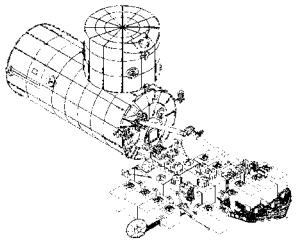


ISS/JEM Utilization Prioritization in Japan

Takuo Sugano
Chairperson,
Space Utilization Research Committee
ISS/JEM Utilization Prioritization Ad hoc Committee
NASDA

IFSUSS Meeting **July 28, 2003** **Augusta, MI,USA**

Outlines

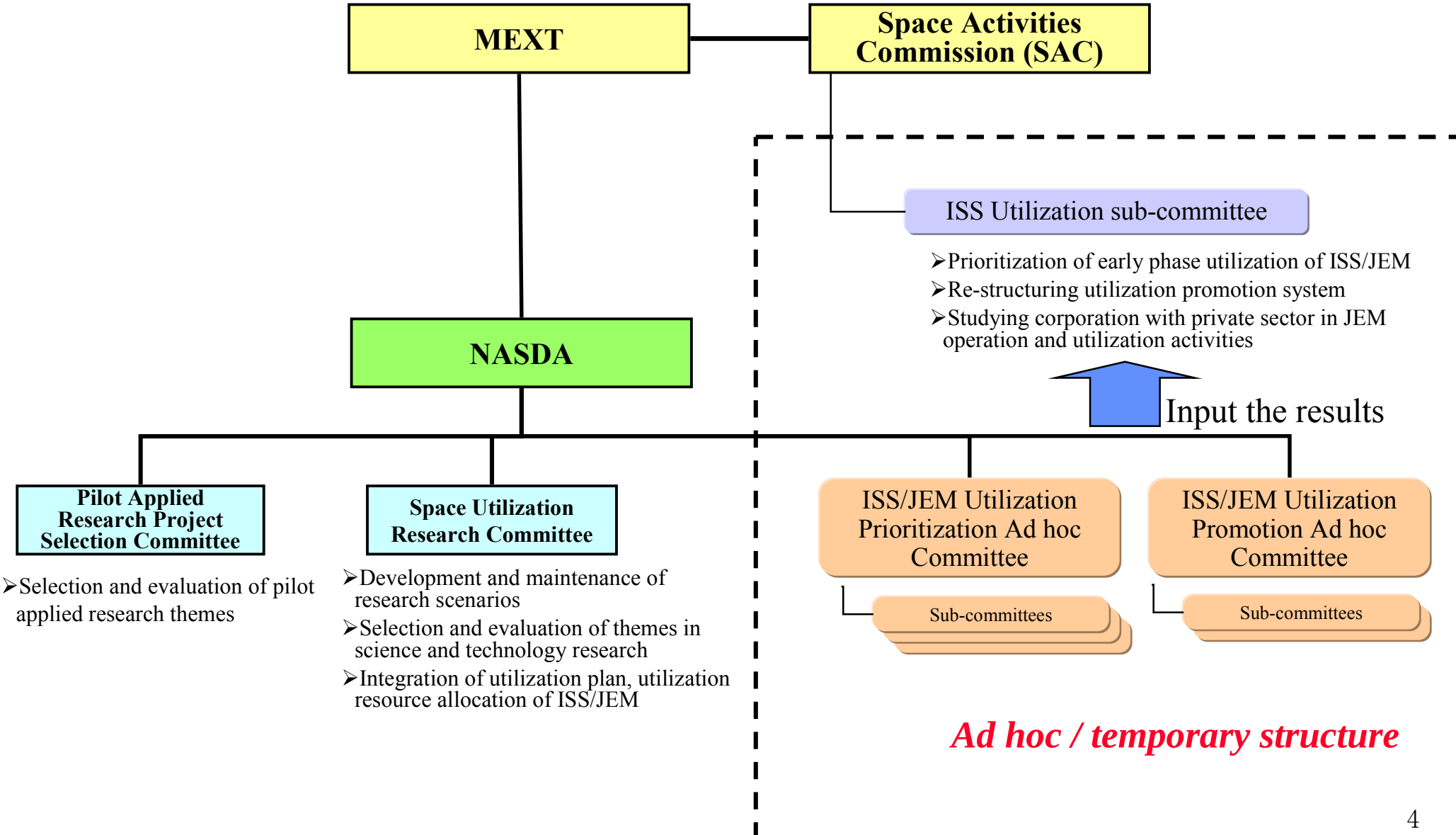
1. Background of the Activity
2. Structure of Prioritization Study
3. Process of ISS/JEM Utilization Prioritization
4. Guideline for Selection and Prioritization of Research Field
5. Review Process and Criteria for Prioritization
6. Prioritization of JEM/ISS Early-phase Utilization
7. Promising Research Fields in Space Utilization Sciences
8. Promising Themes in Space Utilization Applied Research

1. Background of the Activity

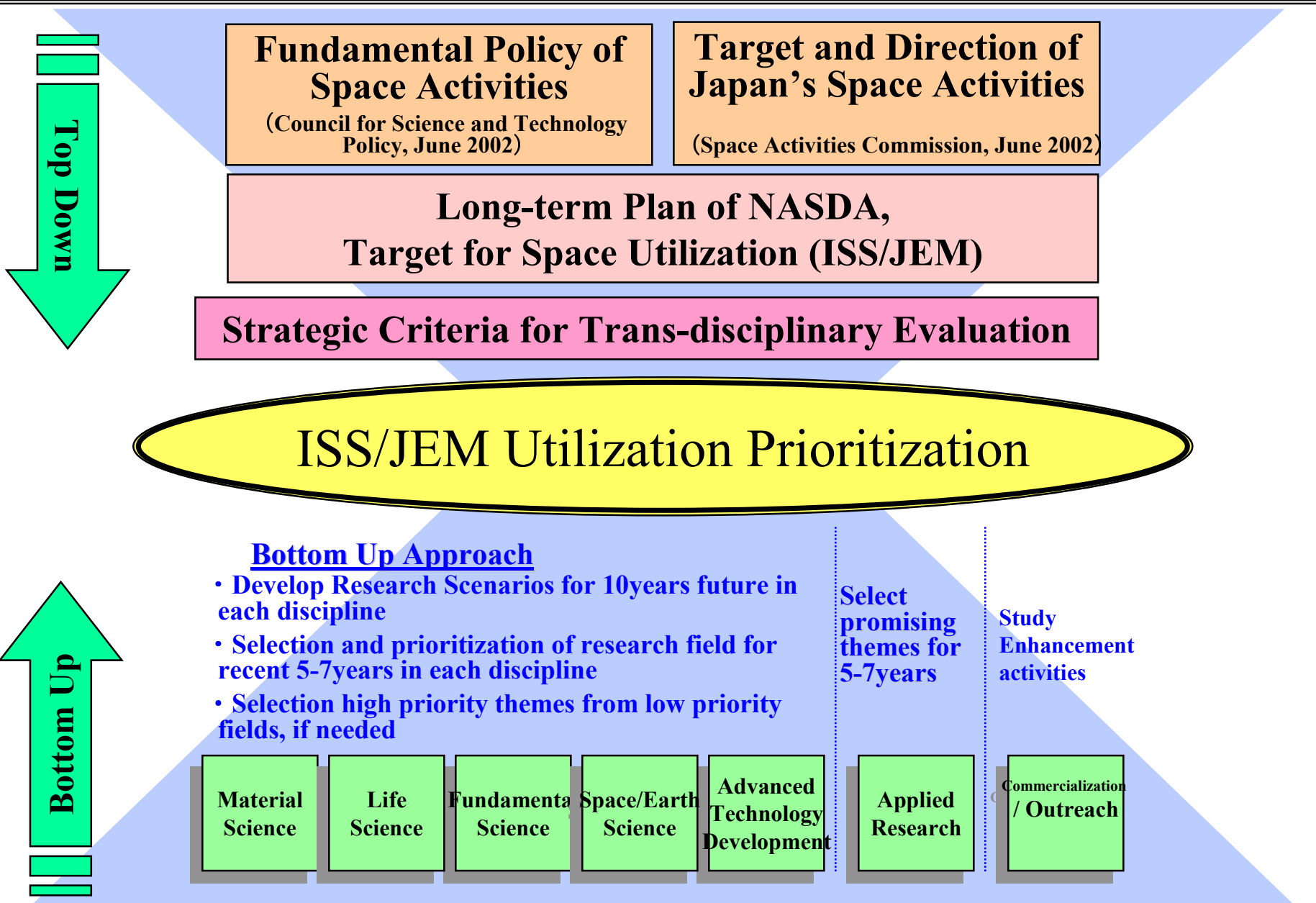
- SAC* recommended MEXT/NASDA to re-plan Japanese ISS/JEM program, especially utilization plan to adapt recent circumstances (below) of ISS/JEM program last June.
  - Re-planning of ISS program in the U.S.A.
  - National financial situation
  - Expansion of space utilization to various fields
  - Consolidation of three Space Organizations (NASDA, ISAS and NAL)
- SAC established ISS Utilization sub-committee under itself, and NASDA established ISS/JEM Utilization Prioritization Ad hoc Committee and ISS/JEM Utilization Promotion Ad hoc Committee.
- NASDA's committees conducted preliminary study to provide a basis for discussion at ISS Utilization sub-committee.
  - Prioritization of early phase utilization of ISS/JEM
  - Re-structuring utilization promotion system
  - Exploring corporation with private sector in JEM operation and utilization activities
- After a few months discussion, ISS Utilization sub-committee issued an interim report to SAC this June.

*)The Space Activities Commission of the Ministry of Education, Culture, Sports, Science and Technology

2. Structure of Prioritization Study



3. Process of ISS/JEM Utilization Prioritization



4. Guideline for Selection and Prioritization of Research Field

＜Scientific Research＞

■Scientific Significance

- ❒ Acquirement of new scientific knowledge
- ❒ Exploration into new intellectual frontier

＜Technological Research＞

■Technological Significance

- ❒ Development of new technology
- ❒ Impact to other technologies
- ❒ Contribution to space technologies

＜Both of Scientific and Technological Research＞

■Superiority：

- ❒ International competitiveness
- ❒ Originality of achievements

■Importance：

- ❒ National policy on science and technology
- ❒ Advancement of space utilization
- ❒ Development of human resources

■Impact：

- ❒ Prosperity of human society or economy
- ❒ Other fields of human activity

5. Review Process and Criteria for Prioritization

■ ISS/JEM Utilization Prioritization Ad hoc Committee evaluated trans-disciplinarily each research field / theme referring to the evaluation by sub-committees according to the following steps.

1)Each sub-committee member reviewed each research field/theme according to the following 8 strategic criteria on a 1-5 scale, and evaluated it as a whole on a 1-4 scale.

2) The sub-committee concluded the evaluation of each research field/theme finally by consensus of all members based on summary of each member's score.

Criteria for Prioritization	Score
1.1) Can it be expected to show effectiveness of space environment utilization soon?	5 4 3 2 1 *1
1.2) Can it be expected to make exciting progress and to give big impact?	5 4 3 2 1
1.2) Can it be expected to contribute to science and technology in other countries, especially Asia-Pacific regions?	5 4 3 2 1
1.4) Can it be expected to promote understanding and participation of public to ISS program?	5 4 3 2 1
2. Can it be expected to contribute to strategic development of ISS/JEM utilization?	5 4 3 2 1
3. Can it be expected to develop applied research (Industrialization /Commercialization) ?	5 4 3 2 1
4. Does it need continuous and long term support as space science and/or technology?	5 4 3 2 1
5. Can it contribute to 4 fields strategically prioritized in Japan's Science and Technology Policy? (Life Science, Material Science and Nano-technology, Information Technology, Environment)	5 4 3 2 1
Evaluation as a whole	A+ A B C *2

***1** 5 : **Excellent** 4 : **Very Good** 3 : **Good (Average)** 2 : **Fair** 1 : **Poor**

***2** A+ : **1st priority**

A : **2nd priority**

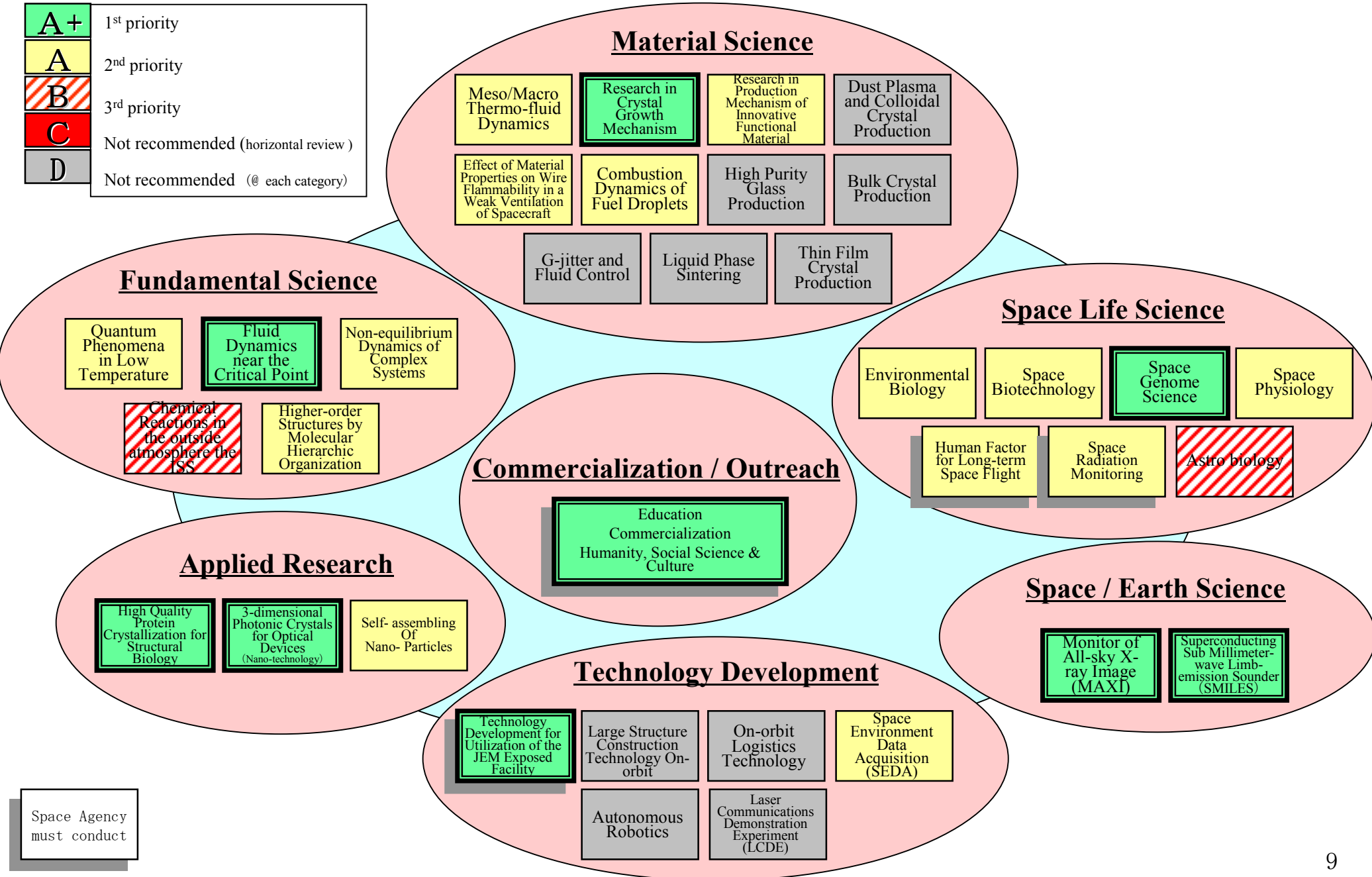
B : **3rd priority**

C : **Not recommended**

6. Prioritization of JEM/ISS Early-phase Utilization

Discipline	Research Fields / Themes	Rank
Material	Research in Crystal Growth Mechanism	A+
Applied R	High Quality Protein Crystallization for Structural Biology	A+
Fundamental	Fluid Dynamics near the Critical Point	A+
Technology	Technology Development for Utilization of the JEM Exposed Facility	A+
Space Science	Monitor of All-sky X-ray Image (MAXI)	A+
Earth Science	Superconducting Sub millimeter-wave Limb-Emission Sounder（SMILES）	A+
Life	Space Genome Science	A+
Applied R	3-dimensional Photonic Crystals for Optical Devices （Nano-technology）	A+
Outreach,	Education, Commercialization, Humanity, Social Science & Culture	A+
Life	Human Factor for Long-term Space Flight	A
Life	Space Physiology	A
Material	Meso/macro Thermo-fluid Dynamics	A
Technology	Space Environment Data Acquisition (SEDA)	A
Material	Effect of Material Properties on Wire Flammability in a Weak Ventilation of Spacecraft	A
Material	Research in Production Mechanism of Innovative Functional Materials	A
Fundamental	Quantum Phenomena in Low Temperature	A
Life	Environmental Biology	A
Life	Space Radiation Monitoring	A
Fundamental	Higher-order Structures by Molecular Hierarchic Organization	A
Material	Combustion Dynamics of Fuel Droplets	A
Life	Space Biotechnology	A
Fundamental	Non-equilibrium Dynamics of Complex Systems	A
Applied R	Self- assembling of Nano- particles	A
Fundamental	Chemical Reactions in the outside atmosphere of the ISS	B
Life	Astro biology	B

6. Prioritization of JEM/ISS Early-phase Utilization



7.Promising Research Fields in Space Utilization Sciences (1/3)

Research Field	Description	Rationale / Impact
Research in Crystal Growth Mechanism and in Production Mechanism of Innovative Functional Materials	◆The following researches should be carried out to establish a systematic model. (1) Crystal growth mechanisms ex. heat and mass transportation, interfacial kinetics and morphological instability (2) Prediction of physical properties (3) Interfacial hydrodynamics ◆Integration of scientific outputs in each research will progress technologies for advanced materials, that the others can not easily catch up. ◆Those outputs will be expected to establish the high intelligence society by developing technologies of high performance semiconductor crystals and high quality protein crystals for drug designs.	◆Early scientific outputs from the ISS/JEM operation are expected since all research themes in this field require experiment facilities which are initially installed in the JEM. ◆There are several themes with high score in the 1st international announcement of opportunity (IAO). ◆It can be expected that more advanced crystal growth model is established, which is based on not only heat and mass balances but also interfacial kinetics. ◆By applying a new model established by this research, high quality and value-added crystals can be obtained with less trials and errors than conventional methods. ◆Collaboration with Asian researchers can be expected in this field.
Space Genome Science: Understanding of Functions of Gravity Sensitive Genes	◆Identify responsive 300 genes through comprehensive analyses of biological effects by space environment. ◆Using leading-edge technology of proteomics and bioinfomatics, systematically elucidate the roles of space environment responsive genes and proteins..	◆Studies focused on space environment responsive genes will find new breakthrough in rapid progressions of genome science and technology. ◆Focusing on space environment responsive gene, as disease related genes in human genome project, unique ◆The development of new scientific field with novel scientific finding and possibility of life. ◆Space genome science have a huge potential for development in conjunction with human genome science. ◆Space genome science must be facilitated together with space behavioristic science and space environment science under a long-range plan.

7. Promising Research Fields in Space Utilization Sciences(2/3)

Research Field	Description	Rationale / Impact
Fluid dynamics near the critical point: Understanding of condensation principle and phase-transition mechanism	◆Fluids show peculiar phenomena near the critical point where they are not liquid nor gas. Near the critical point, we observe a rapid thermal transportation, namely, the piston effect in which thermal energies conduct in a sound velocity even if we put an infinitesimal heat pulse. This effect is another kind of thermal transportation as well as thermal convection, thermal diffusion, and thermal radiation. Our aim is clarification of the universality for phase-transition dynamics by means of precise observation for the elementary process of the piston effect. ◆Compressibility diverges near the critical point. A large density difference occurs in fluids due to hydrostatic pressures on Earth. Quantitative evaluations can be done only in microgravity conditions where densities are uniform over the fluids.	◆Japanese scientists greatly contributed to identify the piston effect near the critical point. We can take advantages through the results of the study. ◆It is recommended to obtain new results by space experiments in the near future, because Japanese physicists have enormous knowledge in the field. ◆It is promising to proceed understanding the mechanism of phase transitions and to contribute to development in calculation techniques for critical fluids. ◆Fruitful results will be produced by space experiments in the near future, because it is effective to utilize the microgravity condition in this field.

7. Promising Research Fields in Space Utilization Sciences(3/3)

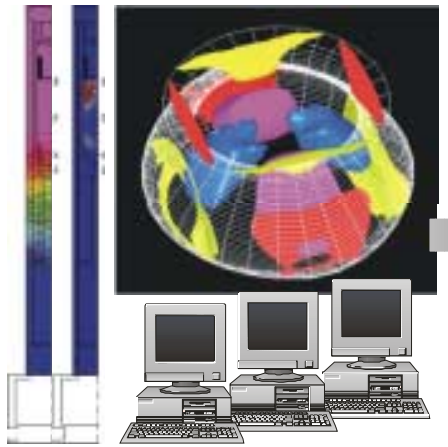
Research Fields	Description	Rationale / Impact
Contribution to Understanding of the Large-scale Structure and Clarifying the Mystery of Birth of Universe (Monitor of All-Sky X-ray Image: MAXI)	◆ Monitoring of high-energy phenomena of X-ray emitting objects in space such as X-ray novae and γ-ray bursts with an extremely high sensitivity ◆ Prompt dissemination of observational results all over the world through the internet	◆ The origin, evolution and structure of the universe is one of the key questions of fundamental importance. Scientific knowledge by the investigations on this question are also expected to have influences of a large extents to other scientific fields and education are also expected form Scientific from the investigation. ◆ Japan leads the field of high-energy astronomy in the world, especially, and MAXI is also expected to have fruitful result in the field. It is important to inherit and develop the international predominance because Japan aims outstanding country in science and technology. ◆ High appreciation will be given to international prompt dissemination of observational results all over the world and cooperative utilization of data as one of the scientific international contribution. ◆ MAXI is a mission with a high compatibilities to aboard JEM Exposed Facility such as an all-sky scanning according to the revolution of ISS. ◆ The implementation of such a mission of high importance above will appeal the significance of existence of ISS and JEM, and the Japanese participation to the ISS program to the public. ◆ Existing research and development team is evaluated to be enough to carry out the development and data utilization of MAXI.
Experimental Observation of Atmospheric Minor Constituents Related to Depletion of the Ozone Layer and Demonstration Of Sensor Technologies as a Forerunner of The World (Superconducting Sub millimeter-Wave Limb-Emission Sounder: SMILES)	◆ Experimental observation of atmospheric minor constituents and demonstration of new sensor technologies as a forerunner of the world ◆ Contribution on development of the Earth environmental science	◆ Demonstration of the Earth observation systems of a new concept witch is effective to understand the environmental variation and to clarify the mechanism of the variation is needed to resolve the problems of nowadays such as the depletion of ozone layers and global warming. ◆ The precise global observation of the altitudinal distribution of atmospheric minor constituents as a forerunner of the world is expected to give a large scientific contribution to the atmospheric chemistry. ◆ The technologies of mechanical coolers and superconducting sensors demonstrated by SMILES are common key technologies in the fields of space and earth science. Hence the demonstration is important to keep the international predominance in these fields and also these technologies are expected to apply to the future Earth environmental watching system. ◆ Japan is expected to contribute to the Earth environmental problems. International cooperative utilization of observational results and research, especially, supplying the observation data to the nations in Asia region is much appreciated as one of the international contribution of Japan. ◆ The implementation of such a mission of high importance above will appeal the significance of existence of ISS and JEM, and the Japanese participation to the ISS program to the public. ◆ Existing research and development team is evaluated to be enough to carry out the development and data utilization of SMILES.

8. Promising Themes in Space Utilization Applied Research

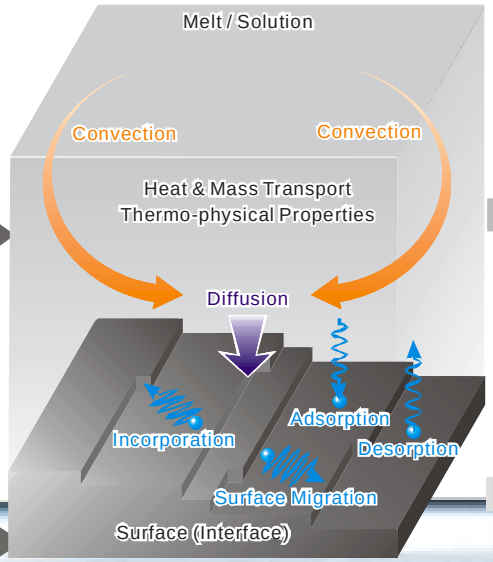
Themes	Description	Rationale / Impact
High-quality Crystallization Project on the Protein Structure and Function Analysis for Application to Contribute to the Development of Structural Genomics National Project and Rational Drug Design Activities.	・NASDA provide fine crystalline proteins made in the ISS to the researchers of structural determination projects and pharmaceutical industries, and contribute to the development of national projects structural genomics and rational drug design. ・NASDA construct effective crystallization process in the ISS , and make up to the ground based main process of structural analysis and application research.	・Increment needs of fine crystalline proteins for structure determination and pharmaceutical application. ・Realization and theoretical confirmation on effectiveness of μg conditions to fine crystal growth of proteins. ・High mass and numerical efficient performance of onboard crystal growth tool, and fast service availability using RSM and GCF for users.
Development of 3-dimensional Photonic Crystals For New Optical Devices of High-performance (Research for Highly Functional Materials Using Self -Assembling of Nano -Particle)	・NASDA develops new high value-added optical device for laser amplification in ISS. Under microgravity nana powders with high refractive index (high density) are arranged uniformly (colloid crystallization) by self-assembling and immobilized by gel matrix. ・NASDA demonstrates the effectiveness of space environment utilization for industrial application of nana and material field and establishes rapid and simple process of space experiment execution.	・Particular R & D Company aims at the development of new manufacturing machine. ・Research on ground has progressed sufficiently which can advance to space experiment. ・Characteristics of microgravity (no sedimentation and no convection) are very effective for colloids crystallization. ・It is considered that space experiment will be realized rapidly by simple apparatus using Russian Service Module.

Back Up

Research in crystal growth mechanism



Numerical Simulation

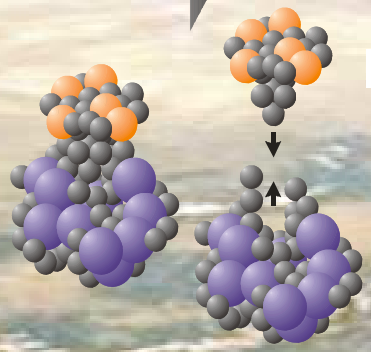


Modeling and Highly accurate data acquisition

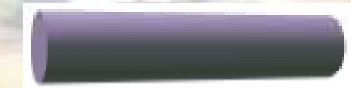
Systematic research of crystal growth mechanism

Ground-based research
Ex) Influence of interfacial phenomena on crystal quality

Bio-Computer Chip

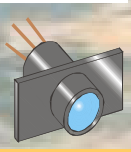


Structure-based Drug Design

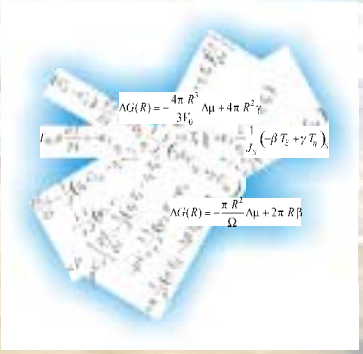


Semiconductor Crystal

Wafer



Infra-red LASER for Optical communication



Research on crystal growth model

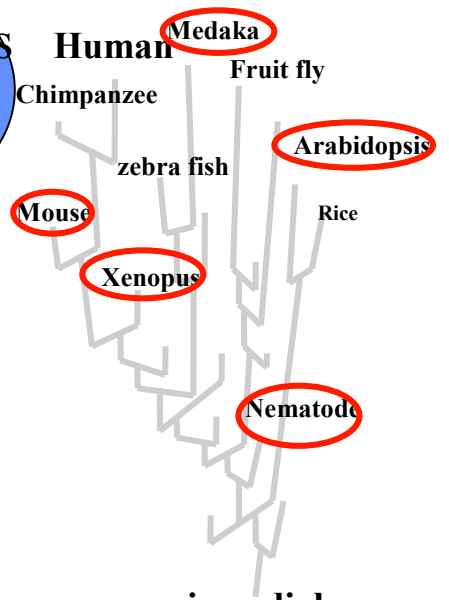
Integration of science outputs can effectively progress technology development for more advanced materials.

Space Genome Science

Expanding Human Activity Beyond Earth

Space

Model Animals
Medaka, Mice, etc



primordial genome

μG
Radiation

Space
Genome Science
300 Space Responsive Genes

Synergy

Ground
Genome Science
focusing on human genome

Ground

Significance and Prospects

- **Elucidation of adaptability and biodiversity**
- **Finding novel biological functions**
- **Conservation biology, comprehensive understanding from individual to ecosystem and biosphere.**
- **Solving global problems such as medical care, ageing, environment.**
- **Expanding platforms of human activity**
- **Establishment of novel industry**

Fluid dynamics near the critical point

Specific aims

To explore such universal laws governing fluctuation of many-particle systems as mechanism of phase transition. Precise experiments for critical fluids can be performed only in microgravity conditions because hydrostatic pressures strongly affect densities of critical fluids.

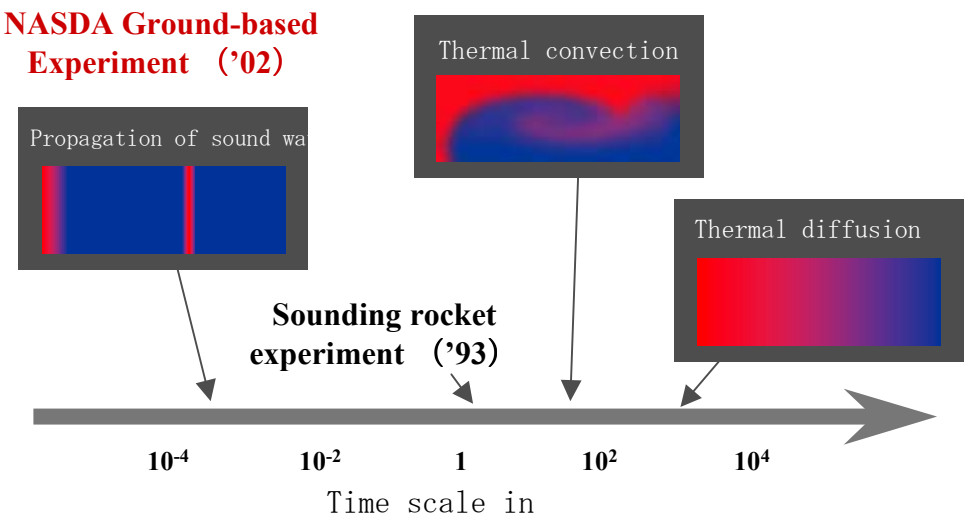
Piston effect near the critical point

・The piston effect is another kind of thermal transportation as well as convection, diffusion, and radiation.

・The European space experiment first observed the effect and Japanese physicist Prof. Onuki, Kyoto Univ. proposed the theoretical model for it.

・The elementary process of the effect never been observed by European experiments. It is very rapid thermal transportation due to peculiar thermal property of critical fluids.

・We are top runners because we first observed the elementary process for the piston effect.

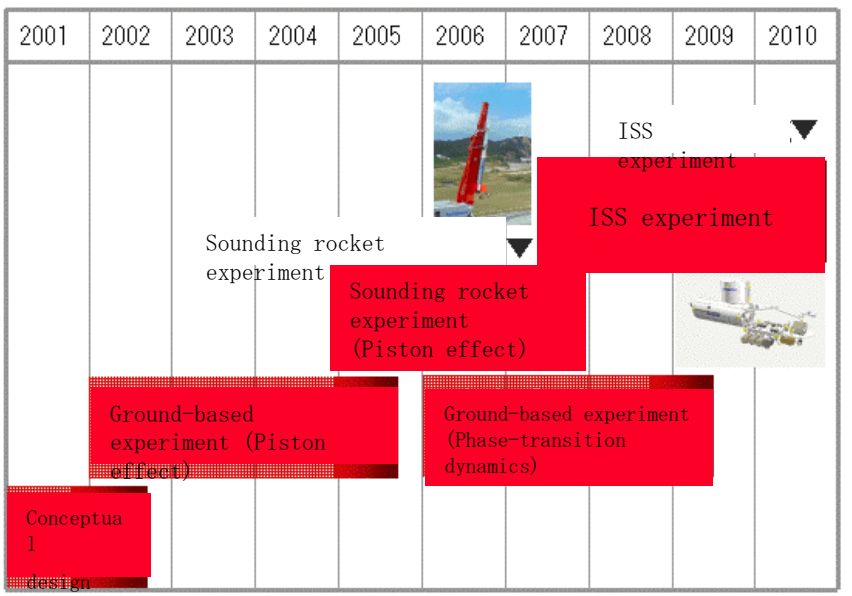


Phase-transition dynamics near the critical point

・Microscopic fluctuation develops to macroscopic scale near the critical point.

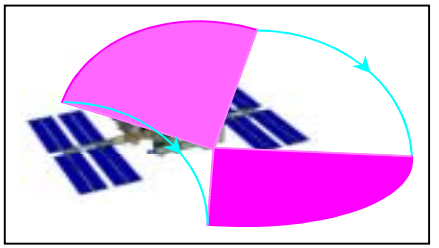
・To explore universal laws for such critical phenomena as boiling, nucleation, and spinodal decomposition.

Time schedule for space experiment



JEM-EF Utilization mission in the first era: Monitor of All-Sky X-ray Image (MAXI) (Most promising candidate in the field of space science)

MAXI
(Engineering Model)



All-sky Scanning by
the revolution of ISS

Scientific Significance

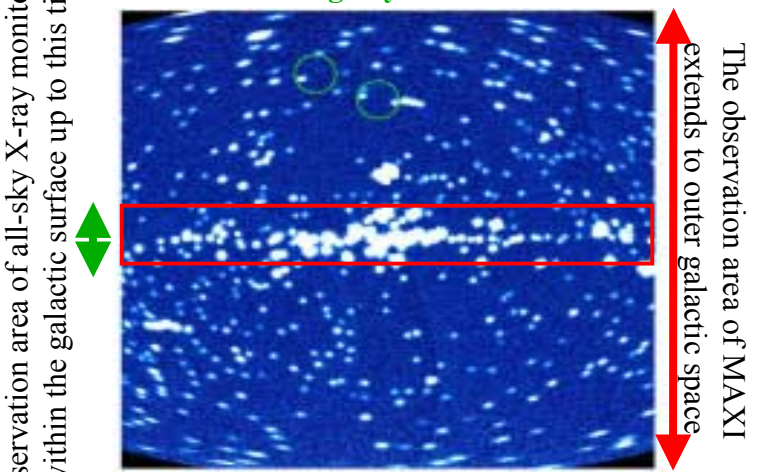
- **Monitoring of long duration of active space phenomena** such as black holes and active galactic nuclear (AGN)
- Mapping of **great structure** of universe
- **Cooperative research** with observations by other bands such as visual, infra-red and radio frequency
  - **Prompt dissemination** of observational results all over the world
  - Maintain the open data base of observational results

➔**Contribution to fundamental space theories** such as origin evolution and structure of universe

Technological Significance

- Observation of All-sky by one evolution of ISS (about 90min.) to **utilize the attitude of ISS suitable to all-sky monitoring**
- **Most sensitive** all-sky X-ray monitoring system never exist
- **Position sensitive proportional counters with largest surface area** adopting carbon fiber reinforced plastics
- Domestic **X-ray CCD with a solid state cooler** of highest technical levels in the world
- **Loop heat pipe cooling system** which can be adopted to future space technology

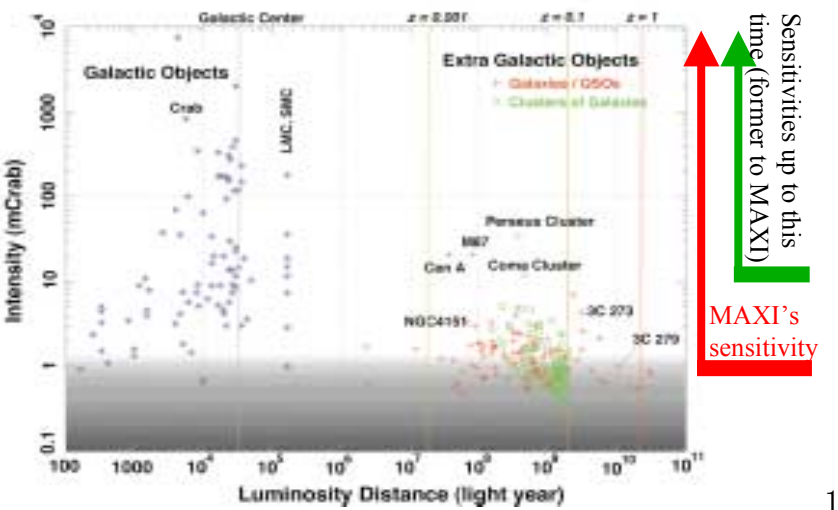
Simulation result of the all-sky X-ray Image by MAXI



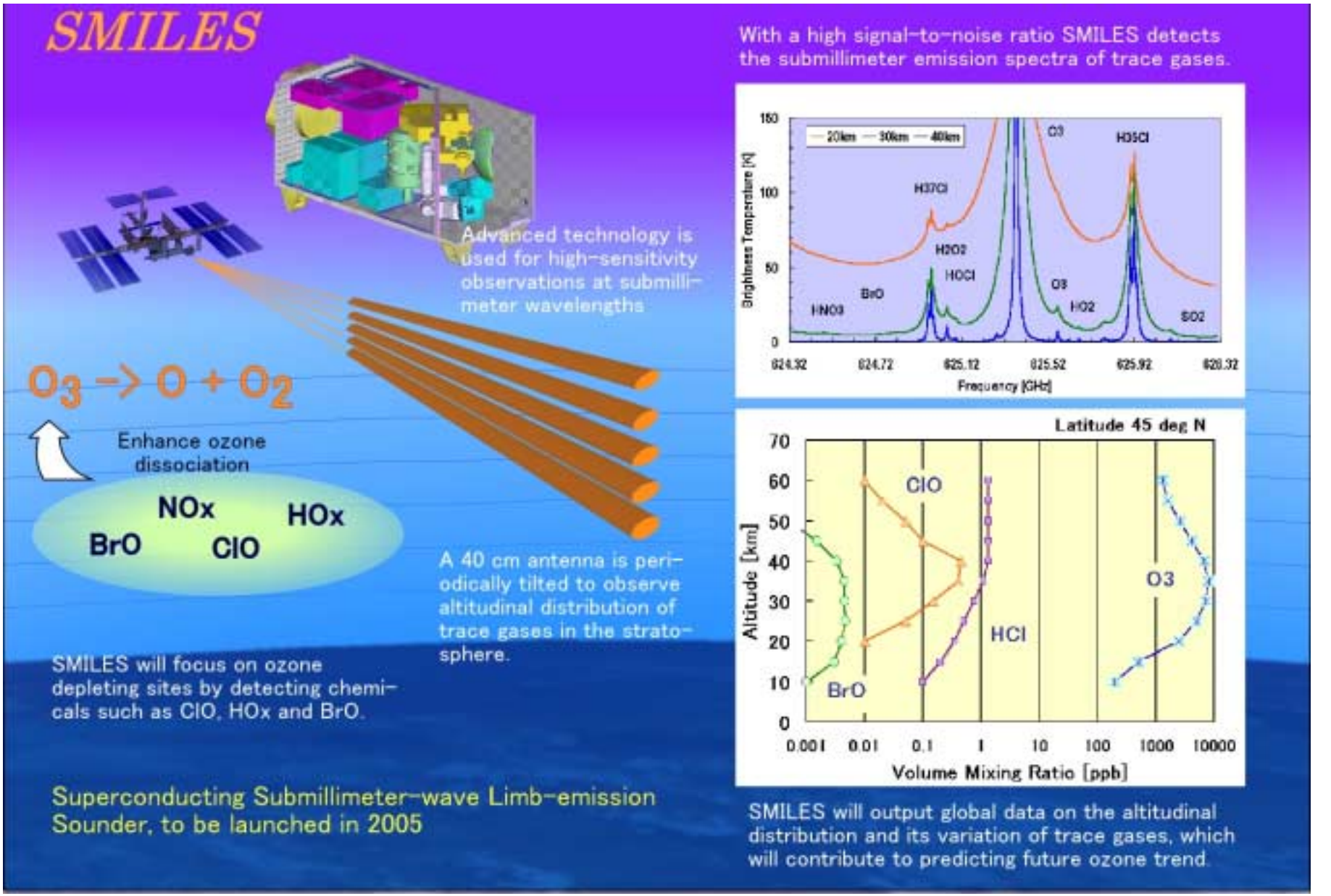
Simulation of cumulative results of 5 months results

Sensitivity of MAXI

Implement highest sensitivity as all-sky monitors never exist



JEM-EF Utilization mission in the first era: Superconducting Sub millimeter-Wave Limb-Emission Sounder: SMILES (Most promising candidate in the field of Earth science)



ISS contribute to the development on structural genomics and pharmaceutical application

Users（Pharmaceutical industries, national research institutes）

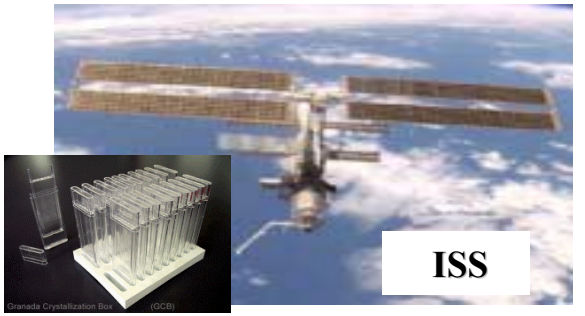
Ground

Cloning and Expression, Protein Purification

Choice of proteins aiming to crystallize in the ISS

Crystal Growth

Crystal growth experiment in ISS



Repeat

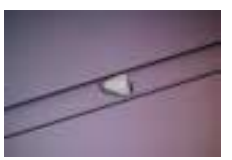
SPring-8

Structural Analysis

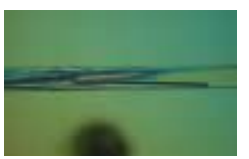
NASDA

Accurate analysis using fine crystalline proteins

Application of development on structural genomics, functional foods products, structure based drug design, and biotechnologies improving of improvement pollution.

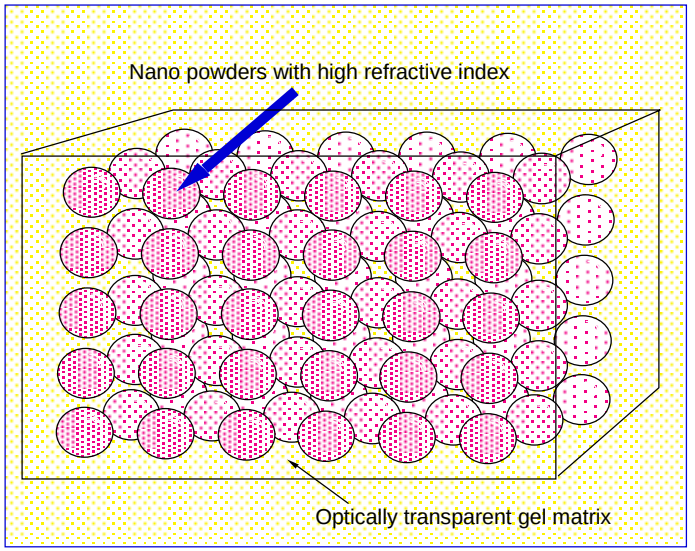


（Crystal under μG）



（Crystal under 1G）

Development of the device for laser pulse amplification using three-dimensional photonic crystal



Objectives

Laser pulse amplification device will be developed using microgravity, in which nano powders with high refractive index (high density) are arranged uniformly by self-assembling and immobilized by gel matrix.

Significances of microgravity

- Nano powders with high density will be floating and self-assembling, which can not be realized on ground.
- High quality and large crystal will grow.

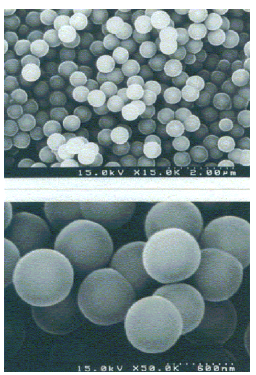
Targets

- Large photonic crystal with highly uniformed lattice spacing
- Tunable lattice spacing by mechanical stress

Research for highly functional material by self-assembling nano particles

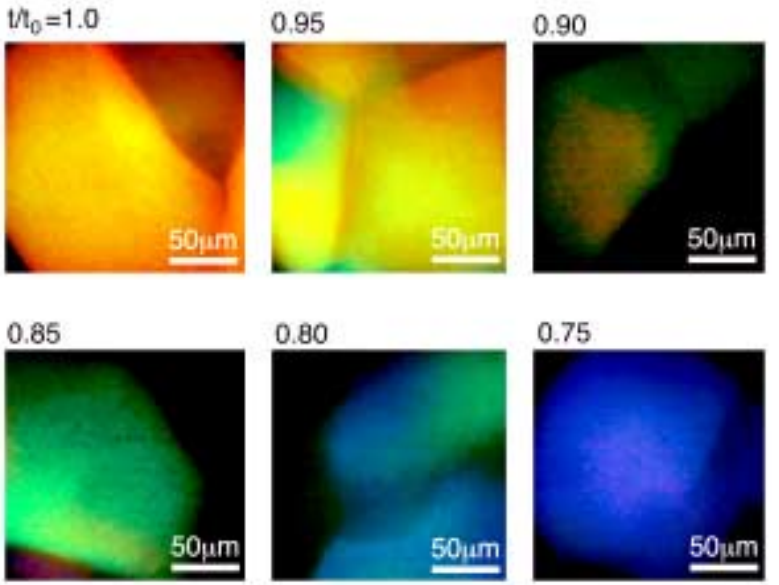
Research on ground

1. Development of nano powders
2. Large single crystallization (cm size)
3. Confirmation of basic characteristics



Newly developed nano particles

Large crystal



Confirmation of tenability of lattice-spacing