NASA SBIR/STTR Technologies

A2.06-9878 - Electron Kinetics in Hypersonic Plasmas

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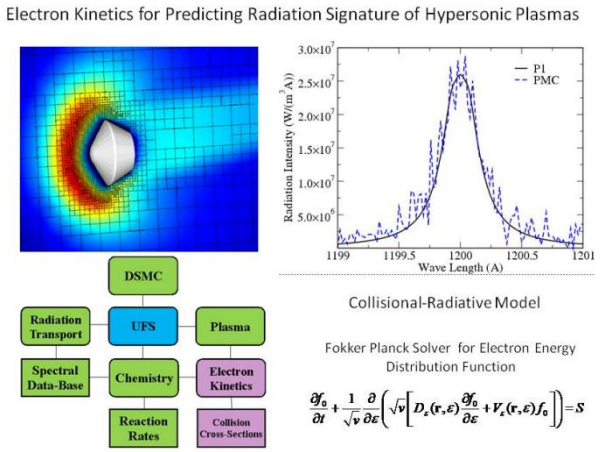
Identification and Significance of Innovation:

- High-fidelity kinetic models for electrons in hypersonic plasmas will allow vehicle developers to leverage plasma properties to perfect the aero-thermal performance of the next generation flight vehicles.
- Proposed models will minimize uncertainty in calculations of ionization processes, enhance predictive capabilities of collisional-radiative models, help solving communication blackout problem, and improve capabilities of flow manipulation by electromagnetic fields.

Innovations:

- Electron kinetic modeling based on accurate and efficient Fokker-Planck kinetic equation for rarefied and continuum flow regimes.
- Adaptive modeling of electric fields employing dynamic use of both the quasi-neutrality assumption and the Poisson equation.
- Intelligent selection of appropriate models for electron transport for multi-resolution, multi-physics, adaptive modeling of hypersonic plasmas.

Expected TRL Range at the end of Contract (1 - 9): 3



Technical Objectives:

1. Develop adaptive multi-scale model for plasma electrons applicable for hypersonic flows over entire vehicle trajectory from rarefied to continuum regimes.
2. Couple the new Electron Kinetics module with existing plasma, chemistry, and radiation transport modules within our Unified Flow Solver (UFS).
3. Assess predictive capabilities of the new model for minimizing uncertainties within the plasma environment and its complex radiation signature.

Results of Phase I Work:

a) Developed an Electron Kinetics Module in UFS framework for solving a Fokker-Planck kinetic equation (FPE) for the Electron Energy Distribution Function;
b) Calculated the energy spectrum of electrons generated by associative ionization in collisions of hot atoms and validated against DSMC simulations;
c) Improved fluid plasma model in UFS and demonstrated formation of a double layer near bow shock and a space-charge sheath near vehicle surface in hypersonic plasmas;
d) Simulated hypersonic flows around RAM-C II and Stardust re-entry vehicles at 61 and 71 km altitudes and demonstrated good agreement with other codes; and
e) Clarified several important properties of hypersonic plasmas and illustrated feasibility of the proposed adaptive multi-scale modeling of electrons by automatic switching between different transport models.

NASA Applications

Technology development programs related to access to space and planetary entry. Prediction of thermal load and thermal protection system design for the Orion spacecraft and the proposed Space Launch System. Predictive models for plasma radiation signature in the ultraviolet spectral range. Communication blackout problems and hypersonic flow control by electromagnetic fields. Simulation of the extreme aero-thermal environment for entry to Earth, Mars and other planetary atmospheres.

Non-NASA Applications

Ballistic missile and hypersonic vehicles (X-51 waverider, Falcon). Radiation signature for plumes, expanding nozzle flows, plasmatrons and other high enthalpy flow systems. Communication blackout and plasma flow control, electric propulsion, shock wave propagation through plasmas. High-speed plasma jets for material processing and biomedical applications, plasma assisted ignition and combustion.

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