# Capture and Delivery of Asteroid to the Earth

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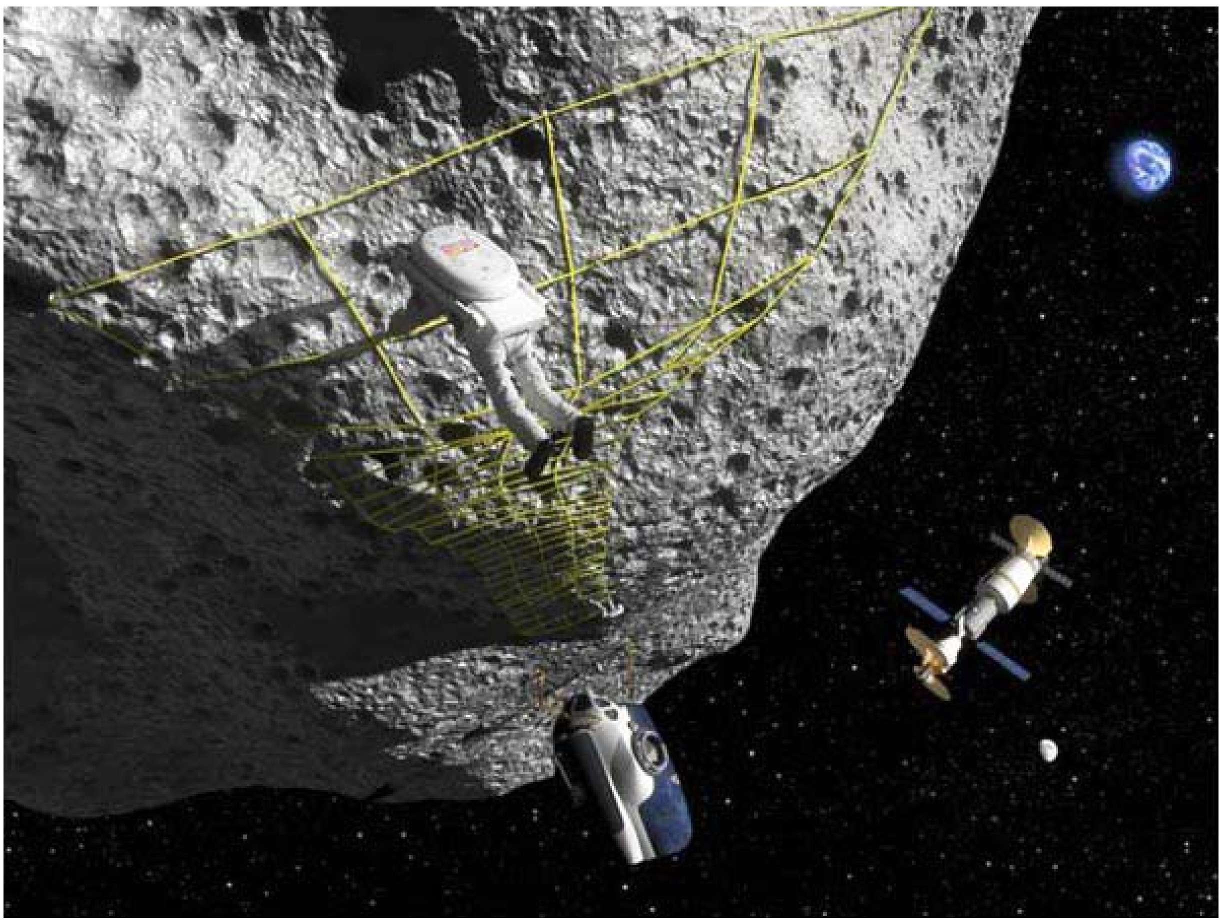

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## Abstract

Authors offer the new method for deliver the asteroid to Earth. That method is cheaper in a lot of times than a conventional method. In our method for braking apparatus and asteroid are used the kinetic energy of apparatus. This energy is used also for charging the apparatus energy storage. The small control parachute allows multiple using the Earth atmosphere for the braking the asteroid without high heating, deliver the asteroid in given point and to avoid the asteroid impact to Earth.

In recent years, industry has produced high-temperature fiber and whiskers. The authors examined and proposed the use of high temperature tolerant parachute for atmospheric air braking. Though it is not large, a light parachute decreases asyeroid speed from 11 km/s to 50 m/s and a heat flow by tens times. The parachute surface is opened with backside so that it can emit the heat radiation efficiently to Earth-atmosphere. The temperature of parachute may be about 1000-1300$^{o}$ C. The carbon fiber is able to keep its functionality up to a temperature of 1500-2000$^{o}$ C. There is no conceivable problem to manufacture the parachute from carbon fiber. The proposed new method of braking may be also applied to the old Space Ship as well as to newer spacecraft designs.

**Key words**: Asteroid delivery to Earth, Atmospheric reentry, Space Ships, thermal protection of asteroid and space apparatus, parachute braking.

## Introduction

### Brief information about asteroids.

There are many small solid objects in the Solar System called asteroids. 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. Ceres, Pallas, and Vesta are the three largest asteroids, with diameters of 785, 610 and 450 km respectively. Others range all the way down to meteorite size. In 1991 the Galileo probe provided the first close-up view of the asteroid Caspra; although the Martian moons (already seen close up) may also be asteroids, captured by Mars. There are many small asteroids, meteorites, and comets outside the asteroid belt. For example, scientists know of 1,000 asteroids of diameter larger than one kilometer located near the Earth. Every day 1 ton meteorites with mass of over 8 kg fall on the Earth. The orbits of big asteroids are well known. The small asteroids (from 1 kg) may be also located and their trajectory can be determined by radio and optical devices at a distance of hundreds of kilometers.

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.

**Asteroid belt.** The mass of all the objects of the asteroid belt, lying between the orbits of Mars and Jupiter, is estimated to be about $2.8\text{-}3.2\times10^{21}$ kg, or about 4 percent of the mass of the Moon. Of this, Ceres comprises $0.95\times10^{21}$ kg, a third of the total. Adding in the next three most massive objects, Vesta (9%), Pallas (7%), and Hygiea (3%), brings this figure up to 51%; while the three after that, 511 Davida (1.2%), 704 Interamnia (1.0%), and 52 Europa (0.9%), only add another 3% to the total mass. The number of asteroids then increases rapidly as their individual masses **decrease.**

The majority of known asteroids orbit within the asteroid belt between the orbits of Mars and Jupiter, generally in relatively low-eccentricity (i.e., not very elongated) orbits. This belt is now estimated to contain between 1.1 and 1.9 million asteroids larger than 1 km (0.6 mi) in diameter, and millions of smaller ones. These asteroids may be remnants of the protoplanetary disk, and in this region the accretion of planetesimals into planets during the formative period of the Solar System was prevented by large gravitational perturbations by Jupiter.

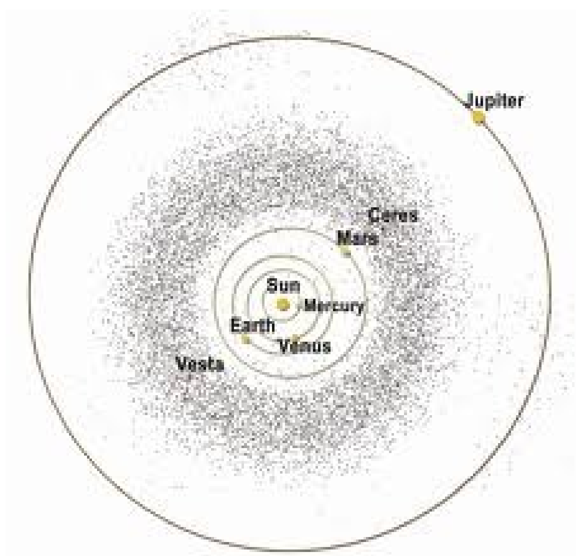


Fig.1. The asteroid belt (white) and the Trojan asteroids (green)

## Near-Earth asteroids

Near-Earth asteroids, or NEAs, are asteroids that have orbits that pass close to that of Earth. Asteroids that actually cross the Earth's orbital path are known as *Earth-crossers*. As of May 2010, 7,075 near-Earth asteroids are known and the number over one kilometre in diameter is estimated to be 500–1,000.

There are significantly fewer near-Earth asteroids in the mid-size range than previously thought.

These are objects of 50 meters or more in diameter in a near-Earth orbit without the tail or coma of a comet. As of May 2012, 8,880 near-Earth asteroids are known, ranging in size from 1 meter up to ~32 kilometers (1036 Ganymed). The number of near-Earth asteroids over one kilometer in diameter is estimated to be about 981. The composition of near-Earth asteroids is comparable to that of asteroids from the asteroid belt, reflecting a variety of asteroid spectral types.

NEAs survive in their orbits for just a few million years. They are eventually eliminated by planetary perturbations which cause ejection from the Solar System or a collision with the Sun or a planet. With orbital lifetimes short compared to the age of the Solar System, new asteroids must be constantly moved into near-Earth orbits to explain the observed asteroids. The accepted origin of these asteroids is that asteroid-belt asteroids are moved into the inner Solar System through orbital resonances with Jupiter. The interaction with Jupiter through the resonance perturbs the asteroid's orbit and it comes into the inner Solar System. The asteroid belt has gaps, known as Kirkwood gaps, where these resonances occur as the asteroids in these resonances have been moved onto other orbits. New asteroids migrate into these resonances, due to the Yarkovsky effect that provides a continuing supply of near-Earth asteroids.

A small number of NEOs are extinct comets that have lost their volatile surface materials, although having a faint or intermittent comet-like tail does not necessarily result in a classification as a near-Earth comet, making the boundaries somewhat fuzzy. The rest of the near-Earth asteroids are driven out of the asteroid belt by gravitational interactions with Jupiter.

There are three families of near-Earth asteroids:

- The *Atens*, which have average orbital radii less than one AU and aphelia of more than Earth's perihelion (0.983 AU), placing them usually inside the orbit of Earth.
- The *Apollos*, which have average orbital radii more than that of the Earth and perihelia less than Earth's aphelion (1.017 AU).
- The *Amors*, which have average orbital radii in between the orbits of Earth and Mars and perihelia slightly outside Earth's orbit (1.017–1.3 AU). Amors often cross the orbit of Mars, but they do not cross the orbit of Earth.

Many Atens and all Apollos have orbits that cross (though not necessarily intersect) that of the Earth, so they are a threat to impact the Earth on their current orbits. Amors do not cross the Earth's orbit and are not immediate impact threats. However, their orbits may evolve into Earth-crossing orbits in the future.
Also sometimes used is the Arjuna asteroid classification, for asteroids with extremely Earth-like orbits.

There are also the asteroids located at the stable Lagrange points of the Earth–Moon system. Most asteroids consist of carbon-rich minerals, while most meteorites are composed of stony-iron.

The majority of NEAs have densities between 1.9 g/cm$^3$ and 3.8 g/cm$^3$.
Asteroid having diameter 4.0 m has weight 93,829 kg for density 2.8 g/cm$^3$ and 127,339 kg for density 3.8 g/cm$^3$. The International Space Station has a mass of 450,000 kg: as a 7-m diameter asteroid.

Present Knowledge

• ~20,500NEAs > 100meters: about 25% discovered to date;

• MillionsofNEAs > 10meters and billions of NEAs > 2meters;

• less than one percent have been discovered;

• Small NEAs discovered only during very close Earth approaches;

• however,280 asteroids approximately 10-m diameter discovered;

• few of these currently have secure orbits;

• none of them have the physical (spectral class, albedos, true diameters…);

Objects with diameters of 5-10 m impact the Earth's atmosphere approximately once per year, with as much energy as the atomic bomb dropped on Hiroshima, approximately 15 kilotonnes of TNT. These ordinarily explode in the upper atmosphere, and most or all of the solids are vaporized. Every 2000–3000 years NEAs produce explosions comparable to the one observed at Tunguska in 1908. Objects with a diameter of one kilometer hit the Earth an average of twice every million year interval. Large collisions with five kilometer objects happen approximately once every ten million years.

A **near-Earth object** (**NEO**) is a Solar System object whose orbit brings it into close proximity with the Earth. All NEOs have an apsis distance less than 1.3 AU. They include a few thousand near-Earth asteroids (NEAs), near-Earth comets, a number of solar-orbiting spacecraft, and meteoroids large enough to be tracked in space before striking the Earth. It is now widely accepted that collisions in the past have had a significant role in shaping the geological and biological history of the planet. NEOs have become of increased interest since the 1980s because of increased awareness of the potential danger some of the asteroids or comets pose to the Earth, and active mitigations are being researched. A study showed that the United States and China are the nations most vulnerable to a meteor strike.

Those NEOs that are asteroids (NEA) have orbits that lie partly between 0.983 and 1.3 astronomical units away from the Sun. When an NEA is detected it is submitted to the Harvard Minor Planet Center for cataloging. Some near-Earth asteroids' orbits intersect that of Earth's so they pose a collision danger. The United States, European Union and other nations are currently scanning for NEOs in an effort called Spaceguard.

In the United States, NASA has a congressional mandate to catalogue all NEOs that are at least 1 kilometer wide, as the impact of such an object would be produce catastrophic effects. As of May 2012, 843 near-Earth asteroids larger than 1km have been discovered but only 152 are potentially hazardous asteroids (PHAs). It was estimated in 2006 that 20% of the mandated objects have not yet been found. As a result of NEOWISE in 2011, it is estimated that 93% of the NEAs larger than 1km have been found and that only about 70 remain to be discovered. Potentially hazardous objects (PHOs) are currently defined based on parameters that measure the object's potential to make threatening close approaches to the Earth. Mostly objects with an Earth minimum orbit intersection distance (MOID) of 0.05 AU or less and an absolute magnitude (H) of 22.0 or less (a rough indicator of large size) are considered PHOs. Objects that cannot approach closer to the Earth (i.e. MOID) than 0.05 AU (7,500,000 km; 4,600,000 mi), or are smaller than about 150 m (500 ft) in diameter (i.e. H = 22.0 with assumed albedo of 13%), are not considered PHOs. The NASA Near Earth Object Catalog also includes the approach distances of asteroids and comets measured in Lunar Distances, and this usage has become the more usual unit of measure used by the press and mainstream media in discussing these objects.

Some NEOs are of high interest because they can be physically explored with lower mission velocity even than the Moon, due to their combination of low velocity with respect to Earth ($\Delta V$) and small gravity, so they may present interesting scientific opportunities both for direct geochemical and astronomical investigation, and as potentially economical sources of extraterrestrial materials for human exploitation. This makes them an attractive target for exploration. As of 2008, two near-Earth objects have been visited by spacecraft: 433 Eros, by NASA's Near Earth Asteroid Rendezvous probe, and 25143 Itokawa, by the JAXA Hayabusa mission.

## Near-Earth meteoroids

Near-Earth meteoroids are smaller near-Earth asteroids having an estimated diameter less than 50 meters. They are listed as asteroids on most asteroid tables. The JPL Small-Body Database lists 1,349 near Earth asteroids with an absolute magnitude (H) dimmer than 25 (roughly 50 meters in diameter). The smallest known near-Earth meteoroid is 2008 $TS_{26}$ with an absolute magnitude of 33 and estimated size of only 1 meter.

## Short description of the delivery method and innovations

1. **Description**. The apparatus for delivery asteroids to the Earth contains the rocket, computer, devices for definition of asteroid composition (for example, the laser spectrometer ), radio receiver/translator, capture net, long cable and mechanical energy accumulator, heat-resistance control rectangular parachute and so on.

2. **Work of delivery apparatus**. Delivery apparatus works the following way. The most asteroids captured by the Earth are moving in the elliptic orbits having in focus the Earth (fig.2a). The delivery apparatus also in most cases will have the elliptic orbits. The elliptic orbit has the perigee – the nearest point to focus (Earth) and apogee – the most far point from focus (Earth). The asteroid speed is maximum in the perigee and minimum in the apogee. The asteroid captured by Earth has speed between 8 km/s and 11 km/s. If his speed is less 8 km/s one falls to Earth. If the speed more 11 km/s the asteroid will fly to space. The speeds in apogee and perigee connected by relation

$$r_a V_a = r_p V_p \ ,$$

where $r_a$, $r_p$ are radius of apogee and perigee and $V_a$, $V_p$ are speed in apogee and perigee respectively. You can see from this ratio: If you want to decrease perigee (for asteroid), the minimal impulse (minimum of fuel consumption) will be in apogee; if you want increase apogee (for capture/delivery apparatus) the minimal impulse will be in perigee.

If the altitude asteroid/apparatus (AA) is less the 100 km over Earth surface, the Earth atmosphere became to brake the asteroids. The apogee decreases (fig.2b). After some contacts of AA to atmosphere the trajectory became the circle and ligament asteroid/apparatus enters into dense atmosphere (fig.4).

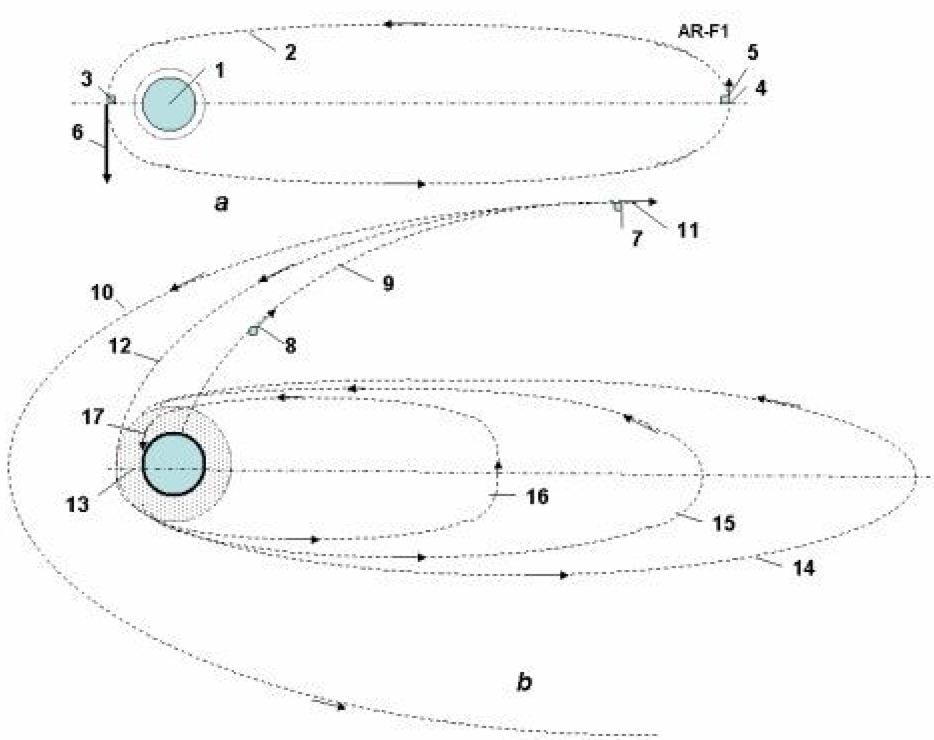


Fig. 2. Cheapest method delivery of asteroid to Earth. *Notations*: (***a***). Elliptic trajectory any asteroid captured by Earth. (***b***) Capture and delivery of asteroid. 1 – Earth; 2 – elliptic trajectory of Earth asteroid; 3 – perigee; 4 - apogee; 5 – asteroid speed in apogee; 6 - asteroid in perigee; 7 – asteroid and the point of meeting the asteroid and delivery apparatus (DA); 8 – delivery apparatus; 9 – trajectory of delivery apparatus; 10 – initial trajectory of asteroids; 11 – speed of DA; 12 – asteroid/DA trajectory after its braking by DA and connection; 13 – Earth atmosphere; 14 - asteroid/DA trajectory after the first parachute braking in Earth atmosphere; 15 - asteroid/DA trajectory after the second parachute braking in Earth atmosphere; 16 - asteroid/DA trajectory after it's third parachute braking in Earth atmosphere; 17 – lending of asteroid/DA by control parachute,

After launch delivery apparatus 8 (fig, 2b) to meeting with the suitable asteroid, 9, 7, the apparatus has speed 11 opposed the asteroid. The authors offer the using the kinetic energy of the apparatus for braking the asteroid and for charging the flywheel accumulator of energy the apparatus. The apparatus 22 (fig.3a) by a net 21 captures the asteroid 20. After capture the apparatus unwind the cable 25 and decreases the asteroid speed for suitable for entrée in upper Earth atmosphere (fig.3b). One also decreases an own speed to value equals the asteroid speed. If kinetic energy of system AA is very big, the apparatus uses the rocket engine. Further the cable is reeled (fig.3c) and delivery apparatus is used for correction of trajectory.

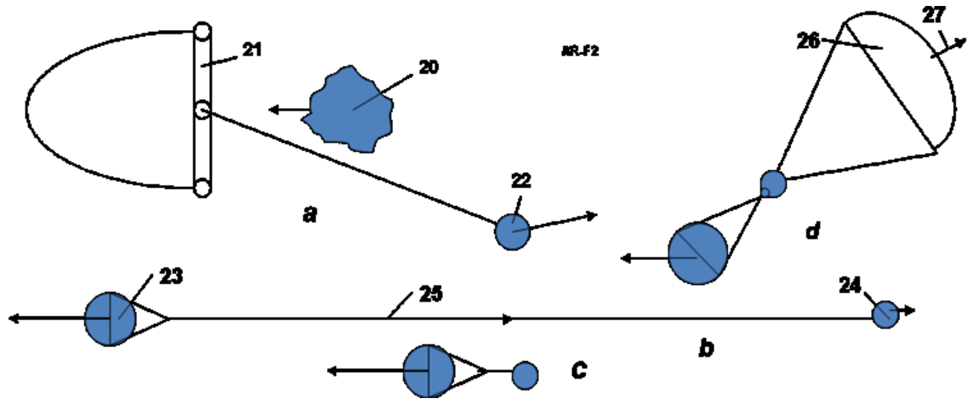


Fig. 3. Capturing of asteroid by Delivery Apparatus (DA). (***a***) Capture of asteroid; (***b***) braking of asteroid by kinetic energy of Delivery Apparatus and charging a flywheel energy storage; (c) – final connection DA and asteroid; (***d***) Lending version of asteroid/DA with control lifting parachute for flight in Earth atmosphere. Notations: 20 – asteroid; 21 – capture net; 22 – delivery apparatus; 23 – asteroid into the capture net; 24 – delivery apparatus in position after braking and charging of mechanical energy storage; 25 – brake cable connecting the asteroid to delivery/drive apparatus; 26 – control parachute; 27 - lift/drag force of parachute.

After entrée in Earth atmosphere the apparatus opens the control lifting/braking parachute 26 (fig.3d). That brakes the system in an upper earth atmosphere, decreases the apogee of elliptic orbits (fig.2b) up to circle orbit (speed is less 8 km/s). If the brake temperature is over the safety value, the apparatus increases the ratio lift/drag of control parachute and lifts in upper atmosphere where the head flow is less.

As result the asteroid and delivery apparatus is not heating and control parachute delivery asteroid in a given place. The parachute is small because the lift parachute has less a vertical speed and lending speed of the system may be high with comparison of man parachute (fig.4).

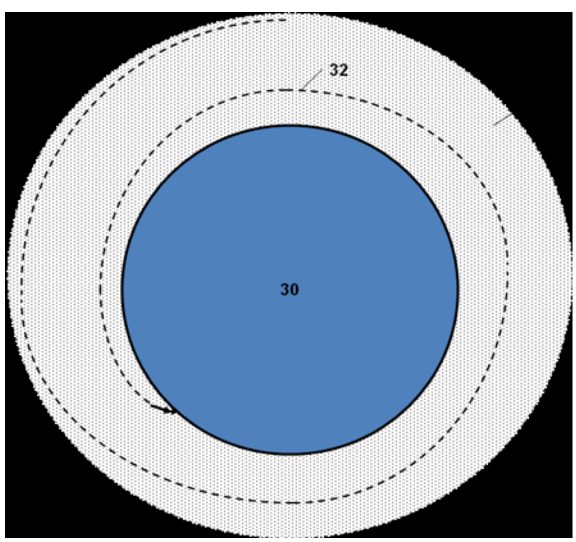


Fig.4. Lending of system with the limited heating: Asteroid/DA on Earth surface. *Notations*: 30 – Earth; 31 – Earth atmosphere; 32 – lending trajectory.

The parachute surface is opened with backside so that it can emit the heat radiation efficiently to Earth-atmosphere. The temperature of parachute may be about 1000-1300$^{o}$ C. The carbon fiber is able to keep its functionality up to a temperature of 1500-2000$^{o}$ C.

The offered delivery method and system has the following advantages:

1) The system uses for the braking of asteroid and apparatus the kinetic energy of the asteroid and apparatus. That saves a lot of fuel.
2) System uses the kinetic energy for the charges of an energy storage (this storage/accumulator may be mechanic, electric, chemical and so on. That allows to get a lot of energy after long flight time.
3) It is offered the method of braking high speed of asteroid by series of entering in atmosphere with serial decreasing of apogee up to circle orbit. That saves a lot of fuel and not request the high head protection. (the head protection of Apollo is 40% from its weight).
4) The system has a special cable and brake mechanism for it. The flywheel not lost the energy because in space is vacuum and no gravity.
5) The system has a control parachute with high ratio lift/drag. That allows avoid the high heating, deliver the asteroid in given place and avoid a shock of system on earth surface. The delivery apparatus may be used again.

Fig.5. Lending of asteroid.

## Economical efficiency of asteroid delivery to Earth.

Only 10% of asteroids contain the metal. In many case it is molybdenum and cobalt.

Some asteroids, like meteorites, are composed of iron, nickel and various stony rock. In composition, they are close to the terrestrial planets.

The other main component – nickel-ferrous iron, which is a solid solution of nickel in iron, and, in any solution, the nickel content in the gland is different - from 6-7% to 30-50%. Occasionally occurs non-nickel iron. Sometimes there are significant amounts of iron sulfides. Other minerals are also found in small quantities. It was possible to identify a total of about 150 minerals, and although even now researchers open more and more it is clear that the number of minerals in the asteroids and

meteorites are very small in comparison with an abundance of them in the rocks of the Earth, where they found more than 1000.
The enthusiasts hope a 1,600-foot diameter asteroid rich in platinum group metals--things like rhodium, palladium, osmium, iridium, and platinum itself--could yield the equivalent of all the platinum group metals ever mined on Earth.

The capture and delivery a big asteroid to Earth requests the gigantic energy (fuel). The delivery of one kg asteroid by current technology request 1 – 5 kg of additional fuel and the launch one kg of the delivery apparatus/fuel costs approximately 30 -100 thousands USD.
The current cost of metals produced in Earth are presented in Table 1.

**Table 1**. Average cost of metals on 16 May, 2012

| Metal | Price \$/Lb | Metal | Price \$/Lb | Metal | Price \$/Lb |
|---|---|---|---|---|---|
| Iron ore | 0.063 | Nickel | 7.69 | Silver | 27.2 |
| Iron scrap | 0.124 | Magnesium | 1,44 | Palladium | 592 |
| Molybdenum | 13.8 | Cupper | 3.5 | Platinum | 1433 |
| Cobalt | 14 | Aluminum | 0.9 | Gold | 1539 |

The profitable exploitation of space resource is possible only after dramatic decreasing the cost of delivery. Our purpose is maximal decreasing the launch cost. One way is offered in [3] which allows decrease the launch cost up 3 ÷ 10 \$/kg.

## Theory, computation and estimation the offered delivery system

Change the speed of space apparatus or asteroid or system the asteroid/apparatus by rocket engine

$$\Delta V = -V_g \ln \frac{M_f}{M}, \qquad (1)$$

where ΔV is change of speed, m/s; $V_g$ is discharge velocity of exhaust gas from rocket engine: solid fuel $V_g \approx 2500 - 2800$ m/s, liquid fuel (kerosene + $O_2$) $V_g \approx 3000 - 3200$ m/s; liquid hydrogen + $O_2$) $V_g \approx 4000$ m/s; $M_f$ is final mass of system, kg; $M$ is initial mass of system, kg.
Equations for computation of trajectory in vacuum space near Earth:

$$r = \frac{p}{1 + e\cos\beta}, \quad p = \frac{c^2}{K}, \quad e = \frac{c}{K}\sqrt{H + \frac{K^2}{c^2}}, \quad c = v^2 r^2 \cos^2 \nu = const,$$
$$H = 2K\frac{M}{R} = const, \quad K = 3.98\cdot 10^{14} \ \frac{m^3}{s^2}, \quad r_a = \frac{p}{1-e}, \quad r_p = \frac{p}{1+e}, \qquad (2)$$
$$T = \frac{2\pi}{\sqrt{K}} a^{3/2}, \quad a = r_a, \quad b = r_p, \quad b = a\sqrt{1-e^2},$$

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; $\nu$ is angle beyween speed and tangent to circle; $M = 5.976\cdot 10^{24}$ kg is mass of Earth; $R$ = 6378 km is Erath 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.

Parameters system after connection of apparatus to asteroid are computed by equations:

$$V=\frac{m_1V_1+m_2V_2}{m_1+m_2}, \quad Fs=\frac{m_1V_1^2}{2}+\frac{m_2V_2^2}{2}-\frac{(m_1+m_2)V^2}{2}, \qquad (3)$$

where $V$ speed of system (connection of asteroid/apparatus), m/s; $m_1$, $m_2$ are masses of asteroid and apparatus respectively, kg; $V_1$, $V_2$ are speeds of asteroid and apparatus respectively, kg; $F$ is force, N; $s$ is length of cable, m.

## Theory of reentry to Earth atmosphere

1. Equations of spaceship reentry are:

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

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; $\theta$ is trajectory angle, radians; $D$ is system drag (asteroid+apparatus), N; $D_P$ is parachute 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 parachute lift force, N; $\omega_E$ 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:

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

where: $g_0$ = 9.81 m/s$^2$ is gravity at Earth surface; $\rho$ 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 parachute radius, m; $S_P$ (or $S_m$) is parachute area, m$^2$; $\rho_{SL}$= 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 parachute in stagnation point in Kelvin, $^o$K; $T$ is temperature of parachute in stagnation point in centigrade, $^oC$; $T_2$ is temperature of the standard atmosphere at given altitude, $^oK$; $D_P$ is parachute drag, N.; $L_P$ is parachute lift force That is control from 0 to 4 $D_p$, N (the ram-air parachute can produce lift force up 1/3 from its drag); $D$ is ship drag, N; $L$ is ship lift force, N; $C_{DP}$ = 1 is parachute 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/($m^2 \cdot K^4$) is coefficient radiation of black body; $\varepsilon$ is coefficient of a black ($\varepsilon \approx 0.03 \div 0.99$).

The control is following: if $T_1$ is more the given temperature than the lift force $L_P$ = maximum = $4D_p$. In other case $L_p = 0$. When the speed is less the sound speed, the control parachute is also used for deliver in given point.

The requested parachute area may be found by equations in lending study at sea level:

$$L_p = C_L \frac{\rho V^2}{2} S_p\,, \quad D_p = C_D \frac{\rho V^2}{2} S_p\,, \quad K = \frac{C_L}{C_D}, \quad V_v = \frac{V}{K}\,, \quad V_v \le V, \qquad (6)$$

where $C_L$ is lift coefficient of parachute, $C_L \approx 2 \div 3$; $C_D$ is drag coefficient of parachute , $C_D \approx 0.5 \div 1.2$; $\rho$ = 1.225 kg/$m^3$ is air density; $V$ is speed system, m/s; $S_p$ is parachute area, $m^2$; $K$ is ratio $C_L/C_D$; $V_v$ is vertical speed, m/s. *Example*. Let us take the mass of system (asteroid + apparatus) 100 tons = $10^6$ N, $C_L$ = 2.5, safety $V_v$ = 20 m/s, $K$ = 4, $V$ = 80 m/s. From equation (6) we receive the parachute aria is $S_p$ = 100 $m^2$. The control rectangle parachute is 5.8 x 17.3 m.

## Conclusion

Authors offer the new method for deliver the asteroid to Earth. That method is cheaper in a lot of times than **conventional** method: flight to asteroid, braking the apparatus to asteroid speed (spending of fuel), braking the asteroid for decreasing of Earth perigee (up to Earth atmosphere)(spending of fuel), non parachute entrée in Earth atmosphere, high heating, destroying of asteroid in atmosphere, non-control flight in atmosphere, powerful impact to Earth surface, possible destructions and earthquake. Delivery of asteroid remains to a plant. Delivery asteroid in cones is impossible because no in space plants which will milting and casting asteroids for the cones.

In our method for braking apparatus and asteroid are used the kinetic energy of apparatus. This energy is used also for charging the apparatus energy storage. The small control parachute allows multiple using the Earth atmosphere for the braking the asteroid without high heating, deliver the asteroid in given point of Earth and to avoid the asteroid impact to Earth.

The delivery of the metallic asteroid to Earth will be profitable if we dramatic decreases the cost of the space launch (up to 3 – 10 $/kg) as it is offered in [3]. In present time we are spending 200 – 300M of USD for delivery a very small piece of asteroid for scientific purpose. Using the offered method we can deliver the full asteroid (up 3 – 50 tons) to Earth.

If asteroids will contain the very precious metals, their delivery may be profitable.

The reader finds useful information about delivery methods also in [2]-[4].

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