Future Atomic Energy Based Space Power Modeling for Journey beyond Martian Orbit – Celebrating the MARS 2020's Touchdown on Red Planet

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1. Introduction

With the great dreams of humankind, the MARS 2020 landed finally on the Red Planet after 6 months' journey [1-4]. It is expedited the Martian colony could be realized where the nuclear energy as well as solar power will be used for the socialized community. The atomic energy based habitations will be built on the Mars where the mass energy productions could be possible, although the solar energy could be accompanied for the initial energy source of colony civilization. The atomic utopia would be followed after the arrival of humans which is in Fig. 1. Fig. 2 shows the feature of trajectory on Mars trip.

One of goal in space nuclear energy development is accomplished incorporated with the energy source for the deep space explorations. Fig. 3 shows the goal of the space energy development. Hence, it is interesting which energy source is better for a long journey, especially beyond the Martian orbit between solar and nuclear energies. The distance to Mars from Sun is 1.666 AU for aphelion and 1.382 AU for perihelion. For future trip to far space region, it is calculated that the comparisons of mass between nuclear energy facility and solar energy equipment in this study.

2. Methods

In the modeling, the comparison of mass between the photovoltaic-battery system and radioisotope thermoelectric generator (RTG) is performed. Even though there are some conditions for the calculations, the simple method could give the reasonable feature in future space explorations. There are shown for the solar energy equipment as follows [5],

$$I_R = \frac{R_e^2}{R^2} I_e \tag{1}$$

where I_R= solar isolation at R; I_e= solar isolation at earth, 1,353 W/m^2; R_e= distance from sun to earth, 1 AU; and R = distance to spacecraft. Furthermore, the cell conversion efficiency for the solar concentration is,

$$\eta = \frac{245.7\ W/kg}{1{,}353\ W/m^2} \times 0.853\frac{kg}{m^2} = 0.155 \tag{2}$$

The specific power for a location is,

$$P_o = \frac{0.155 \times I_R}{0.853\ kg/m^2} \tag{3}$$

The solar power is described as [5-7],

$$P_{SA} = \frac{\frac{P_e T_e}{X_e} + \frac{P_d T_d}{X_d}}{T_d} = \frac{\frac{(5kW_e)(20\text{min})}{0.65} + \frac{(5kW_e)(20\text{min})}{0.85}}{20\text{min}}$$

= 14.932 kW_e

where P_{SA}= solar panel power during daylight period; P_e = power requirement during eclipse, 5 kW_e ; P_d = power requirement during daylight, 5 kW_e; T_e= period of eclipse, 20 min; T_d= period of daylight, 20 min; X_e= power transfer efficiency during eclipse, 0.65; X_d = power transfer efficiency during daylight, 0.85. So,

$$\frac{P_{SA}}{P_o} = \frac{14.932\ kW_e}{\frac{0.155 \times I_R}{0.853\frac{kg}{m^2}}} = \frac{14.932\ kW_e \times 0.853\frac{kg}{m^2}}{0.155 \times I_R} = \frac{14.932\ kW_e \times 0.853\frac{kg}{m^2}}{0.155 \times \frac{(1\ AU)^2}{R^2} \times (1{,}353\ w/m^2)} = 60.735\ kg\ R^2 \tag{4}$$

The battery mass is,

$$\frac{1\ kg}{(150W-h)\times 33\%} \times 0.5h \times 5kW_e = 50.51kg \tag{5}$$

Hence,

$$60.735\ kg\ R^2 + 50.51kg \tag{6}$$

whereas, the specific mass of general purpose heat source (GPHS) is done for 245.7 W (estimated at the power bus [8]) and 57.91 kg (estimated for New Horizons [8]) as follows,

$$m_{GPHS} = \frac{P_{GPHS}}{S_{RTG}} = \frac{5kW_e}{245.7W/57.91kg} = 1{,}178.5kg \tag{7}$$

In addition, for the case of Kilowatt Reactor Using Stirling Technology (KRUSTY) with 134 kg/kw [9],

$$m_{GPHS} = \frac{P_{GPHS}}{S_{RTG}} = \frac{5kW_e}{1{,}000W/134kg} = 670kg \tag{8}$$

3. Results

In this work, the break-even orbital location is slightly below 4.31AU (33%) and 4.326AU (40%) which is Fig. 4. Previously, the distance for the break-even orbital location is 4.183 AU where the different RTG for that of New Horizon [7]. For the case of KRUSTY, it is around 3.2 AU. So, it is reasonable to use in the travel to outer space including Jupiter. The Fig. 5 show the distance for far-away space trip.

4. Conclusions

Following worldwide space development booming, the atomic power has been emerged as the ultimate energy source because the solar energy shrinks rapidly following the distance from Sun. Therefore, one of key issues in space civilization and deep space exploration is how to treat the nuclear energy in the space. The radiation protection to the nuclear facility is basically in the state of relaxation due to the radioactive environment on non-earth space. This could give the flexible development actions using the nuclear materials. The atomic utopia could be accompanied with the success of the space development for the new and final frontier of human civilizations.

Acknowledgements

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Fig. 1. Feature of atomic utopia on Mars.

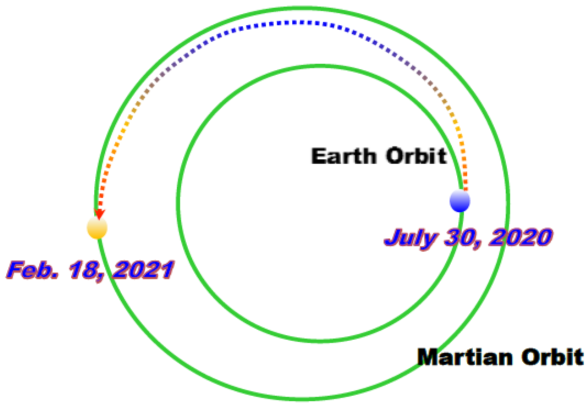


Fig. 2. Feature of trajectory on Mars trip.

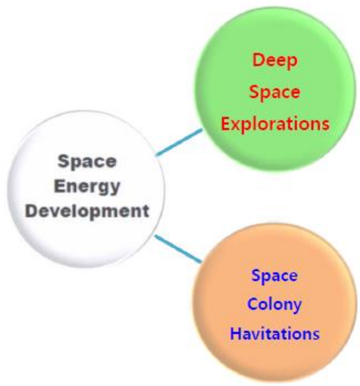
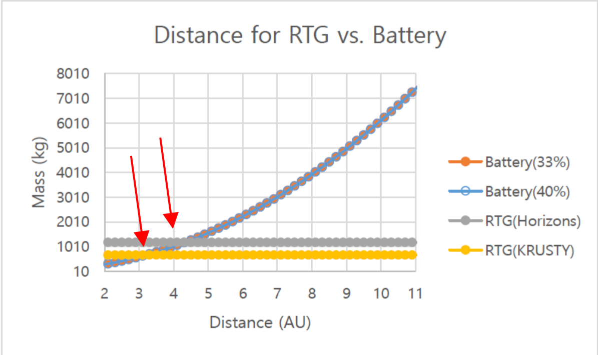
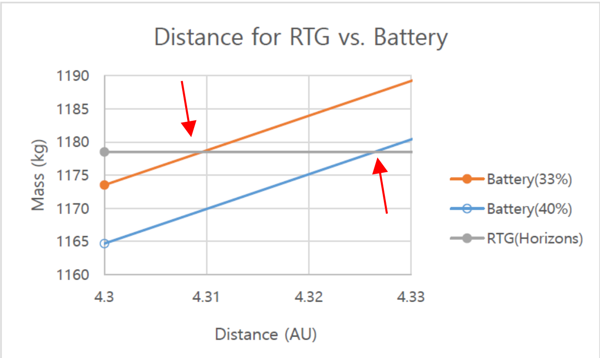


Fig. 3. Goal of the space energy development.



(a)



(b)

Fig. 4. Distance based on RTG vs. photovoltaic battery.

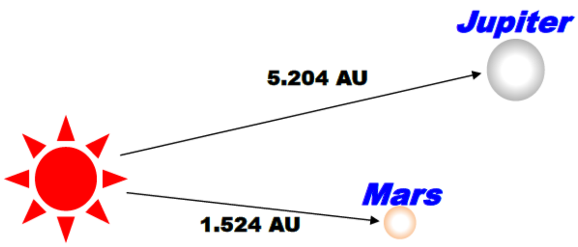


Fig. 5. Distance from Sun to planet.