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TITLE CAPTURING ASTEROIDS INTO BOUND ORBITS AROUND THE EARTH: MASSIVE EARLY RETURN ON AN ASTEROID TERMINAL DEFENSE SYSTEM

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"CAPTURING ASTEROIDS INTO BOUND ORBITS AROUND THE EARTH: MASSIVE EARLY RETURN ON AN ASTEROID TERMINAL DEFENSE SYSTEM"

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ABSTRACT

Nuclear explosives may be used to capture small asteroids (e.g., 20-50 meters in diameter) into bound orbits around the earth. The captured objects could be used for construction material for manned and unmanned activity in Earth orbit. Asteroids with small approach velocities, which are the ones most likely to have close approaches to the Earth, require the least energy for capture. They are particularly easy to capture if they pass within one Earth radius of the surface of the Earth. They could be intercepted with intercontinental missiles if the latter were retrofit with a more flexible guiding and homing capability. This asteroid capture-defense system could be implemented in a few years at low cost by using decommissioned ICMs. The economic value of even one captured asteroid is many times the initial investment. The asteroid capture system would be an essential part of the learning curve for dealing with larger asteroids that can hit the earth.

I. FLUX AND CHARACTERISTICS OF SMALL ASTEROID INTRUDERS

An asteroid 100 meters or larger in diameter (such as the Tunguska impactor of 1908 or the nickel-iron one that produced Meteor Crater in Arizona) hits the earth about every 200 years (Shoemaker, et. al. 1991). If we can ignore gravitational focusing, this requires that such an asteroid pass within 10 earth radii (10 $R_{\oplus}$) = 64,000 km about every other year and within the orbit of the moon every month. An asteroid 30 meters in diameter hits the earth every 5 years, passes with 10 $R_{\oplus}$ about 20 times a year, and passes within the orbit of the moon every day. Since about 5% of the asteroids are nickel-iron, we expect a nickel-iron meteoroid 30 meters or more in diameter to pass within 10 $R_{\oplus}$ every year. Such an object hits the earth about every 100 years and passes within 1 earth-radius of the surface of the earth about every 25 years. The capture of such a nickel-iron meteorite into orbit about the earth would be a major asset for future manned activity in space.

If the approach velocity, V_{∞}, of an asteroid when it is far from the earth is smaller than the escape velocity, V_{esc}, from the earth, the asteroid is particularly easily captured in close approaches to the earth. The velocity of the object at its closest approach distance, d, to the center of the earth is, from energy conservation,

$$V_d = \left[V_\infty^2 + V_{esc}^2 \left(\frac{R_\oplus}{d} \right) \right]^{1/2} . \qquad (1)$$

Here V_{esc} = 11.2 km/s. About 15 % of known NEAs have V_∞ less than V_{esc} and some have V_∞ less than 6 km/s (derived from table provided by Shoemaker, et. al. 1991). If V_∞ = 6 km/s and d = $R_\oplus$, then V_p = 12.7 km/s. This object would only have to be slowed by 1.5 km/s at distance d to bring it into a bound orbit around the earth (to get V_d below V_{esc}). (If a meteoroid is found with an approach velocity of 1 km/s, the required reduction in velocity for capture drops to only 0.04 km/s).

II. CAPTURING THEM WITH NUCLEAR EXPLOSIVES

The only feasible way of capturing such an asteroid into a bound orbit around the earth is with nuclear explosives. Fortunately, such explosives and the means to deliver them to an asteroid passing near the earth are readily available at small marginal cost due to the continued decommissioning of many American and Russian ICMs. Even asteroids passing within the orbit of the moon can be reached by adding a single extra stage to an ICM. This would be particularly easy for missiles with MIRVS such as the MX that could be reduced to one explosive charge.

Properties of nuclear explosions and their capabilities for changing the velocities of asteroids have been outlined in this conference by J. Solem and C. Phipps. We found earlier that to capture an asteroid with a velocity at infinity of 6 km/s requires that we decrease its velocity by only 1.5 km/s if it makes a close encounter to the earth. We consider capturing an iron meteoroid with a diameter of 35 meters, a density of 7.5 grams/cm^3, and a mass of 1.7 $\times 10^5$ metric tons. The energy needed to capture this object into a bound orbit is 150 kt if 20 % of the asteroid mass is blown off in the forward direction and all the energy of the bomb goes into ejecting this mass (at 6.2 km/s). (The energy requirement drops to

30 kt for a 20- meter asteroid. It would drop to less than 1 kt for the larger asteroid if one could be found with an approach velocity of 1 km/s or less.) The bomb has to be several times this minimum value because of various inefficiencies, but this illustration shows that the capture of a nickel-iron asteroid is possible with readily available technology.

The material blown off the front (in the direction of motion) of the asteroid by the explosion has a hyperbolic velocity and escapes the gravitational field of the earth. Because of its high tensile strength, it will not be difficult to hold the captured nickel-iron asteroid in one piece. Stony asteroids are more fragile. We may wish to capture only those with very low approach velocities with respect to the earth to minimize the required explosion energy. Some development work is needed to better understand how nuclear explosives couple to asteroids of various compositions. We also need to develop blankets for nuclear explosives to "cool" them: minimize the gamma rays, x- rays, and neutrons they emit, so they do not harm satellites and the magnetosphere of the earth. We may wish to practice intercepting the asteroids at lunar distances before attempting to intercept one in a close approach to the earth. The ability to capture objects with nuclear explosives is clearly achievable and could be implemented in a relatively short time at a relatively low cost using decommissioned ICMs and nuclear explosives.

A captured asteroid would be a major asset. It costs about $\$10^6$/metric ton to launch to low-earth orbit (LOA) and much more to higher orbit. To launch the mass of a 35-meter nickel-iron meteorite into LOA would cost about $\$\ 2 \times 10^{11}$ or 10% of the GNP of the U.S.A. Alternatively, to capture it into earth orbit may take only one surplus ICM and warhead if the closest approach of the object to the surface of the earth is one earth radius or less. If these missiles and warheads are scheduled to be decomissioned by treaty, the marginal cost of fitting each for this mission may be less than $\$10^7$, which potentially gives a return on the initial investment as high as 10,000 to 1. Development costs and the need for redundant missiles will reduce this return, but is is still substantial.

The captured NI asteroid would be a source of material for future activity in space. It could be hallowed out to produce a large space station. Objects fired off the captured asteroid at its closest approach to earth would be given a boast by being within the potential well of the earth. A rail gun could be used to eject the objects. This physical process is the reverse of the one that allowed the capture of the asteroid into earth orbit. If the object is ejected at 1.5 km/s in the direction of motion of the captured asteroid at its closest approach to the earth, its escape velocity from the earth is 6 km/s. The rail gun could be used to launch cheap probes to the larger earth- crossing asteroids (NCAs). A number of these probes are needed to characterize the various types of NCAs and short-period comets.

The metal in a captured nickel-iron asteroid could be melted using a solar furnace. A good candidate may be the gas lens (a large plastic balloon shaped like a lens and filled with gas) mentioned in this conference by Claude Phipps. A lens several hundred feet across would be lightweight and cheap.

III. DETECTING INTRUDING SMALL ASTEROIDS

An object 35 meters across could be detected with current military radar within 10^5 km of the earth (Greg Canavan, this conference). The U.S. and Soviet strategic radars cover a large fraction of the sky above the earth. Currently, the radars only see objects near the earth to reduce computer processing. The computer software clips off (ignores) signals with long delay times that correspond to objects far from the earth. Because the maximum possible number of Soviet missiles that can be directed to the U.S. is decreasing as the result of arms control agreements, the U.S. Air Force radar has decreasing processing needs. The increasingly available processing capability makes it possible to search a larger volume around the earth. I propose using existing radars with their delays extended so they can observe objects out to at least 10^5 km. This would allow us to detect asteroids several hours before they hit the earth. It would also provide a scientific return by accurately determining the orbital elements of meteoroids that pass near the earth, their sizes and impact velocities. Because of its all-weather capability, radar is likely to be part of the terminal defense system for asteroids. Ultimately, it would be desirable to build radars in the southern hemisphere to provide all-sky coverage of asteroids approaching the earth.

A satellite with even a small aperture camera equipped with a large CCD placed in a distant orbit around the earth (at the moon's distance or greater) could detect small asteroids approaching the earth. A satellite at the Lagrangian L_2 point, which lies inside the earth's orbit around the sun, would be particularly effective. It would always see the asteroids approaching the earth as full (in the sense of the full moon), so they would appear at their brightest (the opposition effect). It would see much smaller objects at large distances from the earth than is possible with radar, which suffers from the r^{-4} dilution effect. It would not suffer from weather or the inability of detecting asteroids that are approaching from the direction of the sun, which are the primary limitations of earth-based camera systems.

IV. HOW SHOULD THIS BE IMPLEMENTED ?

The asteroid-capture program could be operational in less than five years. It also would be the first terminal defense system for asteroids that approach the earth undetected until they pass within the range of the defense radars. This would provide valuable experience for building a more robust system to protect us against all asteroids.

In the first phase of the program, some ICMs that otherwise would be decomissioned under the arms control agreements would become asteroid interceptors. These recommissioned rockets would be used both to capture small asteroids into bound earth orbit and to provide a rudimentary defense against incoming small asteroids. The first such missiles would be ICMs with upgraded guidance and homing capabilities. Their nuclear explosive would not be put in a re-entry vehicle to assure that they cannot be exploded within the atmosphere of the earth. Instead, they would be encased in a blanket provided by the National Laboratories to cool them sufficiently that x-rays, gamma rays, and neutrons from them are not a hazard to spacecraft in earth orbit. These missiles would likely be subject to continuous international inspection to assure that they are not converted to weapons use. We would invite the Russian state to institute a similar program with some of their decommissioned missiles ard nuclear explosives. Their program would be coordinated with ours.

The second phase would be to add another stage to the larger decommissioned ICMs such as the MX. This would extend the range of the missile to escape velocity from the earth. This would allow asteroids to be intercepted much farther from the earth, i.e., at the distance of the moon or greater. This may provide a large enough lever arm to allow many asteroids in collision orbits with the earth to be deflected away from the earth before they strike it. Otherwise, we could only blow them into small pieces and let the atmosphere provide the final defense. This second phase would have the goal of defending against asteroids up to 1 km in diameter that are only detected in their final approach to the earth. It also would allow small asteroids to be captured into large semimajor axis orbits around the earth, which would allow them to be used as way stations for manned intrusions into the solar system.

The phase 2 work would dovetail into the proposed earth-based survey to find nearly all earth-crossing asteroids with diameters greater than 1 km over a 20-year period. These large asteroids can only be deflected away from earth, if they are hit with nuclear explosives several orbital periods before they would otherwise hit the earth.

A Phase 3 or Phase 2b program may be the development of tailored made rockets and nuclear explosives to deal with the asteroid threat. This program can be implemented faster if Russia joins the program. The Russian Zenit 2 rocket would be particularly effective for close-in intercept because it is designed to be fired off on short notice. It is said to have a built-in flexible guidance system that allows the operator to dial in any position and velocity within the energy capabilities of the rocket.

Later, it would be to desirable to extend the catalog of asteroids with known orbits down to those with diameters well below 1 km, so dangerous ones can be deflected at greater distances from the earth. New surveys based on observations from satelli .s orbiting Venus and at the L_2 point of the earth (discussed by the author in another report in the Conference Proceedings) would be used to fill in the systematic gaps left by the earth-based survey and to extend the survey to much fainter asteroids. These satellites would also warn of the approach of long-period comets that currently could hit the earth without warning from the direction of the sun.

III. REFERENCES

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