Development Status of the H-IIB Launch Vehicle

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The H-IIB launch vehicle is currently under development based on the H-IIA launch vehicle. The development of the H-IIB vehicle is linked to the launch of the H-II transfer vehicle (HTV), which is important as Japan's contribution to the International Space Station program. At the same time, the H-IIB launch vehicle is intended to expand the launch capability of the H-IIA family, maintain the development competence of launch vehicles, and ensure the international competitiveness of the Japanese space program. In this paper, we give an outline of the H-IIB launch vehicle and the status of the development tests.

1. Introduction

The H-IIB launch vehicle is currently under development based on the H-IIA launch vehicle. The development of the H-IIB vehicle is linked to the launch of the H-II transfer vehicle (HTV), which is important as Japan's contribution to the International Space Station program. At the same time, the H-IIB launch vehicle is intended to expand the launch capability of the H-IIA family, maintain the development competence of launch vehicles, and ensure the international competitiveness of the Japanese space program. The development of the H-IIB launch vehicle started with a system study in 2003, and the critical design phase was completed in July 2007. Development tests are currently underway, and Test Flight No. 1 is being fabricated. In this paper, we describe the outline of the H-IIB launch vehicle and the status of the development tests.

2. Outline of the H-IIB launch vehicle

2.1 General

The H-IIB launch vehicle is a two-stage launch vehicle that uses liquid oxygen and liquid hydrogen as propellant. Its overall length is approximately 56 m (with a fairing for the HTV), and its gross mass is approximately 531 tonnes at launch (payload mass not included). An overview of the H-IIB launch vehicle is shown in **Fig. 1**, and its major characteristics are listed in **Table 1**. In the H-IIB launch vehicle, the diameter of the first stage was expanded from 4 m for the H-IIA launch vehicle to 5.2 m, and the tank length was stretched by 1 m. A cluster system was also designed for two first-stage engines (LE-7A) to enhance the launch capability. Combined with the second stage, these components are intended to maintain and improve the reliability of the launch vehicle and increase the efficiency of the launch operation by adopting or modifying parts common to the H-IIA launch vehicle.

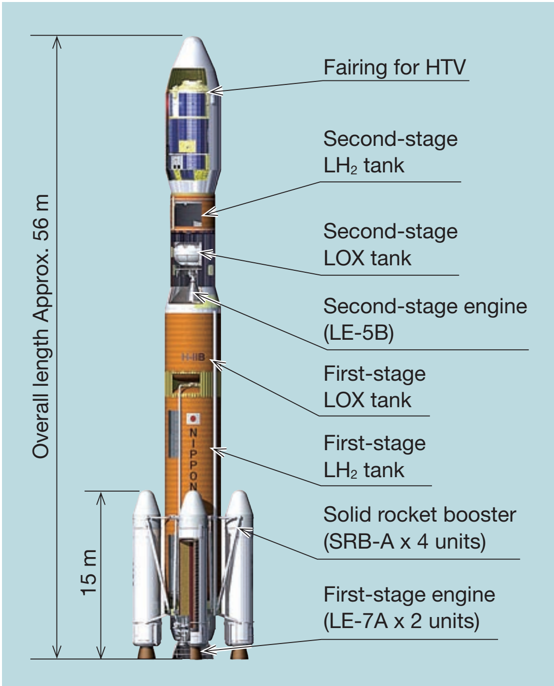

Fig. 1 Overview of the H-IIB launch vehicle

The H-IIB launch vehicle has the launch capability to inject 16.5 tonnes of payload into the HTV injection orbit (apogee altitude of 300 km, perigee altitude of 200 km, inclination 51.65°), and approximately 8 tonnes of payload into the geostationary transfer orbit (GTO). The GTO mission will be a cost effective launch with dual satellites.

The H-IIB launch vehicle is a joint development of the Japan Aerospace Exploration Agency (JAXA) and Mitsubishi Heavy Industries, Ltd. (MHI). MHI concluded the basic agreement with JAXA as a framework for public-private joint

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Table 1 Major characteristics of the H-IIB

	H-IIB	H-IIA (204) (Reference)	Remarks
Overall length (m)	56	53	Payload mass not included
Gross mass (t)	531	445	
First stage			
Tank diameter (m)	5.2	4	
Propellant mass (t)	176	100	
Engine	LE-7A×2	LE-7A×1	
Thrust (t)	112 (×2)	112	in vacuum
Specific impulse (s)	440	440	
Second stage			
Tank diameter (m)	4	4	H-IIA/H-IIB common
Propellant mass (t)	16.7	16.7	
Engine	LE-5B	LE-5B	
Thrust (t)	14	14	in vacuum
Specific impulse (s)	448	448	
SRB-A			
Propellant mass (t/unit)	66	66	H-IIA/H-IIB common
Number of SRBs	4	4	
Fairing			
Name	5S-H (HTV)	5S/4S	
Diameter (m)	5.1	5.1/4	
Length (m)	15	12/12	

development, and is working on the system integration as the primary development manufacturer (**Fig. 2**).

2.2 First stage

The philosophy of the first stage structure is the same as the H-IIA launch vehicle. However, with the enlarged tank diameter, the dome section was domestically fabricated and assembled using a new technology called friction stir welding (FSW). As Japan did not have the necessary technology to fabricate the propellant tank domes when the H-IIA launch vehicle was designed, they were procured from two overseas manufacturers. For the H-IIB launch vehicle, we fabricated the domes domestically to ensure the autonomy of the project and to stabilize quality and supply. The domes are currently fabricated at the Hiroshima Machinery Works of MHI. We adopted FSW to handle the increased thickness of the welds, due to the enlarged tank diameter. FSW has good joint characteristics and provides good weld quality, improving the reliability of the final product. It also allows us to eliminate part of the preprocessing, reducing the cost of the vehicle structures. A

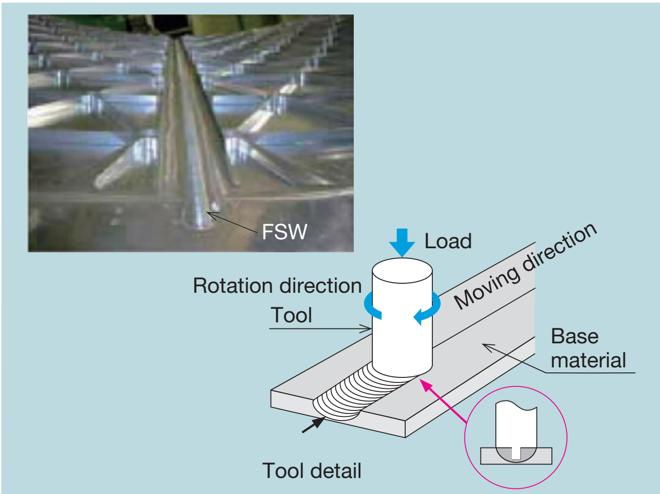

Fig. 3 Conceptual diagram of FSW

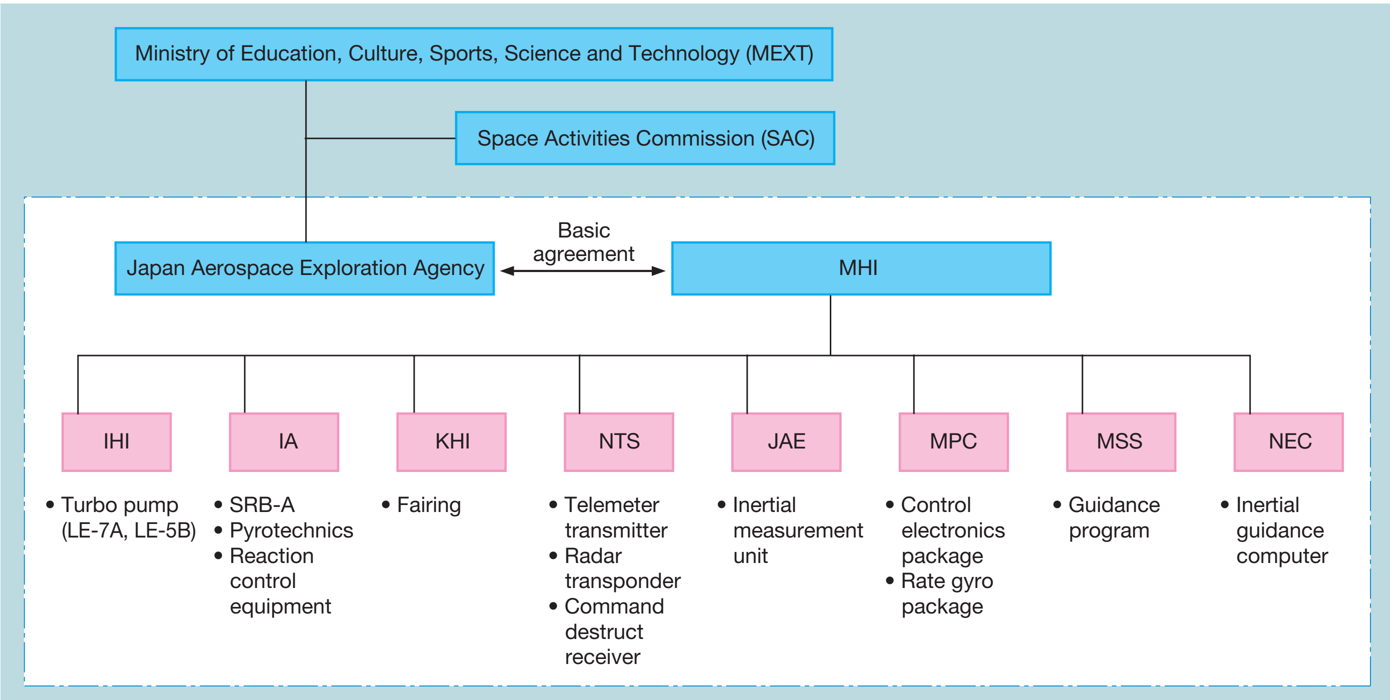

Fig. 2 H-IIB launch vehicle development framework

Fig. 4 LH2 tank for the test flight (diameter: 5.2 m, length: 19.4 m)

conceptual diagram of FSW is shown in **Fig. 3**. The world's first 5.2-m tank (LH_2 tank for the test flight), fabricated by applying FSW, is shown in **Fig. 4**.

The first-stage propulsion system used two clustered main engine units (LE-7A). The development risk involved in the cluster system was reduced by minimizing new development factors, and by standardizing with the H-IIA launch vehicle components. Interchangeability with the H-IIA launch vehicle during fabrication was made possible by adopting a modular design concept and by standardizing large parts, such as the propellant supply piping or bellows. An overview of the first-stage propulsion system is shown in **Fig. 5**.

2.3 Solid rocket booster (SRB)

Four SRB-As common to the H-IIA launch vehicle were installed in the H-IIB launch vehicle. The diameter of the vehicle was changed to 5.2 m, but the separation mechanism remains in common with the H-IIA launch vehicle.

2.4 Second stage

The second stage of the H-IIA launch vehicle was essentially used in the H-IIB launch vehicle. However, the flight load is increased, due to a larger fairing (5S-H type for the HTV mission). To withstand this, the thickness of the forward and aft skirt skin sections and the cylinder section of the LH_2 tank were increased.

2.5 Avionics system

To facilitate the development of a relatively low cost avionics system over a relatively short term, a basic policy was adopted in which the avionics equipment of the H-IIA launch vehicle (including applications, additional on-board features, and modifications) were to be utilized as much as possible.

In response to the engine clustering, a control circuit was added to the first-stage guidance and control computer (GCC1), and the on-board software (OBS) was modified. An electronics package (E-PKG), a power distribution box (PDB1), an umbilical controller (UMC1), and a data acquisition unit (DAU1) were also added.

3. Development tests and test flight

3.1 Development tests

Preliminary system tests, development tests for subsystems, and qualification tests were conducted for development.

In the preliminary system tests, transonic/supersonic wind tunnel tests were completed in 2006. Combined with CFD analysis, the results were incorporated into the detailed system design.

In the structural development tests, manufacturing tests for the first-stage tank dome and FSW were completed by 2007. The strength tests for the first-stage engine section,

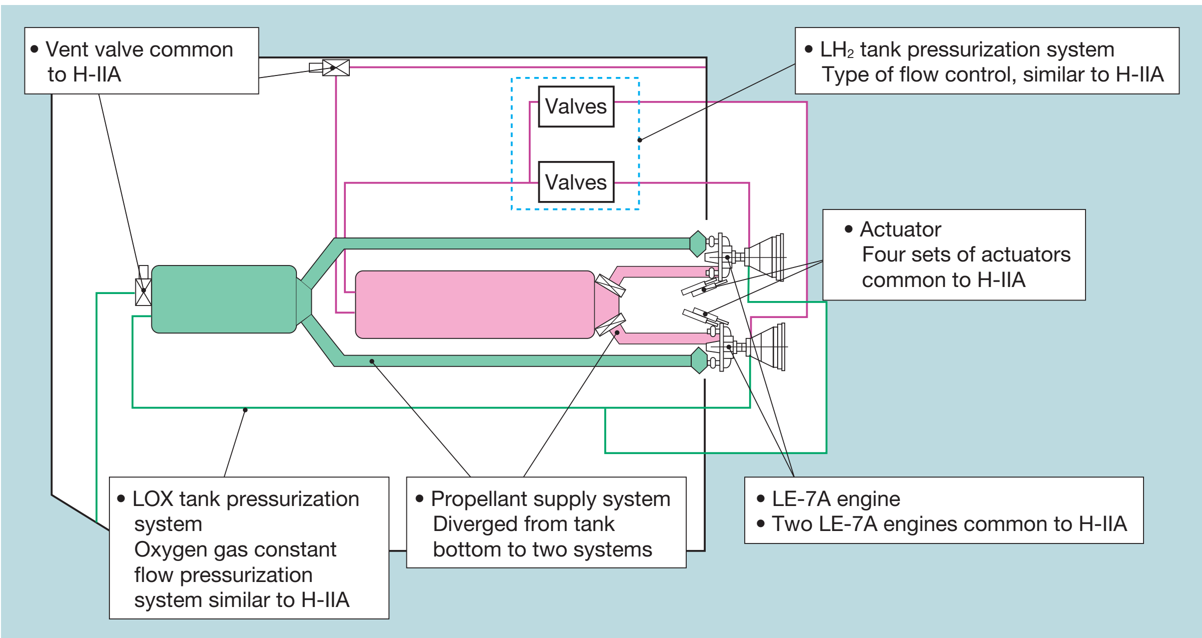

Fig. 5 Overview of the first-stage propulsion system

first-stage LOX tank, center body section, interstage section adaptor, and first-stage LH_2 tank are currently underway.

In the propulsion system development tests, the drainage characteristic confirmation test, which aims to use up as much fuel and oxidizer as possible to maximize the launch capability, was conducted using a model tank. An optimized design based on the Taguchi method was used to minimize the residual propellant in the tank.

In the electrical system development tests, an antenna pattern test, which is influenced by the launch vehicle geometry, was conducted in 2006, and the results were incorporated into the launch vehicle specifications. Modification and system tests of the GCC1, OBS, PDB1, and DAU1 were completed in 2008.

3.2 Battleship tank-firing test (BFT)

BFTs, which are the most important item among the H-IIB launch vehicle development tasks, and are involved in the clustering of Japan's first large-sized liquid rocket engine, were conducted eight times between March and August in 2008. All the tests were completed as planned (see **Figs. 6** and **7**).

In a BFT, a combustion test is conducted with two LE-7A engine units installed on a thick-walled high-pressure-resistance stainless-steel tank that is combined with the engine section using the same design as the actual launch vehicle. The technical data related to the establishment of the start-stop timing of the two engine units, verification of stable combustion, filling of cryogenic propellant, and the launch operation were successfully obtained. In addition to confirming the basic engine performance, we assumed the maximum amount of dispersion in various parameters to improve the verification level of the combustion test.

Fig. 6 BFT (full view)

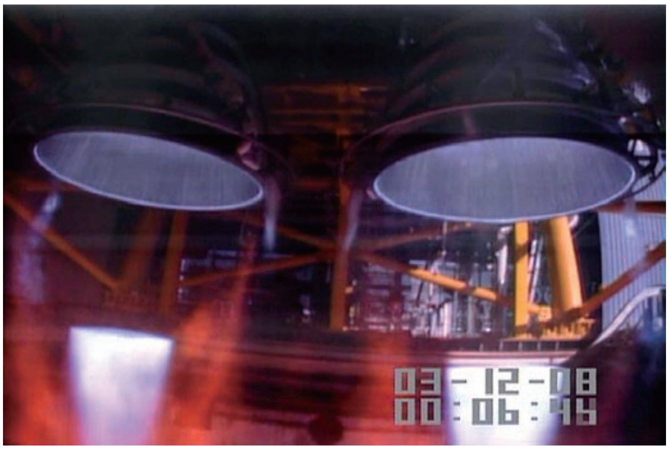

Fig. 7 BFT (two engine units)

3.3 Ground system test (GTV), captive firing test (CFT), and test flight

To complete the H-IIB launch vehicle development, CFTs and GTVs will be conducted at the Tanegashima Launch Site from the beginning of 2009. These tests will be conducted using a test flight vehicle. In the CFT, short and medium second-time firing tests will be conducted at the launch pad. After that, the vehicle will be changed to its flight configuration by installing actual SRB-As, etc. In the GTV, the interface between the launch vehicle and the launch pad facilities will be confirmed, and the operation procedures of the launch site will be established.

After incorporating the development test results, as required, and performing the maintenance operations, Test Flight #1 is scheduled in the summer of 2009.

4. Conclusion

We provided an outline of the H-IIB launch vehicle and described the development tests. MHI has successfully completed the BFT, which is one of the highlights in the H-IIB launch vehicle development program. As we approach the test-flight launch in the summer of 2009, MHI will verify the operational readiness of the H-IIB launch vehicle through CFT/GTV at the launch site.


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