Research and Enlightenment of AIT Technology of Japanese H-II Transfer Vehicle (HIV)

Ruizhao Du, Hailin Dai, Wei Wang, Yun He, Yushuang Li
Beijing Institute of Spacecraft Environment Engineering Beijing, China

Abstract. H-II Transfer Vehicle (HTV, also known as “H-2 rail transport air vehicle) is a new kind of cargo spacecraft jointly developed by Japan Aerospace Exploration Agency (JAXA) and Mitsubishi Heavy Industries Limited Corporation to deliver supplies to the International Space Station (ISS). Based on the research on the AIT technology of HTV, this paper introduces the typical assembly technology of Japanese HTV and puts forward some suggestions for the assembly of Chinese cargo spacecraft by combining with the research status of Chinese cargo spacecraft.

1. Introduction
HTV, jointly developed by Japan Aerospace Exploration Agency (JAXA) and Mitsubishi Heavy Industries Limited Corporation, mainly deliver goods to the international space station (ISS). By September 2018, seven HTV ships had been launched, all of which docked with the international space station and completed various tasks. The successful experience of HTV has important reference significance for the research and development of Chinese cargo spacecraft. This paper introduces the typical general assembly technology of HTV and puts forward some suggestions for the general assembly of Chinese cargo spacecraft.

2. Composition of HTV
HTV is mainly composed of pressure sealed cabin (PLC), non-pressurized cabin (ULC), exposed pallet (EP), instrument cabin and propellant cabin. The composition of HTV is shown in Figure 1. Goods and supplies are loaded in the pressure sealed cabin, and the exposed pallet with exposed goods is installed in the non-pressurized cabin [1].

The pressure in the pressure sealed cabin is maintained at 1 atmosphere, and the internal temperature is controllable. The goods transported (experimental platform, cargo transfer package, food, clothes, etc.) are mainly used for on-orbit use. After the cargo spacecraft is docked with the space station, the pressure sealed cabin was connected to the space station, allowing astronauts to move in and out to transfer cargoes. The pressure sealed cabin is shown in Figure 2.

There is an opening on the side wall of the non-pressurized cabin, and the internal space is used for the storage of exposed pallets, which are equipped with outboard equipment and outboard on-orbit replacement parts. The outboard non-pressurized cabin is equipped with FRGF, and the space station robot arm can grasp the FRGF to guide the HTV to dock at the space station. After docking, the exposed pallets are removed from the space station robot arm. After unloading the equipment, the exposed pallets are placed into the non-pressurized cabin again. The non-pressurized cabin is shown in Figure 3.
The vehicle equipment bay is located in the middle of HTV, with a diameter of 4.2 meters and a length of 1.3 meters. It is composed of four sub-systems, including navigation and control, communication, data processing and electric power. It has a power supply system at the front, electronics at the rear, and antennas and sensors outside. The vehicle equipment bay is shown in Figure 4.

The propellant module is located at the bottom of the HTV, with a length of 1.3 meters. It consists of 8 main engines (500N/unit for orbital transfer), 28 maneuvering control propellers (110N/unit for attitude control), 4 fuel and oxidizer storage tanks, and high pressure air tanks. The propellant module is used for orbit control and attitude control of HTV [2]. The propellant module is shown in Figure 5.

![Figure 1 Constitution of HTV](image1)

![Figure 2 Full figure of pressure sealed cabin](image2)

![Figure 3 Non-pressurized cabin (a. before EP installation, b.EP)](image3)
3. Research on AIT technology of HTV

3.1. HTV cargo installation method

Most cargoes of HTV are shipped in packages. The cargoes are fixed by binding inside the package and cushioned by foam outside. The installation of packages is divided into two forms: one is to pack the cargoes on the ground into the shelf, and then the whole shelf is loaded into the cabin; the other is to directly install packages into the cabin.

3.2. Shelf installation method.

In the cargo installation process, the shelves should be installed first, because there are no other goods and equipment in the cabin, and it is convenient for the shelves to be turned over and installed.

The installation process of HTV shelf in the cabin is shown in Figure 6. First of all, the shelf is lifted from its holder, overturned to a horizontal direction in the air and connected with the holding device on the outer cabin handling tooling. The outer cabin handling tooling has the height and left and right adjustment ability, and the push shelf enters the cargo bay by the front door. After the shelf enters the cargo bay, it lands on the inside overturning tooling, which has the overturning function in two directions and size adjustment function in three directions. The operator realizes the shelf’s overturning, position adjustment and final installation and fixing by means of the overturning tooling in the cabin.
3.3. Installation method of direct loading of packages

The front cabin door of HTV is a square with a side length of 1.2m. The installation process of packages of HTV is shown in Figure 7. Before the packages are put into the cabin, the tooling is installed outside the cabin, and the packages are put in place outside the cabin. Then the crane lifts the packages to the non-powered roller, and the packages are placed on the roller, and then the tooling is removed and the packages transported into the cabin through the roller, and the personnel inside the cabin will support and put the packages into the cargo box.

3.4. Installation method of exposed pallet

The opening of the non-pressurized cabin and the exposed pallet are shown in Figure 8~9. The inside of the non-pressurized cabin is installed with sliding rails, and the outside of the exposed pallet is installed with rollers. The exposed pallets are installed through special tooling on the pallets in a single cabin of non-pressurized cabin. The tooling body adopts the form of guide rail and roller, and the four corners at the bottom are installed with casters and spiral lifting support mechanism. During installation, the spiral lifting support is lowered to support the contact with the ground, thus avoiding shaking during the installation of pallets. The tooling has the function of fine adjustment of height and left and right direction, which is convenient for the precise entry of pallets. The installation process of exposed pallets is shown in Figure 10. The installation tooling of pallets is near the non-pressurized cabin, and the exposed pallets are hoisted onto the pallet installation tooling. Then, the pallets slide into the non-pressurized cabin and complete the final fixation.
Figure. 8 Opening of non-pressurized cabin

Figure. 9 Exposed pallet

Figure. 10 HTV exposed pallet installation process (a. the tooling is in place, b. the pallet is hoisted onto the tooling, c. the pallet slides to the non-pressurized cabin, d. the pallet is installed in place)

4. Enlightenment of HTV to the final assembly of Chinese cargo spacecraft

4.1. Strengthen microbial control during final assembly process
Strict microbial control measures are one of the important characteristics that distinguish manned spacecraft from other spacecrafts. Microbial contamination harms astronauts, materials and spacecrafts
In the final assembly process, especially in the late installation of cargoes, HTV has strict microbial control measures. As can be seen from the photos of HTV cargo site installation, the final assembly personnel are neatly dressed, wearing surgical masks and rubber gloves during final assembly operation. The dressing of operators during HTV installation is shown in Figure 11.

![Figure 11](image)

**Figure 11** Dressing of operators during HTV installation (a. Fastener installation, b. Package installation)

The microorganisms in the ground assembly of cargo spacecraft mainly come from two aspects. One is the microorganisms attached to instruments, equipment, tools and accessories during the ground assembly, and the other is the microorganisms carried by the operators on the ground. Through sorting out the pollution sources, the control of corresponding microbial pollution sources is strengthened, respectively.

Before entering the factory, workers should wash their hands, wear clean work clothes, sterile gloves and hats, as well as clean slippers or disposable shoe covers. Work clothes, hats, masks and shoes should be sterilized. When entering the air shower, air shower time shall be not less than 10 seconds. After air shower, workers should enter the working area through buffer channel, and the working area needs to be controlled by local sterilization regularly. When leaving the final assembly plant, workers should take off the work clothes, gloves and hats after air shower, and sterilize them for later use.

The single unit equipment should be carried out in a clean environment during the manufacturing stage. The materials used should be wiped with disinfectant before manufacturing. After preparation, they should be placed under ultraviolet lamp for irradiation and sterilization. In the final assembly stage, single unit equipment and auxiliary tools in the cabin shall be disinfected before entering the cabin, and special disinfectant shall be used to wipe and clean the surface.

4.2. **Learn from HTV production model, reasonably arrange assembly process**

HTV cargo spacecraft adopts the production mode of sectional assembly and combined test. Parallel assembly of multiple stages improves the assembly efficiency, enhances the responsiveness of assembly production, and reduces the impact on assembly test schedule due to the wrong installation of single unit equipment or tooling. It is suggested that the final assembly process of HTV cargo spacecraft should be used for reference in the development process of Chinese cargo spacecraft.

5. **Conclusion**

With the continuous progress of manned space missions in China, cargo spacecraft will play an increasingly important role as an important means of supply and transport for astronauts. Cargo spacecraft can carry goods with a large weight and wide varieties. In addition to different types of packages, it can also carry Eva spacesuit, cylinder components and other special goods.

Based on the investigation of final assembly technology of HTV, this paper introduces the final assembly process and cargo installation equipment of Japanese cargo spacecraft. The mature final assembly experience of HTV provides useful reference for the final assembly of Chinese cargo spacecraft. According to the implementation process of HTV final assembly and combining with the
research status of Chinese cargo spacecraft, this paper puts forward some suggestions for the final assembly of Chinese cargo spacecraft.

With the arrival of the subsequent batch production and final assembly of cargo spacecraft, it will be of great benefit to the batch production of cargo spacecraft in China to quickly, safely and efficiently complete the final assembly of cargo spacecraft.

References
[1] Chen Yunzong, Cai Manrui, Ding Wenhua. H-IIA Transfer Aircraft. Missile and Space Vehicles. 2006, Issue 4: 25-30
[2] Hiroshi Sasaki: HTV Development and the Future Vision, ISTS., (2006), ISTS 2006-o-1
[3] Shigeyuki Uesagaki, Articles for the Use of 'Kibo' Mounted on Unit 2 of 'Kotori', December 24, 2002 (gold)
[4] Guo Shuangsheng, Research Progress of Experimental Model Project of American NASA Advanced Health Care Program, Aerospace Medicine and Medicine 2001 (4),