ELECTRIC PROPUSION TRANSFER OPTIMIZATION

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In the last decades, electric propulsion (EP) has reached enough technological maturity to become the main propulsion system of spacecraft. Several demonstration missions using electric propulsion have been conducted so far (NASA's Deep Space 1, ESA's SMART-1, JAXA's Hayabusa). In addition, EP thrusters are routinely used in multiple GEO satellites for diverse station keeping manoeuvres. From the past missions, the low thrust engines have accumulated thousands of operating hours and hundreds of ignitions. These successes have given the necessary confidence to select electric propulsion for several incoming scientific missions (NASA's Dawn, ESA's BepiColombo), and it was also considered in the past for potential commercial missions such as ConeXpress, SMART-OLEV, and is coming back with the future VEGA EPSM, Vivisat or ESS concepts. This reliability has allowed the production of full electric GEO telecomm satellites that will use only EP for the LEOP transfer phase from the injection orbit to the final GEO slot.

Electric propulsion permits a large reduction on the propellant mass due to its higher efficiency compared to the chemical propulsion, provided that specific impulse is at least one order of magnitude larger. However, due to its lower thrust (several orders of magnitude) the resulting trajectories are more complex than in the chemical propulsion case, where the instantaneous impulse approximation is valid. Typically low thrust trajectories are composed of an alternating series of thrust and coast arcs, and require longer time of flight. Innovative techniques to optimize such trajectories are required, in order to cope with all the mission and operations requirements of future electric propulsion transfers.

GMV has been awarded by ESA with the EPTOS project whose objective is to develop a flight dynamics prototype able to optimize the transfer trajectory of commercial telecomm GEO satellites using electric propulsion, from launch to injection. The final technical solution would be integrated in GMV's ***focusleop*** product, part of GMV's ***focussuite*** flight dynamics system for ground control of commercial satellites. The new development will be applicable for mission analysis and operations (as required by GEO telecom operators and satellite manufacturers).

The geostationary telecommunications satellite market, the domain where EPTOS activity is aimed at, shows a total number of operators of about 80 and a total of some 454 satellites flying, increasing at a yearly rate about 20-30 satellites.

This paper describes the GMV's solution to satisfy all the mission and system requirements for geostationary telecommunication satellites employing electric propulsion platforms for LEOP that is based on a hybrid optimal control solution technique. This hybrid technique means to provide the robustness and reliability of a direct method while maintaining the swift computation of an indirect method. To achieve this, the secular trajectory is defined by a number of nodes optimized via non-linear programming, and the rapidly changing arcs between nodes are optimized solving a boundary value problem. Every optimization step produces a feasible trajectory, and the convergence radius allows a straight line from the initial to the final orbit to be an adequate initial guess. Furthermore, the number of optimization variables is reduced an order of magnitude with respect to a direct method, yielding a fast and precise trajectory optimization process.