FRAMEWORK FOR THE DESIGN AND OPERATIONS OF SUSTAINABLE ON-ORBIT SERVICING INFRASTRUCTURES DEDICATED TO GEOSYNCHRONOUS SATELLITES

Tristan Sarton du Jonchay

124 pages

Directed by Dr. Koki Ho

After being a concept for decades, the on-orbit servicing industry is finally taking off, with national space agencies and private organizations developing and planning soon-to-be-launched space infrastructures that will revolutionize the way humans operate in space. The advent of this new industry comes at a time when the geosynchronous orbit (GEO) satellite industry faces various pressures whether it be because of ageing fleets or increased competition from nimbler Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) constellations. A new symbiotic relationship is emerging between early OOS players who seek customers and the GEO satellite operators who aim to revive the competitiveness of their fleets.

The first OOS infrastructures will be simple ones, involving a few servicers offering a narrow set of services. These servicers will provide services to a few satellites before running out of propellant and getting discarded in a graveyard orbit or into the atmosphere. However, as technology matures and demand for on-orbit services increases, OOS infrastructures will become more versatile and involve additional elements, such as orbital depots, to enable the sustainable operations of a wide variety of servicers. Thus, planning OOS missions will involve not only finding the best route for every single servicer but also optimizing the in-space supply chain of commodities needed to support the long-term operations of the servicers and their client satellites.

This dissertation presents an OOS planning framework that simultaneously computes the optimal route of the servicers and plans the in-space supply chain of the supporting commodities. The second chapter gives the background of OOS in GEO and the literature review for OOS planning relevant to the work presented in this thesis. The third chapter presents the mission scenario investigated in this work. The fourth chapter generalizes the Time-Expanded Generalized Multi Commodity Network Flow (TE-GMCNF) model used in recent state-of-the-art space logistics studies to accurately model the operations of the servicers across a network of customer satellites and orbital depots. The Rolling Horizon (RH) approach is adapted to the OOS context to properly model uncertain service demand arising from customer satellites. The fifth chapter generalizes the mathematical formulation at the core of the framework developed in chapter 4 to model all kinds of user-defined trajectories and servicer propulsion technologies, such as high-thrust, low-thrust, and/or multimodal servicers. (Multimodal servicers are defined to be equipped with both high-thrust and low-thrust engines.) An assumption inherent to chapter 4 and chapter 5 is that the nodes of the networks are all co-located along the same orbit. Chapter 6 relaxes this assumption by extending the framework developed in chapter 4 through the computation of the relative dynamics of network nodes distributed across orbits of various shapes and orientations. Thus, chapter 6, unlike chapter 4 and chapter 5, optimizes the operations of OOS infrastructures over a network with time-varying arc costs.