Engineering Research & Technical Portfolio

Propulsion, Hypersonics, Computational Optimization, & Emergent Swarm Autonomy

I am developing a regeneratively cooled, additively manufactured 100 N-class micro gas turbine engine built as a largely monolithic polymer structure. The diffuser, combustor, shaft tunnel, and fuel injection system are integrated into a single SLA-printed high-heat-deflection thermoset casing, with only the rotating assembly and nozzle guide vanes metallic. Fuel enters an annular distributor ring, flows through embedded axial channels along the casing and combustor wall, and is injected radially into the combustor, enabling regenerative cooling without brazed tubing or sheet-metal fabrication. Internal flow paths were validated through CFD, and transient heat transfer analysis and FEA were conducted under combined thermal and pressure loading to verify structural and thermal survivability. I designed and built a fully instrumented hot-fire test bench including thrust load cell, tachometer, turbine inlet and exhaust gas temperature measurement, and synchronized IR imaging for signature analysis. Preliminary cold flow and material testing confirms casing temperatures remain within material limits and that emissions are strongly plume-biased. A provisional patent has been filed and SBIR funding is being pursued to mature the architecture.

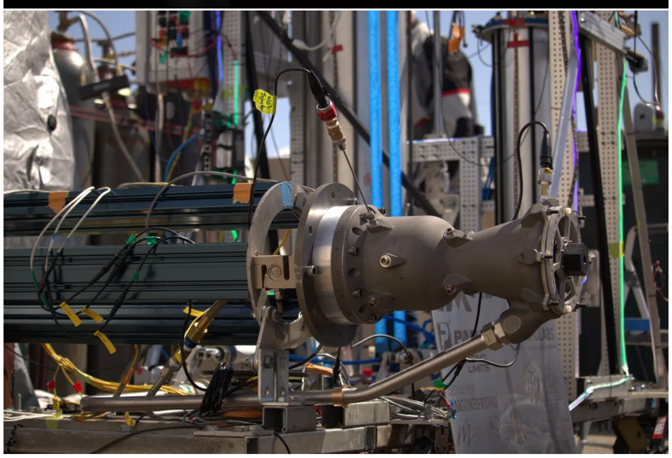
In parallel, I developed *ScramOpt*, a fully automated CFD and Bayesian optimization framework for hypersonic scramjet geometry exploration based on JAXA's M12-02 configuration. The pipeline parametrically generates scramjet geometries in FreeCAD, meshes and simulates compressible Navier–Stokes flow in SU2 at Mach 5.5 freestream conditions, and trains a Gaussian Process Regression surrogate model seeded with Latin Hypercube Sampling to ensure broad design-space coverage. A Bayesian optimization loop iteratively selects promising designs for high-fidelity verification while incorporating adjoint-derived gradient information to accelerate convergence. The framework is structured for headless HPC deployment with automated failure recovery and parallel evaluation across compute nodes. The objective is thrust maximization under thermal and inlet-unstart constraints, enabling efficient exploration of non-convex, high-dimensional hypersonic propulsion design spaces relevant to AFRL-level research problems.

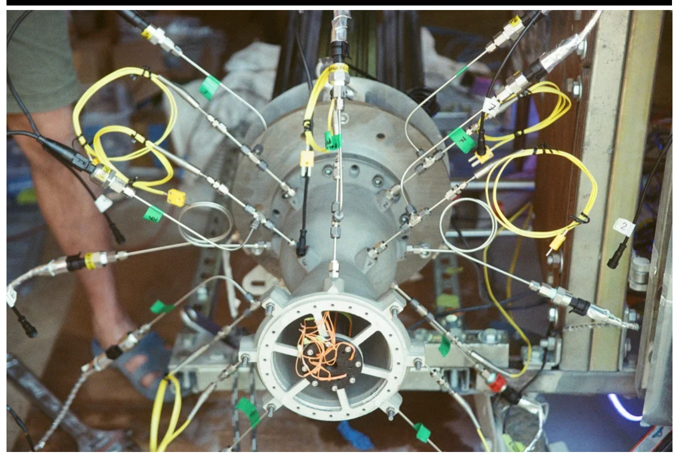
As a Student Propulsion Engineer on Space Enterprise at Berkeley's Eureka 3 bipropellant rocket team, I engineered the quick-disconnect fill system to streamline propellant loading operations, optimized bulkhead geometry for structural performance under pressurization, and performed IPA injector CFD in collaboration with the simulations team to support propulsion subsystem validation. The regeneratively cooled Inconel-718 engine achieved 11 kN thrust in testing.

Beyond propulsion, I developed a modular optimization toolbox and emergent multi-agent swarm simulation framework for decentralized control problems. Using genetic algorithms with customizable crossover and mutation strategies, the system evolves local control laws governing attraction, separation, cohesion, and obstacle avoidance forces for autonomous agents operating in 3D environments. Fitness evaluation is parallelized across CPU cores and validated in full physics-based simulations. The project demonstrates how evolutionary computation can discover robust decentralized strategies in nonlinear, high-dimensional systems where traditional gradient-based methods are ineffective, reinforcing my broader interest in computational optimization for complex aerospace systems.

Selected Visualizations & Demonstrations

Physical Propulsion Projects (Micro Turbine and Liquid Rocket Engine)





Emergent Multi-Agent Intercept Dynamics

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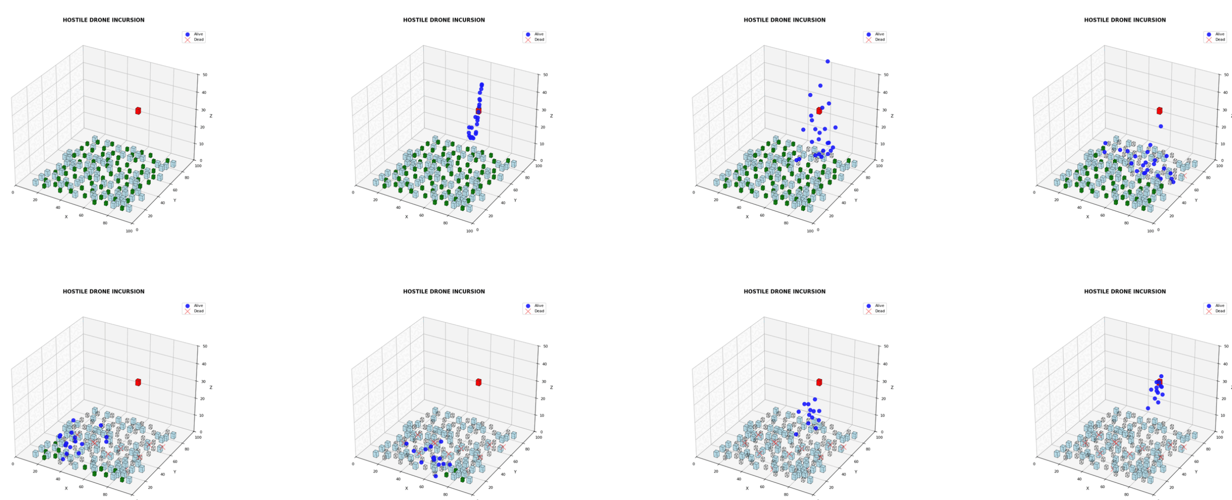

Temporal evolution of decentralized swarm interception governed by genetically evolved local interaction laws.