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Research Article

Analysis of Martian Nuclear Spacecraft Powered by Low Energy Nuclear Reactions (LENRs)

Tae Ho Woo*

Department of Mechanical and Control Engineering, The Cyber University of Korea, 106 Bukchon-ro, Jongno-gu, Seoul 03051, Republic of Korea

Abstract

This paper presents a model to determine the optimum power source for a manned spacecraft to Mars; that is to say, the most economical and reliable power source. Low energy nuclear reactions (LENR) is evaluated for application to several areas including space travel, in which the vacuum of space cannot provide any propellant or other materials. It is assumed that LENR may become a practical source of useable energy. Several things must be considered for a successful journey from Earth to Mars, including the trip rout, the type of rocket, energy source, and the spacecraft speed. These are discussed for space travel using LENR. The velocity of the rocket increases as the mass flow rate decreases. The shortest route of a trip to Mars is selected to reduce cost.

Keywords: Energy, Low energy nuclear reactions (LENRs), Mars, Spacecraft

1. Introduction

I propose to find a power source for a spacecraft to Mars that is optimized to be economical and reliable. Conventional chemical energy is not strong enough compared to things like nuclear fusion. However, it would require a gigantic motor to produce fusion reactions in a spaceship that does from Earth to Mars. LENR is investigated, with the assumption that the vacuum of space cannot provide any propellant or other materials. The astronauts will have only the limited amount of materials they bring from Earth. It is assumed that LENR may become a practical source of useable energy.

Unmanned interplanetary missions from Earth to Mars were first attempted in 1960, when a USSR spacecraft failed to launch. The most recent mission is the InSight rocket, planned in 2016 and launched in 2018 [1]. Several robots and vehicles have operated on Mars. Most have performed detection and measurements of the planet surface. Atmospheric and seismic investigations have also been performed. The goal of many investigations has bene to look for biological substances which could be used to construct and support human colony in the near future. The search for evidence for water is one of the most important tasks. according to a recent report there is evidence for flowing rivulets of salty water in the summer [2].

*E-mail: thwoo@cuk.edu, thw@snu.ac.kr, Tel.: +82 2 6361 1924, Fax: +82 2 6361 1800.

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The average distance from Earth to Mars is 55,000,000 km. Several things must be considered for a successful journey from Earth to Mars, including the trip rout, the type of rocket, energy source, and the spacecraft speed. These are discussed for space travel using LENR. From its introduction in 1989, LENR has been interesting because it is a very abundant, clean and green energy source. Although there have been many studies of LENR, it still needs to be developed for practical or realistic applications. It would be especially effective for comparatively low power applications.

Several propulsion methods for deep-space rockets have been developed [3]. Most spacecraft use chemical fuel, in which the hot reaction mass is expelled from the vehicle [3]. Until now, this has made journeys to Mars vary from 150 to 300 days; Viking 1 (1976) took 335 days, and the Curiosity lander (2012) took 253 days [4]. Charles Bolden of NASA said that in the future, the proposed Variable Specific Impulse Magnetoplasma Rocket (VASIMR) could reach Mars within five months. With this method, radio waves are used to ionize and heat propellant, and magnetic fields would accelerate the plasma to generate thrust [5,6]. In 2009, an experiment was done with a VASIMR in the International Space Station (ISS) with a full operational capacity of 200 kW [7].

In the search for other power sources for interplanetary missions, the LENR catalysis-based nuclear reaction is investigated in this paper. In 1989 Dr. Martin Fleischmann and Dr. Stanley Pons announced success in generating nuclear reactions in laboratory experiments at the University of Utah [8]. This effect is also called Chemically Assisted Nuclear Reactions (CANR), because the nuclear behavior is apparently caused by metallic catalyzed reactions [9]. In the conventional description of nuclear fusion reactions, the electromagnetic force causes the nuclear reaction by fusing the nuclei. In contrast, with lender (or see ANR) it is assumed the nuclear reactions occur in the space of some lattices such as palladium where the vacuum exists with all huge area given the scale of nanoscopic molecules of hydrogen. The area is relatively huge because there is "plenty of space at the bottom" as Richard Feynman put it in his famous lecture [10]. According to Miley [11–21], a highly dense molecular structures of palladium could produce abundant heat, with proton-deuterium interactions occurring at a level of 10^{24} atoms per centimeter. The heat can be converted to electrical energy. The expected energy production is estimated and it is proposed as a strategy for interplanetary travel. Section 2 explains the methods used in this study. Section 3 describes the results of the study. Some conclusions are drawn in Section 4.

2. Method

There are several issues to consider in a journey to Mars, such as route, and the layout of the spacecraft. The velocity of the spacecraft is related to the quality of the trip, and velocity depends upon the energy source. Furthermore, the combinational functions of these issues are important because the failure of a journey could be caused by an accident.

2.1. The route of journey

The distance to Mars is a key issue, and varies depending on the positions of Earth and Mars. The two planets are seldom within the shortest possible distance. The path is not in two-dimensional space, but within the sun's polar coordinate system. Figure 1 shows a diagram of the Mars journey where the orbits of Earth and Mars are plotted. Choosing the shortest distance is very important to reduce the travel duration, the orbits are one of the most important considerations. The target position is predicted. The effect of both Earth and Mars orbits are used to calculate the path. In some cases, a flyby can be used to accelerate the spacecraft. The velocity of the rocket is increased by a factor of two compared to the flyby planet speed. Hence, the flyby is a method of gravity assisted operation [22].

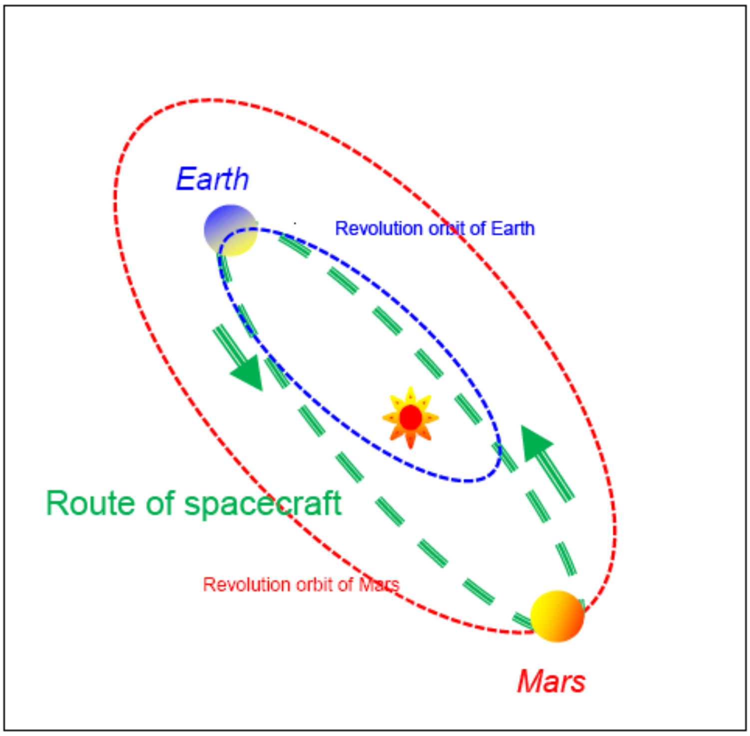

Figure 1. Diagram of the route to Mars journey.

2.2. The design of the spacecraft

In the design of a spacecraft suitable for a man to trip to Mars, there must be a well-protected crew cabin, as shown in Fig. 2. This section of the spacecraft includes a rotating cabin to produce artificial gravity. Even if the gravity is not the same as Earth's, it should be enough to allow humans to stand up and walk. The radiation shielding of the crew cabin is a critical matter to preserve health of the crew during the trip. The ratio of the power produced by the rocket engine and the design energy and velocity of the spacecraft can be calculated.

2.3. The source of energy

The spacecraft would include a heat-driven electric generator. Figure 3 shows the configuration of the LENR in a palladium Face Centered Cubic (FCC) lattice. The LENR heat source produces the combined energy of all of the individual LENR battery units. The heat is produced by D_2 (or H_2) gas reactions with the palladium. In Fig. 4, the heat is converted to electricity which is supplied to the relevant systems of the spacecraft. Figure 5 shows graphs of proton and palladium interactions as the transvers view of collisions, ion ranges, and collision events at 20 keV proton injection into the palladium.

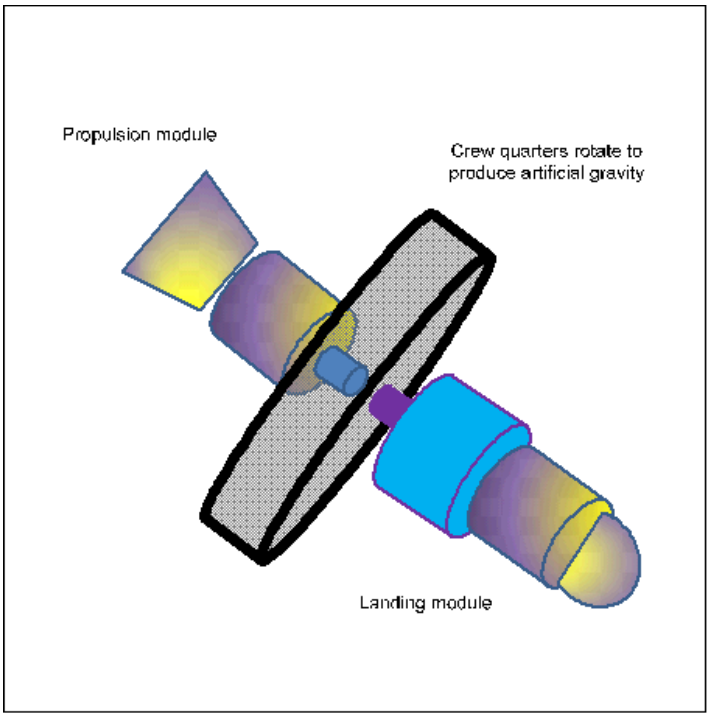

Figure 2. Simplified configuration of Martian spacecraft.

2.4. The speed of spacecraft

Currently, the speed of a Martian rocket is 20,000 km/h (=5.556 km/s) and the duration of the trip averages 114.58 days (about 3 months 25 days) [4]. The relation of power, force, and speed is as follows [23]:

$$P = F\frac{d}{t}, \tag{1}$$

where P is power (kW), F the force (N), d the distance (m), and t is time (s). Using this equation, one can estimate the effects of different power sources. Table 1 shows the relationship between energy and speed of spacecraft [24]. Using Eq. (1), the thrust is 0.5 N in Table 1. So, the velocity of LENR is 2.8 km/s. So, for the source from LENUCO, LLC, the speed is obtained as follows where the power is 1.5 kW [25]:

Table 1. Relationship between energy and speed of spacecraft.

	Min. power/thrust (kW/N)	Effective exhaust velocity(km/s)
Soil fuel rocket	0.5	1
Bipropellant rocket	2.5	5
LENR rocket	1.4	?

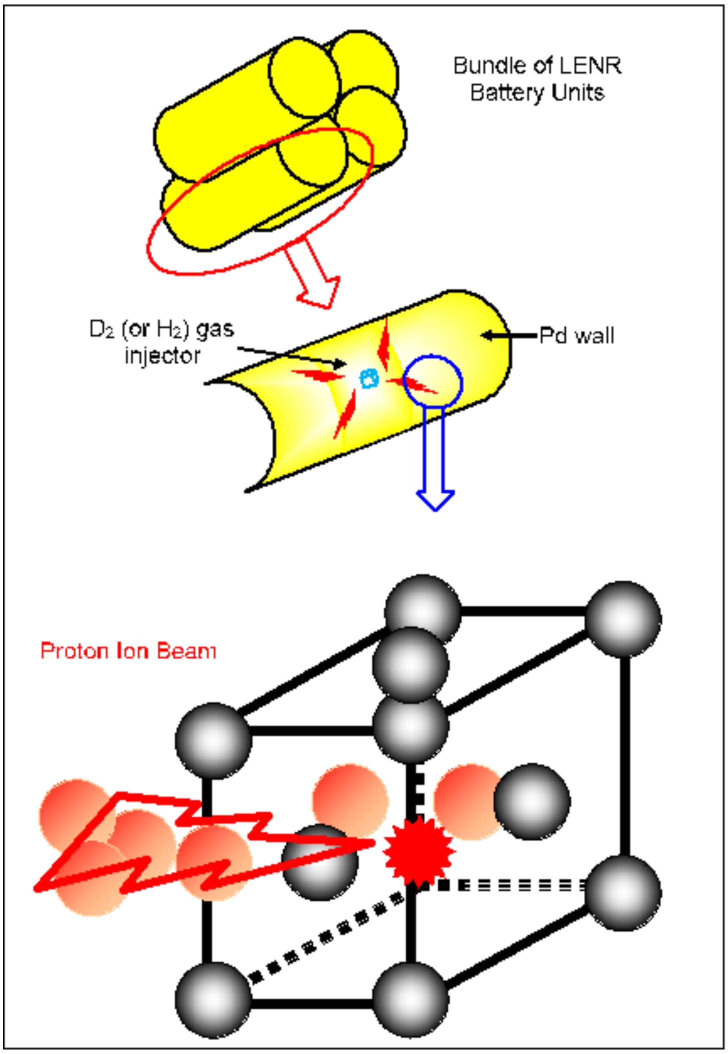

Figure 3. Configuration of the LENR in the palladium's FCC lattice.

$$\frac{d}{t} = \frac{1.5\,\mathrm{kW}}{0.5\,\mathrm{N}} = 3\,\mathrm{km/s}. \tag{2}$$

For the stacked form with 30 kW [25]:

$$\frac{d}{t} = \frac{30\,\mathrm{kW}}{0.5\,\mathrm{N}} = 60\,\mathrm{km/s}. \tag{3}$$

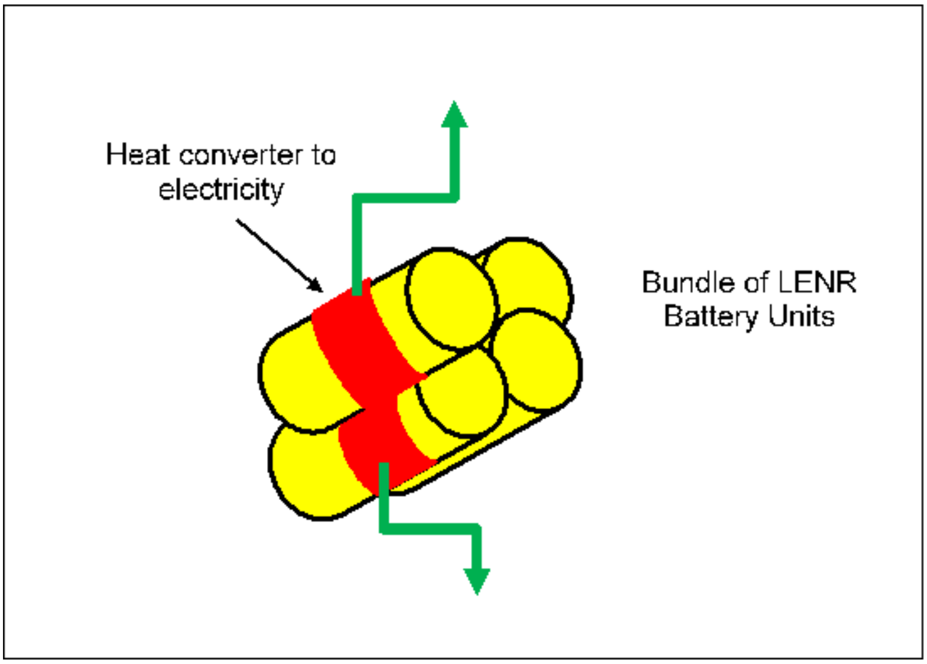

Figure 4. Electric production by the heat coils.

Hence, the period is reduced from 114.58 to 10.61 days:

$$\frac{114.58\,\mathrm{days}}{60\ \mathrm{km\ per\ s}/5.556\ \mathrm{km\ per\ s}} = 10.610\,\mathrm{days}. \tag{4}$$

In another relation, the thrust is [26]:

$$F = \dot{m}(v_2 - v_1), \tag{5}$$

where $\dot{m}$ is mass flow rate (kg/s), v_1 the inlet velocity, and v_2 is the outlet velocity. Assuming $v_1 = 0$ and using Eq. (1) we get:

$$P = (\dot{m}v_2)\,\frac{d}{t} = \dot{m}v_2^2. \tag{6}$$

Then,

$$\sqrt{\frac{P}{\dot{m}}} = v_2. \tag{7}$$

The velocity is obtained from the mass and power.

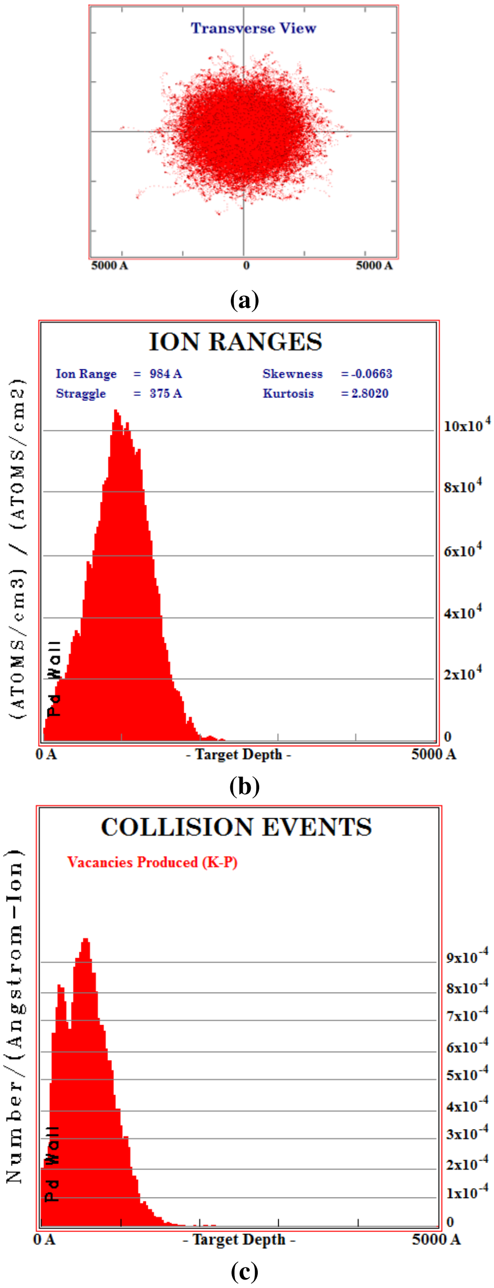

Figure 5. Graphs of proton and palladium interactions. (a) Transverse view of collisions, (b) ion ranges, and (c) collision events (20 keV).

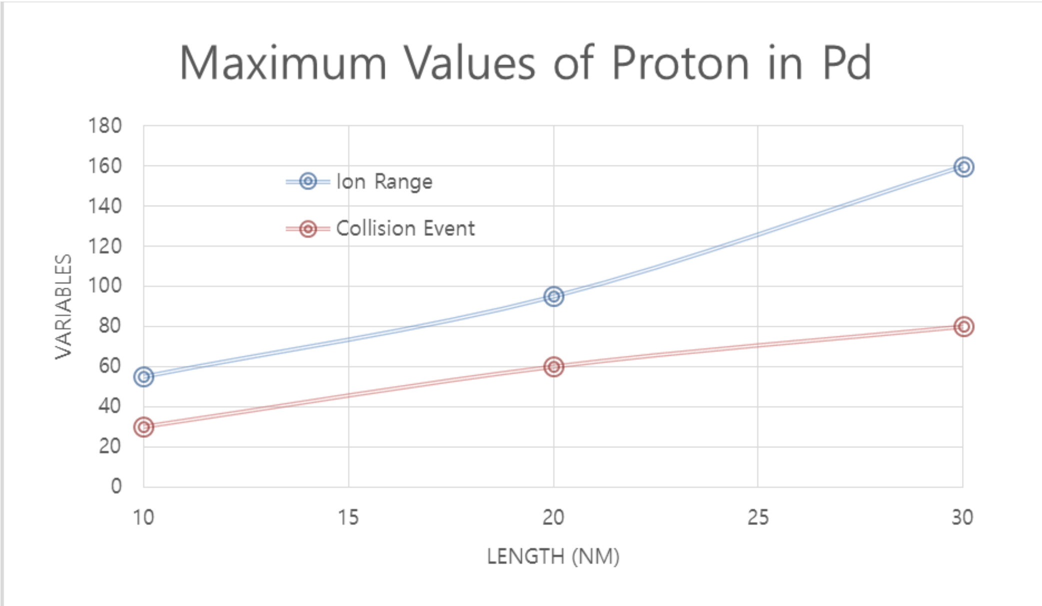

Figure 6. Maximum values of the proton in palladium as ion range and collision event.

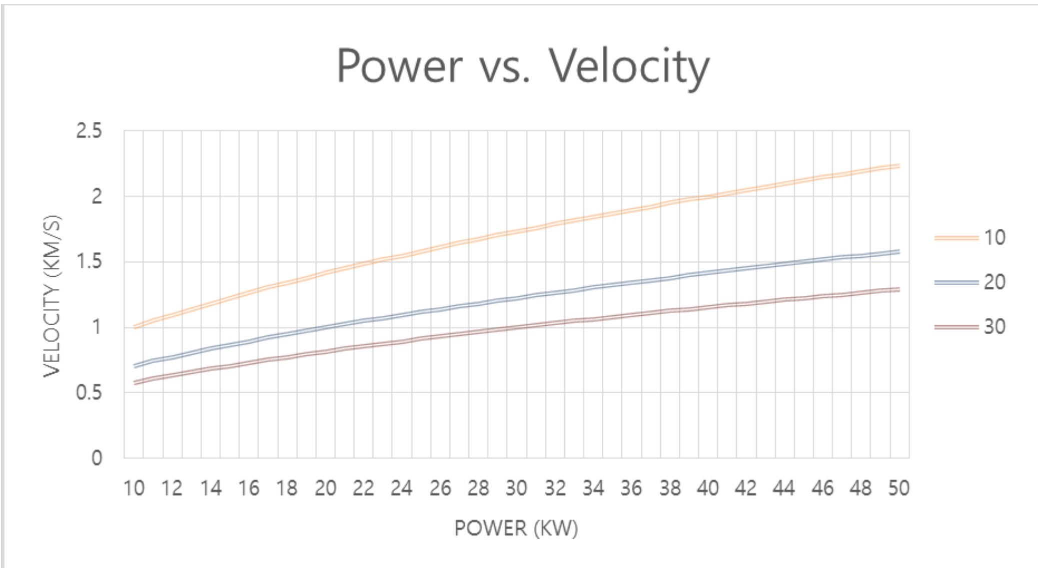

Figure 7. Relation of power and velocity in mass flow rate of 10, 20 and 30 kg/s.

3. Results

Simulations of the energy productions by LENR and the relevant velocity are estimated. Figure 6 is the maximum values of the proton in palladium as ion range and collision event. In Fig. 7, the relation of power and velocity in mass flow rate of 10, 20, and 30 kg/s is seen. The velocity of the rocket increases as the mass flow rate decreases in which the reasonable velocity of spacecraft could be obtained. Regarding the route of the spacecraft, the shortest route of the Martian trip could be selected to reduce the cost of travel.

4. Conclusions

The concept of building a human colony on another planet can be considered. Travel to the other planet is the first step, and then the next step is the building a city including industries like those on the Earth. Here are some findings in this work

- The new kind of power source is investigated.
- LENR might be applied to the spacecraft.
- The effect on a trip to Mars is analyzed.
- Given the large reduction in the duration of the trip, a successful colony on Mars could be established in near future.

An LENR propulsion system would be better, more economical and safer. Conventional power sources such as chemical or solar energy are difficult to make, and a trip using them is of long duration. Therefore, the LENR concept would be an important and attractive perspective energy source. An LENR powered rocket could be considered as one of the best power sources for a trip to Mars. Especially, heavy manned spacecraft systems need a compact and cheap system for the general facility where human and living spaces must be harmonized for the long duration of the trip. Reducing the duration of the trip is a very important matter for interplanetary travel. Especially, for traveling beyond Mars, the current power sources cannot be used for manned exploration because it would take too long.

Using VASIMR power, lunar and Martian missions and deep space travel may be possible at a greatly reduced cost. A high power density source will be needed for destinations or beyond Mars. For the crews, this will be needed to overcome problems such as health and psychological factors. Radiation in the outer parts of the solar system is an extreme hazard to humans. Spacecraft will need to be equipped with strong shielding material. New kinds of alloy metal might be developed for this purpose. For commercial traffic systems, safety is as important as economic factors would be. The radiation shielding will have to be installed on the spaceship surface. Furthermore, very long journeys might cause considerable psychological problems.

International cooperation in developing Martian rocket travel might be a better system than the current individual nations based Mars exploration strategy. If the United Nations (UN) were to take a major role in assembling the exploration systems, the construction would be done effectively. Considering the natural and social structure of the world, it is reasonable to prepare for a future colony on Mars for a new society and industry could be established. This colony might eventually initiate trade between Mars and Earth. The oars from Mars might be shipped to earth by specially designed spacecraft. Once this kind of industry is launched, social relations would be set up and a flourishing space industry would be born.

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