Compact but Powerful “Enhanced Epsilon Rocket”

Enhanced Epsilon rocket responding to needs for small satellite launch

Recent increasing expectations about small satellites. In order to respond to the expectations, the launch capability of an Epsilon rocket has been improved by 30%. This report will introduce IA’s technologies flexibly responding to launching small satellites and value provided by Epsilon rockets.

Enhanced Epsilon rocket: Liftoff ©JAXA

Appearance of enhanced Epsilon rocket ©JAXA

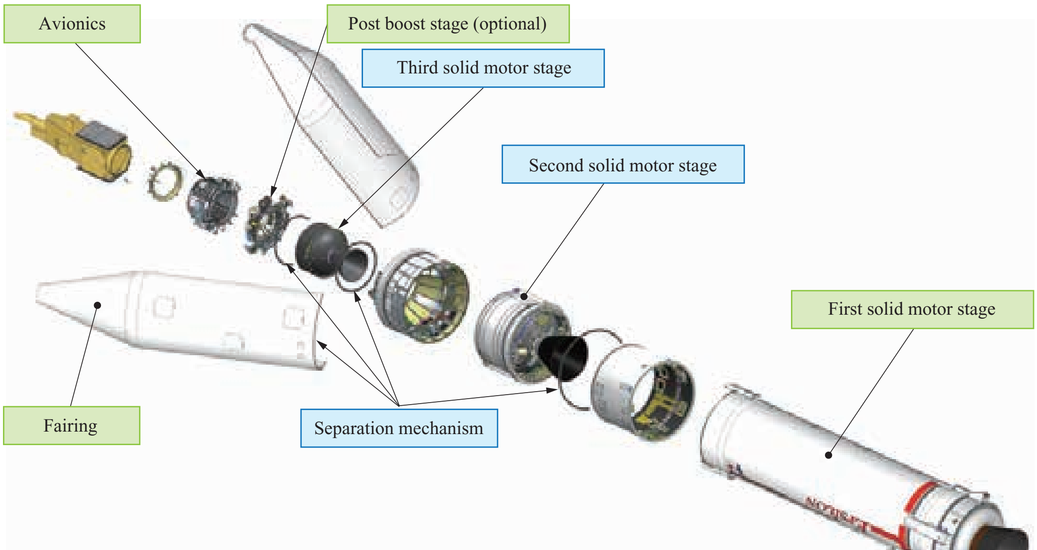
Enhanced Epsilon rocket

The first Epsilon rocket developed by IHI AEROSPACE Co., Ltd. (IA) under the supervision of National Research and Development Agency, Japan Aerospace Exploration Agency (JAXA) was launched in September, 2013, and the mission of placing the spectroscopic planet observatory satellite “HISAKI” in orbit was achieved.

Subsequently, after approximately 3-year improvement and development, we succeeded in launching Epsilon-2 in December, 2016. The Epsilon rocket installed with a solid rocket booster (SRB-A) in the underlying first stage and inheriting DNA from the M-V rocket including all solid rocket stages is being evolved in line with the times. Note that SRB-A was also used for the H-IIA/B rocket and its reliability was highly evaluated.

The purpose of developing the enhanced Epsilon rocket is to enlarge a payload usable volume of a satellite and to improve a launch capability in order to respond to the needs for satellites. The demand for launching small satellites, such as the geospace probe “ARASE” (ERG: Exploration of energization and Radiation in Geospace) launched by Epsilon-2 and the earth observatory satellite “ASNARO-2” launched by Epsilon-3, is increasing. In order to respond to the demand, it was necessary to enlarge the payload usable volume and improve the launch capability while reducing both the cost and period of development.

There were almost three main improvements performed on the launch vehicle.

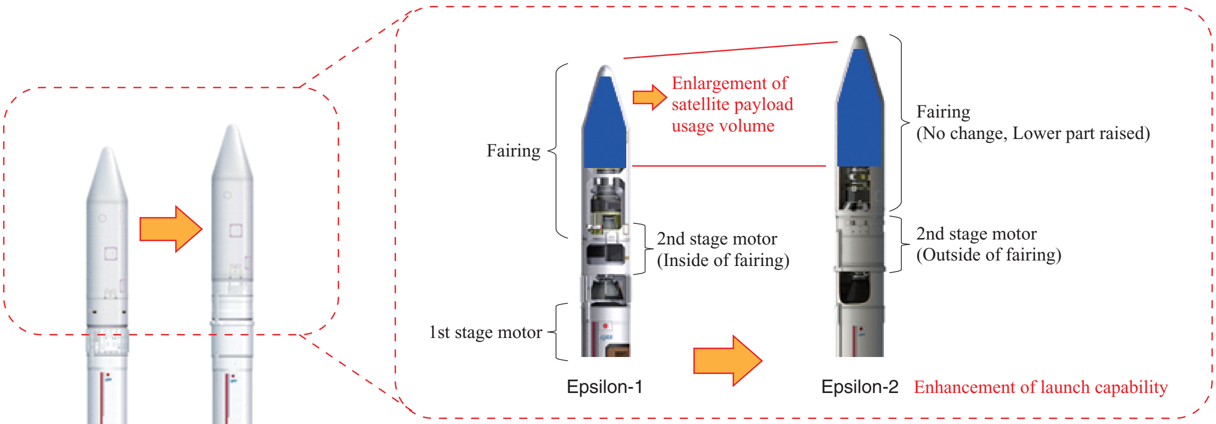


Item	Specification	
Total length	26 m	
Diameter	2.6 m	
Gross weight	96 ton	
Launch capability	SSO (500 × 500 km) Extended elliptical (200 × 30 000 km)	: 590 kg or more (Optional configuration) : 365 kg or more (Basic configuration)

Configuration diagram of enhanced Epsilon rocket ©JAXA

Increase in size of 2nd stage motor

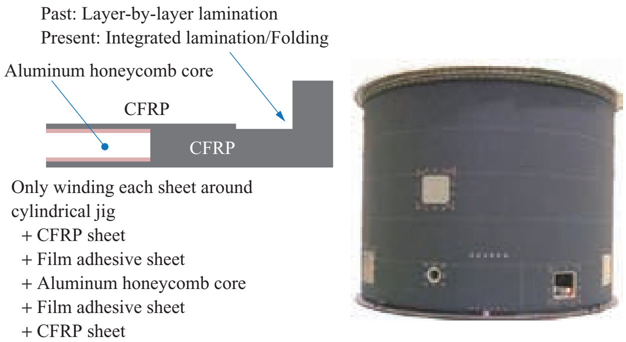
To increase the launch capability, it is necessary to increase the size of a motor. First, we increased the amount of propellant of the second stage motor up to 1.4 times. In order to suppress an increase in weight due to the expand in size of the motor, we reviewed materials and parts configuration to further improve performance. Indeed, it had been 14 years since the last development of a large motor. On the basis of lots of the past manufacturing results achieved by IA, we reviewed the safety factor of the CFRP pressure vessel to reduce the weight while keeping high reliability. Also, a further reduction in weight was achieved by employing a multifunctional heat resistant rubber material prepared by forming the three-layer of rubber into one layer. This multifunctional rubber was developed by IA.



Launch capability	Epsilon-1	Epsilon-2
SSO	450 kg	590 kg
Satellite payload usage volume	4.7 m	5.4 m

Overview of improvements of enhanced Epsilon rocket

Combustion test of 2nd stage motor ©JAXA



Large composite material structure (B1PL)

This development allowed a payload for an earth observatory satellite with strong needs, such as ASNARO-2 launched by Epsilon-3, to be improved by 30%, i.e., from 450 kg to 590 kg. This made it possible to increase the weight of the satellite loaded in Epsilon-2 to 365 kg. Since the payload of Epsilon-1 for carrying the satellite was 300 kg, performance was enhanced so that a satellite heavier by 65 kg was mountable.

Also, the second stage motor installed inside the fairing of Epsilon-1 was increased in diameter and therefore moved outside and upward, maintaining the specification of the fairing, and thereby the length of a payload usable volume was increased by 0.7 m compared with Epsilon-1.

The improvement of the launch capability and the expansion of the payload usable volume associated with the increase in size of the second stage motor realized the world's top-level enhanced Epsilon rocket.

Reduction in size and weight of avionics

To improve the launch capability, it is effective to reduce the weight of the whole Epsilon rocket. For this purpose, we also worked on a reduction in size of avionics (electronic equipment loaded into aircrafts and rockets and controlling flights). By replacing mechanical relays with a Power Sequence Distribution Box (PSDB) and applying semiconductor switches for the first time in Japan, the weight of the avionics was reduced to approximately half and thereby the launch capability was improved.

Although nowadays everyone thinks that using semiconductor switches to reduce size is common, a reduction in size is not easy for space equipment. The failure of a semiconductor device due to space radiations and malfunction due to noise must be absolutely avoided. Only because of IA having the know-how on what kind of load test should be cleared in order to use space equipment under space environment and knowing how to accumulate test data, the reduction in size of the space equipment was achieved. The PSDB with high radiation resistance was developed in collaboration with MEISEI ELECTRIC CO., LTD. of the IHI group.

Light-weight composite material structure

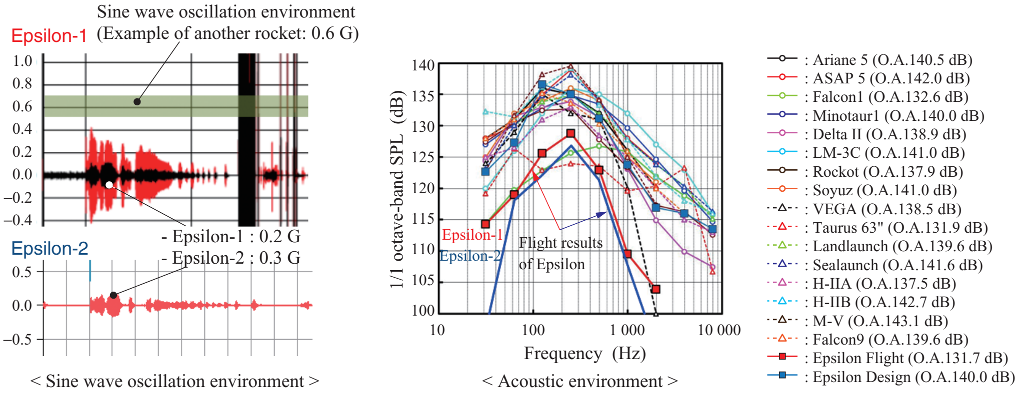
Composite material structure was employed for the lower structures to reduce weight in association with the increase in motor diameter due to the increase in size of the second stage motor.

The employment of the light-weight composite material structure, which is in the field of expertise where IHI and IA had collaborated with each other for aircraft engines, was also intended to enhance performance, reduce cost, and take preparatory steps for the future. We developed a low-cost process structure made of a CFRP material (a process was simplified by changing from conventional hand wrapping lamination to integrated lamination and wrapping a metallic honeycomb together with a CFRP sheet) for the 1/2 inter-stage structure. In doing so, both high performance and low cost were achieved for the CFRP structure, which had been relatively expensive.

Thus, the scientific exploration satellite ERG was launched on December 20, 2016. The satellite was successfully launched on time at the scheduled date. Also, a vibration environment indicating the ride quality of the satellite and injection accuracy into an orbit exhibited the good result that both satisfied corresponding ranges required by the satellite.

Value provided by Epsilon rocket

In order to send the high-performance small radar satellite ASNARO-2 into the space, Epsilon-3 was launched in January, 2018. As with Epsilon-1, Epsilon-3 mounted with the liquid stage PBS is expected to be more highly accurately launched. ASNARO-2 is a small earth observatory satellite, which is mounted with a high-resolution synthetic aperture radar (SAR) and was developed by the Ministry of Economy, Trade and Industry. The emerging space nations also highly desire to own this sort of high-performance earth observatory satellite. Accordingly, ASNARO-2 also served as a touchstone for launching future commercial satellites, and we are currently running PR campaigns in Asian and other emerging nations together with the satellite manufacturer. Under such circumstances, IA frequently adjusted the interface with the satellite site, and got involved in satellite support work including operation at the rocket range more than ever.



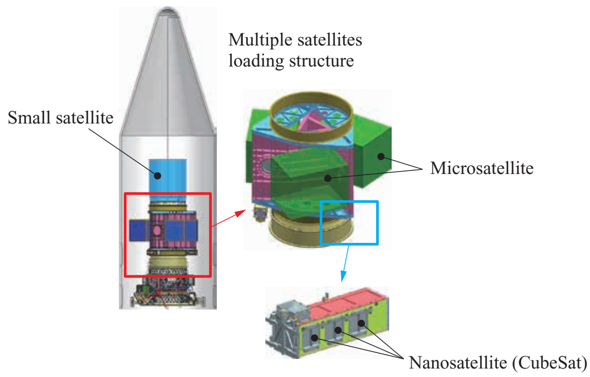
Flight results of enhanced Epsilon rocket

An Epsilon rocket is currently being developed so as to be capable of mounting nanosatellite (CubeSat) and small satellite, which have been extensively and intensively developed by some organizations such as space ventures, universities, and research institutes. That is Epsilon-4 planned to be launched in FY2018 and deploying multiple satellites.

Usually, a small satellite is launched in accordance with a main satellite plan as ride-share launch, and therefore they cannot freely determine anything about launch, such as launch time or target orbit. Accordingly, Epsilon rockets are aiming to flexibly respond to the requirements of such a small satellite as a main customer.

For example, we are planning to improve the fourth liquid PBS to achieve satellite separation in orbit and attitude meeting the requirements of each satellite, and flexibly respond to access to a satellite in the launch site and requests on operation. Currently, even familiar environments such as educational institutions including universities and high schools can develop small satellites, and we are aiming to develop Epsilon rockets for launching satellites for everyone.

Further, toward the 2020s, we will start development in synergy with H3 rocket development. The H3 rocket, a liquid fuel rocket, will also be mounted with a solid booster as with the previous H-IIA rocket, and this will be applied to the first stage motor of an Epsilon rocket. We will further improve competitiveness through such development and variously provide value and service to customers using Epsilon rockets.



Multiple satellites loading configuration of Epsilon rocket

Mini commentary

Geospace

Geospace refers to outer space strongly affected by the earth, where human activities become increasingly significant, such as the operation of weather satellites for weather forecasting and GPS satellites for car navigation. In the outer space affected by the earth, an area called the Van Allen belt filled with high energy particles exists and is violently varied by the disturbance of particles and magnetic field due to variations in solar activities, such as corona discharge caused by solar flares. Such a phenomenon is just called a “cosmic storm.” The failure of space vehicles such as artificial satellites and the safety of astronauts in the space station at the time of extravehicular activities are concerns.

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