# Feasibility Study of Nuclear Power-Based Collision on Asteroid Following NASA's DART Mission: A Giant Step of Humankind for Planetary Space Defense (PSD)

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## 1. Introduction

The first mission of the humankind for the planetary space defense (PSD) was accomplished by NASA in September 2022 [1]. Historically, there were five mass extinctions in this world where the asteroid impacts were major causes in recent three cases as Fig. 1 [2,3]. NASA and associated agencies' Double Asteroid Redirection Test (DART) mission showed a kinetic impactor technology in order to deflect a potential harmful asteroid by impacting an asteroid to adjust its directions with speed, angle, movement and path related factors. The SpaceX Falcon 9 rocket was used near Vandenberg Space Force Base in California [4]. The Fig. 2 shows the asteroids' origins in our Solar system [5] where there are widely spread asteroids numbered 1,113,527 [6]. It is examined to contain between 1.1 and 1.9 million asteroids larger than 1 km in diameter and millions of smaller ones are included [6]. Most asteroids visiting to Earth starts around Asteroid belt with just about three percent of the Moon [7]. The famous Halley's comet originated from the Oort cloud [8].

Fig. 3 shows the description of momentum and energy of DART mission [9] where DART impactor and Light Italian CubeSat for Imaging of Asteroids (LICIACube) are composed of the mission as the DART craft hits Dimorphos in which the speed is variable very negligibly [10]. Table 1 has the specification of DART mission [11-14] and Table 2 shows the specification of asteroid [15,16]. As a result of impact, the spacecraft's impact changed Dimorphos' orbit around Didymos by 32 minutes of reducing from the 11 hour and 55-minute orbit to 11 hours and 23 minutes [17].

## 2. Methods

The momentum and energy of impact are investigated for the mechanics of Dimorphos in the key issue of this work. The general gravitational acceleration is described as,

$$F = G\frac{M\,m}{R^2} = m\,g \qquad (1)$$

If one consider new $g'$ ,

$$g' = g + g' = G\frac{M}{R^2} + g' \qquad (2)$$

It is supposed that $g$ is the Dimorphos acceleration and $g'$ is the impact spacecraft. For a constant acceleration linear motion,

$$v = v_o + gt = 6.1\ km/s + G\frac{M}{R^2}t \qquad (3)$$

where $v$ is the impact spacecraft speed, $t$ is the period to impact, and $G$ is 6.67430 $\times 10^{-11}$ N·m$^2$/kg$^2$. For the case of Dimorphos, the semi-major axis of $R$ is 1.19 ± 0.03 km and mass is ~5 × $10^9$ kg [14,15]. Hence, the force is,

$$F'' = \frac{1}{2}mv^2\ /\ Distance \qquad (4)$$

Using this force, it is applied by the atomic source where the impact spacecraft speed is made by nuclear material of nuclear thermal rocket (NTR) in Table 3 [18]. Table 4 shows the list of NTR velocity (Solid core, 450 MWth, Isp = 900 sec., Nominal core temp. = 2,750 K) [19]. The momentum and energy of the Dimorphos in Fig. 4 that collides with the Dart impactor.

## 3. Results

Fig. 5 shows the orbit changes after impact where the orbit time shortening is seen. Furthermore, if one uses the faster exhaust gas such as $H_2$ or $CH_4$ of NTR in Table 4, the orbit time can be changed that results the asteroid would change the original direction. The shortening time (32min. = 0.53333 hour) is calculated proportionally to the 6.1 km/s, which is seen as arrow lines in Fig. 5.

## 4. Conclusions

In order to evade the potential deep impact on the Earth, the SPD has been investigated where the Dart mission's spacecraft can be imagined to make use of the impactor to the asteroid. There are some important points in this study as,

- The asteroid could be used for preventing the asteroid collision to Earth.
- The PSD is studied by the future disaster.
- Quantitative analysis of the nuclear rocket is performed.
- NRT could be a new kind of the nuclear industry.

By improving a new hazard asteroid finding, the efficiency of SPD system could be enhanced using the mechanics of the asteroid's behaviors.

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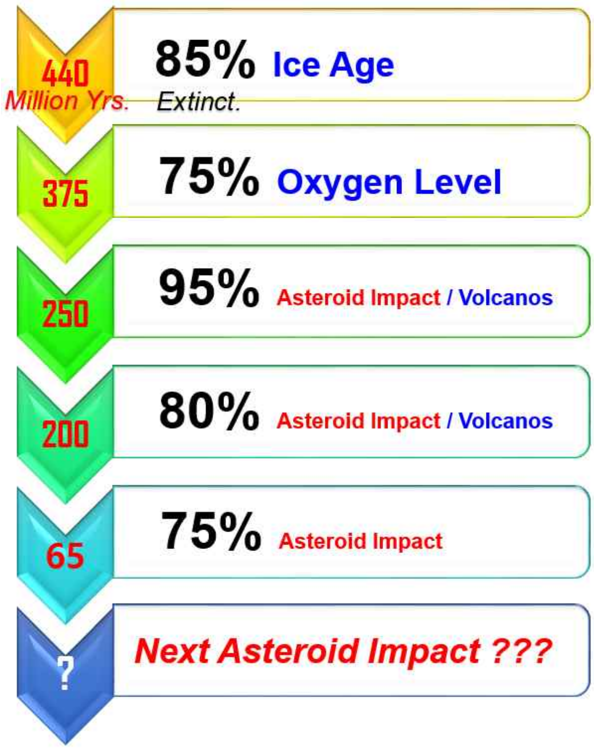


Fig. 1. Mass extinctions in Earth [2,3].

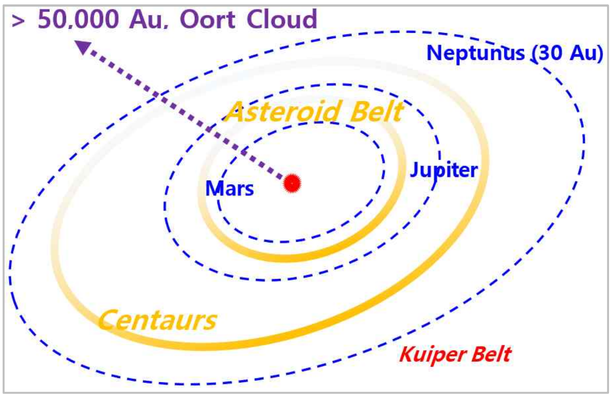


Fig. 2. Configuration of Small Solar System body [5].

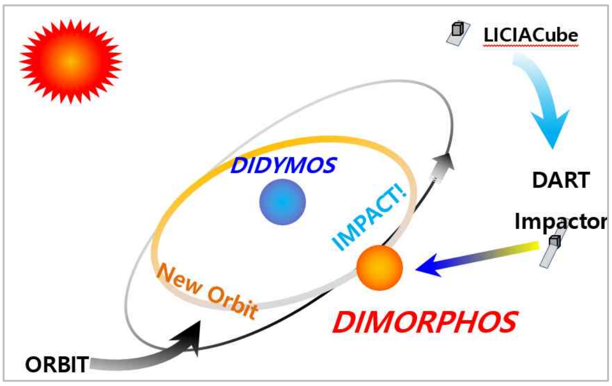


Fig. 3. Configuration of DART mission [5].

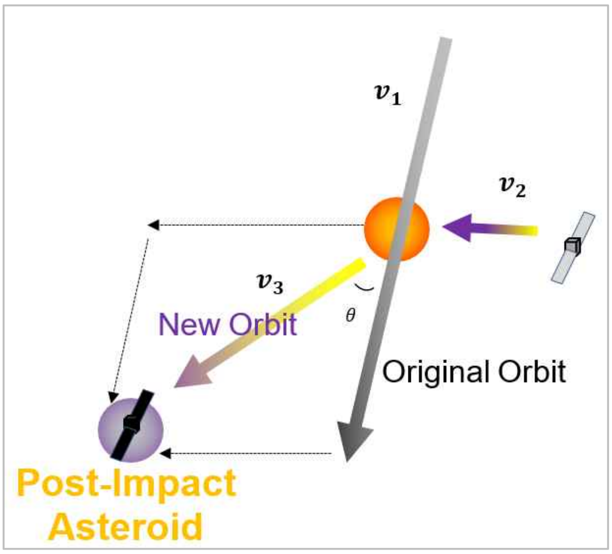


Fig. 4. Depiction of momentum and energy.

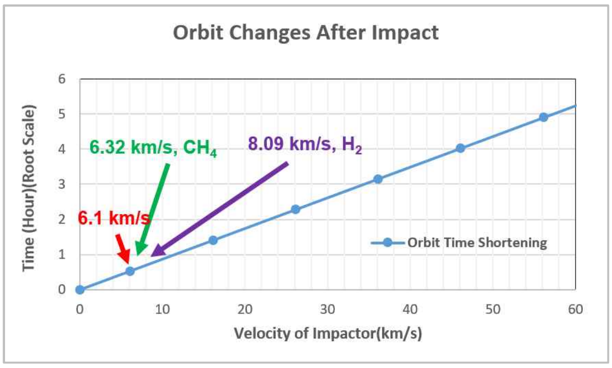


Fig. 5. Orbit changes after impact.

Table Ⅰ: Specification of DART mission [11-14].

| Sort | | Content |
|---|---|---|
| LICIACube | Dimension | 10 cm × 20 cm × 30 cm |
| | Mass | 14 kg |
| | Power | Solar Array × 2 |
| | Owner | Italian Space Agency |
| | Manufacturer | Argotec |
| Impactor Spacecraft | Dimension | 1.2 m × 1.3 m ×1.3 m |
| | Mass | 610 kg (At Launch), 570 kg (At Impact) |
| | Power | Hydrazine propellant, Xenon |
| | Speed | 6.1 km/sec |
| Mission Rocket | Name | SpaceX Falcon 9 |
| | Height | 70 m |
| | Diameter | 3.7 m |
| | Mass | 549,054 kg |
| | Payload | 8,300 kg |

Table II: Specification of asteroid [15,16].

| Sort | | Content |
|---|---|---|
| Dimorphos | Discovered | 20 November 2003 (By Pravec et al.) |
| | Dimension | 208 m × 160 m × 133 m |
| | Mass | ~5 × $10^9$ kg |
| 65803 Didymos | Discovered | 11 April 1996 (By Sspacewatch) |
| | Dimension | 832 m × 838 m × 786 m |
| | Mass | ~5.2 × $10^{11}$ kg |

Table III: Specification of Nuclear Engine for Rocket Vehicle Application (NERVA) [18].

| | Content |
|---|---|
| Engine | NERVA-derived / UC-ZrC in graphite |
| Propellant | $LH_2$ |
| $I_{sp}$ Range | 925 s (2750 K) |
| Arrival Vinf (Cargo Mission) | ~3.480 km/s |

Table IV: List of nuclear thermal rocket (NTR) velocity (Solid core, 450 MWth, Isp = 900 sec., Nominal core temp. = 2,750 K) [19].

| NTR exhaust gas | Velocity (km/s) |
|---|---|
| $H_2$ | 8.093 |
| $CH_4$ | 6.318 |
| $NH_3$ | 5.101 |
| $H_2O$ | 4.042 |
| $CO_2$ | 3.306 |