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# AN AUTONOMOUS ARCHITECTURE FOR CONSTELLATION MANAGEMENT OPERATIONS: MISSION CONTROL IN THE ERA OF MEGA-CONSTELLATIONS

**Abstract**

Over the last five years, the number of active satellites dramatically surged, exceeding three thousand units. These figures are expected to grow even more with the deployment of several mega-constellations of satellites, counting hundreds to thousands of units. Concurrently, the pool of stakeholders engaged with the space economy is similarly growing. The increased competition demands higher payoffs and mission efficiency at reduced costs. Such disruptive changes to the well-established paradigms of the aerospace sector require innovative solutions.

Currently, spacecraft operations heavily depend on human involvement and frequent communications between space and ground segments. This approach does not scale well with the increasing number of satellites, being mainly limited by communication opportunities and operations cost.

Our work introduces a preliminary model of a modular AI-based architecture that will enable an enhanced level of operational autonomy. This will result in two major benefits, providing a cost-effective solution and increased efficiency when compared to human-in-the-loop operations. The key point of this research work focused on defining a system that, despite acting on single elements of a constellation, takes decisions basing on global - rather than local- optimizations.

The proposed approach deals with three major criticalities that will affect the new generation of space systems. A first module handles the whole set of activities related to station keeping, acting holistically to produce a globally optimized set of AOCS commands. Such capabilities are expanded by a constellation reconfiguration module, providing extra flexibility through prompt modifications of the flight geometry according to temporary mission needs (e.g. the failure of a unit). Lastly, a third module implements autonomous collision avoidance, coping with all the risks deriving from the exponential growth of space traffic.

In our discussion, we start with an overview of the state-of-the-art in constellation management and autonomous satellite systems, introducing the framework and the promising solutions available in the literature. Then, we present our AI-based architecture, detailing the features of the modular structure. A description of the problem as a multi-objective optimization is given, along with a discussion of the algorithmic choices implemented to solve it. Validation was performed in a simulated scenario based on Earth Observation applications. We discuss the results of these tests, comparing their performances to the classical mission control and constellation management approaches. In conclusion, we briefly discuss how this work can pave the way towards the design of an autonomous and cooperative constellation.