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INTEGRATED OPTIMIZATION OF TRAJECTORIES AND LAYOUT PARAMETERS OF SPACECRAFT WITH AIR-BREATHING ELECTRIC PROPULSION

Abstract

The operation of small spacecraft in ultra-low Earth orbits (150-250 km) can provide advantages in solving problems for which heavy spacecraft are currently used. At the same time, the long-term maintenance of the spacecraft in such orbits requires the delivery of a significant fuel supply from the Earth to compensate the aerodynamic drag. An increase in the lifetime can be achieved with the help of air-breathing electric propulsion (ABEP) using outboard atmospheric gases as a propellant.

For long-term maintenance of spacecraft with ABEP in ultra-low orbits, the following conditions must be met:

1. It is necessary to ensure ABEP stable operation at changing the characteristics of the external environment.

2. The momentum imparted to the gas accumulated from the rarefied external atmosphere should compensate the spacecraft aerodynamic drag.

3. It is necessary to provide the required electric power supply to the ABEP.

These conditions are substantially interconnected. In particular, lowering the orbit height in order to increase the concentration of ionized gas is accompanied by a rise in aerodynamic drag, the required thrust to compensate it and, therefore, the required power supply. In turn, an increase in the area of solar arrays leads to a greater increase in aerodynamic drag, etc.

This paper provides the solution of the problem of integrated optimization of the trajectories and layout parameters of spacecraft by the criterion of the average ABEP power consumption at the given payload volume. Variations in the density and composition of the atmosphere and the periods of shading of the spacecraft are taken into account.

An analytical solution is obtained depending on generalized parameters that combine such characteristics as the specific power of solar arrays, total thruster efficiency, etc. The dependencies of the orbit characteristics enabling the long-term maintenance of spacecraft with ABEP on the generalized parameters are determined. The results obtained make it possible to formulate requirements for the characteristics of ABEP, power supply system and spacecraft layout, which are necessary to fulfill a various applied and scientific missions.