An Analysis of Mars Terraforming Using Nuclear Energy

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1. Introduction

Following interdisciplinary convergence R&D trend, the space technology is incorporated with the nuclear energy. As the historic challenge of a human being, the Martian colonization has been initiated by nuclear energy by Mr. Elon Musk, a billionaire, in the SpaceX/Tesla, Inc. Fig. 1 shows the concept for the terraforming of Mars in which it would be changed to the Earth's conditions such as the atmosphere, environment, and some other ecological systems. This is the mimicking of the early conditions of Earth that was the harsh and non-comfortable to biological creatures. Hence it takes very long time to make the new world like the Earth. However, it is one of critical points to develop the new planet to reduce the timeline of the terra-formation from a thousand-year scale to several hundred-year scale or less.

Astronomer Dr. Carl Sagan imaged for the terra-formation of Venus in Science (1961) where the seeding or algae could change the environment of the planet. After that time, NASA proceeded to make the preparation studies. Considering the space planet, it is possible to classify by temperature and water content. There are several types of the planet in Fig. 2. The wet and warm condition could be an optimized one to the humans considering that of Earth in which the atmosphere is very active and versatile that could make many kinds of climates following the geological states.

According to Table I, although the percentage of the carbon dioxide in Mars is comparatively higher than that of Earth, the quantity is very low (Wikipedia, 2018). So, it is needed to produce the carbon dioxide from the frozen one in the dry iced forms in the poles. Hence, Mr. Musk intends to use the nuclear bomb to melt the ice and emit the carbon dioxide to Martian atmosphere. According to Zubrin and McKay (1993), it is believed that the carbon dioxide is in volatile form as much as from 300 to 600 mb in frozen or regolith form in south pole. Although there are several options to release the carbon dioxide such as mirror to use the sunshine, impact by asteroid, or halocarbon gases (CFC's) by nuclear energy. If one can think the nuclear energy which is a very effective and possible way, it needs about 1,000 MWe type nuclear power plant (NPP) (Zubrin and McKay, 1993). There is the relation between temperature and CFC-Power in Fig. 3. It is possible to consider the temperature of making atmospheric conditions.

2. Methods and Results

It is proposed to construct the artificial environment by the designed method. Fig. 4 is the procedure of terraforming in Mars. It is used the nuclear energy to produce the carbon dioxide which is iced on the south pole of the Mars. Mr. Musk would like to use the nuclear bomb to melt the carbon dioxide. There is the comparison between NPP and nuclear bomb for the usage in Table II. The grand finale of Cassini, spacecraft for Saturn, was the case to avoid the radioactive contamination in the satellite including the Enceladus in Fig. 5, which was powered by 32.7 kg of Pu-238 (Krivobok, 2009; Coates, 2017; NASA, 2017). Therefore, it is not good to use of the energy to melt the iced carbon dioxide. So, it is better to make use of newly designed NPPs. Fig. 6 shows the imaginary view of site in Mars where the carbon dioxide dried ice and NPPs around the south pole. So, considering the fact of Fig. 3, it is reasonable to use the NPPs. So, it is possible to increase the 40 K using about 43 units of 1,000 MWe NPPs. Table III show about Mr. Elon Reeve Musk (Wikipedia, 2019). Considering the thermal efficiency instead of electrical efficiency, the generated powers increase to three times. Hence, the proposed NPPs are about 13 units which are one third of 43 units. Furthermore, the longer operation time also reduces the unit number.

If one thinks the nuclear reactor rover (NRR), in the system, it is possible to make a new moving NPP type where the heat is transferred to the ice as the conduction. Fig. 7 shows the design of the moving NPP in which the reactor is moving and heat is transferred to the ice to melt and the carbon dioxide are emitted to the atmosphere in Fig. 7(a). The conductor pad could give the heat transfer which is analyzed as the conduction to the ice surface. The track is shown in the Fig. 7(b) and the NRR goes downward in Fig. 7(c). There are two kinds of melting methods in NRR system where the main heat is transferred by nuclear reactor and the friction heat is done by caterpillar. In NRR, heats are transferred on the ice surface by piping lines. The typical heat conduction is as,

$$Q_1 = -k\frac{dT}{dx} \tag{1}$$

where Q_1 is the heat flux, k is the thermal conductivity and $\frac{dT}{dx}$ is the temperature gradient. This describes the hot water flows into the piping of the conduction part, which is made by the conventional technology by the hear transfer system simply.

Furthermore, there is another heat transfer in the caterpillar as follows (Böttcher et al., 2017),

$$Q_2 = \frac{C_f F_{nor} L}{p} \tag{2}$$

where Q_2 is the frictional heat, C_f is the coefficient of friction, F_{nor} is the normal force, L is the slider length, and p is the contact point. It is regarded as the total heat energy of thermal conducted away energy and remaining energy (Böttcher et al., 2017). This gives the melting of the tracks. So, the summations of ice melting are accelerated after the reactor energy.

$$Q_{tot} = Q_1 + Q_2 \quad (3)$$

where Q_{tot} is the total heats produced by the nuclear energy and friction of the caterpillar. The NRR moves by the caterpillar output power and gravity on the slop made by the nuclear reactor energy and friction energy of the caterpillar. Total power of the system is,

$$Energy\ for\ Movement_{NRR} = E_{cat} + Q_1 + Q_2 \quad (4)$$

where $Energy\ for\ Movement_{NRR}$ is the total energy for NRR movement and E_{cat} is the energy for caterpillar operations.

The important matter in the design is how to make the caterpillar to move the reactor and its facilities, although the major conductive heat transfer is made by the heat conducted part in Fig. 7(c). So, the slider length and contact point are proposed. Fig. 8 shows the normalized heat transfer by slide length and contact point where they are normalized as 1.0 and 10.0 respectively. Even though the slider length of the caterpillar is proportional to heat transfer, the contact point shows the adverse values. Longer slider length and less contact point could be the optimized heat production system by the caterpillar which is the additional heat source except the other nuclear reactor.

3. Conclusions

It is examined to consider the nuclear energy to increase the atmosphere temperature up to the ecological system. There are some important points in this study as follows;

- The space terraforming of Mars is studied.
- Nuclear energy is used to melt the ice.
- It is proposed to make use of the nuclear power.
- The other planet could be one of candidates.

Following the development of Martian colony, the other planets could be candidates. However, the environments are different, especially in the content elements of atmosphere. It is able to be considered that oxygen is one of major gas elements that could be used for the breath of humans. Hence oxygen, water and carbon dioxide could be examined for the important factor in the new planet.

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Fig. 1. Configuration of terraforming of Mars.

Fig. 2. Configuration of planet type.

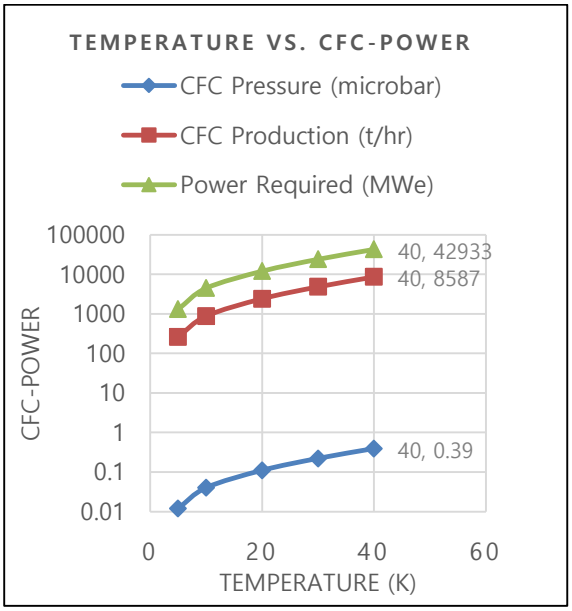


Fig. 3. Configuration of Temp. vs. CFC-Power.

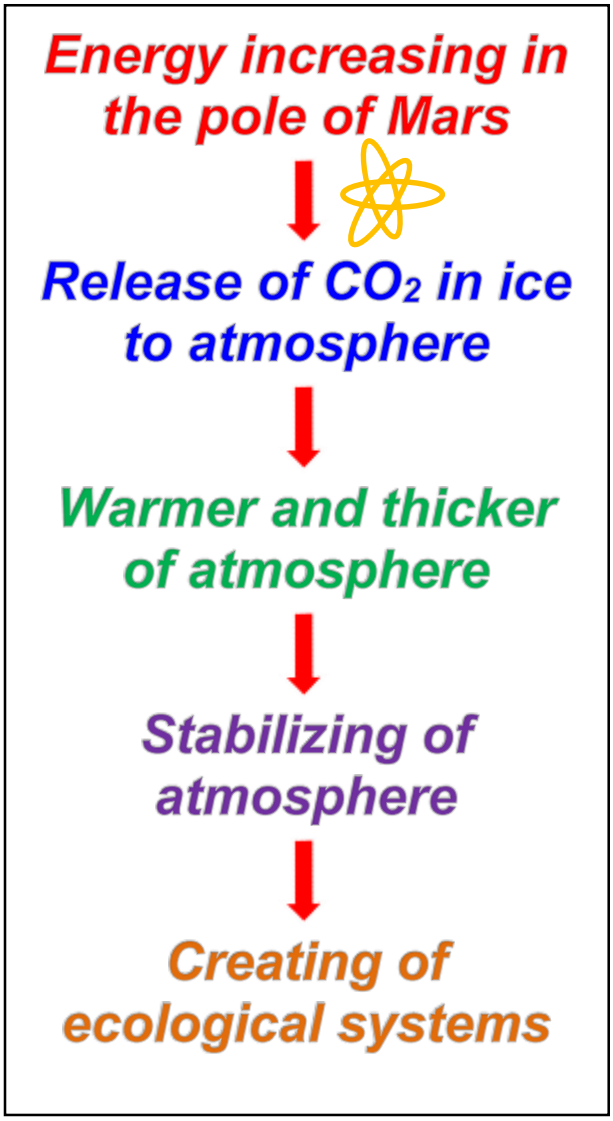


Fig. 4. Procedure of terraforming in Mars.

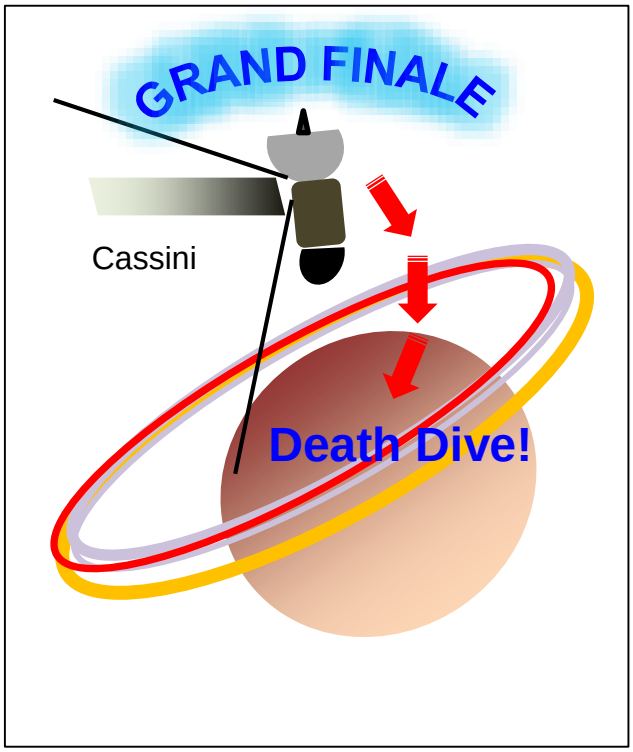


Fig. 5. The Cassini's grand finale on Saturn.

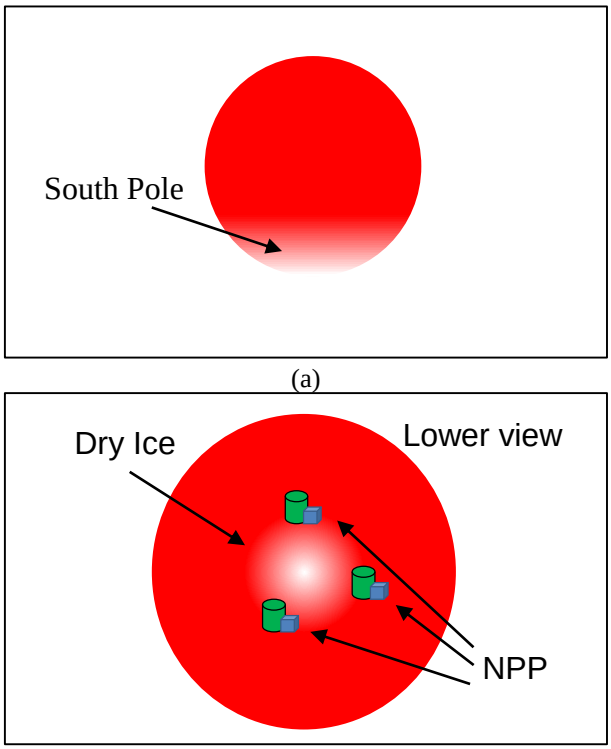
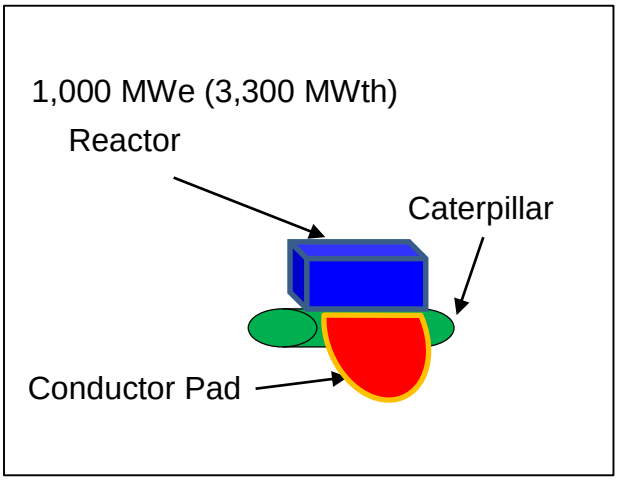
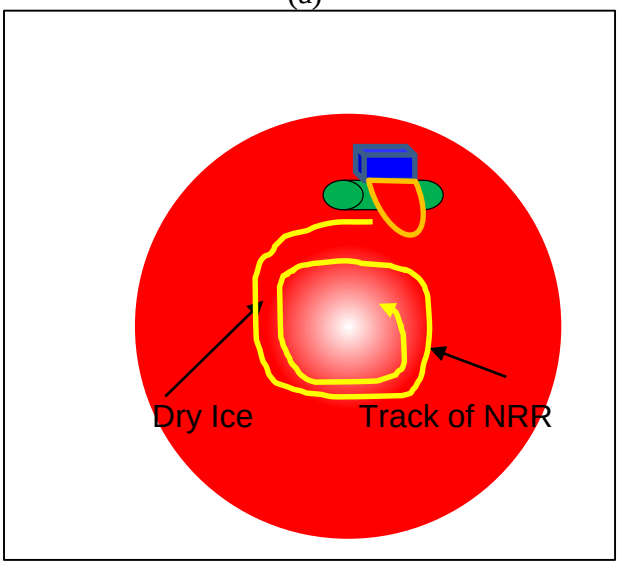


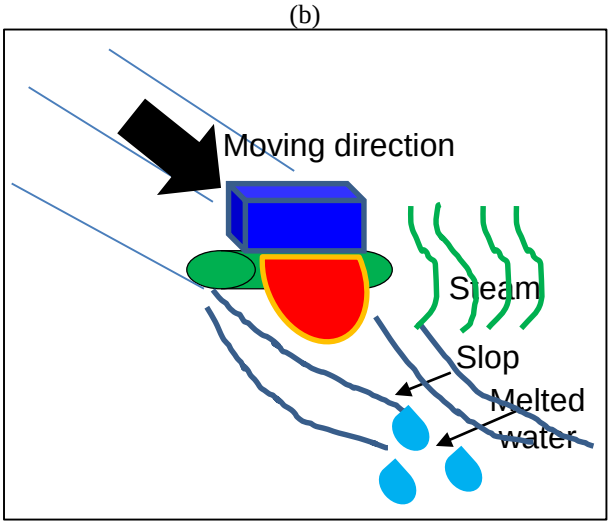
Fig. 6. Imaginary view of site in Mars.



(a)



(b)



(c)

Fig. 7. A newly designed NPP, (a) Nuclear reactor rover (NRR), (b) Track of reactor and (c) Moving direction.

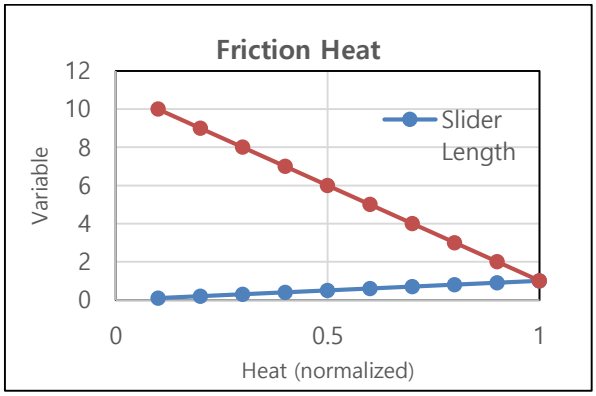


Fig. 8. Normalized heat transfer by slide length and contact point.

Table I: Content of atmosphere

Content	Earth	Mars
Co_2	0.04 %	96.0 %
O_2	20.94 %	0.145 %
N_2	78.08 %	1.9 %
Pressure	101.3 kPa	0.6 kPa

Table II: Comparison between nuclear power plant and nuclear bomb

Content	Nuclear power plant	Nuclear bomb
Power	Steady and stable	One impact
Range	Controllable	Very wide
Contamination	None	Very long
Cost	Higher	Lower

Table III: Who is Mr. Elon Musk?

	Content
Born	June 28, 1971 (age 48), Pretoria, Transvaal, South Africa
Education	University of Pennsylvania (B.S., Economics, Physics), Stanford University (Dropout of Ph.D. degree)
Worth	$ 21.4 Billion (2019)
Job	Founder, CEO, Lead Designer of SpaceX CEO, Product Architect of Tesla, Inc. Co-founder, CEO of Neuralink Founder of The Boring Company Co-founder of Zip2 Founder of X.com (later became PayPal) Co-founder of OpenAI Chairman of SolarCity