FY24 whitepaper call for RF Test Cell Canonical Focus Experiments (CFE)

AFOSR Propulsion and Power Portfolio

I am looking for basic science whitepapers linked to an RF (or, more broadly, an AC-driven) test cell. At very simplest, imagine a (r,z,θ) cylindrical geometry with helical coils centered on the z-axis wrapped around the exterior. Despite its simplicity, there are enormous opportunities for adaptivity: magnetic field shaping (from a uniform bias field along the z-axis to strongly curved configurations), alternative antenna configurations / variable waveforms to access different modes (e.g. RF Helicon, MW ECR, pulsed inductive, etc), DC-biasing / holes in end caps to drive / permit plasma flow (operation as a cathode/thruster/simply ionization cell), the ability to handle different gases at a large range of different densities and/or flow rates, relatively easy reconfiguration of plasma-facing materials, and multiple opportunities for transient control inputs. The adaptability of an RF test cell can provide myriad experimental configurations to really challenge the rigor of our understanding of relevant EP plasma processes and it will likely anchor future CFEs for magnetic nozzles and induced current physics.

The ultimate engineering goal of this effort is to move towards improved a priori ability to predict the overall state and dynamic evolution of the plasma. To be clear, I do NOT think it is reasonable nor fundable to reach full a priori omniscience; however, I truly believe that it is possible to mature physical understandings and deploy appropriate combinations of models and diagnostics to provide improved accuracy and horizons of forecast capability beyond what is possible today. Based on community inputs, we have identified a number of science areas / knowledge gaps which can be studied with an RF test cell. These include but are certainly not limited to:

- Molecular C-R processes (inelastic/elastic collisions along with radiation emission)
- Surface material interactions in plasma sheaths
- Nonequilibrium, finite-rate plasma chemistry
- Current drifts in magnetized plasma
- Non-ideal effects (anomalous skin depth, curved field lines, non-Maxwellian effects)
- High information density compressed representations for complex system states

Please explore the boundaries of your curiosity. This CFE effort is designed to provide space to explore the “why?” and “how?” science questions which are often overlooked in the desire to demonstrate new levels of thruster efficiency.

Understandably, the CFE description I have provided is still enormously vague. During this first round of efforts and especially during the next year, I will expect a diversity in the science goals (e.g. focus on ionization vs convective processes) and physical engineering decisions (plasma density/temperatures, RF test cell geometries, gases mixtures, diagnostics selection, etc) to be proposed and executed. I am incredibly excited to have the opportunity to coordinate a series of workshops to facilitate the process of team forming and collaboration. I have avoided top-down direction because this is not an engineering project with a specific performance target. Instead, I want to cultivate a more adaptable, science-first approach to what testbeds are matured, what codes are developed, and what diagnostics are deployed.

Whitepaper Call

I am looking for whitepapers to address these (and other) science challenges linked to the RF test cell (and whatever variants you might propose.) The whitepaper should clearly articulate:

- What is the underlying science problem you want to target? (You do not need more than a sentence linking your research to the larger USSF/USAF mission.)
- What is your proposed approach and why do you think that this approach is appropriate to deliver the desired scientific insight?
- What do you expect to accomplish and when (with a more focus on the first year)?
- How might your proposed approach and accomplishments support the rest of the CFE community?
- ROM cost estimate

Three pages represents a good target for a maximum upper page limit but this is not a hard criteria. Please don't sweat the formality – if you feel that writing in first person or drawing cartoon sketches is the ideal way to communicate effectively, please do not hesitate to do so. Each whitepaper should represent a complete and severable effort – I am not looking for massive projects spanning multiple PIs. You may propose multiple efforts.

I expect a diverse range of approaches – this effort may require multispecies diagnostics, multiple fidelities of numerical simulation, theoretical models for subgrid processes, and inspired data analytics /assimilation approaches to rapidly refine mountains of data into knowledge. Also, there is no need to propose directly towards the RF test cell – some of the science challenges will likely leverage exquisite measurement facilities (e.g. gathering basic plasma materials data) and/or live purely in computing spaces (e.g. synthetically demonstrating novel data assimilation techniques). Finally, and above all, please don't shy away from being innovative in your approach and bragging about it.

Updated Timeline

~~15~~ Feb 2024: Posting of CTE proposal call with request for whitepapers (this is not a formal process so submit directly to justin.koo@us.af.mil)

~~15~~22 Mar 2024: Last date for acceptance of whitepapers (submit early if you'd like)

15 Apr or sooner 2024: Request for Proposals

Summer 2024 – Successful Proposals funded and first CFE workshop/collaboration event

Additional Notes

If you wish to propose a scientific investigation which will enable a different propulsion concept, you are welcome to do so but review will be delayed by CFE proposal selection.

Feel free to reach out to me at my official e-mail – justin.koo@us.af.mil. I will attempt to provide as much feedback as possible but please understand that I plan to involve other government folks in the review process and can provide no guarantees on my availability to address all concerns prior to submission

-jwk, 23 Feb 2024