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## Electric propulsion

Hall effect thrusters (HET) have been steadily gaining acceptance on Western spacecraft. Space Systems/Loral has now launched seven spacecraft with Fakel stationary plasma thrusters; two more are scheduled for this year, five for 2012; and an additional five for spacecraft currently in construction. The Aerojet/Lockheed Martin Space Systems BPT-4000 HET system has performed nearly a complete orbit transfer of the first Air Force AEHF (advanced extremely high frequency) satellite, firing two thrusters at 9.5 kW as a work-around following an anomaly in the bipropellant propulsion system at the beginning of the mission. Snecma (Safran Group) provided HET thruster module assemblies for five spacecraft, with a sixth planned for the end of this year. Production of TMA units for small GEO satellites and the development of approximately 300-W and 20-kW HETs are under way. Busek's second 200-W HET system is successfully operating in space on the FalconSat-5. Busek's 20-kW HET and the NASA Glenn 20-kW HET, designated 300M, were tested in the Glenn facility and demonstrated excellent performance. The high-voltage Hall accelerator, a high-specific-impulse engineering model HET built by Glenn and Aerojet, has undergone performance testing. Busek characterized a HET fueled by iodine, which appears to be a promising propellant.

Ion thrusters are breaking endurance records. Jet Propulsion Lab's Dawn spacecraft, powered by its three-engine ion propulsion system, entered Vesta's orbit in September. The propulsion system operated for a total of almost 24,000 hr, delivered 6.8-km/sec delta-V, and used 254 kg of propellant. ESA's GOCE (gravity field and steady-state ocean circulation explorer)

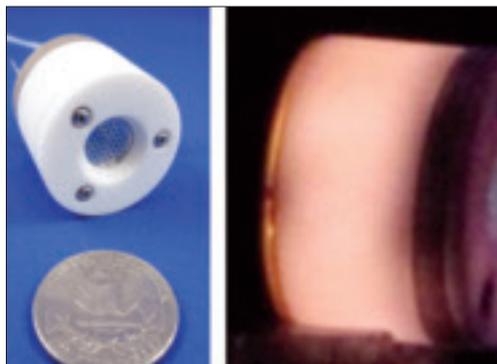
satellite is successfully operating at an orbit as low as 240 km with propulsion provided by a QinetiQ T5 gridded ion engine system. NASA's NEXT 7-kW ion thruster achieved a total propellant throughput exceeding 645 kg, 24 MN-sec impulse, and 37,600 hr of operation. On the opposite side of the power spectrum are the 1-cm-class RF ion thrusters that can operate at less than 10 W, in development by the University of Giesen in Germany and by Busek in the U.S.

Novel electric propulsion devices under development include the VASIMR thruster by Ad Astra Rocket and the HEMP thruster by Thales Electron Devices in Germany. The VASIMR VX-200 device operating at 200 kW demonstrated 70% thrust efficiency, thrust of 5.8 N, and 4,900-sec  $I_{sp}$ . The HEMP thruster is in a qualification program and has completed its critical design review. It is intended for small GEO satellites.

Academic researchers in the U.S. are developing several classes of EP instrumentation, including two projects at MIT aimed at the cusped-field thruster and MEMS electro-spray thruster module for Cubesats. Each MEMS module is estimated to produce about 50  $\mu$ N of thrust at more than 3,000 sec  $I_{sp}$ . George Washington University is developing a microcathode thruster. Measurements performed there and at the University of Southern California indicate that thrust bit is about 10  $\mu$ N and specific impulse up to 3,000 sec. University of Michigan continued the development of the X2 nested-channel Hall thruster, completing a series of performance tests at powers up to 11.7 kW. In addition, an advanced high-speed dual Langmuir probe measured Hall thruster plasma properties with a temporal resolution of 1  $\mu$ sec.

New business and research activities were announced. NASA Glenn selected five companies to develop mission concepts for demonstrating solar electric propulsion. The Air Force Research Laboratory selected Busek and CU Aerospace to develop high-performance propulsion for Cubesats. QinetiQ, Aerojet, and EADS Astrium Crisa agreed to jointly market the Xenith propulsion system, based on QinetiQ's T6 gridded ion engine. Astrium (Germany) and Fakel (Russia) have signed a partnership agreement to develop and market the RIT-22 radio frequency ion thrusters. A new large EP facility opened at DLR-Gottingen. And over 300 papers were presented at the 2011 International Electric Propulsion Conference in Wiesbaden, Germany.  $\Delta$

*Busek's RF ion thruster is in the 1-cm class.*



by **Vlad Hruby**