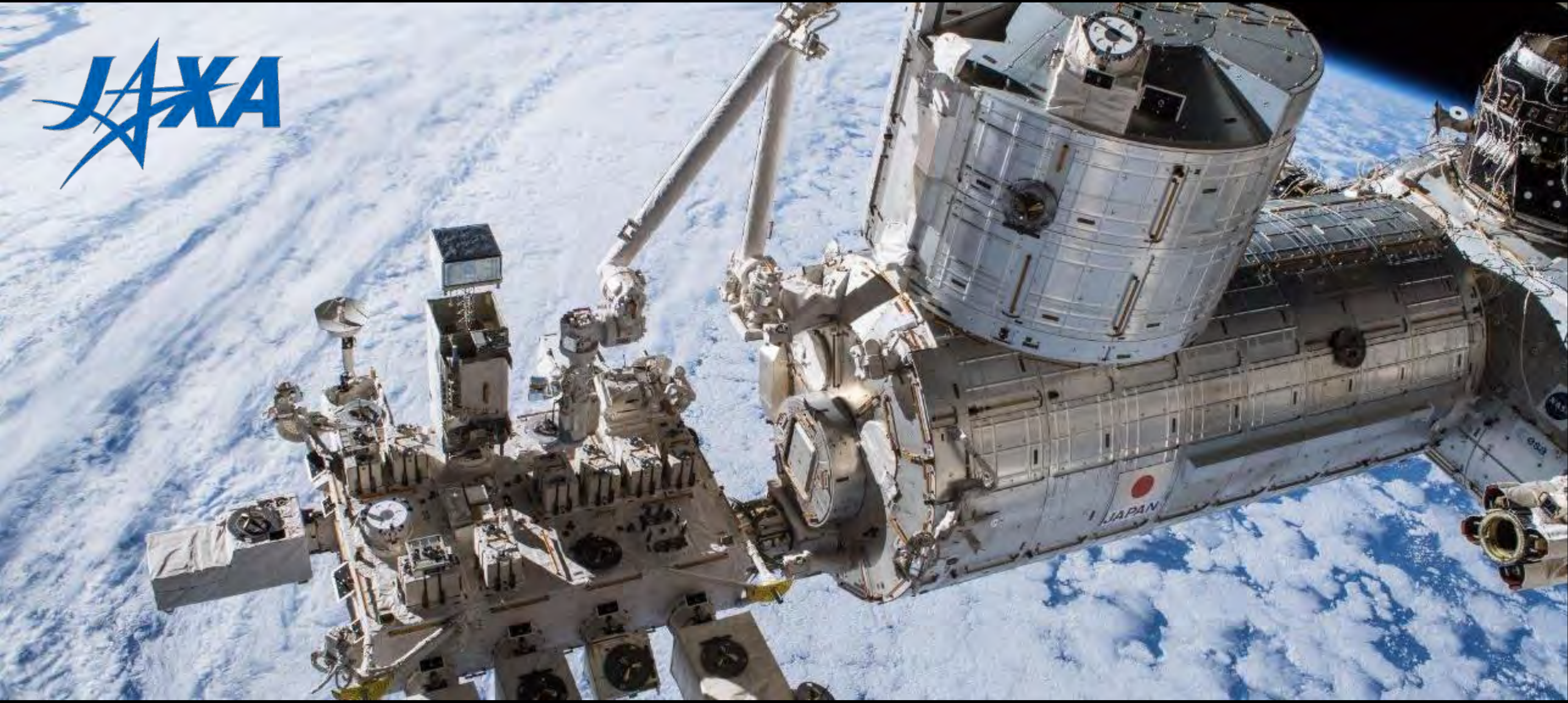
Kibo Utilization Symposium Online November 5, 2020



Opening Remarks

DOI, Shinobu

JEM (Kibo) Utilization Center
Human Spaceflight Technology Directorate
Japan Aerospace Exploration Agency (JAXA)

International Space Station

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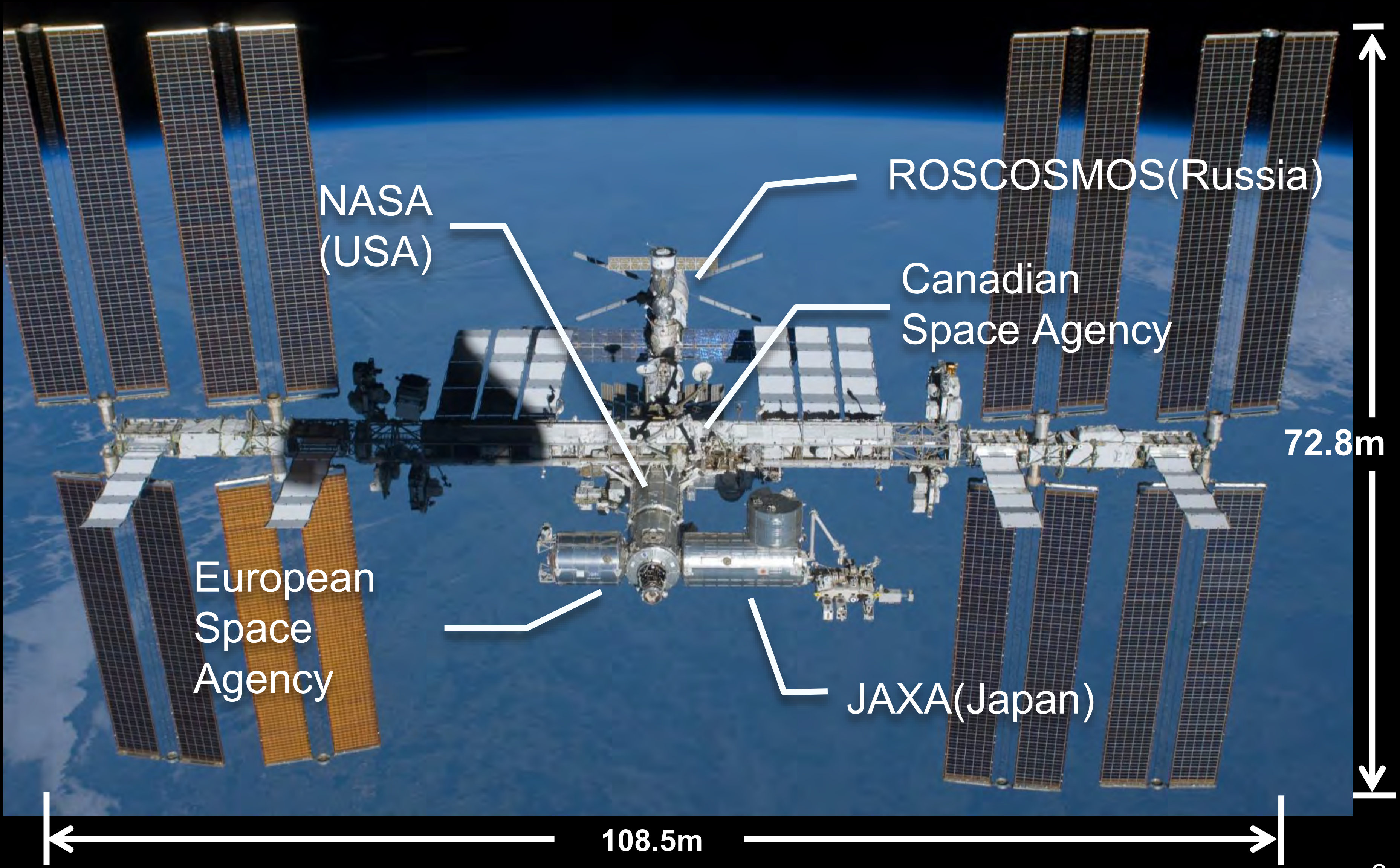
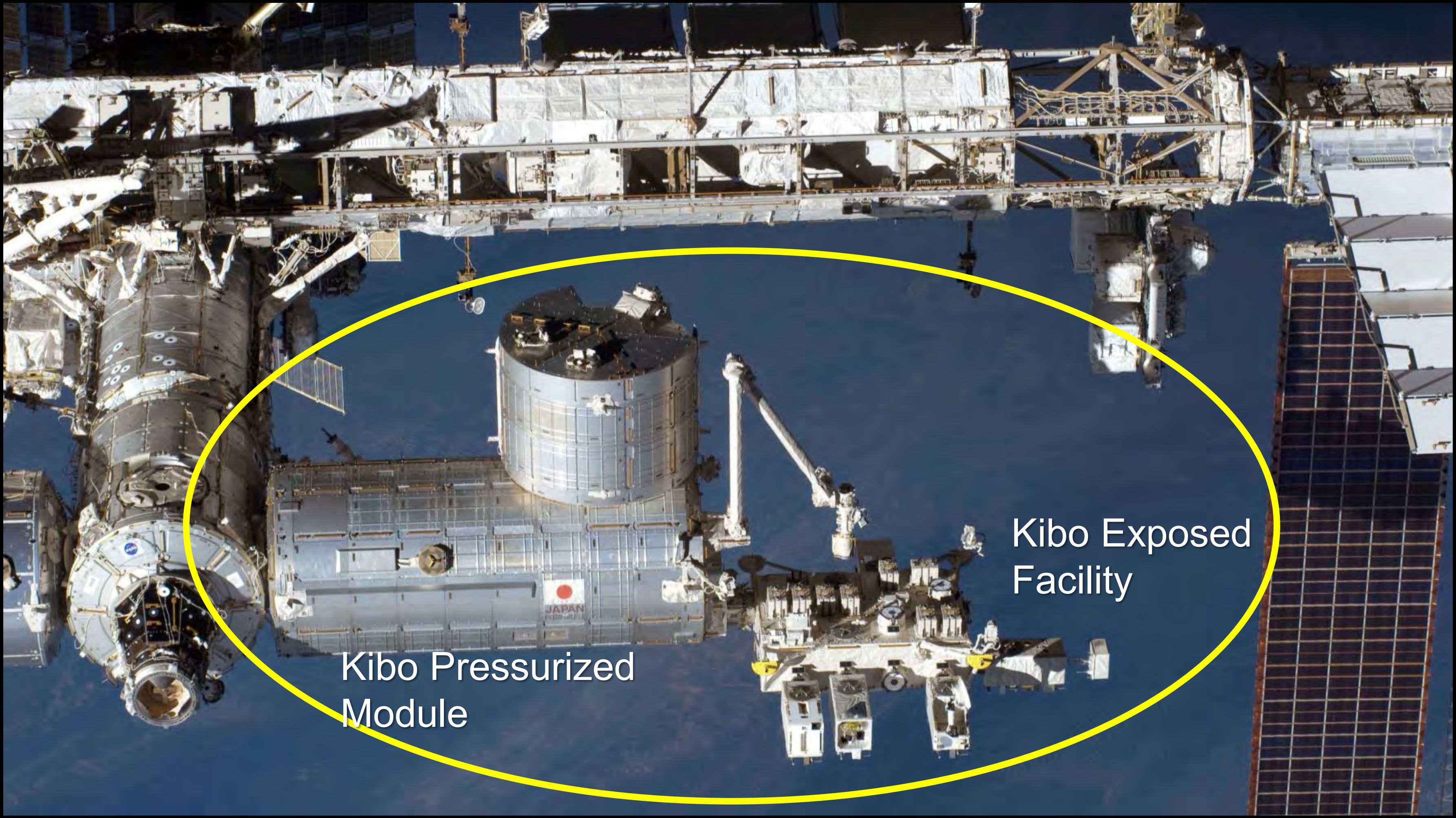


“Kibo” Module (Japanese Experiment Module)



©NASA/JAXA

Inside and Outside of “Kibo” Module

©NASA/JAXA

Pressurized Cabin – JEM PM

©NASA/JAXA

Exposed Facility – JEM EF

What is the expectation from this session?

Have you ever thought about what kind of activities have been conducted on the ISS/Kibo?

Let’s learn;

- ✓ What kind of benefits are brought to humankind on the earth from these activities?
- ✓ What kind of outcomes are expected to expand the human activities from the Low Earth Orbit to the moon and beyond?

Once you have an understanding of the capability of Kibo utilization; then,

let’s explore your idea on what kind of experiment or demonstration you want to do onboard if you had a chance to launch something you want!!!

Kibo Utilization Symposium Online November 5, 2020

JAXA Human Spaceflight Strategy

WAKATA Koichi, Ph.D.
Senior Advisor, Astronaut
Japan Aerospace Exploration Agency (JAXA)

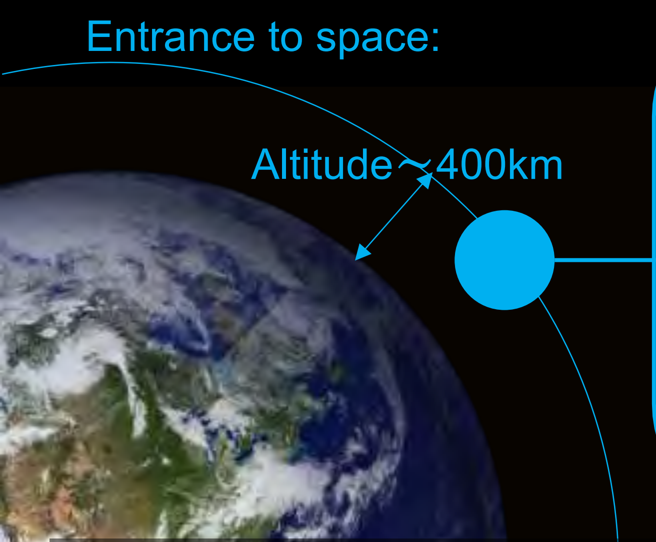
JAXA Human Spaceflight Strategy

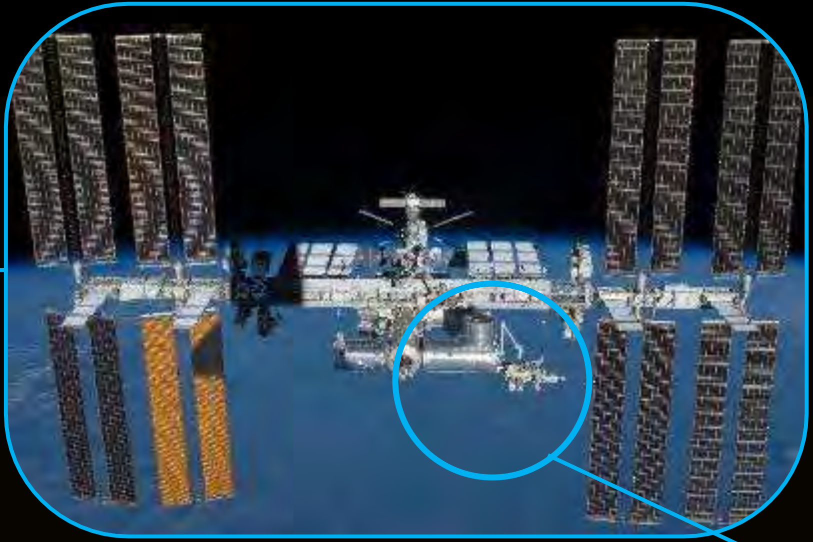
- ISS/LEO and Beyond -

1. Human Space Flight Activities in LEO
   - ✓ “Kibo” & “Kounotori”
   - ✓ “Kibo” Utilization after 2025 (pending decision on ISS operation beyond 2025)
   - ✓ Future Perspectives of ISS & LEO Utilization
2. Beyond LEO ~ Space Exploration to the Moon and Mars~
   - ✓ Japanese Space Policy
   - ✓ JAXA’s Scenario for International Space Exploration
3. Collaboration and Future

１． Human Space Flight Activity in LEO
~ “Kibo” & “Kounotori” ~

International Space Station (ISS)
Japanese Experiment Module "Kibo"





International Space Station (ISS)

- Dimensions: 108.5 m x 72.8 m
- Mass: 420 tons
- Assembly complete: 2011
- Jointly operated by Canada, Europe, Japan, Russia, and the United States
- Continuous human presence since Nov 2, 2020

Japanese Experiment Module "Kibo"

- 2008: Utilization start
- 2009: Assembly complete
- Japan's 1st human-rated experiment facility in space.
- Consists of pressurized and exposed sections

What can be done in "Kibo"?

- Experiments utilizing "μG environment" that cannot be achieved on the ground
- Acquisition of technology and knowledge for human to stay and work in space
- Provision of stable platform for tech demo (verification & testing of equipment, sensors, etc.)
- Various usage, such as entertainment, commercial, and non-R&D activities.

Japanese Cargo Transfer Spacecraft
HTV "Kounotori" and HTV-X

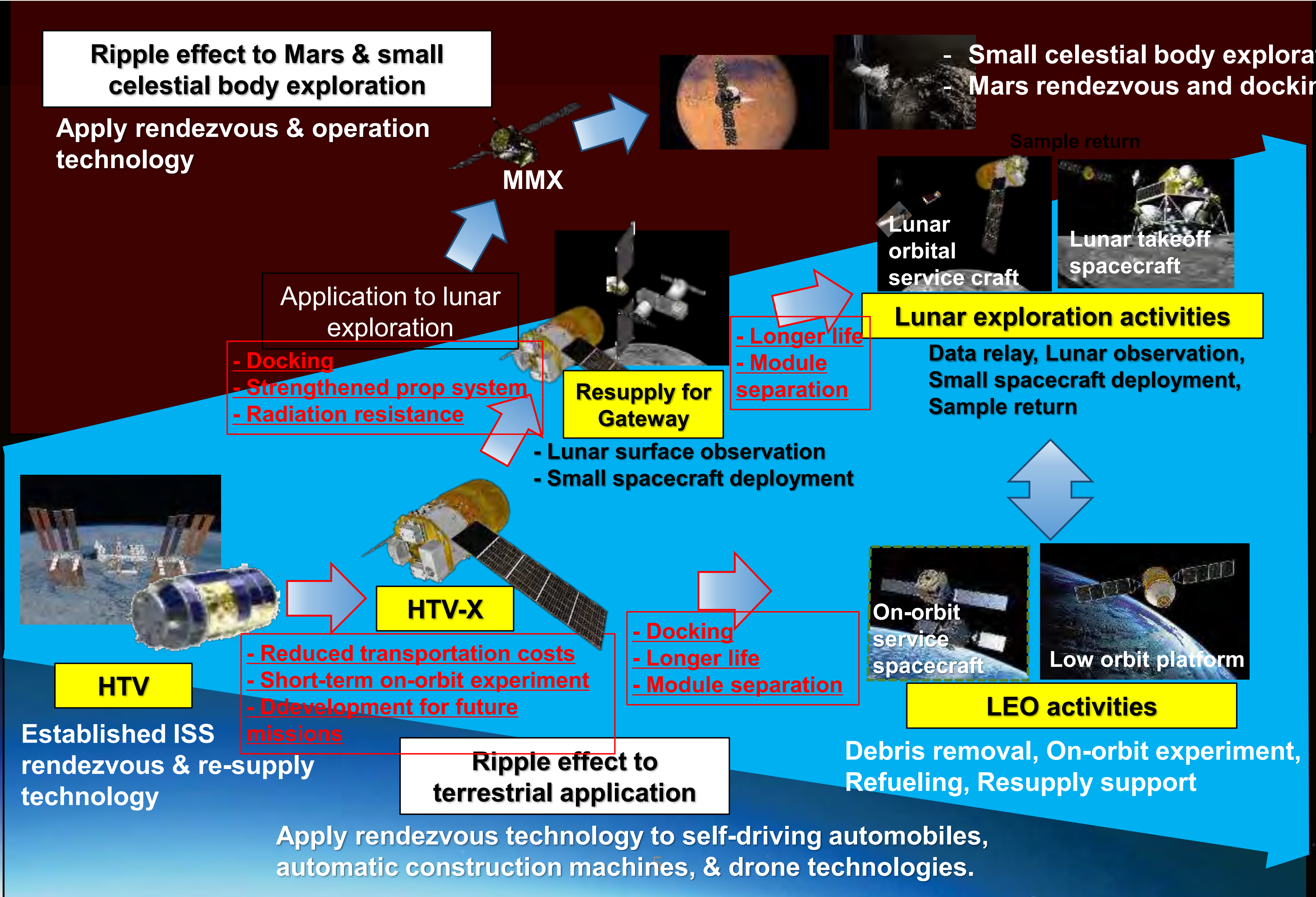
H-II Transfer Vehicle (HTV), "Kounotori"

- Delivers supplies to the International Space Station (ISS)
- Successfully completed 9 mission.
- "Kounotori" means "Stork" in Japanese.

HTV-X

- Successor to "Kounotori" (HTV)
- Currently being developed by JAXA

HTV “Kounotori”, HTV-X, and development of deep space resupply technology (proposed by JAXA)



Ripple effect to Mars & small celestial body exploration

Apply rendezvous & operation technology

MMX

- Small celestial body exploration
- Mars rendezvous and docking

Sample return

Application to lunar exploration

- Docking
- Strengthened prop system
- Radiation resistance

Resupply for Gateway

- Lunar surface observation
- Small spacecraft deployment

- Longer life
- Module separation

Lunar exploration activities

Data relay, Lunar observation, Small spacecraft deployment, Sample return

HTV

Established ISS rendezvous & re-supply technology

HTV-X

- Reduced transportation costs
- Short-term on-orbit experiment
- Ddevelopment for future missions

- Docking
- Longer life
- Module separation

LEO activities

Debris removal, On-orbit experiment, Refueling, Resupply support

Ripple effect to terrestrial application

Apply rendezvous technology to self-driving automobiles, automatic construction machines, & drone technologies.

Current status of JAXA's human space activities (1/2)

1. Expansion of utilization

- ■ Providing new ways to use "Kibo" and expanding utilization
  - Fee-based utilization developed ahead of other ISS Partners:
    - Protein crystal growth (since 2008), Small satellite deployment (since 2012), Material exposure (since 2015), Mid-size external experiment (from 2016), etc.
  - Frequent opportunities and "packaged" utilization so users can plan Kibo utilization easily
  - More than 250 small satellites deployed from "Kibo". Demonstrated usefulness of "Kibo" in global small satellite market.
- ■ Increase in fee-based utilization by private sector
  - 3 cases (FY2007) → 21 cases (FY2018). 85 contracts concluded.
  - Widely used in R&D, human resource development, expansion of startups, etc.
- ■ Initiation of transferring "Kibo" utilization services to the private sector
  - Small satellite deployment (2018).
  - Mid-size experiment in exposed environment (2019)

Current status of JAXA's human space activities (2/2)

2. International contribution

- ■ Utilizing unique capabilities of "Kibo" , such as deployment of small satellites
  - Capacity building in Asian pacific regions and other countries, collaborating with strategic partners, i.e. universities and the UNOOSA through "KiboCUBE" program.
- ■ Expansion of ISS utilization through Japan-U.S. cooperation (JP-US-OP3)
  - Partial-G mouse habitation mission to understand the effect of space environment on mammals and robotics experiments for future human space exploration beyond LEO.

3. Increase in technology demonstration

- ■ Human habitation and deep space resupply
  - Water recovery system
  - Real-time radiation monitoring system
- ■ Spacecraft system
  - Loop heat pipe radiator･･･Preliminary demo for Engineering Test Satellite-9 and next generation communication satellite bus
  - Optical communication terminal･･･Sony CSL to demonstrate commercial technology

１． Human Space Flight Activity in LEO

~ “Kibo” Utilization after 2025~

How to proceed with “Kibo” after 2025 (JAXA proposal)

While some roles will shift to exploration, significance of the ISS will remain if operation continues beyond 2025.

Three major pillars of the significance of “Kibo”.

- Expansion of LEO utilization based on Japan-US cooperation (promotion of JP-US-OP3)
- International presence
- Industrial promotion & innovation in science and technology

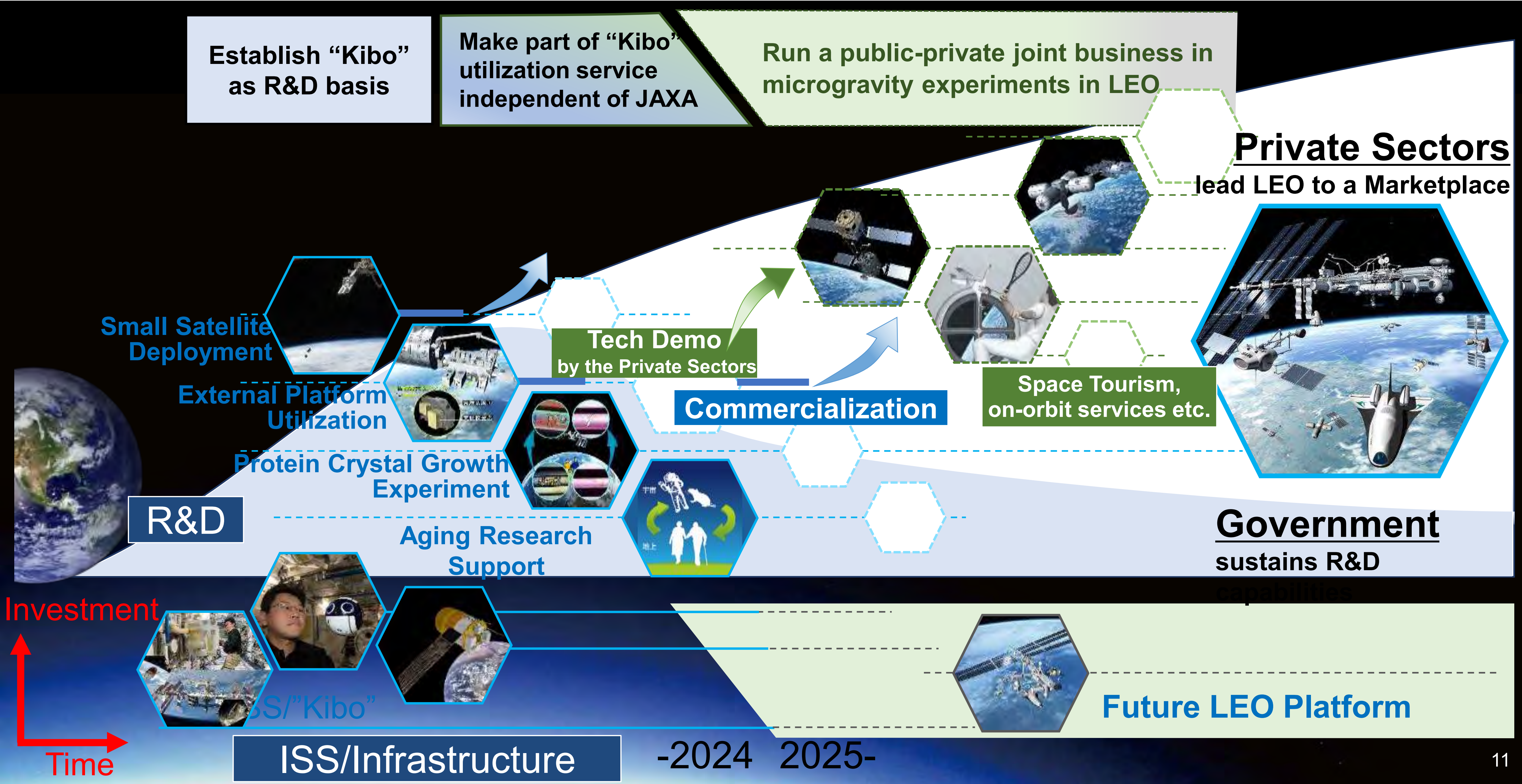
Necessary to organize activity plan based on the progress of the Artemis Program in order to promote Japan’s space exploration especially on lunar surface and LEO activities mainly through the ISS program.

Essential to maintain presence of Japanese astronauts in long duration space flights and focused utilization of space environment by fully utilizing “Kibo”.

１． Human Space Flight Activity in LEO

~ Future Perspectives of ISS & LEO Utilization ~

Long-Term Vision of LEO Activities



Establish "Kibo" as R&D basis

Make part of "Kibo" utilization service independent of JAXA

Run a public-private joint business in microgravity experiments in LEO

Private Sectors
lead LEO to a Marketplace

Small Satellite Deployment

External Platform Utilization

Protein Crystal Growth Experiment

Aging Research Support

Tech Demo
by the Private Sectors

Commercialization

Space Tourism, on-orbit services etc.

R&D

Government
sustains R&D capabilities

Investment

Time

SS/"Kibo"

Future LEO Platform

ISS/Infrastructure

-2024 2025-

2. Beyond LEO ~ Space Exploration ~ Japanese Space Policy

Decision by the Government of Japan (October 18, 2019)

Strategic Headquarters for National Space Policy, led by Prime Minister Shinzo Abe, was held on October 18, 2019, and the Government of Japan officially decided to join the international space exploration, and will proceed on international coordination in the following four cooperation areas:

1. Provision of technology and equipment in Japan's areas of strength for Gateway Phase1
2. Cargo and fuel resupply missions for Gateway using HTV-X and H3 Launch Vehicles
3. Sharing of lunar surface data and technologies contributing to the selection of landing sites, etc.
4. Developing transportation vehicles to support lunar surface exploration

Joint Exploration Declaration of Intent for Lunar Cooperation (JEDI）(July 10th, 2020)

- Signed on July 10th, 2020 by Minister of Education, Culture, Sports, Science and Technology(MEXT) and NASA Administrator.
- Following contents are agreed.
  - Government of Japan’s contributions

    ①Provision of equipment and components to the Gateway habitation capability infrastructure functions (batteries, ELCSS, etc.)

    ②Logistics resupply (with technology demonstration on the ISS)

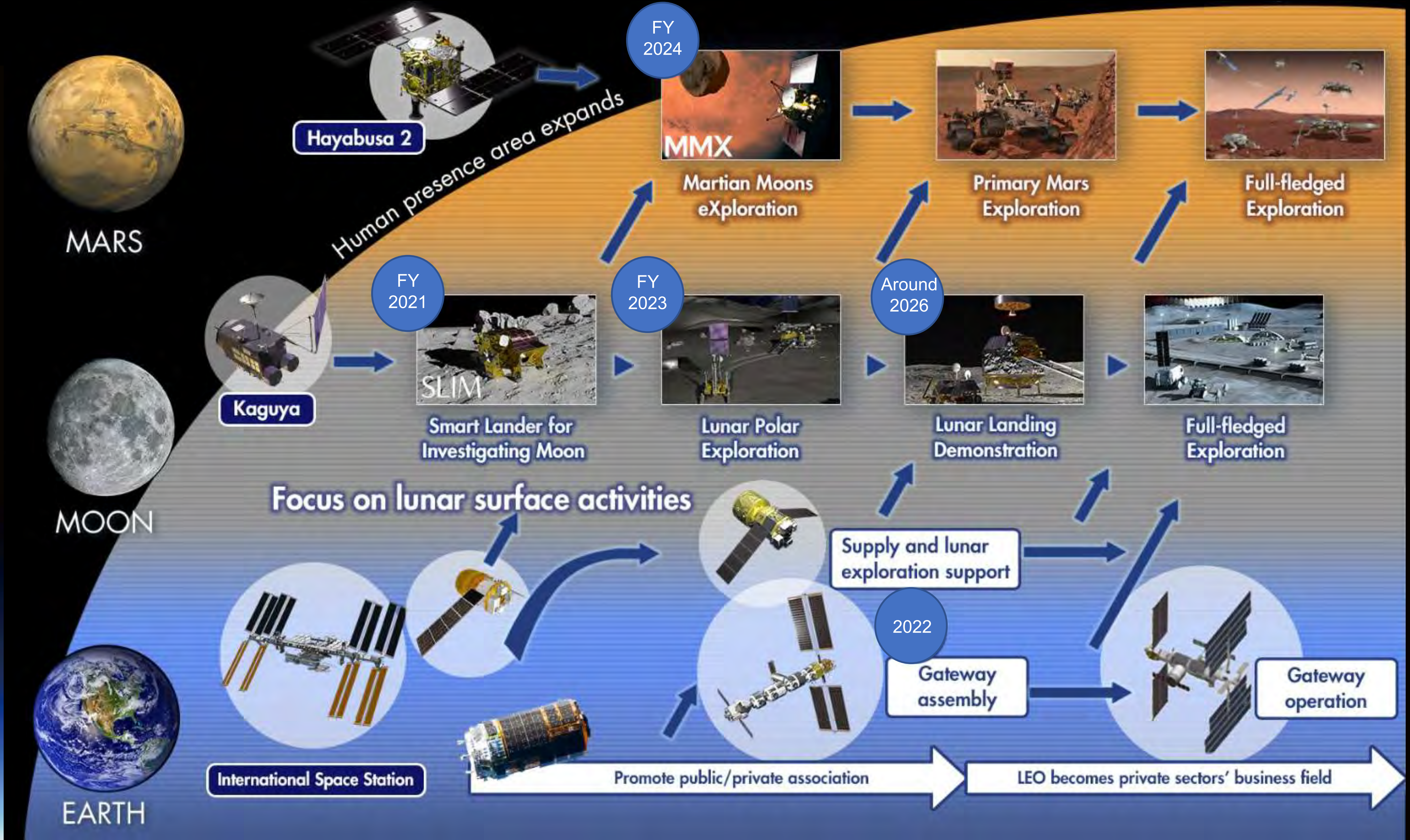
    ③Lunar surface data sharing (SLIM, LUPEX, etc.)

    ④Crewed pressurized lunar rover (Concept study for lunar rover development and operations)
  - Japanese Astronauts’ flight opportunities for
    - Gateway
    - Lunar surface exploration activities
- MEXT and NASA agreed to determine the details in the implementing arrangements.

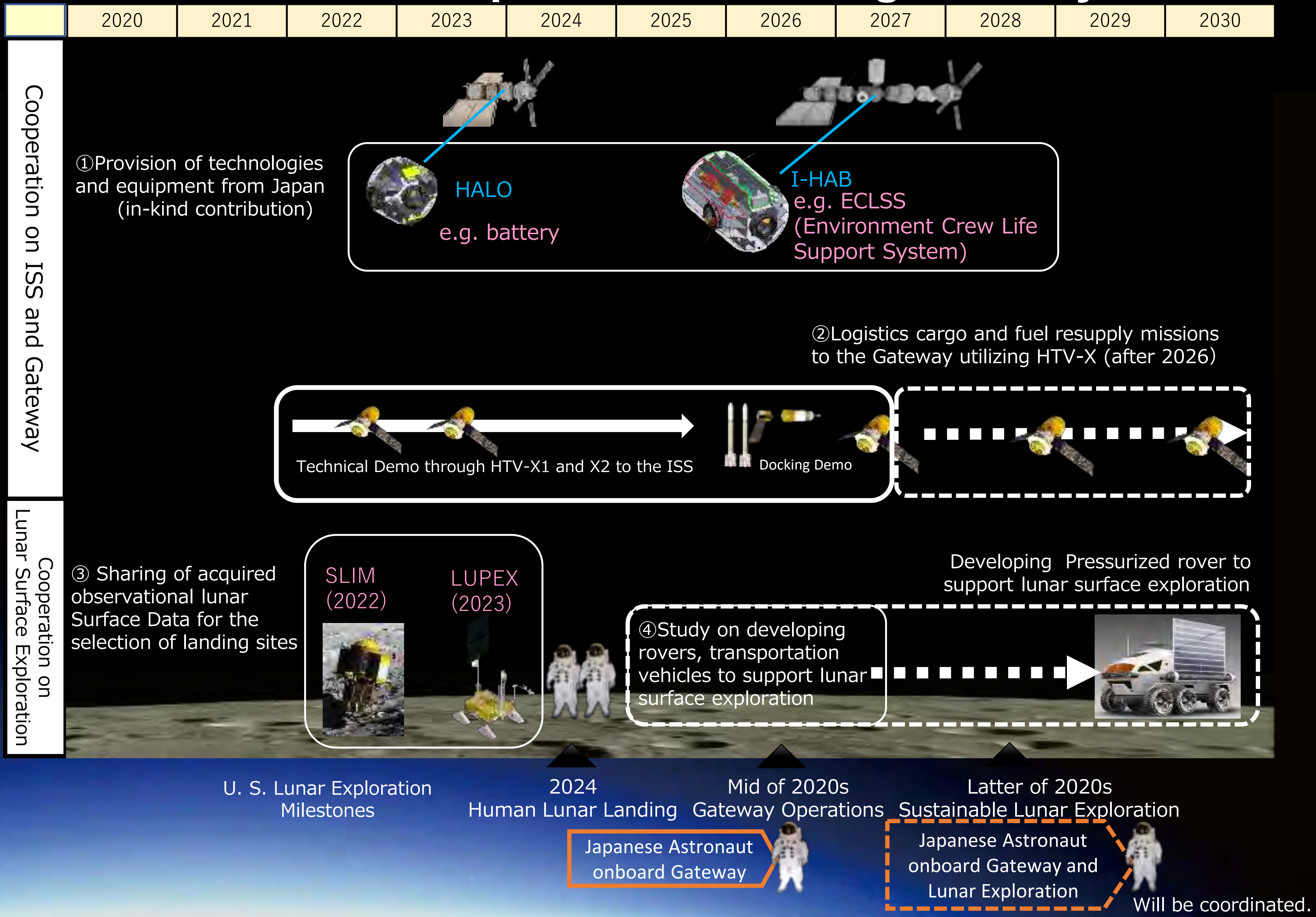
2. Beyond LEO ~ Space Exploration ~

JAXA’s Scenario for International Space Exploration

JAXA's Scenario for International Space Exploration



Japan's four items of cooperation that contribute to the Moon exploration including Gateway



①Provision of technologies and equipment from Japan (in-kind contribution)

HALO

e.g. battery

I-HAB

e.g. ECLSS (Environment Crew Life Support System)

②Logistics cargo and fuel resupply missions to the Gateway utilizing HTV-X (after 2026)

Technical Demo through HTV-X1 and X2 to the ISS

Docking Demo

③ Sharing of acquired observational lunar Surface Data for the selection of landing sites

SLIM (2022)

LUPEX (2023)

④Study on developing rovers, transportation vehicles to support lunar surface exploration

Developing Pressurized rover to support lunar surface exploration

U. S. Lunar Exploration Milestones

2024
Human Lunar Landing

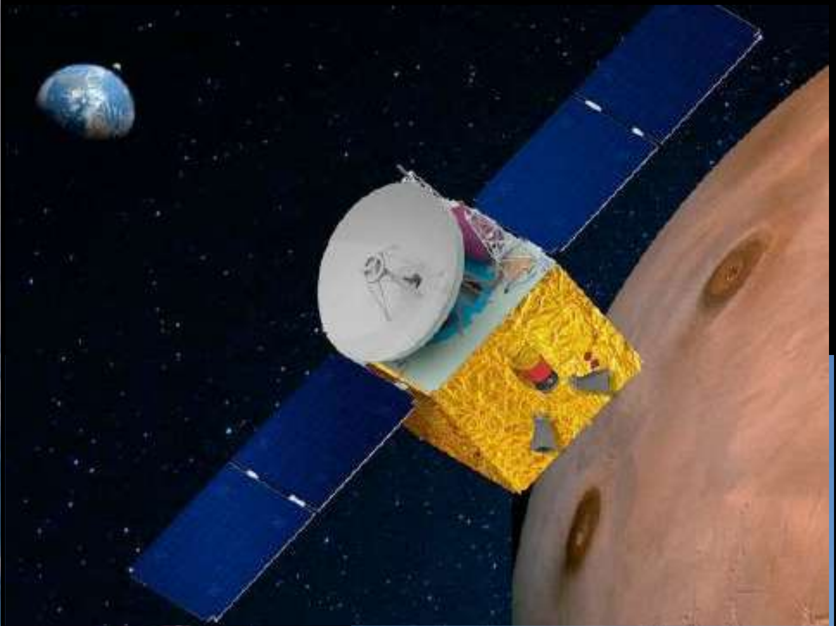
Mid of 2020s
Gateway Operations

Latter of 2020s
Sustainable Lunar Exploration

Japanese Astronaut onboard Gateway

Japanese Astronaut onboard Gateway and Lunar Exploration

Will be coordinated.



مشروع الإمارات لاستكشاف المريخ ✦ EMIRATES MARS MISSION

مسبار الأمل
HOPE

3. Collaboration and Future

Collaboration between UAE and JAXA, and Future

1. JAXA-MBRSC educational project by Astronaut Al Mansoori with "Int-Ball"

- On September 30, 2019, the first Emirati astronaut,Hazzaa Al Ma gave a special lecture aboard “Kibo” with camera robot "Int-Ball".

2. 1st Kibo Robot Programming Challenge

- At preliminary round in UAE, UAE Space Agency selected the winner, “999-IN-SPACE ”, who won the Programming Skills Award 2nd Place in the final round.

3. Asian Herbs in Space (AHiS)

- UAE participation in the program starting in 2020

We will continue to collaborate in the future

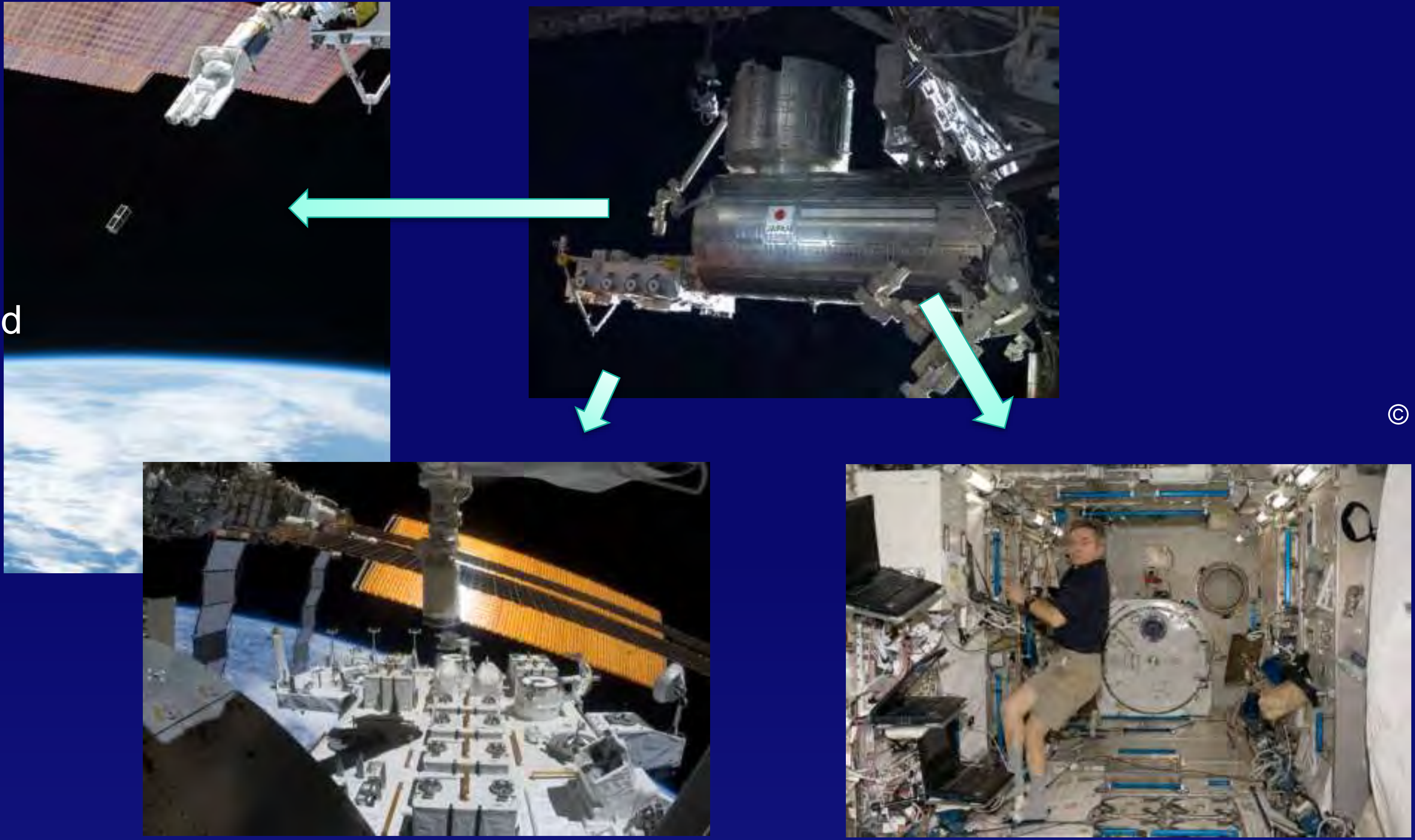
Explore to Realize

Kibo Utilization Symposium Online November 5, 2020

JAXA’s Kibo Utilization Overview

SHIRAKAWA, Masaki
JEM (Kibo) Utilization Center
Human Spaceflight Technology Directorate
Japan Aerospace Exploration Agency (JAXA)

Kibo, the largest lab in ISS for various fields of science



Kibo’s dedicated robotic arm

© NASA/JAXA

The largest external platform in ISS

The largest pressurized (internal) lab in ISS

Unique feature of ISS/Kibo

You can observe anywhere in ISS:

- ◆ Rapid decrease of bone & muscle
- ◆ Biological changes caused by space env.
- ◆ Physical phenomenon without gravity and convection
- ◆ Earth and Space

But,

Only in Kibo, you can observe

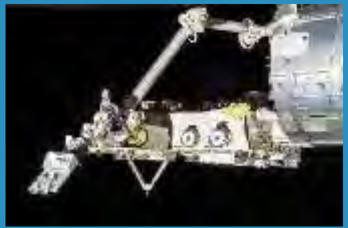
- ◆ Biological changes on-orbit in real time with cutting-edge devices: confocal microscope, optical imaging device, etc.
- ◆ Critical phenomenon: Combustion, crystallization

Only in Kibo, you can do

- ◆ Artificial-g or lower-g research on mammal (mice)
- ◆ Various use of external env.: small-sat deploy, easy-to-use attachment for user-equipment, material exposure

Centrifuge-equipped biological exp. facility

New largest centrifuge in ISS (Φ 0.76m)



Only in Kibo, you can measure

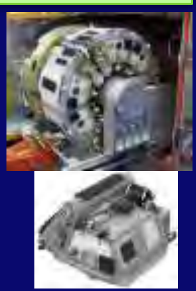
- ◆ Thermophysical properties in container-less or floating condition using electrostatic force
  - ➢ Up to 3,000 °C for glass, ceramics

On Earth (1G) In Space (μG)

Kibo Pressurized (internal) Utilization Facilities

SAIBO Rack

CBEF (Cell Biology Experiment Facility)



MHU
(Mouse Habitat Unit)

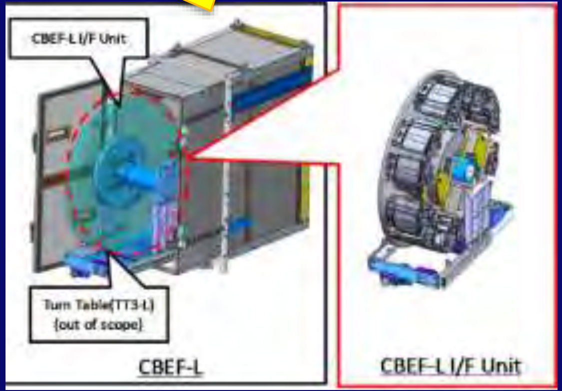
Confocal microscope

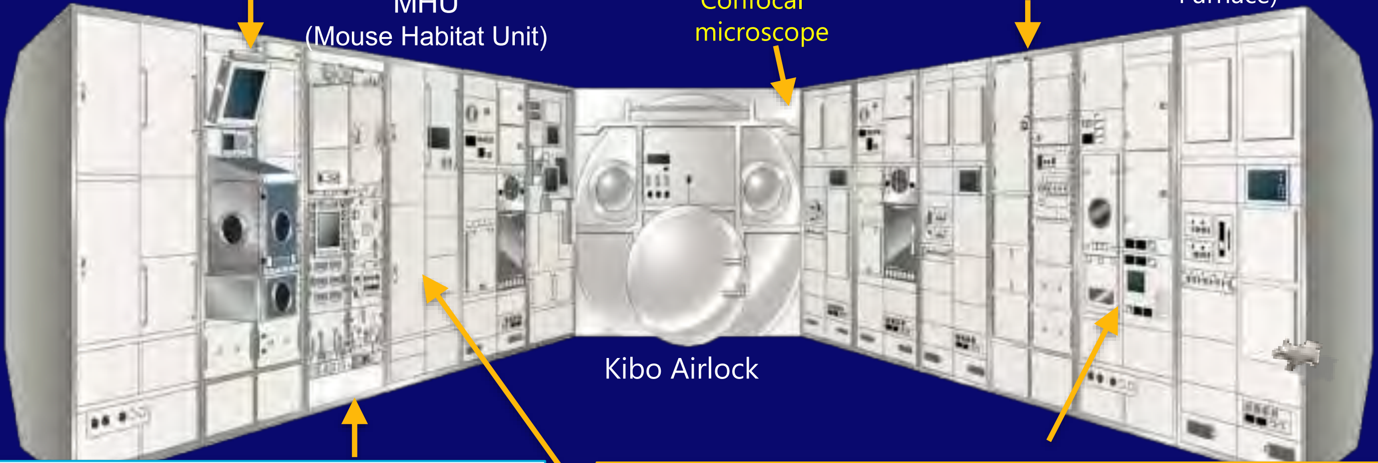
KOBAIRO Rack

GHF (Gradient Heating Furnace)

FROST
(On-board Refrigerator)

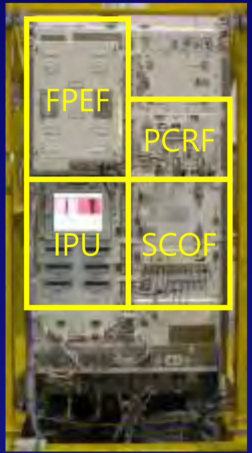
CBEF-L with a new large centrifuge (φ0.76m)





Kibo Airlock

RYUTAI Rack



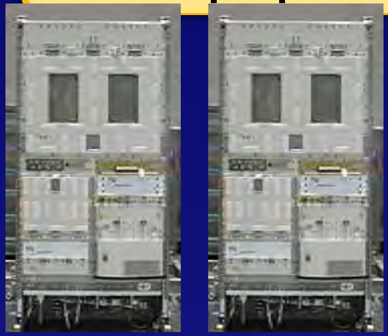
FPEF
(Fluid Physics Experiment Facility)

IPU
(Image Processing Unit)

SCOF (Solution Crystallization Observation Facility)

PCRF (Protein Crystallization Research Facility)

Multi-purpose Small Payload Rack 1,2



MSPR #1, #2

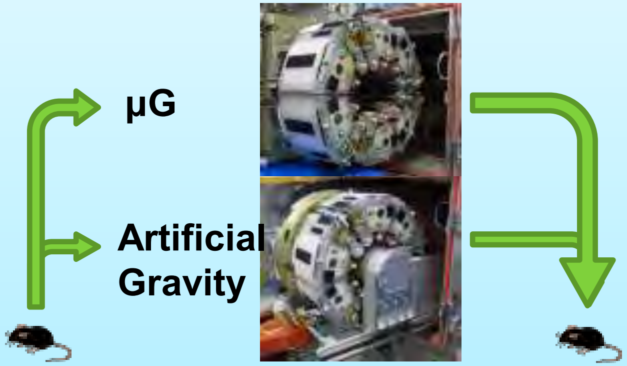
CCE
(Chamber for Combustion Experiment)

ELF (Electrostatic Levitation Furnace)

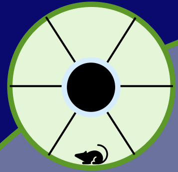
Fluorescence Microscope

JAXA rodent mission

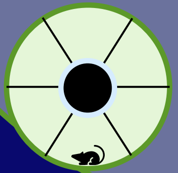
Unique feature of JAXA rodent research system



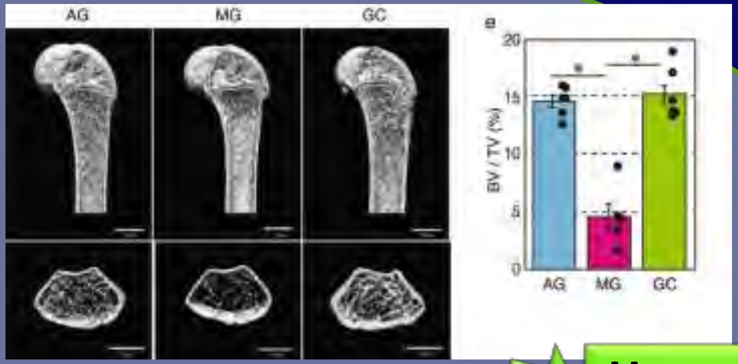
- ✓ Artificial gravity
- ✓ Individual housing and monitor
- ✓ Successful 5 consecutive live return
- ✓ Max. 24 mice



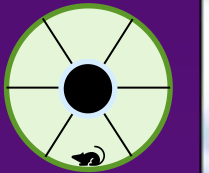
µG



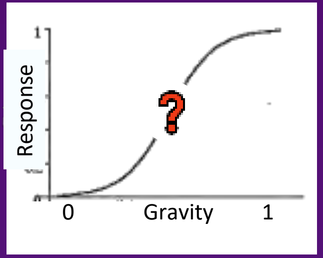
Artificial 1G



Human Health on Earth



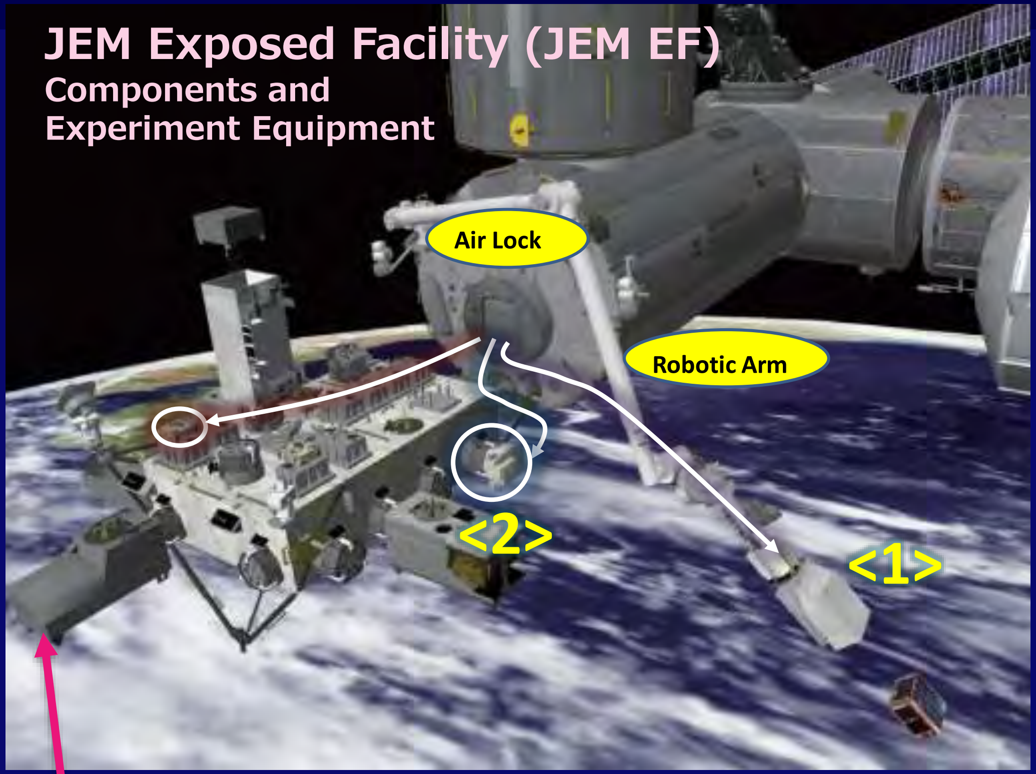
Partial-G



Human Exploration

Some samples/tissues taken at previous missions are available. Please contact us if you’re interested in.

Kibo Exposed Facility



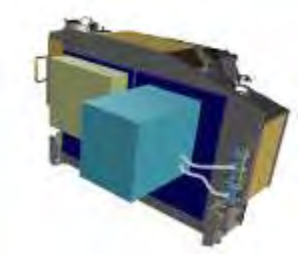
<1> JEM Small Satellite Orbital Deployer (J-SSOD)

- Commercial service provides: Space BD Inc. and Mitsui Bussan Aerospace Co., Ltd.

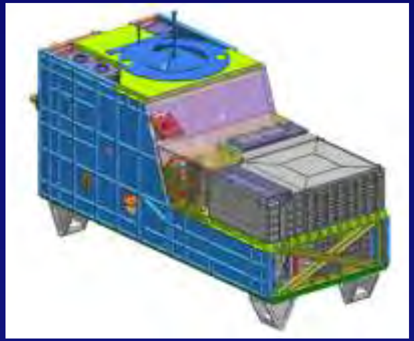
© JAXA

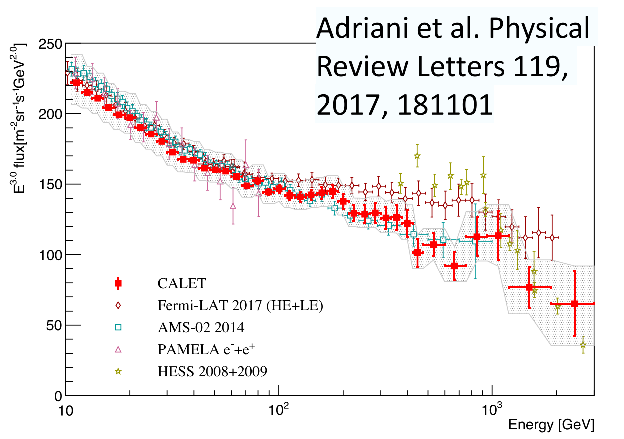
<2> IVA-replaceable Small Exposed Experiment Platform (i-SEEP)

- Space BD Inc. is a service provider.



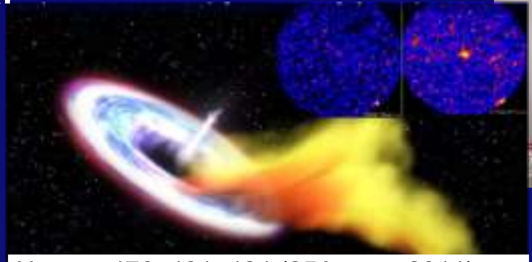
CALorimetric Electron Telescope: CALET



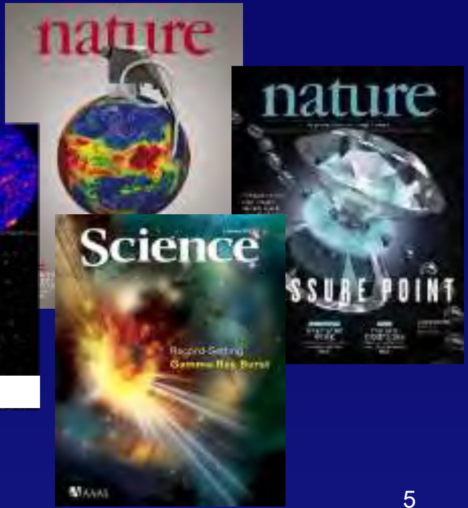


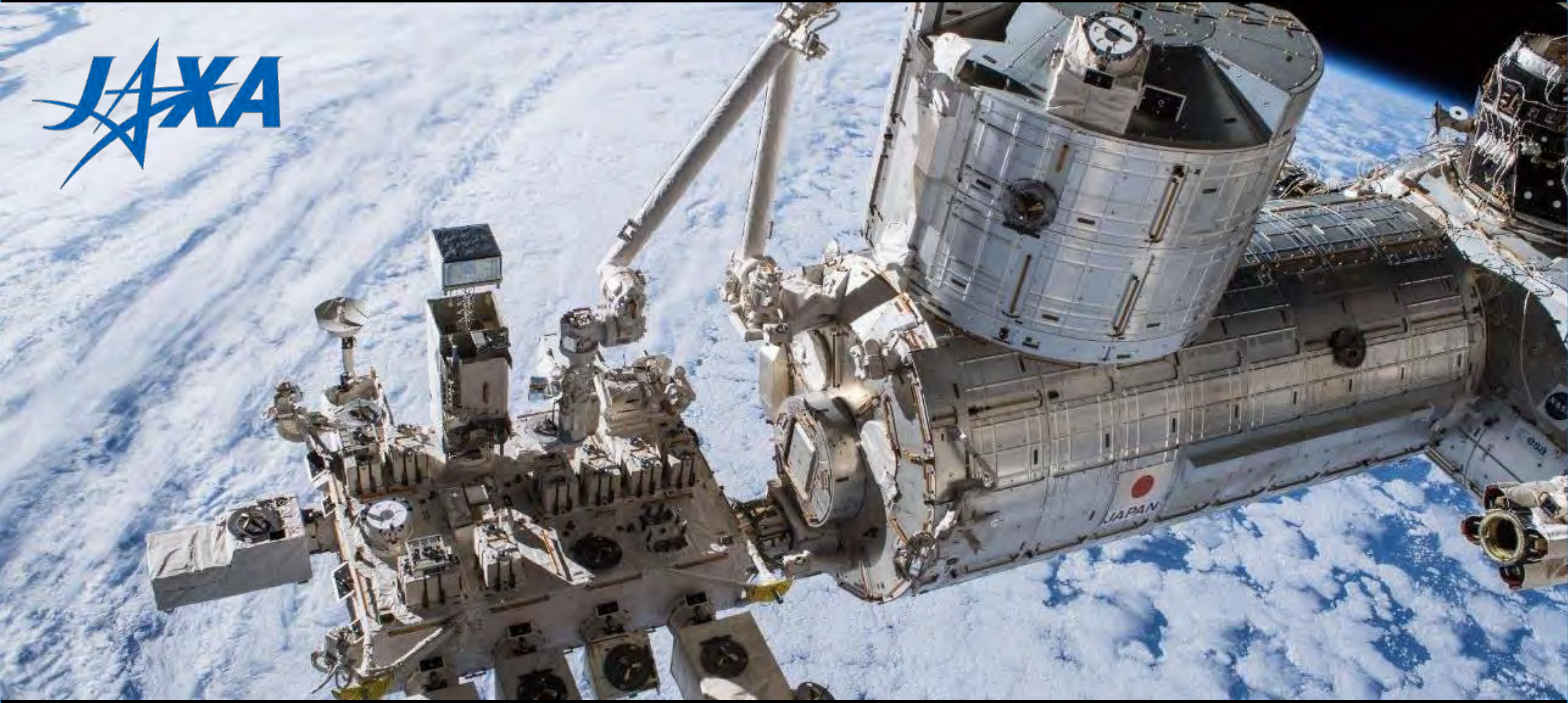
Adriani et al. Physical Review Letters 119, 2017, 181101

Monitor of All-sly X-ray Image: MAXI



Nature, 476, 421–424 (25August 2011)





JAXA Protein Crystal Growth experiment

YOSHIZAKI Izumi

JEM (Kibo) Utilization Center
Human Spaceflight Technology Directorate
Japan Aerospace Exploration Agency (JAXA)

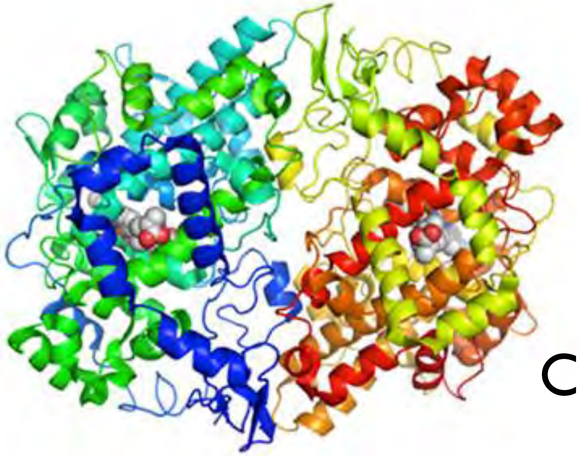
JAXA PROTEIN CRYSTAL GROWTH PROJECT

CONTRIBUTE TO HUMANITY BY DETERMINING THE PRECISE PROTEIN STRUCTURE FROM HIGH QUALITY CRYSTALS OBTAINED ONBOARD ISS.

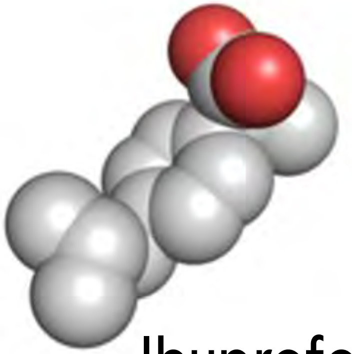
EXPECTED OUTCOMES

- ✓DRUG DESIGN BY PHARMACEUTICAL COMPANY
- ✓INDUSTRIAL ENZYME DESIGN
- ✓NEW FINDINGS IN BIOLOGY/BIOCHEMISTRY BY ACADEMIC USERS

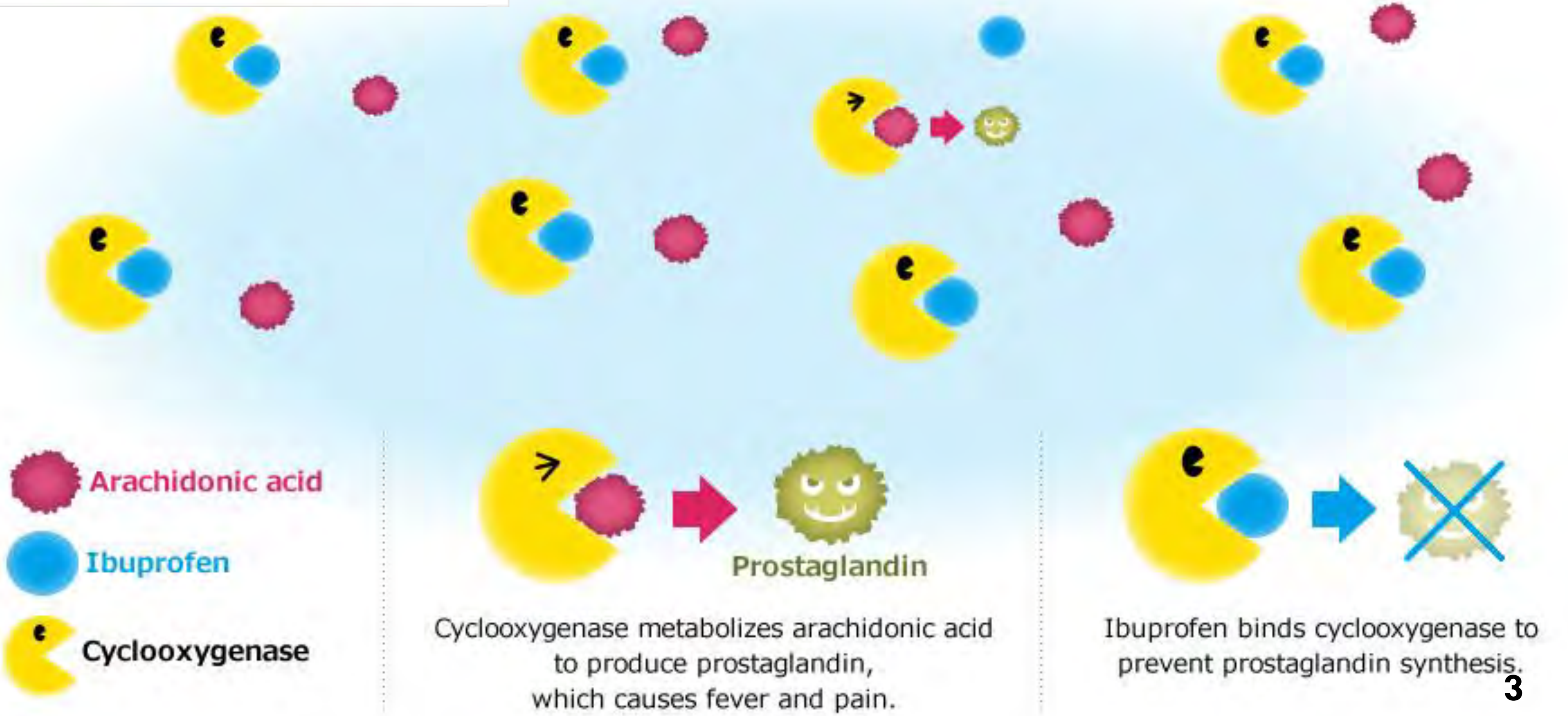
HOW THE PAINKILLE WORKS



Cyclooxygenase(COX)-2



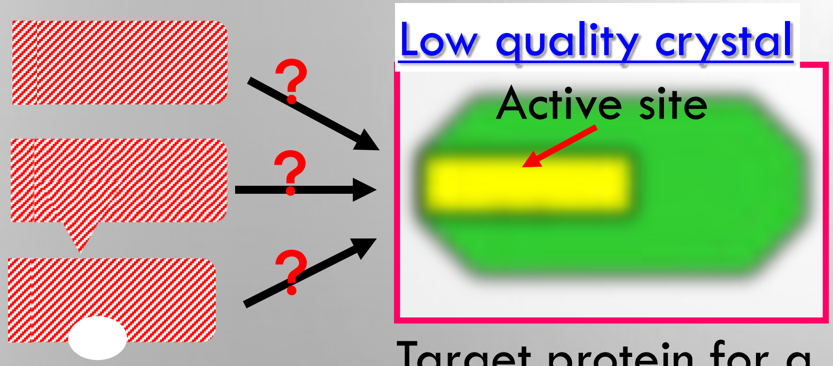
Ibuprofen



Cyclooxygenase metabolizes arachidonic acid to produce prostaglandin, which causes fever and pain.

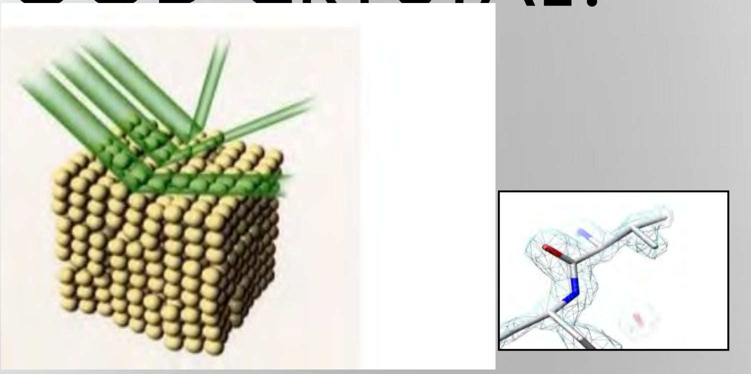
Ibuprofen binds cyclooxygenase to prevent prostaglandin synthesis.

WHY DO WE WANT A GOOD CRYSTAL?

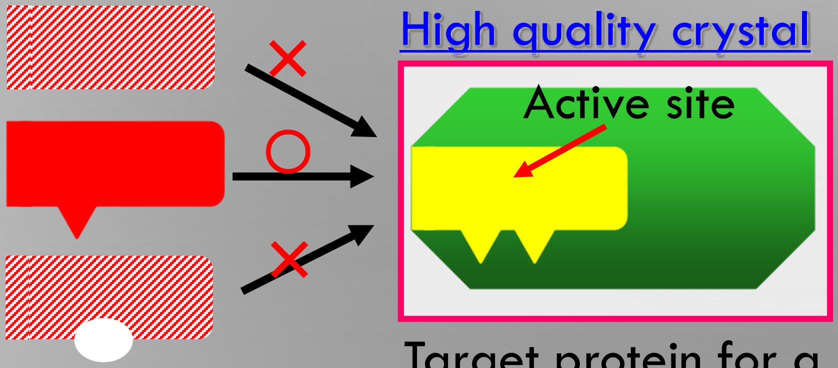


Low quality crystal

Target protein for a certain disease

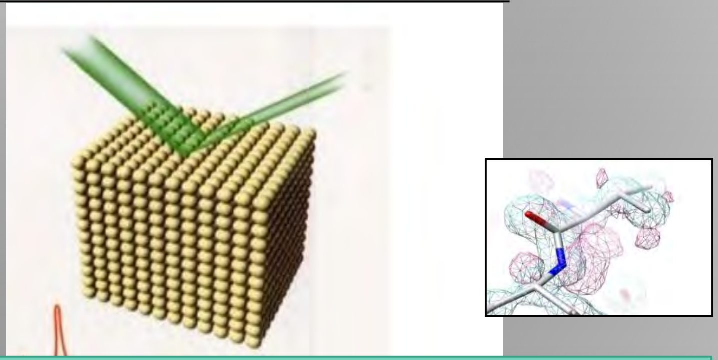


The binding site is not clearly shown from a low quality crystal



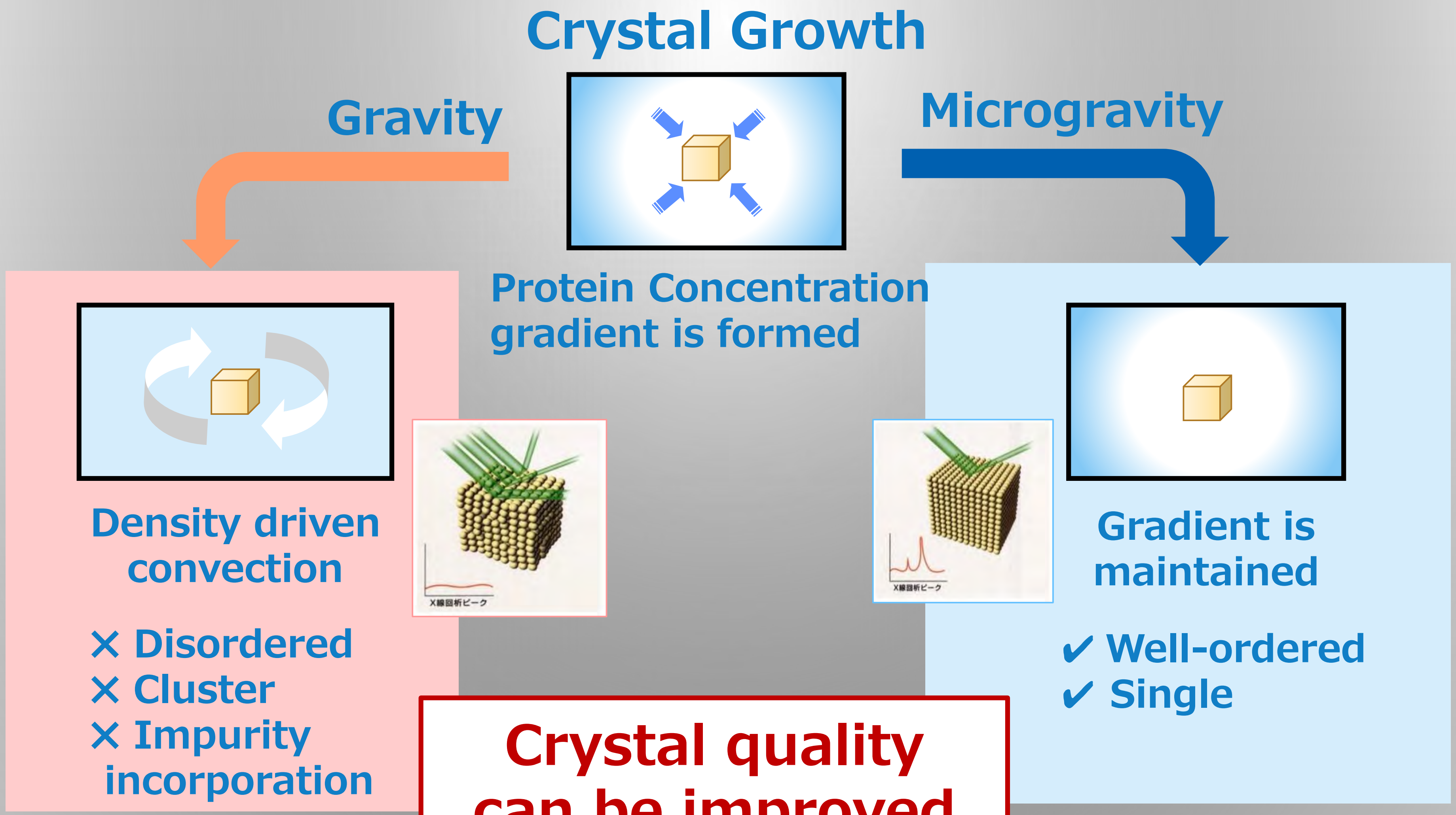
High quality crystal

Target protein for a certain disease



The binding site is clearly shown using a high quality crystal

Why Microgravity?



Crystal Growth

Gravity

Microgravity

Protein Concentration gradient is formed

Density driven convection

× Disordered
× Cluster
× Impurity incorporation

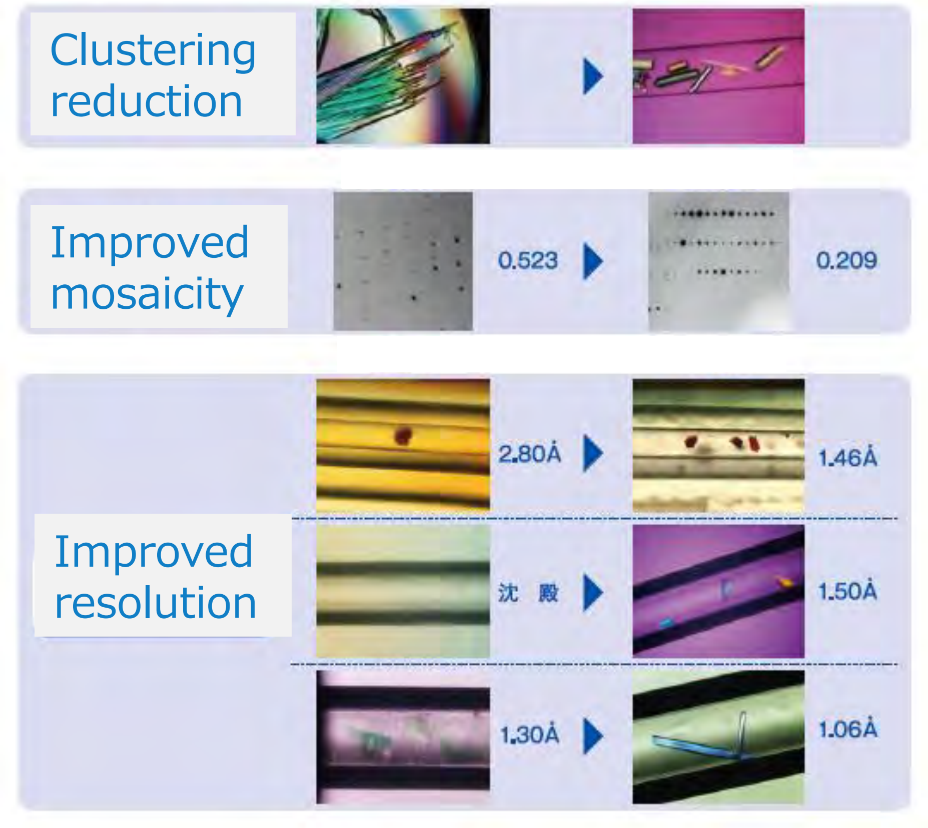
Gradient is maintained

✔ Well-ordered
✔ Single

Crystal quality can be improved in space

Effect of Microgravity

Ground Space



Clustering reduction

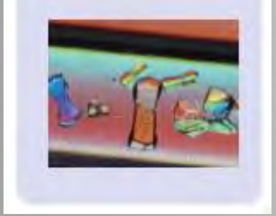
Improved mosaicity

Improved resolution

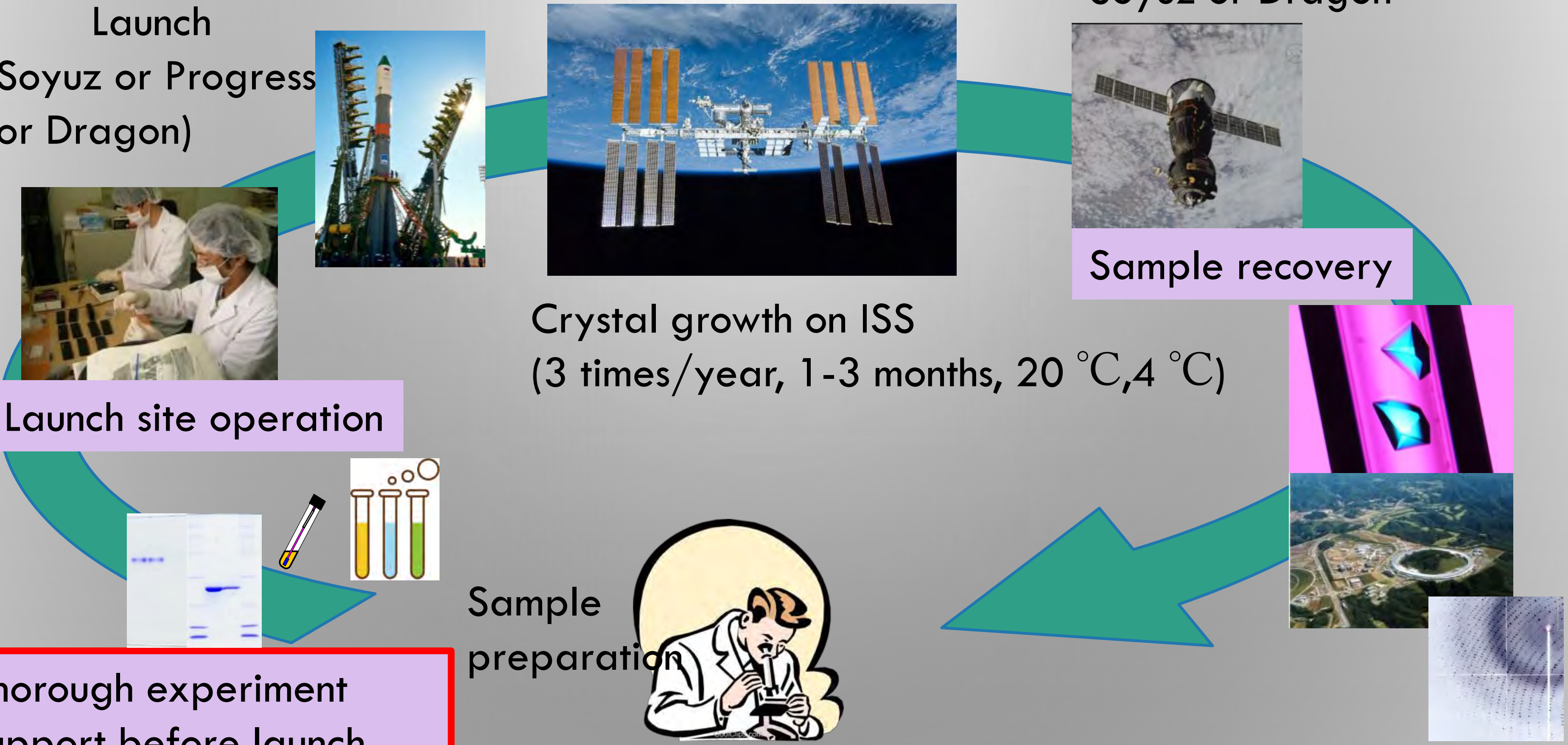
Ground Space

Different space group

Twinning reduction



JAXA PCG EXPERIMENT



Launch
(Soyuz or Progress
or Dragon)

Crystal growth on ISS
(3 times/year, 1-3 months, 20 ℃,4 ℃)

Soyuz or Dragon

Sample recovery

Launch site operation

Sample preparation

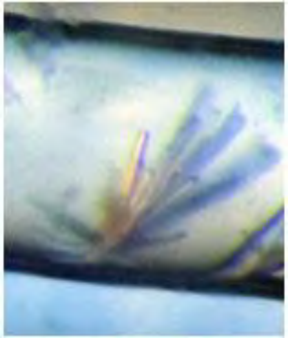
Principal Investigator

Thorough experiment support before launch (some service optional)

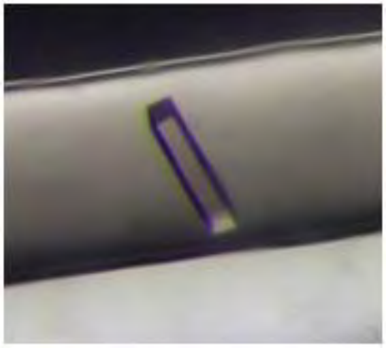
Return the crystals to PI (diffraction data)

Successful results obtained in JAXA PCG

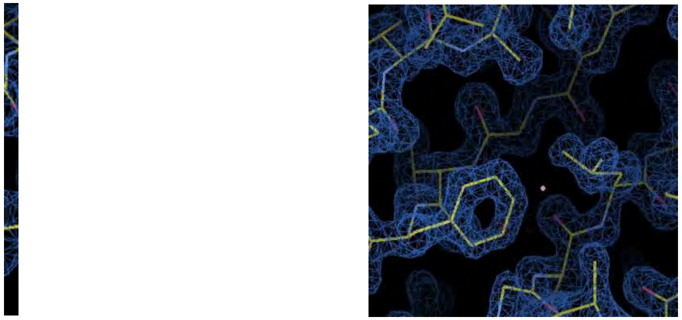
Application to the design of drug candidates
Mitogen-activated protein kinase kinase 7 (MAP2K7)
ーOsaka Prefecture Universityー



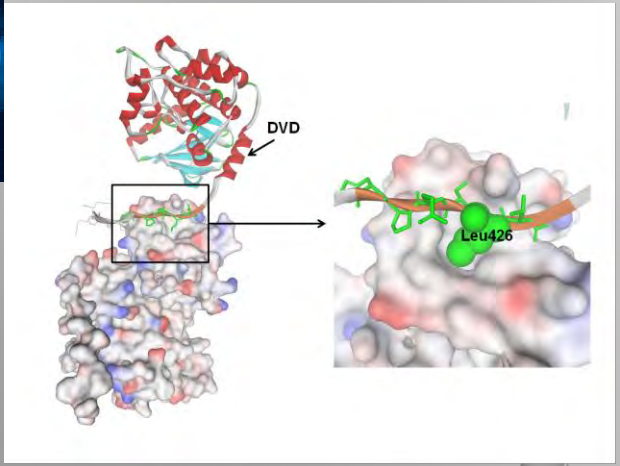
Ground



Space



(a) 2.1 Å resolution (b) 1.3 Å resolution



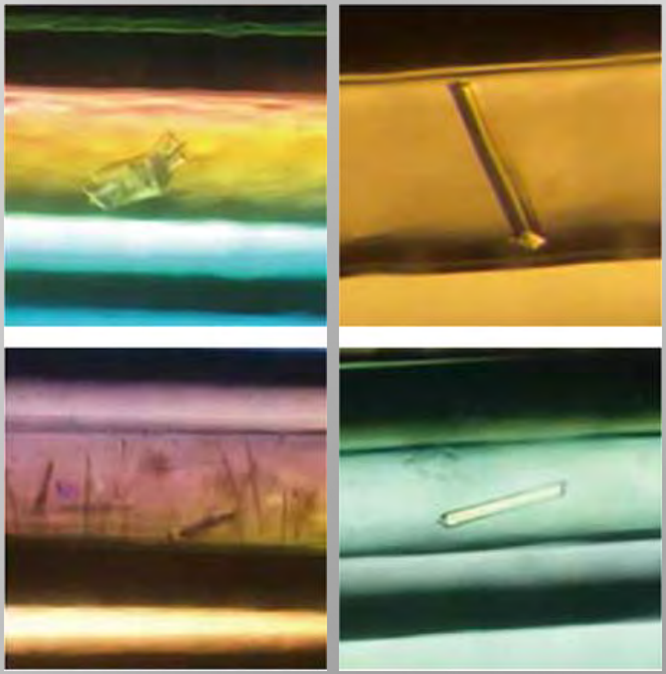
Biochem Biophys Res Commun. 2017 Nov 4;493(1):313-317

Successful results obtained in JAXA PCG

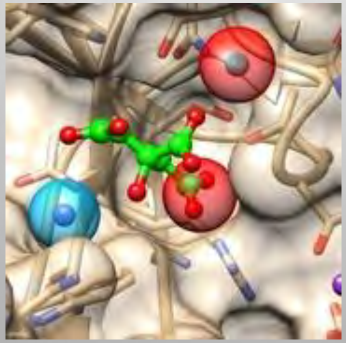
Application to the design of drug candidates

DPP11（Important enzyme for growing multi-drug resistant bacteria and periodontal bacteria）

ーIwate Med. Univ., Showa Univ., and Nagaoka Univ. of Technol.ー



Scientific Reports, volume 9, 13587 (2019)



1.50 Å resolution

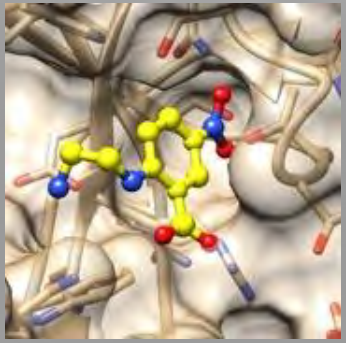
~4,000,000 compounds (drug candidate)

Various screening and computer docking simulations based on the precise DPP11 structure

13 drug candidates

In Vitro experiments

A compound “SH-5” showed a significant inhibitory effect against the growth of *P. gingivalis*.

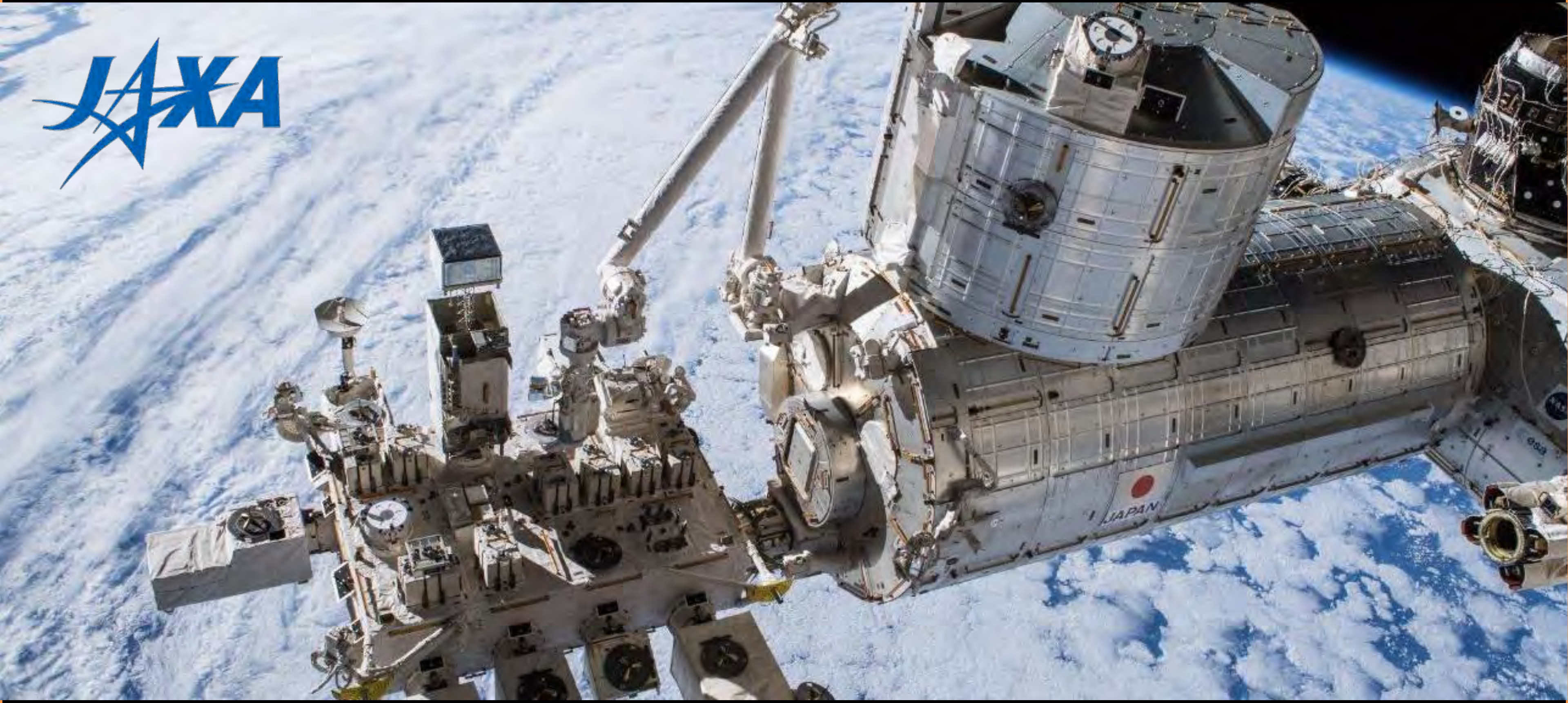


It was shown clearly from space grown crystals that SH-5 binds to the active site of DPP11.

SUMMARY OF JAXA PROTEIN CRYSTAL GROWTH PROJECT

- **A TOTAL PACKAGE SERVICE COVERING SAMPLE CHARACTERIZATION TO STRUCTURE DETERMINATION.**
- **SIGNIFICANT RESULTS ARE COMING OUT.**
- **IF YOU ARE INTERESTED IN OUR PROJECT, PLEASE CONTACT US!**

Contact:
JAXA JEM utilization center
z-kibo-promotion@ml.jaxa.jp



JAXA ELF (Electrostatic Levitation Furnace)

ODA Hirohisa
JEM (Kibo) Utilization Center
Human Spaceflight Technology Directorate
Japan Aerospace Exploration Agency (JAXA)

1. What is ELF (1/2)

ELF stands for Electrostatic Levitation Furnace.

When you want to heat and melt material, you will use container.
If you heat and melt high melting point material (above 2,000 deg C), the material react with container, and there is contamination from container.
So, we cannot melt high melting point material using container.

ELF can levitate sample. ELF do not use container.

- ✓ ELF can heat and melt super high melting point (3,000℃) material.
- ✓ There is no contamination from container. ELF can obtain high temperature material thermophysical properties.

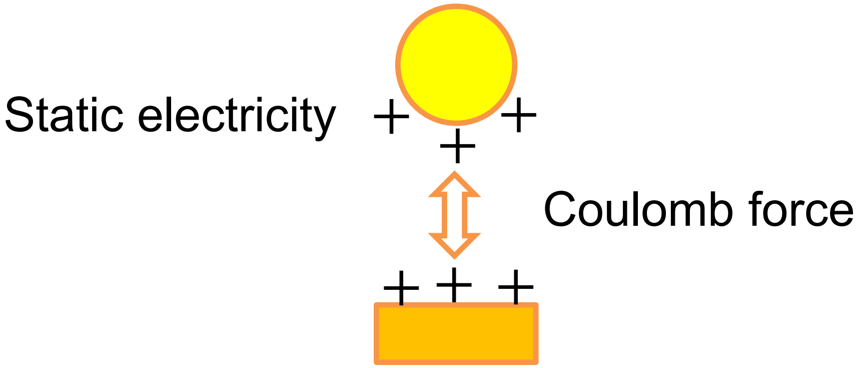
With container

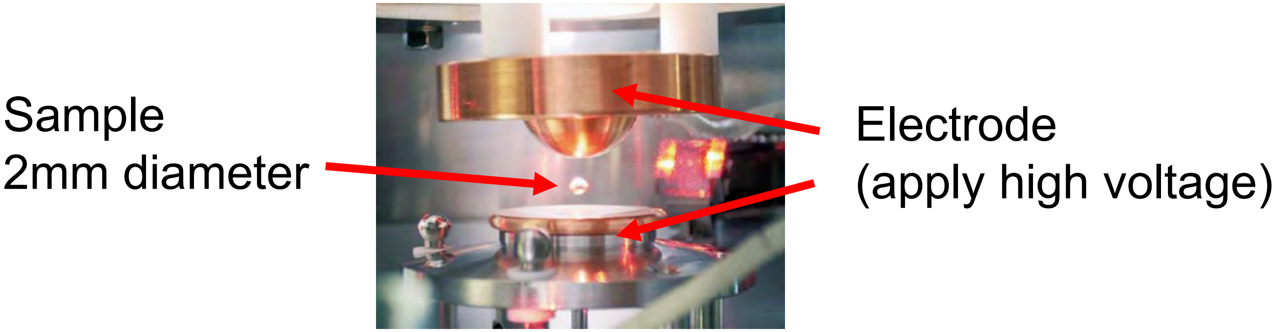
Without container

1. What is ELF (2/2)

How ELF levitate sample ?

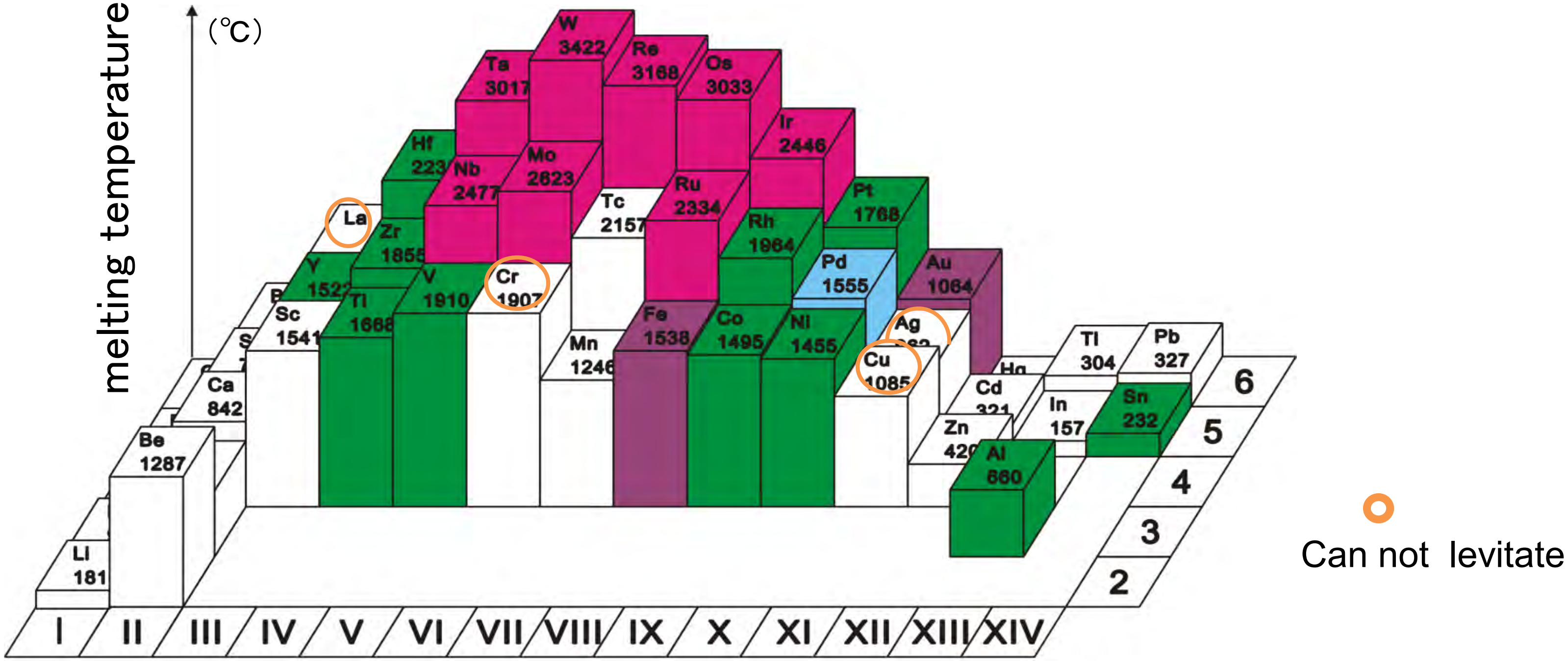
All material has a few static electricity on their surface.
ELF apply high voltage (max. 3kV) to the sample, then control sample position using Coulomb force.





2. Thermophysical properties (metal)

ELF can acquire thermophysical properties (density, surface tension, viscosity) !



🟪 Achieved levitation and melt

🟦 density

🟩 Density, Surface tension, Viscosity

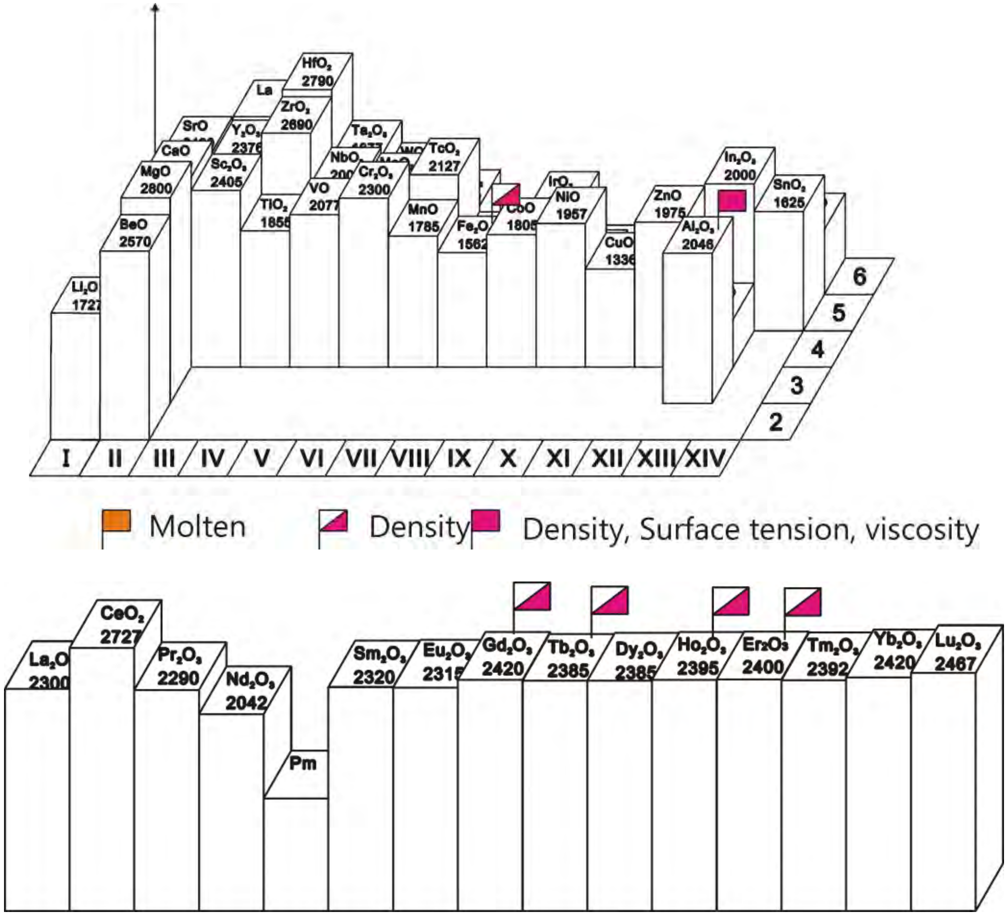
🟥 Only Eelectrostatic Levitation Furnace can obtain viscosity

High-temperature thermophysical property acquisition data of metal element melts acquired by experimental equipment developed by JAXA

JAXA has measured high-temperature thermophysical data for many metal elements through research over 10 years.
Published in the database, contributing to physical physics research and industry.

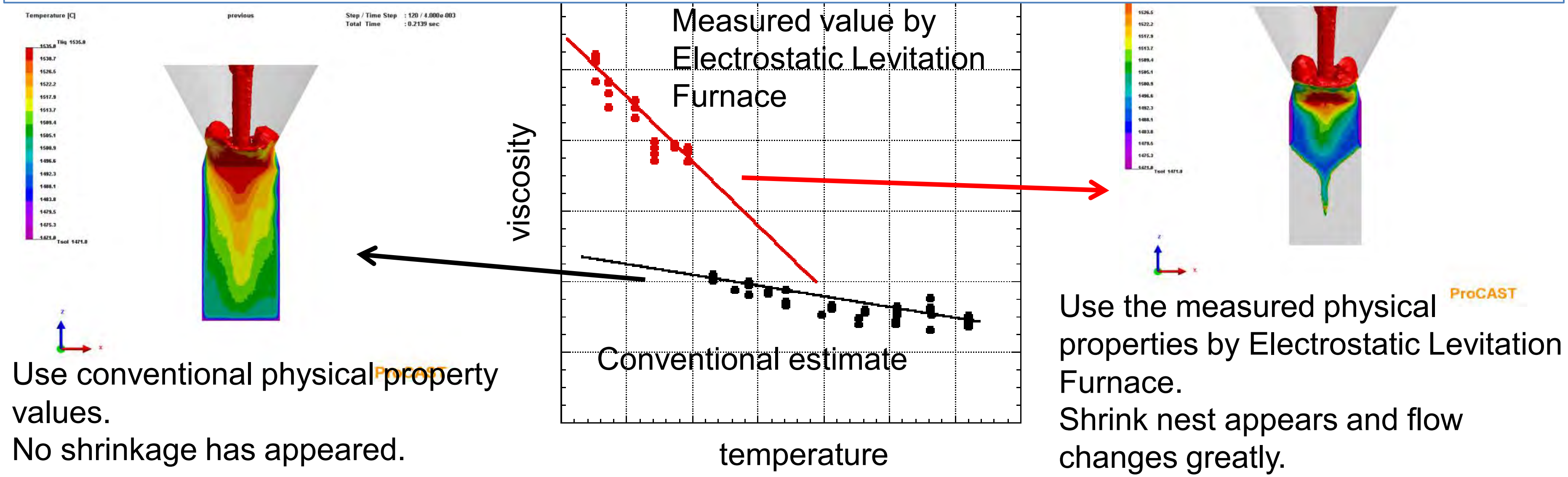
2. Thermophysical properties (oxides)

- ✓ Generally, oxides (ex. Al2O3, ZrO2) have high melting point. Oxides are difficult to melt and these thermophysical properties have not measured.
- ✓ ELF successfully acquired these thermophysical properties of various oxide which has more than 2,000℃ melting point.



3. Application of thermophysical properties

If you acquire accurate thermophysical properties, you can utilize it to simulation.



Use conventional physical property values.
No shrinkage has appeared.

Use the measured physical properties by Electrostatic Levitation Furnace.
Shrink nest appears and flow changes greatly.

- Results of measuring temperature dependence of viscosity in an Electrostatic Levitation Furnace on the ground, the actual measurement value was significantly different from the previous estimated value.
- When this measured value was input to the casting simulation, flow analysis results have changed significantly.
- Actually analyze the blade shape, detected defects caused by and contributed to studying countermeasures before casting.

Measurement of viscosity data has greatly changed the simulation results !

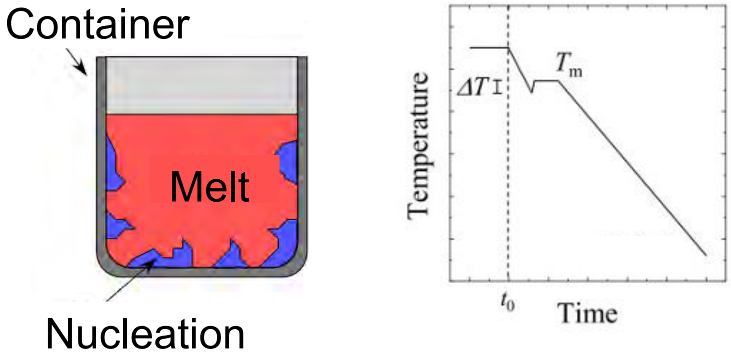
4. Super cooling

If melt is cooled with container, heterogeneous nucleation will occur on the surface of container at solidification point.

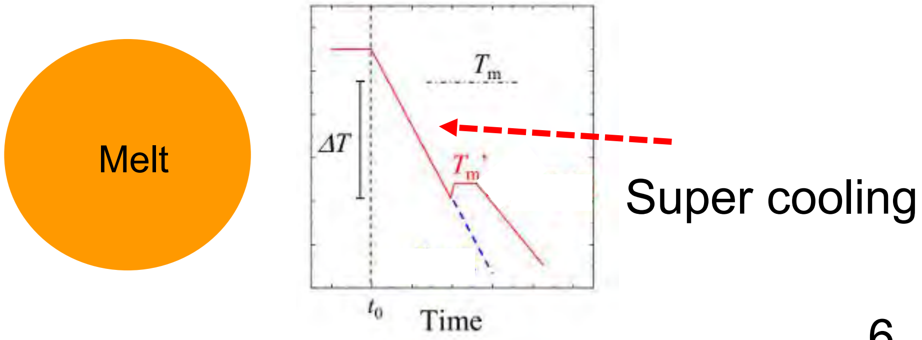
But, if melt is cooled without container, heterogeneous nucleation will not occur.
So melt is cooled under solidification point.
→ super cooling !

ELF can achieve this super cooling. ELF can investigate melt in super cooling which is impossible by conventional method.
There is a possibility to produce new material using this super cooling.

Container

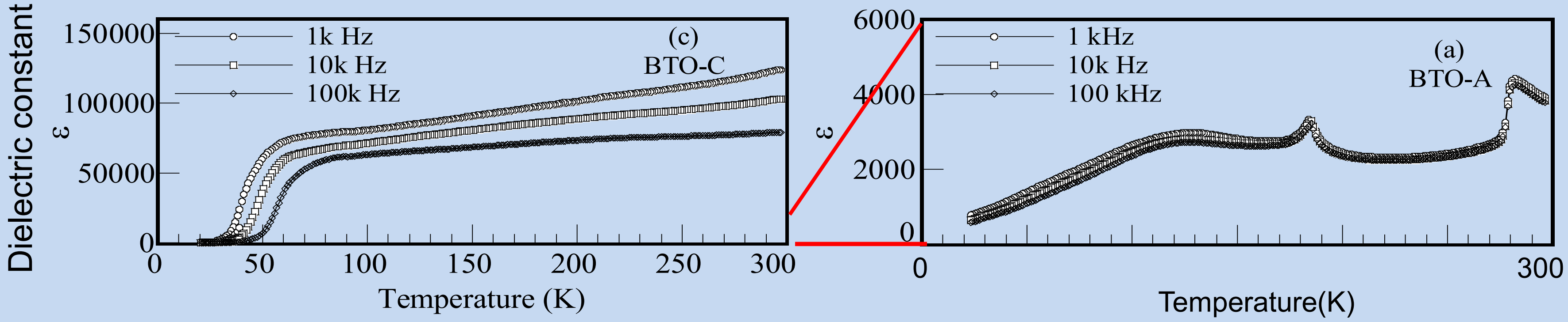


No Container



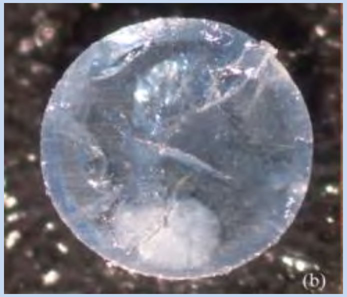
5. Application of super cooling

Realize materials with high industrial value by container less and supercooled solidificatio



$BaTiO_3$ capacitor processed by Electrostatic Levitation Furnace

Commonly used $BaTiO_3$ Capacitor



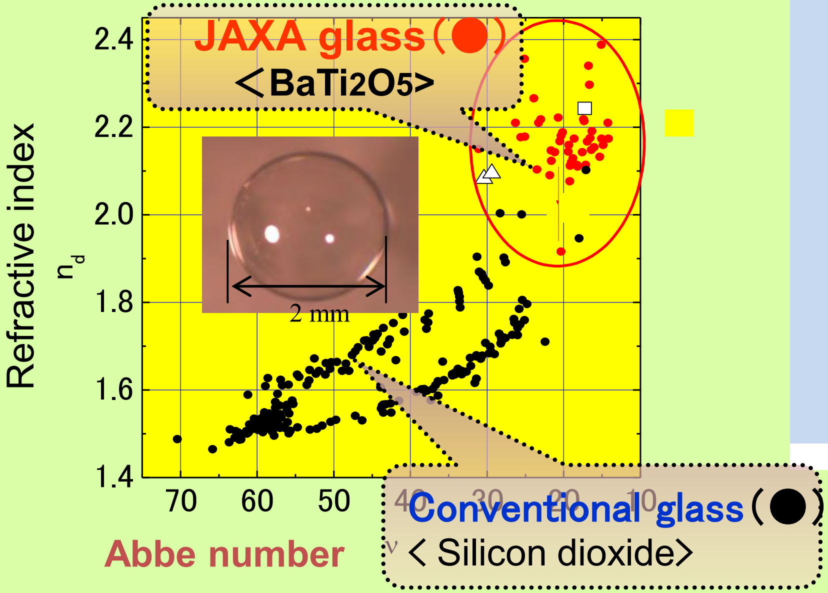
Creation of ferroelectric

30 times the dielectric constant

→ Ultra-small capacitor by TDK

Barium titanate

Hexagonal (high temperature phase) single crystal



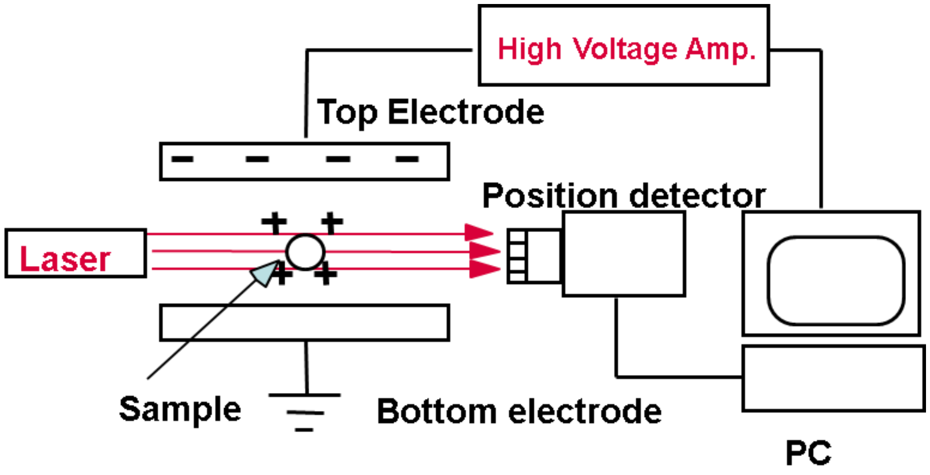
Refractive index comparison

Creation of high refractive index glass

(Maximum refractive index **2.4**)

→ High density DVD ball lens by Nippon Sheet Glass

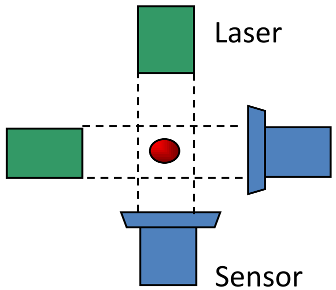
6. How ELF works



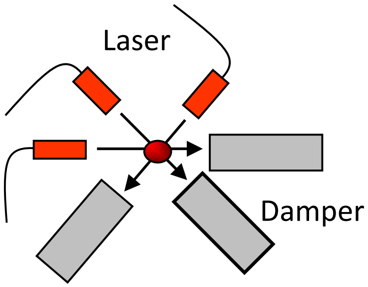
1. Position control
ELF detects sample position in high accuracy by position detector, and control sample position by feedback to electrodes.

2. Heating
Once sample position is controlled in right position, then sample is heated by laser.

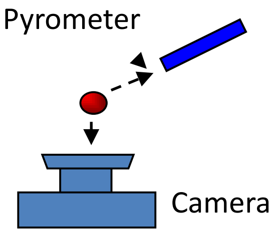
3. Temperature measurement
Sample temperature is measured by pyrometer.



Position control



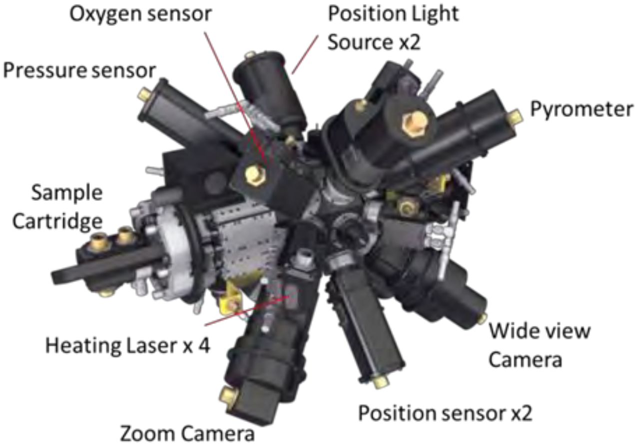
Heating



Temperature measurement

7. Specification

ELF installed in ISS-KIBO module



ELF components
- ✓ chamber
- ✓ sample cartridge
- ✓ laser (x4)
- ✓ pyrometer
- ✓ position sensor (x2)
- ✓ observation camera (x2)
- ✓ pressure sensor
- ✓ oxygen sensor

item	specification
sample type	oxide, insulator, metal, alloy
sample size	2mm diameter
atmosphere	Ar, N_2, Air (max 2atm)
heat	semiconductor laser (980nm), max 40W x4
measurement temperature	299～3,000℃

8. Operation

space

Transfer sample holder to ISS by visiting vehicle.

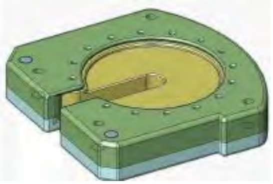
Astronaut install sample holder to ELF.

ELF experiment in KIBO

Retrieve sample holder to the ground.

ground

Launch sample holder by rocket



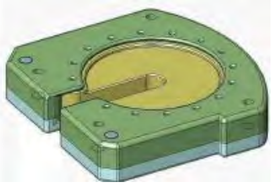
Sample holder
Size: 86 x 53 x 24 mm
mass : 70g

Samples are loaded to sample holder.
Sample holder can storage 20 samples.

Bi-directional communication via satellite.

Ground operation in Tsukuba

ELF experiment is remotely operated from ground station.



Investigator analyze retrieved samples.

9. Experiment image

Summary

1. ELF (Electrostatic Levitation Furnace) can levitate, melt and solidify sample without container. JAXA have developed and installed ELF in ISS-KIBO.

2. ELF has following strong points.
   ① Can melt high melting point material.
   ② Can measure thermophysical properties (density, surface tension, viscosity).
   ③ Can achieve super cooling.

3. JAXA welcome new ELF users !

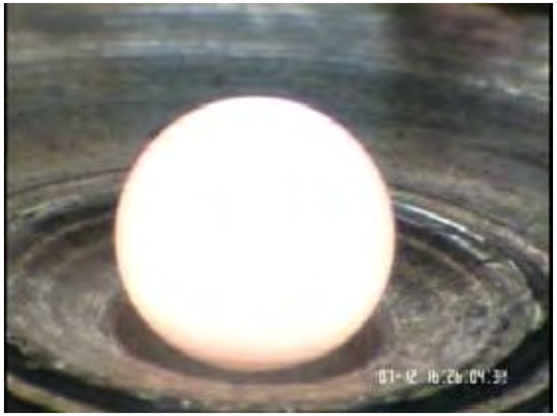
Backup

1. What is ELF

1.1 Levitation furnace

There are 3 types for levitation furnace.

1. Gas levitation



Sample is levitated by gas flow.

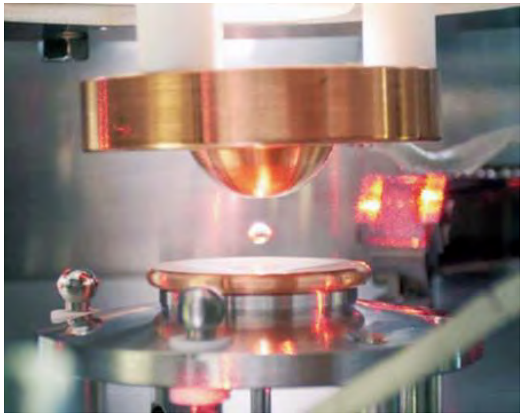
Melt samples is deformed by gas flow.
Not good for measurement of thermophysical properties.

2. Electromagnetic levitation

Sample is levitated by Electromagnetic force using coil.

Sample is limited to conductor.

3. Electrostatic levitation



Sample is levitated by Coulomb force using electrode.

We can use various sample (conductor, insulator, etc.)

1. Overview of ELF
1.3. Why in space ?

	Ground (1G)	Space（microgravity）
Electric field	• Need large electric field which can overcome gravity (8kVcm^{-1}<)(1)	• Need small electric field because no need to overcome gravity (<3kVcm^{-1})
Feasibility of levitation	• Metals, alloys: easy for levitation because they have much charging on surface. • Oxides: difficult for levitation because they do not have enough charging on surface.	Easy for levitation both metals, alloys, and oxides.
Atmosphere	• high vacuum (to prevent electrical discharge by high electric field) • can not use inactive gas (will occur electrical discharge)	Can use inactive gas, vacuum (because small electric field)
Effect of sample evaporation	• Metals: little effect • Alloys, oxides: sample composition will change by evaporation	Can suppress sample evaporation by using inactive gas

[1] Ishikawa et al., *J. Jpn Soc. Microgravity Appl.,* 18 (2001),106

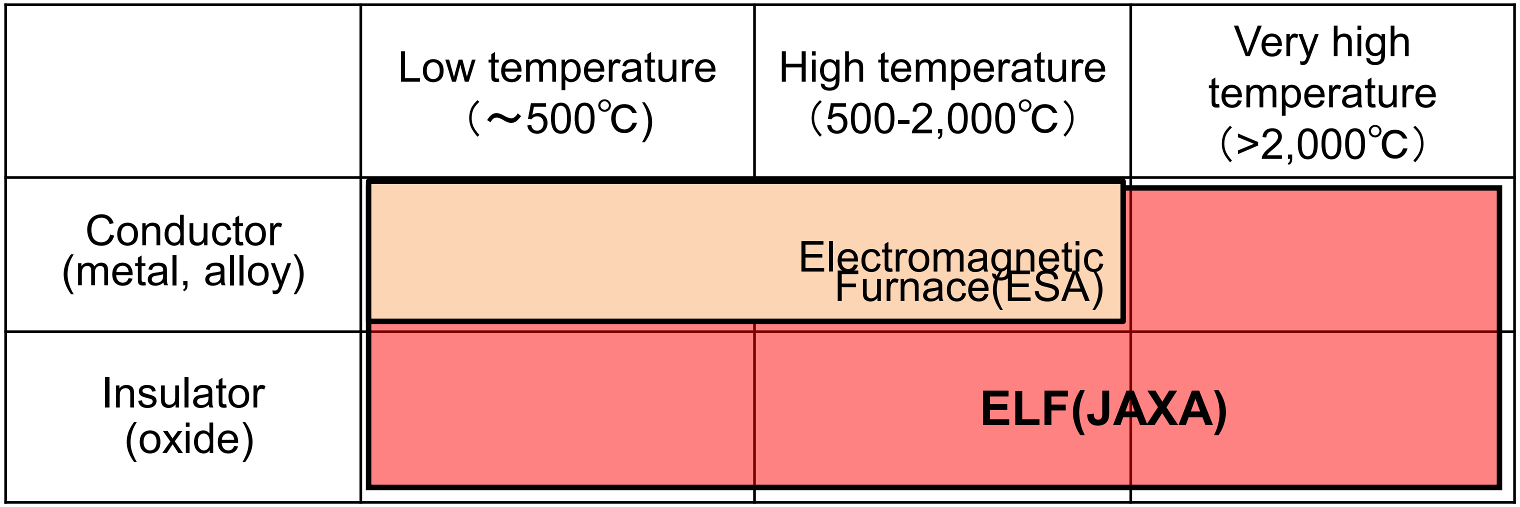
1. Overview of ELF
1.4. Comparison with other facility

- **ESA：Electromagnetic Furnace（launched on ATV5 in 2014）：**

Sample is limited for conductors (metal, alloys), because sample is levitated by Lorentz force.
Can heat 5–8 mm diameter sample max. 2,000 degree Celsius.

- **JAXA:ELF (launched in 2015)：**

Can accommodate various materials, and wide temperature range, because utilize coulomb force between charged sample and electrodes.



	Low temperature （～500℃）	High temperature （500-2,000℃）	Very high temperature （>2,000℃）
Conductor (metal, alloy)		Electromagnetic Furnace(ESA)	
Insulator (oxide)		**ELF(JAXA)**	

Comparison of IP facility cover range on ISS

1. Overview of ELF
1.5. ELF target

(1) Measurement of unknown thermophysical properties

Acquisition of unknown oxides thermophysical properties.

Develop database of thermophysical properties which is important for industry.

Acquisition of high accuracy thermophysical properties corresponded for request from company.

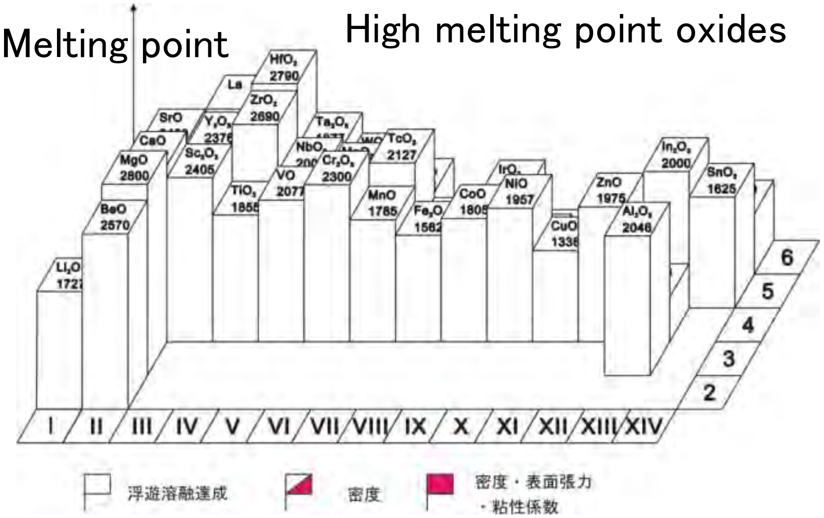
(e.g.) practical alloy (TiVAl alloy, etc.), heat resistance material (ZrO2, SiO2, etc.)

JAXA try to obtain thermophysical properties of binary oxides which have high melting point.

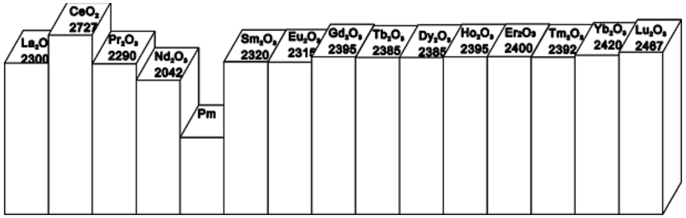
(2) Search for new high performance materials

ELF has a possibility to develop new material using super cooling.

Sample is retrieved to the ground and be analyzed its fine structure.


High melting point oxides

Rare earth oxide

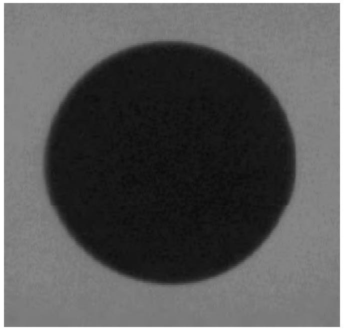


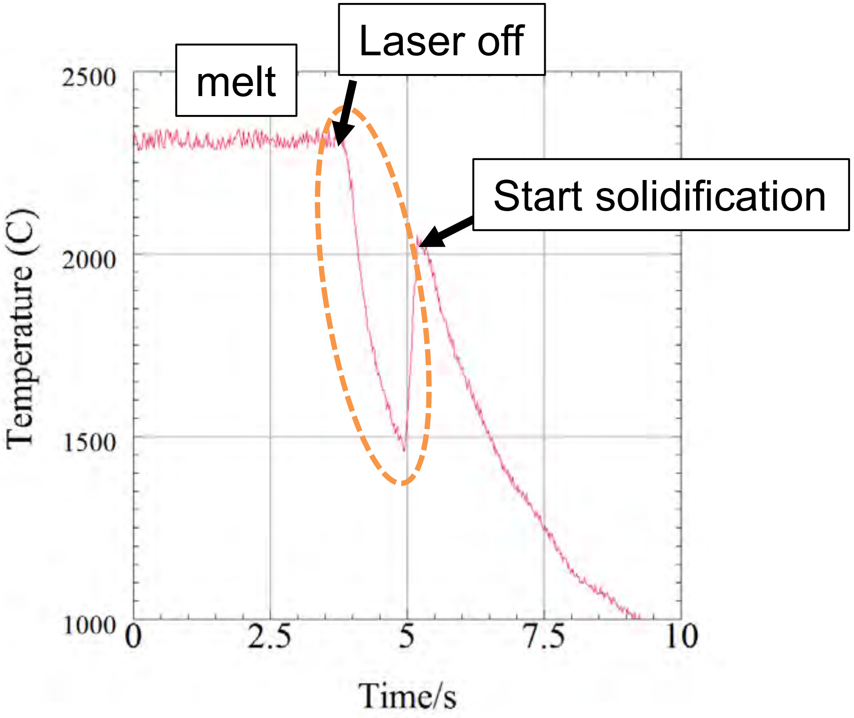
2. Measurement of thermophysical properties
2.2. Density

1. Sample is heated and melt by laser.
2. Sample is cooled by stopping laser.
3. Images of sample in each temperature are obtained. Volume is measured by image analysis.
4. Sample is taken out from ELF, and retrieved to the ground.
5. Mass is measured on the ground.
6. Density is obtained from following equation.

$$\rho = \frac{m}{V}$$

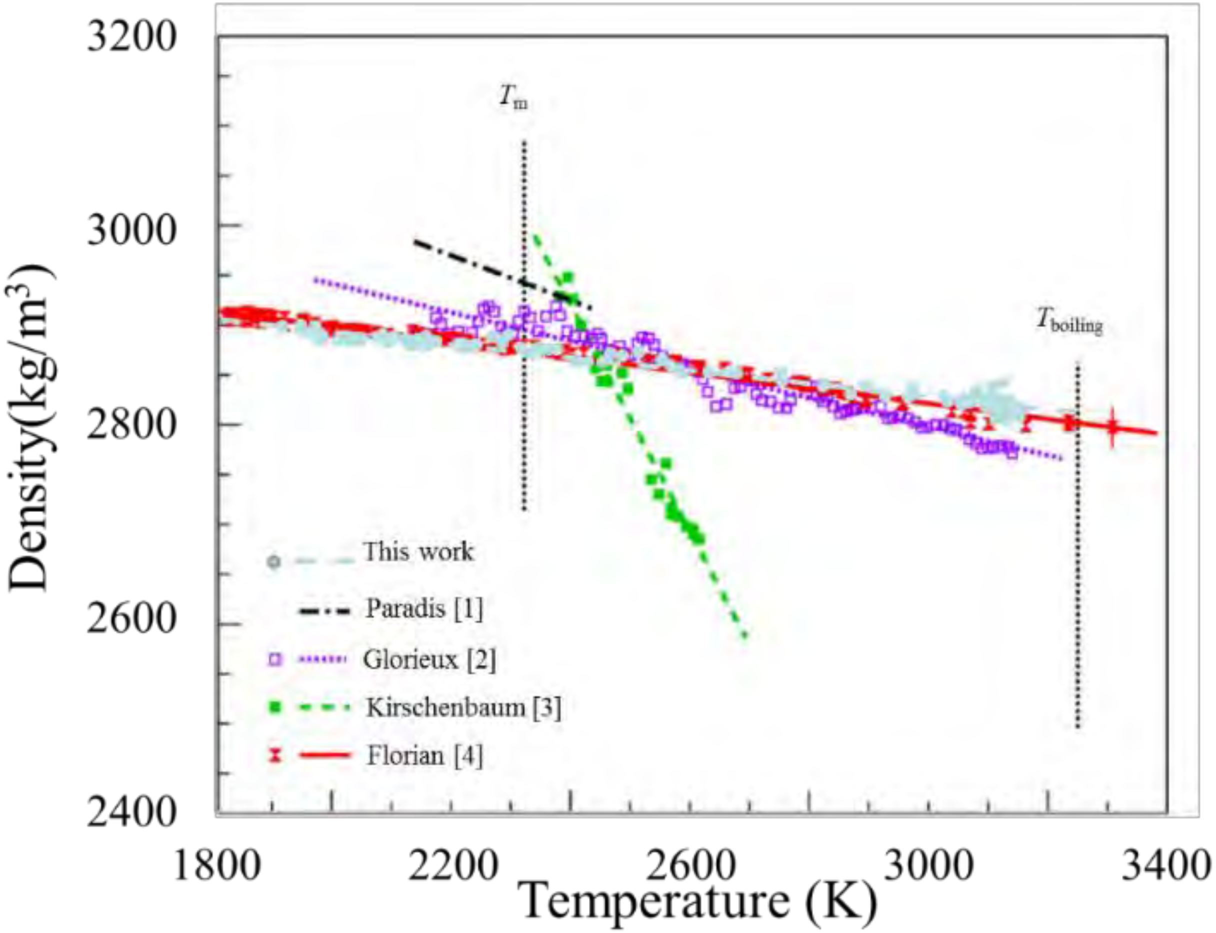
ρ :density
m :mass
V :volume





Temperature profile of molten aluminum oxide

2. Measurement of thermophysical properties
2.3. Density of aluminum oxide



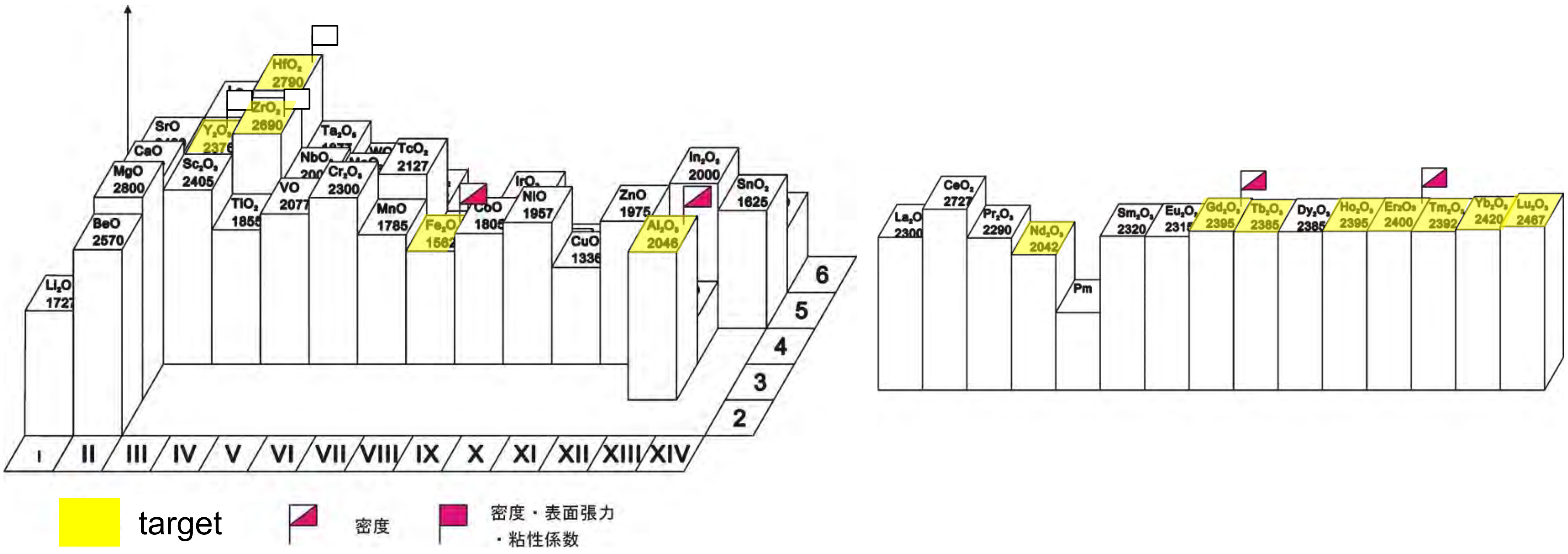
Temperature dependence of aluminum oxide density

- ✓ Obtained wide temperature range (from 1,800 to 3,200K)
- ✓ good consistency with other reference

2. Measurement of thermophysical properties
2.5. Density of other oxides

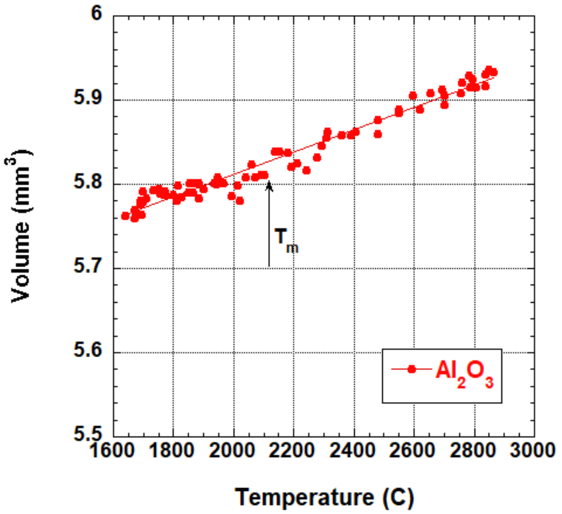
ELF have obtained densities of following oxides successfully.

- ✓ Iron oxide（Fe_2O_3）
- ✓ Erbium oxide（Er_2O_3）
- ✓ Gadolinium oxide（Gd_2O_3）

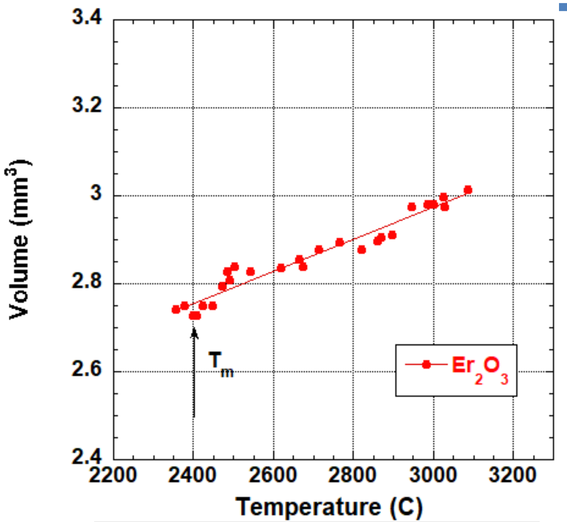


density   density, surface tension, viscosity

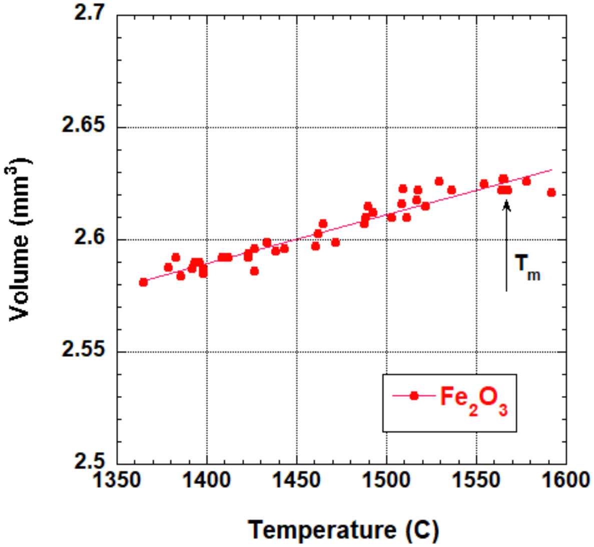
2. Measurement of thermophysical properties
2.4. Thermal expansion coefficient (1/2)



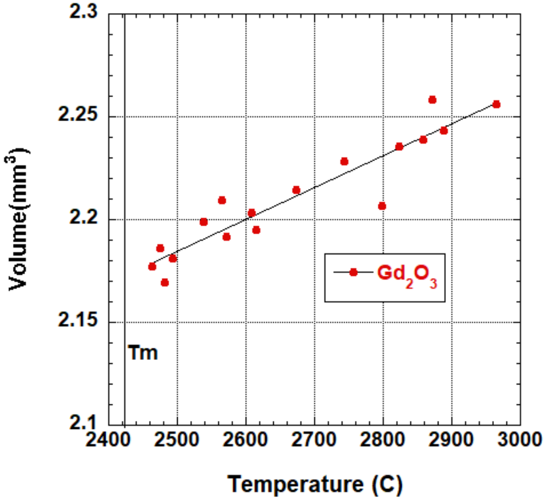
Volume change of Al_2O_3



Volume change of Er_2O_3



Volume change of Fe_2O_3



Volume change of Gd_2O_3

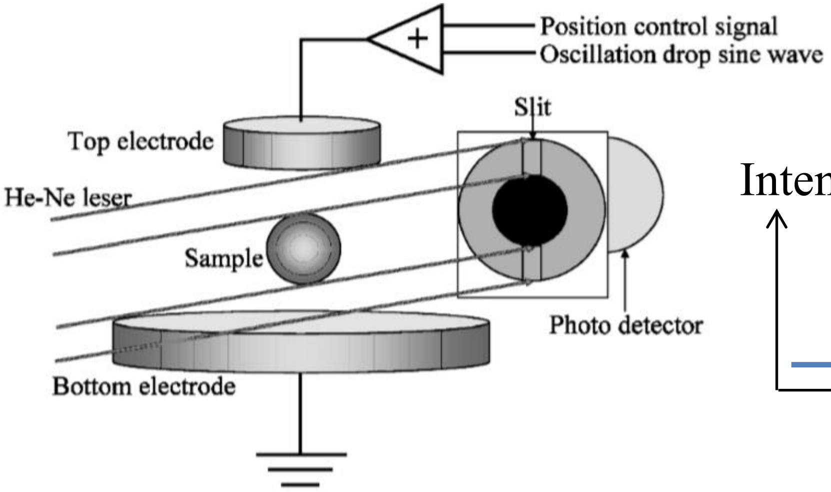
2. Measurement of thermophysical properties
2.4. Thermal expansion coefficient (2/2)

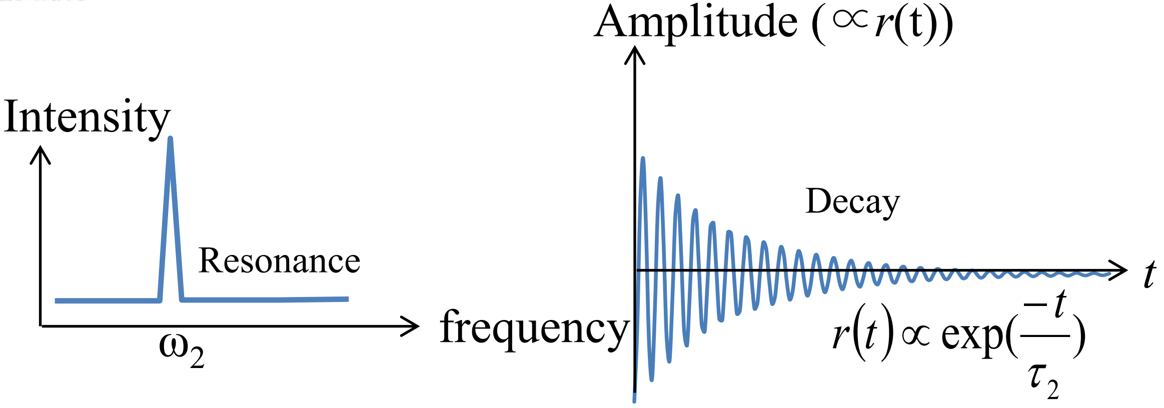
Thermal expansion coefficient of oxides

	Melting Temperature (T_m:℃)	**Thermal expansion coefficient (a:K^{-1})**
Al_2O_3	2,054	2.26×10^{-5}
Er_2O_3	2,400	1.31×10^{-4}
Fe_2O_3	1,565	8.31×10^{-5}
Gd_2O_3	2,420	7.17×10^{-5}

2. Measurement of thermophysical properties
2.6. Measurement of surface tension and viscosity (1/3)

Surface tension and viscosity are obtained from droplet oscillation





ω_2 :resonance frequency

τ :decay rate

r_0 :sample radius

η :viscosity

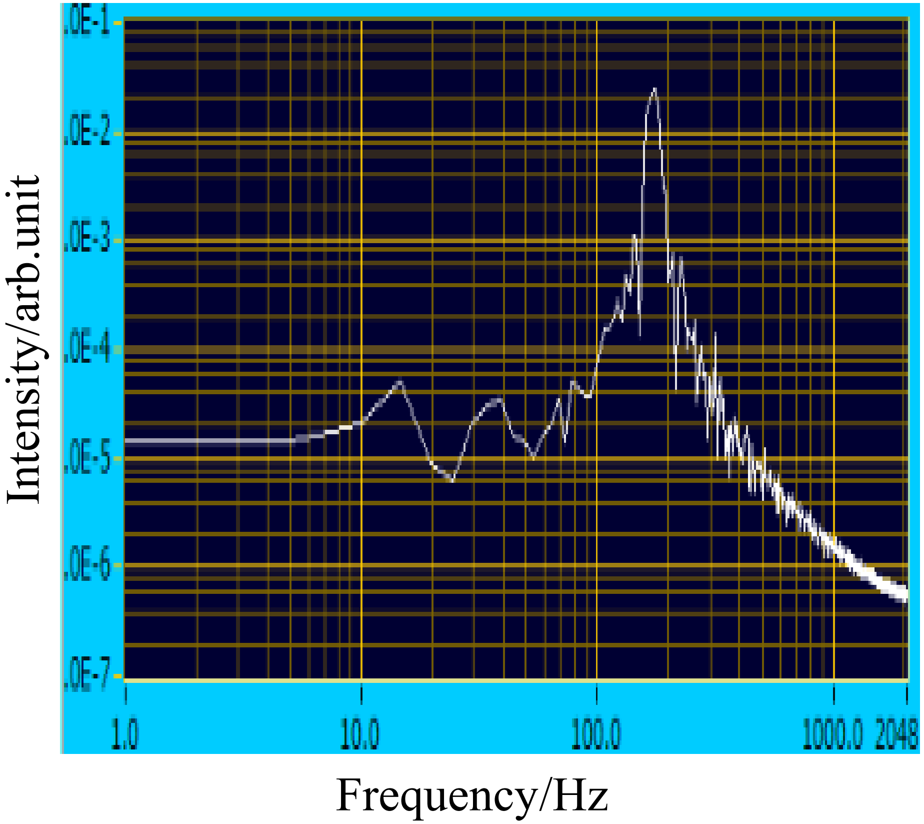
γ :surface tension

$$\gamma = \frac{\omega_2^{\ 2} \rho r_0^{\ 3}}{8}$$

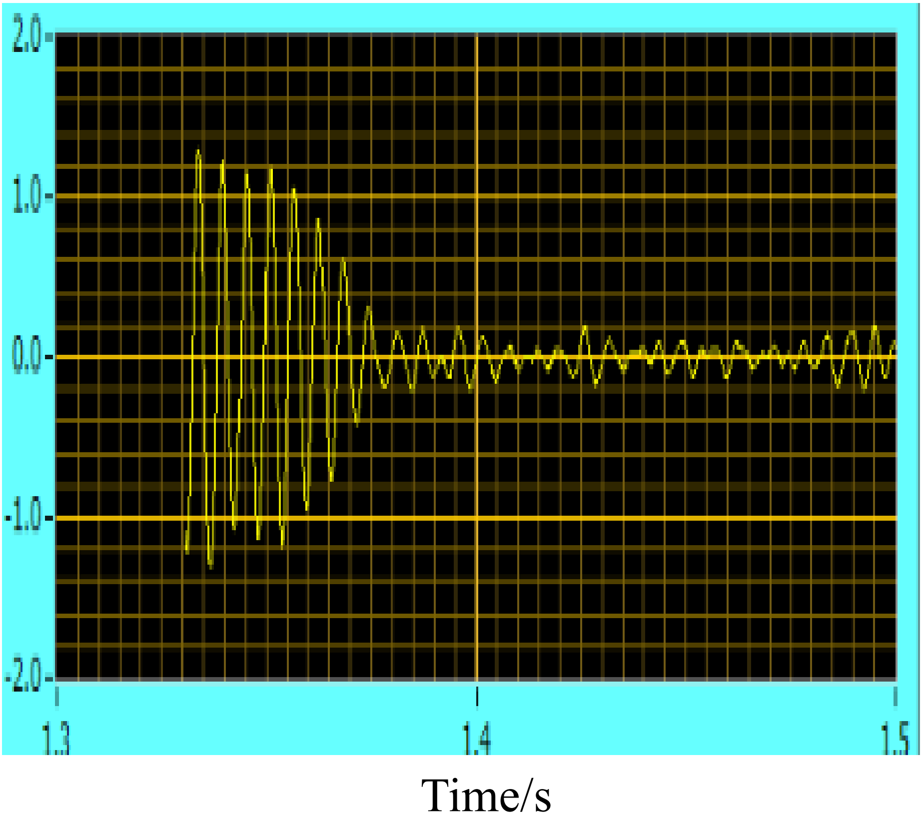
$$\eta = \frac{\rho r_0^{\ 2}}{5\tau}$$

Rhim et al., *Rev. Sci. Instrum.* 70 (1999), 2796

2. Measurement of thermophysical properties
2.6. Measurement of surface tension and viscosity (2/3)

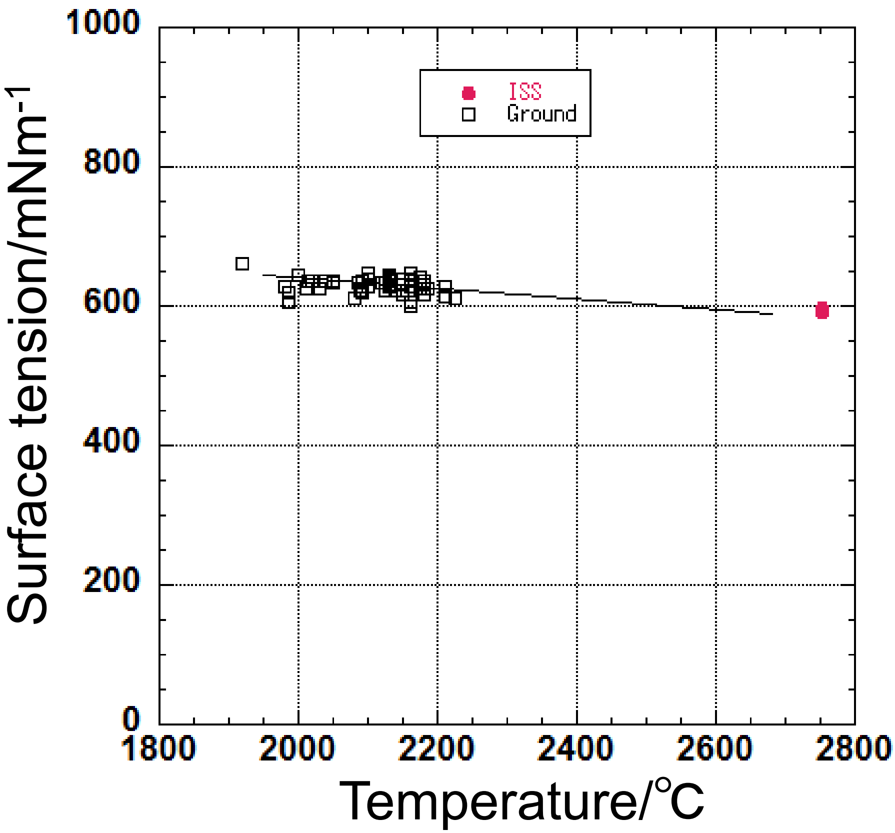


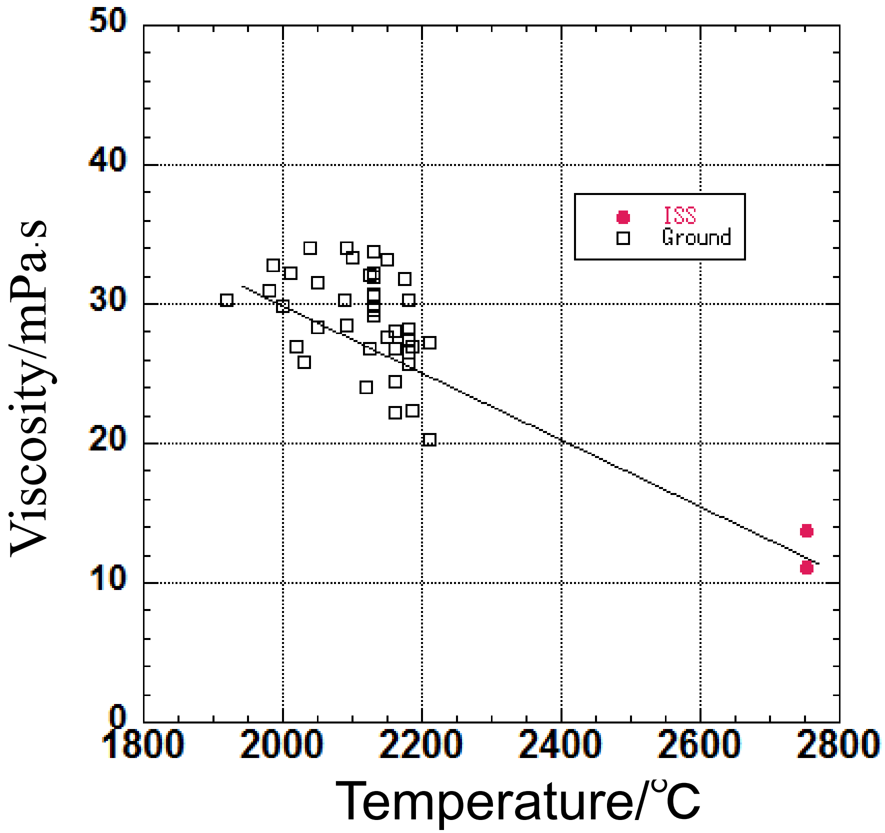
resonance frequency



Oscillation decay

2. Measurement of thermophysical properties
2.6. Measurement of surface tension and viscosity (3/3)





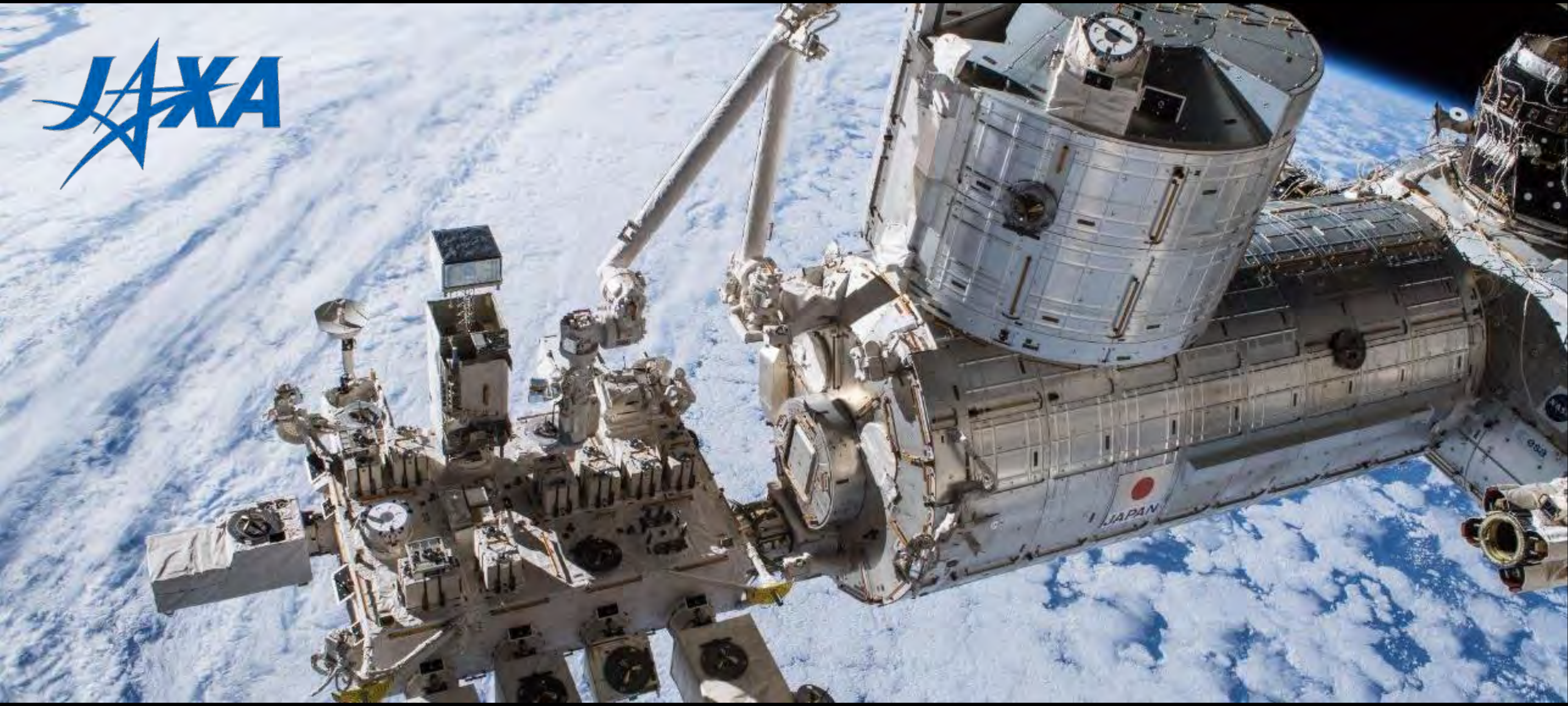
good consistence with data which obtained on the ground

*Paradis, et al., J. Jpn. Appl. Phys. 44 (2005) 5082.

ELF have obtained surface tension and viscosity of aluminum oxide successfully.

4. ELF experiments

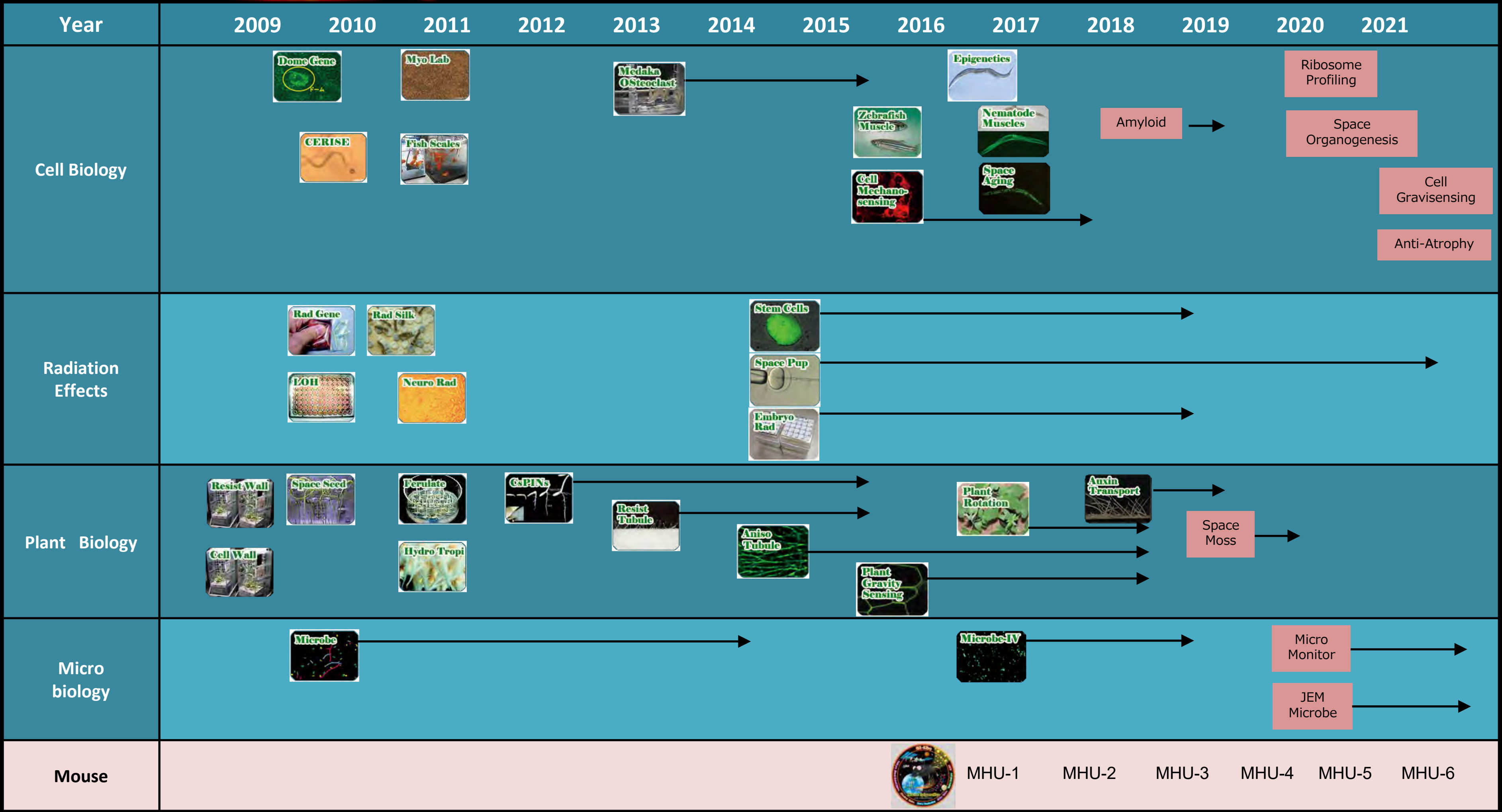
No.	PI	organization	title	abbreviation	status
1	Prof. Masahito Watanabe	Gakushuin University	Interfacial phenomena and thermophysical properties of high-temperature liquids -Fundamental research of steel processing using electrostatic levitation-	Interfacial Energy	On-orbit experiment
2	Dr. Shinji Kohara	National Institute for Materials Science	The origin of fragility in high-temperature oxide liquids - towards fabrication of novel non-equilibrium oxide materials	Fragility	Waiting on-orbit experiment
3	Prof. Shinsuke Suzuki	Waseda University	Thermo-physical properties of liquid and heterogeneous solidification behavior of powder metals for 3D printer	Hetero-3D	In preparation
4	Prof. Douglas Matson	Tufts University	Round Robin - Thermophysical Property Measurement	Round Robin	In preparation



Overview of the JAXA Life Science Research

HIGASHIBATA Akira
JEM (Kibo) Utilization Center
Human Spaceflight Technology Directorate
Japan Aerospace Exploration Agency (JAXA)

Life Science Experiments in KIBO (2009-2021)



Year

2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

Cell Biology

Dome Gene

CERISE

Myo Lab

Fish Scales

Medaka OSteoclast

Zebrafish Muscle

Cell Mechano-sensing

Epigenetics

Nematode Muscles

Space Aging

Amyloid

Ribosome Profiling

Space Organogenesis

Cell Gravisensing

Anti-Atrophy

Radiation Effects

Rad Gene

Rad Silk

LOH

Neuro Rad

Stem Cells

Space Pup

Embryo Rad

Plant Biology

Resist Wall

Cell Wall

Space Seed

Ferulate

Hydro Tropi

CsPINs

Resist Tubule

Aniso Tubule

Plant Gravity Sensing

Plant Rotation

Auxin Transport

Space Moss

Micro biology

Microbe

Microbe-IV

Micro Monitor

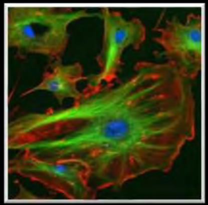
JEM Microbe

Mouse

MHU-1 MHU-2 MHU-3 MHU-4 MHU-5 MHU-6

Specimen for Space Experiments (Animals)

Small 10 μm << 1 mm << 3~5 cm << 3~20 cm



Cells

Worms

Nematode

Silkworm

Fishes

Medaka

Zebrafish

Toadfish

<< 5~20 cm << 1.5-1.8 m Large

Amphibians

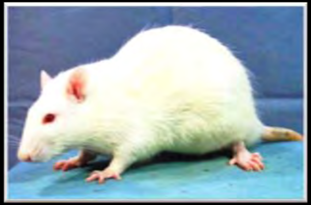
Newt

Frog

Mammals

Rodents

Mouse



Rat

Human

Specimen for Space Experiments (Plants)

Arabidopsis
Life cycle

Rice
Anti-gravity reaction

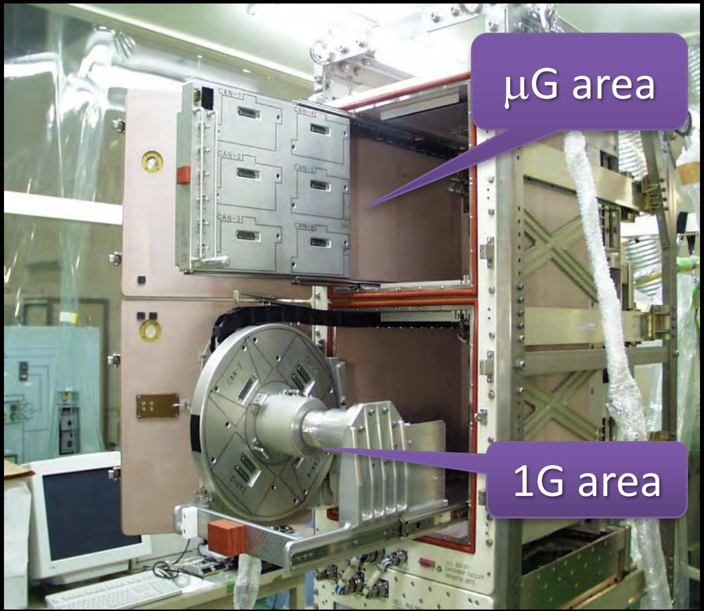
Cucumber
Hydro-tropism

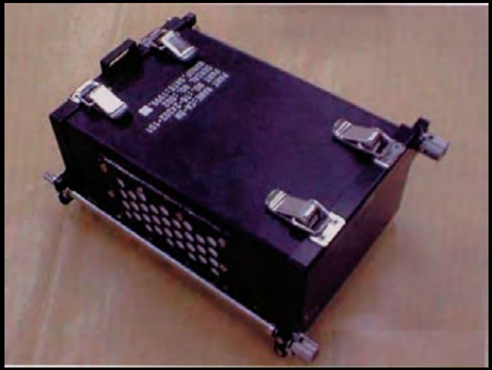
Morning glory
Gravity effect on rotating motion

Pea
Gravity effect on morphogenesis

Cherry-blossom
Education program

Cell Biology Experiment Facility (CBEF)



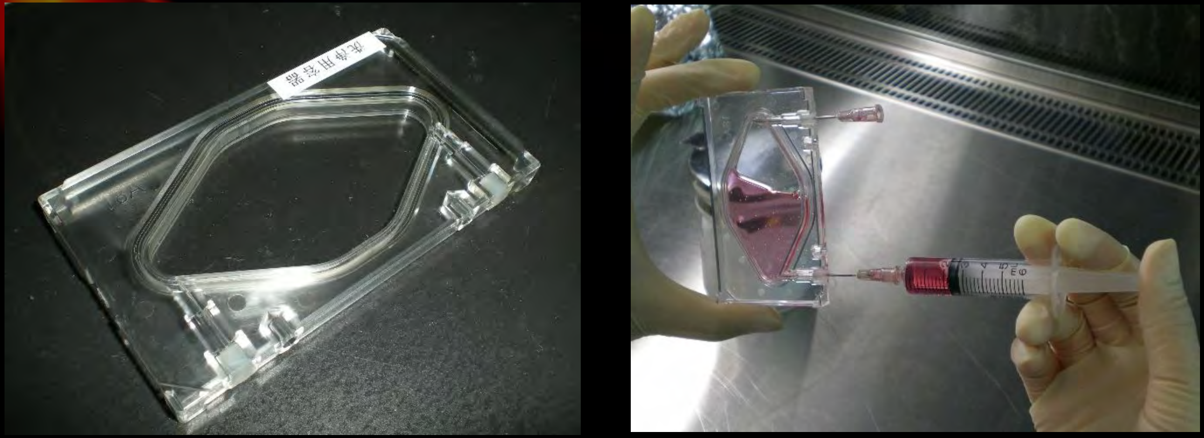


Biological Experiment Units (BEUs)

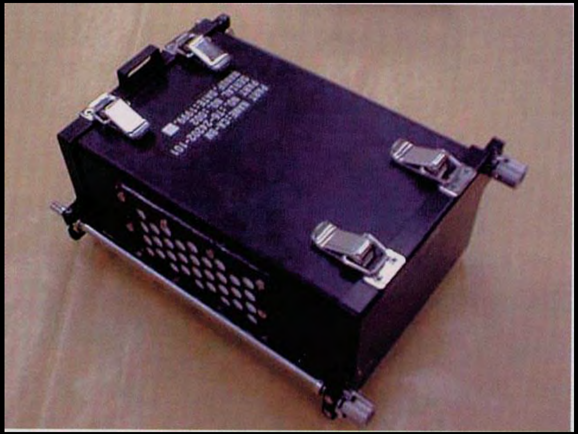
4 types of BEU are prepared (CEU、PEU、MEU、V-MEU). These units interface with CBEF.

- CEU (Cell Experiment Unit): for cell biology experiments
- PEU (Plant Experiment Unit): for plant biology experiment (with camera)
- MEU (Measurement Experiment Unit): Inside of the unit is designable by researchers. V-MEU is MEU with camera.

Equipment for Cell Culture in Space (1/2)



Cell Culture Dish for space（Disposal Culture Chamber(DCC))



MEU

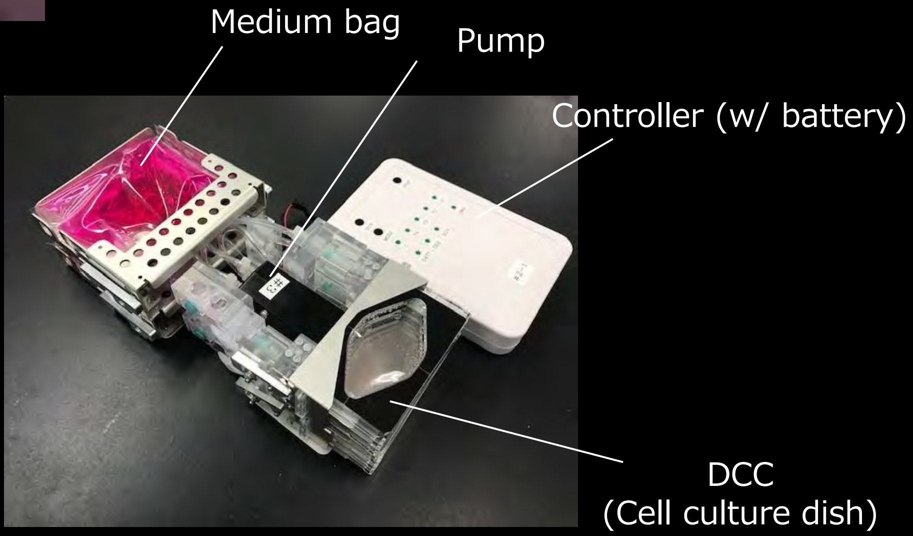
DCC cage

Anaeropack (CO_2 generator)

Equipment for Cell Culture in Space (2/2)

Medium Exchange by crew in KIBO

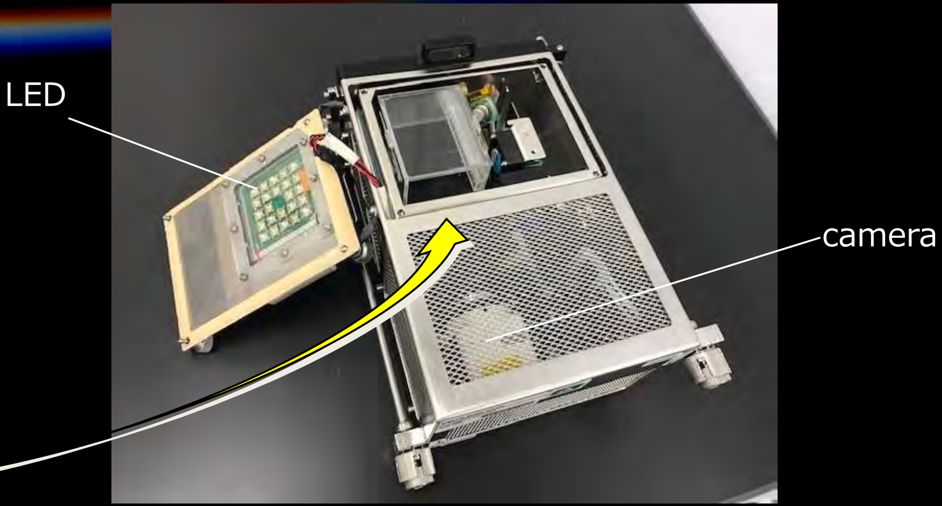
Medium Exchanger (manual)



Medium Exchanger (semi-auto)

Equipment for Plant Growth in Space

Plant Growth Chamber



PEU（Plant Experiment Uinit)

Growth of Arabidopsis in the chamber （artificial 1G in space)

etiolated pea (*Pisum sativum* cv. Alaska) seedlings grown on 1 g conditions

etiolated pea (*Pisum sativum* cv. Alaska) seedlings grown under microgravity conditions in space for 6.5 days

Diffential growth of pea seedlings

upper : 1G reference on the ground
lower : μG on board

Plants shows “automorphogenesis” under μG. Automorphogenesis is potential ability to form of plant-body.

Dr. Ueda, Osaka Pref. Univ. STS-95 (1998)

Live-imaging System (COSMIC)

(Confocal Laser Microscope)

Confocal Space Microscopy is a versatile automated microscopy platform in KIBO.

Key features:

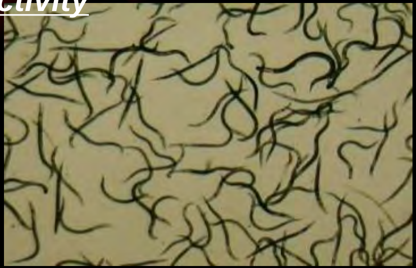
- **Multiple imaging methods**
  Confocal, epifluorescence, brightfield and phase contrast
- **Ideal for live cell imaging**
  Spinning disk confocal unit, on-stage incubator, autofocus and high-sensitivity camera enable advanced live cell imaging.
- **Fluorescence ratio imaging**
  Split View enables simultaneous dual-color imaging of FRET experiments.
- **Remote automatic image acquisition**
  Multicolor, time-lapse, Z-stack, tiling, etc.

Spaceflown worms (CERISE experiment)

Launch site operation

Flight experiment

Ground activity



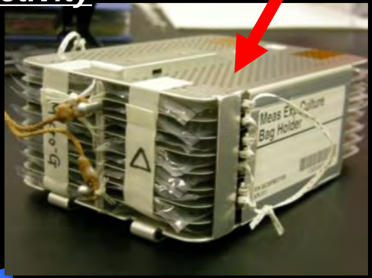
Packing

Culture Bag

insert

In-flight activity

Remove the pins (Exp. activation)



Culture Bag Holder

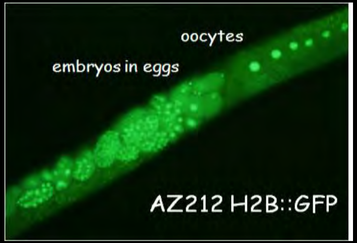
Install

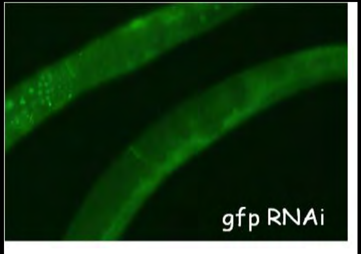
Install (1G)

Install (μG)

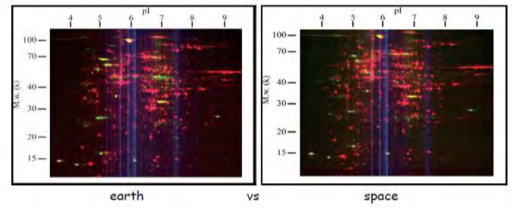
CBEF & Mesa Exp Unit

Post-flight analyses





RNA interference was induced under μG as the same as on the ground.



Differential analysis of protein expression by 2D electrophoresis

Points of planning your experiment

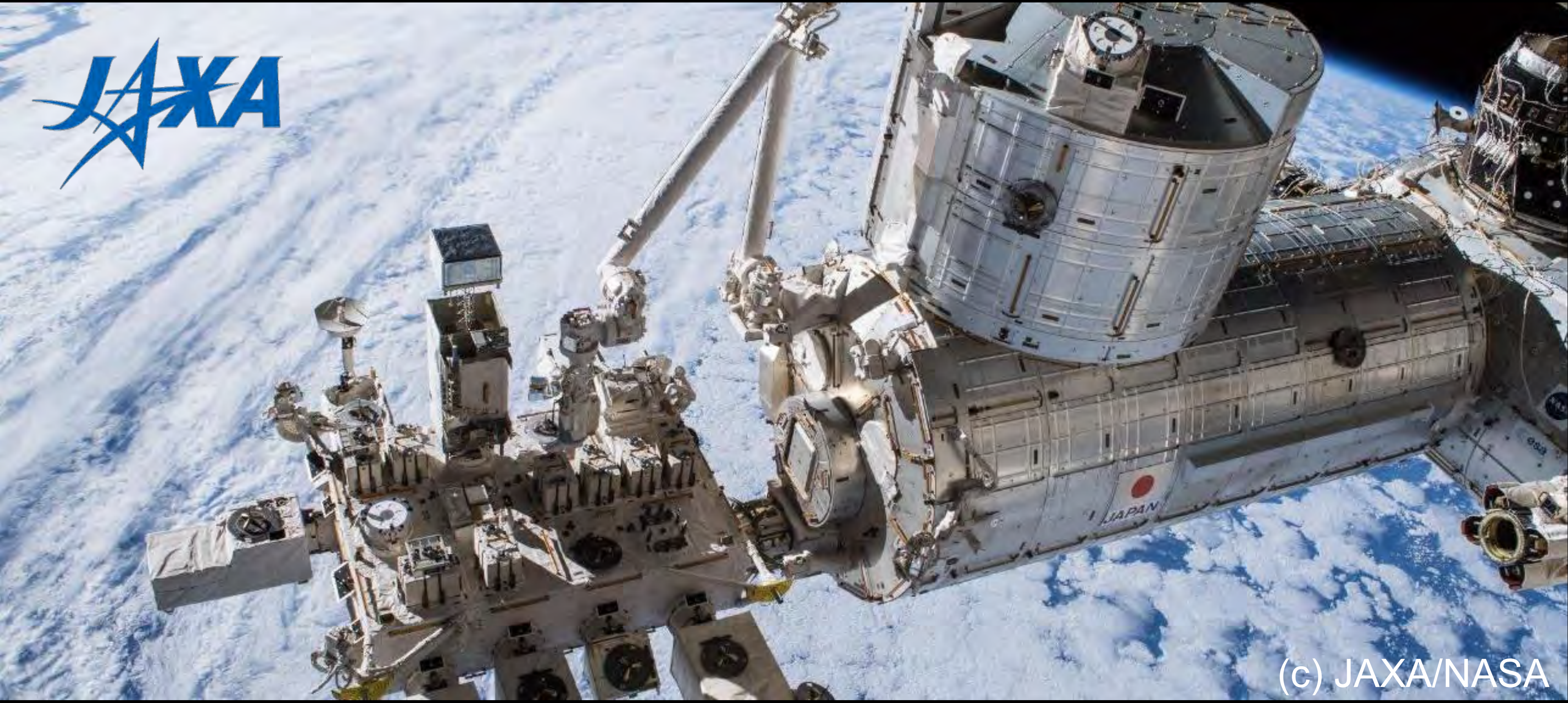
Design your experiment that anyone can do

- More complicated experiment induces the more failures.
- Astronauts are NOT experts in your experiment.

Work-time is limited on board

- Work-time of astronauts is strictly managed and limited.
- Reduce the steps that require crew operation. (ex. Automation)

Consider your experiment in which the maximum results can be obtained from a simple experimental design.


(c) JAXA/NASA

Overview of JAXA Space Medicine

FURUKAWA, Satoshi
Astronaut Operation and Technology Unit
Human Spaceflight Technology Directorate
Japan Aerospace Exploration Agency (JAXA)

Purpose of Space Medicine

Keep Human Health in Space

1. Clinical Medicine – for the present
    1) Keep Astronauts' Health
2. Research – for the future
    1) Resolve Medical Challenges during Stays in Space
    2) Use Space Environment to Enhance Life on Earth

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Introducing an example research

Bisphosphonates as a Countermeasure to Spaceflight-Induced Bone Loss (Bisphosphonate)

PIs: Dr. LeBlanc, Dr. Sibonga, Dr. Matsumoto
International Collaboration

Background

- Bone loss and urinary stone are well-known problems for astronauts to overcome during extended stays in space under microgravity.
- Bisphosphonate, which inhibits bone absorption, is a therapeutic agent for osteoporosis patients on Earth.

Bisphosphonates as a Countermeasure to Spaceflight-Induced Bone Loss (Bisphosphonate)

PIs: Dr. LeBlanc, Dr. Sibonga, Dr. Matsumoto
International Collaboration

Purpose

- Investigate the effects of prophylactic use of Bisphosphonate during long-duration spaceflight on the prevention of bone loss and urinary stone in astronauts.

Published Paper 1

LeBlanc A, Matsumoto T et al. Bisphosphonates as a supplement to exercise to protect bone during long-duration spaceflight. Osteoporos Int 2013 Jul;24(7):2105-14. doi: 10.1007/s00198-012-2243-z.

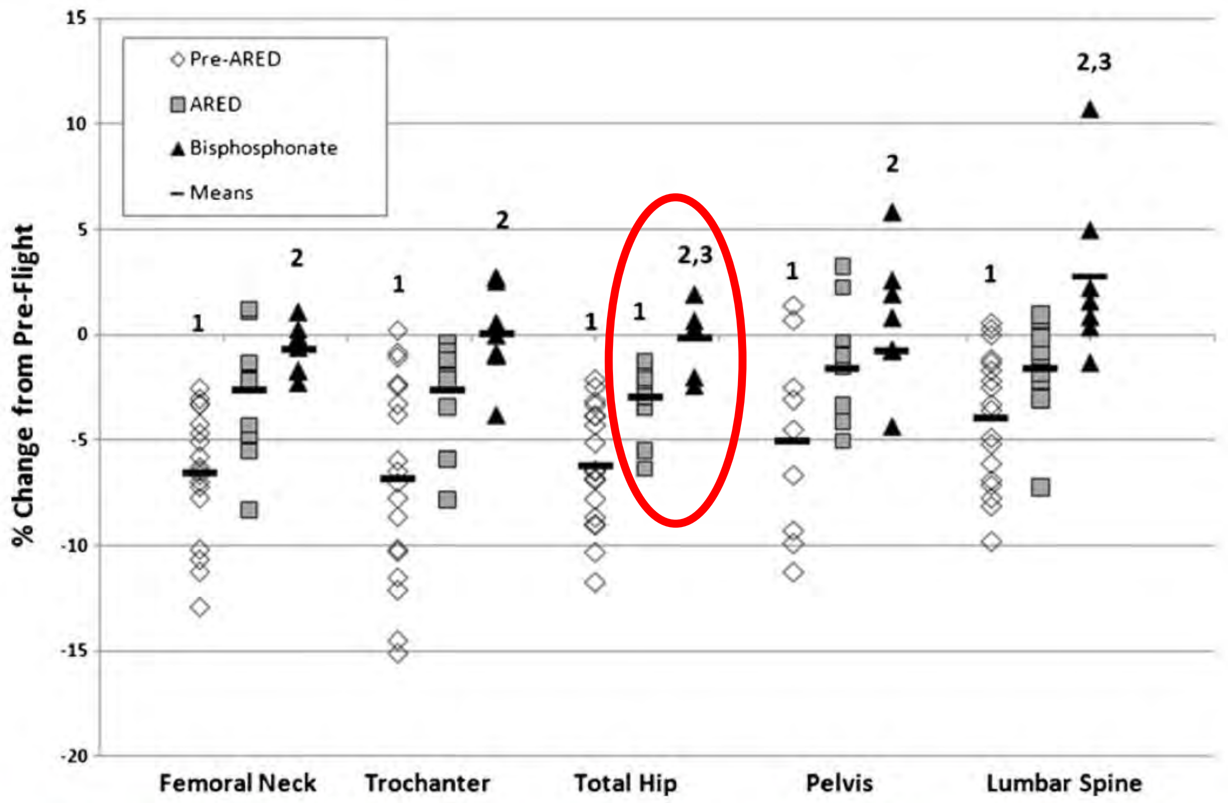


Fig. 1 Change in DXA BMD after long-duration space flight. *1* $p<0.05$, pre vs. post; *2* $p<0.05$ (bisphosphonate group significantly different from pre-ARED); *3* $p<0.05$ (bisphosphonate group significantly different from ARED). Pre-ARED ($n=18$); ARED ($n=11$); bisphosphonate ($n=7$)

The ARED alone group showed postflight decreases in the total hip bone mineral density (3%/6months), while ARED+ Bisphosphonate group had 0% decrease in average.

ARED: Advanced Resistive Exercise Device

Published Paper 2

Sibonga J, Matsumoto T et al. Resistive exercise in astronauts on prolonged spaceflights provides partial protection against spaceflight-induced bone loss.
Bone 2019 Nov;128:112037. doi: 10.1016/j.bone.2019.07.013.

Regarding post-flight changes from preflight of about 6-month space missions, ARED+Bisphosphonate prevented declines in all DXA and QCT hip densitometry. ARED alone partially attenuated declines in bone mass. It did not prevent declines in hip trabecular volumetric BMD, but prevented reductions in cortical volumetric BMD of the femoral neck and in areal BMD of the femoral neck.

ARED: Advanced Resistive Exercise Device, BMD: Bone Mineral Density
DXA: Dual-energy X-ray Absorptiometry, QCT: quantitative computed tomography

Purpose of Space Medicine

Keep Human Health in Space

1. Clinical Medicine – for the present
    1) Keep Astronauts' Health
2. Research – for the future
    1) Resolve Medical Challenges during Stays in Space
    2) Use Space Environment to Enhance Life on Earth

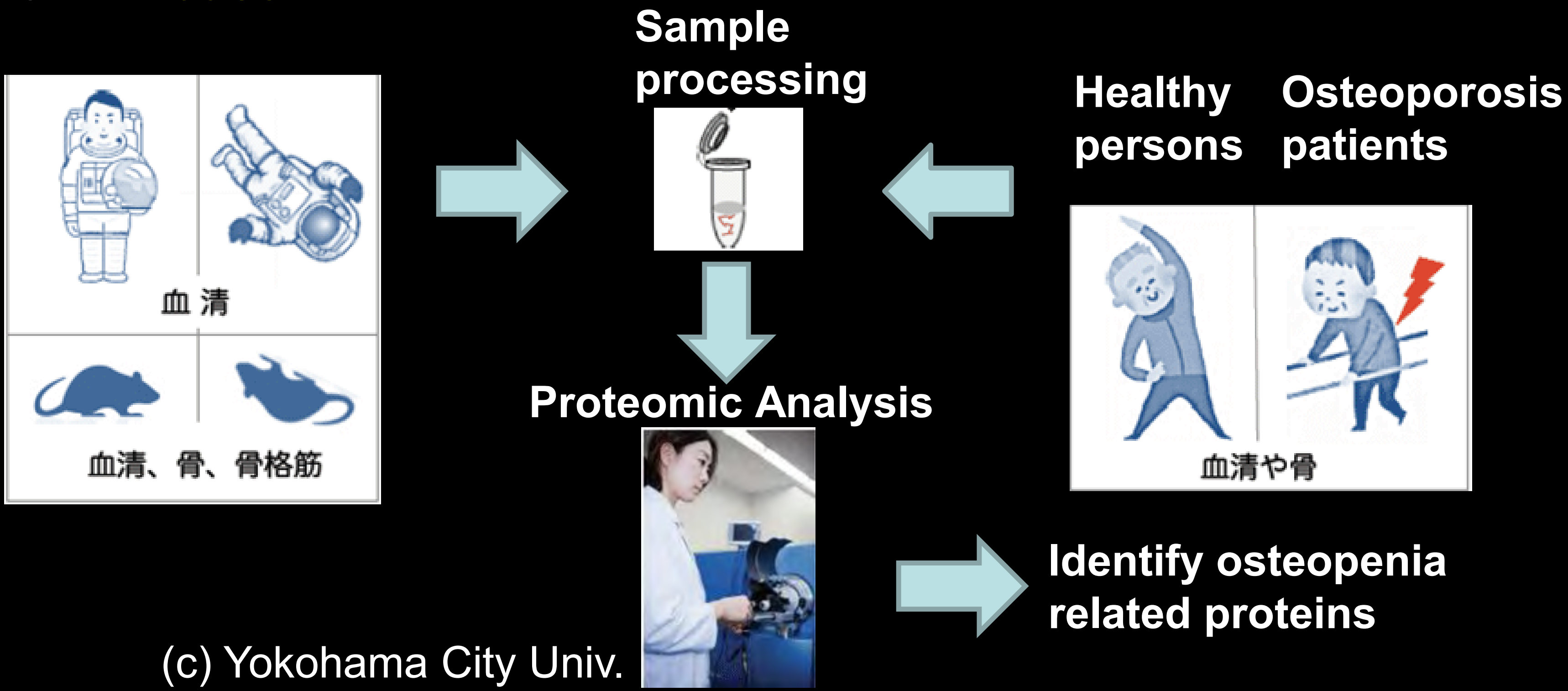
Introducing an example research

Medical proteome analysis of osteoporosis- and bone mass-related proteins using the Kibo of ISS (Medical Proteomics)

PI: Dr. Hirano

To identify osteopenia related proteins

- Investigate blood proteins of astronauts before, in and after spaceflight by using state-of-the-art proteomic analysis technology
- Investigate proteins in blood, bone and skeletal muscle of space-flown mouse



Sample processing

Healthy persons

Osteoporosis patients

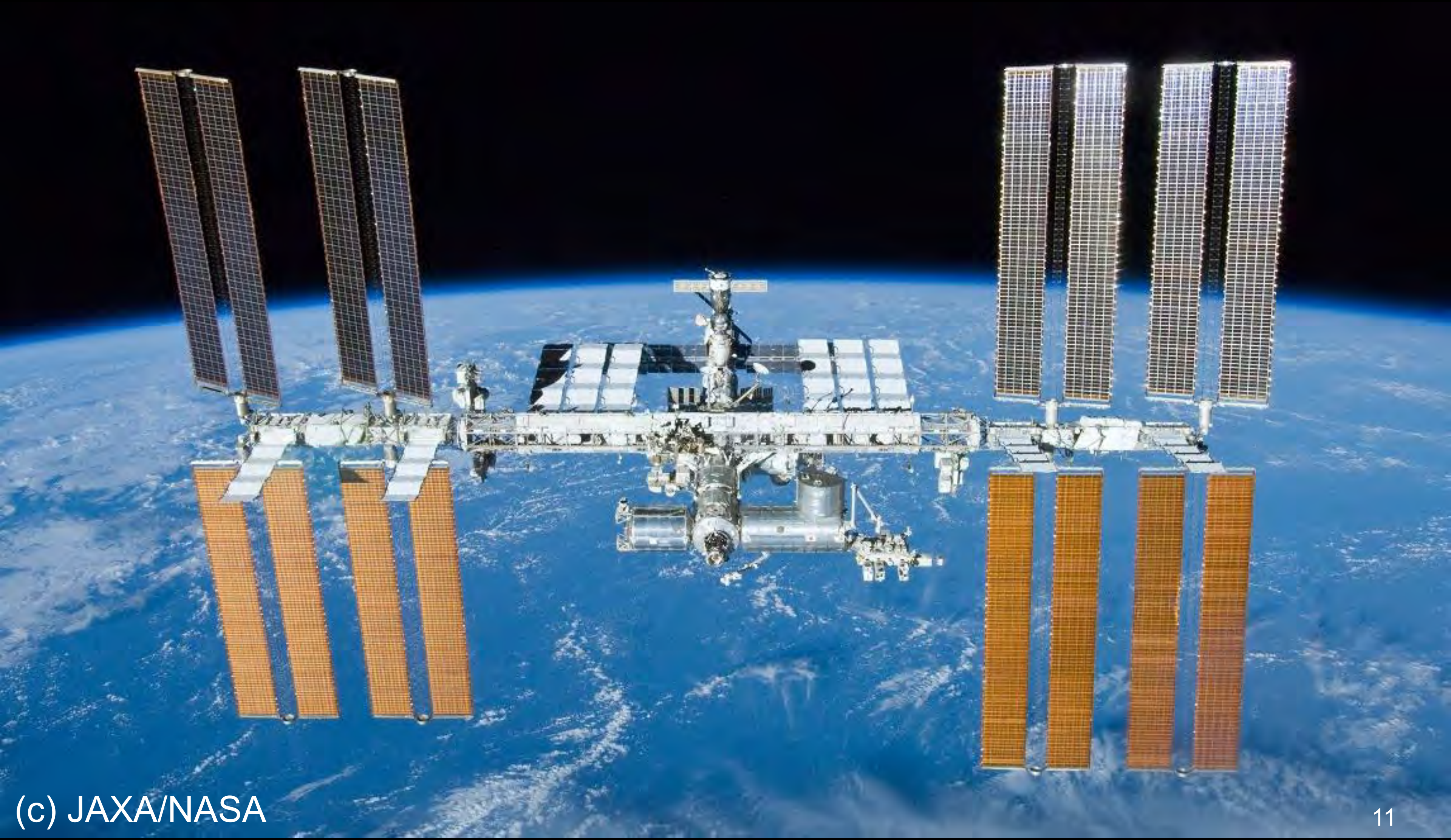
Proteomic Analysis

Identify osteopenia related proteins

(c) Yokohama City Univ.

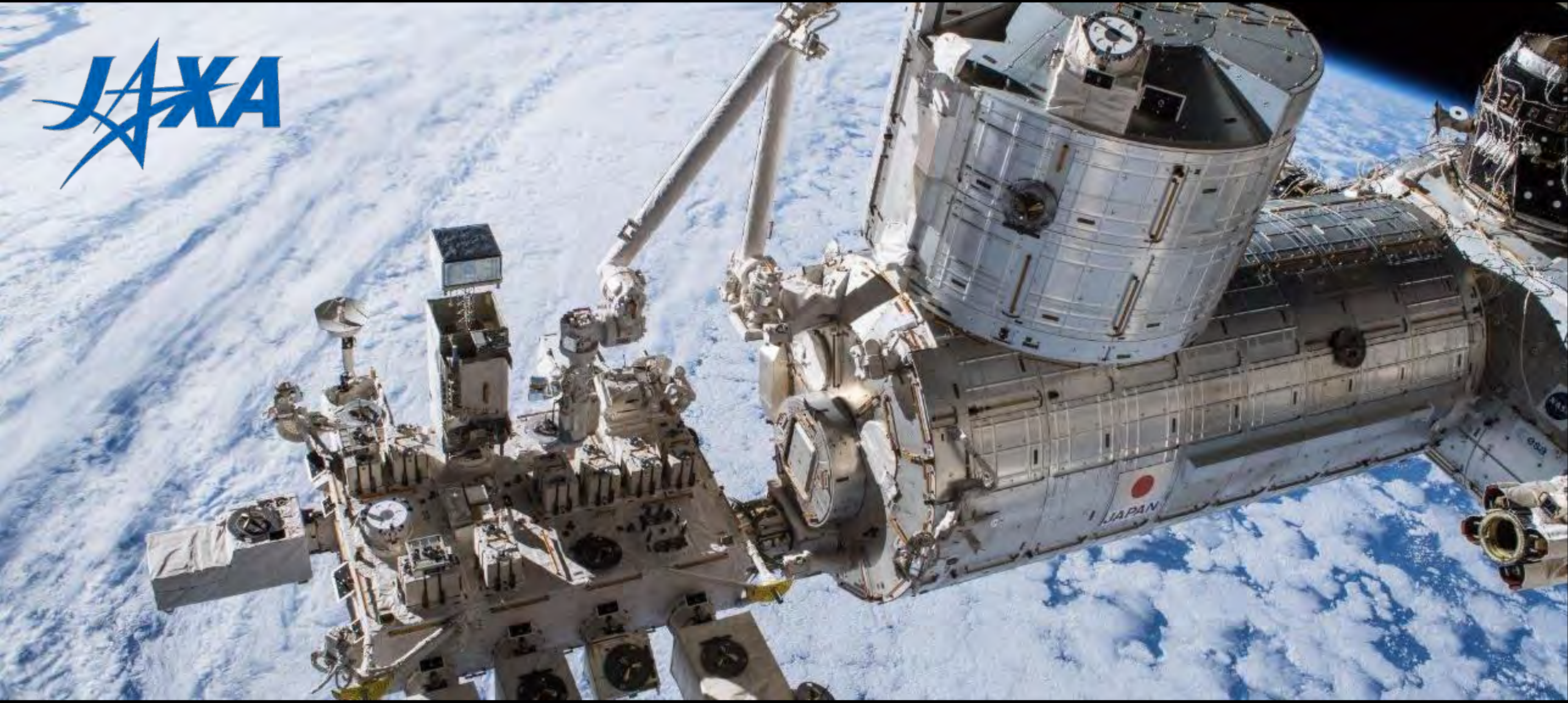
An example of space research that enhances life on Earth.

Thank you for your attention



(c) JAXA/NASA

Kibo Utilization Symposium Online November 5, 2020



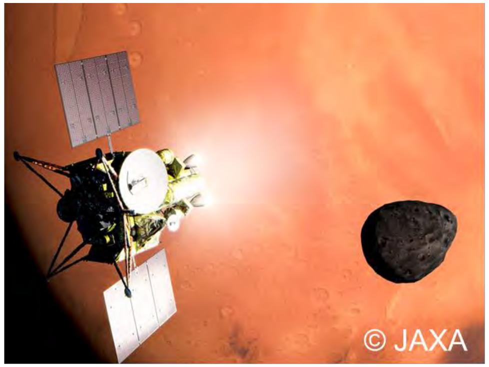
Hourglass
(Technical demonstration for future space exploration)

PI : Masatsugu Otsuki
Co-PI: Takao Maeda , Masataku Sutoh Shingo Ozaki, Genya Ishigami, Taizo Kobayashi , Hideaki Miyamoto , Koji Wada

KUROSAWA Chihiro
JEM (Kibo) Utilization Center
Human Spaceflight Technology Directorate
Japan Aerospace Exploration Agency (JAXA)

1. Introduction

LUNAR CRUISER



Martian Moons eXploration (MMX)

Conditions of the Moon, Martian Moons

- Surfaces are covered by soft granular regolith
- Low gravity

Understanding of the granular materials and
the machine-terrain interaction in low gravity environments

1. Introduction

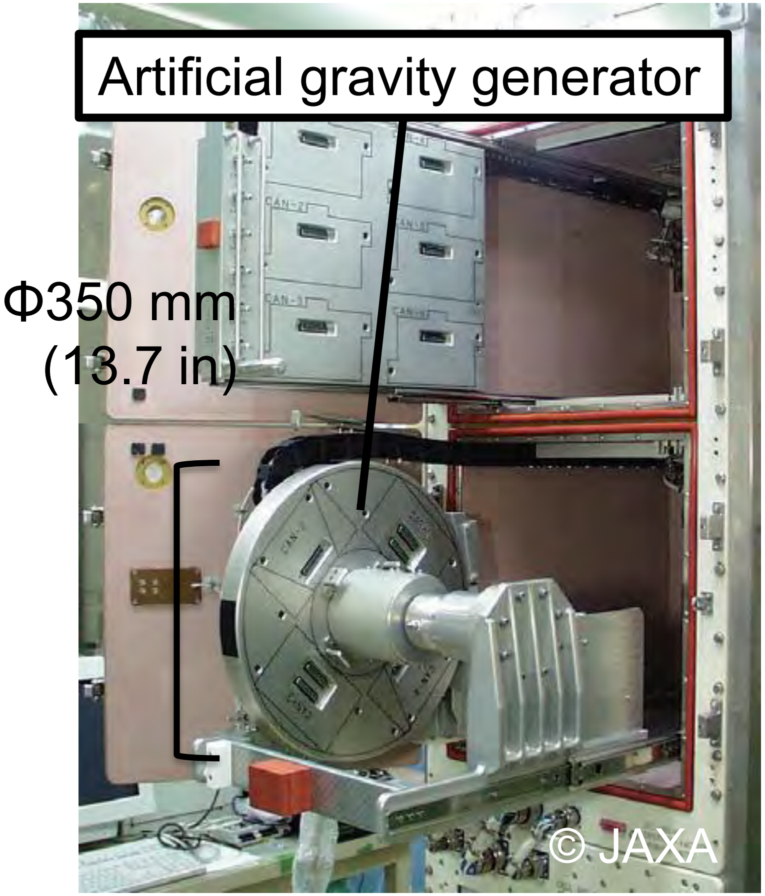
Objectives and goals of Hourglass Mission

- The characteristics of granular materials under high quality low gravity environment using an artificial gravity generator on the Japanese Experiment Module “ KIBO ” of the International Space Station (ISS).

- The goal is to obtain the information that contributes to a future spacecraft design.

Hourglass Mission decal

2. Methods



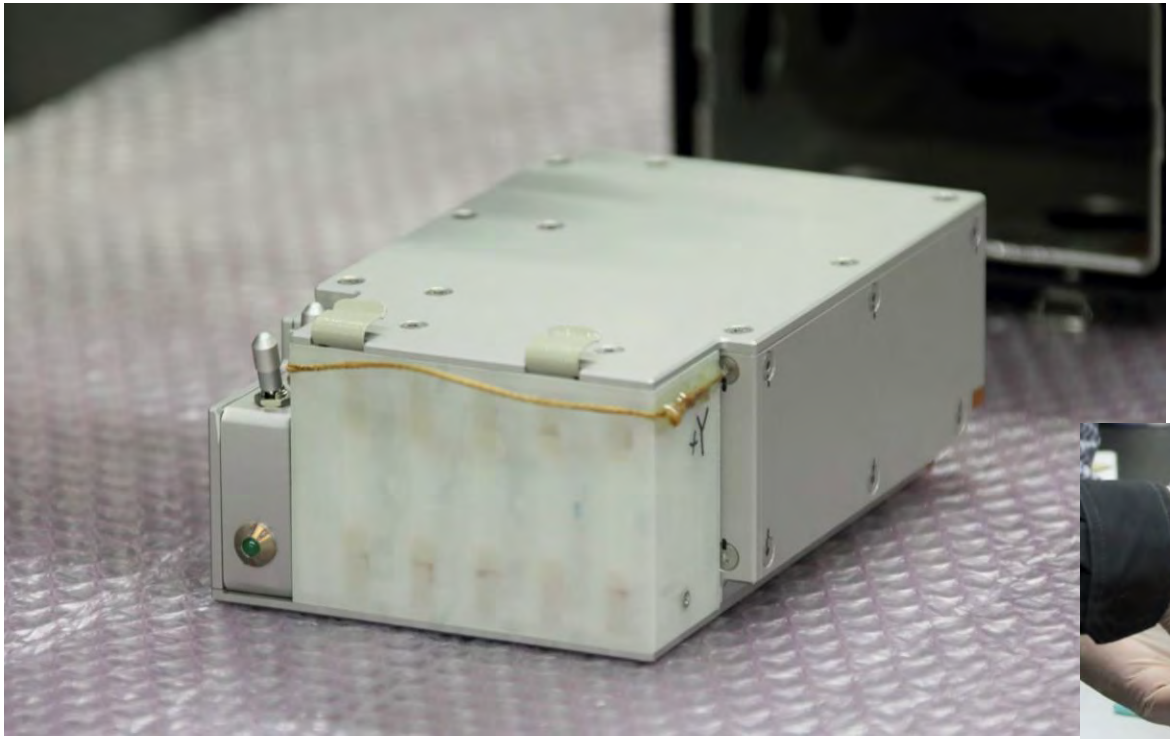
Cell Biology Experiment Facility (CBEF)

Artificial gravity generator

- The low-gravity environment is created by using an artificial gravity generator.
- The settable artificial gravity is from 0.06 G to 2.0 G.
- In this mission the gravity conditions are changed as 0.06, 0.16, 0.33, 0.5, 0.75, 1, 1.5, 2G.

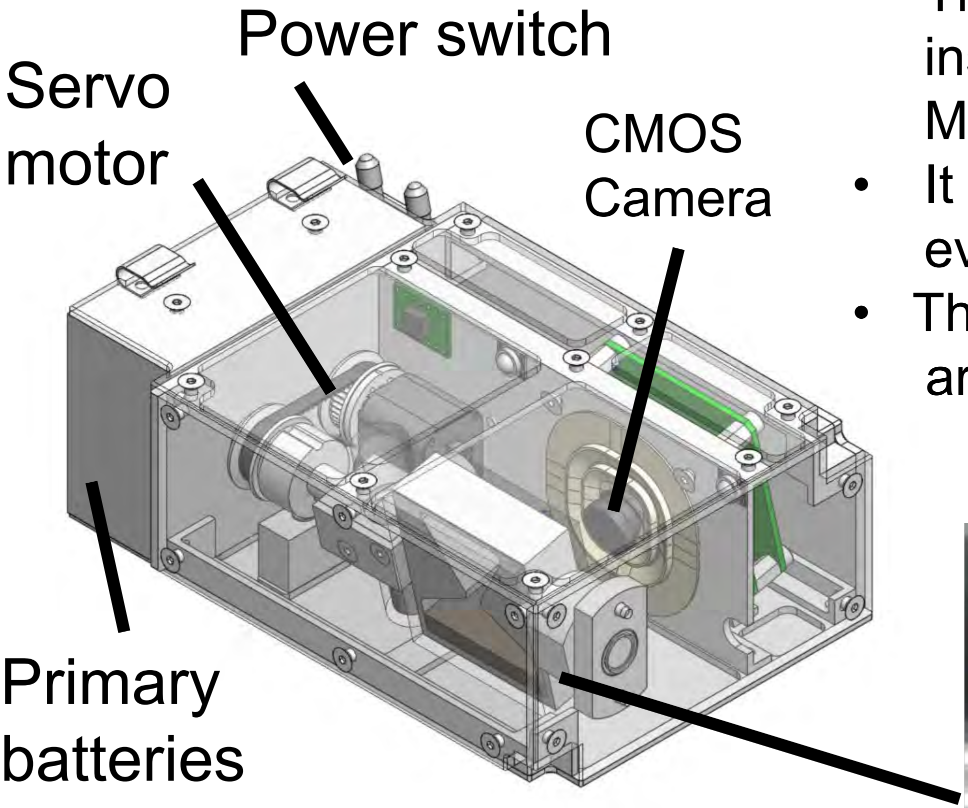
Lunar gravity Mars gravity

2. Methods
Experiment Hardware



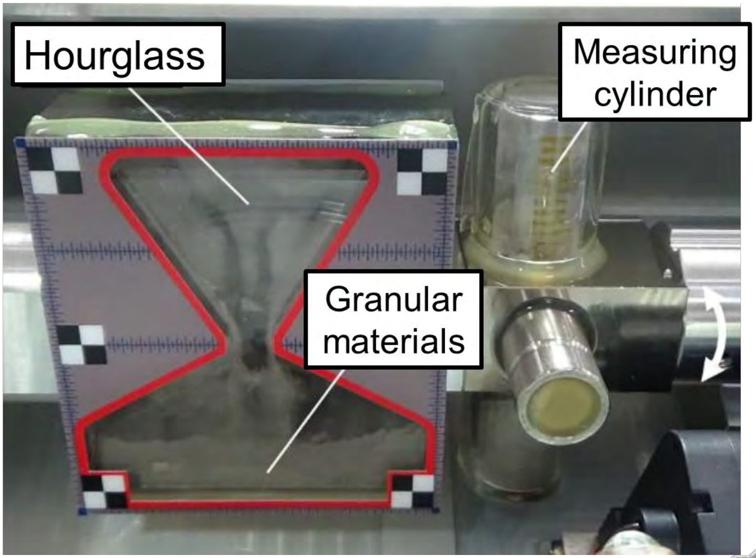
Hourglass Box

2. Methods
Experiment Hardware



Schematic of Hourglass Box

- The samples of granular materials are installed in the Hourglass and Measuring cylinder.
- It automatically reversed every one minute by a servo motor.
- The behavior of granular materials are observed by CMOS Camera.



2. Methods

Samples

Eight kinds of granular materials are selected as samples.

Alumina beads

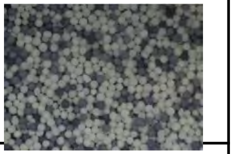
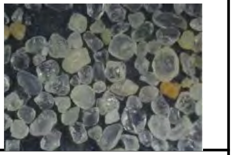
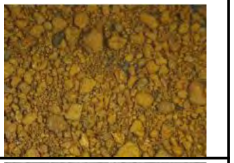
- A standard shape against other various samples.

Silica sand #5, Toyoura sands

- Standard for civil engineering.

Lunar, Mars Moon and Mars regolith simulants

- There are targets of future exploration.

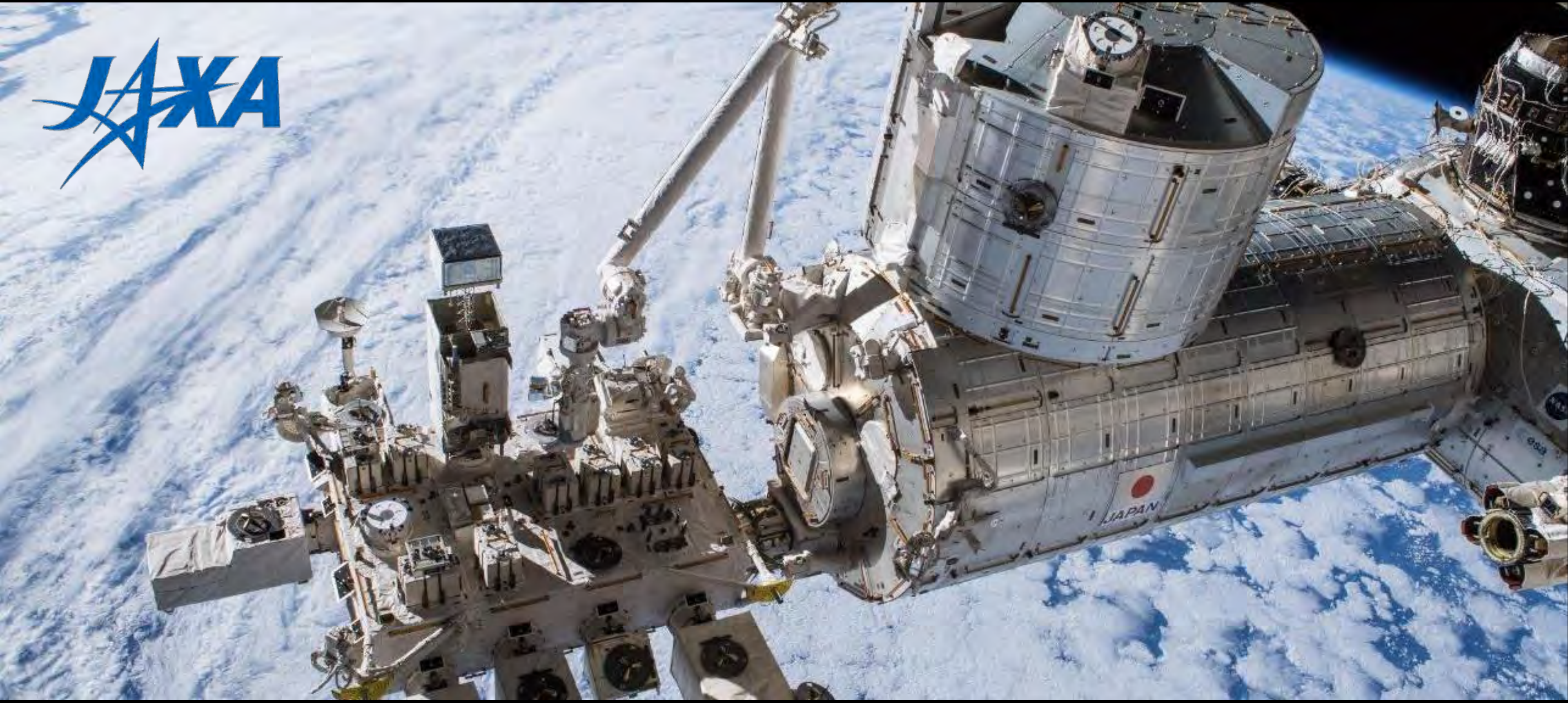
#	Name	Particle size distribution	Images
1	Alumina beads	approx. 200 um	
2	Silica sand#5	75um to 850um	
3	Toyoura sand	75um to 850um	
4	Lunar regolith simulant （FJS-1, sieved)	1.3um to 850um	
5	Mars moon regolith simulant (sieved)	10um to 850um	
6	Mars regolith simulant (JSC Mars-1, sieved)	5um to 850um	
7	Silica sand#8	38um to 212um	
8	Lunar regolith simulant （FJS-1 original, sieved)	1.3um to 425um	

3. Summery

- JAXA plans to conduct “ Hourglass Mission ”
  for developing the spacecraft for future exploration missions.

- We observed the behavior of granular materials under low gravity
  by using Hourglass Box and Artificial gravity generator
  which can provide high quality low gravity.

- Eight kinds of granular materials are selected as samples.



Environmental Control and Life Support System in Space JAXA

YAMAGIWA Kana
JEM Mission Operations and Integration Center
Human Spaceflight Technology Directorate
Japan Aerospace Exploration Agency (JAXA)

About ECLSS

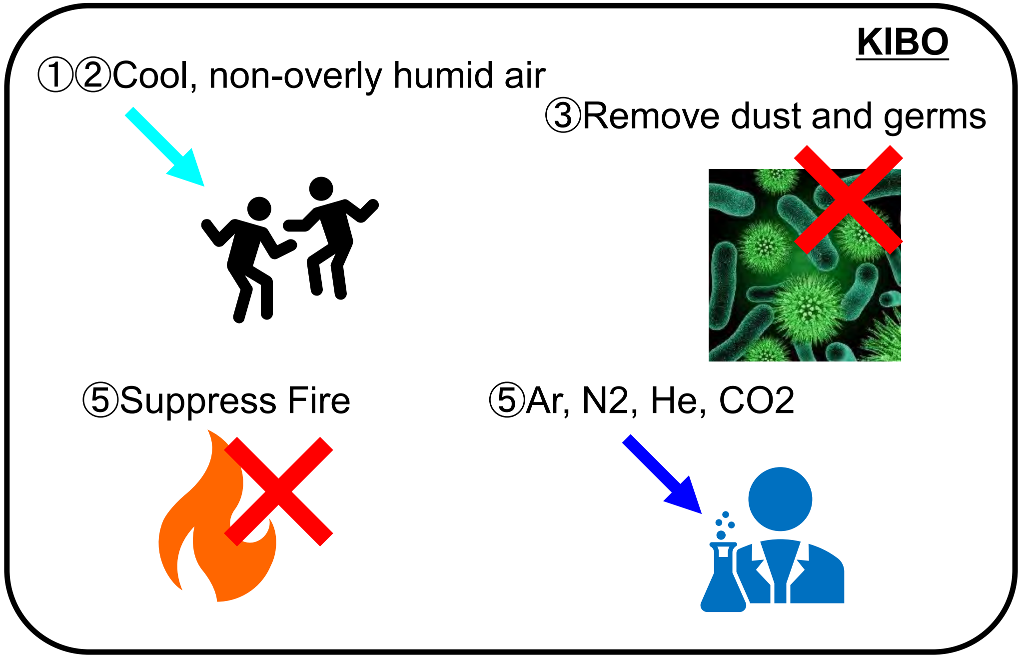
- The International Space Station is a completely isolated environment with almost no gravity; Hence there are numerous phenomenon that do not happen on Earth
  - CO2 accumulation around your face
  - Humidity/heat buildup from exhale & sweat
  - Buildup of particles/dust and microorganisms

- The Environmental Control and Life Support System (ECLSS) provides a comfortable environment for the crew on the ISS by targeting the above issues

Images from:
https://gigazine.net/news/20161101-iss-fisheye-fly-through/
https://iss.jaxa.jp/kibo/

ECLSS in KIBO

- The major ECLSS equipment in the KIBO(The Japanese Experiment Module) is as below:
  ① Atmosphere Control and Supply
  ② Temperature and Humidity Control
  ③ Atmosphere Revitalization
  ④ Fire Detection and Suppression
  ⑤ Provide Gas to Payloads



KIBO

①②Cool, non-overly humid air

③Remove dust and germs

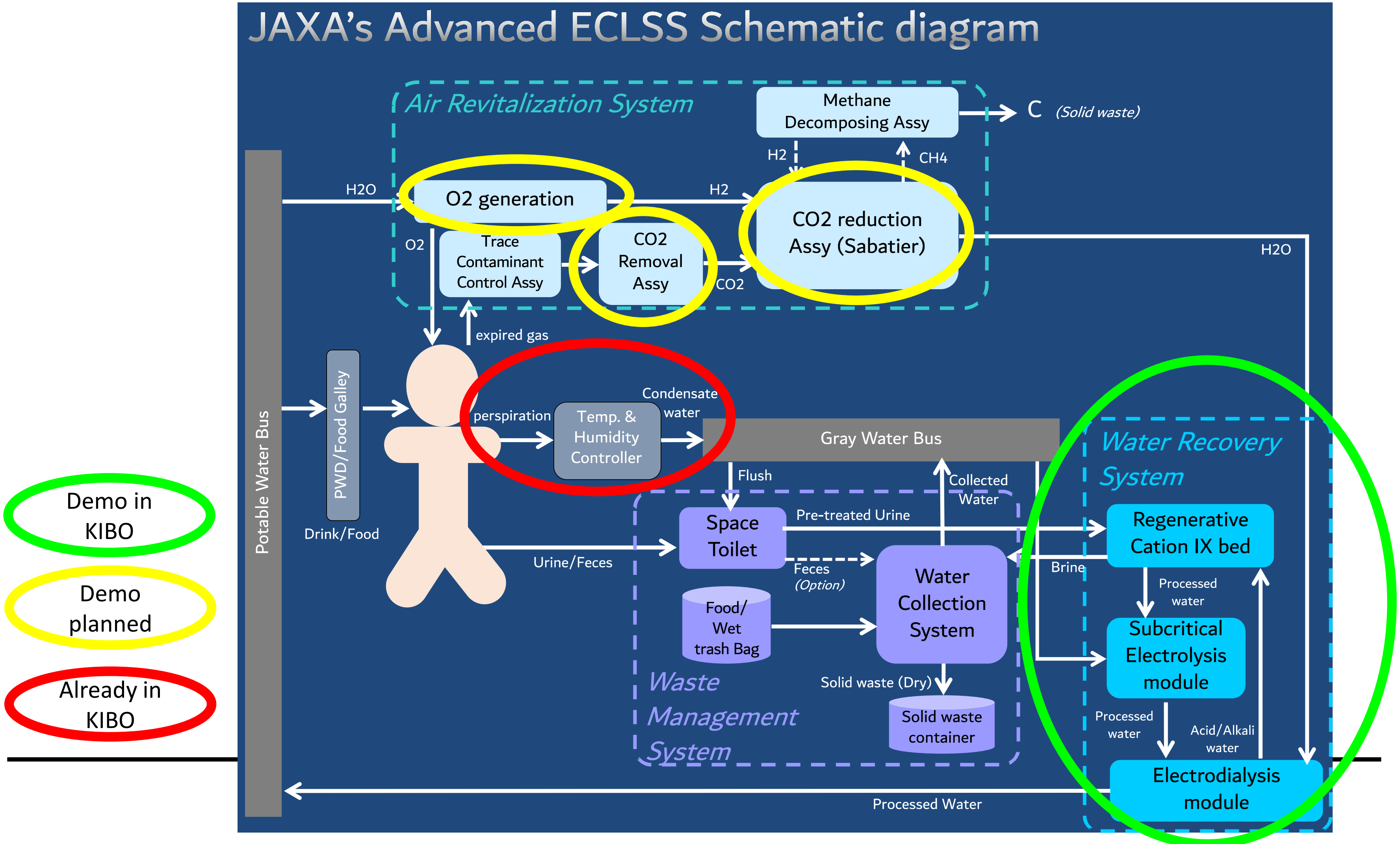
⑤Suppress Fire

⑤Ar, N2, He, CO2

- However, these are basic ECLSS technologies, and the JEM is heavily dependent on other modules for other ECLSS equipment. Below are some examples.
  - **Trace Contaminant Control:** Remove toxic gases from cabin air
  - **CO2 Removal:** Remove CO2 from cabin air
  - **Water Recovery:** Recycles urine/sweat to potable water

The Future of ECLSS and Space Exploration

- The next step in space exploration: Long term stays in space, which requires less Earth-dependent systems i.e. regenerative technology
- JAXA aims to resolve this issue by striving for more “green” ECLSS technology.



JAXA’s Advanced ECLSS Schematic diagram

Air Revitalization System

Methane Decomposing Assy

C *(Solid waste)*

H2

CH4

H2O

O2 generation

H2

CO2 reduction Assy (Sabatier)

O2

Trace Contaminant Control Assy

CO2 Removal Assy

CO2

H2O

expired gas

Potable Water Bus

PWD/Food Galley

Drink/Food

perspiration

Temp. & Humidity Controller

Condensate water

Gray Water Bus

Flush

Collected Water

Urine/Feces

Space Toilet

Pre-treated Urine

Feces *(Option)*

Food/ Wet trash Bag

Water Collection System

Solid waste (Dry)

Solid waste container

Waste Management System

Brine

Water Recovery System

Regenerative Cation IX bed

Processed water

Subcritical Electrolysis module

Processed water

Acid/Alkali water

Electrodialysis module

Processed Water

Demo in KIBO

Demo planned

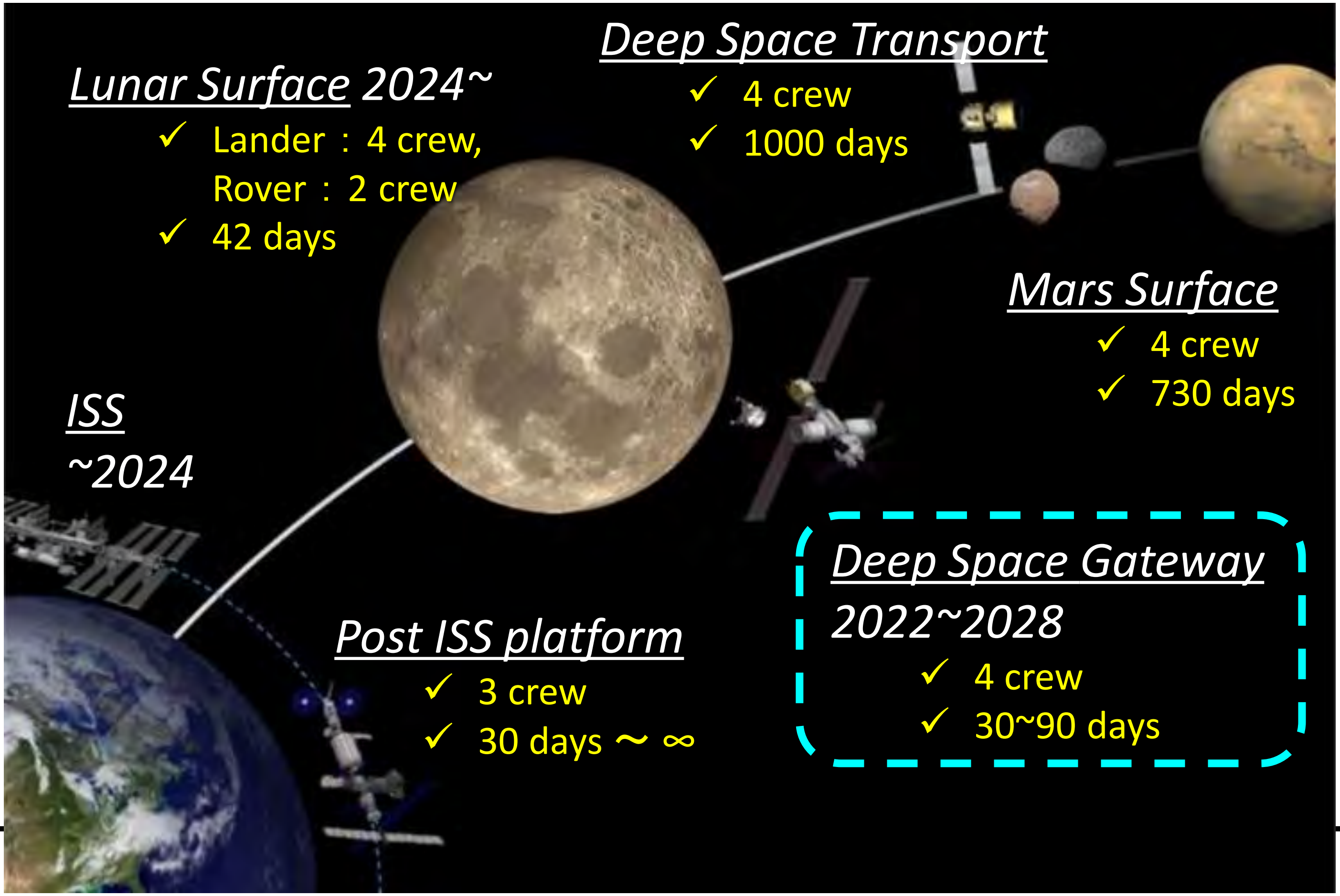
Already in KIBO

BACKUP SLIDES

THE GATEWAY PROJECT

Introduction: Deep Space Exploration

- Currently, astronauts are residing in the International Space Station, 400km from the Earth.
- As the next step in deep space exploration, international space agencies are striving for Mars. However, it is difficult to directly travel to Mars; Hence the Deep Space Gateway was conceptualized as a human base for exploring both the Lunar surface and Mars.



Lunar Surface 2024~

- ✓ Lander : 4 crew, Rover : 2 crew
- ✓ 42 days

Deep Space Transport

- ✓ 4 crew
- ✓ 1000 days

Mars Surface

- ✓ 4 crew
- ✓ 730 days

ISS

~2024

Post ISS platform

- ✓ 3 crew
- ✓ 30 days ～ ∞

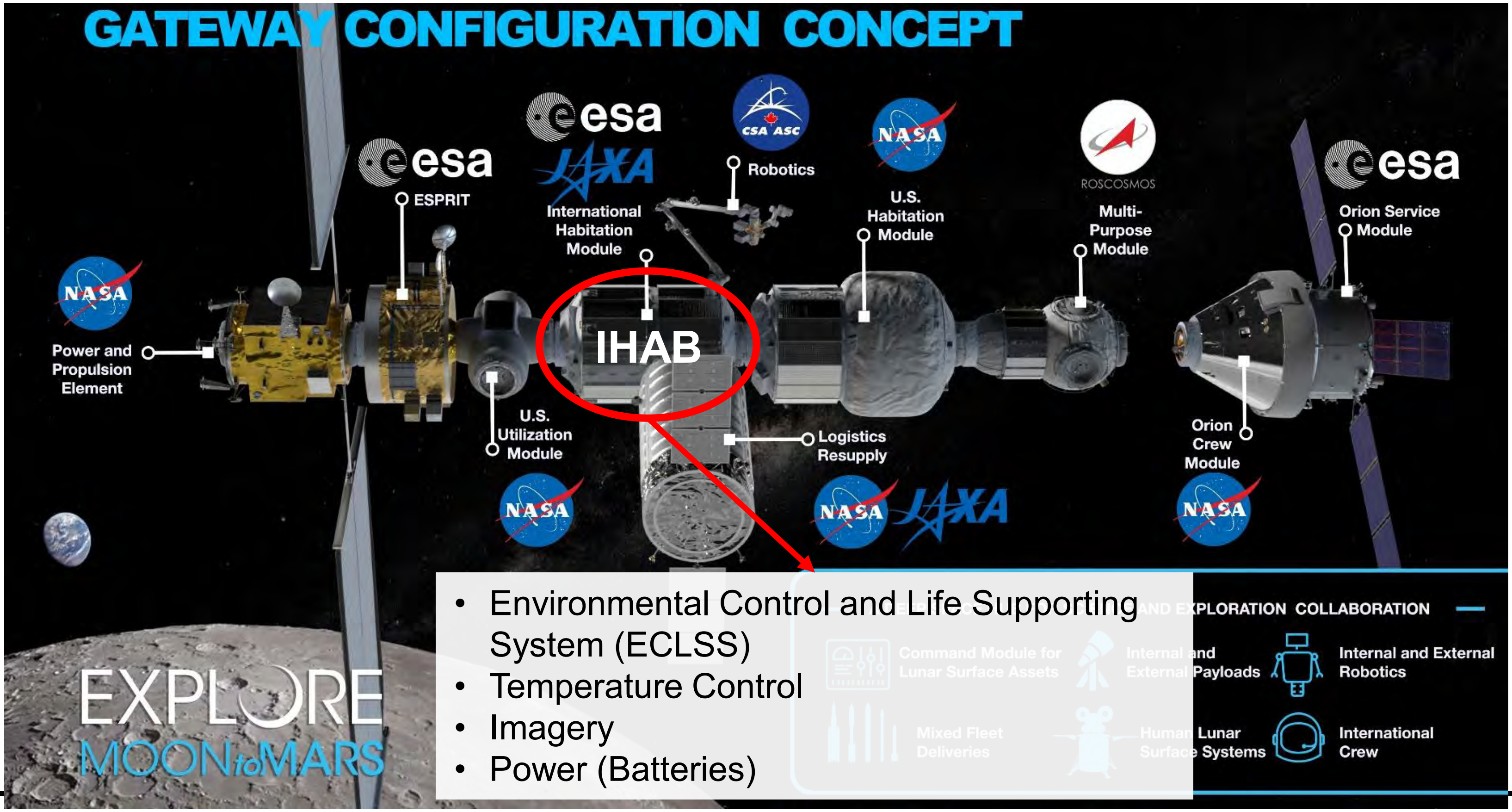
Deep Space Gateway

2022~2028

- ✓ 4 crew
- ✓ 30~90 days

Overview: Lunar Orbital Platform - Gateway

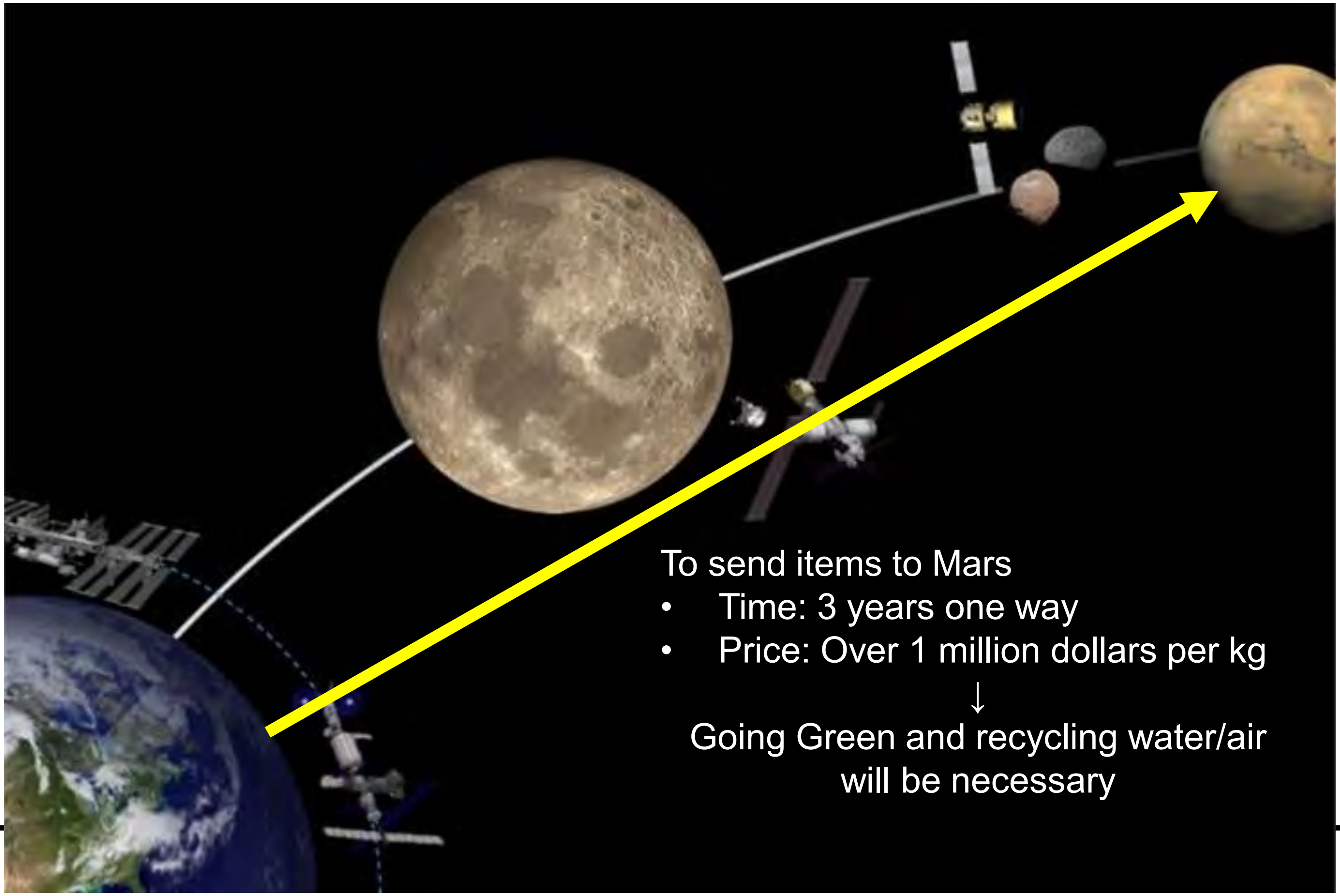
- The Gateway is the next human spacecraft orbiting around the Moon, serving as a home base for astronaut expeditions on the Moon, and future human missions to Mars.
- JAXA plans to contribute through participation in the development of the International Habitation Module (IHAB) along with ESA.



- Environmental Control and Life Supporting System (ECLSS)
- Temperature Control
- Imagery
- Power (Batteries)

JAXA's Contribution to Gateway
- Environmental Control and Life Supporting System

- Traveling to Mars takes about 3 years one way, which means that it will take time and money to transport consumables to astronauts.
- Thus JAXA plans to contribute to the Gateway concept by providing a fully regenerative ECLSS system, which will recycle water/gas to minimize consumable transportation.

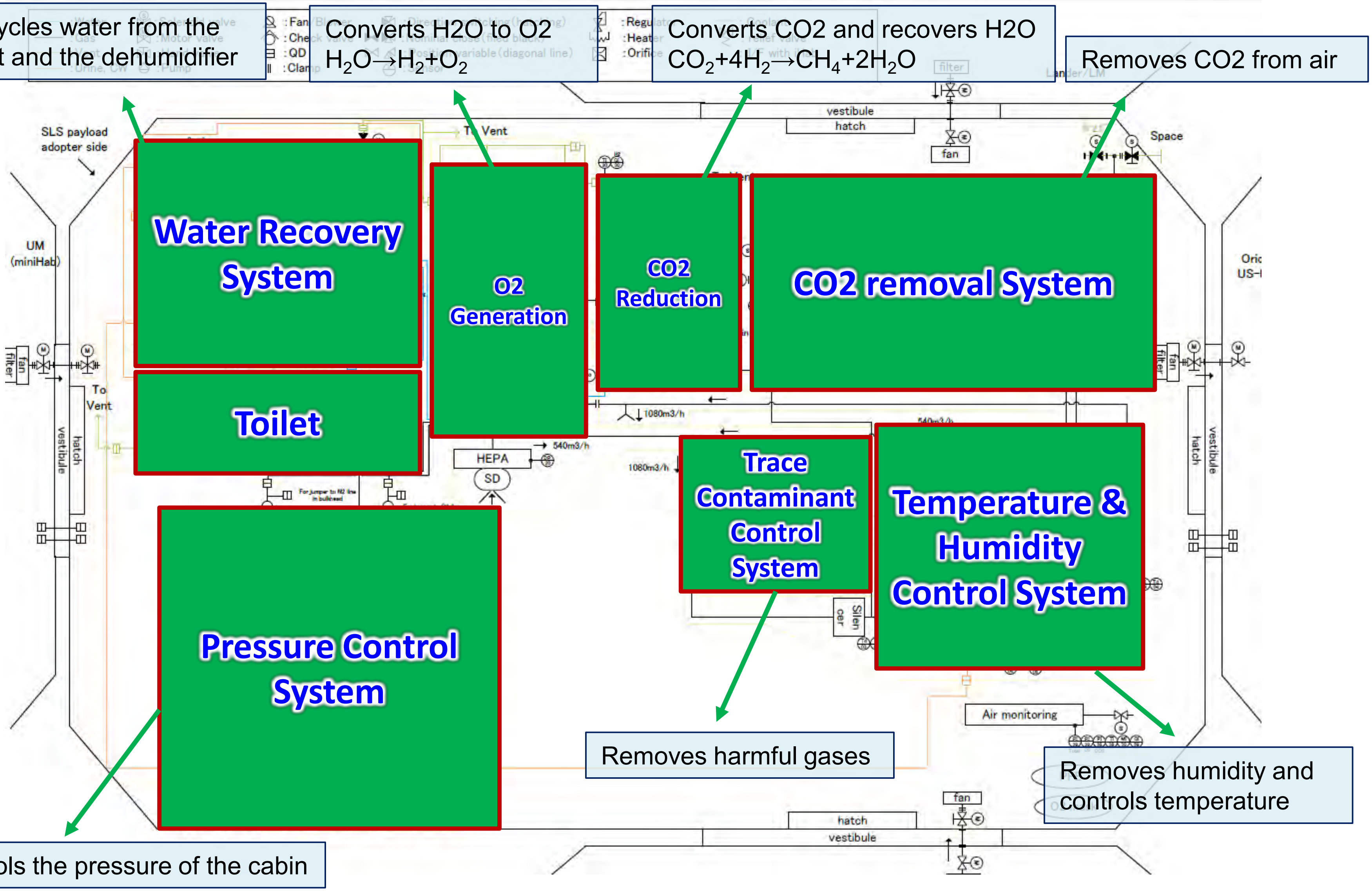


To send items to Mars
- Time: 3 years one way
- Price: Over 1 million dollars per kg

↓

Going Green and recycling water/air will be necessary

JAXA's Contribution to Gateway
- Environmental Control and Life Supporting System



Recycles water from the toilet and the dehumidifier

Converts H2O to O2
$H_2O \rightarrow H_2 + O_2$

Converts CO2 and recovers H2O
$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

Removes CO2 from air

Water Recovery System

Toilet

O2 Generation

CO2 Reduction

CO2 removal System

Trace Contaminant Control System

Temperature & Humidity Control System

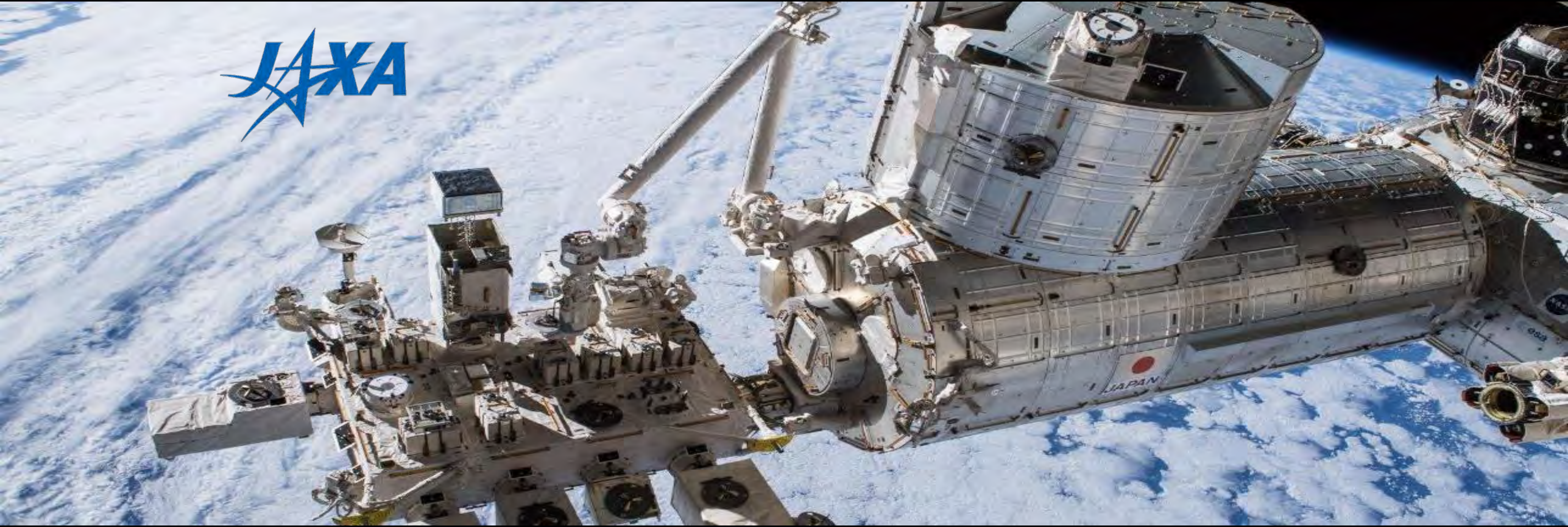
Pressure Control System

Removes harmful gases

Removes humidity and controls temperature

Controls the pressure of the cabin

Kibo Utilization Symposium Online November 5, 2020

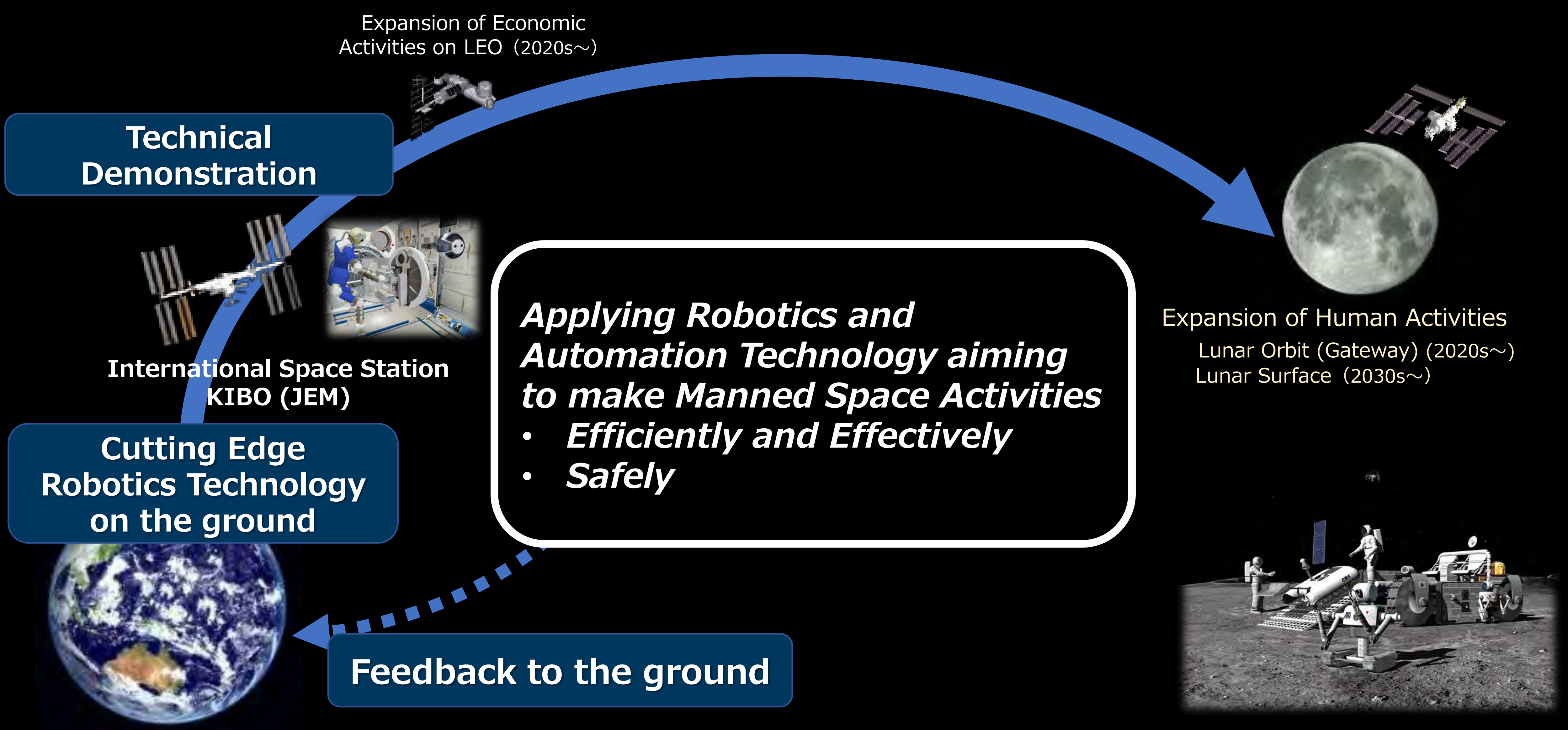


JAXA's IVR Activity

- Applying Robotics and Automation Technology for Safe and Efficient Manned Space Activities -

YAMAGUCHI Seiko
Spaceflight Technology Center
Human Spaceflight Technology Directorate
Japan Aerospace Exploration Agency (JAXA)

JAXA’s Vision in Application of Robotics Technologies to Human Spaceflight



Expansion of Economic Activities on LEO（2020s～）

Technical Demonstration

International Space Station KIBO (JEM)

Cutting Edge Robotics Technology on the ground

Applying Robotics and Automation Technology aiming to make Manned Space Activities

- ***Efficiently and Effectively***
- ***Safely***

Expansion of Human Activities

Lunar Orbit (Gateway) (2020s～)

Lunar Surface（2030s～）

Feedback to the ground

JAXA's IVR R&D

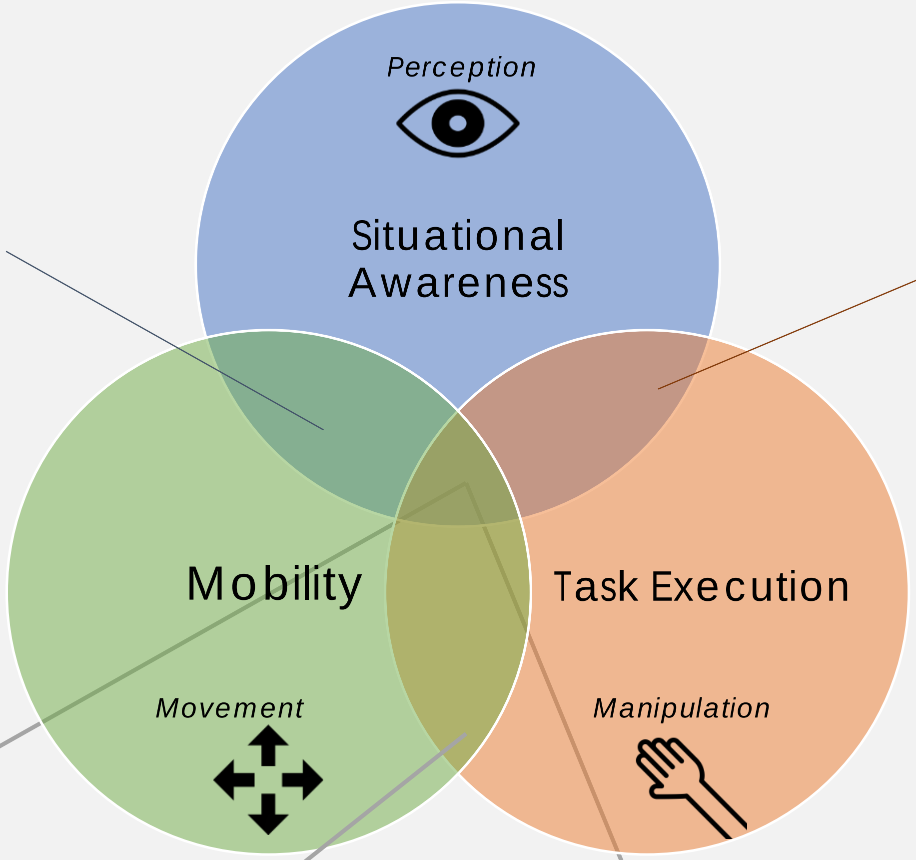
Int-Ball Project

Replacing Video Shootings Crew-tasks on ISS,JEM
- Int-Ball launched in 2017.
- Int-Ball2 developed with increased autonomy

R&D Areas: IVR Mobility, Localization & Navigation
Autonomy, Crew Interaction

Crew-Baddy Robot

Supporting crew wellbeing
and assist with simple tasks



Perception

Situational Awareness

Mobility

Task Execution

Movement

Manipulation

Advanced Manipulation

Support crew activities on space station and beyond

- JEMRMS (EVR)
  Operating on JEM. EF manipulation / Satellite Deployment etc.
- IVR Manipulation tests
  Ground tests with crew tasks reference to Kibo
  Verifying various manipulators as well as assessment of application to ISS/Gateway

R&D Areas: Autonomous Control, Remote control
Communication latency, IF design

Human/Robotic IF Design Guidelines

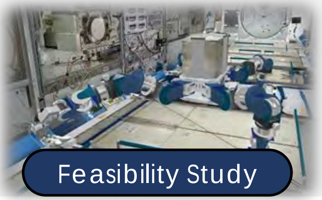
Man-Robot Compatible IF Design

Robotic technology for Moon Exploration

In human lunar exploration, robot is anticipated to handling of unknown objects (e.g. rocks), need to be adopted to external environment. While maintaining compliance to work safely with crew

Automated Cargo handling

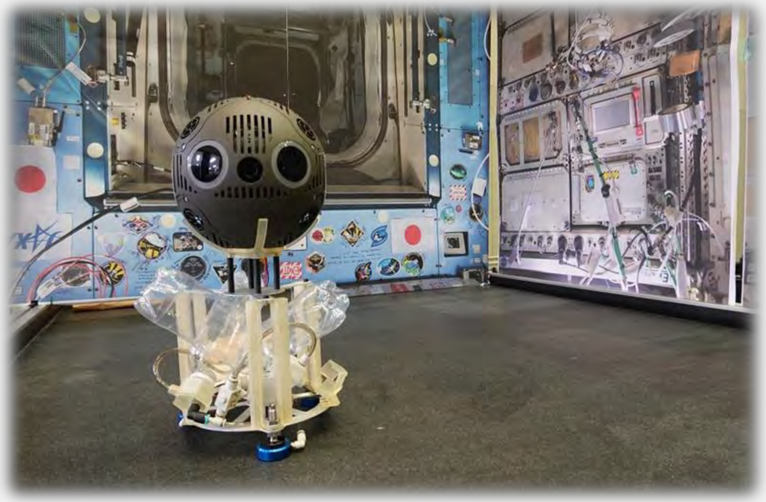
IVR Mobility and capability to handle common transfer bag will allow automated cargo handling, increasing the efficiency of human spaceflight missions.



Intravehicular task assistance robot

Replacement and Support of IVA crew tasks to reduce current crew workload It aims to automate the repetitive and predefined tasks by IVR.

KIBO as a testbed for Robotic R&D



IVR R&D, Ground Tests

JEM Internals Robotics Test Field

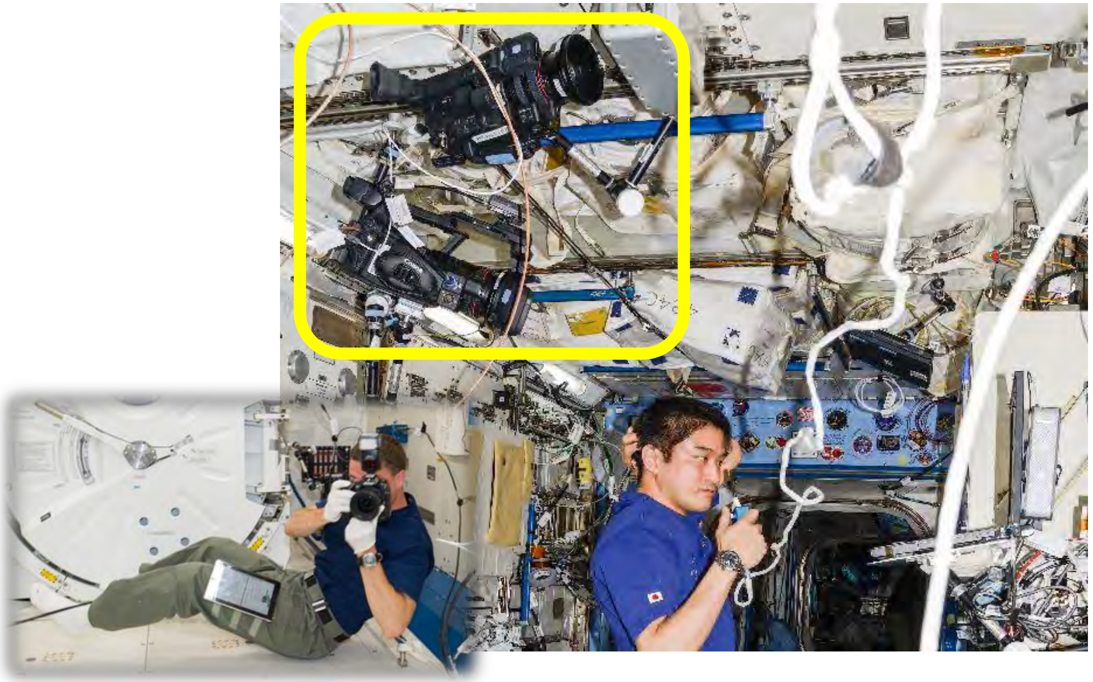
ISS demo

KIBO Internals

KIBO Externals

Space Drone (Int-Ball)

- Aims to reduce the crew time for video shooting onboard.
  The crew spends up to10% of their current working hours to prepare cameras and engage in photographing operations.
- The initial ISS flight demonstration and data acquisition proceeded in 2017.
- Currently the next generation of the Int-Ball is under development
  Increasing its degree of autonomy and targets to achieve “crew time zero”.



Int-Ball on ISS

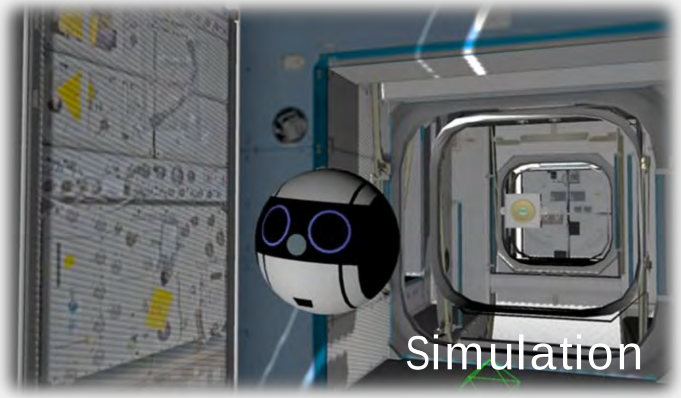
Educational Utilization of Robotics

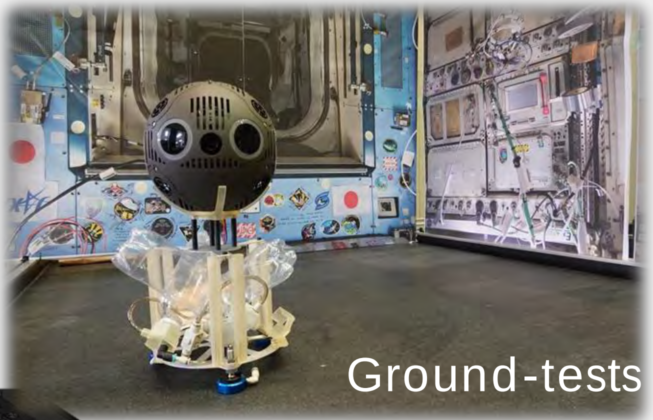
- 2019 **:** Cooperation between JAXA and MBRSC in the educational project using Int-Ball
- 2020 **:** Kibo Robot Programming Challenge with International Parterns including UAESA

©MBRSC

Int-Ball2 Development

- Int-Ball2 is currently under development
- It will increase its degree of autonomy and targets to achieve "crew time zero"
- Key features includes:
  - ✓HD camera/ video transmission
  - ✓V-SLAM and PtP navigation
  - ✓Autonomous docking
  - ✓Increased mobility (8 fans)
  - ✓Crew Support (LED light)
  - ✓Extendable software (ROS)
  - ✓Additional HW extension (USB)





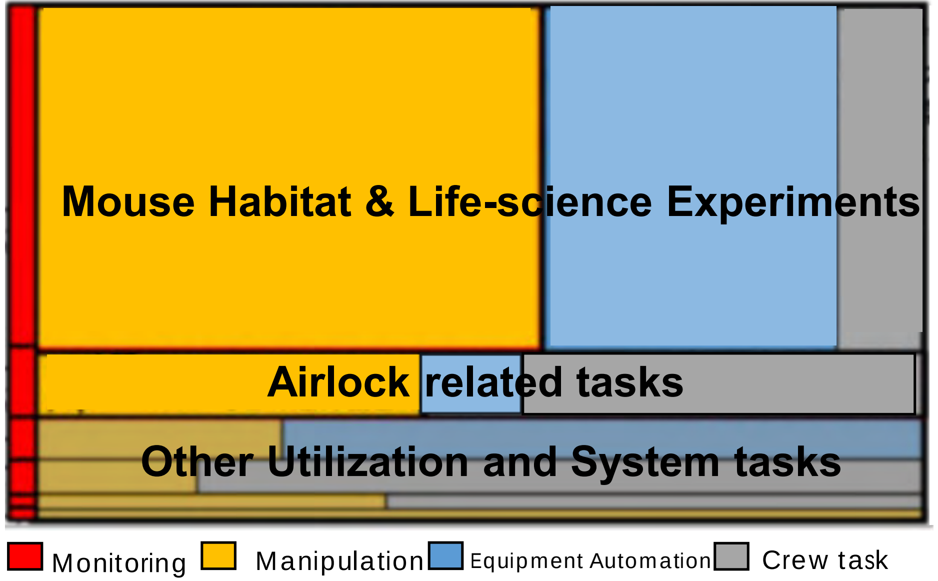
Int-Ball2 Conceptual Image
(Under development)

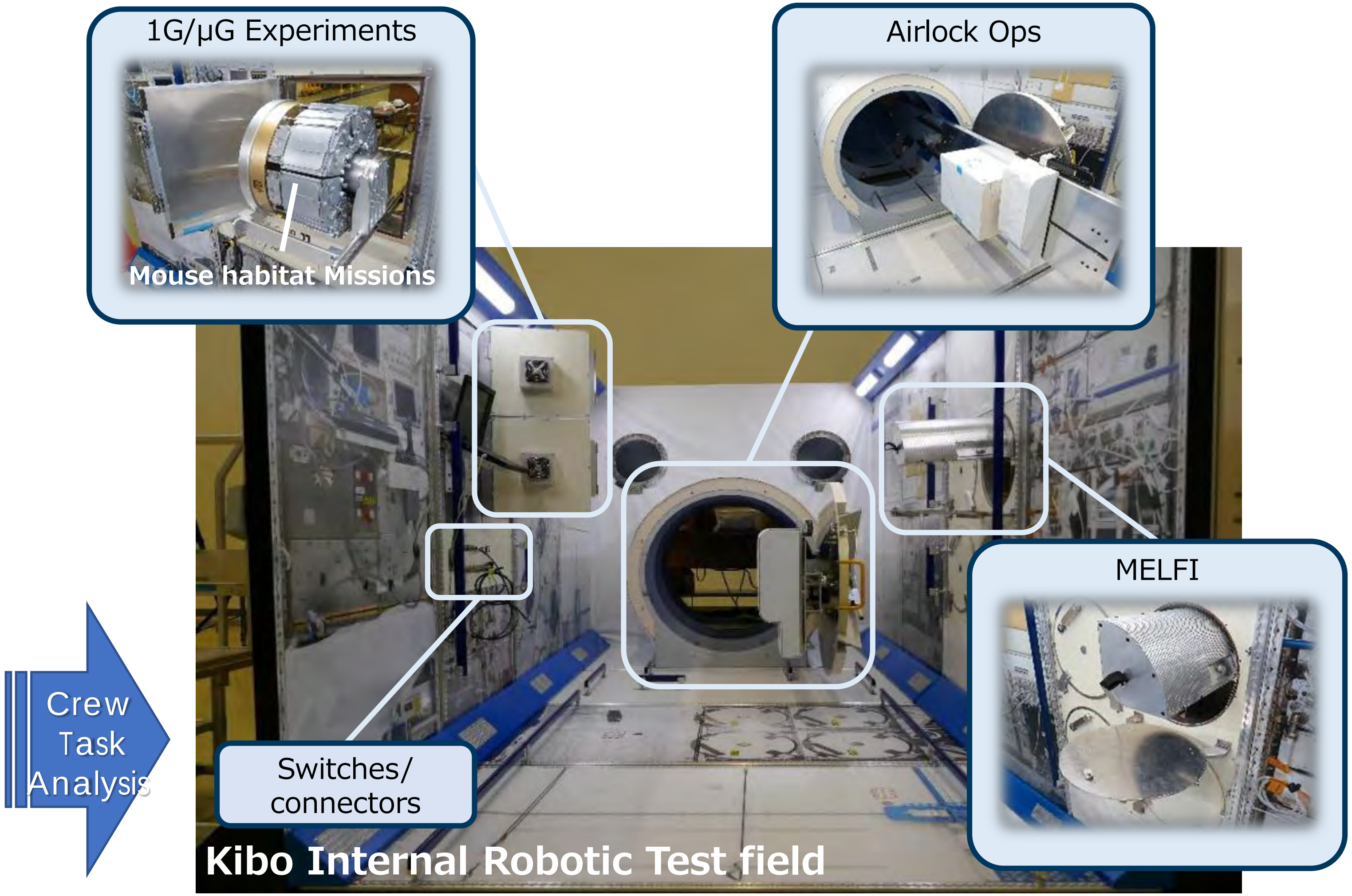
Robotic Test Filed

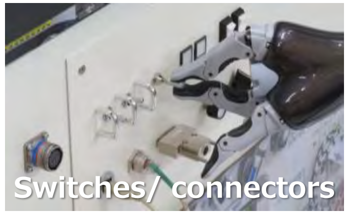
- Analyzed Crew Operation in JEM and chosen prioritized tasks for automation
- Developing technology for the crew time optimization in Kibo Utilization
- Kibo Robotic Test Field for ground tests

IVR anticipated task analysis

Based on 2017 JEM utilization





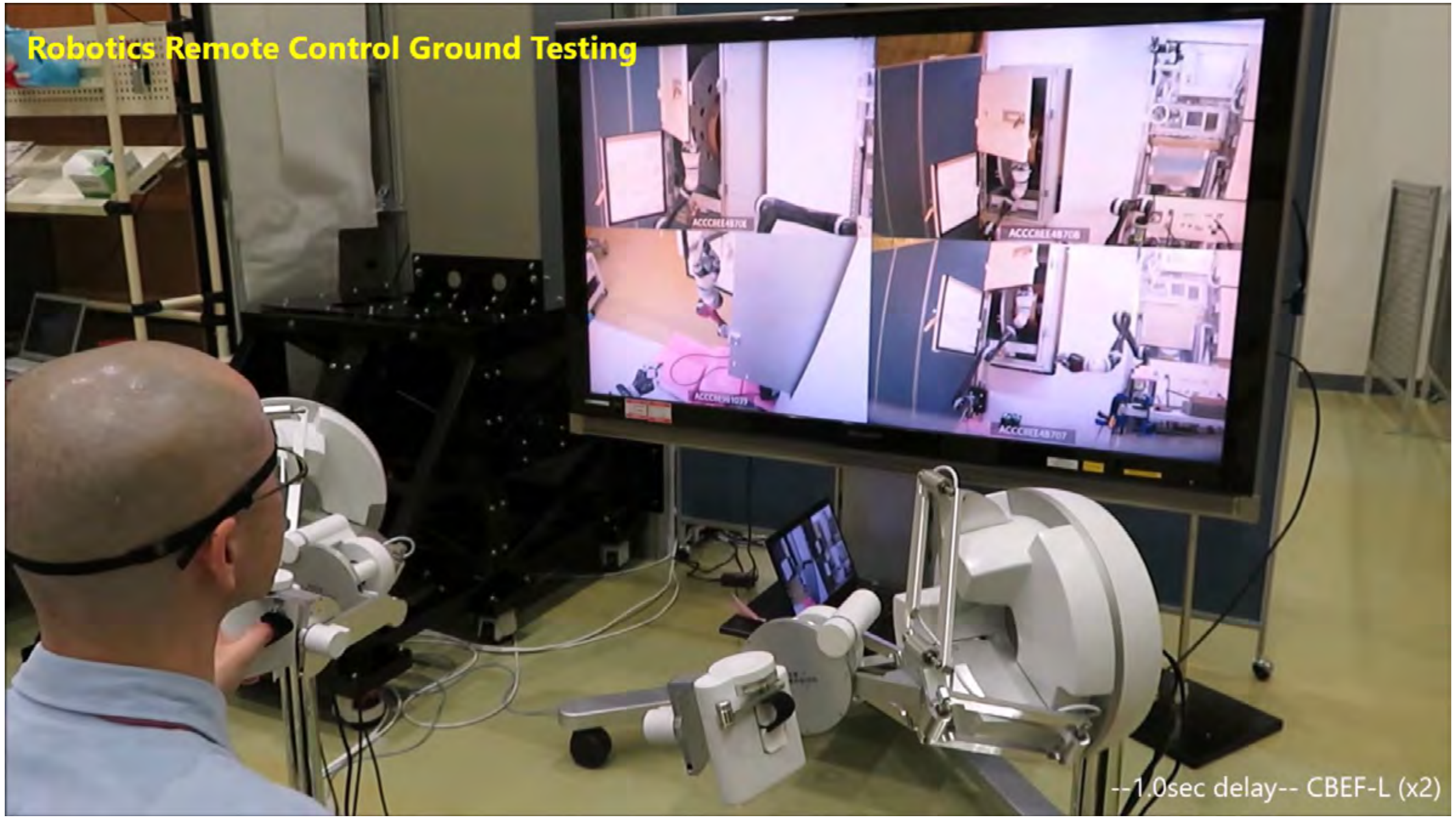


IVR Remote Control Manipulation Tests

Communication
(simulated delay)

Operator
- Visual Information(camera, various views)
- Remote control device(force feedback)

Robot (Manipulator / cameras)
- Visual Information(camera, various views)
- Remote control device(force feedback)



Capabilities of the robot

×

Task Motion Required

×

Target Hardware Spec.

Prospects

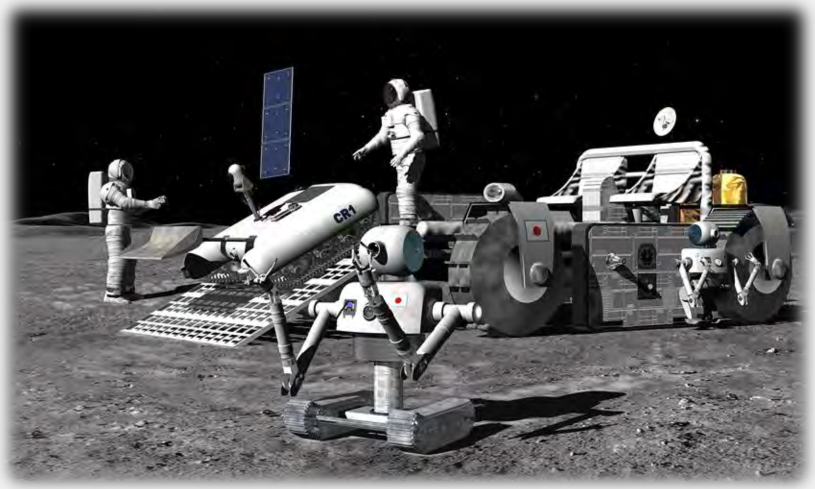
Intravehicular task assistance robot

With Human/Robotic IF Design Guidelines

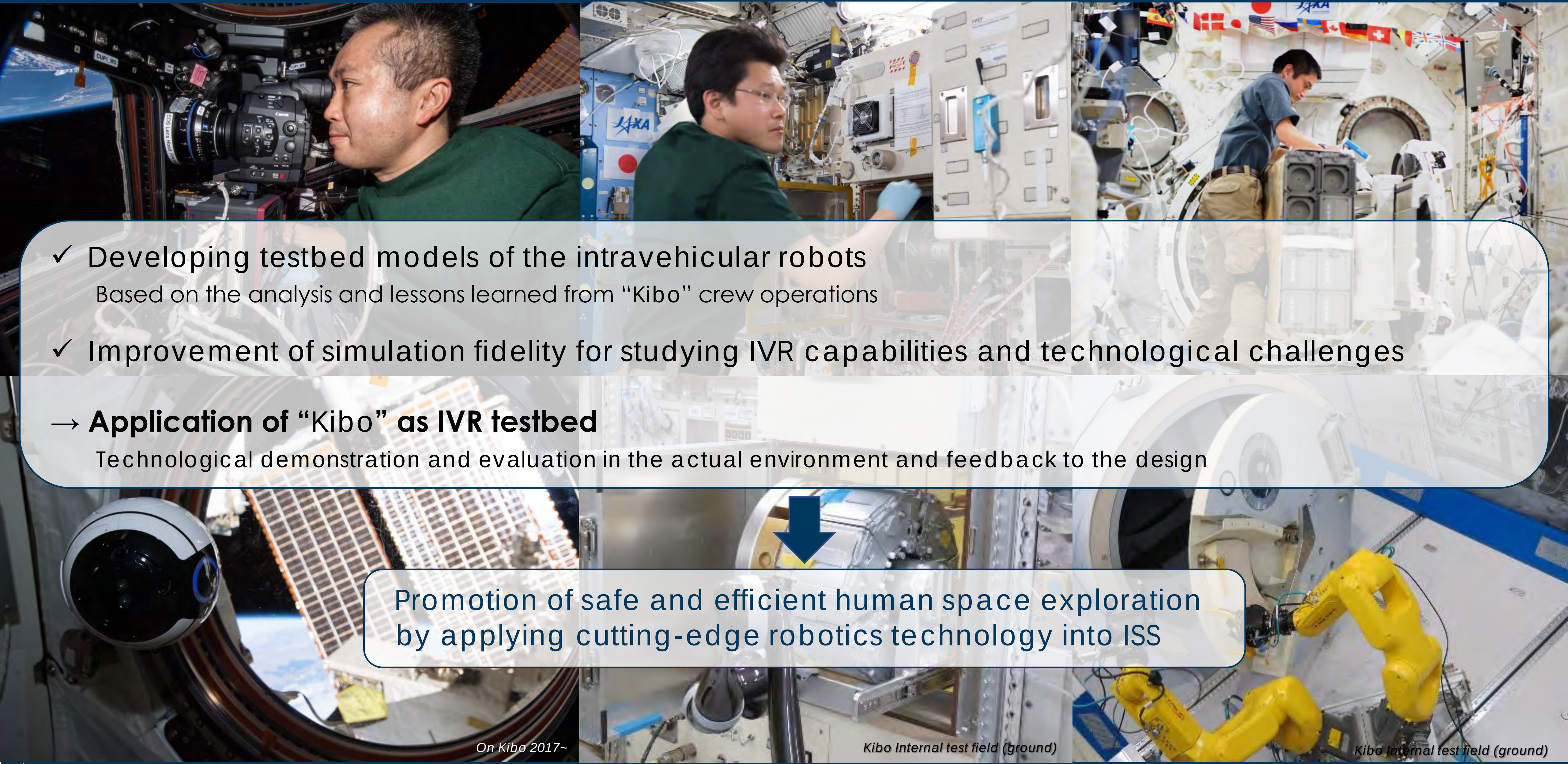
Crew-Baddy Robot

Automated Cargo handling

Robotic technology for Moon Exploration



Summary



On Kibo 2017~

Kibo Internal test field (ground)

Kibo Internal test field (ground)

✓ Developing testbed models of the intravehicular robots

Based on the analysis and lessons learned from "Kibo" crew operations

✓ Improvement of simulation fidelity for studying IVR capabilities and technological challenges

→ **Application of "**Kibo**" as IVR testbed**

Technological demonstration and evaluation in the actual environment and feedback to the design

Promotion of safe and efficient human space exploration by applying cutting-edge robotics technology into ISS