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History and Prospects on Research, Development and Application of Electric Rockets
電気ロケットの発展経緯と今後の研究開発利用

Hitoshi Kuninaka
國中　均

Japan Aerospace Exploration Agency
Yoshinodai, Chuo, Sagamihara , Kanagawa, Japan
宇宙航空研究開発機構　神奈川県相模原市中央区由野台

The electric propulsion, initiated by the founders in 1950's, has achieved Geostationary Satellites for North-South Station Keeping in 1990's and Deep Space Powered Flights in 2000's as new eras in space technology, where Japanese activities deeply contributed. EP will open a next new world: In-Space Transportation for human exploration and constructions of solar power satellite, and so on. Japanese R&D efforts should be concentrated to realize 10-100kW electric propulsion.

1. History of Electric Propulsion

The electric propulsion (EP), initiated by the founders such as Tsiolkovsky and Goddard in 1950's, has been researched on ground and tested in space in 1960's and 1970's, enthusiastically as seen in Fig.1. The ion engine has progressed in the Western world, and Hall thruster in the Eastern bloc. These activities were shrunk at once in 1980's because R&D effort was concentrated to launching rockets. In 1990's various countries applied EP to Geostationary Satellites for North-South Station Keeping (GEO-NSSK) in order to prolong their life in space and developed many series of satellite bus installing EP in the standpoint of economy. In 2000's NASA, ESA and JAXA succeeded the Deep Space Powered Flights, independently, so that the new era of space exploration was opened for expansion of human intelligence to the solar system. Japanese activities have deeply contributed to progression of EP technology. In 2010 the largest EP BPT4000 of Hall thruster with 4kW has just made a debut and lifts up 6-ton satellite to GEO. This is a precursor of In-Space Transportation. Figure 2 shows chronology on EP growth in thrust, which achieved 300mN, for the last few decades.

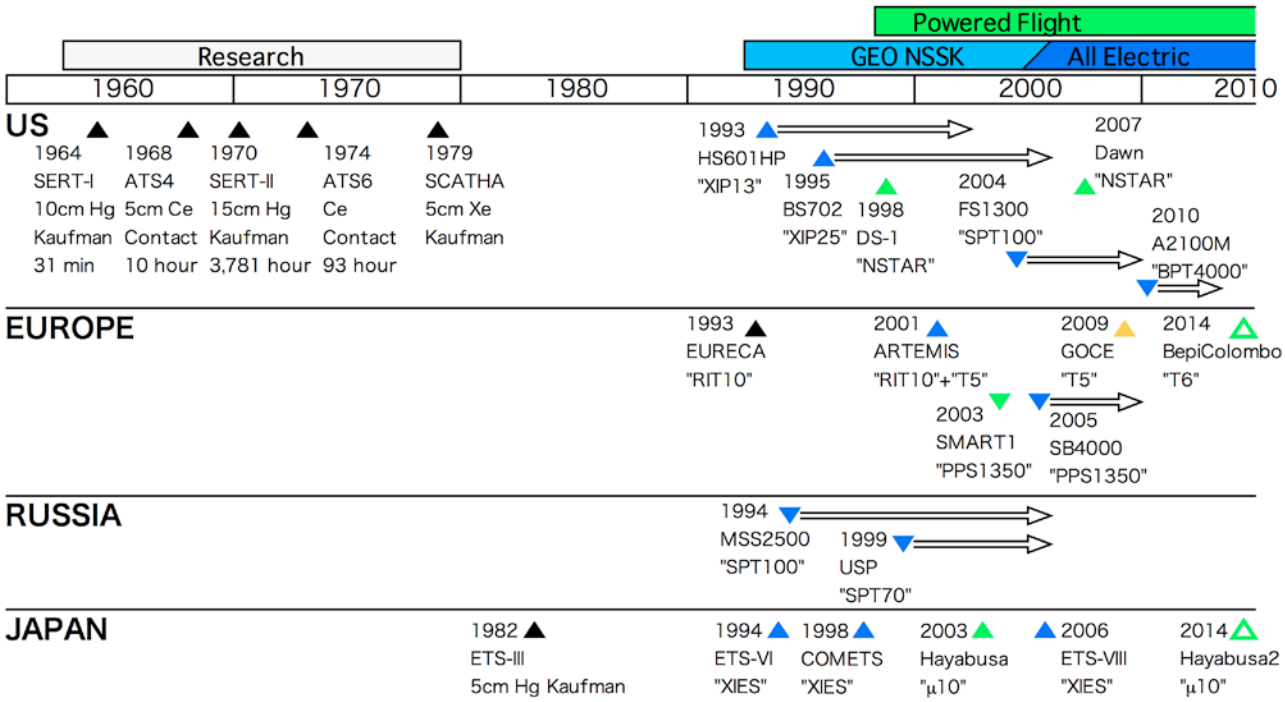

Fig.1. Flight Chronology of Electric Propulsion

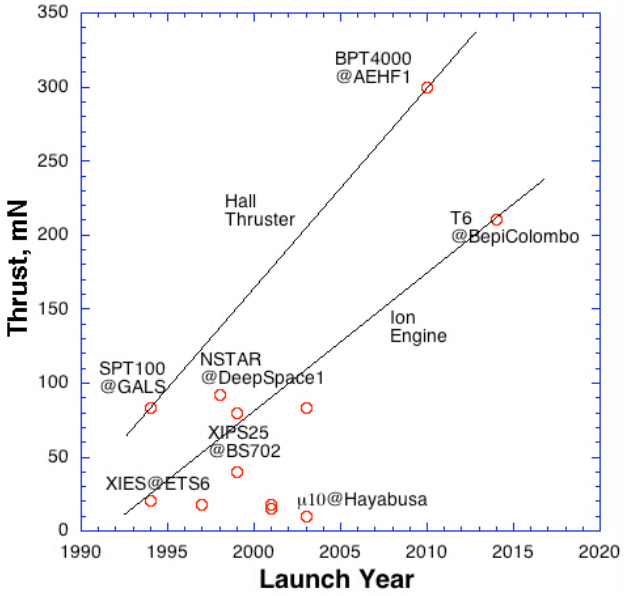

Fig.2. Growth of EP in Thrust Force

2. World Trends on R&D

NASA had developed NSTAR ion engine[1] rated at 2.3kW since 1990 and succeeded Deep Space 1 and Dawn missions for space exploration, in 1998 and 2007 respectively. At beginning of 2000 they started to develop NEXT ion engine with 6.9kW and perfected it in 2010[2]. The Herakles Thruster with 20-40kW was proposed in order to adapt space nuclear power plant in Project Prometheus, which was cancelled in 2003. In the latter half of 2000's the concept of In-Space Propulsion, in which EP with high specific impulse makes spacecraft long reach and high maneuverability instead of larger launch vehicle, has been now fully accepted. In 2010 President Obama announced the flexible path on the human approach to Mars through asteroids instead of Moon. This idea stimulates to apply EP to 300-700kW solar electric propulsion cargo for the human space exploration[3] and construction of space solar power satellites and to research and develop high power EP with 40-60kW in US. A US private company has developed 1N Hall thruster with 20kW[4].

European Commission has funded several institutes in Europe since 2008 to R&D on high power EP as the program of HiPER (High Power Electric propulsion Roadmap).

This world trend implies In-Space Transportation, succeeding GEO-NSSK and Powered Flight in deep space, a new frontier for EP in next few decades.

3. Proposed Approach in Japan

Japan has executed GEO-NSSK[5] and Deep Space Powered Flight[6] by EP leading the international space community. JAXA and a space sector have developed 35cm ion engine and 5kW Hall thruster independently, which are candidates for In-Space Transportation in near term at Japanese local activities. The author believes Japanese EP academy and institutes should move on to develop 10-100kW class EP for future In-Space Transportation of international collaboration, gathering together our intelligence. At this moment "selection" and "concentration" of our domestic activities are very important[7]. Figure 3 shows the scenario to research and develop high power EP in Japan.

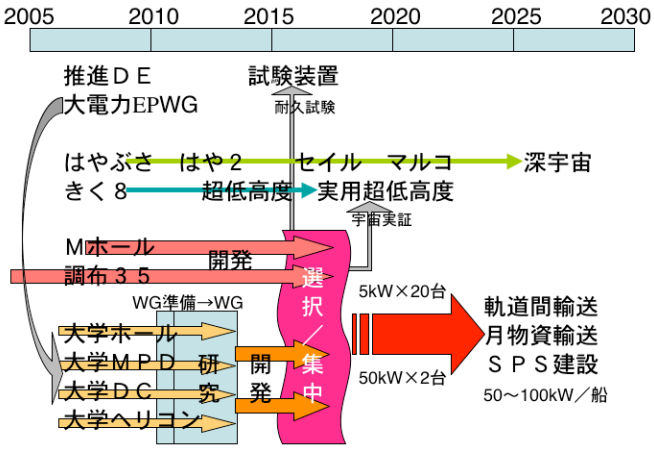

Fig.3. R&D Scenario of High Power EP in Japan

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