Guest Editorial Introduction to the Special Issue on Plasma Propulsion

THIS Special Issue is dedicated to the physics, technology, and application of plasma propulsion for spacecraft. The field of plasma propulsion includes a broad variety of thrusters that can achieve high propellant exhaust velocity, thereby offering a large mass savings for space vehicles compared to chemical (combustion) rockets. These thrusters are broadly categorized by their propellant acceleration mechanism into three groups: 1) electrothermal; 2) electrostatic; and 3) electromagnetic [1]. Research into plasma propulsion dates back several decades, with a first application in space in 1964 on the Soviet Zond-2, which used an ablative pulsed plasma thruster to control the spacecraft orientation. Today, plasma propulsion is a very rapidly growing area of plasma science and technology, with over 250 operational spacecraft employing plasma propulsion in a variety of applications. Many new plasma thrusters have been recently developed, including numerous successful attempts to scale previously known systems to lower and higher power levels, ranging from a few watts to over 100 kW [2], [3]. As space exploration shifts toward small and efficient satellites, or micro and nanosatellites [4], [5], there are many near-future space missions involving science, military, and commercial payloads utilizing micro and nanosatellite platforms. These platforms require very small levels of thrust for very fine attitude control, high resolution. Earth imaging and astronomy, as well as very precise positioning requirements and other very precise positioning requirements for spacecraft performing formation flying and interferometry missions. Miniaturized propulsion systems are required to satisfy these emerging needs for both the low-thrust missions and the propulsion on small-sized spacecraft.

Robust research and development programs are using experimental test campaigns, physical modeling, and computer simulations to contribute significantly to our overall understanding and advancement of the technology. In plasma thrusters, the conditions span from a collisionless nonequilibrium state to that of a collisionally dominated equilibrium plasma, and is in some cases highly magnetized. Propellants can range from monatomic gases to ablated polymer solids, resulting in complex, nonhomogenous plasma populations. In recent years, significant advances have been made in the development and application of both theoretical and experimental methods for studying thruster thrusters, including plasma generation, propellant acceleration, electron and ion transport, and plasma-wall interactions. Many traditional and new plasma diagnostic tools and methods, including electrostatic and electromagnetic probes and sensors and advanced spectroscopic methods, have been developed to characterize the harsh and complex environments found in plasma propulsion systems. A variety of simulation techniques, such as particle-in-cell (PIC), direct simulation Monte Carlo, fluid modeling, hybrid fluid-PIC approaches, and multidimensional analysis, are now commonly used for studying thruster discharges and predicting thruster performance and lifetime.

This Special Issue consists of papers presented at the 33rd International Electric Propulsion Conference (IEPC 2013) held at the George Washington University in Washington, DC, USA from October 6 to 10, 2013. The IEPC is the premier international forum for developers, researchers, managers, scholars, and students in the field of electric propulsion for spacecraft. This conference has traditionally been the venue for presentations on groundbreaking developments arising from investigations on plasma propulsion. More than 443 people attended the IEPC 2013, delivering 356 technical papers. The record participation included record-breaking international participation from 25 countries, standing as a testament of significant growth and recognition of the electric propulsion field. Papers ranged in subjects from basic research on new technologies for micropropulsion to large scale solar electric propulsion vehicle concept studies supporting missions such as NASAs Asteroid Redirect Mission. The conference also included a presentation of the Ernst Stuhlinger Medal for Outstanding Achievement in Electric Propulsion to Hitoshi Kuninaka. Dr. Kuninaka led the propulsion team for the Japanese Hayabusa spacecraft, which used ion propulsion to return samples to Earth from the asteroid Itokawa. The Hayabusa spacecraft was the first to successfully land and take-off from the surface of an asteroid. Hayabusa studied and photographed asteroid Itokawa for more than two months before setting off on its journey back to Earth, where the sample capsule was successfully recovered. This mission was made possible only by the efficiency and long life of the well characterized ion propulsion system that used rf energy to generate a plasma, and electrostatic forces to accelerate the ions.

We are pleased to introduce this Special Issue, which addresses plasma science aspects in several key directions of modern plasma propulsion. This is the second Special Issue on Plasma Propulsion published by IEEE TRANSACTIONS ON PLASMA SCIENCE (the first was published in 2008 and contained 25 papers [6]). The present issue contains about 50 papers spanning a range that represents a substantial fraction of the existing efforts in the field of plasma propulsion. Contributions cover a variety of plasma thruster technologies (Hall thrusters, microthrusters, hollow cathodes, and so on)

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and include papers discussing various experimental techniques for plasma diagnostics and state-of-the-art modeling results. We have also included several papers on the mission application of plasma propulsion to give context for the development of these plasma devices and their underlying plasma processes.

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