



On-Board Optical Emission Spectroscopy Measurements in Plasmatron X for HyCUBE

Ultrafast Laser and Plasma Diagnostics Laboratory: University of Minnesota

UIUC Plasmatron X

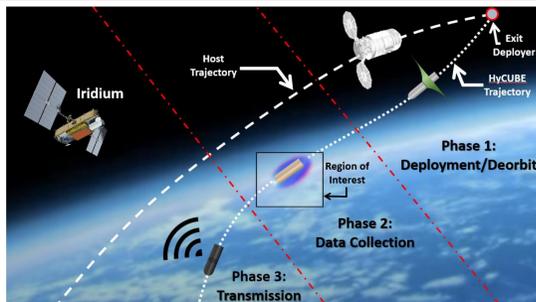
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Hypersonic Configurable Unit Ballistic Experiment (HyCUBE)

Motivation: Take direct measurements of reentry plasma properties to validate simulation models

Proposed Experimental Procedure

- 1U X 3U CubeSat carries an embedded spectrometer to orbit.
- A drag skirt will deorbit the CubeSat.
- In the traditional blackout period, where a spectrometer will collect measurements of the **plasma emission**.
- Reestablish connection with Iridium to transmit all collected data before sinking into the ocean.

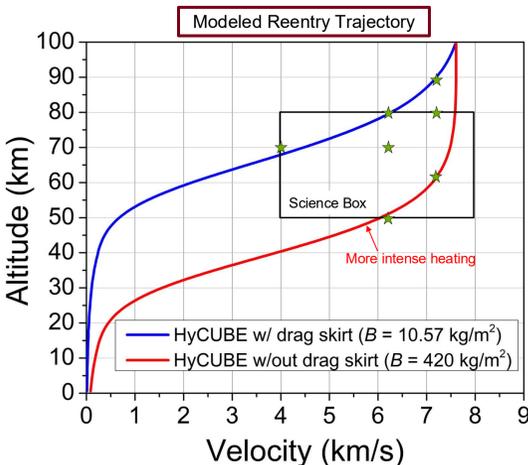
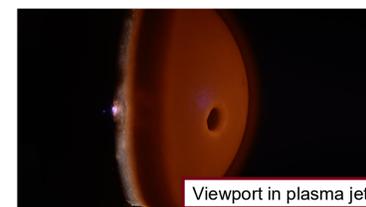
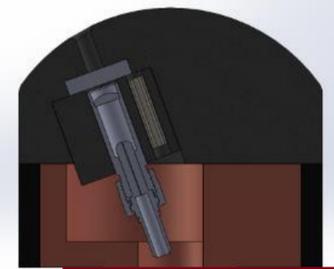


Ground Testing at UIUC's Plasmatron X

Motivation: Evaluate the survivability of AETB and sapphire optical viewport. Testing on-board OES feasibility

Ground Testing Experimental Results

- Scale samples were manufactured to test AETB, RCG coating, Sapphire viewports, Fiber optics, and thermocouple response to heat loads.
- The internally collected data can be compared to external measurements from spectrometers, pyrometers, and high-quality real-time imaging.
- Compare ablation rates and products to measure effects on spectral quality and intensity.

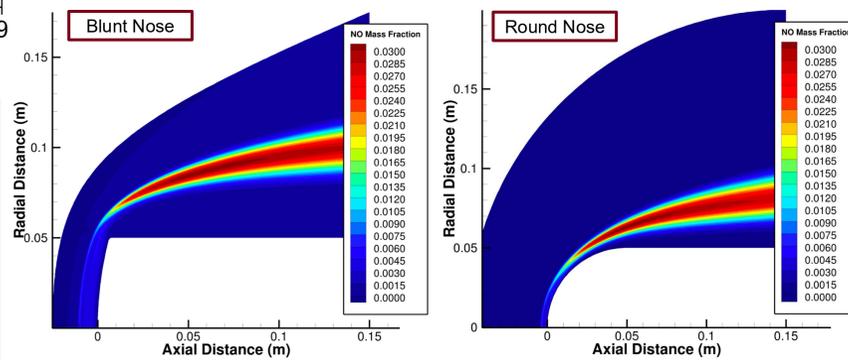


Modeling Reentry

- Reentry path can be modeled based on the geometry of the HyCUBE satellite and estimates of the drag chutes survivability.
- Aerothermodynamic properties can be estimated based on estimated altitudes and velocities.
- Using GPS and gyroscopic data the real flight path can be reconstructed to match experimental and simulation results.

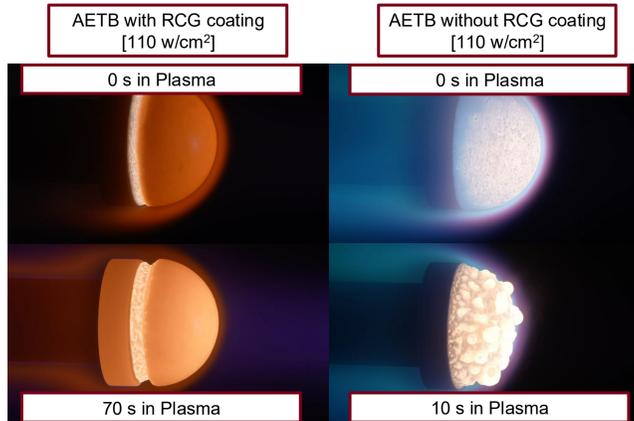
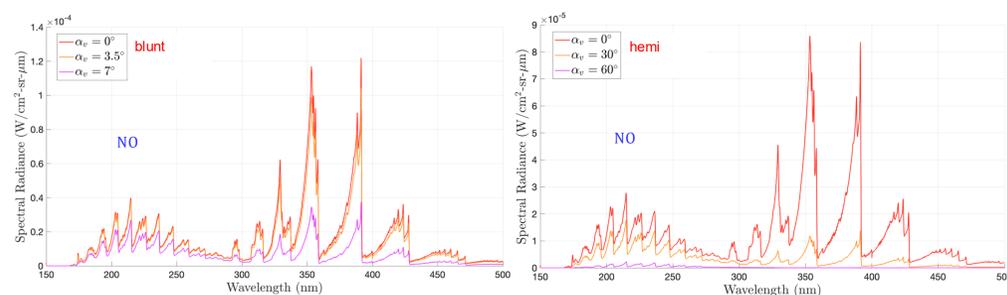
US3D Used to Model Flow Field

- US3D can spatially model gas dynamics, gas temperatures, and gas phase chemistry driven by hypersonic vehicles.
- The distribution of reactive species can be used to estimate plasma properties.



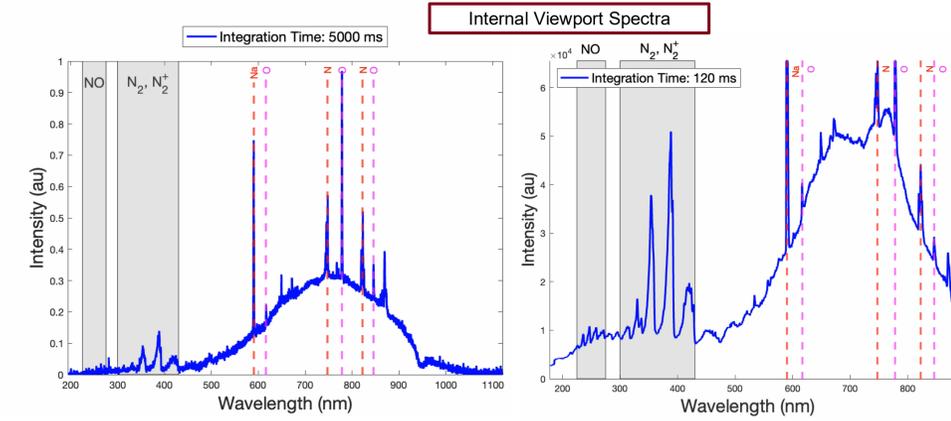
NEQAIR Simulations

- NEQAIR is used to calculate the spectral radiance of the plasma emission based on US3D temperature and species concentrations.
- Estimates calculated based on line of sight of the spectrometer.



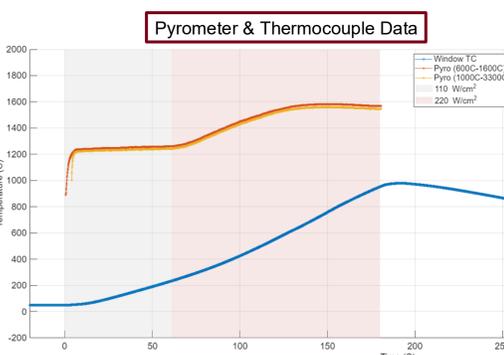
AETB Ablation

- To measure spectral properties a non-ablating heat shield is needed to avoid spectral contamination.
- AETB requires a high emissivity coating like RCG to be non-ablative.



Spectral Measurements

- Time resolved measurements through the sapphire window validated the survivability.
- NO and N₂ systems can be used to calculate gas temp. vibrational temp. and electron number density through fitting

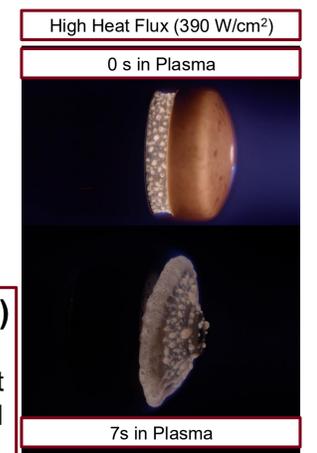


Thermal Measurements

- 2 color pyrometer data can be used to directly measure surface temperature.
- This informs thermal models used to estimate surface temperature from thermocouple data

Maximum Heating (390 W/cm²)

Under max expected heat load (bottom right of science box) AETB & RCG did not survive, sapphire window and fiber optical cables did survive.



References:
 1. Gardi, A., et. al, 2024. *AIAA SCITECH 2024 Forum* (p. 0229).
 2. Rao, A.P., et. Al, 2025. *Journal of Spacecraft and Rockets*, pp.1-10.
 3. Johnson, Candler and Alba (2010), 40th Fluid Dynamics Conference and Exhibit
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