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(Review)

The Vision, Strategy and Roadmap of Space Environment Utilization Science

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Abstract

The roadmap of microgravity-applied sciences is overviewed by reviewing the outputs of ISS experiments, the emerging subjects of on-ground sciences, the progress of space tourism, etc. We are convincing that the Science Union for Human Planetary Habitation in Space (SUHPHS) is necessary to progress the technologies of solving the social problems, such as population explosion, resource depletion and global warming. Our collaborative actions of integrating the physical and life sciences in space are very promising to push forward the ISS utilization beyond 2020.

Keyword(s): Roadmap, ISS Utilization, Human Habitation in Space
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1. Introduction

The Japan Society of Microgravity Application (JASMA) has successfully boosted the science of Space Environment Utilization, especially in the field of materials processing and physical science under the cooperation of universities, companies and JAXA. The scientific outputs are comparable with those of Europe and USA, and contributing to the execution of ISS program.

Figure 1 shows a unique aspect of Japanese microgravity experiment. Our space experiments have been well organized in the "Front" and the "Back" programs. The "Front" program is a kind of strategic research, such as new materials processing, semiconductor growth, biotechnology, etc. using space shuttle, recoverable satellite, and ISS also. The "Back" program includes many varieties of idea-testing experiments using short-period facilities. Our success of catching up NASA and ESA is owing to the repeated cycle of going back and forth between these two types of programs. On this line, we can inform you a new type of short-period facility, reusable rocket by ISAS/JAXA. The details are described in the other paper.

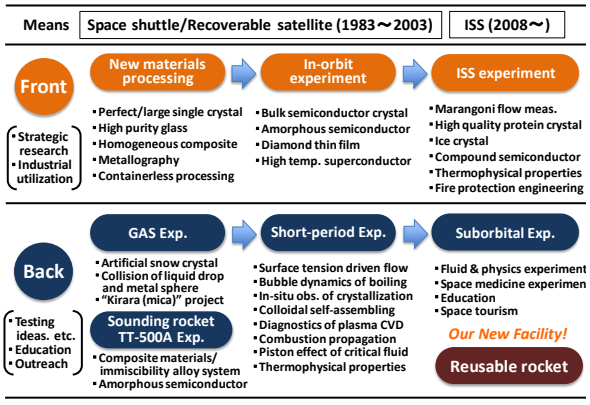

Fig. 1 The "Back" and "Front" of space experiment in Japan.

Now we are required to answer the next target and plan of microgravity program since the planned ISS experiments have executed successfully and the remaining number of experiments diminishes in physical science, on the other hand the number of experiment concerning life/medical science is increasing. In this paper, the new direction of space environment utilization science is proposed under the extensive collaboration of ISS researchers in Japan.

2. JASMA's Strategy of Microgravity Program

2.1 Action Principle

The JASMA's action principle is the following: "We develop science and technology to solve the global problems that our society now confronts, using unique microgravity environment in space." According to the principle, we carry on integrated research programs that consist of 1) Basic research, 2) Applied research, and 3) Space project, as described below, respectively.

Basic research: We propose new discipline to establish research funds under the corporation with other academic societies.

Applied research: We link ISS research outputs to the governmental innovation programs of Energy, Green, and Medical Technologies.

Space project: We connect ISS researches to human planetary habitation programs, student education programs, space tourism, etc..

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2.2 Society's Activities

A. Review of Microgravity Experiment

The first one is the review of recent microgravity experiments on board Kibo/ISS. The creation of new scientific target is concerned in the review. We clarify the subject that creates the new discipline of space utilization science by reviewing the scientific and technological outputs obtained from ISS experiments, and we plan future programs beyond ISS, connecting academia, industry and the public. The papers are published quarterly in our free-access e-Journal, the International Journal of Microgravity Science and Application, IJMSA. Recently, the reviews of Marangoni flow, Crystal Growth, Combustion, etc. have been published in the journal. Please see the Website: http://www.jasma.info/journal/.

B. Education Program

We are encouraging young students to join microgravity experiments. The Japanese astronaut Mamoru Mohri encourages the presentation by poster in the annual meeting of JASMA. In ISPS-6, Mohri poster session was held and the students were awarded to honor good presentation. The other activities are preparing educational materials concerning microgravity in the form of video archives, textbooks. An international education mission on board ISS (tentatively called "ISS Zero-G Contest") is planned under the international collaboration with partner countries.

C. International Collaboration

We strongly promote the international collaboration by coordinating the meetings in the Asian region. In addition to the ISPS-6/ITTW2015 in Kyoto, the 11th Asian Microgravity Symposium, AMS-11 is scheduled in October 2016, in Sapporo. Seven countries (Japan, China, Korea, Malaysia, India, Thailand, and Pakistan) participate in the symposium.

3. Roadmap Beyond 2020

Several missions on board Kibo/ISS are planned as shown in **Table 1**. The missions include the subjects of crystal growth, Marangoni flow, boiling and heat transfer, materials processing by levitation, colloidal crystallization, combustion and dust plasma. To visualize JASMA's activity during future 10 years and announce our ISS utilization plan to JAXA and scientific community, we depicted the roadmap of each research subject.

Figure 2 is a summary of JASMA's roadmap beyond 2020. Through the discussion, we confirmed the target of ISS utilization up to 2024. The details in each subject are discussed in the proceedings papers of the ISPS-6. Here we further mention the future outcome of the ISS program.

Astronauts working in ISS are now changing our mind of living in the Spaceship Earth. Japanese astronaut Satoshi Furukawa reported interesting phenomenon from ISS, such as aurora, shooting star, sprite, and impressed us the miracles

Table 1 The missions and outcomes of space experiments on board Kibo/ISS

Mission (2015～, planned)	Phenomena under μG	Outcome (Field)
Protein Crystal Growth NanoStep2 Hicari-II	Perfect & large single crystal	Drag discovery Semiconductor (Medicine, IT)
JEREMI Boiling Two Phase Flow	Marangoni flow Heat transfer by boiling	Thermoal fluid control (Energy saving)
Material 100	Free liquid drop by electrostatic levitation	High temperature materials (Energy materials)
Kikuchi-Kossel	Colloidal crystallization	Test kit for bio-inspection (Medicine)
Group Combustion Oxy-Fuel Combustion Solid Combustion	Diffusion flame Flammability limit	Fire protection engineering (Environment, Safety)
Plasma Experiment	Dust plasma stability	Plasma processing (Environment)

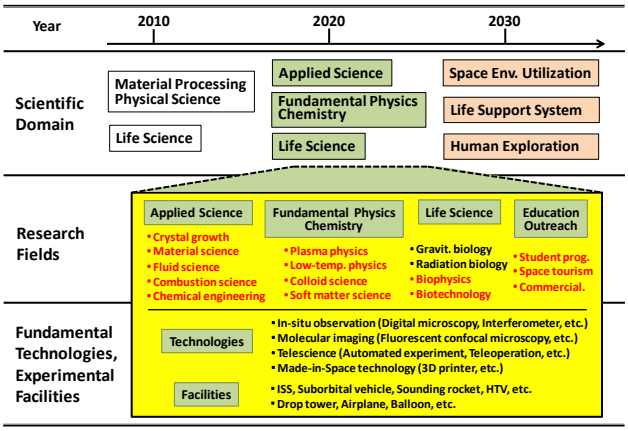

Fig. 2 The summarized roadmap of ISS researches beyond 2020. Red subjects are the fields of JASMA's concern.

occurred in the low Earth orbit. By viewing High-Vision videos taken in ISS, we could share the new feeling of Living Earth, and the space environment was named as the Cosmic Shore.

As a result of frequent reports from ISS, we cannot avoid thinking the close connectivity between Earth and Space environment, and the future planetary events happening to every Life on the Earth. Finally reaching the vision of space development: "To enable Human and Life on the Earth to inhabit in space environment using the planetary resources, energies etc., we create the new system of space science and technology by integrating existing physical science, life science, applied science, social science and art."

4. Toward the Future

We are now faced with the critical problems of population explosion, resource depletion, global warming, and so on. What is the science of enabling Human and Life on the Earth to inhabit sustainably in space environment? To answer the question, we need to understand the mechanism of action that threatens the survival of life in space environment and to construct the technological system of planetary habitation in

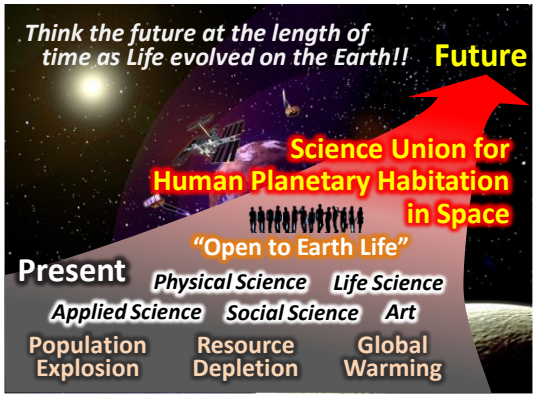

Fig. 3 The prospect of space environment utilization sciences.

space. What kind of international understandings are necessary for human planetary habitation? We need to settle the problems of population explosion, resource depletion and global warming, more over, and to get the consensus of reforming planets towards the ubiquitous habitation of Life in space.

Now, JASMA starts "The Science Union for Human Planetary Habitation in Space (SUHPHS)" in corporation with the Japanese Society for Biological Sciences in Space (JSBSS) and the Japanese Association of Space Radiation Research (JASRR). The community of Physical and Life Sciences in Space, initiated by NASA and ESA, is now expanding so that the programs include the Asian countries. And now, we can share a dream of human planetary habitation as a result of our future collaboration with not only space scientists but also people who wish a prosperous world supported by Earth Life.

"It is ultimately impossible for Life on the Earth to survive in space without the science and technology of human beings. Simultaneously, it is ultimately impossible for human beings to inhabit sustainably in space environment without the aid of non-human species."

We hope you to join our new vision and look out over the future of our ISS.

(The paper was completed based on the Society Talk of ISPS-6)