IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control (1) (1)

Author: Dr. Yun Xu
School of Aerospace, Tsinghua University, Beijing, China

Dr. Zhaokui Wang
Tsinghua University, China
Prof. Zhang Yulin
School of Aerospace, Tsinghua University, Beijing, China

ANALYSIS ON SELF-ORGANIZING CONTROL MECHANISM FOR MEGA CONSTELLATIONS

Abstract

In recent years, LEO mega constellations containing thousands of satellites have received widespread attention, due to their potential to provide high-speed and full-coverage telecommunication services. With the dramatic increase of satellite number, the limited ground monitoring stations can hardly provide the motion information of all satellites in the mega constellation in real time. The numerical method for mega constellation analysis will also cost a lot of time and computing resources. Moreover, mega constellations hold enormous risks in view of the potential catastrophic impact on the space debris environment, while the existing ground monitoring resources cannot support real-time collision warning. The huge number of satellites have made control issue a challenge.

Instead of control the whole giant space system in a preplanned optimized way, this paper innovatively proposed self-organizing control mechanism for mega constellations. Self-organizing control means that satellite individuals have autonomy and intelligence to organize their own behaviors and coordinate with each other to realize the expected movement. Trajectories of satellite members are shaped by relative motion constraints rather than explicit constellation configurations. Satellites may adjust their trajectories autonomously in real time to improve coverage performance, maintain communication links and avoid suddenly collisions. Note that coverage, communication and collision avoidance are three main essential aspects to be considered during the lifetime of mega constellations. In order to achieve the control issues of mega constellations in a self-organizing way, the coverage constraint, communication constraint and collision avoidance one are expressed analytically in terms of relative motion bounds only.

On the other hand, it is neither necessary nor feasible to continually monitor neighbors' movements for each satellite. With the increase of monitoring interval, the influence of perturbations on mega constellations become of significance. This paper deals with the stability analysis under perturbations based on the decomposed relative motion model, which is a high-precision model applicable to large relative motion scale. The emphasis is on studying the influence of J2 perturbations on relative motion bound between satellites in the mega constellation. At last, the sustaining time of a given mega constellation without control is estimated, taking consideration of coverage, communication and collision avoidance constraint. Results indicate that the mega constellation will maintain long-term stability and the proposed control mechanism will work at a very low frequency.