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Stochastic Constellation Replenishment Planner

In the frame of the European GNSS Evolution Programme (funded by ESA), Deimos Space studied, designed and developed a stochastic simulator with the objective of computing and trading-off different constellation replenishment plans, that are able to guarantee a given service availability of satellite constellations, for any satellite constellation (GNSS, Satcom, etc).

During the first phase of the study, a set of replenishment strategy candidates have been designed, characterised in terms of launchers, spacecraft types, launch scenarios and transfer to the Constellation final slot. A comprehensive trade-off definition has been performed and a sub-set of candidates have been selected as the most promising ones to be further analysed by means of the Replenishment Planner. To perform the replenishment strategy candidate characterization, different methods have been used, spanning from bibliography research to low-thrust transfer optimization using an improved Edelbaum method which takes into account Earth eclipses.

In a second phase of the study, the Replenishment Planner has been thus designed and implemented, based on a stochastic approach in order to calculate the probability of having a certain number of satellites in each plane of a user-given constellation. These statistics combined with satellite and launcher reliability figures, an input provided by system studies, give the key figure to be maintained by the simulator: the service availability.

The Replenishment Planner is able to maintain the system service availability above a user defined threshold by means of different launch strategies, and using the selected strategy candidates as "building blocks". The simulator enables flexibility to accept as inputs generic satellites types, configurable launchers and transfer strategies (direct injection, electric thrust transfer to one or several planes, and staggered separation to inject satellites into different orbital planes at different altitudes), and a wide set of conditions and constraints. As launch strategies, the simulator is able to trigger corrective launches to replace failed satellites, preventive launches to anticipate the decrease of the service availability, preventive launches to avoid the loss of spare satellite capability, or a combination of the previous. The simulation can also consider satellite decommissioning.

The tool is able to run simulations in the order of one hundred years, considering the decay of the current satellites and the replacement with given future satellites, using different launchers, computing relocation of spare satellites and considering temporary outages.

Study cases have been run to validate the novel approach implemented in the Constellation Replenishment Planner, and the preliminary analyses yield promising results.

Summary

In the frame of the European GNSS Evolution Programme (funded by ESA), Deimos Space studied, designed and developed a stochastic simulator with the objective of computing and trading-off different constellation replenishment plans, that are able to guarantee a given service availability of satellite constellations, for any satellite constellation (GNSS, Satcom, etc).

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