Construction of Sustainable Mars Logistics System 
and Feasibility Assessment

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The realization of a sustainable manned Mars stay mission cannot be achieved using conventional methods because the mission conditions, such as available resources, hazards and journey time, differ significantly from previous manned space missions. Therefore, construction of a sustainable interplanetary transportation network, a Mars-based resource management system and a hazard management system should be considered. In addition, new technologies such as a fully regenerative environmental control and life support system (ECLSS), Mars in-situ resource utilization (ISRU) and advanced propulsion systems (APS) are very important. Hence, the logistics system constructed in this research considers not only mission requirements, such as human transfer time and stay time, but also available technology levels and required safety levels. As a result of the simulation of the logistics system, the required initial mass in low earth orbits (IMLEO) to operate the Mars base is approximately 370 t/year with current technologies. However, the IMLEO decreases to approximately 90–140 t/year using a nuclear light bulb engine or water extraction on Mars. In addition, to further minimize IMLEO, it is also suggested that the development of advanced technologies can lead to a change in the optimal interplanetary transportation method from the cycler transportation to stop-over transportation.

Key Words: Manned Space Mission, Space Logistics, Mars Exploration

1. Introduction

Manned space missions are superior to unmanned missions with respect to readiness and flexibility although they are much more expensive and require many more resources than unmanned missions. Therefore, manned Mars missions are preferred and have been planned several times. Furthermore, continuous manned Mars explorations are desired for more advanced missions. The sustainable manned Mars missions using a permanent outpost not only realize continuous and large-area exploration but also become the milestone of manned space activity. This is because the Mars outpost has the probability of physical independence considering the utilization of Mars resources. Furthermore, the consideration of a Mars logistics system to realize the sustainable Mars stay missions is required.

However, research and experience regarding the operations of extraterrestrial outposts are insufficient to realize sustainable manned Mars missions at present. The International Space Station (ISS) and the Mir space station, the only two experiences of sustainable manned space missions, were launched in low earth orbits (LEOs). In other cases, the duration of the Apollo mission, which provided the only experience of an extraterrestrial manned space mission, was only 10 days.

These missions are too near or short when compared with an actual sustainable Mars mission. Above all, the most significant difference between these missions and a sustainable Mars mission is the difficulty associated with journeying from Earth. The transfer time and change in velocity (delta-V) therefore increase significantly when compared with the values required for LEOs or lunar missions, and the launch window also become narrower. This implies a drastic increase of the required initial mass in LEO (IMLEO).

Another problem that arises when planning a long journey is the increased mission risk. In the case of the ISS, the crew can escape from the ISS via a Soyuz spacecraft in the event of a hazard. With Apollo, a contingency plan would have allowed escape to Earth in only approximately 3 days. In comparison to these missions, the journey for the Mars mission would increase requiring approximately 200 days to return to Earth. In addition, the launch window is narrow because of the relative motion of Earth and Mars. As a result, escape would not be possible at all times with the Mars outpost. That is, in the event of a serious hazard, an emergency return plan, such as that employed in conventional manned space missions, would not be effective.

Extensive research has been done to overcome these problems in order to allow progress toward manned space missions. Development of transfer orbit is important to reduce the transportation time of delta-V. The cycler trajectory can reduce the delta-V of an interplanetary spacecraft in continuous transportation.1,2) This advantage is achieved by the usage of interplanetary transfer spacecraft as a sustainable base. Although this method demands high initial launch mass, total mass can be saved in the long term because the mass needed for each transit decreases. However, most of the previous research has focused on trajectory optimiza-
tion. Hence, studies that consider the efficiency of cycler transportation from the viewpoint of configuring an entire system for sustainable Mars missions are insufficient.

There has also been much research on advanced technologies such as the advanced propulsion system (APS), fully regenerative environmental control and life support system (ECLSS) and in-situ resource utilization (ISRU).\textsuperscript{3–5} In addition, the effects of these technologies have been studied.\textsuperscript{6,7} These studies suggest that advanced technologies can reduce the resource consumption of each subsystem. However, studies that compare the efficiencies of these technologies are few. The cost to develop the technologies and their effects should be compared and evaluated to determine the priority that should be given to them.

Finally, hazards in a sustainable manned Mars mission and the survivability of the crew have not been sufficiently investigated. Table 1 shows categories of risks in manned space missions. In conventional manned space missions, risks that cause the loss of crew are mainly considered. To counter these risks, the introduction of redundancies in subsystems and improved reliability of each component have been considered. In addition, an emergency return spacecraft is included as a final safety device. Therefore, countermeasures against other types of risks are not necessary and their priorities are low in previous missions. However, the lack of resources must be considered in a manned Mars mission because emergency return and emergency transportation options would not be available on a Mars outpost. However, this research has not yet been conducted.

Therefore, in this study, a logistics system for a sustainable manned Mars mission is constructed to address the problems such as large delta-V and long periods of isolation described above. This logistics system comprises an interplanetary transportation network and resource management in the Mars outpost. Via an optimization calculation that uses a logistics system, the configuration of a suitable Mars stay system has been identified. Optimization is performed to minimize the total IMLEO of the logistics system installation. In particular, the effects of operational demands such as transportation time, stay time, technology level and safety level are considered.

\section{Structure of the Mars Logistics System Model}

In this study, it is assumed that the manned Mars mission requires a sustainable stay on the Mars outpost on a rotation schedule. In this section, the basic structure and mass estimation of the logistics system such as the interplanetary trajectories, propulsion system, ECLSS system and hazard management are discussed. The elements of the logistics system are separated into two subsystems: the transportation system that handles the transportation between LEO and the Mars surface, and the base system that handles resource management on the Mars base. Details of both the subsystems are also described in this section.

\subsection{Transportation subsystem model}

The main part of the transportation subsystem is interplanetary transportation. Direct transportation and stop-over transportation are the traditional trajectories used for Earth–Mars transportation. These are one-way or round-trip transportation using two-impulse transfer. In addition, cycler transportation has been considered for Earth–Mars transportation. These trajectories are considered in the transportation subsystem. Another important element of this subsystem is emergency transportation. In this study, rescue transportation in an emergency is considered in addition to a traditional emergency return. The effects of these methods are compared when discussing various scenarios.

Figure 2 shows the interplanetary trajectories considered in this research. The direct trajectory is the most basic trajectory and includes the Hohmann trajectory. This trajectory is used for a two-impulse transfer. The spacecraft can reduce delta-V using an aerobrake upon arrival at Mars. The stop-over trajectory has the same features as the direct trajectory, but is suitable for a round-trip because the spacecraft can remain in a low Mars orbit (LMO). In contrast, the space-

| Range       | Short term | Medium term | Long term |
|-------------|------------|-------------|-----------|
| Risks       | Loss of crew | Delay of repair | Lack of resources |
| Measures    | Hazard matrix | MTBF | MTBF |
|             | FTA | MTTR | Failure rate |
| Failure tolerance | Availability | Compatible parts |
| DFMR        | Resource stock | Rescue spacecraft |

Fig. 1. Image of the logistics system of a sustainable manned Mars outpost.

Fig. 2. Transportation trajectories between Earth and Mars.
is constructed as follows. The combination of trajectories and spacecrafts. The combination of trajectories both cargo and crew is therefore achieved using different methods. The transportation of Earth–Mars transportation.

A cycler spacecraft can therefore be used as a staging base of an ongoing transfer of crews and resources. A cycler spacecraft is used as the rescue spacecraft and it rushes to Mars during an emergency in the rescue from the cycler case. Thus, additional resources must be stocked beforehand in the cycler spacecraft.

The standard conditions of transportation systems for the Mars stay are shown in Table 3. In this study, a continuous transportation cycle should therefore be modeled to enable an ongoing transfer of crews and resources.

In addition, a mission date and duration are not fixed because the objective of this study is to understand the general trends associated with sustainable manned Mars missions. Two assumptions are therefore introduced for simplification. First, the eccentricity of the trajectory of Earth and Mars is 0. Second, a single cycle for crew rotation and resource transportation is equal to the synodic period of Earth and Mars.

As shown in Table 3, three types of spacecraft are used for Earth–Mars transportation: the cycler transit, the interplanetary vehicle and the Mars lander. The cycler transit is needed only for cycler transportation and the unmanned vehicle is used for cargo transfer. Furthermore, regenerative ECLSS is used in the interplanetary vehicle because of the long transfer time. However, non-regenerative ECLSS is used in other vehicles because they only need to be used for a few days. The mass estimation of the ECLSS is based on the advanced life support system (ALS) model that was developed by NASA. Details of the ECLSS model are described below.

The structure mass of the crew habitation module is assumed to be 100 kg/m³ and is based on Mir and ISS data. The volume of living space for each crew-member in past manned spacecraft is shown in Table 4. In this study, we used 18.41 m³/person for the interplanetary spacecraft and 0.88 m³/person for other vehicles. These volumes are selected with reference to their stay time.

### Table 2. Stay plan (/synodic period).

|         | Stop-over [days] | Cycler [days] |
|---------|------------------|---------------|
| Out-bound | 200              | 145           |
| Stay     | 520              | 733           |
| In-bound | 200              | 145           |
| Total    | 920              | 1,023         |

### Table 3. Spacecraft and crew transportation phase.

|                     | Stop-over | Cycler |
|---------------------|-----------|--------|
| LEO–Cycler          | N/A       | Cycler Transit |
| Inter planetary     | Inter planetary vehicle | Inter planetary vehicle |
| Cycler–LMO          | N/A       | Cycler transit |
| LMO–Mars            | Mars lander | Mars lander |

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Fig. 3. Trajectories for emergency transportation.

craft re-enters Mars in a direct transfer. The cycler trajectory is suitable for continuous transportation because the spacecraft can continuously rendezvous with both Earth and Mars without consuming fuel via a repetitive flyby. A cycler spacecraft can therefore be used as a staging base of Earth–Mars transportation.

In this study, multiple trajectories are combined to effectively transfer crews and resources. The transportation of both cargo and crew is therefore achieved using different trajectories and spacecrafts. The combination of trajectories is constructed as follows.

(a) Stop-over type: Cargo: Direct + Human: Stop-over
(b) Cycler type: Cargo: Direct + Human: Cycler

The Hohmann trajectory is used for cargo transfer to minimize delta-V. However, a stop-over or cycler trajectory is used for crew transportation because a return trip is required. These trajectories are designed using the patched-conic method. The standard stay plan is shown in Table 2. Transportation times of both trajectories are set at less than 200 days.

A method for emergencies such as rescue transportation is considered for each transportation method as a countermeasure against the limited resources. Figure 3 shows the methods that are considered for emergency transportation and details of each method are described as follows.

(a) Endurance: Emergency transportation is not planned
(b) Emergency return: Crews return to Earth immediately
(c) Rescue from Earth: Rescue spacecraft is launched from Earth
(d) Rescue from cycler: Cycler spacecraft rushes to Mars

In the endurance case, emergency transportation is not performed even in an emergency. Therefore, the astronauts must await the scheduled return date. Of course, enough resources must be stocked on the Mars base beforehand. The emergency return is the traditional method used to deal with short-term hazards. However, the transportation time and delta-V for interplanetary transportation differ significantly from moment to moment because of the relative movement of Earth and Mars. Therefore, additional propellant and life resources must be stocked to ensure survival even if an accident occurs in the worst-case transportation scenario. In the case of rescue from Earth, the transportation plan is the opposite of the traditional return method. In the case of an emergency, additional resources are transferred to the Mars outpost to enable survival until the crew returns to Earth using the scheduled return vehicle. Therefore, this method also has the problem of periodical change in transportation time and delta-V. The case of rescue from the cycler is similar to that of rescue from Earth, the only difference being in their departure points. A cycler spacecraft is used as the rescue spacecraft and it rushes to Mars during an emergency in the rescue from the cycler case. Thus, additional resources must be stocked beforehand in the cycler spacecraft.

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The improvement of the propulsion system is very important to reduce the IMLEO. A high-energy propulsion system that can increase $I_{sp}$ has therefore been researched. In particular, a nuclear engine is expected because it will achieve high $I_{sp}$ and high thrust. In this study, these APS are considered as representative examples to evaluate their effect. Specifications of these propulsion systems are listed in Table 5. The calculation of the propulsion system mass is simplified by the linear scaling of these engines.

### 2.2. Mars base subsystem model

The ECLSS is the most important system for manned space missions because crews cannot survive without it. In addition, the ECLSS may have the largest mass of all the Mars base systems. It is predicted that on Mars, the resource consumption of an astronaut would be approximately 30 kg/person-day.\(^3\) The resource consumption for the Mars mission would be greater than that for previous manned space missions because water is needed for both drinking and performing other daily activities during a long-term mission. The regeneration of resources by ECLSS is expected to reduce the total resource consumption because it can reduce IMLEO. Figure 4 shows the block diagram of atmospheric management for the ISS. In the ISS, half of the $H_2$ is consumed during one cycle because $CH_4$ is released into space. The regenerative ratio is therefore set to be less than 50%.

It is important to increase the regeneration ratio of ECLSS in order to reduce the resource consumption and IMLEO. Many studies therefore aim to develop advanced versions of ECLSS. For example, there has been a study to investigate a method for recovering hydrogen from $CH_4$, which is released, in order to increase the oxygen regeneration ratio. Vapor phase catalytic ammonia removal (VPCAR) is another method used to decrease the filter consumption and increase the water regeneration ratio.\(^{12}\) These advanced ECLSS methods will increase the regeneration ratio of life resources such as oxygen and water.

Furthermore, ISRU is also expected to significantly reduce the total IMLEO because the propellant and life resources that are transferred from Earth would be sourced on Mars using ISRU. However, the efficiency of ISRU depends on the availability and accessibility of Mars resources such as soil, ice and air. However, the quantity of these resources and the form in which they exist are not yet known. Therefore, several types of ISRU methods are assumed in this study to consider various scenarios. An example block diagram of a fully expanded ISRU and ECLSS plant is shown in Fig. 5.

The equivalent system mass (ESM) method is commonly used to perform mass estimation of ECLSS. In this study, an ALS model that is a part of the ESM parameter list is used to calculate the ECLSS and ISRU system mass.\(^3\) The configuration of the ECLSS and ISRU system is selected by considering the regeneration ratio and ISRU capacity. Examples of ESM parameters and mass are shown in Table 6. The table also shows the mass estimation of the ECLSS shown in Fig. 4.

Countermeasures against hazards that limit the available resources are also considered for the Mars base system. However, this type of hazard assumes that the resource regeneration cycle has failed. Effective methods are therefore very limited on the Mars base itself. The simplest solution to this problem is to ensure that there is sufficient amount of resources on the Mars base. This approach is considered in this study. In an emergency, crews would therefore be required to survive until rescued or until they return using resources stored on the Mars base. A more mass-effective resource management or hazard management method...
should therefore be developed to reduce the total IMLEO. However, this estimation can suggest an upper limit for such resource management in emergency scenarios from the perspective of mass. The result of this study can therefore be used as a benchmark for various hazard management methods. The required mass of stored resources is calculated from the following formula.

\[ M_{stock} = (m_s \times \text{mass consumption} + m_w \times \text{water consumption} + m_f \times \text{food consumption}) \times N_c \times T_{emergency} \]

To estimate mass of stock resources \( M_{stock} \), oxygen consumption \( m_s \), water consumption \( m_w \) and food consumption \( m_f \) should be considered. These resources are needed for each crew. Thus, the number of crew members \( N_c \) is considered. Finally, resources are stocked to ensure survival even in the worst case. In this study, the worst case is the case which needs the longest time before crews are rescued \( (T_{emergency}) \).

2.3. Integration of the Mars logistics system

The total is calculated by integrating the transportation subsystem and Mars base subsystem. The flow of this calculation is shown in Fig. 6. At first, the specifics of spacecraft such as delta-V of interplanetary spacecraft and emergency transportation are set. Then, the trajectory of interplanetary transportation is calculated using the patched-conic method. In this section, transportation and the Mars stay schedule is fixed. Next, the resource mass of ECLSS is calculated using the Mars base subsystem. The calculation method of life resources and resupply mass are described in section 2.2. Then, the propulsion system mass is calculated. The parameters used in this calculation are mentioned in section 2.1 as the transportation subsystem. Lastly, total IMLEO is calculated as the sum of all these masses.

To minimize the total IMLEO, the specification is adjusted using a genetic algorithm. In addition, there are some constitution conditions such as the minimum stay time and maximum transportation time.

3. Mars Logistics System in the Standard Case

Various technological scenarios should be considered and compared to evaluate the effect of future technology trends. However, consideration in the present technical context is meaningful as a starting point of this analysis. Table 7 shows the standard condition used in this study, which is based on present technological realities. In addition, the size of the crew is assumed to be six. Our calculations assume that the maximum crew transportation time is set to 200 days, which is based on previous research. For comparison purposes, cases involving interplanetary transportation such as stop-over and cycler transportation are calculated using the standard conditions. The objective of this optimization calculation of the Mars logistics system is to minimize the total IMLEO on the initial journey. Genetic algorithms are used for optimization.

The optimized mission plans for the stop-over and cycler transportation are shown in Table 8 and Figs. 7 and 8. In the stop-over case, the trip time is the same as in the constrained maximum time. The minimum IMLEO is therefore achieved by minimizing the delta-V of the crew transportation vehicle and the propulsion system mass. In contrast, the trip time for the cycler transportation is shorter than that in the stop-over case. The reason for this is that the degree of freedom of the cycler trajectory is low because it is restricted by the orbital motion of Earth and Mars. Under the conditions of this study, only one trajectory is available for cycler transportation.

The IMLEO for this calculation is shown in Tables 9 and 10. Table 9 shows the mass needed for installation of the Mars base and Table 10 shows the mass needed for maintenance of the Mars base. As shown in Figs. 7 and 8, the period for the transportation of additional supplies is 2.14 years. This period is the same as the synodic period of Earth and Mars. These results show that cycler transportation can realize a sustainable manned Mars mission with a smaller IMLEO when compared with that of the stop-over case. In particular, the difference in the IMLEO for transporting new supplies is effective for continuous transportation.
This result can be described from the perspective of the material that flows for interplanetary transportation. In the stop-over case, life resources and propellant for the return trip must be transported to Mars. In contrast, in the cycler transportation case, the interplanetary spacecraft can be resupplied when it passes near Earth using transit spacecraft. Although cycler transportation has disadvantages when compared with stop-over transportation, such as multiple interplanetary spacecraft and high delta-V of the transit spacecraft, this advantage is more effective in standard conditions.

4. Mass Penalty of Hazard Management System

As a countermeasure against risks that can cause a lack of resources, four types of hazard management methods are proposed. In this section, the IMLEO associated with these methods are compared to evaluate each method. Then, the mass penalty of hazard management is discussed.

First, Figs. 9 and 10 compare the IMLEO of each hazard management method. These results show the inefficiency of the emergency transportation methods. In particular, the emergency return method and cycler rescue method both
require a high initial IMLEO, because the propulsion system and the life resources for emergency transportation must be provided beforehand on the Mars base or the cycler spacecraft. For the Earth rescue scenario, rescue materials do not have to be provided beforehand because the rescue spacecraft will be launched from Earth. From the viewpoint of risk management, the mass of the rescue spacecraft should therefore be considered when determining the IMLEO in proportion to the failure rate of the resource regeneration cycle. However, the failure rate of the ECLSS cycle cannot be estimated because of the lack of basic statistical data regarding the ECLSS. In this calculation, the failure rate is therefore assumed to be 0.1 for a brief evaluation. Additional calculations suggest that Earth rescue is not effective to reduce IMLEO even if the failure rate becomes low. This is because a stock of resources is needed on the Mars base while the crew waits for the rescue spacecraft. These results suggest that the endurance case is the method that can reduce the total IMLEO.

It is also clear that the endurance method as a hazard management method increases the total IMLEO compared to the case without the hazard management method. Therefore, the effect of the mass penalty of the hazard management method should be considered in evaluations.

The effect of the mass penalty of resource stock was considered in a previous study. This study can explain part of the tendencies of mass penalty in this study. The increase of IMLEO occurs for both the initial transportation and the resupply transportation because resources should be stocked in the interplanetary transportation vehicle too in order to allow survival during hazards in interplanetary transportation. As a result of these resources, additional propellant is needed even with the resupply transportation.

In contrast, the results of the analysis of this study show that although this phenomenon also occurs in the cycler transportation case, the mass of the interplanetary transportation vehicles does not increase in this case because they do not need additional delta-V. Furthermore, the cycler transportation is more tolerable than in the stop-over case from the point of view of the mass penalty. In other words, the cycler method is more suitable for resource stock.

5. Effect of Technology Development

Finally, the effects of advanced technologies are evaluated. In this study, the fully regenerative life support system on Mars, ISRU and the high-energy propulsion system are considered to be advanced technologies. Details of these cases are shown in Table 11. Case 1 represents the same condition as the standard condition considered in the previous discussion.

Figure 11 shows the calculation results. Although the fully regenerative resource cycle can reduce the resupply IMLEO, the initial IMLEO decreases slightly. This is because a certain amount of resources must first be stocked on the Mars base and interplanetary spacecraft to enable survival during hazards. ISRU is more effective because both resupply resources and the initial resources can be obtained on Mars. In addition, the store of propellant for the return trip is important to reduce IMLEO because approximately 260 t of propellant is needed for the return trip. Furthermore, water generated by ISRU can lead to further savings.

Under standard conditions, cycler transportation can save the IMLEO effectively. This is because the delta-V of the interplanetary transportation vehicle can be reduced in the long term for the reason mentioned above. However, ISRU can decrease the propulsion mass that is to be transferred from Earth. Stop-over transportation is therefore more effec-

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Table 11. Tuning parameters for the Mars logistics system.

| Case No | Resource regeneration rate [%] | ISRU (for pre-deploy) | ISRU (for return propulsion) | Propulsion system [s] |
|---------|--------------------------------|------------------------|-----------------------------|-----------------------|
| 1       | O₂ 50 100 100 100 50 50         | O₂ No No Yes Yes No No | O₂ No No Yes Yes No No   |
| 2       | H₂O 50 100 100 100 50 50        | H₂O No No Yes Yes No No | H₂O No No Yes Yes No No   |
| 3       | ISRU (for pre-deploy)           | ISRU (for return propulsion) |
| 4       | Isp 466 466 466 466 850 2,700   | Isp 466 466 466 466 850 2,700 |
tive under ISRU conditions. Advancements of the propulsion system that lead to a decrease in the propellant mass would have the same effect as ISRU.

6. Conclusion

In this study, we constructed a logistics system for a sustainable manned Mars mission. Then, the effects of hazard management method and advanced technology were evaluated using this logistics system. In this evaluation, the IMLEO was used as an evaluation index. The conclusions of this research are as follows.

The cycler transportation can save approximately 10–20% of IMLEO compared to the stop-over method under standard conditions. This is caused by differences in propellant mass. Furthermore, the cycler method is effective with current technologies. However, the IMLEO required to operate a Mars base is approximately 3701/year. This is too heavy for the present launch system. This result suggests that advanced technology should be developed.

When compared to emergency return or rescue transportation, resource stock is the best method as a countermeasure against risks that may lead to a lack of resources, from the perspective of the IMLEO. In addition, it is suggested that the cycler method is more suitable for this method.

Advances in technological developments are expected to further reduce IMLEO. However, the IMLEO would decrease to approximately 90–1401/year when using a nuclear light bulb engine or water extraction on Mars. In addition, this effect is larger for stop-over transportation than for cycler transportation. Therefore, using a high-energy propulsion system or Mars ISRU, the IMLEO for stop-over transportation becomes lower than that for cycler transportation.

References

1) McConaghy, T. T., Longuski, J. M. and Byrnes, D. V.: Analysis of a Class of Earth-Mars Cycler Trajectories, J. Spacecraft Rockets, 41 (2004), pp. 622–628.
2) Byrnes, D. V., Longuski, J. M. and Aldrin, B.: Cycler Orbit between Earth and Mars, J. Spacecraft Rockets, 30 (1993), pp. 334–336.
3) Hanford, A. J.: Advanced Life Support Baseline Values and Assumptions Document, NASA/CR-2004-208941, 2004.
4) Odegard, R., Keller, J. and Landis, G. A.: Oxygen Generation and Storage for a Mars Sample Return Mission Utilizing In-situ Resources, AIAA SPACE 2007 Conference and Exposition, AIAA Paper 2007-6066, 2007.
5) Zubrin, R., Mascatello, T. and Birnbaum, B.: Progress in Mars ISRU Technology, AIAA Aerospace Sciences Meeting and Exhibit 40th, AIAA Paper 2002-0461, 2002.
6) Drake, B. U.: Reference Mission Version 3.0 Addendum to the Human Exploration of Mars: The Reference Mission of the NASA Mars Exploration Study Team, NASA/SP-1998-6107, 1998.
7) Drake, B. G.: Human Exploration of Mars Design Reference Architecture 5.0, JSC/NASA, 2008.
8) Larson, W. J. and Pranke, L. K.: Human Spaceflight, McGraw Hill, New York, 1999.
9) Wertz, J. R. and Larson, W. J.: Space Mission Analysis and Design, 3rd Ed., Microcosm Press and Kluwer Academic Publishers, El Segundo, 1999.
10) Bruno, C., Lawrence, T. A., Fearn, D. G., Auweter-Kurtz, M., Kurtz, H. and Lenard, R. X.: IAA Position Paper on Nuclear Power and Propulsion, 57th International Astronautical Congress, IAC-06-D2.8/ C3.5/C4.701, 2006.
11) Latham, T. and Joyner II, C. R.: Summary of Nuclear Light Bulb Development Status, Conference on Advanced SEI Technologies, AIAA Paper 91-3512, 1991.
12) Tomes, K., Long, D., Carter, L. and Flynn, M.: Assessment of the Vapor Phase Catalytic Ammonia Removal (VPCAR) Technology at the MSFC ECLS Test Facility, NASA 2007-01-3036, 2007.
13) Akiyama, Y. and Inatani, Y.: Construction of Logistics Network for Future Sustainable Manned Mars Exploration to Reduce Logistics Risk, 49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition, AIAA Paper 2011-331, 2011.