Handbook for Use of Laboratory in Kibo

E-version, revised Feb. 2014
Japan Aerospace Exploration Agency

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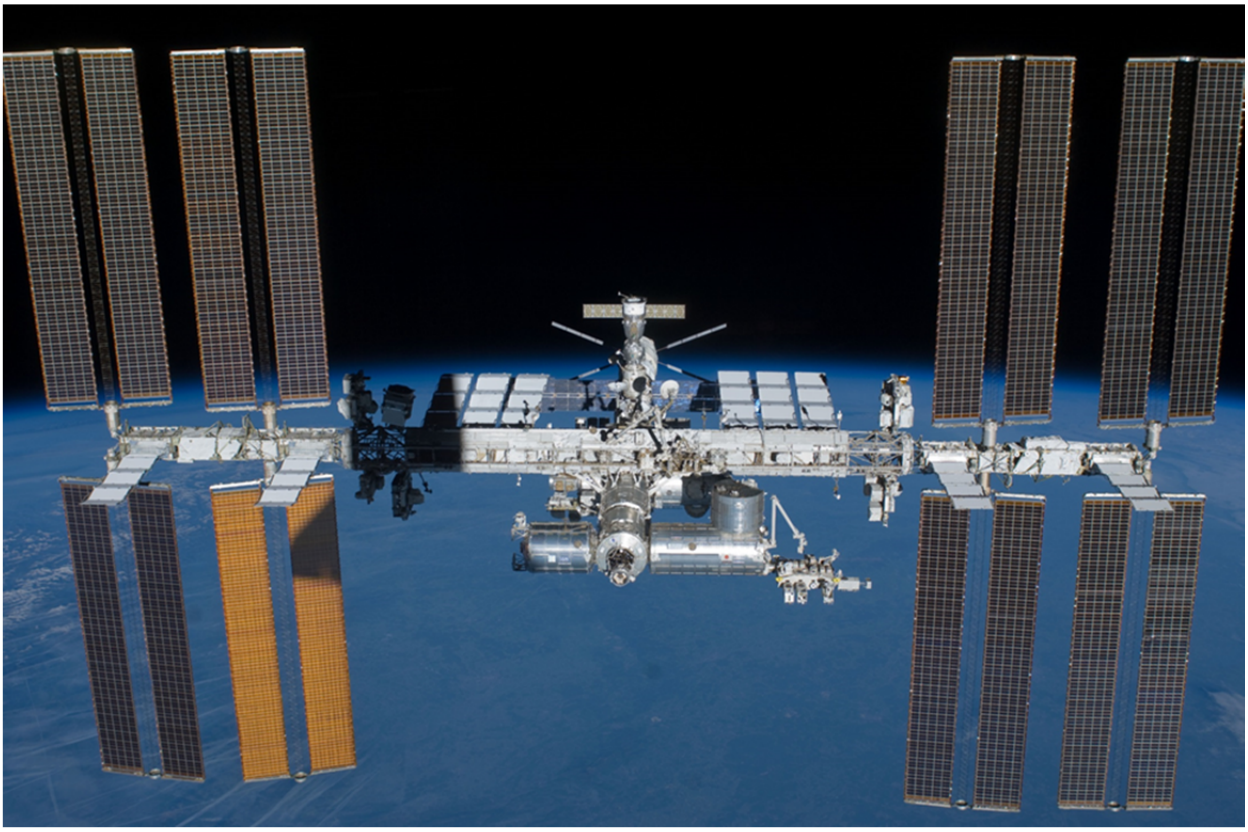


International Space Station (shot in May 2011)

Japanese Experiment Module (Kibo) at International Space Station (shot in May 2010)

Introduction

Because it is not completely gravity-free inside Kibo and small changes in gravity of 10^{-4} g or smaller may be unavoidable for various reasons, the term "microgravity" is used. Stable microgravity can be considered the most prominent characteristic of the space environment because it is impossible to achieve microgravity for a long period on earth. It is also an environment in which objects are exposed to cosmic radiation; this differs from the radiation on earth's surface, which is shielded by terrestrial magnetism and the atmospheric layer.

The idea of addressing problems that we cannot solve on earth by actively exploiting these differences is space environment utilization, and its implementations are called space experiments.

This document provides an overview of the experimental environment in the Pressurized Module (PM), the experimental systems and specimens (container, apparatus to put a sample to test in combination with an experimental devise) that can be used, various control conditions for managing experiments, and other information. It serves as a guideline for those who are considering planning or proposing space experiments using the PM of Kibo.

Although this document was prepared using the latest information at the time of its preparation, please use it strictly as a reference document, because some items may be changed in the future.

I. Outline of the Pressurized Module (PM) and experimental systems in Kibo

1 Laboratory in Kibo

1.1 What is the Pressurized Module (PM) in Kibo?

The PM is used to accommodate the astronauts, conduct experiments, and control the entire facility in the experimental module Kibo. The inside of the PM is maintained at 1 atm, and the atmospheric composition is similar to that of Earth. Its temperature and humidity are constantly controlled to provide a comfortable environment for astronaut activities. Therefore, astronauts can work in clothing similar to what we normally wear on earth instead of in space suits. Most of the devices that are installed in the PM can be described as experimental devices for conducting experiments or system devices that are necessary for maintaining the facilities of Kibo.

[Experimental devices]

The experimental devices are a set of special apparatuses for conducting various experiments in the PM, and they provide their functions only when they are organically linked with the system devices mentioned above. The PM can accommodate up to 10 units of experiment racks (5 for the U.S. and 5 units for Japan), and they are used for various space experiments, mainly in biological and materials science.

[System devices]

These devices provide functions that are crucial to the operation of Kibo and the activities of the astronauts. They include devices that supply electrical power to the entire Kibo facility, enable communication, provide air conditioning, control the cooling water used to cool many of the electronic devices, and support space experiments. The manipulator console for exchanging devices on the Experiment Logistics Module-Exposed Section (ELM-ES), the Inter-Orbit Communication equipment, and air lock for passing devices to or from the ELM-ES are also important system devices, and loss of any of these functions seriously affects operation. Table 1.1 shows an outline of Kibo.

Table 1.1 Outline of PM and stowage module in Kibo

Item	Laboratory	Stowage module
Shape	Cylindrical	Cylindrical
Diameter	Inner diameter: 4.4 m, outer diameter: 4.2 m	Inner diameter: 4.4 m, outer diameter: 4.2 m
Length	11.2 m	4.2 m
Weight	15.9 t	4.2 t
Number of racks mounted	Total number of racks: 23 (including 10 experiment racks)	8 inboard experiment racks
Power	24 kW, 120 V (DC) at max.	
Environmental control performance	Temperature: 18.3 to 26.7°, humidity: 25% to 70%	

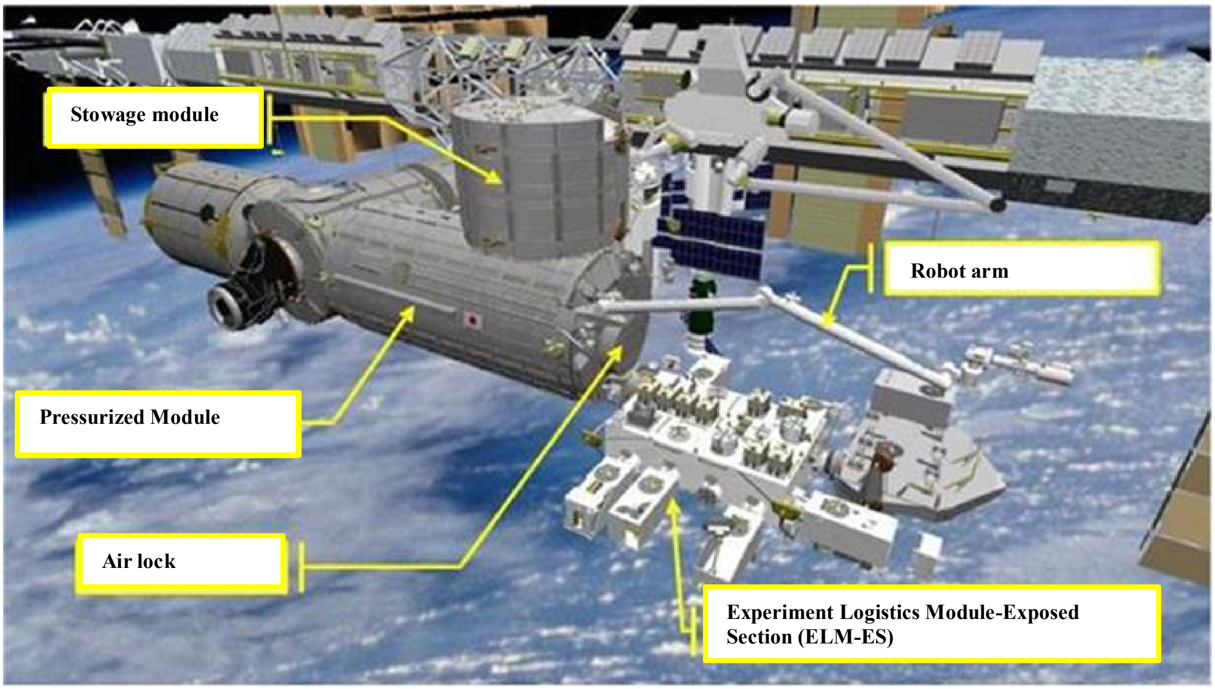


Fig. 1.1-1 External view of Japanese Experiment Module Kibo

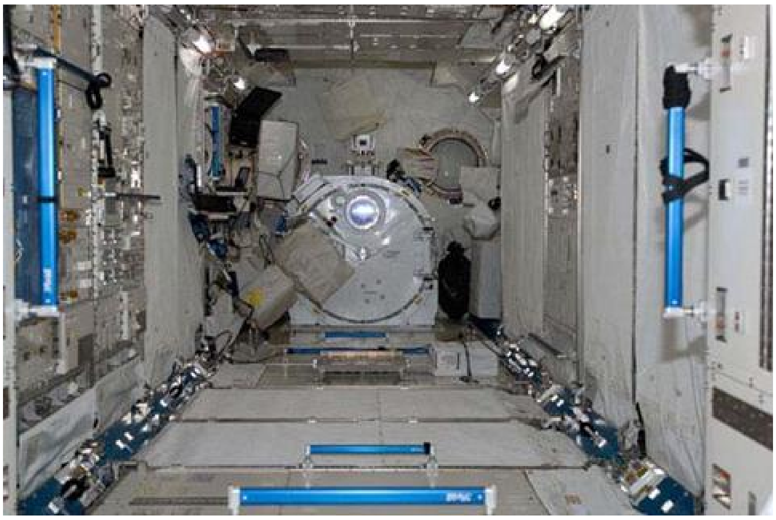


Fig. 1.1-2 Inside the PM in Kibo

1.2 Environment in Kibo's Pressurized Module (PM)

(1) The International Space Station (ISS) orbit

The ISS usually circles Earth in approximately 90 min in a circular orbit with a nominal altitude of approximately 400 km and an orbital inclination of 51.6°. Although the orbital altitude of the ISS drops by about 200 m per day on average because of atmospheric drag, the altitude is recovered (the ISS is reboosted) regularly by the thrusters of the ISS itself or the transport vehicle to compensate for this. Thus, the altitude fluctuates between approximately 350 km and 460 km.

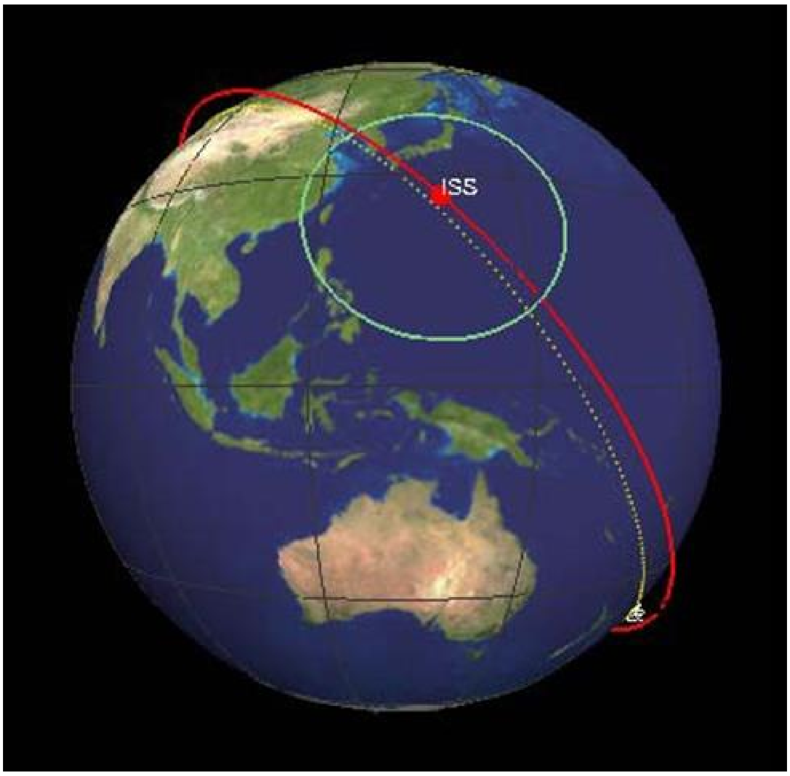


Fig. 1.2-1 ISS orbit

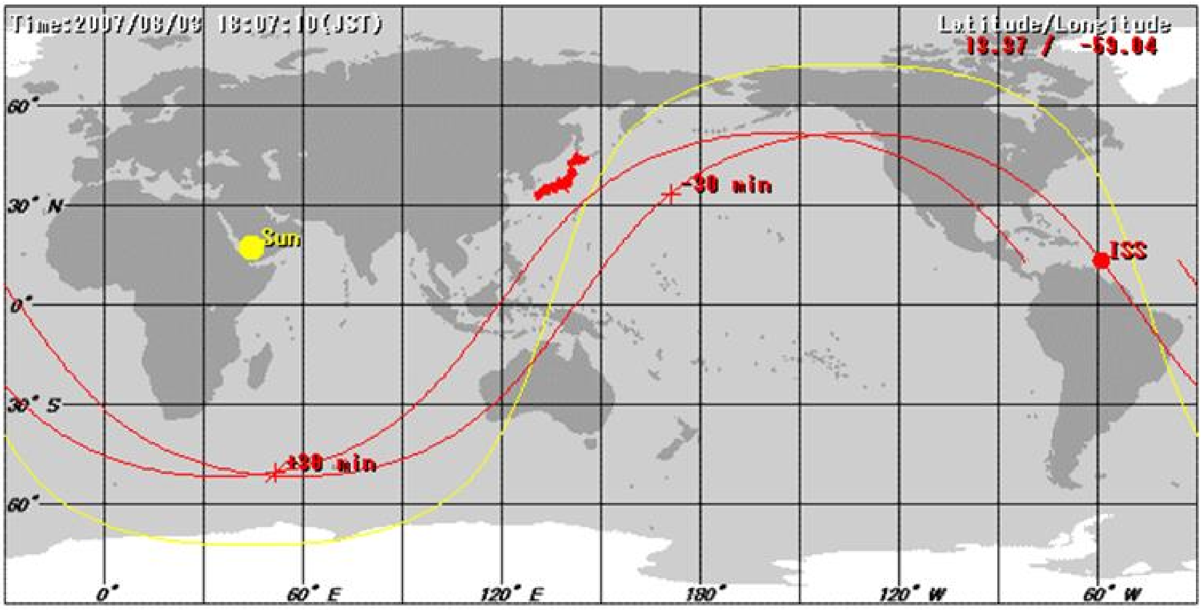
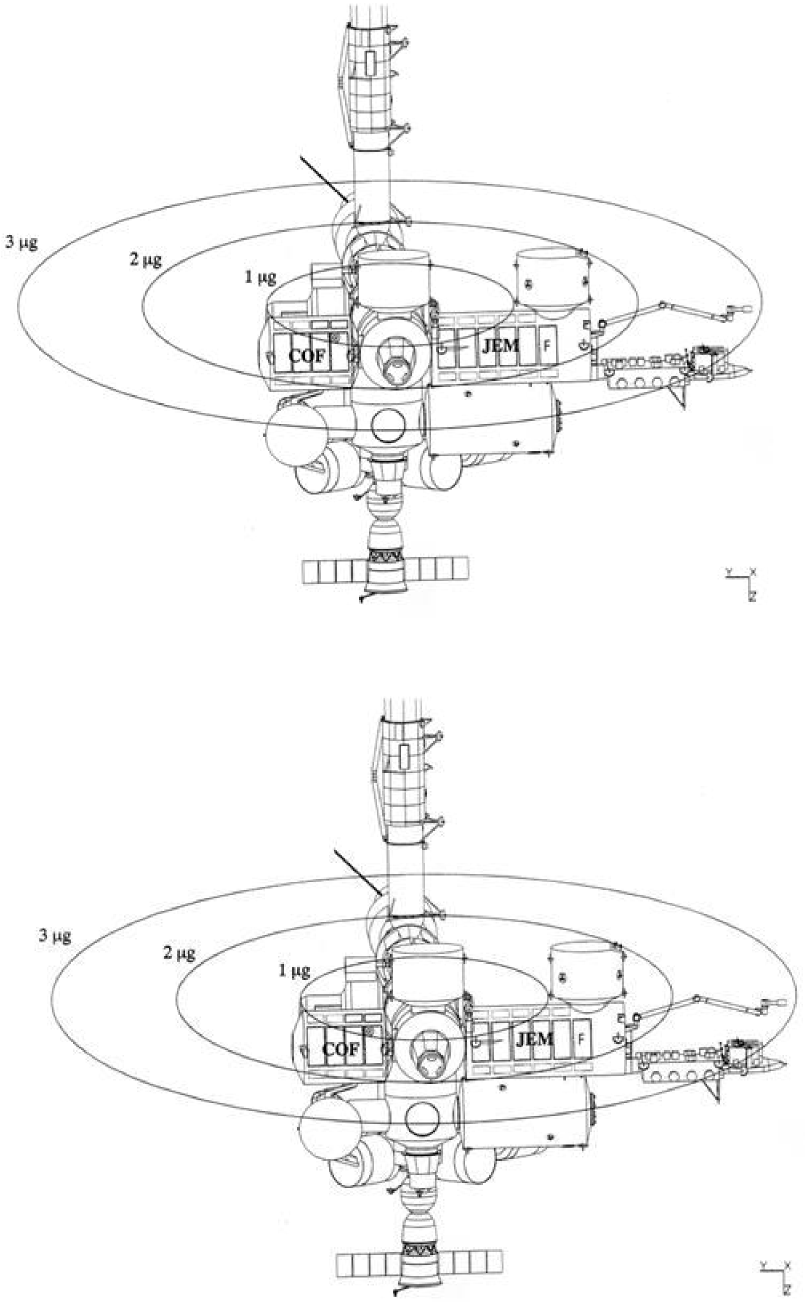


Fig. 1.2-2 Ground track of ISS orbit (red line)

(2) Microgravity environment

Disturbances such as atmospheric drag and a gravity gradient apply constantly on the ISS, generating quasi-static acceleration. As shown in Fig. 1.2-3, quasi-static acceleration in the order of 10^{-6} g (μ g) is predicted for the ISS. In addition, the internal disturbances affecting the quasi-static acceleration of the ISS include crew activities (e.g., exercise) and the rotation of the solar cell array.



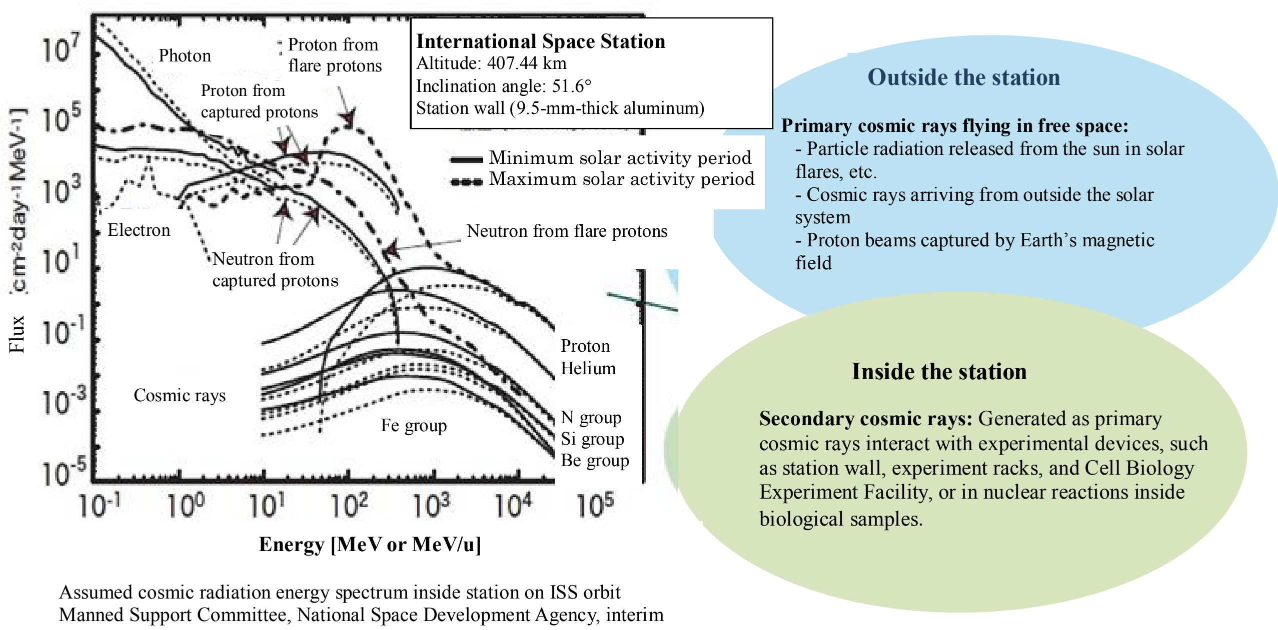
Note: The above figure shows the results of an analysis based on the ISS assembly sequence Rev. D. It is strictly for reference, as the actual assembly sequence, mass properties of the ISS, and other factors will vary.

Fig. 1.2-3 Quasi-static acceleration environment for ISS (example of NASA analysis results)
(Source) ISS Microgravity Environment, SSUAS, June 23, 1999

(3) Radiation environment

The environment outside the ISS orbit contains particle radiation released in solar activities including solar flares, proton beams captured by Earth's magnetic field, and galactic cosmic rays arriving from outside the solar system.

The interior of the ISS becomes a complex radiation environment as these cosmic rays collide with the ISS's structural and atmospheric components and generate secondary cosmic rays.



Assumed cosmic radiation energy spectrum inside station on ISS orbit
Manned Support Committee, National Space Development Agency, interim report guideline examination material, March 1999.

Fig. 1.2-4 Assumed cosmic radiation energy spectrum inside ISS on orbit

According to measurements by the Passive Dosimeter for Life Science Experiments in Space (PADLES, see Chapter 2.6), within the Russian module of the ISS, the radiation to date is 150 to 300 µGy/day and 300 to 600 µSy/day during a period equivalent to the maximum solar activity period. The exposure dose may vary depending on the shielding environment or solar activity.

Table 1.2-1 Results of cosmic radiation measurement in ISS on orbit

Flight	Location of measurement	Measurement period	Detector	Measurement results		
				Absorbed dose	Dose equiv.	Quality factor
ISS	Russian service module	Aug. 21, 2001 to Oct. 31, 2001 (71 days)	PADLES	0.28	0.53	1.9
		Aug. 21, 2001 to May 5, 2002 (257 days)	PADLES	0.23	0.41	1.8
		Aug. 21, 2001 to Nov. 10, 2002 (446 days)	PADLES	0.18	0.37	2.1
		Jan. 29, 2004 to Oct. 11, 2005 (621 days)	PADLES	0.16	0.32	2.0
		Dec. 23, 2005 to Apr. 9, 2006 (107 days)	PADLES	0.26	0.51	1.9

See Chapter 2.6 for details on PADLES. See International Space Environment Utilization Research Data Base (ISRDB): http://idb.exst.jaxa.jp/db_data/padles/NI005.html.

1.3 Operation of the ISS and Kibo

(1) Transportation of goods

Starting in 2010, goods have been launched to and collected from the ISS by the Russian Soyuz and Progress, European ATV, Japanese KOUNOTORI (HTV), and other commercial transport services to replace the space shuttles. The capacities of the transport vehicles that are currently in operation are listed in Table 1.3-1.

Table 1.3-1 Transport vehicles to ISS (as of February 2012)

	Launch vehicle Launch base	Load capacity	Load capacity for collection	Remarks
Progress (Russia)	Soyuz rocket Baikonur Launch Complex	1,800 kg at max.	-	Docks on Russian side Reboost function Replenishment of fuel, water, and gas
Soyuz (Russia)	Soyuz rocket Baikonur Launch Complex	30 kg at max.	50 kg at max.	Docks on Russian side Manned
ATV (ESA)	Ariane-5 rocket Guyana Space Center	5,500 kg at max.	-	Docks on Russian side. Reboost function Replenishment of fuel, water, and gas
KOUNOTORI HTV (JAXA)	H-II B rocket Tanegashima Space Center	Approx. 6,000 kg Pressurized 4,500 kg Exposed 1,500 kg	-	Docks on U.S. side Transport in units of racks possible in pressurized cabin; transport of exposed goods also possible
Dragon (SpaceX)	Falcon 9 rocket Cape Canaveral Air Station	3,000 kg	2,500 kg	Docking by grasping with robotic arm
Cygnus (OSC)	Antares rocket NASA Wallops Flight Facility	2,000 kg	1,200 kg	Docking by grasping with robotic arm

Fig. 1.3-1 Progress (©S.P. Korolev RSC Energia)

Fig. 1.3-2 Soyuz (Photo: NASA)

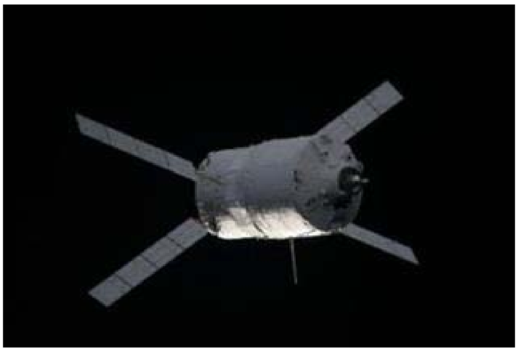


Fig. 1.3-3 ATV (Photo: NASA)

Fig. 1.3-4 KOUNOTORI (HTV)

Fig. 1.3-5 Dragon (Photo: NASA)

Fig. 1.3-6 Cygnus (Photo: NASA)

(2) Operation of Kibo

Although the U.S. makes adjustments affecting the overall operation of the ISS, the relevant government or agency for the U.S., Russia, Japan, Europe (11 ESA countries), and Canada is responsible for operating the ISS systems or devices they developed.

ISS operation has two aspects: system operation, which controls the orbit, posture, power, internal environment, and so forth, and experimental operation, which controls various devices mounted for research and experiments.

System operation and experimental operation in the Japanese Experiment Module (Kibo) are conducted from Tsukuba Space Center. In principle, communication is maintained between Tsukuba Space Center and Kibo via the U.S. tracking and data relay satellite. It is also possible to directly transmit experimental data to Tsukuba Space Center using Kodama, a data relay technology satellite (DRTS).

[Tsukuba Space Center]

System operation:

A team of more than 50 flight directors and flight controllers monitors Kibo in a three-shift system for 24 h/day.

They constantly check that data indicating the conditions of various systems, including the thermal control system, power system, communication system,

environmental control/life support system, and robotics system, are normal during system operation. In addition, they provide instructions so that the astronauts staying in the ISS can take appropriate actions in case of fire, emergency pressure reduction, or air pollution.

They also select the goods to be transported and replenished at Kibo and examine the measures, timing, and other aspects of transport on the basis of the Kibo maintenance plan.

Experimental operation:

The Japanese experimental operation plan which is prepared by Tsukuba Space Center is incorporated into the overall operation plan for the ISS after adjustments at the George C. Marshall Space Flight Center. Experiments are then conducted accordingly. Experiment users can monitor their own experiments from the User Operations Area of Tsukuba Space Center and conduct the experiments while communicating with the ISS.

Fig. 1.3-7 User Operations Area

[Tanegashima Space Center]

KOUNOTORI(HTVs) loaded with goods to be carried to the ISS are launched from Tanegashima Space Center using the H-IIB rocket. Processes such as assembly of the H-IIB rocket, preparation for launch, preparation of the HTV, and loading of the HTV onto the H-IIB rocket are also conducted in Tanegashima Space Center.

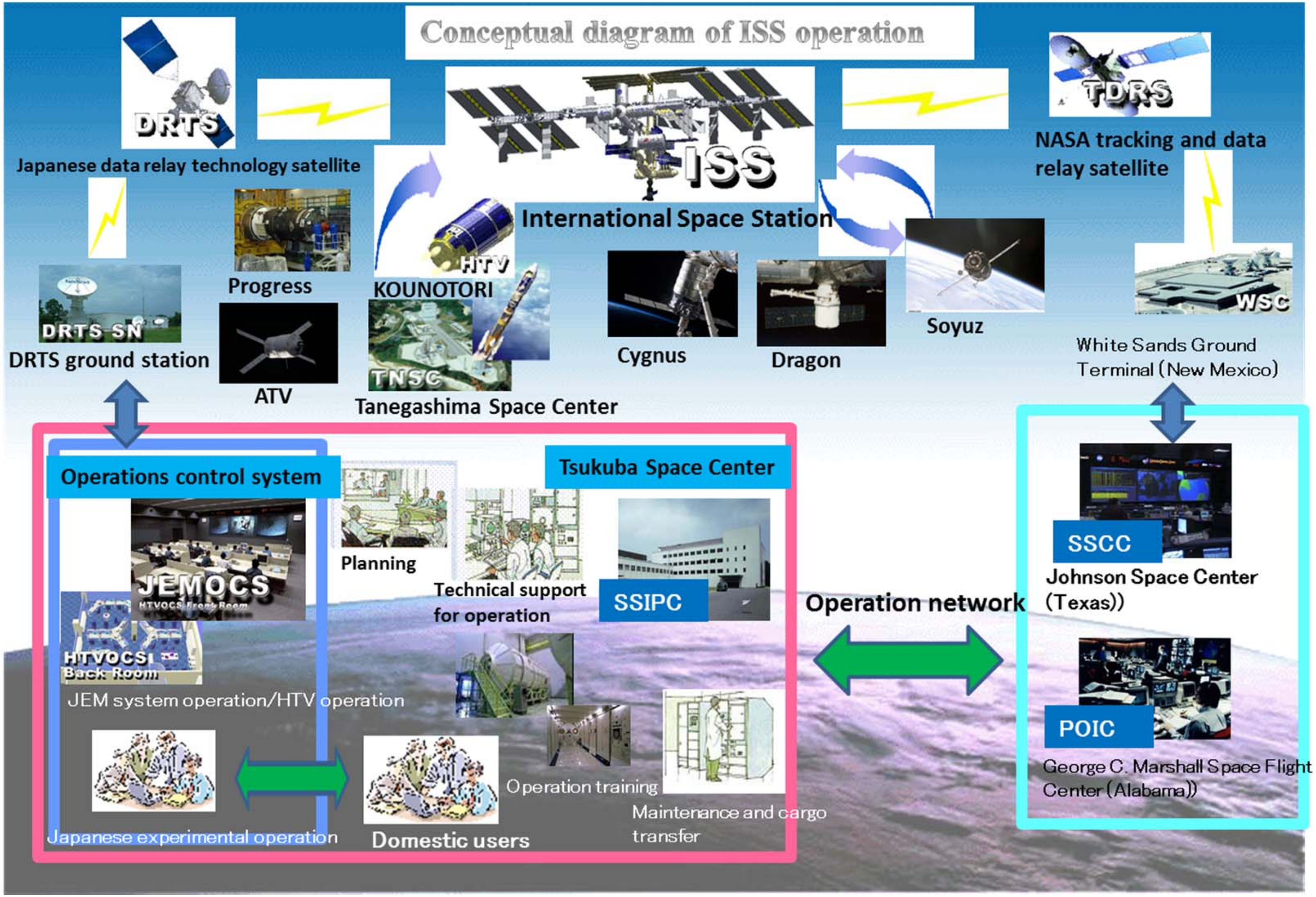


Fig. 1.3-8 Outline of Kibo operation system

1.4 Japanese experimental and other devices mounted on Kibo's PM

Until now, three experiment racks for life science and material science research, the SAIBO Rack, RYUTAI Rack, and KOBAIRO Rack, were mounted in Kibo. Moreover, the Multipurpose Small Payload Rack which provides experimental space to unstall the various experimental devices and supplies power was mounted. Experiments using the devices mounted in these Racks as shown in Table 1.4, will be possible. In-vessel space can be used in addition to this equipment.

The above experiment systems in Kibo were prepared with basic necessary functions and common measurement functions for various experimental fields, and experiments are conducted by combining them with specimens, which include the experimental sample and its container, and the necessary functions specific to the experiment. In planning experiments using these systems, specimens, and functions, it is necessary to check the details for each component and make sure that the experimental specifications are within the performance and functions of each system.

Table 1.4-1 Major experiment and other systems provided in Kibo's PM

Field	Rack	Name of system	Abbreviation	Date mounted	Section No. in this document for detailed description
Life sciences	SAIBO	Cell Biology Experiment Facility/Clean Bench Cell Experiment Unit Plant Experiment Unit Measurement Unit	CBEF/CB CEU PEU MEU	2008	2.2/2.3 2.1.1 2.1.2 2.1.3
	Multipurpose Small Payload Rack	Aquatic Habitat	AQH	2012	2.5
	Minus Eighty Degree Celsius Laboratory Freezer		MELFI	2008	2.4
	Passive Dosimeter for Life Science Experiments in Space		PADLES	2008	2.6
Material science	RYUTAI	Fluid Physics Experiment Facility	FPEF	2008	3.1
		Solution Crystal Observation Facility	SCOF	2008	3.2
		Protein Crystallization Research Facility	PCRF	2008	3.3
		Image Processing Unit	IPU	2008	-
	KOBAIRO	Gradient Heating Furnace	GHF	2011	3.4
	Multipurpose Small Payload Rack	Chamber for Combustion Experiment	CCE	2012	5.1
		Electrostatic Levitation Furnace (To be mounted)	ELF	2012	3.5
Common	Multipurpose Small Payload Rack		MSPR	2011	5.1
	Microscope Observation System		-	-	5.3
	In-vessel space		-	-	5.5

Note: Although Table 1.4-1 classifies the systems as suitable for the life sciences or material science, it is also possible to use them outside of these fields, e.g., for a life-science-related experiment using only the temperature control function of the Protein Crystallization Research Facility, if the functions and performance of these devices are suitable.

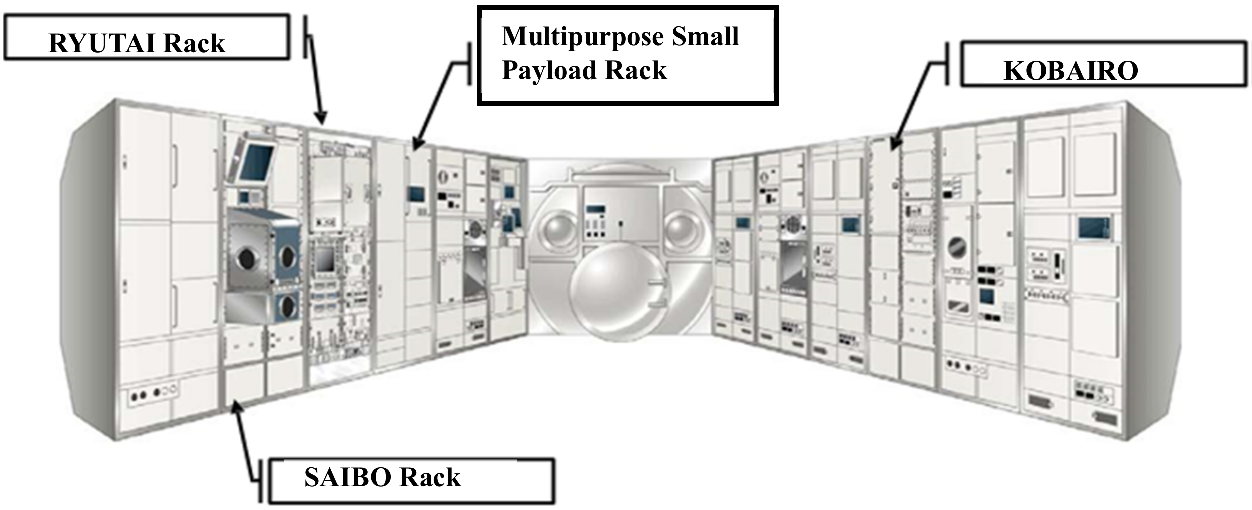


Fig. 1.4-2 Experiment rack assignment in the PM

2 Life Sciences Experiment Facility

2.1 Biological Experiment Unit (BEU)

The Biological Experiment Unit (BEU) is an automated experiment unit for conducting experiments in life sciences in combination with the Cell Biology Experiment Facility (CBEF) and Clean Bench (CB), which are described later.

The BEUs developed for use in the Pressurized Module (PM) of Kibo to date are the Cell Experiment Unit (CEU), Plant Experiment Unit (PEU), and Measurement Experiment Unit (MEU).

- **The CEU is used to conduct cell culture experiments using animal cells and so forth as samples; it contains large and small culture chambers.**
- **The PEU was developed to conduct a series of life cycle experiments from germination to seed formation using plant seeds as samples.**
- **The MEU is equipped with an internal temperature measurement sensor, and experiments can be conducted by setting various culture chambers inside the unit.**

2.1.1 Cell Experiment Unit (CEU)

The CEU contains a small pump, a temperature sensor, and the control unit in a medium-size canister [210 mm (W) × 80 mm (H) × 130 mm (D)], and samples can be cultured in one each of the large chamber (30 cm^2 cultivation area) and small chamber (15 cm^2 cultivation area). Culture medium replacement, circulation, and other functions, as well as monitoring of the culture environment, can be executed automatically. Each chamber has an independent culture circulation system, which can be attached or removed easily with a sterilized quick disconnector. The <u>detailed functions and performance are outlined in Table 2.1.1-1.</u>

The culture chambers are assembled types with a surface for cell growth equivalent to that of commercial flasks and a membrane structure with high gas exchangeability. They are made of materials that can be treated with chemicals.

By removing only the chamber from the CEU and using the Pre-Fixation Kit (PFK) and Cell Fixation Kit (CFK), which are available as accessory devices, a series of sample treatment processes, including culture medium ejection, washing with a buffer, and injection of a chemical fixing agent, can be conducted. There are both large and small PFKs and CFKs, and two each of the large and small chambers can be treated. After treatment with a chemical fixing agent and other treatment, the culture chambers can be stored in the Minus Eighty Degree Celsius Laboratory Freezer for ISS (MELFI) and other locations set inside the CFK.

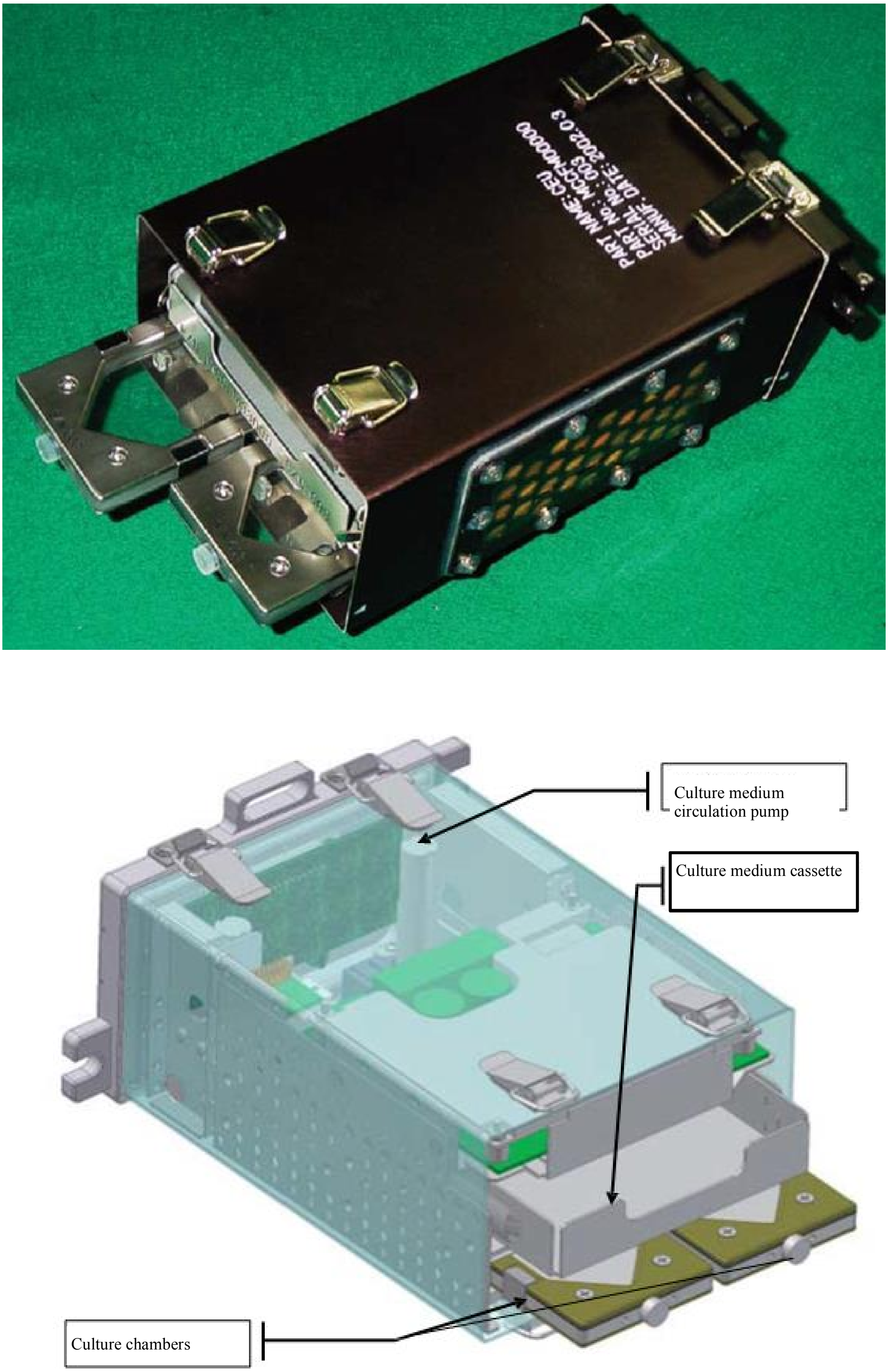


Fig. 2.1.1-1 Cell Experiment Unit (CEU)

Fig. 2.1.1-2 Culture chambers: large (right) and small (left)

Fig. 2.1.1-3 Pre-Fixation Kit (PFK)   **Fig. 2.1.1-4 Cell Fixation Kit (CFK)**

Table 2.1.1-1 Specifications of CEU

<table>
<tr><th>Item</th><th>Design specifications</th></tr>
<tr><td>Canister</td><td>Type: Special-order canister (dimensions equivalent to those of a medium canister)
Number of canisters that can be mounted: six (microgravity compartment), four (artificial gravity compartment)</td></tr>
<tr><td>Specimen configuration</td><td>Culture chambers, culture medium cassette, control segment, liquid feeding pump, gas separator</td></tr>
<tr><td>Culture chamber</td><td>- A culture chamber has a single-layer structure with a gas exchange membrane on the top surface.
- Chemical fixation is possible by using accessories.
- Phase difference/fluorescence microscopy observation is possible using a microscope inside CB.
<table>
<tr><td>Type</td><td>Large</td><td>Small</td></tr>
<tr><td>Size</td><td>55 × 116 × 10 (mm)</td><td>55 × 64 × 10 (mm)</td></tr>
<tr><td>Cultivation area</td><td>Approx. 30 cm^2</td><td>Approx. 10 cm^2</td></tr>
<tr><td>Culture medium capacity</td><td>Approx. 9 mL</td><td>Approx. 3 mL</td></tr>
<tr><td>Cultivation plate</td><td colspan="2">Material: Polystyrene or polycarbonate
Surface treatment: Surface treatment equivalent to commercial dish is possible.
Note: Cultivation plate can be attached or removed, and is discarded after every experiment.</td></tr>
</table>
</td></tr>
<tr><td>Culture medium cassette</td><td>Cassette size: 110 × 80 × 20 (mm)
Contains two sets each of fresh medium bags, spent medium bags (combinations of bags for large and small chambers)
Bag for large chamber: 60 × 72 (mm), 50 mL
Bag for small chamber: 40 × 72 (mm), 20 mL</td></tr>
<tr><td>Automated functions</td><td>Culture medium replacement: Automatic culture medium replacement is possible using liquid feeding pump (drift method, replacement rate approximately 70%).</td></tr>
<tr><td>Control</td><td>Controlled by built-in CPU and laptop computer for experiments (ULT: User Laptop Computer). Control from the ground also possible via ULT.</td></tr>
<tr><td>External interface</td><td>Utility connector: With power supplied from CBEF, conducts command input and sensor output (specimen inner circuit board block temperature)
RS-485: Connected to ULT. ULT is capable of communication with the ground via Ethernet in Kibo.</td></tr>
<tr><td>Observation</td><td>- Uses phase difference/fluorescence microscope in CB
- Object lens magnification: 40× for fluorescence (phase difference lens can also be used for cases other than UV excitation), 4, 10, 20, and 40× for phase difference
- Microscope image: Microscope image data are sent to Image Processing Unit (IPU) via CB to be recorded or down-linked with MPEG2 compression.</td></tr>
<tr><td>Other</td><td>Temperature and humidity measurement near the culture chamber.
Air with temperature, humidity, CO_2 concentration, and other parameters controlled by CBEF is taken in as the specimen tmosphere.</td></tr>
</table>

2.1.2 Plant Experiment Unit (PEU)

The PEU encompasses the plant chamber, a LED illumination unit for growth, a ventilation pump for humidity control, a water supply pump, temperature and humidity sensors, a water content sensor, and the control unit in a medium canister size [210 mm (W) × 80 mm (H) × 130 mm (D)], and can be used to cultivate small plants in the plant chamber (20 cm^2 sowing area). It is capable of water delivery control, humidity control, and illumination and video observation under automatic control, and the entire life cycle from germination to seed formation can be studied for small plants such as *Arabidpsis thaliana*. The detailed functions and performance are outlined in Table 2.1.2-1.

The plant growth container can be separated into top and bottom parts, and plants are cultivated by inserting a supporting bed such as rock wool in the bottom part. Although the height for plant growth is as small as 50 mm because of restrictions on the rotor radius of the artificial gravity compartment, approximately 110 µmol/m^{2}s of light can be delivered to plant area using the thin illumination unit for growth (red and blue LEDs). The humidity is controlled passively; toxic or undesirable gases are ejected and the humidity is reduced by taking in cabin air for ventilation.

The illumination switches to a special white LED during video observation so that the video image can be recorded or transmitted to the ground.

Plant samples are harvested by the astronauts, chemically fixed using the KSC Fixation Tube (KFT), and stored in Minus Eighty Degree Celsius Laboratory Freezer for ISS (MELFI) or other facility.

Fig. 2.1.2-1 Plant Experiment Unit (PEU)

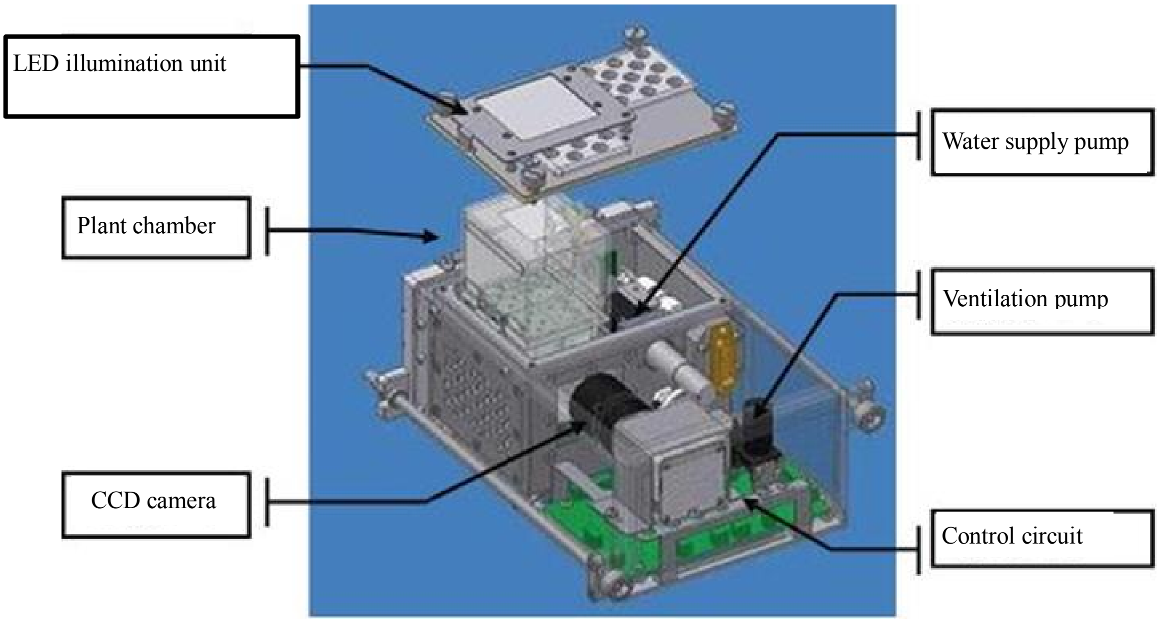


Fig. 2.1.2-2 Plant Experiment Unit (PEU)

Fig. 2.1.2-3 *Arabidpsis thaliana* growth

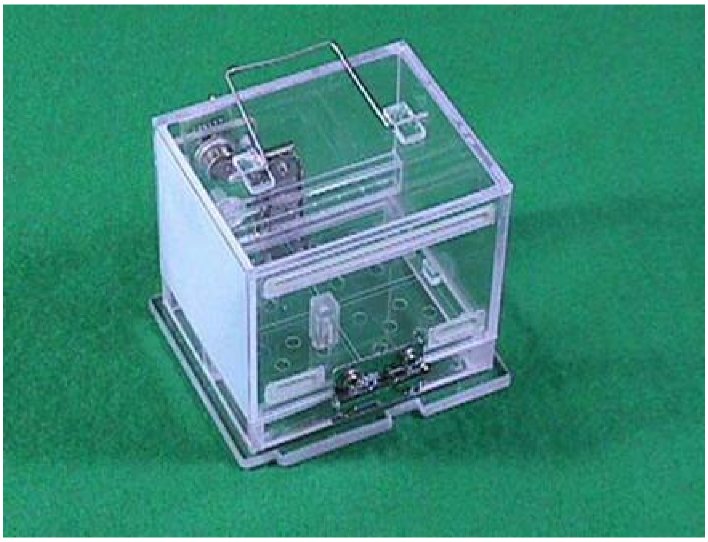


Fig. 2.1.2-4 Plant chamber

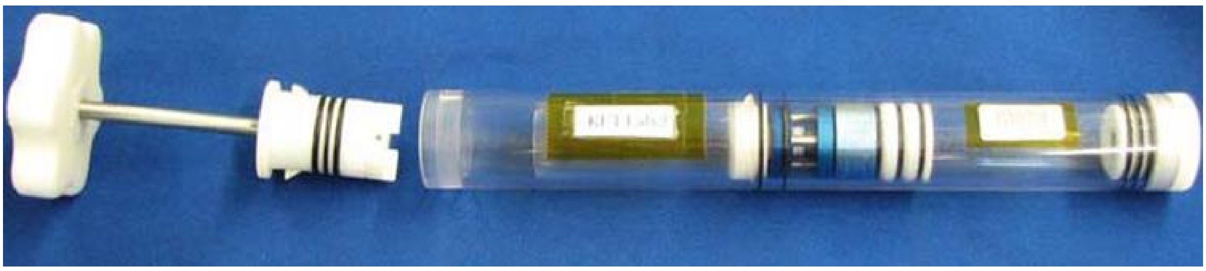


Fig. 2.1.2-5 KFC Fixation Tube

Table 2.1.2-1 Specifications of PEU

Item	Design specifications
Canister	Type: Special-order canister (dimensions equivalent to those of a medium canister) Number of canisters that can be mounted: six (microgravity compartment), four (artificial gravity compartment)
Specimen configuration	Plant chamber, control segment, water supply pump, ventilation pump, LED illumination unit, CCD camera, water content sensor, and temperature and humidity sensors
Plant chamber	Structure: Two-part (top and bottom) type (Bottom) Rock wool bed and bed moisture sensor port (Top) Temperature and humidity sensor and ventilation port Size: (External) 60 × 50 × 60 (mm) (Internal) 56 × 46 × 58 (mm) Capacity: 149 mL Support bed sowing area: Approx. 20 cm^2 Support bed size: 42 × 52 × 10 (mm)
LED illumination	Illumination for plant growth: - LED illumination provided from the side of the container - Red (660 nm) and blue (470 nm) LEDs are combined for use. - Brightness of 26 $\mu mol/m^2 s$ at center of plant area Illumination for image observation: White LED is used (switched from illumination for plant growth)
Water bag	Size: 85 × 75 × 25 (mm) Capacity: Approx. 100 mL Stowed in plant container block and maintained at experiment temperature
Automated functions	Water delivery: Water content in bed is measured by near-infrared absorption to conduct active automatic water delivery with liquid feeding pump or regular water delivery operation. Humidity control: Humidity detection with sensor for active control with ventilation pump Gas phase components: Forced ventilation of container by operation of ventilation pump (air in CBEF is taken in) Illumination: Arbitrary light/dark cycle setting possible Image observation: Automatic image observation using built-in CCD camera (pan-focus)
Control	Controlled by built-in CPU and laptop computer for experiment (ULT: User Laptop Computer). Control from the ground also possible via ULT.

External interface	**Utility connector: With power supplied from CBEF, conducts command input and sensor output (specimen inner circuit board block temperature)** **Image: The image data from inside each specimen are switched by CBEF as necessary so that one string of data is output to IPU. Recording or down link with MPEG2 compression possible with IPU.** **RS-485: Connected to ULT. ULT can communicate with the ground via the Ethernet in Kibo.**
Observation	**Built-in 1/3-in. color CCD camera** **Lens: Brightness: f1.4, focal length: 4.5 mm** **Light source: White LED is used for color image observation; illumination for plant growth is turned OFF during this time.** **Valid pixels: 400,000 pixels** **Image output: NTSC**
Other	**Temperature and humidity are measured near the plant chamber. Air with temperature, humidity, CO_2 concentration, and other parameters controlled by CBEF is taken in as the specimen atmosphere.**

2.1.3 Measurement Unit (MEU)

The MEU has a casing that contains various cultivation chambers and two temperature sensors inside a medium-size canister [210 mm (W) × 80 mm (H) × 130 mm (D)]. It can contain up to six commercial T-25 flasks. In combination with Sample Holder A or B prepared for cell culturing, our original cell culturing bag (for floating cells) or disposal containers (for adherent cells; Disposable Cultivation Chamber: DCC) can be placed inside the MEU, which is then attached to the CBEF for stationary culturing. When the DCC is used, culture medium exchange and buffer replacement are possible simultaneously for four units by astronaut operation using the Pre-Fixation Kit 2 (PFK2) (although the use of reagents such as RNAlater is possible, it would be necessary to develop new equipment to keep hazardous substances enclosed during use of fixing agents and other chemicals). The detailed functions and performance are outlined on Table 2.1.3-1.

The Video Measurement Unit (V-MEU) is an experiment unit equipped with a CCD camera for the PEU and sample container retaining unit inside the MEU canister. It is suitable for experiments in which users would like astronauts to manually conduct the initial operations, such as supplying water, and implement only observation within the unit.

The current V-MEU contains two white LEDs that provide illumination for observation and two types of sample containers (plant type and tank type) 60 mm × 90 mm × 95 mm in size. The containers need to be prepared to suit each experiment sample, and the unit needs to be modified if observation at infrared or other wavelengths is desired.

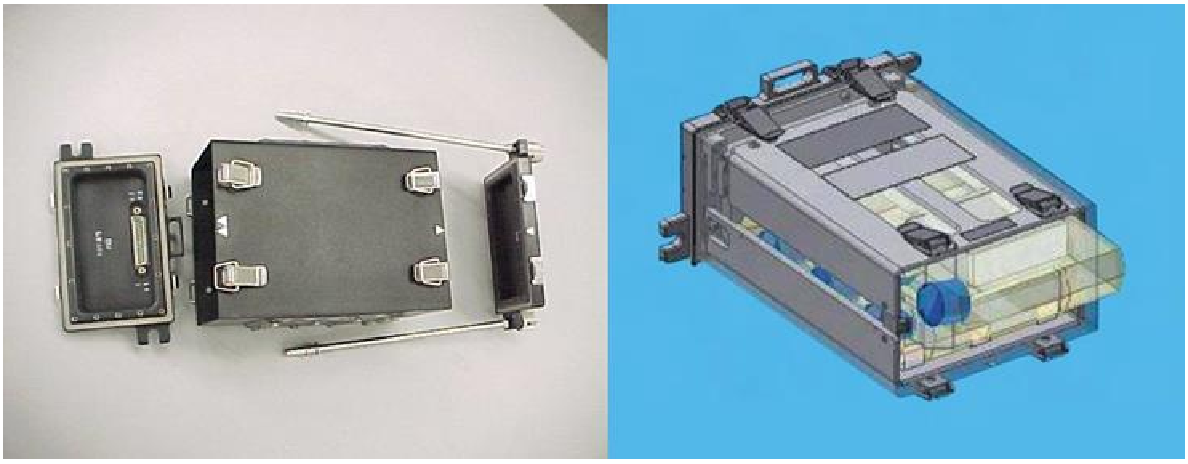


Fig. 2.1.3-1 Measurement Unit (MEU & V-MEU)

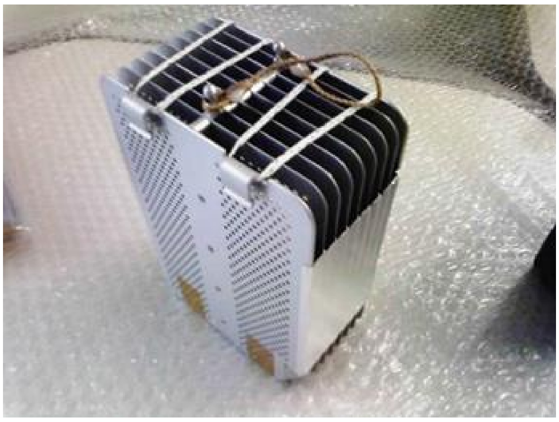


Fig. 2.1.3-2 Sample Holder A

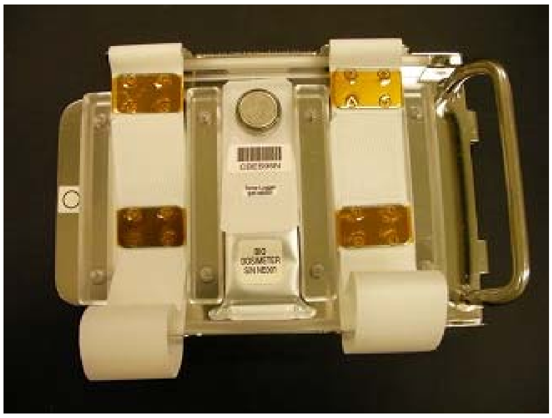


Fig. 2.1.3-3 Sample Holder B

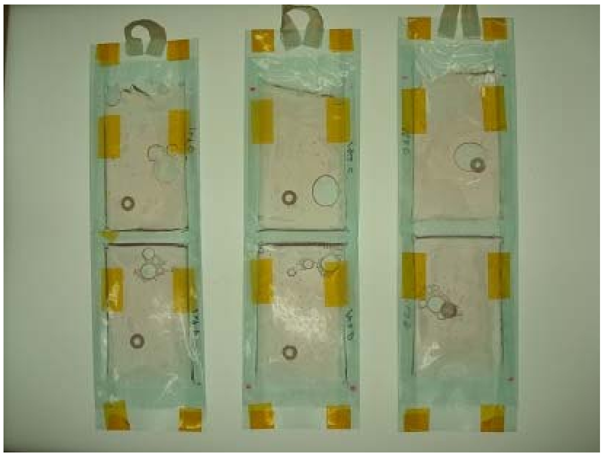


Fig. 2.1.3-4 Original culturing bag

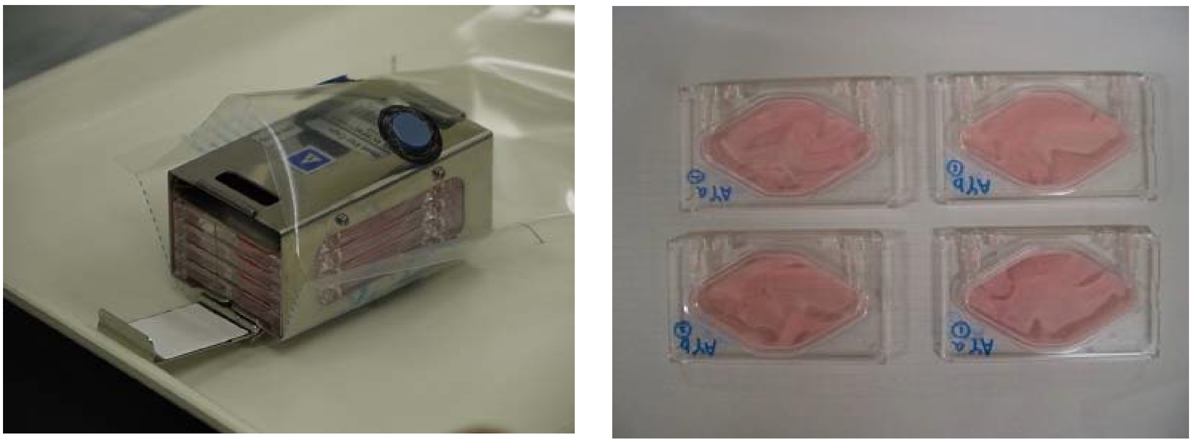


Fig. 2.1.3-5 DCC case (left) and DCC (right)

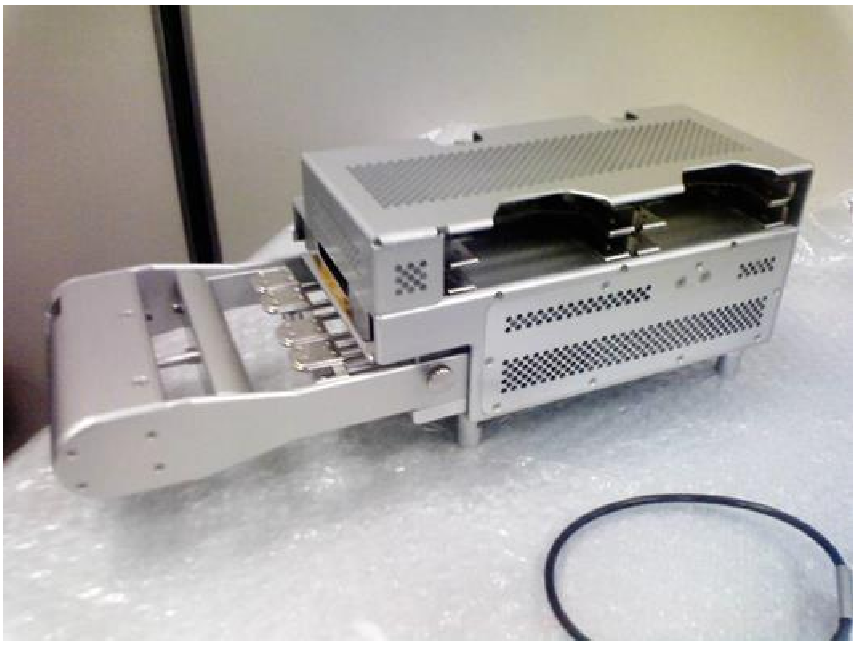


Fig. 2.1.3-6 PFK2

Table 2.1.3-1 Specifications of MEU and V-MEU

Item	Design specifications
Canister	Type: Medium canister Number of canisters that can be mounted: six (microgravity compartment), four (artificial gravity compartment)
Specimen configuration	Casing, control segment, two temperature sensors Optional: CCD camera, illumination for observation (V-MEU)
Automated functions	Temperature measurement: Temperature detected at two temperature sensors and transmitted to the ground Optional (V-MEU) Image observation: Automatic image observation with CCD camera (pan-focus)
Units that can be set	Sample Holder A: Has 15 slots (5 mm (T) × 17 cm (H) × 50 mm (D)) Sample Holder B: Attaches two cases capable of containing four DCCs and holds them in MEU. A case has one slot to hold such as a moisture bag.
Containers that can be used	- Commercial T-25 flasks: Up to six can be used - Original culturing bag: Plastic bag to culture floating cells and other material. Used by pouring in approximately 20 mL cell suspension and sealing bag with heat. - DCC: Has cell attachment plate with culturing area of 15 cm^2, gas permeation membrane, and septum; liquid exchange possible

2.2 Cell Biology Experiment Facility (CBEF)

The Cell Biology Experiment Facility (CEBF) is used to cultivate various cells, microorganisms, small plants, and so forth to conduct life science experiments in the Pressurized Module (PM) of Kibo. The CBEF consists of an incubator and a control unit that controls the incubator and communicates with the Kibo system. The incubator unit has a microgravity compartment and an artificial gravity compartment (centrifugal type), the gravity in which can be set within a range of 0.1 to 2.0g for comparison experiments with the microgravity compartment on orbit. The culture chamber and automated devices (Biological Experiment Unit, BEU) are inserted into a container called a canister that is placed in the incubator of the facility.

In the incubator unit, the temperature, humidity, and carbon dioxide concentration can be controlled in the range of 15 to 40°C, 30% to 80% (humidity control only), and 0% to 10%, respectively. These environments are constantly monitored with a sensor, and the environmental data are transmitted to the ground.

The canisters (up to six for the microgravity compartment and four for the artificial gravity compartment) are connected to the facility's main unit with a connector so that the BEU can be controlled and image and sensor data can be obtained.

The detailed functions and performance are shown in Table 2.2-1.

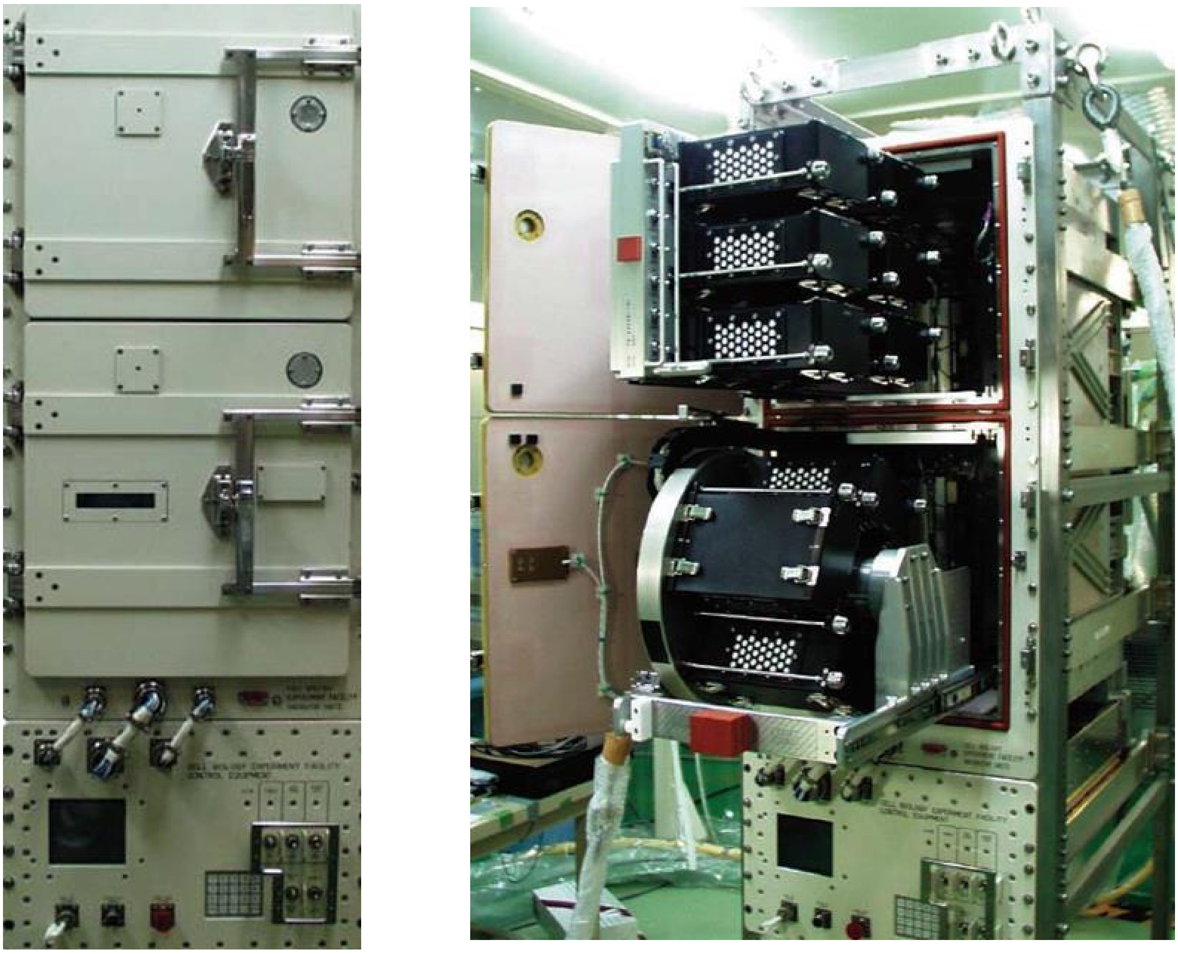


Fig. 2.2-1 Cell Biology Experiment Facility

(Left: Facility with its door closed, right: with six medium canisters in the microgravity compartment and four in the artificial gravity compartment)

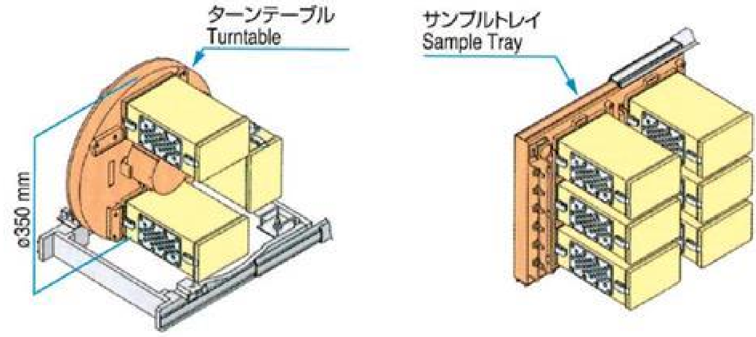


Fig. 2.2-2 Artificial gravity compartment attachment conditions

Fig. 2.2-3 Medium canister

Table 2.2-1 Specifications for CBEF

<table>
<tr><th colspan="2">Item</th><th>Design specifications</th></tr>
<tr><td rowspan="3">Structure</td><td>Volume</td><td>Incubator unit: 130 l</td></tr>
<tr><td>Incubator unit</td><td>- Consists of microgravity compartment and artificial gravity compartment, each of which has equipment for environmental control and various sensors
- Capable of maintaining and controlling the temperature, humidity, and CO_2 concentration within the incubator unit with canisters installed
- The artificial gravity compartment can generate an arbitrary artificial gravity of 0.1–2.0g using the artificial gravity generator and provides nearly the same environment as the microgravity compartment except for the gravity. These compartments can be used to conduct parallel experiments.
- A canister and canister tray are prepared as accessories to place the sample inside the canister for experiments.
- An interface provides the necessary power/signal/video to user-prepared devices inside the canister for experiments.</td></tr>
<tr><td>Control unit</td><td>- Capable of various controls upon command input using application software and user program input from the ground or a User Laptop Computer for experiments.</td></tr>
<tr><td rowspan="3">Incubator unit</td><td>Canister type</td><td>Size: Medium (default specification)
Style: Closed, gas permeation type
Closed: Seals against gas and liquid under pressurized environment in Kibo’s PM
Gas permeation type: Has a window of gas-permeable membrane and delivers gas permeation function under normal environment. Seals against liquid under pressurized environment in Kibo’s PM</td></tr>
<tr><td>Medium-size canister</td><td>External dimensions: 127.5 × 205 × 83 (mm)
Internal dimensions: 120 × 195 × 71 (mm)
[However, the minimum internal dimension is 106 × 175 × 57 (mm) because there is a dead space at each corner.]</td></tr>
<tr><td>Number of canisters mounted</td><td><table><tr><th></th><th>Microgravity compartment</th><th>Artificial gravity compartment</th></tr><tr><td>Medium</td><td>6</td><td>4</td></tr></table></td></tr>
</table>

Table 2.2-1 Specifications of CBEF (continued)

<table>
<tr><th colspan="2">Item</th><th>Design specifications</th></tr>
<tr><td rowspan="5">Temperature control system</td><td>Temperature control</td><td>15 to 40°C ± 1°C (when canister does not generate heat)</td></tr>
<tr><td>Humidity control</td><td>30% to 80%RH ± 5%RH
(The minimum humidity that can be provided depends on the environmental humidity outside the container and the maximum humidity at the set temperature.)</td></tr>
<tr><td>CO_2 concentration control</td><td>0% to 10% by volume</td></tr>
<tr><td>Gravity generation method</td><td>Centrifugal force</td></tr>
<tr><td>Gravity value setting</td><td>0.1 to 2.0g (value at a point 112.5 mm from the rotation center); gravity value setting is controlled by varying the number of revolutions (1 rpm)</td></tr>
<tr><td rowspan="4">User interface</td><td>Number of utility connectors installed</td><td>
<table>
<tr><th></th><th>Microgravity compartment</th><th>Artificial gravity compartment</th></tr>
<tr><td>Utilities (e.g., power, command sensor output)</td><td>6 in total</td><td>4 in total</td></tr>
<tr><td>Image</td><td>6 in total</td><td>4 in total</td></tr>
<tr><td>RS-485 connection</td><td>6 in total</td><td>4 in total</td></tr>
</table>
※There is only one output system to outside of the CBEF.</td></tr>
<tr><td>Utility breakdown</td><td>The following resources can be used as utilities for each connector when a medium canister is used:
<table>
<tr><th colspan="3"></th><th>Microgravity compartment</th><th>Artificial gravity compartment</th></tr>
<tr><td rowspan="4"></td><td>Power</td><td>+5 V (DC)
+12 V (DC)
−15 V (DC)
+15 V (DC)</td><td>1
1
1
1</td><td>1
1
1
1</td></tr>
<tr><td colspan="2">Command (1 bit)</td><td>2</td><td>2</td></tr>
<tr><td colspan="2">Sensor output (0–5 V)</td><td>2</td><td>2</td></tr>
<tr><td colspan="2">Shield (GND)</td><td>1</td><td>1</td></tr>
<tr><td></td><td colspan="2">Video output</td><td>1</td><td>1</td></tr>
<tr><td colspan="3">RS-485 connection</td><td>1</td><td>1</td></tr>
</table></td></tr>
<tr><td>User programs</td><td>Users can implement intermittent operation of the incubator, temperature/humidity cycle control, canister operation control, and other procedures using the special language provided by the CBEF.
- 16 kB per program
- Up to three programs can be executed simultaneously.</td></tr>
<tr><td>Acquisition of video data</td><td>Video output from six points in microgravity compartment and two points in artificial gravity compartment (four points in total, as each branches into two on the turntable) is switched at the control unit, and only one point is output to Kibo’s PM. Video output is switched by command or program.</td></tr>
</table>

2.3 Clean Bench (CB)

The Clean Bench (CB) provides a sterile closed work space to manipulate various cells and microbial tools and so on used in life science experiments in the Pressurized Module (PM) of Kibo. This system consists of the Operation Chamber, the Disinfection Chamber for material introduction, and a control unit to control them and communicate with the Kibo system.

The capacities of the Operation Chamber and Disinfection Chamber can be expanded by drawing them out from the experiment rack. The Operation Chamber is equipped with an inverted phase difference/fluorescence microscope and a CCD camera for monitoring. The CB is also equipped with a color display that can show images from the microscope.

The temperature in the Operation Chamber can be controlled in the range 20 to 38°C. Cleanliness is maintained by using a high-efficiency particulate absorption (HEPA) filter and an ultraviolet lamp and wiping with disinfectants such as ethyl alcohol. To adjust the atmospheric components of the Operation Chamber, cabin air is introduced through the HEPA filter. Disinfectants such as alcohol are absorbed and treated by a special activated charcoal after the disinfection process. The sensors monitor the temperature, humidity, ethyl alcohol concentration, and other environmental factors in the Operation Chamber (the use of alcohol within the ISS is limited).

Teleoperation of the inverted phase difference/fluorescence microscope has been enabled, and switching between phase difference and fluorescence, movement of the microscope stage in the *X*-, *Y*-, and *Z*-axis directions, and object lens selection can be executed by remote operation from the ground. Observations are made by obtaining the object lens image directly using a CCD camera; object lenses with magnifications of 4, 10, 20, and 40× are installed for phase difference observations, and one with a magnification of 40× is installed for fluorescence observations. Fluorescence observations adopt the epifluorescence method, which uses a xenon lamp as the excitation light source. The observation images from the microscope are displayed on the control system screen and can also be transmitted to the video system in the PM in Kibo for recording or down link. The <u>detailed functions and performance are outlined in Table 2.3-1.</u>

Fig. 2.3-1 CB (with Astronaut Furukawa operating)

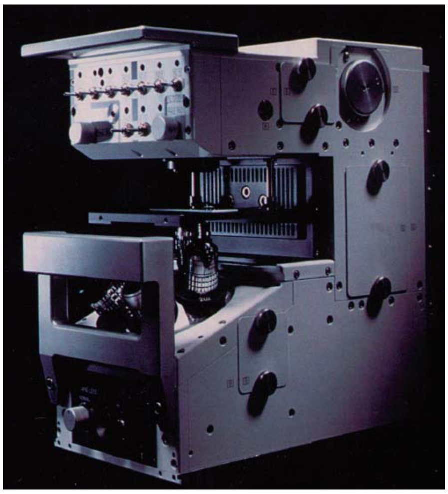


Fig. 2.3-2 Built-in phase difference/fluorescence microscope

Fig. 2.3-3 Work in the Operation Chamber

Table 2.3-1 Specifications of CB

No	System	Design specifications
1	Structural system	Airtight case Shape: Drawer, airtight case, three operation gloves Sterilization: Ultraviolet lamp Volume: 50 L Work area: 0.04 m^2 OC door: 180 mm × 250 mm
2	Disinfection Chamber (DC) system	Space to wipe the experimental tools, etc. with wipe Shape: Airtight case, two operation gloves Volume: 16 L Work area: 0.07 m^2 DC door: 180 mm × 250 mm
3	Operation Chamber (OC) system	The following devices are installed inside the Operation Chamber (OC): (1) Inverted phase difference/fluorescence microscope (2) Internal monitoring camera (OC Observation Camera)
4	Environmental control system for OC and DC	4.1 Gas monitoring mechanism Detects when concentrations of the following gases are at specified value or higher in OC: Ethanol, glutaraldehyde, formaldehyde, methanol, glacial acetic acid, chloroform, acetone, and ammonia 4.2 Environmental control mechanism (1) Average temperature at inlet/outlet for circulated air: Controlled at 20°C to 38 ± 2°C (2) Temperature is controlled using low-temperature cooling water. 4.3 Disinfection and disinfectant treatment device (1) DC: Wiping with sterilizing agents (Rebulus, ethanol), ultraviolet lamp (8 W × 2, 28 V, 260 nm) (2) OC: Wiping with sterilizing agents (Rebulus, ethanol) (3) Absorption treatment of ethanol gas generated in wiping processes in OC or DC using activated charcoal 4.4 Particulate removal system Installation of two HEPA filters at outlet and inlet of circulated air for OC 4.5 Illumination OC illumination lamp: 20 W OC work floor: 108 lx or higher
5	Control system	(1) Operation panel: Operation display (4.8", 320 × 256 dots), controls the operation of various devices with switch set on front surface of CB (2) Partial control also possible from joystick and the OC switchbox (inside the OC)

6	Experiment support devices	**6.1 Inverted phase difference/fluorescence microscope** Image taken by built-in CCD camera is displayed on LCD monitor, etc. Object lens magnification: 4, 10, 20, and 40× (for phase difference and light field) 40× (for fluorescence) Focusing range: 0–10 mm on stage (range of stage movement on *Z* axis) Stage movement range: ±12.5 mm each on *X* and *Y* axes Illumination: Halogen lamp, 12 V, 50 W (for phase difference and light field) Xenon lamp, 125 W (for fluorescence)
		6.2 Internal monitoring camera Work inside the OC can be observed.
		6.3 Joystick Installed on front surface outside OC. It can be used to change the microscope stage movement focus adjustment.
		6.4 OC switchbox Provides camera switching, microscope stage movement, focus adjustment, and magnification change without glove removal.
		6.5 LCD monitor 10.5-in. thin-film transistor display Displays the images from the microscope, internal monitoring camera, and user camera
		6.6 Other Shading cover, storage bag, and storage case
7	User interface	**7.1 Connection terminals for cameras supplied by the user** NTSC method: one system Displayed on LCD monitor
		7.2 Power supply outlet 5 V (DC): 0.2 A, +12 V (DC): 2 A, ±15 V (DC): 0.2 A
		7.3 Pressurized block and penetrating connector with the OC Round 22-pin × 1 system
		7.4 Microscope Equipped with mounts for external CCD camera that can connect cameras provided by the user (C mount and F mount)
		7.5 User cell interface Absorption cell for gas removal specific to the experiment can be installed.

<table>
<tr><td rowspan="2">8</td><td rowspan="2">Other</td><td>8.1 Telescience
The following operations are possible from the gorund:
(1) Some phase difference/fluorescence microscope operations
(2) Switching among images from CCD camera inside the microscope, internal monitoring camera, and camera supplied by the user
(3) Changing temperature setting inside OC</td></tr>
<tr><td>8.2 CB peripheral device stowage block
Power supply block and storage case are stowed inside 1/8DR.</td></tr>
</table>

2.4 Minus Eighty Degree Celsius Laboratory Freezer for ISS (MELFI)

The Minus Eighty Degree Celsius Laboratory Freezer for ISS (MELFI) has been prepared to store experimental samples, chemical agents, and other materials on orbit for experiments in space, especially those in biotechnology and the life sciences. It is installed inside the Pressurized Module (PM) of Kibo.

Experimental samples are launched and brought to Kibo's PM in cultured, frozen, dried, and other conditions to conduct culturing experiments inside the PM. When an experiment is completed, the experimental samples can be stored in a refrigerated or frozen condition until they are returned to the ground. The assumed experimental temperatures are +4°C, –26°C, and –80°C. Currently, it has been operating at -95 ℃ and 2 ℃.

The freezer's capacity is 300 L, which is divided into four 75-L compartments. Each compartment can be set to one of the above temperatures independently.

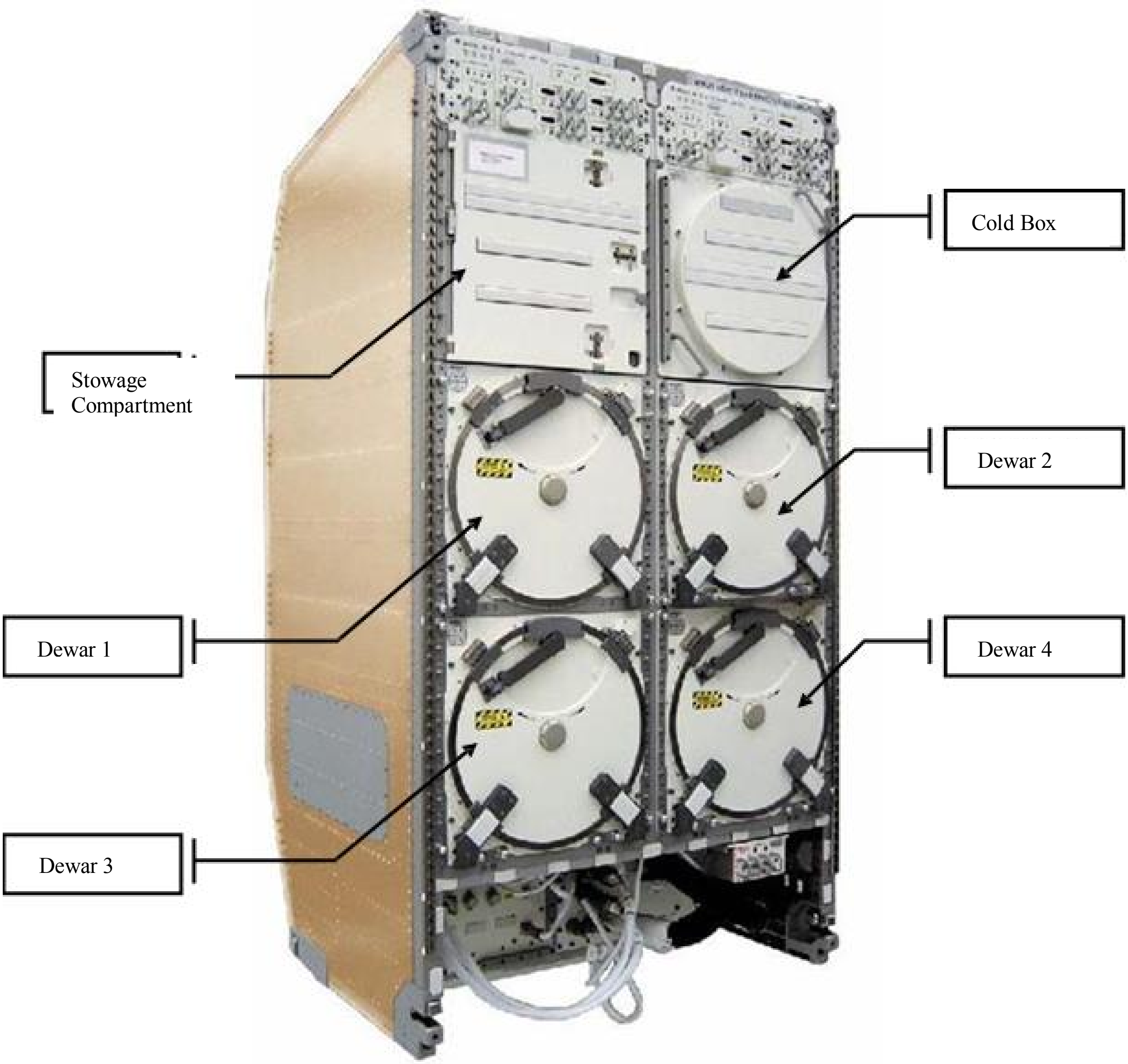


Fig. 2.4-1 MELFI

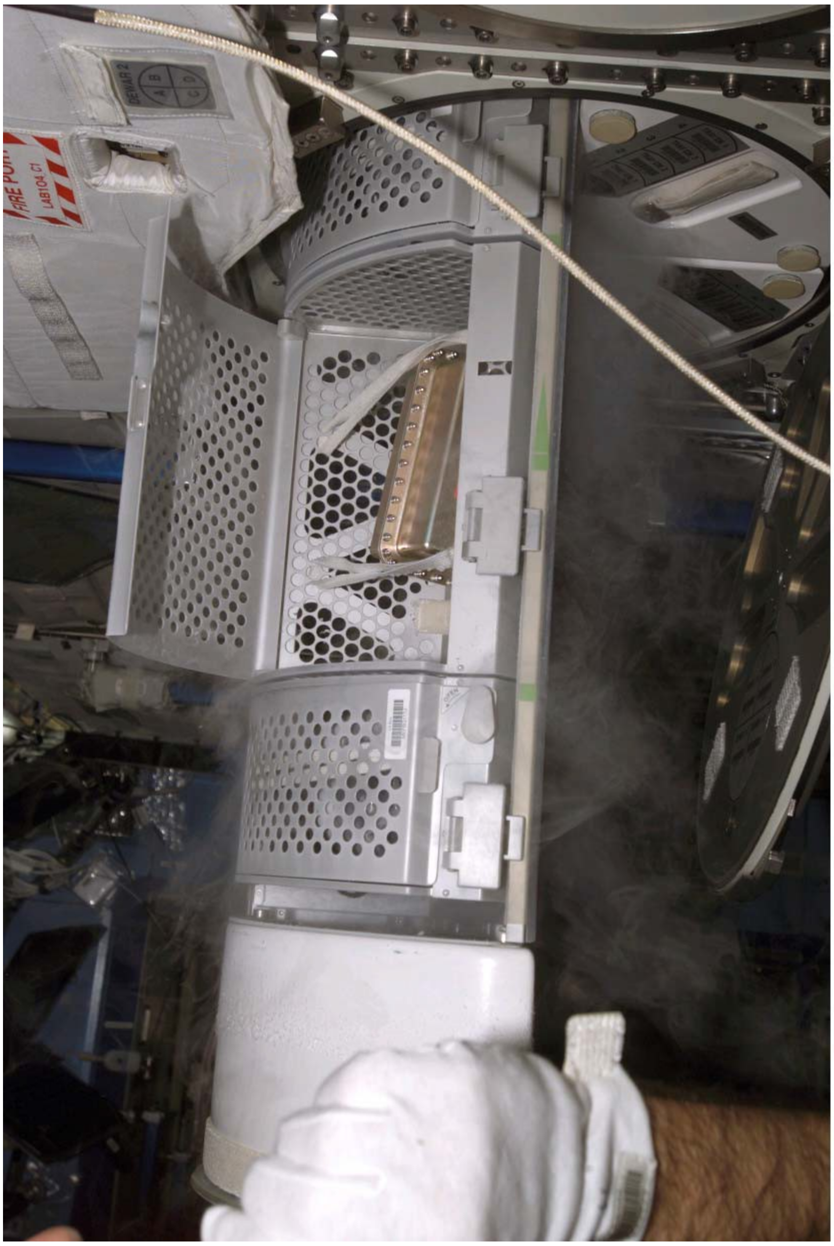


Fig. 2.4-2 Tray for MELFI on ISS

2.5 Aquatic Habitat (AQH)

(1) AQH outline

Aquatic Habitat (AQH) has the capabilities to accommodate small freshwater fish, medaka or zebrafish, which have many advantages as vertebrate model. The AQH is installed in Multi-Purpose Small Payload Rack (MSPR) in Japanese Experiment Module (Kibo) of ISS and is utilized for the experiments to investigate how microgravity and the space radiation environment, particularly over the long term, affect living things including human being.

Medaka (*Oryzias latipes*)

Zebrafish (*Danio rerio*)

The AQH is composed of one closed water circulation system with two aquariums. The aquarium has automatic feeding system, LED light for day/night cycle and CCD camera for observation. The aquarium environment will be maintained by water flow rate control, water temperature control, dissolved gas exchange with air, and biological/physical filtrations. Also, the AQH will have on-orbit maintenance capabilities, such as water quality check, water exchange, and waste filter replacement and so on, to achieve long-term experiments up to 90days. Outline of the AQH is shown in Fig. 2.5-1 and Fig. 2.5-2. AQH water flow diagram is shown in Fig. 2.5-3.

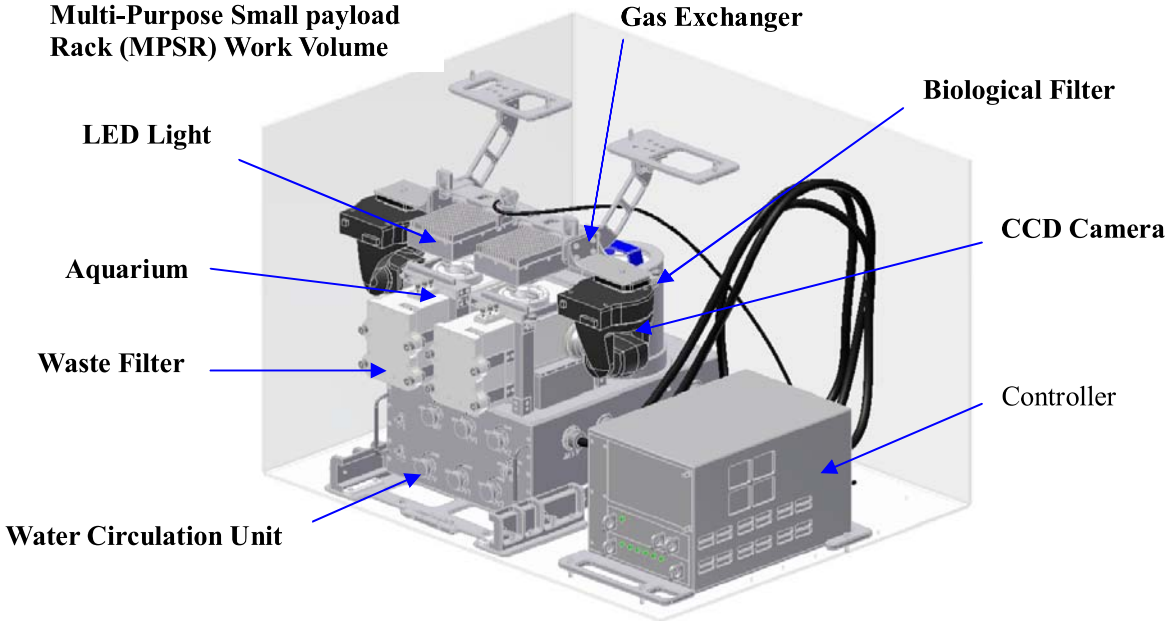


Fig. 2.5-1 Outline of AQH

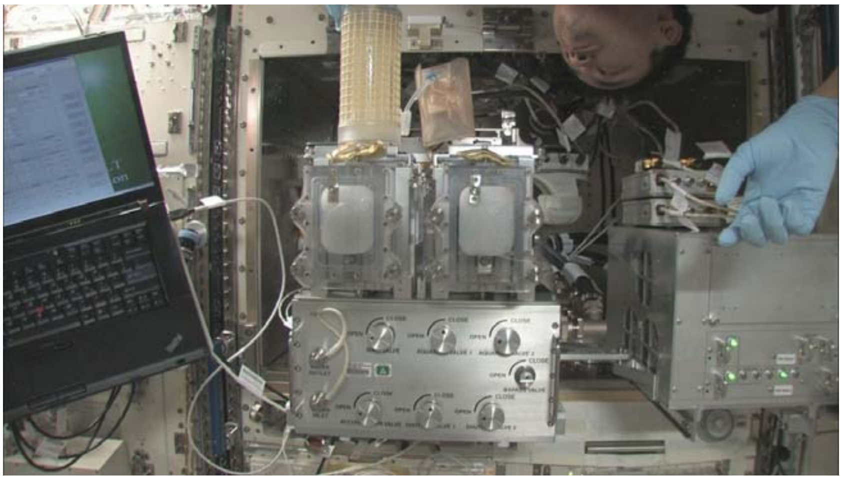


Fig. 2.5-2 AQH installed in MSPR WV in "Kibo"

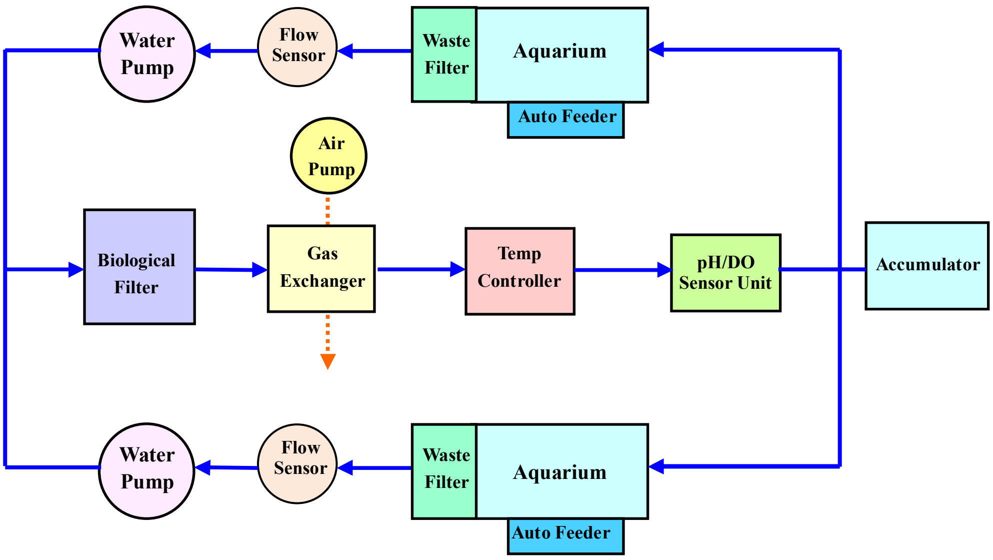


Fig. 2.5-3 Water flow diagram of AQH

Fig. 2.5-4 Medaka in AQH Aquarium
(Space experiment)

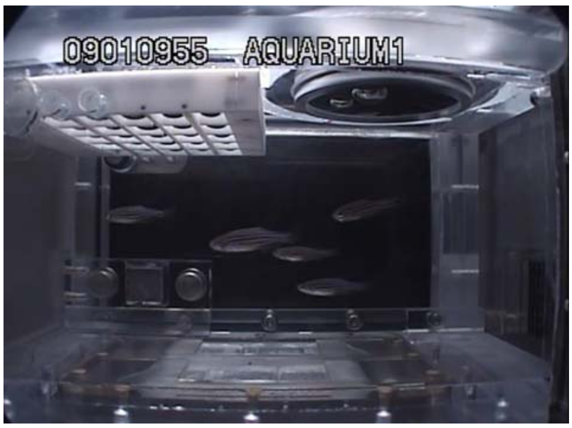


Fig.2.5-5 Zebrafish in AQH Aquarium
(Ground experiment)

(2) AQH major specifications

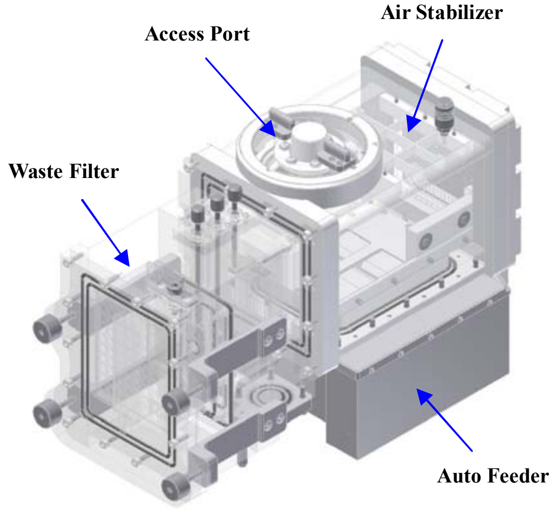


Fig.2.5-6 AQH Aquairum

- Experiment duration
  Up to 90 days
- Water circulation system
  One closed water loop with two aquariums
  Total water volume: 3.2 L
- Aquarium
  Inner dimensions: 150 X 70 X 70mm
  Inner water volume: 0.7 L/aquarium
  Air Stabilizer is equipped for air/water interface control and Access Port is equipped for fish sampling
- Water temperature control
  Water temperature range: 25-30 degree C
  Water temperature accuracy: ±1 degree C of set point
- Water flow rate control
  Water flow rate can be controlled for each aquarium
  Water flow rate range: 0-0.4 L/min
  Water flow rate accuracy: ±10 % of set point
- O_2 supply/CO_2 removal
  Gas exchange with air by artificial lung (gas permeable membrane)
- Water quality maintenance
  Biological filter with nitrifying bacteria for NH_4/NO_2 removal
  Water exchange for NO_3 removal
  Physical filter with activated carbon for waste trap and organic material adsorption
- Day/night cycle
  Two LED lights for each aquarium
  Light intensity: selectable in the range of 0-1000 Lux
  Light/dark cycle: selectable within total 24 hours
- Automatic feeding
  Artificial powdery food can be used
  Feeding amount and timing are programmable according to fish developmental stages
  Feeding frequency: selectable

Feeding point of
Auto Feeder

- Observation
  Two CCD cameras for each aquarium
  Infrared camera observation is available
- Data monitor
  Water temperature, water flow rate, water pressure, dissolved oxygen, pH, lighting status, feeding status
- Commanding
  Water temperature set point, water flow rate set point, lighting control, feeding control, CCD camera control

(3) AQH Accessories

The AQH has various accessories for fish transportation to "Kibo" of ISS, fish sampling and preservation for post-flight analysis, generational separation and change for supporting medaka multi-generational experiment and also AQH maintenance.

- **Fish Carrier**
  Container for live fish transportation from launch site to "Kibo"
- **Fish Retriever**
  Container for live fish transportation from "Kibo" to landing site
- **Fish Catcher**
  Apparatus to catch fish in the aquarium and took out for chemical treatment or generational change
- **Fish Fixation Apparatus**
  Apparatus to fix fish chemically and retrieve for post-flight analysis
- **Egg Collection Kit**
  Kit to collect medaka eggs in the aquarium and maintain them until hatch for multi-generational experiment
- **Water Quality Test Kit**
  Kit to check NH_4, NO_2, NO_3 concentrations of sampled AQH circulation water
- **Water Exchange Kit**
  Kit to exchange AQH circulation water

(4) AQH Operations

The AQH Breeding Unit including Aquariums and AQH accessories are supposed to be transported to "Kibo" by HII Transfer Vehicle (HTV) from Tanegashima Space Center in Japan or other vehicles for each experiment. Biological samples such as fish will be transported by Soyuz or Progress from Baikonur Cosmodrome due to their late loading requirements and the experiment will be started just after their arrival.
Samples for post-flight analysis will be retrieved by Soyuz Descent Module or Dragon Spacecraft.
The AQH operational flow is shown in Fig.2.5-7.

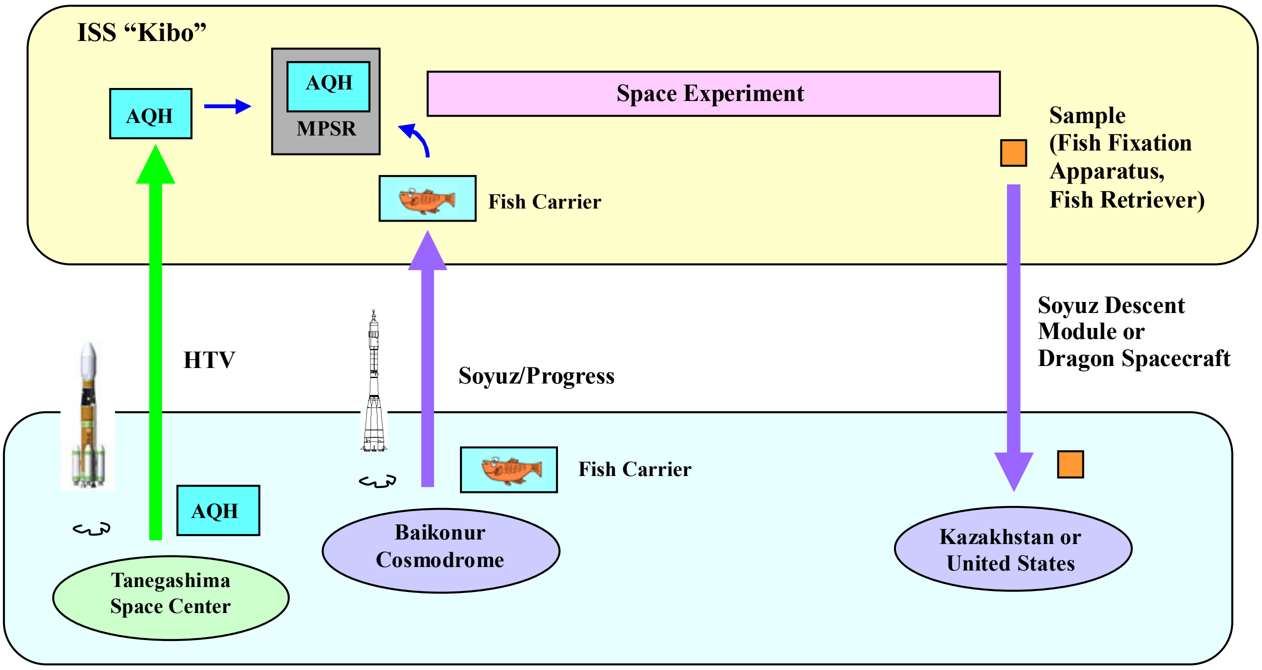


Fig.2.5-7 AQH operational flow

2.6 Passive Dosimeter for Life Science Experiments in Space (PADLES)

Using the Passive Dosimeter for Life Science Experiment in Space (PADLES), the Japan Space Utilization Promotion Center at JAXA has implemented cosmic radiation environmental monitoring in Kibo (Area PADLES), dose measurement to evaluate the effect of radiation on biological samples used in life science experiments (Bio PADLES), and measurement of individual exposure doses for the Japanese astronauts staying at the International Space Station (ISS) for long periods (Crew PADLES) since Kibo docked with the ISS.

It is important to measure the cosmic radiation environment in space experiments in the life sciences conducted in the ISS and on the space shuttle as an indicator for physical and chemical analysis of the effects of cosmic radiation on biological samples. JAXA provides measurement of the exposure doses for biological samples, data analysis, and disclosure, which are important for space experiments in the life sciences (Fig. 2.6-1).

The dosimeter package (Figs. 2.6-1 and 2.6-2) combines two types of dosimeter device (the nuclear track detector, CR-39, and thermoluminescent dosimeter, TLD), which were developed by JAXA to be optimal for cosmic radiation environment measurements. The PADLES analyzes the measurement results automatically. Data from a dosimeter package mounted with biological samples are analyzed approximately two weeks after the return to the ground and presented as a summarized report in English on the detailed dosimeter mounting environment and dose analysis results (Fig. 2.6-3).

The analysis items provided by the PADLES are as follows (Table 2.6-1):

- **Absorbed dose (units of mGy): Absorbed energy per unit weight**
- **Linear energy transfer (LET) spectrum: Measurement of LET spectrum, which is necessary to calculate the load coefficient**
- **Equivalent dose (units of mSv): The product value of the load coefficient for the absorbed dose depending on the radiation quality and absorbed dose**

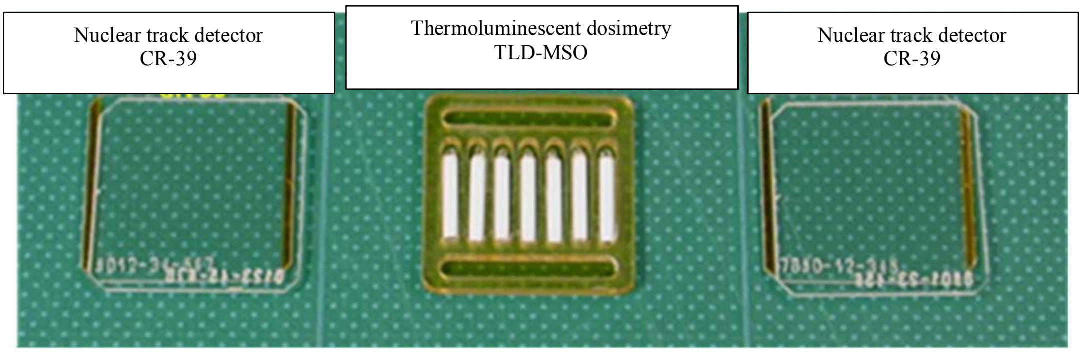


Fig. 2.6-1 Devices comprising PADLES dosimeter package (CR-39, TLD)

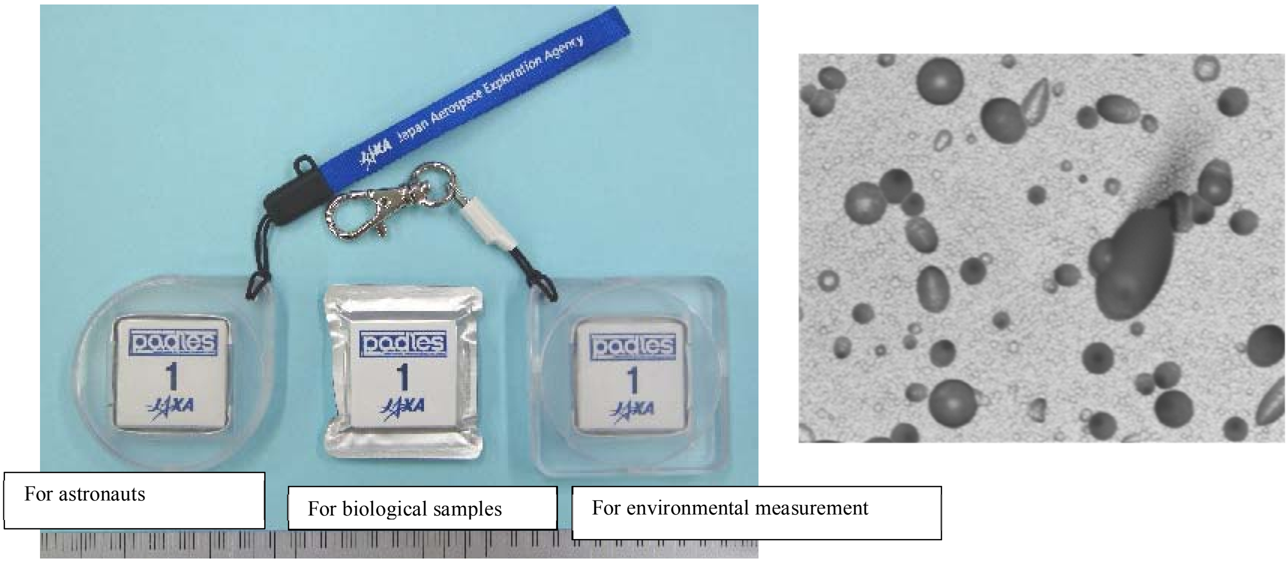


Fig. 2.6-2 (left) PADLES dosimeter package may have the device enclosed in heated aluminum sealing (3 cm × 3 cm × 0.5 mm) or polycarbonate case (4.6 cm × 4.6 cm × 0.9 mm) depending on the application. (right) Nuclear track detector CR-39, which was mounted inside ISS Kibo for 278 days. The tracks of heavy charged particles that passed through the dosimeter on orbit (etch pits) were visualized. The LET spectrum can be calculated by measuring the shapes and number of these etch pits.

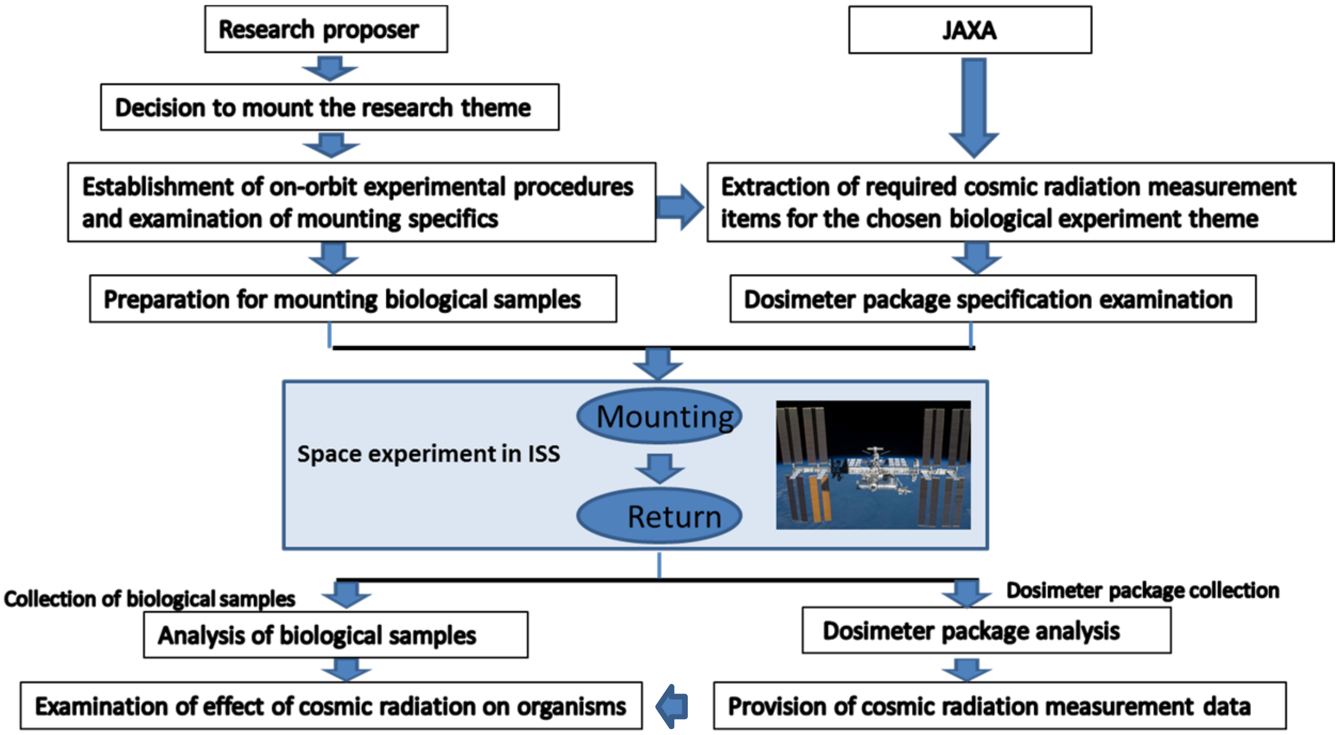


Fig.2.6-3 Radiation measurement flow in space experiments in life sciences

Table 2.6-1 PADLES package specifications

	Device	Measurement function	Subject radiation type	LET range (keV/µm)
TLD	MSO-S	Absorbed dose[*1]	Photons, charged particles	0.2–10
CR-39	HARZLAS (TD-1/TNF-1)	LET spectrum for particle fluence	Charged particles	2–1000
	BARYOTRK/HARZLAS (TD1)	Particle tracking	High *Z*, high *E* charged particles	40 or higher[*3]
TLD	MSO-S	Absorbed dose[*1]	Photons, charged particles	0.2–1000
CR-39	HARZLAS (TD-1/TNF-1)	Equivalent dose[*1]	Photons, charged particles	
		Effective quality factor[*2]	Photons, charged particles	

Temperature range	-80–40°C
Atmosphere	1 atm, in air
Dimensions	25 mm(W) × 25 mm(L) × 4 mm (H) [Minimum area for CR-39, 20 mm (W) × 15 mm (L) × 0.45 mm(H)]
Mounting period	Three months by default (one week minimum, one year maximum)

[*1] Integrated value during period of biological sample mounting
[*2] Average value during period of biological sample mounting
[*3] Equivalent to charged particles with *Z* equal to or higher than the Si atom in relativistic energy

2.7 Particle Counter

This handy measuring instrument detects airborne particles in air and records the value for each particle size. It can measure the temperature and humidity while also recording data on six particle size classes: 0.5 µm and larger, 1.0 µm and larger, 2.0 µm and larger, 3.0 µm and larger, 5.0 µm and larger, and 10.0 µm and larger. It can take measurements at an arbitrary interval and accumulate up to 500 measurement results in the main unit. The accumulated data are transmitted to the laptop PC located in the International Space Station (ISS) Kibo for down link to the ground.

This particle counter was developed for “Microbial dynamics in International Space Station, OpNom (Microbe),” a theme for Kibo Pressurized Module use in the second period. It is based on a commercial product (RION Co., Ltd., KR-12A) and modified for mounting in the ISS and for this experiment theme.

The specifications of the particle counter are listed in Table 2.7-1, and a photograph is shown in Fig. 2.7-1.

Table 2.7-1 Specifications of Particle Counter

Item	Specification
Optical system	Sideways scattering method
Light source	Semiconductor laser (Class 1)
Photodetector	Photodiode
Rated flow rate	2.83 L/min
Particle size classes for measurement	six classes 0.5 µm and larger, 1.0 µm and larger, 2.0 µm and larger, 3.0 µm and larger, 5.0 µm and larger, and 10.0 µm and larger
Maximum rated particle number and concentration	70,000 particles/L
Inspiration time for measurement	6 s (0.01 CF), 21 s (1 L), 1 min (0.1 CF, 2.83 L), 3 min and 32 s (10 L), 10 min (1 CF, 28.3 L), arbitrary (1 s– 59 min and 59 sec or manual on/off). CF: Cubic foot
Number of measurements	1 to 100 and infinite
Sample exhaust	Filter (0.1 µm)
Memory capacity	Memorizing and recalling up to 500 measurement values
External data recording	Utility software installation on PC Connected to a PC via USB cable for storage in CSV format
LCD display	Maximum digits indicated: 8 (with a backlight)
Possible measurement range for temperature and humidity sensors	10 to 40°C, 20% to 90% (guideline)
Operating conditions	10 to 40°C, 20% to 90%
Power supply	Size D alkaline batteries (four), capable of taking measurements every 15 min for 24 h or longer continuously

Accessories	USB cable
Other	With Velcro and tether (1 m) for prevention of floating loss
Dimensions	115 mm (W), 104 mm (D), 334 mm (H) (main unit dimensions)
Weight	Total weight: 2.01 kg (Main unit: 1459 g, cable: 23 g, four batteries: 532 g)

Fig. 2.7-1 Particle Counter
(Silver part at the bottom is the size D battery box.)

3 Experimental facilities for material science

3.1 Fluid Physics Experiment Facility (FPEF)

(1) Outline

This is an experimental facility for conducting basic experiments related mainly to fluid physics around room temperature (such as Marangoni convection experiments). It is equipped with a three-dimensional observation camera, infrared thermometer, strobe light, overall observation camera, and other equipment.

It has an electrical interface with the experiment cell that can transmit data from the control/measurement/observation devices inside the experiment cell and transmit the image signals to the Image Processing Unit (IPU, described later). It also has an interface with the fluid system (gas/water, QD).

Because the FPEF performs its major functions in conjunction with a general-purpose experiment cell, they are described in the next section.

Fig. 3.1-1 shows a photograph and schematic drawing of the FPEF.

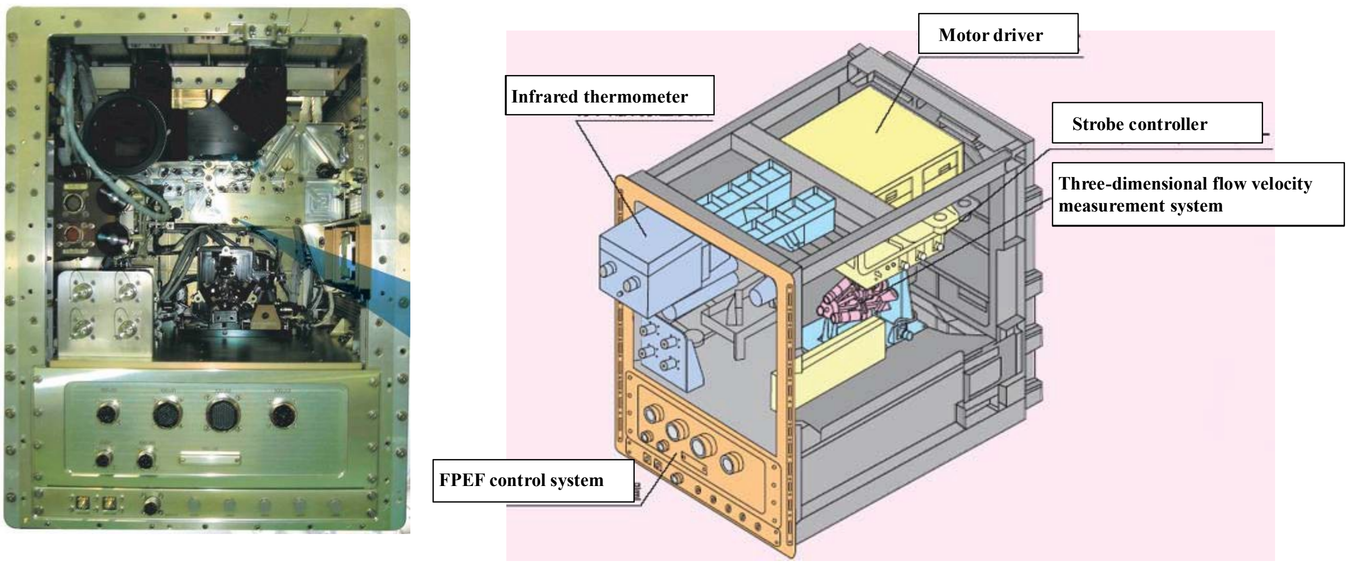


Fig. 3.1-1 Photograph and schematic drawing of FPEF

(2) Experiment cell

The removable experimental cell stows the sample and devices around the sample.

As long as certain interface and safety conditions are satisfied between the cell and the main body of the FPEF system, the experiment cell can be customized to suit the purpose of an experiment.

Table 3.1-1 shows the system functions and resources (user interfaces provided by the system) that are available to the experiment cell, and Fig. 3.1-2 shows the envelope that can be used for the experiment cell.

As an example, the general-purpose experiment cell for Marangoni convection experiments that were actually conducted in Kibo is shown in Fig. 3.1-3, and its specifications are listed in Table 3.1-2.

Table 3.1-1 System functions and resources available to experiment cell

Item	Functions and resources
Power supply	12 V ± 2 V, ≤4 A, 1 ch 24 V ± 2 V, ≤3.5 A, 1 ch ±15 V ± 0.5 V, ≤0.8 A/ch, 3 ch
Power control	4–65 V/5–180 W, 3 ch 1–30 V/5–180 W, 1 ch
Solenoid valve driving	24 V ± 2 V, ≤1.3 A, 3 ch
Power supply for motor	24 V, 3 A, 4 ch (motor: For PK543-A)
General-purpose analog input	0–10 V, 8 ch
General-purpose digital input	8 ch
General-purpose digital output	8 ch
Contact signal input	15 ch
Platinum temperature sensor input	5 ch
Thermocouple temperature sensor input	6 ch, K thermocouple supported
CCD camera input	IK-TU40D supported, 1 ch
Video input	NTSC, 2 ch
Tolerable size (See Fig. 3.1-2.)	230 (W) × 580 (L) × 363 (H) mm (Some parts cannot be used even in the above envelope.)
Ar gas	88.2–101.3 kPa, 20 nL/min
Cooling water	8.5 kg/h, in: 16–23°C, out: ≤43°C
Exhaust pressure	0.13 Pa–101 kPa
Exhaust heat rate	≤255 W (with room for adjustment)
Weight	38 kg or smaller

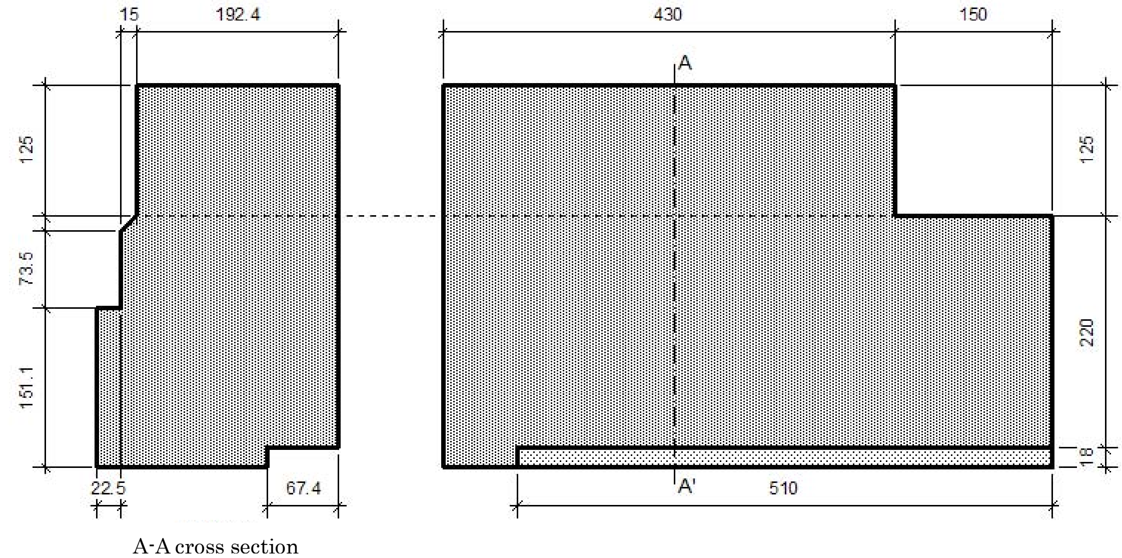


Fig. 3.1-2 Available dimensions of experiment cell
(External dimensions for general-purpose experiment cell for Marangoni convection experiments)

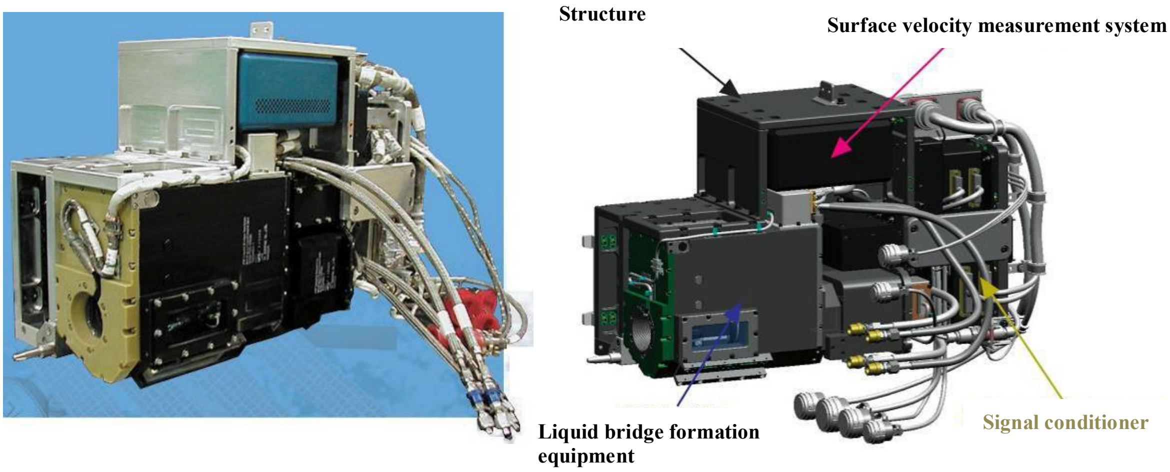


Fig. 3.1-3 Photograph and illustration of general-purpose experiment cell for Marangoni convection experiments

Table 3.1-2 Specifications of general-purpose experiment cell for Marangoni convection experiments

Item	Specifications
Liquid bridge formation	Sample: Silicone oil (5 cSt/10 cSt) Diameter: Ø30/Ø50 (mm) Length: ≤60 mm Liquid volume adjustment range: ±9.6 mL
Temperature monitor	Heating disk temperature: 10–100°C Cooling disk temperature: Room temperature to 0°C Observation window temperature: Room temperature to 60°C Ambient temperature: Room temperature to 100°C Liquid bridge internal temperature: 0–100°C
Temperature control	Heating disk: ≤90°C Cooling disk: ≥5°C Observation window: ≤50°C
Three-dimensional flow velocity measurement[*1][*3]	CCD camera pixel number: 768 (H) × 494 (V) Strobe illumination frequency: 60 Hz
Overall observation[*3]	CCD camera pixel number: 768 (H) × 494 (V)
Surface temperature distribution measurement[*3]	Infrared thermometer Detection wavelength range: 8–14 µm Measurement temperature range: 0–100°C
Surface velocity measurement[*2]	Laser radiation: two points Illumination frequency: 4.57 × 10^{-4} to 10 Hz (±1%) Illumination count: 1–4097 times

[*1] For observing the behavior of tracer particles mixing in liquid bridge using the three-dimensional observation camera

[*2] For visualizing the flow on the liquid bridge by developing pixel color mixing in the liquid bridge by irradiating the laser intermittently

[*3] Among the acquired data, image data are recorded and transmitted to Earth mainly via the IPU. Although the data rates are set to 17–42 Mbps/ch (MPEG/MotionJPEG compression) for video recording and 15 Mbps max/ch (MPEG2 compression) for transmission to Earth, they are subject to change because of various operational restrictions.

3.2 Solution Crystal Observation Facility (SCOF)

(1) Outline

This is a system for observing the crystal forms and environmental phase temperature/concentration field on site during crystal growth in a supersaturated solution or supercooled melt prepared by temperature/pressure control. It is equipped with a two-wavelength Mach–Zehnder interference microscope, amplitude modulation microscope, and other equipment as observation devices.

It has an electrical interface with the Experiment Cell Cartridge that can supply power to the Experiment Cell Cartridge and control its temperature. Further, it transmits the measurement data, such as the temperature, and transmits the image signals to the Image Processing Unit (IPU, described later). It also has an interface to the fluid system (nitrogen gas, gas exhaust).

Fig. 3.2-1 shows a photographs and schematic drawings of the external appearance and internal structure of the SCOF. Fig. 3.2-2 shows the optical path for the entire observation system, and Table 3.2-1 lists the main functions and basic specifications of the SCOF.

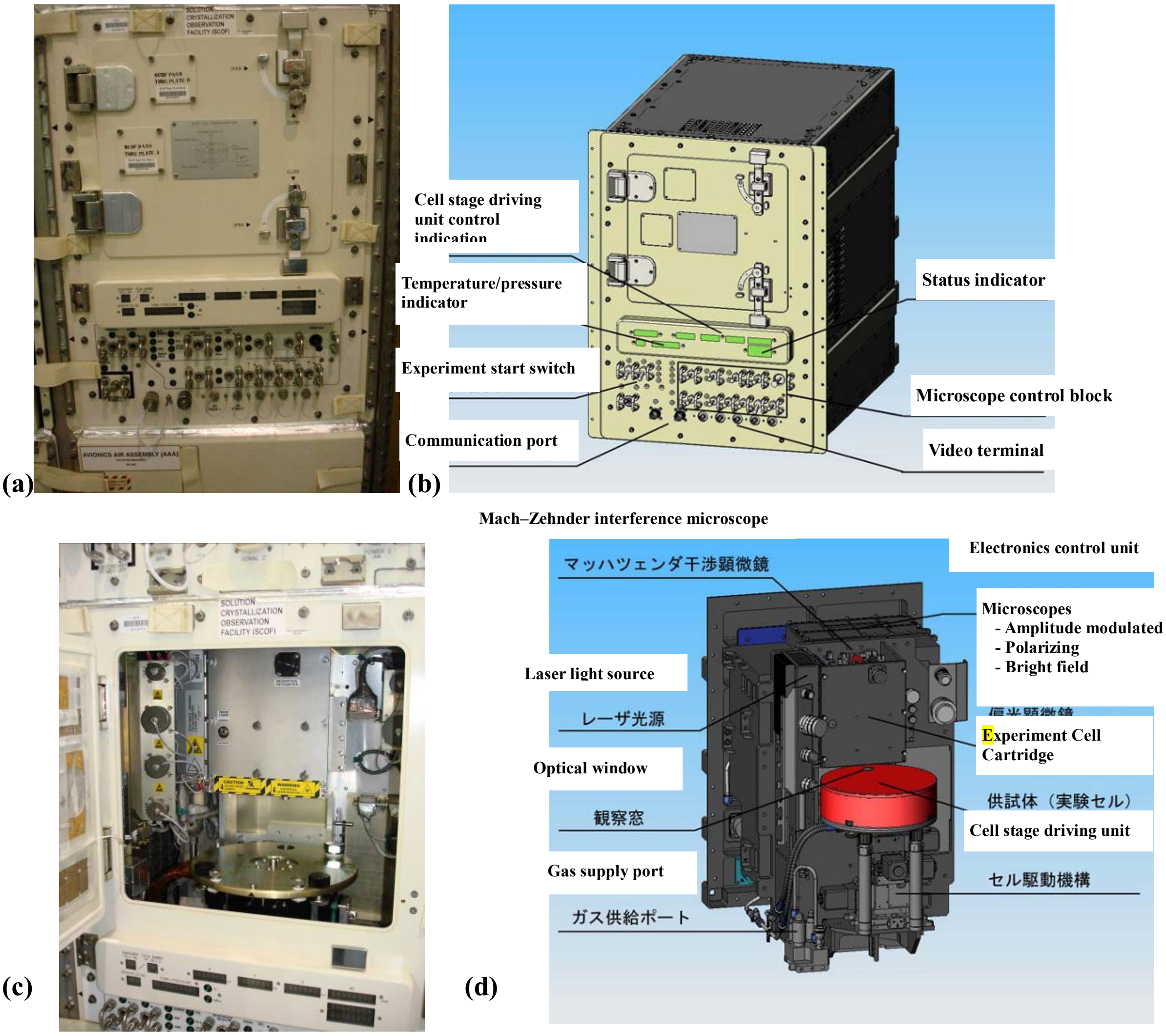


Fig. 3.2-1 Photographs and schematic drawings of SCOF

(a) External photograph, (b) schematic drawing of external appearance, (c) photograph of internal structure, (d) schematic drawing of internal structure

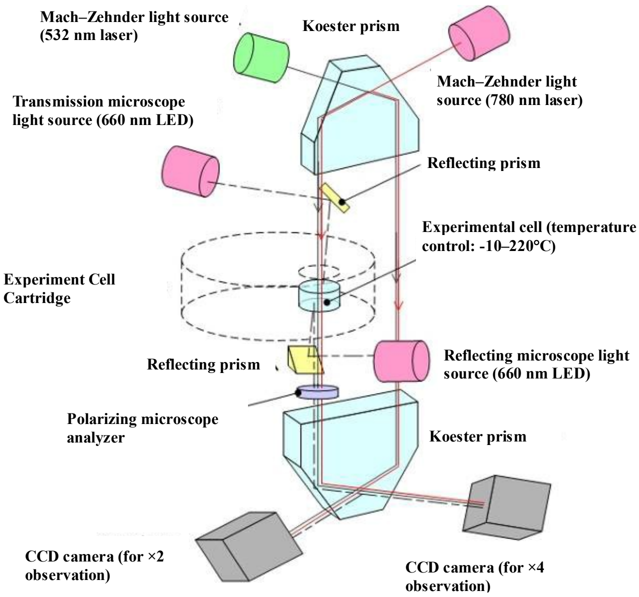


Fig. 3.2-2 Optical path for entire observation system

Table 3.2-1 Main functions of SCOF (excerpt)

Main function		Basic specifications
Experimental control		(1) Experiments are mostly controlled automatically using a program. (2) System is capable of telescience operation.
Observation system	Crystal surface observation	Method: Amplitude modulation microscope (installed on Mach–Zehnder two-wavelength interference microscope) Magnification: 2 and 4× Light source: LED (wavelength 660 mm) Observation field: 2.4 × 3.2 mm/2×, 1.2 × 1.6 mm/4 × Phase resolution: ≥0.2 wavelength (132 nm) Sample illumination: Transmitted beam observation/reflected light observation switching Imaging device: ½-in. CCD camera Focus adjustment: By Experiment Cell Cartridge driving Other: Light field/polarization observation possible
	Measurement of temperature/ concentration distribution in liquid phase	Method: Mach–Zehnder-type two-wavelength interference microscope Magnification: 2 and 4× Light source: laser diode (LD) and LD excitation solid laser (wavelength 780/532 mm) Observation field: 2.4 × 3.2 mm/2× to 1.2 × 1.6 mm/4× Phase resolution: ≥0.2 wavelength Imaging device: ½-in. CCD camera
	Particle size distribution measurement	Method: Dynamic light scattering measuring device (with delayed fluorescence measurement function) Light source: LD (wavelength 532 nm) Particle detection capacity: 100 nm Analysis method: Multiple hard correlator method Minimum gate time: 200 ns Other: Detector is installed on the Experiment Cell Cartridge side.
Experiment Unique Cartridge driving system		Method: Stage method Movement axes: X, Y, Z, θ X = 3.55 to -3.73 mm Y = 3.67 to -3.61 mm Z = 3.65 to -3.5 mm θ = ±5° (X, Y, and Z stroke: ≥±3 mm)
Pressure control function		Pressure control range: 1–147.10 MPa (interface to pressure control block necessary on Experiment Cell Cartridge side) Pressure increase function: None (installed on Experiment Cell Cartridge side)
Gas supply/exhaust		N_2 gas supply pressure: 0 to approx. 827.4 kPa Gas exhaust operation pressure: 101 kPa to 0.13 Pa [interface (QD) to pressure control block necessary on Experiment Cell Cartridge side]
Temperature measurement/control system		Described in Table 3.2-2 because it depends on the functions of the Experiment Cell Cartridge

Note: Amongthe obtained data, image data are recorded and transmitted to the earth mainly via the IPU. Although the data rates are set to 17–42 Mbps/ch (MPEG/MotionJPEG compression) for video recording and 15 Mbps max/ch (MPEG2 compression) for transmission to Earth, they are subject to change because of various operational restrictions.

(2) Experiment Cell Cartridge

The removable Experiment Cell Cartridge stows the sample and the tools and materials around the sample.

As long as certain interface and safety conditions are satisfied between the cartridge and main body of the SCOF system, the experimental cell can be optimized to suit the purpose of an experiment.

Table 3.2-2 shows the functions and resources that are available to the Experiment Cell Cartridge, and Fig. 3.2-3 shows the envelope that can be used for the Experiment Cell Cartridge.

As an example, the individual Experiment Cell Cartridges for two themes for which experiments are to be conducted in Kibo are shown in Fig. 3.2-4. These themes are as follows:

● Ice Crystal theme [Fig. 3.2-4(a), (b)]

- **Experiment Cell Cartridge envelope: Individual shape**
- **Cell: one set each of crystal growth cells and nucleation cells**
- **Temperature control/measurement: 3-ch Peltier element (2 ch for control/measurement thermistor, 1 ch for measurement thermistor)**
- **Observation functions: one-axis bright field microscope/one-axis, one-wavelength Mach–Zehnder-type interference microscope (coaxial, with optical adjustment functions and control box)**
- **Other: Bubble removal mechanism (manual), gas exchange port in Experiment Unique Cartridge**

● FACET theme [Fig. 3.2-4(c), (d)]

- **Experiment Unique Cartridge envelope: standard shape (cylindrical: Ø220 mm × H65 mm: external dimensions)**
- **Cell: two sets of crystal growth cells (one set in figure)**
- **Temperature control/measurement (per cell): 2-ch Peltier element (2 ch for control/measurement thermistor, 2 ch for measurement thermistor, 2 ch for measurement thermocouple, 1 ch for thermistor for zero contact)**
- **Other: Gas exchange port in Experiment Cell Cartridge**

Table 3.2-2(1) System functions available to Experiment Cell Cartridge when electrical parts are prepared (1)
(The system has electronic circuits corresponding to the specifications below.)

Item		System specifications	No. of ch
Temperature measurement /control	Thermistor (for standard measurement) [TS1–8]	・Measurement range: -20–230°C ・Measurement precision: ±0.70°C [-20 to -10°C] ±0.45°C [-10–70ºC] ±2.19°C [70–220ºC] ±2.60°C [220–230ºC] ・Resistance: 72.24–0.0808 kΩ ・Measurement frequency: 10 Hz	8
	Thermistor (for high-precision measurement 1) [TS9–16]	・Measurement range: 10–80°C ・Measurement precision: ±0.130°C [10–20°C] ±0.097°C [20–70°C] ±0.120°C [70–80°C] ・Resistance: 18.26–1.625 kΩ ・Measurement frequency: 10 Hz	8
	Thermistor (for cold contact temperature measurement) [TS17]	・Measurement range: 15–65°C ・Measurement precision: ±0.097°C ・Resistance: 14.86–2.527 kΩ ・Measurement frequency: 10 Hz	1
	Thermistor (for high-precision measurement 2) [TS18–21]	・Measurement range: -1.5–0.5°C or 2.5–4.5°C* ・Measurement precision: ±0.044°C ・Resolution: 0.001°C (target value) ・Resistance: 30.11–27.52 kΩ (TBD) ・Measurement frequency: 10 Hz	4
	Thermocouple (K type) [TC1–12]	・Measurement range: -10–220°C ・Measurement precision: ±0.8% FS ・Voltage: -2.209–8.301 mV ・Measurement frequency: 10 Hz	12
	Thermocouple (J type) [TC13]	・Measurement range: -10–70 ºC ・Measurement precision: ±1.6% FS ・Voltage: -2.822–2.836 mV ・Measurement frequency: 10 Hz	1
Heating/cooling	Peltier element [TM1–12]	・Driving current: ≤4.2 A/ch (≤13 A・ 12 ch) ・Driving precision: ±5% FS ・Supplied power: ≤30 W/ch	12
	Heater (for standard control) [HT1,2]	・Driving voltage: 0–10 V ・Driving precision: ±5% FS ・Supplied power: ≤30 W	2

Table 3.2-2(2) System functions available to Experiment Cell Cartridge when electrical parts are prepared (2)
(the system has electronic circuits corresponding to the specifications below.)

Item		System specification	No. of ch
Motor driving	DC motor [MT1, 2]	・Driving voltage: ≤±6 V ・Driving precision: ±10% FS ・Supplied power: ≤1.1 W ・Direction of rotation: CW/CCW	2
	Stepping motor [MT3, 4]	・Number of phases: two ・Driving current: ≤0.75 A/phase ・Direction of rotation: CW/CCW	2
Pressure measurement	Pressure sensor [PR2]	・Power supply voltage: 24 V ± 1% ・Measurement range: -3–33 mV, 0–69.03 MPa	1
	Pressure sensor [PR3]	・Power supply voltage: 24 V ± 10% ・Available current: ≤50 mA ・Measurement range: 0–5 V, 0–147.10 MPa ・Measurement precision: ±1% FS	1
Detection	Limit switch [LM1–4]	・Contact current: 2 mA ・Mechanical type	4
	Photo sensor [PM15]	・Power supply voltage: 1.2 V ・Detected current: ≥0.5 mA (with light entrance), ≤10 μA (shading)	1
Light source	LED driver [LED1]	・Supplied current: ≤50 mA ・Driving voltage: 6 V	1

Note: The measurement range can be selected according to the experimental parameters.

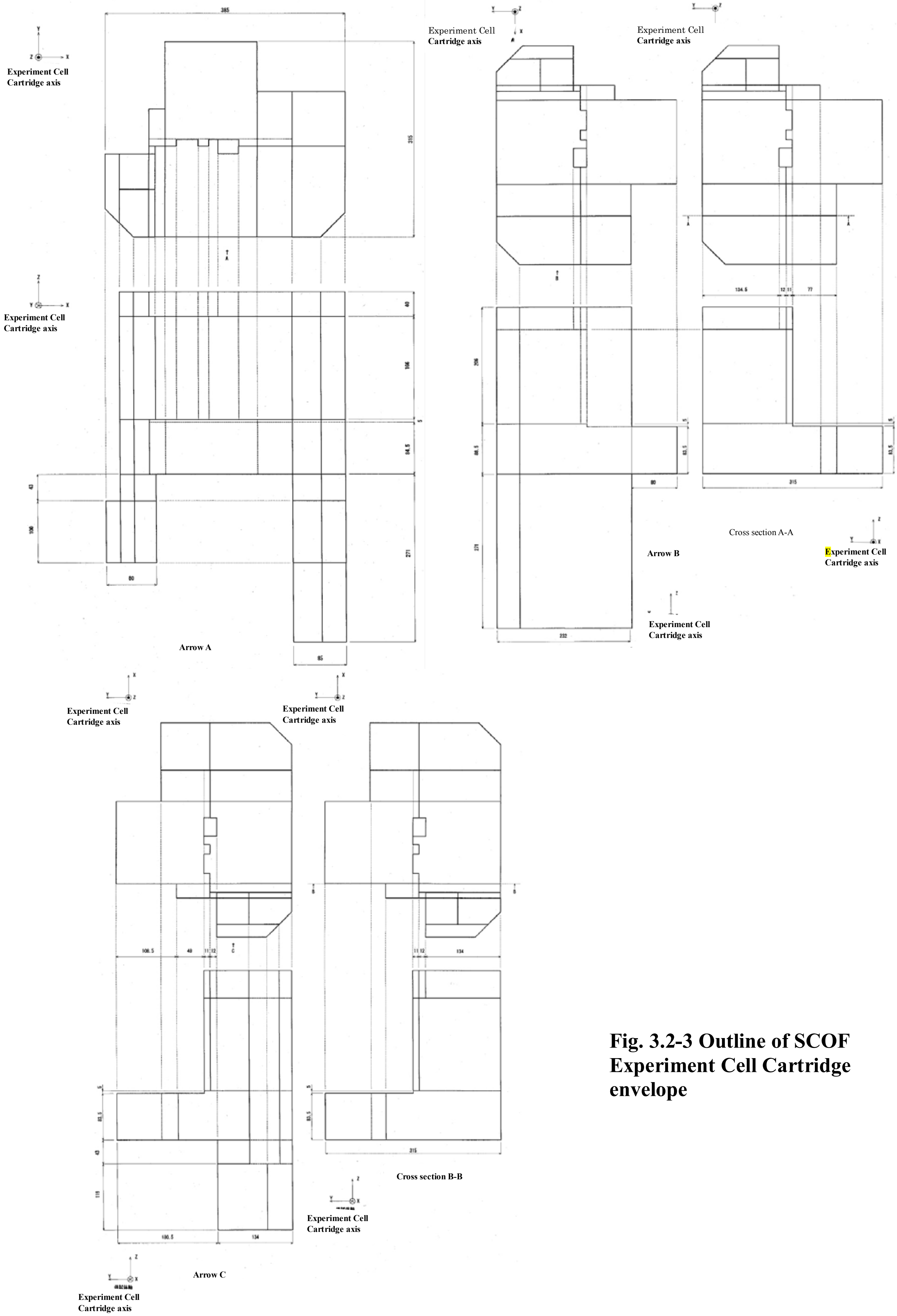
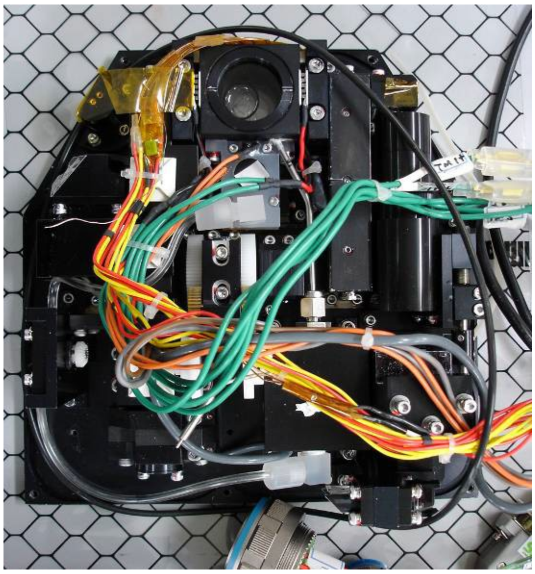
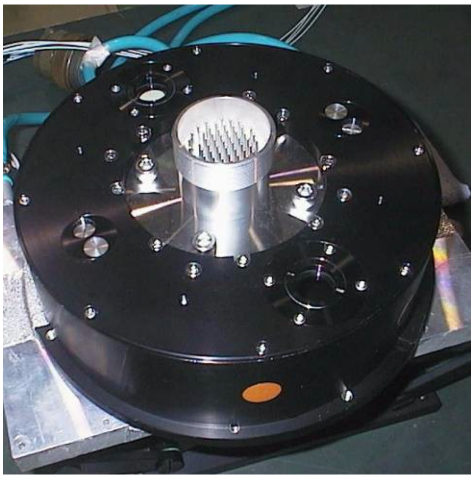
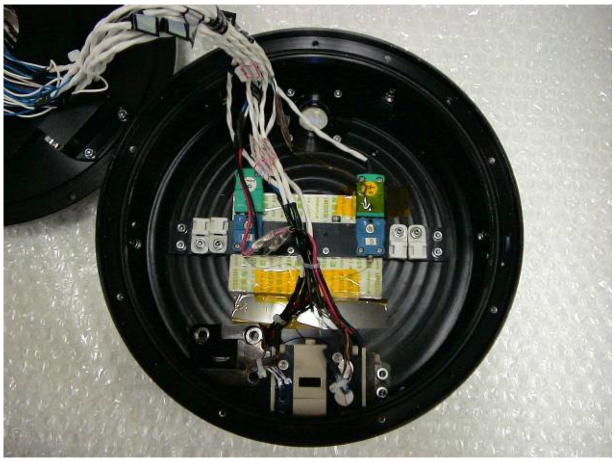


Fig. 3.2-3 Outline of SCOF Experiment Cell Cartridge envelope

(a) 

(b) 





(c) (d)

Fig. 3.2-4 Examples of Experiment Cell Cartridge (Engineering Model)

(a), (b): Experiment Cell Cartridge for Ice Crystal theme

(c), (d): Experiment Cell Cartridge for FACET theme

3.3 Protein Crystallization Research Facility (PCRF)

(1) Outline

The Protein Crystallization Research Facility (PCRF) is a system for generating high-quality protein crystals by using the space environment. It can mount up to six cell cartridges with electrical and thermal interfaces in the cell tray.

An operable CCD camera and illumination LED, which can be used to observe the actual sample, are installed in the cell tray.

Table 3.3-1 shows the main functions and basic specifications of the PCRF, and Fig. 3.3-1 shows photographs and schematic drawings of the exterior of the PCRF and interior of the cell tray.

Table 3.3-1 Main functions of PCRF (excerpts)

Main function	Basic specifications
Experimental control	(1) Experiment is conducted mostly by automatic control based on a program. (2) Telescience operation is possible
Observation system	Light source: LED (660 µm, 3000 mcd ×2) Valid pixels: 768 × 494 pixels Observation field: Ø6.7 mm ± 0.1 mm Resolution: ≥40 µm Sample illumination: Switching between transmitted light observation/reflected light observation Imaging device: 1/2-in. CCD camera Focus adjustment: Pan-focus Depth of field: 6 mm
Cell tray (see 2.5.2)	Allowable space: 300 mm (W) × 300 mm (L) × 80 mm (H) Electric interface: six systems (= number of cell cartridges that can be mounted simultaneously) Heat exhaust: By cold plate on bottom surface of cell
Temperature measurement/control system	Described in Table 3.3-2; depends on cell cartridge functions

Note: Among the obtained data, the image data are recorded and transmitted to Earth mainly via the Image Processing Unit (IPU). Although the data rates are set to a maximum of 25 Mbps (MPEG/MotionJPEG compression) for video recording and a maximum of 15 Mbps (MPEG2 compression) for transmission to Earth, they are subject to change because of various operational restrictions.

(a) (b) (c) (d)

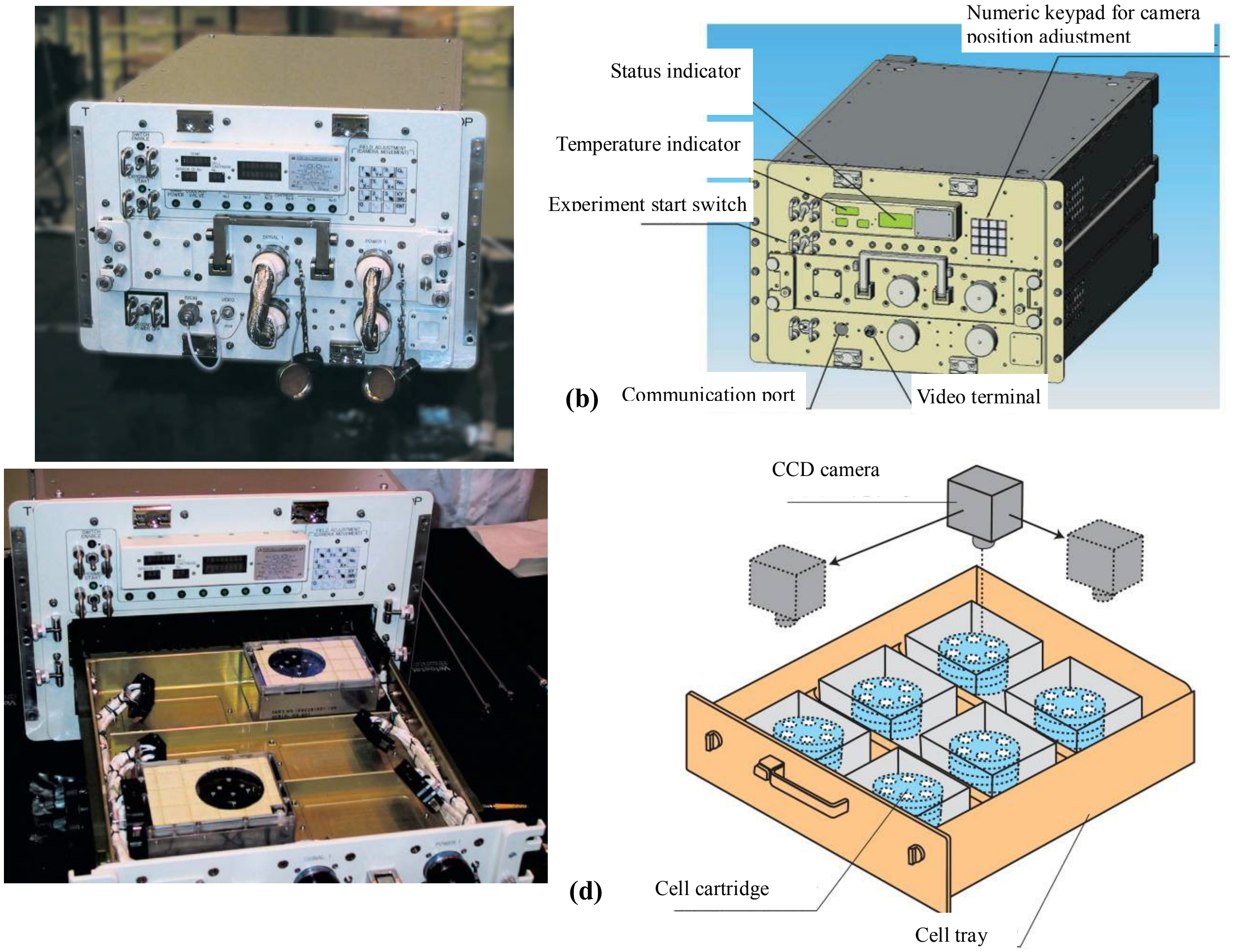


Fig. 3.3-1 External photographs and schematic drawings of PCRF:
(a) External photograph, (b) schematic drawing of external appearance,
(c) photograph of cell tray interior, (d) schematic drawing of cell tray interior

(2) Cell cartridge

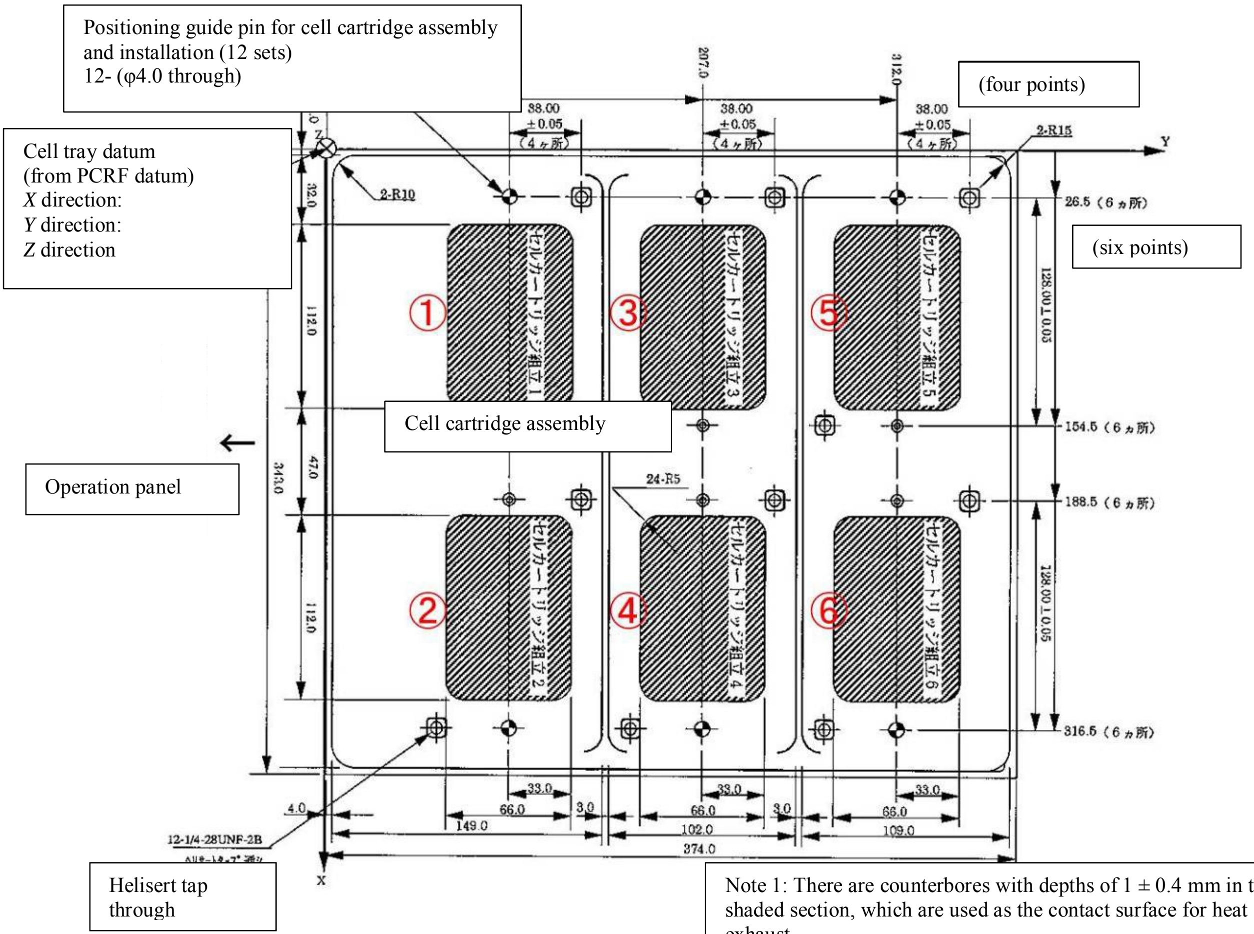
The removable cell cartridge stows the sample and the tools and materials around the sample.

As long as certain interface and safety conditions are satisfied between the cartridge and the main body of the PCRF system, the cell cartridge can be customized to suit the purpose of an experiment.

Table 3.3-2 shows the functions and resources available to the cell cartridge, and Figs. 3.3-2 and 3.3-3 show the available envelope, installation position, and heat exhaust surface.

Table 3.3-2 System functions available to cell cartridge (1) when electrical parts are prepared (The system has the corresponding electronic circuits.)

Item		System specifications	No. ch
Temperature measurement/ control	Thermistor	・Measurement range: -30–60°C ・Measurement precision: ±0.45°C ・Resistance: 113.6–2.89 kΩ ・Measurement frequency: 10 Hz	2
Heating/cooling	Peltier element	・Supplied current: ≤±4.2 A/ch ≤20 A/6 cell cartridges ・Control precision: ±5% FS ・Supplied power: ≤120 W/6 cell cartridges	1
Motor driving	Stepping motor	・No. of phases: five ・Supplied current: 0.75 A/phase (average value) ・Driving voltage: 15 V (DC) ・Supplied power: 2.5 W	1
Position detection	Photo sensor	・Supplied current: 10 mA ・Supplied power: 0.012 W ・Detection precision: ±10%	1
Optional power supply	-	・Driving current: 12 V ・Supplied current: ≤2 A	1



Note 1: There are counterbores with depths of 1 ± 0.4 mm in the shaded section, which are used as the contact surface for heat exhaust.
Note 2: Cell cartridge assembly number in cell tray is as shown in this figure.
Note 3: Open circles at cell tray pin positions indicate the reference datum for each cell cartridge.
Note 4: The dimensional tolerance is ±0.2 unless otherwise specified.

3.3-2 Interface for cell unit installation part

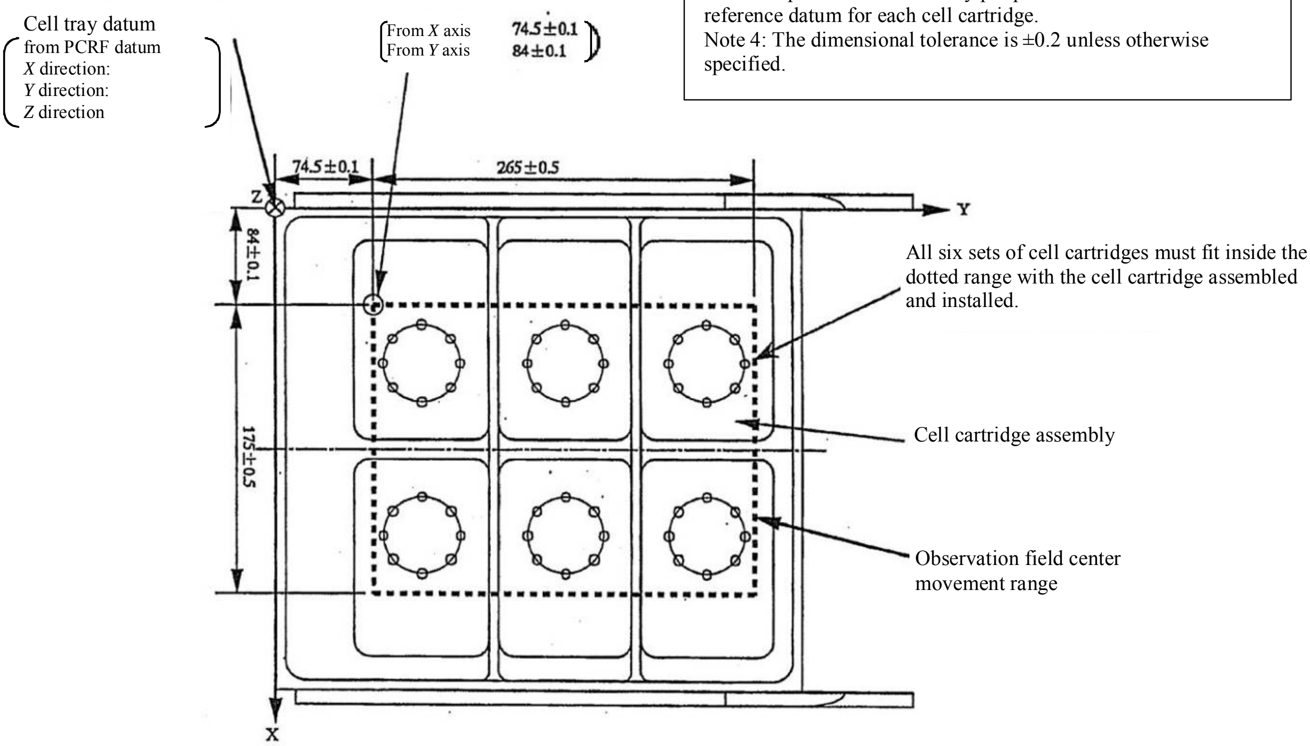


Fig. 3.3-3 Movement range of observation field center

3.4 Gradient Heating Furnace (GHF)

(1) Outline

The Gradient Heating Furnace (GHF) is a vacuum heating furnace capable of providing various temperature profiles by high-precision operation of three heating zones (central zone, end zone, and auxiliary zone), whose temperature can be controlled independently, installed inside the vacuum chamber. The temperatures of the zones can be controlled independently to support unidirectional solidification or crystal growth of the sample.

Table 3.4-1 shows the system specifications. Fig. 3.4-1 shows an external photograph and schematic drawing of the furnace main body, and Fig. 3.4-2 shows the sample cartridge and an example assignment of the three heating zones.

Table 3.4-1 Basic specifications of GHF

Item	Specifications
Method	Resistance heating, moving heating zone type
Heating temperature range	End zone: 500–1600°C (range of motion: ≤200 mm) Central zone: 500–1600°C (range of motion: ≤250 mm) Auxiliary zone: 500–1150°C (range of motion: ≤250 mm)
Temperature stability	≤ ±0.2°C
Temperature setting precision	≤ ±0.4%
Temperature gradient	≥ 150°C/cm (@1450°C)
Moving speed	0.1–200 mm/h and 600 mm/h
Moving speed stability	Moving speed setting value ≤ ±1% (moving speed 10–200 mm/h) Moving speed setting value ≤ ±10% or lower (moving speed 0.1–10 mm/h)
Heating zone insertion slot diameter	Ø40 mm
Measurement functions	Temperature: 10 points × 2 systems (individual sample cartridge: for high/medium to low temperatures) 5 points × 2 systems (for standard sample cartridge: for high/medium to low temperatures) Furnace pressure: Diaphragm-type pressure gauge, Pirani gauge, ion gauge
Marking mechanism	Has an interface capable of supplying pulse current to the sample cartridge
Operable cumulative time	300 h (@ maximum temperature)
Power consumption	≤ 5300 W

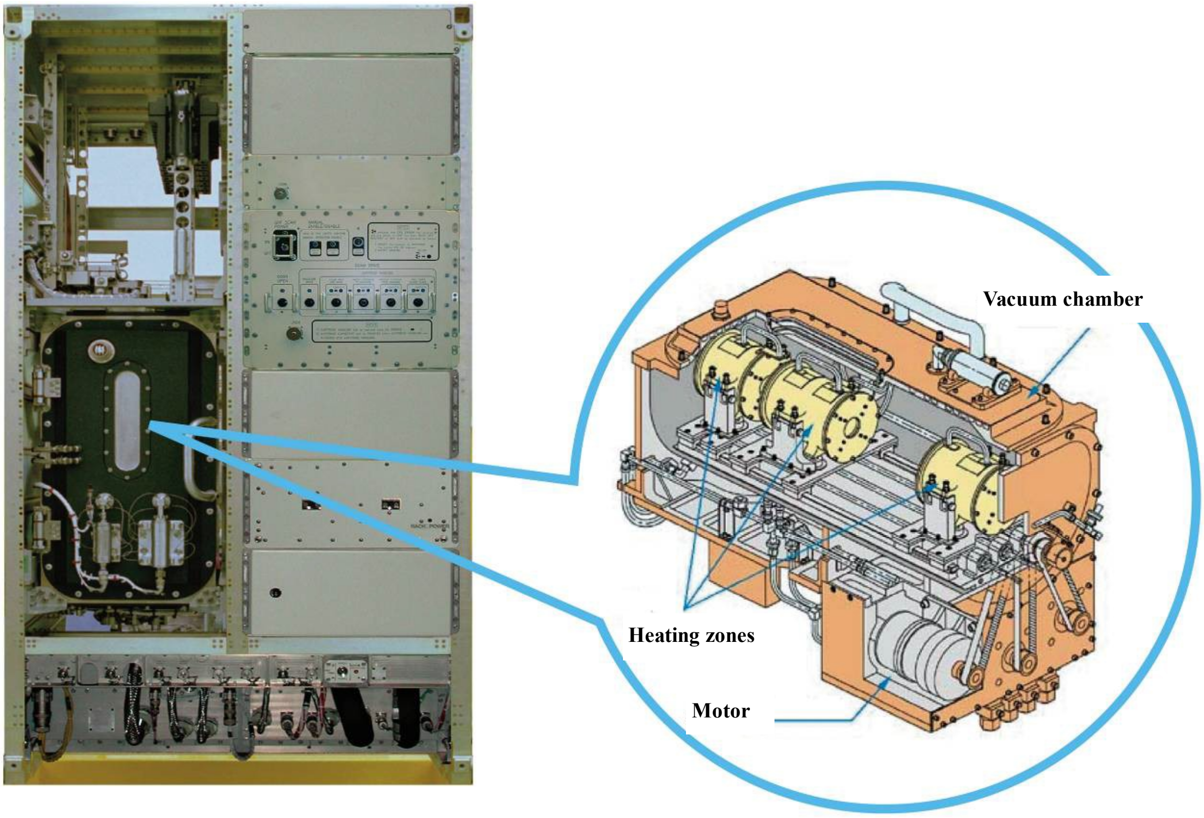


Fig. 3.4-1 External photograph and schematic drawing of furnace main unit

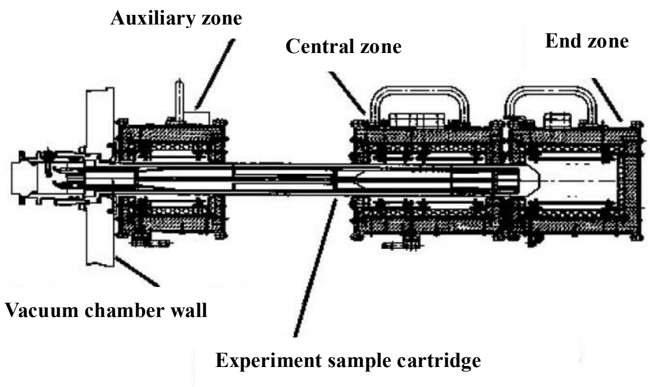


Fig. 3.4-2 Sample cartridge and example assignment of three heating zones

(2) Sample cartridge
Experiments are conducted in units of sample cartridges.

At present, one type of standard sample cartridge is defined. By presetting up to 15 of these standard sample cartridges in the Sample Cartridge Automatic Exchange Mechanism, experiments can be conducted fully automatically.

Table 3.4-2 shows the standard sample cartridge's specifications, and Fig. 3.4-3 shows its cross section.

Table 3.4-2 Basic specifications of standard sample cartridge

Item	Specifications
Dimensions	Boss part: - 93 mm Cartridge part: - 505 mm (Ø34.4–36.1 mm)
Weight characteristics	≤6 kg
Maximum sample dimensions	Ø31 mm × 370 mmL
Temperature measurement function	Normally at 5 points (≤10 points)

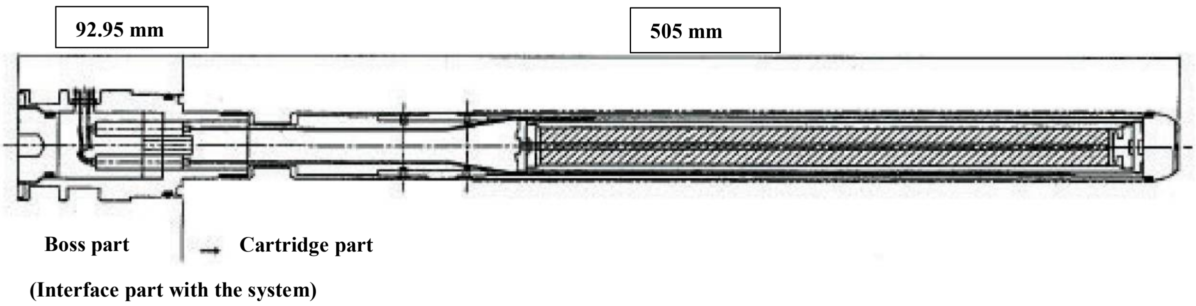


Fig. 3.4-3 Cross section of standard sample cartridge

3.5 Electrostatic Levitation Furnace

The Electrostatic Levitation Furnace is a material experiment system capable of heating or cooling a sample without a container by charging it to make it levitate under the Coulomb force and heating it with a laser (Fig. 3.5-1). Because this process does not require containers, it can be used to measure the thermophysical properties of high-temperature melts or search for new substances by supercooling solidification. Other types of levitation furnaces include the electromagnetic, ultrasonic, and gas levitation furnace. In comparison with these types, the Electrostatic Levitation Furnace has the following characteristics:

- **Any substance that can be charged, metal or insulator, can be used as the experimental sample.**
- **The atmosphere can be vacuum or gas.**

Fig. 3.5-1 Floating and heating in Electrostatic Levitation Furnace on earth

This system is mounted on the Multipurpose Small Payload Rack (MSPR) of the Japanese Experiment Module (Kibo) on the International Space Station. Because experiments using the Electrostatic Levitation Furnace under microgravity do not require large electric fields to balance gravity, the system has the following advantages:

- **Position control is easily realized for oxides with small charges and samples that are heavier than those used in levitation furnace experiments on earth.**
- **Because position control is realized in a gas atmosphere, in which discharge between electrodes tends to occur, experiments on alloys and oxides that evaporate in vacuum can be conducted. The Electrostatic Levitation Furnace consists of the main unit mounted in the MSPR Work Volume (WV), a UV light block mounted in the Small Experiment Area, and an Ar gas supply mounted at the bottom of the MSPR. By setting the sample holder packed with 15 samples into the sample cartridge and inserting it into the furnace's main unit, experiments can be conducted by command control from a terminal on Earth. The thermophysical properties, density, surface tension, and viscosity coefficient of the sample can be measured, and solidification phenomena can be observed in a supercooling solidification experiment; further, the solidified sample can be collected for investigation on Earth.**

Schematic drawings of the Electrostatic Levitation Furnace main unit and the other components are shown in Fig. 3.5-2, and a schematic drawing of the sample placement is shown in Fig. 3.5-3. The basic specifications are listed in Table 3.5-1.

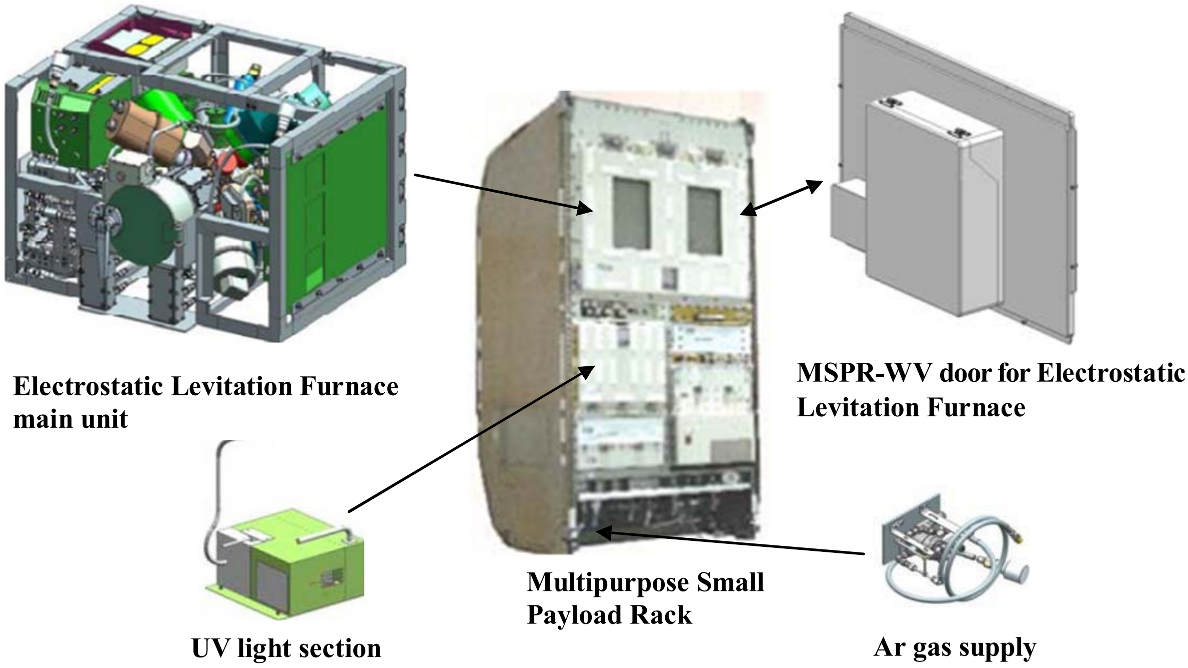


Fig. 3.5-2 Electrostatic Levitation Furnace

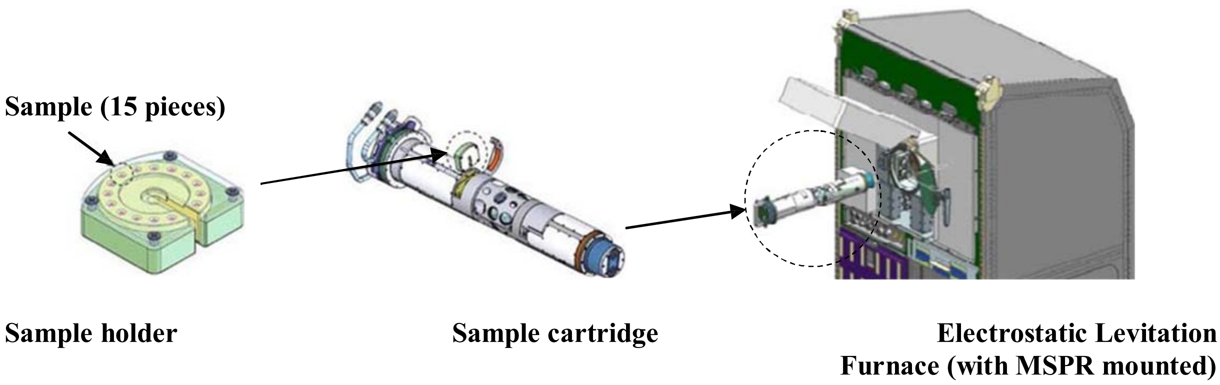


Fig. 3.5-3 Schematic drawing of sample placement

Table 3.5-1 Specifications of Electrostatic Levitation Furnace

Item	Specifications
Subject sample	**Mainly oxides. Metals, alloys, and semiconductors can also be used.** **- Shape: Spheres with diameter of 1.5 to 2.1 mm** **(Diameters of up to 5 mm can be obtained by sample cartridge replacement.)**
Position control	**Three-axis control** **- Control cycle: 1 kHz at max.** **- Control precision: ±100 μm or lower**
Atmosphere control	**- 2 atm air (oxygen concentration 10%)** **- 2 atm nitrogen** **- 2 atm argon** **- Vacuum (JEM exhaust system is used.)**
Heating function	**Heating laser (semiconductor laser)** **- Wavelength: 980 nm** **- Maximum optical output: 40 W × 4**
Temperature measurement	**- Measurement range: 300°C to 3000°C** **- Measurement frequency: 100 Hz**
Density measurement	**By using UV background light, the outline of a sample emitting light at high temperatures can be observed at 140 pixels/radius or better when the diameter is 2 mm.**
Surface tension/viscosity measurement	**Surface tension: Measurement using resonant frequency of melt** **Viscosity: Measurement using vibration damping factor** **- Vibration excitation: 1 to 600 Hz**
Solidification status observation	**- Resolution: 640 × 480 dots** **- Frame rate: 30 fps** **- Dynamic range: 120 dB or higher**

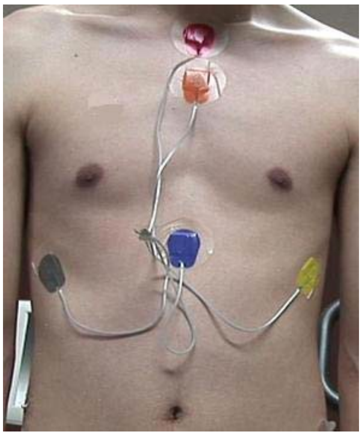
4 Devices for experiments with human subjects and for physiological research

4.1 Simplified biological function monitoring device (Holter electrocardiograph)

The simplified biological function monitoring device is a commercial Holter electrocardiograph (manufactured by Fukuda Denshi, Model FM-180, dimensions: 65 mm × 62 mm × 18 mm), which is a digital electrocardiogram recorder used for measurement and recording of electrocardiographic waveforms continuously for 24 h on orbit as sold commercially. The Holter electrocardiograph is shown in Fig. 4.1-1, and its specifications are listed in Table 4.1-1.

The electrocardiograph signals indicate the action potential of the heart, which is input from the special electrodes attached to the body surface [there are two intake channels (bipolar leads); see Fig. 4.1-2 for the electrode positions]. The action potential is converted into digital signals and recorded in a specially initialized multimedia card. After the measurement is complete, the data are first stored in the on-orbit PC to implement a down link to Earth. To reproduce and analyze the electrocardiographic data on Earth, special analysis software (manufactured by Fukuda Denshi, SCM-510J or SCM-510W) will be required.

Fig. 4.1-1 Holter electrocardiograph



(1) Ch1 lead name: CM5 lead
   Ch1 (-): Red electrode, upper end of breast bone
   Ch1 (+): Yellow electrode, V5 position
(2) Ch2 lead name: NASA lead
   Ch2 (-): Orange electrode, upper end of breast bone
   Ch2 (+): Blue electrode, lower end of breast bone
* Gray electrode is for grounding, V5R position.

Fig. 4.1-2 Electrode positions
(Measurement points: Bipolar leads)

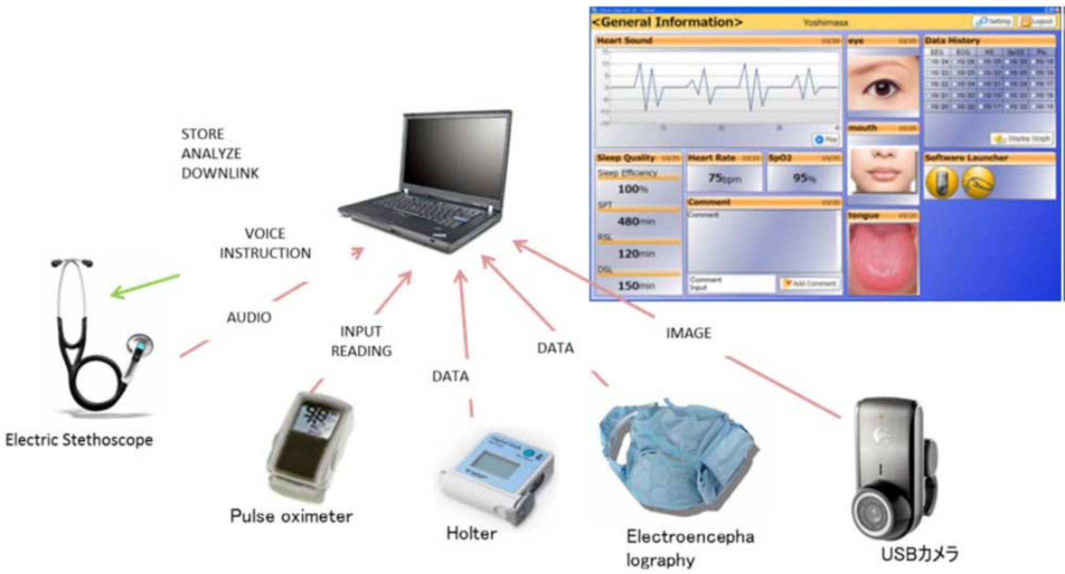
Table 4.1-1 Specifications of Holter electrocardiograph

Item	Specifications
Dimensions (reference: weight)	65 mm × 62 mm × 18 mm (78 g, including battery and memory card)
Power supply	1 AAA alkaline battery
Internal clock	RTC
Recording time	24 h
Recording media	Multimedia card (MMC-64)
CPU	16-bit single chip
Recording channels	Bipolar, two channels
Electrode voltage	±350 mV
Input impedance	10 MΩ or higher
Suppression of in-phase signal	60 dB or higher
Amplification rate	300 times (A/D input, monitor output)
Frequency characteristic	0.05/0.067 to 40 Hz
Monitor output	300 mV/1 mV
Quantization bit number	10-bit
Sampling frequency	125 Hz
Maximum input	±5.00 mV
Minimum resolution	±9.76 µV
Sensitivity precision, stability	Precision: Less than 5%, stability: maximum change 3% or smaller
Noise level	50 µVp-p or smaller
Interference between channels	0.2 mVp-p or smaller

Although the electrocardiograph also has acceleration sensors in the directions of the three axes (static position information detection), pacemaker pulse detection, and functions related to subject event recording functions, they are omitted from the range and procedures for on-orbit operation.

4.2 Onboard Diagnostic Kit

Onboard Diagnostic Kit (ODK) is a health-monitoring system capable of integrated management on orbit and simple analysis for the medical experiment data acquired from small high-performance various medical equipment. The various experimental devices such as electric stechoscope, sleep monitor, USB camera are used. USB camera is used to make a medical examination in the situation of eyes and teeth from the ground. The data of USB camera and electric stechoscope can be sent to the ground in real time. We plan to establish additional components in stages in the future for the development of space medicine research.



Constitution of the medical equipment which medical experiment data are collected and maneged in a space medicine experiment support system.

Main equipments are as follows.

(1) Laptop PC for medical experiments (Lenovo, Thinkpad T61p)

This is a standard laptop PC for use on orbit and is equipped with a special software program for medical experiments. The software is designed to take in medical data from the medical devices connected to the laptop and execute control, indication, and other functions on orbit through a simple interface.

The experimental devices that are supported include the USB camera, electronic stethoscope, and pulse oxymeter listed below, and it is also possible to take in the data from the Holter electrocardiograph described in Section 4.1. The data obtained from these devices are synchronized using the same software mounted on the ground system after a simple analysis on orbit so that medical personnel on Earth can check an electronic chart similar to that on orbit.

Furthermore, it is possible to easily down link the data from the laptop PC with a command from Earth, as long as the data can be saved on the laptop PC even if they have been obtained from a new device.

Laptop PC for medical experiments **Electronic chart software for on-orbit diagnosis**

(2) USB camera (Logitec, Webcam C905)

This is a standard on-orbit USB camera, and it is used to check for changes in physical conditions by imaging the eyes, tongue, and other areas or to support on-orbit work as an alternative in-station camera. It can also be used to connect with the ground system in a TV conference for real-time medical interviews and other communication.

USB camera

○Video: Up to 2 million pixels
(HD720p wide-screen mode supported)
○Still images: Up to 8 million pixels
○Communication with PC: USB 2.0

(3) Electronic stethoscope (3M Littman, Model 3200)

This can be used to convert the auscultatory sound into digital sound and transmit it to the laptop PC in real time via a Bluetooth interface. The obtained data are analyzed on site to detect heart murmurs. It can also transmit the auscultatory sound to the ear tips on Earth in real time; this enables on-orbit diagnosis while the physician stays on Earth.

electronic stethoscope

○Filter: Bell mode, Diaphragm, Extended mode
○Power supply: 1 AA alkaline battery
○Communication with PC: Class 2 Bluetooth

(4) Pulse oxymeter (Japan Precision Instruments, Inc., OxiHeart OX-700)

This can be used to measure the blood oxygen saturation and pulse rate by a simple procedure. The data can be checked visually and input manually on the laptop PC.

○Measurement range: Blood oxygen saturation and pulse rate
○Power supply: Two AAA alkaline batteries

Pulse oxymeter

(5) Head set (Sennheiser Communications, CC550)

This is a monaural head set for both ears that can be used to connect with Earth in TV conferences for real-time medical interviews and other communication. It is connected to the laptop PC with a USB connector via the head set cable (UUSB6). Its strong noise-canceling function improves the voice quality even in environments with high levels of noise.

○Cable length: 1 m [3 m in total in combination with head set cable (2 m in length)]

4.3 Devices for space medicine research by agencies other than JAXA

There are other devices and systems that are owned by PIs other than JAXA and that can be used for space medicine research as follows.
These devices are used by international cooperation, and they are not always available depending on the space experiment plans.

Table 4.3-1 Devices and systems used for space medicine research

Hardware Available to Support Human Subject Research	**Agency**	**Website**
Physiological Monitoring		
Blood Pressure/Electrocardiograph	NASA	Sally Davis, CheCS Hardware, sally.p.davis@nasa.gov
Automatic Blood Pressure Cuff	NASA ESA	Sally Davis, CheCS Hardware, sally.p.davis@nasa.gov http://www.cnes.fr/web/CNES-fr/8781-epm.php
Continuous Blood Pressure Device	NASA ESA	http://www.nasa.gov/mission_pages/station/research/experiments/625.html http://www.cnes.fr/web/CNES-fr/8781-epm.php
Pulmonary Function System	NASA/ESA	http://www.nasa.gov/mission_pages/station/research/experiments/336.html http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Pulmonary_Function_System_PFS
Portable Pulmonary Function System	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Pulmonary_Function_System_PFS
ECG Holter Monitor	NASA/ JAXA/ESA	http://www.nasa.gov/mission_pages/station/research/experiments/614.html http://kibo.jaxa.jp/en/experiment/pm/holter/holter.pdf http://www.cnes.fr/web/CNES-fr/8781-epm.php
JAXA Onboard Diagnostic Kit	JAXA	Ask the JAXA contact person http://www.nasa.gov/mission_pages/station/research/experiments/843.html
Ultrasound 2 Doppler	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/749.html
Thermolab	ESA	http://eea.spaceflight.esa.int/portal/exp/?id=9338
SKIN B H/W Kit	DLR	http://eea.spaceflight.esa.int/portal/exp/?id=9392
Space Linear Acceleration Mass Measurement Device	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/640.html
Sample Collection and Stowage		
Human Sample Collection Kits	NASA	TBD
Refrigerated* Centrifuge *refrigeration function is failed	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/639.html
Exercise		
Cycle Ergometer	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/841.html
Treadmill	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/765.html

Cycle Ergometer	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/841.html
Treadmill	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/765.html
Advanced Resistive Exercise Device	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/1001.html
Muscle Strength, Torque, and Joint Angle		
Muscle Atrophy Research and Exercise System	NASA/ESA	http://www.nasa.gov/mission_pages/station/research/experiments/352.html http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Muscle_Atrophy_Research_Exercise_System_MARES http://www.cnes.fr/web/CNES-fr/8783-mares.php
Percutaneous Electrical Muscle Stimulator	NASA/ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Percutaneous_Electrical_Muscle_Stimulator_PEMS
Hand Grip/Pinch Force Dynamometer	NASA/ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Hand_grip
Activity Monitoring		
Actiwatch	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/858.html
Armband monitoring	ESA	http://www.cnes.fr/web/CNES-fr/8914-energy.php
Coordination		
ELITE-S2	ASI	http://www.nasa.gov/mission_pages/station/research/experiments/78.html
Eye Tracking Device (ETD)	DLR	http://eea.spaceflight.esa.int/portal/exp/?id=8225
HPA	ASI	http://www.nasa.gov/mission_pages/station/research/experiments/223.html
European Physiology Modules		
Multi Electrode EEG Mapping Module	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/International_Space_Station/European_Physiology_Modules http://www.cnes.fr/web/CNES-fr/8781-epm.php
Portable EEG (PORTEEMM)	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/International_Space_Station/European_Physiology_Modules http://www.cnes.fr/web/CNES-fr/8781-epm.php
Sample Collection Kit (SCK)	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/International_Space_Station/European_Physiology_Modules http://www.cnes.fr/web/CNES-fr/8781-epm.php
CARDIOLAB	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/International_Space_Station/European_Physiology_Modules http://www.cnes.fr/web/CNES-fr/8781-epm.php

5 Devices common to multiple fields

5.1 Multipurpose Small Payload Rack (MSPR)

The Multipurpose Small Payload Rack (MSPR) has been developed to provide a work space equipped with a power supply, communication functions, and other functions assuming that users would develop and install their own equipment and conduct experiments.

The MSPR provides three experimental spaces: the Work Volume (WV), Work Bench (WB), and Small Experiment Area (SEA). The WB is a table that can be used for sample adjustment, maintenance work, and similar activities, and experimental devices can be installed in the WV and SEA.

For users who wish to conduct combustion experiments, the Chamber for Combustion Experiments (CCE), which can be installed in the WV, is provided as a component of the MSPR. The CCE comes with an explosion-proof structure against the Japanese Experiment Module (JEM) and an interface (I/F) with the JEM gas supply and exhaust system. It simplifies the development of combustion experiment devices by users because the power/communication I/F inside the WV can be used via the CCE.

The MSPR is shown in Fig. 5.1-1, and its proposed basic specifications are listed in Table 5.1-1.

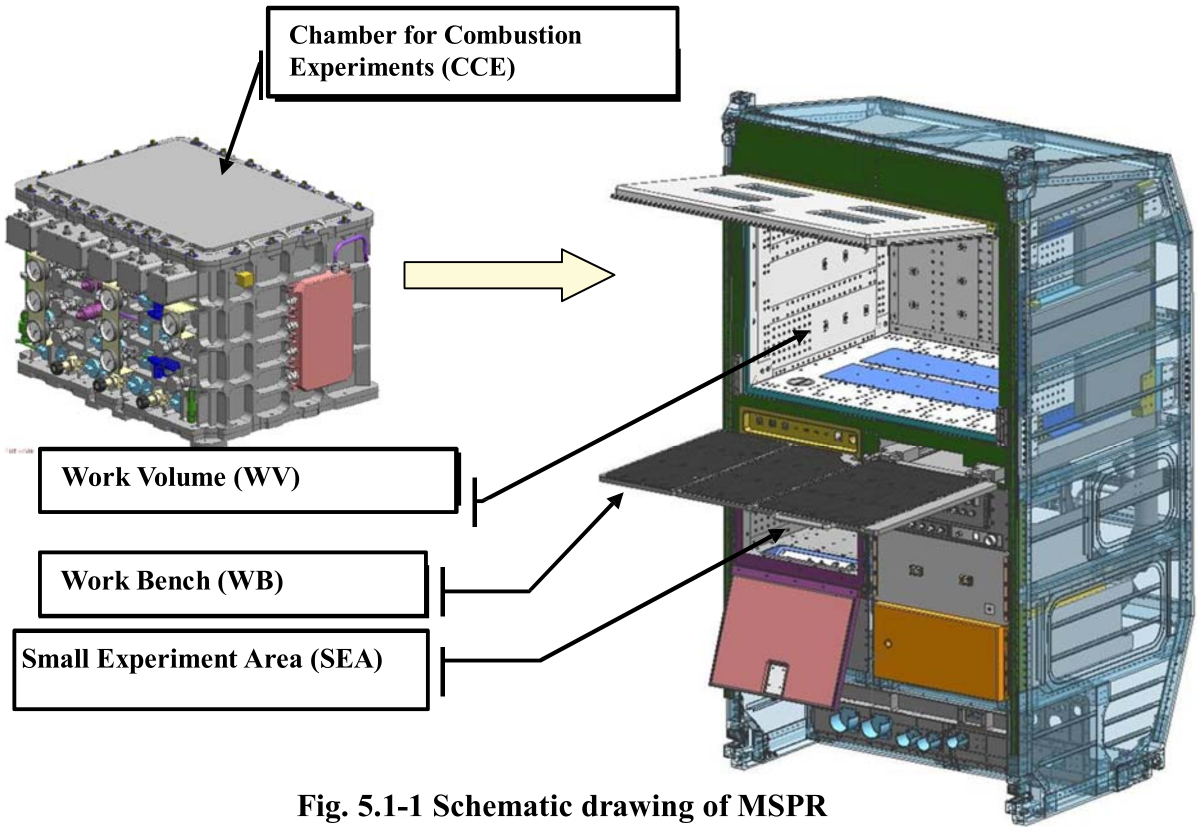


Fig. 5.1-1 Schematic drawing of MSPR

Table 5.1-1 (1/3) Specifications of MSPR

Experimental area	Item	Specifications
Work Volume (WV)	Volume	900 mm (W) × 700 mm (D) × 600 mm (H)
	Supplied power	28 V (DC): 400 W × 1, 16 V (DC): 100 W × 1, 12 V (DC): 100 W × 1 to total of 600 W
	Heat exhaust mechanism	Combination of avionics air cooling, cold plate cooling, and water cooling - Avionics air - Flow rate: 90 kg/h - Exhaust heat rate: Approx. 370 W - Supply temperature: Approx. 17 to 32.5°C - Cold plate or water cooling (switched by selection) - Exhaust heat rate: 450 W at max.
	Gas exhaust	Operating pressure: 101 kPa to 0.13 Pa Exhaust temperature: 13 to 45°C Exhaust control: User enables and disables gas release/cut off at a valve in the user equipment.
	Gas supply	Supplied gas: GN2 (supplied from JEM GN2) Supplied pressure: 0.52 to 0.83 MPa (1.38 MPa in case of abnormality) Supply rate: 72 nL/min or lower Supply temperature: 15.6 to 45°C
	Communication system	Communication port: IEEE1394 (400 Mbps) × 1, Ethernet (100Base-T) × 2, USB2.0 (series A) × 3 VIDEO (coaxial: unbalanced) × 3, ANALOG (±10 V) × 3 (3 ch at maximum with simultaneous use by WV and SEA) TS (thermostat signal) × 1

Table 5.1-1 (2/3) Specifications of MSPR

Experimental area	System	Design specifications
Work Bench (WB)	Size	900 mm (W) (TBD) × 540 mm (D) (TBD)
	Supplied power	16 V (DC): 100 W × 2 [of these, one system is branched and shared with the 16 V (DC) for the WV, 100 W in total]: For laptop PC
	Communication system	Communication port: IEEE1394 (400 Mbps) × 1 Ethernet (100Base-T) × 3 USB2.0 (series A) × 1 USB2.0 (series B) × 2 VIDEO (coaxial: unbalanced) × 2 TS (thermostat signal) × 1
Small Experiment Area (SEA)	Volume	412 mm (W) × 530 mm (D) × 300 mm (H)
	Supplied power	12 V (DC): 100 W × 1
	Commun-ication system	Communication port: Ethernet (100Base-T) × 1 USB2.0 (series A) × 1 VIDEO (coaxial: unbalanced) × 2 ANALOG (±10 V) × 3 (3 ch at maximum with simultaneous use by WV and SEA) TS (thermostat signal) × 1
	Heat exhaust mechanism	Avionics air cooling - Flow rate: 35 kg/h - Exhaust heat rate: Approx. 140 W - Supply temperature: Approx. 17 to 30°C

Table 5.1-1 (3/3) Specifications of MSPR

<table>
<tr><th>Experimental area</th><th>Item</th><th>Specifications</th></tr>
<tr><td rowspan="6">Chamber for Combustion Experiments (CCE)</td><td>Size</td><td>Space available for user equipment:
(from the bottom surface inside CCE to 20 mm in height)
550 mm (W) × 351 mm (D) × 520 mm (H)
(Height 20 mm to 520 mm)
550 mm (W) × 354 mm (D) × 520 mm (H)</td></tr>
<tr><td>Supplied power</td><td>In accordance with WV specifications above (WV supply power is introduced into the chamber via a hermetic seal connector on chamber wall.)</td></tr>
<tr><td>Heat exhaust mechanism</td><td>Avionic air cooling (CCE external surface) and cold plate cooling (CCE bottom surface)
See the section on the WV above for heat exhaust capacity. However, the user equipment exhausts heat by thermal contact conductance on the bottom surface inside the CCE.</td></tr>
<tr><td>Gas exhaust</td><td>Exhaust performance conforms to specifications for WV above. However, it also depends on the pressure drop inside the CCE internal piping, including the user equipment. It also has an area and connection port to install a contamination removal filter prepared by the user for combustion gas exhaust. The gas exhaust method depends on the nature of the experiment; the options are a method in which gas passes through the filter once (one path) and a circulation method that removes contamination sufficiently by letting it pass through the filter several times.</td></tr>
<tr><td>Gas supply</td><td>- N_2 gas supply (from JEM GN2 line)
- Supply pressure: 0.2 MPa (controlled by CCE regulator)
- Maximum supply flow rate: 4.47 L/min @27°C, 0.1 MPa (TBD)
- Supply temperature: 15.6 to 45°C
- User gas bomb A (prepared by user)
The user installs gas bomb A for the experiment inside the SEA and supplies it to the chamber using the penetration port between the WV and SEA. Flammable gas cannot be used.
- Bomb volume: Selected from two options (1 L and 2.25 L)
- Maximum filling pressure: 10 MPa or lower
- Maximum supply flow rate: 4.8 L/min @27°C, 0.1 MPa (TBD)
- User gas bomb B (prepared by user)
An area and connection port are available in which the user can prepare gas bomb B for an experiment on the chamber’s inner wall.
- Bomb volume: Selected from two options (1 L and 300 cc)
- Maximum filling pressure: 10 MPa or lower
- Maximum supply flow rate: 73.82 L/min @27°C, 0.1 MPa (TBD)</td></tr>
<tr><td>Commun-ication system</td><td>The communication port conforms to that in the WV described above (like the supplied power). However, the user cannot use ANALOG × 3 because they are used for a pressure sensor (× 1) and CO_2 sensors (× 2) in the CCE. ANALOG cannot be used in WV or SEA in addition to the CCE because the CCE uses all three lines.</td></tr>
</table>

5.2 Super-Sensitive High-Definition Television Camera (SS-HDTV) system

The Super-Sensitive High-Definition Television Camera (SS-HDTV) system is a camera system equipped with an electron-multiplying CCD that is sensitive from the visible range to the infrared range. It can be used to shoot color video under illumination equivalent to moonlight, and it is suitable for shooting video of Earth at night from the window of Kibo or Cupola.

The shot video is stored temporarily in the built-in SD card in the recorder and is down-linked to Earth as it is reproduced.

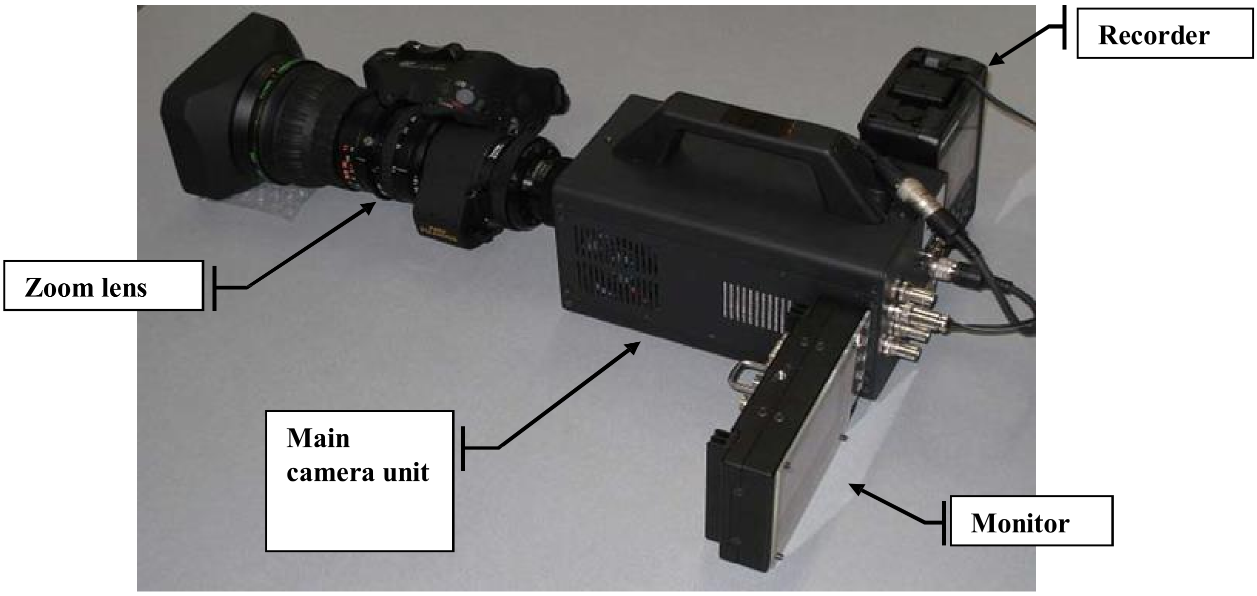


Fig. 5.2-1 SS-HDTV system

Table 5.2-1 Specifications of SS-HDTV system

Item	Specifications
Video recording standard	1920 × 1080i
Frame rate	59.94 Hz
Image pickup device	2/3-type EM-CCD
Effective pixels	Approx. 1.2 million pixels
Minimum object illumination	0.02 lx
Lens	4.8 mm, 8 mm, 17 mm, 25 mm (fixed focal length lens) 7.6 to 137 mm 16× (zoom lens)
Filter	IR Cut Filter, etc.

5.3 Microscope Observation System

The Microscope Observation System consists of a microscope, a power supply and control unit (Microscope Controller), a VGA-NTSC converter, and an Experiment Laptop Terminal (ELT). It is used to conduct transmitted light observation, phase difference observations, and fluorescence observations. It also supports live imaging for use of gene recombinants such as cyprinodonts and zebrafish. A schematic drawing of the system is shown in Fig. 5.3-1.
It is installed inside the Work Volume of the Multipurpose Small Payload Rack (MSPR) or on top of the Maintenance Work Area (MWA) in Kibo. During an experiment, the crew at the International Space Station set up the biological sample, and remote observations and operations are conducted by command from Earth via the ELT. The recorded image files are transferred to Earth.

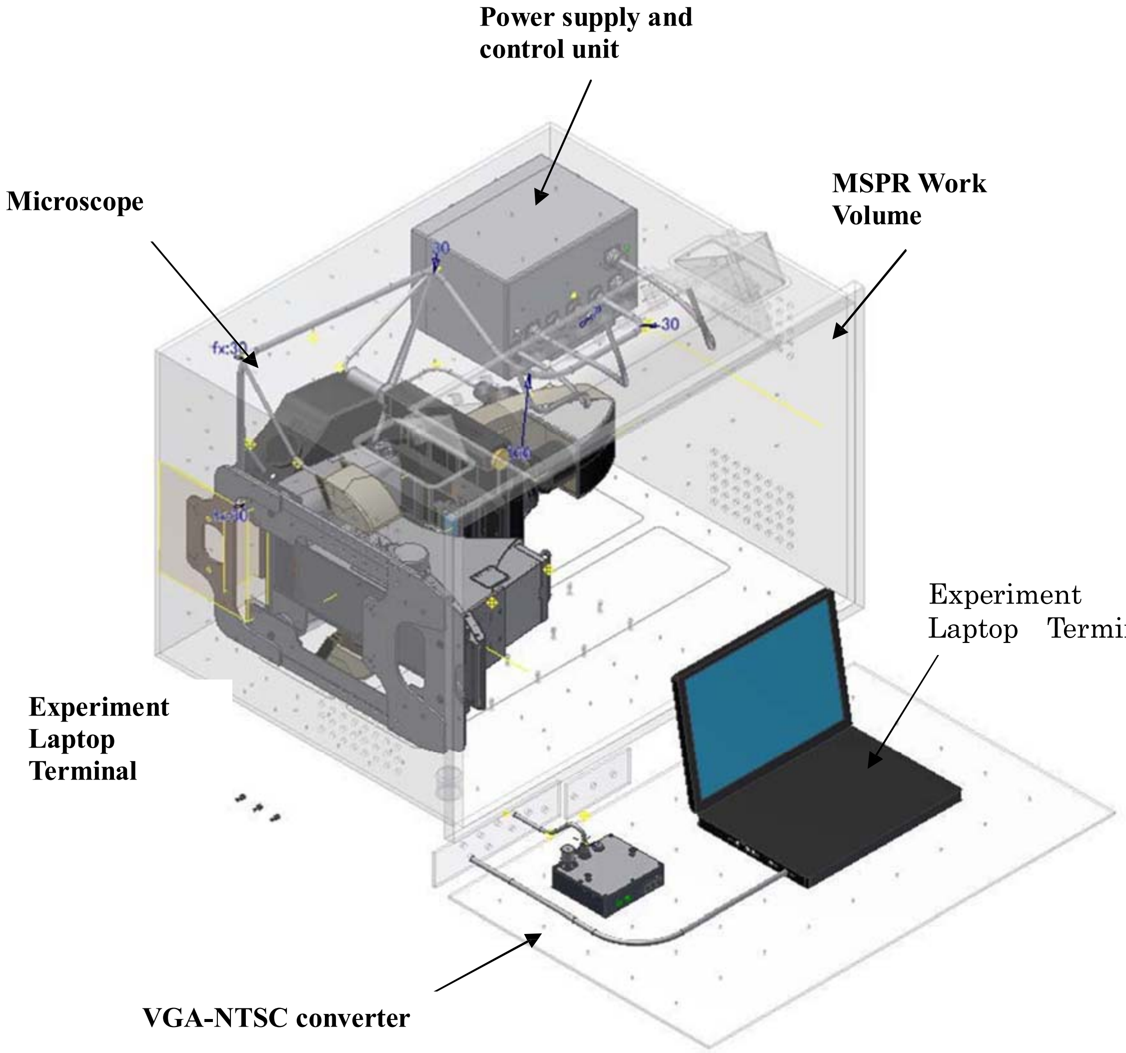


Fig. 5.3-1 Microscope Observation System

(1) Microscope

The microscope is an inverted vertical illumination fluorescence microscope (DMI6000B, Leica Microsystems) partially modified to fit the space. It is shown in Fig. 5.3-2, and its main specifications are listed in Table 5.3-1. Because it is based on a commercial product, its object lens and fluorescence filter can be replaced with those suited to an experiment. All the microscope operations on the stage, object lens revolver, fluorescence filter turret, and capacitor are conducted electrically.

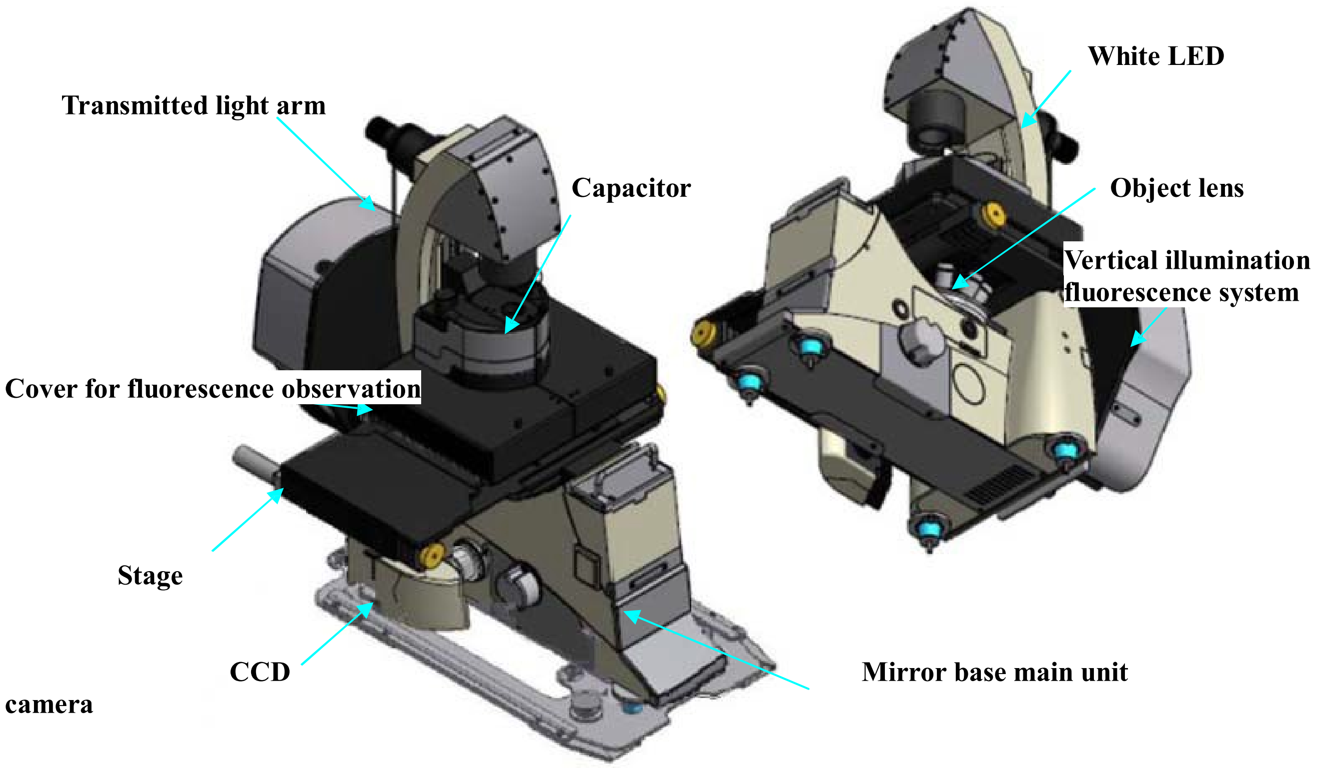


Fig. 5.3-2 Microscope

(2) Power supply and control unit (Microscope Controller)

The power supply and control unit control the power supply to the microscope and the communication interface between the ELT and the microscope.

(3) VGA-NTSC Converter

The screen of the ELT on orbit is transmitted to Earth via the VGA-NTSC converter for real-time monitoring.

(4) ELT

This is installed with a software program for microscope control that communicates with the power supply and control unit, and controls and monitors the microscope operation. The obtained microscope image file is recorded on orbit to be transmitted to Earth in response to a command from Earth.

Table 5.3-1 Specifications of microscope (1/2)

Item	Specifications	Remarks
Mirror base main unit	Basic specifications - Electric object lens revolver (six at max.) - Electric Z drive focus (stroke 9 mm) - Camera port (left-side port) Transmitted light path control - Aperture stop/field stop (electric) - Filter magazine (electric) Vertical illumination light path control - Brightness/aperture stop/field stop (electric) - Filter turret (electric/filter cube, six sets at max.)	Binocular tube is already removed for operation and observation via PC.
Object lens	- N PLAN 5X/0.12 PH0 (working distance 14 mm) - N PLAN 10X/0.25 PH1 (working distance 17.6 mm) - N PLAN 20X/0.35 PH1 (working distance 6.9 mm) - HI PLAN I 40X/0.50 PH2 (working distance 2.0 mm) - PLAN APO 20X/0.70 PH2 HC (working distance 0.59 mm) - PL APO 40X/0.75 PH2 HCX (working distance 0.28 mm)	For fluorescence, phase difference, and bright field observations
Capacitor	Capacitor (mot S70) - Capacitor turret (seven holes) - Supports object lens magnifications of 1.25× to 100× - Built-in aperture stop (electric) Light ring - PH0 (object lens 5×, phase difference observation) - PH1 (object lens 10×, 20×, phase difference observation) - PH2 (object lens 20×, phase difference observation)	
Stage	XY scanning stage - Stepping motor operation - Range of motion 83 × 127 mm Holder for microtiter - Microtiter plate (83 × 127 mm) supported - Clamp is used to maintain sample container holder.	Sample container holder is customized for the mounted sample.
Transmitted light arm	TL arm mot. - Built-in electric shutter - Built-in gray filter N2 Collimated white light LED - Wavelength 435 to 675 nm	Collimated white light LED is used as the transmitted light source.

Table 5.3-1 Specifications of microscope (2/2)

Item	Specifications	Remarks
Vertical illumination fluorescence system	**LED fluorescent light source SFL7000** **- Up to five LED modules installed** **LED module** **- 365 nm (excitation light 365 nm)** **- 470 nm (excitation light 470 nm, EGFP supported)** **- 530 nm (excitation light 530 nm, DsRed2 supported)** **- 620 nm (excitation light 620 nm)**	
Fluorescence filter cube	**- A4 (excitation filter 340–380 nm, absorption filter 470/40 nm)** **- L5 (excitation filter 480/40 nm, absorption filter 527/30 nm)** **- N3 (excitation filter 546/12 nm, absorption filter 600/40 nm)** **- Y5 (excitation filter 620/60 nm, absorption filter 700/75 nm)**	**UV excitation** **EGFP observation supported** **DsRed2 observation supported** **Infrared range**
CCD camera	**DFC 360FX camera** **- Pixel number: 1392 × 1040** **- Scan area: 9.0 × 6.7 mm** **- Pixel size: 6.45 × 6.45 µm** **- Exposure time: 4 µs to 600 s in 1 µs increments** **- Binning possible**	**Connected via the C mount adapter 0.7 X HC**
Cover for fluorescence observation	**Cover for fluorescence observation** **- For stage shading**	

5.4 Laboratory Support Equipment (LSE)

The laboratory support equipment that can be used in Kibo is listed on the following pages. This equipment can be mounted immediately because various certifications for mounting have already been completed.

To pack the launched samples, air cushions (List No. 34-36), foam cushions (No. 44), and similar materials can be used. Please take their weight into consideration.

LSE (Laboratory Support Equipment) catalog

No.	Name	Product	Dimensions	Weight	Remarks	Photo
1	ZIPLOC Sandwich bag	LSE-ZIP001	6 1/2in x 5 7/8in (16.5cm × 14.9cm)	298 g/93 pieces Includes weight of box		
2	ZIPLOC Snack Bags	LSE-ZIP002	6 1/2in x 3 1/4in (16.5cm × 8.3cm)	246 g/100 pieces Includes weight of box		
3	ZIPLOC Sandwich Bags	LSE-ZIP003	7 in. × 8 in. (medium) (17.8 cm × 20.3 cm)	296 g/40 pieces Includes weight of box	Sandwich bag has no printing. Product procured by Japan has “freezer” printed on it.	
4	ZIPLOC FREEZER BAGS	LSE-ZIP004	One pint (17.7cm x 12.7cm)	130 g/20 pieces Includes weight of box		
5	ZIPLOC FREEZER BAGS	LSE-ZIP005	One quart (20.3cm × 17.7cm/ 7in × 8in)			No Picture
6	ZIPLOC FREEZER BAGS	LSE-ZIP006	One gallon (large) (26.8 cm × 27.9 cm/109/16 in. × 11 in.)	310 g/30 pieces Includes weight of box	30 pieces/box	
7	ZIPLOC FREEZER BAGS	LSE-ZIP007	Two Gallon (33.0cm × 39.7cm/ 13in x 15 5/8in)	244 g/12 pieces Includes weight of box	12 pieces/box	
8	ZIPLOC BIG BAGS	LSE-ZIP008	X-Large (60.96cm × 51.82cm/ 2ft × 1.7ft)	350 g/4 pieces Includes weight of box	4 pieces/box	
9	ZIPLOC BIG BAGS	LSE-ZIP009	XX-Large (60.96cm × 82.3cm/ 2ft × 2.7ft)	354 g/3 pieces Includes weight of box	3 pieces/box	No Picture

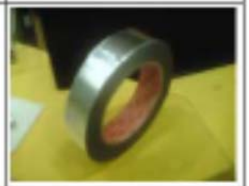
LSE (Laboratory Support Equipment) catalog

No.	Name	Product No.	Dimensions	Weight	Remarks	Photo
10	Antistatic ziploc bag	LSE-ZIP010	4 in. × 6 in. (size: 100 × 150)	212 g/110 pieces	Antistatic clean vinyl zipper-type bags	
11	Antistatic ziploc bag	LSE-ZIP011	8 in. × 12 in. (size: 200 × 300)	85 g/5 pieces	Antistatic clean vinyl zipper-type bags	
12	Antistatic ziploc bag	LSE-ZIP012	10 in. × 14 in. (size: 250 × 350)	950 g/90 pieces	Antistatic clean vinyl zipper-type bags	
13	Antistatic ziploc bag	LSE-ZIP013	12 in. × 16 in. (size: 300 × 400)	558 g/42 pieces	Antistatic clean vinyl zipper-type bags	
14	Velcro Hook	LSE-VH001	1 in. wide		Rating A HI-AIR Brand hook66 1" Natural 017 Sew-on 0399 (re-order part#:190525)25yard/roll 100% Nomex-nylon	
15	Velcro Loop	LSE-VL001	1 in. wide	210g/14m	Rating A HI-AIR Brand Loop003 1" Natural 017 Sew-on 0399 (re-order part#:190995) 25yard/roll 100% Nomex-nylon	
16	Grove (Medium size)	LSE-GV001	15 cm × 23 cm (box size) thickness: 0.5 mm (when spread out)	742 g/100 pieces Includes weight of box	New nitrile ultrathin glove	
17	Grove (Large size)	LSE-GV002	13 cm × 250 cm × 80 cm (box size)	686 g/100 pieces Includes weight of box	New nitrile ultrathin glove	
18	Benzalkonium Chloride Antiseptic Towelette	BCCK003	5 cm × 5.5 cm thickness: 3 mm	4 g/1 piece	Import of this product into Japan is prohibited. Ref/ Recorder No. D35100, NDC10619-3737-1	

LSE (Laboratory Support Equipment) catalog

No.	Name	Product No.	Dimensions	Weight	Remarks	Photo
19	Sterilized Water Bottle	BCCK002			3.0R	
20	Sanita-kun	BCCK001-1			Quick type for fungi	
21	Blower	E-270A	φ 5.5cm(Max) × 13.5cm	50 g/1 piece	Jet blower (black)	
22	Lint Free Wipe	LSE-DW001	30.4 cm × 30.4 cm; thickness: 1 mm	1298 g/100 pieces	Kimtech Pure CL4 critical task wiper (crew) 100% Polypropylene	
23	Cable tie	PLT1M-C702Y	Width 0.5 cm (max) × 10 cm; height 5 mm (max)	30 g/48 pieces	Rating A Halar material L: 102 mm, W: 2.5 mm, T: 101 mm	
24	Cagle tie	PLT2S-C702Y	Width 0.8 cm (max) × 19 cm; height 6 mm (max)	116 g/50 pieces	Rating A Halar material L: 188 mm, W: 25 mm, T: 1.1 mm	
25	Waste cloth (small)	SWC-30	28 cm × 30 cm thickness: 2 mm	28 g/1 pieces	Super wiping cloth, gray	
26	Waste cloth (large)	SWC-60	29 cm × 60 cm thickness: 2 mm	56 g/1 pieces	Wiping cloth	
27	Towel	P-GJ-MU	32 cm × 35 cm thickness: 0.5 mm	1234 g/54 pieces	Knitted fabric waste cloth (1 kg type)	

LSE (Laboratory Support Equipment) catalog

No.	Name	Product No.	Dimensions	Weight	Remarks	Photo
28	Aluminum tape	P-100	15 mm (0.59 in.)			
29	Kapten tape (polyimide tape)	LSE-KAP001	No. 5413 (1 in. wide)	92 g/1 roll	・Rating A	
30	Cotton swabs	P1506-30	φ10 cm wide 2.5 cm		Cotton ball: One end, cotton diameter: 1.0 (±0.5) mm, stick material: Paper, stick length: 150.0 (±3.0) mm, bag qty: 30	
31	Paper diapers	LSE-WA001				
32	Ziploc bag with holes (Velcro?)	LSE-ZIP014				
33	Double-sided tape	LSE-DST001	Width 1 in.		Rating A	
34	Electrostatic discharge (ESD) bubble wrap (large)	528-43072-8	345 mm * 78 mm * 7 mm	200 g	Air cushion with antistatic function	
35	Electrostatic discharge (ESD) bubble wrap (medium)	528-43072-2	320 mm * 320 mm * 7 mm	70 g	Air cushion with antistatic function	
36	Electrostatic discharge (ESD) bubble wrap (small)	528-43072-7	125 mm * 210 mm * 7 mm	20 g	Air cushion with antistatic function	

LSE (Laboratory Support Equipment) catalog

No.	Name	Product No.	Dimensions	Weight	Remarks	Photo
37	HDV Tape	PHDVM-63DM	66 mm * 48 mm * 13 mm	19.6g	Mini-DV tape for high definition	
38	Soft Bag 1/2X Size	JMH-074127-HX001	248 mm * 502 mm * 235 mm	0.98 kg	Bags for launch/storage in ISS	
39	Soft Bag 1X Size	JMH-074127-1X001	248 mm * 502 mm * 425 mm	1.7 kg	Bags for launch/storage in ISS	
40	Soft Bag 2X Size	JMH-074127-2X001	502 mm * 502 mm * 425 mm	2.04 kg	Bags for launch/storage in ISS	
41	Soft Bag 3X Size	JMH-074127-3X001	749 mm * 502 mm * 425 mm	2.7 kg	Bags for launch/storage in ISS	
42	Soft Bag 6X Size	JMH-074127-6X001	749 mm * 502 mm * 913 mm	4.0 kg	Bags for launch/storage in ISS	No Image
43	Jettison Stowage Bag	JMH-083713-001	400 mm * 400 mm * 25 mm	0.65 kg	Bags for disposal	
44	New Belca	SX-300H	1000 mm *2000 mm * 100 mm	-	Foam cushioning material for launch 25% compression supported: 45 kPa Density: 30 kg/m^3 Antistatic	

5.5 Other (in-vessel space)

Although adjustments need to be made individually for the use of in-vessel laboratory spaces, the rough restrictions at present are listed in Table 5.5-1.

Table 5.5-1 Outline of restrictions on use of in-vessel laboratory spaces

Item	Restriction
Weight	≤24 kg recommended (soft bag launching assumed)
Volume	- Projection from rack surface: 43 cm - Air flow must not be blocked.
Mechanical interface	Seat track (standard installation position)
Thermal interface (exhaust heat)	≤40 W (air cooling by avionics)
Electrical interface (supplied power)	- 120 V (DC) or 28 V (DC) - Payload laptop terminal (PC; USB port/PCMI card slot): 5 V (DC)
Communication interface (data)	Ethernet use: It is assumed that the connection with Earth is not constant, but instead communication is conducted in bulk at appropriate times.
Communication interface (video)	- Video shooting: Use of common devices at station (described later) - Down link from camera in user-supplied system: Via Image Processing Unit (IPU)*1 or Multipurpose Small Payload Rack
Fluid system interface	None
Safety (typical example)	- Off gas (check possible on test by JAXA) - Sharp edges - Device surface temperature (≤49°C) - Electromagnetic compatibility
Noise/microgravity disturbance	- Noise: Compliance with NC-40 specification (when operating continuously for 8 h or longer) - Vibration: Indicating that there is no problem with analysis, etc.
Other devices that can be used	- Payload laptop terminal - DV camera - HDV camera - Digital still camera, etc.

*1: Among the obtained data, image data are recorded and transmitted to Earth via the IPU. Although the data rates are set to 17–42 Mbps/ch (MPEG/MotionJPEG compression) for video recording and 15 Mbps max/ch (MPEG2 compression) for transmission to Earth, they are subject to change because of various operational restrictions.

6 Other Reference Information

The web sites listed below provide information regarding experimental devices and other matters. Please refer to them for reference.

Overall information on use of Kibo
http://iss.jaxa.jp/kiboexp/

Information on experimental devices
http://iss.jaxa.jp/kiboexp/equipment/pm/

Information on experimental themes
http://iss.jaxa.jp/kiboexp/field/scientific/

http://iss.jaxa.jp/kiboexp/field/applied/

http://iss.jaxa.jp/kiboexp/field/medical/

II. Precautions for Planning Space Experiments

1. Features in proposing space experiments

The environment and operating conditions in the Pressurized Module (PM) of Kibo (as described below) vary widely from those of most laboratories on earth. Because it is extremely difficult to conduct experiments in space using similar methods and scales to those used in laboratories on earth, a thorough understanding of these restrictions is necessary in order to plan feasible space experiments.

- Uniqueness of the space environment: Working and processing must be possible under microgravity conditions (especially liquid behavior).
- Restrictions due to the use of manned facilities in space: Strict safety precautions (i.e., completely sealing toxic substances such as samples and chemical fixing agents)
- Restrictions in transport opportunities and capacities: Although the volume and weight that can be launched by spacecraft are subject to important restrictions, the volume and weight that can be collected are subject to even more rigid restrictions, given the limited number of spacecraft that can collect samples.
- Work period on orbit: The work period by astronauts is extremely limited, with the average work period that can be assigned to each experiment being approximately 10 hours. Considering the microgravity conditions and the unique sealing requirements mentioned above, a work volume that is equivalent to only several hours of laboratory work on earth can be ensured.
- Refrigeration and freezing capacity: The on-orbit refrigerator/freezer capacity is limited and there are also restrictions due to the extremely small refrigeration and freezing volume allocated for launching and collection.

Clearly, there are many differences between proposals for space experiments and proposals for normal experiments. In the actual examination and selection of space experiment proposals, technical evaluation will be conducted in addition to scientific evaluation on the proposed study. Even if their scientific merit is high, proposals that are expected to have many technical difficulties in implementation or that have extremely low mounting feasibilities are not likely to be selected.

2. Feasibility for mounting

Principle investigators of space experiments are required to specify "experiment requirements," including the type of experiment to be conducted, the methods and procedures used, and the rationale.

Experiment requirements that conflict with the "restrictions unique to space experiments" in Section 5 of this document are considered risk factors that reduce the mounting feasibility. For example, an experimental requirement to mount a quantity of sample that exceeds the launch capacity will be considered a risk factor.

The level of mounting feasibility will be determined by how many risk factors there are and how difficult it is to overcome them. Proposals with extremely low mounting feasibility levels will never be selected.

In addition, the mounting feasibility evaluation results, including problems identified in the technical evaluation and suggested improvement measures to overcome them, are returned to the proposing party. For researchers whose proposals are selected, working on solving the identified problems will be added to the criteria for being selected during the space experiment preparation stage.

The planning of space experiments with minimized risk factors will be described in Section 5. Life science and material science are two different fields and have two different requirements when it comes to experiment samples, devices, tools, and whether astronauts are needed for space experiments. Therefore, the concepts and procedures involved in planning space experiments for life science and material science will be listed separately in this handbook.

3. Experiment resources

To conduct experiments on Kibo, information regarding experiment samples, material to be launched, weight that will be collected and transported to earth, work period of astronauts (crew time) necessary for experimental operations on orbit, electric power needed to operate the experiment system, heat exhaust, and data communication will be necessary.

There are strict restrictions regarding these resources due to launch opportunities, the capacity for transport in spacecraft, the number of astronauts staying on the ISS, and the capacity of ISS devices. Furthermore, these resources ensured for the ISS as a whole are first assigned to the activities necessary to maintain the ISS and the life of the astronauts. The remaining resources are then distributed based on the set rate for each international partner (12.8% for Japan).

The experiment resources necessary to conduct the research plan will be digitized through joint examination with JAXA to develop specific experiment plans after getting selected as a candidate theme.

- Launch weight: Samples (including transport containers and equipment), consumable goods, and devices required in experiment
- Collection weight: Items including samples (including transport containers and equipment) and data recording media
- Work period: Every step in the experiment that the astronaut conducts will be included in the work period (including removal of sample from the storage location, installation of the equipment, observation of sample, replacement of consumable goods, removal of sample from the system, treatment for storage, stowing of sample into the storage space, data transmission processes, reading of the work instructions). In experiments where astronauts are used as the test subjects, the work period will be the total experiment periods for both test subject and operator.
- Electric power, exhaust heat, data communication: Calculated from operation plan for the experiment device
- Refrigeration and freezing requirements: Requirement to use refrigeration or freezing facilities common to the ISS, temperature zone and volume

When planning experiments, please use Table 1 as a reference for calculating the scale of resources. Experiments need to be planned with high efficiency using the least amount of resources in order to deliver the most effective outcomes.

Table 1 Reference information used to calculate experiment resources

System	Guideline	Remarks
Life science experiments (e.g., cell culturing, plant experiments)	For plant growth: 2 kg/piece For cell culturing: 1 kg/8 containers Medium replacement tool: 2 kg/piece Chemical fixing tool: 1 kg/piece	Specimen includes the sample and sample container. The experiment scale (n value) must be multiplied.
	Work period: 10 h per experiment theme	Processes such as specimen installation, fixing process, and storage in refrigerator are assumed. A work period twice that on earth should be expected considering the microgravity environment.
Space medicine experiments	Specimen weight: 1–5 kg/piece	Depends on the experiment details
	10 h per experiment theme	Total time for test subject and operator. The experiment count must be multiplied for repeated experiments.
Fluid physics experiments	Specimen weight: 40 kg/piece	Items such as packing materials for transport must be considered separately.
	20 h per experiment theme	Installation and replacement of specimen are assumed.
Liquid crystallization observation experiments	Specimen weight: 15 kg/piece	Items such as packing materials for transport are also necessary.
	3 h/experiment theme	Installation and replacement of specimen are assumed.
Semiconductor crystal experiments	Specimen weight: 5 kg/piece	Items such as packing materials for transport are also necessary. Multiple specimens may be necessary depending on the experiment conditions.
	1 h/experiment theme	Installation and removal of specimen are assumed.

4. Safety requirements

For each individual experiment theme, it is necessary to ensure the safety of the experiment specimen, the experiment samples, and the operation procedures (i.e., that there will be no risk of damage to the astronauts, the ISS, or Kibo). The planning and design of experiments as well as the testing of experiments on specimens must be conducted based on the following safety requirements, and the results must pass the safety examination. While this work will be mainly implemented by JAXA after the selection of the experiment theme, it will be necessary for the proposing party to provide alternative ideas if the safety of the experiment samples or reagents cannot be ensured.

Hazards will be identified for safety requirements. If a hazard is identified, proper control of the hazard and an appropriate method of verification must be indicated.

In general, the following hazards are considered. Proper control and verification methods must also be indicated if there are any mission-specific hazards besides those listed below.

(1) Structural damage

Any structural damage in experiment devices that may cause harm to the transport spacecraft or station will be prevented. The safety of the structure must be ensured through design using specified safety coefficients regarding launch, emergency landing, and on-orbit load (including crew load) as well as use of proper parts and materials.

(2) Movable parts

If there are rotary bodies such as motors and shafts, such equipment must be designed such that contact with the astronaut is prevented. The equipment must also have a mechanism in which damage to the rotary body itself will not result in any harm to the station and so forth.

(3) Temperature of the parts with which astronauts come in contact

The temperatures of parts that astronauts may touch must be controlled such that they reach a maximum of 49 °C.

(4) Sharp edges

To prevent injury to astronauts, any equipment surfaces must be smooth and free of burring. Chamfering and so forth according to the NASA specifications (SSP500050) must be conducted on corners and edges.

(5) Prevention of catching

Gaps in movable parts need to be protected or designed with spaces of specified size or greater to prevent astronauts from getting their hands caught.

(6) Pollution

The equipment must be designed to not release substances that may be hazardous to the transport spacecraft or space station. Specifically, sealing properties must be assured at the corresponding level of single, double, or triple barriers according to toxicity (level 1/2/3). This is done by requesting a toxicity evaluation from NASA for experiment samples and reagents.

(7) Materials that are used

Volatile gases generated from mounted equipment must be lower than the specified value. If there is a possibility that the specified value may be exceeded, measures must be taken to reduce the level to or below the specified value by either changing the material or by releasing the gas beforehand at a tolerable maximum temperature.

Regarding flammability of materials, specified materials shall be used to ensure prevention of fire and permission to use other materials must be obtained by demonstrating that the fire will not be propagated.

(8) Glass parts

If glass is used, protective measures must be taken not to cause hazards to astronauts in case of breakage.

(9) Pressure containers and sealed containers

Sealed containers that contain gas and that may contain internal energy of approximately 2×10^4 J or more (based on adiabatic expansion of perfect gas), containers that are subjected to maximum design load of approximately 7×10^5 Pa or more, and containers that contain fluid with approximately 1×10^5 Pa or more may pose release hazards and are defined as pressure containers, while other containers are defined as sealed containers. Safety must be verified for each by conducting proof tests and fatigue analysis for the specified pressure corresponding to each classification.

(10) Electric shock

Equipment must be designed according to the station rules (SSP30240 and SSP30245) regarding grounding and continuity so that there will be no harm to the astronauts through electric shock. It shall be designed so that astronauts will not come in contact with high-voltage parts (30 V or higher).

(11) Electric circuits

Protective circuits such as current limiters and fuses shall be provided, or wiring of proper size must be established to prevent propagation of failure to the upstream parts (such as the stations) by overcurrents or short-circuiting. It also needs a design for connectors to prevent 2 or more of the hazard suppression functions from becoming invalid simultaneously by short-circuiting between connector pins, caused by bent pins.

(12) Electromagnetic compatibility test (EMC)

The equipment needs an EMC designed according to station rules (SSP30237) to prevent malfunctions that may result in loss of safety features (of the equipment itself or other station devices) through electromagnetic interference.

(13) Optical devices

Any equipment using lasers and so forth must be designed so that the laser will not irradiate the astronaut by mistake during operation.

5. Specific restrictions for space experiments and precautions for planning space experiments

Restrictions and matters to be noted in planning space experiments are listed as follows, ordered by stages from the date of spacecraft launch until the completion of all experiments. Experiments should be proposed within feasible scope with due consideration of these items, and any points that do not have sufficient examination will be examined in cooperation with JAXA after the selection process.

5.1 Life science experiments

Item	Restriction	Matters to be noted in planning space experiments
Date of spacecraft launch	Since the date of launch is determined overall by ISS management, adjustment and preparations need to be made to match the date (the researcher's wish will not be reflected). The launch date is also often changed due to progress in management plans, spacecraft servicing conditions, weather, and so forth.	- Biological samples need to be prepared and procured to meet the planned launch date. When seasonal biological species or samples at specific development stages are to be used, they need to be prepared as necessary to be mounted. - If the life of a biological sample is short, backup samples need to be prepared at the location of launch in case launch is delayed.
Mounted samples and goods	[Sample species – quantity] There are restrictions to the sample species and quantity that can be mounted for each type of equipment to be used.	The launch weight and volume need to be minimized as much as possible so that the experiment is planned efficiently. - It is necessary to provide information on all samples and devices used, including biological conditions on the name of sample species, strain used, weight, age, and so forth. - The quantity of prepared and arranged samples must be several times larger than that of the on-orbit experiment sample in order to prepare for any sudden changes in launch date. These samples should be considered in addition to the sample quantity necessary for on-orbit control experiments and control experiments on earth. - Experimentation on the sample should be possible within the equipment range based on checks of its functions and performance. - Although there are restrictions on the quantity of samples that can be mounted, it is necessary to set up an experiment system that can ensure the "N value" necessary to obtain statistically significant difference. It is recommended that the optimal quantity and minimum quantity to allow sufficient analysis are specified in the proposal.

	[Experiment system and specimen] In principle, experiments are conducted on the experiment systems that are mounted. To use experiment tools or systems typically used on earth, modification to use them on the ISS and tests to confirm their safety need to be conducted.	When the experiment is to be conducted using the experiment systems in Table 1.4 of the 1.4 chapter, the following are true. - The experiment must be executable within the equipment range based on checks of its functions and performance. - In principle, experiment systems provided by JAXA cannot be modified. - Regarding the requirements for individual experiments, experiments need to be addressed within the range of the specimen, in conjunction with the system used to conduct the experiments. When the experiment uses experiment tools and so forth belonging to the proposing party and that are not in Table 1.4 of the 1.4 chapter, the following are true. - To use experiment tools and so forth belonging to the proposing party, the weight, dimensions, structure, component materials, functions, and performance for each of these tools need to be clearly described. - Development, manufacture, and function verification need to be completed at least 1 year before experiment implementation. - The goods for space experiments are quite different from the goods used regularly in laboratories on earth in terms of required levels of safety and operability. Whether or not the tools will operate properly in a microgravity environment also must be checked in advance. They must be designed, manufactured, and tested with sufficient examination. [Characteristics of space experiment systems] - The mounted systems have characteristics different from those on earth. For example, special caution is required in handling liquids under a microgravity environment. It is impossible to separate air bubbles by using gravity, and the solution will be distributed inside the container by the relationship with the container wall (wettability) as it is released from the governing force of gravity. Therefore, liquids are generally handled by fully finning the container in a sealed system without bubbles. - Liquids must always be sealed in containers, even if they are not toxic (even water). Multiple levels of sealing (depending on the toxicity) must be ensured for toxic samples or reagents in all phases. - Since there is no heat convection, disturbances such as stirring will be necessary in order to ensure temperature uniformity. - Although the Cell Biology Experiment Facility (CBEF) can generate artificial gravity using centrifugal force, the conditions of gravity vary with the distance from the rotation center.

	[Reagents, goods, etc.] The Pressurized Module of Kibo is a closed environment, and any leak of reagents such as chemical fixing agent will cause a safety problem. There are strict regulations for using reagents on orbit, even if the type or quantity of reagent can be used without problem in laboratories on earth.	- Information on all reagents and tools that will be used shall be provided and all objects used must pass the safety evaluation. - While hazardous materials can be used by sealing them in special containers, there are also goods whose use will not be permitted. In this case, examination of alternative ideas will be necessary. - In principle, use of tools with sharp edges cannot be allowed, even including scissors and tweezers, which are used casually on earth. - Having water droplets floating inside the ISS and allowing them to adhere to or enter devices must be avoided. Therefore, it must be ensured that liquids do not leak from their containers, even in the case of water.
Loading onto the spacecraft for transport	[Difficulty in mounting fresh samples] The experiment materials need to be mounted by several days to 14 hours before launch at the latest, and about several days will be necessary before experiments can be started on the ISS. [Sample storage conditions for launch] There are restrictions in the capacities of hot storage, freezer, and refrigerator units for the space craft that transports the samples.	Loading experimental materials into the transfer rocket for launch varies by the model. <<Doragon >> Loading is possible until 24 h before launch. It takes about 2 days until arrival at the ISS. During this period, room temperature (about 15–30 °C), refrigeration (+4 °C), or freezing (-95 °C) environments can be used for the samples. <<Soyuz/Progress>> Loading is possible until 14 h before launch. It takes 6 to 48 h until arrival at the ISS. During this period, the samples are placed in the room temperature (15–30 °C) environment. <<ATV/HTV>> Final loading occurs several days prior to launch, and it takes about 1 week until it arrives at the station. During this period, the samples are placed in the room temperature (15–30 °C) environment. - The sample must be maintained for a period after the sample is loaded until the experiment is started in the above range. It is necessary to design the experiment system with consideration of the characteristics of samples and so forth and without exceeding the loading capacity and environmental restrictions of the transport spacecraft. - It takes at least 5 days after launch until experiments can be started. The requirements for temperature and storage conditions for the samples during this period need to be clearly presented, including the tolerated ranges.

Time until experiment start	At least 5 days will be required after launch until the experiment is started in the Pressurized Module of Kibo.	- In principle, experiment procedures cannot be undertaken for at least 5 days after launch. Therefore, it is difficult to conduct space experiments on study subjects whose intended phenomenon will end within the 5 days before on-orbit experiments can be started. Although it may be possible to reduce the waiting period by using Russian spacecraft, there are great restrictions in place at the launch complex. - It may be possible to select methods to start the experiment by launching plant seeds and supplying water on orbit, to launch frozen cells and defrost them on orbit to start culturing and so forth. [Steps until on-orbit experiments are started] - Final preparation of samples to be loaded on earth -> handing over to person in charge of launch -> loading on spacecraft for transport -> transport to the ISS -> setting up experiment system on the ISS - It takes about 5 days after launch until the experiment can be started.
On-orbit experiment	[Experiment period] Due to management reasons, it may not be possible to ensure the requested experiment period.	- It is necessary to clearly specify the optimal experiment period as well as the tolerable range that can be compromised. - It is necessary to determine how long is required to detect the effects of the space environment (microgravity and cosmic radiation) based on assumptions with high probability in experiments on earth.
	[Experiment operation procedures] Experiment operations may not always be conducted as requested.	- The operation procedures need to be described for each step from experiment start to completion. - Devices, tools, and other objects required to carry out each step shall be specifically described. - The timing of execution and tolerable time range need to be specified for each step. It is somewhat possible to monitor the progress in experiments carried out in Kibo from earth and give instructions to change the operation procedures from earth based on observation; however, such actions are restricted in many cases.

	[Operations to be implemented by the astronauts] The astronauts may not be specialists in experiments. The hours that can be spent in experiments are limited.	[It is desired that the operation procedures are as simplified as possible.] - Although astronauts receive training on experiment operations before launch, in many cases they are not specialists in the field of experiments. It is recommended that the construction of the experiment system and experiment procedures be developed as simply as possible so that it will not be complicated or require time in execution. - Experiments that require continuous operation for 30 minutes or longer, operation periods of at least 6 h/week, or total operation periods of 10 hours or more will have low mounting feasibility. [An operation period twice that of earth is usually required.] - Experiment operations that can be conducted on earth in only 30 minutes will usually take twice that time (60 minutes) in space.
	[Monitoring of on-orbit experiments] Progress in experiment or sample conditions at all stages from experiment start to completion cannot be monitored constantly.	- Due to the restrictions applied to communications satellites, communication between the ISS and earth is not always maintained. Although the conditions vary every day, communication is typically cut off for about 10–50% of the time. - It is possible to downlink important data, such as confirmation of the start or completion of experiment operations or operating conditions for the experiment system (data or images from the temperature sensors and so forth equipped on the system), to earth, although this may not occur in real time. - It is recommended that there be a differentiation between data for real-time downlink and data for downlink when possible after recording and that the experiment be planned with flexibility.
	[Interference in on-orbit experiments] It may be difficult to change procedures depending on sample conditions.	- Although it is possible to change the experiment procedures based on the above downlink information, including changes in operating conditions for the on-orbit experiment system, there are restrictions (similar to those above) limiting the amount of data that can be uplinked to address changes or timing issues.

Sample storage on orbit and sample collection	It may take time after experiment completion before the samples can be collected on earth. It takes time after the transport aircraft lands before the sample can be retrieved, and the landing point may not have the facilities for sample processing.	- Only small amounts of experiment samples, systems, tools, and so forth can be collected and brought back to earth. This is limited to several kg, including the sample containers, packing materials, and so forth, and it is very difficult to collect such items under frozen or refrigerated conditions. - The trip of spacecraft to and from the ISS occurs about every 3 months. Thus, it is necessary to check before launch if there are changes such as denaturation and deterioration during the storage period, even for samples that have been frozen, treated chemically, and so forth at completion of the experiment.

5.2 Space medicine experiments

Consent of the test subject	Agreement on implementation	- It is necessary for the experiment which uses astronauts as test subject to explain experiment description to candidate's crew through the approval of each space agency and Ethical Review Board between IP agencies, and to obtain the consent of participation. - Explanation to subjects is usually given 1.5 years before a space stay start. The data acquisition on the ground becomes possible after the consents and nine months before a space stay start.
Date of spacecraft launch	Astronauts are launched in Russian Soyuz. Since the date of launch is determined overall by ISS management, adjustment and preparations need to be made to match the date	- BDC is usually conducted at Johnson Space Center in Houston, U.S.A. It is also possible to conduct it in Japan to coincide with a particular astronaut's visit to Japan. Two sets of experiment systems will be necessary if experiments need to be conducted after returning to earth. - Since astronauts move to Russia several weeks before launch, feasibility is low for ground experiments immediately before launch (baseline data collection or BDC). These should be set up 1 month or more prior to launch.
Number of test subjects, mounted goods		It is necessary to plan an efficient experiment by minimizing the number of test subjects and the weight and volume of goods.
Experimental equipment	[Experiment system and specimen] In principle, experiments are conducted on the experiment systems that are mounted. To use experiment tools or systems typically used on earth, modification to use them on the ISS and tests to confirm their safety need to be conducted.	When the experiment is to be conducted using the experiment systems in Table 1.4 of the 1.4 chapter, the following are true. - The experiment must be executable within the equipment range based on checks of its functions and performance. - In principle, experiment systems provided by JAXA cannot be modified. When the experiment uses experiment tools and so forth belonging to the proposing party and that are not in Table 1.4 of the 1.4 chapter, the following are true. - To use experiment tools and so forth belonging to the proposing party, the weight, dimensions, structure, component materials, functions, and performance for each of these tools need to be clearly described. - Development, manufacture, and function verification need to be completed at least 1 year before experiment implementation. - Even systems and tools that have been approved as medical devices on earth need to be re-evaluated for safety in space use.

Mounted samples and goods	[Reagents, goods, etc.] The Pressurized Module of Kibo is a closed environment, and any leak of reagents such as chemical fixing agent will cause a safety problem. There are strict regulations for using reagents on orbit, even if the type or quantity of reagent can be used without problem in laboratories on earth.	- Information on all reagents and tools that will be used shall be provided and all objects used must pass the safety evaluation. - While hazardous materials can be used by sealing them in special containers, there are also goods whose use will not be permitted. In this case, examination of alternative ideas will be necessary. - Having water droplets floating inside the ISS and allowing them to adhere to or enter devices must be avoided. Therefore, it must be ensured that liquids do not leak from their containers, even in the case of water. - In principle, use of tools with sharp edges cannot be allowed, even including scissors and tweezers, which are used casually on earth. - Special conditions must be set up for use of injection needles and any instrument with sharp tips or edges.
The intervention conditions to a subjects	[The requirements for subjects, intervention conditions] It is necessary to consider restrictions, intervention conditions and the number of subjects.	- The description is required about all the necessity of experiment operators other than the number of subjects, the requirements for a subject, intervention conditions (medication, movement load, etc.), the measurement item, the use apparatus, the number of times and time of an experiment on an orbit, the measurement item, the number of times and the enforcement schedule of the experiment before and behind boarding, and a subject. - There is the necessity to indicate all the matter which may affect the measurement items for human experiments. - It is necessary to indicate all the matter which restricts the activities (use of the large business of physical and mental loads, such as operation of an airplane and activities outboard, movement, mental health care, and medical supplies, the meal containing alcoholic caffeine, sleep, etc.) of a crew including the time of ground stay for the purpose of an experiment. - On ISS, six (6) astronauts (half year stay) are planning to stay as a set, and three (3) astronauts who belong to Japan, the U.S., Europe, and Canada in principle. Two (2) of them may be test subjects in half a year. If four (4) astronauts are required as a subject, it will be required for completion of an experiment for at least one year. If six astronauts are required as a subject, it will be required for completion of an experiment for one and a half year. PI should consider duration (yeas) to satisfy statistically significant "N number".
	It is assumed that at least about 1 week is required after launch until an experiment can be started.	- In principle, experiment operations for space medicine cannot be conducted for at least ~1 week after launch. There are also many restrictions during the first few weeks. Therefore, it is difficult to conduct space experiments on study subjects whose intended phenomenon will end before on-orbit experiments can be started.

On-orbit experiment	[Experiment period] Due to management reasons, it may not be possible to ensure the requested experiment period.	- It is necessary to clearly specify the optimal experiment period as well as the tolerable range that can be compromised. - The time required for an experiment appropriate for detecting the effects of the space environment (e.g., microgravity, closed system, cosmic radiation) must be determined based on assumptions with high probability from experiments conducted on earth. - There are restrictions on experiments to be conducted immediately before return as well as immediately after launch.
	[Experiment operation procedures] Experiment operations may not always be conducted as requested.	- The operation procedures need to be described for each step from experiment start to completion. - Devices, tools, and other objects required to carry out each step shall be specifically described. - The timing of execution and tolerable time range need to be specified for each step. It is somewhat possible to monitor the progress in experiments carried out in Kibo from earth and give instructions to change the operation procedures from earth based on observation; however, such actions are restricted in many cases.
	[Operations to be implemented by the astronauts] The astronauts may not be specialists in experiments. The hours that can be spent in experiments are limited.	[It is desired that the operation procedures are as simplified as possible.] - Although astronauts receive training on experiment operations before launch, in many cases they are not specialists in the field of experiments. It is recommended that the construction of the experiment system and experiment procedures be developed as simply as possible so that it will not be complicated or require time in execution. - Experiments that require continuous operation for 30 minutes or longer, operation periods of at least 6 h/week, or total operation periods of 10 hours or more will have low mounting feasibility. [An operation period twice that of earth is usually required.] - Experiment operations that can be conducted on earth in only 30 minutes will usually take twice that time (60 minutes) in space. - Considerations designed to keep the body steady must be made, including footholds in the microgravity environment.
	[Monitoring of on-orbit experiments] Progress in experiment or sample conditions at all stages from experiment start to completion cannot be monitored constantly.	- Due to the restrictions applied to communications satellites, communication between the ISS and earth is not always maintained. Although the conditions vary every day, communication is typically cut off for about 10–50% of the time. - It is recommended that there be a differentiation between data for real-time downlink and data for downlink when possible after recording and that the experiment be planned with flexibility.

		- It is possible to downlink important data, such as confirmation of the start or completion of experiment operations or operating conditions for the experiment system (data or images from the temperature sensors and so forth equipped on the system), to earth, although this may not occur in real time.
	[Interference in on-orbit experiments] It may be difficult to change procedures depending on the conditions of test subjects.	- Although it is possible to change the experiment procedures based on the above downlink information, including changes in operating conditions for the on-orbit experiment system, there are restrictions (similar to those above) limiting the amount of data that can be uplinked to address changes or timing issues. - There are restrictions in downlinking images of the astronauts to ptotect personal information .
Experiment after return to earth	Astronauts return to Kazakhstan and go back to Houston within 24 hours (except for Russian and European astronauts).	- In principle, experiments after returning are conducted at Johnson Space Center in Houston, U.S.A. - The period for experiments on the day of return (day of arrival in Houston) is extremely limited. - There are many restrictions for 10 days after return. - BDC at several weeks or several months after return will also be conducted at Houston. - The astronaut will need to take trips to Houston for the number of BDCs to be taken in addition to the experiment before launch (for example, an astronaut may need to take a maximum of 20 trips to Houston in total, when there is 1 experiment before launch and 3 after return, and the number of test subjects may be 5 (N = 5)).

5.3 Material and Physical Science

Date of spacecraft launch	Since the date of launch is determined overall by ISS management, adjustment and preparations need to be made to match the date .	- If experiments are to be conducted by mixing multiple samples, it must be assumed that the samples may be mixed before launch and stored in the spacecraft for launch and transport or on the ISS for several months in the mixed condition.
Mounted samples and goods	[Sample species – quantity] There are restrictions to the sample species and quantity that can be mounted for each type of equipment to be used.	The launch weight and volume need to be minimized as much as possible so that the experiment is planned efficiently. - Experimentation on the sample should be possible within the equipment range based on checks of its functions and performance. - Although there are restrictions on the quantity of samples that can be mounted, it is necessary to set up an experiment system that can ensure the “N value” necessary to obtain statistically significant difference. It is recommended that the optimal quantity and minimum quantity to allow sufficient analysis are specified in the proposal.

Experiment system	[Experiment system and specimen] In principle, experiments are conducted on the experiment systems that are mounted. To use experiment tools or systems typically used on earth, modification to use them on the ISS and tests to confirm their safety need to be conducted.	When the experiment is to be conducted using the experiment systems in Table 1.4 of the 1.4 chapter, the following are true. - The experiment must be executable within the equipment range based on checks of its functions and performance. - In principle, experiment systems provided by JAXA cannot be modified. - Regarding the requirements for individual experiments, experiments need to be addressed within the range of the specimen, in conjunction with the system used to conduct the experiments. When the experiment uses experiment tools and so forth belonging to the proposing party and that are not in Table 1.4 of the 1.4 chapter, the following are true. - To use experiment tools and so forth belonging to the proposing party, the weight, dimensions, structure, component materials, functions, and performance for each of these tools need to be clearly described. - The goods for space experiments are quite different from the goods used regularly in laboratories on earth in terms of required levels of safety and operability. Whether or not the tools will operate properly in a microgravity environment also must be checked in advance. They must be designed, manufactured, and tested with sufficient examination. - Development, manufacture, and function verification need to be completed at least 1 year before experiment implementation. [Characteristics of space experiment systems] - The mounted systems have characteristics different from those on earth. For example, special caution is required in handling liquids under a microgravity environment. It is impossible to separate air bubbles by using gravity, and the solution will be distributed inside the container by the relationship with the container wall (wettability) as it is released from the governing force of gravity. Therefore, liquids are generally handled by fully finning the container in a sealed system without bubbles. - Liquids must always be sealed in containers, even if they are not toxic (even water). Multiple levels of sealing (depending on the toxicity) must be ensured for toxic samples or reagents in all phases.

Mounted samples and goods	[Reagents, goods, etc.] The Pressurized Module of Kibo is a closed environment, and any leak of reagents such as chemical fixing agent will cause a safety problem. There are strict regulations for using reagents on orbit, even if the type or quantity of reagent can be used without problem in laboratories on earth.	- Information on all reagents and tools that will be used shall be provided and all objects used must pass the safety evaluation. - While hazardous materials can be used by sealing them in special containers, there are also goods whose use will not be permitted. In this case, examination of alternative ideas will be necessary. - In principle, use of tools with sharp edges cannot be allowed, even including scissors and tweezers, which are used casually on earth. - Having water droplets floating inside the ISS and allowing them to adhere to or enter devices must be avoided. Therefore, it must be ensured that liquids do not leak from their containers, even in the case of water.
Loading onto the spacecraft for transport	[Difficulty in mounting fresh samples] The experiment materials need to be transported to Johnson Space Center in Houston, U.S.A by several months before launch at the latest, [Sample storage conditions for launch] There are restrictions in the capacities of hot storage, freezer, and refrigerator units for the space craft that transports the samples.	- If samples need to be loaded within 1 month before launch, the basis for this must be clearly indicated along with clearly defined timing. It is recommended that the experiment system be assembled without exceeding the restrictions by taking into consideration the characteristics of the sample and so forth.
Time until experiment start	At least 35 days will be required after launch until the experiment is started in the Pressurized Module of Kibo.	- In principle, experiment procedures cannot be undertaken for at least 5 days after launch. [Steps until on-orbit experiments are started] - Final preparation of samples to be loaded on earth -> handing over to person in charge of launch -> loading on spacecraft for transport -> transport to the ISS -> setting up experiment system on the ISS - It takes about 5 days after launch until the experiment can be started.

On-orbit experiment	[Experiment period] Due to management reasons, it may not be possible to ensure the requested experiment period.	- It is necessary to clearly specify the optimal experiment period as well as the tolerable range that can be compromised. - The interval between experiments must be specified for repeated experiments (for sample replacement and so forth). - The operation procedures need to be described for each step from experiment start to completion. - Devices, tools, and other objects required to carry out each step shall be specifically described. - The timing of execution and tolerable time range need to be specified for each step. It is somewhat possible to monitor the progress in experiments carried out in Kibo from earth and give instructions to change the operation procedures from earth based on observation; however, such actions are restricted in many cases.
	[Operations to be implemented by the astronauts] The astronauts may not be specialists in experiments. The hours that can be spent in experiments are limited.	[It is desired that the operation procedures are as simplified as possible.] - Although astronauts receive training on experiment operations before launch, in many cases they are not specialists in the field of experiments. It is recommended that the construction of the experiment system and experiment procedures be developed as simply as possible so that it will not be complicated or require time in execution. - Experiments that require continuous operation for 30 minutes or longer, operation periods of at least 6 h/week, or total operation periods of 10 hours or more will have low mounting feasibility. [An operation period twice that of earth is usually required.] - Experiment operations that can be conducted on earth in only 30 minutes will usually take twice that time (60 minutes) in space.
	[Monitoring of on-orbit experiments] Progress in experiment or sample conditions at all stages from experiment start to completion cannot be monitored constantly.	- Due to the restrictions applied to communications satellites, communication between the ISS and earth is not always maintained. Although the conditions vary every day, communication is typically cut off for about 10–50% of the time. - It is possible to downlink important data, such as confirmation of the start or completion of experiment operations or operating conditions for the experiment system (data or images from the temperature sensors and so forth equipped on the system), to earth, although this may not occur in real time. - It is recommended that there be a differentiation between data for real-time downlink and data for downlink when possible after recording and that the experiment be planned with flexibility.

	[Interference in on-orbit experiments] It may be difficult to change procedures depending on sample conditions.	- Although it is possible to change the experiment procedures based on the above downlink information, including changes in operating conditions for the on-orbit experiment system, there are restrictions (similar to those above) limiting the amount of data that can be uplinked to address changes or timing issues.
Sample storage on orbit and sample collection	It may take time after experiment completion before the samples can be collected on earth. It takes time after the transport aircraft lands before the sample can be retrieved, and the landing point may not have the facilities for sample processing.	- Only small amounts of experiment samples, systems, tools, and so forth can be collected and brought back to earth. This is limited to several kg, including the sample containers, packing materials, and so forth, and it is very difficult to collect such items under frozen or refrigerated conditions. - The trip of spacecraft to and from the ISS occurs about every 3 months. Thus, it is necessary to check before launch if there are changes such as denaturation and deterioration during the storage period, even for samples that have been frozen, treated chemically, and so forth at completion of the experiment. - Normally, experiment samples are handed over at Johnson Space Center in Houston, U.S.A., about 1 month after landing. Then, time for processing and transport to Japan, among other activities, will also be required.

The collection of abbreviation

ATV	Arian Transfer Vehicle
AQH	Aquatic Habitat
BEU	Biological Experiment Unit
CB	Clean Bench
CBEF	Cell Biology Experiment Facility
CEU	Cell Experiment Unit
CFK	Cell Fixation Kit
DC	Disinfecting Chamber
DCC	Disposable Cultivation Chamber
DRTS	Data Relay Test Satellite
DV	Digital Vide
ESA	European Space Agency
FPEF	Fluid Physics Experiment Facility
GHF	Gradient Heating Furnace
HDV	High-Definition Video
HTV	H-II Transfer Vehicle
IPU	Image Processing Unit
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
JEMOCS	JEM Operation Control System
JSC	Johnson Space Center
KFT	KSC Fixation Tube
KSC	Kennedy Space Center
KOBAIRO	
MELFI	Minus Eighty degree Celsius Laboratory Freezer
MEU	Measurement Experiment Unit
MSPR	Multi-purpose Small Payload Rack
NASA	National Aeronautics and Space Administration
OC	Operation Chamber
PADLES	Passive Dosimeter for Life science Experiments in Space
PCRF	Protein Crystallization Research Facility
PEU	Plant Experiment Unit
PFK	Pre Fixation Kit
POIC	Payload Operation Integration Center
QD	Quick Disconnector

RRMDIII	Real-time Radiation Measurement Device III
RYUTAI	
SAIBO	
SCAM	Sample Cartridge Automatic Exchange Mechanism
SCOF	Solution Crystal Observation Facility
SSCC	Space Station Control Center
SSIPC	Space Station Integration and Promotion Center
STS	Space Transportation System
TDRS	Tracking and Data Relay Satellite
TNSC	Tanegashima Space Center
ULT	User Laptop Computer
V-MEU	Video Measurement Experiment Unit
WSC	White Sands Complex