Development of the GX Launch Vehicle, New Medium Class Launch Vehicle of Japan

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The GX launch vehicle is a medium class launch vehicle, objectives of which are to support launching demand for medium-size satellite flexibly, to be back-up for the national main space transportation system, and to establish LNG propulsion system technology. This paper describes outline of the GX program such as its configuration, program merits including establishment of the LNG propulsion system, the main characteristics and its performance, etc. The future development concept of the GX is also described.

1. Introduction

The GX launch vehicle is a Japanese medium class launch vehicle developed for operations beginning in the middle of the 2010s to flexibly meet diverse future launching demands for small-and medium-size satellites and to back up the main national space transportation system. **Figure 1** shows the appearance of the GX launch vehicle. Its second stage will be equipped with an engine burning liquefied natural gas (LNG) for which there are high expectations. By acquiring LNG engine technologies in the process of development, Japan is expected to exhibit international advantages in the development of future space transportation systems.

This paper provides an outline of the GX project, such as merits and specifications of the GX launch vehicle and also describes its future development concept.

2. Outline of the GX launch vehicle

2.1 Configuration of the GX launch vehicle

The GX launch vehicle is a two-stage liquid launch vehicle.

Fig. 1 Conceptual image of the GX launch vehicle

Figure 2 shows the configuration of the GX launch vehicle.

The GX launch vehicle adopts the first stage of Atlas V launch vehicles, which are the most-advanced launch vehicles developed in the United States and are highly evaluated among all countries of the world for its high degree of reliability. The second stage of the GX launch vehicle is equipped with a LNG engine, which is developed in Japan for practical application for the first time in the world. The GX launch vehicle is made of a combination of leading-edge launch vehicle technologies in Japan and the United States, and this project is becoming symbolic of the cooperation between Japan and the United States in space exploration.

There are expectations for the GX launch vehicle to be launched in Japan sometime in the future. However, in order to perform a demonstration flight as soon as possible to put the GX launch vehicle into service, Japan and the United States are considering modifying and sharing a launch site on the West Coast of the United States (Vandenberg Air Force Base, hereinafter called VAFB) currently used for launching the Atlas V launch vehicles. **Figure 3** shows the launch site candidate (VAFB) for a demonstration flight of the GX launch vehicle.

2.2 Merits of the GX launch vehicle

With the configuration described in **Section 2.1**, the GX launch vehicle has several merits: ① acquiring LNG engine technology, ② backing up the main national space transportation system, ③ utilizing the most-advanced technologies in the United States, and ④ flexible utilization of the launch site.

2.2.1 Acquisition of LNG engine technologies

Table 1 shows the merits of the LNG engine. With these merits, the LNG engine is attracting attention not only as an engine for launch vehicles, but also as an engine that can be mounted on spacecraft to the Moon and Mars. Future space transportation technologies will be acquired through the development of the GX launch vehicle.

In the period from June to September 2009, a series of engine firing tests were successfully conducted, including

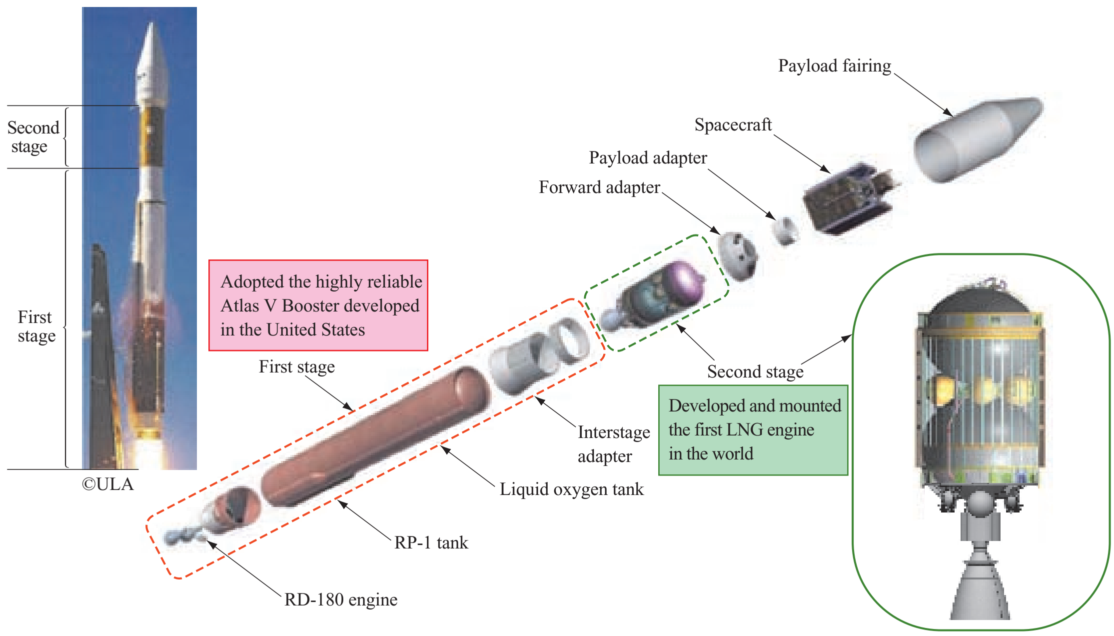
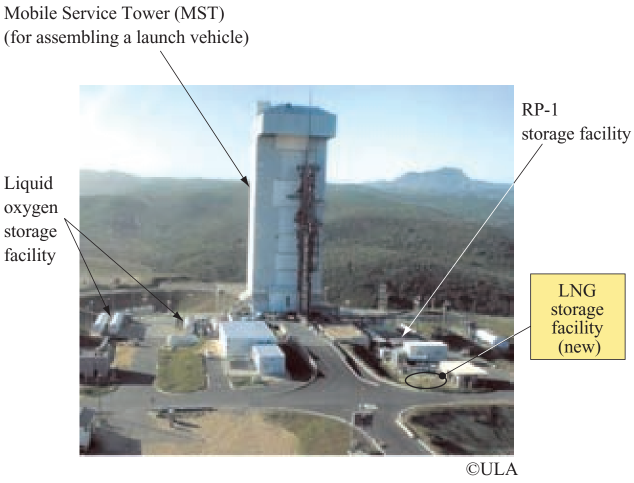


Fig. 2 Major components of the GX launch vehicle



(Note) RP-1 : Kerosene as a fuel for launch vehicle engines

Fig. 3 Launch site candidate for demonstration flight of the GX launch vehicle (VAFB)

Table 1 Merits of LNG (methane) engine

Merits	Description
Environmentally-friendly	Unlike solid propellants, the combustion gas of this propellant does not include chloride and causes no destruction of the ozone layer. Among hydrocarbon fuels, methane (the major constituent of LNG) has the lowest molecular weight and imposes less of a burden on the environment.
Low cost	The cost per unit mass is about 1/250 of that of liquid hydrogen.
Easy to handle	This fuel has a higher boiling point (about –160°C) and a higher density (0.43 g/cm^3) compared to liquid hydrogen (with a boiling point of –253°C and a density of 0.07 g/cm^3). This fuel contributes to relaxing operating temperatures conditions and specifications of valves and other components, and reducing devices in size, resulting in easier production and testing.
Storable for extended periods	Due to the boiling point being higher than that of liquid hydrogen, this fuel can be stored for a long time in space with less vaporizing.
Nontoxic	Unlike hydrazine and other storable propellants, this fuel is not toxic and can be safely used for manned missions.

a test with a duration of 600 seconds, which is longer than the actual operation time. This success assured technical feasibility of the LNG engine and led to a large step forward for practical application of the GX launch vehicle.

2.2.2 Backup for the main national space transportation system

Even 1 out of 20 highly reliable launch vehicles fail to launch on average. If a launch vehicle fails to launch, it cannot be launched again until the cause of the failure is investigated and corrective measures are taken. This is to prevent the same failure from occurring not only in launch vehicles of the same type, but also in those of other types that use the same technology. For this reason, it is considered to be important to have a backup vehicle that uses a technology different from that used for the main national space transportation system.

Figure 4 shows that the H-IIA launch vehicles are based on independent Japanese technologies originating from the technologies used for US Delta launch vehicles. The GX launch vehicle was developed jointly by Japan and Lockheed Martin Corporation (currently, United Launch Alliance, LLC. (ULA)) to follow in the footsteps of the technologies used for Atlas and Titan launch vehicles. This means that the GX launch vehicle uses different technologies from those used for H-IIA vehicles.

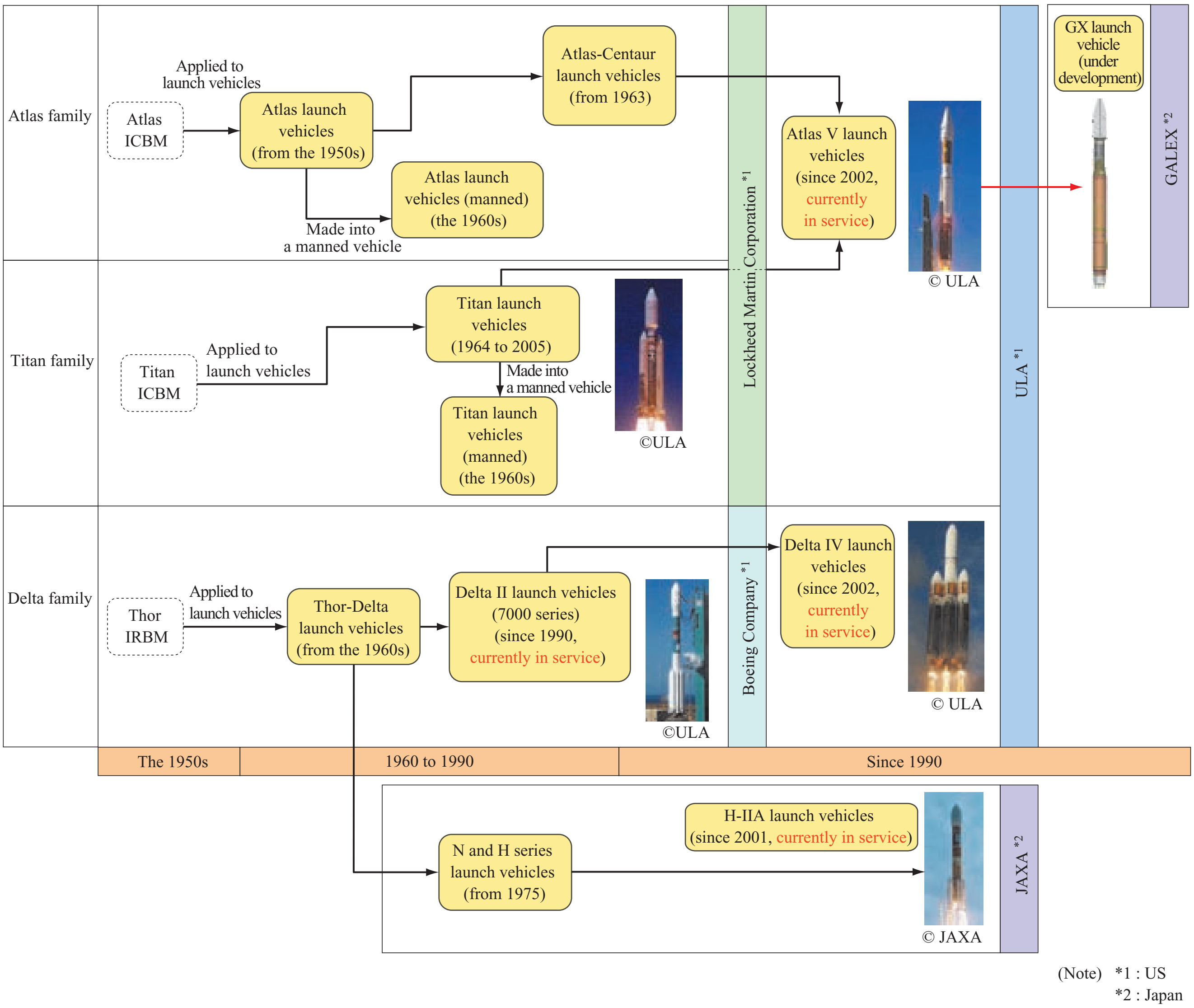


Fig. 4 Japan-U.S. launch vehicle lineage

Figure 5 (1) shows that most failures were caused by propulsion systems. The GX launch vehicle equipped with the LNG engine uses different technologies from those used for H-IIA launch vehicles equipped with liquid hydrogen engines.

Due to the independence of these technologies, the GX launch vehicles can play a role as a backup for H-IIA launch vehicles.

2.2.3 Utilization of the latest technologies developed in the United States

Atlas launch vehicles have been operated since the earliest development stage of launch vehicles in the United States and Russia, and technical know-how has been accumulated over its long history. With this background, the Atlas-Centaur series (operated since 1963), which are the original forms of the current Atlas launch vehicles, have the highest degree of reliability (mean predicted probability of success for next launch attempt) in the world. **Figure 6** shows the reliabilities (mean predicted probabilities of success for next launch attempt) of major launch vehicles. More than

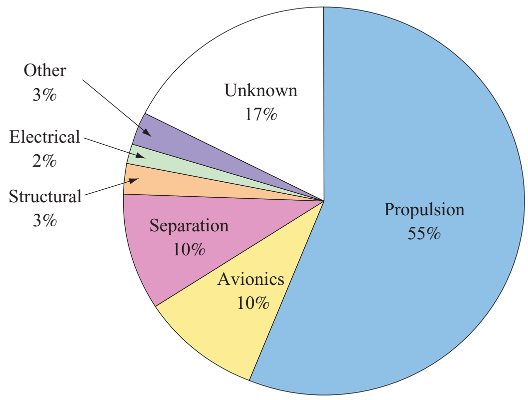


Fig. 5 Launch vehicle subsystem failures (1980–1999)

80 continuous Atlas launch vehicles have been successfully launched since 1993, and they are evaluated as the most reliable launch vehicles.

Atlas V launch vehicles are the main national space transportation system that was developed by the U.S. Air

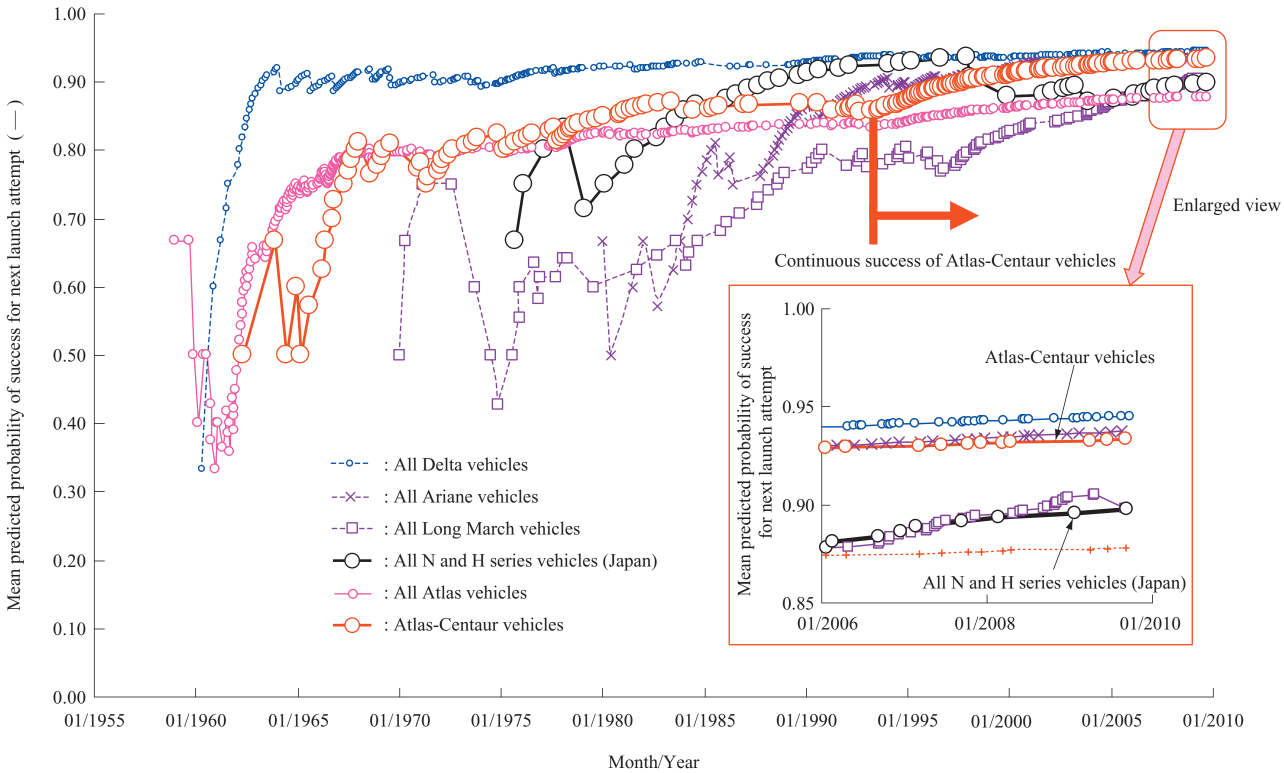


Fig. 6 Major launch vehicle reliability (Mean predicted probability of success for next launch attempt)

Force as Evolved Expendable launch vehicles (EELV) and were put into service in 2002 as the latest addition to the Atlas series. They are designed with leading-edge technologies and with consideration for standardization of operation and maintenance, and future enhancement.

The GX launch vehicle is expected to have a high degree of reliability by using this Atlas V launch vehicle and the highly reliable engineering technologies that have been proven by Atlas launch vehicles.

2.2.4 Flexible utilization of the launch site

The VAFB launch site in the United States has the following advantages over launch sites in Japan.

(1) Maximized launching capability (polar orbit)
Earth observation and other polar orbit satellites can be launched straight southward without passing over land or islands.

(2) No limitations on launch times
Vehicles can be launched at any time of day throughout the year.
Launch sites currently operated in Japan have a limitation in that the period available for launching is 190 days a year maximum. Even if a minor abnormality occurs, launches could be postponed for several months in the worst case.

(3) Highly security environment
VAFB is located in a U.S. Air Force base and strict perimeter monitoring and facility control are available to keep potentially dangerous people out.
These advantages can be utilized if the GX launch vehicle is launched at VAFB for its demonstration flight. In addition, technical risks in future development and operation of launch sites in Japan can be reduced by utilizing the acquired experience.

3. Performance and characteristics of the GX launch vehicle

3.1 Main characteristics of the GX launch vehicle

Table 2 shows the main characteristics of the GX launch vehicle. It is slightly over 50 meters long and weighs slightly more than 300 tons when it is fully loaded, including propellants, but not including a satellite. It will usually be equipped with a payload fairing (cover used for protecting satellites) with a diameter of 3.3 meters for a medium-size satellite. To ensure compatibility with H-IIA launch vehicles, an optional payload fairing with a diameter of 4 meters is also under consideration.

3.2 Flight profile and launch capability

Figure 7 shows the flight profile of the GX launch vehicle. After it is lifted off, the first-stage engine will burn for about four minutes, and then it will be cut off. Then the second-stage engine will start and burn for about eight minutes, and this will put the spacecraft into orbit. The payload fairing will be separated and jettisoned during the second-stage flight.

To minimize creation of space debris, it is required that propellants and pressurized gas in the upper stage of launch vehicles be discharged after use. After separating the satellite, the launch vehicle will change its orbit and emit residual propellants and gas in such a way that the satellite will not be exposed to the emissions.

Table 2 Major characteristics of the GX launch vehicle

Item		Unit	First stage	Second stage	Payload fairing
Length	Length	m	Approx. 42	Approx. 10	Approx. 11
	Total length	m	Approx. 53		
	Diameter	m	3.8	3.1	3.3 *1
Mass	Mass of each stage (loaded)	t	Approx. 311	Approx. 21	Approx. 1
	Mass of all stages (loaded)	t	Approx. 333		
Propulsion system	Type of propellant	—	Kerosene (RP-1) / Liquid oxygen	Liquefied natural gas (LNG) / Liquid oxygen	—
	Thrust in vacuum	kN	4152 (variable)	107	—
	Specific impulse in vacuum	s	338.4	313	—
Guidance method		—	Inertial guidance system		—
Control	Pitch and yaw	—	Gimbal	Gimbal *2	—
	Roll	—	Gimbal	Gas jet	—

(Notes) *1 : An optional four-meter payload fairing is also under consideration.
*2 : Gas jets is also used for pitch and yaw control during coasting flight.

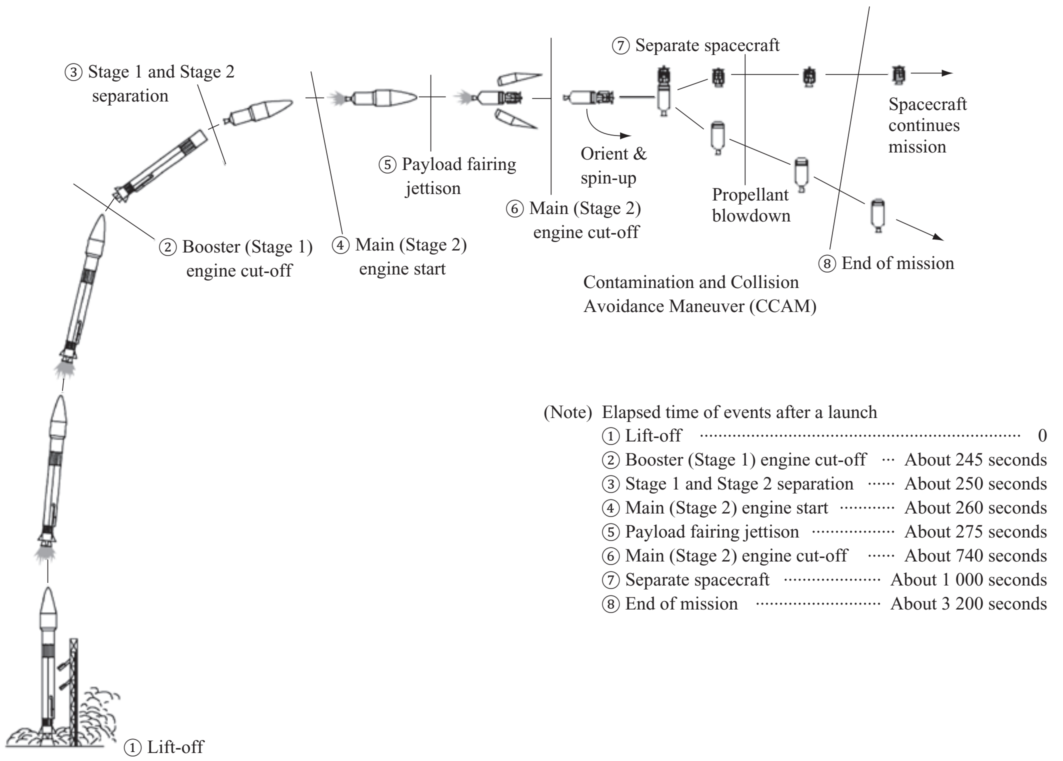


Fig. 7 GX launch vehicle flight profile

Figure 8 shows the payload performance of the GX launch vehicle at VAFB. It can launch satellites of about 3 tons (to an altitude of 500 km) into a sun-synchronous orbit used by earth observation satellites. The payload performance at VAFB is maximized to about 4.5 tons (to an altitude of 300 km) when satellites are launched into orbit south-southeast at an inclination of about 63 degrees.

4. Future concept of the GX launch vehicle

The GX launch vehicle is expected to be launched at the launch site on the West Coast of the United States (VAFB) for its demonstration flight and then at Japanese launch sites. IHI Group will continuously use VAFB as a backup for Japanese launch sites and provide flexible satellite launch services after the demonstration flight to contribute to space utilization by Japan.

In addition, we will turn the technologies acquired in the development of the GX launch vehicle into our

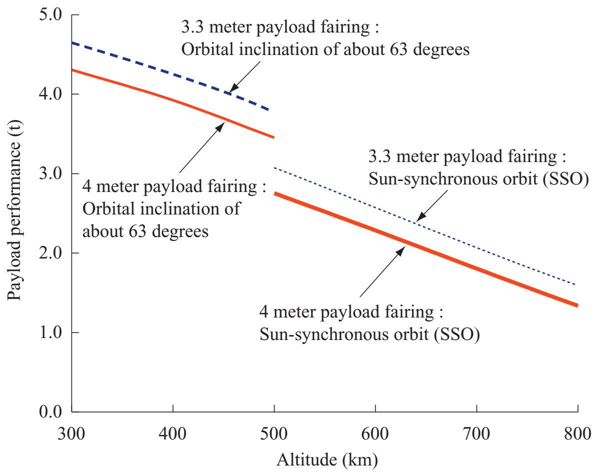


Fig. 8 Payload performance of the GX launch vehicle

own independent technologies and utilize them for the development of next-generation launch vehicles (GX-X) equipped with LNG engines in all stages.

5. Conclusion

This paper has provided the outline of the development of the GX launch vehicle, centering on its merits. The GX launch vehicle is vital as a backup for the main national space transportation system in terms of providing efficient transportation means meeting social needs for space utilization as well as to ensure Japan's continuous access to space.

In addition, further innovation of launch vehicle technologies is expected by merging Japanese technologies with launch vehicle technologies of the different families. Based on this project, IHI Group will make a great leap forward as a launch vehicle manufacturer that has the latest launch vehicle technologies.

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