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# The Development of Singapore's Miniature Hall Effect Thruster and Gradually Expanding Rotamak Thruster for Space Propulsion

**S. Xu, I. Levchenko, S. Y. Huang, L. X. Xu, C. S. Chan, J. W. M. Lim, Z. L. Zhang, Y. M. Wang, G. S. Tan, Y. H. Loo, M. W. A. B. Rohaizat, Y. N. Guo, Y. Xu, J. S. Yee, E. L. Goh, K. L. Ong, R. Z. Sim, B. Y. Li, S. Levchenko**
Plasma Sources and Applications Centre/ Space and Propulsion Center Singapore, NIE, and Institute of Advanced Studies, Nanyang Technological University, Singapore

**Y. C. Francis Thio**
U.S. Department of Energy, USA

**Xiaogang Wang**
Harbin Institute of Technology, China

**Kay Soon Low**
Satellite Technology and Research Centre, NUS

**Peng Hwee Seah**
Satcom and Sensor, ST Electronics , SIngapore

Miniaturized electric propulsion devices are the heart and pivotal sub-system of small satellites and satellite systems. Further exploration of Moon [1], manned Mars exploration [2], sending long-living probes to Jupiter and Saturn, comets, asteroids [3] and deep space4, and much more intense usage of near-Earth space for the benefit of the whole mankind – for advanced communication, global internet access, precise weather prediction and many other practical aims. All these tasks require efficient, reliable, robust control systems capable of controlling the spacecraft velocity vector, as well as orientation and location in space with the maximum possible mass and energy efficiency of the propulsion devices (thrusters). They should work in adverse space conditions (low and high temperatures and extremely high rates of temperature change, vacuum, radiation, possible attack of high-speed dust particles) for long time reaching years, with very high system fault tolerance.

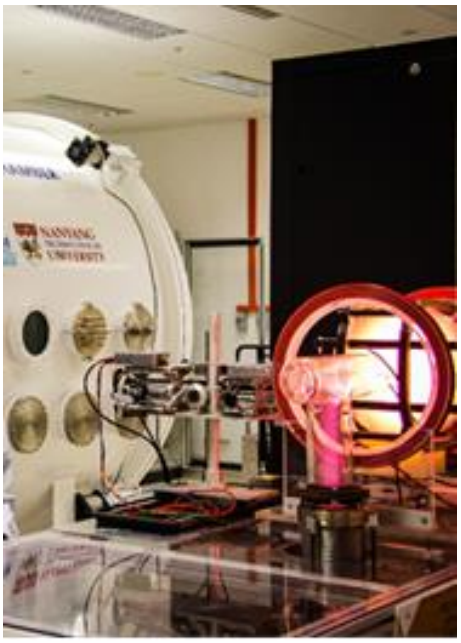

**Figure 1**. PSAC's Gradually-Expanded-Rotamak prototype operating

This talk presents the status of the development of electric propulsion technology at the Plasma Sources and Applications Centre/ Space and Propulsion Center Singapore (PSAC-SPCS), NIE, Nanyang Technological University, Singapore. Our team at PSAC-SPCS, NIE is focused on the development, commissioning, optimization and operation of two types of highly distinctive space propulsion systems: a miniaturized Hall-thruster for cube- and nano-sats propulsion, and a radio frequency rotating magnetic field driven Gradually-Expanded-Rotamak (GER) electromagnetic thruster. Conceptualization, physical understanding and modelling, engineering development and performance characterization will be discussed in terms of steady state current drive, compact torus formation, thruster efficiency, plume configuration and ion flex and energy. The supporting technologies, including Space Environment Simulation Facility; Thruster Performance Measurement System; in situ Plasma Diagnostics System will also be briefly discussed.

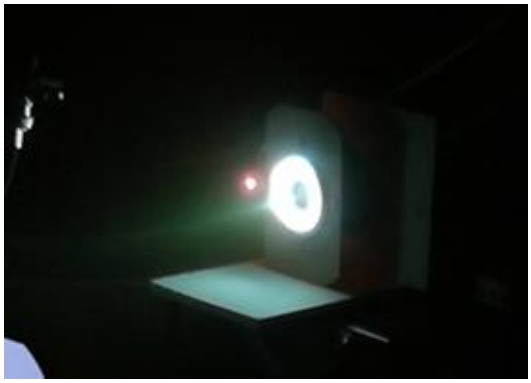

**Figure 2.** PSAC's miniature Hall Effect Thruster operating

[1] D. Estublier, G. Saccoccia, J.G. Amo, Electric propulsion on SMART-1, *ESA Bulletin* **129** (2007) 41–46.

[2] Y. Takahata, T. Ikeda, M. Nishida, T. Kagota, T. Kakuma and H. Tahara, Research and Development of High-Power, High-Specific-Impulse Magnetic-Layer-Type Hall Thrusters for Manned Mars Exploration, *IEPC-2015-151/ISTS-2015-b-151*, 2015.

[3] H. Kuninaka, K. Nishiyama, Y. Shimizu, I. Funaki, H. Koizumi, S. Hosoda and D. Hayabusa, ASTEROID Explorer Powered by Ion Engines on the Way to Earth; IEPC 2009-267, 2009.

[4] Kuninaka, H. and Kawaguchi, J., Lessons Learned from Round Trip of HAYABUSA Asteroid Explorer in Deep Space, 2011 IEEE Aerospace Conference, Big Sky, MT, 5-12 March 2011.