"International Symposium on Sustainable Space Development and Space Situational Awareness"

Grand Hall, Tokyo

The Vision, Strategy and Roadmap of Space Environment Utilization Science

February 27th, 2015

Dr. Masamichi Ishikawa, President

The Japan Association of Microgravity Application, JASMA

History of μG Experiment in Japan

Year	Missions/Programs	Paradigm of Space Exp.
1980	1979 Start of Japanese Manned Space Plan 1980～1983 Sounding Rocket: TT-500A 1983 Start of FMPT 1983 GAS Experiment (Asahi Shimbun, NEC) 1989～2003 Drop Shaft (JAMIC) 1988 Space Station Cooperation Agreement	Manned Space Laboratory Creation of New Materials Space Commercialization
1990	1990～ Parabolic Flight: (DAS) 1991～1998 Sounding Rocket: TR-1A 1992～1997 Spacelab (Space Shuttle): IML-1, FMPT, D2, IML-2 , MSL-1 1993～2010 Drop Shaft (MGLAB) 1995 Space Flyer Unit (Reentry Space System)	Short-Term Microgravity In-Orbit Laboratory Applied Research Program
2000	2000 USERS (Reentry Space System) 2003 Columbia Space Shuttle Disaster 2003～2009 ISS Russian Module 2008～Kibou Module: MEIS, IceCrystal, Facet	ISS Utilization International Cooperation
2010	2012 NanoStep 2013～ Hicari, Alloy Semiconductor 2014～ Dynamic Surf	Priority Subjects Basic Plan for Space Policy

Industrial Utilization of Space Environment: New Materials of Made-in-Space (FMPT)

Field	Materials (Industrial View Point)	Merit of Microgravity
Compound semiconductor	▪ PbSnTe (Infrared sensor) ▪ InSb (Ultra LSI substrate) ▪ SiAsTe (Amorphous solar battery) ▪ PbSnTe (Infra-red image sensor)	▪ Low defect density, high quality single crystal ▪ Crystal growth from melt in large size ▪ Perfect amorphous material ▪ Homogeneous single crystal in large size
Inorganic materials	▪ Optical materials of non-visible wavelength (Infrared transparent material) ▪ Samarskite (Photocatalyst)	▪ High purity glass ▪ Homogeneous mixing of row materials
Composite material	▪ AlPbBi alloy (High-temp. superconductor) ▪ Particle dispersed alloy (Heat-resistant material) ▪ Carbon fiber/Al composite alloy (Super light-weight material)	▪ Homogeneous ingot alloy ▪ Homogeneous particle dispersion in Ni alloy ▪ 3-dimensional blending of carbon fiber
Organic material	▪ Organo-metallic crystal (Electric conductor)	▪ Perfect single crystal
Materials processing	▪ Deoxidized mechanism of steel (Quality control) ▪ Liquid phase sintering (Superalloy) ▪ Metal particle formation in gas phase ▪ Si drop and surface oxidation (Ultra LSI) ▪ Glass behavior in melt ▪ Solidification of eutectic alloy (Metallography) ▪ Counter diffusion in metal melt (Metallography)	▪ Homogeneous chemical reaction ▪ Homogeneous phase distribution ▪ Evaporation-condensation of met ▪ Surface tension controlled growth ▪ Thermophysical properties of glass melt ▪ Floating phenomena of crystallite in melt ▪ Diffusion coefficient in melt
Containerless processing	▪ Drop dynamics (Drop handling) ▪ Bubble dynamics (Bubble exclusion) ▪ Marangoni convection (Heat transfer)	▪ Manipulation by acoustic levitation ▪ Bubbles under stationary acoustic field ▪ Fluid dynamics induced by surface tension

Development of In-Orbit Laboratory

Exp. means	Research theme	New technology/Experiment facility
Sounding rocket (TR-1A, TEXUS, MASER)	・In-situ observation of crystal growth ・Self-assembling of colloidal particles ・Marangoni convection in liquid bridge ・Heat transfer by very big bubble formation ・Bubble dynamics under g-jitter ・Thermophysical meas. of metal and Si melt ・Combustion	・Real time interferometry of growth field ・Spectrophotometer and light scattering ・Large liquid bridge, 3D measurement of flow ・High precision measurement of pool boiling ・Handling of bubbles ・Shear cell measurement of counter diffusion ・In-situ observation of flame field
Space shuttle (IML, MSL)	・Convection due to human g-jitter ・Mixing in multi-comp. semiconductor melt	・Damper technology for g-jitter ・Control of Marangoni convection
Recoverable satellite (SFU, USERS)	・Facet crystal growth ・Synthesis of diamond thin film ・Crystal growth of compound semiconductor ・Bulk growth of high temp. super conductor	・In-situ observation of solid-liquid interface ・Plasma CVD using space vacuum environment ・Floating-zone method ・Gradient Heating Furnace
ISS	・Science: Marangoni Experiment in Space Ice Crystal, NanoStep ・Applied: 3D Photonic Crystal Growth, Protein Crystal Growth	・Fluid Physics Experiment Facility ・Solution Crystallization Observation Facility ・3D Photonic Crystallization Growth Facility ・Protein Crystallization Research Facility

Application of ISS Research

Research field	Phenomena under μG	Mission	Application (Field)
Crystallization	Perfect/large single crystal	Crystallization of semiconductor, ice, protein	IT, Drag discovery (IT, Medicine)
Free liquid	Surface tension driven fluid flow	Non-stationary Marangoni convection	Large size wafer (IT)
Wetting	Free liquid drop	Electrostatic levitation furnace	High temperature materials (Energy materials)
Diffusion	Stabilized temp. & concentration gradient	Thermodiffusivity measurement	Chemical process (Energy saving)
Dispersion/ coagulation	Weak inter-particle force	Colloidal crystallization	Test kit for bio-inspection (Medicine)
Bubble	Bubble dynamics	Boiling/two phase flow	Cooling system (Energy saving)
Chemical reaction	Diffusion flame/flammability limit	Solid combustion	Fire protection engineering (Security/safety)
Plasma	Plasma stability	Dust plasma experiment	Plasma processing (Environment)

“Back” and “Front” of Space Experiment

Means	Space shuttle/Recoverable satellite (1983～2003)	ISS (2003～)

Front

- Strategic research
- Industrial utilization

New materials processing

- Perfect/large single crystal
- High purity glass
- Homogeneous composite
- Metallography
- Containerless processing

In-orbit experiment

- Bulk semiconductor crystal
- Amorphous semiconductor
- Diamond thin film
- High temp. superconductor

ISS experiment

- Marangoni flow meas.
- High quality protein crystal
- Ice crystal
- Compound semiconductor
- Thermophysical properties
- Fire protection engineering

Back

- Testing ideas. etc.
- Education
- Outreach

GAS Exp.

- Artificial snow crystal
- Collision of liquid drop and metal sphere
- “Kirara (mica)” project

Sounding rocket TT-500A Exp.

- Composite materials/ immiscibility alloy system
- Amorphous semiconductor

Short-period Exp.

- Surface tension driven flow
- Bubble dynamics of boiling
- In-situ obs. of crystallization
- Colloidal self-assembling
- Diagnostics of plasma CVD
- Combustion propagation
- Piston effect of critical fluid
- Thermophysical properties

Suborbital Exp.

- Fluid & physics experiment
- Space medicine experiment
- Education
- Space tourism

JASMA's Vision, Strategy and Roadmap

●Vision

- **JASMA's action principle: We develop new Science & Technology to solve the global problems that our society now confronts by using unique microgravity environment in space.**
- **We carry on the integrated research programs that consist of 1) Basic research, 2) Applied research and 3) Space project, based on the JASMA's abundant experience.**

●Strategy

(1) Basic research: We propose new discipline to establish research funds under the corporation with other academic societies, such as Japanese Society for Biological Sciences in Space, etc.

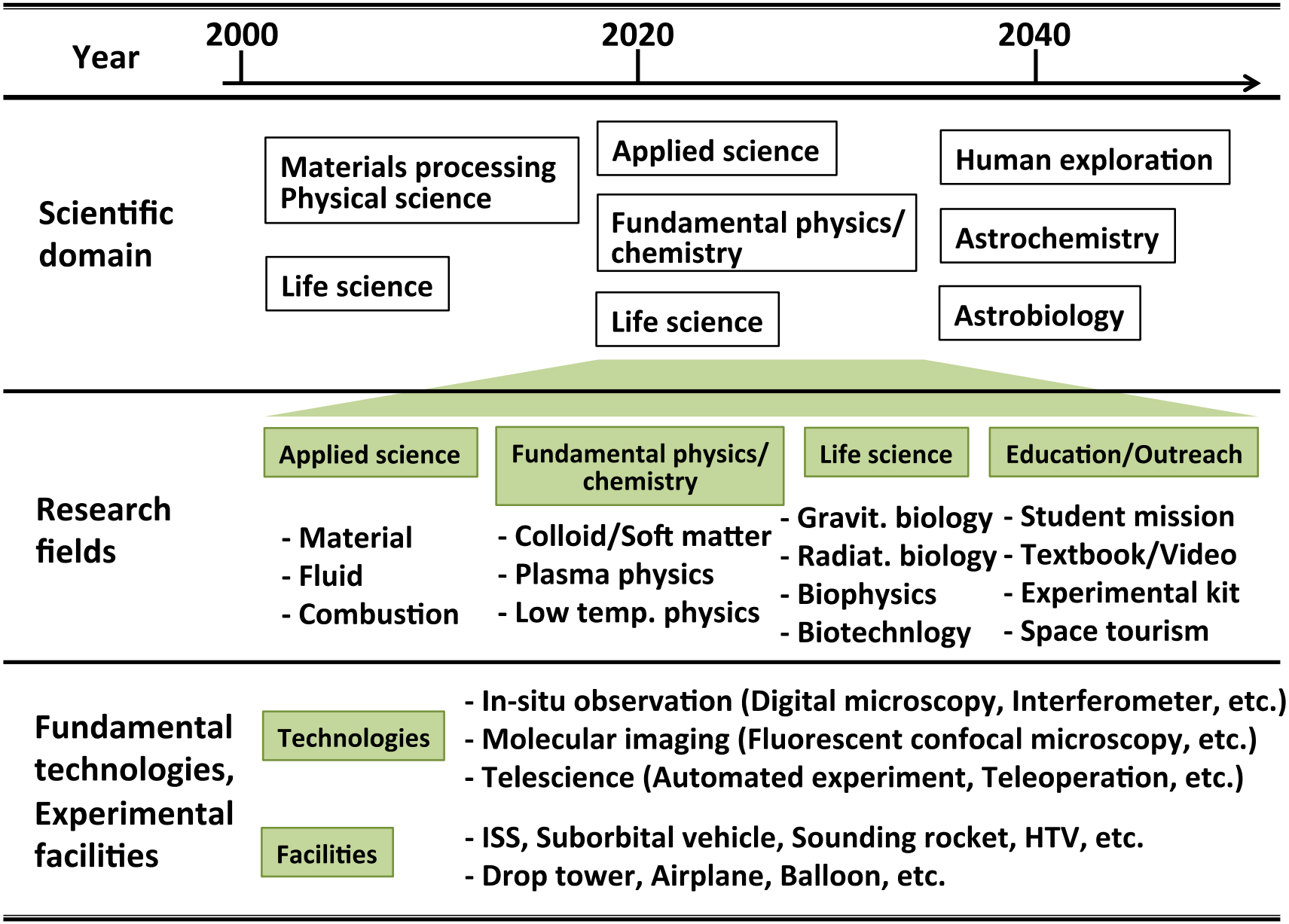
(2) Applied research: We link ISS research output to the governmental innovation programs of Energy, Green, and Medical technologies.

(3) Space project: We extend microgravity research to human planet habitation program, space education program, etc.

●Roadmap

- **To visualize JASMA's activity for the 10 to 20 years and announce our future plan to JAXA and academic community, etc.**

Roadmap of Microgravity Science (JASMA Version)



Action I: Review of μG Experiment

1. Objectives

a. To clarify the subject that creates the new discipline of space utilization science by reviewing the scientific and technological outputs obtained from ISS experiments, and to plan future programs beyond ISS.

b. To connect people from academia, industries and the public in the field of microgravity science and application.

2. Approach

a. Publication of International Journal of Microgravity Science and Application (free access e-journal).

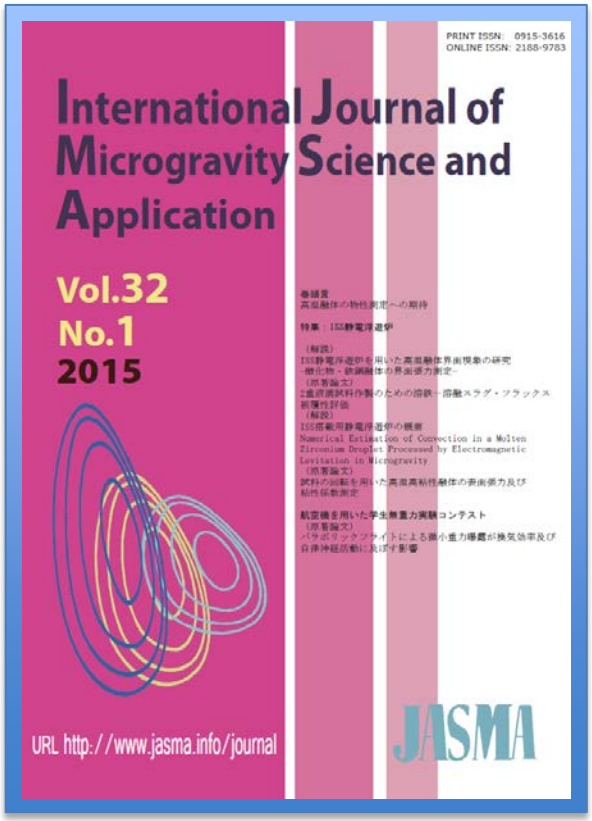
b. Hosting sessions in the academic meetings, JASMAC, ISPS, AMS, etc.

3. Recent outputs

a. Editing and sales of the DVD archive of JASMA articles during 30 years.

b. Publication of the special issue of Marangoni Experiment in Space.

c. Honoring to full members and industrial supporting members with JASMA Award.



Action II: Education programs

1. Objectives

a. To provide the opportunities of getting first hand experiences of space by participating in microgravity experiment.

b. To prepare educational materials concerning microgravity in the form of video archives, text books, etc.

2. Activities

a. Mohri Poster Award: To honor student poster presentations in the annual meeting of JASMA.

b. Student Zero-G Contest: To select and support student airplane experiment contest in corporation with JAXA/JSF.

c. Summer school: To prepare gravity switch for airplane experiments.

3. Future Plans

To realize an international education mission in ISS (ISS Zero-G Contest).

Mohri Poster Award for Student

Action III: International Collaboration

1. Sponsorship of International Symposium

a. **ISPS-6 & ITTW2015, 14-18 September 2015**, Doshisha Univ., Kyoto
"The Joint Conference of 6th International Symposium on Physical Sciences in Space (ISPS-6) and 10th International Conference on Two-Phase Systems for Space and Ground Applications (ITTW2015)".

b. **11th Asian Microgravity Symposium**, AMS-11 (October 2016, Sapporo)
Japan, China, Korea, Malaysia, India, Thailand, Pakistan (7 countries).

2. Common Targets

a. Preparation of **Joint Human Space Exploration Program**.

b. Creation of **International Education Mission** in ISS program.

AMS-10 (Korea, 2014)