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INNOVATIVE SPACE PROPULSION TECHNOLOGY USING VACUUM ARC THRUSTERS

Abstract

The use of an on-board propulsion system to manoeuver around in space is a highly attractive feature for small satellites, which are being increasingly used in space research and commercial services. However, developing such a system can be highly challenging. With limited power (1–20 W) and on-board fuel, many existing types of propulsion systems suffer from poor performance. Another important, but often overlooked aspect is safety. Many propulsion systems utilise exotic and volatile chemicals or gases stored under high pressure, which exposes the satellite to dangerous and catastrophic failure. To address these problems, a PhD project was initiated under the South African National Space Agency to develop a high-performing, safe and flexible small satellite propulsion system based on vacuum arc thrusters (VATs). The vacuum arc thruster is a device that produces dense, high-speed plasma jets by ionising fuel with a pulsed arc discharge. A unique feature of VATs is its ability to utilise any electrically-conducting solid material such as metal for fuel. This design flexibility gives VATs a wide range of thruster performance and eliminates the complexity and associated failure modes of a fuel storage and piping system. The aim of the research project was to develop performance improvements to the vacuum arc thruster over the current state-of-the-art. To accomplish this task, the nation's first and only space propulsion laboratory was built at Wits University. Detailed thrust, ion detection and fuel consumption measurements were taken on several thruster prototypes, resulting in the discovery of a number of novel VAT design improvements. This work demonstrated enhanced VAT designs with nearly a three-fold increase in performance (specific impulse values, i.e. thrust-to-fuel ratio from 300-400 s up to 900-1000 s) over traditional VAT designs and a ten-fold increase over some existing commercial (chemical, cold gas) propulsion solutions for small satellites. Laboratory VAT prototypes were also shown to easily operate within power limits of 1–20 W with a total system mass of less than 0.5 kg. The potential impact of these findings is such that collision avoidance with space debris, precision-tracking and ambitious long-term space missions for small satellites, including Cubesats, is now within near-term capability for South Africa and other space nations.