Two Stage Hall Thruster Simulations and Experiments

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A 2.3 kW two-stage Hall thruster with intermediate cathode was designed, built and tested by Busek Co. Inc. This new thruster was developed as part of a NASA Glenn Research Center sponsored SBIR program to develop high specific impulse Hall thrusters. It features a star-like arrangement of solenoids and a unique discharge chamber. The goal was to achieve two disparate acceleration zones, which would enable higher electrical and utilization efficiencies. Key elements of the design process included finite element modeling of the magnetic field, and fully kinetic Particle-In-Cell (PIC) modeling of the plasma discharge. Performance of the actual thruster was measured under vacuum. Plasma properties were measured via probes. Simulation techniques will be discussed and predictions will be compared to measurements.

The 2D3V full PIC Hall thruster code models electrons, neutrals, and ions as particles. An artificial electron to heavy particle mass ratio speeds computations. The electric potential is calculated by solving a form of Poisson's equation. The permittivity of free space is increased to allow longer time-steps (by slowing plasma oscillations) and a coarser grid (by increasing the Debye length). Ion-electron recombination is modeled at dielectric boundaries, and neutrals are recycled. The sheath is calculated by collecting the residual charges and incorporating them into the potential calculation. The simulation includes elastic and inelastic (excitation, ionization) electron-neutral collisions, electron-ion ionizing collisions, ion-neutral scattering, and charge exchange collisions, all of which are modeled using the Monte-Carlo Collision (MCC) methodology. Secondary electron emission is also included. Coulomb collisions are accounted for. Anomalous diffusion is included via an equivalent scattering frequency. Typical runs take several days.