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Enhancements of Catching Resources in Asteroids by Atomic Power Propulsions: Nuclear Space Mining, Super-Jackpot for $10,000 Quadrillion

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1. Introduction

From an economic perspective, space resource mining is a very interesting business. When bringing an asteroid floating in space to Earth on a rocket, not only the rocket but also the mass and speed of the asteroid are important. Asteroids containing metals and rare earths, which are extremely abundant in space, could be brought to Earth or processed in space and sold. In this study, a lot of energy is needed to recover asteroids, which is an important element of rocket design, and to achieve this, the relationship between rockets and meteors is studied from a mechanical perspective. Nuclear energy has an advantage comparing to the existing solar energy in which it can generate high output. In Table 1, the list of space mining market is shown [1].

Table I: List of space mining market (Fortune Business Insights, 2024) [1].

Classification	Content
Asteroid	C, S, M Types
Nations	USA, EU, RUSSIA, Asia Pacific etc.
Phase	Space Vehicle, Launch, Thrust, Operation
Applications	Resource harvesting, Construction, 3D Printing

Commercially using nuclear energy in space comes with many conditions, one of which is whether it will work properly in space situations. Radioisotope thermoelectric generators (RTGs) have already proven themselves well in use on several space probes, including Voyager, which continued to operate beyond the end of its life and transmitted information from the furthest reaches of space in human history. In the space mining business, the output is low, ranging from hundreds of watts to thousands of watts, so various types of nuclear energy use methods must be utilized to produce high output. There is a nuclear thermal rocket (NTR) that uses the heat of a nuclear reactor to expand hydrogen gas and obtain steam from the expanded hydrogen gas. Additionally, nuclear electric propulsion (NEP) is a method of converting heat generated from nuclear reactions into electrical energy and using it in propulsion systems [2]. In this work, Fig. 1 shows the target asteroid capture configuration with the capture rocket and target asteroid indicated.

In the previous studies, Paikowsky and Tzezana showed the space mining venture [3]. Steffen studied for the regulatory regime to take rights for the mining [4]. In addition, Xu and Su worked for the benefits of Space Mining [5]. Furthermore, Semerád studied for the way of taxing asteroid mining [6]. Proksik et al. showed for Q-methodology of revealing stakeholder positions [7].

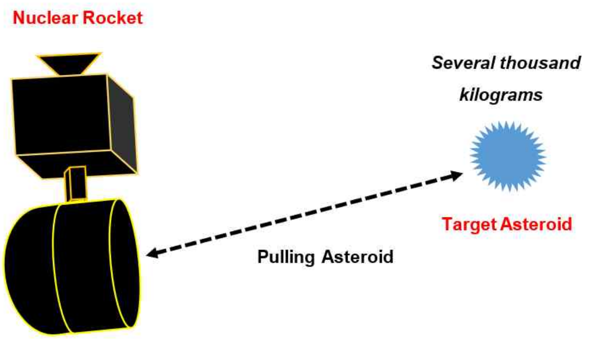

Fig. 1. Feature of nuclear rocket and target asteroid.

2. Methods

The first step in mining an asteroid is using the power of a spacecraft to transport it. The best way is to place it in a spaceship container. Additionally, there are cases where it is brought in firmly fixed to the outside of the spacecraft. In order to load a spaceship container, there must be a way for the spacecraft to approach the asteroid and load it onto the spacecraft. In this case, the movement speed of the asteroid must be exceeded, so the spacecraft's operation must be adapted to the movement of the asteroid. The method of connecting a spacecraft to an asteroid and pulling it can be considered a more desirable method because it allows the asteroid to move as desired.

The equation of motion expresses the relationship between attaching a string to an asteroid and pulling it into a spacecraft. So, the equation of motion shows as,

$$v_R = a_R t + v_o \quad (1)$$

where, v_R is the speed of rocket, v_o is the stopping speed, a_R is the acceleration of rocket, and t is the time. For the distance,

$$s = s_R + s_A = \left(v_{oR} t + \frac{1}{2} a_R t^2\right) + \left(v_{oA} t + \frac{1}{2} a_A t^2\right) \quad (2)$$

where, v_{oR} is the stopping speed of rocket, v_{oA} is the stopping speed of asteroid, a_A is the acceleration of asteroid, s_R is the distance of rocket, s_A is the distance of rocket, and s is the total distance. For $v_{oR} = v_{oR} = 0$,

$$s = s_R + s_A = \frac{1}{2}a_R t^2 + \frac{1}{2}a_A t^2 = \frac{1}{2}(a_R + a_A)t^2 \quad (3)$$

So,

$$t^2 = \frac{2s}{(a_R+a_A)} = \frac{2s}{F(\frac{1}{m_R}+\frac{1}{m_A})} = \frac{2s}{F(\frac{m_R+m_A}{m_R m_A})} = \frac{2s\, m_R m_A}{F(m_R+m_A)} \quad (4)$$

where, m_R is the mass of rocket, m_A is the mass of asteroid, a_A is the acceleration of asteroid, s_R is the distance of rocket, and s_A is the distance of rocket. Also,

$$t \propto \sqrt{\frac{m_R m_A}{F(m_R+m_A)}} \quad (5)$$

Fig. 2 has the pulling force of a spacecraft when comparing rocket and asteroid masses. When the two

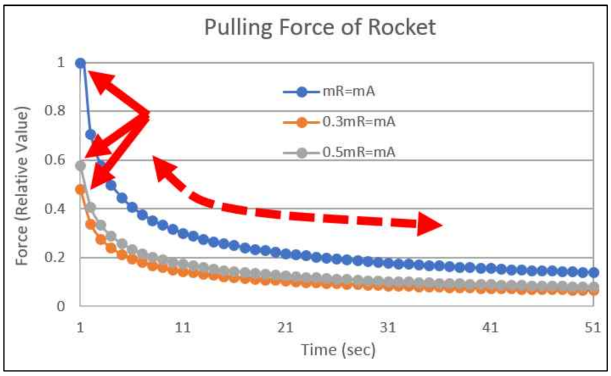

Fig. 2. Pulling force for catching asteroid.

masses are equal, the graph is at the top. Otherwise, the mass of the lightest asteroid would be at the bottom, about a third of the mass of the rocket. In the energy equation of the rocket and asteroid after catching,

$$E_R = \frac{1}{2}m_R v_R^2 \quad (6)$$

$$E_A = \frac{1}{2}m_A v_A^2 \quad (7)$$

Since $v_R = v_A$,

$$E = E_R + E_A = \frac{1}{2}(m_R + m_A)v_R^2 = \frac{1}{2}(m_R + m_A) \times \left(\frac{Orbt}{t}\right)^2 \quad (8)$$

$$t \propto \sqrt{\frac{1}{E}} \quad (9)$$

where E is the energy of rocket. In Fig. 3, the tug rocket energy decreases as time goes on. The energy can be used

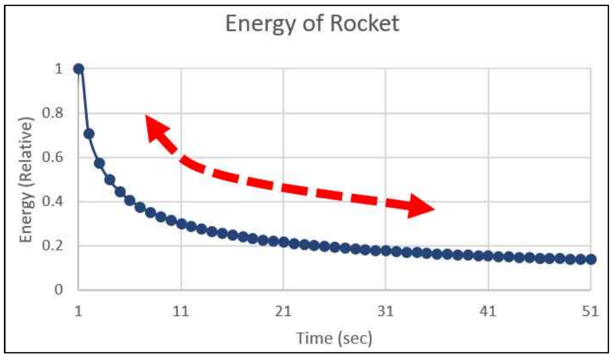

Fig. 3. Energy after taking asteroid.

not only as a direct propellant through nuclear power, but also as power through electricity production. Electricity is used as power to connect an asteroid with a string and pull it to a spacecraft.

3. Results

With the masses of the rocket and asteroid, the capabilities of the towing system are estimated. The string will lead to a 1km rocket and asteroid. Furthermore, using 1km of distance and 8,000kg of $m_R + m_A$, it is modeled. Force is assumed as 500 newtons. Form equation (4), assuming the rocket's mass is 2,000 kg and changing the asteroid's mass,

$$t = \sqrt{\frac{2s\, m_R m_A}{F(m_R+m_A)}} = \sqrt{\frac{2(1km)(2{,}000)m_A}{500\,(2{,}000 + m_A)}} = \sqrt{\frac{(4{,}000)m_A}{1{,}000{,}000 + 500\, m_A}} \quad (10)$$

Fig. 4 gives the trend of asteroid moving time by the asteroid mass variations. When the asteroid's mass

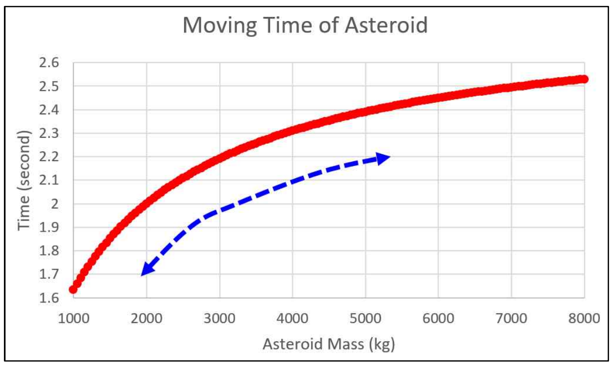

Fig. 4. Trend of asteroid moving time for asteroid mass variations.

exceeds 2,000 kg, the time required slows down. So, asteroids weighing less than 2,000 kg will be pulled out in a short period of time, so be careful of collisions with rockets.

4. Conclusions

Space mining will have a major impact on human life. In this work, various variables were studied to maximize the effect. Although theoretical research has been conducted, various conditions must also be considered for practical applications. Some important things are as;

- Space mining is investigated by the role of nuclear energy.
- The masses of spacecraft and asteroids are modeled.
- Asteroid pulling time factor is important in mining operations.
- Present effective work is proposed for future space mining.

One of the important things in space mining is energy, and electricity generation using nuclear energy could enable sustainable operations in space, unconstrained by the energy of the sun or stars. In this study, the masses of asteroids and spacecraft were considered, and the force that attracts spacecraft is also operated by electrical energy, which is related not only to mass but also to work time. If the working time is fast, collisions accidents may occur. Hence it is important to manage an appropriate working time for safety reasons. Fig. 5 shows that UAE nuclear power plant exports are expected to be $20 billion, Czech nuclear power plant exports are expected to be $17.3 billion for 2 units, $34.6 billion when all 4 units are contracted, and space mining is expected to be $10,000 Quadrillion [8].

Fig. 5. Price of three cases.

Acknowledgments

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