

The Unified Scientific Program of Space Environment Utilization and Human Planetary Habitation

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Abstract

It is ultimately impossible for life on the Earth to survive in space without the science and technology of human beings. To enable human and life on the Earth of inhabiting sustainably in space environment, we need to create the new system of space science and technology by integrating existing sciences, such as physical science, life science, applied science, social science and art. The action principle of the Japan Society of Microgravity Application (JASMA) states: "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. In this paper, the roadmaps of microgravity-applied sciences are overviewed by reviewing the outputs of ISS experiments and a unified program of space environment utilization on the Moon is proposed as a post ISS program.

Keyword(s): Microgravity, ISS, Moon, Human Habitation in Space

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1. Introduction

Since the construction of International Space Station (ISS) was completed in the year 2011, many microgravity experiments have progressed favorably. During the years, we were able to see TV video programs on a daily basis that astronauts are working under microgravity with their voices of enjoying their space life. As a result, people become very familiar with space, and understand that one's space travel has taken on a touch of real possibility.

On the other side, ISS Program extended to 2024, therefore there are 8 years left until the time limit. In this situation, JASMA has been tackling the problem to re-direct the next space utilization program under the cooperation with Japanese microgravity related societies, such as, the Japanese Society for Biological Sciences in Space (JSBSS), the Japanese Association of Space Radiation Research (JASRR), and the Japan Society of Aerospace and Environmental Medicine (JSASEM). Here, I'd like to report the results of our discussion and to offer you a grand landmark and ideas to be shared in the symposium.

2. Roadmap beyond 2020

Let's start from the vision, strategy and roadmap¹⁾. JASMA has been a strong partner of JAXA during 30 years, almost the same history of Japanese manned space program. Our action principle is as follows: "We develop science and technology to solve the global problems that our society now confronts, using unique microgravity environment in space." To do that, "We carry on integrated research programs that consist of 1) basic research, 2) applied research, and 3) space project."

Figure 1 shows you the roadmap of microgravity science toward future 20 years. The starting disciplines are subdivided into many scientific subjects. They are now grouped as Applied Science, Fundamental Physics and Chemistry, Life Science, etc. Now, the next targets have broad spectrum of science and technology concerning Space Environment Utilization beyond Low Earth Orbit (LEO), Life Support System, Human Exploration, and so on. Then, we show you the several scenarios and future projects of representative disciplines in a similar roadmap style.

The first area is concerning material science. Please note that our roadmap consists of targeted science, space mission, on-ground basic research and applications. As shown in **Fig. 2**, its scientific target is: "Measurement of high-temperature melts using containerless processing and synthesis of noble functional material." The outputs of space experiment are to be extended to "In-Situ Resource Utilization (ISRU)" and "Synthesis of Noble Functional Materials" for the use in space and on the Earth. Concerning fluid science (**Fig. 3**), its scientific target is: "Control of mass and heat transfer driven by surface-tension at gas-liquid interface of bubble, liquid drop and liquid film." The outputs of space missions are "Heat Management in Space Systems" and "Innovative Heat Waste System" by realizing, controlled surface tension, high performance heat pipe, and small size and light weight.

Next is combustion science (**Fig. 4**). Its scientific target is: "Foundation of combustion limit enabling sustainable burning under microgravity." The output of space missions is making "Protocol of Space Fire Safety."

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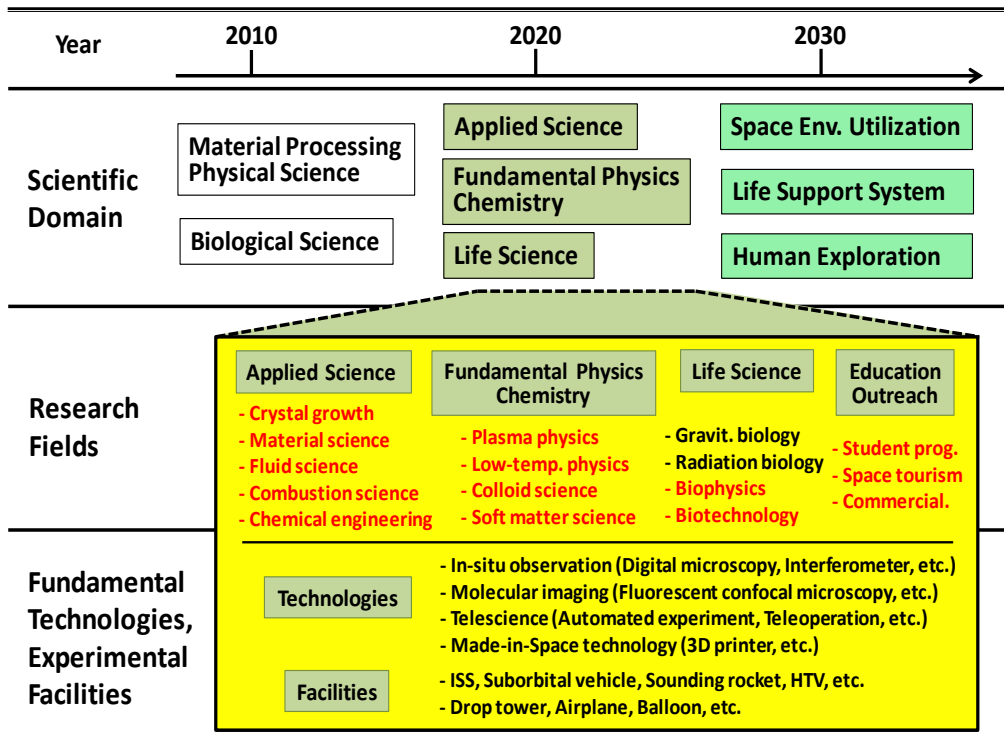


Fig. 1 The summarized roadmap of ISS researches beyond 2020. The red subjects are the fields of JASMA’s concern.

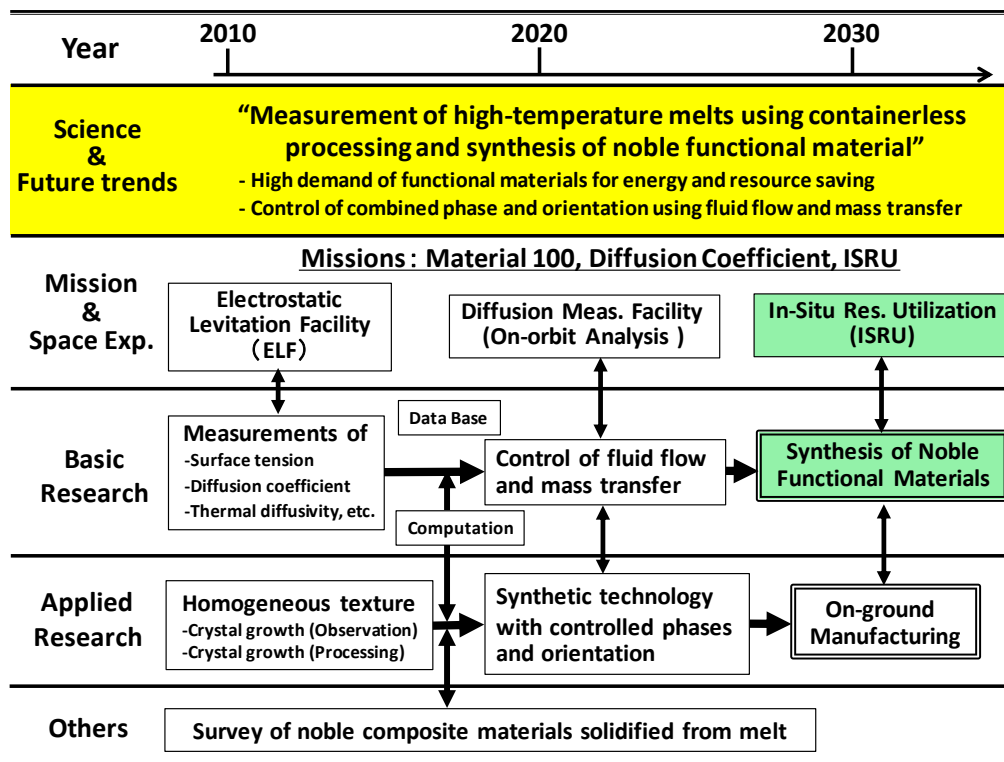


Fig. 2 The roadmap of material science.

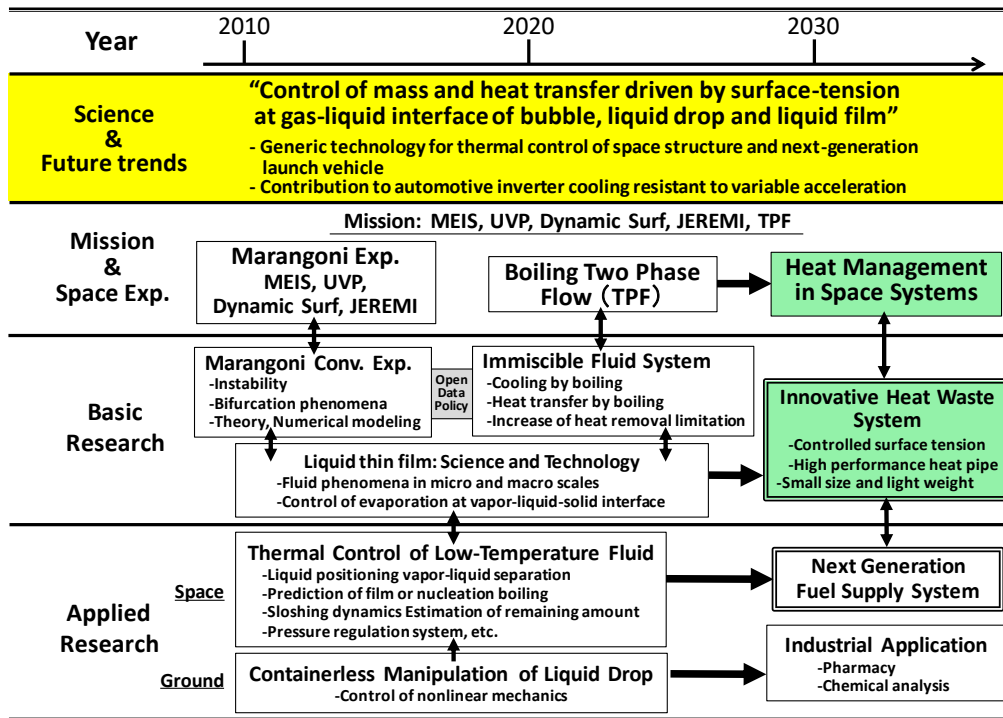


Fig. 3 The roadmap of fluid science.

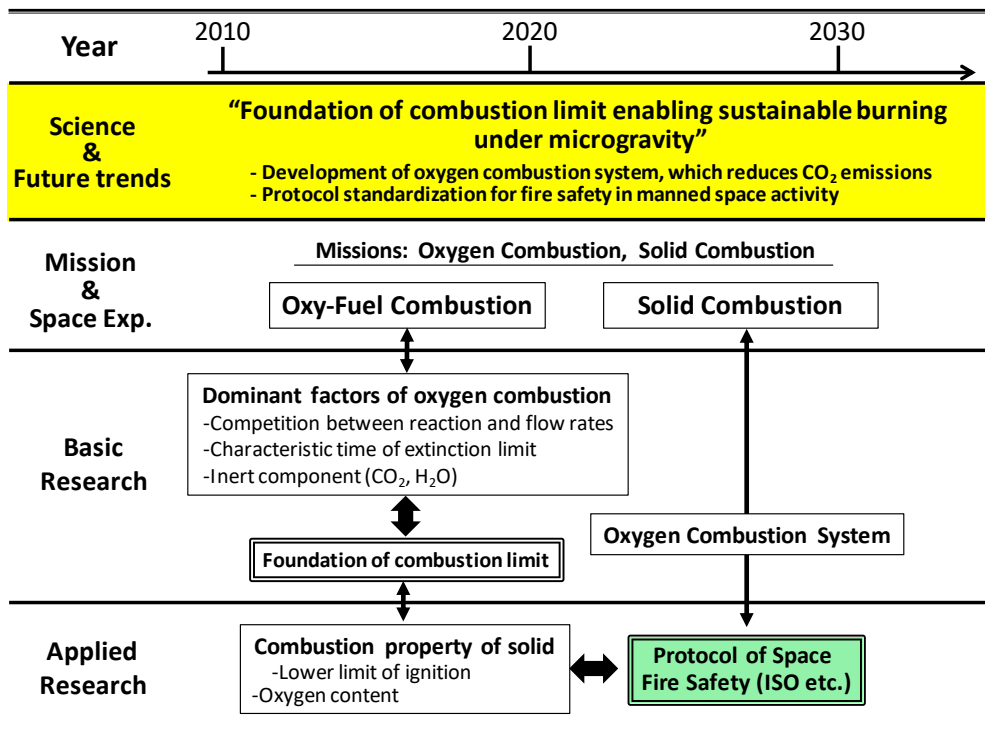


Fig. 4 The roadmap of combustion science.

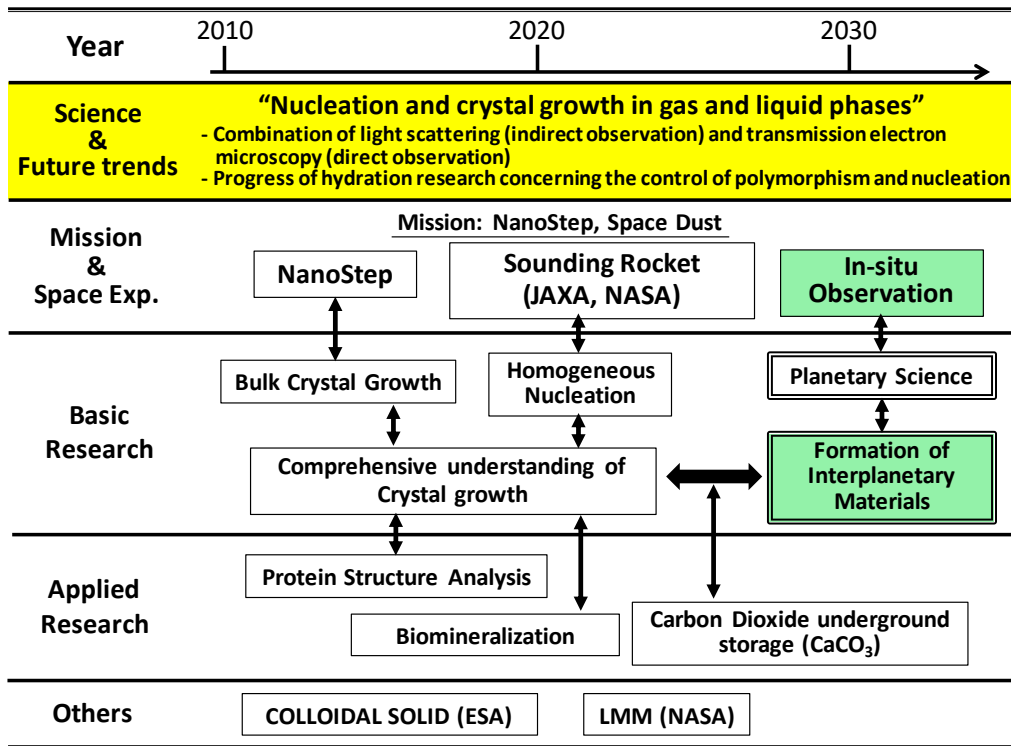


Fig. 5 The roadmap of crystal growth.

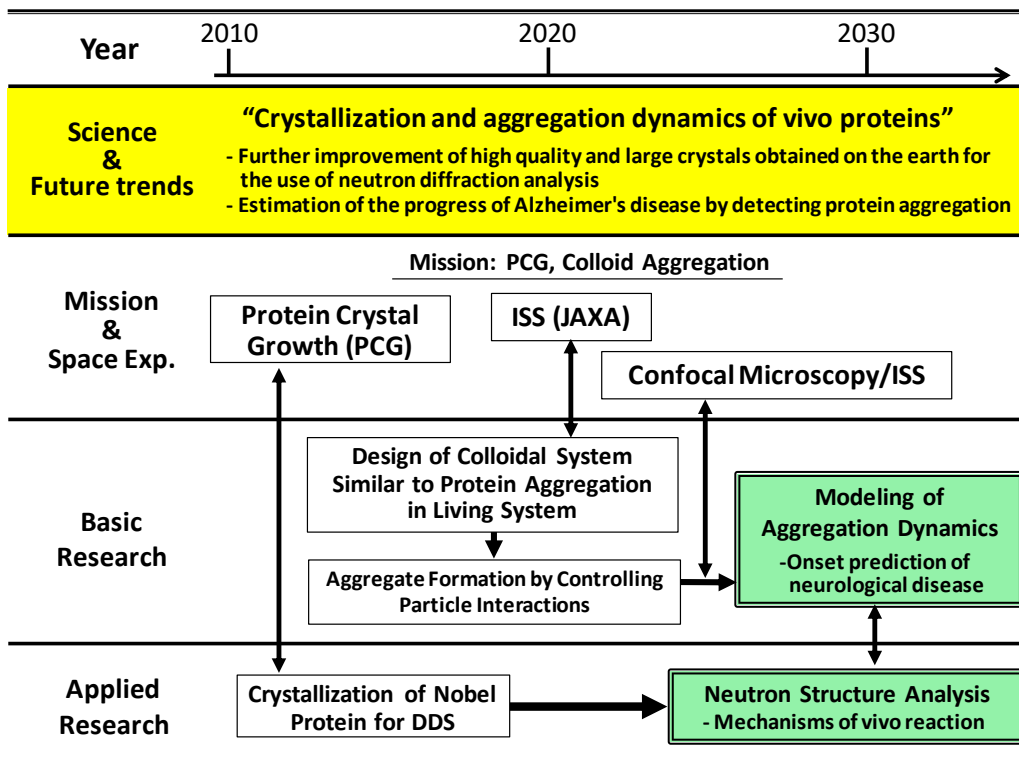


Fig. 6 The roadmap of biophysics.

Concerning crystal growth (Fig. 5), its scientific target is: “Nucleation and crystal growth in gas and liquid phases.” The outputs of space missions are extended to “In-situ Observation in Planetary Science” and to understand “Formation of Interplanetary Materials.”

The last is biophysics (Fig. 6). Its scientific target is: “Crystallization and aggregation dynamics of vivo proteins.” The outputs of space missions are used in the “Modeling of Aggregation Dynamics” to understand “Onset Prediction of Neurological Disease” and grown crystals are used in “Neutron Structure Analysis” to understand “Mechanisms of Vivo Reaction.”

3. Science of Human Planetary Habitation in Space

According to the detailed discussion of each disciplines, we appoint to promote “The Science Union for Human Planetary Habitation in Space (SUHPHS)” in corporation with the Japanese Academic Societies: JSBSS, JASRR and JSASEM. Our common destination of this Union is as follows²⁾:

- 1) We further pursue the validity of research outputs obtained so far, in the investigation of physical and life sciences in space.
- 2) According to the science and technology established during ISS operation, we integrate various applied sciences and engineering in the viewpoint of human space exploration, and aim to expand human habitation from the low-earth orbit to the planets, such as Moon and Mars, under the collaboration with the humanities and social science.
- 3) We contribute to overcome the critical problems of population explosion, resource depletion, global warming on the Earth, by investigating the mechanisms of action that threatens the survival of life in space environment and to construct the technological systems of planetary habitation in space.

Then, we can go to the breakdown of our grand concept. The Moon is quite appropriate target of the next space environment utilization.

4. Research Strategy and Projects on the Utilization of Moon Environment

How about the characteristics of the Moon environment? You know gravity on the Moon is one sixth of the Earth gravity. Temperature is ranging from very low temperature to 100 degree centigrade. Others are ultrahigh vacuum, zero-magnetic field, no earthquake, and very strong solar radiation (Table 1). We can conclude the reason for Moon environment utilization as:

- 1) Many findings of microgravity researches obtained in ISS are further verified and extended using the low-gravity environment (0.17G) on the Moon, which interpolates the phenomena between 0G and 1G.

Table 1 Comparison between moon and earth environment

Parameters	Moon	Earth
1. Gravity	1.62 m/sec ² (1/6 G)	9.81 m/sec ² (1 G)
2. Temperature	-238 °C (South Pole)~ 107 °C (Equator)	-89 °C ~ 58 °C
3. Atmosphere	10 ⁴ (Day) ~ 10 ⁵ (Night) Mol./cm ³	2.5 × 10 ¹⁹ /cm ³
4. Magnetic field	0	24 ~ 56 A/m
5. Earthquake	2 × 10 ¹⁰ J/Yr (except Meteorite impact)	10 ¹⁷ ~ 10 ¹⁸ J/Yr
6. Natural radiation	100~7000 mSv (Solar particles)	2.4 mSv (Average)

2) The Moon environment is characterized as a combination of important physical parameters, such as very low temperature, ultrahigh vacuum, zero-magnetic field, strong solar radiation, etc. Experimental sciences (physics, life science, applied science) on the Earth are further re-evaluated and integrated to the universal science.

3) The Moon is the next target of space development beyond LEO, because the distance is only 3 days travel from the Earth. Moreover, resources available on the Moon offer indispensable logistics in the manned planetary exploration.

Our research strategy and projects are shown in Fig. 7. The grand landmark is “Human Planetary Habitation”. There are two major disciplines as: Microgravity Science and Space Life Science. We aim to promote two flight programs. One is “Moon Orbiting Satellite” and the other is “Laboratory on the Moon.” Moon Orbiting Satellite program consists of microgravity experiment and life science experiment. And also, Laboratory on the Moon program consists of science on the Moon and life support experiment.

We mapped our program “Human Planetary Habitation” in the world-wide Solar System Exploration Programs as shown in Fig. 8. Our program contains the subjects, such as microgravity science, life science and space medicine. We continue to execute microgravity experiments using ISS, then, Moon orbiter and Moon laboratory operated in SELENE of JAXA and EML-2 under the collaboration between NASA and JAXA.

5. Toward the Future

Our space is vast and boundless. However, the Earth is limited. Now, we feel the reality of Russian scientist K.E. Tsiolkovsky’s saying, “The Earth is the cradle of humanity, but mankind cannot stay in the cradle forever.” We can further say the Earth is the cradle of every life surrounding humanity. Mankind has to carry on the important mission of continuous existence of life in space, as well as on the Earth against the global problems, such as population explosion, resource depletion and global warming.

Now, returning to the symposium subject, I propose you an idea concerning our future collaboration.

The number of presentations submitted to AMS2016 reaches to 209. In my memory, the number is the record of AMS. In this point, we very much acknowledge the participation of the many scientists from China, Korea, Malaysia, Indonesia, USA and

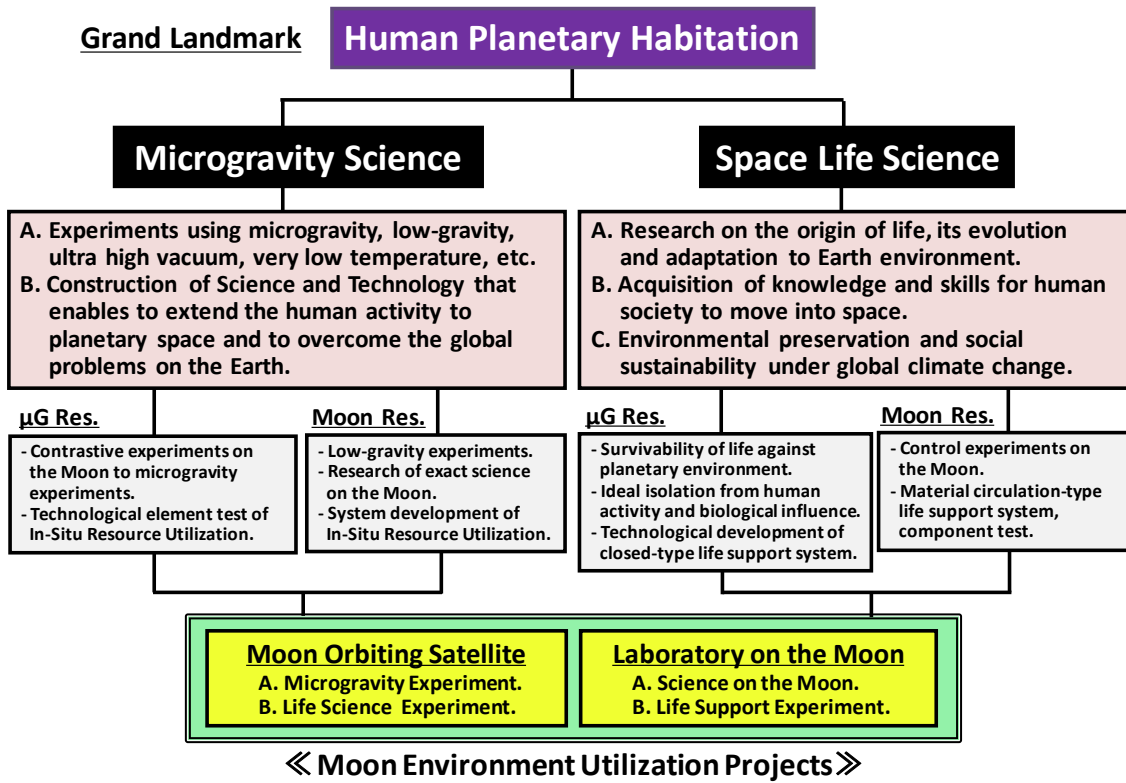


Fig. 7 The research strategy and projects of human planetary habitation.

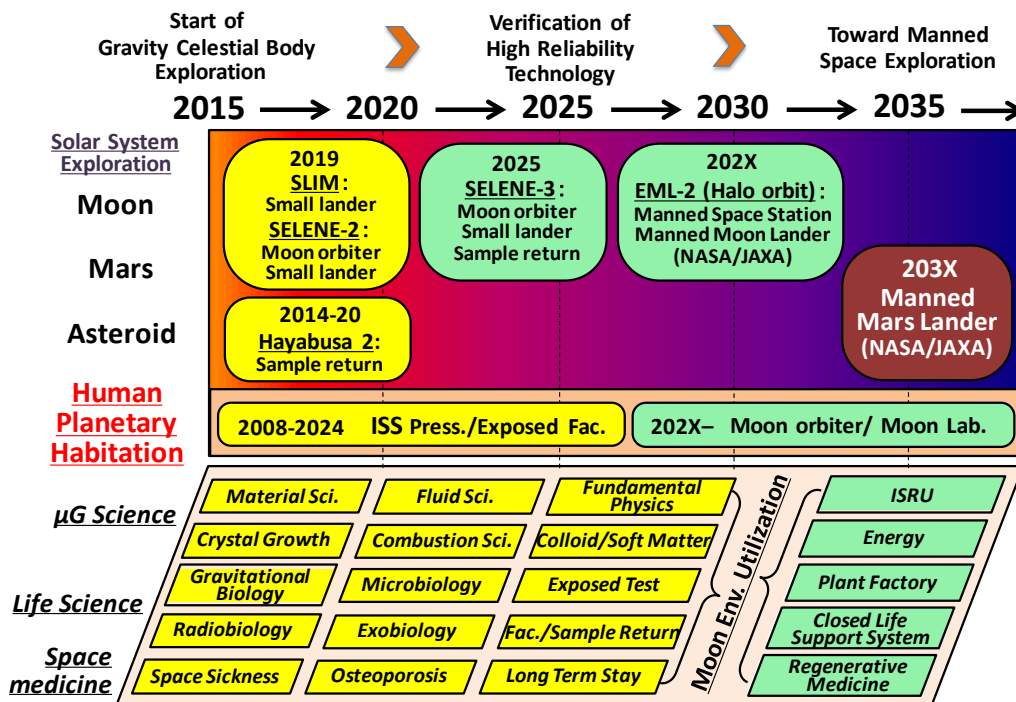


Fig. 8 The roadmap of human planetary habitation in concert with solar system exploration programs.

European countries, and also from Japan. On the other point, the number encourages us to promote the “Asian” Science Union for Human Planetary Habitation in Space.

We hope you to confirm our friendship and ties through this symposium, and please discuss the many ideas of keeping the close relationship between us, and also the international and Asian microgravity communities.

References

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(The paper was completed based on the Plenary Talk of AMS2016)