Targeted Experimental Measurements to Refine an Operational Model for Porous Electrospray Thruster Arrays

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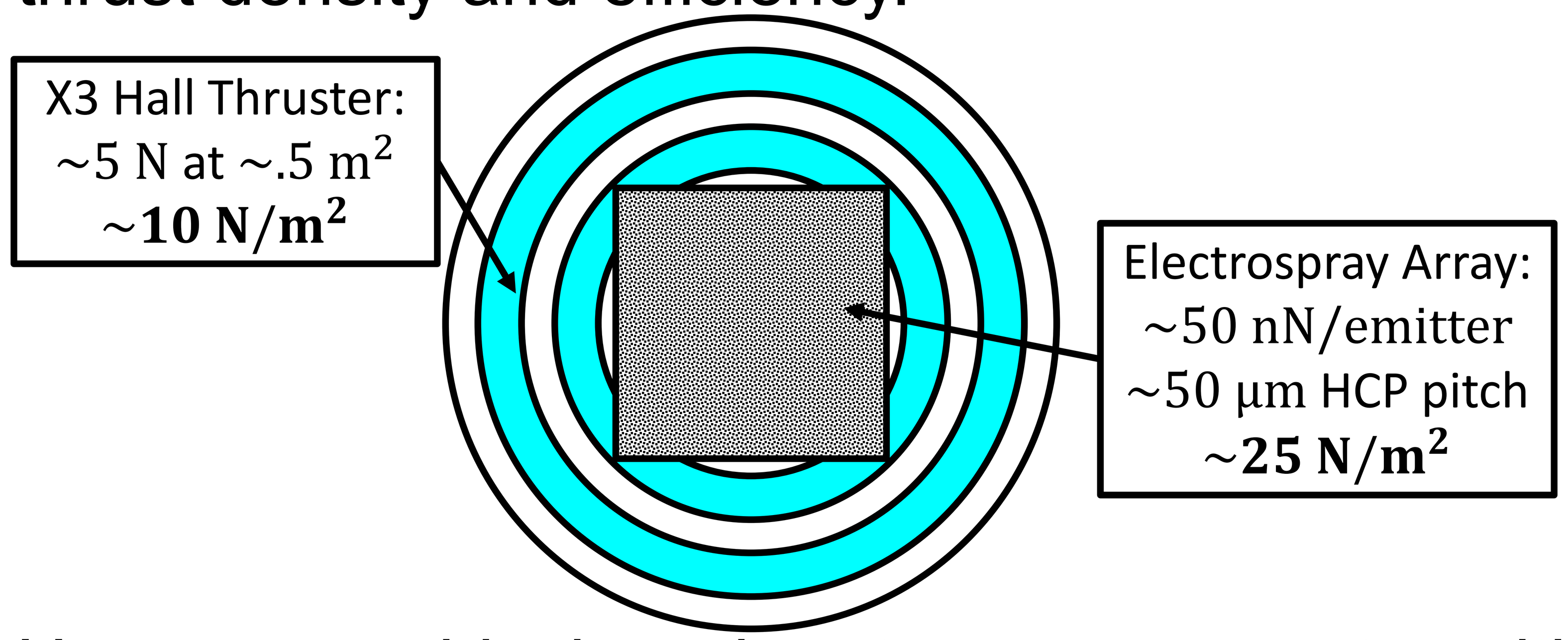
Motivation

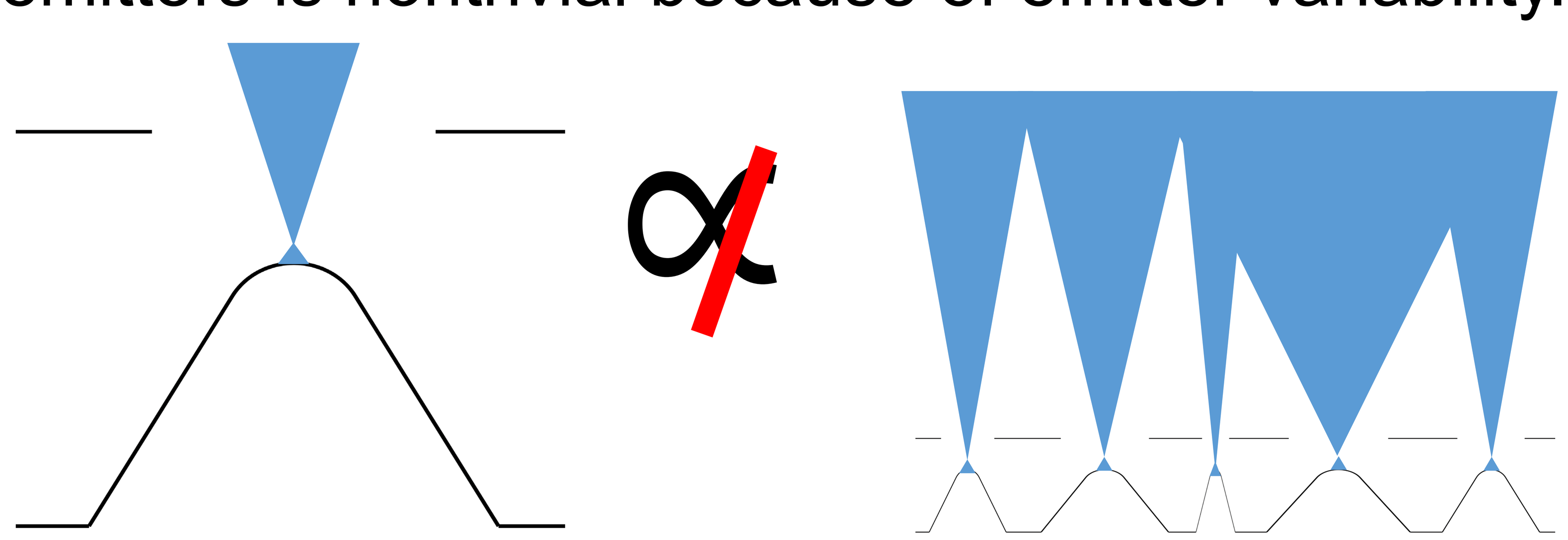
Electrosprays are potentially revolutionary for space propulsion because of their high innate thrust density and efficiency.



However, achieving thrust commensurate with SOA EP would require $O(10^5\text{-}10^8)$ emitters. At this scale finite manufacturing tolerances become significant, resulting in variable emitter behavior. Reduced-fidelity models could be a key design tool, but they require calibration from data.

Compute New Optimal Design → **Manufacture & Characterize New Thruster** → **Update Models through Inference**

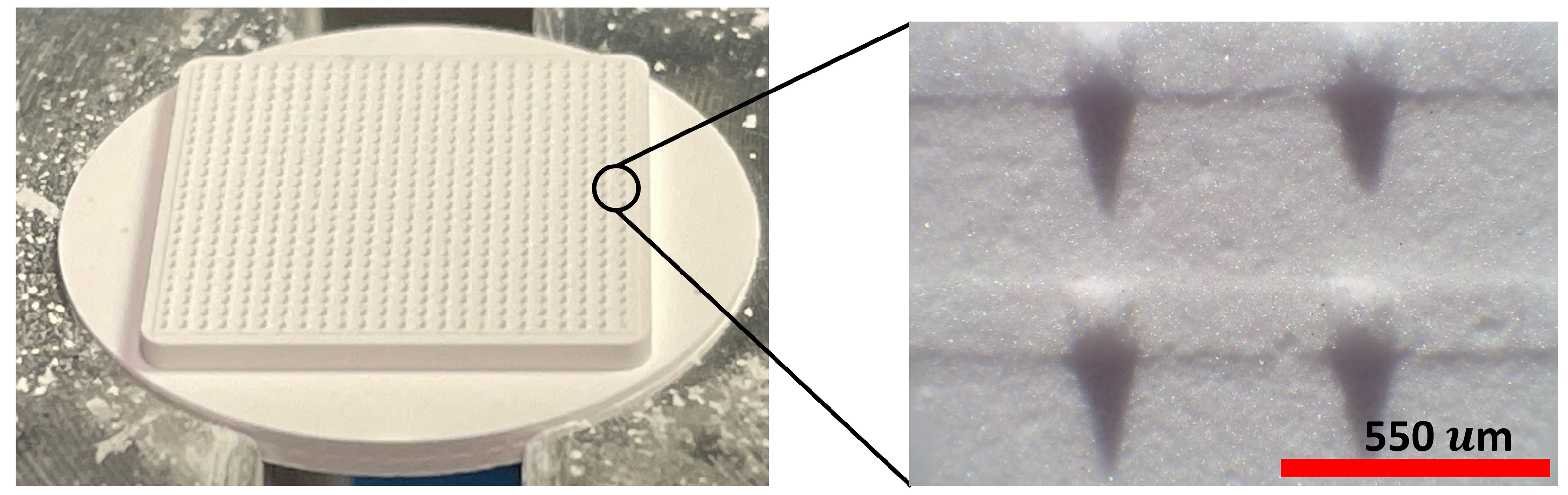
However, mapping bulk behavior to individual emitters is nontrivial because of emitter variability.



Objectives

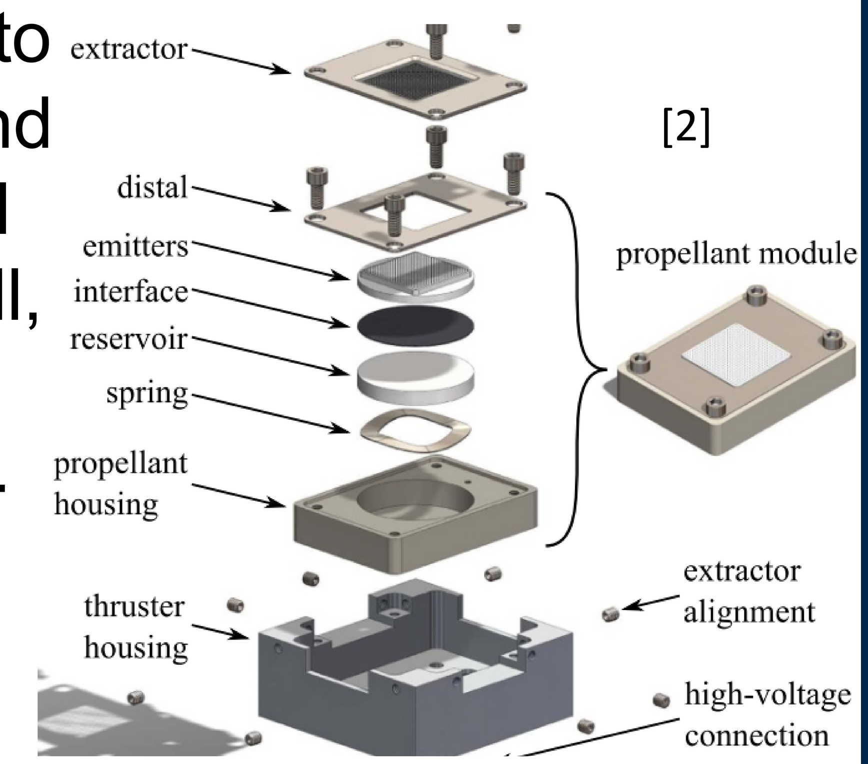
- Manufacture a thruster consisting of an array of electrospray emitters.
- Validate inferential methodology on data in literature.
- Characterize thruster by experiment to update inference.

Thruster Manufacturing

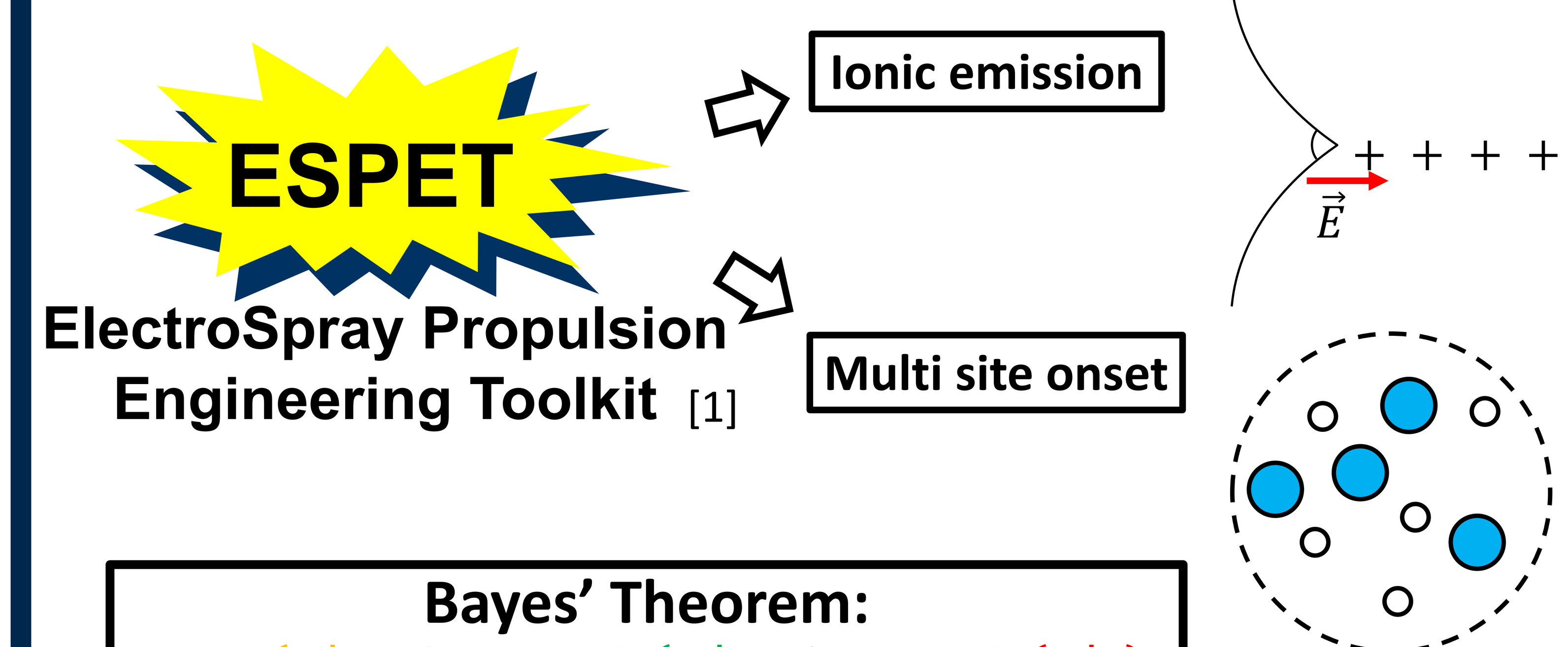


emitter chip

The thruster is designed to mimic AFRL's AFET-2, and consists of 576 pyramidal emitters, each 300 μm tall, micromachined from porous borosilicate glass. A steel plate with 500 um apertures serves as an extraction electrode.



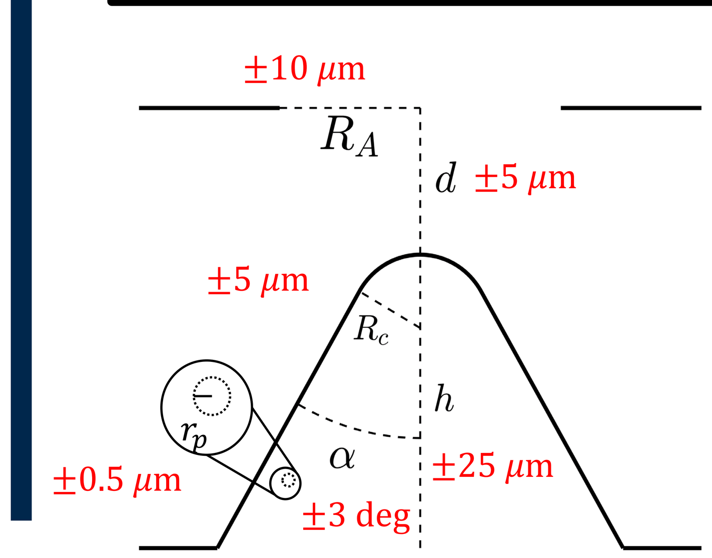
Model Inference



Bayes' Theorem:

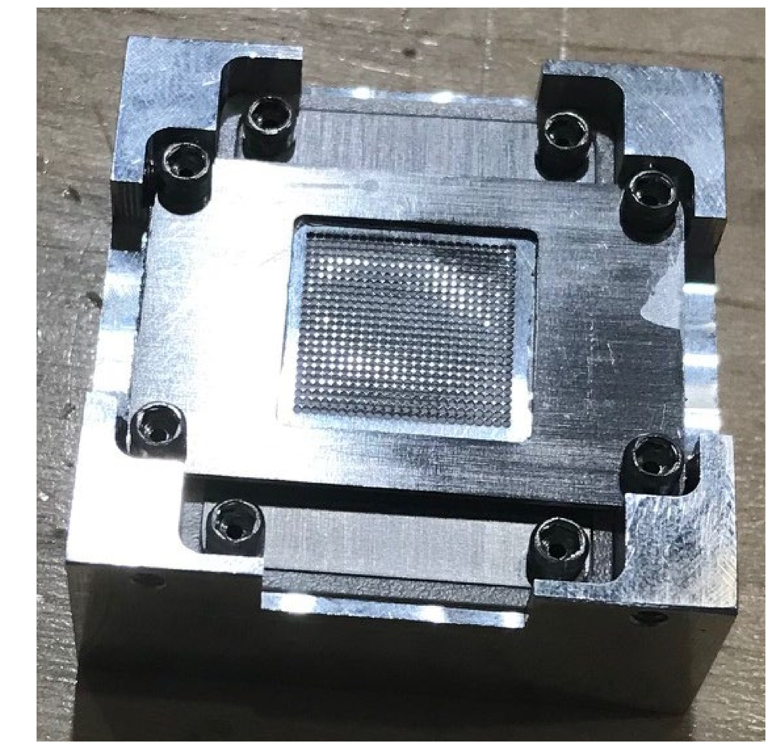
$$\text{prob}(\theta|X,I) \propto \text{prob}(X|\theta,I) \times \text{prob}(\theta|I)$$

θ: model parameters
X: data
I : background knowledge



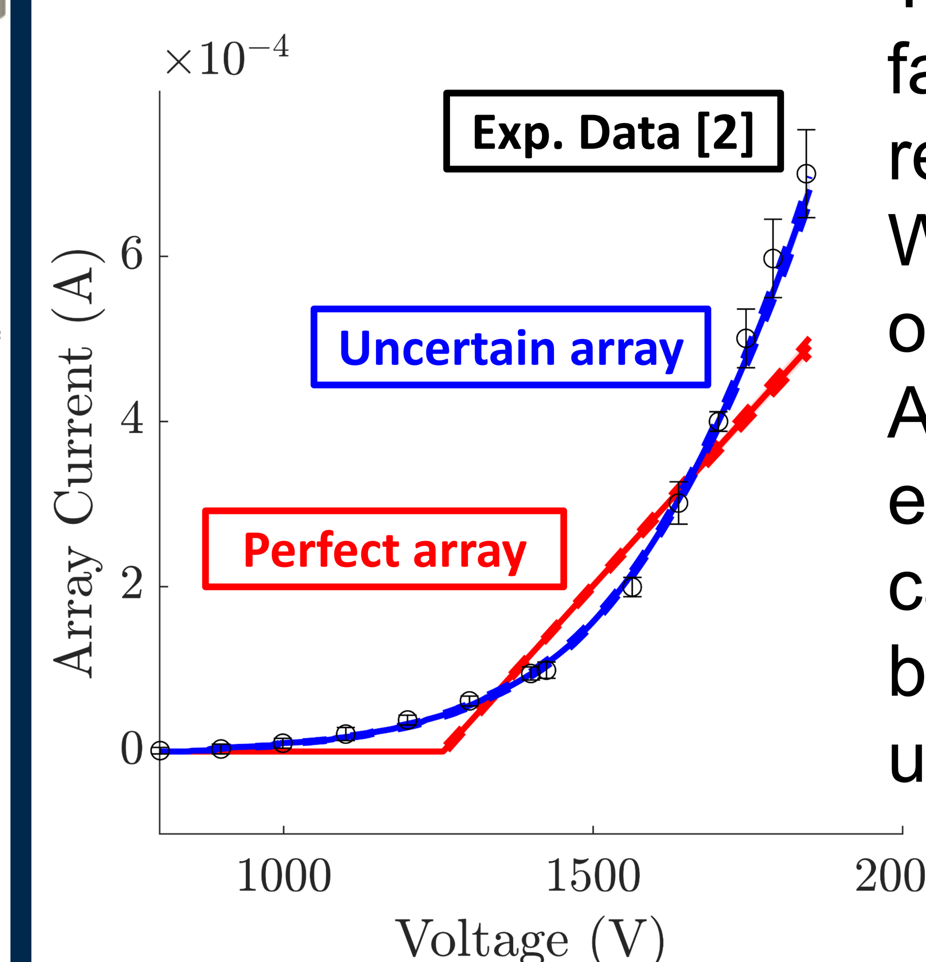
To account for uncertainty in geometry, we use a single realization of an array for our model predictions.

Results



assembled thruster

The thruster is assembled and preparing for testing. Dust evacuation during emitter machining was key to emitter sharpness. Manufacturing resulted in a bowed extractor which may impede function.



The emission model failed to predict onset for real operating conditions. We believe this is a failure of the electrostatic model. Artificially increasing the electric field was able to capture emission behavior, but only for an uncertain geometry.

Conclusions

- A refined manufacturing procedure is needed to ensure a flat electrode geometry.
- Variable emitter geometry may be necessary to explain nonlinear thruster behavior.
- More complete electrostatic model needed to predict onset for large-aperture geometries.

References & Acknowledgements

[1] B. St. Peter et al., Aerospace. **7**, 91 (2020).
[2] Natisin et al. 37th IEPC, 522 (2019).

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