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The design of low thrust engine spacecraft for near-Earth asteroid exploration

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Abstract

This paper discusses the application of computer-assisted design systems to development of low thrust spacecraft intended to take an exploratory flight to potentially hazardous asteroids. The design model of the low thrust spacecraft that is created with computer-aided design systems is described. The mathematical motion model within the heliocentric system of coordinates for such type of spacecraft is considered and used for a motion simulation session. The simulation of flight to the potentially hazardous asteroid is performed with the aid of special complex software that is developed for the purpose of the work. The results of the paper consist of a detailed three-dimensional model of the low thrust spacecraft, heliocentric trajectory of the spacecraft, the values of flight duration and propellant consumption during exploratory flight.

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Keywords: low thrust engine; spacecraft; design of spacecraft; near-Earth object; near-Earth asteroid; computer-aided design system.

1. Introduction

Research into interplanetary travel and circumsolar space provides an opportunity to answer many fundamental scientific questions and to use the achievements of astronautics for exploiting the virtually unlimited resources of the Solar system. Scientific research in space requires considerable expenditure and does not ensure fast returns[1, 2, 3].

Nowadays scientists and society pay a huge attention to celestial bodies, such as asteroids. Asteroid research affords an opportunity to modern science to understand how the Solar system was formed. The investigation can also bring usefulness. It is known that a wide range of mining fields, such as diamonds, lead, mercury, copper, etc., occurs in celestial body impact points on the Earth's surface. That is why delivery of minerals to Earth from asteroids is a very prospective mission. Besides, asteroid investigation will help us to solve a problem of Earth's safeguard from celestial bodies.

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2. Near-Earth object characteristics

Asteroids are small, airless rocky worlds revolving around the sun that are too small to be called planets. They are also known as planetoids or minor planets[4]. Asteroids measure in size from a few centimeters to several kilometers in diameter. The largest asteroid, Ceres, is about 950 kilometers wide. Like most asteroids, it lies in the asteroid belt between Mars and Jupiter[5].

Near-Earth Objects (NEO) – are any small Solar System body whose orbit brings it into proximity with Earth. NEOs are asteroids and comets with perihelion distance rπ less than 1.3 AU. The vast majority of NEOs are asteroids, referred to as Near-Earth Asteroids (NEAs). NEAs are divided into groups (Aten, Apollo, Amor) according to their perihelion distance $r\pi$, aphelion distance $r\alpha$ and their semi-major axes a[6]. The most dangerous NEAs are Apophis, Eros, Pan, Castalia, Ptah and Minos. Table 1 demonstrates the NEAs characteristics[7].

Table 1. NEAs characteristics

№	Name	Diameter D_{Ast}, km	Mass M_{Ast}, kg	Rotation period, hours	Orbital period, days	Semi-major axis a_{Ast}, AU	Eccentricity e_{Ast}, AU	Inclination i_{Ast}, deg
99942	Apophis	0.325	$2.7x10^{10}$	30.4	323.545	0.92	0.191	3.332
433	Eros	16.84	$6.69x10^{15}$	5.27	643.035	1.49	0.223	10.829
4450	Pan	0.965-2.158	n/a	60	632.889	1.44	0.59	5.5
4769	Castalia	1.4	$5x10^{11}$	4.095	400.525	1.06	0.48	8.9
5011	Ptah	1.011-2.259	n/a	n/a	764.095	1.64	0.50	7.4
6239	Minos	0.474	n/a	3.56	451.356	1.15	0.41	3.945

3. Design model of low thrust spacecraft

The paper describes the model of low thrust engine spacecraft designed by means of computer-aided design system (CAD system) on the base of space probe Dawn (Fig. 1)[4]. The design model is intended to explore a surface of asteroids and other celestial bodies. The spacecraft body frame is rectangular parallelepiped, which contains scientific hardware and other needed equipment inside. The designed low thrust spacecraft is equipped with solar cell batteries, stationary plasma jet engines SPJ-70[8] and electro optical equipment. Table 2 describes the mass-dimensional characteristics of the spacecraft.

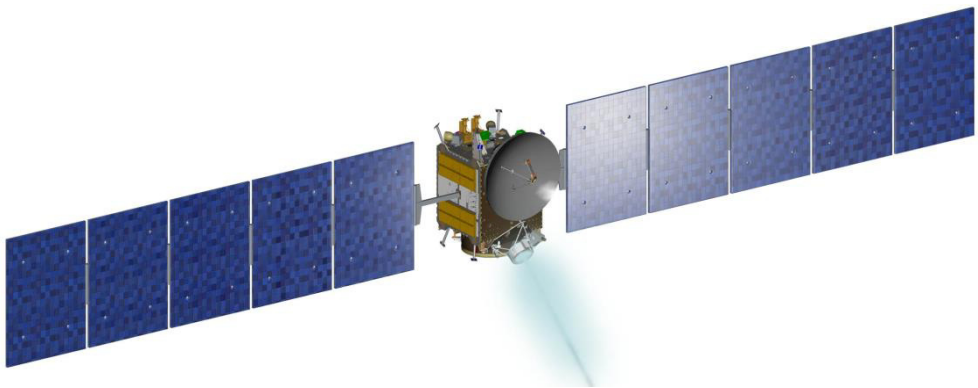

Fig 1. Spacecraft Dawn