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DETERMINATION OF DESIGN PARAMETERS OF THE SYSTEM FOR COMBINED DE-ORBITING  
OF THE UPPER STAGES OF CYCLONE-3 LAUNCH VEHICLE FROM LOW-EARTH ORBITS

**Abstract**

One of the potential sources of increasing the number of near-Earth space objects is the presence of large orbital debris in low Earth orbits. Among them, special attention should be paid to the upper stages of Cyclone-3 launch vehicles. At one time this launch vehicle was the most widely used and ensured the launch of various satellites throughout the 80s, 90s and 2000s. Since these launch vehicles were not equipped with a disposal system, most of them remain in low Earth orbits. At the moment their number exceeds 100 pieces. Over time, these upper stages began to explode. This may indicate their instability in the medium-term and an increase in the likelihood of emergencies.

Taking into account the fact that the ballistic coefficient of Cyclone-3 upper stage does not exceed  $0,005 \text{ m}^2/\text{kg}$ , the estimated time of its existence in near-Earth orbits is tens and hundreds of years. One of the possible solutions to the task of removal of the upper stages of Cyclone-3 from low Earth orbits is the use of a combined de-orbiting method. The technical implementation involves joint use of a jet propulsion system and an aerodynamic sailing device installed on a service vehicle. The de-orbiting is carried out by forming the perigee of disposal orbit in the upper layers of Earth's atmosphere. Then, on the first orbit pass, the aerodynamic sailing device is deployed. The end-of-life of orbital debris occurs under the influence of the aerodynamic drag force of the Earth's atmosphere. For the launch of the service vehicle, it is planned to use the upper stage of Cyclone-4 launch vehicle designed by Yuzhnoye State Design Office.

As a result of the research, a de-orbiting scheme was developed, the minimum mass of propellants and the size of the aerodynamic sailing device were defined, which are necessary to ensure the de-orbiting of the upper stages of Cyclone-3 launch vehicle from low Earth orbits within 25 years. The simulation of the demise process is carried out, mechanical and thermal loads that occur during this process are determined.