The Successful Launch of the Fourth Epsilon Launch Vehicle and its Future Rideshare Plans

Makoto Horikawa, Hitomi Izumi, Yusuke Ohagi, Yuichi Noguchi, Kazuhiro Yagi
IHI AEROSPACE Co., Ltd.
900, Fujiki, Tomioka, Gunma, Japan; +81-274-62-7729
makoto-horikawa@iac.ihi.co.jp

Takayuki Imoto
Japan Aerospace Exploration Agency
2-1-1 Sengen, Tsukuba, Ibaraki, Japan; +81-29-868-5000
imoto.takayuki@jaxa.jp

ABSTRACT

The fourth Epsilon launch vehicle conducted its first rideshare mission on January 18, 2019. It successfully delivered seven satellites to the Sun Synchronous Orbit (SSO). In order to accommodate the demands in carrying satellites with various sizes, the Epsilon Satellite Mount Structure (ESMS) and the Epsilon Small Satellite Orbital Deployer (E-SSOD) was developed.

The paper first introduces features of the rideshare configuration of the Epsilon. Then, the mission design and the injection accuracy of the fourth Epsilon launch are described. Further, plans for the future rideshare opportunities are presented.

INTRODUCTION

In the morning of January 18, 2019, the fourth Epsilon launch vehicle was successfully launched from the Uchinoura Space Center (USC) in Kagoshima, Japan to place seven satellites to their designated orbits (Figure 1). It was the first rideshare mission for the Epsilon since its maiden flight in 2013.

Figure 1: Fourth Epsilon Launch Vehicle

The Epsilon launch vehicle is a three-stage solid propellant launch vehicle developed by Japan Aerospace Exploration Agency (JAXA) with the rocket system integrator, IHI AEROSPACE Co., Ltd., which integrated heritage of the two Japan's launch vehicles, the H-IIA launch vehicle and the M-V launch vehicle. The flight proven technologies used in the H-IIA and M-V launch vehicle made the Epsilon a reliable launch vehicle. The Epsilon aimed to satisfy the needs for small satellite launches. It can equip an optional Post Boost Stage (PBS) to acquire higher orbit injection accuracy and provide more flexible option for customers. It has payload friendly environment because of its low sinusoidal vibration achieved by newly designed Payload Attach Fitting and low acoustic vibration by modified smoke tunnel and soundproof blanket inside the payload faring.

During the past three launches, the Epsilon demonstrated its high injection accuracy and payload friendly environment as described, but for a single launch. 1,2,3 The rapid technological improvements in electronics motivated more people including private companies and colleges to make their own satellite, which increased the demands for more launch opportunities for smaller satellites. JAXA planned to develop a rideshare option for the Epsilon to respond to their requests and provide its high injection accuracy and payload friendly environment for smaller satellites.

This paper first introduces some features of the rideshare option of the Epsilon launch vehicle. Then, the mission design of the fourth Epsilon's flight and its result are described. Finally, the future rideshare plans are illustrated.

FEATURES OF RIDESHARE ON EPSILON

Total of seven satellites were selected by JAXA's Innovative Satellite Technology Demonstration program to demonstrate thirteen themes as shown in Table 1. 4 The size of satellite varies; one 200kg-class small satellite, three 60kg-class microsatellite, one 3U CubeSat, one 2U CubeSat and one 1U CubeSat. In order to fit these satellites inside the payload faring, a new structure and deployer called the Epsilon Satellite Mount Structure (ESMS) and the Epsilon Small Satellite Orbital Deployer (E-SSOD) were developed. The configuration of the fourth Epsilon is shown in Figure 2.

Table 1: Satellites selected by JAXA's Innovative Satellite Technology Demonstration program

Name	Mission(s)	Size
RAPIS-1	Perform orbital demonstration of the components and equipment selected in the Innovative Satellite Technology Demonstration Program	200kg class
MicroDragon	Earth observation for expanding satellite usage	60kg class
RISESAT	High-resolution/multi-spectrum Earth observation	
ALE-1	Verifying the feasibility to generate man-made meteor showers	
OrigamiSat-1	On-orbit demonstration of Multi-Functional Deployable Membrane Structure	CubeSat
Aoba VELOX-IV	On-orbit demonstration of the attitude/orbit control and low-light camera	
NEXUS	On-orbit demonstration of next-generation amateur satellite communication technology	

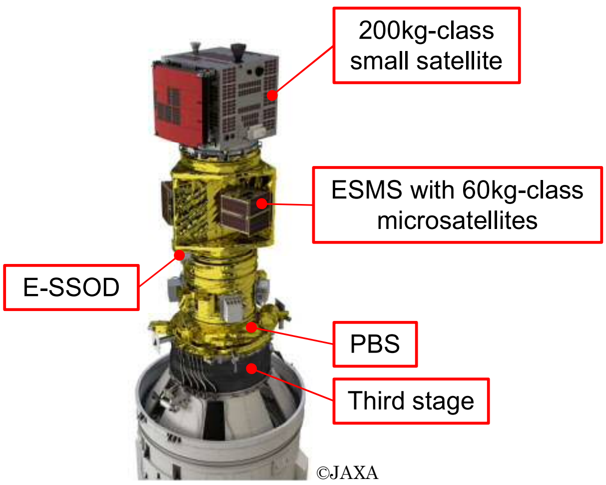

Figure 2: Satellites integrated to the launch vehicle

The ESMS, placed on top of the PBS, is the structure specifically designed to carry one 200kg-class small satellite and three 60kg-class microsatellite (Figure 3). It attaches E-SSOD at the bottom which carries CubeSats. A 200kg-class small satellite would be separated from ESMS by the low-shock separation mechanism produced by Kawasaki Heavy Industries, Co., Ltd., which is flight proven on the third Epsilon. Three 60kg-class microsatellites would be separated from ESMS by the 8-inch Lightband® designed by Planetary Systems Corporation. The Lightband® has a proven track record of deploying various satellites into orbit.

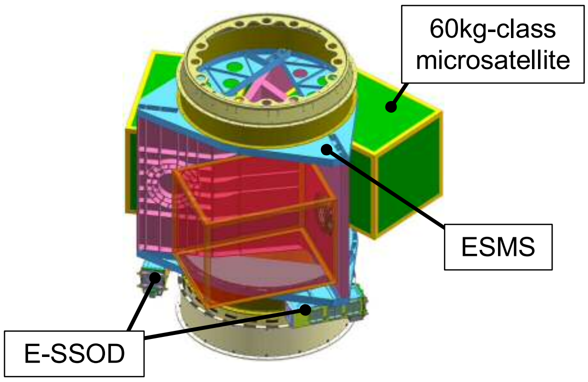

Figure 3: ESMS with E-SSODs and microsatellites attached

Microsatellites are placed sideways inside the ESMS, forming a triangle, to use the space effectively while avoiding unwanted contact with the launch vehicle during their separation. Due to this ESMS's unique feature, attaching a microsatellite from the side while on the ground would not be a good option since it may damage both satellite and the ESMS. Therefore, a device to allow safe mate/demate of a microsatellite was made(Figure 4). It rotates the ESMS 90 degrees sideways and 360 degrees to its roll direction. This device allows a microsatellite to mate or demate only by vertical motion, just as ordinary single launch satellites do.

The E-SSOD, attached at the bottom of the ESMS, is the CubeSat deployer developed from the JEM Small Satellite Orbital Deployer (J-SSOD) which is a CubeSat deployer installed on the Kibo Japanese Experimental Module of the ISS. It could deploy any CubeSat of a size up to 3U, and it could handle combinations of CubeSats such as three 1U CubeSats or one 2U and one 1U CubeSats. The E-SSOD would be integrated to the ESMS after it stores CubeSats inside (Figure 6).

Figure 4: The rotating device used during fit-check of ALE-1

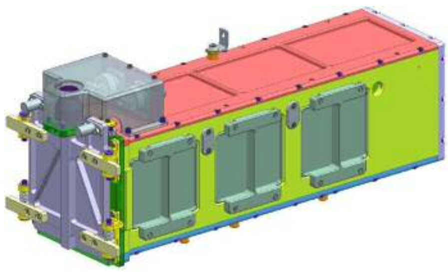

Figure 5: E-SSOD

Figure 6: E-SSOD attached to ESMS with CubeSats stored inside

If customers request, the fit-check of a satellite may be performed in Japan approximately seven months prior to the launch. The mating of a satellite to the launch vehicle occurs approximately two month prior to the launch.

MISSION DESIGN

To manage the interface between a satellite and a launch vehicle, the Interface Control Document (ICD) was utilized. The results of the preliminary and final mission analysis were shared with customers and updated the ICDs based on the results.

One of the demands which had to be considered for the fourth Epsilon's mission design was to have RAPIS-1 separating first, while ALE-1 having the lowest orbit and separating last. ALE-1, the world's first satellite to create an artificial meteor shower, had a plan to lower its orbit from where the Epsilon injects, thus it preferred no other object in its way to avoid any unwanted contact.

We determined to separate RAPIS-1 first, and then separate two other microsatellites and CubeSats prior to ALE-1. The nominal mission sequence for a rideshare mission was planned to lower PBS's orbit as it separates the satellites to avoid collision (Figure 7). The PBS would be placed in the lowest orbit after the separation of the final satellite by performing the contamination and collision avoidance maneuver (CCAM) followed by discharge of the remaining propellant. To accommodate ALE-1's request, the PBS's orbit was raised for CCAM.

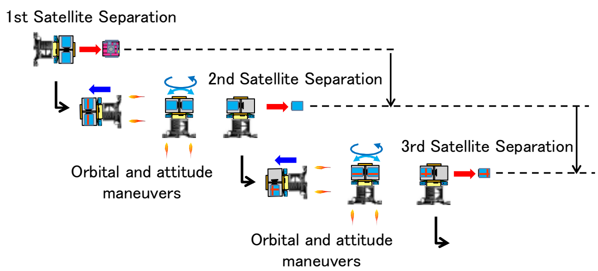

Figure 7: Nominal sequence for rideshare mission

The flight path of the fourth Epsilon is shown in Figure 8. The flight data shows that the launch vehicle flew as expected. The difference in the duration of the first PBS burn comes from the error in the solid propellant phase, which was inside the expectation and could be easily fixed by the PBS. Specific for this flight, the separation data of microsatellites and CubeSats were downlinked and confirmed at stations in Japan after the launch vehicle first circled around the Earth.

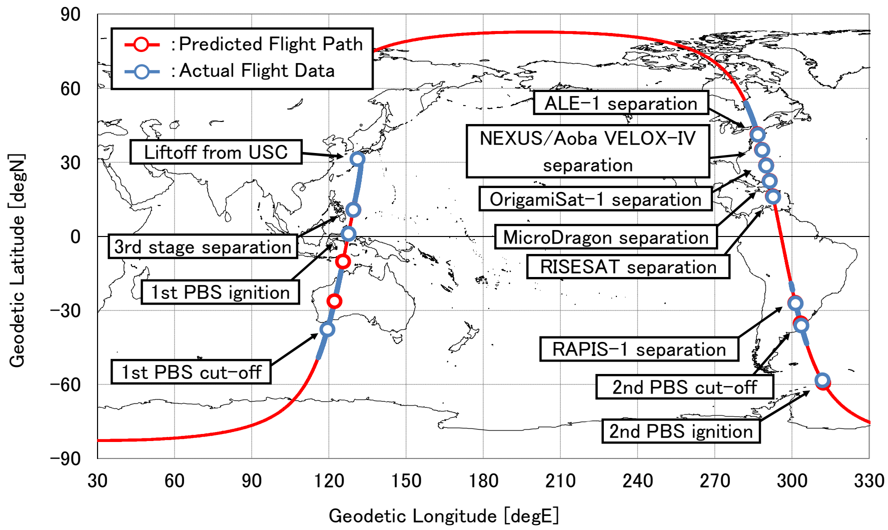

Figure 8: Flight path of the fourth Epsilon

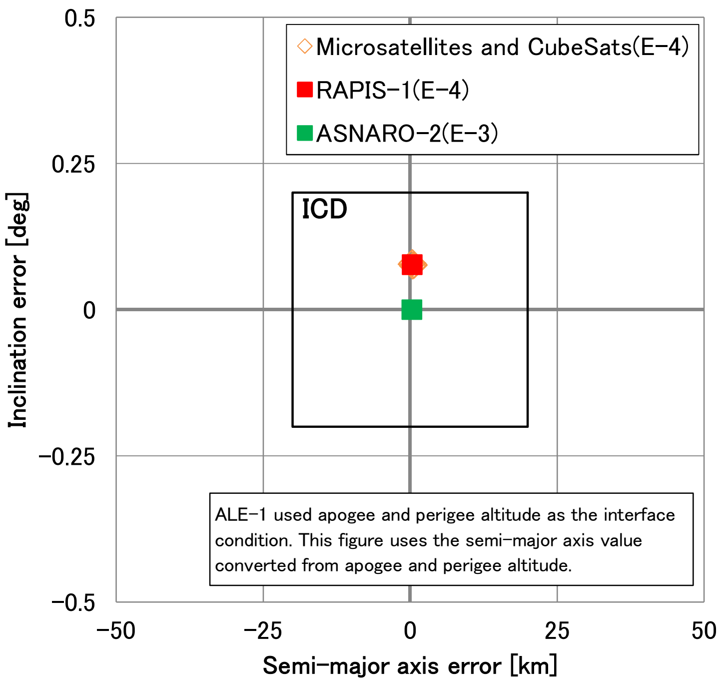

Figure 9: Injection Accuracy of the third and fourth Epsilon

The results of injection for all seven satellites are shown in Figure 9. Along with the third Epsilon flight which delivered a 600kg-class satellite "ASNARO-2" made by NEC, Epsilon has shown its high injection accuracy to Sun Synchronous Orbit (SSO).

FUTURE RIDESHARE OPPORTUNITIES

The next Epsilon's rideshare launch will carry satellites selected by the second Innovative Satellite Technology Demonstration program produced by JAXA. Fifteen themes were selected including one small satellite, three microsatellites and four CubeSats; two 3U, one 2U and one 1U size. In order to deliver four CubeSats into orbit, some minor modifications will be carried out to operate 3 E-SSODs.

Along with the operation of the Epsilon, the new Epsilon launch vehicle is being planned by JAXA to obtain synergy effect with the next-generation Japan's flagship launch vehicle, H3. As the current Epsilon does with the H-IIA launch vehicle, the new Epsilon will use the H3's new solid rocket booster, SRB-3, as its first stage. Obtaining a synergy effect with H3 would certainly reduce the cost for launch and would allow more chance for satellites to have rideshare opportunity.

CONCLUSION

The first rideshare launch of the Epsilon concluded with a success. Total of seven satellites were deployed to their designated orbit with high injection accuracy. The newly developed ESMS and E-SSODs allowed the Epsilon to carry satellites with various sizes.

The next rideshare launch is planned, and the Epsilon would carry out some minor modification to deliver more satellites. Further, the new Epsilon launch vehicle is planned by JAXA to obtain a synergy effect with H3 launch vehicle. The Epsilon will continue to provide launch opportunities for small satellites.

REFERENCES

1. Y.Morita and T.Imoto, "EPSILON LAUNCH VEHICLE FIRST FLIGHT RESULTS AND ITS EVOLUTIONS," 65th Congress of the International Astronautical Federation (IAC), Toronto, Canada, 2014.
2. T.Kanechika, Y.Segawa, K.Yagi, T.Imoto, "Epsilon Launch Vehicle –Second Flight and its Evolutions," 31nd International Symposium on Space Technology and Science (ISTS), Ehime, Japan, 2017.
3. K.Oribe, Y.Noguchi, M.Sakamoto, M.Fujimura, K.Yagi, T.Imoto, "The Result of Epsilon Launch Vehicle Third Flight and Plan for Multi-Launch," 69th Congress of the International Astronautical Federation (IAC), Bremen, Germany, 2018.
4. Innovative Satellite Technology Demonstration program Press Kit. (2018) Retrieved from http://fanfun.jaxa.jp/countdown/kakushin-epsilon4/pdf/kakushin01_press_kit_web.pdf