26th IAA SYMPOSIUM ON SMALL SATELLITE MISSIONS (B4)
Small Satellite Operations (3)

Author: Mr. Carles Araguz
Technical University of Catalonia (UPC), Spain, carles.araguz@upc.edu

Ms. Elisenda Bou-Balust
Technical University of Catalonia (UPC), Spain, elisenda.bou@upc.edu
Prof. Eduard Alarcon
Technical University of Catalonia (UPC), Spain, eduard.alarcon@upc.edu

SYSTEM-LEVEL AUTONOMOUS DECISION-MAKING FOR EARTH OBSERVATION SATELLITE SYSTEMS

Abstract

The need to provide autonomy to space systems is today more apparent than ever. The benefits of implementing autonomous functions onboard spacecraft include the improvement of science return, fault tolerance, resiliency, reduction of operation costs, or the ability to cope with communication delays. In parallel, the field of Earth Observation (EO) is experiencing two complementary trends: the consolidation of small satellite technologies, and the need to deploy Distributed Satellite Systems (DSS) to satisfy stringent revisit times and near-real-time access to data. New mission architectures are envisioned to hybridise small-satellite platforms with traditional space assets to perform collective sampling and in-orbit communication networks. These DSS are expected to leverage many of the benefits of generic distributed systems: better availability, graceful degradation, incremental deployment, upgradeability, etc. In this context, autonomous decision-making frameworks that orchestrate such dynamic, large-scale, heterogeneous DSS are seen as one of the enablers for novel EO systems.

The purpose of this paper is twofold: it presents an autonomous operational scheme for DSS; and it shows the results of its validation at system level. The autonomous operational scheme is fundamentally grounded upon the Multi-Agent System paradigm and has been conceived to capture the resource constraints of small satellite platforms (i.e. power and communications). Instead of targeting regional areas, satellite agents contribute to a global sampling task with a maximum revisit time goal for any point in the Earth. Constrained by power and storage capacity, satellites coordinate to one another in a decentralised manner in order to achieve this global observation function. Autonomous operations are achieved by means of a two-tiered on-board decisional frame: at the lowest level, agents maintain a local beliefs of the state of the environment that is constantly reinforced and corrected through exchange of information. With this information, each satellite implements a local mission planner that schedules observation activities in accordance to the expected revisit times of the areas covered by the agent's footprint. The second decisional layer defines a message exchange policy by which agents share partial local information (i.e. scheduled activities) and indirectly acquired knowledge from the other agents.

This paper shows the implementation of this decentralised decision-making framework and its application in a simulation environment. Parametric modelling of satellites allows to represent different EO scenarios, e.g. swarms of resource-constrained small satellites, structured orbital geometries, opportunistic constellations, large-scale heterogeneous systems, etc. Autonomous operations are assessed both through performance metrics and system-level metrics.