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Combined Use Reactive Solid Fuel Complexes for Protection Against Asteroids

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Summary: *One of the problems of humanity is to defend the Earth from collisions with large asteroids. Statistics, the study of these phenomena shows that for several centuries occurs, at least one collision capable of causing an explosion on the surface of the Earth, a powerful explosion similar to a nuclear warhead. The last of such disasters occurred in 1908 - the Tunguska phenomenon. No less dangerous is the high-altitude explosion and fragments of small asteroids such as the Chelyabinsk meteorite occurred on 15 February 2013. Modern means of detection, placed on the Earth, unable, as it turned out, identify quickly most of those objects, and does not provide adequate security to the population of the planet. According to expert, the asteroids with a diameter of 300 m and more may cross earth's path and cause a global catastrophe. This makes the problem of planetary defence from asteroids and comets universal, the solution of which requires joint efforts and funds of the entire world community. One of the best ways to protect against collision with an asteroid to date provides for the insertion into orbit of the Earth system for the early detection of satellites and rockets carrying nuclear warhead, sufficient to destroy dangerous space object or adjustments to their orbits. To minimize the mass of the nuclear charge intended for vaporization or destruction of the elements of a celestial body, the charge before detonation it is necessary to bury in the body of the object. For this purpose, we use the solid recoilless explosive-reactive complexes, which will ensure penetration of a nuclear warhead in the rock of the asteroid to destroy the object.*

Key words: *Protection from asteroids, solid-fuel, recoilless explosive-reactive complexes, nuclear charge.*

1. INTRODUCTION

Asteroids know it that or small planets that have no atmosphere, carry the heavenly bodies with a diameter over 30 m. On the composition of asteroids can judged by the results of the spectral analysis or analysis of the mineral composition falling on the earth's surface of meteorites. In the most general form, depending on the mineral composition, there are three categories (or class) asteroids: Class C - carbonaceous (carbon); S-class – flint (silica) - discovered the presence of magnesium-iron island silicates (olivines), pyroxenes, plagioclases; Class M – metal is present on the surface of the outputs of the metals (Nickel iron), the main minerals kamacite and tanit.

The most numerous is the Class C, which accounts for more than 75% of known asteroids, in a detailed classification there are another group of asteroids of unknown composition, which characterized by a dark surface with very low albedo and a moderate absorption at the wavelength of 0.85 μm.

The number of detected asteroids decreases with increasing their size. The most well known in quantitative terms the asteroid in diameter of 1000 m and more. Asteroids are related to cold bodies, a surface temperature of approximately 160 K. Body density of asteroids (out of a hundred the most famous) is in the range from 1100 kg/m^3 (Danae, the 82 km diameter; Eugenia, size 232x193x161 km) to 6610 kg/m3 (Evfrosina, diameter 255,9 km) [1].

The sizes of asteroids undoubtedly influence the nature of the cataclysm in the collision with the Earth. Global economic and environmental implications for civilization begin with the catastrophe with an asteroid 50 m in diameter, and the complete destruction of humanity will cause a collision with a space body more than 3 km.

The greatest danger on the element of surprise are small cosmic bodies, such as the Chelyabinsk meteorite. Explosion that turned out to be stronger by 2-3 orders of magnitude the atomic bomb dropped on Hiroshima.

Large asteroids pose a greater threat with orbits crossing or passing potentially close to the Earth. For example, the most dangerous now is considered the 330-meter asteroid Apophis, dangerous rapprochement with the Earth will be in 2036 (according to the calculations of the distance between them is ~ 38000 km). Although NASA has completely ruled out the possibility of Apophis collision with Earth, according to the conducted modeling of the consequences of the fall of the asteroid Apophis to Earth would be catastrophic. When the density of the body of the object 3000 kg/m3, speed of entry of 12.6 km/s, the energy of collision with the Earth is ~103 megatons, which is almost an order of magnitude more energy the Tunguska explosion [2].

The system of missile attack warning Russia and the U.S. to register annually with about a dozen events and explosions in the stratosphere of celestial objects of various capacities that makes the problem of protection from a collision of asteroids with Earth particularly relevant.

2. WAYS TO ELIMINATE THE THREAT OF ASTEROID COLLISION WITH THE EARTH

Currently a number of ways to eliminate the threat of asteroid collision with the Earth that use different physical principles, the strategic plan offer the deflection of asteroids or fragmentation [3].

As one of the methods considers the impact of powerful pulse laser radiation onto the asteroid to burning or additional pulse with the aim of changing the trajectory. The advantages of this method include remote action that does not require mechanical contact with the erodible surface and, as shown by the results of investigations of pulsed laser effects on natural silicates; intensive ablation observed at low power in the pulse due to the resonant properties of the absorbing medium [4-6]. However, the effect of laser ablation in relation to asteroids will require further research and experimentation.

A preliminary assessment of the effects of pulsed laser radiation on the asteroid, showed for the mass of the object M = 109 kg and pulse power 1 GW that the acceleration of the asteroid will be

$2 \cdot 10^{-3}$ m/s^2, and with prolonged exposure it is possible to achieve the required adjustments in the orbit of the asteroid. On the other hand, this method requires certain technical solutions and high economic costs associated with the creation of laser space-based solar power [7].

In completed in 2015 the international research project NEOShield was investigated all possible preventive prevent the threat, among them a nuclear explosion near a hazardous asteroid was selected as the most effective way to prevent its collision with the Earth.

As noted in the project TSNIIMash, safer conduct a nuclear explosion in deep space to have sufficient time before the close approach of an asteroid with the Earth. Not necessarily to achieve complete destruction of the asteroid, but at the expense of jet thrust arising from heat emission and reduce the mass of the object, you can change the orbit of an object (Figure 1).

Figure 1. The emergence of the jet thrust of the asteroid's thermal emission

The solution of such a complex task involves careful study of the individual steps, and, of course, the main problem of the implementation of the project apart from technical difficulties is the financial component. By far the most rational and economically viable are projects that use proven technology solutions.

This paper proposes a combined method –a partial correction shaved asteroid with its subsequent destruction of the nuclear charge that is included in the body of the asteroid, and the use of shock-kinetic effect of a thermonuclear explosion.

3. IMPROVING THE EFFICIENCY OF A NUCLEAR EXPLOSION AT A DEPTH

Found that when we put the charge to a depth of several meters, nuclear explosion produces a much more powerful and destructive than explosion on the surface. Figure 2 shows a curve of change "equivalent power" for a similar charge depending on the depth of the explosion, which shows that when the depth of charge is less than a meter equivalent ratio of the power of the explosion increases by more than an order of magnitude [8].

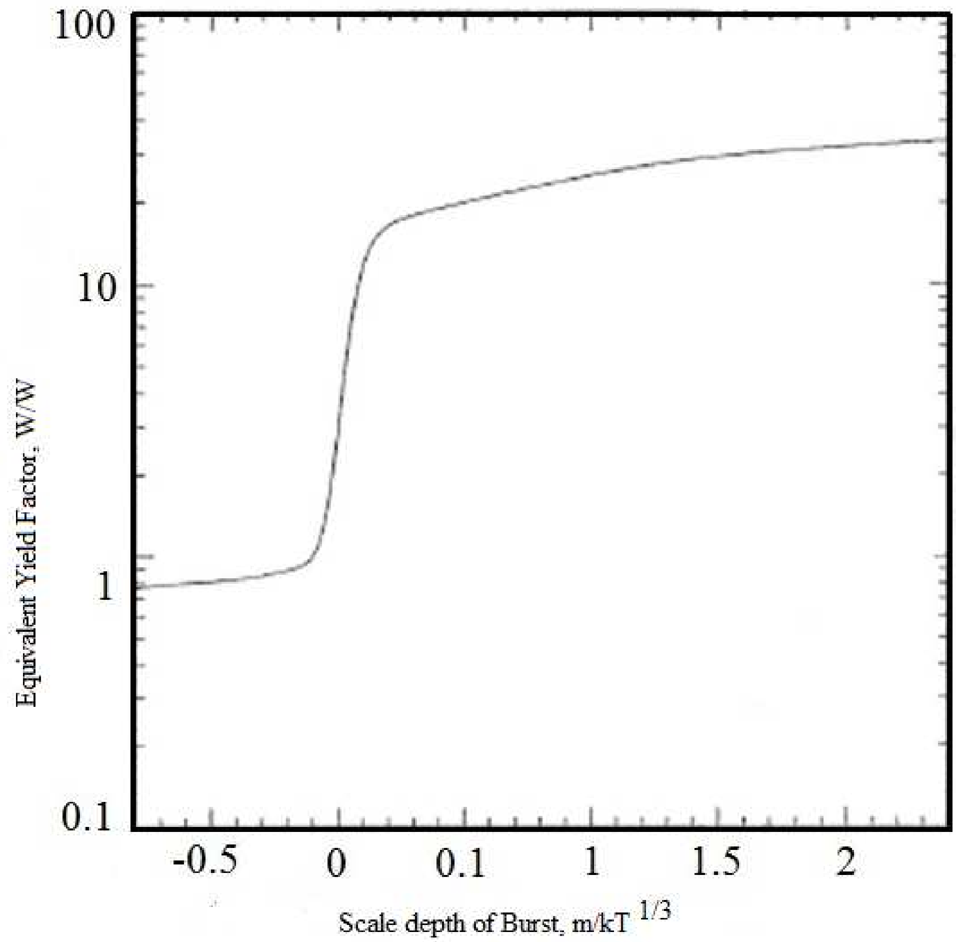

Figure 2. The dependence of the coefficient equivalent to the power of the explosion from the depth of the explosion

Thus, the effectiveness of the explosion can increased if the depth of charge is over 1 meter into the body of the asteroid.

The desired depth of penetration for the full retention of a nuclear explosion depends on the physico-technical properties of rocks composing the object. In [9,10] gives the empirical formula (1), (2) used at the test site in Nevada, to calculate the depth of nuclear warheads, depending on their power:

$$L_{min} \geq 92 \cdot T^{1/3} \quad (1)$$

$$L = 122 \cdot T^{1/3} \quad (2)$$

whre:
L_{min}, L - minimum and maximum threshold depth of the nuclear charge, m;
T – TNT equivalent nuclear warhead, kT ($4.184 \cdot 10^{12}$ J).

When placing the charge close to the minimum L_{min} of depth, often after blowing up the warhead there was a depressurization of the mine and the implementation of radioactive emissions on the earth's surface. The data presented in Figure 3 shows, that to keep down underground nuclear explosion emissions with a capacity of 0.1 T, the charge should place at a depth of not less than 43 meters.

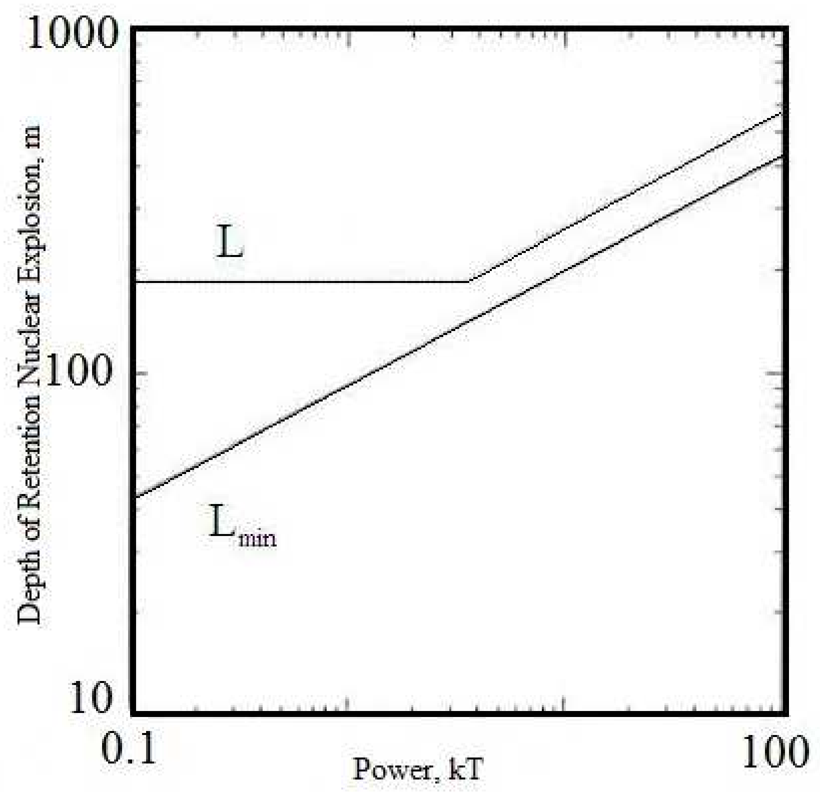

Figure 3. Minimum (Lmin) and recommended (L) the depth of the nuclear charge depending on its capacity to keep emissions underground nuclear explosion

The effectiveness of the penetrator assess criterion characterizing the process of useful work during penetration of the body in a solid medium:

$$0{,}5\eta m\omega^2 > S \cdot L \cdot \sigma \qquad (3)$$

where:
η - efficiency of penetration, taking into account all types of losses;
m - average mass of the penetrator during penetration to its recommended depth, kg;
ω - average rate of penetration, m/s;
S - average area (midsection) of the formed cavity, m^2;
L –recommended depth of the charge, m;
s - tensile strength (resistance) load of the environment, MPa.

Analyzing the criterion (3) one can notice that the depth of sinking (recommended depth of the nuclear charge-L) the main influences penetration rate - ω.

Bulson [11] analyzes a number of empirical formulas describing the implementation of the penetrator into the concrete, came to the conclusion that the most accurate results based on extensive data of wartime British laboratory studies of road surfaces, which correspond to the formula (4). In the U.S. data obtained by Sandia Laboratories, summarized in empirical formulas in [12] for ω >60 m/s, which serves for the calculation formula (5):

$$\frac{L}{l} = \frac{2\rho(\omega/533)^n}{\sqrt{\sigma_t}} \qquad (4)$$

$$\frac{L}{l} = 1.3N\rho(\omega - 30)(1 - \frac{\sigma_t - 14}{115}) \quad (5)$$

where:
L - penetration depth into the concrete of the punch, m;
l - length of the steel punch, m;
ρ - density of the material of the punch, kg/m3;
ω - initial velocity of penetration, m/s;
$n = 3,1(\sigma_t)^{-1/4}$
σ_t – strength concrete destructible, Pa.
N = (0,56 – 1,34) - coefficient accounting for changes in the shape of the nose of the penetrator from flat to conical.

In our case, these formulas are only valid when the impact velocities at which the missile can considered a rigid punch of length unchanged.

Experimental studies have shown that at an impact speed of over 900 m/s, steel mandrels seriously deformed, and when ω_{max} = 1200 m/s is excessive plastic deformation and their subsequent destruction into small fragments [13].

In real conditions, the actual depth of the vertical migration will be significantly less than estimated by the formulas (4) and (5). Primarily, to ensure the integrity of the missiles before detonation, the impact velocity must be significantly less than the maximum speed obtained from the condition (3).

Since the rocket is made of solid metal, its average density will be somewhat less accepted here the density of the full metal missiles. Thus, we conclude that the penetrator cannot enter the reinforced concrete deeper than four hull missiles, or 12 meters for the rocket length of 3 meters.

A different approach penetration in hard materials and hard rocks provide a recoilless explosive-reactive complexes, made of sequentially destructible tapes, are equipped with chemical explosives [14-18].

4. RECOILLESS EXPLOSIVE-REACTIVE COMPLEXES

Explosive-reactive complex (ERC) are recoilless products are created by a series of controlled explosions to form wells in rocks of different strength.

The explosive complex consists of a set of sequentially destructible tapes are bonded together and block electrical initiation (BEI) coupled with the cassette through the adapter, made in the form of tubular elements for internal wiring of electric wires, which are connected with a special electric detonators (SED) [19,20].

Mounting cassette can done in different ways, for example, by bolted or adhesive connection. In each tape at the top and bottom surfaces formed corresponding to the cavity-reflectors, which are placed, respectively, downhole and pressure (jet) charges of explosives and set the SED, connected through electrical wires with BEI.

Downhole and pressure (jet) explosives charges interconnected by connecting channels located near the SED. The channels are equipped with explosives.

Cavity-reflectors cassettes can been made in the form of one or several open cavities located around the perimeter of the corresponding surface of the cassette, the longitudinal axis can have different positions in space depending on the particular task.

ERC includes independent power (IP), remote control unit (RCU), the connecting electrical cable, starting device (SD).

The basis of the complex is explosive-reactive unit (ERU) which includes an electrical trigger and a working body, consisting of working modules (WM) and a set of destructible tapes. Each cassette is equipped with destructible downhole pressure and cumulative charges, which has an annular shape and are specially designed electric detonators instant action.

BEI allows you to initiate the SED with a frequency up to 10 kHz, wherein the initiating have perform sequentially, starting from the bottom and ending with top cassette. It is possible to control the optimal frequency of initiation of the destroyed tapes for maximum effective destruction of rocks on the bottom and the discharge of sludge to the surface.

As required, the stacked number of the WM may vary. General view of the developed complex ERC -21 shown in figure 4. Depending on the physico-technical properties of soil in three working modules, the borehole diameter is in the range of 0.2-0.6 m, depth of 0.37-2.7 m [3].

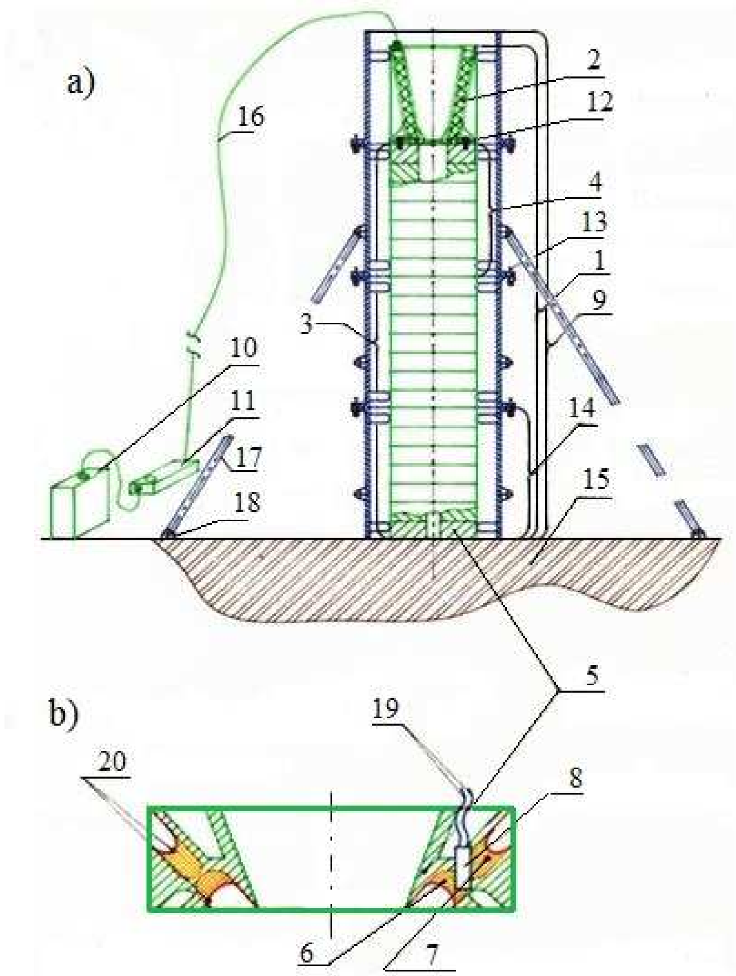

Figure 4. Complex ERC-21 (a – general view; b – destructible cassette):
1 – ERU -21; 2 – BEI; 3 –RO; 4 –RM; 5 – cassette curb the explosive charge and ED; 6-down-hole shaped charge explosive annular shape; 7 - clamping the shaped explosive charge annular shape; 8 ED; 9 – SD; 10 - IP; 11 – RCU; 12 – retaining ring; 13 – bracket; 14 – unit SD; 15- rock; 16 – electric cable; 17 – mounting rack; 18 – fastening the boots; 19 – power cord, from BEI to ED; 20 – cumulative funnel annular shaped charges of explosives

Calculations show that the asteroid with a diameter of d = 50 m, the average density is $2 \cdot 10^3$ kg/m^3, flying at a speed of 20 km/s only by the detonation of 3 modular charge (average detonation velocity of 4.2 km/s) velocity correction will be ~ 15 m/s.

When detonation of buried nuclear charge, we should expect a significant adjustment of traction or momentum, depending on the properties of the asteroid fragment.

Let us formulate the main provisions of the proposed method (Figure 5):
1. The approach of the space module to the body of the asteroid from the direction of the Earth's surface.
2. Predrilling ERC provides jet thrust, the asteroid away from the Earth's surface.
3. Undermining the nuclear charge.
4. The release of explosion products from the well provides additional traction force (the asteroid garbage and residues from the surface of the Earth).
5. The destruction of the asteroid (its full evaporation or fragmentation).

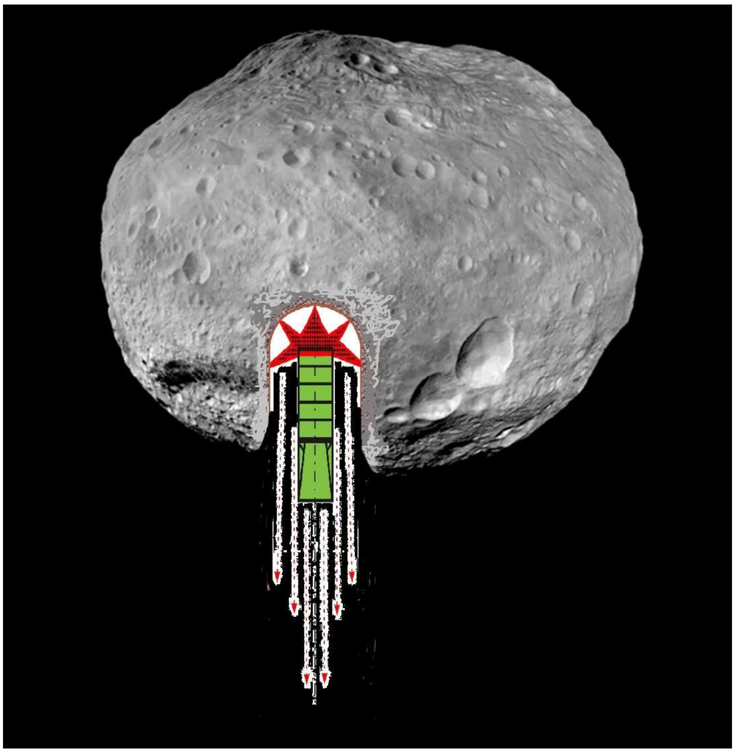

Figure 5. Correction of the orbit of the asteroid with the help of ERC

Use explosive-reactive complexes on solid fuels to bury a nuclear warhead in the body of the asteroid can considered very promising in the correction of its orbit or its destruction.

Moreover, that the efficiency of such complexes substantiated in the conduct of engineering and construction works in difficult geological and climatic conditions [21-23].

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