Kibo HANDBOOK

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Japan Aerospace Exploration Agency (JAXA)
Human Space Systems and Utilization Program Group

Contents

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1. Background on Development of Kibo

1.1 Summary

The International Space Station (ISS) is “the first borderless world“ mankind has ever had in history. The United States of America (US), Japan, Canada, European countries and Russia are participating in this ISS program. These partners have been collaboratively promoting the construction, assembly, and utilization of the ISS. This type of collaboration, which utilizes the state-of-the-art technologies from many different countries for constructing a single facility, has never been done before. The ISS, in many ways, is truly a symbol of global cooperation and peace, as well as an important research facility to provide a major breakthrough in the world’s space development endeavors.

The conceptual design of the space station’s drawing was initiated in 1982. The first ISS component, the Zarya Module, was launched in 1998 overcoming numerous obstacles through the international cooperation of the ISS partner countries. The ISS construction was once suspended due to the Space Shuttle Columbia accident in 2003. However, from 2006, the ISS construction has resumed with the target completion year set at 2010.

This chapter describes the background and the surrounding issues related to the development of Kibo from the perspectives of cross-border collaboration and Japan’s domestic activities.

1.2 International Space Station (ISS) Program

1.2.1 Outline

The International Space Station (ISS) is a manned research facility flying about 400 km above the earth. While the ISS orbits the earth at a rate of 90 minutes per orbit, earth observation, astronomical observations and scientific experiments are conducted on-board.

The primary objectives of the ISS are to provide a facility for conducting long-term experiments and researches by using the environment unique to space, to promote science and technology by utilizing the results from these experiments and researches, and to contribute to the betterment of mankind and a means for commercial development.

For the assembly and construction of the ISS, the US space shuttles and Russia’s Proton and Soyuz launch vehicles are used for transporting the ISS components, one segment after another, more than 40 launches projected to assemble the ISS. The US, Japan, Canada, Russia and 11 of the 17 member countries of the European Space Agency (ESA), including Italy, Denmark, Norway, Belgium, Netherlands, France, Spain, Germany, Swedish, Switzerland and the United Kingdom (UK), are participating in this international collaborative program, as ISS partner countries. Japan contributes to the ISS program through the development and utilization of Kibo.

Figure 1.2.1-1shows an overview of the ISS. Table 1.2.1-1 shows the ISS specifications.

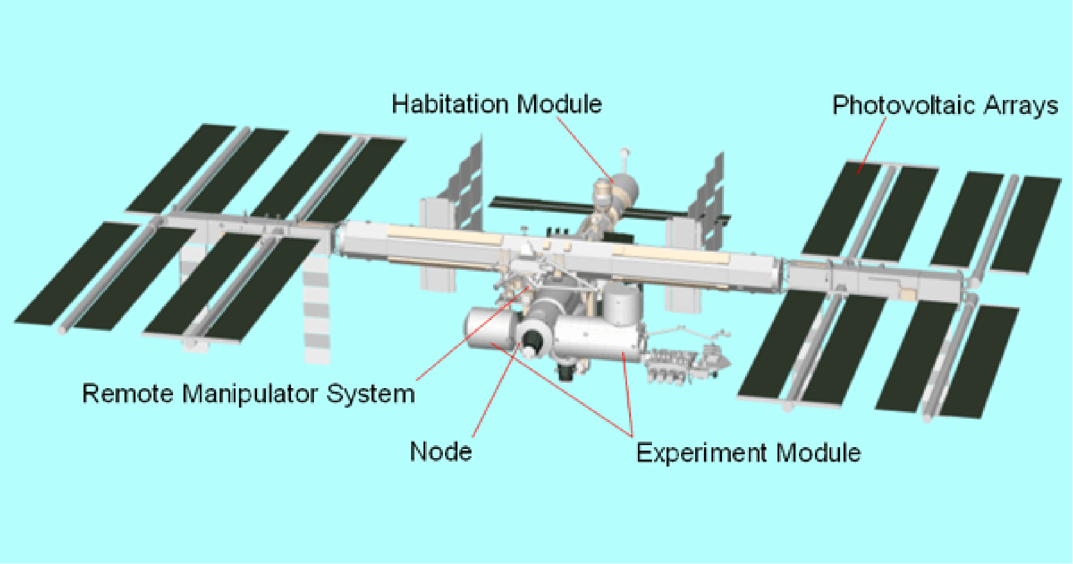


Figure 1.2.1-1 ISS Overview

Table 1.2.1-1 ISS Specifications

Items	Specifications
Size	108.5 m x 72.8 m (Size is equivalent to an American football field)
Mass (Weight)	420 t
Power Generation	110 kW
Number of pressurized modules	Experiment Modules: 5 (includes: US 1 (Destiny), Japan 1 (Kibo), ESA 1 (Columbus), Russia 2 (RM, MLM))
	Habitation Modules: 1 (Russia 1 (Zvezda))
External Research Accommodations	10 on the ISS truss 10 on Kibo’s Exposed Facility (EF) 4 on Columbus
Number of crew (capacity)	6 (2 to 3 during the construction/assembly phase)
Orbit	Circular Orbit (Altitude 330 to 480 km) Inclination 51.6 degree
Transportation system/launch vehicle	Assembly flight: Space Shuttle (US), Soyuz launch vehicle / Proton launch vehicle (Russia) Logistics flight: Space Shuttles (US), Soyuz launch vehicle (Russia), Ariane launch vehicle (ESA), H-IIB launch vehicle (Japan)

1.3 Background of Kibo Development

In June 1982, the government of Japan was requested from NASA to participate in the Space Station Program. In response to this request, a technical study led by the National Space Development Agency of Japan (NASDA) was initiated to establish the basic framework for Japan’s participation in the Space Station Program. In August 1982, the Space Station Program Task Force was formed under the auspices of the Space Development Committee. Deliberations on Japan’s participation in the Space Station Program Framework were started.

In April 1985, the "Basic Framework for Participating in the Space Station Program" was established based on the results from the studies conducted by the Space Development Committee's Space Station Taskforce. Japan’s participation in the Space Station Program was then officially announced. In the "Basic Framework for Participating in the Space Station Program", the significance of Japan’s participation in the program was described. The following is a summary of the framework.

(1) High Technology Acquisition

The space station is expected to actively and extensively use advanced technologies. This will ultimately lead to acquiring techniques for supporting manned space flight and the developing leading edge space technologies while this large construction project in space is ongoing. The space station will also lead to the promotion and development of advanced technologies in several fields including robotics, computers, and communications. In addition, significant improvements in advanced technology standards are anticipated.

(2) Promotion of Science and Technology for the Next Generation, and Expansion of Space Activity Scope

The space station has the capability to 1) extend the amount of time that humans can spend in space, 2) accommodate many crew members, and 3) increase power supply and crew time. This capability would enable extensive scientific observations or conducting larger experiments in space. It would also increase the opportunity for new scientific findings and promote the development of new technologies. In addition, the space station has the capability of being an outpost for on-orbit space activities, or could be a base station for supporting manned explorations to the moon and other planets. These capabilities will lead to expanding the scope of human activities in space.

(3) International Contribution

Japan is expected to fulfill Japan’s share of international responsibility by contributing to the world’s space development through the technologies fostered by Japan’s own independent developments or by utilizing the space shuttles. Through collaboration and participation in the Space Station Program, the relationship between the US and Japan can be maintained or enhanced. In addition, Japan’s technology will be enhanced by keeping pace with the world’s space development. Specifically, Japan will be able to internationally contribute to the advanced technology fields, including electronics, optical communication and robotics, which are technological strengths of Japan.

(4) Promotion of Practical Application of Space Environment Utilization

Recently, experiments using the space environment, including the development of materials and the production of medicines, are being promoted. The utilization of the space environment has received a significant amount of attention. The Space Station Program will advance space environment utilization. Space utilization is generally targeted for commercial activities. Expansion of commercial activities in space is a goal for many countries, including the United States.

With the aim of achieving the above objectives, Kibo has been developed as Japan's first manned spacecraft. Table 1.3-1 shows the background of Kibo development.

Table 1.3-1 Background of Kibo Development (1/2)

Timeline	Activities
April, 1984	In response to US President Reagan's request, NASDA and the commissioned companies began studies on Japan's participation in the Space Station Program
May, 1985	The government of Japan signed a Memorandum of Understanding (MOU) with NASA that pertained to Japan's participation in the space station's preliminary design. The preliminary design was continued for two years thereafter. Policy-related discussions with NASA were conducted under the auspices of Japan's Science and Technological Agency (STA). Technical and engineering-related discussions with NASA were conducted under the auspices of NASDA.
March, 1987	Completion of the space station's preliminary design.
March, 1989	A MOU was signed between NASA and the government of Japan.
June, 1989	Japan's Diet (Japan's legislature) approved the Inter-Governmental Agreement (IGA) that covered the detailed design, development, operation and utilization of a regularly manned civil space station, and included the US government, European countries that are members of the ESA, the government of Japan and Canada's government. Japan officially started the full-scale development of the Japanese Experiment Module for the Space Station Program.
January, 1990	Japan initiated basic designs of Kibo's systems and components.
March, 1990	The "Tokyo Agreement" was executed to establish standardization requirements for the International Standard Payload Rack (ISPR) for use with the ISS modules. The standardizing requirements for the ISPR had been discussed amongst NASA, ESA and NASDA, as part of their trilateral cooperation. The standardizing requirements stipulated and defined the system interfaces, including the rack structure envelope, attachment mechanisms to the ISS modules, power, cooling, data, and video interfaces.
March, 1994	Design of a newly reconfigured space station, also renamed as the "International Space Station (ISS)", was approved. During the reconfiguration and review, the interfaces between Kibo and the ISS were revised. The control documents related to Kibo's launch, operations and development were also reviewed.
March, 1994	Development of the Kibo Flight Model (PFM) was initiated.

Table 1.3-1 Background of Kibo Development (2/2)

Timeline	Activities
July, 1996	Development of Kibo's Inter-orbit Communication System (ICS), which will be used for communications between Kibo and the Data Relay Test Satellite (DRTS), also known as "Kodama", was decided, based on the consensus to utilize the DRTS.
April, 1999	The name of the Japanese Experiment Module was domestically solicited and, "Kibo" was selected from the numerous names that were submitted.
May, 2000	Kibo's Experiment Logistics Module-Pressurized Section (ELM-PS) arrived at Tsukuba Space Center (TKSC). A series of tests on the ELM-PS systems were initiated.
November, 2000	Kibo's Exposed Facility (EF) was shipped from the prime contractor to TKSC. A series of tests on the EF systems were initiated.
December, 2000	Kibo's Experiment Logistic Module-Exposed Section (ELM-ES) was shipped from the prime contractor to TKSC. A series of tests on the ELM-ES systems were initiated.
September, 2001	After completing a series of system tests, Kibo's Pressurized Module (PM) was shipped from the prime contractor to TKSC.
October, 2001	Kibo's total system test was conducted from October 2001 to May 2002.
April, 2003	At the NASA-NASDA PM Pre-shipment Review meeting held on April 7th, the PM was verified as satisfying the requirements for transferring to the US. On April 22nd, the PM departed on a river barge from Tsuchiura New Harbor to Yokohama Harbor.
May, 2003	The PM departed on an ocean vessel from Yokohama Harbor to NASA's Kennedy Space Center (KSC). The PM arrived at Port Canaveral, which is adjacent to the KSC on May 30th.
August, 2003	At KSC, the PM went through the Multi-Element Integrated Test-III (MEIT-III), which is a test that verifies the system functionality and interface compatibility between the PM and the connection module, Node 2.
September, 2003	From September 2003 to March 2004, a series of tests on the PM were conducted, including the functionality verification tests, the Flight Crew Interface Test (FCIT), leak tests and a series of checkouts and inspections prior to classifying the PM as, "in loading process". One year prior to launch is set as the "functionality maintenance period". During this period, various tasks are scheduled that's targeted to the loading of the PM on to the space shuttle.
January, 2007	On January 12th, Kibo's robotic arm, Japanese Experiment Module Remote Manipulator System (JEMRMS) was shipped via air transport, from TKSC to KSC. On January 26th, Kibo's ELM-PS was shipped from TKSC. The ELM-PS was shipped via river barge from Tsuchiura New Harbor to Yokohama Harbor.
February, 2007	On February 7th, the ELM-PS departed on an ocean vessel from Yokohama Harbor to KSC. The ELM-PS arrived at Port Canaveral, which is adjacent to KSC on March 12th.

2. Kibo Elements

2.1 Kibo Elements

The Japanese Experiment Module (JEM), also known as Kibo, consists of six components: two experiment facilities of the Pressurized Module (PM) and the Exposed Facility (EF), a Logistics Module that is attached to each of the PM and EF, a Remote Manipulator System(RMS), and an Inter-Orbit Communication System(ICS). Figure 2.1-1 shows an overview of the assembled Kibo structure.

Air, electrical power, heat and communications, which are essential for Kibo's operation, will be supplied from the International Space Station (ISS).

Inside the space shuttle cargo bay, electrical power is provided to the Kibo's elements from the Space Shuttle to prevent the coolant water lines from freezing, and to maintain optimal temperatures within the critical components prior to final attachment to the ISS.

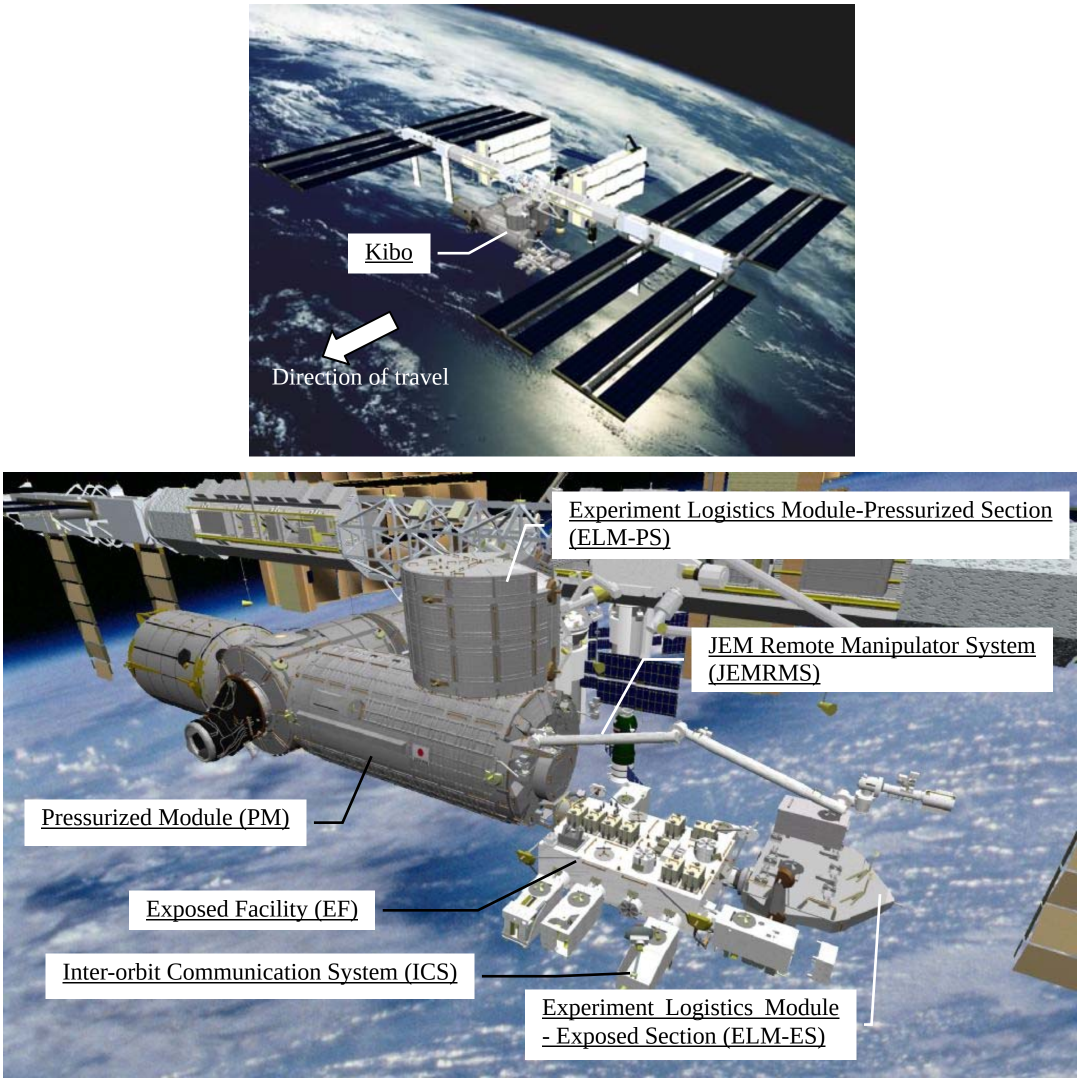


Figure 2.1-1 Kibo Structure

2.1.1 Pressurized Module (PM)

Kibo's Pressurized Module (PM) is 11.2 meters in length and 4.4 meters in diameter. The PM's internal air pressure is maintained at one atmosphere (1 atm), thus providing a shirt-sleeve working environment for the crew. ISS crew will conduct unique microgravity experiments within the PM. The PM will hold 23 racks - ten of which are International Standard Payload Rack (ISPR) for experiment payloads. The remaining 13 racks are dedicated to Kibo's systems and storage.

Kibo also has a scientific airlock, the "JEM Airlock", through which experiments are transferred and exposed to the external environment.

Figure 2.1.1-1 shows a picture of the PM.

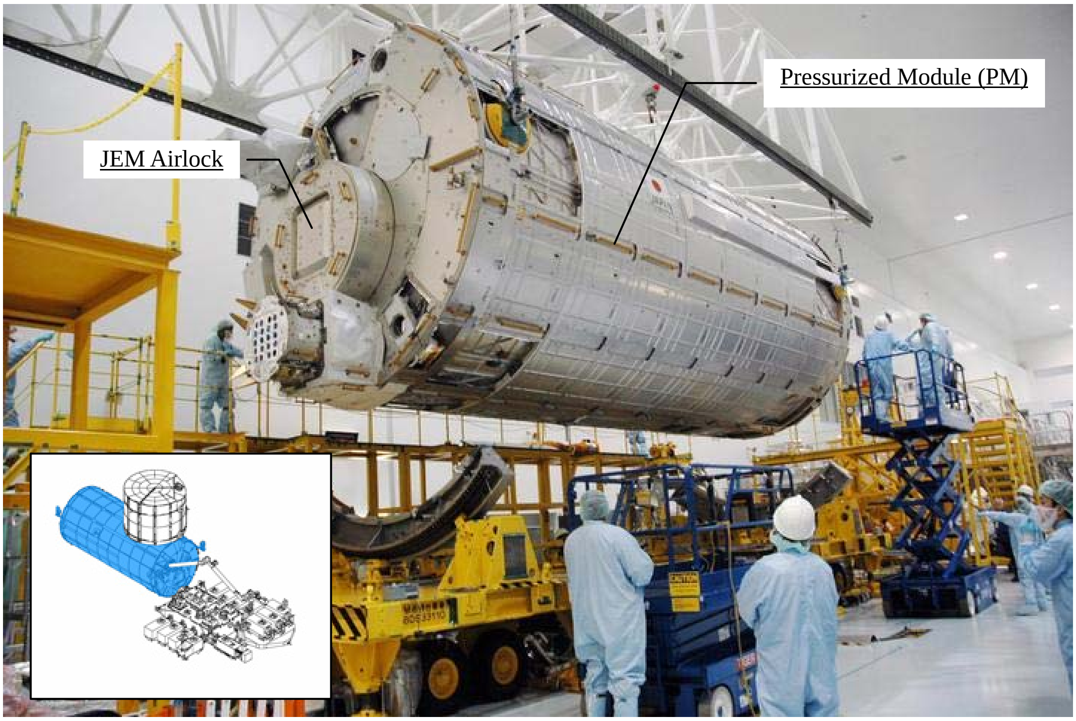


Figure 2.1.1-1 Pressurized Module (PM)

2.1.2 Experiment Logistics Module - Pressurized Section (ELM-PS)

Kibo's Experiment Logistics Module - Pressurized Section (ELM-PS) provides a storage space for experiment payloads, samples and spare items. The interior of the ELM-PS is controlled and maintained at the same air pressure and temperature as that of the PM, and astronauts will be able to freely move between the ELM-PS and the PM. Among the ISS research facilities/modules, Kibo is the only experiment module with its own dedicated storage facility.

Figure 2.1.2-1 shows an external view of the ELM-PS.

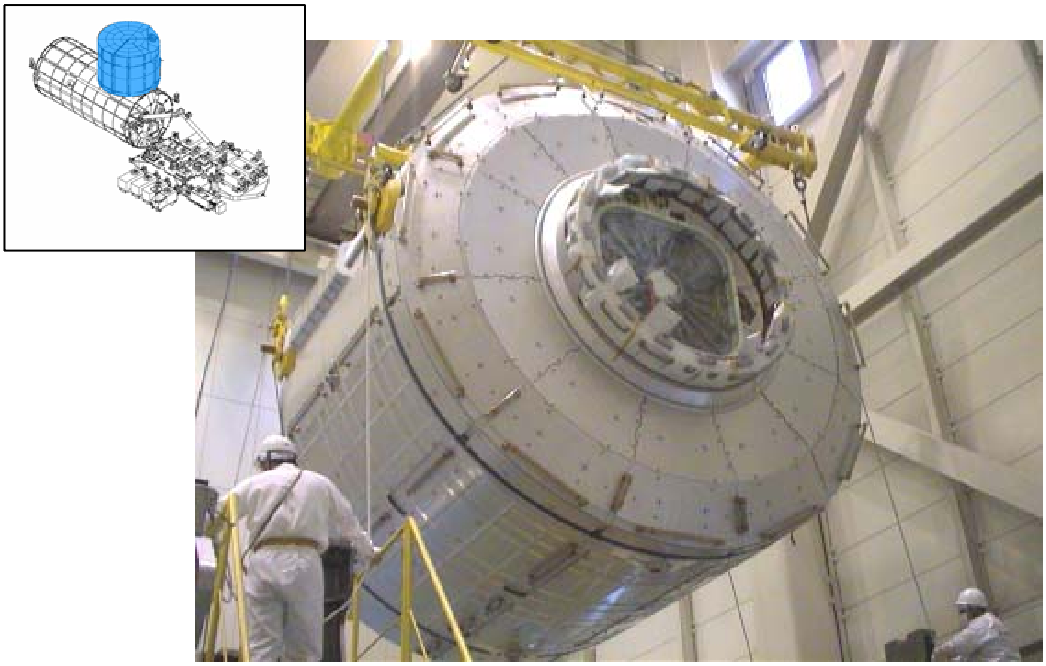


Figure 2.1.2-1 Experiment Logistics Module-Pressurized Section (ELM-PS)

2.1.3 Exposed Facility (EF)

Kibo's Exposed Facility (EF) provides a multipurpose platform where science experiments can be deployed and operated in the exposed envirnment. The experiment payloads attached on the EF will be exchanged or retrieved by using Kibo's robotic arm, the "JEM Remote Manipulator System (JEMRMS)", which will be operated by the crew from inside the PM.

Figure 2.1.3-1 shows an external view of the EF.

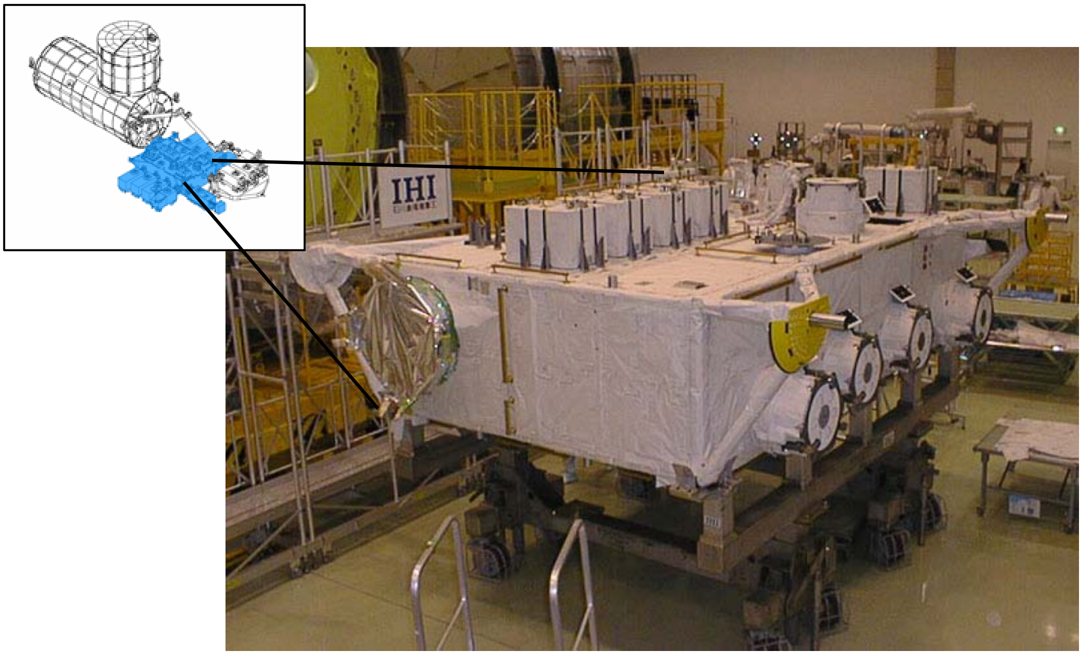


Figure 2.1.3-1 Exposed Facility (EF)

2.1.4 Experiment Logistics Module - Exposed Section (ELM-ES)

Kibo's Experiment Logistics Module-Exposed Section (ELM-ES) is attached to the end of the EF and provides a storage space for experiment payloads and samples. Experiment payloads and samples are stored for later use for the experiments on the EF. Up to three experiment payloads can be stored on the ELM-ES. In addition, the ELM-ES provides a logistics function where the ELM-ES can be detached from the EF and returned to the ground aboard the space shuttle along with completed experiments or samples. The ELM-ES can be re-stocked and then launched again on missions to the ISS.

Figure 2.1.4-1 is an overview of the ELM-ES.

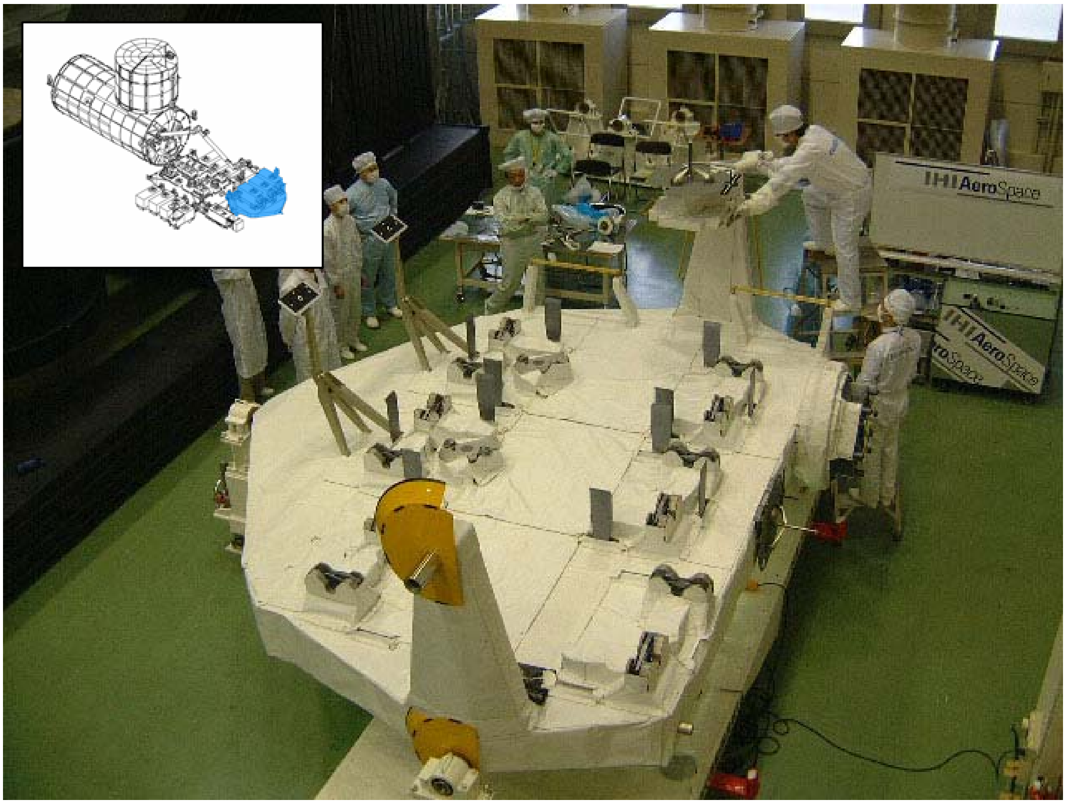


Figure 2.1.4-1 Experiment Logistics Module-Exposed Section (ELM-ES)

2.1.5 JEM Remote Manipulator System (JEMRMS)

Kibo's robotic arm, JEM Remote Manipulator System (JEMRMS), serves as the human arm and hand in supporting the experiments conducted on the EF. The JEMRMS is composed of the Main Arm (MA) and the Small Fine Arm (SFA). Each arm has six joints. The MA is used primarily for exchanging external EF payloads and for moving large items. The SFA, which is attached to the end of the MA, is used for more delicate operations. The crew will operate these robotic arms from a remote operations console, the JEMRMS Console, located inside the PM. The crew will watch external images, taken from the cameras that are attached to the MA, on a television monitor at the JEMRMS Console.

Figure 2.1.5-1 shows a picture of the JEMRMS.

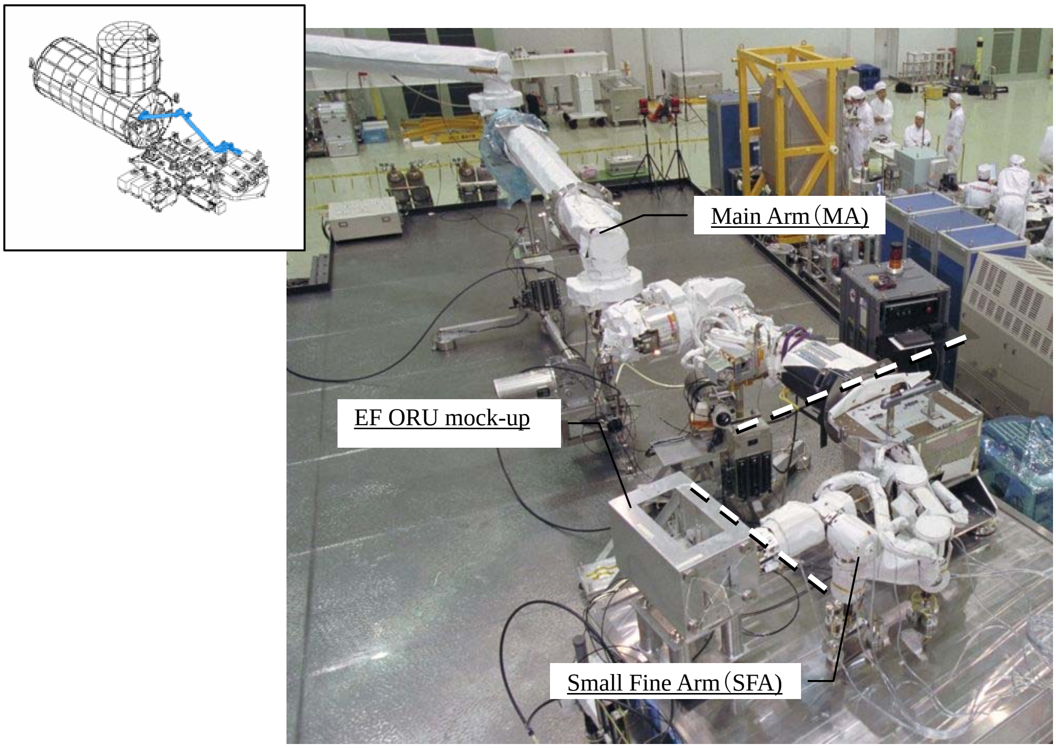
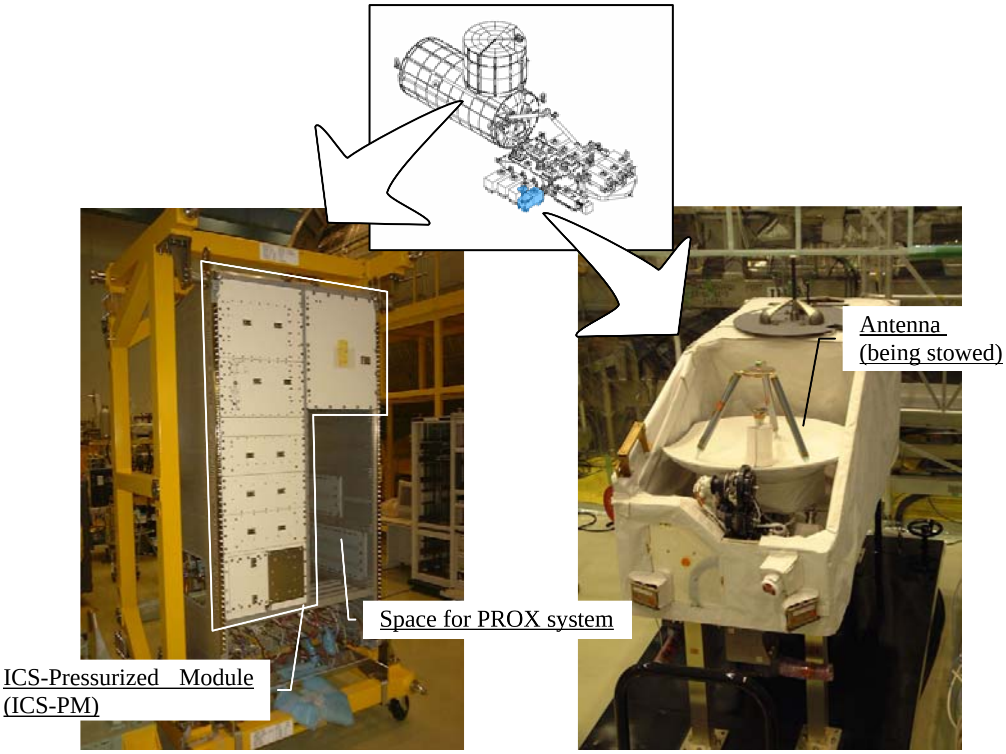


Figure 2.1.5-1 JEM Remote Manipulator System (JEMRMS) -Combination Operation Test

2.1.6 Inter-orbit Communication System (ICS)

Kibo's Inter-Orbit Communication System (ICS) provides independent intercommunications between Kibo and the Tsukuba Space Center (TKSC). Through the JAXA's Data Relay Test Satellite (DRTS), commands and voice are uplinked from the ground to Kibo, and experiment data, image data or voice are downlinked from Kibo to the ground for scientific payload operations. The ICS consists of two subsystem components: ICS-Pressurized Module (ICS-PM) and ICS-Exposed Facility (ICS-EF). The ICS-PM, which is installed in the PM, provides command and data handling functions. The ICS-EF has antenna and pointing mechanism that will be used to communicate with the DRTS.

Figure 2.1.6-1 shows pictures of the ICS subsystems.



ICS-Pressurized Module (ICS-PM)

ICS Exposed Facility subsystem (ICS-EF)

PROX (Proximity Communication System) is a communication system which will be used for a rendezvous operation of the H-II Transfer Vehicle (HTV)

Figure 2.1.6-1 Inter-orbit Communication System (ICS)

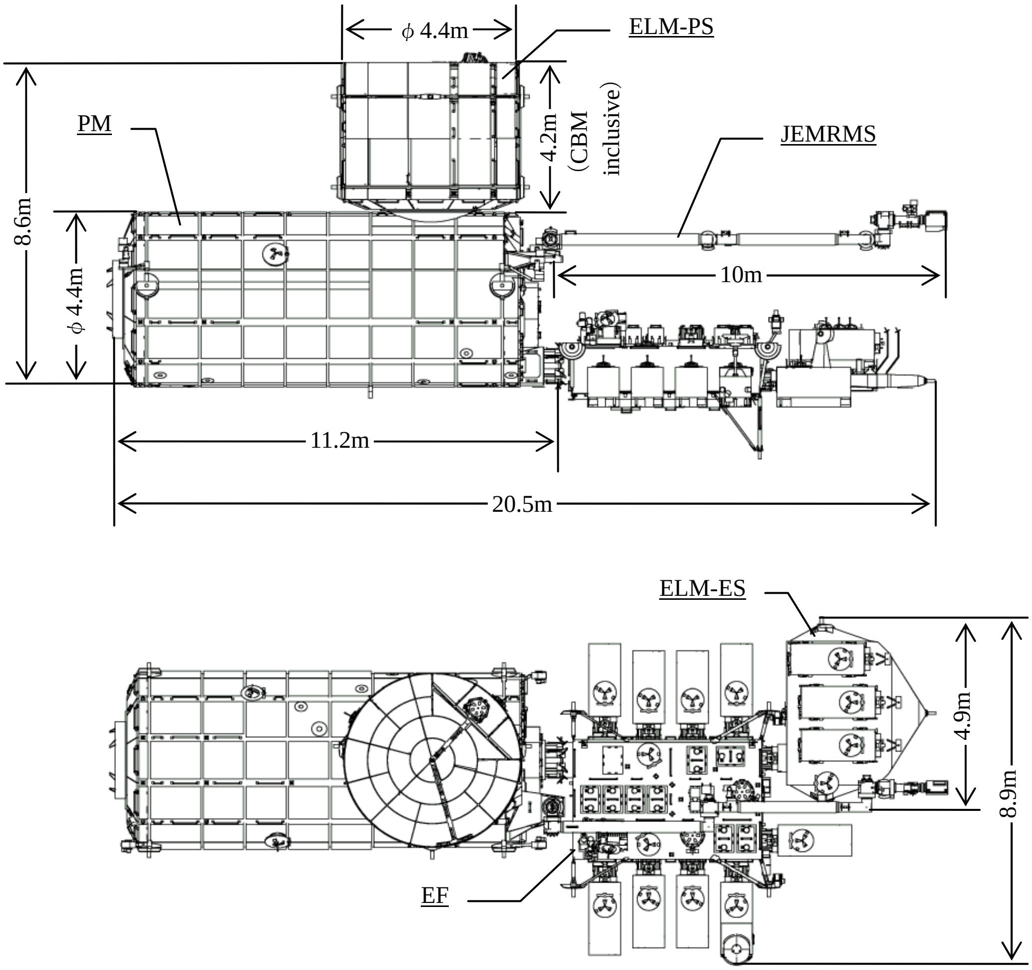
3. Kibo Specifications

3.1 Specifications of Kibo Components

Table 3.1-1 shows the specifications for Kibo's components. Figure 3.1-1 shows Kibo's configuration diagrams. For further details on Kibo's components, please refer to Chapter 4.

Table 3.1-1 Specifications

Component	Dimension (m)	Mass (t)	Number of racks or ISPRs installed
Pressurized Module (PM)	Outer Diameter: 4.4 Inner Diameter: 4.2 Length: 11.2	15.9	23 racks (11 Kibo's System Racks and 12 International Standard Payload Racks (ISPR))
Experiment Logistic Module-Pressurized Section (ELM-PS)	Outer Diameter: 4.4 Inner Diameter: 4.2 Length: 4.2	4.2	8 racks
Remote Manipulator System (JEMRMS)	Length: Main Arm: 10 Small Fine Arm: 2.2	1.6 (Includes RMS console)	Main Arm's maximum lifting capacity: 7 t
Exposed Facility (EF)	Width: 5.0 Height: 4.0 Length: 5.6	4.1	12 attachments for EF payloads (10 for payloads and 2 for systems. In addition, one space for temporary storage/attachment is available)
Experiment Logistic Module-Exposed Section (ELM-ES)	Width: 4.9 Height: 2.2 Length: 4.2	1.2	3 EF payloads
	Total	27	



CBM: Common Berthing Mechanism

Figure 3.1-1 Kibo Configuration Diagram

3.2 Kibo Operation Mode

Four different operation modes are used for managing Kibo's systems. Kibo operation mode varies according to the Kibo's operations and/or the upper ISS operation modes. Kibo operation modes and the corresponding descriptions are shown in Table 3.2-1. The operation mode can be switched manually by crew or by commands sent from the ground. Figure 3.2-1 shows the Kibo operation mode transition.

Similarly, the International Space Station (ISS) has seven operation modes. All the ISS operation modes are switched by commands sent from the ground or by the crew. The ISS operation modes and their corresponding descriptions are shown in Table 3.2-2.

There are situations where Kibo operation modes are constrained depending on the status of the ISS operation mode. For example, the ISS operation mode has to be set as "External Operation Mode" when switching the Kibo operation mode from "Standard Operation Mode" to "Robotics Operation Mode" for JEMRMS operation. The relation between Kibo operation modes and ISS operation modes are shown in Table 3.2-3. In the event of an ISS emergency, the ISS operation modes will be switched accordingly; however if Kibo operation mode at this point is not applicable, then Kibo operation mode will be switched to "Standby Mode" automatically.

Table 3.2-1 Kibo Operation Modes

Kibo Operation Mode	Mode Description and Status
Standard Operation Mode	Kibo primary operation mode. The crew can conduct experiments. However, the crew can not use the JEMRMS.
Robotics Operation Mode	The mode where the crew operates Kibo's robotic arms. The other features are the same as those of "Standard Operation Mode".
Standby Mode	Mode for when an emergency occurs with Kibo's systems. In emergency cases, Kibo will be operated with minimal systems by prohibiting all the experiment supports.
Isolation Mode	Mode for when the pressurization in the Kibo's pressurized section cannot be maintained. In this mode, the hatch between Kibo and ISS will be closed and crew will not be able to enter either the PM or ELM-PS.

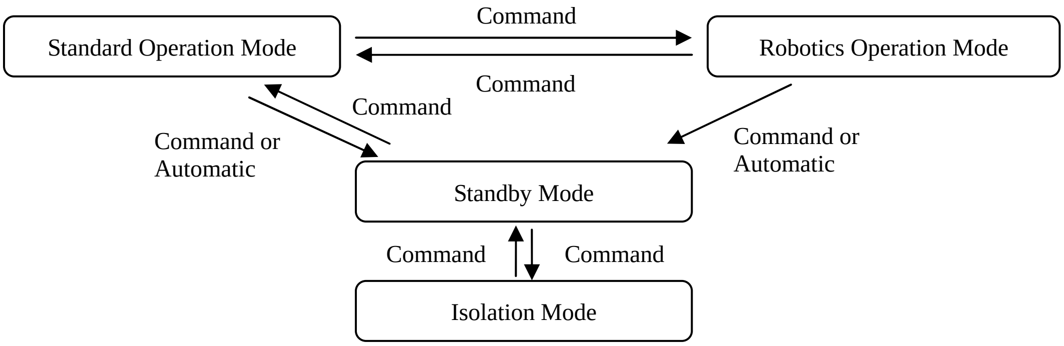


Figure 3.2-1 Kibo Operation Mode Transitions

Table 3.2-2 ISS Operation Modes

ISS Operation Mode	Mode Description and Status
Standard Mode	ISS primary operation mode.
Re-boost Mode	Mode for when the ISS changes orbital altitude (re-boost).
Microgravity Mode	Mode for operating the experiment payloads that require a microgravity environment.
Survival Mode	Mode for ISS critical emergency situations (eg when a verified anomaly occurs with the ISS power or attitude control systems). This mode is used to sustain the long-term operation/survivability of the ISS.
Proximity Operation Mode	Mode for when spacecrafts, including the space shuttles, Soyuz spacecrafts and Progress cargo ships are in proximity operations to dock or undock/depart from the ISS.
Assured Safe Crew Return (ASCR) Mode	Mode for when the life of the ISS crew is in danger and for supporting the swift departure (undock/separation) of the Soyuz for returning the crew safely back to the ground.
External Operation Mode	Mode to support Extravehicular Activities (EVAs) or robotic arm operations for external assembly or maintenance.

Table 3.2-3 Applicability of Kibo Modes to ISS Operation Modes

ISS Operation Mode / Kibo Operation Mode	Standard	Re-boost	Microgravity	Survival Operation	Proximity Operation	Assured Safe Crew Return (ASCR)	External Operatione
Standard	A	A	A	NA	A	A	A
Robotics Operation	NA	NA	NA	NA	NA	NA	A
Standby	A	A	A	A	A	A	A
Isolation	A	A	A	A	A	A	A

A: Applicable
NA: Not Applicable

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4. Kibo System Components

4.1 Pressurized Module (PM)

4.1.1 Brief Summary

Kibo's Pressurized Module (PM) is a research facility where astronauts will enter and conduct scientific experiments or control Kibo's systems. The air composition inside the PM is nearly the same as that on earth. The air pressure is maintained at one atmospheric pressure (1atm), thus providing a comfortable working environment for the astronauts. The temperature and humidity inside the PM are also controlled so that the astronauts will be able to work in a shirt-sleeve environment.

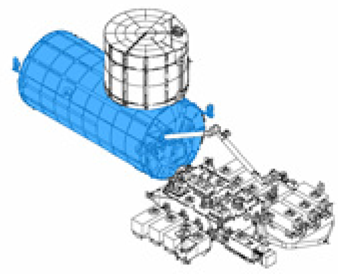


Figure 4.1.1-1 PM location

The racks that will be installed inside the PM are basically divided into two categories; JEM system racks which will control and maintain Kibo's facilities, and payload racks which will be used for experiments inside the PM.

The JEM system racks includes, power supply, communications, air conditioning, thermal control and experiment support systems. The console for Kibo's robotic arms (JEMRMS Console) and the scientific airlock (JEM Airlock) are Kibo's unique system.

The research payloads are for conducting experiments that have been solicited and selected from applications submitted from the general scientific community. The PM will hold ten International Standard Payload Racks (ISPRs) for various types of experiments; mainly for life science and material science experiments.

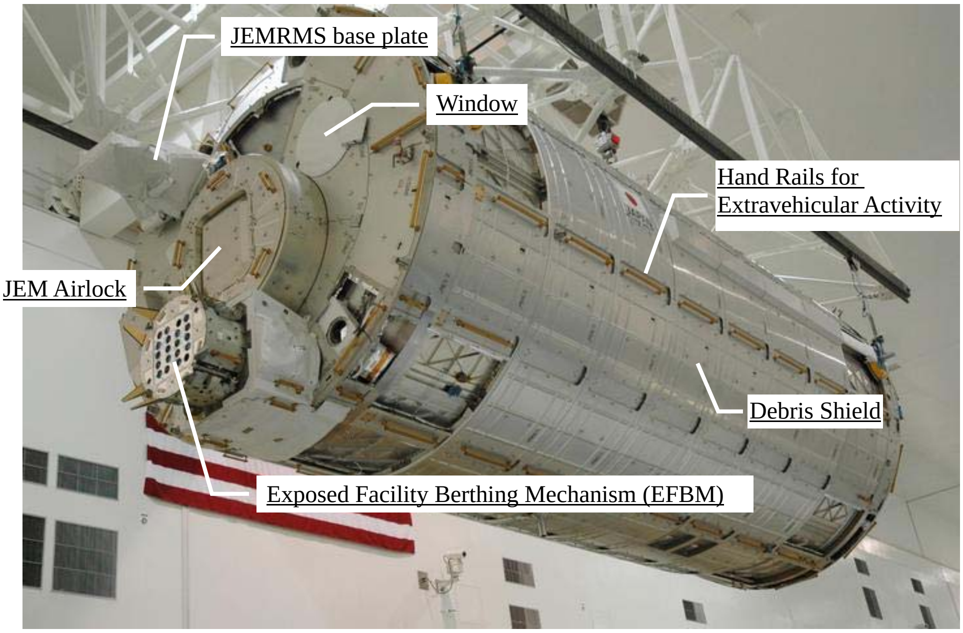
Table 4.1.1-1 shows the specifications for the PM.

Table 4.1.1-1 PM Specifications

Items		Specifications
Shape		Cylindrical
Diameter	Outer diameter	4.4 m
	Inner diameter	4.2 m
Length		11.2 m
Mass		15.9 t
Number of Payload Racks		23 racks JEM system racks: 11 Scientific experiment racks: 12 (10 research/experiment racks, one refridgerator rack, and one stowage rack)
Electrical Power		Max. 24kW, max. 120V DC
Data management system		32-bit computer system High-speed data link: max. 100 Mbps
Environmental control	Temperature	18.3 to 26.7 degrees Celsius (°C)
	Humidity	25 to 70 %
Number of crew		2 persons for normal operation (max. 4 persons)
Life time		More than 10 years

4.1.2 Layout

Figure 4.1.2-1 shows an external view and structure of the PM.



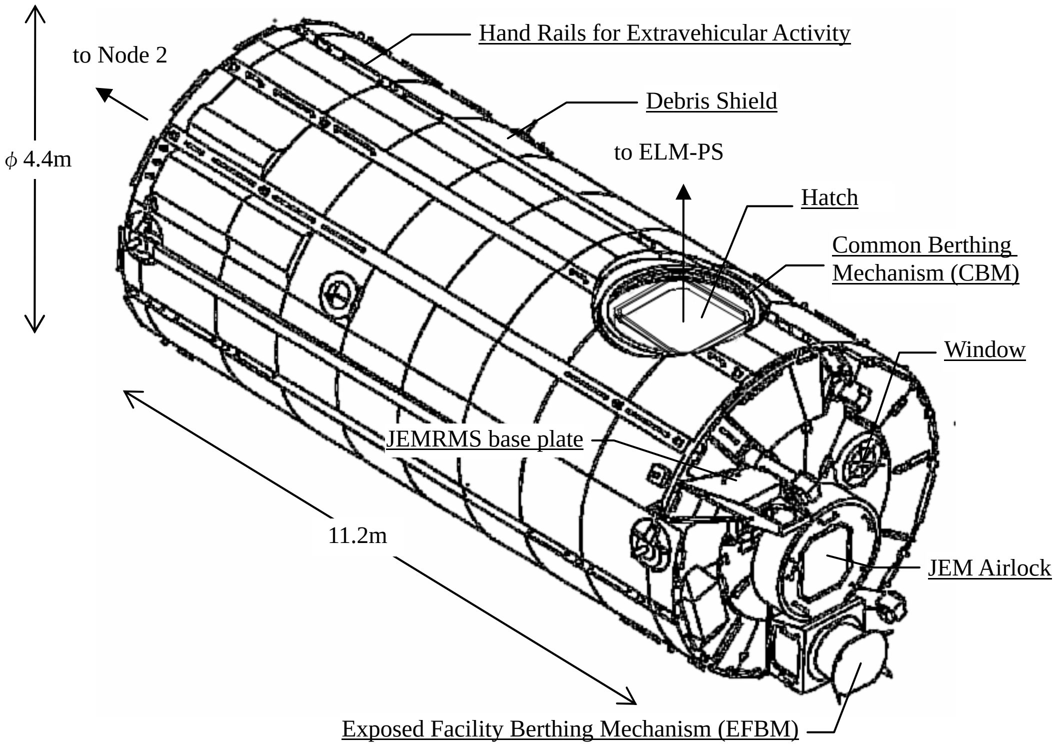
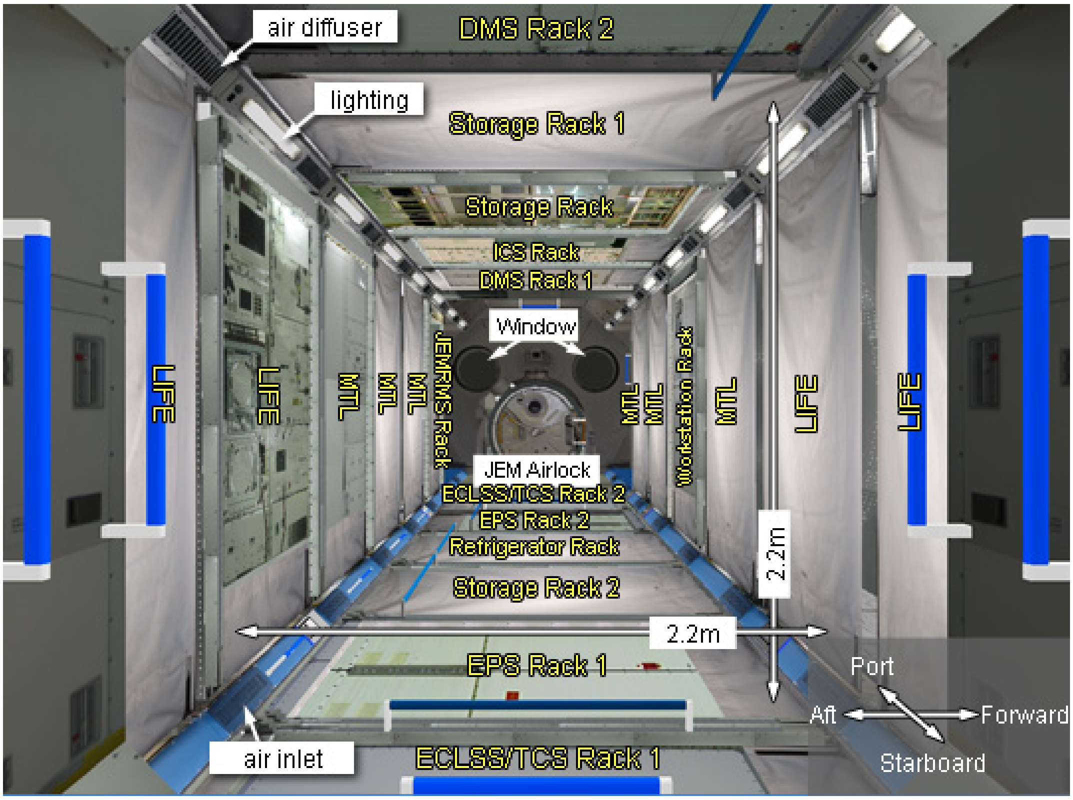


Figure 4.1.2-1 Kibo's PM

Inside the PM, the inner walls will hold racks that are composed of either JEM system or scientific research payloads. The work space inside the PM is almost square in shape and is 2.2 m in height and width. An internal view of the PM is shown in Figure 4.1.2-2.

The PM can hold a total of 23 racks. The racks are built into the inner four walls of the PM. Of the four inner walls, six racks will be built into three of the walls, and five racks will be built in the remaining wall. Of these racks, 11 racks are for JEM system, and 12 are for payloads. The racks can be attached or detached on orbit. Figure 4.1.2-3 shows the locations of the JEM system racks. Figure 4.1.2-4 shows the locations of the payload racks. A schematic of how to attach and/or detach the racks is shown in Figure 4.1.2-5.

The payloads racks are designed according to the standardized specifications for hardware interface power and data interface. These racks built in accordance with the required standardized specifications are called "International Standard Payload Rack (ISPR)". Of the 12 payload racks inside of the PM, 11 racks are ISPRs and one rack is for storing experiment materials.



DMS: Data Management System
EPS: Electric Power System
ECLSS: Environmental Control and Life Support System
TCS: Thermal Control System
LIFE: Life Science Payload Rack
MTL: Material Science Payload Rack

Figure 4.1.2-2 Internal Image of PM (view as may be seen from the Harmony Module)

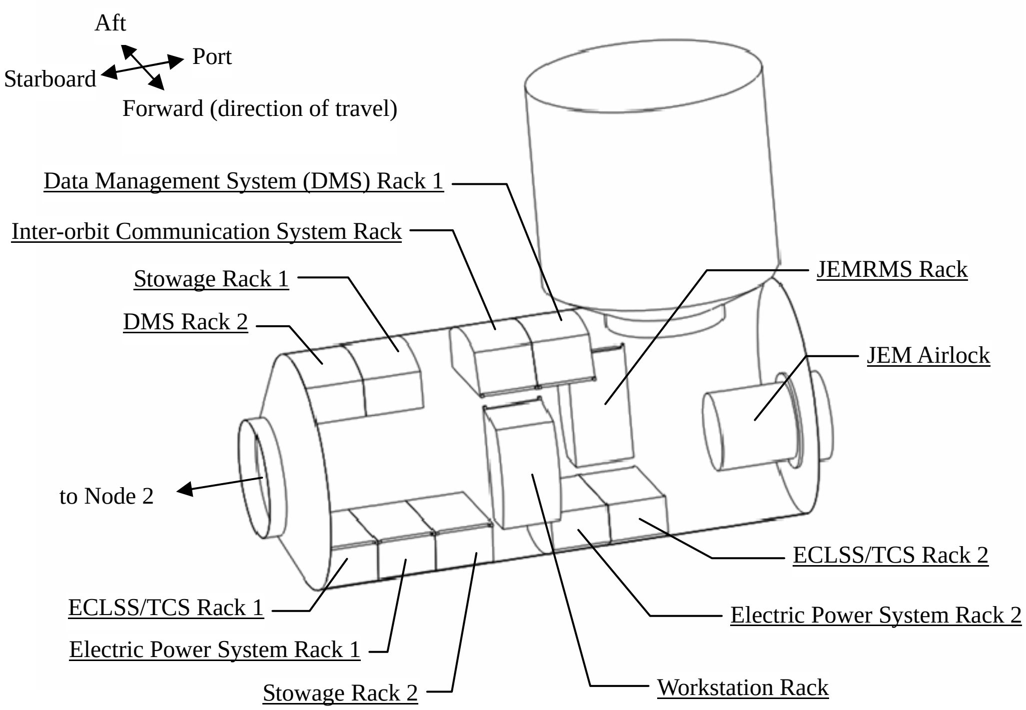


Figure 4.1.2-3 JEM System Racks inside PM

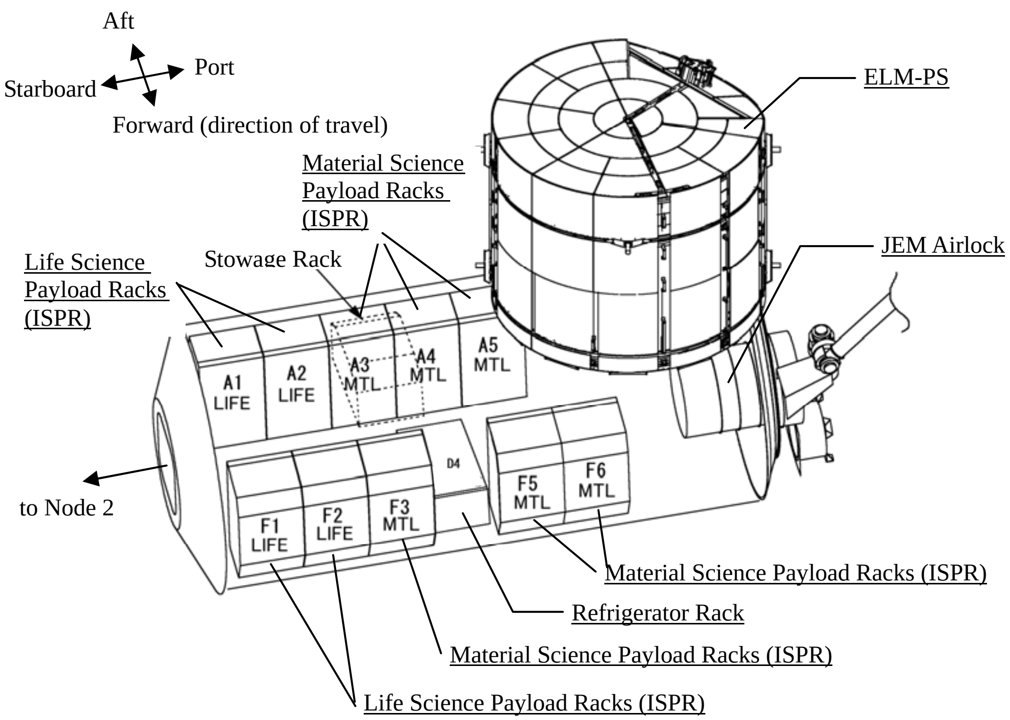


Figure 4.1.2-4 Experiment racks (ISPRs) inside PM

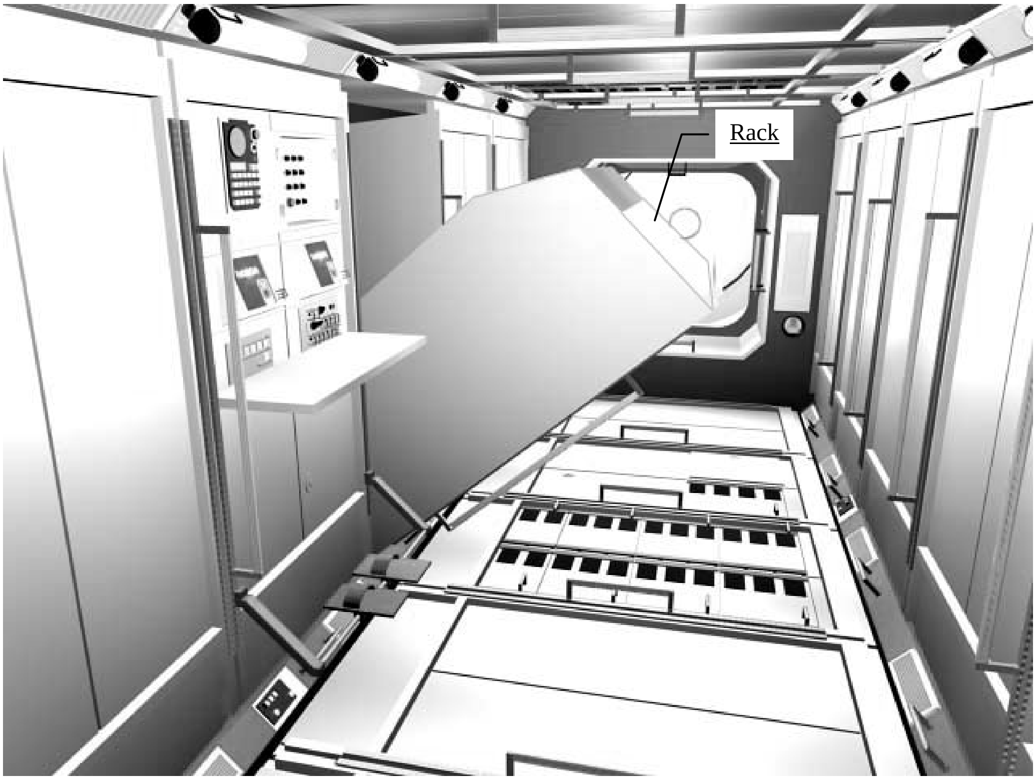


Figure 4.1.2-5 Schematic of how to attach or detach the racks: Each rack can individually be attached and detached for relocation, exchange, or maintenance.

4.1.3 System Components of PM

The PM is composed of the following subsystems.

- Command and Data Handling (C&DH)
- Electrical Power System (EPS)
- Communication and Tracking (C&T)
- Thermal Control System (TCS)
- Environmental Control and Life Support System (ECLSS)
- Experiment Support System (ESS)
- Structure
- Mechanical System
- Crew Support System (CSS)

The Command and Data Handling (C&DH), the Electric Power System (EPS), the Communication and Tracking (C&T), the Thermal Control System (TCS) and the Environmental Control and Life Support System (ECLSS) are in particular critical systems, and thus, have redundant structures composed of primary and secondary strings. If a system's primary string fails, the secondary string will takeover the primary's function and capability, and will fully or partially maintain the system. When the PM is in an operational status, basically, both primary and secondary strings of the above listed systems will be activated. The followings are details of the systems/subsystems.

(1) Command and Data Handling (C&DH)

The Command and Data Handling (C&DH) system includes the JEM Control Processor (JCP), which is Kibo's central subsystem that controls and monitors the status of Kibo's system and experiment payloads. The JCP also controls the setting of Kibo Operation Mode in concert with the ISS Operation Modes. For further information on Kibo's and ISS operation modes, please refer to Chapter 3, Section 3.2.

This subsystem also has data processing functions, including collecting and compiling Kibo's system status data and experiment data for downlink to the ground, relaying data files to each of Kibo's systems through the Communication and Tracking (C&T) system, or relaying the actual time data provided from the ISS to each payload or system onboard Kibo. Kibo is equipped with two JCP units for redundant purposes. If one of the JCP units fails, the second JCP unit will automatically take over the control and fully maintain the functions and capabilities that the JCP is responsible for.

(2) Electrical Power System (EPS)

The Electric Power System (EPS) converts and distributes the electrical power (two electrical power channels, 120V DC each) that is supplied from the Node 2 of the ISS. The EPS consists of various units including, Power Distribution Boxes (PDBs) and Power Distribution Units (PDUs) that distributes power to payloads and system equipments.

(3) Communication and Tracking (C&T)

The Communication and Tracking (C&T) consists of Low /Medium/High Data Rate Systems, Video System and Audio System.

The Low Rate (max. 1Mbps), Medium Rate (max. 10Mbps) and High Rate (max. 100 Mbps) Data Systems relays the data sent from the C&DH system to each subsystem, and collects data from the JEM system or payloads to be relayed to the C&DH system.

The Video System is composed of Television Cameras (TVCs) which are installed inside and outside of Kibo, Television Monitors and Camera Control Panels (CCPs). The Video System will transmit visual images taken by the TVCs.

The Audio System is composed of Audio Terminal Units (ATUs) installed in the Work Station Rack (WS Rack) and JEMRMS rack. The ATU is a unit common to the ISS. ATUs are installed in several locations within the ISS. The crew can use the ATUs as an interphone for communicating with another crew in a different segment of the ISS.

(4) Thermal Control System (TCS)

The Thermal Control System (TCS) consists of the following two systems: An Active Thermal Control

System (ATCS) which transfers the heat generated in the Kibo's equipments by means of circulating coolant water in the coolant loops, and a Passive Thermal Control System (PTCS) which controls and maintains the temperature of Kibo's equipment through the use of insulating materials or heaters. Two water coolant loops, the Low Temperature Loop (LTL) and Moderate Temperature Loop (MTL) are included in the PM. The heat generated in Kibo is collected and discharged through two external ammonia coolant loops (medium and low temperature), known as the Interface Heat Exchanger (IFHX), which is located on the Node 2 exterior. A maximum of 25kW of heat can be discharged through the medium temperature IFHX, and a maximum of 9 kW can be discharged through the low temperature IFHX.

(5) Environmental Control and Life Support System (ECLSS)

The Environmental Control and Life Support System (ECLSS) controls and maintains the temperature inside of the PM within a range of 18.3 to 26.7 degree Celsius (°C) and humidity within a range of 25 to 70 %. The astronauts will be able to conduct experiments in a shirt-sleeve environment. This system provides a comfortable and safe intra-vehicular environment.

The pressurized air is adjusted by a mixture of oxygen and nitrogen supplied from the US segment of the ISS. The air is circulated inside Kibo by fans for inter-module ventilations, and then returned to the ISS US segment.

Kibo has fire detection and suppression function. Smoke sensors will detect any fire. The fire's location will be isolated by power shut down. Fire extinguishers (carbon dioxide) will be used to suppress the fire.

(6) Experiment Support System (ESS)

The Experiment Support System (ESS) supplies argon (Ar), helium (He), nitrogen (N2) and carbon dioxide (CO2) to the payload racks located in the PM. The ESS also conducts vacuum ventilation and evacuates the gasses from the payload racks. The Common Gas Supply Equipment (CGSE) is a unique special element of Kibo. The CGSE contains gas bottles of Ar, He and CO2, and supplies these gases to each experiment rack. Nitrogen gas that will be supplied to the experiment racks is provided from NASA's Environment Control and Life Support System (ECLSS).

(7) Structure

The structural body of the PM is designed to bear loads imposed during the space shuttle's launch, ascent, ISS attitude control and maneuver. At the same time, the system will maintain a pressurized environment inside the PM through a shielding of aluminum alloy panels. The Debris Shield covers the PM's outer shell structure to protect the body from debris impacts. The PM is equipped with two windows located on the side of the EF docking port. Astronauts will be able to look outside through these windows. The Node 2 side's Passive Common Berthing Mechanism hatch is part of the PM's structure.

(8) Mechanical System

The Mechanical System consists of the following three mechanisms: 1) the Common Berthing Mechanism (CBM) which will be used as the berthing port for the Node 2 or the ELM-PS, 2) the JEM Airlock and 3) the Exposed Facility Berthing Mechanism (EFBM). The following are further details on the CBM and the JEM Airlock. For details of the EFBM, please refer to Section 4.3.3 in this chapter.

(a) Common Berthing Mechanism (CBM)

The Common Berthing Mechanism (CBM) is an ISS common mechanism designed to connect different ISS modules (except Russian modules). The CBM ensures that the modules berthed by the CBM maintain a pressurized environment where astronauts and materials can move freely between different ISS modules.

The CBM is paired and composed of active and passive parts: the Active CBM (ACBM) that uses electric motors for berthing and the Passive CBM (PCBM). The PM has both the PCBM and the ACBM. The PCBM is located on the Node 2 berthing port, and the ACBM is located on the berthing port for the Experiment Logistics Module's Pressurized Section (ELM-PS). Figure 4.1.3-1 shows an outline and configuration of the CBM.

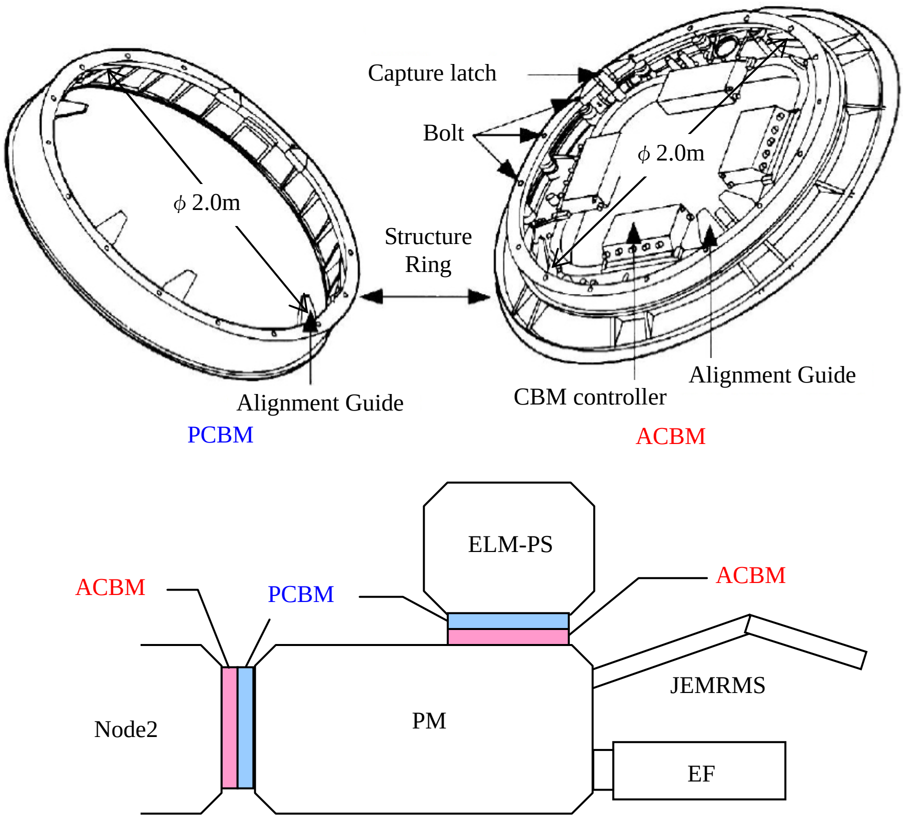


Figure 4.1.3-1 Common Berthing Mechanism (CBM)

(b) JEM Airlock

An airlock is basically a passage or small area where air pressure can be adjusted for differences between two docked neighboring compartments so as to allow astronauts or equipments to move between the two compartments.

The JEM Airlock is designed for transferring experiments and supplies; humans cannot enter this airlock. The JEM Airlock inside is pressurized with air at one atmospheric pressure and the EF which is exposed to the vacuum space environment. The JEM Airlock is used for transferring experiment payloads or samples between PM and EF.

The JEM Airlock is cylindrical and equipped with the Inner Hatch which is located inside of the PM side and "Outer Hatch" which is located outside of the EF side. Experiments and supplies that will be transferred through the airlock are first fastened on a slide table, and then, transferred by extending the slide table. The "Inner Hatch" is equipped with a small window so that astronauts can visually check the inside of the airlock.

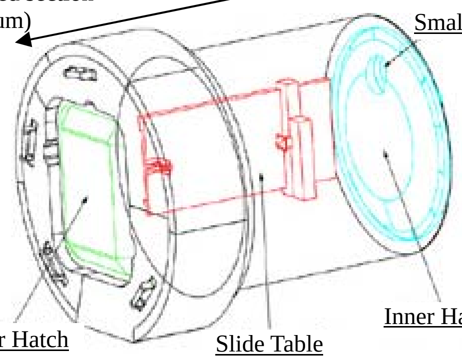


Figure 4.1.3-2 JEM Airlock

Table 4.1.3-1 JEM Airlock Specifications

Item		Specifications
Outer Diameter	Outer side	1.7 m
	Inner side (inside the PM)	1.4 m
Length		2.0 m
Pressure proof performance		1047 hPa
Allowable size for transfer		0.64×0.83×0.80 m
Allowable weigh for transfer		300 kg
Power Consumption		Less than 600 W

(9) Crew Support System (CSS)

The Crew Support System (CSS) is composed of support equipment which will be used by astronauts during inter-vehicular activities. The CSS includes in-board lightings, emergency lightings, handrails, and foot restraints.

4.2 Experiment Logistics Module- Pressurized Section (ELM-PS)

4.2.1 Brief Summary

The Experiment Logistics Module – Pressurized Section, or ELM-PS will initially be used as a logistics container for carrying payload racks and system racks from the ground to the ISS. Once the ELM-PS is on orbit, the ELM-PS will be used as a stowage facility. Maintenance tools for the system and payloads, samples and spare items will be stored inside the ELM-PS. The ELM-PS volume is less than that of the PM. A total of eight racks can be stored inside the ELM-PS

Table 4.2.1-1 shows the ELM-PS specifications.

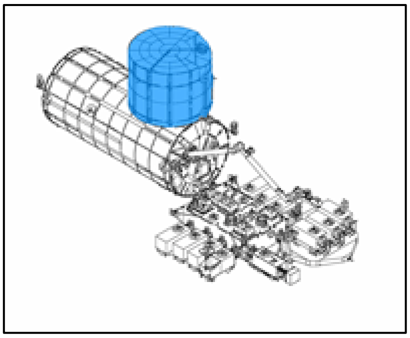


Figure 4.2.1-1 ELM-PS location

Table 4.2.1-1 ELM-PS Specifications

Items		Specifications
Structural Type		Cylindrical
Diameter	Outer Diameter	4.4 m
	Inner Diameter	4.2 m
Length		4.2 m
Mass		4.2 t
Number of Racks		8 racks
Power provided		3kW 120V DC
Environment		Temperature: 18.3 to 29.4 degree Celsius (°C) Humidity: 25 to 70 %
Life Time		More than 10 years

4.2.2 Layout

Figure 4.2.2-1 shows the ELM-PS structure. Figure 4.2.2-2 shows the rack locations inside the ELM-PS.

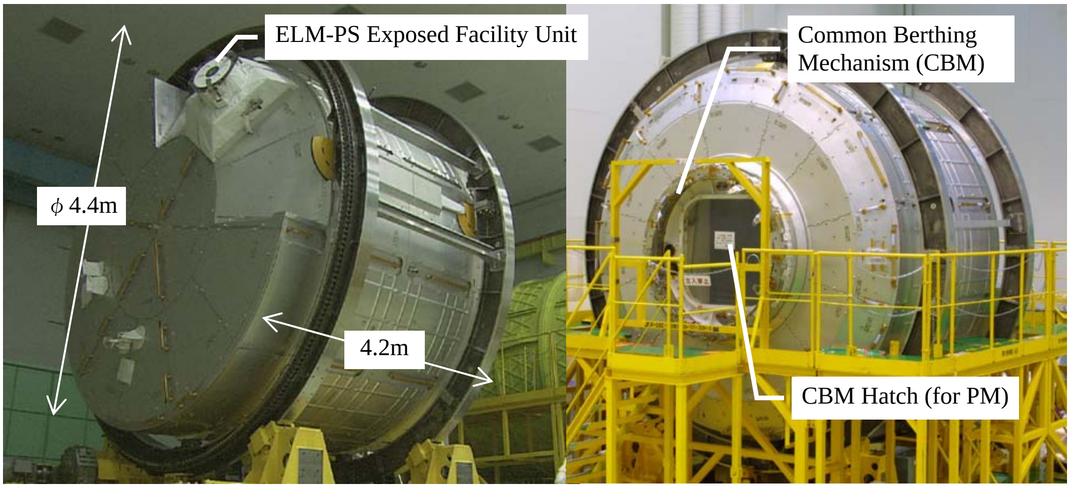


Figure 4.2.2-1 ELM-PS Structure

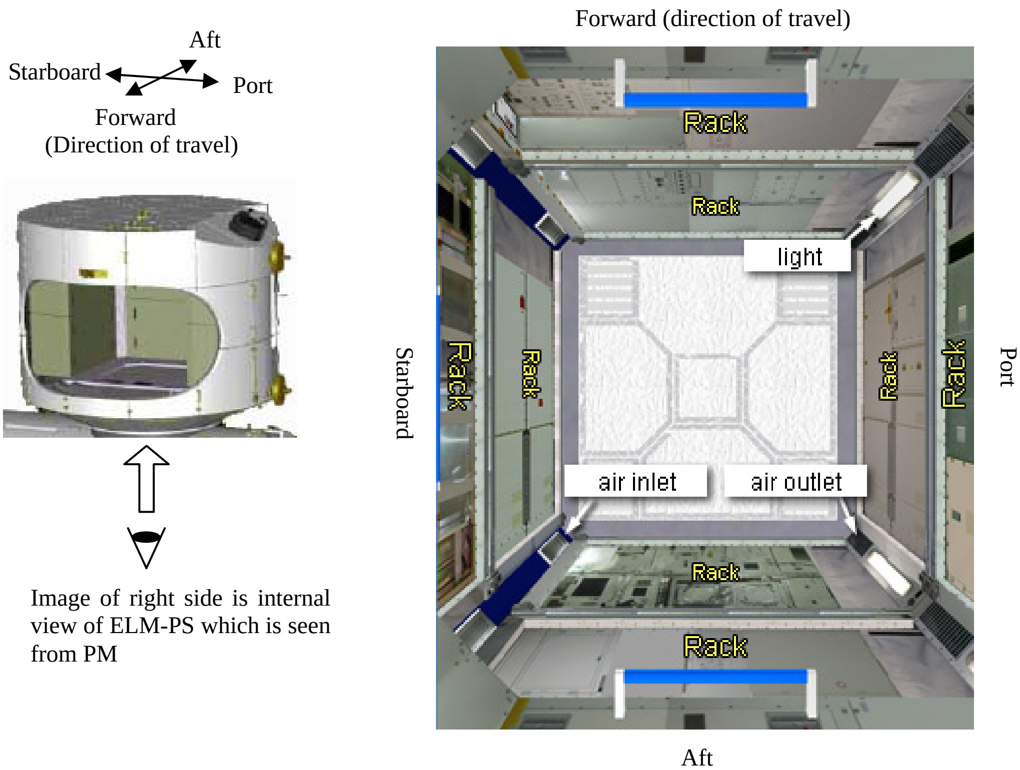


Figure 4.2.2-2 Rack Locations inside ELM-PS

4.2.3 System Components of ELM-PS

The ELM-PS consists of the following subsystems.

- Electrical Power System (EPS)
- Communication and Tracking (C&T)
- Thermal Control System (TCS)
- Environmental Control and Life Support System (ECLSS)
- Structure
- Mechanical System
- Crew Support System (CSS)

Each ELM-PS subsystem is driven with one-string system, whereas the PM's subsystems have a redundant functionality. The followings are details of the ELM-PS subsystems.

(1) Electrical Power System (EPS)

The Electrical Power System (EPS) distributes electrical power provided by the PM's EPS to each ELM-PS subsystem. In the event that the PM EPS fails, a second PM EPS channel is available as backup; however the crew will need to change the wiring. When the ELM-PS is attached temporarily to the Node 2 awaiting arrival of the PM (Please refer to Chapter 5, Section 5.2.1), the electrical power will be supplied to the ELM-PS from the Node 2.

(2) Communication and Tracking (C&T)

The Communication and Tracking (C&T) consists of a Medium (max. 10 Mbps) Data System, Video System and Audio System. The C&T relays the data from the ELM-PS subsystems or images inside of the ELM-PS to the PM's Communication and Tracking (C&T) system.

(3) Thermal Control System (TCS)

The Thermal Control System (TCS) maintains the temperature inside the ELM-PS, within a required range, by means of a Passive Thermal Control System (PTCS) that controls the thermal environment through the use of thermal insulating materials and heating devices.

(4) Environmental Control and Life Support System (ECLSS)

The Environmental Control and Life Support System (ECLSS) controls the atmospheric pressure, temperature and humidity inside the ELM-PS so as to provide a shirt-sleeve working environment. This subsystem provides a comfortable inner vehicular environment similar to that of the PS. In the ELM-PS, air is circulated by fans and supplied from the PM.

In addition, this subsystem has fire detection and suppression functions. Smoke sensors will detect any fire. The fire will be isolated by power shut down. The fire will be suppressed by fire extinguishers (carbon dioxide).

(5) Structure

Similar to the PM, the ELM-PS structural body is designed to bear loads imposed during the space shuttle's launch, ascent, ISS attitude control and maneuver. The ELM-PS is also designed to maintain a pressurized environment inside the ELM-PS through shielding by aluminum alloy panels. Debris Shield covers the ELM-PS's outer shell structure so as to protect the body from debris hit. The berthing hatch for the PM is part of the ELM-PS's structure.

(6) Mechanical System

The Mechanical System consists of a Common Berthing Mechanism (CBM), which will be used as the berthing port for the Node 2 or the PM, and the ELM-PS Unit Replacement Mechanism (Note: A Passive CBM (PCBM) is attached to the body of the ELM-PS). The followings are details of the ELM-PS Exposed Facility Unit (EFU). For details on the CBM, please refer to Section 4.1.3 in this chapter.

(a) ELM-PS Exposed Facility Unit (EFU)

While the H-II Transfer Vehicle (HTV) is berthed to the ISS, payloads or cargo on the Exposed Pallet (EP) carried by the HTV will be unloaded. The Exposed Pallets carried by the HTV needs to be attached to the ELM-ES. For this purpose, the ELM-ES is temporary attached to the ELM-PS whenever the HTV arrives. At this stage, the ELM-ES is attached to the ELM-PS EFU. While the ELM-ES is berthed to the ELM-PS EFU, the ELM-ES is provided electrical power and enables data-exchange. Figure 4.2.3-1 shows an image of the ELM-ES being berthed to the ELM-PS EFU. For information on the HTV, please refer to Chapter 8.

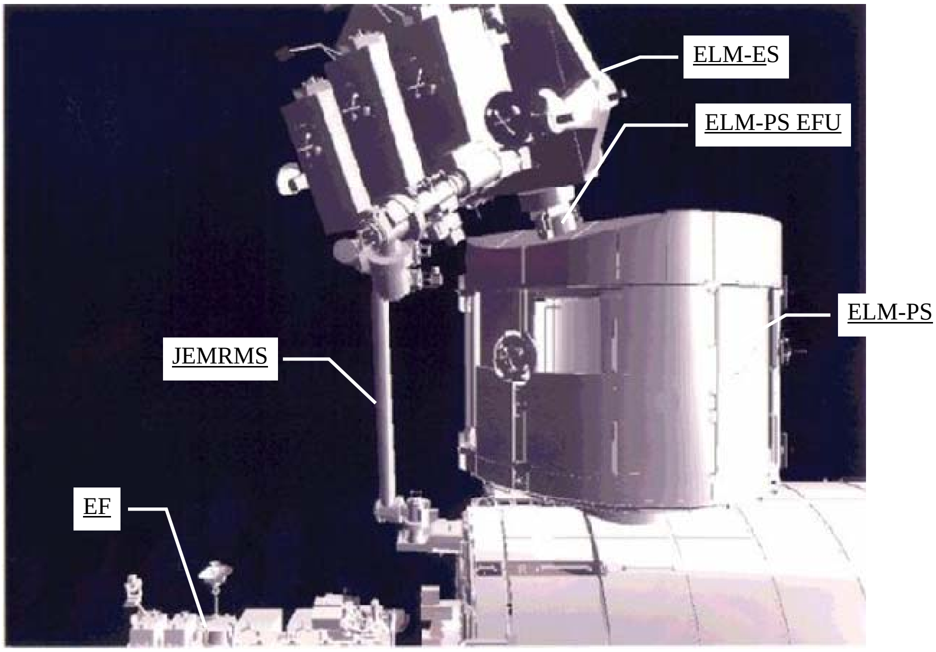


Figure 4.2.3-1 ELM-ES berthed to ELM-PS EFU (image)

(7) Crew Support System (CSS)

The Crew Support System (CSS) provides in-board lightings and emergency lightings inside the ELM-PS.

4.3 Exposed Facility

4.3.1 Brief Summary

Kibo's Exposed Facility (EF) is a multipurpose experiment platform where various scientific activities, including scientific experiments, earth observation, communication, scientific and engineering experiments or material experiments can be conducted by utilizing the microgravity and vacuum space environment. The EF can be used when the EF is berthed to the PM. The Equipment Exchange Unit (EEU) will accommodate a maximum of 12 payloads, including the Exposed Facility (EF) payloads, ELM-ES and the Inter-orbit Communication System (ICS). Since the EF payloads can be exchanged on orbit, it is expected that several different types of scientific experiments can be conducted on the EF.

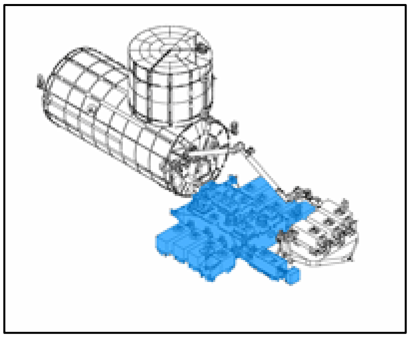


Figure 4.3.1-1 EF location

In order to support the space-exposed experiments on the EF, the EF will provide the necessary electrical power to each payload, will circulate coolant so as to keep the payloads within a required temperature and will collect experiment data.

Table 4.3.1-1 shows the EF specifications.

Table 4.3.1-1 EF Specifications

Items	Specifications
Shape	Box shaped
Size	5.0 m (width) x 5.6 m (length) x 4.0 m (height)
Mass	4.1t
Number of attached payload	12 (including 2 for JEM system and 1 for temporary storage)
Electrical power provided	Max. 11 kW (max. 1 kW for system, 10 kW for EF payloads) 120 V DC
Data management system	16-bit computer system High-speed data link: max. 100 Mbps
Environment control	None
Life time	More than 10 years

The EF Equipment Exchange Units (EF-EEUs) are used to attach the EF payloads to the EF. Figure 4.3.2-1(2/2) shows the configuration of the EF with eight EF payloads and the ICS Exposed Facility subsystem (ICS-EF) attached on the EF. The standard EF payload envelope is assumed to be less than 1.85m x 1.0m x 0.8m, with a weight of 500kg. Figure 4.3.1-2 shows a standard EF payload configuration.

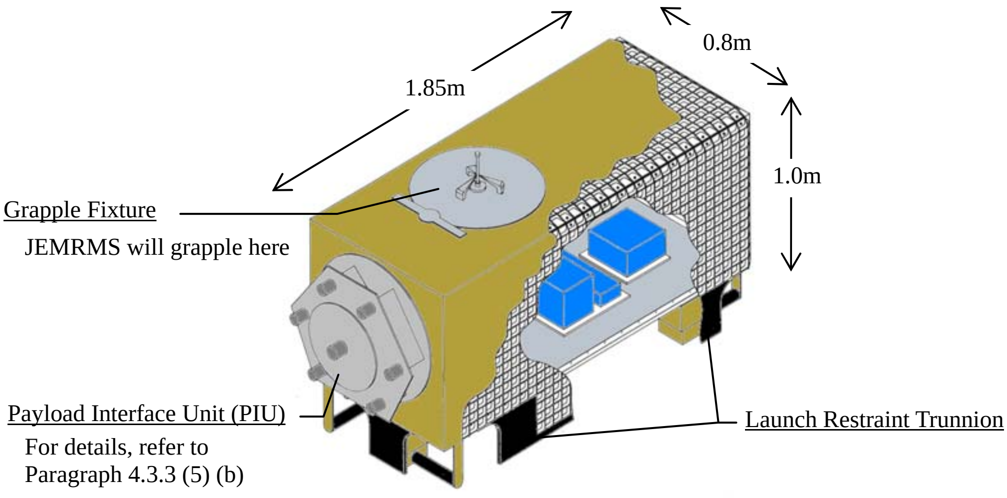


Figure 4.3.1-2 Standard EF Payload

4.3.2 Layout

EF Configuration diagram is shown in Figure 4.3.2-1.

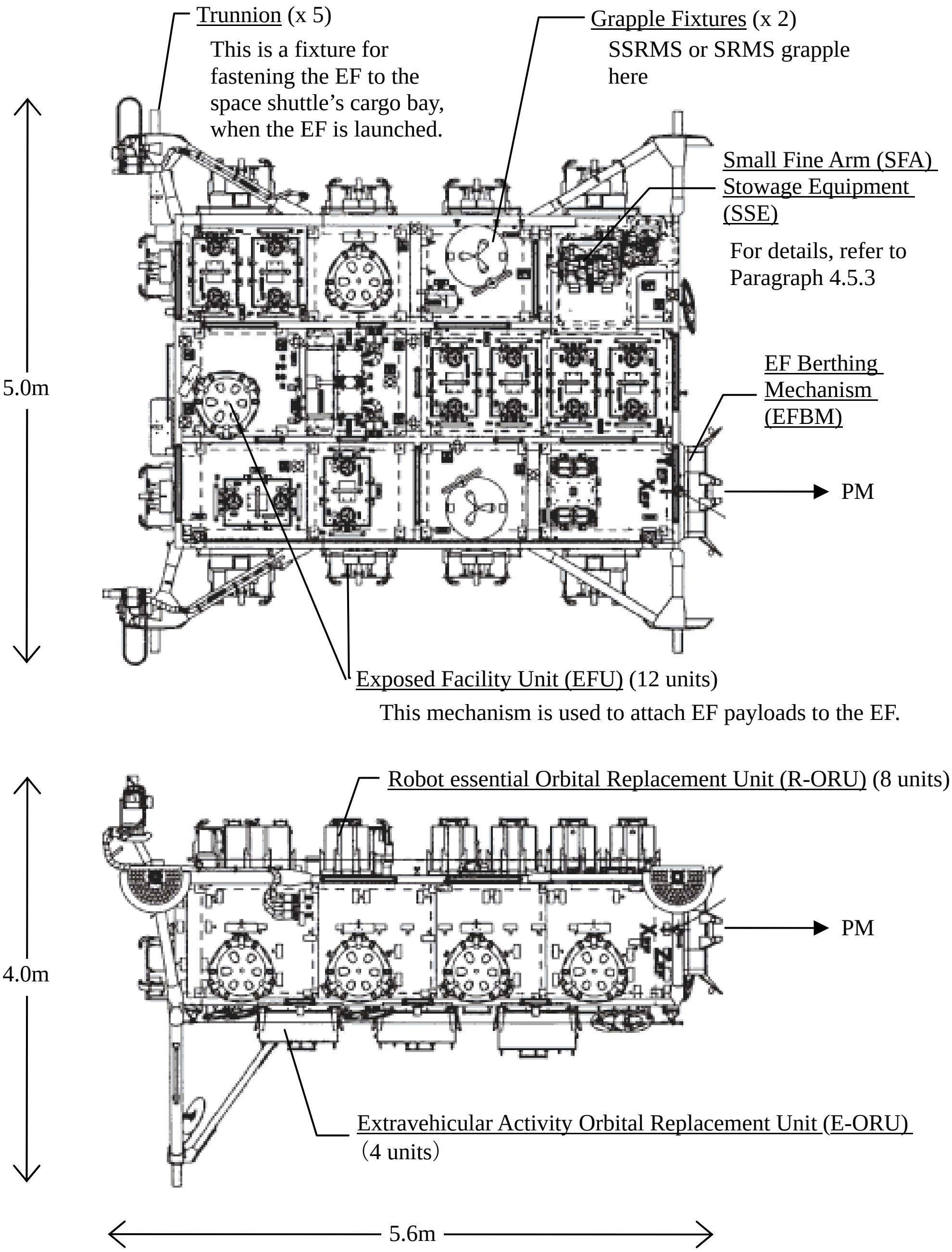


Figure 4.3.2-1（1/2） EF Structure

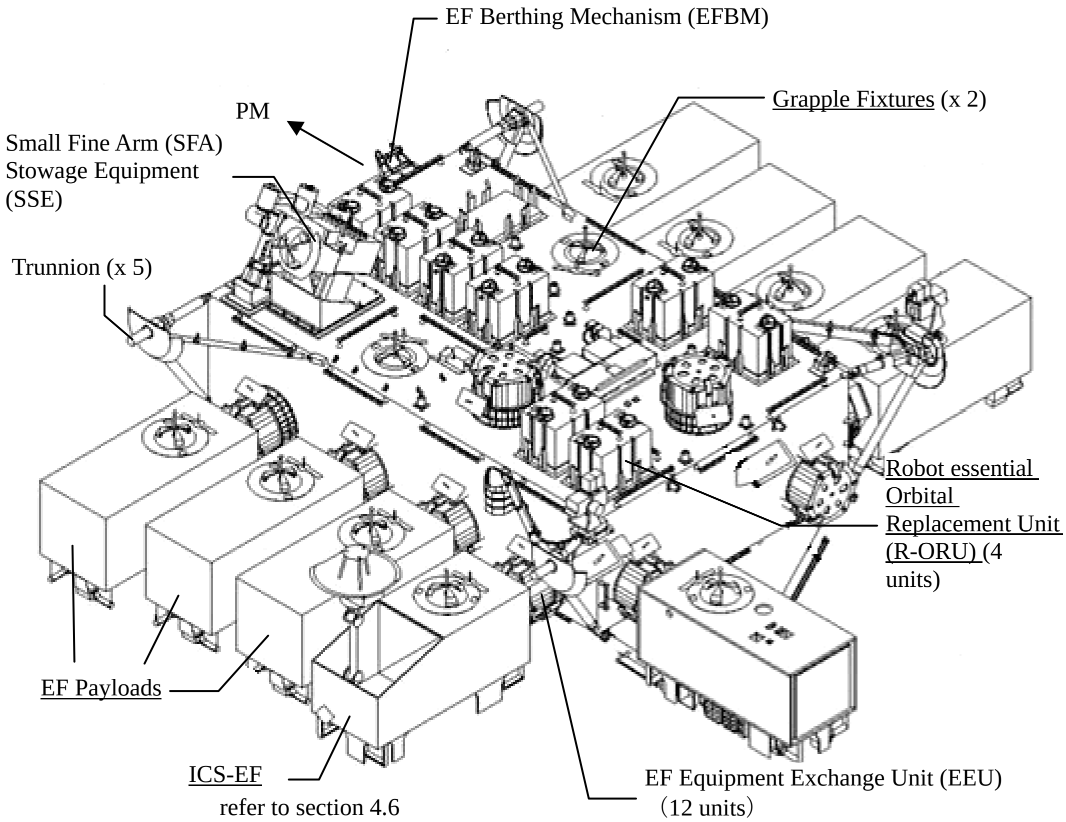


Figure 4.3.2-1（2/2） EF Structure

4.3.3 System Components of EF

The EF consists of the following subsystems;

- Electrical Power System (EPS)
- Communication and Tracking (C&T)
- Thermal Control System (TCS)
- Structure
- Mechanical System

The Electrical Power System (EPS), Communication and Tracking (C&T) and Thermal Control System (TCS) have redundant functionality. If the primary strings of these subsystems fail, the secondary strings will take over and maintain their system functions. The following are details of the subsystems.

(1) Electrical Power System (EPS)

The Electrical Power System (EPS) receives electrical power from the PM and distributes power to the EF equipment, Exposed Pallet (ELM-ES), and EF payloads attached to the EF respectively.

(2) Communication and Tracking (C&T)

The Communication and Tracking (C&T) includes the Exposed Facility System Controller (ESC), which is installed on the EF and controls the EF equipment or system devices by communicating with the JEM Control Processor (JCP). The ESC also relays data between the PM and the EF payloads, such as experiment data, image, temperature and pressure data.

(3) Thermal Control System (TCS)

The Thermal Control System (TCS) is composed of the following two systems. The Active Thermal Control System (ATCS) which transfers heat generated in the equipment and payloads by circulating the coolant, Fluorinert^{TM}, and the Passive Thermal Control System (PTCS) which maintains the temperature of the EF system equipments or payloads through the use of thermal insulators or heaters. The TCS manages the temperature environment for the EF system and payloads operation by protecting the EF from the extreme space thermal environment. The heat collected by the ATCS will be transferred to the Heat Exchanger installed on the PM structure. Coolant loops pipes have no redundancy; however other components, such as pumps, have redundancy.

(4) Structure

The Structure of the EF is composed of box shaped units, which consist of aluminum alloy frames, panels, and trunnions that are used to attach the EF to the space shuttle's cargo bay.

(5) Mechanical System

The Mechanical System is composed of Exposed Facility Berthing Mechanism (EFBM) that is used to connect the EF with the PM, and Exposed Facility Equipment Exchange Unit (EEU) that attaches EF payloads to the EF.

(a) Kibo's Exposed Facility Berthing Mechanism (EFBM)

The EF Berthing Mechanism (EFBM) is a mechanism to connect the EF to the PM. It is paired and composed of an Active EFBM and a Passive EFBM. The Active EFBM, which has a pull-in torque structure and fastens bolts by motor drive, is located on the PM. The Passive EFBM is located on the EF. Once both Active and Passive EFBMs are connected, the electrical power system, communication and tracking, and thermal control system will be simultaneously connected. Data and power transfer between the PM and EF will be initiated. The external view of the EFBM is shown in Figure 4.3.3-1.

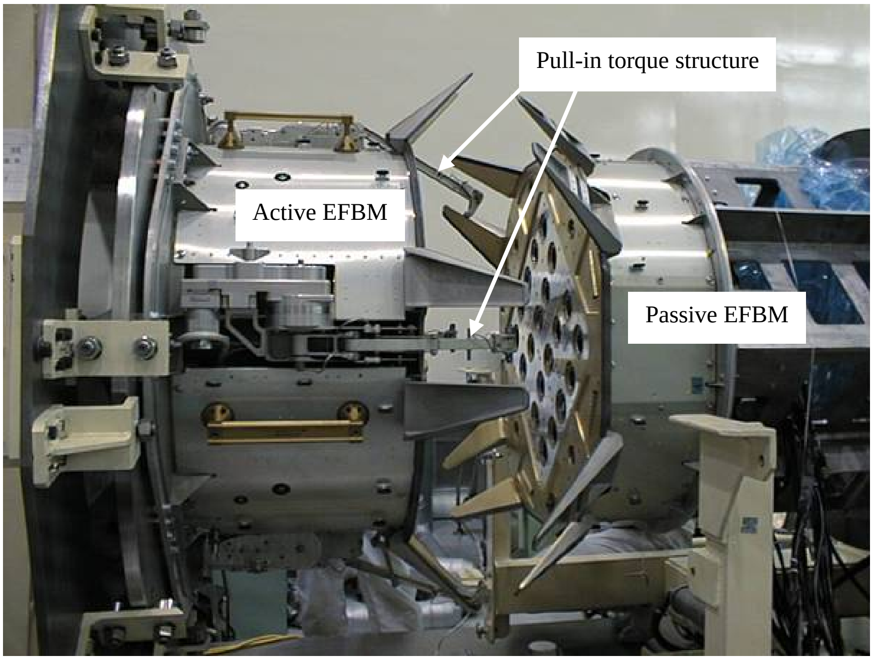


Figure 4.3.3-1 Exposed Facility Berthing Mechanism（EFBM）

(b) Kibo's Exposed Facility's Equipment Exchange Unit (EF-EEU)

The EF Equipment Exchange Unit (EEU) is a mechanism that attaches the EF payloads to the EF. Once a payload is attached to the EF by the EEU, the electrical power system (EPS), communication and tracking (C&T) and thermal control system (TCS) will be simultaneously connected and power supplies to the payloads, data transactions, and thermal control become operable.

The EEU is composed of an active EEU known as the Exposed Facility Unit (EFU) and is located on the side of the EF. The passive EEU, known as the Payload Interface Unit (PIU), is located on the EF payloads. Figure 4.3.3-2 shows the EEU (EFU and PIU) structures.

The EEU accommodates the EF payloads to be exchanged on orbit, thus several different types of experiments can be conducted compared to existing spacecrafts, and thus will flexibly meet the demands for future technology development.

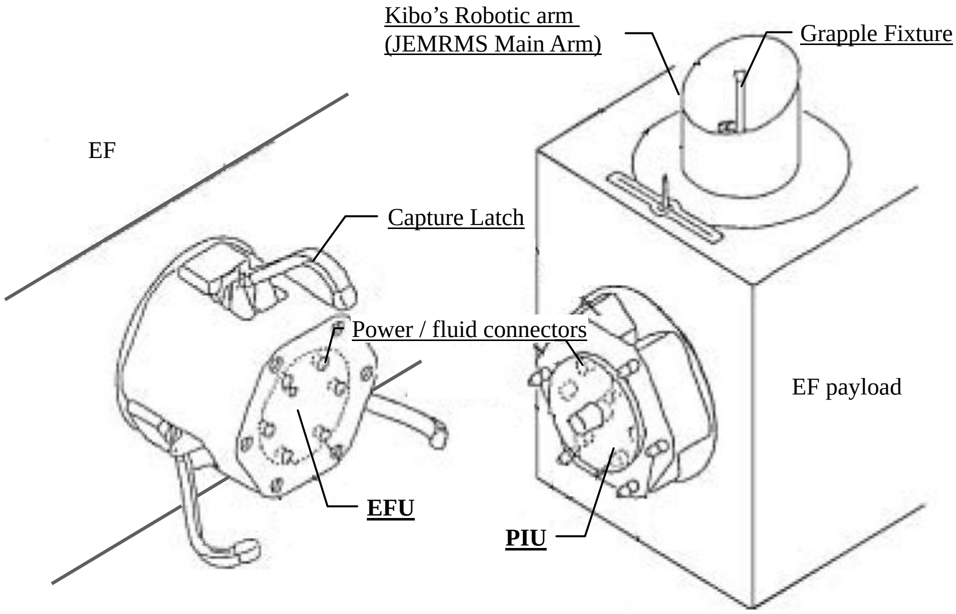


Figure 4.3.3-2 EEU (EFU and PIU) Structures

(c) Exposed Facility's Orbital Replacement Units (ORUs) – Extravehicular Activity ORU (E-ORU) and Robot essential ORU (R-ORU)

Electrical Power System (EPS), Communications and Tracking (C&T) or Thermal Control System (TCS) are critical systems for operating the EF, thus these system units are designed as ORUs. In case of failure, these units can be exchanged on orbit. There are two types of ORUs on the EF. The first type of ORU is the Extravehicular Activity ORU (E-ORU), which is attached to the nadir side of the EF, and will be exchanged by extravehicular activities. The second ORU type is Robot essential ORU (R-ORU) which is attached to the zenith side, and will be exchanged by JEMRMS, Kibo's robotic arm.

4.4 Experiment Logistic Module-Exposed Section (ELM-ES)

4.4.1 Brief summary

Kibo's Experiment Logistics Module-Exposed Section (ELM-ES) is a Kibo's component, which carries Exposed Facility (EF) payloads and EF system ORUs. The ELM-ES will supply and transfer the system ORUs and the EF payloads to the Kibo's Exposed Facility (EF), as well as, store completed EF payloads exchanged from the EF. The ELM-ES will be delivered to the ISS by space shuttles and attached to the EF. After the ELM-ES is attached to the EF, the EF payloads on the ELM-ES will be removed and transferred to the EF by using the JEMRMS.

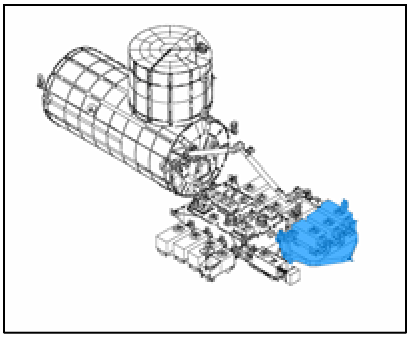


Figure 4.4.1-1 ELM-ES location

The used payloads will be retrieved from the EF using the JEMRMS and stored on the ELM-ES. Then, the ELM-ES will return to the ground aboard the space shuttles.

Figure 4.4.1-2 shows the ELM-ES operations concept. Table 4.4.1-1 shows the ELM-ES specifications.

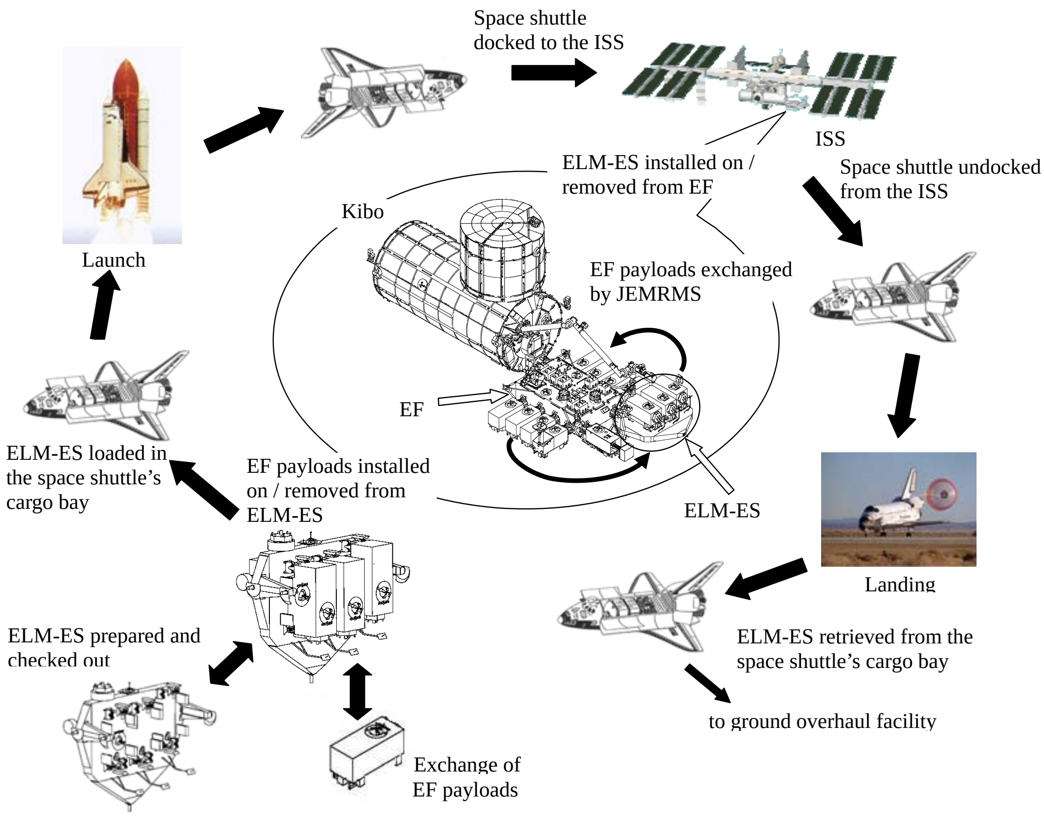


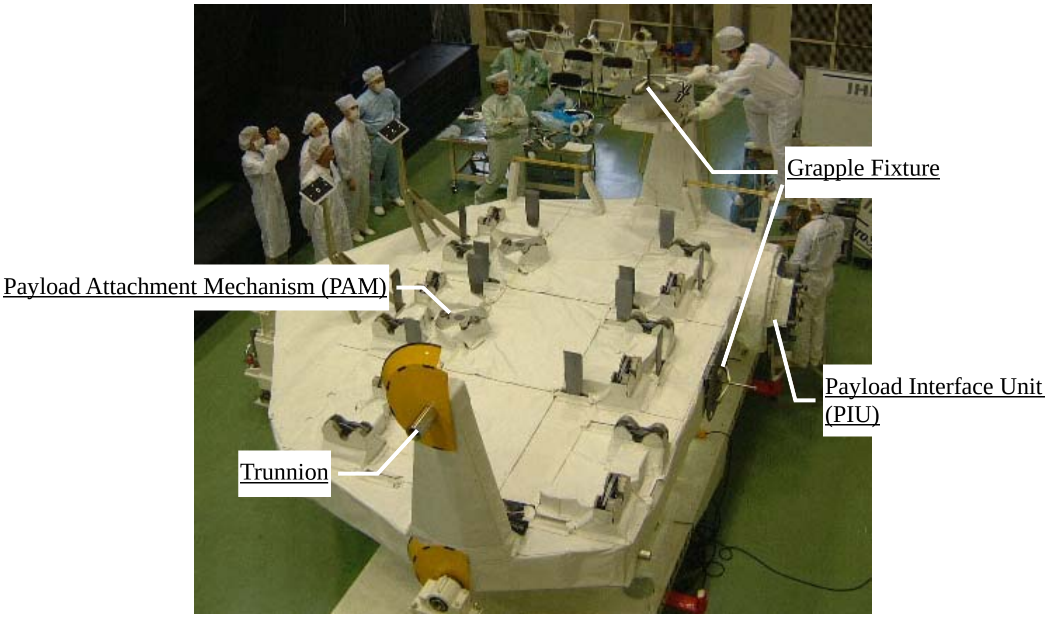
Figure 4.4.1-2 ELM-ES operation concept

Table 4.4.1-1 ELM-ES Specifications

Items	Specifications
Structure type	Frame
Width	4.9 m
Height	2.2 m (including the height of the payloads)
Length	4.2 m
Mass (Dry weight)	1.2 t (excluding payloads)
Number of Payloads (loading style variable)	Three EF payloads Two EF payloads + three R-ORUs Two EF payloads + two E-ORUs
Electrical power supply	Max. 1.0 kW 120 V DC
Thermal control	Heater and thermal insulator
Life time	More than 10 years

4.4.2 Layout

ELM-ES configuration is shown in Figure 4.4.2-1.



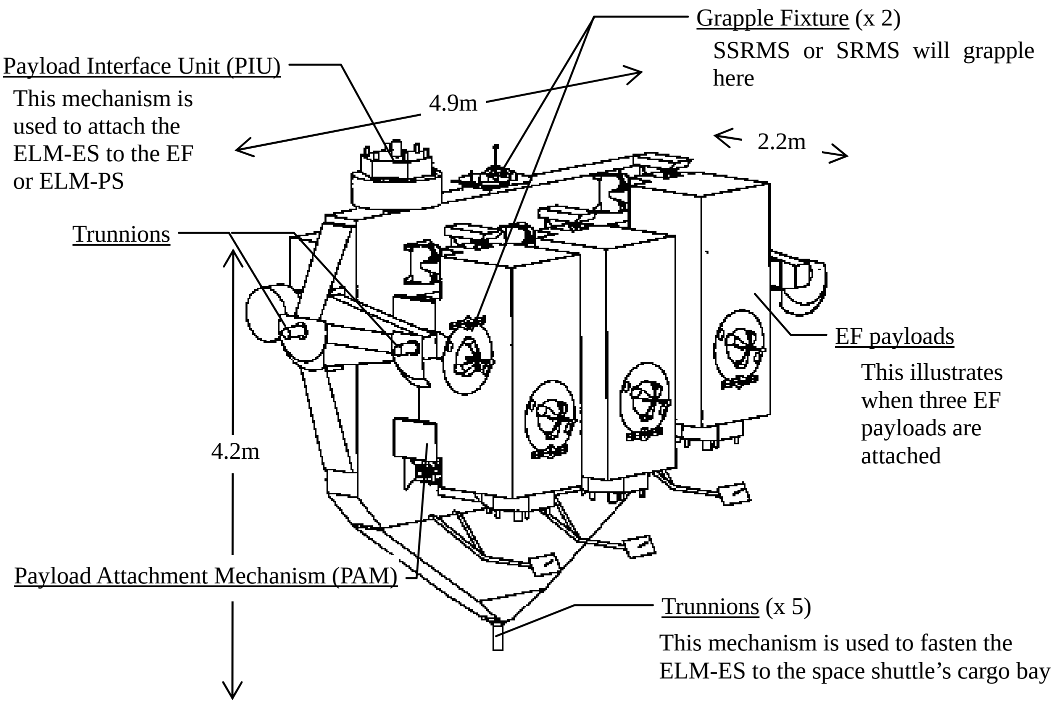


Figure 4.4.2-1 ELM-ES Configuration

4.4.3 System Components of ELM-ES

The Experiment Logistics Module-Exposed Section (ELM-ES) is composed of the following subsystems.

- Electrical Power System (EPS)
- Communication and Tracking (C&T)
- Thermal Control System (TCS)
- Structure
- Mechanical System

Details of the subsystems are as follows.

(1) Electrical Power System (EPS)

The Electrical Power System (EPS) receives power from the space shuttles during the period from launch to docking with the ISS, and distributes the power to ELM-ES system and Exposed Facility (EF) payloads. Power will be supplied from the EF while the ELM-ES is operated on orbit.

(2) Communication and Tracking (C&T)

The Communication and Tracking (C&T) includes the Electronic Control Unit (ECU) that is installed on the ELM-ES. The ECU monitors the status of the ELM-ES, temperature of the EF payloads attached on the ELM-ES, and the status of the Payload Attachment Mechanisms (PAMs) by communicating with the JEM Control Processor (JCP) on the PM. The ECU also controls the PAMs or temperature of the attached EF payloads.

(3) Thermal Control System (TCS)

The ELM-ES is entirely covered with thermal insulating materials in order to prevent the temperature of the ELM-ES system from exceeding the operating temperature. In addition, to maintain the ELM-ES thermal environment, heating devices are installed in the areas where thermal insulating material are not sufficient and the temperature may exceed tolerable temperature ranges. In addition, heating devices are installed in the EF system ORU and EF payloads which are attached on the ELM-ES.

(4) Structure

The ELM-ES structure is designed to bear loads imposed during the space shuttle’s launch, ascent, ISS attitude control and maneuver. The main sections of the ELM-ES are composed of aluminum alloy panels in a reticular pattern. A mechanism called “Trunnion” fastens the ELM-ES to the space shuttle’s cargo bay. The ELM-ES has five Trunnions.

(5) Mechanical System

The Mechanical System consists of Payload Attachment Mechanisms (PAMs), which locks the EF payloads on to the ELM-ES, and a Payload Interface Unit (PIU), which connects the ELM-ES to the EF or the ELMPS. For information on the PIU, please refer to Section 4.3.3 (5) (b).

(a) Payload Attachment Mechanism (PAM)

The Payload Attachment Mechanism (PAM) fastens the EF payloads to the ELM-ES while the ELM-ES is being launched to the ISS or returned to the ground aboard the space shuttle. In addition, this mechanism is used to install and remove EF payloads; for instances when these payloads need to be moved on orbit by using the robotic arms. In addition, the PAM has electrical connectors that provide heater power for keeping the EF payloads temperature. Figure 4.4.3-1 shows an overview of the PAM.

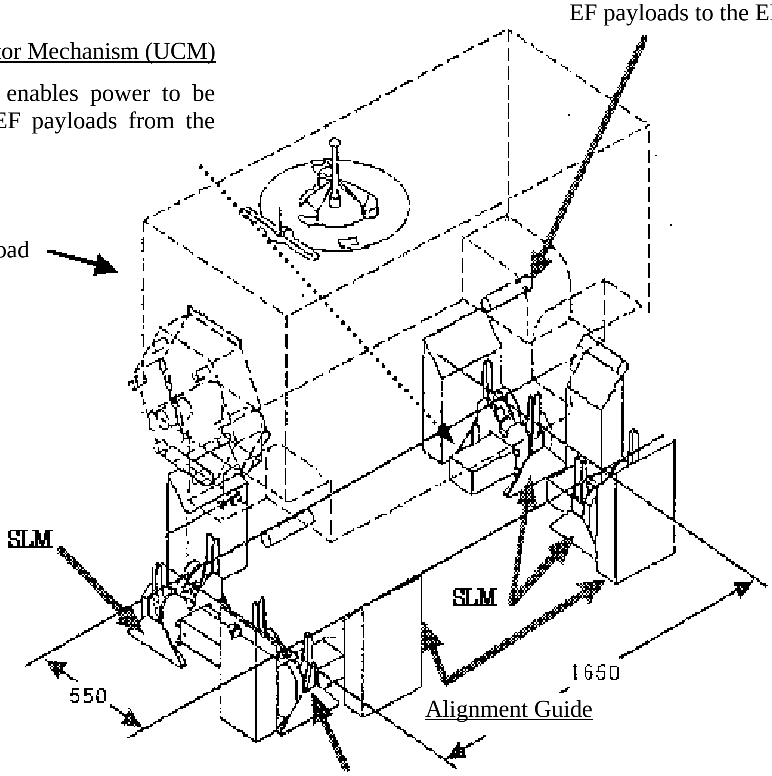


Figure 4.4.3-1 Payload Attachment Mechanism (PAM)

4.5 Japanese Experiment Module Remote Manipulator System (JEMRMS)

4.5.1 Brief Summary

Japanese Experiment Module Remote Manipulator System (JEMRMS), Kibo's robotic arm, is a robotic manipulator system intended for supporting experiments being conducted on Kibo and/or for supporting Kibo's maintenance tasks in space. The JEMRMS will be the third remote manipulator robotic arm system designed for space operations that Japan will have flown into space. The JEMRMS follows Japan's Manipulator Flight Demonstration (MFD)*[1] in August 1997 and the Engineering Test Satellite VII (ETS-VII)*[2], also known as "KIKU No.7", in November 1997. The JEMRMS is composed of two arms, the Main Arm (MA) and the Small Fine Arm (SFA). The robotic control workstation, known as the JEMRMS Console, is used to operate the JEMRMS.

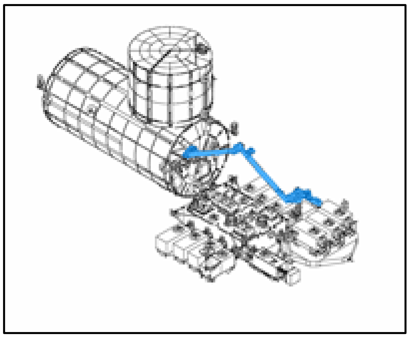


Figure 4.5.1-1 JEMRMS Location

Both the Main Arm (MA) and Small Fine Arm (SFA) have six joints and allow for similar movements with the human arm. Inside the PM, the crew will control the JEMRMS, while watching images on the TV monitor, located on the JEMRMS Console, which are taken from the cameras attached to the arm.

With these arms, the crew can conduct several tasks including exchanging EF payloads or EF system ORUs that are located on the EF and ELM-ES. The ten-meter-long Main Arm transfers (grapple and move) large objects, and the two-meter-long Small Fine Arm is used for precise, delicate and fine-tuned operations.

The JEMRMS will be operated for more than ten years on orbit. Thus, the JEMRMS has exchangeable or repairable design in case of failure. These arms can be repaired by intra-vehicular or extravehicular activities. (Repair of the Main Arm will be conducted only by extravehicular activity.)

Table 4.5.1-1 shows the specifications for the JEMRMS (Main Arm and Small Fine Arm).

*[1] The Manipulator Flight Demonstration (MFD) test, conducted on STS-85 in August 1997, used a test model (equivalent to the JEMRMS), that verified some of the JEMRMS functions.
*[2] The Engineering Test Satellite VII (ETS-VII), "KIKU No.7", launched in November 1997, evaluated the remote-manipulation system and studied the basic techniques for using robotics in space.

Table 4.5.1-1 JEMRMS (Main Arm and Small Fine Arm) Specifications

Items		Specifications	
		Main Arm (MA)	Small Fine Arm (SFA)
Structure type		Main Arm with attached Small Arm.　Both arms have 6 joints	
Degrees of freedom		6	6
Length	m	10	2.2
Mass (weight)	kg	780	190
Handling Capacity	kg	Max. 7,000	Max. 300
Positioning accuracy	mm	Translation 50(+/-)	Translation 10(+/-)
	degree	Rotation 1(+/-)	Rotation 1(+/-)
Translation / rotation speed	mm/s	60 (P/L: less than 600kg)	50 (P/L: less than 80kg)
		30 (P/L: less than 3,000kg)	25 (P/L: less than300kg)
		20 (P/L: less than 7,000kg)	-
Maximum tip force	N	More than 30	More than 30
Life time		More than 10 years	

4.5.2 Layout

Compositions of the Main Arm, Small Fine Arm and the JEMRMS Console are shown in Figure 4.5.2-1.

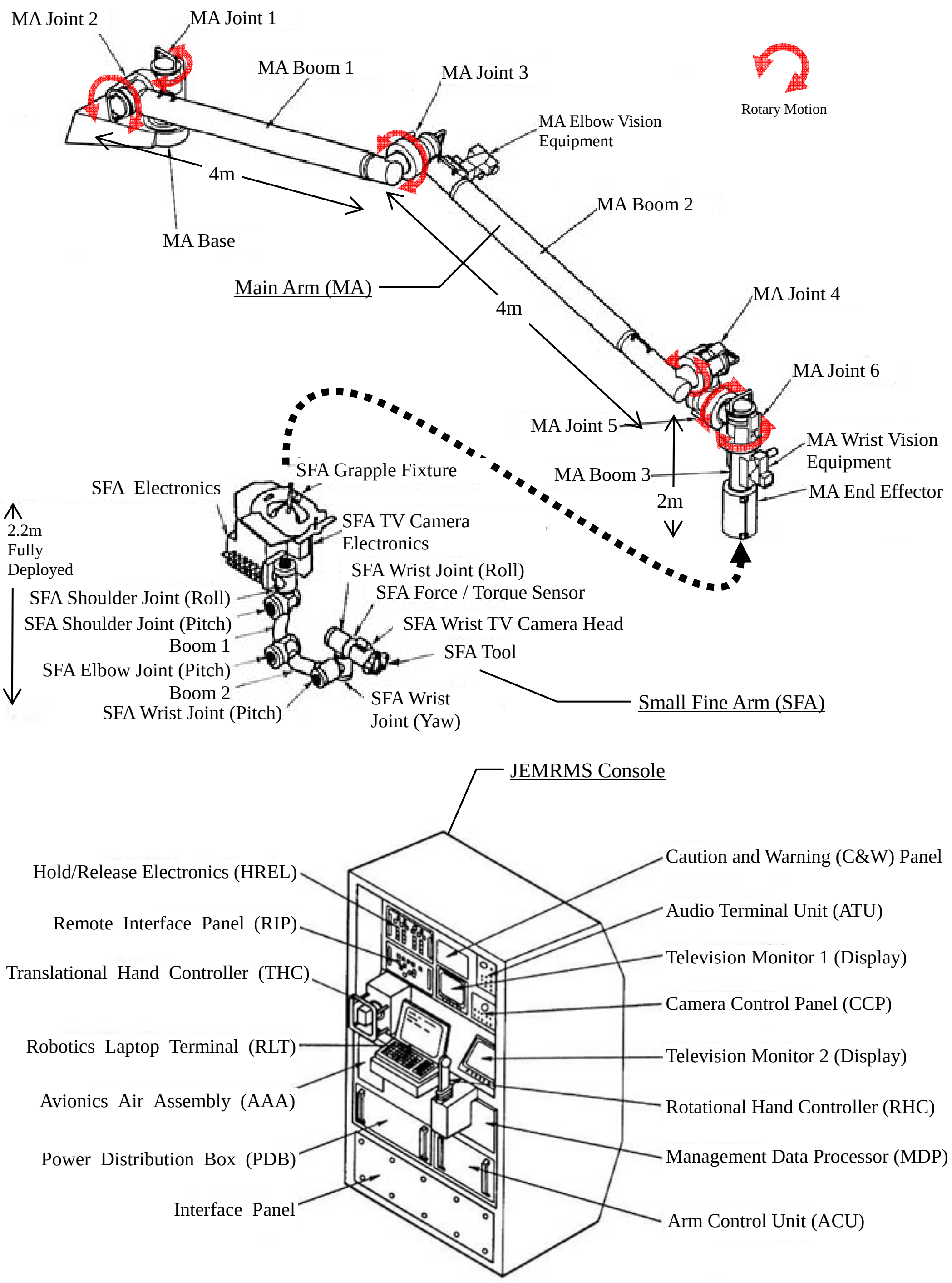


Figure 4.5.2-1 Main Arm (MA), Small Fine Arm (SFA) and JEMRMS Console

4.5.3 System Components of JEMRMS

The JEMRMS is composed of the following subsystems.

- Main Arm
- Small Fine Arm
- JEMRMS Console
- SFA Stowage Equipment
- JEMRMS Visual Equipment
- Hold and Release Mechanism

The following are details of the subsystems.

(1) Main Arm (MA)

The Main Arm (MA) consists of MA Booms, MA Joints, MA Television Cameras (TV Cameras), MA Camera Pan Tilt Unit (PTU), a light and the MA End Effector (grapple fixture) that grapples EF payloads. There are three MA Booms, known as MA Boom 1, 2 and 3. Vision equipments (TV Cameras, PTU and light) are attached to the MA Boom 2 and MA Boom 3. The crew will control the JEMRMS while watching the images, which are taken with the visual equipment, on the TV monitor located on the JEMRMS Console.

The Main Arm is primarily used for exchanging EF payloads (Standard payload envelope is planned to be 1.85m x 1.0m x 0.8m and weighing less than 500kg). The EF payload is grappled and moved by the JEMRMS Main Arm End-Effector.

(2) Small Fine Arm (SFA)

The Small Fine Arm (SFA) consists of SFA Electronics, SFA Booms, SFA Joints, end effectors called “Tool”, and SFA TV Cameras. The SFA is used when the SFA is grappled by the MA End Effector.

The SFA is primarily used for precise, delicate and fine-tuned tasks, which include exchanging the Orbital Replacement Units (ORU) on the EF. (ORU size is planned to be 0.62 x 0.42 x 0.41 m, and weighing 80 kg max)

The SFA is designed with a compliance function that was validated on the Manipulator Flight Demonstration (MFD) during the STS-85 mission. This feature allows the crew to easily operate the arm. The SFA compliance function utilizes the Force/Torque Sensor on the arm to sense when a target is touched, after which the attitude of the arm is automatically controlled.

(3) JEMRMS Console

The JEMRMS Console is installed in the PM. Crew will control the JEMRMS while watching the images, which are taken with TV cameras, on the TV monitor located on the JEMRMS Console. The JEMRMS Console is composed of a Management Data Processor (MDP), Laptop Computer, Hand Controllers, TV Monitors and Hold/Release Electronics (HREL). The MDP controls the JEMRMS systems by communicating with the JCP and the ISS Command and Control Multiplexer/Demultiplexer (C&C MDM) that controls the ISS. The Laptop Computer and Hand Controllers (RHC and THC) are used to manipulate the JEMRMS. The TV monitor displays images taken from the external cameras. The Hold/Release Electronics (HREL) is used to operate the Hold and Release Mechanism (please refer to (5)).

(4) Small Fine Arm (SFA) Stowage Equipment (SSE)

The Small Fine Arm (SFA) Stowage Equipment (SSE) is a device to stow the SFA when the SFA is not in-use. The SSE is installed on the EF. The location of the SSE is shown in Figure 4.3.2-1.

(5) Hold and Release Mechanism (HRM)

While the Main Arm (MA) is launched to the ISS, the Hold and Release Mechanism (HRM) locks the Main Arm to the PM. After the PM is docked with the ISS, the crew will manipulate the HREL on the JEMRMS Console to release the locked Main Arm from the HRM. Afterward, the Main Arm will be deployed. The HRM holds the Main Arm’s elbow, wrist and Boom3. Figure 4.5.3-1 shows the position of the JEMRMS locked to the PM. (Launch configuration).

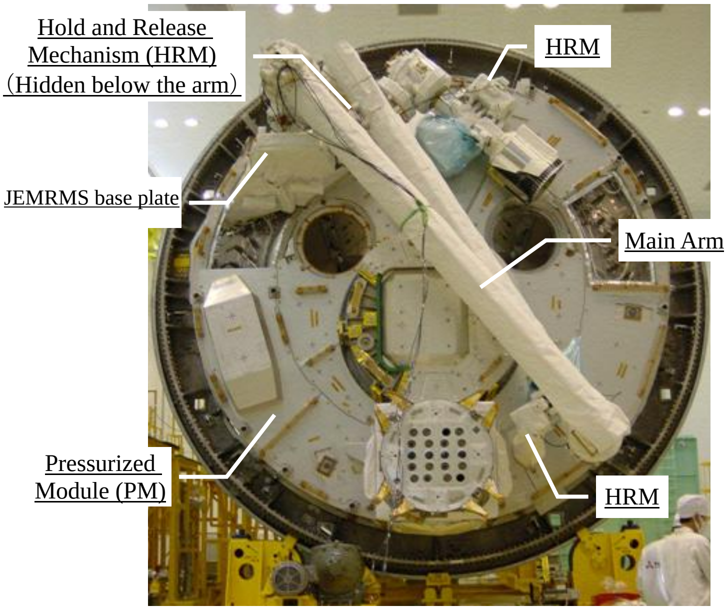


Figure 4.5.3-1 JEMRMS locked to PM (Launch configuration)

4.6 Inter orbit Communication System (ICS)

4.6.1 Brief Summary

The Inter-orbit Communication System (ICS) is Japan's unique system for uplink/downlink data, images and voice data between Kibo and the Mission Control Room at the Tsukuba Space Center (TKSC). The ICS uses the 80-centimeter diameter antenna that is installed on the EF and JAXA's data relay satellite, the Data Relay Test Satellite (DRTS), also known as Kodama.

The ICS consists of the following two subsystems. The ICS Pressurized Module (ICS-PM) subsystem located in the PM provides the data communication functions. The ICS Exposed Facility (ICS-EF) subsystem composed of an antenna installed on the EF.

Table 4.6.1-1 shows the ICS specifications.

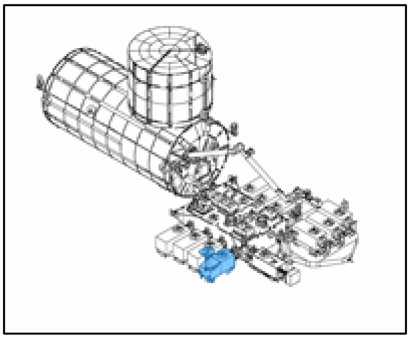


Figure 4.6.1-1 ICS Location

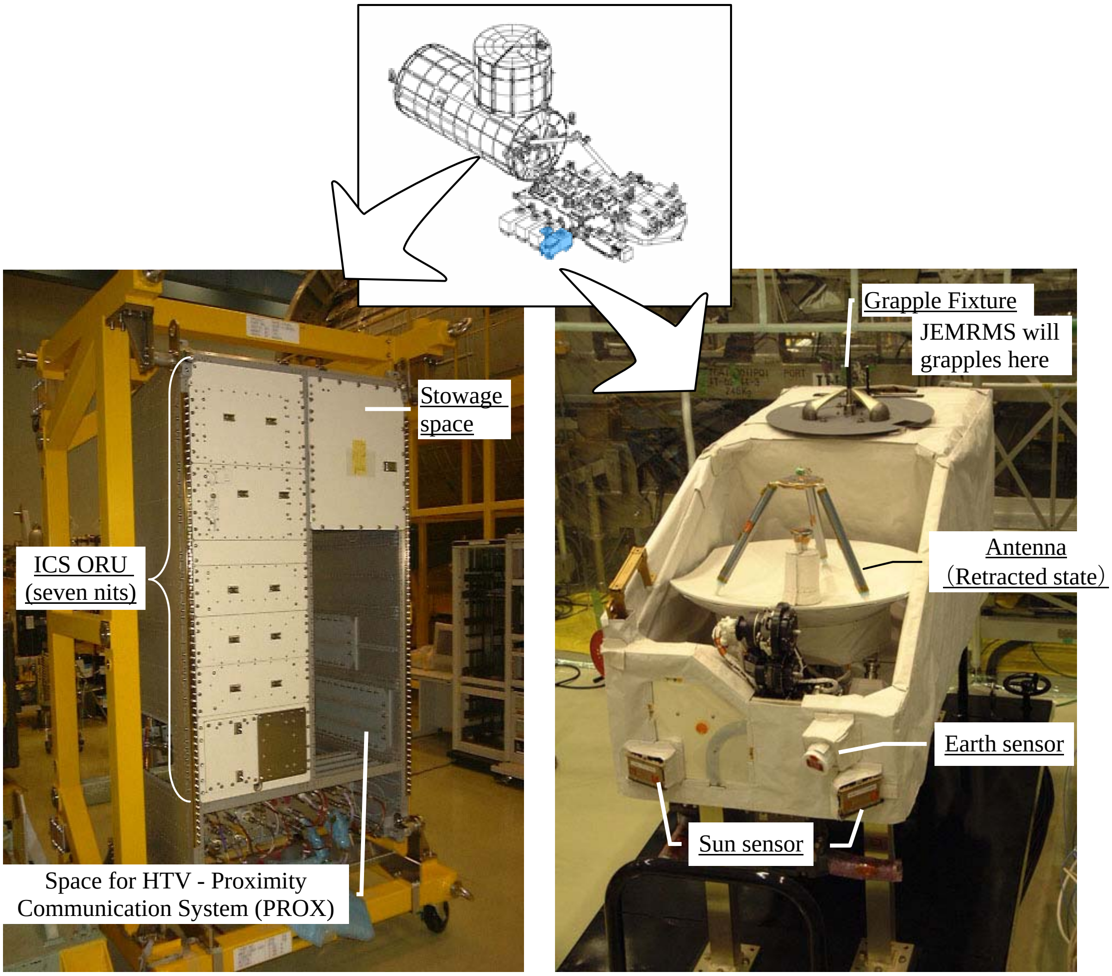
Table 4.6.1-1 ICS Specifications

Items		Specifications	
		ICS-PM	ICS-EF
Size (m)		2.0 x 1.0 x 0.9	1.1 x 0.8 x 2.0 (antenna retracted) 2.2 x 0.8 x 2.0 (antenna deployed)
Mass (weight) (kg)		330	310
Data rate / frequency / modulation method	Downlink	50 Mbps / About 26 GHz / QPSK	
	Uplink	3 Mbps / About 23 GHz / BPSK	
DRTS Visible Window*		Total of 7.8 hours per day (DRTS currently consists of only one satellite) Max. 40 min. per orbit	

*: The actual amount of time available for the DRTS communication may be shorter than the data in the above table since the above time is based on calculated estimations. In addition, DRTS communication time may occasionally be allocated for other satellites.
QPSK (Quadrature Phase Shift Keying)
BPSK (Binary Phase Shift Keying)

4.6.2 Layout

The ICS configuration is shown in Figure 4.6.2-1.



ICS Pressurized Module (ICS-PM) subsystem   ICS Exposed Facility (ICS-EF) subsystem

Figure 4.6.2-1 Inter-orbit Communication System (ICS)

4.6.3 System Components of ICS

The following are details of the ICS subsystems, ICS-PM and ICS-EF components.

(1) ICS Pressurized Module (ICS-PM) subsystem

The ICS Pressurized Module (ICS-PM) subsystem is comprised of seven Orbital Replacement Units (ORUs). Equipment or devices, such as the Base Band Data Processing Unit, are included in those ORUs. These ORUs are installed in the ICS rack and manages the ICS.

Primarily, the ICS-PM multiplexes the data of the Kibo's system and experiment payloads for downlink from Kibo to the ground, demultiplexes the data uplinked from the ground, and modulates the data before sending or demodulates the data after receipt.

In addition, the ICS-PM has an automatic operation scheduling function where, commands are uplinked from the ground in advance while the DRTS is in a communication window. The commands uplinked from the ground are stored in the ICS-PM. Each command is executed at the scheduled time. This provides ICS scheduled automatic operations. In addition, the ICS-PM has data recording function for later downloading to the ground, whenever real time communication is not available.

(2) ICS Exposed Facility (ICS-EF) subsystems

The ICS Exposed Facility (ICS-EF) subsystem is comprised of several components, including Pointing Mechanism, frequency converters, High-Power Amplifier, as well as, various sensors, including the Earth sensor, Sun sensor and Inertial Reference Unit.

Data downlinked from Kibo to the ground are relayed to the ICS-EF by the ICS-PM. The data is passed through the frequency converter and power amplifier, and then, sent to the DRTS. Data uplinked from the ground will pass through the frequency converter, converted to a low frequency, and then, relayed to the ICS-PM.

In addition, the ICS antenna can automatically track the DRTS. The ICS-EF determines the antenna's attitude based on data from the Earth sensor, Sun sensor and Inertial Reference Unit, while at the same time, calculating the antenna's directions based on the ISS and DRTS orbital positions The ICS-EF moves the antenna using the Antenna Pointing Mechanism by estimating the variability of the ICS attitude, and tracks the DRTS automatically. Further, while communicating with the DRTS, the ICS can calibrate the direction of the DRTS by detecting any pointing error based on the high-frequency signals that the antenna receives.

5. Kibo Operations

5.1 Launch and Flight Plan

Kibo's components will be launched to the International Space Station (ISS) in three assembly flights as shown in Table 5.1-1 below.

Table 5.1-1 Kibo Launch Plan

ISS Assembly Flight *1	Kibo Component	Launch Target
1J/A	Experiment Logistics Module -Pressurized Section (ELM-PS)	No earlier than February 14, 2008
1J	Pressurized Module (PM) with JEMRMS	No earlier than April 24, 2008
2J/A	Exposed Facility (EF) and Experiment Logistics Module –Exposed Section (ELM-ES)	Japanese Fiscal Year (JFY) 2008

After being attached to the ISS, every ISS component including Kibo's component is and will be operated according to the operations overview as shown in Table 5.1-2. Each country or organization that develops an ISS component is responsible for operating their own components. Kibo operations are controlled from the Mission Control Room in the Space Station Integration and Promotion Center (SSIPC) at the Tsukuba Space Center (TKSC). For details on the ground facilities and Kibo's mission operations, please refer to Section 5.3.

Table 5.1-2 Operations of ISS Components after launch

Operations	Overview
Assembly Activation and Checkout	Assemble and activate, and verify whether the components are operational
System Operations	Control and monitor the component's operational status
Utilization	(For Kibo) Conduct experiments in space using experiment payloads onboard Kibo
Maintenance	Exchange or repair failed or failing equipment

Supplies, which are necessary for maintaining or exchanging experiment payloads on-orbit, are delivered to the ISS by the space shuttle, the H-II Transfer Vehicle (HTV) that is currently under development by Japan, the Russian Progress spacecraft, and the Automated Transfer Vehicle (ATV) developed by the European Space agency (ESA). For information on the HTV, please refer to Chapter 8.

[*1] For the ISS Assembly Flight Numbers, the letter "J" represents the mission relating to Japan's element, and "A" represents the mission relating to US elements. For example, "2J/A" is the second assembly flight which delivers elements of Japan and US.

5.2 Kibo Assembly Sequence

5.2.1 1J/A Flight

During the 1 J/A Flight, the Experiment Logistics Module – Pressurized Section (ELM-PS) will be delivered to the ISS. The ELM-PS will be carrying Kibo's system racks (JEM system racks) and payload racks. Figure 5.2.1-1 shows the expected external view of the ISS after completion of the 1J/A Flight Mission. The planned cargo bay layout during launch of the 1J/A Flight is shown in Figure 5.2.1-2.

After the docking of the space shuttle to the ISS, the following procedures will be used to attach the ELM-PS to the ISS. Figure 5.2.1-3 shows the procedures for attaching the ELM-PS to the ISS.

1. Space shuttle docks to ISS
2. Canadarm2 (ISS robotic arm) grapples the Orbiter Boom Sensor System (OBSS) and removes the OBSS from the space shuttle's cargo bay. (This will provide sufficient clearance for the safe removal of the ELM-PS from the space shuttle's cargo bay.) (Figure 5.2.1-3 (1))
3. The Shuttle Remote Manipulator System (SRMS) removes the ELM-PS from the space shuttle's cargo bay. (Figure 5.2.1-3 (1) to Figure 5.2.1-3 (3))
4. The ELM-PS is attached, by the SRMS, to the Common Berthing Mechanism (CBM) at the zenith side of Node 2. (Figure 5.2.1-3 (4))
5. The CBM vestibule is pressurized. The crew connects the electrical power cables and air ducts between the ELM-PS and Node 2.
6. The ELM-PS is powered up and activated. The operational status of the ELM-PS is checked.
7. The crew enters the ELM-PS from Node 2.

Eventually, the ELM-PS will be attached to the PM. However, since the ELM-PS will be launched before the PM, the ELM-PS will temporarily be attached to the Node 2 until the PM is delivered to the ISS.

Note: The above procedures are based on NASA/JAXA coordination as of March 2007. The above procedures are subject to change dependent on possible changes.

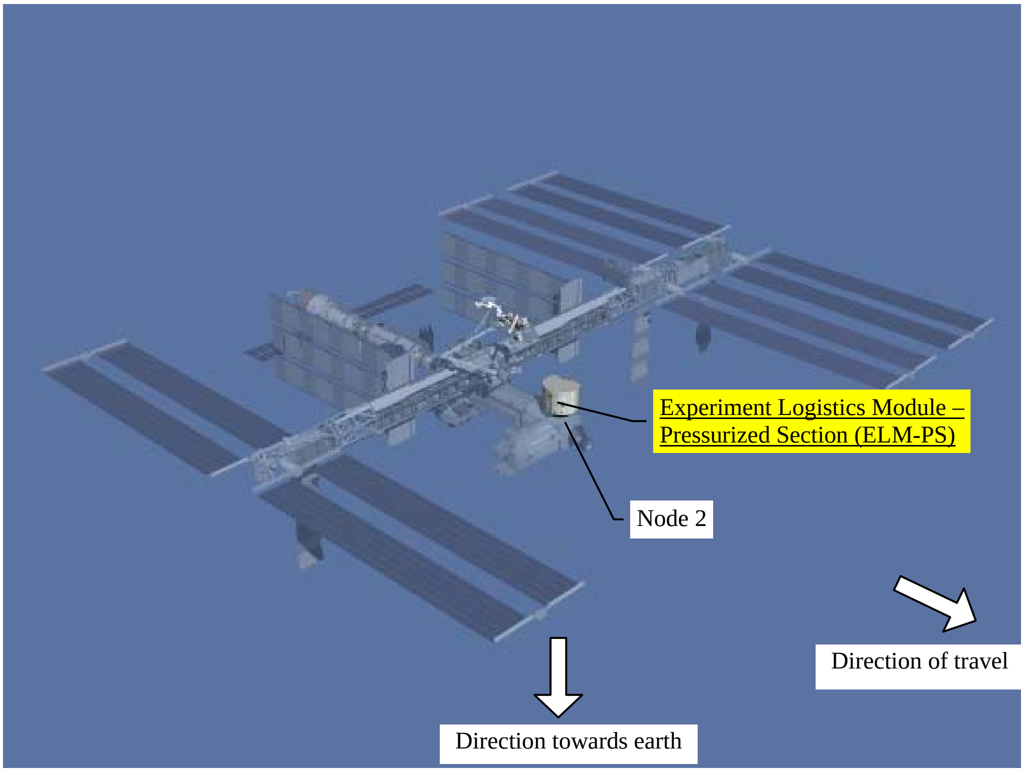


Figure 5.2.1-1 ISS after completion of 1J/A Flight

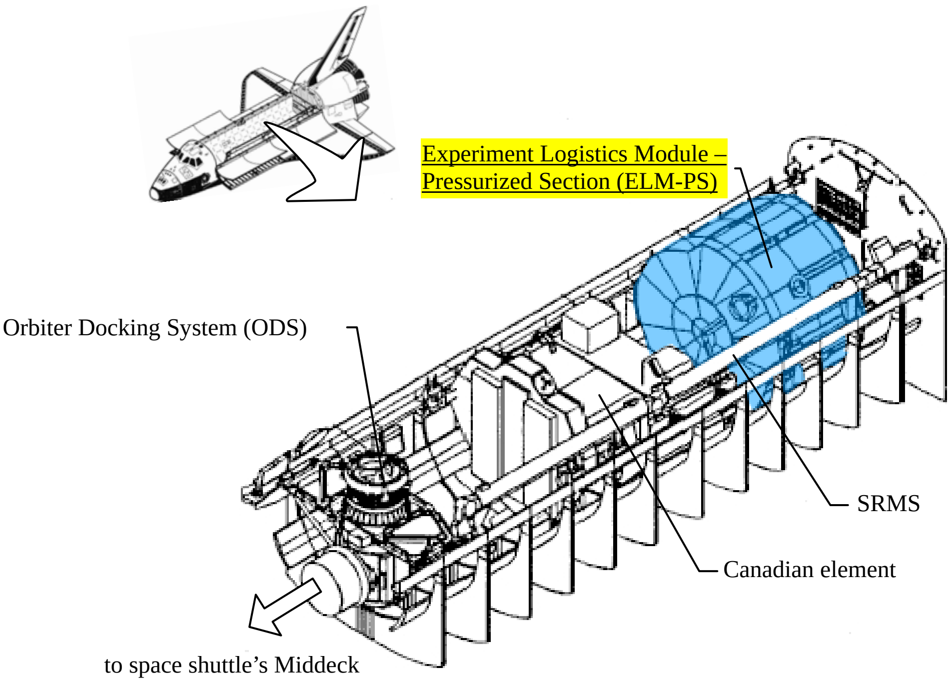


Figure 5.2.1-2 Cargo bay layout during launch of 1J/A Flight (Image)

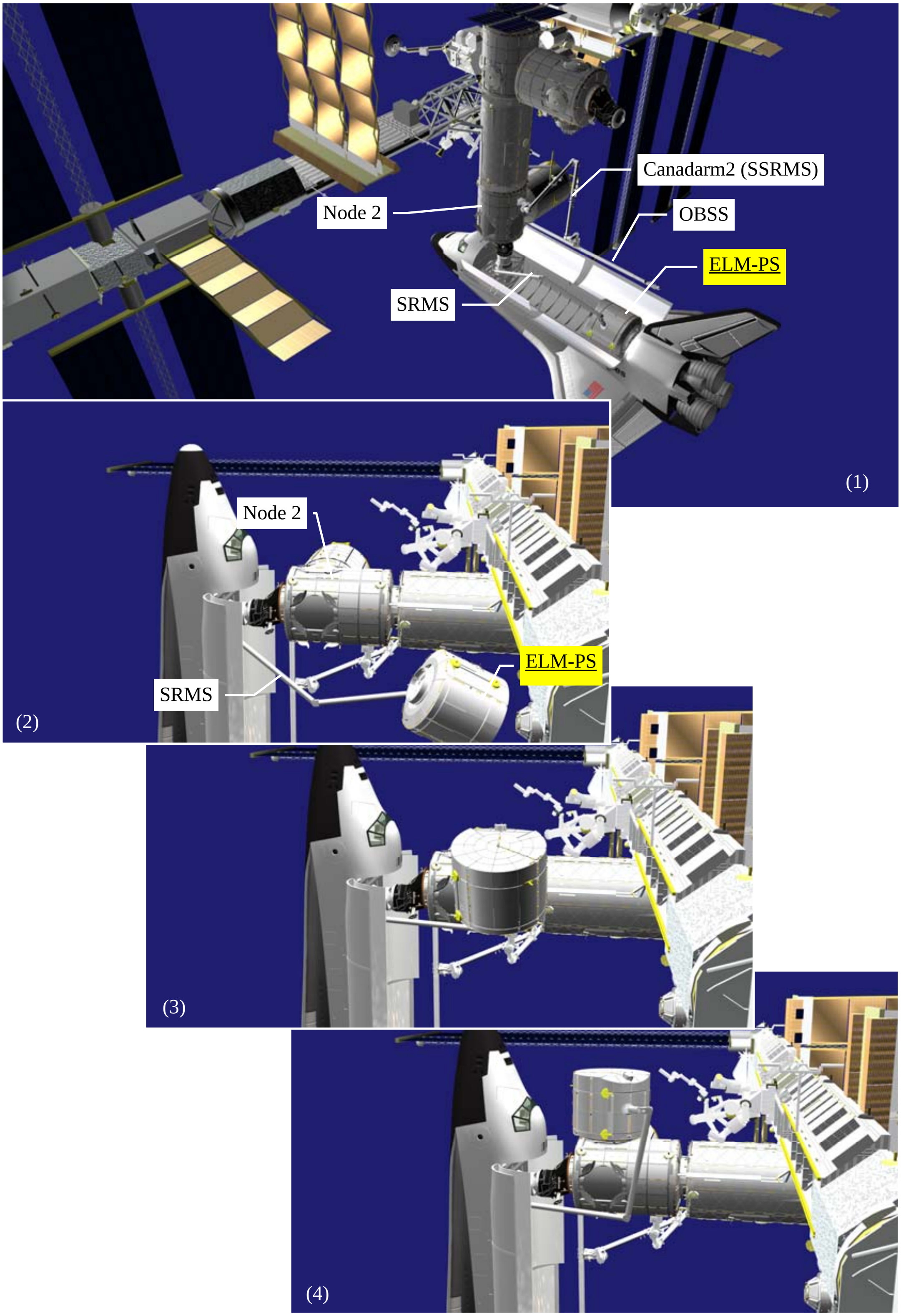


Figure 5.2.1-3 Procedures for connecting ELM-PS to ISS

5.2.2 1J Flight

During the 1J Flight, the Pressurized Module (PM) and Kibo's Remote Manipulation System (JEMRMS) will be delivered to the ISS. Figure 5.2.2-1 shows the expected external view of the ISS after completion of the 1J Flight. The Planned cargo bay layout during launch of 1J Flight is shown in Figure 5.2.2-2. The JEMRMS will be securely locked to the PM when the JEMRMS is launched to the ISS.

Following the space shuttle's docking to the ISS, the PM will be berthed to the ISS according to the following procedure. Figure 5.2.2-3 shows the procedures for berthing of the PM to the ISS. Figure 5.2.2-3 shows the procedures for relocating the ELM-PS from the Node 2 to the PM.

1. Space shuttle docks to ISS
2. Canadarm2 removes the PM from the space shuttle's cargo bay (Figure 5.2.2-3 (1) to Figure 5.2.2-3 (2))
3. The PM is berthed to the CBM on the port side of Node 2. (Figure 5.2.2-3 (3) to Figure 5.2.2-3 (4))
4. The CBM vestibule is pressurized. The crew connect electrical power cables and other cables or lines.
5. The PM is powered up. The operational status of the PM system is checked through the activation of one (B string) of the two strings (A & B strings) of the PM system.
6. The air conditioning and air ventilations are activated. The crew enters the PM.
7. Three JEM system racks and JEMRMS Console, which were launched during the 1J/A Flight while being stored in the ELM-PS, are transferred to the PM through the Node 2.
8. The "A" string (second string) of the PM system is activated. The system's operational status (two strings activated) is checked.
9. The JEMRMS Console is activated. The JEMRMS is deployed.
10. The other racks are transferred from the ELM-PS to the PM.
11. After closing the ELM-PS hatches, the ELM-PS is deactivated. And the Canadarm2 removes the ELM-PS from the Node 2 CBM and relocate to the PM CBM. (Figure 5.2.2-4 (1) to Figure 5.2.2-4 (4))
12. The ELM-PS system is reactivated, and the crew enters the module.

Note: The above procedures are based on NASA/JAXA coordination as of March 2007. The above procedures are subject to change dependent on possible changes.

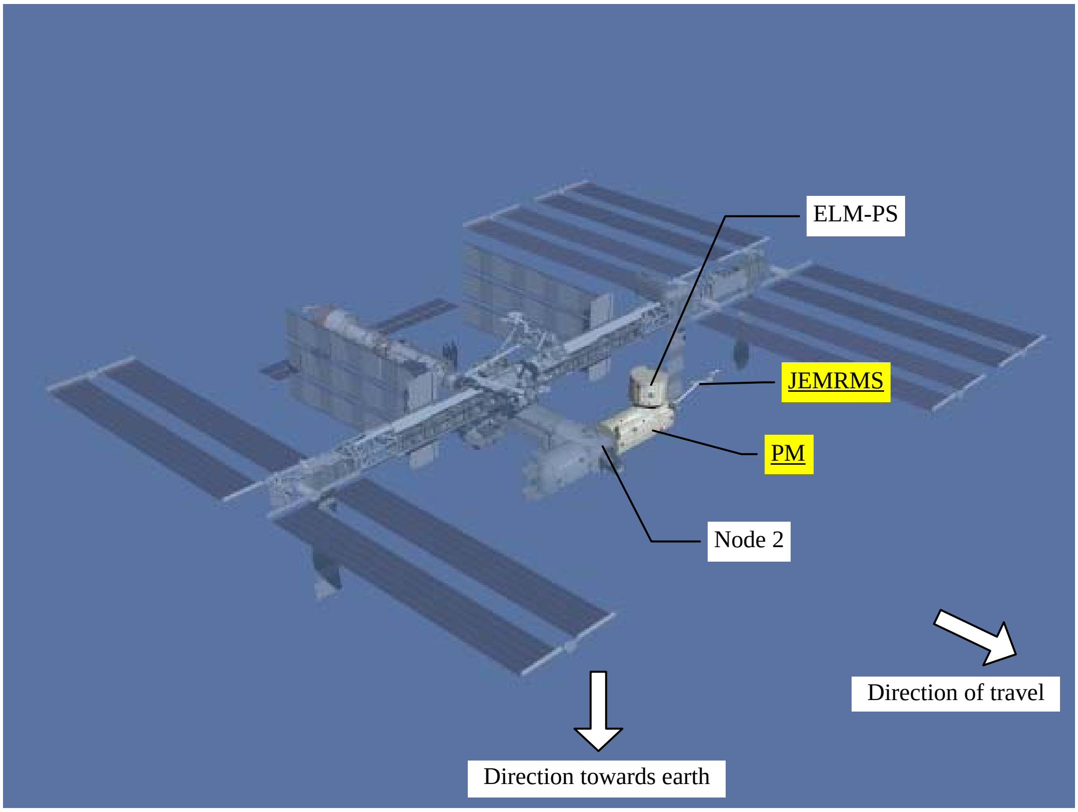


Figure 5.2.2-1 ISS after 1J Flight is completed

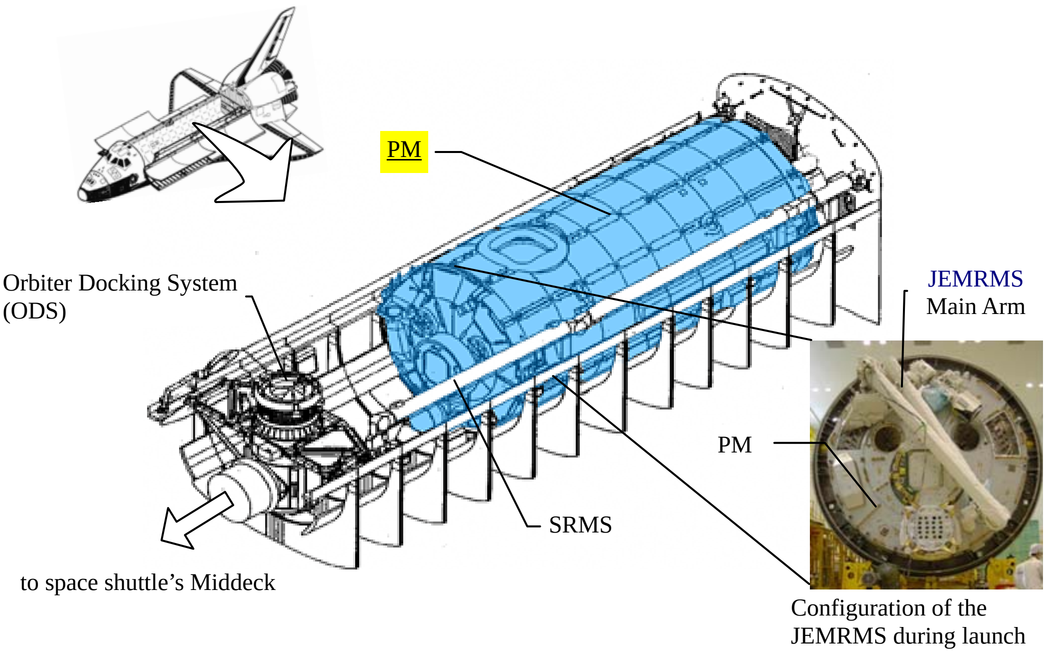


Figure 5.2.2-2 Cargo bay layout during launch of 1J Flight (Image)

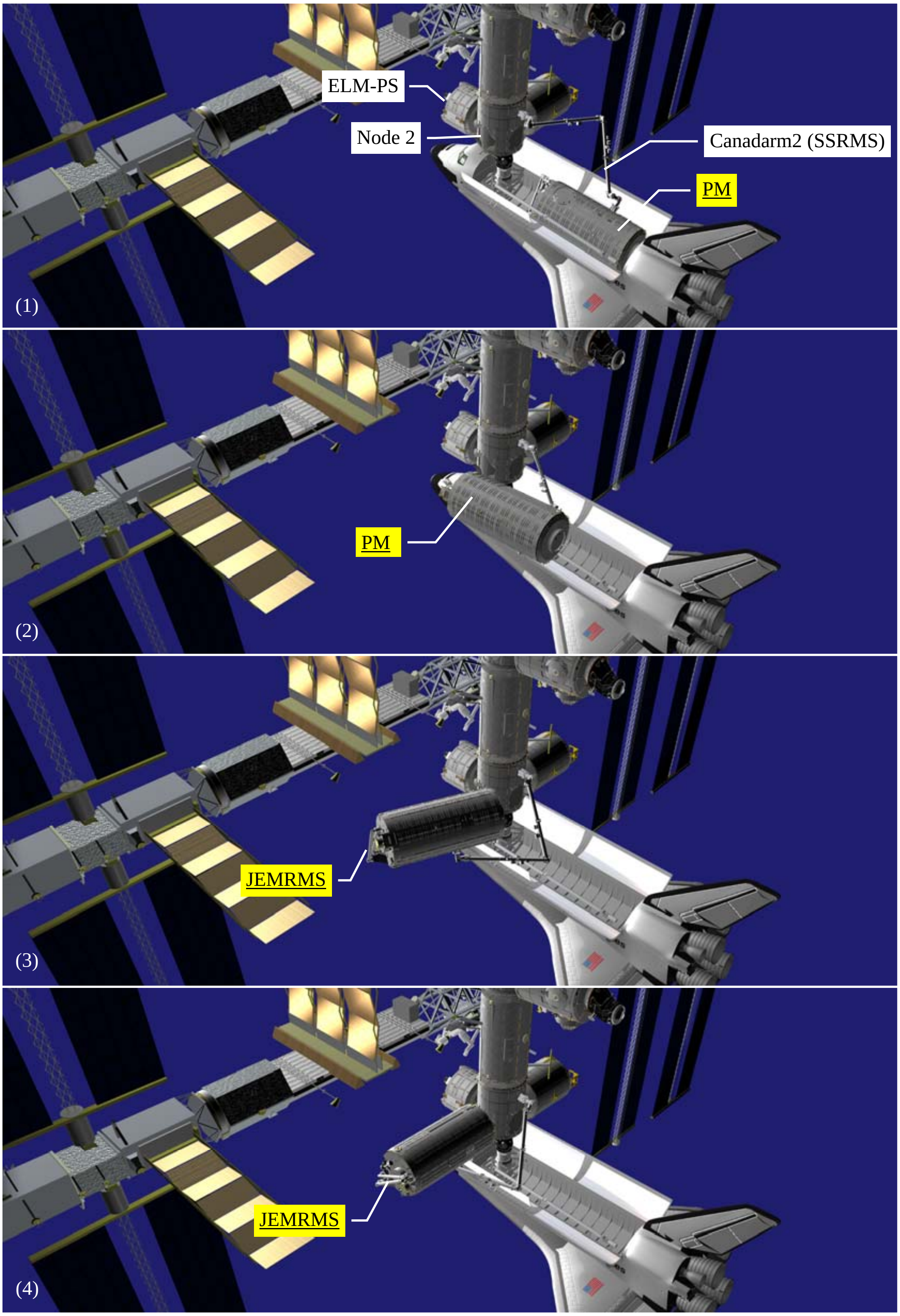


Figure 5.2.2-3 Procedures for attaching PM to ISS

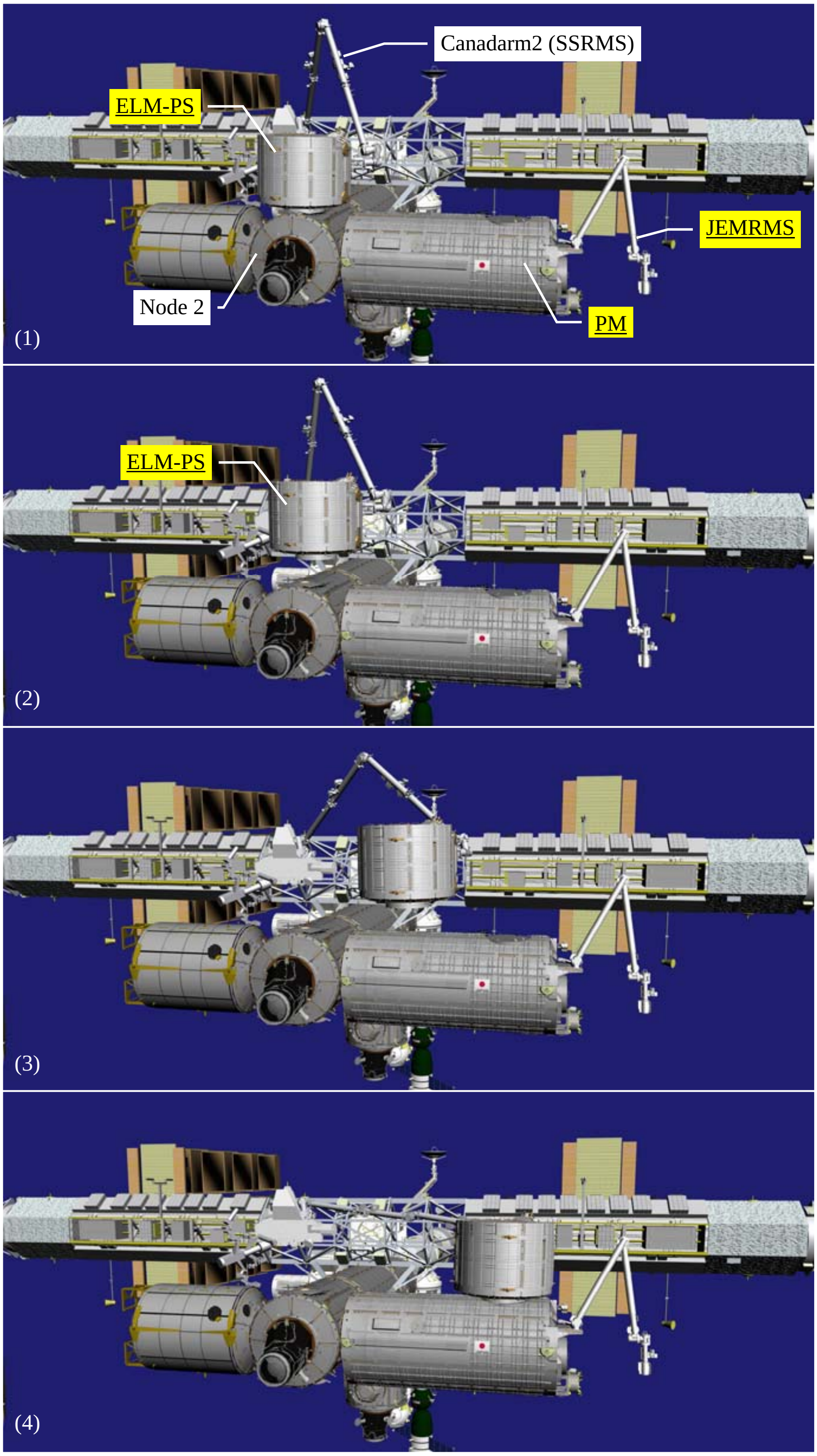


Figure 5.2.2-4 Procedures for relocating ELM-PS (space shuttle is not included)

5.2.3 2J/A Flight

During the 2J/A Flight, the Exposed Facility (EF) and the Experiment Logistics Module – Exposed Section (ELM-ES) will be launched to the ISS. Figure 5.2.3-1 shows the expected external view of the ISS after completion of the 2J/A Flight. The Planned cargo bay layout during launch of the 2J/A Flight is shown in Figure 5.2.3-2.

After the docking of the space shuttle to the ISS, the EF and ELM-ES will be attached to the ISS according to the following procedures. The procedures for attaching the EF and ELM-ES to the ISS are shown in Figure 5.2.3-3.

1. Space shuttle docks to the ISS
2. Canadarm2 removes the EF from the space shuttle's cargo bay (Figure 5.2.3-3 (1) to Figure 5.2.3-3 (2))
3. The EF is attached to the Exposed Facility Berthing Mechanism (EFBM) on the PM by the Canadarm2 (Figure 5.2.3-3 (3) to Figure 5.2.3-3 (4))
4. The EF is powered up and activated The EF's operational status is checked.
5. The SRMS removes the ELM-ES from the space shuttle's cargo bay (Figure 5.2.3-3)
6. The ELM-ES is handed over from the SRMS to the Canadarm2 (Figure 5.2.3-3 (6))
7. The ELM-ES is attached to the EF by the Canadarm2 (Figure 5.2.3-3 (7) to Figure 5.2.3-3 (8))
8. The ELM-ES is powered up and activated The ELM-ES's operational status is checked.
9. The payloads carried on the ELM-ES during launch are relocated to the EF by the JEMRMS

Note: The above procedures are based on NASA/JAXA coordination as of March 2007. The above procedures are subject to change dependent on possible changes.

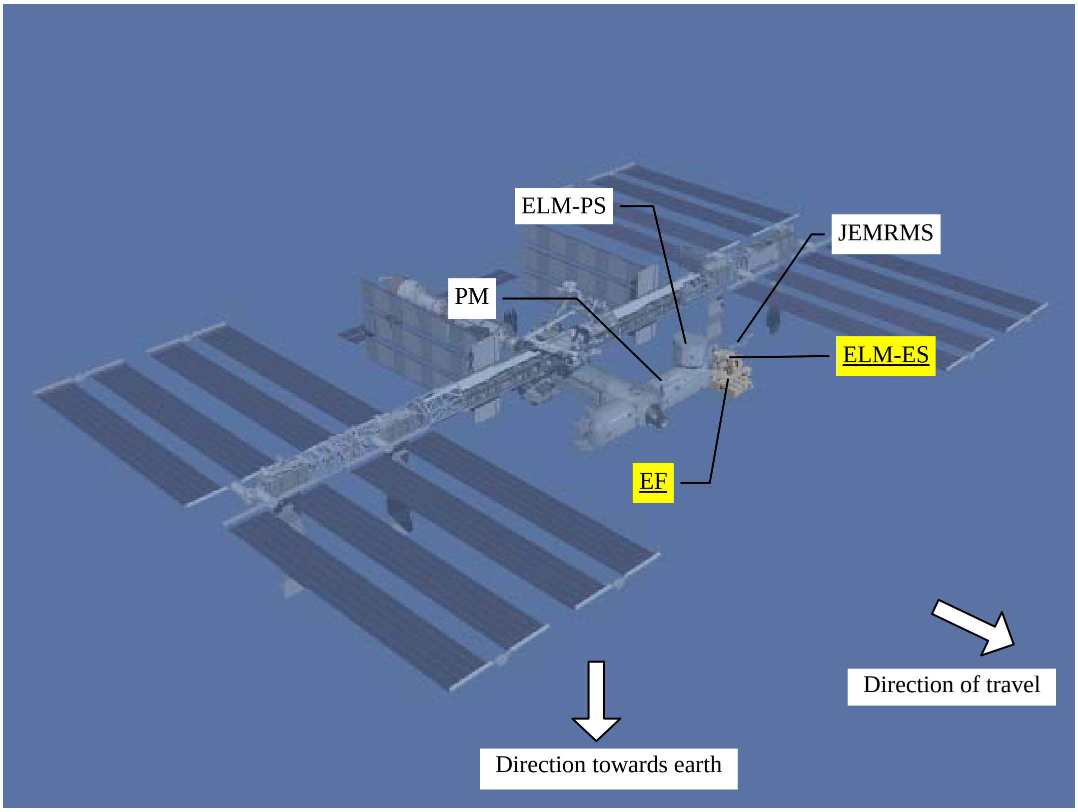


Figure 5.2.3-1 ISS after completion of 2J/A Flight (Illustration provided by NASA)

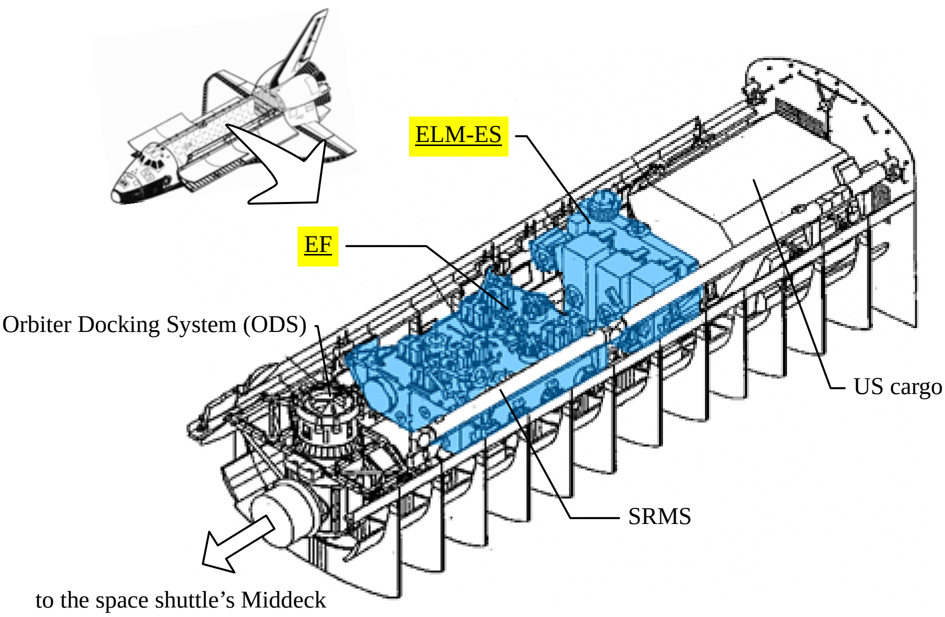


Figure 5.2.3-2 2J/A Cargo bay layout during launch of 2J/A Flight (Image)

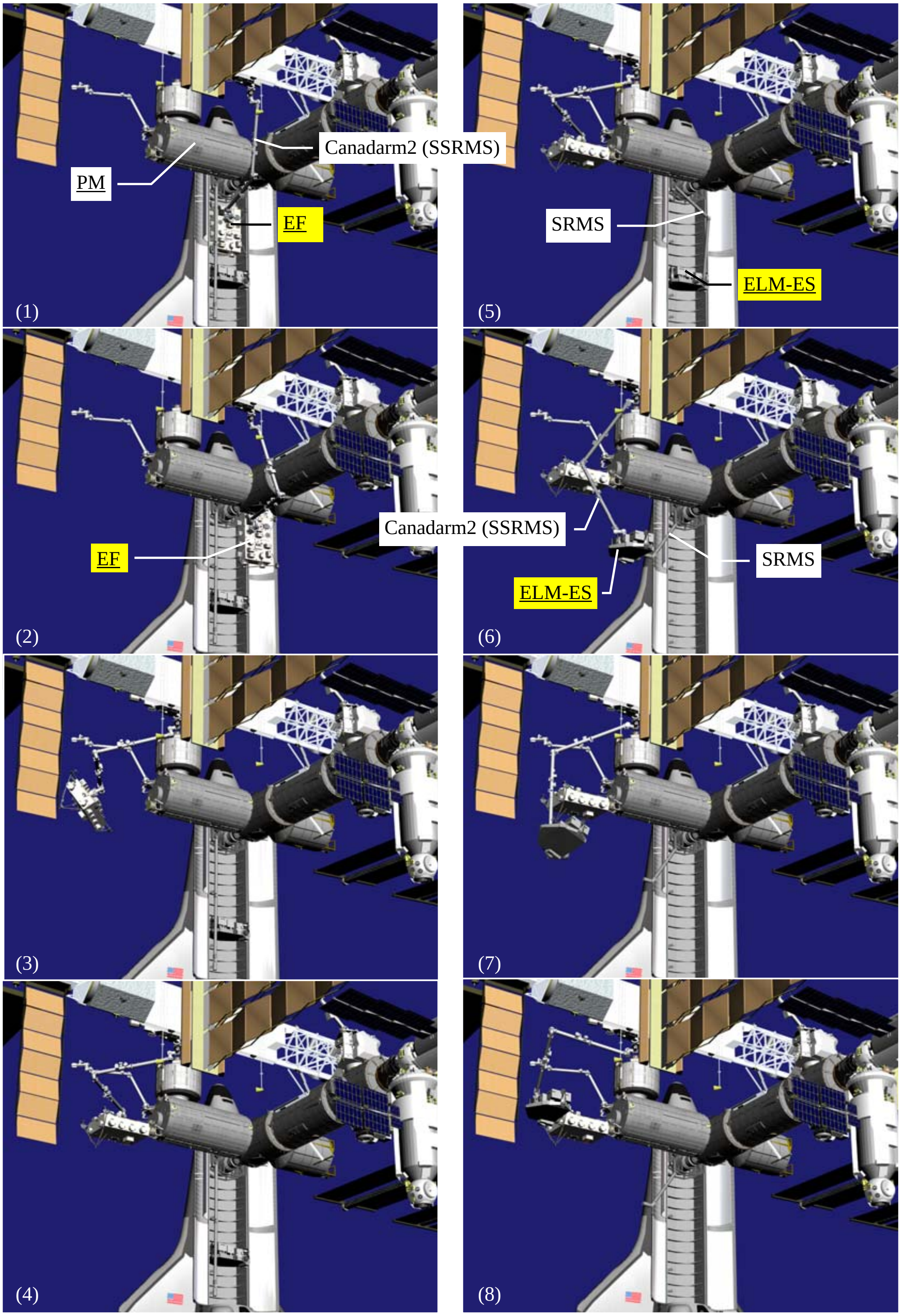


Figure 5.2.3-3 Procedures for connecting EF and ELM-ES to ISS

5.3 Kibo Operations Control

The International Space Station (ISS) program, which includes the construction, assembly, and utilization of the ISS, has been promoted by the United States (US), Japan, Canada, 11 European countries that belong to the European Space Agency (ESA), and Russia. Overall operations of the ISS are coordinated by the US. Each International Partner is responsible for operating each country's own ISS component including ISS components/modules/segments, ISS payloads or equipment.

Communications between the ISS and the International Partners are conducted through the Tracking and Data Relay Satellite (TDRS) by way of NASA Johnson Space Center (JSC) and White Sands Ground Station. Japan will alternatively use JAXA's Data Relay Test Satellite (DRTS), known as Kodama, for communicating with Kibo. Russia communicates with the ISS only when direct communications with the ISS are permitted, and uses the TDRS as a backup communication method.

Figure 5.3-1 shows the conceptual diagram for the ISS operations.

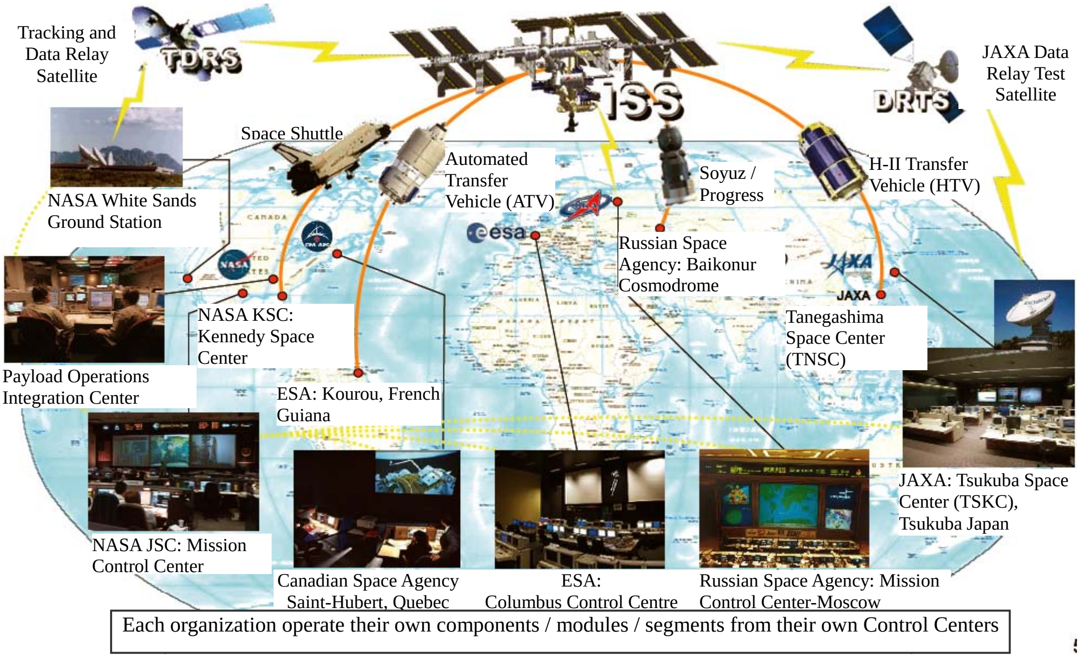


Figure 5.3-1 ISS Operations Conceptual Diagram

After all of the Kibo components are assembled and attached to the ISS, Japan's full-scale experiments in space will commence.

Experiments, which will be performed in or on Kibo, are operated and controlled from the Space Station Operations Facility (SSOF) in the Space Station Integration and Promotion Center (SSIPC) at Tsukuba Space Center (TKSC) in collaboration with the Space Station Control Center (SSCC) at NASA's Johnson Space Center (JSC), where the overall operations of the International Space Station (ISS) are controlled and managed. Overview of the SSIPC that consists of several related ground facilities is shown in Figure 5.3-1.

The SSOF is responsible for Kibo's operations control, including (1) controlling and monitoring Kibo's ongoing systems, (2) operating Japan's experiment payloads onboard Kibo, (3) implementing operations plans, and (4) supporting launch site processing.

Kibo's operations systems are categorized by the following systems: (a) Operations and Utilization Planning System, (b) Operations Control System, (c) Crew Operations Training System, (d) Engineering Support System, (e) Logistics and Maintenance Operations Management System and (f) Operations Data Network System.

Overview of the Operations Control System (OCS), which is the most critical system for Kibo operations, is shown in Figure 5.3-2.

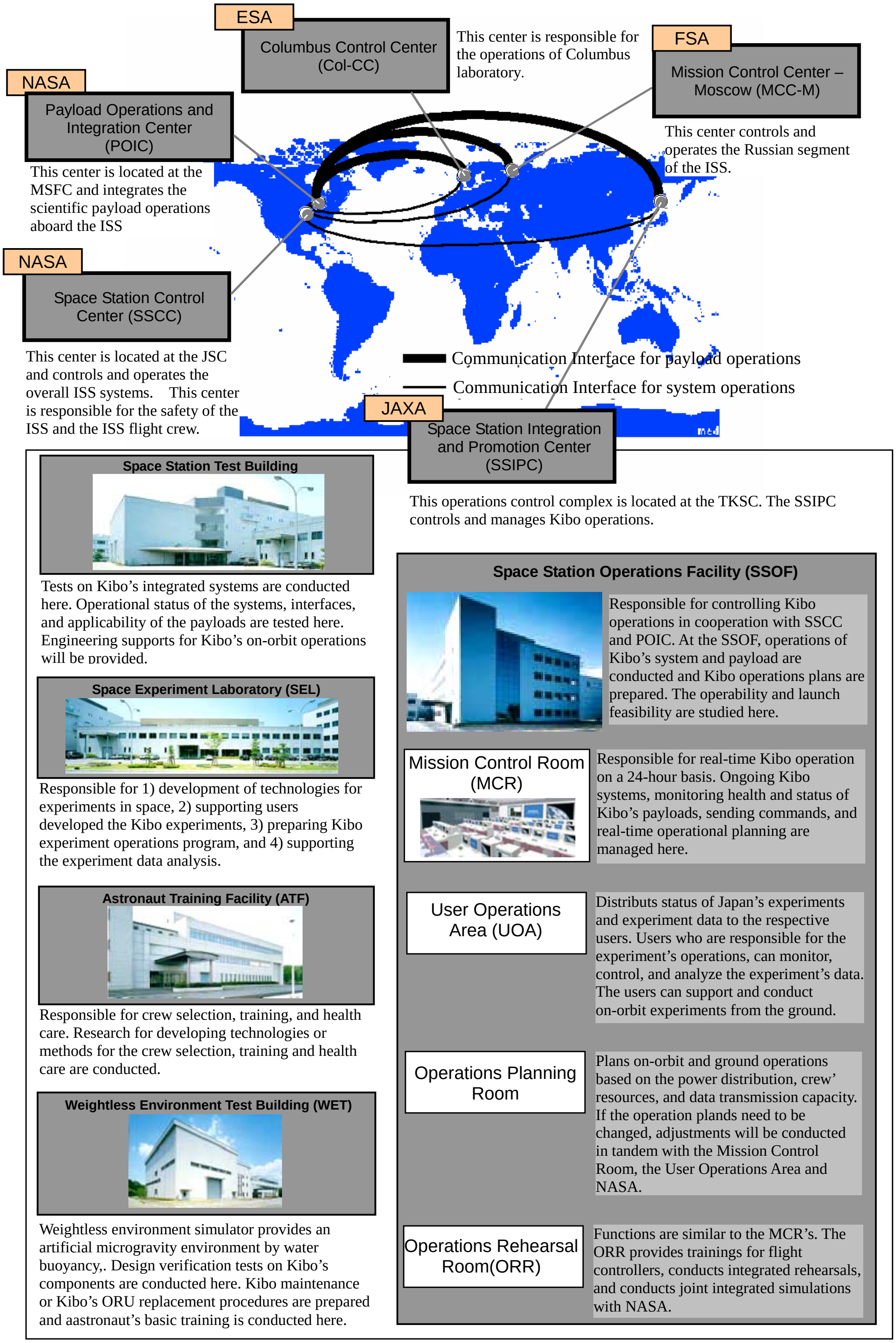


Figure 5.3-1 Space Station Integration and Promotion Center (SSIPC) Ground facilities

Operations Control System (OCS)

Along with the SSCC operations control, the Operations Control System (OCS), which is a core component of the SSIPC, controls and monitors Kibo’s systems and the status of Japan’s and international partners experiment payloads aboard Kibo. The OCS also conducts data management and provides user support.
In addition, the OCS prepares and manages the operations plans for Kibo’s systems and payload operations within the available resources that are allotted to Kibo in cooperation with the SSCC/POIC that is responsible for integrating the overall ISS system and payload operations.

- **Monitoring Control subsystem**

  The Monitoring Control subsystem is responsible for: (1) the processing and display of telemetry data required for the real time monitoring and control of Kibo’s onboard payloads (Japan’s and international partners’), (2) control and verification of commands that are transmitted, (3) operations history data archive, (4) transmission, control and/or verification of on-orbit operations files, and (4) fault detection, isolation, and recovery.

- **Experiment Operations Support subsystem**

  This subsystem provides several types of supports for users who operate their experiments on or in Kibo including: (1) distribution and display of experiment data and ancillary data that is downlinked from Kibo to the users, (2) input and transmission of commands from the users, and (3) interfacing the uses’ provided equipment for standard interfacing.

- **Strategic and Tactical Planning subsystem**

  This planning subsystem manages: (1) planning and preparation of Kibo’s systems or payloads, (2) ground operations planning for Kibo on-orbit operations, and (3) revising or modifying ground operations plans, and (4) data management for operations planning.

- **Operations Data Management subsystem**

  This data management subsystem manages: (1) operations data of Kibo’s system and Kibo’s on-board payloads (both Japan’s and international partners’), (2) experiment data for Japan’s experiment payloads, (3) accumulation of ancillary data and statistical processing, (4) data processing, long-term storage management and distribution of data, and (5) data search management.

- **Operations Data Network subsystem**

  This network subsystem manages: (1) the equipment for interfacing between NASA and Kibo’s ICS and (2) OCS network operations.

- **Common Equipment subsystem**

  This subsystem provides equipment and information that are common to either the Kibo’s flight controllers or Kibo’s operations staff. This subsystem is composed of: (1) audio and video communication equipment, (2) large displays, (3) standard time provision equipment, and (4) consoles at the MCR.

Figure 5.3-2 Kibo Operations Control System

5.3.1 Orbital Interface (between the ground to/from Kibo)

There are two types of communication links between Tsukuba Space Center (TKSC) and Kibo for data uplink/downlink. In general, Kibo operations are conducted by using NASA's communication link.

(1) NASA Data Communication Link

This link provides the data communication interface between Kibo and TKSC through NASA's Tracking and Data Relay Satellite System (TDRSS). Commands or data from the TKSC are first received at NASA JSC and White Sands Ground Station and forwarded to Kibo through the TDRSS and the ISS. This link utilizes two types of communication bands. Each band relays different types of data.

(a) S band

The S band relays commands (power-on and power-off commands to Kibo), telemetry data (Kibo's health status data) and voice.

(b) Ku band

The Ku band relays larger bandwidth data that is acquired at Kibo to the ground, including, experiment data or video images.

(2) JAXA Data Communication Link

This link provides a direct interface between the TKSC and Kibo through JAXA's Data and Relay Test Satellite (DRTS). The data sent from TKSC are relayed through the DRTS and received by the Inter-orbit Communication System (ICS) installed on Kibo. This link uses the Ka band. The types of the data to be uplink/downlink are nearly the same as the types of data for NASA's communication link, including, commands, telemetry, voice, video images, experiment data and experiment images. JAXA's Data Communication Link is also known as the "ICS link".

5.3.2 Ground Interface (between TKSC and NASA Mission Control Centers)

There are two types of ground links between JAXA and NASA. Both links between the two control centers are via leased lines/channels.

(1) Link between the Tsukuba Space Center (TKSC) and NASA's Johnson Space Center (JSC)

This link interfaces the Tsukuba Space Center (TKSC) with NASA's Johnson Space Center (JSC). Commands (power-on and power-off commands to Kibo), telemetry data (Kibo's health status data), voice and video images are sent and received.

(2) Link between Tsukuba Space Center (TKSC) and NASA's Marshall Space Flight Center (MSFC)

This link interfaces Kibo with the TKSC through the Huntsville Operations Support Center (HOSC) at NASA's Marshall Space Flight Center (MSFC). Experiment data downlinked from Kibo is sent to the TKSC.

Figure 5.3-3 shows a conceptual diagram of the orbital/ground interfaces for Kibo operations.

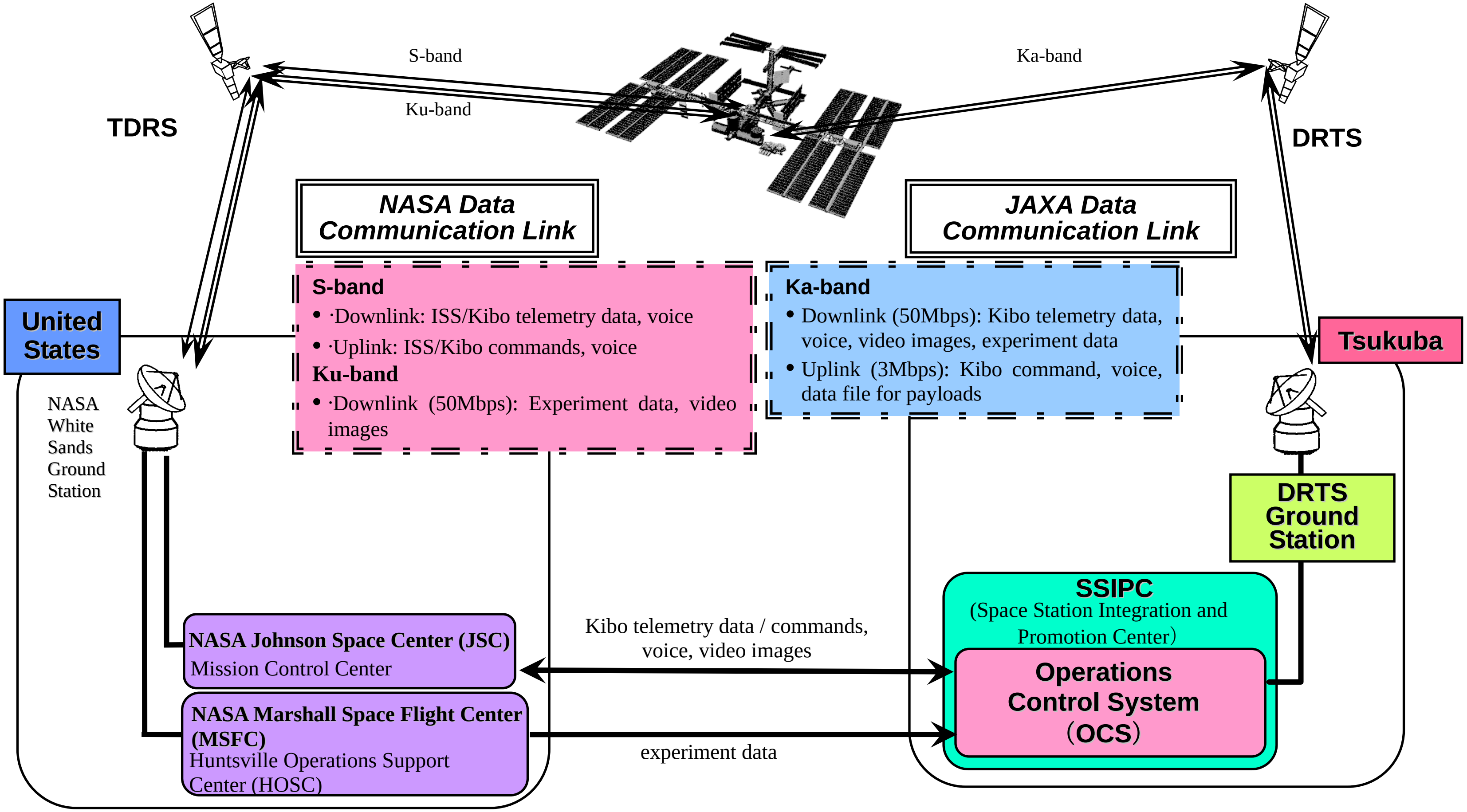


Figure 5.3-3 Conceptual Diagram of orbital/ground communication interfaces for Kibo Operations

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6. Kibo Utilization

6.1 Summary

400 km above the earth, construction and assembly of the International Space Station (ISS) is ongoing. Aboard the ISS, various scientific experiments are currently or will be conducted by utilizing an environment unique to space. The space environment is characterized by microgravity, space radiation, vast views, very high vacuum and an abundant source of solar energy. These environmental conditions are completely different and difficult to fully duplicate from what is available on earth. The results from these experiments are expected to enhance the capabilities of our 21st century industry and will also be used for the betterment of mankind. On Kibo, several types of scientific experiments that will use Kibo's pressurized and exposed facilities are planned. This chapter describes Kibo's space experiment environment and the experiment payloads planned to be used inside or outside of Kibo, and introduces Kibo's utilization plans during Kibo's initial utilization phase.

6.2 Environment

6.2.1 Microgravity

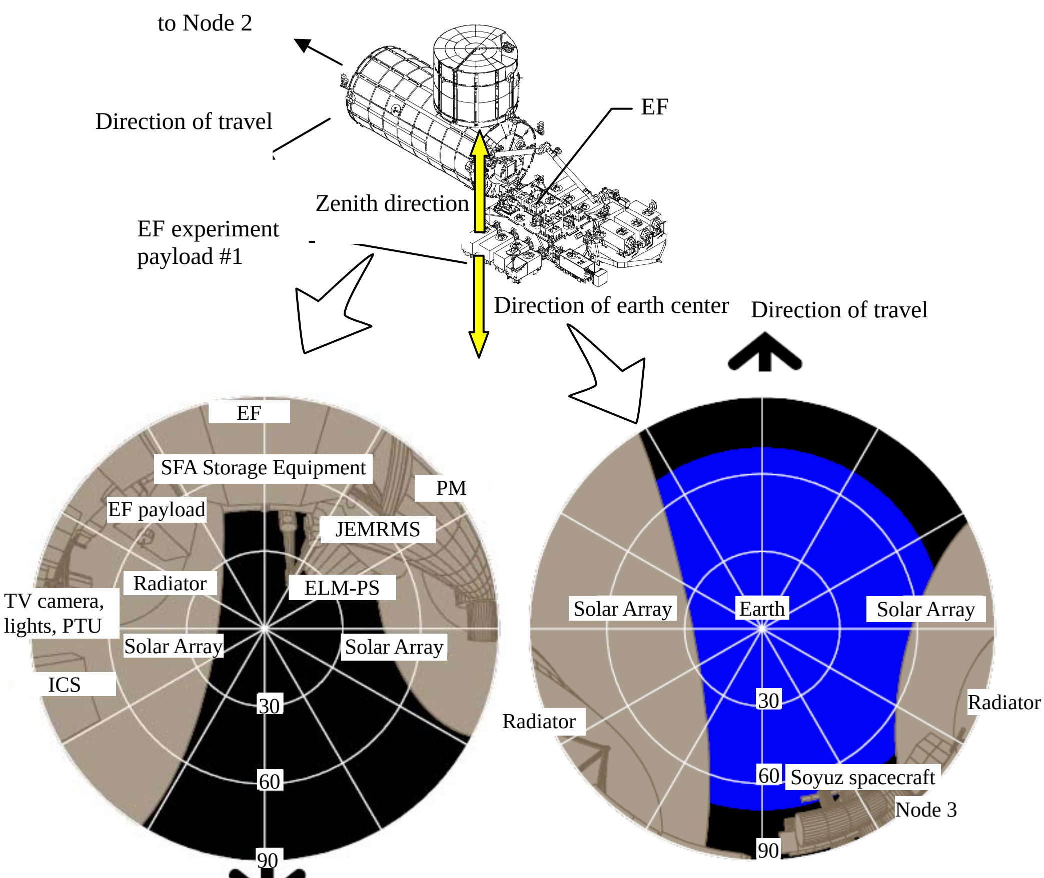
Every object orbiting the earth, like the ISS, is in a state of continuous free-fall towards the center of the earth. Under these conditions, these orbiting objects are under the influence of microgravity or near zero gravity conditions. On-board the ISS, several factors including atmospheric drag, gravity gradient (tidal force), crew activities, and the station's solar array rotations may affect the ISS gravitational environment. However, microgravity is still only about 10^{-6} to 10^{-4} g of that on earth, and thus can be utilized for long-term research on-board the ISS. (Note: 1 g is a measurement expressed as an object's nominal acceleration at 9.80665 m/s^2 due to gravity on Earth at sea level and known as G-force or G-load). Utilizing this microgravity environment, several types of experiments or studies on the effects of gravity on life are under consideration for Kibo's future experiments.

6.2.2 Line of Sight and field of view from the ISS

The line of sight from certain sites of the ISS can be blocked by the ISS structural components, including the pressurized modules or rotating solar arrays. The field of view or what can be seen depends on location and the direction of the line of sight.

Since Kibo will be located at the front of the ISS (ISS's direction of travel), a relatively wider field of view can be seen from the Exposed Facility (EF) experiment payloads site attached to the front (ISS's direction of travel) of the Kibo's Exposed Facility (EF).

The field of view from the EF experiment payload #1, that will be attached to the EF, was estimated by a field of view analysis. Figure 6.2.2-1 shows an estimated field of view from the EF experiment payload #1. Mission planning for an experiment, which will be conducted using an EF experiment payload on the EF and a view is of importance, will need to factor in the results of the field of view analysis.



Note: The rotation envelopes for the station's solar arrays and radiators are indicated. Both figures illustrate a hemispheric view.
SFA: Small Fine Arm
PTU: Pan Tilt Unit

Figure 6.2.2-1 Estimated field of view for EF experiment payload #1 site on EF

6.2.3 Background Atmosphere

The degree of vacuum at the ISS orbit (at an altitude of 400 km) is approximately 10^{-5} Pa. Water dumps from the ISS or water dumps from the space shuttle being docked to the ISS could affect this vacuum environment. In addition, the atmospheric density of the environment surrounding the ISS may vary depending on solar and geomagnetic activities.

At the altitude where the ISS orbits, a significant amount of atomic oxygen exists. The atomic oxygen is formed from dissociated oxygen molecules exposed to ultraviolet (UV) radiation. Atomic oxygen is known to oxidize, erode and contaminate spacecraft materials on orbit.

Excluding water dumps from the ISS, there are many contamination sources in Kibo's surrounding environment, including out-gassing from the ISS components (gasses emitted from organic materials) or thruster burns by the space shuttles or other spacecrafts. When planning experiments for the EF, atmospheric factors will need to be taken into consideration.

6.2.4 Space Radiation

The environment where the ISS orbits are comprised of cosmic radiations, including a radiation belt (Van Allen belts) consisting of particles captured by the earth's magnetic field, solar flare particles (solar protons) generated by solar activities, and galactic cosmic rays that originates from outside the solar system. The environment outside and inside the ISS can be affected by cosmic radiations impacted with the ISS structural components or the atmosphere, which in turns generates secondary radiations. The cosmic radiation may cause malfunctions with the ISS equipment, which is known as a “single event effect”. Additionally, the cosmic radiation may adversely affect the health of the ISS crew. Therefore, observations and researches on cosmic radiation have become increasingly important.

6.2.5 Thermal Environment

The ISS and Kibo’s thermal environments are complex and composed of direct solar exposure, sun light reflected from the earth (albedo), infrared radiation and cosmic background radiation. The temperature surrounding the ISS and Kibo ranges from -150 °C to +120 °C (degree Celsius), depending on the shaded or un-shaded area of the ISS or Kibo. The thermal environment can also vary depending on the relative position of the sun and the ISS orbital plane.

Before designing an EF experiment payload, as well as Kibo’s components, verification that EF experiment payload itself is strong enough to endure the severe thermal conditions of space including interruptions or reflections attributed to ISS’s surrounding components should be done.

6.2.6 Micrometeoroid and Space Debris

In space, micrometeoroids which are believed to originate from comets or asteroids and space debris, which originate from artificial satellites, spacecraft components, old launch vehicles or orbit burns of solid rocket fuel, are orbiting the earth. These orbiting micrometeoroids and space debris may possibly impact the ISS or Kibo. Under an altitude of 2,000 km above the earth, more than 10,000 pieces of space debris, the size of 10 cm or greater, have been confirmed. If a piece of debris that may impact the ISS is predicted or confirmed, a debris avoidance maneuver that alters the ISS orbital altitude will be implemented. In addition, debris shields or debris bumpers are installed around the outside surface of the PM and ELM-PS for protecting these components’ structural bodies from possible space debris impacts. Moreover, these components are designed not to break apart even if a hole is made in the component’s surfaces from debris impacts. The safety of the ISS crew can be ensured by evacuating the crew to a different ISS module, and then, closing and securing the hatches of the affected module.

6.3 Experiment Payloads

6.3.1 Experiment Payloads for Kibo's Pressurized Module (PM)

(1) Cell Biology Experiment Facility (CBEF)

The Cell Biology Experiment Facility (CBEF) is equipped with an incubation environment where the temperature, humidity and carbon dioxide (CO2) concentration can be controlled. The basic phenomena of life in space can be studied through the use of cells from animals, plants, microorganisms, etc. A centrifuge will be used to generate an artificial gravity environment, thus experiments in both a microgravity and artificial gravity environment can be conducted in Kibo.

The culture chamber will be set in a "canister" and installed within the CBEF. Through a utility connector inside the CBEF, the canister can receive power, command input, sensor output, video output. These utilities will provide support for an efficient experimental environment. In addition, by placing the canister in the Clean Bench (CB), the ISS crew can, by using the Clean Bench's glove box, directly handle the samples inside the canister.

Figure 6.3.1-1 shows an overview of the CBEF. Table 6.3.1-1 shows the CBEF specifications.

The CBEF will be installed in the "SAIBO" experiment payload rack in Kibo's Pressurized Module (PM). The Clean Bench (CB) will also be installed in the "SAIBO" rack. The CBEF will be operated at the location as shown in Figure 6.3.1-2.

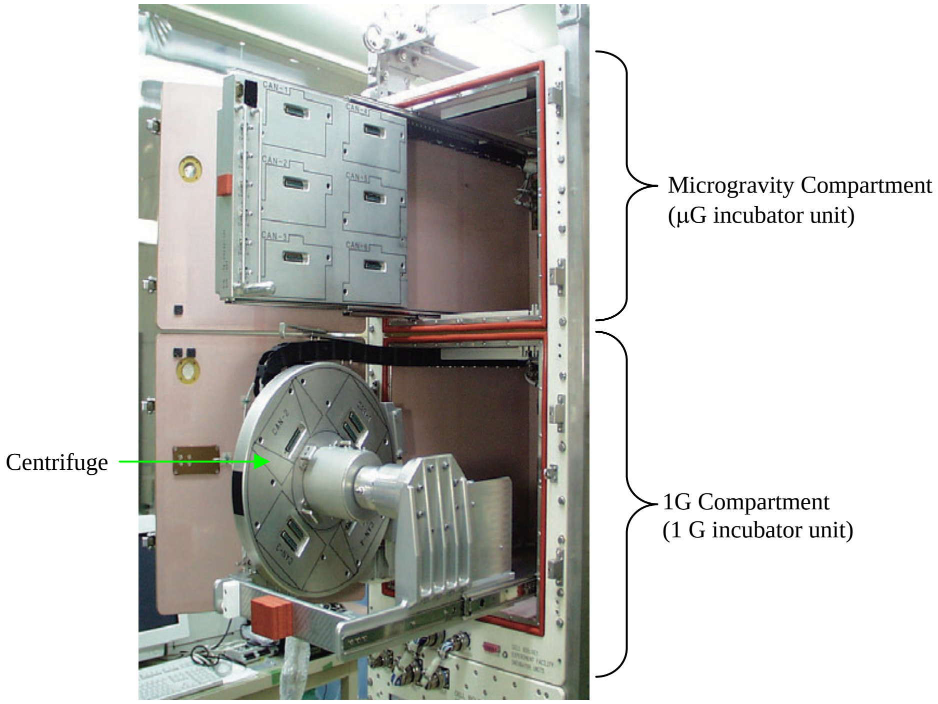


Figure 6.3.1-1 CBEF

Table 6.3.1-1 CBEF Specifications

Items	Specifications
Temperature setting	15 to 40 °C
Humidity setting	Max. 80 ± 10 % RH
CO_2 concentration setting	0 to 10 % (0.1 % step)
Gravity setting	0.05 to 2 G (at 112.5 mm radius point)
Utility	Power: DC+5V, +12V, ±15V Sensor output: 0 to 5 V Command: 1 bit Video output

Figure 6.3.1-2 Location of SAIBO Rack in Pressurized Module (PM)

(2) Clean Bench (CB)

The Clean Bench (CB) will provide an aseptic glove-box operating compartment called “Operation Chamber (OC)” where germfree operations can be conducted. Life Science and biotechnological experiments can be performed on-board Kibo through the use of the CB. The CB has a Disinfection Chamber (DC), which is separated from the OC. This separation prevents the OC from becoming contaminated by microorganisms while transferring samples or equipment. In addition, the OC is equipped with ultraviolet lamps for sterilization and High Efficiency Particle Air (HEPA) Filters. These filters eliminate particles that are suspended in the air. Consequently, germfree experiments can be conducted by the Clean Bench. The front of the OC is comprised of transparent materials so as to provide good views of the inside of the OC. The ISS crew will be able to conduct germfree experiments by directly monitoring the insides of the OC. In addition, to support the experiments, a phase-contrast/fluorescent microscope and a monitor camera are installed in the CB.

Figure 6.3.1-3 shows an overview of the CB. Table 6.3.1-2 shows the CB’s specifications.

The CB will be installed in the “SAIBO” experiment payload rack in the PM together with the CBEF, and will be operated at the location as shown in Figure 6.3.1-2.

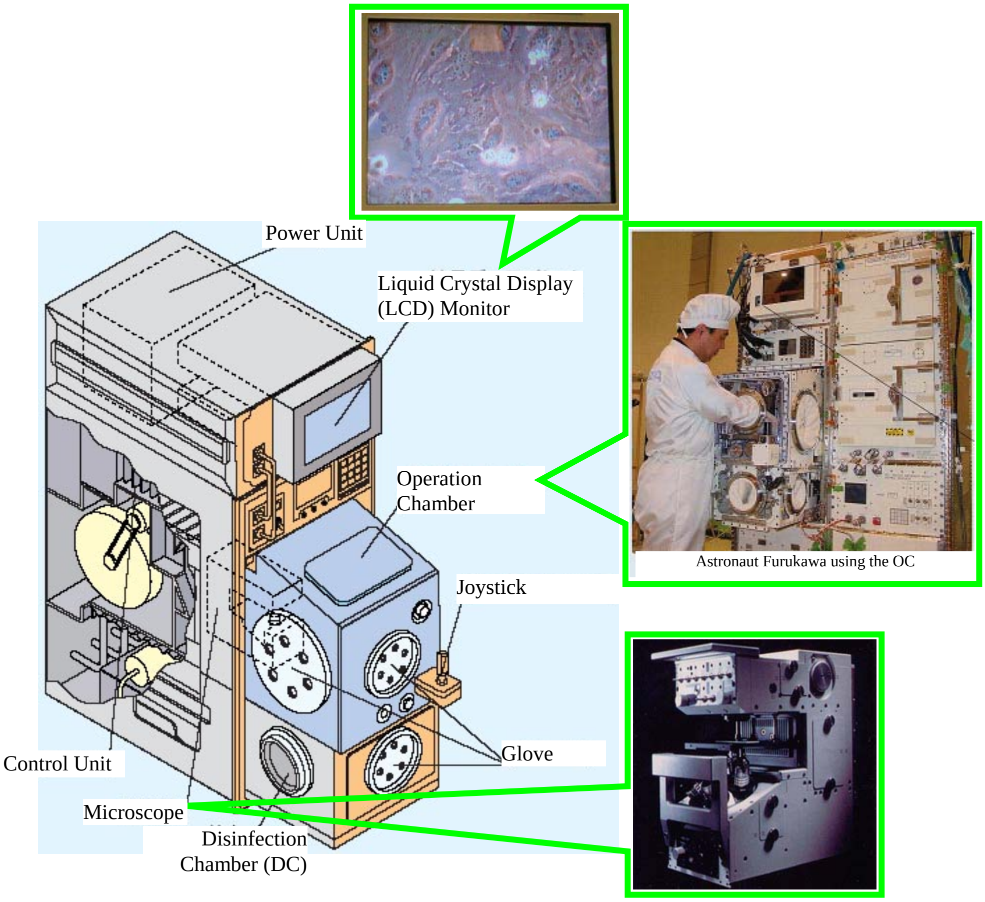


Figure 6.3.1-3 CB

Table 6.3.1-2 CB Specifications

Items	Specifications
Cubic Volume	Operation Chamber: 52 L Disinfection Chamber: 14 L
Environment Control	Air duct filtering system: particle are eliminated by HEPA filters (two) Sterilization method: UV-germicidal lamp Temperature setting: 20 to 38 °C
Equipment installed	Phase-contrast/fluorescent microscope (objective lens: x4, x10, x20, x40 magnification)
Utility	Power: DC+5V, +12V, ±15V Video output

(3) Fluid Physics Experiment Facility (FPEF)

The Fluid Physics Experiment Facility (FPEF) is an experiment facility for conducting fluid physics experiments at ambient temperature and in a microgravity environment. In space or in a microgravity environment, the effects from thermal convection are lower than that on earth. Thus, Marangoni convection (convection attributed to differences between surface tensions) is significant. The primal objective of the FPEF is to investigate the Marangoni convection in a space environment which affects such as the semiconductor single crystal growth experiment. The results from investigating the Marangoni convection are expected to facilitate control of convections that are currently hampering industrial applications. The results, by deepening our understanding of the Marangoni convection, may be applied to methodologies for eliminating foam or bubbles in fluids.

As part of the FPEF standard functions, the FPEF has the following features for observing, measuring or monitoring: (1) two-dimensional (2D) and three-dimensional (3D) flow field observation for observing flow distributions, (2) surface temperature measurement, (3) velocity profile measurement using ultrasound, and (4) surface flow velocity monitoring. Currently, the "Liquid Bridge" application is being planned for the FPEF for investigating the Marangoni convection. In addition, several Experiment Cells are being developed to meet several diverse experiment purposes. Figure 6.3.1-4 shows an overview of the FPEF. Table 6.3.1-3 shows the FPEF specifications.

The FPEF will be installed in the "RYUTAI" experiment payload rack inside the PM. The FPEF will be operated at the location as shown in Figure 6.3.1-5.

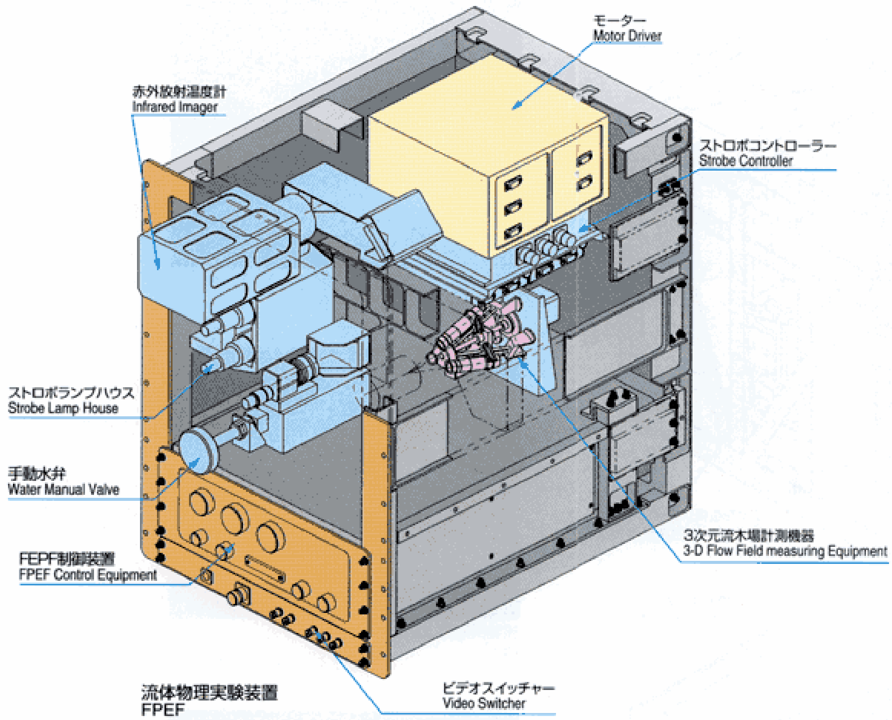


Figure 6.3.1-4 FPEF

Table 6.3.1-3 FPEF Specifications

Items	Specifications
Liquid Bridge Formation	Sample: Silicone Oil Diameter: 30 mm, 50 mm Length: 65 mm maximum
Temperature Control	Heating Disk: 90 ℃ (degrees Celsius) maximum Cooling Disk: 5 ℃ (degrees Celsius) minimum
3D Flow Field Observation	CCD camera (effective pixel: 768 (H) x 494 (V))
Liquid Bridge Overview Observation	CCD camera (effective pixel: 768 (H) x 494 (V))
Surface Temperature Distribution Measurement	Infrared Imager *spectral response: 8 to 14 μm *measurement range: 0 to 100 °C
Surface Flow Velocity Measurement	Photochromic dye actuation with nitrogen gas laser (two points irradiation)
Utility	Power source: 12 ± 2V, 4A (Max), 1ch 24 ± 2V, 3.5A (Max), 3ch ± 15V ± 0.5V, 0.8A (Max)/ch, 1ch Analog Input: 0 to 10V, 8ch Digital Input: 8ch Digital Output: 8ch Gas supply: Argon (Ar) gas

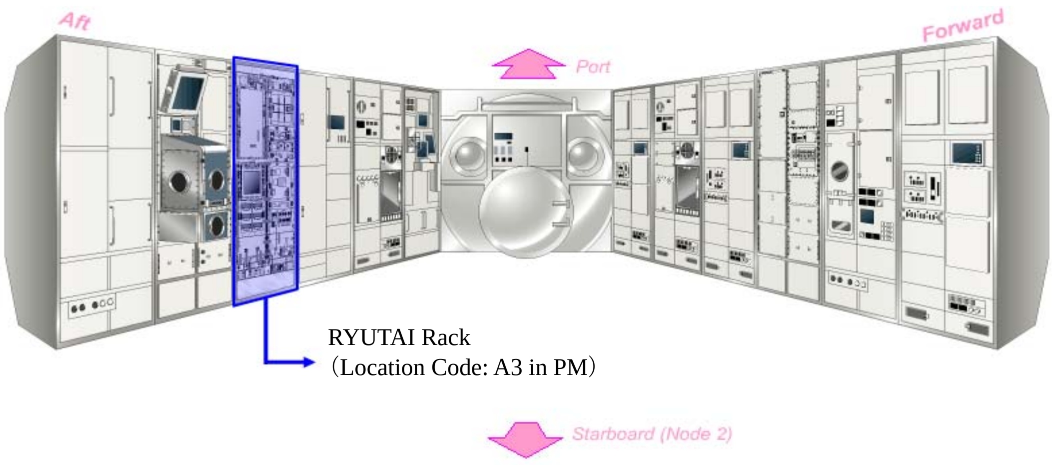


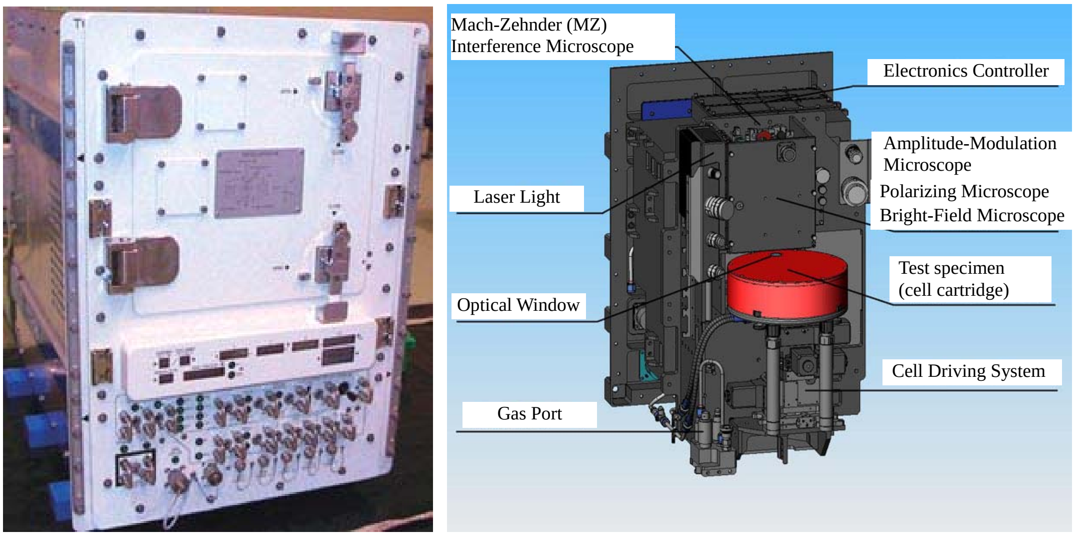
Figure 6.3.1-5 Location of RYUTAI Rack

(4) Solution/Protein Crystal Growth Facility (SPCF)

The Solution/Protein Crystal Growth Facility (SPCF) is an experiment facility for conducting basic researches related to crystal growth in various solutions or proteins in a space environment. The SPCF consists of the Solution Crystallization Observation Facility (SCOF) and the Protein Crystallization Research Facility (PCRF). The SCOF uses cell cartridges for growing solution crystals. In-situ observations can be performed while the crystals are growing by controlling the temperature and pressure in the cell cartridge. A Mach-Zehnder (MZ) Interference Microscope and a Dynamic Light Scattering unit are mounted in the SCOF for crystal growth observation, crystal surface observation, liquid-phase temperature/concentration distribution measurements, and/or particle size distribution measurements. The second SPCF facility, the PCRF, is a facility for growing large and high-quality protein crystals for ground structural analyses.

The SCOF and PCRF can be operated separately as independent facilities. The overviews of the SCOF and PCRF are shown in Figure 6.3.1-6 and Figure 6.3.1-7, respectively. The specifications for the SCOF and PCRF are shown in Table 6.3.1-4 and Table 6.3.1-5, respectively.

The SPCF will be installed in the “RYUTAI Rack” in the PM together with the FPEF, and will be operated at the location as shown in Figure 6.3.1-5.



(SCOF Front) (SCOF Inside)

Figure 6.3.1-6 SCOF

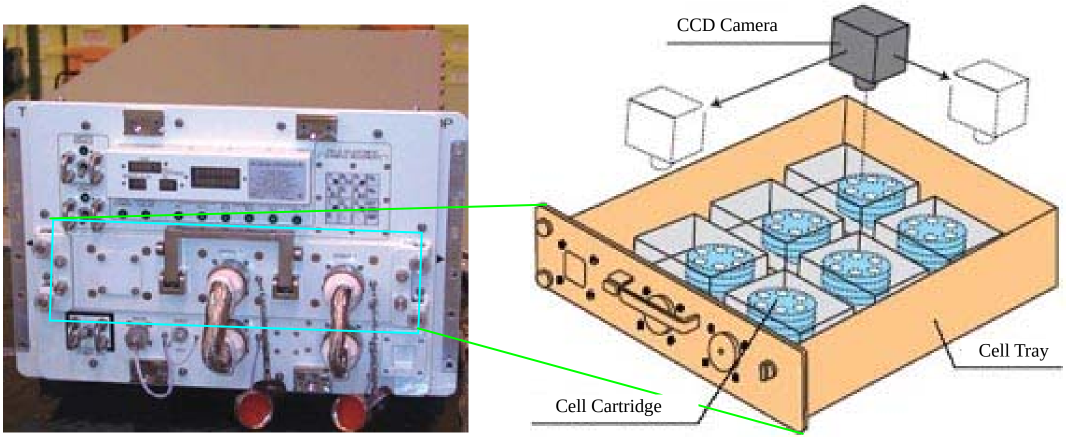


Figure 6.3.1-7 PCRF

Table 6.3.1-4 SCOF Specifications

Items	Specifications
Mach-Zehnder (MZ) Interference Microscope	Magnification: x2, x4 Light source: LD and solid-state laser diode (λ = 532 nm, 780 nm) Phase resolution: More than 0.2 λ
Amplitude-Modulation Microscope	Magnification: x2, x4 Light source: LED (λ = 600 nm) Phase resolution: More than 0.2 λ
User Interface	Temperature Control: Peltier element Temperature Measurement: Thermister (standard or high precision measurement), Thermocouple (K, J type)
Options	Dynamic Light Scattering Fluorescence Decay Reflecting Spectrophotometer Absorption Photometer

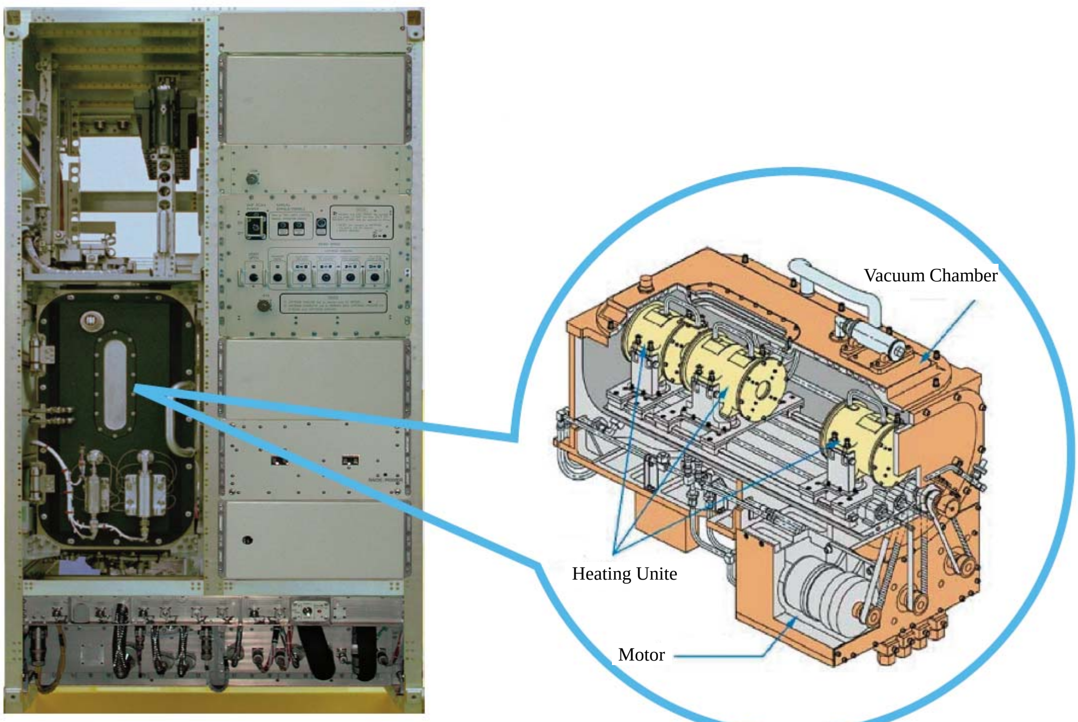
Table 6.3.1-5 PCRF Specifications

Items	Specifications
Cell Cartridge	Number of cartridges: 6 Temperature control: 0 to 35 °C Harvesting method: Vapor Diffusion, Batch, Membrane, Liquid-liquid diffusion
Observation systems	Camera: 1/2 CCD camera Light source: LED Resolution: More than 40 μm

(5) Gradient Heating Furnace (GHF)

The Gradient Heating Furnace (GHF) is a multipurpose electrical furnace for conducting experiments related to vapor deposition and crystal growth of semiconductor materials. The GHF is comprised of a furnace, a Control Equipment, and a Sample Cartridge Automatic Exchange Mechanism (SCAM) with a controller. Samples will be heated or cooled in the Furnace Section. The Control Equipment will receive commands from the ground to control the experiments while relaying data to the data communication system of Kibo. The SCAM can accommodate up to 15 samples and can automatically exchange the samples. There are three heating units in the Furnace Section. Each heating unit can independently be controlled or maneuvered. Thus, different temperature profiles can be set for conducting various experiments. When running the experiments in the GHF, fusion and unidirectional solidification of the samples can be conducted. The GHF overview is shown in Figure 6.3.1-8. The GHF specifications are shown in Table 6.3.1-6.

The GHF will be installed in the “KOBAIRO” experiment payload rack, with power or coolant water being supplied from the PM. Data can be sent to or received from the ground.



(GHF installed in the KOBAIRO Rack)

GHF Material Processing Unit (Furnace)

Figure 6.3.1-8 GHF

Table 6.3.1-6 GHF Specifications

Items	Specifications
Heating Temperature Range	500 to 1600 °C
Temperature Stability	Within ±0.2 °C
Temperature Gradient	150 °C / cm or higher at temperature 1450 °C
Speed	0.1 to 200 mm / h
Temperature Monitoring	Five points (max. 10 points)

Figure 6.3.1-9 Location of KOBAIRO Rack in PM

6.3.2 Exposed Facility (EF) Experiment Payloads

(1) Monitor of All-sky X-ray Image (MAXI)

The Monitor of All-sky X-ray Image (MAXI) will monitor X-ray variations from more than 1,000 X-ray sources. The observations will encompass the entire sky during a time period ranging from a day to a few months. The MAXI will conduct monitoring once per orbit.

The MAXI is equipped with two types of slit cameras. The first camera is a Gas Slit Camera (GSC) with a gas proportional counter. The GSC is equipped with 12 counters. The GSC has a total effective area of 5000 cm2. The second camera is a Solid-state Slit Camera (SSC) with peltier-cooled X-ray sensitive CCD. The MAXI is equipped with two SSCs that provide a total effective area of 200 cm2. By combining these cameras, an x-ray in a low to high-energy range can be captured over a wide range of wavelengths. Color image data can be obtained using an X-ray.

An overview of the MAXI is shown in Figure 6.3.2-1. The specifications for the slit cameras mounted on the MAXI are shown in Table 6.3.2-1.

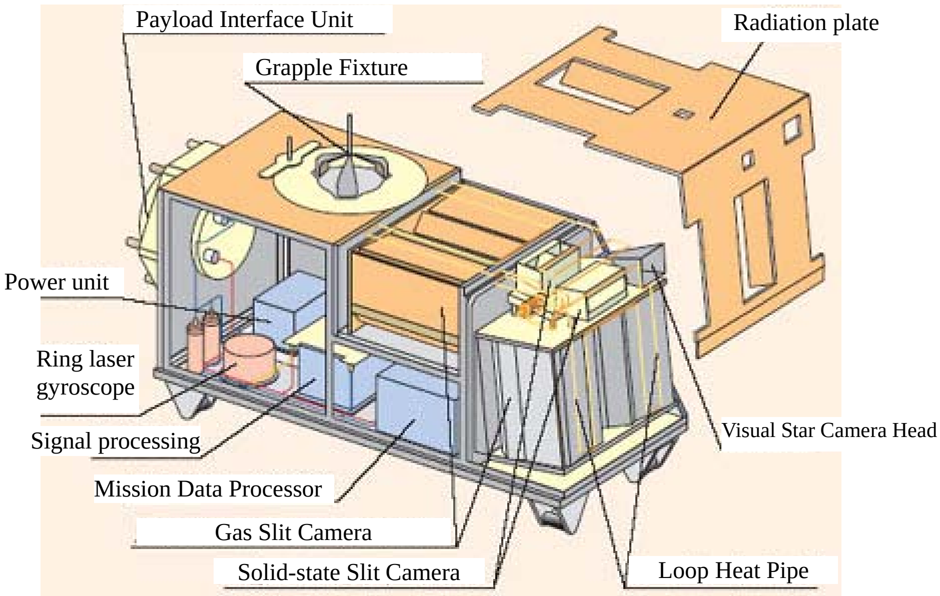


Figure 6.3.2-1 MAXI

Table 6.3.2-1 Specifications of Slit Cameras mounted in MAXI

	Items	Specifications
GSC	Sky coverage	FOV: 160 degree (L) x 1.5 degree (FWHM), 2 directions Scope of instant observation: 2 % of the entire sky Scanning: 90 to 98 % of the entire sky (per orbit)
	Imaging capability	Point spread function (PSF): 1.5 degree (FWHM) Pointing Accuracy: Less than 6 arc min.
	Spectroscopy	X-ray photons of 2 to 30 keV
	Resolution	18 % at 5.9 keV
	Timing accuracy	120 μ sec. with respect to GPS time
	Sensitivity	10 m Crab (1 orbit), 1 m crab (1 week)
SSC	Sky coverage	FOV: 90 degree (L) x 1.5 degree (FWHM), 2 directions Scope of instant observation: 1.3 % of the entire sky Scanning: 70 % of the entire sky (per orbit)
	Imaging capability	Point spread function (PSF): 1.5 degree (FWHM) Pointing Accuracy: Less than 6 arc min.
	Spectroscopy	X-ray photons of 0.5 to 10 keV
	Resolution	150 eV at 5.9 keV
	Timing accuracy	3 to 16 sec. (Dependent on CCD read-out methods)
	Sensitivity	20 m Crab (1 orbit), 2 m crab (1 week)

Note: mCrab = unit, 1/1000 of the X-ray intensity of the Crab Nebula

(2) Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES)

The Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) will observe submillimeter wavelengths that are emitted from trace gases in the stratosphere. These observations will be conducted by pointing the SMILES antenna (Submillimeter Antenna (ANT)) at the upper reaches of the atmosphere. The SMILES can determine the amount of trace gases that exist in the ozone layer. The SMILES measures the distribution and changes in the trace gases in the stratosphere, globally, with a high degree of accuracy.

The Submillimeter-wave Receiver installed in SMILES is comprised of a superconductive sensor and amplifiers (low noise). The SMILES uses a highly sensitive superconductive sensor and a 4-Kelvin mechanical cooler that are world leading edge components.

An overview of the SMILES is shown in Figure 6.3.2-2. The specifications of SMILES sensors and measuring instruments are shown in Table 6.3.2-2.

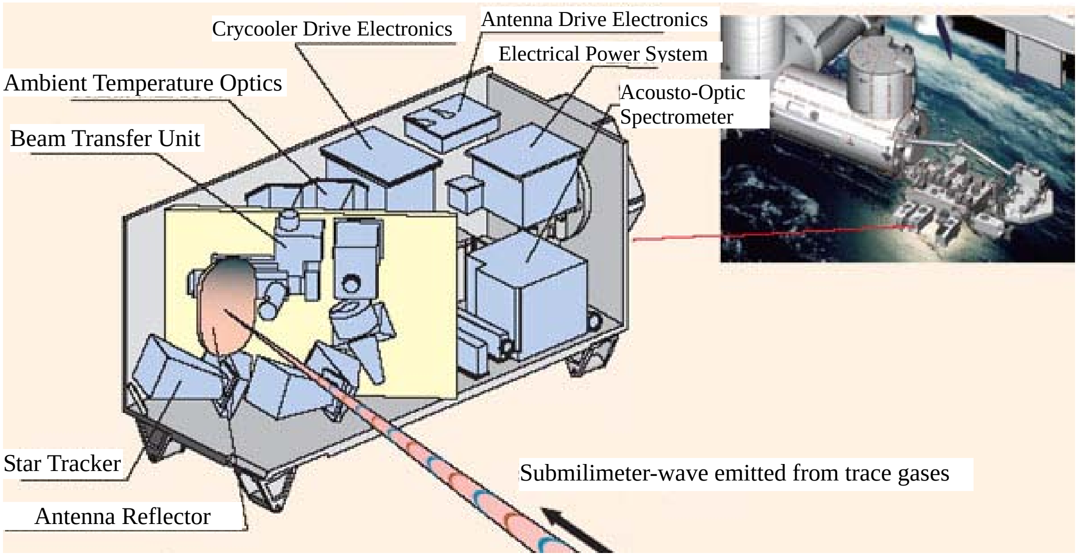


Figure 6.3.2-2 SMILES

Table 6.3.2-2 SMILES / Equipment Specifications

	Items	Specifications
Main body	Mass (weight)	Less than 500 kg
	Electrical power	Less than 900 W (tentative)
	Observation band	640 GHz Band
	Target gases	O_3, HCI, CIO, HO_2, H_2O_2, HOCI, BrO, HNO_3, SO_2, etc.
	Latitude range	65N to 38S
	Altitude range	10 to 60 km
	Sensitivity	1 K (rms) in a single scan
Sensor & measuring instruments	Submillimeter Antenna (ANT)	Structure type: Offset Cassegrain reflector Size: 400 mm x 200 mm HPBW: 0.09 degree (El) x 0.18 degree (Az)
	Submillimeter-wave Receiver	RF: 624.32 to 626.32 GHz (LSB) 648.32 to 650.32 GHz (USB) LO frequency: 637.32 GHz Intermediate frequency: 11.0 to 13.0 GHz
	Mechanical 4-K Cooler	Joule - Thomson Cryocooler: 4.5 K Stirling Cryocooler (x2): 20 K, 100 K
	Acousto-optical Spectrometer (AOS)	Band: 1.2 GHz Channel: 1500 per unit Resolution: 1.8 MHz

(3) Space Environment Data Acquisition equipment-Attached Payload (SEDA-AP)

The Space Environment Data Acquisition equipment-Attached Payload (SEDA-AP) will measure the space environment (neutrons, plasma, heavy ions, high-energy light particles, atomic oxygen, and cosmic dust) at the ISS orbit. Using the SEDA-AP, the space environmental effects on materials and electronic devices will be investigated.

A number of sensors and equipment are mounted in the SEDA-AP, including the Neutron Monitor (NEM) and the Plasma Monitor (PLAM). Space environment data obtained by the SEDA-AP will be applied to the development of future spacecraft designs. The data will also be utilized for ISS operations and related scientific researches, and space weather forecast (prediction of solar activity trends).

The SEDA-AP will conduct measurement and monitoring by extending a mast, on which the Neutron Monitor (NEM) - Sensor and the Plasma Monitor (PLAM) are attached. The mast extends to over 1 m from the SEDA-AP structural body. The experiments using the SEDA-AP sensors and electronic devices will measure, monitor, and collect data, simultaneously, for three consecutive years.

An overview of the SEDA-AP is shown in Figure 6.3.2-3. The specifications for the SEDA-AP sensors and measuring instruments are shown in Table 6.3.2-3.

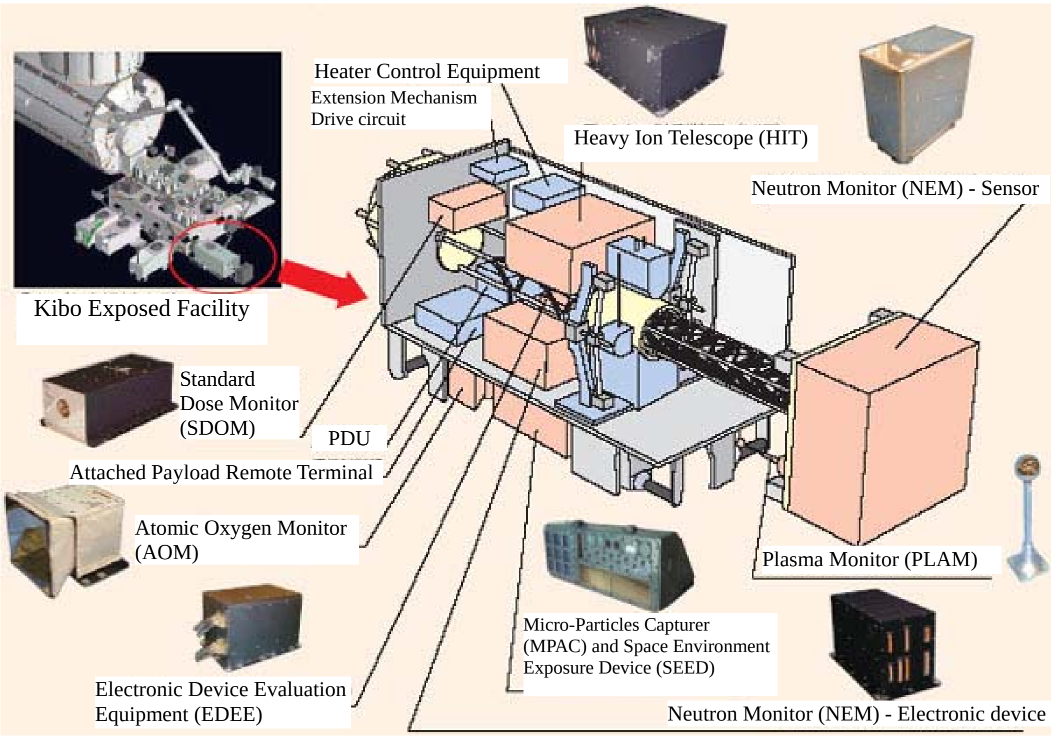


Figure 6.3.2-3 SEDA-AP

Table 6.3.2-3 SEDA-AP / Equipment Specifications

	Items	Specifications
Main body	Dimension	Mast stowed : W800 x H1000 x L1850 mm Mast extended : W800 x H1000 x L2853 mm
	Mass (weight)	Approx. 450 kg
	Power Consumption	Approx. 220 W (Nominal operation)
	Extension Capacity	NEM Sensor extends to over 1 m from the SEDA-AP structural body
Sensor and Electronic Device	Neutron Monitor (NEM)	Bonner Ball Neutron Detector (BBND) Measuring energy range : 0.025 eV (thermal neutron) to 15 MeV Maximum number of measurable particles : 1 x 10^4 count/sec Scintillation Fiber Detector (FIB) Measuring energy range : 15 MeV to 100 MeV Maximum number of measurable particles : 50 event/sec
	Heavy Ion Telescope (HIT)	Li: 10 to 43 MeV/nuc C: 16 to 68 MeV/nuc O: 18 to 81 MeV/nuc Si: 25 to 111 MeV/nuc Fe: 34 to 152 MeV/nuc
	Plasma Monitor (PLAM)	Langmuir probe mode : High Gain -0.2 μA to +2 μA Low Gain -0.04 mA to +0.4 mA Floating probe mode : High Gain ±5 V Low Gain ±100 V
	Standard Dose Monitor (SDOM)	Electron : 0.5-21 MeV (7 ch) Proton : 1.0-200 MeV (15 ch) Alpha : 7.0-200 MeV (6 ch) Heavy Ion : ID only (1 ch)
	Atomic Oxygen Monitor (AOM)	Measuring range : 3 x 10^{17} to 3 x 10^{21} atoms/ cm^2 Resolution : 3 x 10^{17} atoms/ cm^2
	Electronic Device Evaluation Equipment (EDEE)	Memory (1MSRAM) Micro-Processor Unit (V70-MPU) Power MOSFET
	Micro-Particles Capturer (MPAC) and Space Environment Exposure Device (SEED)	Micro-particle capture : Silica-aerogel (34 mm x 34 mm x 9 pcs) Golden plate (119 mm x 60 mm x 2 pcs 76 mm x 25.5 mm x 1 pcs) SEED onboard sample : Scheduled to be selected prior to launch

6.4 Utilization Plan

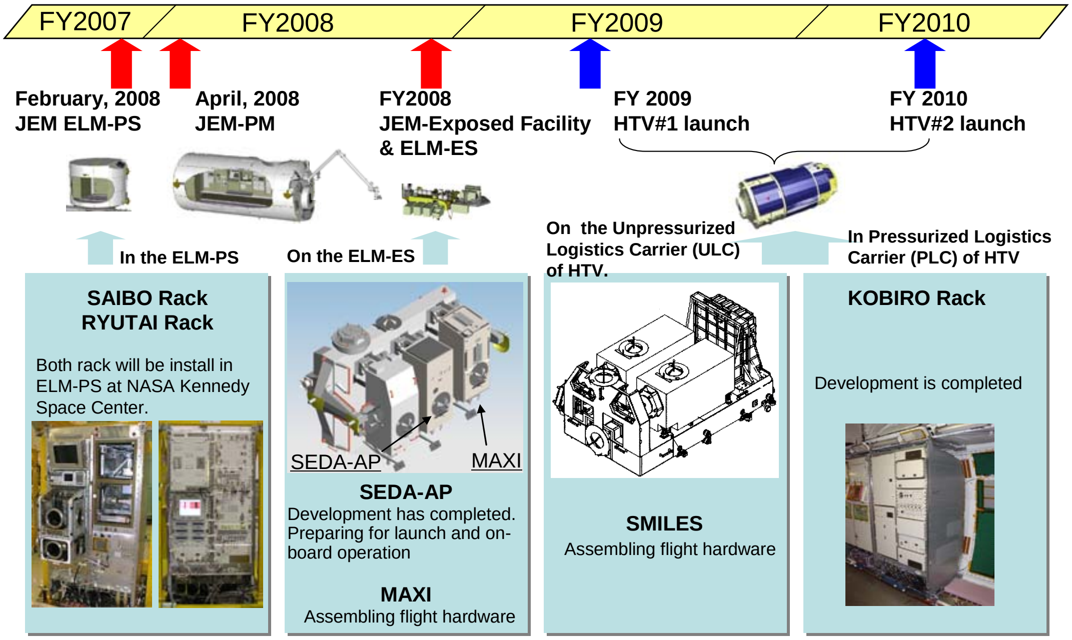
6.4.1 Overall Schedule

With the exception of the GHF, all of the experiment payloads, as shown in section 6.3.1, will be installed in the SAIBO Rack or the RYUTAI Rack. The SAIBO Rack and RYUTAI Rack will be stored in Kibo's Experiment Logistics Module-Pressurized Section (ELM-PS). The ELM-PS is scheduled for launch during Japan Fiscal Year 2007.

Both racks will be transferred from the ELM-PS to Kibo's Pressurized Module (PM), and will be installed at the locations as shown in Figure 6.3.1-2 and Figure 6.3.1-5, respectively. After functions of the two racks are verified on orbit, experiments using these two racks will commence, based on the schedule as shown in Figure 6.4.1-1. Transfer method of the GHF in the KOBAIRO Rack is currently under consideration. The KOBAIRO Rack may be launched on-board the HTV toward the ISS.

The SEDA-AP and MAXI will be launched aboard the space shuttle, and will be attached onto Kibo's Exposed Facility (EF) on orbit.

The SMILES is currently planned for launch on-board the HTV.



(July 2007 updated)

Figure 6.4.1-1 Major Milestone (tentative) for Experiment Payload Launches

6.4.2 Utilization Fields

The period of two-and-half years starting after Kibo launch until the completion of the ISS construction, scheduled for the middle of 2010, is defined as the First Utilization Phase (Initial Utilization Phase). Toward the First Utilization Phase, the following preparation tasks for Kibo utilization are in progress.

Scientific Research

- Preparations of the 16 experiment themes related to Life Science and Material Science, which were selected from domestic or international applications, and will be conducted in the PM, are progressing.
- Development of the three Exposed Facility (EF) experiment payloads (SEDA-AP, SMILES and MAXI) to be conducted on Kibo's EF are progressing.
- Preparations of the three Life Science and space-medicine experiment themes, which were selected from international applications, and will be using ISS facilities (non Kibo facilities), are progressing.

Applied Research

- Research activities related to protein crystallization and nano application study are under consideration at the Application Research Center.

Space Medicine and Human Space Technology

- Researches focusing on medical risk mitigation for long-duration manned space exploration are progressing. (Telemedicine, reducing bone and muscle atrophy, etc.)

Diversified Utilization, including Education and Culture

- Educational missions targeted for students and on-orbit scientific educational experiments are being planned.
- Ten experiments have been selected as pilot studies for the Art field with preparations currently in process.

Utilization by the Asia Pacific Region

- Utilization of Kibo facilities is being proposed at the Asia-Pacific Regional Space Agency Forum (APRSAF). Feasibility assessment of Kibo experiments after 2010 is in process.

Commercial Utilization (fee base)

- Supporting the Private sector businesses through commercializing the results from application researches or Space Open Lab Program.
- Using Kibo facilities for a fee are currently under consideration.

6.4.3 Experiment Themes

The scientific experiment themes, which will be conducted in Kibo's Pressurized Module (PM), were domestically solicited in 1992. The preliminary selections of the domestic experiments were conducted in August 1993. Life Science and microgravity-science experiment themes that will be conducted in Kibo's Pressurized Module (PM), were also solicited internationally. Preparations of the selected experiment themes from domestic and international applications have been in progress as part of the collaborative activities between the themes' principal investigators and Japan Aerospace Exploration Agency (JAXA). The preparations include preparations of the experiment plans (protocols), refinement of the specifications for the payloads, evaluations on the experiment operational tasks, and pilot studies on experiments using the space shuttles. Through these activities, the required techniques and methods for conducting experiments utilizing Kibo facilities have been accumulated.

Table 6.4.3-1 shows the experiment themes of Kibo (Material Science and Life Science) that will utilize Kibo's Pressurized Module (PM) during the First Utilization Phase. Table 6.4.3-2 shows the experiment themes that will utilize Kibo's Exposed Facility (EF) or other ISS facilities (non-Kibo facilities).

Table 6.4.3-3 shows the utilization themes currently under consideration from such diverse fields as, application research, space medicine, manned space exploration, culture and education.

Table 6.4.3-1 Scientific Experiment Themes (Material Science & Life Science)

Kibo's Pressurized Module (PM)

Fields		Title
Pressurized Module	Material Science	• Spatio-temporal Flow Structure in Marangoni Convection (Marangoni1; Yasushi Takeda, Hokkaido University) • Chaos, Turbulence and its Transition Process in Marangoni Convection (Marangoni2; Hiroshi kawamura, Science University of Tokyo) • Investigation on Mechanism of Faceted Cellular Array Growth (Facet; Yuko Inatomi, JAXA) • Study on micro-gravity effect for pattern formation of dendritic crystal by a method of in-situ observation (Ice Crystal; Yoshinori Furukawa, Hokkaido University) • Experimental Assessment of Dynamic Surface Deformation Effects in Transition to Oscillatory Thermo capillary Flow in Liquid Bridge of High Prandtl Number Fluid (Marangoni3; Satoshi Matsumoto, JAXA) • Interfacial Stability under Microgravity (Succinonitrile; Yasunori Miyata, Nagaoka University of Technology) • Role of the short range order on the self-and impurity diffusion of group 14(IVB) elements with a different degree of complexity* (Diffusion; Toshio Itami, Hokkaido University/JAXA) • Growth of Homogeneous In0.3Ga0.7As Single Crystals in Microgravity* (Hicari; Kyoichi Kinoshita, JAXA)
	Life Science	• Control of cell differentiation and morphogenesis of amphibian culture cells (Dome Gene; Makoto Asashima, Tokyo University) • Biological effects of space radiation and microgravity on mammalian cells (Neuro Rad; Hideyuki Majima, Kagoshima University) • Detection of Changes in LOH Profile of TK mutants of Human Cultured Cells (LOH; Fumio Yatagai, RIKEN) • Gene expression of p53-regulated Genes in Mammalian Cultured Cells after Exposure to Space Environment (Rad Gene; Takeo Ohnishi, Nara Medical University) • Cbl-Mediated Protein Ubiquitination Downregulates the Response of Skeletal Muscle Cells to Growth Factors in Space (Myo Lab; Takeshi Nikawa, T University of Tokushima) • Regulation by Gravity of Ferulate Formation in Cell Walls of Wheat Seedlings (Ferulate; Kazuyuki Wakabayashi, Osaka City University) • Integrated assessment of long-term cosmic radiation through biological responses of the silkworm, Bombyx mori, in space (Rad Silk; Toshiharu Furusawa, Kyoto Institute of Technology) • Life Cycle of Higher Plants under Microgravity Conditions (Space Seed; Seiichiro Kamisaka, Toyama University) • RNA interference and protein phosphorylation in space environment using the nematode Caenorhabditis elegans (CERISE; Atsushi Higashitani, Tohoku University)

Table 6.4.3-2 Scientific Experiment Themes

Kibo’s Exposed Facility (EF) or other ISS facilities

Fields		Title
Exposed Facility		• Monitoring the Space Environment and Research on Its Effects on Parts & Materials (SEDA; Tateo Goka, JAXA) • Experimental Observation of Atmosphere Using ”SMILES” (SMILES; Masato Shiotani, Kyoto University) • Research on Long-and Short-Term Variations of ALL Sky A-ray Sources (MAXI; Masaru Matsuoka, JAXA)
Other Module	Material Science	• Effect of Material Properties on Wire Flammability in a Weak Ventilation of Spacecraft (Osamu Fujita, Hokkaido University) • Containerless Crystallization of Silicon in Microgravity (CCSM; Kazuhiko Kuribayashi, JAXA)
Other Module	Life Science	• Role of Microtubule-Membrane-Cell Wall Continuum in Gravity Resistance in Plants (Cell-Wall; Takayuki Hoson, Osaka City University) • Reverse genetic approach to exploring genes responsible for cell-wall dynamics in supporting tissues of Arabidopsis under gravity conditions. (Resist-Wall; Kazuhiko Nishitani, Tohoku University) • Effects of Microgravity and Neuromuscular Activity on Skeletal Muscle Fibers (Akihiko Ishihara, Kyoto University) • The Effect of Microgravity on Vestibular Neurotransmission (Shinichi Usami, Shinshu University) • Hydrotropism and auxin-inducible gene expression in roots grown in microgravity conditions (Hydro Tropi; Hideyuki Takahashi, Tohoku University)
Other Module	Space Medicine	• Preflight zoledronate infusion as an effective countermeasure for spaceflight-induced bone loss and renal stone formation (Bisphosphonates; Toshio Matsumoto, University of Tokushima)

Table 6.4.3-3 Utilization Themes other than scientific experiments (tentative)

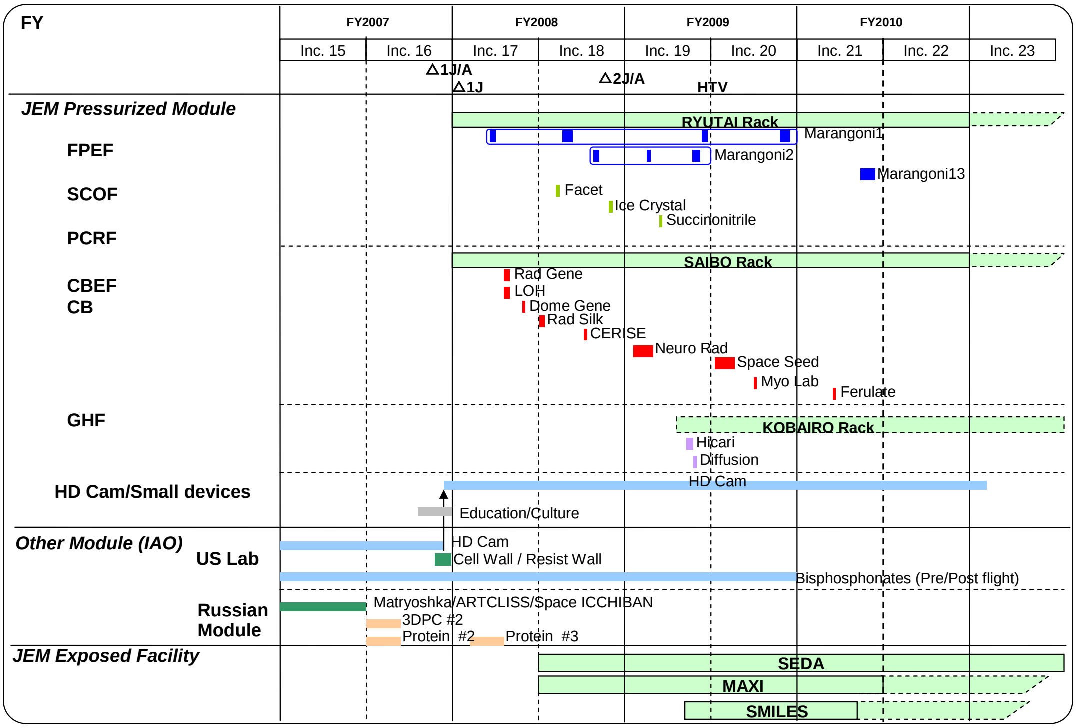
<table>
<tr><th colspan="2">Fields</th><th>Title</th></tr>
<tr><td rowspan="4">Pressurized Module</td><td>Applied research</td><td>• Protein Crystallization (Osaka University)
• Nano-material (Nagoya Institute of Technology)
• Dynamics of Interfaces (Tokyo University of Science)</td></tr>
<tr><td>Space Medicine Human Space Technology</td><td>• Physiological Countermeasure; Prevention of bone loss and urinary stone, Countermeasure for muscle atrophy
• Psychological Support; Psychological monitoring for adaptation of isolation and human interaction, Cross-cultural Issue
• Radiation; Bio-dosimetry, Personal dosimetry (advanced type)
• Medical System; Small and Portable Medical data monitoring equipment (Tele-medicine), Autonomous Diagnostic Medical equipment
• Environment; Gas monitoring and analyzing system (advanced type)
• Habitation Technology(Japanese Space Foods, e.t.c.)</td></tr>
<tr><td>JEM utilization by Asia Pacific region</td><td>• Research collaboration with Asia Pacific region
• Educational program using ISS/JEM</td></tr>
<tr><td>Commercial utilization</td><td>• Protein Crystallization
• 3 Dimensional Photonic Crystallization
• High Definition Video filing</td></tr>
</table>

6.4.4 Utilization Plan

For the First Phase Utilization, which will continue for three years from the beginning of the Kibo operations until 2010, the detailed operations plans have been deliberated at the ISS/Kibo Utilization Promotion Committee, which is an external advisory committee to JAXA. The allocation of the utilization resources per study field or the experiment payloads that will be loaded on Kibo, or the experiment themes that are targeted for international coordination in 2008, were arranged in 2005.

For international coordination, the allocation of the ISS utilization resources and optimization of the ISS overall resources are currently being evaluated based on the ISS overall logistics plan and the ISS overall operations plan.

Figure 6.4.4-1 shows the tentative schedule for the First Utilization Phase



(July 2007 updated)

Figure 6.4.4-1 Schedule for the First Utilization Phase (tentative)

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7. H-II Transfer Vehicle (HTV) Overview

7.1 Summary

The H-II Transfer Vehicle (HTV), designed and being built in Japan, is an unmanned cargo transfer spacecraft that will deliver supplies to the International Space Station (ISS).

The HTV will be launched from the Tanegashima Space Center in Japan aboard an H-IIB Launch Vehicle (currently under development). When the HTV approaches close proximity to the ISS, the Space Station Remote Manipulator System (SSRMS), also known as "Canadarm2," will grapple the HTV and berth it to the ISS. The HTV will deliver up to 6,000 kg of supplies, including food, clothing and several types of experiment payloads to the ISS. After the supplies are unloaded, the HTV will then be loaded with waste materials, including used payloads or used clothing. Afterward, the HTV will undock and depart from the ISS, and will de-orbit and reenter the atmosphere. While the HTV is berthed to the ISS, the ISS crew members will be able to enter and remove supplies from the HTV Pressurized Logistics Carrier (PLC).

Figure 7.1-1 shows an image of the HTV on-orbit.

Figure 7.1-1 Image of HTV during Flight

The HTV will be utilized for delivering supplies to the ISS as with the Russian Progress cargo spacecraft, the U.S. space shuttle, and the Automated Transfer Vehicle (ATV) developed and built by the European Space Agency (ESA),. The HTV can carry both pressurized (for inside use) and un-pressurized (for outside use) cargo, and this is a unique special feature of the HTV.

The launch of the HTV "Technical Demonstration Vehicle" (initial flight vehicle) is scheduled during Japan’s fiscal year 2009 (JFY 2009). Thereafter, one or two HTVs per year are planned for launch.

7.1.1 HTV Components

The H-II Transfer Vehicle (HTV) consists of two logistic carriers: Pressurized Logistics Carrier (PLC) and Un-pressurized Logistics Carrier (UPLC) which carries an Exposed Pallets (EP), and an Avionics Module and a Propulsion Module.

Proximity Communication System (PROX), antennas and reflectors which enable inter-orbit communications between Kibo and the HTV, are installed on Kibo, and will be utilized when the HTV approaches the ISS. Table 7.1.1-1 shows the HTV specifications.

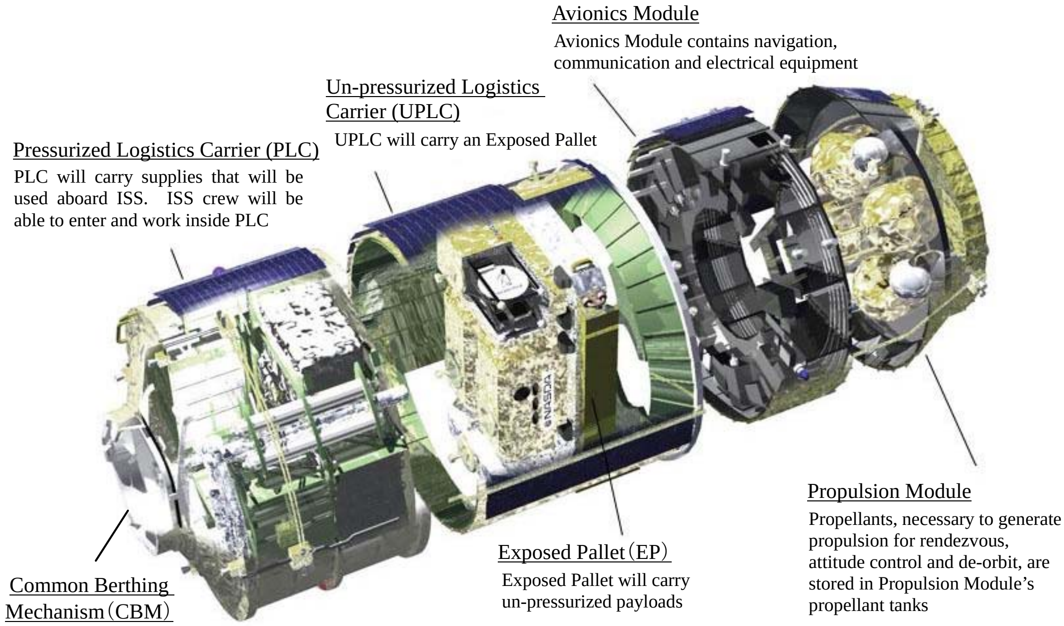


Figure 7.1.1-1 HTV Configuration Diagram

Table 7.1.1-1 HTV Specifications

Items	Specifications
Length	10 m (including thrusters)
Diameter	4.4 m
Mass (weight)	10,500 kg (exclude cargo mass)
Cargo capacity (supplies)	6,000 kg -Pressurized cargo: 4,500 kg -Un-pressurized cargo: 1,500 kg
Cargo capacity (waste)	6,000 kg
Target orbit to ISS	Altitude: 350 km to 460 km Inclination: 51.6 degrees
Maximum duration of a mission	Solo flight: 100 hours Stand-by (on-orbit): More than a week Berthed with the ISS: Maximum 30 days

(1) Pressurized Logistic Carrier (PLC)

The Pressurized Logistics Carrier (PLC) will carry cargo, including International Standard Payload Racks (ISPR), drinking water, and clothes that will be used aboard the ISS. The PLC's internal air pressure is maintained at one atmospheric pressure (1atm). Temperature inside the HTV is controlled until it is berthed to the ISS. After the HTV is berthed to the ISS, the PLC's and the ISS's internal air will be circulated throughout the ISS using fans. While the HTV is berthed to the ISS, the ISS crew will be able to enter the PLC to unload the supplies. After the supplies are unloaded, the HTV will de-orbit and reenter the atmosphere carrying the waste materials. The HTV's berthing port is equipped with a Common Berthing Mechanism (CBM).

(2) Un-pressurized Logistic Carrier (UPLC)

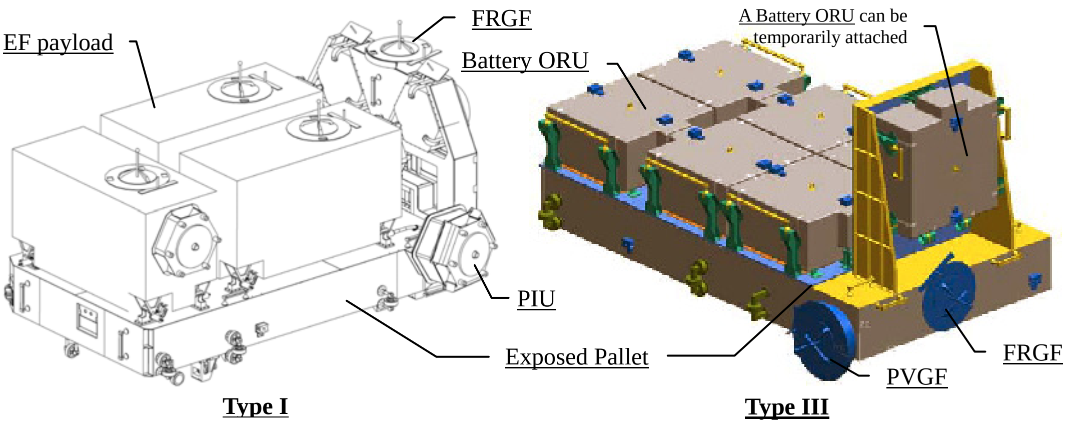
The Un-pressurized Logistic Carrier (UPLC) will carry an Exposed Pallet (EP) (Please refer to (3))

(3) Exposed Pallet (EP)

The Exposed Pallets (EPs) will carry EF payloads, as well as, the ISS battery Orbital Replacement Units (ORU). There are two different types of Exposed Pallets, Type I and Type III. To meet different and specialized purposes, development of other types of Exposed Pallets, in addition to Type I and Type III, are under consideration. An outline of the Exposed Pallets is shown in Figure 7.1.1-2.

Type I: This type of pallet carries the Exposed Facility (EF) payloads that will be used on Kibo's Exposed Facility (EF). Two or three EF payloads per flight can be delivered. This pallet will be attached to the EF.

Type III: This type of pallet carries the US ORUs, such as the battery ORU. This pallet will be attached to the station's Mobile Base System (MBS). Up to six battery ORUs can be delivered.



FRGF: Flight Releasable Grapple Fixture. JEMRMS grapples here.
PVGF: Power Video Grapple Fixture. Canadarm2 grapples here.
PIU: Payload Interface Unit (Passive part of EEU). For detail, please refer to Chapter 4 Section 4.3

Figure 7.1.1-2 Exposed Pallets (EP) (left: Type I, right: Type III)

(4) Avionics Module

The Avionics Module contains guidance navigation & control, communication and electrical power systems. The Avionics Module controls and navigates the HTV's remote-controlled flight by receiving commands from the ground or by HTV autonomous flight. In addition, the Avionics Module distributes power to each component of the HTV.

(5) Propulsion Module

The Propulsion Module has four propellant tanks. These tanks supply propellant to the HTV thrusters. The propulsion for orbital adjustment or attitude control will be produced by commands sent from the Avionics Module. The HTV has 32 thrusters installed. Specifications of the HTV thrusters are shown in Table 7.1.1-2. Locations of the thrusters are shown in Figure 7.1.1-3

Table 7.1.1-2 HTV thruster specifications

Items	Specifications	
	Main thruster	Attitude Control Thruster
Number of units	4 units	14 units x 2 string (redundant structure) *Of 28 units, 12 units are installed on the Pressurized Logistics Carrier (PLC)
Thrust (per unit)	490N	110N

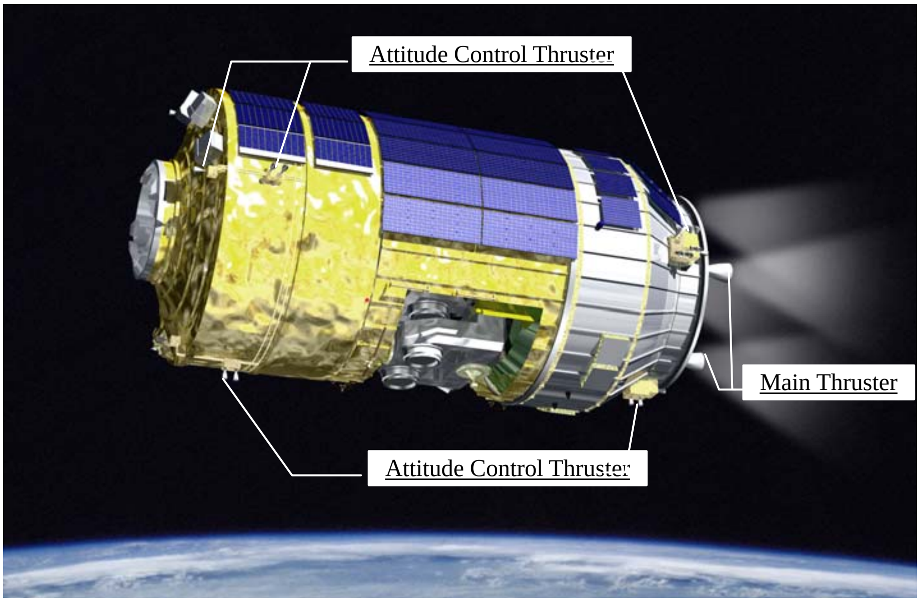


Figure 7.1.1-3 Location of HTV thrusters

(6) Proximity Communication System (PROX)

The Proximity Communication System (PROX), which is installed in Kibo, consists of PROX antennas, PROX-GPS antennas, PROX communication equipment, and a Hardware Command Panel (HCP). With the exception of the PROX antennas, the PROX-GPS antennas and the HCP, the PROX related equipments are installed in the Inter-orbit Communication System (ICS) rack, which is one of the JEM system racks installed in the JEM Pressurized Module (PM).

When the HTV approaches in close proximity to the ISS, the PROX antenna will initiate communications with the HTV. This antenna contains GPS receivers. The ISS's orbital location and speed will immediately be relayed to the HTV through the PROX. At the same time, data from the HTV will be relayed to the ISS. In addition, the antenna will relay commands sent from the ground to the HTV.

(7) Reflector

The reflectors are installed on the nadir (bottom) side of Kibo. The reflectors will reflect the lasers that are beamed from the HTV's Rendezvous Sensor (RVS) when the HTV is in ISS Proximity Operations and as the HTV approaches the ISS from the nadir side (direction of earth). For locations of the reflectors, please refer to Figure 7.1.1-4

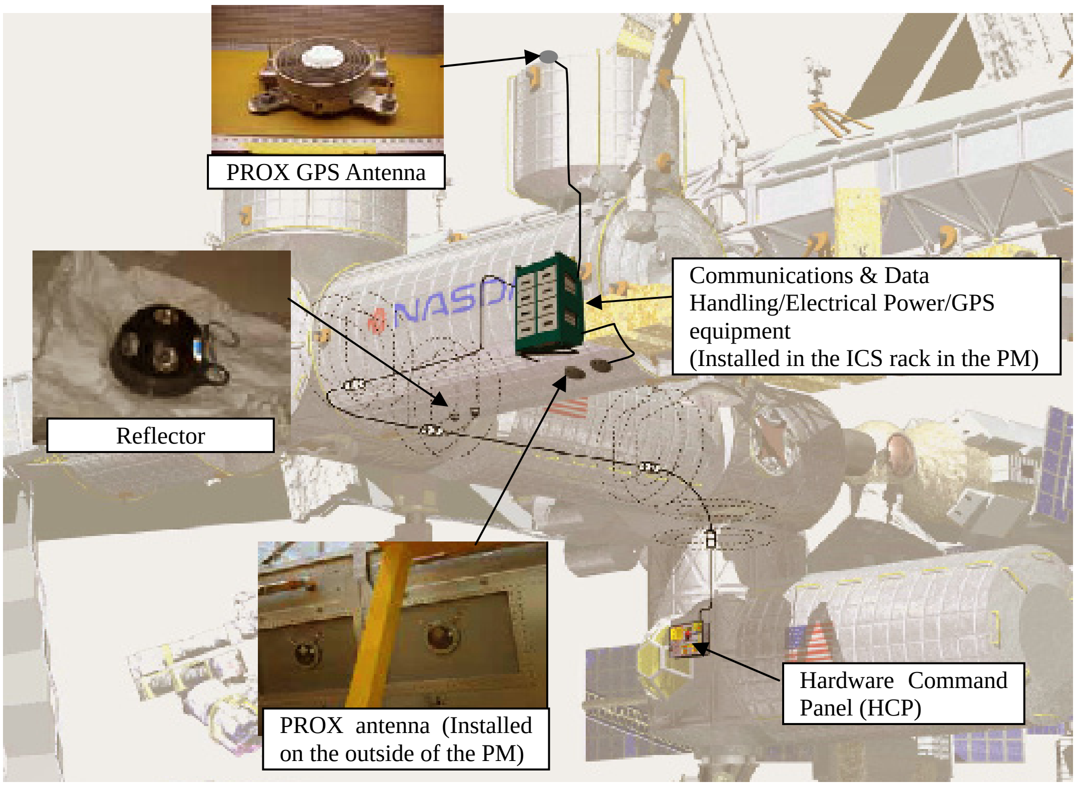


Figure 7.1.1-4 PROX and Reflectors

7.2 HTV Operations

The HTV will be operated in the following sequence. An outline of the HTV operations is shown in Figure 7.2-1

1. Launch
2. Rendezvous with the International Space Station (ISS)
3. Berthing with the ISS
4. Operations while berthed with the ISS
5. Undock/Departure from the ISS/Reentry

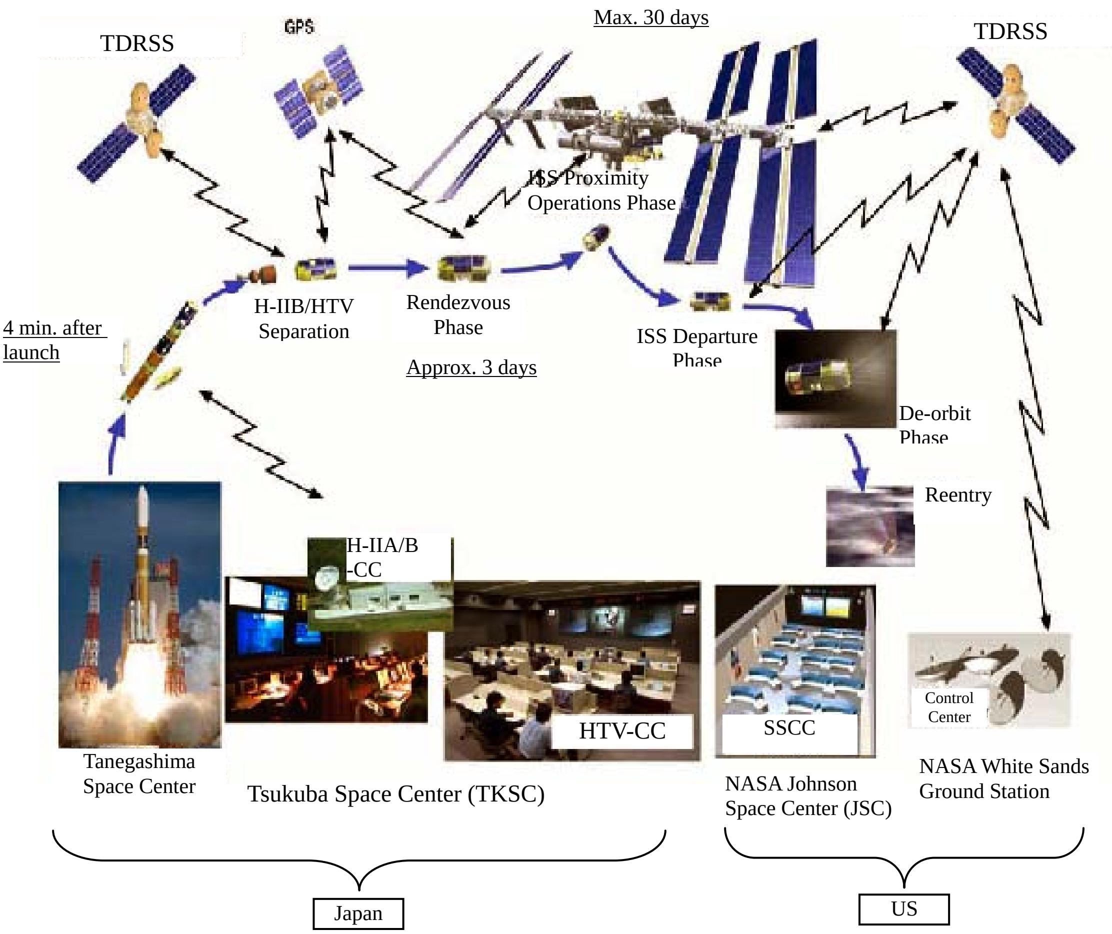


Figure 7.2-1 HTV Operations

7.2.1 Launch

The HTV will be launched from the Tanegashima Space Center aboard an H-IIB launch vehicle (Figure 7.2.1-1 above). The HTV's launch opportunity will be once a day, since the HTV's launch time has to be adjusted and scheduled for when the ISS's orbital plane is passing over the Tanegashima Space Center launch site.

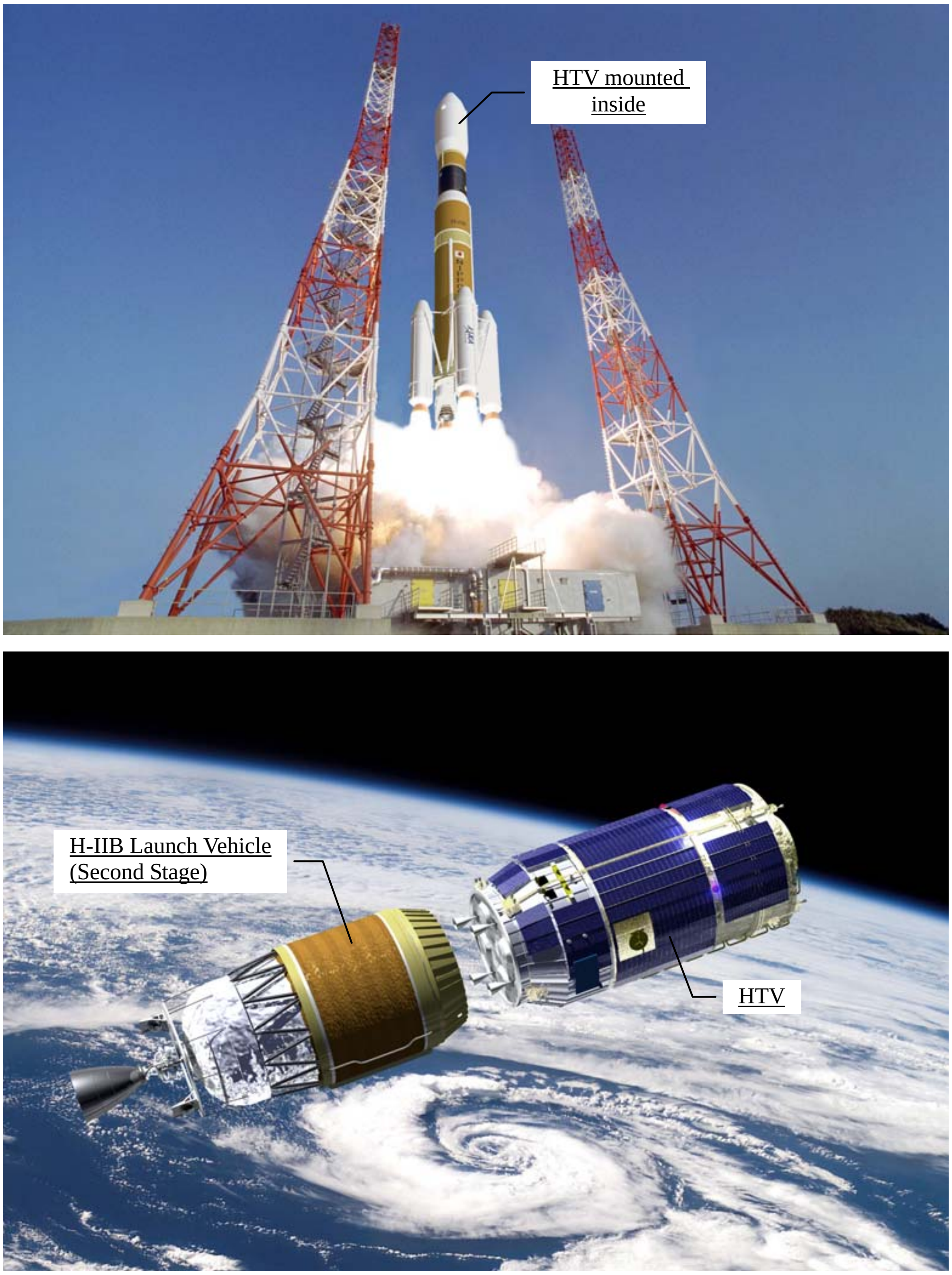


Figure 7.2.1-1 HTV Launch Image (above) and HTV/H-IIB Separation Image (below)

Following the launch phase, the HTV will be inserted into an elliptical orbit with an altitude of 200 km (perigee) x 300 km (apogee) and a inclination of 51.6 degree.

After separating from the H-IIB launch vehicle, 1) the HTV will automatically activate the HTV subsystems, 2) maintain its attitude,3) perform a self-check on the HTV's components, and 4) initiate communications with the HTV Control Center (HTV-CC) at Tsukuba Space Center (TKSC).

7.2.2 Rendezvous

After separating from the H-IIB launch vehicle, the HTV will approach the ISS in the following sequence as described below. Figure 7.2.2-1 shows the HTV Rendezvous Flight profile that depicts how the HTV will approach the ISS, by boosting (adjusting) the HTV's orbital altitude.

1. After separating from the H-IIB launch vehicle, the HTV will automatically activate HTV's communication system and initiate communications with NASA's Tracking and Data Relay Satellite (TDRS).
2. The HTV status will be monitored from the ground. Next, the HTV will then start orbital flight towards the ISS.
3. After three days of orbital flight, the HTV will reach close proximity to the ISS.
4. The HTV will reach the proximity "Communication Zone" (23 km from the ISS), at which point the HTV can directly communicate with the ISS
5. The HTV will establish communications with the Proximity Communication System (PROX).
6. While communicating with PROX, the HTV will approach the ISS, guided by GPS signals (Relative GPS Navigation), until the HTV reaches the "Approach Initiation (AI) Point, 7 km behind the ISS . At this point, the HTV will maintain this distance from the ISS.

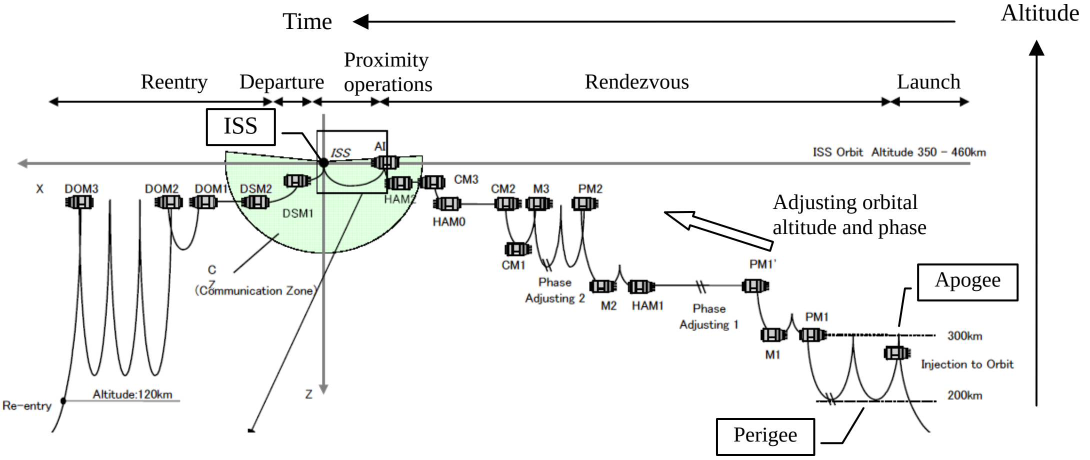


Figure 7.2.2-1 HTV Rendezvous Flight Profile

7.2.3 Berthing with the ISS (Proximity Operation Phase)

The HTV will slowly approach the ISS from the nadir (bottom) side of the ISS (from the direction of Earth). The HTV will then be grappled by the Canadarm2 and berthed to the ISS.

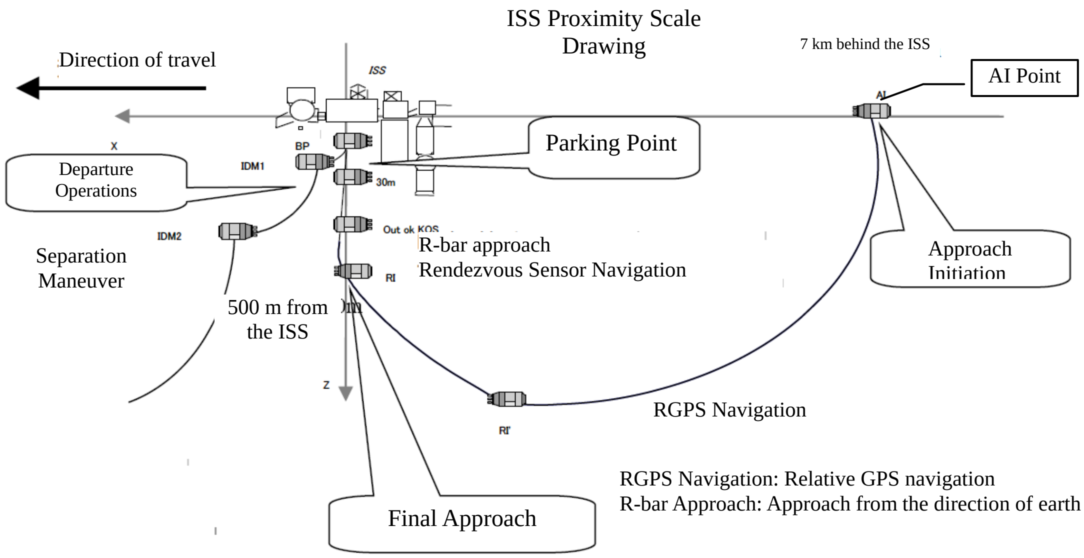


Figure 7.2.3-1 HTV Proximity Operations

The HTV's approach to the ISS during the Proximity Operation Phase is as follows.

1. The HTV will move from the Approach Initiation (AI) Point to a point 500 meters below the ISS, as guided by Relative GPS Navigation
2. Using a laser radar called "Rendezvous Sensor (RVS)", the HTV will approach closer to the ISS. Laser reflectors are installed on Kibo (This is called "RVS Navigation")
3. The HTV will slowly and gradually approach the ISS. The HTV will hold its approach twice, when reaching the following points: HTV will stop 300 m below the ISS (hold point), and will stop 30 m below the ISS (Parking Point).
4. Eventually, the HTV will approach a proximity area called "Berthing Point". This point is set 10 m below the ISS, and is in a predetermined area which is called "Berthing Box". Next, while at the Berthing Point, the HTV will maintain its distance from the ISS

The HTV's approach speed during the RVS Navigation phase is 1 to 10 meters per minute. During the approach, the ISS crew can send commands including "HOLD," "RETREAT" or "ABORT" to the HTV. In addition, if an emergency occurs and further approach can not be permitted, the HTV will be controlled to depart from the ISS orbit.

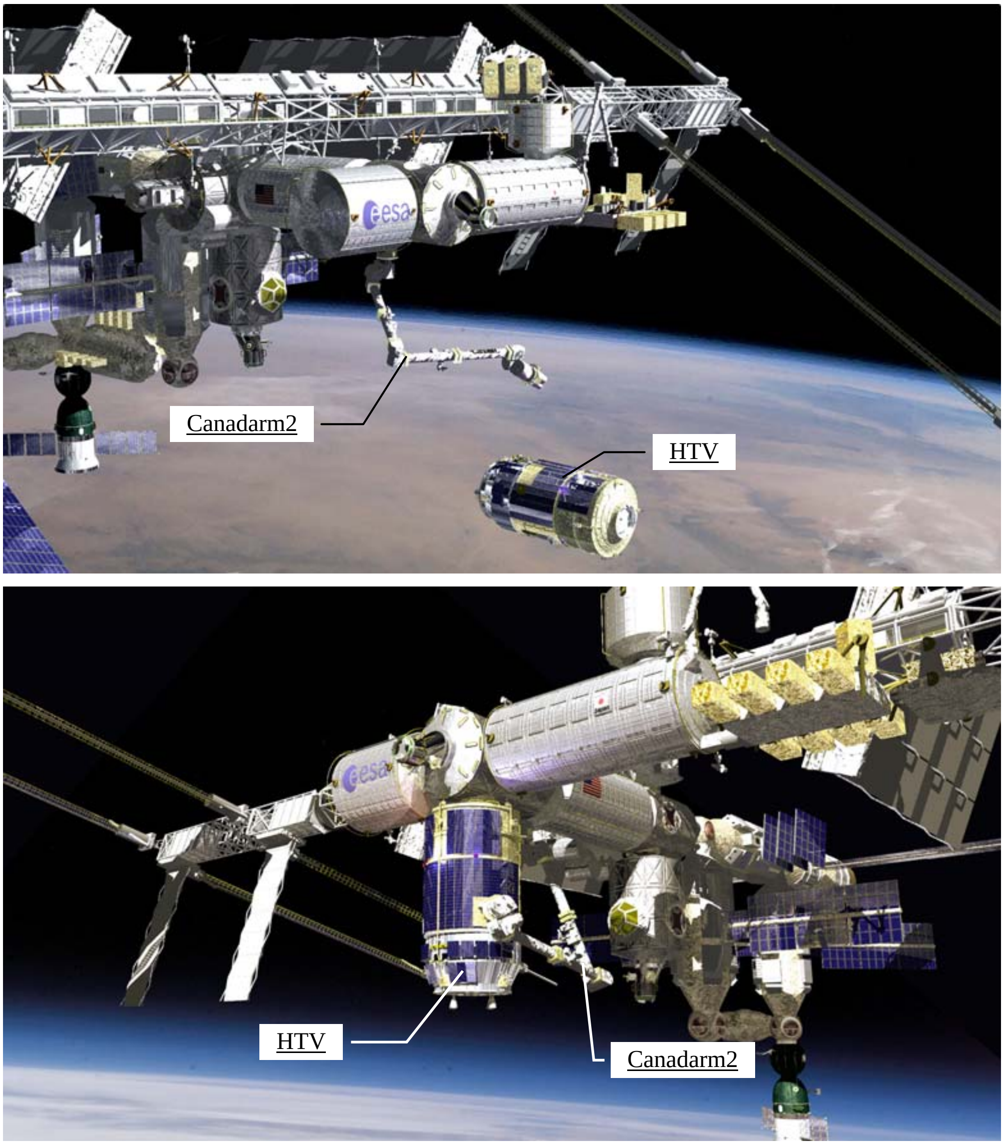


Figure 7.2.3-2 Images of HTV approaching the ISS (above) and HTV Berthing to the ISS (below)

Once the HTV Control Center (HTV-CC) at the TKSC confirms that the HTV's approach and distance from the ISS is within the Berthing Box, the ISS crew will inhibit the HTV thrusters (Figure 7.2.3-2 above). Next, the Canadarm2 will grapple the HTV and berth the HTV to the CBM located at the nadir side (earth side) of the Node 2. The HTV will then be berthed to the ISS (Figure 7.2.3-2 below).

7.2.4 Operations while berthed to the ISS

Once the HTV is berthed to the ISS, the lights in the PLC will be powered up and the air pressure in the PLC will be adjusted by ISS crew or the HTV-CC for ingress preparation. After completing these preparatory tasks, both the HTV and ISS hatches will be opened. The temperature inside of the PLC will be maintained at 15.6 °C (degrees Celsius) before the ISS crew enters the PLC. This is a preemptive measure to hinder the possible formation of dew upon the crew entering the PLC. While the HTV is berthed to the ISS, power will be supplied from the ISS to the HTV.

After the hatches between the ISS and HTV opened, the ISS crew will start transferring the supplies (ISPRs, drinking water, clothes, etc.) from the PLC to the ISS. After the supplies are transferred, the HTV will be loaded with waste from the ISS.

In addition, in order to unload the supplies from the Exposed Pallet (EP), the EP will be removed from the HTV’s Unpressurized Logistics Carrier (UPLC) and will be attached to the ISS Mobile Base System (MBS) or Kibo's Exposed Facility (EF). An example of the EP Type I transfer procedure is as follows.

1. The Canadarm2 will grapple the EP, and remove the EP from the UPLC (Figure 7.2.4-1)
2. The EP will be handed from the Canadarm2 to the JEMRMS, Kibo’s robotic arm (Figure 7.2.4-2 (2))
3. The EP will be attached to Kibo’s Exposed Facility (EF) by the JEMRMS (Figure 7.2.4-2 (4))

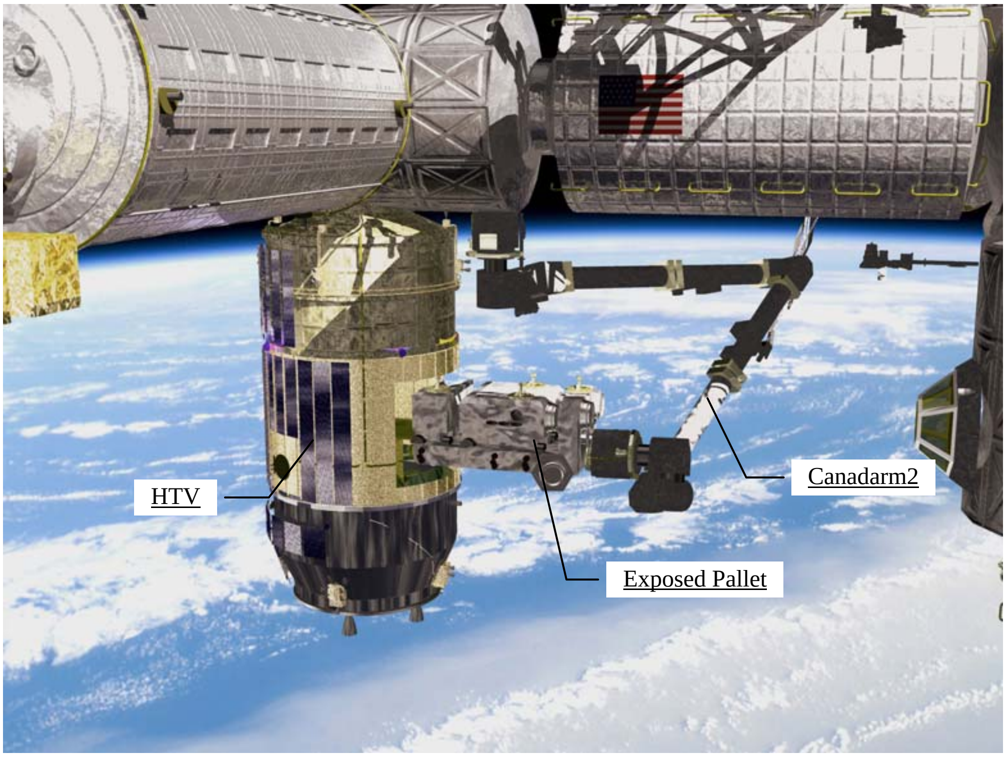


Figure 7.2.4-1 Image of EP being removed from UPLC

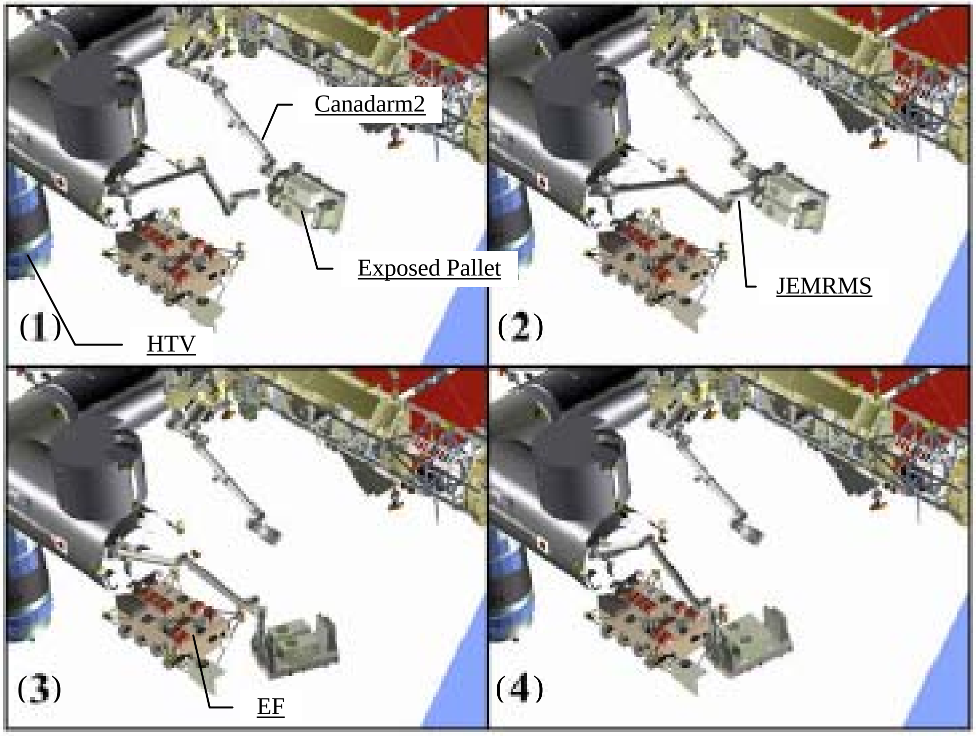


Figure 7.2.4-2 Image of EP attached to EF

7.2.5 Departure from the ISS and Reentry

After being loaded with waste, the HTV will undock and depart from the ISS. The HTV will be destroyed while reentring the atmosphere. The procedures for the HTV's undocking and departure from the ISS are as follows.

1. The hatch of the HTV will be closed and the power supply will be switched to the HTV's internal power supply by the ISS crew
2. The Canadarm2 will grapple the HTV
3. The Common Berthing Mechanism will be disengaged
4. The Canadarm2 will move the HTV to the release point
5. The Canadarm2 will release the HTV
6. The HTV thrusters will be activated by the ISS crew.
7. The HTV will depart from the ISS

Figure 7.2.5-1 Image of HTV reentering the atmosphere

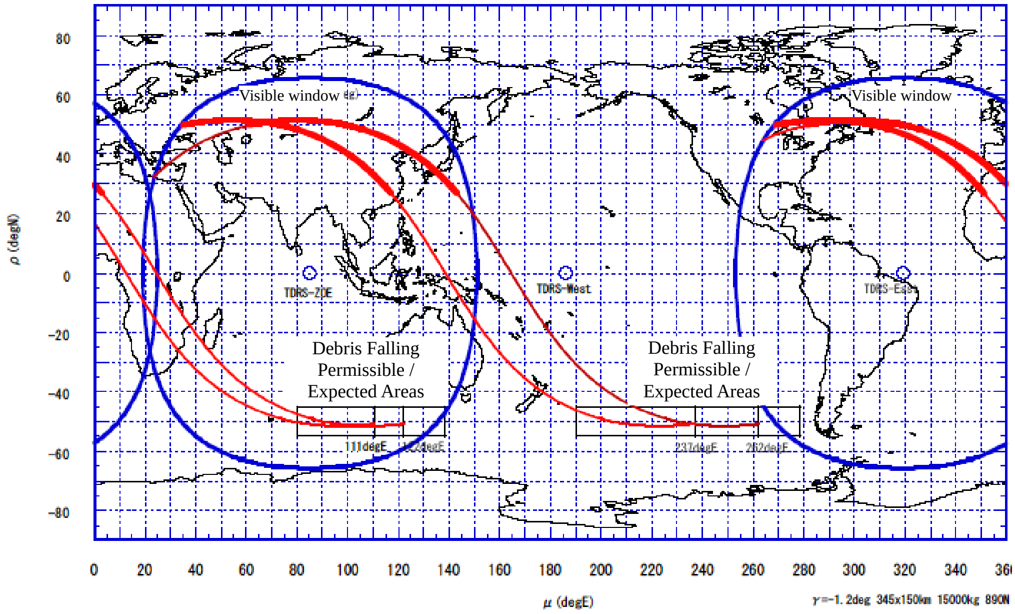


Figure 7.2.5-2 HTV Debris Falling Permissible (Allowed or Expected) Areas and HTV's Orbit (Red lines)

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Appendix Acronyms and Abbreviations

Acronym/Abbreviation	Name
ACBM	Active Common Berthing Mechanism
AEFBM	Active Exposed Facility Berthing Mechanism
AI	Approach Initiation
AOM	Atomic Oxygen Monitor
AOS	Acousto-optical Spectrometer
APRSAF	Asia-Pacific Regional Space Agency Forum
ASCR	Assured Safe Crew Return
ATCS	Active Thermal Control System
ATF	Astronaut Training Facility (TKSC)
ATU	Audio Terminal Unit
ATV	Automated Transfer Vehicle
BBND	Bonner Ball Neutron Detector
C&C MDM	Command and Control Multiplexer/Demultiplexer
C&DH	Command and Data Handling
C&T	Communication and Tracking
CB	Clean Bench
CBEF	Cell Biology Experiment Facility
CBM	Common Berthing Mechanism
CDR	Critical Design Review
CGSE	Common Gas Supply Equipment
CMG	Control Moment Gyro
Col-CC	Columbus Control Center
CSA	Canadian Space Agency
CSS	Crew Support System
DC	Docking Compartment
DMS	Data Management System
DRTS	Data Relay Test Satellite
ECLSS	Environmental Control and Life Support System
ECU	Electronic Control Unit
EDEE	Electronic Device Evaluation Equipment
EEU	Equipment Exchange Unit
EF	Exposed Facility
EFBM	Exposed Facility Berthing Mechanism
EFU	Exposed Facility Unit
ELM-ES	Experiment Logistics Module-Exposed Section
ELM-PS	Experiment Logistics Module-Pressurized Section

Acronym/Abbreviation	Name
E-ORU	Extravehicular activity Orbital Replacement Unit
EPS	Electrical Power System
ERA	European Robotic Arm
ESS	Experiment Support System
EVA	Extravehicular Activity
FCIT	Flight Crew Interface Test
FIB	Scintillation Fiber Detector
FSA	Federal Space Agency
FPEF	Fluid Physics Experiment Facility
FRGF	Flight Releasable Grapple Fixture
GHF	Gradient Heating Furnace
GPS	Global Positioning System
GSC	Gas Slit Camera
HCP	Hardware Command Panel
HEPA	High Efficiency Particulate Air
HIT	Heavy Ion Telescope
HOSC	Huntsville Operations Support Center
HREL	Hold and Release Electronics Unit
HTV	H-II Transfer Vehicle
HTV-CC	HTV Control Center
ICS	Inter-orbit Communication System
ICS-EF	ICS Exposed Facility Subsystem
ICS-PM	ICS Pressurized Module Subsystem
IFHX	Interface Heat Exchanger
ISPR	International Standard Payload Rack
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
JCP	JEM Control Processor
JEM	Japanese Experiment Module
JEMRMS	Japanese Experiment Module Remote Manipulator System
JFY	Japan’s fiscal year
JSC	Johnson Space Center
LCD	Liquid Crystal Display
LTL	Low Temperature Loop
LVLH	Local Vertical Local Horizontal
MA	Main Arm (JEMRMS)

Acronym/Abbreviation	Name
MAXI	Monitor of All-sky X-ray Image
MBS	Mobile Base System or MRS(Mobile Remote System) Base System
MCC	Mission Control Center
MCC-M	Mission Control Center - Moscow
MCR	Mission Control Room (TKSC)
MEIT	Multi-Element Integration Test
MLM	Multi-Purpose Laboratory Module
MOU	Memorandum of Understanding
MPAC&SEED	Micro-Particles Capturer and Space Environment Exposure Device
MSFC	Marshall Space Flight Center
MTL	Moderate Temperature Loop
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NEM	Neutron Monitor
OBSS	Orbiter Boom Sensor System
OCS	Operation Control System (TKSC)
ODS	Orbiter Docking System
OPR	Operations Planning Room (TKSC)
ORR	Operations Rehearsal Room (TKSC)
PAM	Payload Attach Mechanism
PCBM	Passive Common Berthing Mechanism
PCRF	Protein Crystallization Research Facility
PDB	Power Distribution Box
PDR	Preliminary Design Review
PDU	Power Distribution Unit
PEFBM	Passive Exposed Facility Berthing Mechanism
PIU	Payload Interface Unit
PLAM	Plasma Monitor
PLC	Pressurized Logistics Carrier (HTV)
PM	Pressurized Module
PMA	Pressurized Mating Adapter
POIC	Payload Operations and Integration Center
PROX	Proximity Communication System
PTCS	Passive Thermal Control System
PVGF	Power & Video Grapple Fixture
RM	Research Module

Acronym/Abbreviation	Name
R-ORU	Robot essential Orbital Replacement Unit
RUR	Reference Update Review
RVS	Rendezvous Sensor
SCOF	Solution Crystallization Observation Facility
SDOM	Standard Dose Monitor
SEDA-AP	Space Environment Data Acquisition equipment － Attached Payload
SEL	Space Experiment Laboratory (TKSC)
SFA	Small Fine Arm (JEMRMS)
SFU	Space Flyer Unit
SLM	Structure Latch Mechanism
SLT	System Laptop Terminal
SMILES	Superconducting Submilimeter-Wave Limb-Emission Sounder
SPCF	Solution/Protein Crystal Growth Facility
SRMS	Shuttle Remote Manipulator System
SSC	Solid-state Slit Camera
SSCC	Space Station Control Center
SSE	Small Fine Arm Storage Equipment
SSIPC	Space Station Integration and Promotion Center
SSOF	Space Station Operations Facility (TKSC)
SSRMS	Space Station Remote Manipulator System
TCS	Thermal Control System
TDRS	Tracking and Data Relay Satellite
TKSC	Tsukuba Space Center
UCM	Umbilical Connector Mechanism
UOA	User Operations Area (TKSC)
UPLC	Un-pressurized Logistics Carrier
URM	Unit Replacement Mechanism
WET	Weightless Environment Test Building (TKSC)