Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: SUSTSP / SPEXPLO / UAVFUT *(3 maximum from the list of topics)*
Corresponding author: FROLOV Valery
e-mail of corresponding author: frolov47@ukr.net
Type: Oral / Poster *(select)*
Status of corresponding author: Regular / Student *(select)*

Title

Current problems of modeling and monitoring of near-earth orbital debris population for the safety of the future space missions

Authors

Valery Frolov [1], Mikhail Medvedsky [2], Vadym Naumov [3], Petro Smertenko [3], Arnolds Ubelis [4], Vidvuds Beldavs [4]*

** Corresponding author*
[1] Aerospace Society of Ukraine, Kyiv, Ukraine, frolov47@ukr.net
[2] Main Astronomic Observatory, National Academy of Sciences of Ukraine, Kyiv, Ukraine, medved@mao.kiev.ua
[3] Institute of Physics, National Academy of Sciences of Ukraine, Kyiv, Ukraine, vadym.naumov@gmail.com
[4] FOTONIKA-LV, University of Latvia, Riga, Latvia, e-mail arnolds@latnet.lv; vidvuds.beldavs@lu.lv

Abstract

The problems of near-Earth orbital debris are considered very serious for global safety and future space missions [1-3]. Over the past decades, more than 6,400 rocket launches have put into orbit more than 15,100 space objects. About 7,200 are functional, and the rest are space debris, i.e. orbiting objects that are out of use. Almost 90% of tracked debris is fragments of break-ups or explosions of satellites and vehicles. Besides, there is a huge amount of small debris that cannot be traced: 1 million pieces of 1 cm and 130 million pieces of 1 mm or less. Due to the high speed and impact energy, even the smallest objects are dangerous for spacecraft, and random collisions with objects larger than 10 cm will cause catastrophic destruction releasing clouds of debris, followed by cascading collisions (*Kessler effect*). The debris distribution follows a power law, when the number of pieces increases dramatically with decreasing size. The total mass of debris already exceeds 10,000 tons. To avoid the threat, many active and passive methods for space debris mitigation and remediation have been proposed [2]. These measures, if done properly, help to reduce the space debris population. However, single actions may not be enough to prevent the debris re-growth, reaching 6-9% per year. Obviously, it needs a complex approach. In addition to debris measurements by various ground and space based observations (radar, optical, etc.), this also requires appropriate modeling for prediction and assessment.

There are many space debris models to describe the pollution of near-Earth orbits from 200 to 36,000 km (i.e. LEO and GEO) developed by NASA, ESA and others. They are divided into two types: orbital debris engineering models to assess current risks and evolutionary models to predict future risks. Both are used in R&D, but all have uncertainties: 1) changing physical and ballistic characteristics of debris objects of past launches; 2) uncertain data on future launches; 3) instability of debris after cascade collisions; 4) ambiguity of long-term degradation in different orbits; 5) indefiniteness of some gravitational, electromagnetic and radiation effects of cyclic changes in the Earth's atmosphere. The latter seems to be especially important in order to take into account a) population of space debris in the Earth-Moon libration centers (*Lagrange points*) and b) expansion of the Earth's upper atmosphere to capture space debris in low orbits and aerodynamic removal upon re-entry. Therefore, to improve the reliability of the simulation, the next adjustments are proposed: i) modeling of space debris accumulation at the Earth-Moon *L*-points; ii) modeling of self-cleaning in low-Earth orbits during 11- and 22-year cycles of solar activity; iii) modeling of atmospheric density changes with seasonal variations; iv) identification of space debris by statistical pattern recognition; v) correlation of the eco-state of the near-Earth space and the Earth's biosphere [4]. Advanced simulation models of space debris are developed using modern computer methods and tested in R&D centers of Ukraine and partners. Research is in progress.

References

[1] *NASA Orbital Debris Program Office Quarterly News* **26** (4), Dec 2022. http://orbitaldebris.jsc.nasa.gov
[2] *ESA Space Debris Office Annual Space Environment Report* 2022. http://www.esa.int/space_safety/space_debris
[3] V. Beldavs *et al*., Towards the International Lunar Decade, *EPSC Abstracts* **12**, EPSC2018-268 (2018).
[4] V.F. Frolov, *Ecological Safety of the Biosphere of Earth and Space*. Kyiv: Interservice, 2015. 220 p.

Key words

aerospace technology, space debris, remote sensing, environmental monitoring, mathematical modeling