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# PHYSICAL GROUNDS AND CONTROL OPTIMIZATION OF ULTRALOW-ORBIT SPACECRAFT WITH ELECTRIC RAMJET

**Abstract**

The conditions for the long-term maintenance of spacecraft on ultralow orbits due to the use of an electric ramjet (ER) are studied. ER accumulates the working gas (WG) from the surrounding atmosphere and after ionization accelerates it in the ER, imparting the impulse to the spacecraft to compensate the aerodynamic drag. The use of the surrounding atmosphere, as a propellant, increases significantly the payload fraction. For practical implementation of the concept of spacecraft with ER it is necessary to solve the following problems:

• To ensure the accumulation of a sufficient mass of gas from the rarefied external atmosphere;
• To impart the sufficient velocity to the accumulated gas in ER;
• To provide the necessary electric power supply;
• To optimize the control of the ER, the electric power source (EPS) (depending on its type) and the spacecraft orientation (affecting the aerodynamic drag and, in case of the use of solar batteries, the rate of energy storage);
• To ensure heat fluxes acceptable for a long spacecraft's existence on low orbits.

All these problems are considered in complex.

A physico-mathematical model of mass transfer processes is developed on the basis of the concept of diffuse reflection of molecules from the surface. Experimental studies have confirmed adequacy of the model for ER air intakes of various shapes. It is shown that the WG density in the ER accumulator can be made in two or three orders greater than the atmosphere density.

Parameters characterizing the feasibility conditions of spacecraft with ER, such as the spacecraft shape, permissible heat fluxes, available electric power, WG mass and ER efficiency, and orbit parameters, are combined into two generalized parameters. The regions of existence of the ultralow-orbit spacecraft with ER in terms of these generalized parameters are determined.

The synthesis of the optimal control of the ER, EPS and spacecraft orientation to maintain the spacecraft at a given low orbit and to provide the fastest change of orbit parameters (apogee altitude and inclination) is obtained. Analytical estimates are confirmed by numerical results in the altitude range from 100 to 400 km.