BLUE WATERS
SUSTAINED PETASCALE COMPUTING

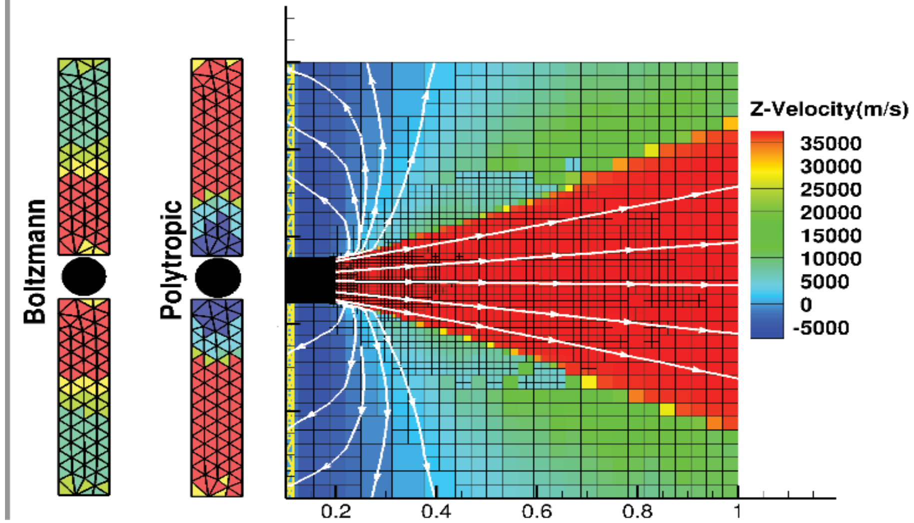
Allocation: Illinois/224 Knh

PI: Deborah Levin

University of Illinois at Urbana-Champaign

Space Propulsion/Science

MODELING PLASMA FLOWS WITH KINETIC APPROACHES USING HYBRID CPU-GPU COMPUTING



CEX ion streamlines (white) superimposed on an ion thruster, ion velocity field. Vertical strips are notional solar cell arrays. Ion impact fluxes differ for two electron models (Boltzmann vs. polytropic.)

Research Challenge

Ion thruster engines, which are used on spacecraft (satellites), create plasma plumes. Improving prediction of long-term effects of engine emissions on spacecraft surfaces will improve their efficiency and longevity.

Characterize the backflow contamination environment due to the plasma created by electric-propulsion (EP) plumes, and their interaction with the spacecraft environment and neutralizer sources.

Methods & Codes

Plasma modeling method based on modified DSMC (Direct Simulation Monte Carlo) code, CHAOS (Cuda-based Hybrid Approach to Octree Simulations).

For modeling the electric field, using AMR (Adaptive Mesh Refinement) involved single and multiprocessor stages.

To compute volume of cut-leaf nodes, it utilizes the Morton Z-curve octree structure, a volume-of-fluids (VOF) method, and ray-tracing, which is very efficient on GPUs.

Why Blue Waters

Blue Waters has allowed testing and development of algorithms on a large number of GPUs for three-dimensional, fully kinetic plasma simulations. Compared to the present state-of-the art plasma simulations, a uniform grid in 3D would require a factor of at least ten more cells than the use of AMR/octree. The use of GPUs vs. CPUs decreased the runtime by at least another factor of five.

Results & Impact

High level: Satellites that are more efficient and last longer will save money, as billions of dollars are spent annually building and launching these craft.

Able to model the actual xenon-to-electron mass ratio for three-dimensional geometries (previous modeling of electrons as a separate species in electric-propulsion plumes was limited to two-dimensional cases).

Results support the hypothesis that the ion beam is trapping the electrons, which, in turn, damps the electron oscillations.