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DETERMINATION OF DESIGN PARAMETERS OF THE SYSTEM TO DE-ORBITING OF THE  
UPPER STAGE OF ZENIT-2 LAUNCH VEHICLE FROM NEAR-EARTH ORBITS

**Abstract**

Large satellites and upper stages of launch vehicles that have completed their mission are objects of the potential danger for navigation in low Earth orbits due Kessler's syndrome development. The upper stages of the Zenit-2 launch vehicles are needed a special attention among used space objects. This two-stage medium-class launch vehicle was developed by Yuzhnoye State Design Office (Ukraine) at 1985. Since 1985, Zenit-2 launch vehicles have completed more than 30 successful missions. These launch vehicles were not equipped with a de-orbiting system. Now, there are 22 of Zenit-2 upper stages in low Earth orbits at 620-1000 km altitudes. It should be noted that the value of the ballistic coefficient of the upper stage is about  $0.0015 \text{ m}^2/\text{kg}$ . As a result, the lifetime of such objects is hundreds of years. Taking to account this fact, the different incidents are possible in medium term and long term with their participation.

To de-orbiting of the upper stages of the Zenit-2 launch vehicle from low Earth orbits the Cyclone-4 launch vehicle is planned to use, which was designed by Yuzhnoye State Design Office. A comparative analysis of de-orbiting methods for Zenit-2 launch vehicle during a standard period of 25 years using a service vehicle was considered herein. There are next de-orbiting methods were analyzed: method using a jet propulsion system, method using an aerodynamic sailing device, and combined method (joint use of a jet propulsion system and an aerodynamic sailing device). The optimal criteria of de-orbiting method are total mass of the service vehicle.