Hybrid PIC-DSMC Simulation of a Hall Thruster Plume on Unstructured Grids

Shannon Cheng*, Mark Santi*, Murat Celik*, Manuel Martinez-Sanchez**, Jaime Peraire**
*Graduate student, Department of Aeronautics and Astronautics, MIT
**Professor, Department of Aeronautics and Astronautics, MIT

Hall thrusters and other types of electric propulsion have become a tempting alternative to traditional chemical propulsion systems due to the high specific impulses they provide at relatively high efficiencies. Unlike conventional chemical propulsion systems, electric propulsion devices do not rely on the internal energy stored within their propellant. Instead, an external power source is used to impart energy to the working fluid. As no inherent limitation due to the propellant exists, a high I_{sp} is attainable which translates to a highly desirable mass savings. Higher exhaust velocities and thus higher specific impulses are only constrained by the power processing unit (PPU) which provides the external energy and is the primary contributor to the electric propulsion system's mass. By trading I_{sp} against PPU mass, Hall thrusters are found to fall in an optimum operation regime well-suited for missions such as station-keeping and orbit transfers.

However, a major stumbling block to their widespread integration is uncertainty about the thruster plasma plume's interaction with sensitive spacecraft components. As a result, many efforts have been made to study these effects through simulation. A major limitation of most work in Hall thruster plume simulation has been the capability of a single code to accurately predict plume behavior in dissimilar environments, ranging from imperfect vacuum tank conditions to the actual in-space environment. Another shortcoming has been the inability to model realistic geometries. AQUILA, a hybrid PIC-DSMC simulation of the plume, strives to overcome these challenges.

The hybrid-PIC code has been implemented on a 3D unstructured grid that enables modeling of complicated and realistic geometries. In order to ensure the proper plume expansion, a new source model divides the source particles into separate populations to accurately reproduce the particle distributions at the thruster exit plane. Furthermore, while the bulk of the plume is considered to be quasi-neutral, a Poisson solver is used to solve for fields in regions where this assumption no longer holds. The DSMC collision model has been altered to account for particles with very different weightings to enable simulations with a background. Results show progress in implementing the model and show comparisons to recent experimental data.