Space Exploration Strategy with High Power Plasma Propulsions
大電力プラズマ推進による宇宙探査構想

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Electric plasma propulsions are more effective device to propel spacecrafts than conventional chemical, or combustion-based propulsions. It has been applied to numerous space missions so far because of their great propellant consumption efficiency. Recently, with improvement of performance, durability and reliability of them, the use of plasma propulsions has been expanding further. The expected future missions using plasma propulsions include both satellite transportation to higher orbit and deep space exploration, and both require high power thruster. Background of the future space exploration missions and R&D activities of plasma propulsions in Japan to contribute these missions will be discussed in this paper.

1. Introduction

Effective space transportation systems are needed to expand the field of space activities beyond the low earth orbit. Plasma propulsions, or electric propulsions are promising technologies for the orbital transportation for future large-scale missions due to their high specific impulse, that is, high propellant consumption efficiency.

Electric propulsion is an energy conversion device that convert electric energy into kinetic energy of plasma jet through electrostatic, electromagnetic or electrothermal acceleration that propel orbital spacecrafts. It has been used for attitude control of GEO (geosynchronous orbit) satellites like ETS series and for orbit transfer of space exploration probes like Hayabusa asteroid explorer in Japan so far. Nowadays, electric propulsions begin to be applied to obit rising for GEO satellites as well, i.e. all-electric satellites, because they give great cost reduction to launch. A great attention has been paid to electric propulsion system especially high power, more than 5 kW class systems.

The International Space Exploration Coordination Group, ISECG, has been discussing human space exploration toward the Moon, NEAs (Near Earth Asteroids), and Mars [1] as a following activity after the retirement of International Space Station, ISS. They have been insisting on the necessity of high power electric propulsion systems for these missions as shown in Fig. 1.

Japan Aerospace Exploration Agency, JAXA, has been contributing to the establishment and operation of ISS for years, and now considering the contribution to the future international space exploration by Japanese own space technologies. Electric propulsion is one of the candidates because Japan has lots of heritage in this field.

In this paper, the future space exploration missions discussed in ISECG will be introduced. Then, R&D activities of electric plasma propulsions in Japan toward to these missions will be explained.

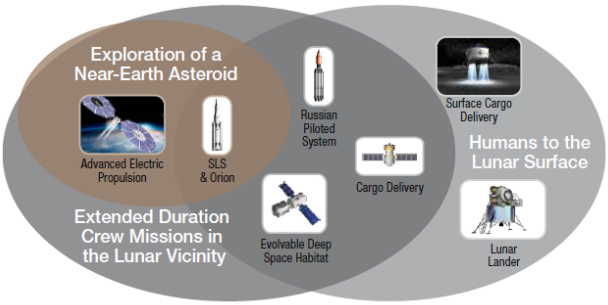

Fig. 1 Critical technologies for human space exploration [1].

2. Future Space Exploration Missions [2]

2.1 *Asteroid Redirect Mission (ARM)*

ARM will offer chances of human exploration of an asteroid. In ARM, a robotic spacecraft with high power electric propulsion such as Hall effect thruster to rendezvous with, capture and redirect an asteroid. The spacecraft will redirect it to a stable orbit around the moon. After that, astronauts aboard a manned spacecraft, launched from a heavy rocket, will explore the asteroid around the moon.

2.2 *Human Lunar Exploration*

As a first step for the human lunar exploration, a plan to establish a space station around the moon is discussed internationally. The promising location is an Earth-Moon Lagrange point. To effectively deliver supplies to the station, space cargo vehicle with electric propulsion is favorable. The station will play important role as a stepping stone to the lunar surface exploration as shown in Fig. 2.

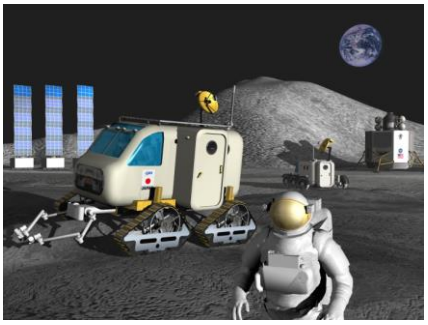

Fig. 2 Image of human lunar surface exploration [2].

2.3 *Human Mars Exploration*

The final destination described in ISECG/GER is Mars. Very high power plasma propulsion on the order of > 1 MW is the one of critical technology needs and can more efficiently deliver cargo and crew to beyond low Earth orbit destinations. The candidates of the 1 MW class thruster would be MPD (Magnetoplasmadynamic) and arcjet thrusters.

3. Electric Plasma Propulsion R&D in Japan

3.1 *Hall Effect Thruster [3]*

Hall effect thruster produces thrust through electrostatic acceleration of ions and one of the major candidates for the near term application of high power electric propulsion. Hall thruster is especially suitable for all-electric satellites because it enables shorter trip time to GEO due to its higher thrust. JAXA is now promoting R&D activity of Hall thrusters with both universities and industries. Figure 3 shows a snap shot of the high power hall thruster during operation in the vacuum chamber in ISAS/JAXA.

3.2 *MPD Thruster and Arcjet Thruster [4]*

MPD and arcjet thrusters are electromagnetic and electrothermal type plasma accelerators, respectively. They are promising plasma thrusters for very high power application. They can be easily adapted to the high power operation due to their higher thrust density, or lighter system weight. The performances of MPD thruster and arcjet are improved by using cryogenic liquid hydrogen as a propellant. However, storing liquid hydrogen for a long period of time in orbit is a difficult problem. JAXA has developed cryogenic propellant storage technologies as well as development of plasma thrusters. The activities will realize high-performance innovative space vehicles for efficient mass transfer. Figure 4 shows an arcjet thruster operation with hydrogen propellant in the vacuum chamber in ISAS/JAXA.

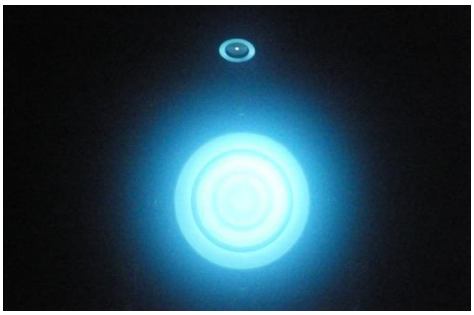

Fig. 3 High power xenon hall thruster operation in vacuum chamber in ISAS/JAXA.

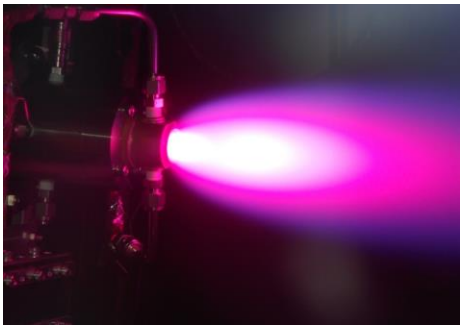

Fig. 4 15 kW class hydrogen arcjet thruster operation in vacuum chamber in ISAS/JAXA.

4. Conclusion

High power electric plasma propulsions are strongly required for next generation space missions, such as all-electric satellite mission, and large scale space exploration beyond the earth orbit. Hall, MPD and arcjet thrusters are candidates for the high power operation, therefore, JAXA is now promoting R&D activities of such thrusters.

References

[1] International Space Exploration Coordination Group (ISECG): Global Exploration Roadmap (GER), http://www.globalspaceexploration.org, 2013.

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