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Investigation of orbital characteristics of spacecraft

Mankind has made extraordinary strides in space exploration. With the evolution of telescopes, new secrets of "dark space" were revealed. Since the beginning of the space age more than 5,000 satellites and ships have been launched into space, which has further created an incredible load and pollution of the orbit. Each of these objects has a huge charge of kinetic energy and can cause serious damage to satellites.

Due to active space activities, space becomes crowded. "Space debris", which is a non-functioning spacecraft, or their wreckage, poses a serious threat to future development and even the existence of the space industry. Only 6 percent of satellites in orbit are operational, while approximately 30 percent of orbiting objects can be attributed to decommissioned satellites, spent stages, and flight-related objects [1].

According to the theory, called "Kessler's syndrome" [2], garbage in space is especially dangerous "domino effect". There is a risk of collision of objects in space, which could cause an explosion. As a result of the explosion, many fragments are formed, which will come into contact with each other until they cover the entire Earth's space.

ESA estimates that there are now 170 million different fragments in space, and these are the only ones that radars can detect. Satellite fragments, rocket accelerators and spacecraft collisions are used around the Earth.

As follows from Fig.1, most of the space debris is concentrated near low orbits (LEO). Communication satellites are mainly located in such orbits. Currently, it is planned to deploy new LEO communication systems from several thousand Starlink and OneWeb satellites. The life span of a spacecraft is 10-15 years. And, of course, over time, both the existing systems and the newly created ones will turn into space debris.

For years, NASA, ESA and other space agencies have studied the problem of removing or disposing of space debris. Some startups have offered the use of nets, harpoons and robotic arms. In recent years, scientists have made significant progress in research. For example, Japanese scientists are developing a satellite that magnets captures space debris and destroys it, in 2018, a British experimental device first caught a satellite mannequin with a net.

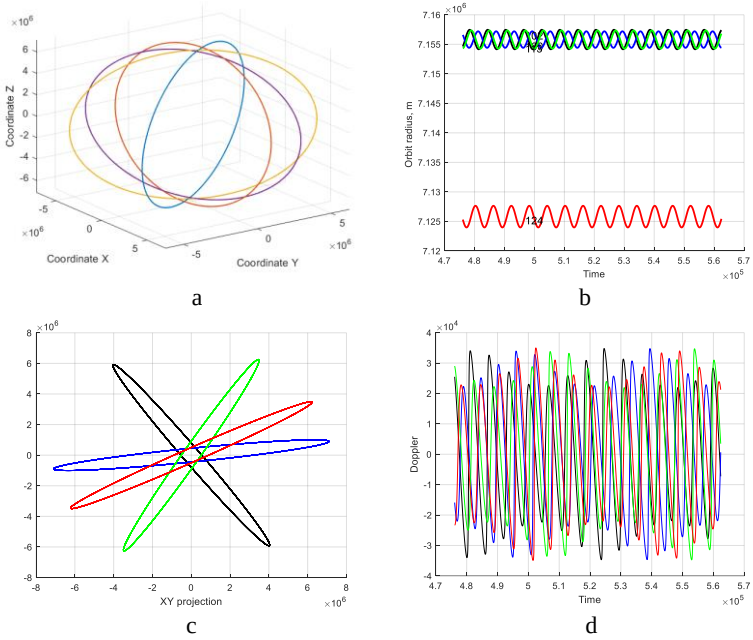
Among the technologies for the disposal of space debris in countries with a developed space industry, including in Ukraine, the possibility of creating a spacecraft capable of delivering satellites from orbit that has exhausted their service life or carrying out preventive work with satellites whose equipment has failed is being explored [4].

One of the problems is the navigation of the service spacecraft. This problem has been partially investigated for navigation in the geostationary orbit area [5, 6]. When navigating in low orbits, it is necessary to know the load of the orbits by

spacecraft. In this regard, it seems relevant to investigate the orbital characteristics of spacecraft of the Starlink and OneWeb systems.

The study was carried out according to the following method. Using the data from [7], models of the orbital motion of the operating system Iridium next (the system was selected for comparison), Starlink and OneWeb were constructed. The data on these systems were converted into the YUMA format, which is widely used to solve satellite navigation problems, and then the basic parameters in digital and graphical form were obtained from the equations for the orbital motion of satellite aviation systems. The main results are presented graphically below.

Iridium. Communication system, 75 satellites, located in 4 orbital planes.

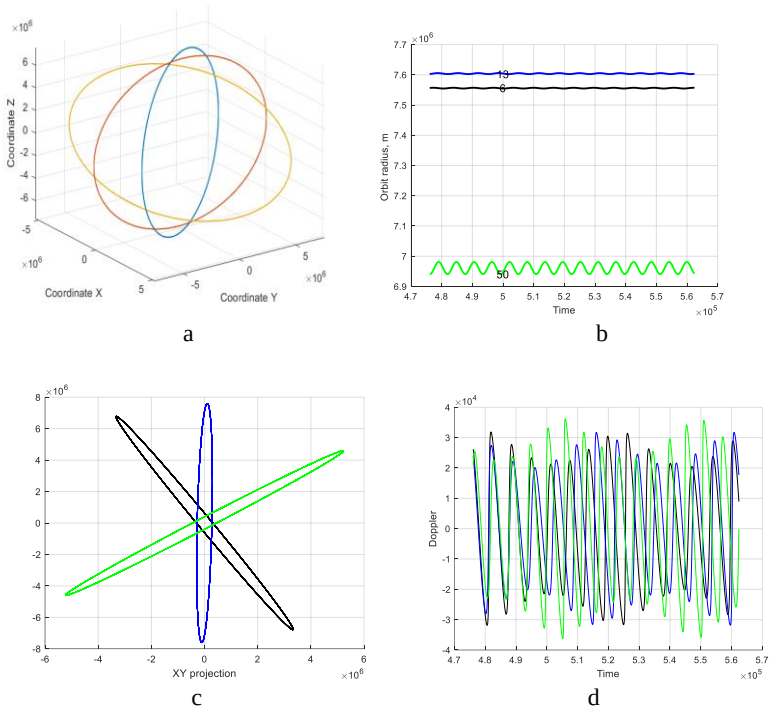


a b c d

Fig. 1

Fig. 1a shows four orbital planes in which 75 satellites are located, Fig. 1, b shows the radii of the satellites' orbits (measured from the center of mass of the Earth in meters), the time in seconds is counted along the horizontal axis, Fig. 1, c shows the projection of the orbital planes on the plane of the earth's equator. This nature of the projections suggests that the inclination of the orbital planes is close to ninety degrees, that is, the satellites can be located above the north and south poles. Fig. 1, d the vertical axis is the Doppler frequency in hertz, the horizontal is the time in seconds.

OneWeb. Telecommunication systems. It currently contains 110 satellites in three orbital planes.



a b

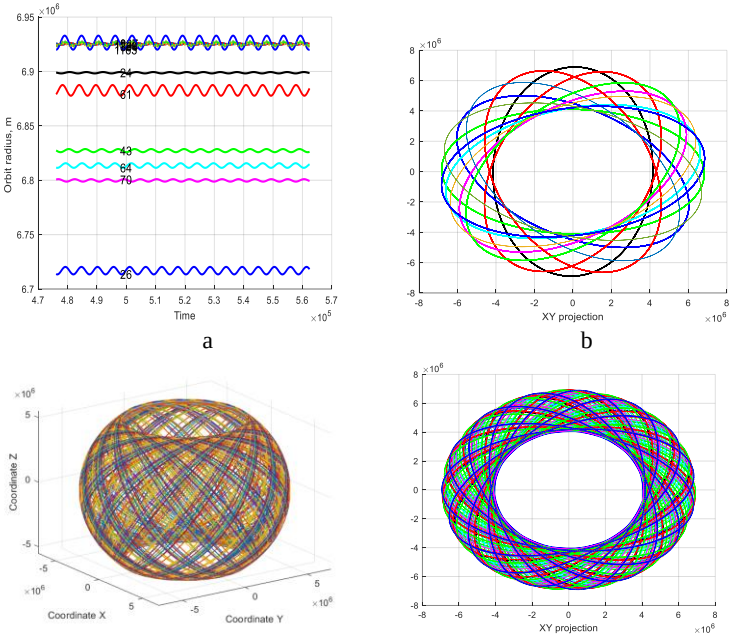
c d

Fig. 2

Images in Fig. 2 differ from Fig. 1 by the number of orbital planes, orbital radii. The OneWeb satellites are located above the Iridium satellites.

Starlink system. According to the information provided by the developers, it is intended to provide Internet to any point on the surface of the Earth. The minimum number of satellites is 12,000. As of March 14, 2021, 1,070 satellites are available. These satellites were studied in this work. The difference between Starlink and the considered systems consists in a large number of satellites (so far 1070), located today in 12 orbital planes, the orbits of the satellites are inclined, the radii of the orbits are shown in Fig. 3, a. Since the orbits are inclined, the satellites do not fly over the north and south poles (Fig. 3, b, c, d), Images in Fig. 3, c, d were obtained for the conditions of the Earth's rotation and satellite motion. If we consider the rotation of the Earth and the movement of 110 OneWeb satellites and 1070 Starlink

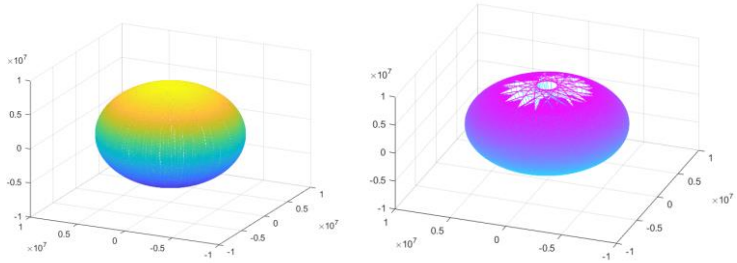
satellites, it is possible to obtain an image of the "surfaces" around the Earth from which the emission of satellite signals occurs (Fig. 4, a, b).



a b c d

Fig. 3

Starlink has no satellites above the poles. As already noted, the results obtained in digital form make it possible to estimate the coordinates of satellites at any time, at any time interval and at any pace. This makes it possible to design the trajectory of the service spacecraft when performing technological work in space.



a b

Fig. 4

We draw your attention to the fact that the saturation of outer space near the Earth requires deep research on the creation of technologies for the elimination of objects that have exhausted their resource. From the studies carried out, it can be seen that the Earth is surrounded by several layers of moving satellites. We have considered only three, and in fact there are many more.

In conclusion, we note that this research was carried out in the satellite navigation laboratory of the National Aviation University within the framework of the discipline “Satellite aerospace technologies and systems.

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