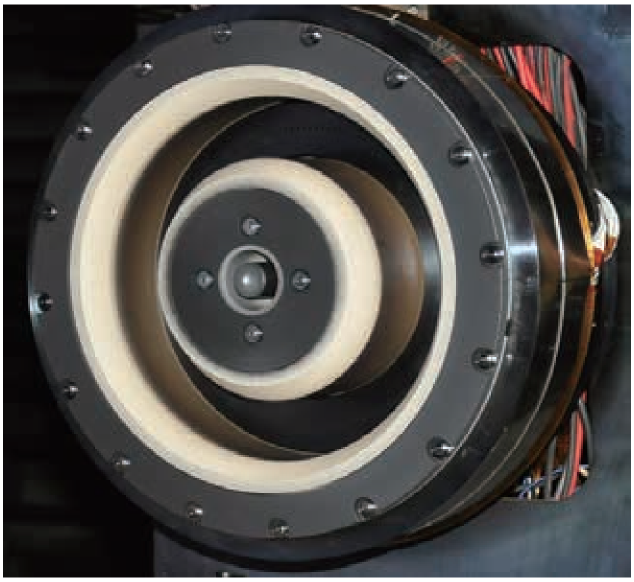
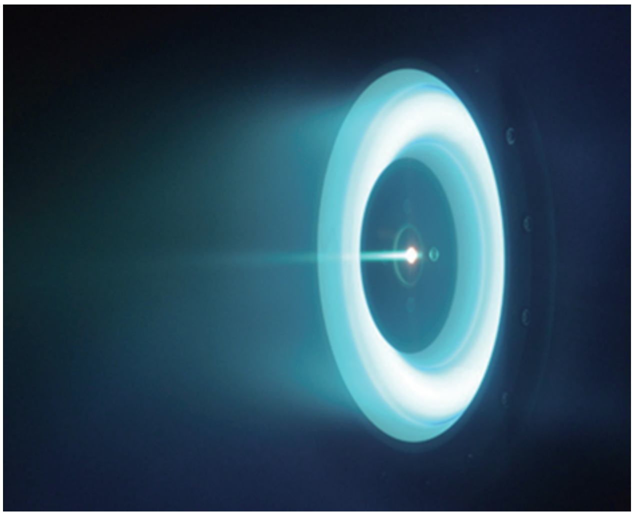
All Electrification Prolongs Lifetime of Satellites

Hall thruster for all-electric satellites
High thrust and low fuel consumption achieved by single thruster

A Hall thruster is a sort of electric propulsion device used in a satellite. Electric propulsion devices had been used previously for only station keeping in geostationary orbit, and for orbit raising, chemical propulsion devices have been used.
The global trend developing all-electric satellites which use only Hall thrusters is now accelerating.



Hall thruster under development ©JAXA



Hall thruster during operation ©JAXA

Business environment

Propulsion systems mounted on satellites can be roughly divided into a chemical propulsion system and an electric propulsion system. The former has high thrust, and is therefore used for orbit raising to change the position of a satellite. However, the chemical propulsion increases weight because it requires a large amount of propellant. On the other hand, the electric propulsion is characterized by high specific impulse (= low fuel consumption), and suitable for the attitude control of a satellite operating over a long period of time.

One of the features of "all-electric satellites" now attracting great attention worldwide is to dramatically reduce fuel weight by using the electric propulsion technology, which has been used for attitude control, for orbit raising as well. All-electric American satellites mounted with an ion engine, a sort of electric propulsion system, have been already put into practical use. On the other hand, regarding Hall thrusters among the same electric propulsion systems, only small ones have been used for station keeping in geostationary orbit in the past. However, a method that uses a larger Hall thruster for orbit raising is becoming mainstream as well because its thrust-to-power ratio can be higher than ion engine.

In such a situation, IHI AEROSPACE Co., Ltd. (IA) is working on the research and development of a Hall thruster for all-electric satellites in cooperation with IHI, the National Research and Development Agency, Japan Aerospace Exploration Agency (JAXA), and Tokyo Metropolitan University (TMU). Our Hall thruster under development is capable of achieving high thrust with a high thrust-to-power ratio.

Differentiation

Hall thrusters put into practical use overseas have an operating voltage of approximately 300 to 400 V and an electric power of 5 kW or less.

To set the development target of the Hall thruster, the following basic specifications were selected as a dual operating Hall thruster satisfying both an increase in specific impulse and high thrust operation in terms of future change of satellite specifications and differentiation from competitors.

- Maximum electric power: 6 kW
  Responds to an increase in supply power associated with an increase in size of a satellite, and enables a high thrust-to-power ratio.
- Maximum supply voltage: 800 V
  Enables high specific impulse.

However, the below-described Engineering Test Satellite 9 (ETS-9) is planned to use a voltage range of 300 to 400 V for reliable verification. On the basis of the results of the verification, we will aim to achieve an increase in thrust due to an increase in current and an increase in specific impulse due to an increase in voltage.

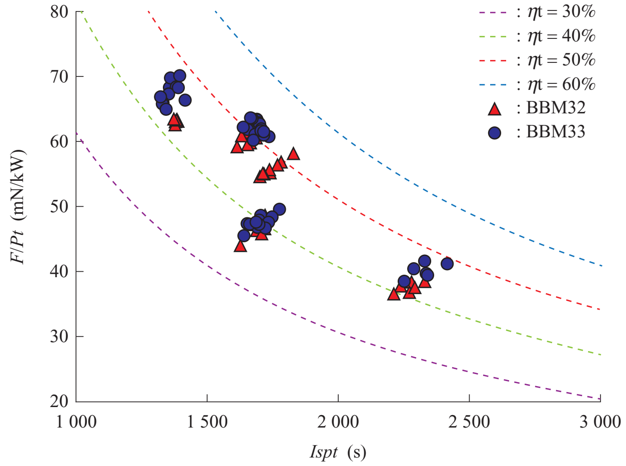
Development status

Phased project planning is used as a satellite development method. This is a method adapted to divide the entire plan into seven phases, define content for each of the phases, and examine result to proceed to the next phase.

The new Hall thruster is currently in the third phase, and we are advancing the development and test of a prototype test model called a Bread Board Model (BBM).

The performance of BBM is checked using a vacuum chamber of Georgia Institute of Technology (USA). This facility has exhaust velocity of world's top level, and performance data can be acquired under condition satisfying the degree of vacuum (3×10^{-5} Torr = 4×10^{-3} Pa) recommended for performance evaluation. In the current model BBM3, we are working on the improvement of a magnetic field configuration and the optimization of a propellant jet configuration and a channel geometry with a focus on the further improvement of propulsion performance while following the size of the thruster and the installation position of the cathode as test results of BBMs 1 and 2. In addition, we are also proceeding with checking the performance of a cathode under development by IA/JAXA in combination with the thruster.

The figure shows the performance evaluation results of BBM3 thrusters. BBM32 has the basic configuration of the BBM3 series, and BBM33 has a configuration in which the magnetic field configuration and channel geometry are changed from BBM32. The horizontal axis represents the specific impulse *Ispt*, whereas the vertical axis represents the thrust-to-power ratio *F*/*Pt*, and efficiency ηt curves are also illustrated (These performance indices include the power and flow rate at the anode, power and flow rate at the cathode,



Performance evaluation results of BBM3 thruster

and power at the coil).

It has been confirmed until now that BBM33 in the diagram exhibits a thrust-to-power ratio of 70 mN/kW in a high thrust mode and a specific impulse of 2 415 s in a high specific impulse mode. In both the modes, the development targets are about to be achieved, and we are proceeding with examination for further performance improvement.

Future efforts and problems

The development of the Hall thruster has been started toward mounting on the next Engineering Test Satellite 9 (ETS-9). We are currently optimizing design suitable for an operating mode corresponding to a voltage range required for ETS-9 and evaluating operating characteristics such as performance.

Although there are many problems such as the structural evaluation of ceramic materials and the performance prediction of the thruster because of the development of the Japan's first flight model of the Hall thruster, we are proceeding with solving the problems in cooperation with the IHI group.

In the future, we will advance the development in accordance with the following schedule. That is, the development will transfer to the next phase, i.e., the EM (Engineering Model) phase within FY 2017, the qualification test will be complete within FY 2019, and the FM (Flight Model) phase will be completed around the middle of FY 2020. In addition, the launch in 2021 will be the on-orbit verification of the first Hall thruster in Japan.

Inquiries:
Liquid Propulsion Office,
Space Systems Department,
IHI AEROSPACE Co., Ltd.
Phone: +81-274-62-7675
https://www.ihi.co.jp/ia/en/