seems the best choice in planetary missions, and the relevant analysis will focus on the attainable performance.