Technologies and Prospects of the H-IIB Launch Vehicle

KOKI NIMURA[*1] KATSUHIKO AKIYAMA[*2]
KENJI EGAWA[*3] TAKUMI UJINO[*4]
TOSHIAKI SATO[*5] YOUICHI OOWADA[*6]

The Flight No. 3 H-IIB launch vehicle carrying the H-II Transfer Vehicle (HTV3), launched at 11:06 am on 21 July 2012 from Tanegashima Space Center, successfully injected the HTV3 into its designated orbit. Following this success, Japan Aerospace Exploration Agency (JAXA) and Mitsubishi Heavy Industries, Ltd. (MHI) concluded an agreement where MHI would carry on the H-IIB launches commencing with Flight No. 4 as a launch service business. This paper introduces the development accomplishments of the H-IIB launch vehicles and the prospects of our launch service with the H-IIB launch vehicle added to the lineup.

1. Introduction

The H-IIB launch vehicle is the Japanese flagship launch vehicle developed jointly by Japan Aerospace Exploration Agency (JAXA) and Mitsubishi Heavy Industries, Ltd. (MHI) for the purpose of launching the H-II Transfer Vehicle (HTV) in a shared role to participate in the International Space Station (ISS) program, as well as expand the launch capability of the H-IIA launch vehicle family to ensure international competitiveness.

The development of the H-IIB started with a system review from 2003, through preliminary design that began in July 2005, culminating in the successful launch of the HTV technical demonstration vehicle from the Flight No. 1 H-IIB launch vehicle on 11 September 2009, just 3 short years from the start of critical design.

The Flight No. 2 H-IIB launch vehicle demonstrated controlled re-entry after injecting the HTV into the designated orbit and re-igniting the second stage engine after orbiting the earth to drop the second stage safely in the ocean. This could be attempted because the launch result of Flight No. 1 had proved that the H-IIB had the desired launch capability and that some propellant remained after separating the HTV. As a result, the controlled re-entry method was developed in just about one year after the Flight No. 1 launch and the demonstration was successfully carried out.

On 21 July 2012, the Flight No. 3 H-IIB launch vehicle was successfully launched. Following this success, on 26 September 2012, MHI concluded agreement with JAXA to carry on the H-IIB launches commencing with the Flight No. 4 as a launch service business.

*1 General Manager, Aerospace Systems/Space Systems Division
*2 Chief Staff Manager, Aerospace Systems/Space Systems Division
*3 Deputy Manager, Aerospace Systems/Space Systems Division/Space Systems Engineering Department
*4 Chief Engineer, Space Transportation Program Systems Engineering Office, JAXA
Director, Space Transportation Mission Directorate, JAXA
(Former Project Manager, H-IIB Project Team)
*5 Senior Engineer, Innovative Launch Capabilities Office, Space Transportation Mission Directorate, JAXA
(Former Manager for System Integration, H-IIB Project Team)
*6 Associate Senior Engineer, Innovative Launch Capabilities Office, Space Transportation Mission Directorate, JAXA
(Former Associate Senior Engineer, H-IIB Project Team)

2. H-IIB launch vehicle

2.1 Overview

The H-IIB is a two-stage launch vehicle with an overall length of approximately 57 m (including the fairing for the HTV) and a gross mass of approximately 530 tons (satellite mass not included) (**Figure 1**). The first-stage diameter was expanded from the 4 m H-IIA to 5.2 m, and the propellant quantity was increased approximately 1.7 times by adding 1 m to the tank length. A cluster of two-first stage LE-7A engines was used instead of a single engine to enhance the launch capability. To maintain and improve the reliability of the launch vehicle and to increase the launch operation efficiency, in addition to minimizing development risk, MHI used common or modified flight proven parts of the H-IIA, including the second stage.

The H-IIB is capable of launching 16.5 tons of payload into the HTV injection orbit (300 km apogee altitude, 200 km perigee altitude, 51.65 degrees inclination), and approximately 8 tons of payload into a geostationary transfer orbit (GTO). In GTO missions, MHI aims to boost cost competitiveness by simultaneously launching two 2 to 4 ton class satellites, which account for approximately 50% of satellite demand.

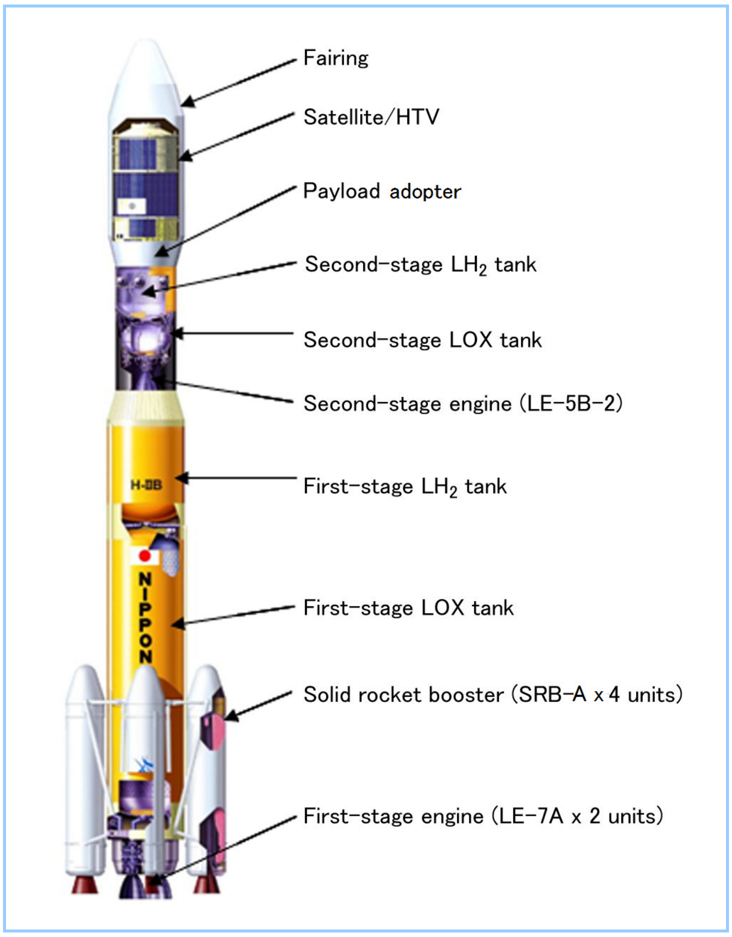

Figure 1 Overview of the H-IIB launch vehicle

2.2 Primary development achievements

This section introduces the primary development achievements of the H-IIB.

- Development of 5.2 m diameter tank
- The first-stage engine cluster technology
- Controlled re-entry of the second stage

(1) Development of 5.2 m diameter tank

MHI established integral forming technology to fabricate the tank dome and friction stir welding (FSW) technology to weld the tank joints in tank development.

Since the integral forming technology was not available domestically, the tank domes were procured from abroad. In order to ensure self-reliance and constant quality and supply, we developed one of the largest integrally-formed domes through in-house experimentation and research at Hiroshima Machinery Works of MHI, where the available existing plant facilities were used to develop a considerable amount of heavy machinery and equipment.

For the tank joint welding, we adopted FSW technology in conformity with the increased thickness of joints due to the expansion of the tank diameter. FSW is a method of joining materials by stirring while softening them with frictional heat, by pressing a rotating tool with a protrusion against the desired joints. This can enhance the weld quality and reliability with good joint characteristics and without some of the preprocessing, reducing the manufacturing cost.

(2) The first-stage engine cluster technology

The first-stage engine uses cluster technology under the policy of fully utilizing the technology acquired from the H-IIA. Two propellant supply systems were setup individually and they supply propellant to the two engines in order to exclude the mutual effect and to reduce the development risk. A proper distance is provided between the two engines to suppress as much of the effect from the interference of injected gas as possible.

The engines were combustion tested 8 times at the Tashiro test site in Akita Prefecture from March to August in 2008 in order to confirm the basic performance. In addition, we improved the verification level of the combustion test by conducting tests assuming the dispersion of the various parameters. As a result, we obtained cluster technology for a Japanese launch vehicle for the first time.

(3) Controlled re-entry of the second stage

MHI developed the de-orbit technology that reignites the second-stage engine by utilizing the remaining propellant while maintaining HTV launch capability requirements. Generally, after the separation of the HTV, the second stage is expected to fall randomly in an area between 51° north latitude and 51° south latitude after flying around the earth for 3 to 4 days in a geocentric orbit. The second stage disintegrates as a result of aerodynamic heating and dynamic pressure during re-entry, and most of the fragments will burn out. As a result, the level of risk on the ground is very low. However, we decided to develop a controlled re-entry method to bring the second stage to a safe ocean area to minimize as much of the risk of an accident occurring as possible. This was achieved through a minimal system change that included the verification of the low thrust burn mode of the engine, the development of a ground control system (conducted by JAXA) and the addition of a helium bottle for tank re-pressurization of the vehicle.

The controlled re-entry of the upper stage of a launch vehicle has only been attempted on a few actual missions worldwide, such as Ariane 5 EPS/ATV and DELTA-IV/DMSP-17, but MHI obtained state-of-the-art technology that can bring the vehicle out of orbit safely and quickly through the development of the H-IIB.

3. Launch results

Until the present time, three H-IIB launch vehicles have delivered three HTVs, commencing with Flight No. 1 (test vehicle) on 11 September in 2009, No. 2 on 22 January 2011 and No. 3 on 21 July 2012. The HTV has to be launched without so much as one second of delay with only one chance to launch each day within the designated period, because the location of the International Space Station (ISS) changes from moment to moment. Under this condition, Flights No. 1 to No. 3 were successfully launched without any delays other than due to weather conditions. Along with the lower level of error in orbital injection shown in **Figure 2**, the launches proved Japan's high level of development in space technology.

With the successful H-IIB launch, the H-IIB launch vehicle has maintained a 100% success rate – 95.8% including the H-IIA – demonstrating the high reliability of the technology that is essential to the launch of commercial satellites.

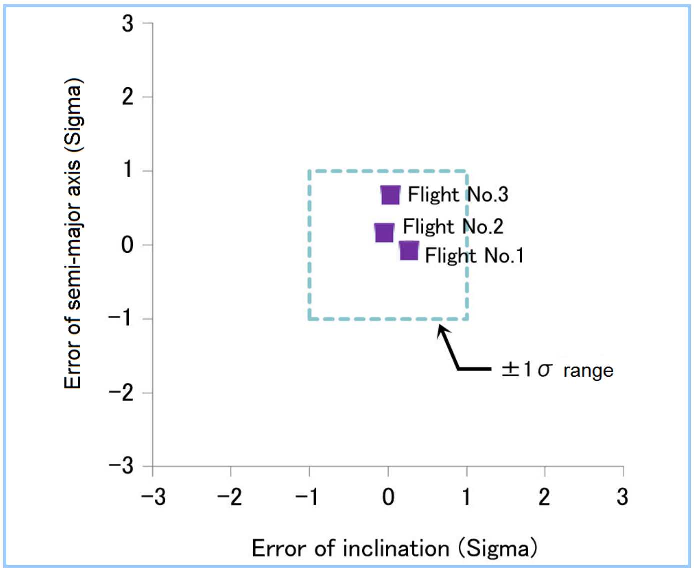

Figure 2 Orbit insertion accuracy

4. Privatization and the future

4.1 Privatization

Following the consecutive successes up to Flight No. 3, MHI concluded an agreement with JAXA to carry on the H-IIB launches commencing with Flight No. 4 as a launch service business. Accordingly, the technologies that established the program through flight demonstration were transferred from JAXA to MHI. We will thereby take the entire role in H-IIB launches hereafter.

Since the H-IIB launch vehicle was privatized, the demand for injecting satellites up to 8 tons into GTO and the simultaneous launching of two large satellites has come into view. The conventional H-IIA launch vehicles were applicable to 50% of the commercial satellite market, but the H-IIB launch vehicle expanded its applicable range to more than 90% of market demand (**Figure 3**).

Meanwhile, the H-IIB launch vehicles also face the significant challenges of weakened international price-competitiveness due to the influence of the post-Lehman Shock rise of the yen against the Russian ruble and the latest European currency crisis. While addressing continual cost reduction, MHI is planning to present various proposals such as the utilization of the H-IIB launch vehicles for various piggy-back satellites, as has been done with the H-IIA, as well as to export space infrastructure concentrating on satellite delivery services to emerging countries as a package.

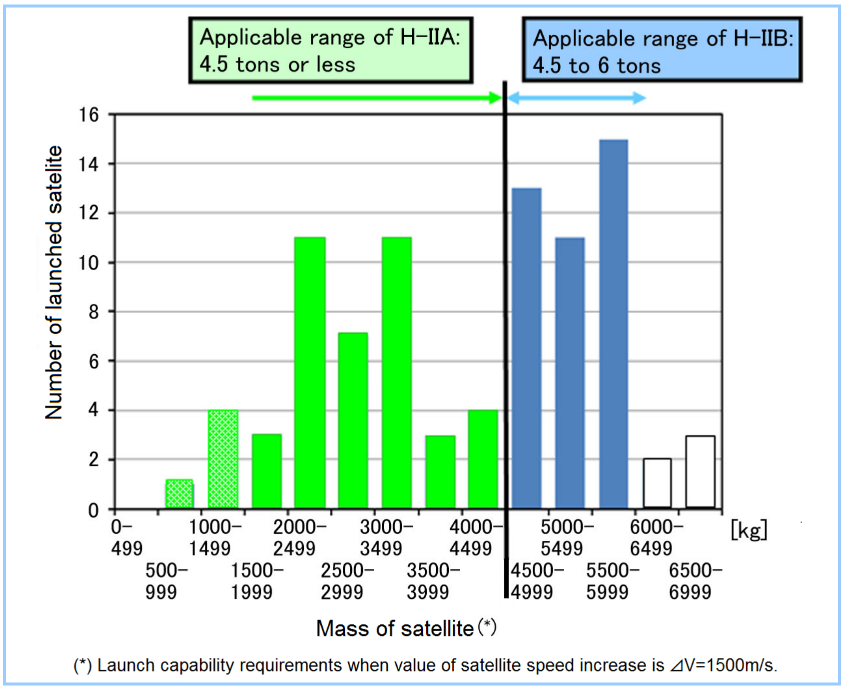

Figure 3 Global commercial satellite launch record (2008 to 2011)

4.2 Future of the flagship launch vehicle

MHI is currently planning to launch the development of the "next flagship launch vehicle" as a future concept of the H-IIA/B launch vehicle (**Figure 4**). This launch vehicle sets out to carry customer's satellites to space with "more comfortability, availability, and affordability," aiming to contribute to the expansion of space utilization by providing better access to space transportation. We are going to continue to meet various needs through modular vehicles and drastically reduce costs by applying the general-purpose technology used in domestic cutting-edge industries outside of the aerospace industry.

We are also working on upgrading the current flagship launch vehicle as the first phase of continual system development toward the next flagship launch vehicle, with a central focus on the second stage for the enhancement of geostationary satellite launch capability and the mitigation of the satellite storage environment, enabling better transportation services to be provided to satellite customers. This development is scheduled to be completed by 2013.

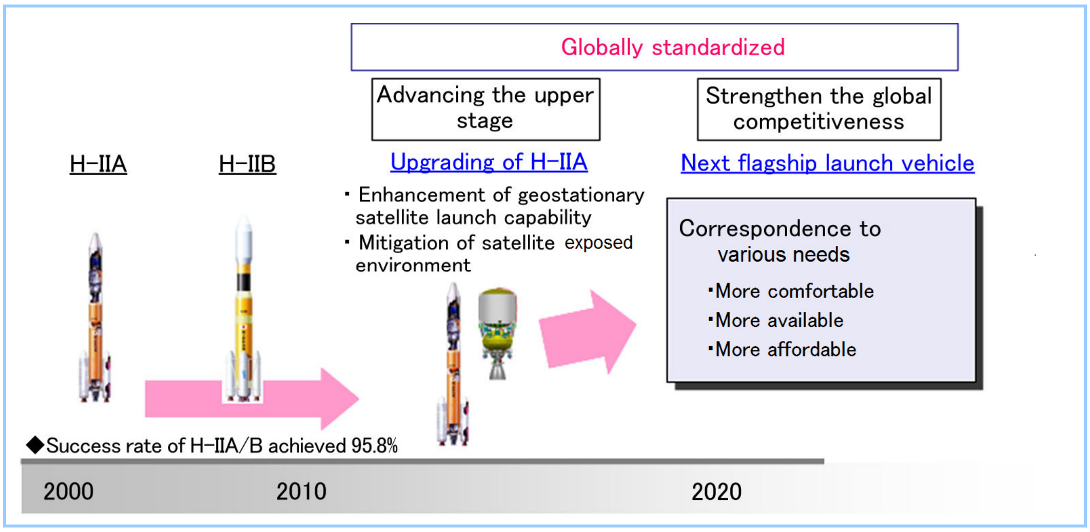

Figure 4 Roadmap of the flagship launch system

5. Conclusion

MHI was able to realize the short-term, low-budget development of the H-IIB launch vehicle by fully utilizing the technologies obtained from the H-IIA launch vehicle, which contributed to narrow down the development range and reduce the risk of new development. The same can be said about the development of the controlled re-entry technology of Flight No. 2, which allowed us to maintain the high reliability of the H-IIA launch vehicle. Moreover, it was a significant accomplishment that we were able to obtain the world-class technologies as shown in section 2.2, and above all, we could pass on the developed technologies to a new generation of engineers.

We are planning to launch another four H-IIB launch vehicles to deliver the HTVs from Flights No. 4 to No. 7 after 2013, as the H-IIB has been added to the launch transportation services already deployed by H-IIA launch vehicles. With this H-IIA/B family, we will address continual cost reduction, with the intent to strengthen global competitiveness by aggressively exploring the global market for diverse launch needs, including commercial satellites from home and abroad.