MAE SEMINAR

On a Path to Electric Propulsion Immortality: Magnetic Shielding of Hall-effect Plasma Accelerators

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It has taken decades of research and technology development to elevate high-performance laboratory plasma thrusters, like ion engines and Hall thrusters, to flight-qualified status. Today the major limitation of these thrusters for deep space missions is lifetime. Hall thrusters for example are, in general, simpler and less costly to develop than ion engines, can deliver more thrust, and scale better to high power levels. Their performance also allows for significant reductions in propellant mass and overall system cost compared to conventional chemical propulsion. Yet, despite the fact that >240 Hall thrusters have been used onboard near-earth spacecraft since the 1970s without a failure, Hall thrusters have never propelled a NASA spacecraft on a deep space mission. This is largely because deep space missions require from Hall thrusters prohibitively higher propellant throughput than near-earth missions.

Hall thrusters generate an ion beam through the formation of an azimuthal electron current – the Hall current – that interacts with an applied, quasi-radial magnetic field to produce a largely axial electromagnetic force on the ions. The main reason for their limited life is erosion of the acceleration channel by ion bombardment, a limitation that was recognized many decades ago. In fact, techniques to reduce or eliminate ion bombardment of the walls were considered in as early as the 1960s. Since then many schemes have been proposed to address the problem. Though some of them have managed to reduce wear, channel erosion was never eliminated or diminished sufficiently to retire the risk for deep space science missions, making it one of the longest-standing problems in electric propulsion (EP).

In late 2008 the development of a new physics-based computer code called "Hall2De" began at JPL's EP Group to interrogate plasma and erosion physics in Hall thrusters. Soon after the completion of Hall2De, numerical simulations identified a method now called "magnetic shielding" with which the unmagnetized ion beam produced by these thrusters can be controlled by an applied magnetic field in a manner that reduces significantly deleterious ion bombardment of the channel walls. During a 2010-12 research effort the fundamental principles of magnetic shielding were demonstrated for the first time at JPL. Experiments confirmed the predictions of numerical simulations that the energy and flux of ions to the walls of an existing laboratory Hall thruster would be diminished significantly if it was modified to incorporate magnetic shielding. Subsequently, it was illustrated also that the erosion of the acceleration channel in this thruster had been reduced by at least two orders of magnitude. The findings constitute the most significant EP advancement in the last 20 years since magnetically shielded Hall thrusters may now allow for space exploration missions that could not be undertaken in the past, such as a new Asteroid Redirect Mission currently in the mission development phase at NASA. The results were published last year in the Applied Physics Letters and will be summarized in this presentation.