PROPOSAL FOR EXTENSION OF PLANETARY PROTECTION POLICY TO AVOID BIOLOGICAL CONTAMINATION OF MARS WITH MANNED EXPLORATION SUPPORTED BY SPACE AGRICULTURE

Hirofumi Hashimoto[1)], Junpei Koike[2)], Masamichi Yamashita[3)], Tairo Oshima[4)] and Space Agriculture Saloon[5)]

[1] Graduate School of Systems and Information Engineering, University of Tsukuba, Tsukuba, Ibaraki 305-8573, Japan
Phone&Fax: +81-29-853-619 E-mail: hhashi@kz.tsukuba.ac.jp
[2]Tokyo Institute of Technology, Nagatsuta, Midori, Yokohama 226-8501, Japan
[3] Institute of Space and Astronautical Science /JAXA Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan
[4] Institute of Environmental Microbiology, Kyowa Kako Co., Ltd Tadao, Machida, Tokyo 194-0035, Japan
[5] URL: http://surc.isas.ac.jp/space_agriculture/, E-mail: yamashita@surc.isas.jaxa.jp

(Received 31 October, 2005 Accepted 24 April, 2006)

(Abstract)

The major purpose of manned exploration on Mars is to find extraterrestrial life in either extant or extinct forms. Space agriculture is necessary to carry out such manned exploration on Mars in the long term, as it is very reasonable method to provide human beings with foods and to recycle materials. A conceptual design of space agriculture for habitation on Mars is developed by Space Agriculture Saloon. We design confined greenhouse dome to create living environment on Mars based on the constraints from planetary protection together with humanistic requirements and wellness. Hyper-thermophilic aerobic composting microbial ecology is proposed to process metabolic wastes and inedible biomass for recycling materials. A great number of bacteria were brought by human beings from the Earth to Mars. It is eventually a keen issue whether terrestrial life forms brought into Mars could prevent the forward contamination on exploration sites or not. When we plan unmanned and manned exploration of Mars, whole scenario should be carefully planned based on the requirements of astrobiology. We should avoid contamination of Mars before we could find life forms exist and well characterized, or confirm that life have never evolved on Mars. We propose an extension of the planetary protection policy, which has been discussed and issued by COSPAR and IAU at scoping the horizon of manned missions. Any planning of space agriculture or manned exploration should meet such international regulation defined and revised for the new scope.

(Key words) Space agriculture, Planetary protection, Mars, Manned exploration, Hyper-thermophilic bacteria

Introduction

Exploration of extraterrestrial life is associated with one of most important subjects in modern science. Mars is one of promising and unique planetary bodies for this kind of exploration, and may be the body on which human can explore within a few decades. Space agriculture is necessary to carry out such manned exploration on Mars in the long term, as it is very reasonable method to provide human beings with foods and to recycle materials [1]. Simultaneously, extension of the planetary protection should be considered and proposed to avoid the biological contamination by space agriculture.

Space agriculture supports human life in the extraterrestrial outpost by the function of biological and ecological components. Space agriculture might be a unique engineering solution to manage and control materials circulation and energy flow in the closed system to sustain manned activity safely and confidently on distant extraterrestrial bodies. We design greenhouse dome to create living environment on Mars. The greenhouse dome is a pressurized structure to provide total gas pressure at a feasible range for terrestrial living organisms transplanted to space agricultural ecology. Such dome provides environment that meet the humanistic requirements and wellness, and also confinement of those organisms in it to prevent contamination of exploring sites on Mars. Utilization of hyper-thermophilic aerobic composting bacteria in the greenhouse dome is proposed to recycle the biomass in the closed environment [2]. A great number of bacteria were brought by human beings from the Earth to Mars. It is eventually a keen issue whether terrestrial life forms brought into Mars could prevent the forward contamination on exploration sites or not. When we develop manned exploration scenario on extraterrestrial bodies, the planetary protection should be considered as a top-prioritized item, since it deeply associates with mission objective itself. Advantage of having men and women on site of exploration is evident in many ways, and learned from missions conducted in the past.

On the other hand, less risk of contamination is secured by unmanned missions at its limited capability of exploration. Considering on such pros and cons, whole sequence of unmanned and manned exploration should be carefully developed based on the requirements of astrobiology. We should avoid contamination of Mars before we could find and characterize life forms either exist or extant, or confirm that life have never evolved on Mars. At the present time, though planetary protection policy, having been discussed and managed by COSPAR [3] and IAU exists, it deals with no more than Earth-Moon travel in manned missions or sample return in Mars missions. This planetary protection policy has not dealt with manned exploration on Mars yet. Therefore, we strongly propose that the planetary protection policy should be further extended at scoping the horizon of manned missions.

Scientific Objective and Planetary Protection

Major scientific objective is the exploration of extraterrestrial life (or its absence) to know the universal principle of life and its origin and the research of the comparative planetology to understand the origin and the history of the solar system and its planets. In case Martian sample return missions will be conducted in prior to manned mission to Mars, it will give a chance to know Martian life, if any, will be carried from Mars to the Earth. During this phase of exploration, traditional process of planetary protection could be applied. It aims that exploring bodies is not contaminated by terrestrial organisms and life associated substances, and terrestrial life is protected from exotic organisms or substances. Procedures applied are named planetary quarantine and reverse-quarantine depending on the direction of possible contamination.

Development of Planetary Protection Policy

Present COSPAR planetary protection policy is applied to unmanned missions of flyby, orbiter, probe, and lander to Mars or Europa, and manned missions to moon. These are required to be further developed, revised and adapted to new horizon of planetary exploration now we envision. Key issues are summarized as below.

(1) When we develop a manned exploration scenario on extraterrestrial bodies, the planetary protection should be considered as the most critical item at starting planning.

(2) Whole sequence of unmanned and manned exploration should be carefully planned based on the requirements of astrobiology that is the core of science at space exploration.

(3) We should avoid contamination of Mars before we could find life forms exist and well characterized, or confirm that life have never evolved on Mars. Sequence of exploration is arrayed after examining the scientific scenario and technical feasibility. When such scenario is developed, protection policy should be stated and defined for each phase of Mars exploration, following unmanned missions, sample return phase, manned exploration with space agriculture, and terraforming [4].

1. Unmanned Exploration

In prior to manned mission to Mars, following survey should be conducted to secure success of manned missions. At first, it is necessary for us to photograph images detailed the surface and to observe the weather on Mars. By geological survey of stratigraphy, diastrophism, atmosphere, and water, thermal history of Mars should be comprehended. Secondly, we have to select the site to conduct search of Martian life and unmanned survey of life and fossil. In order to assess the contamination risk, the chance of survival of terrestrial organisms using model living species on Mars should be verified. In engineering matter, use of on site resource to support manned exploration should be assessed and life support system function on Mars should be verified.

During this phase of exploration, the protection policy and practical measure required is sterilization of spacecraft based on the well established criterion defined by COSPAR.

2. Sample Return

In round trips of space crafts to Mars and bringing Martian sample back, protection issues are as follows. Sterilization of spacecraft following the established criterion to avoid the forward contamination and cataloguing of contaminants should be conducted. We have to consider quarantine protocol of spacecraft and the sample applied at their entry to Earth. Facility for analysis and inspection of the sample without terrestrial contamination should be established.

3. Manned Mars Base

We should conduct the trade-off study between risk of contamination and advantage of manned mission with naked eyes of scientists on the field of exploration. Science (astrobiology) should keep the top priority to determine Go / No Go decision for manned Mars activities, if irreversible contamination is expected with a certain probability.

Protection measures to prevent forward contamination are as follows. Physical isolation between the manned base and the astrobiology survey sites is important. Risk of microbial contamination and its spreading speed over exploring site should be assessed. Effective sterilization method and process to clean the outer surface of Mars manned base should be considered. Cleaning of matter taking out from Mars base including outer surface of spacesuit should be conducted. We have to catalogue possible contaminants that will be brought into living section of manned base (microbial or organics).

In addition to protection of Mars environment, we should prevent contamination of living section from harmful exotic organisms or substances as follows. We should develop protocol to utilize Martian resource (regolith, rock, ice) for space agriculture in safe. Isolation of sample and matter taking into Mars base from outside for quarantine is important. Establish criterion of inspection and develop facility and technique for analysis and inspection of life support resources and science sample should be conducted.

As a similar example of protection, Antarctic environment is protected for scientific researches. We can learn from its protocol. Waste of disposal especially at its shore zone is prohibited. Off-limit areas for non-science visitors are set up. International science forum for discussing measures of avoiding contamination is provided.

The quarantine conducted during the Apollo era is served as another reference for our consideration.

4. Terraforming

In the future, unless Martian life could be well characterized scientifically, either in live or dead, we should not step forward to interact and modify Mars, such as terraforming which converts the red planet to green in the whole of Mars.

In these missions, present COSPAR planetary protection policy could deal with unmanned exploration and sample return. But mission of manned Mars base and terraforming could not be controlled by present COSPAR planetary protection policy. It is necessary for us to extend planetary protection policy. Therefore, we strongly propose that the planetary protection policy should be further extended at scoping the horizon of manned missions.

Conclusion

We propose that planetary protection policy, having been discussed at COSPAR and IAU, should be further extended to meet the new situation at scoping the horizon of manned missions to Mars, as discussed in this paper. Such action should be taken well in advance before planning the future missions, regardless to unmanned or manned. Astrobiology shall be treated as a key decision maker in this process, because of its unique position to judge scientific criticality on keeping the planet without contamination. Manned missions give both risks and merits for astrobiology. Trade should be made based on scientific basis on those points. Present planetary protection policy is limited to the case of unmanned mission. We are proposing to initiate a new step to discuss and agree on Planetary Protection Policy and its measure to meet manned exploration on Mars. After such policy stated, engineering specification could be defined against space agriculture, which is the core system to make manned mission on Mars feasible. There will be iterative process to trade between risk and merit, after the technical feasibility of space agriculture and planetary protection is examined.

References

1. 1. Yamashita, M. et al. Engineering issues of microbial ecology in space agriculture, Biol. Sci. Space, 19(1), 25-36 (2005).
2. 2. Yamashita, M. et al. Conceptual Study of Space Agriculture, Proc. of 21st Space Utilization Symp., 21, 323-326 (2005).
3. 3. COSPAR Planetary Protection Policy (20 Oct. 2002), http://www.cosparhq.org/scistr/PPPPolicy.htm
4. 4. McKay, C. P. et al. Making Mars habitable, Nature, 352, 489-496 (1991).

Return to Japanese Contents

Return to English Contents