Protection of the Earth from the Asteroid

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New York, 2012

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Abstract

For Protection of the Earth from asteroid we need in methods for changing the asteroid trajectory and theory for an estimation or computation the impulse which produces these methods. Author develops some methods of this computation. There are: impact of the space apparatus to asteroid, explosion the conventional explosive having form of plate and ball on asteroid surface, explosion the small nuclear bomb on the asteroids surface, entry asteroid to Earth atmosphere, braking of asteroid by parachute.

Offered method may be also used for braking of apparatus reentering in the Earth from a space flight. The offered theory also may be used for protection the Earth from impact of a big asteroid.

Key words: protection of the Earth from asteroids, asteroid delivery to Earth, impact to asteroid, nuclear explosion, atmospheric entry, Space Ships, thermal protection of asteroid and space apparatus, parachute braking of asteroid.

Introduction

There are many small solid objects in the Solar System called asteroids [1]. The vast majority are found in a swarm called the asteroid belt, located between the orbits of Mars and Jupiter at an average distance of 2.1 to 3.3 astronomical units (AU) from the Sun. Scientists know of approximately 6,000 large asteroids of a diameter of 1 kilometer or more, and of millions of small asteroids with a diameter of 3 meters or more.

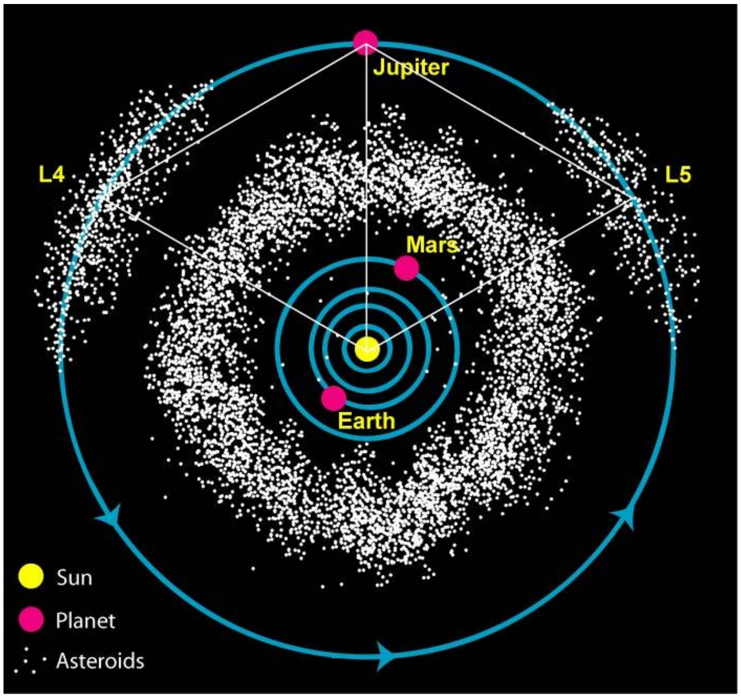

Fig.1. Asteroid belt.

Radar observations enable to discern of asteroids by measuring the distribution of echo power in time delay (range) and Doppler frequency. They allow a determination of the asteroid trajectory and spin and the creation of an asteroid image.

For Protection of the Earth and for delivery asteroid to the Earth author considers theory of three main methods: impact of the space apparatus to asteroid, explosion the conventional explosive on asteroid surface having form of plate and ball, explosion the small nuclear bomb on the asteroids surface, braking asteroid by parachute in Earth atmosphere.

Fig.2. Asteroids.

Kinetic impact.

The impact of a massive object, such as a spacecraft or another near-Earth object, is one possible solution to change the trajectory of the Near Earth asteroid or Object (NEO). Another object (for example, space apparatus) with a high mass close to the Earth could be forced into a collision with an asteroid, knocking it off course.

When the asteroid is still far from the Earth, a means of deflecting the asteroid to Earh is to directly alter its momentum by colliding a spacecraft with the asteroid.

The European Space Agency is already studying the preliminary design of a space mission able to demonstrate this futuristic technology. The mission, named Don Quijote, is the first real asteroid deflection mission ever designed.

In the case of 99942 Apophis it has been demonstrated by ESA's Advanced Concepts Team that deflection could be achieved by sending a simple spacecraft weighing less than one ton to impact against the asteroid. During a trade-off study one of the leading researchers argued that a strategy called 'kinetic impactor deflection' was more efficient than others.

Nuclear bomb for deflection of asteroid.

Detonating a nuclear explosion above the surface (or on the surface or beneath it) of an NEO would be one option, with the blast vaporizing part of the surface of the object and nudging it off course with the reaction. This is a form of nuclear pulse propulsion. Even if not completely vaporized, the resulting reduction of mass from the blast combined with the radiation blast and rocket exhaust effect from eject could produce positive results.

Another proposed solution is to detonate a series of smaller nuclear bombs alongside the asteroid, far enough away as not to fracture the object. Providing this was done far enough in advance, the relatively small forces from any number of nuclear blasts could be enough to alter the object's trajectory enough to avoid an impact. The 1964 book *Islands in Space*, calculates that the nuclear megatonnage necessary for several deflection scenarios exists. In 1967, graduate students under Professor Paul Sandorff at the Massachusetts Institute of Technology designed a system using rockets and nuclear explosions to prevent a hypothetical impact on Earth by the asteroid 1566 Icarus. This design study was later published as Project Icarus which served as the inspiration for the 1979 film *Meteor*.

Theory of the asteroids movement and changing trajectory.

In Table 1 are computed the mass M of the ball asteroid, his energy E for speed V = 16 km/s and explosive power P of asteroids. One ton TNT has 4.184×10^9 joules of energy.

Table 1. Diameter D, mass M of ball asteroid having density 3500 kg/m³, energy E for speed V = 16 km/s and explosive power P of asteroids.

D, m	10 m	30 m	100 m	300 m	1 km	3 km	10 km	30 km
M, kg	$1.83\cdot10^{6}$	$16.5\cdot10^{6}$	$1.83\cdot10^{9}$	$16.5\cdot10^{9}$	$1.83\cdot10^{12}$	$16.\cdot10^{12}$	$1.83\cdot10^{15}$	$16.5\cdot10^{15}$
E, J	$2.34\cdot10^{14}$	$21.1\cdot10^{14}$	$2.34\cdot10^{17}$	$21.1\cdot10^{17}$	$2.34\cdot10^{20}$	$21.1\cdot10^{20}$	$2.34\cdot10^{23}$	$21.1\cdot10^{23}$
P, ton	$0.56\cdot10^{5}$	$5.11\cdot10^{5}$	$0.56\cdot10^{8}$	$5.11\cdot10^{8}$	$0.56\cdot10^{12}$	$5.11\cdot10^{11}$	$0.56\cdot10^{14}$	$5.11\cdot10^{14}$

The Hiroshima nuclear bomb had power about 15 kilotons of TNT explosive. The small ball asteroid having diameter 10 m has energy in 4 times more for speed 16 km/s.

1. Equations for computation of trajectory in vacuum space near Earth.

These equations are following:

$$r=\frac{p}{1+e\cos\beta},\quad p=\frac{c^2}{K},\quad e=\frac{c}{K}\sqrt{H+\frac{K^2}{c^2}},\quad c=v^2r^2\cos^2 v=const,$$
$$H=2K\frac{M}{R}=const,\quad K=3.98\cdot10^{14}\ \frac{m^3}{s^2},\quad r_a=\frac{p}{1-e},\quad r_p=\frac{p}{1+e},\qquad (1)$$
$$T=\frac{2\pi}{\sqrt{K}}a^{3/2},\quad a=r_a,\quad b=r_p,\quad b=a\sqrt{1-e^2},$$

where r is radius from Earth center to point in trajectory, m; p is ellipse parament, m; e is ellipse eccentricity, e = 0 for circle trajectory, e < 1 for ellipse, e = 1 for parabola, e > 1 for hyperbola; β is angle from perigee, K is Earth constant, v is speed, m/s; v is angle between speed and tangent to circle; $M = 5.976\cdot10^{24}$ kg is mass of Earth; R = 6378 km is Earth radius; r_a is apogee, m; r_p is perigee, m; b is small semi axis of ellipse, m; a is small semi axis of ellipse, m; T is period of rotation, sec.

2. Change asteroid trajectory by impact of space apparatus.

Inelastic head-on collision space apparatus (SA) in the asteroid (As):

$$W=\frac{1}{2}m_1V_1^2+\frac{1}{2}m_2V_2^2,\quad Q=\frac{m_1m_2V_1^2}{2(m_1+m_2)},\quad \eta=\frac{W-Q}{W}=\frac{m_1}{m_1+m_2},\qquad (2)$$

Where W is energy of system, J; Q is heat loss in impact, J; m_1 is mass of space apparatus, kg; m_2 is mass of asteroid, kg; V_1 is speed of SA about center mass of the system asteroid-SA, m/s; V_2 is speed of asteroid about center mass of system asteroid-SA, η is coefficient of efficiency.

Let us place the origin at the center of gravity of an asteroid. The speed of system asteroid-SA will be

$$\Delta V=V\left[\frac{m_1}{m_1+m_2}\left(1-\frac{m_2}{m_1+m_2}\right)\right]^{0.5},\quad \Delta I=(m_1+m_2)\Delta V,\qquad (3)$$

Where ΔV is change of asteroid speed, m/s; V is SA speed relative asteroid, m/s; ΔI is additional impulse of system As+SA.

Example. Let us take the asteroid having diameter 10 m (m_2 = 1830 tons) and SA having mass m_1 = 10 tons and speed about asteroid V = 1 km/s. From equation (3)-(2) we find ΔV = 5.43 m/s, η = 0.00543.

3. **Change trajectory by conventional plate explosive located on the asteroid surface.**

In this case we get the impulse from the explosive gas.

The maximal speed of an explosion gas and asteroid speed received from explosion are

$$V_1 = \sqrt{2q}\ , \quad V_2 = V_1 \frac{m_1}{m_2}\ , \tag{4}$$

where V_1 is speed of explosion gas, m/s; q is specific energy of the explosive, J/kg ($q \approx 5.4$ MJ/kg for TNT), V_2 is asteroid speed received from explosion, m/s; m_1 is mass of explosive, kg; m_2 is mass of asteroid, kg.

Example. Let us take the asteroid having diameter 10 m (m_2 = 1830 tons) and explosive having mass m_1 = 10 tons and specific energy of the explosive $q \approx 4.2$ MJ/kg. From equation (4) we find the change of speed of asteroids $V_2 = \Delta V$ = 15.8 m/s.

If explosive is not plate (not optimum) and located in one point (ball) on the asteroid surface, the effect from the explosion will be less. Maximum speed is $\pi/4 = 0.785$ from the plate explosion speed: $V_2 = \Delta V = 15.8 \times 0.785 = 12.4$ m/s.

3. Nuclear point explosion on the asteroid surface.

In this case the asteroid gets the impulse from evaporation part of asteroid. The asteroid rest can get the significant speed. If the energy of the nuclear bomb is E, bomb is located on asteroid surface, change the asteroid speed may be estimated by next equations

$$V_1 = \sqrt{\lambda}\ , \quad m_1 = \frac{E}{2\lambda}\ , \quad v = \frac{m_1}{\rho}, \quad r^3 = \frac{3v}{2\pi}, \quad I = m_1 V_1\ , \quad \Delta V = \frac{I}{m_2 - m_1}, \tag{5}$$

where V_1 is speed of evaporation gas, m/s; λ is specific energy of the asteroid evaporation, J/kg (heating + melting + heating + evaporation), v is the volume of a sold evaporation mass, m³; ρ is the asteroid density kg/ m³; I is impulse, kg m/s; ΔV is change of the asteroid speed received from nuclear explosion, m/s; m_1 is the asteroid evaporation mass in explosion, kg; m_2 is initial mass of asteroid, kg; r is radius of explosion cavity, m.

For basalt the λ = heating + evaporation = 1191 + 3500 = 4691 kJ/kg, ρ = 3500 kg/ m³. For iron $\lambda \approx 8200$ kJ/kg, ρ = 7900 kg/ m³; for ice $\lambda \approx 3000$ kJ/kg, ρ = 1000 kg/ m³..

Example. Let us take the iron asteroid having diameter 10 m (m_2 = 1830 tons) and energy of a small nuclear bomb is E = 1 kton = $4.2 \cdot 10^{12}$ J. From equation (4) we find V_1 = 2863 m/s; m_1 =256 tons, the change of speed of asteroids $V_2 = \Delta V$ = 460 m/s.

The impact from nuclear explosion is very strong and aster0id may spell.

4. Computation of the asteroid trajectory when asteroid is towing by aircraft the Earth atmosphere.

Equations for computation of trajectory are (for the system of asteroid + space apparatus):

$$\dot{r}=\frac{R_0}{R}V\cos\theta,$$
$$\dot{H}=V\sin\theta,$$
$$\dot{V}=-\frac{D+D_p}{m}-g\sin\theta, \qquad (4)$$
$$\dot{\theta}=\frac{L+L_P}{mV}-\frac{g}{V}\cos\theta+\frac{V\cos\theta}{R}+2\omega_E\cos\varphi_E,$$

where r is range of ship flight, m; R_0 = 6,378,000 is radius of Earth, m; R is radius of ship flight from Earth's center, m; V is ship speed, m/s; H is ship altitude, m; θ is trajectory angle, radians; D is system drag (asteroid + apparatus), N; D_P is asteroid drag, N; m is system mass, kg; g is gravity at altitude H, m/s^2; L is apparatus lift force, N; L_P is asteroid lift force, N; ω_E is angle Earth speed; $\varphi_E = 0$ is lesser angle between perpendicular to flight plate and Earth polar axis; t is flight time, sec.

The magnitudes in equations (4) compute as:

$$g=g_0\left(\frac{R_0}{R_0+H}\right)^2, \quad \rho=a_1e^{(H-10000)/b}, \quad a_1=0.414, \quad b=6719,$$
$$Q=\frac{0.5\cdot 11040\cdot 10^4}{R_n^{0.5}}\left(\frac{\rho}{\rho_{SL}}\right)^{0.5}\left(\frac{V}{V_{CO}}\right)^{3.15}, \quad R_n=\sqrt{\frac{S_P}{\pi}},$$
$$T_1=100\left(\frac{Q}{\varepsilon C_S}+\left(\frac{T_2}{100}\right)^4\right)^{1/4}, \quad T=T_1-273, \qquad (5)$$
$$D_P=0.5C_{DP}\rho aVS_P, \quad L_P\approx(1\div 4)D_p, \quad L=2\alpha\rho aVS, \quad D=L/4,$$
$$\Delta V\approx\frac{0.5C_{DP}\rho a\, S_p L}{m},$$

where: g_0 = 9.81 m/s^2 is gravity at Earth surface; ρ is air density, kg/m^3; Q is heat flow in 1 m^2/s of parachute, J/s·m^2; R_n (or R_p) is asteroid radius, m; S_P (or S_m) is asteroid area, m^2; ρ_{SL}= 1.225 kg/m^3 is air density at sea level; V_{CO} = 7950 m/s is circle orbit speed; T_1 is temperature of asteroid/apparatus in stagnation point in Kelvin, ^{o}K; T is temperature of parachute in stagnation point in centigrade, ^{o}C; T_2 is temperature of the standard atmosphere at given altitude, ^{o}K (T_2 = 253 ^{o}K at H = 60 km) ; D_P is asteroid drag, N.; L_P is asteroid lift force That is control from 0 to 0.4 D_p, N; D is ship drag, N; L is ship lift force, N; C_{DP} = 1 is asteroid drag coefficient; a = 295 m/s is sound speed at high altitude; $\alpha = 40^o = 0.7$ rad is apparatus attack angle. C_S = 5.67 W/(m^2·K^4) is coefficient radiation of black body; ε is coefficient of a black ($\varepsilon \approx 0.03 \div 0.99$), ΔV is loss of speed in atmosphere on distance L.

The control is following: if T_1 is more the given safety temperature than the lift force L = maximum. In other case L = 0. If T_1 is less the given safety temperature than the lift force L = negative minimum.

Conclusion

For protection of the Earth from asteroids we need in methods for changing the asteroid trajectory and theory for an estimation or computation the impulse which produces these methods. Author develops some methods of this computation. There are: impact of the space apparatus to asteroid, explosion the conventional explosive on asteroid surface having form of plate and ball, explosion the small nuclear bomb on the asteroids surface.

The reader finds useful information about protection methods also in [1]-[7].

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