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Moon-based planetary defense campaign

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ABSTRACT

The Moon is an ideal location to launch intercepting missions to life-threatening and catastrophic asteroids. The effectiveness of the interception greatly depends on the weight of the spacecraft. Unfortunately, interceptors launched from the Earth lose more than 98% of their weight by burning the majority of their onboard fuel and by jettisoning their lower stage structures before entering a heliocentric orbit. However, if interceptors are launched from the Moon by a lunar surface accelerator, they can enter a heliocentric orbit without consuming any onboard fuel or jettisoning any part of the spacecraft. A 5-ton construction package, which consists of robots and industrial production equipment, would enable mining on the moon and construction of a 3.5 km-long, 5,000-ton accelerator.

Large asteroid impacts have and will inevitably occur, and it is important to be prepared to avoid catastrophes, but they may not happen immediately or even within the next fifty years. The future planetary defense system must be a dual-use system, which continuously provides a secondary benefit to justify its operation and maintenance costs. When it is not defending the planet, the Lunar Electromagnetic Interceptor Launch System (LEILAS) can send over a thousand tons of construction material and fuel annually to the Low Earth Orbit (LEO) or Earth-Moon Lagrange Point Two (EML-2) to build space stations and to construct large spacecraft for deep space missions.

1. Introduction

The Moon could be the ideal location to launch intercepting missions to hazardous asteroids. Hazardous asteroids could be slowed down to not hit the Earth, by ramming heavy spacecraft into them. This mitigation method is known as the kinetic impactor approach, and is considered to be the most technologically mature approach to mitigate hazardous asteroids [32]. The effectiveness of the kinetic impactor greatly depends on the weight of spacecraft.

Sending heavy spacecraft near an asteroid is a challenge. Fig. 1 shows various orbits of Near Earth Asteroids (NEA). Before a spacecraft can intercept an asteroid, the spacecraft has to leave orbits around the Earth and enter orbits around the sun, called heliocentric orbits. Interceptors launched from the Earth lose more than 98% of their weight by burning the majority of onboard fuel and by jettisoning their lower stage structures before entering a heliocentric orbit.[2] In contrast, interceptors launched from the Moon by a lunar surface accelerator can enter a heliocentric orbit without consuming any onboard fuel or jettisoning any part of the spacecraft. Although it takes a lot of resources to bring materials to the Moon, the vast majority portion of lunar-launched interceptors can be made of the material mined and processed on the Moon. Because the weight of spacecraft is a crucial factor for the effectiveness of the kinetic impactor, it is far more efficient to launch the interceptors from the Moon, instead of launching them from the Earth. The lunar surface accelerator can also be used to launch bulk material and fuel from the Moon for deep space and near-earth missions.

While the kinetic impactor is considered the most mature deflection method, they are not effective against asteroids larger than 1 km in diameter or warning time is very short. For these instances, nuclear detonation may be the only option [37]. Even with the nuclear option, currently available launch vehicles are not powerful enough to deliver a nuclear warhead large enough to deflect an asteroid with a diameter of 2 km or larger [32]. In order to deploy an interceptor with a large nuclear warhead, a Moon launch is also more efficient than a launch from the Earth.

Launch vehicles from the Earth must accelerate the interceptor spacecraft with a large nuclear warhead to at least 11.2 km/s. In order to deploy the same spacecraft to a heliocentric orbit from the Moon, the spacecraft has to accelerate only to 2.42 km/s by the lunar surface

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[2] If Apollo spacecraft was used for this purpose, 6.5-million-pound Saturn V would deliver 110,000-pound interceptor to a heliocentric orbit.

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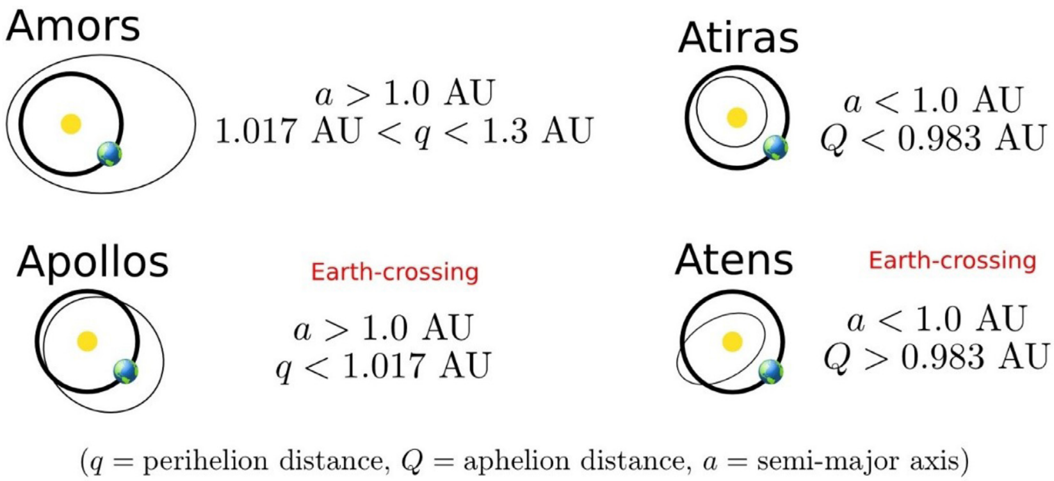

Fig. 1. Near Earth Asteroid orbit types [17].

accelerator. It takes less than 5% of energy to place the spacecraft from the Moon on a heliocentric orbit, compared to placing the same spacecraft from the Earth into a heliocentric orbit. The majority of the materials needed to make thermonuclear weapons might be available on the Moon as well. Gamma-ray spectrometers onboard the Japanese spacecraft Kaguya strongly suggest the existence of uranium and thorium on the Moon [42], and Helium-3 from the Sun is deposited on the Moon sand, regolith, and industrial mining of Helium-3 on the Moon is possible [49] (Table 2).

The effect of the impact of a 20-m asteroid with the Earth will be limited to local destruction, as observed in Chelyabinsk in 2013. It is estimated that there are 10 million Near Earth Asteroids with a 20 m diameter, and one of them is likely to collide with the Earth every 50–200 years [12]. Because of their numbers and our detection limitations, the most probable event will be a very late warning followed by evacuation, sheltering, destruction, and recovery [37], considering the current posture of our planetary defense. In order to be more effective, the future planetary defense system must be able to respond to a small asteroid quicker, at least within a few weeks.

The asteroid that impacted Tunguska in 1908 is estimated to have been 50 to 100 m in diameter, and the frequency of these hitting the Earth is estimated to occur as often as every 200 to 2000 years. The asteroid which hit Chicxulub 66 million years ago was estimated to be 10 km in diameter and caused a global catastrophe and mass extinction. It is estimated that impact occurs every 100 million years [12]. In order to counter these threats, the lifespan of an individual human being is too short to help. Even the lifespan of a government may not be long enough to maintain the planetary defense system against an asteroid. There has been no government which maintained their power over 2000 years in the past.

In order to stay in service over 2000 years, the future planetary defense system must be a dual use system, which continuously provides a secondary benefit, tangible and valuable enough to justify its operational and maintenance costs. While governments were established and overthrown, vital infrastructures such as roads, tunnels, bridges, harbors, aqueducts and sewers were maintained and expanded since the time of the Roman Empire, over 2000 years. Moon-based interceptor launch systems can provide the required response time, and can become part of the space infrastructure which annually sends over a thousand tons of construction material and bulk fuel to the Low Earth Orbit (LEO) and other parts of our Solar system.

2. Lunar Electromagnetic Interceptor Launch System (LEILAS)

Launching heavy kinetic impactor interceptors from the Earth requires an enormous launch vehicle such as the Saturn V rocket. The first thing an Earth-launched interceptor has to do is to consume considerable amounts of fuel to get out of the Earth's atmosphere to avoid atmospheric drag and aerodynamic heating. Then, the interceptor has to accelerate itself to the Earth's escape velocity (11.2 km/s) to get out of the Earth's gravity to enter a heliocentric orbit. This mission profile is very similar to the mission profile of the Saturn V rocket shown in Fig. 2, which interjected the Lunar Module Spacecraft into the Lunar Transfer Orbit.

The Saturn V rocket burned 3000 tons of fuel to get a 50-ton spacecraft out of the atmosphere and accelerate it to 10.8 km/s to place it into the Trans Lunar Injection [39]. Based upon estimations from Fig. 3, if the Apollo spacecraft burned additional 15,000 pounds of fuel (about the half of fuel used for the Lunar Orbit Insertion) during the Trans Lunar Injection, the Apollo spacecraft would have gained about 0.4 km/s more delta V and entered a heliocentric orbit instead of the lunar transfer orbit. If used, gravity assist from the Moon should be able to add 0.1 km/s delta V to the spacecraft, thus reducing the fuel requirement to reach a heliocentric orbit slightly.

Launch vehicles are complicated machines with a long lead time to manufacture. Their rocket engines are turbo engines with fuel and oxidizer pumps and turbines, designed to operate very close to the material's limit. Every time a spacecraft launch is planned, first, the funding must be secured. Then, numerous components are purchased or fabricated with the funds, then shipped to where the launch vehicle is built. Then, the vehicle is transported to the launch site, and expended for a single use. Fuels and oxidizers for the launch vehicles are expensive and difficult to store for a long time and a launch vehicle consumes millions of pounds of fuel for a single launch. This is why space operations are a very expensive endeavor, even for wealthy nations.

On the Lunar surface, interceptors can be electromagnetically accelerated to 2.42 km/s to enter a heliocentric orbit. An electromagnetic accelerator is a technology to accelerate heavy material to high speeds, mature enough to be used for public transportation, currently at 0.167 km/s [27]. However, on the Earth's surface, spacecraft cannot be accelerated to the escape velocity of 11.2 km/s and maintain the speed long enough to exit the atmosphere, because of aerodynamic heating and atmospheric drag. On the Moon, this practical limit by the atmosphere does not apply. This is the basis of the Lunar Electromagnetic Interceptor Launch System (LEILAS), powered by solar power or nuclear reactors.

Fig. 4 is a painting of a lunar electromagnetic accelerator displayed during the Lunar and Planetary Science Conference in Houston, TX [30]. The electromagnetic accelerator was designed to launch 4 kg of lunar soil to a location in deep space. The soil was then to be used as raw material for construction. The four large cylinders were the habitat,