HTV4 (KOUNOTORI 4) Mission Press Kit

August 2, 2013, Revision A

Japan Aerospace Exploration Agency

Revision history

No.	Date	Page(s) revised	Reasons for the revision
NC	2013.07.31	—	
Rev.A	2013.08.02	P2-1, 3-2, 4-3, 4-4, 4-6, 4-9, 4-12, 5-1, 5-2 Annex1-1,1-13,1-15, 3-9	Added 4K resolution camera information Trajectory image before HTV4 reentry added as 5.1-2, updated information, added figures, supplement information, and others

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Annex

1. Overview of the HTV

The H-II Transfer Vehicle (HTV), developed and built in Japan, is an unmanned cargo transfer spacecraft that delivers supplies to the International Space Station (ISS). The initial HTV1 (Technical Demonstration Vehicle) was launched on September 11, 2009. Subsequently the HTV2 was launched on January 22, 2011, and the HTV3 on July 21, 2012, with the H-IIB launch vehicle. From the second model onward, the HTV was nicknamed “KOUNOTORI (White Stork).”

For its configuration and specifications, see Annex 1.

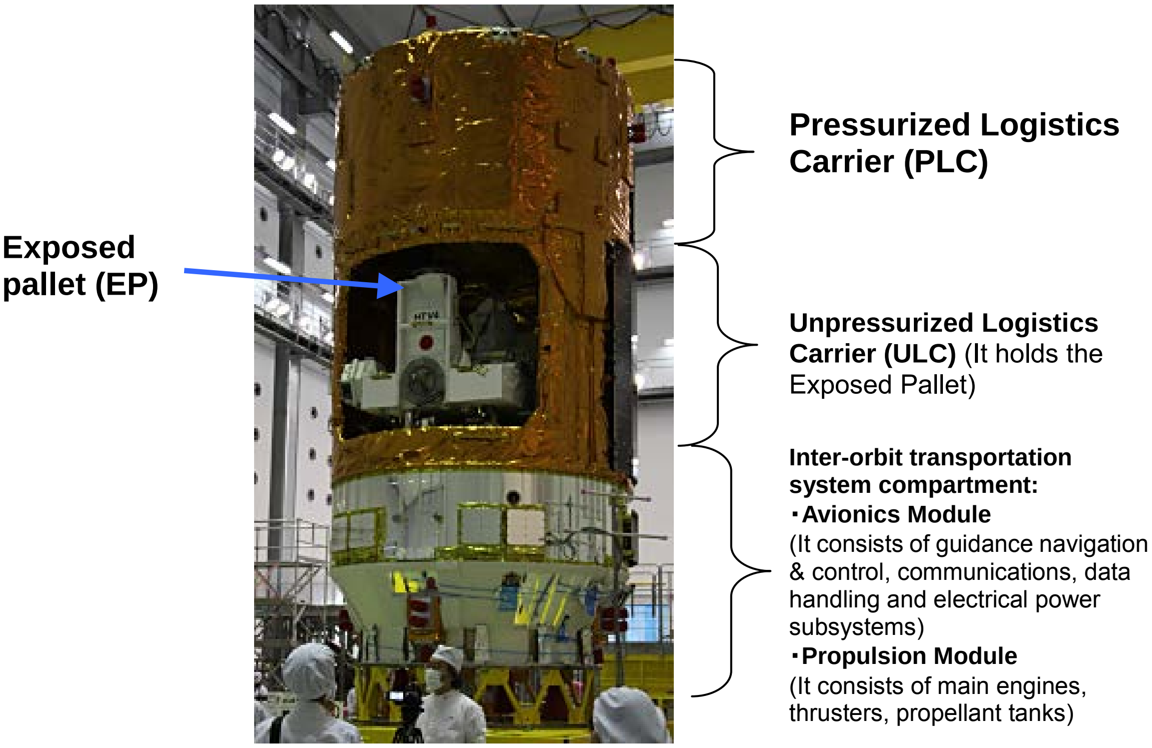


Figure 1.1-1 Configuration of “KOUNOTORI” (photo: HTV4)

1.1 Goals of the HTV

As one of the supply vehicles to the ISS and under the International Space Station Intergovernmental Agreement (ISS IGA), the HTV delivers cargo to supply materials to the ISS that equals to the cost allocated to Japan for ISS common system operations and that is necessary items for operating and using the Japanese Experiment Module “Kibo.”

Under the ISS program, each supply vehicle of the International Partners (IP) carries necessary materials for each IP. Thus, besides materials used on Kibo, the HTV also plays a role in delivering ISS common supplies and NASA cargo.

1.2 Features of HTV4 mission

HTV development was completed through the experience of the HTV1-3. As the domestic production of major components was sufficiently advanced, the HTV4-7 aims to keep safe and stable mission operations.

- Improvement of convenience has been continuously made as a cargo transfer vehicle. The HTV increased the amount of late access cargo, and a cool box has been developed for cargo that requires low temperature environment.
- The HTV4 carries only NASA's cargo in the ULC.
- The HTV4 aims to obtain technical data including its reentry data and the surface potential in order to continuously improve the HTV operations.

1.3 Overview of the HTV4 mission

(1) Cargo delivery to the ISS
The HTV4 carries about 3.9 metric tons of pressurized cargo and 1.5 metric tons of unpressurized cargo as listed below.

●Pressurized cargo
Approximately 3/4 of the pressurized cargo consists of international partners' cargo including NASA, and the rest 1/4 of the cargo is JAXA's.

Category	Examples of cargo	Agency
System supplies	Supplies of the ISS systems, oxygen gas tanks for Extravehicular Mobility Unit (EMU)	NASA
	Supplies for Kibo, Kibo's Freezer-Refrigerator of Stirling Cycle (FROST)	JAXA
Crew items	Potable water (of 24bags)	NASA
	Food (food in retort pouch, rehydrating food, and Japanese space food),	NASA/JAXA
	Commodities (clothes, shampoo, etc)	NASA/JAXA
Experiment related items	Experimental hardware, samples, small satellites (CubeSats)	NASA/ESA/J JAXA
Commercial items	KIROBO（Kibo Robot Project） An DVD as one the Education Payload Observation (EPO)	JAXA

Figure 1.3-1 Inside the HTV4 PLC (before loading the late access cargo)

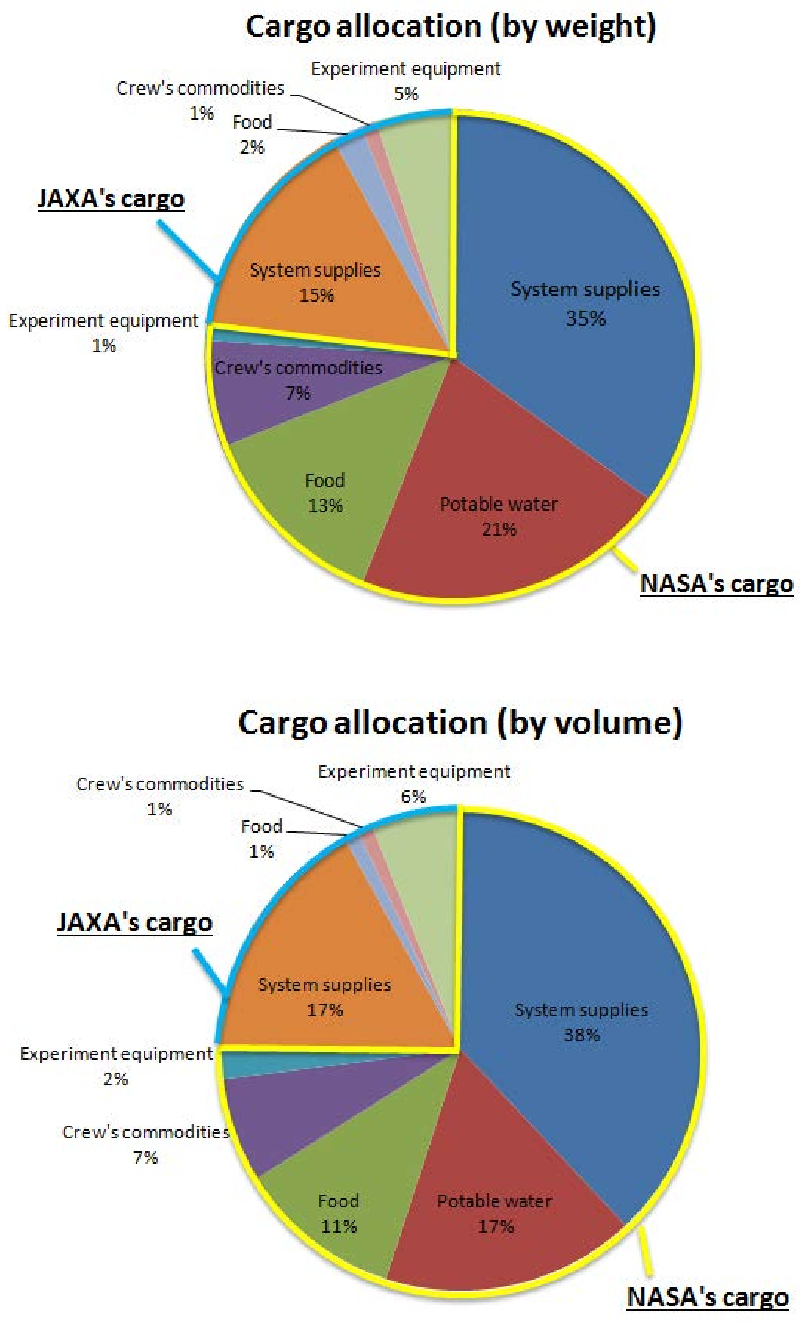


Figure 1.3-2 HTV4 cargo breakdown (by weight and volume)

●Unpressurized cargo

Two ISS common system supplies, called Orbital Replacement Units (ORU) and one U.S. payload will be delivered.

Category	Items	Agency
System supplies	Utility Transfer Assembly (UTA) Main Bus Switching Unit (MBSU)	NASA
Experiment hardware	The Space Test Program – Houston 4 (STP - H4)	NASA

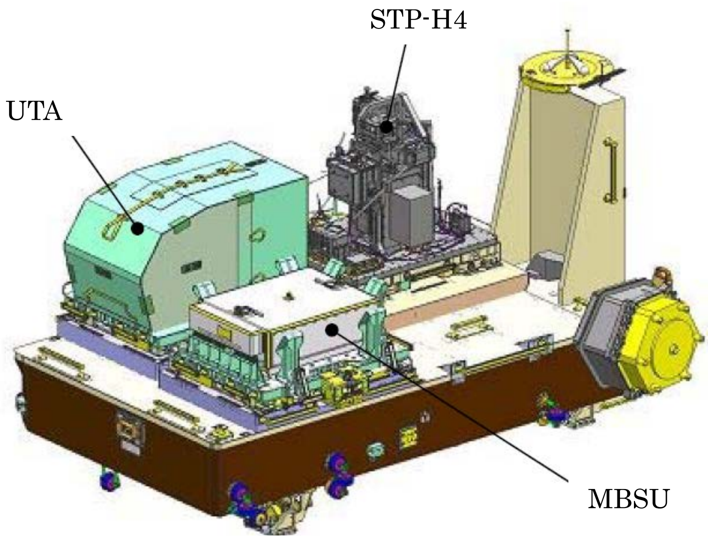


Figure 1.3-3 Cargo layout on the Exposed Pallet (NASA/JAXA)

(2) Waste disposal

The HTV4 can reentry into the atmosphere carrying up to 6 metric tons cargo that becomes no longer necessary. The HTV4 will re-entry into the atmosphere with the U.S. experiment apparatus “STP-H3” on the ULC, which will be the first time for KOUNOTORI to use the ULC for disposal.

STP-H3 is a conglomerate experiment apparatus (weighs 319kg) that was carried aboard the space shuttle (STS-134 mission) on May, 2011. It was used to test a thermal control system and sensor and to measure space environment.

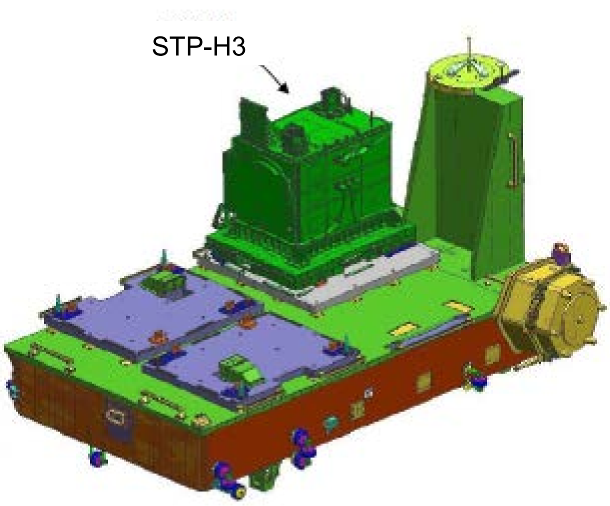


Figure 1.3-4 Waste cargo layout on the EP (image courtesy of NASA)

2. Outline of launch/flight plan for the KOUNOTORI4 (HTV4) mission

Table 2-1: Outline of launch/flight plan for the HTV4 mission

As of August 2, 2013

※: All times are Japan Standard Time (JST)

Items	Mission details	
HTV flight name	"KOUNOTORI4" (HTV4)	
Time and date of launch (scheduled)	04:48:46 a.m., August 4, 2013	
Launch windows	August 5 through September 30, 2013	
Launch site	The Launch Pad 2 (LP-2) for large rocket launches at the Tanegashima Space Center (TNSC), Japan	
Berthing time and date to the ISS (scheduled)	SSRMS grapple: around 8:29p.m., August 9, 2013 Berthing start: around 10:30p.m., August 9, 2013 Berthing completion: early in the morning of August 10. (Note: JAXA's "Berthing completion" is defined as the time when all the electrical cables and communication lines are mated.)	
Departure time and date from the ISS (scheduled)	September 5, 2013	
Reentry time and date (scheduled)	September 7, 2013	
Orbital altitude	Insertion: About 200 × 300 km (elliptical orbit) Rendezvous with the ISS: About 410 km	
Orbit inclination	51.6 degrees	
Main cargo to be loaded	Pressurized Logistics Carrier (PLC)	Supplies for on-board use (HTV Resupply Rack x 8)
	Unpressurized Logistics Carrier (ULC)	STP-H4, MBSU, UTA (NASA cargo)

You can access to the latest information as well as in-flight information on the HTV4 mission at the JAXA's website: http://iss.jaxa.jp/en/htv/mission/htv-4/

Note: Please note that the mission schedule may vary depending on the operational timeline of the ISS.
In addition, the duration of berthing with the ISS may change.

3. HTV4 mission timeline

Table 3-1 HTV4 Mission Timeline

As of July 23, 2013

Flight Day	HTV Mission Events
FD 1	Launch/Orbit insertion: HTV post-insertion auto sequence (the HTV subsystem activations, attitude control and three-axis stabilization, self-check, communications establishment with the Tracking and Data Relay Satellite (TDRS), initiation of communication with the HTV Mission Control Room (MCR) at Tsukuba, initiation of orbit control for rendezvous maneuver)
FD 1-5	The rendezvous phase with the ISS
FD5	Final approach Captured by the ISS robotic arm (SSRMS) Berthing to the ISS ・ The HTV4 is berthed to the Common Berthing Mechanism (CBM) at the nadir port of Harmony ・ Vestibule outfitting (e.g. installation of lines and cables) ・ Activation of HTV power supply from the ISS / Switching of the communications line (from wireless to wired communications)
FD6	Crew ingress into the HTV Pressurized Logistic Carrier (PLC) ・ Removal of the Controller Panel Assemblies (CPAs) from the active CBM ・ HTV PLC hatch open ・ Activation of the Inter-Module Ventilation (IMV) ・ Transfer of the Portable Fire Extinguishers (PFEs) and the Portable Breathing Apparatus (PBA) into the HTV
	Removal of the Exposed Pallet (EP) from the HTV Unpressurized Logistics Carrier (ULC) / Transfer and installation of the EP on the platform of the Kibo's Exposed Facility (EF)
	Transfer of the off-board US experimental equipment STP-H4 and ORUs mounted on the EP to the installation location using the SSRMS Transfer of the US STP-H3 using the SSRMS to the EP for disposal
	Reinstallation of the empty EP back into the ULC of the HTV
	Transfer of cargo / Trash loading
The day before departure from the ISS	Preparation for HTV Unberthing Operations Removal of lights, PFEs and PBA (stored at the ISS), installation of controller panel assemblies on the CBM, stoppage of the Inter-Module Ventilation(IMV), hatch closure and switching of the communications line (from wired communications to wireless communications)
Departure day from the ISS	HTV Unberthing Operations from the ISS ・ Deactivation of HTV power supply from the ISS ・ Vestibule de-outfitting ・ Capture of the HTV by the SSRMS ・ Common Berthing Mechanism (CBM) bolts release ・ SSMRS moves the HTV to the release position ・ HTV's Guidance Navigation Control (GNC) and propulsion system activation ・ The SSMRS releases the HTV, and the HTV leaves the ISS orbit
Reentry	Deorbit maneuvers / Reentry

Please note that the mission schedule may vary depending on the operational timeline of the ISS.

【Reference】The HTV4 Mission Major Events

During the HTV4 Mission, the HTV will be berthed to the ISS on Flight Day (FD) 5. While the HTV stays at the ISS, supply / cargo transfer between the HTV and the ISS will be performed. Following cargo transfer, the HTV will be loaded with trash and unnecessary materials and unberthed from the ISS. Finally, the HTV will reenter into the Earth's atmosphere.

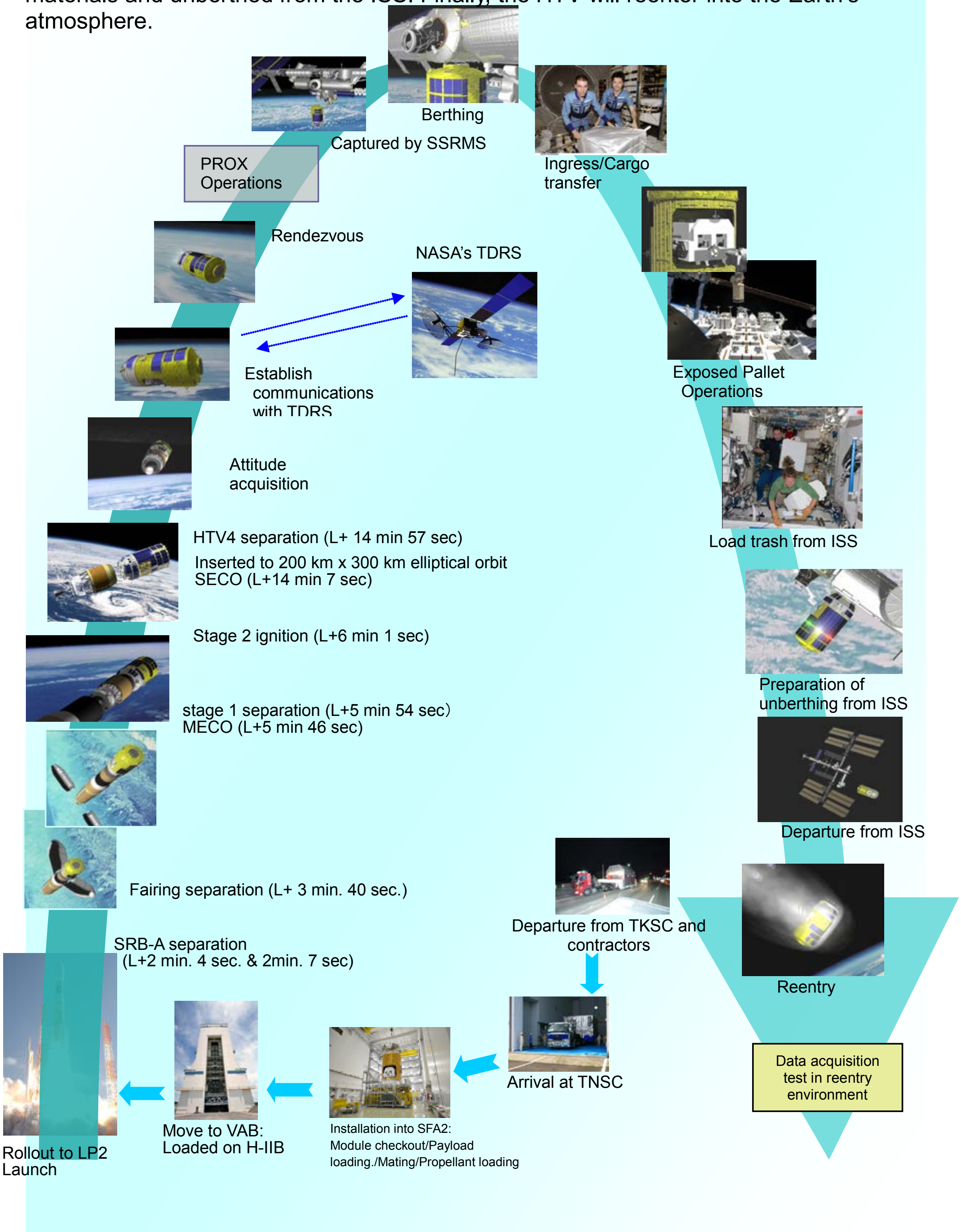


Figure 3-1 HTV4 Mission Event Sequence

4. Cargo delivery by the HTV

The HTV4 delivers a total 5.4 metric tons of cargo to the ISS, including unpressurized and pressurized cargo

4.1 Cargo in the Pressurized Logistics Carrier (PLC)

The HTV4 PLC carries about 3.9 metric tons of cargo. (The HTV1 carried 3.6 tons, the HTV2 carried 4 tons, and the HTV3 carried about 3.5 tons of cargo for on-board use.)

Pressurized supplies are loaded in eight HTV Resupply Racks (HRR).

The Cargo Transfer Bags (CTBs) that contain a wide variety of supplies, including space food (food in retort pouch, rehydrating food, snacks, rehydrating beverages and Japanese space food), supplies and spare parts for Kibo and NASA, and other commodities for the ISS crew, and small satellites (CubeSats) are loaded in the HRRs. In order to make the most use of the PLC, extra CTBs that exceed the HRR capacity are strapped to the surface of the HRR.

In the HTV4, about 230 of single-sized CTBs will be delivered. 72 CTBs of them are to be loaded at late access, about a week before the launch.

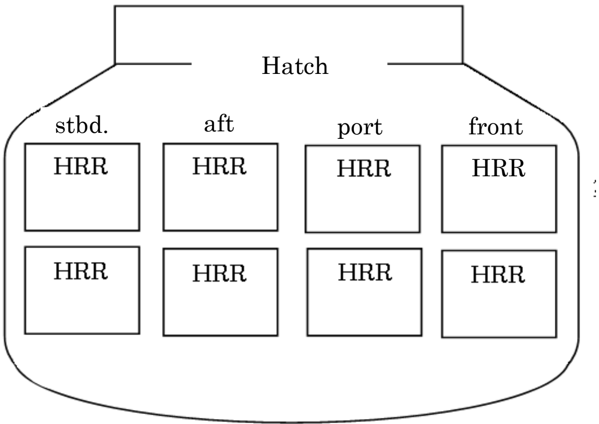


Figure 4.1-1 Rack layout in the HTV4 PLC

HTV Resupply Rack (HRR)

Food, daily commodities and experiment samples are packed in the CTBs and installed in the HRRs.

Figure 4.1-2 Packing and loading images in the PLC

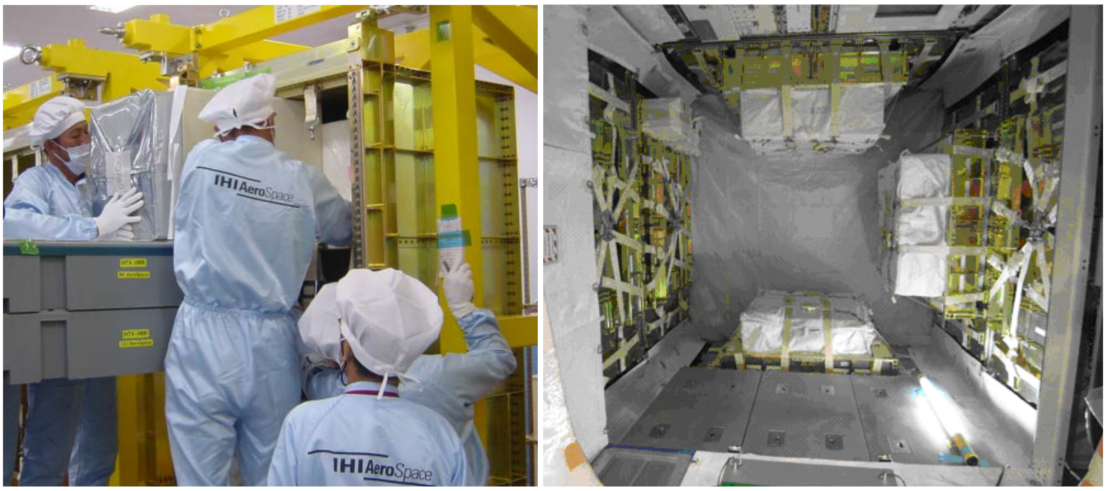


Figure 4.1-3 CTBs being installed in an HRR
Right: HRRs being installed in the PLC (HTV2)*
*This photo was taken during the cargo loading process.
More CTBs are to be added later at the front of the HRR.

Figure 4.1-4 Left: CTBs installed at the front of a rack (HTV2)
(Right: KOBAIRO Rack)

Figure 4.1-5 Cargo transfer bags (CTBs)
(The photo shows half-sized (left) and single-sized (right) CTBs.)
* Several sizes of CTBs are available to accommodate various sizes of goods. See Annex 2-8 to see more sizes.

4.1.1 System cargo

(1) ISS common supplies/ NASA cargo

The HTV4 delivers common supplies on the ISS, such as rechargeable batteries, recharger and distributor, e.g., oxygen tanks for EMU, and the Simplified Aid for EVA Rescue (SAFER).

(2) System cargo for Kibo

a) CANA (First time launch)

The CANA has been developed to accumulate Kibo's actual environmental data to design an future Environmental Control and Life Support System (ECLSS). It aims to obtain data for an environmental indicator on Kibo. Additional sensors and data gathering system will be added to Kibo to devote to the development of manned space technology.

b) Freezer-Refrigerator of Stirling Cycle (FROST) (first time launch)

A Stirling cooler that is able to keep up to -70 deg C. New domestic refrigerants have been developed to keep cold even in a case of power outage. ISS has three freezer-refrigerators (Minus Eighty degree Celsius Laboratory Freezer for ISS: MELFI). Since the freezer-refrigerators are shared by each IP, Japan has made its own to secure enough space.

Figure 4.1.1-1 FROST

c) ISS Cryogenic Experiment Storage Box (ICE Box) (First time launch)

A cool box for delivery made to keep the container cool without the electrical power during a flight to the ISS. FROST's refrigerants have been applied and combined with the high-performance adiabatic box. A data logger and experimental samples will be loaded inside as this flight is the validation test for the ICE Box.

Figure 4.1.1-2 ICE Box

d) Others

Spare parts of Kibo's main processor and electrical parts of the Inter-orbit

Communication System (ICS) will be delivered. The ICS equipment has been repaired after returned on the ground on August, 2011, due to its failure. As such, different from the unmanned spaceships, hardware on the manned ISS can be returned to Earth for repairs to maintain the function.

4.1.2 Cargo for the ISS crew

Food (retort pouches, dried food, snacks, beverages, and Japanese space food), 480 liters of potable water, and commodities (clothes, hygiene products) will be delivered.

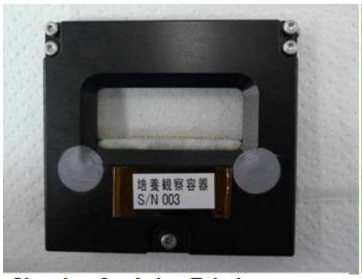
4.1.3 Utilization/experiment related items

The HTV4 delivers the experiment devices and samples to be performed on Kibo and also experiment items for NASA and the ESA

Life science and physical science experiments related cargo

(1) Life science experiments

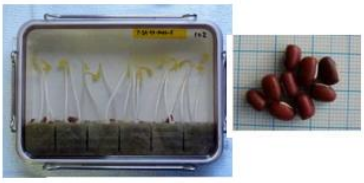
Experiment name	Formal experiment name / Summary	Experiment sample	URL
Aniso Tubule	Roles of cortical microtubules and microtubule-associated proteins in gravity-induced growth modification of plant stems	*Arabidopsis* (Thale-cress)	http://iss.jaxa.jp/en/kiboexp/pm/pdf/2_soga.pdf
Space Pup	Effect of space environment on mammalian reproduction	Mouse's freeze-dried sperm	http://iss.jaxa.jp/en/kiboexp/theme/second/pmlatter/wakayama_e.pdf
Resist Tubule	Mechanisms of Gravity Resistance in Plants - from Signal Transformation and Transduction to Response	*Arabidopsis* (Thale-cress)	http://iss.jaxa.jp/en/kiboexp/theme/second/pm/hoson_e.pdf
Asian Seed 2013	An educational mission that broadcasts downlinked video to Asian countries to show how *Azuki* beans grow where there is no gravity or light and to compare them with the beans grown on the ground.	*Azuki* beans	http://iss.jaxa.jp/en/kuoa/ssaf/



Chamber for Aniso Tubule experiment (plant seeds are set inside)

PEU for Resist Tubule experiment


Space pup (samples and the container)


Asian seeds 2013 (on ground) and Azuki beans

(2) Cargo for the physical science experiment

Experiment equipment for Ice crystal2 (Pattern Formation during Ice Crystal Growth)

- An experiment to observe the crystal growth carefully.
- Freeze aqueous solution that includes a trace of unfreezable glycoprotein and grow the ice crystal. Observe the growth of the ice crystal and the interface under several temperature conditions. By observing from several angles, how unfreezable glycoprotein affects the growth of ice crystal will be investigated.

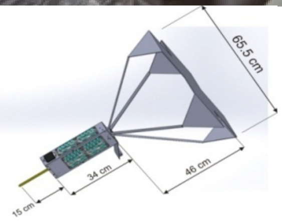
・By this experiment, how fish and insects that hold unfreezable glycoprotein protect themselves from low temperatures can be understood.
・The reserch results will contricute to a real life such as organ transplants, by keeping organs with a temperature as low as possible without freezing them and the development of more delicious frozen food.

(3) CubeSats (will be released from Kibo)

On the ISS, only Kibo is equipped with an airlock and robot arm. By using them, CubeSats can be released without doing Extravehicular Activities (EVA).
5 CubeSats and the JEM Small Satellite Orbital Deployer (J-SSOD) were delivered by the HTV3 and succeeded in the deployment from the ISS. The HTV4 carries 4 CubeSats as well.

For more information for CubeSats, see Annex 3.

Table 4.1.3-1 4 CubeSats to be delivered by the HTV4

Satellite	Pico Dragon	Ardusat-1	Ardusat-X	TechEdSat-3
				 
Size	1U	1U	1U	3U
Investigator (s)	The University of Tokyo / Vietnam National Satellite Center / IHI Aerospace	Nanorack (US) / NanoSatisfi (US)		NASA Ames Research Center (ARC)
Mission	Earth imaging	Technology validation of an open platform that has re-programming function. Developed with the money raised through a crowd-funding. Investors will be given the opportunity to access the satellite to take pictures. http://www.kickstarter.com/projects/575960623/ardusat-your-arduino-experiment-in-space		Technology validation of the aero braking mechanism called Exo-brake on its deorbiting.
Sponsoring Agency	JAXA	NASA		

(4) 4K resolution camera

This camera aims to shoot Comet ISON, the newly founded commet approaching to Earth this December and is expected to be “the comet of the century.” In December, astronaut Koichi Wakata will be on the ISS and attempt to shoot the comet. Carrying a 4K resolution camera to the ISS and using it in there is the world’s first trial. This is the high resolution camera with the number of pixels of 4-times than the current high-definition television (HDTV), and it has been specially altered to shoot the comet with more than 8 times of ultrahigh-sensitivity than the existing one.

4.1.4 Cargo for civilian use

(1) “KIROBO” (KIBO ROBOT PROJECT)

Astronaut Koichi Wakata, a crew member for the ISS Expedition 38/39, will perform a conversation test with this communication robot during his stay on the ISS.

KIBO ROBOT PROJECT website: http://kibo-robo.jp/en/

(2) A set of DVDs as part of Education Payload Observation (EPO)

Website: http://www.jsforum.or.jp/event/education/teraheart/ (Japanese)

4.1.5 About late access

Late cargo accessing is scheduled for late July, opening the HTV hatch through the access door of the rocket fairing. Late cargo accessing requires careful loading in a closed space in the fairing, by setting a scaffold and ladder in a narrow opening.

Since the HTV3 mission, the amount of late access has increased. In the HTV4 mission, the amount limit has further been increased to accommodate large CTBs.

This enables a wide variety of loading requests and timely delivery to the ISS. CubeSats and ICE Box, i-Ball are loaded at late access.

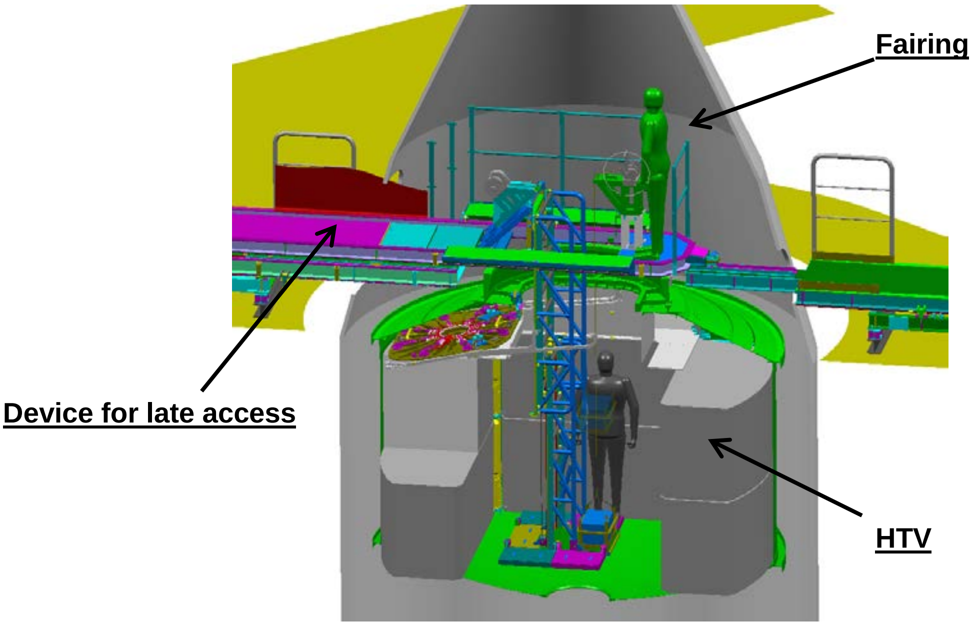


Figure 4.1.5-1 Late access diagram

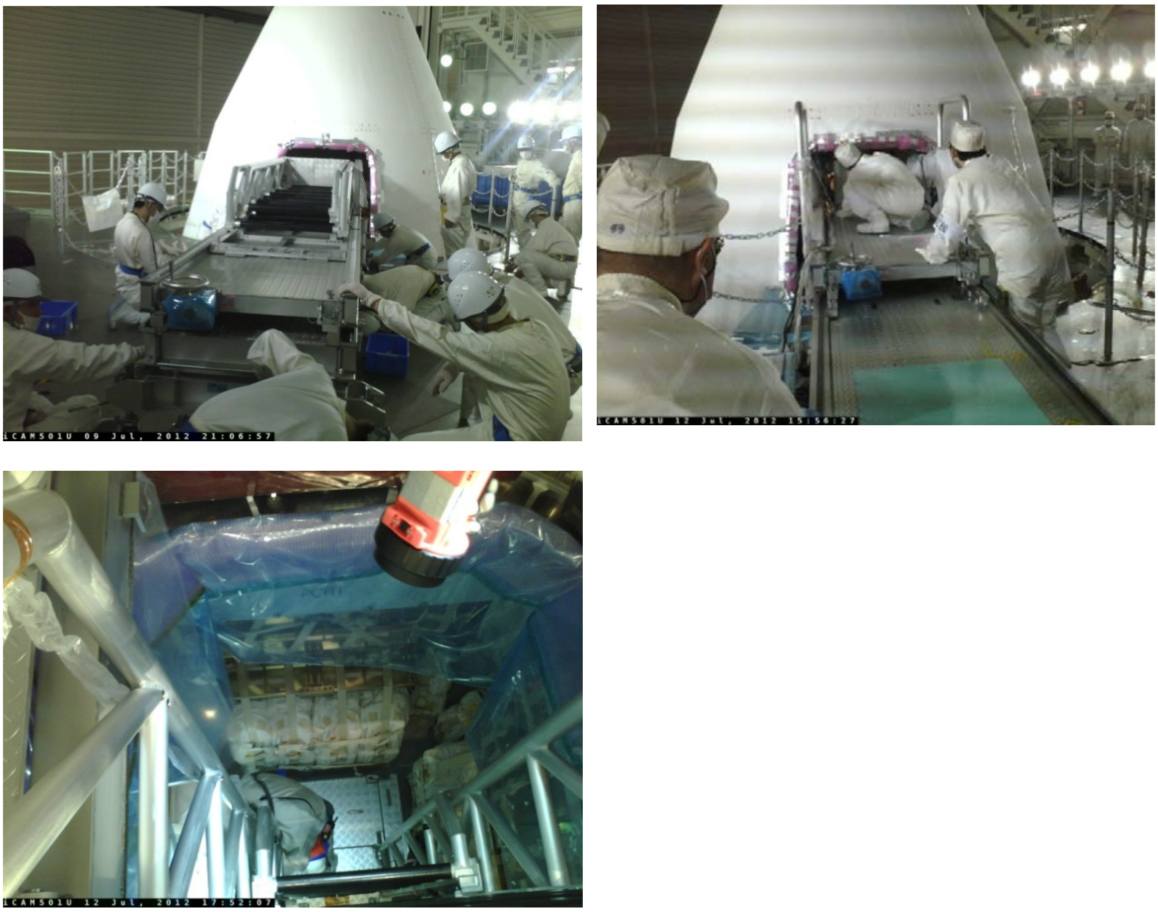


Figure 4.1.5-2 Late cargo accessing

Figure 4.1.5-3 Double-sized CTB

Figure 4.1.5-4 M02 bag

4.2 Unpressurized Logistics Carrier (ULC)

The HTV4 Unpressurized Logistics Carrier (ULC) carries two Orbital Replacement Units (ORUs) and an US experiment payload to be installed on the EP (1.5 metric tons in total).

Figure 4.2-1 EP of the HTV3

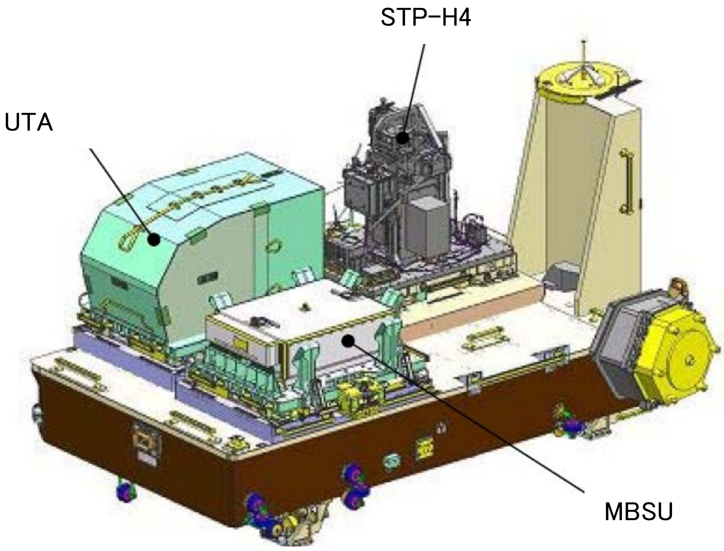


Figure 4.2-2 Cargo loaded on the EP (HTV4)

Figure 4.2-3 UTA and MBSU loaded on the EP (HTV4)

4.2.1 ISS system supplies

(1) Main Bus Switching Units (MBSU)

There are four MBSUs installed on the S0 truss. The MBSU is an important hardware that distributes electronic loads to each system on the ISS.

If a MBSU is down, 1/4 of electronic power of the US segment will be lost. Therefore Extravehicular Activity becomes necessary to exchange the failed part. MBSU spare parts had been placed on the External Stowage Platform 2 (ESP-2). Now there is only one space part is left since astronauts Sunita Williams and Akihiko Hoshide used one for replacement between August to September in 2012.

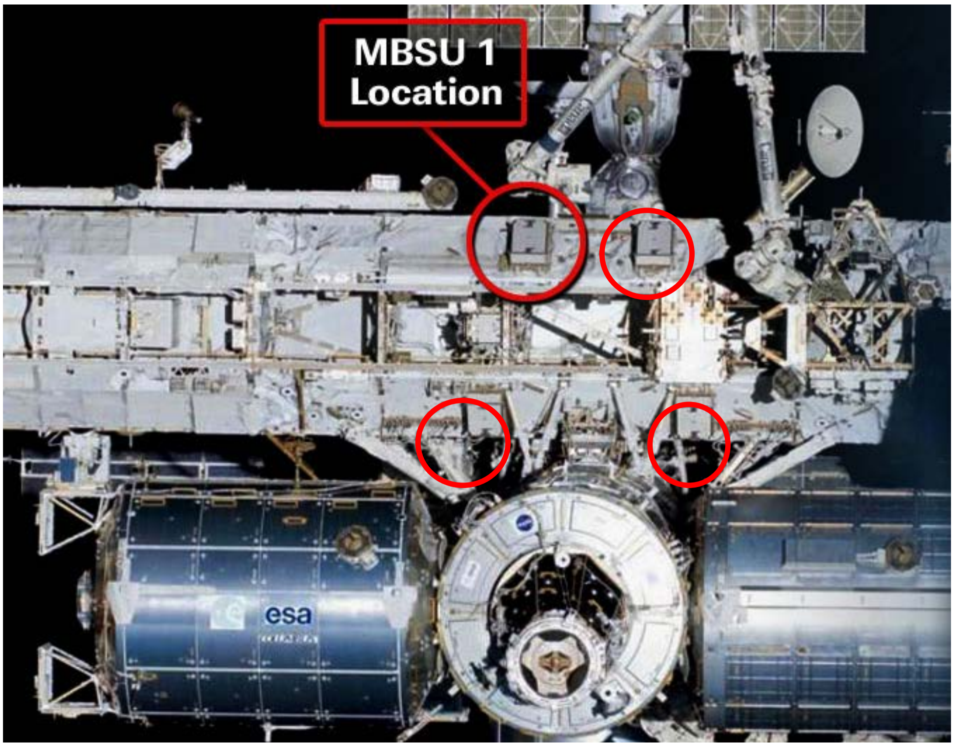


Figure 4.2.1-1 Four MBSU installed on the S0 truss of the ISS
(Photo: NASA)

Figure 4.2.1-2 MBSU to be delivered by the HTV4
(From NASA Astronaut Mike Hopkins' Twitter)

(2) Utility Transfer Assembly (UTA)

The UTA is placed on the center of the Solar Array Rotary Joint (SARJ) located on the P3-P4 and S3-S4 trusses and is used to provide power and data interface without tangling wires.

The UTA is an important hardware that, if the UTA fails, half of electronic power of the US segment will be lost. Currently there is only one spare part, the HTV4 will carry additional one.

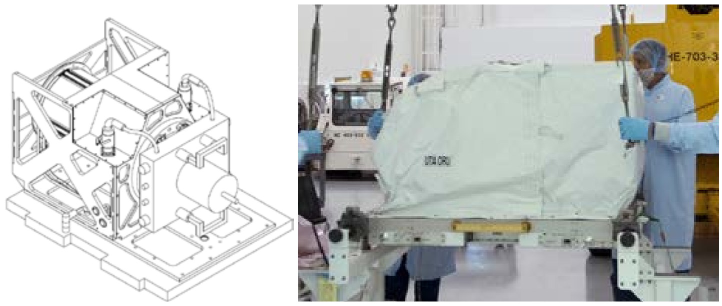


Figure 4.2.1-3 UTA (Photo taken before shipping to Japan)
(Photo courtesy of NASA)

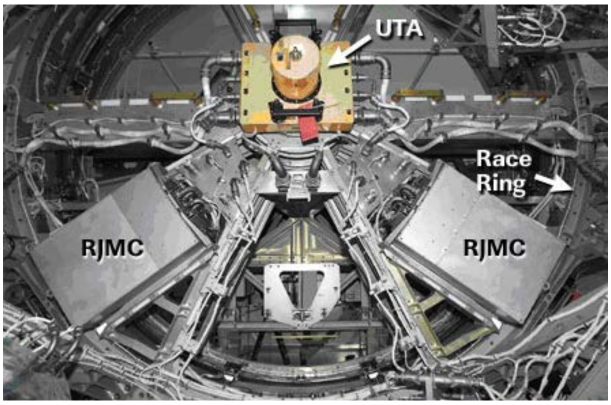


Figure 4.2.1-4 UST installed to the center of SARJ
(Photo courtesy of NASA)

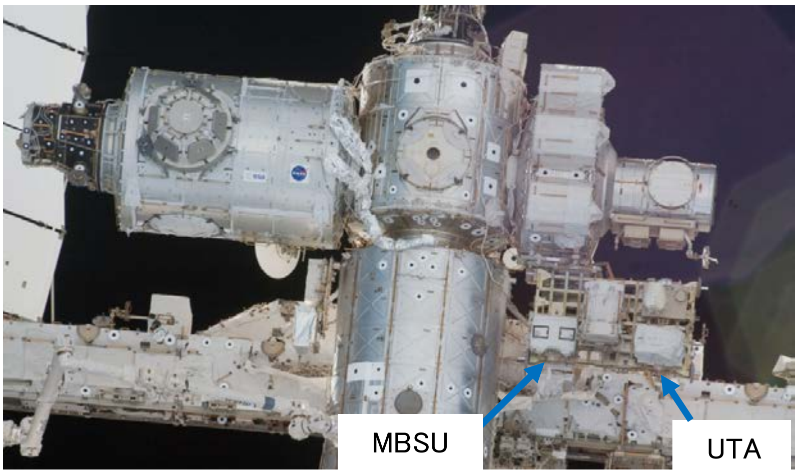


Figure 4.2.1-5 MBSU and UTA spare parts (covered in thermal insulating covers) stored on the ISS ESP-2
(Photo courtesy of NASA. Photo taken after STS-130 mission)

【Reference】Solar Alpha Rotary Joints (SARJ)

SARJ are the rotation mechanisms that rotate the solar arrays to the Sun, with each diameter of 3.5 meters and 1,134 kg of weight. As the ISS circles around the Earth, SARJ rotates one revolution (in addition to this alpha axis rotation, the solar arrays can rotate beta axis.) One SARJ is placed on S3-S4 truss and another on P3-P4 truss. Generated power and communication data are transmitted to the ISS modules through the UTA.

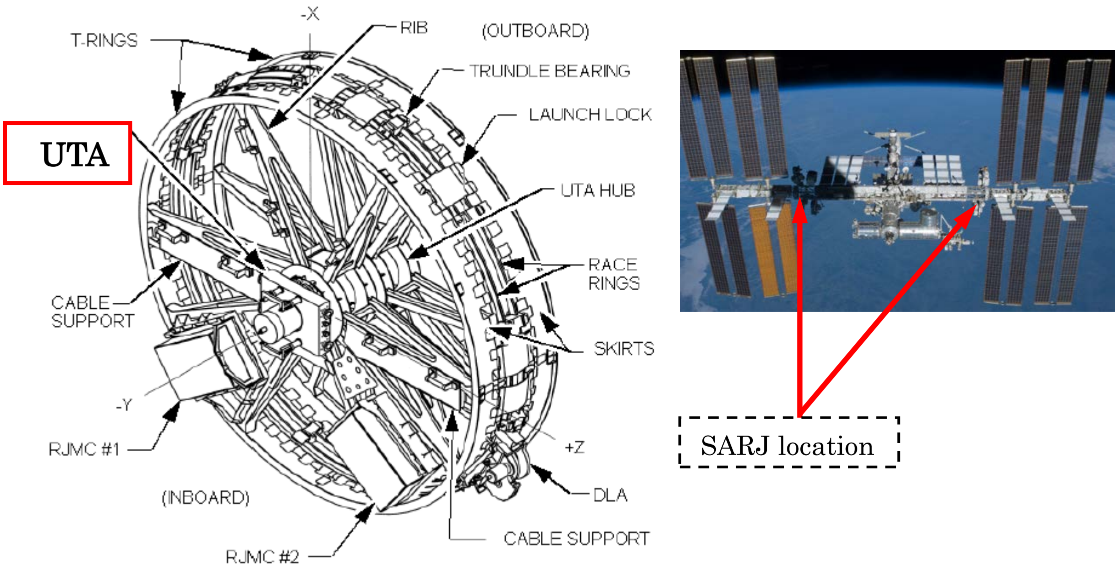


Figure 4.2.1-6 SARJ structure (From NASA STS-115 Press kit)

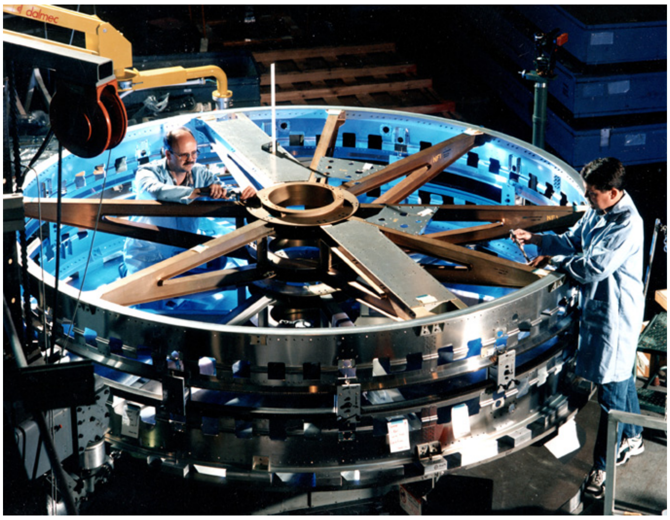
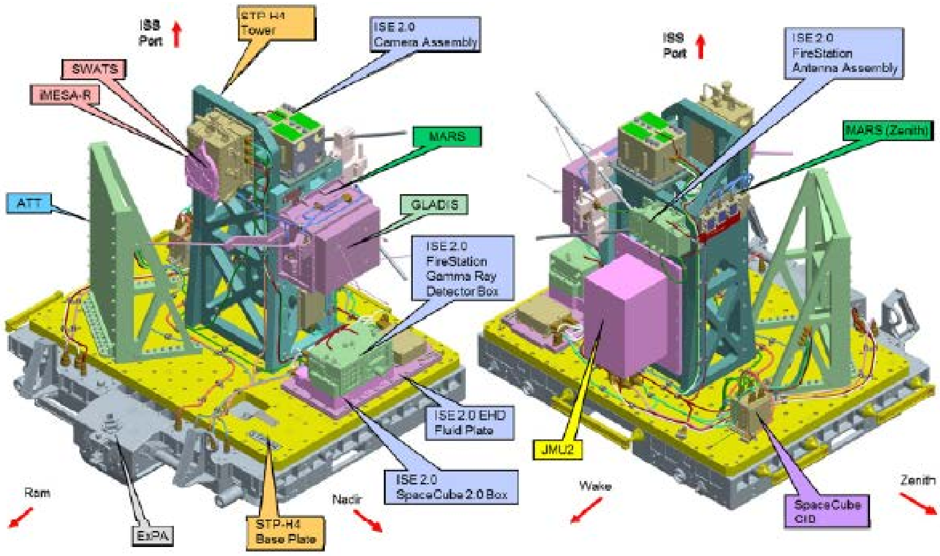


Figure 4.2.1-7
SARJ rotating ring (Photo courtesy of Lockheed Martin)

4.2.2 NASA's exposed payload

(1) STP-H4 (Space Test Program – Houston 4)

The STP-H4 is a conglomerate payload comprising eight experiment equipments. The payload performs atmospheric observation, thermal control experiment, radiation measurement, data processing module testing, and phenomenon observation caused by lightning and others.



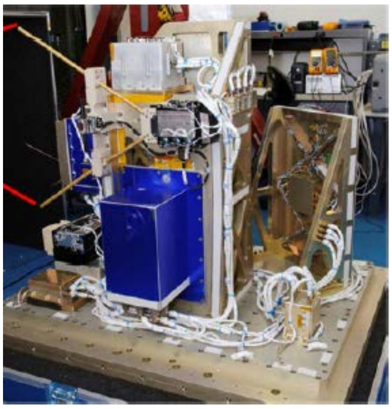


Figure 4.2.2-1 STP-H4 (image courtesy of NASA Press kit)

4.2.3 Transfer of the exposed hardware

EP loaded with equipments is taken out of the ULC using the Space Station Remote Manipulator System (SSRMS) to temporarily locate it on the ISS. Each equipment on the EP is transferred by maneuvering the Special Purpose Dexterous Manipulator (SPDM), which is grappled by the edge of the SSRMS. Each equipment is to be placed on the ExPRESS Logistics Carriers (ELCs). At last, STP-H3 will be transferred to the EP for disposal.

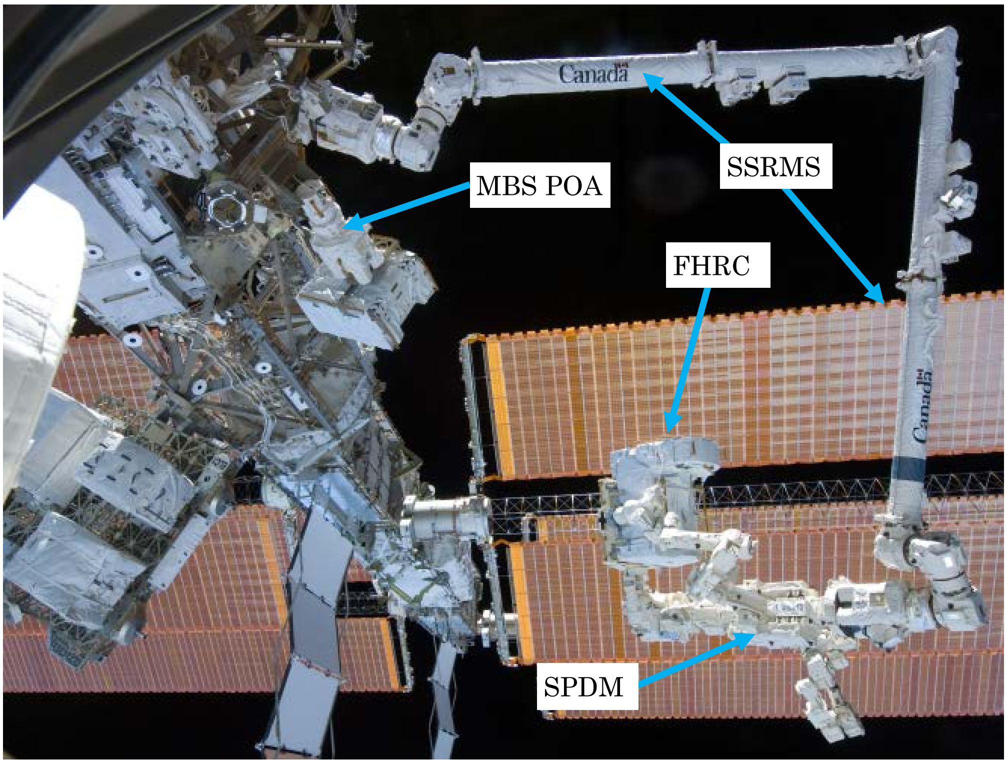


Figure 4.2.3-1 A US payload being transferred using the SPDM (FHRC transfer on the HTV2 mission) (Photo courtesy of NASA)

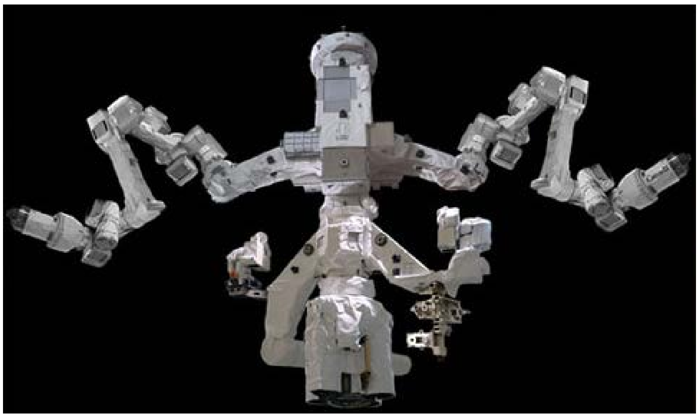


Figure 4.2.3-2 SPDM called “Dextre” (Credit: NASA/CSA)

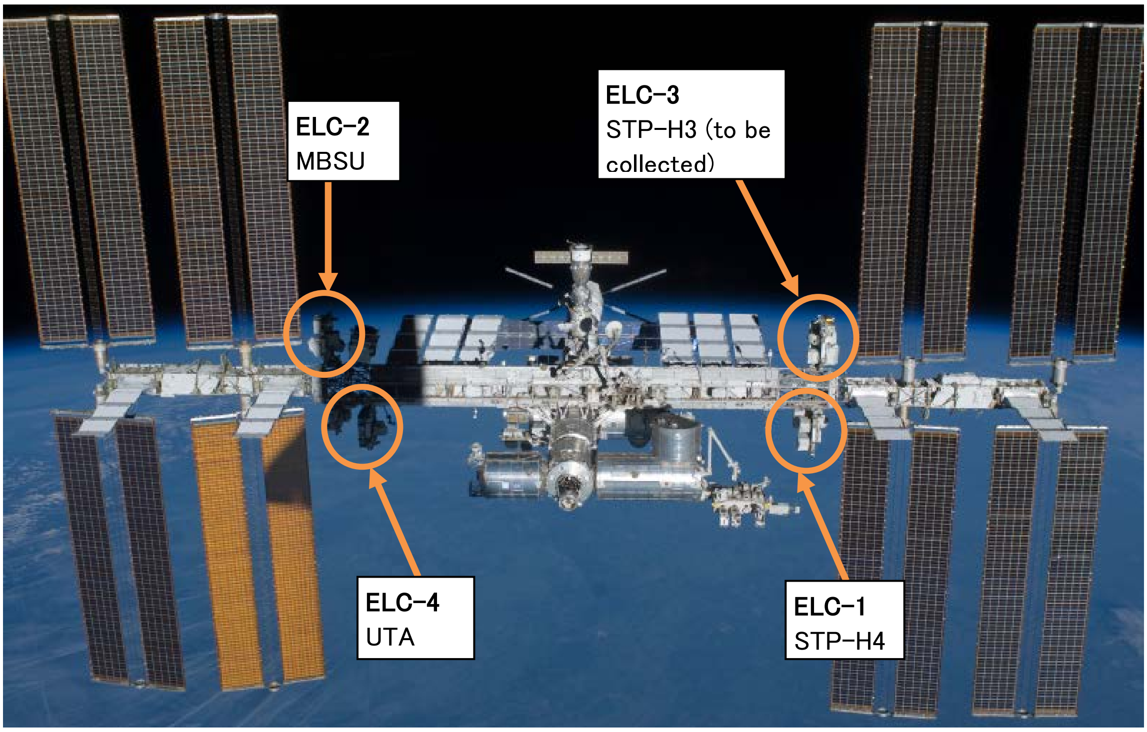


Figure 4.2.3-3 Installation location for each equipment to be delivered and collected by the HTV4 mission (courtesy of NASA)

Figure 4.2.3-4 STP-H3 to be disposed with the HTV4's fiery reentry
(Photo taken before the STS-134 mission)

5. Technology accumulation using the HTV

The HTV contributes not only cargo delivery to the ISS, but is used to accumulate technology as described below.

5.1 Reentry observation

In the HTV3 mission, the reentry data recorder “i-Ball” successfully obtained data during its reentry. The HTV4 will also load an i-Ball to obtain reentry data.

In addition, HTV4’s reentry will be shot from the ISS for the first time (see Figure 5.1-2.)

The objective of data acquisition is to, by specifying the breakup phenomenon of a spacecraft during reentry, narrow the splashdown warning areas based on improved prediction accuracy for the rocket’s fall, and to gather data that is useful for designing the heating rates, etc. of future reentry vehicles (i.e. verification of heat resistance for a vehicle that is recovered; design of the main body that is easily burnt out with reduced heat resistance and strength for a vehicle that is discarded).

Since one-time data acquisition does not generate a precise data, several data acquisition becomes necessary to increase the accuracy.

Based on the data acquired in the previous mission, scope of the data acquisition has been narrowed to obtain detailed data in the HTV4 mission.

Refer to Annex3 for more details of i-Ball.

Table 5.1-1 Brief summary of i-Ball

Developer	IHI Aerospace
Data acquisition	・ Temperature (inside of i-Ball and HTV PLC [data acquisition has been added] ・ Acceleration, angular velocity [data collection frequency has increased from 1/sec. to 20/sec.] ・ Still photo images ・ GPS navigation data ・ Pressure of the HTV PLC [new]
Size	Weight：22.1kg (including the container：24.9kg) i-Ball Diameter：400mm Dimension (including the container)：410×440×435mm
Splashdown and data communication method	After decelerated by a opened parachute, it splashdowns on the ocean. While floating with a flotation bag, i-Ball sends data via an Iridium satellite.

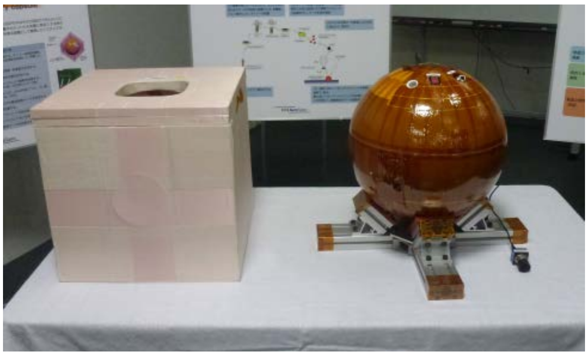


Figure 5.1-1 i-Ball and its container

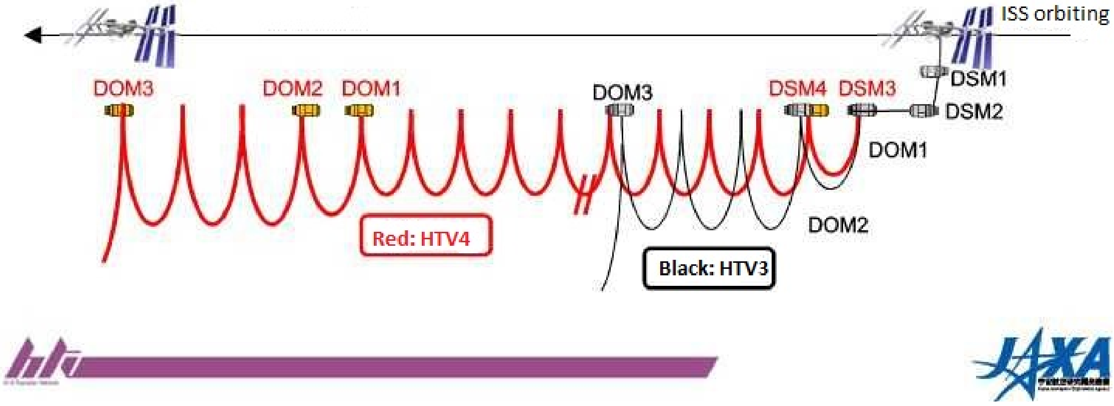
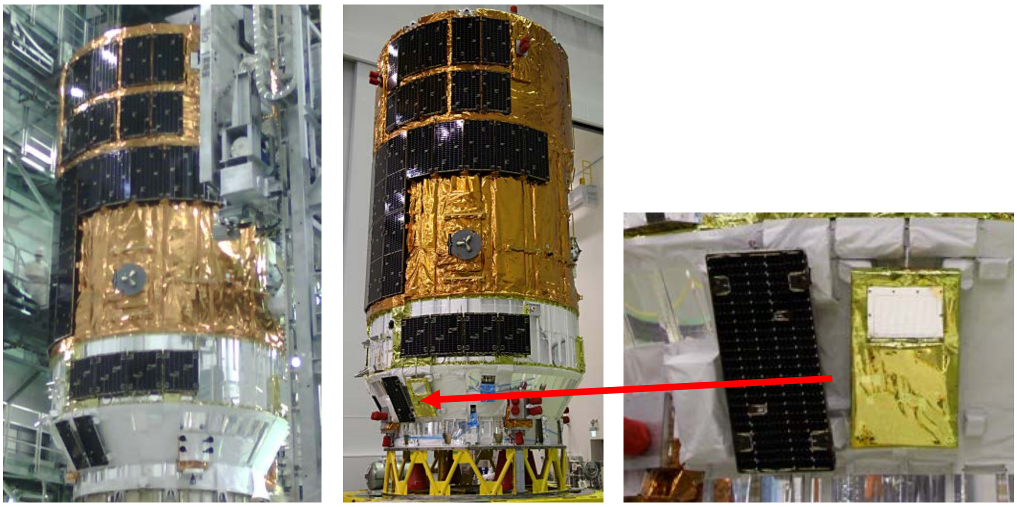


Figure 5.1-2 Trajectory differences with the HTV3 and HTV4

In the HTV4 mission, in order to shoot the reentry of the HTV4, Descending Maneuver (DSM) 3 and 4 will be added to let the HTV4 descend and fly single Earth orbit ahead of the ISS. At the timing of the HTV returns and flies below the ISS, HTV's De-Orbit Maneuver (DOM) will be performed.

5.2 Measurement of surface potential (first time measurement)

The ISS adopts solar power, and the current is generated with a voltage of 160 volts. The Plasma Contactor Unit (PCU) disperses the electrical charge and keeps the ISS about a same with the surrounding plasma environment. Under such environment, it is important to know how the electric potential changes when the HTV, which operates at 50 volts, is berthed to the ISS. To clarify this, one solar array panel has been removed to install a surface potential sensor panel on the body of the HTV4.



HTV3 HTV4

Figure 5.2-1 The surface potential sensor "ATOTIE-mini"（Advanced Technology On-orbit Test Instrument for space Environment - mini）

6. What has been obtained through the HTV

- **Acquired rendezvous and docking technology as a nation's essential technology by bringing together the technology of domestic space industry (succession of manufacturing technology and human resources in Japan.)**

  HTV's seven times of cargo deliveries to the ISS have and will lead to the advancement of manufacturing technology of their own and succession of human resources for space industry and about 350 companies including small-medium ones in Japan.

- **As the only spacecraft which to deliver large unpressurized and pressurized cargo, the HTV plays an indispensable role in the ISS operation**

  After the retirement of space shuttles, the HTV, is now the only spaceship which can accommodate large unpressurized and pressurized cargo (such as experiment racks, unpressurized large ISS ORUs and payloads), is a dispensable spaceship for the entire operation of the ISS.

  HTV's three times of accurate launches and docking, and its powerful loading capacity boosted Japan's presence.

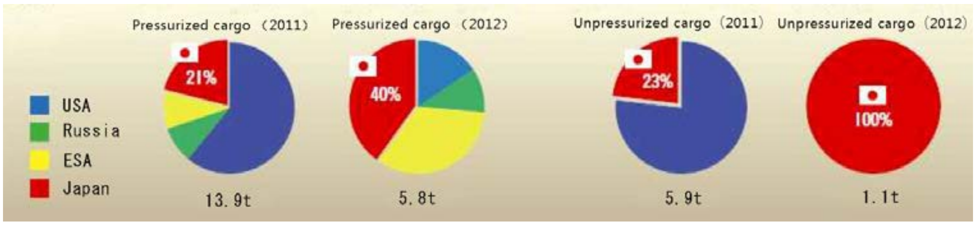


Figure 6-1 Percentage of contributions of cargo delivery to the ISS in 2011 and 2012

- **The Japanese technology was adopted as an international standard method, which promoted commercial production orders from abroad.**

  Through the HTV, a new and Japan's own rendezvous and berthing methods, which realize a safe relative-proximity to the ISS and spaceship capture with the SSRMS have been established.

  Japan's secure rendezvous and berthing methods were adopted to the US commercial spacecrafts such as Dragon and Cygnus, which resulted in that Japanese companies received purchase orders. JAXA will give a technical support through NASA for the rendezvous and berthing operations.

Figure 6-2 Japanese hardware to be used in the Cygnus spacecraft

To see the representative cargo delivered by the HTV1-3, refer to Annex 2-20 to 23.

Annex 1　Configuration of HTV

The H-II Transfer Vehicle (HTV) consists of a Pressurized Logistics Carrier (PLC), an Unpressurized Logistics Carrier (ULC), an Exposed Pallet (EP), an Avionics Module, and a Propulsion Module.
Cargo and supplies are loaded inside the PLC and on the EP, which is installed in the ULC.
Proximity Communication System (PROX) equipment that enable radio frequency (RF) communications between the HTV and the ISS, as well as PROX antennas and Laser Radar Reflector (LRR) are installed on the Japanese Experiment Module, Kibo, and are to be used when the HTV arrives within the ISS proximity range.

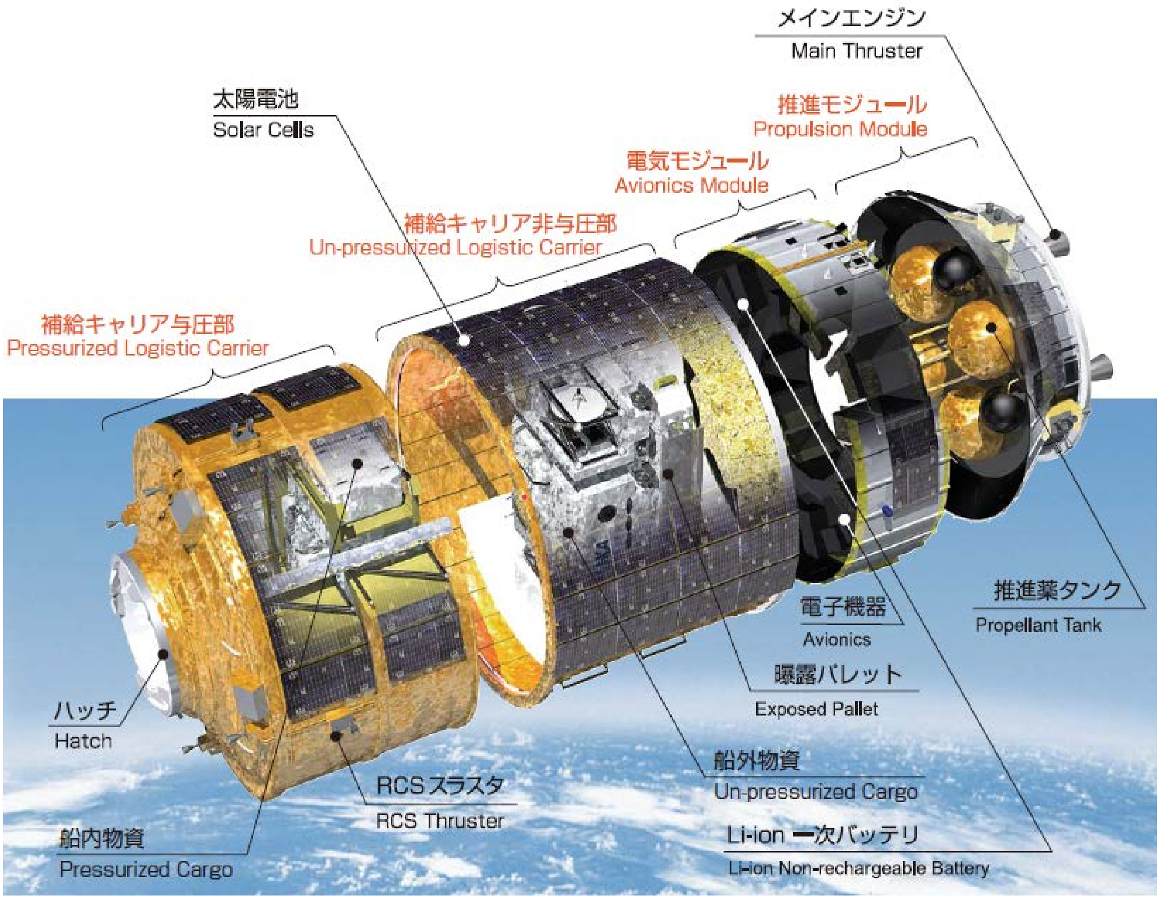


Figure A1-1 Configuration of HTV

Table A1-1 HTV Specifications

Item	Specification	
Length	9.8m (including main thrusters)	
Diameter	Approx. 4.4m	
Weight (without cargo)	Approx. 10,500kg	
Total Mass	Up to 16,000kg	
Propellant	Fuel	MMH (Monomethylhydrazine)
	Oxidizer	MON-3
Cargo Capacity (For supplies) (*1)	Up to approx. 6,000 kg	
	Pressurized carrier: Up to approx. 5,200kg (Pressurized cargo including, food, clothing, and potable water for crew, experiment racks, experiment equipments, which are used inside the ISS.)	
	Unpressurized carrier: Up to approx. 1,500 kg (Unpressurized cargo including exposed experiment payload or Orbital Replacement Units (ORU), consumables used outside the ISS)	
Cargo Capacity (For waste)	Up to approx. 6,000 kg	
Target Orbit	Altitude: 350 km to 460 km Inclination: 51.6 degrees	
Mission Duration	Rendezvous flight: Approx. 5 days Berthed operations: Approx. 45 days Emergency stand-by duration (on-orbit): Approx. 7 days	

(*1) The sum of the maximum amount of pressurized cargo and unpressurized cargo exceeds 6,000 kg. In actual planning, the amount is to be adjusted not to exceed more than 6,000 kg.

Table A1-2 Summary of HTV missions

		Technical Demonstration Vehicle (HTV1) (actual values)	HTV2 (actual values)	HTV3 (actual values)	HTV4 (planned values)
Launch date		September 11, 2009	January 22, 2011	July 21, 2012	August 4, 2013
Reentry date		November 2, 2009	March 30, 2011	September 14, 2012	September 7, 2013
Amount of cargo delivered to the ISS (approximately)					
	Pressurized Cargo	3,600kg	4,000kg	3,500kg *2	3,900kg
	Unpressurized Cargo	900kg	1,300kg	1,100kg	1,500kg
	Total	4,500kg *1	5,300kg	4,600kg *2	5,400kg
Total Mass		16,000 kg	16,000 kg	15,400 kg	16,000 kg
Target Orbit					
	Altitude (circular orbit)	330×347km	352km	Approx. 400 km	Approx. 400 km
	Inclination	51.6 degrees	51.6 degrees	51.6 degrees	51.6 degrees
Mission Duration		53 days (planned: 37days)	67 days (planned: 37 days)	56 days (planned: 49 days)	Planned: 39 days
	Rendezvous Flight (Solo flight)	7 days	5 days *3 (planned: 7days)	6 days	5 days
	Berthed Operations	43 days (required design was for 30 days)	60 days *4 (required design extended up to 45 days)	48 days	27 days (subject to change due to the ISS operational status)
	Unberthing to reentry	3 days	2 days	2 days	3 days

*1) HTV1 Mission's total cargo up-mass was adjusted to 4,500 kg since it had to carry extra 4 batteries and extra propellant for rendezvous flight demonstrations.
*2) In the HTV3, supplies were fully loaded in the PLC. Simple weight comparison may not apply since there are large, but light equipments.
*3) It was shortened due to 2 days of the launch delay by bad weather.
*4) Berthing period was extended under the adjustment with NASA because the HTV2 mission overlapped with the STS-133 mission due to the launch delay of the STS-133 mission.

A1.1 Pressurized Logistics Carrier (PLC)

The Pressurized Logistics Carrier (PLC) carries cargo for onboard use (experiment racks, food, and clothes). Internal air pressure of the PLC is maintained at one atmospheric pressure (1 atm.). The temperature inside the HTV is controlled during its solo flight phase and berthing phase. Once it is berthed to the ISS, internal air will be circulated between the PLC and Harmony (Node 2) through the Inter-Module Ventilation (IMV) system.
The PLC is equipped with the hatch (1.27m x 1.27m) and passive half of a Common Berthing Mechanism (CBM) for berthing to the active half of the CBM on Harmony. From the hatch, ISS crew will enter the PLC to unload the Cargo Transfer Bags (CTB) or science/system racks. After cargo unloading is complete, the HTV will then be loaded with trash and used materials.

Figure A1.1-1 PLC exterior (HTV1)

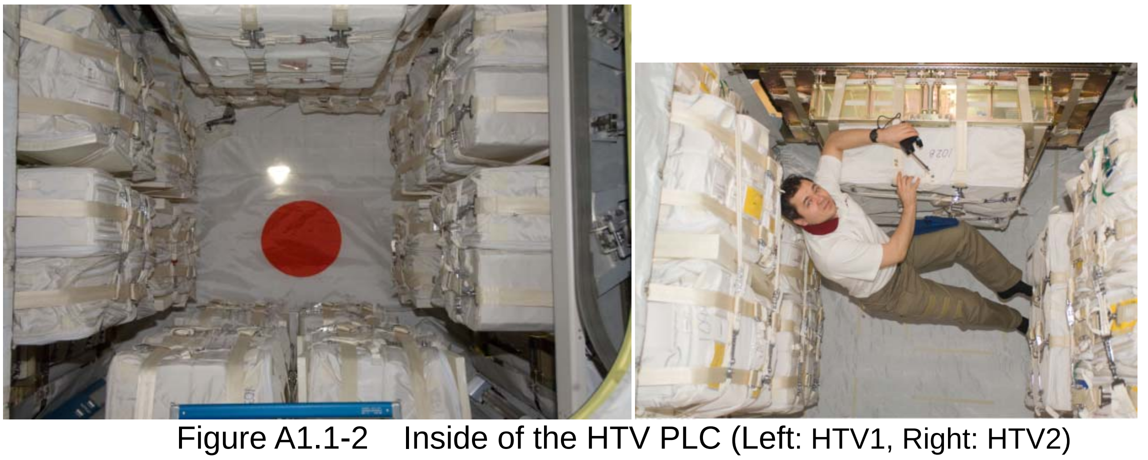


Figure A1.1-2 Inside of the HTV PLC (Left: HTV1, Right: HTV2)

The interior of the Pressurized Logistic Carrier (PLC) is separated into two bay areas: the first rack bay (Bay #1) located on the hatch side, and the second rack bay (Bay #2) in the rear. Each bay accommodates four racks; thus, up to eight racks may be accommodated per flight. HTV’s rack size is 2m by 1.05m, which is the same with the racks on the ISS.

Figure A1.1-3 Rack Layout inside the HTV2 (photo taken from the hatch side, during loading)

First Rack Bay (Bay #1)	Bay #1, located on the hatch side, accommodates the International Standard Payload Rack (ISPR) or a fixed type of HTV Resupply Racks (HRRs). The ISPR is removable so that the rack can be transferred into the ISS cabin during HTV's berthing phase.
Second Rack Bay (Bay #2)	Bay #2, located in the rear, accommodates only a fixed type of HRRs, and those HRRs will not be transferred into the ISS cabin. After the Cargo Transfer Bags (CTB) are unloaded from the fixed type HRRs, trash and other discarded items are loaded into them.

A1.2 Unpressurized Logistic Carrier (ULC)

The Unpressurized Logistic Carrier (ULC) has a wide opening of 2.9m by 2.5m that accommodates an Exposed Pallet (EP), which carries external experiments and/or unpressurized orbital replacement units (ORUs). Since the opening is located on the side of the body, area around the opening section should experience intensified aerodynamic load during launch/ascent phases. The structures of the ULC are designed to withstand such ascent loads, which makes the design difficult.
The ULC is equipped with a Flight Releasable Grapple Fixture (FRGF). The station's robotic arm (SSRMS) grapples this FRGF for berthing the HTV to the ISS.

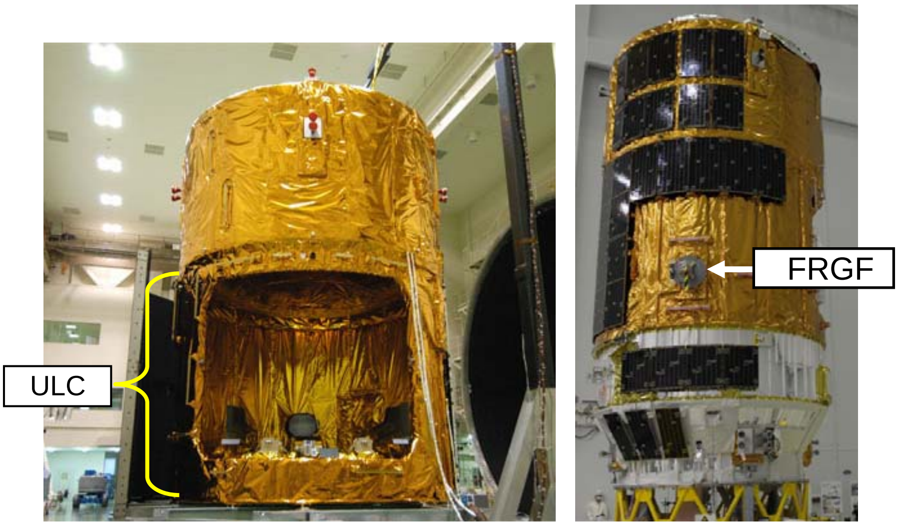


Figure A1.2-1 ULC before Installation of the EP (HTV1)

After the HTV is berthed to the ISS, the Exposed Pallet (EP) will be removed from the ULC by the station's robotic arm (SSRMS). Then, the EP will be temporarily attached to the Mobile Base System (MBS) or Kibo's Exposed Facility (EF) for unloading of the carried payloads.
Once the payloads are unloaded, the EP will be re-stowed in the ULC.

Figure A1.2-2 EP Being Loaded (HTV3)

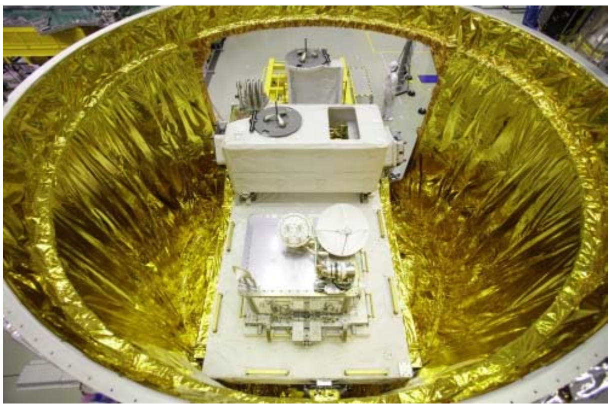


Figure A1.2-3 EP Installed into the ULC (HTV3)

Mechanisms of Unpressurized Logistics Carrier (ULC)

- Tie-down Separation Mechanism (TSM)
  The Unpressurized Logistic Carrier (ULC) is equipped with four Tie-down Separation Mechanisms (TSMs). The TSMs are used to fasten the Exposed Pallet (EP) in the ULC during launch to the ISS. After the HTV is berthed to the ISS, the TSMs enable removal or reinstallation of the EP to the ULC by the SSRMS.

- Harness Separation Mechanism (HSM)
  The Harness Separation Mechanism (HSM) is located near the opening of the ULC. The HSM is used to separate heater power and data cables between the ULC and the EP.

- Guide rails/wheels
  The guide rails and wheels are devises to minimize resistive load when the EP is reinstalled into the ULC. The mechanisms also support proper alignment for re-stowing of the EP. The guide rail is located on the ULC side, and the wheel (roller) is attached on the EP side.
  Three guide rails are located near the aperture of the ULC, one each on the port side, the starboard side, and the nadir side. Nine wheels are located on the port side and the starboard side, and one on the nadir side of the EP.

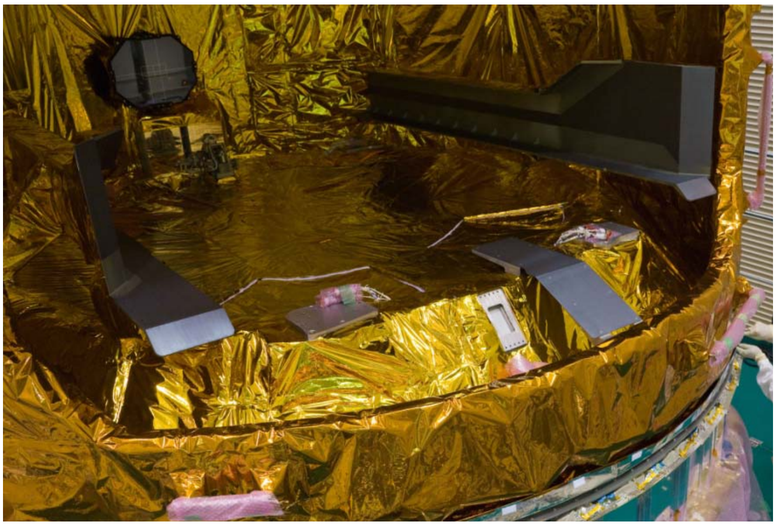


Figure A1.2-4 Enlarged View: Opening of the ULC (HTV1)
Wheel on the EP (HTV2)

A1.3 Exposed Pallet (EP)

The Exposed Pallet (EP) is used to carry unpressurized payloads such as orbital replacement units (ORUs), which are installed outside the ISS modules. The EP is removed from the ULC and temporarily attached to the ISS for unloading the carried payloads. After the payloads are unloaded, the EP is re-stowed in the ULC. The EP accommodates up to 1,500 kg of unpressurized cargo.

From launch to berthing to the ISS, the EP receives electrical power from the PLC. When attached to the Kibo's EF, it receives electrical power from the EF side.

The Exposed Pallet - Multi-Purpose (EP-MP) has been used from the HTV3. The size is 2.8m (D) x 4.1m (W) x 2.3m (H), with a mass of 600kg.

Figure A1.3-1 Exposed Pallet (EP-MP of the HTV3)

There are two types of EPs to meet various logistics needs.

Exposed Pallet for Kibo's Exposed Facility (EF) Payload (Type I)

Type I is temporary attached to Kibo's Exposed Facility (EF)
On the HTV1 Mission, two EF payloads were delivered using this Type I pallet while on the HTV2 Mission, NASA's two unpressurized ORUs were delivered using this type with U.S. attachment mechanisms (NASA's Flight Releasable Attachment Mechanisms: FRAMs).

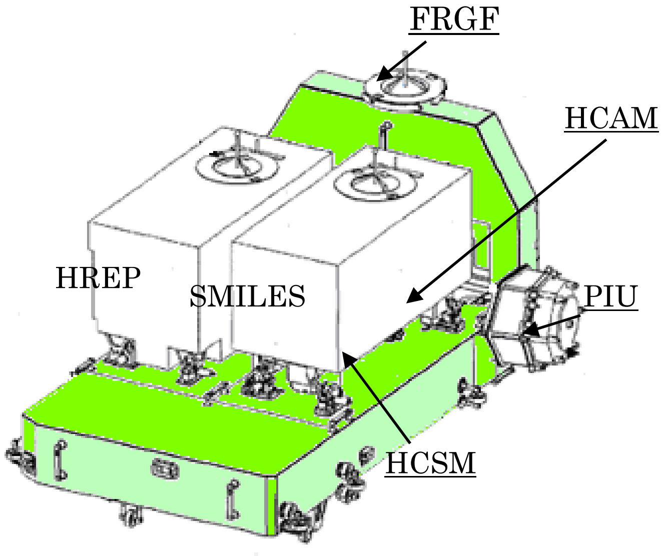


Figure A1.3-2 Exposed Pallet for EF Payload (Type I)
(Note: Configuration for the HTV1 Mission)

Exposed Pallet-Multi-Purpose (Type EP-MP)

Type EP-MP can accommodate various combinations of external experiment hardware and ORUs. On orbit, the EP-MP can be attached to either the EF (adapted on the HTV3 mission) or the station's Mobile Base System (MBS).
The EP-MP, which is attached to the EF, carries a combination of an EF payload and an ISS-common ORU). The EP-MP, which is attached to the MBS, carries only ISS-common ORUs such as battery ORUs. This type can carry up to six batteries per fight.

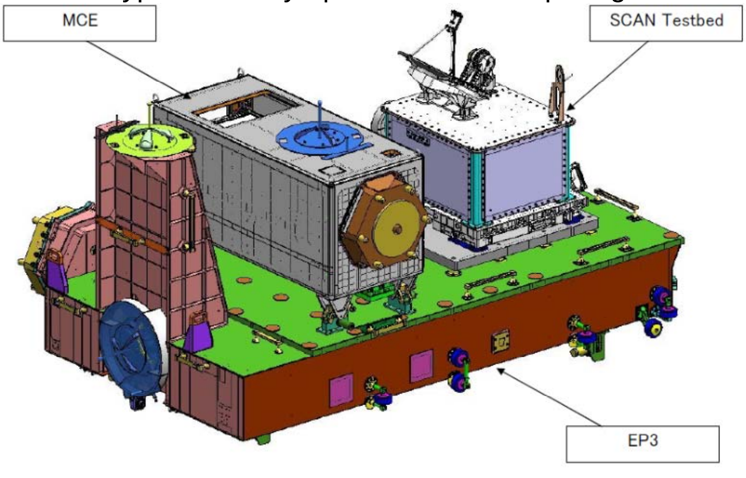


Figure A1.3-3 Exposed Pallet-Multi-Purpose (Type EP-MP)
(HTV3 configuration)

Mechanisms of Exposed Pallet (EP)

The Exposed Pallet (EP) is equipped with an EF interface (HPIU), Cargo Attachment Mechanisms (HCAMs), Connector Separation Mechanisms (HCSMs), a TV camera (HBCS), and two types of grapple fixtures (FRGF and PVGF).

- HTV Payload Interface Unit (HPIU)
  The HTV Payload Interface Unit (HPIU) is used to connect the EP to Kibo's Exposed Facility (EF). It provides an interface between the EP and the EF.

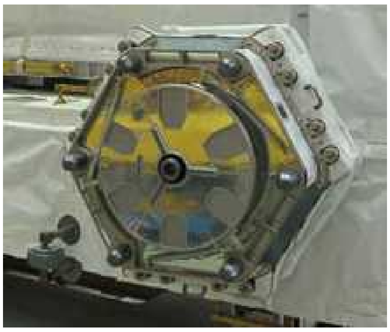


Figure A1.3-4 HTV Payload Interface Unit (HPIU)

- HTV Cargo Attachment Mechanism (HCAM)
  The HTV Cargo Attachment Mechanism (HCAM) is used to fasten an EF payload while the HTV flies to the ISS. It fastens each of the four corners of an EF payload.

- HTV Connector Separation Mechanism (HCSM)
  The HTV Connector Separation Mechanism (HCSM) is used to separate heater power cables between the Exposed Pallet (EP) and an EF payload or ORU.

- FRGF/PVGF
  The Grapple Fixture is an ISS-common mechanism that the SSRMS or JEMRMS grapples and holds. The PVGF provides an interface to supply heater power and data communications between the EP and the ISS through the SSRMS.

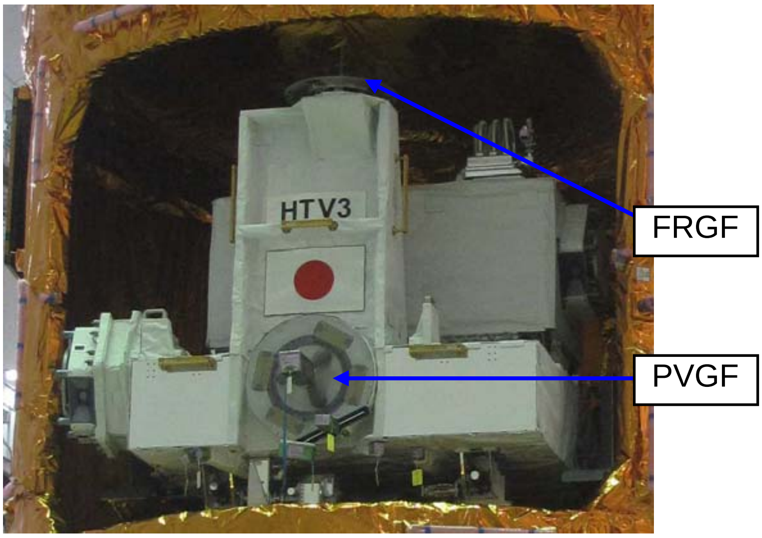


Figure A1.3-5 Exposed Pallet (HTV3)

- HTV Berthing Camera System (HBCS)
  The HTV Berthing Camera System (HBCS) is located on the front portion of the EP. It helps align position of the EP while the EP is re-stowed into the ULC by the SSRMS. Camera target is located on the ULC side.

Figure A1.3-6 HTV Berthing Camera System (HBCS)

A1.4 Avionics Module (AM)

The Avionics Module (AM) consists of guidance navigation & control, communications, data handling, and electrical power subsystems. These subsystems support HTV's autonomous and/or remotely controlled rendezvous flight. The Avionics Module distributes power to each component of the HTV. The AM is 4.4 meters in diameter, 1.2 meters in height, with a mass of 1,700 kg.
The subsystems of the Avionics Module are shown in Table A1.4-1.

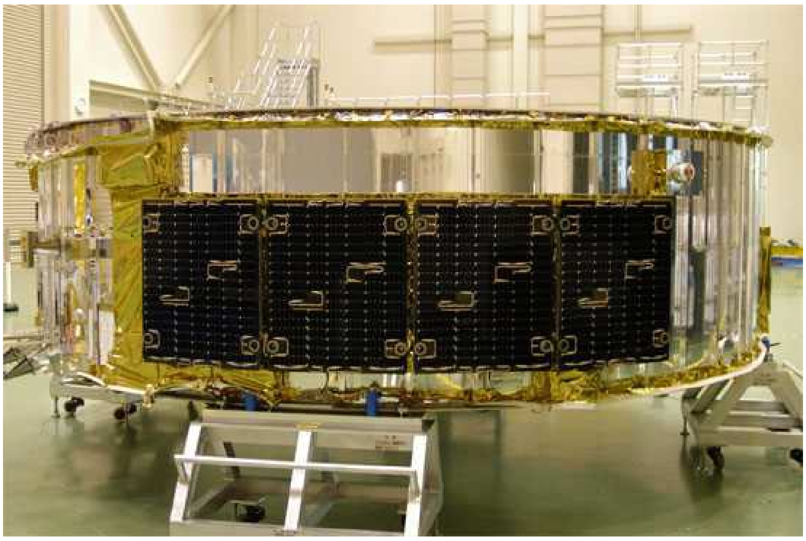
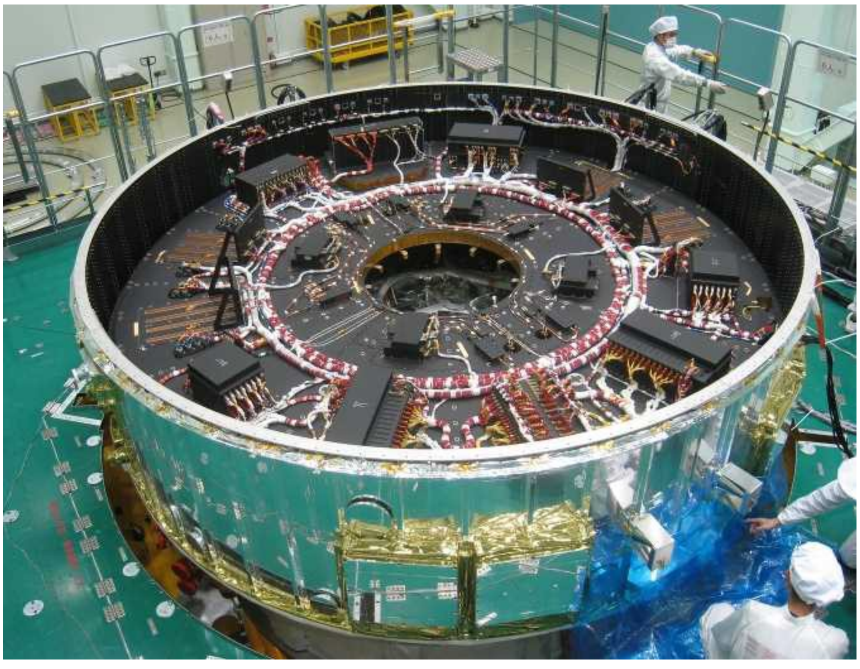


Figure A1.4-1 Avionics Module (Side View) (HTV1)



FigureA1.4-2 Avionics Module (Top View) (HTV2)

The AM receives commands sent from the ground through NASA's Tracking and Data Relay Satellite (TDRS) and or the Proximity Communication System (PROX) installed in Kibo, and then, relays the commands to each HTV component. It also sends HTV's telemetry data to the ground through the TDRS and or the PROX.

Table A1.4-1 Avionics Module Subsystems

Navigation Control Subsystem	▪ Once the HTV is inserted into the predetermined orbit, this subsystem obtains the navigation information using the position/attitude sensors. ▪ This subsystem mainly consists of GPS antennas, rendezvous sensors, Earth sensor, navigation control computer, and abort control unit. ▪ This subsystem, right before the capture by the SSRMS, controls the relative position within 76cm, with the relative speed less than 7mm/sec. As the ISS and HTV fly 8,000m/sec, their relative speed is controlled to .0001% difference.
Communications Subsystem	▪ This subsystem consists of the Inter-Orbit Link System (IOS) that enables communications through NASA's TDRS, and the Proximity Link System (PLS) that enables direct wireless communications with the ISS within the ISS proximity range. Both communications use S-band. ▪ PLS is used when the HTV establishes communication with the ISS at 200 km away from the ISS and until it reaches the capturing point at 10m below the ISS.
Data Handling Subsystem	▪ This subsystem receives commands from the ground, and sends HTV telemetry to the ground. ▪ This subsystem supports thermal controls of the Avionics Module and Propulsion Module, environment control of the PLC, fault detection/caution and warning for HTV's equipment, and data handling/control of the other subsystems.
Electrical power Subsystem	▪ This subsystem consists of seven Primary Batteries (P-BATs) and one Secondary Battery (S-BAT). ▪ The Power Control Unit (PCU) that regulates and provides the power generated by the solar panel when the HTV is flying in the daytime and recharges the surplus power in the S-BAT. ▪ When the HTV is flying in the Earth eclipse, the power in the S-BAT and the P-BAT will be provided to each system component. ▪ When the power supply from the ISS is out during the berthing phase, the power from the P-BAT will be provided to each system component of the HTV. ▪ While the HTV is berthed to the ISS, it receives power at 120V DC from the ISS and convert/stabilize it to 50V DC and distributes to each component of the HTV.
Solar Array Panel 	▪ 56 solar panels are installed on the external wall of the HTV. - PLC: 20 panels - ULC: 23 panels - Avionics Module: 8 panels - Propulsion Module: 4 panels* * 6 panels were used in HTV1 and 2. One panel was removed in the HTV3 due to an interference. Another one has been removed to place a sensor instead. (HTV1&2: 6 panels, HTV3: 5 panels, HTV4: 4 panels)

A1.5 Propulsion Module (PM)

The Propulsion Module (PM) has four spherical propellant tanks with a capacity of 2,000 kg of propellant per flight. MMH is used as fuel, and MON3 is used as an oxidizer.
The propellant will be supplied to HTV's four main engines (two units x two strings) and 28 Reaction Control System (RCS) thrusters (14 units x two strings) from the propellant tanks. Propulsion for orbital maneuvers (rendezvous maneuvers and attitude maneuvers) will be controlled by command signals sent from the Avionics Module.
From the HTV3, domestically produced main engines and RCS thrusters have been used.

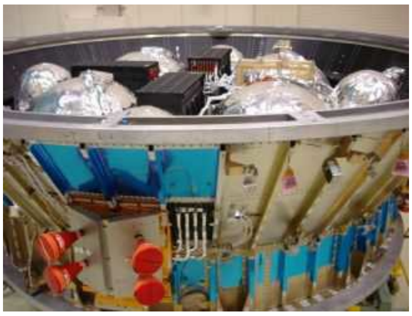


Figure A1.5-1 Propulsion Module
(Before installation of MLI covers)

Figure A1.5-2 Propulsion Tanks

Figure A1.5-3 Propulsion Module Photographed from the ISS (HTV1)
(Four nozzles seen in the bottom are main engines)

Table A1.5-1 Thrusters of the HTV

	Specifications	
	Main engines	Reaction Control System (RCS thrusters)
Number of units	2 units x 2 strings (redundant) Total 4 units	14 units x 2 strings (redundant) Total 28 units *
Thrust per unit	IHI Aerospace's HBT-5 500N (HTV3 and later) Aerojet's R-4D 500N (HTV1, 2, 4)	IHI Aerospace 120N (HTV3 and later※) Aerojet's R-1E 120N (HTV1, 2, 4)

* Of the 28 units, 12 units are installed on the outer wall of the PLC.

For the HTV4, imported engines and thrusters (remaining spare parts of the HTV1-3) are used.

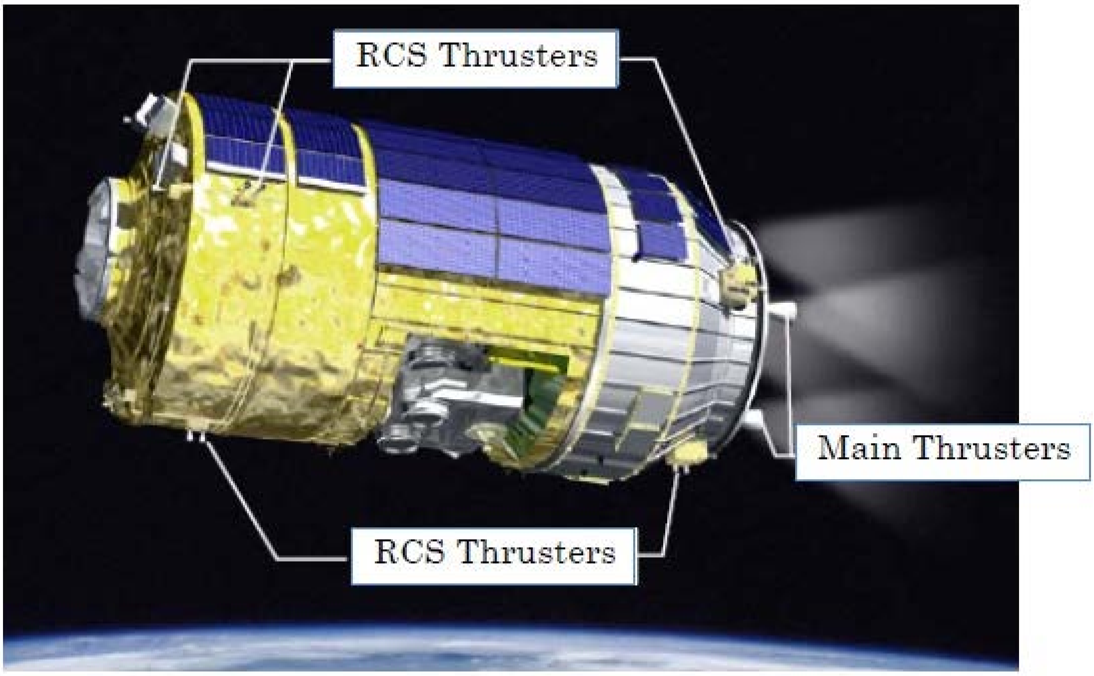
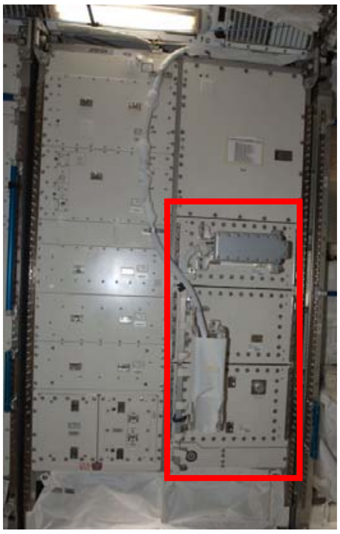


Figure A1.5-4 Locations of Main Engines and RCS Thrusters

A1.6 Proximity Communication System (PROX)

The HTV Proximity Communication System (PROX) is a radio frequency (RF) communications system that enables direct communications between the HTV and ISS when the HTV is in the proximity communications range. It is installed on board the ISS. The PROX consists of communication equipment, data handling equipment, PROX-GPS equipment, Hardware Command Panel (HCP), PROX antennas, PROX-GPS antennas. The PROX equipment, except for the HCP, is installed in the Inter-orbit Communication System (ICS) Rack on Kibo's Pressurized Module (PM).
The HCP is deployed on the Robotics Work Station in the Cupola before arrival of HTV. The PROX antennas are located on the side of the PM outer wall. Two units of the PROX-GPS antennas are located on the top of Kibo's Experiment Logistics Module-Pressurized Section (ELM-PS).

- PROX Communications Equipment



PROX communication systems are installed on the right side of the ICS/PROX Rack, which is located on the zenith poet side on the Kibo's PM.

【Note】
Nine PROX Communications Equipments were sold to Orbital Sciences, US at 66 million USD, to use for their Cygnus spacecraft, which is now being developed. This is the first case that the Japanese space technology (deliverables resulted from the ISS program) has been commercially exported.

Figure A1.6-1 PROX Communications Equipment

- PROX Antenna

The PROX antennas support HTV's direct RF communications with the ISS during Proximity Operations.

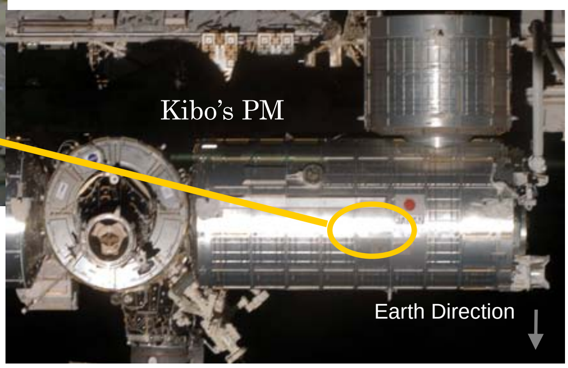


Figure A1.6-2 PROX Antenna

- Hardware Command Panel (HCP)

Figure A1.6-3 Hardware Command Panel (HCP)

●ABORT
This command will force the HTV to move away from the ISS

●FRGF SEP
This command will force the HTV to be detached from the SSRMS (In case the SSRMS is unable to ungrapple the FRGF) on the HTV. In that case, the FRGF will be disengaged from the HTV.)

●RETREAT
This command will force the HTV to retreat to 30 m or 100 m below the ISS

●HOLD
This command will force the HTV to hold its approach

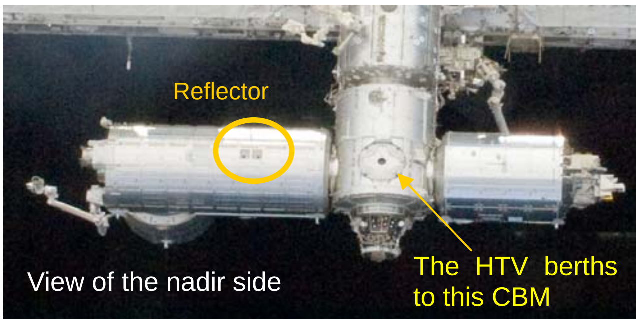
●FREE DRIFT
This command will disable the HTV thrusters for the SSRMS to grapple the HTV

The Hardware Command Panel (HCP) will be used for a contingency during the HTV's final approach. Using the HCP, the ISS crew can send commands to the HTV for immediate critical operations, such as holding the HTV's approach. The HCP is deployed on the Robotics Work Station in the Cupola before HTV's Proximity Operations.

Space X's Crew Command Panel (CCP). Experience gained in HTV missions has been applied to the US commercial spacecraft. Cygnus will use the HCP as it adopts PROX system.

Figure A1.6-4 Dragon spacecraft's CCP

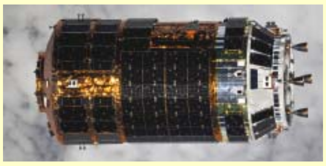
A1.7 Laser Rader Reflector (LRR)



The Laser Rader Reflectors (LRRs) are located on the nadir side of the PM. The reflectors will reflect the lasers beamed from the HTV's Rendezvous Sensor (RVS) when the HTV approaches from the nadir side of the ISS.

Figure A1.7-1 LRR for HTV installed on Kibo

Comparison of ISS Resupply Vehicles

Resupply Vehicle	Total Mass (Approx.)	Resupply Capability (Approx.)	Launch Vehicle	Features
HTV (Japan) 	16,500 kg	6,000 kg	H-IIB	First flight: 2009 Wide hatch opening: 1.27 m × 1.27 m Accommodates unpressurized payloads
ATV (ESA) 	20,500 kg	7,500 kg	Ariane 5 (ES-ATV)	Operation duration:2008-2014 (till ATV5) Docks to the aft docking port of the Zvezda service module Hatch opening diameter: 0.8 m Has capabilities to support ISS reboost and propellant supply
Progress (Russia) 	7,200 kg	2,000 kg	Soyuz U	First flight: 1978 Cargo delivery to the ISS began in 2000 Hatch opening diameter: 0.8 m Has capabilities to support ISS reboost and propellant supply
Space Shuttle (NASA) 	120,00 kg (Orbiter and Cargo)	14,000 kg	Space Shuttle	Operation duration: 1981-2011 Manned Spacecraft Hatch opening diameter: 0.8m Can berth to a hatch with a size of 1.27 × 1.27 m using the MPLM Accommodates unpressurized payloads Has a capability to support ISS reboost.
Dragon Space Exploration Technologies Corp., U.S. 	8,700 kg	3,000 kg (estimated)	Falcon 9	First flight: October, 2012 Commercially developed spacecraft (Successful first flight and the capsule return in December, 2010. Successful docking to the ISS in May, 2012.). Wide hatch opening: 1.27m x 1.27m Accommodates unpressurized payloads Pressurized cargo can return to Earth
Cygnus Orbital Sciences Corp., U.S. 	5,300 kg	2,000 kg	Antares	In Development Stage Commercially developed spacecraft Scheduled to start its logistics flight in 2013. Mitsubishi Electric Corp. (Japanese Company) participates in the development. Hatch opening diameter: 0.94m × 0.94 m

Annex 2: HTV Operations Overview

Common HTV operations overview is described below.

Operations on Flight Day (FD) 1

Summary

- Launch/Orbit insertion
- Post-insertion Auto Sequence (activation of the HTV subsystems, establishment of three-axis stabilized attitude control, self-check, acquisition of TDRS communications and initiation of communications with the HTV Mission Control Room (HTV MCR)
- Rendezvous Flight

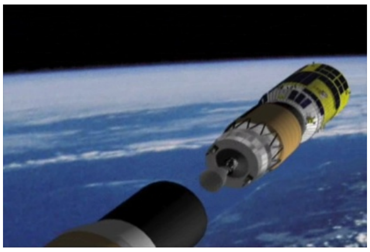
● Launch/Orbit insertion

The HTV will be launched from the Tanegashima Space Center (TNSC) aboard the H-IIB launch vehicle. There is only one launch opportunity daily because its launch time has to be adjusted with the time the ISS orbit plane passes over Tanegashima Island.

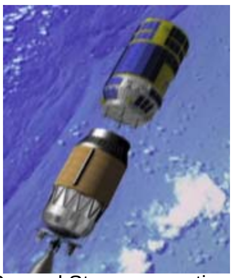
Lift-off of the H-IIB launch vehicle and launch of HTV2

Solid Rocket Boosters (SRB-A) separation will occur two at a time, 2 minutes 4 seconds and 2 minutes 7 seconds respectively after the launch. The fairing will separate 3 minutes 40 seconds after the launch. The First Stage Engine will burn out at 5 minutes 47 seconds and the First Stage separation will take place 5 minutes 54 seconds after the launch. Thereafter, the Second Stage Engine will be ignited to insert the HTV into the predetermined elliptical orbit at an altitude of 200 km (perigee) x 300 km (apogee) and an inclination of 51.6 degrees. The Second Stage Engine will burn out at 14 minutes 20 seconds and release the HTV 15 minutes 11 seconds after the launch.

Fairing separation



First Stage separation



Second Stage separation

● Post-Insertion Auto Sequence

Once the HTV is separated from the Second Stage of the H-IIB launch vehicle, the HTV will automatically activate the HTV subsystems, stabilize its attitude and perform self-checks on the HTV components. Then, the HTV will establish communications with NASA's Tracking and Data Relay Satellite (TDRS) and initiate communications with the HTV Mission Control Room (HTV MCR) at Tsukuba Space Center (TKSC).

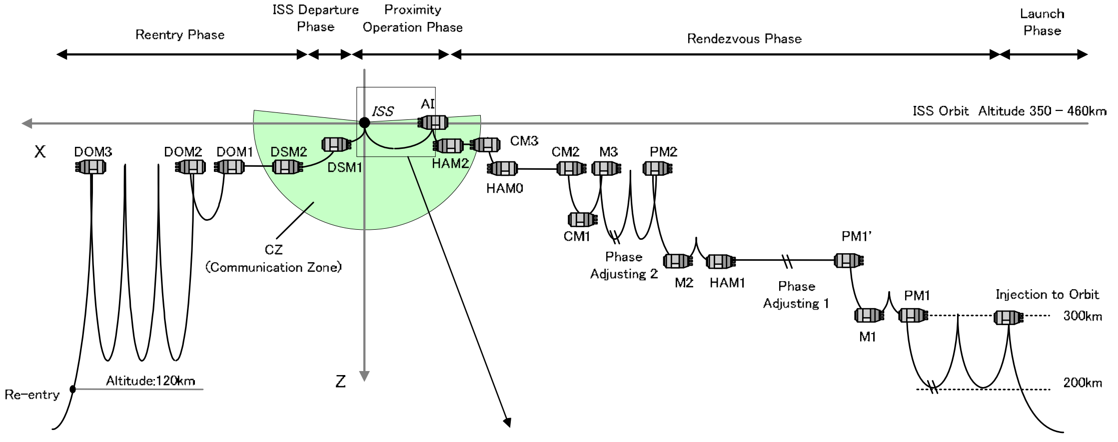
Rendezvous operations

Summary
- Orbit control for rendezvous flight

- **HTV rendezvous flight**

The HTV approaches the ISS taking 5-6 days increasing its orbital altitude.

The HTV2 in flight



See Annex 2-4 for an enlarged view.

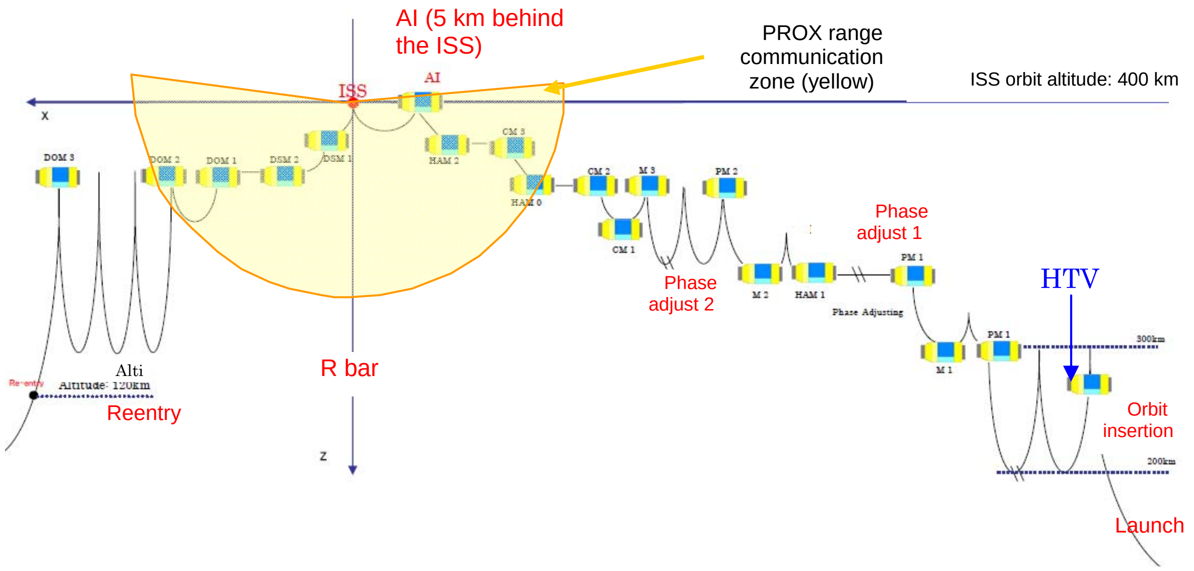
Proximity operation

Summary

- Proximity operation
- Final approach to the ISS
- Capture by the SSRMS on the ISS
- Berthing to the Common Berthing Mechanism (CBM) on the nadir side of Harmony (Node 2)
- Vestibule outfitting (e.g. installation of lines and cables)
- Activation of HTV power supply from the ISS / Switching of the communications line (from wireless communications to wired communications)

● Proximity operation

After the HTV reaches the "proximity communication zone," where it can communicate directly with the ISS, the HTV will establish communications with the Proximity Communication System (PROX) and start Relative GPS Navigation. The HTV will conduct maneuvers using the Relative GPS Navigation until it reaches the "Approach Initiation (AI) point," located about 5 km behind the ISS. At this point, the HTV makes relative stoppage against the ISS and maintains this distance from the ISS. (Both the ISS and HTV travel at a velocity of around 7.8km per second. If their speed difference is adjusted to zero, the two appear to stop relative to each other.)



From 90 minutes before the HTV reaches the AI point, HTV integration operations by the HTV MCR and the Mission Control Center at NASA's Johnson Space Center (JSC) in Houston (MCC-H) will begin. The HTV may have to adjust and reschedule its flight timeline up to 24 hours during the rendezvous phase since the HTV proximity operation will have to be performed during ISS crew on-duty hours.

● Final approach to the ISS (See the figure on the next page)

After the final approach is approved by the MCC-H, the HTV MCR will command the HTV to begin the AI maneuver (final approach to the ISS).

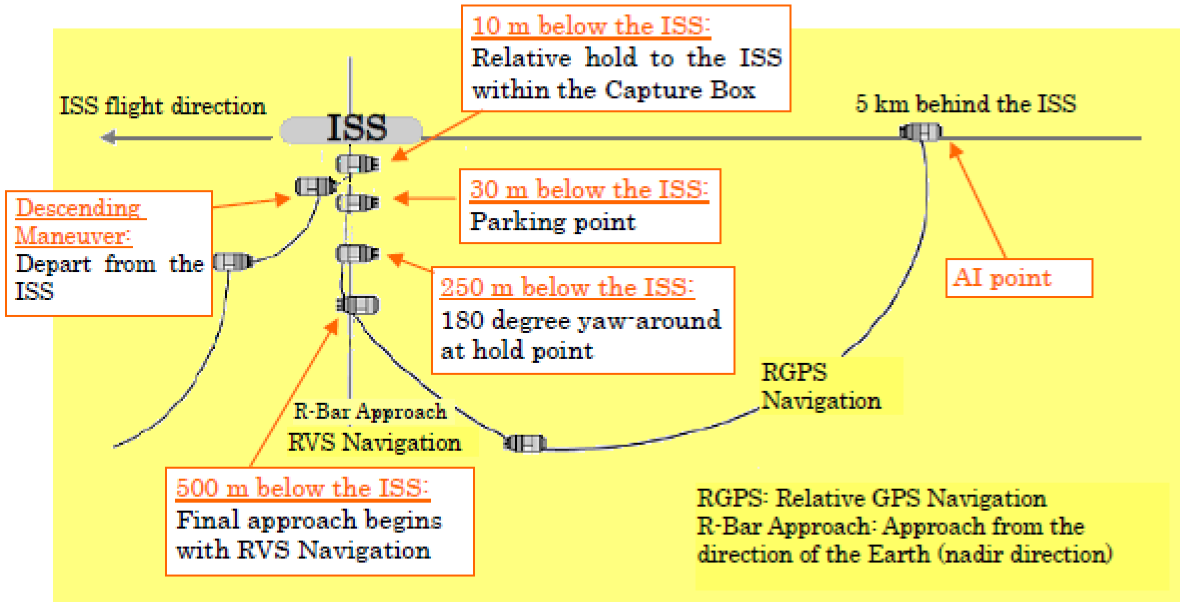
The HTV will move from point AI to RI, located approximately 500 meters below the ISS (on the R-bar), guided by Relative GPS Navigation. By reflecting a laser from the "Rendezvous Sensor (RVS)" on the Laser Rader Reflector mounted on the nadir side of Kibo's on-board experiment room to confirm locations, the HTV will approach the ISS.

The HTV will automatically hold its approach at 250 meters below the ISS (hold point) and at 30 meters below the ISS (parking point). Eventually, the HTV will make a relative stop at around 10 meters below the ISS and maintain its distance from the ISS.

During the final approach, the ISS crew can send commands from the HTV Hardware Command Panel (HCP), including "HOLD," "RETREAT" and "ABORT," to the HTV in the event of an emergency.

At the holding point located 250 meters below the ISS, the HTV will perform a (yaw-around) to change the directions of the main thrusters to the opposite direction. This allows the HTV to perform a Collision Avoidance Maneuver (CAM), which safely moves the HTV away from the ISS in a forward direction, in the event of an emergency.

HTV capturing and berthing to the ISS



- Capture by the SSRMS

Once the HTV MCR confirms that the HTV has reached 10 m below the ISS and is maintaining this distance, the ISS crew will send commands to disable the HTV thrusters (free drift state).

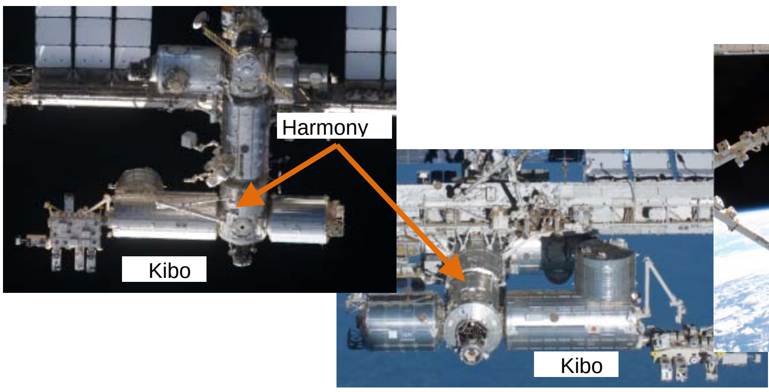
Subsequently, the station's 17.6 m-long robotic arm SSRMS will hold the Grapple Fixture (FRGF) of the HTV.

Capture of the HTV (HTV1)

FRGF

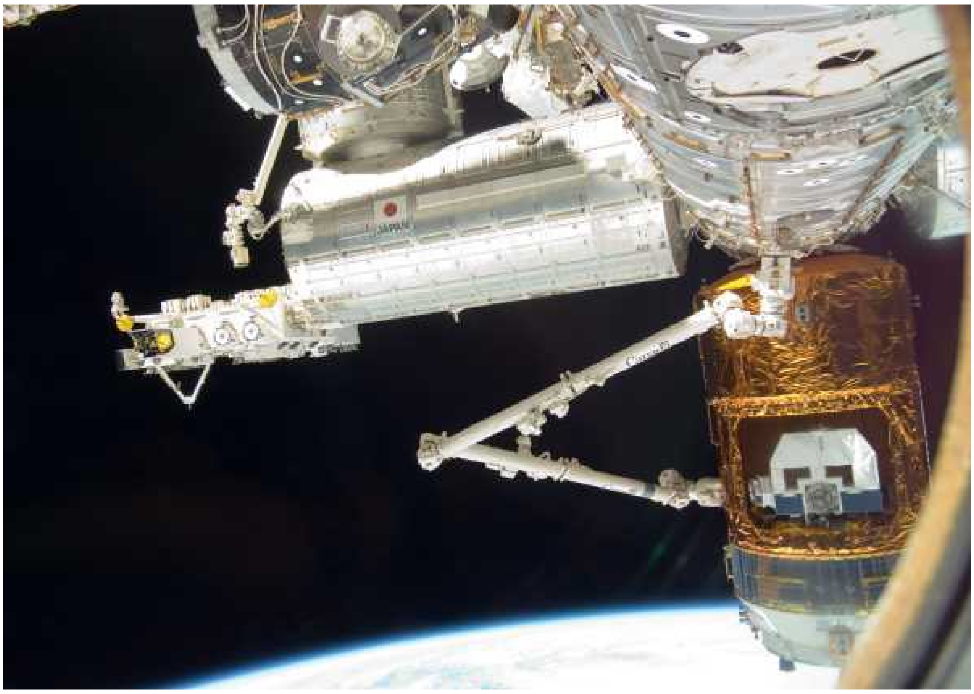
- Berthing to Harmony (Node 2)

The HTV being grappled by the SSRMS will be berthed to the Common Berthing Mechanism (CBM) at the nadir port (on the Earth-facing side) of Harmony.



(continued) HTV capturing and berthing to the ISS

SSRMS Console used to grapple the HTV (HTV1 mission) (Credit: JAXA/NASA)



The HTV1 berthing to the ISS (Credit: JAXA/NASA)

Crew Ingress Operation

Summary

- Crew Ingress to the Pressurized Logistics Carrier (PLC)
- Removal of the Controller Panel Assemblies from the CBM
- Hatch opening
- Activation of the Inter-Module Ventilation (IMV)
- Transfer of the Station's Portable Fire Extinguishers (PFEs) and Portable Breathing Apparatus (PBA) into the HTV

- Crew Ingress to the Pressurized Logistics Carrier (PLC)

In preparation for ingress, the ISS crew will perform vestibule outfitting (removal of the heat-insulating covers, removal of the Controller Panel Assemblies from the CBM and installation of electric cables, communication lines and air duct) between the Pressurized Logistics Carrier (PLC) and Harmony. Once this is done, the ISS crew will equalize the air pressure, while the HTV MCR will turn on the lights inside the PLC and open its hatch. The crew will view the inside from the central window of the CBM hatch and check if there is any abnormality e.g. floating objects.

Once the hatch is opened, the Inter-Module Ventilation (IMV) will be activated and air between Harmony and the PLC will be circulated with the circulation fan unit. Then, the ISS crew will enter the PLC (wearing masks and goggles initially for safety), confirm the lack of any abnormality by obtaining air samples, and install the station's Portable Fire Extinguishers (PFEs) and Portable Breathing Apparatus (PBA) inside the PLC.

Inside of the HTV PLC (HTV2)

Operations from HTV ingress to HTV separation

Summary

- Cargo transfer from the HTV to the ISS
- Loading trash and used materials into the HTV after cargo transfer

● Cargo transfer from the HTV to the ISS

The ISS crew will transfer Cargo Transfer Bags (CTBs) and other goods from the Pressurized Logistics Carrier (PLC) to the ISS.

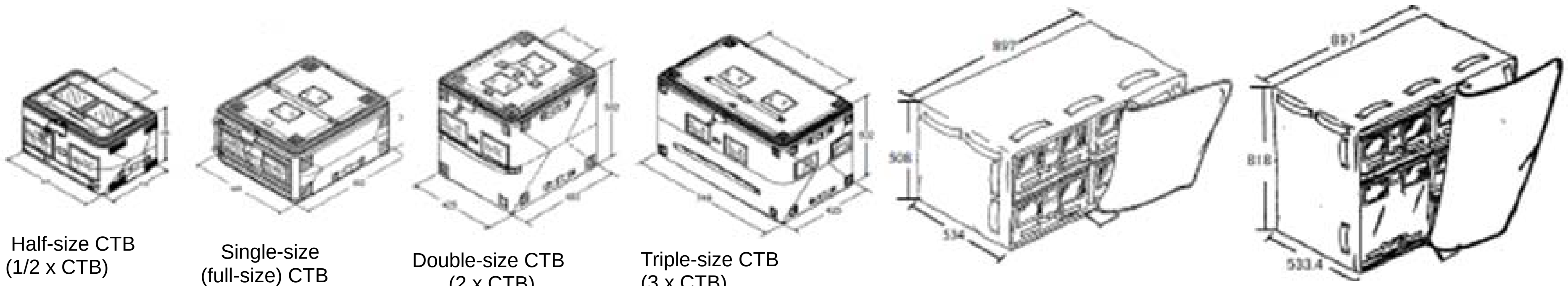
Astronaut Hoshide opening the hatch (HTV3)
(Credit: JAXA/NASA)

CTB containing foods, commodities or experiment samples

Left: A photo of crew members in the HTV2 (ESA/NASA)
Right: Astronaut Hoshide entering the HTV3 PLC wearing a mask and goggle

● Loading trash and used materials from the ISS to the HTV after cargo transfer

→ Please refer to “Trash loading into the HTV” section described later. Trash will be loaded into the HTV, even during cargo transfer operations, rather than being loaded after all supplies and goods are transferred to the ISS and the racks are emptied.



Half-size CTB
(1/2 x CTB)

248 × 425 × 235 mm

Single-size
(full-size) CTB
(1 x CTB)

Basic single-size (full-size) CTB measures 502 mm (L) x 425 mm (W) x 248 mm (H)

Double-size CTB
(2 x CTB)

502 × 425 × 502 mm

Triple-size CTB
(3 x CTB)

749 × 425 × 502 mm

M02 Bag
(4 x CTB)

534 × 897 × 508 mm

M01 Bag
(6 x CTB)

749 × 897 × 508 mm or less

Figure A2-1 Several sizes of CTBs are available to transfer goods to the ISS

【Potable water delivery】

The HTV2 delivered potable water for the first time as the HTV. As the second delivery, the HTV4 accommodates increased amount of potable water and delivers 24 bags (480 liters) of potable water, compared with (4 bags) 80 liters in the HTV2. The water is Tanegashima Island’s purified water, in which a small amount of iodine (sterilizing agent) is added, meets NASA's potable water quality requirements. The purified water is packed in NASA’s Contingency Water Container-Iodine (CWC-I).

Figure A2-2　Above: A water bag (CWC-I, labeled purple) (left) and the packed image (right) (In the HTV2 mission)
Below: HTV4 mission

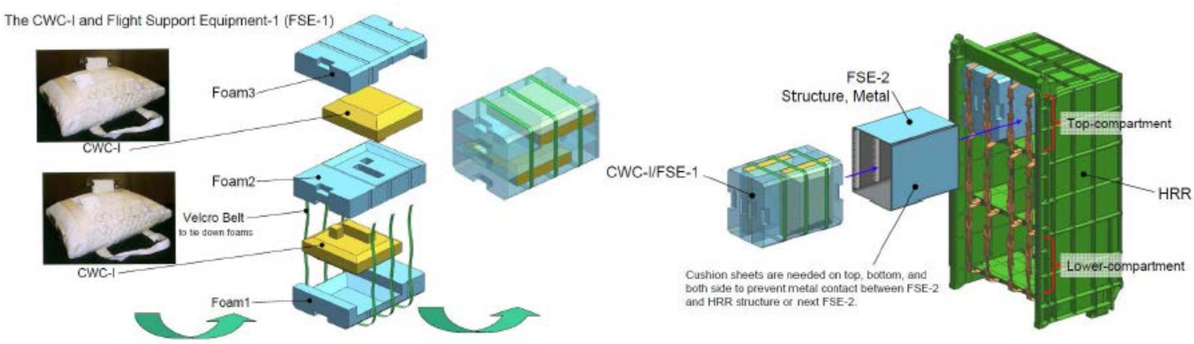


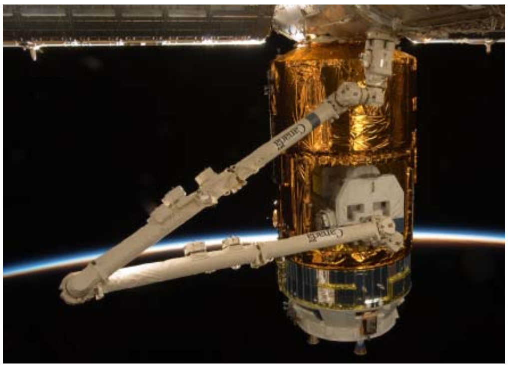
Figure A2-3 Water loading image

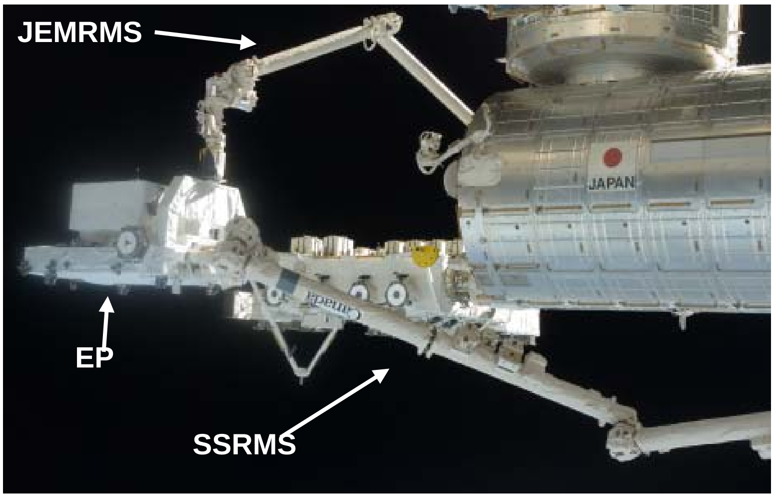
Exposed Pallet (EP) Transfer Operations

Summary
- Removal of the Exposed Pallet (EP) from the HTV Unpressurized Logistics Carrier (ULC)
- Temporary Installation of the EP on Kibo's Exposed Facility (EF)

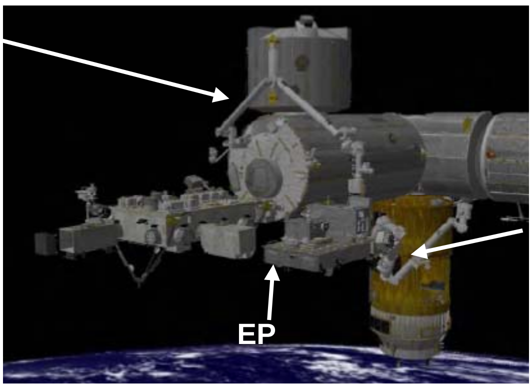
● Removal of the Exposed Pallet (EP) from the HTV Unpressurized Logistics Carrier (ULC) / Temporary Installation of the EP on Kibo's Exposed Facility (EF)

The Exposed Pallet (EP) will be removed from the HTV Unpressurized Logistics Carrier (ULC) by the SSRMS. The EP will then be handed over to Kibo's robotic arm (JEMRMS). The JEMRMS will attach the EP on Kibo's Exposed Facility (EF) for temporary installation.


The SSRMS removing the EP from the ULC



The EP being handed over from the SSRMS to the JEM Remote Manipulator System (JEMRMS) for temporary installation on the EF (image of HTV1)



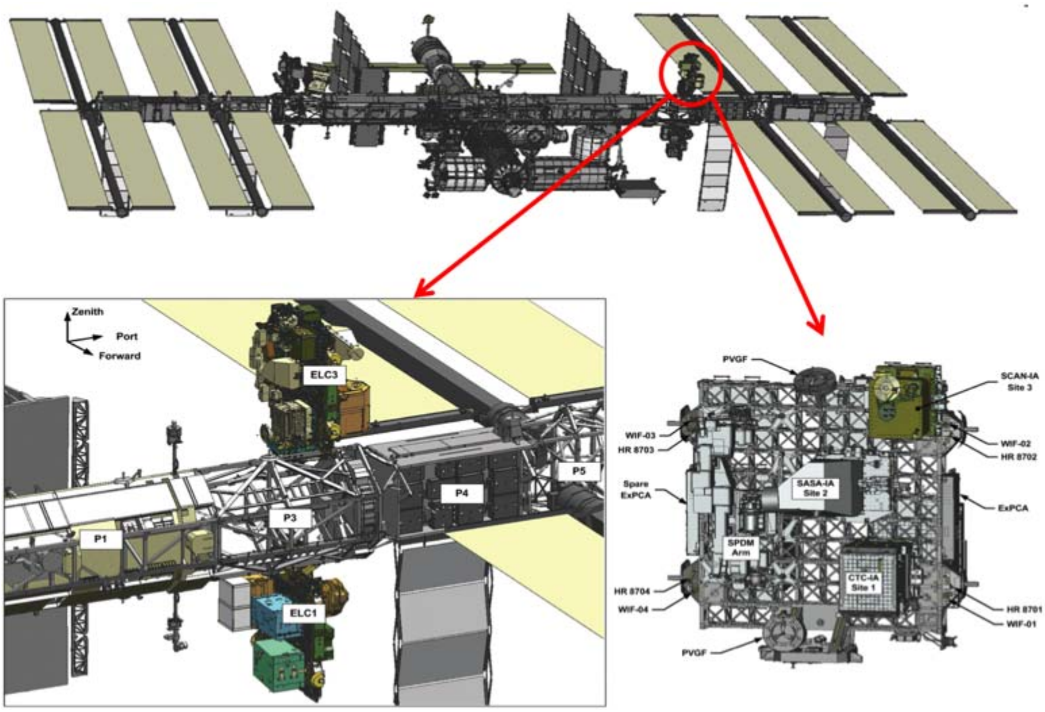
Transfer Operations by DEXTER (SPDM) and JEMRMS Operations

Summary

- Transfer of unpressurized cargo loaded on the EP to the installation site

- The JEMRMS is used to transfer the EP and install it on Kibo's EF. (Note: The HTV4 mission adopts this transfer method even though it delivers only NASA's cargo)

- The Canadian Special Purpose Dexterous Manipulator (SPDM), called DEXTER, grappled on the edge of the SSRMS, is used to transfer NASA's payload or the ORUs. These JEMRMS and SPDM operations are performed from the ground. JEMRMS manipulation from the ground was performed for the first time in the HTV3 mission. NASA and control centers in Canada and Japan make coordination to perform the international operations from the ground.



Examples of installation location of unpressurized cargo (ELC-3)

Reinstallation of the Exposed Pallet (EP)

Summary

- Reinstallation of the Exposed Pallet (EP) into the ULC

● Reinstallation of the Exposed Pallet (EP) into the ULC

After cargo transfer from the EP to the ISS is completed, the empty EP (or with discarded items) will be re-stored in the HTV Unpressurized Logistics Carrier (ULC).

First, Kibo's robotic arm (JEMRMS) will remove the EP from the EF. Then the EP will be handed over to the Space Station Remote Manipulator System (SSRMS). Finally, the EP will be reinstalled into the ULC.

EP being temporally installed to the edge of the EF (HTV1)

EP being reinstalled into the ULC (HTV3)

Trash loading into the HTV

Summary

- Trash loading from the ISS to the HTV

- Trash loading from the ISS to the HTV

After cargo transfer from the HTV PLC to the ISS, the station's discarded items will be loaded into the PLC of the HTV3.

A trash list will be prepared a few weeks before HTV's unberthing from the ISS. Since it is necessary to consider the proper position of the center of gravity during trash loading, items to be loaded need to be coordinated between NASA and JAXA.

Loading trash and installing the i-Ball (Credit: JAXA/NASA)
(Astronaut Hoshide holding the i-Ball)

Unberthing Preparation (On the day before unberthing from the ISS)

Summary

- Preparation for HTV unberthing (Removal of lights, portable fire extinguishers and portable breathing apparatus, installation of CPAs on the CBM, deactivation of IMV system, and switching of the communication mode from wired to wireless)
- HTV hatch closure

● Preparation for HTV unberthing

For reuse purposes, reusable items like lights on-board the HTV will be removed and transferred to the ISS before HTV unberthing. Safety tools deployed inside the PLC, such as Portable Fire Extinguishers (PFEs) and Portable Breathing Apparatus (PBA), will also be removed and transferred back to the ISS. Lastly, ISS crew will de-mate cables in the vestibule and close the hatches between the HTV and Harmony. Then, the Inter-Module Ventilation (IMV) system will be deactivated.

Left:
Portable Fire Extinguisher (PFE)

Right:
Portable Breathing Apparatus (PBA)

● Installation of the Controller Panel Assemblies (CPAs)

ISS crew will install 4 CPAs which will control the actuators of the 16 bolts on the CBM.

Four silver boxes shown are CPAs

Unberthing operations (On the Unberthing Day)

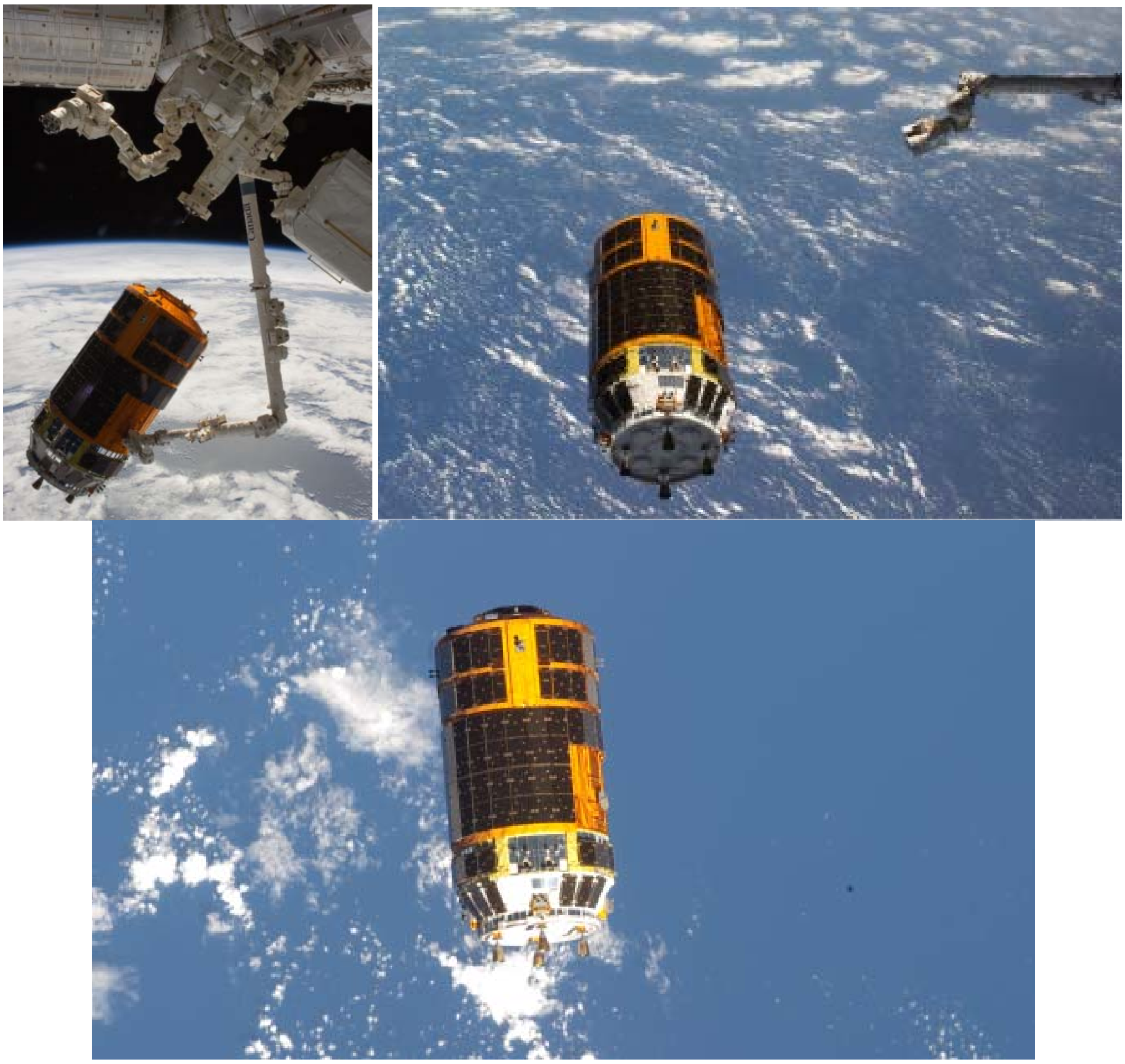
Summary

- Deactivation of HTV Power Supply from the ISS
- Vestibule cable/wire de-mating
- HTV unberthing

- Unberthing and release of the HTV from the ISS

The HTV is unberthed form the ISS and released into space according to the following procedures:

1. The HTV will be grappled by the SSRMS.
2. The Common Berthing Mechanism (CBM) between the HTV and Harmony will be de-mated. (After the air between the 2 hatches will be vacuumed and decompressed, the crew will send a command (usually from a laptop PC) to the CBM to release 16 bolts and unlock the CBM.)
3. The SSRMS will move the HTV to the release position.
4. HTV Guidance Navigation Control (GNC) will be activated.
5. HTV Propulsion System will be activated. (Switching from the thruster propulsion halt state to the propulsion activation state.)
6. The SSRMS will release the HTV, and the HTV will perform departure maneuver to depart from the ISS orbit.



HTV2 release

Reentry Operations

Summary

- Deorbit maneuvers
- Reentry, Data recording during reentry

● Reentry and data recording during the reentry

The HTV performs deorbit maneuvers, and then, reenter the Earth's atmosphere.

From the HTV3 onward, reentry data recorder "i-Ball" was carried to obtain data during its reentry and breakup. i-Ball records the HTV's reentry and breakup and is expected to understand how the vehicles are broken during the reentry and to minimize the warning area of the splashdown.

【Reference】ATV-1's Reentry photographed from an airplane (http://atv.seti.org/)

HTV3's fiery reentry was taken by the i-Ball (Credit: JAXA/IHI Aerospace)

After the HTV departs from the ISS orbit, it conducts two orbital maneuvers. These maneuvers insert the HTV into the preparatory orbit for reentry. In the pre-reentry orbit, timing of deorbit maneuvers is adjusted. The HTV enters the atmosphere with the deorbit maneuvers. The HTV's planned splashdown area is the South Pacific Ocean, where human safety concerns are very small. Other international partners, such as ESA and Russia, used this area as an expected debris falling area for oceanic disposal of their spacecrafts (such as Russian Mir Station, Progress cargo spacecrafts, and ATV).

Under the international rule, when disposing spacecrafts, a NOTAM has to be issued beforehand so that the ships and airplanes will not enter the expected splashdown area.

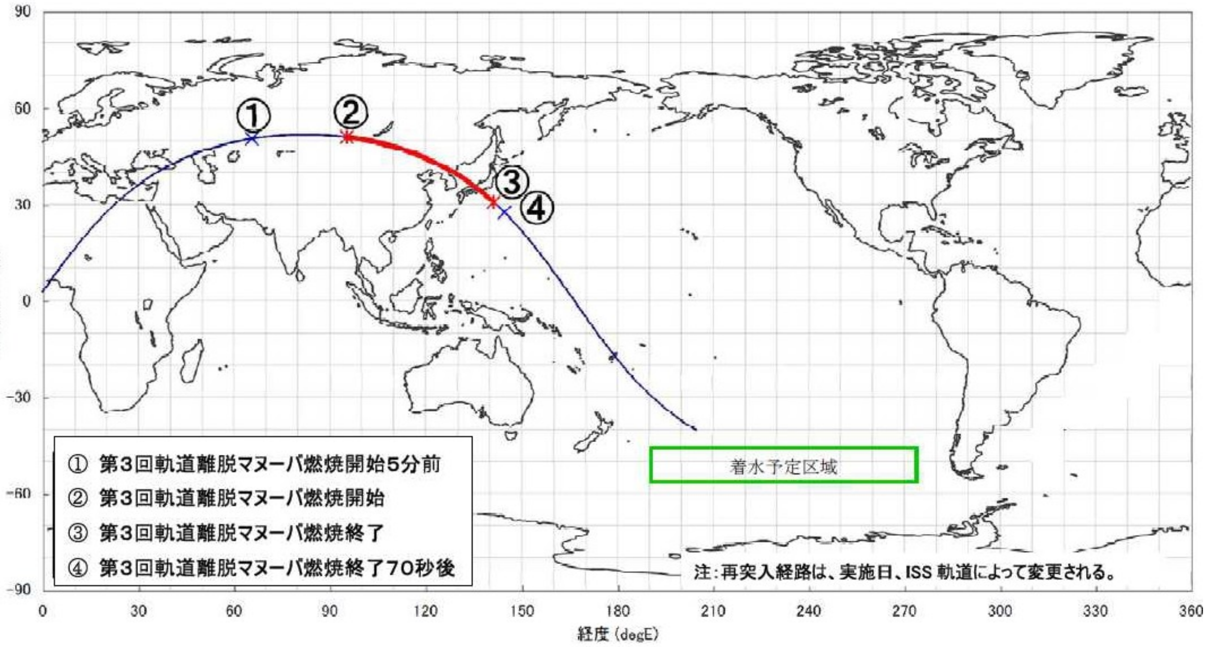


Figure A2-4 HTV's projected reentry path
Expected deorbit burn duration (red line) and HTV splashdown area (green box)

Reference: Ministry of Education, Culture, Sports, Science and Technology (MEXT) website
http://www.mext.go.jp/b_menu/shingi/uchuu/reports/1321150.htm

KOUNOTORI” (HTV) Operations Control

After separated from the H-IIB launch vehicle, the HTV will automatically activate the HTV subsystems, stabilize its attitude, and perform self-checks on the HTV components. Then, the HTV will establish communications with the NASA TDRS and initiate communications with the HTV MCR located in the Space Station Operations Facility (SSOF) at the Tsukuba Space Center (TKSC) via the NASA Mission Control Center.

Once communications between the HTV and the HTV MCR are established, HTV operations and flight control by the HTV MCR will begin. The HTV MCR will monitor HTV’s telemetry and flight data, and send commands from the ground for controlling the HTV subsystems and maneuvering its flight.

From 90 minutes before the HTV reaches 5 km behind the ISS (Approach Initiation (AI) point), the HTV MCR and MCC-H at the NASA Johnson Space Center will begin collaboratively operating the HTV mission.

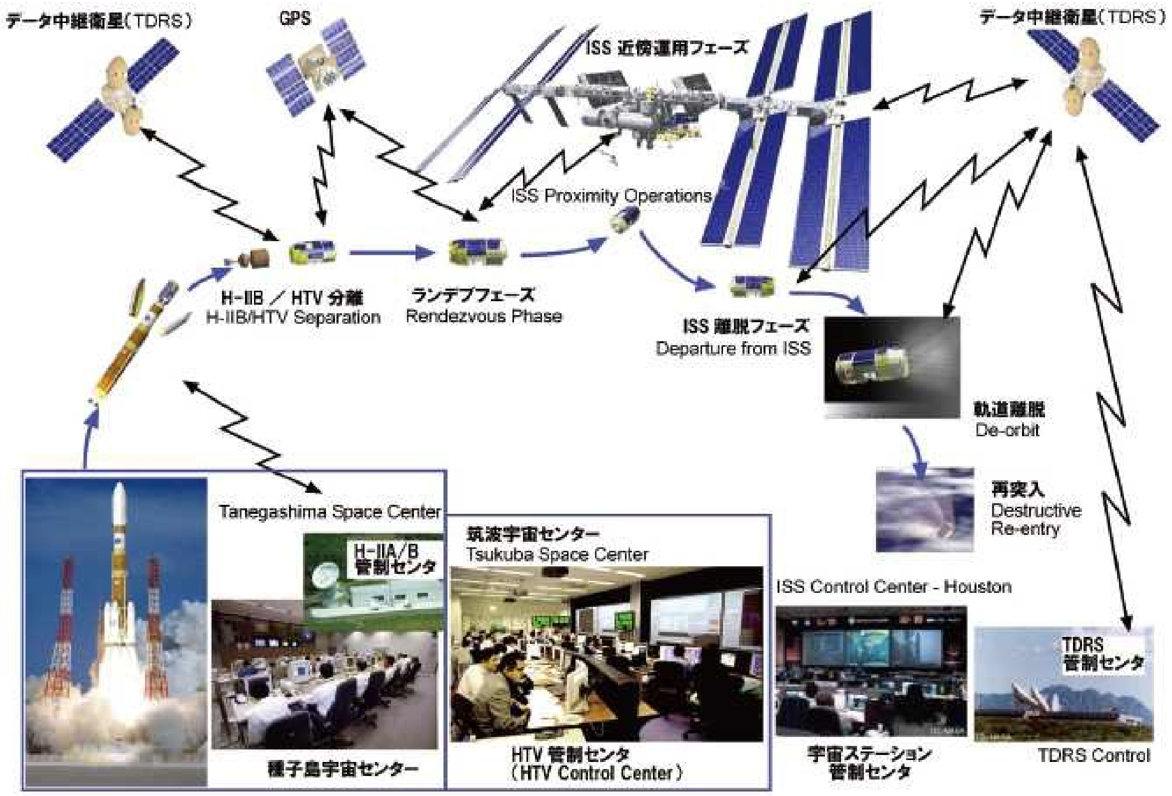


Figure A3-5 HTV Operation Control Overview

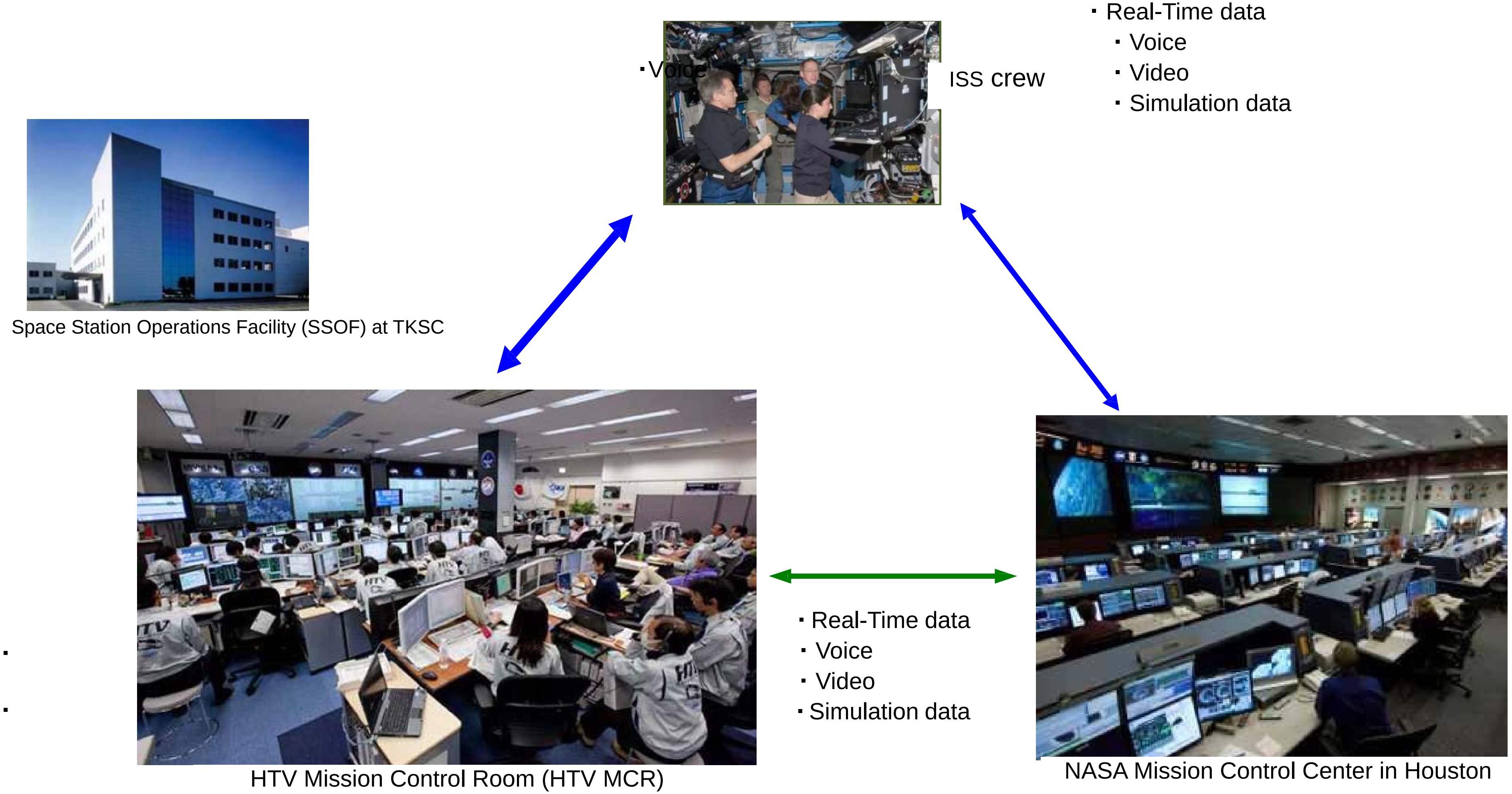


Figure A2-6 HTV Mission Control Room (HTV MCR)

Reference: HTV's representative cargo items delivered to the ISS

Below is the major cargo items that the HTV1-3 delivered to the ISS.

(1) Payloads in the EF

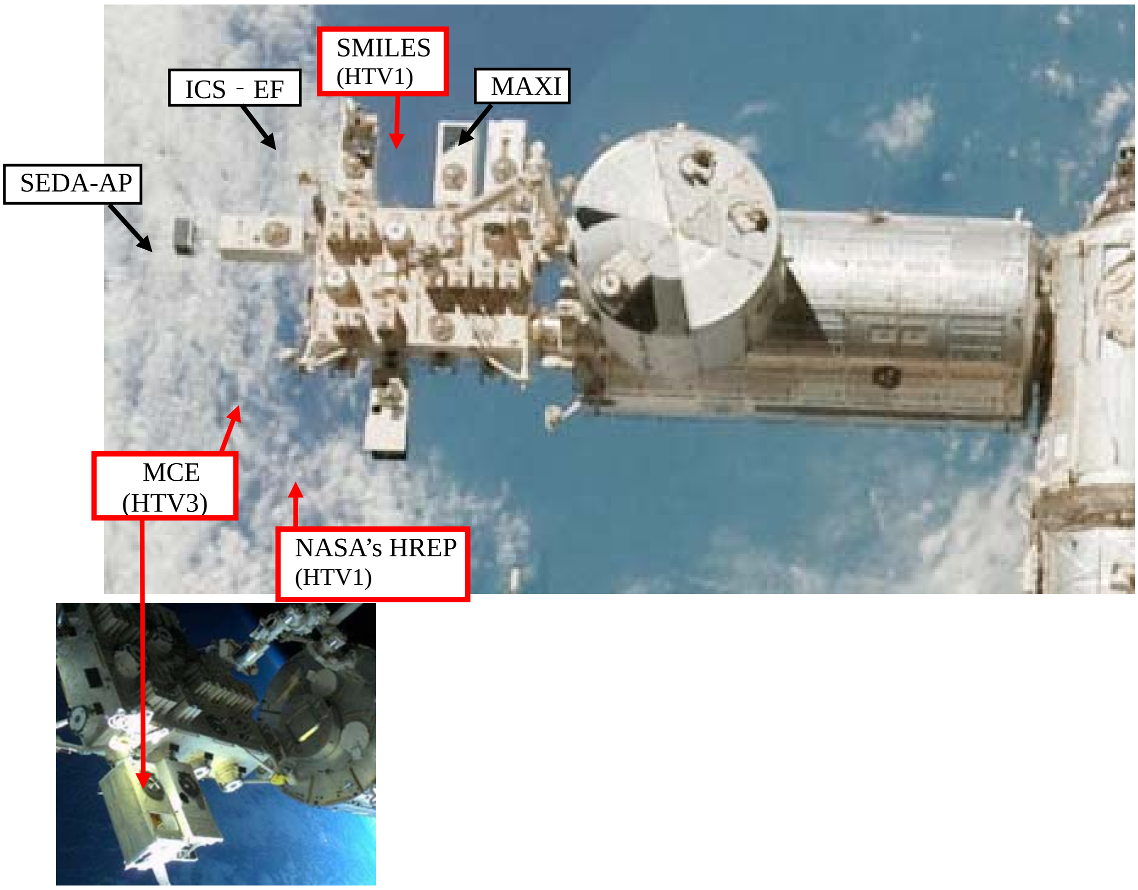


Figure A2-7 EF payloads delivered by the HTV1-3

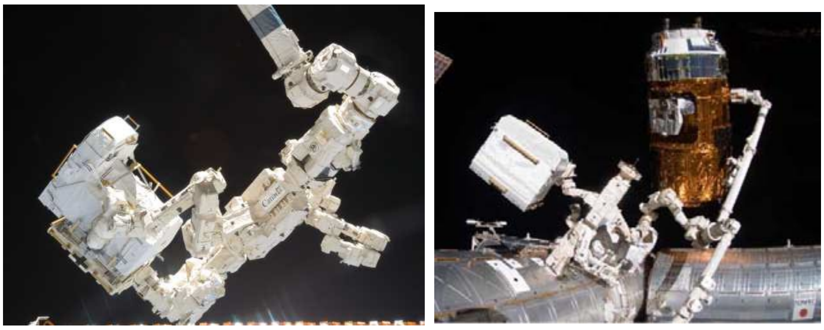


Figure A2-8 US ORUs: (Flex Hose Rotary Coupler: FHRC) and Cargo Transport Container: CTC (Delivered by the HTV2)

Figure A2-9 US payload SCAN Testbed (Delivered by the HTV3)

(2) Major pressurized cargo items other than general items such as space food, drinking water, and clothes, etc.

(3)

Figure A2-10 Small Fine Arm (SFA) of the Kibo's Remote Manipulator System (JEMRMS) (Delivered by the HTV1)

Figure A2-11 Gradient Heating Furnace (GHF), Multi- purpose Small Payload Rack: MSPR (Delivered by the HTV2)

Figure A2-12 JEM Small Satellite Orbital Deployer (J-SSOD) (Delivered by the HTV3)

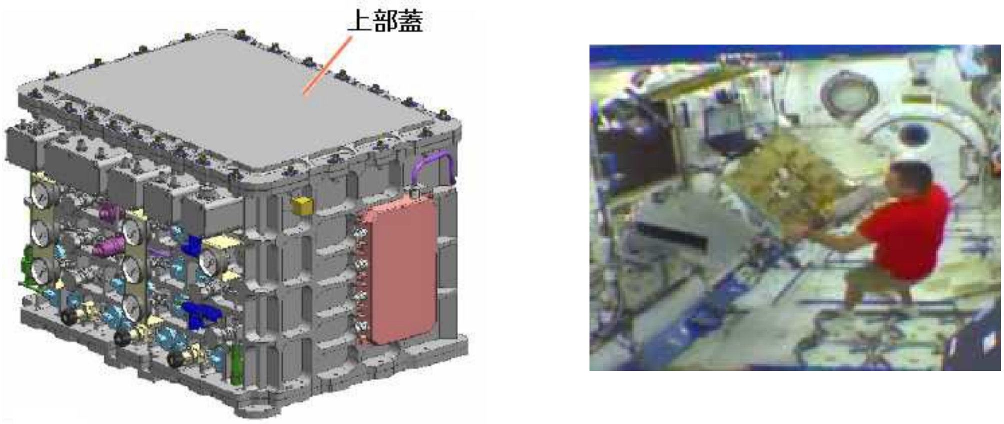


Figure A2-13 Chamber for Combustion Experiment (CCE) (Delivered by the HTV2)

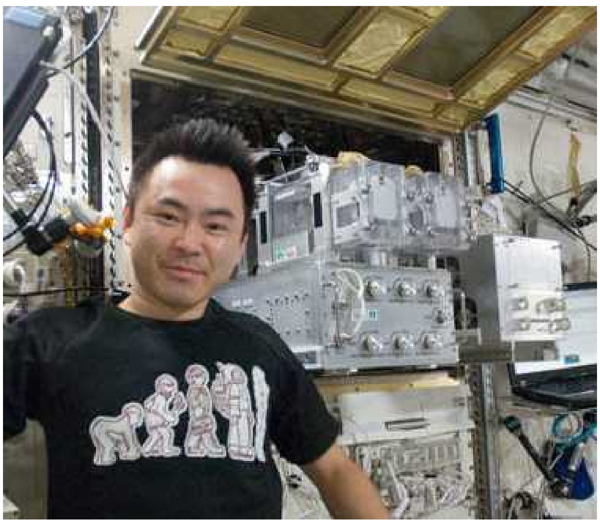


Figure A2-14 Aquatic Habitat (AQH) (Delivered by the HTV3)

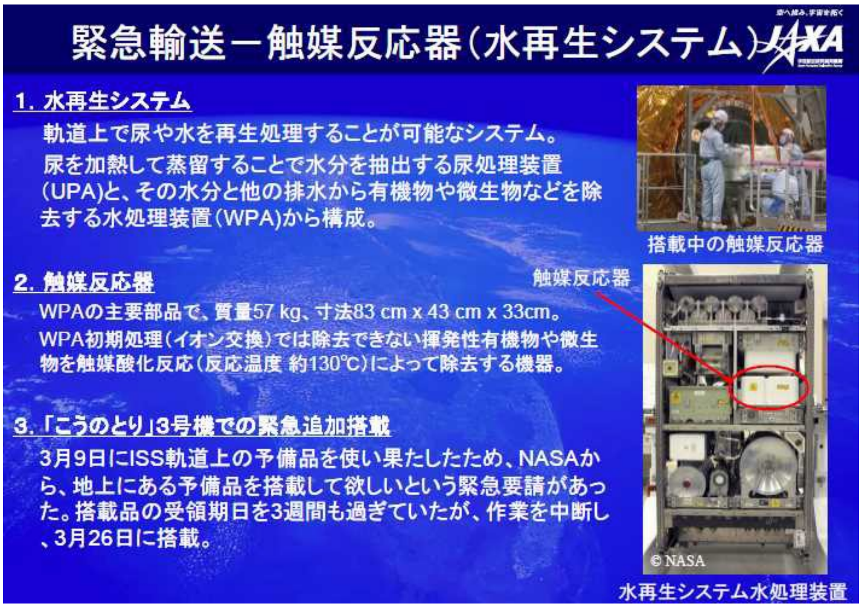


Figure A2-15 Catalytic Reactor (a part of Water Recovery System (WRS))
delivered as expedite shipment upon a request from US
(Delivered by the HTV3)

Annex 3: More information on i-Ball and CubeSats deployment

(1) Reentry data recorders

In the HTV2 mission, the ReEntry Breakup Recorder (REBR) developed by Aerospace Corporation in the USA was delivered, and the REBR successfully obtained data of the space vehicle being broken up during reentry for the first time in the world.

The HTV3 carried the REBR and also domestically produced reentry data recorder (i-Ball) to make another attempt at collecting data during reentry. The HTV4 carries an i-Ball while it does not carry the REBR this time.

The Japanese i-Ball is a globular-shaped recorder that will fall down with a parachute after standing high heat with ablator and send data after splashdown via an iridium satellite. Although i-Ball will stay afloat for a while for data transmission, it will sink in the water eventually and will not be recovered.

As i-Ball does not have a mechanism of being released from the PLC of the HTV, it will be pushed out in the air at the time of HTV breakup. It is thus expected that the attitude of i-Ball will not get stable for a while after breakup. By taking multiple photos during the fall, i-Ball might be able to record the breakup scene of the HTV. If any image will be taken, we basically have an intention to publicize it. We will see if it will be successful or not.

Meanwhile, the camera installed in the PLC will be used to capture the temperature distribution inside the vehicle. As it is expected that breakup will start from the hatch and the surrounding area, the camera will be directed toward the hatch to record images of breakup.

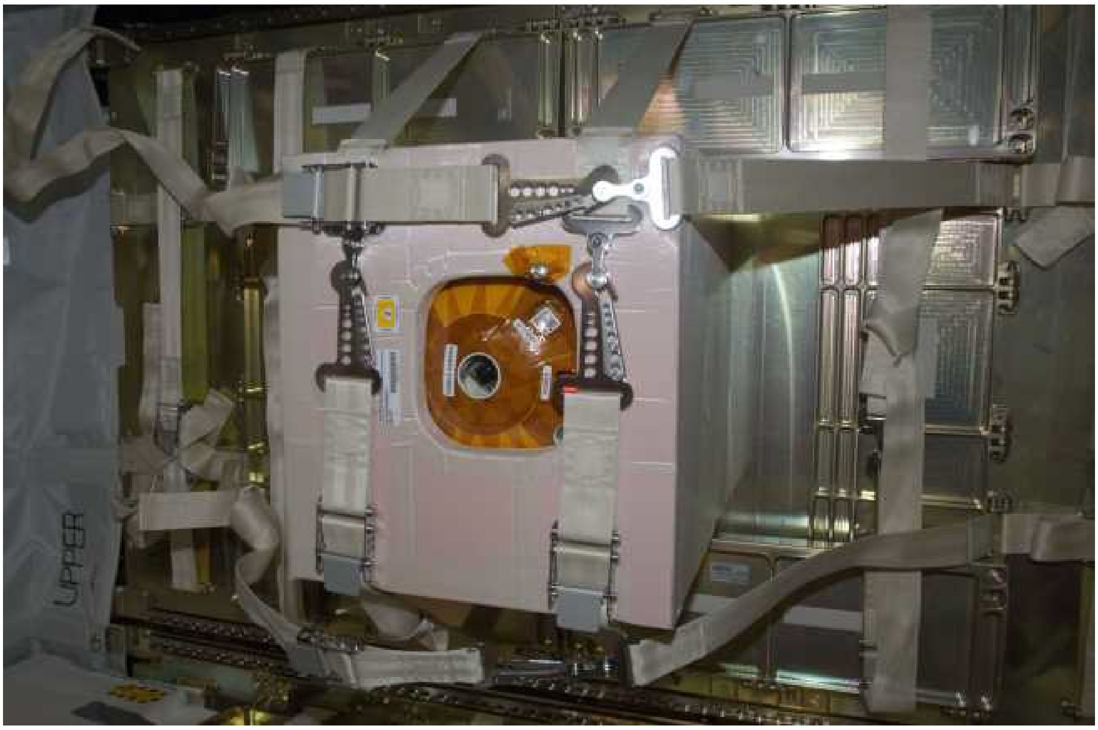


Figure A3-1
i-Ball installed on the PLC of the HTV3
(Before closing the hatch, astronauts strap it and turn on the power)

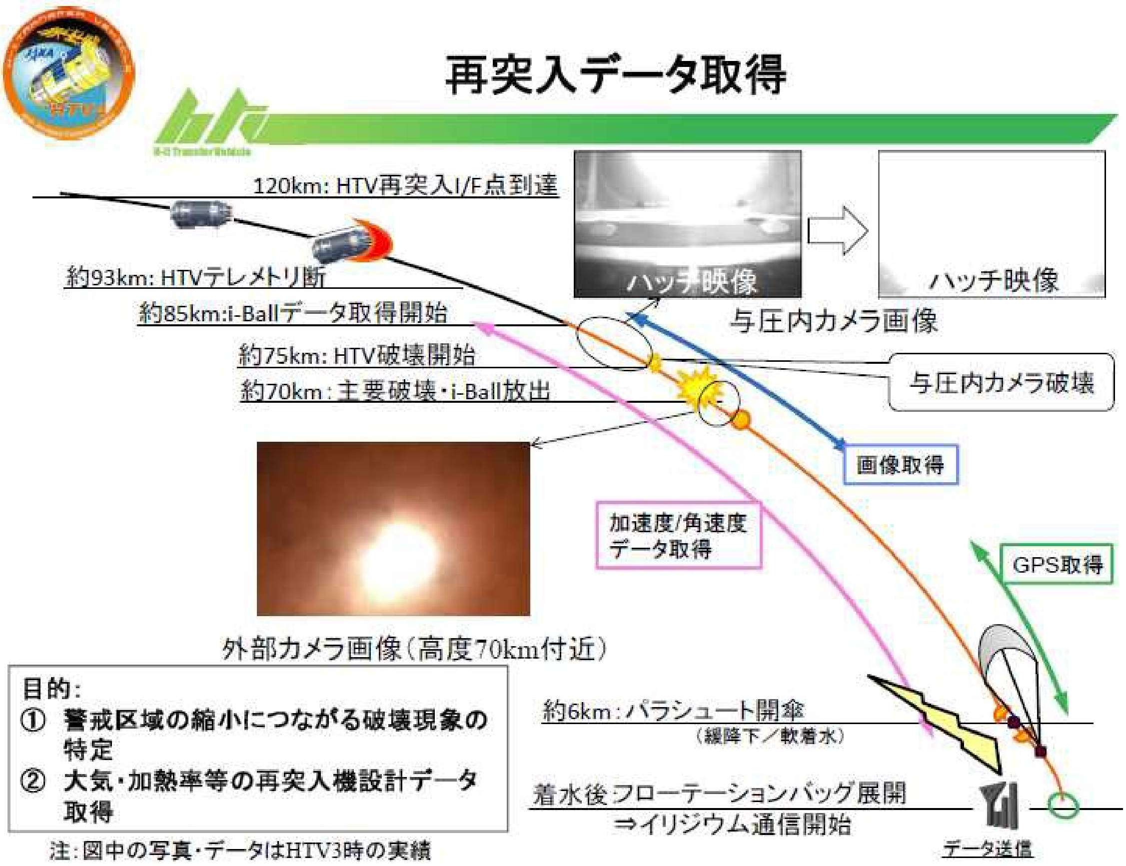


Figure A3-2 Planned data acquisition by the i-Ball during reentry

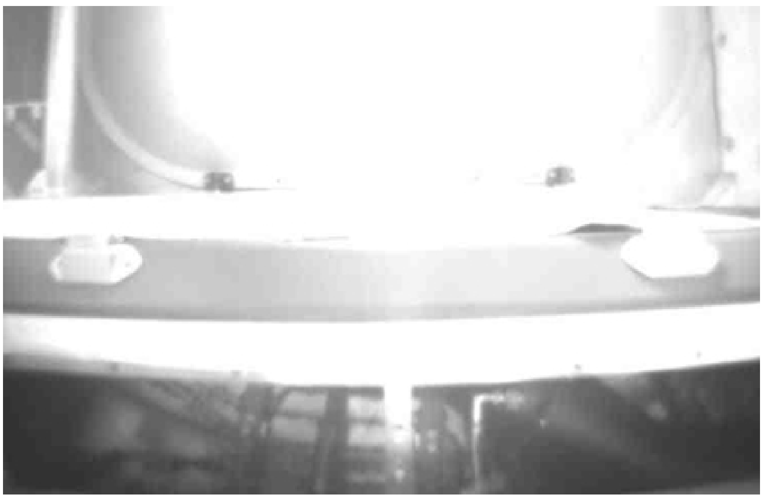


Figure A3-3 Hatch taken with the front camera (at about 80 km altitude)
(Credit: JAXA/IHI Aerospace)

Figure A3-4 A part of HTV taken by the rearward camera
(At about 70 km altitude)
(Credit: JAXA/IHI Aerospace)

(2) CubeSats

On the ISS, only Kibo is equipped with an airlock and robot arm. By using these, JEM Small Satellite Orbital Deployer (J-SSOD) can release small satellites without doing extravehicular activities (EVA).
The J-SSOD and 5 small satellites (CubeSats) were loaded on the HTV3 to perform the technology demonstration.

(2-1) Summary of the small satellite release procedures

1. Satellites will be installed in satellite-mounting cases, packed in soft bags and transported to the ISS by vehicle. CubeSats were carried on the HTV so far, but transportation is also possible via resupply vehicles owned by Russia, the USA or Europe.

2. After arrival at the ISS, the soft bags will be transferred to Kibo.
3. After opening the inner hatch of Kibo's airlock, the airlock slide table will be extended inward the vehicle.
4. The JEM-Small Satellite Orbital Deployer (J-SSOD) mounted with satellites and the Multi Purpose Experiment Platform (MPEP) of the parent arm will be attached to the adapter of the airlock slide table. (While in this state, an operation check will be performed to confirm no abnormality.)
5. After housing the slide table inside the airlock, the inner hatch of the airlock will be closed and then be depressurized.
6. After opening the outer hatch of the airlock, the airlock slide table will be extended outside the vehicle.
7. By grappling the MPEP with Kibo's robotic arm, the platform will be released from the slide table.

8. The robotic arm will move the MPEP to a release position, and ensure exact positioning.
9. Following a command from the Kibo's laptop or from ground, a satellite will be released from the J-SSOD (one side). On completion, another satellite will be released from the other side of the J-SSOD. Satellites are pushed out via spring loading when the cam on the J-SSOD is rotated and the front lid is opened. (3 satellites can be released altogether with the 1U type.)
10. The robotic arm will move the MPEP back to the airlock slide table, the hatch will be closed for repressurization and the J-SSOD will be retrieved back into the vehicle.
11. It is set so that satellite antennas will not unfold and there will be no radio emissions for 30 minutes after release.

Figure A3-5 MPEP and J-SSOD installed in the Kibo's airlock

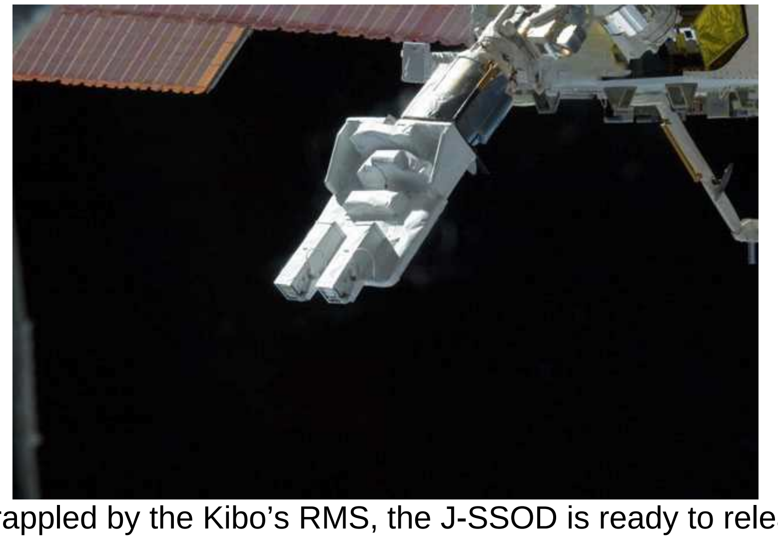


Figure A3-6 Grappled by the Kibo's RMS, the J-SSOD is ready to release CubeSats

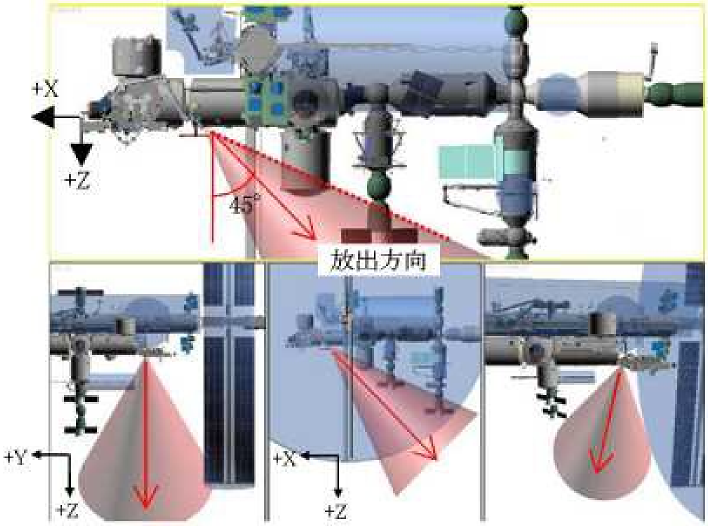


Figure A3-7 Images of CubeSats release operations and release angles

Figure A3-8 CubeSats
3 CubeSats that were transported on the HTV3 and released in October, 2012

(2-2) About small satellites (CubeSats)

Small satellites come many different types. The J-SSOD releases 10cm-cube, miniaturized satellites called CubeSats that can be held in one hand. Their sizes and specifications are internationally standardized: a CubeSat sized 10 × 10 × 10 cm (weighing 1.33 kg or less) is called 1U, a 20 × 10 × 10 cm size is termed 2U and a 30 × 10 × 10 cm is called 3U. CubeSats were first launched into space on a rocket in June 2003 using the rocket's excess capacity. (Of the six CubeSats then launched, two came from Japanese universities.) Since CubeSats can be developed in a shorter period of time compared with ordinary satellites and are relatively inexpensive, they are mainly used by universities and companies for education, human resource cultivation and technical demonstrations.

In a satellite-carrying bag to be loaded in the J-SSOD, three 1Us, or one 2U and one 1U, or one 3U can be loaded, and will be released into space via spring loading.

Figure A3-9 CubeSat (Astronaut Hoshide holding a 1U-sized CubeSat in his left hand)

If released from the altitude of 400 km, small satellites reenter into the atmosphere at about 250 days after.

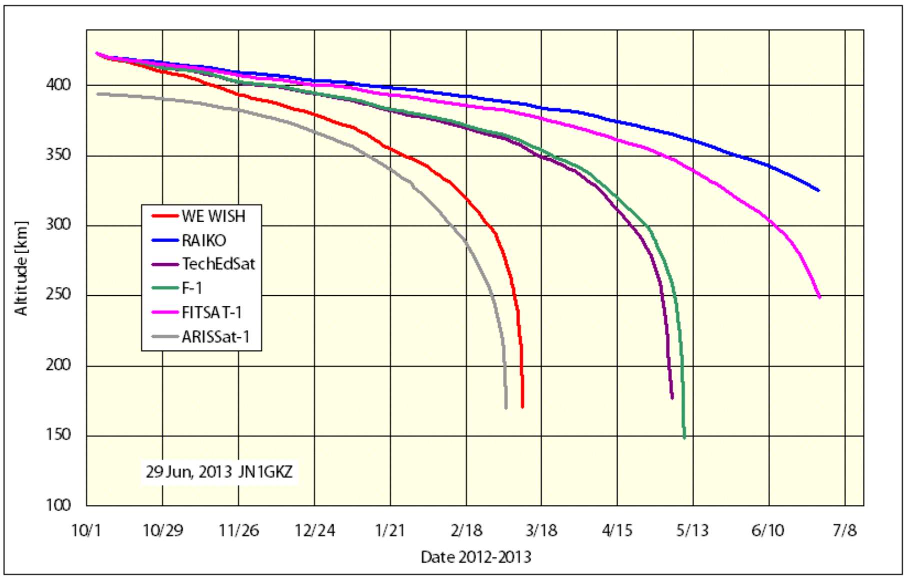


Figure A3-10 Altitude status of five CubeSats released from Kibo in October 2012

Altitude compared with ARISSat-1
(Masahiro Arai JN1GKZ)

http://amsat-uk.org/2013/06/29/fitsat-1-ham-radio-cubesat-to-de-orbit-reports-requested/
(ARISSat-1 shown as a comparison is a 30kg-satellite that was released during the Russian EVA in August, 2011.

Annex 4: HTV/ISS Acronym

Acronym	Name
ACU	Abort Control Unit
AI	Approach Initiation
AM	Avionics Module
AQH	Aquatic Habitat
ARO	One of the HTV operations control teams
ATOTIE	Advanced Technology On-orbit Test Instrument for space Environment
ATV	Automated Transfer Vehicle
BCS	Berthing Camera System
BDCU	Battery Discharge Control Unit
CALET	Calorimetric Electron Telescope
CAM	Collision Avoidance Maneuver
CANA	
CAPCOM	Capsule Communicator
CARGO	―
CBM	Common Berthing Mechanism
CCE	Chamber for Combustion Experiment
CG	Computer Graphics
CG	Center of Gravity
CM	Co-elliptic Maneuver
CMD	Command
COMM／DH	One of the HTV operations control teams
COTS	Commercial Orbital Transportation Services
COTS	Commercial off - the - shelf
CPA	Controller Panel Assemblies
CRS	Commercial Resupply Services
CTB	Cargo Transfer Bag
CTC	Cargo Transport Container
CWC-I	Contingency Water Container-Iodine
CZ	Communication Zone
DH	Data Handling
DMS	Data Management System
DOM	Deorbit Maneuver
DSM	Descending Maneuver
ECLSS	Environmental Control and Life Support System
EF	Exposed Facility
EFU	Exposed Facility Unit
ELC	EXPRESS Logistics Carrier
EMC	Electro-Magnetic Compatibility
EP	Exposed Pallet
EP	One of the HTV operations control teams
EPC	Exposed Pallet Controller
EP-MP	Exposed Pallet - Multi-Purpose
EPS	Electrical Power System
ESA	Earth Sensor Assembly
ESP-2	External Stowage Platform-2
EUVI	Extreme Ultraviolet Imager
ExHAM	Exposed Experiment Hadrail Attachment Mechanism
FD	Flight Day

Acronym	Name
FD	Flight Director
FDS	Fire Detection and Suppression
FHRC	Flex Hose Rotary Coupler
FOR	Flight Operations Review
FRAM	Flight Releasable Attach Mechanism
FROST	Freezer-Refrigerator of Stirling Cycle
FRR	Flight Readiness Review
FRGF	Flight Releasable Grapple Fixture
FWD	Forward
GCC	Guidance Control Computer
GF	Grapple Fixture
GHF	Gradient Heating Furnace
GHF-MP	GHF-Material Processing Unit
GLIMS	Global Lightning and Sprite Measurement Mission
GMT	Greenwich Mean Time
GNC	Guidance Navigation Control
GNC	One of the HTV operations control teams
GPS	Global Positioning System
GPSR	GPS Receiver
GSE	Ground Support Equipment
GTO	Geostationary Transfer Orbit
HAM	Height Adjusting Maneuver
HBCS	HTV Berthing Camera System
HC	Hand Controller
HCAM	HTV Cargo Attachment Mechanism
HCE	Heater Control Electronics
HCSM	HTV Connector Separation Mechanism
HCP	Hardware Command Panel
HDEV	High Definition Earth Viewing
HDM	Holddown Mechanism
HDTV-EF	High Definition TV Camera-Exposed Facility
HEFU	HTV Exposed Facility Unit
HGA	High Gain Antenna
HGAS	HTV GPS Antenna Subsystem
HPIU	HTV Payload Interface Unit
HRR	HTV Resupply Rack
HREP	Hyperspectral Imager for the Coastal Ocean (HICO)＆Remote Atmospheric & Ionospheric Detection System (RAIDS) Experimental Payload
HSM	Harness Separation Mechanism
HTV	H-II Transfer Vehicle
HTV-FLIGHT	HTV Flight
HTVGC	One of the HTV operations control teams
HTV OCS	HTV Operations Control System
HTVPLAN	One of the HTV operations control teams
HTVSYS	One of the HTV operations control teams
i-Ball	JAXA’s reentry data recorder
ICE Box	ISS Cryogenic Experiment Storage Box
ICS	Inter-orbit Communication System
IMAP	Ionosphere, Mesosphere, upper Atmosphere, and Plasmasphere mapping
IMMT	ISS Mission Management Team

Acronym	Name
IMV	Inter-Module Ventilation
IOS	Inter-Orbit Link System Inter-Orbit Communication System
I/O	Input / Output
IOCU	Input / Output Controller Unit
ICS	Inter-orbit Communications System
ISERV	ISS SERVIR Environmental Research and Visualization System
ISPR	International Standard Payload Rack
ISS	International Space Station
ITCS	Internal Thermal Control System
JAXA	Japan Aerospace Exploration Agency
JEF	JEM Exposed Facility
JEM	Japanese Experiment Module
JEMRMS	JEM Remote Manipulator System
JPM	JEM Pressurized Module
JSC	Johnson Space Center
J-SSOD	JEM Small Satellite Orbital Deployer
JST	Japanese Standard Time
KOS	Keep Out Sphere
KOZ	Keep Out Zone
LED	Light Emitting Diode
LGA	Low Gain Antenna
LP1	Launch Pad1
LP2	Launch Pad2
LRR	Laser Rader Reflector
MAXI	Monitor of All-sky X-ray Image
MBS	Mobil Base System
MBSU	Main Bus Switching Unit
MBU	Main Bus Unit
MCC	Mission Control Center
MCC-H	MCC-Houston
MCE	Multi-mission Consolidated Equipment
MET	Mission Elapsed Time
MGA	Medium Gain Antenna
MLI	Multi-Layer Insulation
MMH	Monomethylhydrazine
MON3	Mixed oxides of nitrogen contains 3% nitric oxide
MPEP	Multi-purpose Experiment Platform
MSPR	Multi-purpose Small Payload Rack
MT	Mobile Transporter
NASA	National Aeronautics and Space Administration
NET	No Earlier Than
OBS	On-Board Software
ORU	Orbital Replacement Unit
OSE	Orbital Support Equipment
PAS	Payload Attach System
P-ANT	PROX Antenna
P-BAT	Primary Battery
PBA	Portable Breathing Apparatus
PCBM	Passive CBM
PCS	Portable Computer System
PCU	Plasma Contactor Unit

Acronym	Name
PFE	Portable Fire Extinguisher
PEV	Pressure Equalization Valve
PIM	Position Inspection Mechanism
PIU	Payload Interface Unit
PLC	Pressurized Logistics Carrier
PLS	Proximity Link System
PM	Phase Adjusting
PM	Pressurized Module
PM	Propulsion Module
PMM	Permanent Multipurpose Module
POA	Payload and Orbital Replacement Unit Accommodation
POCC	Payload Operations Control Center
POIC	Payload Operations Integration Center
POWER	One of the HTV operations control teams
PROP	One of the HTV operations control teams
PROX	Proximity Communication System
Psi	Pounds per square inch
PSL	Permanent Solid-state Lighting
PSRR	Pressurized Stowage Resupply Rack
PVGF	Power& Video Grapple Fixture
RCS	Reaction Control System
REBR	Reentry Breakup Recorder
REX-J	Robot Experiment on JEM
RGPS	Relative Global Positioning System
RNDV	One of the HTV operations control teams
ROE	One of the HTV operations control teams
RPCM	Remote Power Controller Module
RSP	Resupply Stowage Platform
RVFS	Rendezvous Flight Software
RVS	Rendezvous Sensor
SARJ	Solar Array Rotary Joint
S-BAT	Secondary Battery
SCAM	Sample Cartridge Automatic Exchange Mechanism
SCAN Testbed	Space Communications and Navigation Testbed
SDR	Software Defined Radios
SEA	Small Experiment Area
SEDA-AP	Space Environment Data Acquisition equipment-Attached Payload
SFA	Small Fine Arm
SFA2	Second Spacecraft and Fairing Assembly Building
SIGI	Space Integrated GPS/INS(Inertial Navigation System)
SIMPLE	Space Inflatable Membranes Pioneering Long-term Experiments
SMILES	Superconducting Submillimeter-Wave Limb-Emission Sounder
SPDM	Special Purpose Dexterous Manipulator
SRB	Solid Rocket Booster
SRCA	System on/off Remote Control Assembly or Switch Remote Control Assembly
SSCC	Space Station Control Center
SSIPC	Space Station Integration and Promotion Center
SSM	Shockless Separation Mechanism
SSRMS	Space Station Remote Manipulator System
STBD	starboard

Acronym	Name
STP-H	Space Test Program-Houston
SYS-J	One of the HTV operations control teams
TDRS	Tracking and Data Relay Satellite
THERMAL	One of the HTV operations control teams
TRAJ	One of the HTV operations control teams
TRRJ	Thermal Radiator Rotary Joint
TSM	Tie-down Separation Mechanism
TKSC	Tsukuba Space Center
TNSC	Tanegashima Space Center
ULC	Unpressurized Logistics Carrier
ULF	Utilization and Logistics Flight
UPA	Urine Processor Assembly
UTA	Utility Transfer Assembly
VAB	Vehicle Assembly Building
VDC	Volt Direct Current
VISI	Visible and Infrared Spectral Imager
WB	Work Bench
WORF	Window Observational Research Facility
WPA	Water Processor Assembly
WV	Work Volume
ZOE	Zone of Exclusion