

ON THE CHOICE OF A PARKING ORBIT FOR A SERVICE SPACECRAFT

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At present, the requirements for increasing spacecraft active life and operational reliability and reducing spacecraft operation costs become more and more stringent. Because of this, on-orbit servicing becomes more and more attractive. One of the most promising ways to increase the efficiency of transport operations in space is to carry out on-orbit servicing using reusable spacecraft with low-thrust solar electrojet engines. The aim of this paper is to develop a mathematical model for the choice of an optimal low near-Earth parking orbit for a reusable service spacecraft. The case of noncoplanar near-circular orbits of spacecraft and a shuttle scenario of their servicing is considered. The solution of the problem of choosing an optimal parking orbit for a reusable service spacecraft involves repeated solutions of the problem of determining the delta-velocity of the service spacecraft's orbital transfers between its parking orbit and the orbits of the serviced spacecraft. In this connection, using the averaging method, a mathematical model is developed for the analytical determination of orbital transfer program controls and trajectories and assessing orbital transfer energy expenditures. With its use, a mathematical model is developed for the choice of a service spacecraft's optimal parking orbit. The objective function is the total delta-velocity of the service spacecraft's orbital transfers from its parking orbit to the orbits of the serviced spacecraft and vice versa with the inclusion of the orbital transfer frequency. The optimizable parameters are the service spacecraft parking orbit parameters. The use of the proposed models is illustrated by an example of service spacecraft parking orbit optimization. What is new is the mathematical models developed. The results obtained may be used in the preliminary planning of on-orbit servicing operations.

Keywords: reusable spacecraft, optimization, parking orbit, on-orbit servicing, low thrust, averaging method.

1. Ivanov V. M. Conceptual foundations of orbital servicing for advanced automatic space vehicles. Spacecraft and Rockets. Vestnik Moskovskogo Aviationsnogo Instituta. 2008. V. 15. No. 3. Pp. 5-7. (in Russian).
2. Vasiliev V. V. Introduction to On-Orbit Servicing. Kyiv: Elmis, 2013. 28 pp. (in Russian).
3. Stephen J. Design for on-orbit spacecraft servicing. Specialist Conference, Paper AAS 14-374, October 2014. Pp. 1-12.
4. Alpatov A. P., Holdshtein Yu. M. Serviced spacecraft orbit clusterization technique. System Technologies. 2019. No. 3. Pp. 93-97. (in Russian).
<https://doi.org/10.34185/1562-9945-3-122-2019-11>
5. Dron N. M., Khololsky P. G., Dubovik L. G. Assessment of the energy and mass characteristics of active systems for the removal of space objects from low near-Earth orbits. Aviationsno-Kosmicheskaya Tekhnika i Tekhnologiya. 2015. No. 7. Pp. 39-44. (in Russian).
6. Cerf M. Low-thrust transfer between circular orbits using natural precession. J. Guid. Contr. Dynam. 2016. V. 39. No. 10. Pp. 232-239.
<https://doi.org/10.2514/1.G001331>
7. Ipatov A. P., Holdshtein Yu. M. On the choice of the ballistic parameters of an on-orbit service spacecraft. Teh. Meh. 2019. No. 1. Pp. 25-37.
<https://doi.org/10.15407/itm2019.01.025>
8. Ipatov A. P., Holdshtein Yu. M. On the choice of an optimal on-orbit servicing route. Teh. Meh. 2019. No. 4. Pp. 21-28. (in Russian).
<https://doi.org/10.15407/itm2019.04.021>
9. Han C., Zhang C., Wang X. On-orbit servicing of geosynchronous satellites based on low-thrust transfers considering perturbations. Acta Astronaut. 2019. No. 159. Pp. 658-675.
<https://doi.org/10.1016/j.actaastro.2019.01.041>
10. Zhao S. G., Gurfil P., Zhang J. R. Optimal servicing of geostationary satellites considering Earth's

triaxiality and lunisolar effects. J. Guid. Contr. Dynam. 2016. V. 39. No. 10. Pp. 1-13.
<https://doi.org/10.2514/1.G001424>

11. Chen X. Q., Yu J. Optimal mission planning of GEO on-orbit refueling in mixed strategy. Acta Astronaut. 2017. No. 133. Pp. 63-72.
<https://doi.org/10.1016/j.actaastro.2017.01.012>

12. Zhang. S., Han C., Sun X. New solution for rendezvous between geosynchronous satellites using low thrust. J. Guid. Contr. Dynam. 2018. V. 41. No. 6. Pp. 1397-1406.
<https://doi.org/10.2514/1.G003270>

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