# Optimal control of trajectories using PSO for an ionic rocket spacecraft

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## Abstract

An ion engine is a method of space propulsion that, like solar sails, allows, through small accelerations imparted over long periods, to reach, in principle, high speeds. This technique was already suggested by the pioneer of astronautics Hermann Oberth in a work published in 1929. The basic idea consists of ionizing the atoms of the gas and accelerating these ions in an electric field at enormous speeds of up to 30 km/s. These accelerated ions are expelled allowing, by conservation of the moment, to propel the ship. In this way, high specific impulses, $I_{sp}$, are reached in the range of 2000-5000 seconds.

Our objective is to find the optimal low-thrust orbital transfer from the Earth until the insertion into the orbit of an outer planet or asteroid. This requires calculating the thrust pointing-angle-time-history that minimizes the time of flight and verifies the conditions for insertion into the final orbit. We also consider the optimization of the time window for the spacecraft launch in the near future.

Optimal control theory starts with the definition of a Hamiltonian in terms of the spacecraft position and velocity and of the costate variables. By applying Pontryagin minimum principle we obtain the control, i.e., the thrust pointing-angle, in terms of the costates and the objective function to be minimized includes the time of flight and a weighted sum of the absolute value difference among the terminal position and velocity and those necessary for orbital insertion [1].

In order to minimize this objective function, we use a population of solutions in the particle swarm optimization method. The study shows that rockets with ion engines can achieve optimal orbital transfers in times of flight that could be shorter than those obtained with other types of engines.

## References

[1] Conway, B. A. *Spacecraft Trajectory Optimization* 2010, Cambridge University Press, DOI: 10.1017/CBO9780511778025.

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