***Project 1: Quantitative Flow Visualization Using Plenoptic Background Oriented Schlieren (BOS)***

***Mentor:*** *Louis Cattafesta*

**Synopsis:** The goal of this project is to develop a Plenoptic Background Oriented Schlieren (BOS) imaging system to capture the volumetric nature of a simple compressible flow; in particular, to understand the intricacies of the system setup, to perform a bench top test and analyze the data. With the knowledge gained from the bench top tests, a Plenoptic BOS system will be used to capture the density flow field in an open cavity flow at high subsonic speeds.

***Summer Program:*** Students learn fundamentals of flow visualization, imaging processing and optical diagnostic techniques. They work with graduate students in test preparation, including model prototyping, instrumentation calibration, and data & image acquisition. They acquire two-dimensional BOS flow field data for baseline testing of the technique and generate whole-field illumination for the application of volumetric Plenoptic image acquisition, as well as calibrate the Plenoptic BOS system and perform 3-D density field for final data analysis. As part of the mentoring program, the students will prepare a laboratory module of the instrument. The module will provide background theory, the experimental setup and test procedure for a canonical experiment, data reduction and analysis, and presentation of results.

***Project 2: Flow Field Characterization of a Generic Rocket Nozzle***

***Mentor:*** Rajan Kumar

***Synopsis*:**  Recent advances in commercial space transportation emphasize rocket engine reusability and its operation over a wide range of operating conditions. Rocket nozzles are designed for optimal performance at a certain design point in the rocket trajectory, which happens to be typically in the vacuous, upper atmosphere. Therefore, these rocket nozzles underperform at sea level conditions where they operate at highly over-expanded pressure conditions. Operation at highly over-expanded pressures leads to flow separation and flow entrainment from the ambient conditions that lower nozzle efficiency and causes shock boundary layer interactions. The flow separation inside the nozzle is inherently asymmetric and associated with high-frequency fluctuations, resulting in side loading and nozzle fatigue.

**Summer Program**: Students familiarize themselves with rocket nozzle design, gas dynamics, and microjet control. They perform pressure measurements to determine pressure distributions inside the nozzle, with and without, microjet control over a range of nozzle pressure ratios. They also characterize the flow-separation location as a function of the nozzle pressure ratio and implement microjet control to manipulate local separation while improving the rocket nozzle performance.

***Project 3: Modeling, Design and experimental characterization of Swirl-Jet Actuators***

***Mentor:*** Chiang Shih/Farrukh Alvi

***Synopsis:*** Active flow control (AFC) technologies are being increasingly explored for their potential to yield enhanced performance in a variety of systems, especially in the aerospace field. However, realizing this potential requires actuators with the requisite performance characteristics in terms of control authority, frequency range, scalability and robustness. Under this program, we are developing and characterizing a new actuator design, that allows one to inject precisely controlled momentum (or mass) both wall-normal as well as angular (rotational).

***Summer Program:*** This project is mostly an experimental study where the REU student will collaborate with, and be guided by, graduate students as needed throughout this project. The research will consist of: exploring actuator design parameters using simulations, down-selecting actuator designs to be fabricated, setting up simple, canonical flow(s) to test the actuators, and finally, evaluating their performance in terms of relevant fluid dynamic parameters. Research involves diagnostic/hardware setup; writing/using programs for data acquisition and control; conducting experiments and processing and analyzing experimental results. The diagnostics will include both laser-sheet flow visualization and particle image velocimetry measurements in a water towing tank facility.

***Project 4: Design and Construction of a Flexible Wind Tunnel with Tilt Capability***

***Mentor:*** Kourosh Shoele

***Synopsis*:** In the study of several heat transfer and flow phenomena wind tunnels are utilized as controlled environments. This project consists of the design and construction of a small table top wind tunnel with tilt capability. The tilt capability will allow the angle to vary between the main flow direction and the gravitational field. The table top wind tunnel will be useful in the study of films of condensate, flexible membrane structures, energy harvesting, among others.

***Summer program*:** The Fellow will be involved in designing and building a tabletop wind tunnel. The flow will be driven by fans arranged symmetrically with wind velocities between 0-10 m/s. The Fellow will be involved in the tunnel characterization using a pitot tube and an anemometer. The wind tunnel will be built with transparent acrylic plates to allow video and photo recording at the test section. High-speed cameras and image processing will be used to capture flow behaviors along with other quantitative measurements.

***Project 5: Optimization of Missile Maneuver Flight Control***

***Mentor:*** Rajan Kumar/Nair Unnikrishnan

***Synopsis*:** To optimize a pre-existing baseline missile model to provide enhanced aerodynamic characteristics while limiting any negative effects to existing baseline metrics. The baseline model is a missile model with only tail fins to control. In this process, students will be testing two different models: the addition of either a delta wing or split canards. The added delta wings will reduce the drag while increasing lift for higher payload capabilities. The split canards will increase the maneuverability of the projectile at lower angles of attack and an increase lift.

***Summer program*:** Two Fellows will be involved in the feasibility design analysis and preliminary wind tunnel testing of both models. Use the CFD Solver to predict the performance of models under the startup process of the supersonic wind tunnel to ascertain that they can withstand the extremely high loads by the passage of the initial shock wave.

***Project 6: Characterization of 3D Printed Fractal Structures***

**Mentor:** William Oates

**Synopsis**: Fractals can be characterized by geometric structures that repeat over all length scales. Random fractals (multifractals) are more common in nature which contain a distribution of fractal dimensions. The concept of fractals plays an important role in the properties in nature (blood flow, breathing rates), but minimal work has explored their role in materials science, fluid dynamics, and engineering mechanics to understand complex structure and functional properties relations.

**Summer Program:** A student will work in a multidisciplinary group of engineers and mathematicians to understand how 3D printed fractal structures give rise to predicted viscoelastic and thermal transport properties. The REU student will print fractal and multifractal structures and test their viscoelastic and thermal transport properties as a function of the fractal dimension. Additional experiments that involve electostriction and photostriction of soft and glassy polymers will be evaluated. This will involve microscopy imaging, using the box count method to compute the fractal dimension, and comparing structure to electromechanical properties (via voltage applied to the dielectric) and photomechanical properties using load cell measurements and laser excitation. The student will work with graduate students and post doc. researchers to compare the data to fractional calculus modeling using Bayesian uncertainty quantification for model validation. The data and modeling will be summarized and disseminated at conferences and in journal publications where the REU student is expected to be the lead author.

***Project 7: Next Generation Tribological Materials for Aerospace Applications***

***Mentor:*** Krick

***Synopsis:*** Aerospace vehicles and devices have numerous mission-critical moving mechanical assemblies that depend on efficient and reliable actuation of sliding interfaces. Traditional lubricants are precluded from use in these extreme environments because of extreme temperatures, differences in the local environment (*e.g.* ultrahigh vacuum in space, high altitude flight environment or other harsh terrestrial environments) and in many cases the inability to retain traditional lubricants. There are a handful of solid lubricant materials that have emerged as leaders for these applications, however each of them have some critical flaws. This work studies 1) ***Polymer nanocomposites:*** design multifunctional, self-lubricating materials and 2) ***Next generation coatings:*** leverage processing-structure-property relationships of traditional and emerging coating deposition techniques to create next-generation wear, corrosion and thermal-barrier materials. From an educational standpoint, tribology has significant financial (estimated $1 trillion per annum in the US), performance, energy and environmental impacts, yet most undergraduate students finish their degree with little to no exposure to the field.

***Summer Program:*** This project will immerse the student into synthesis, characterization and experimentation for tribological applications. The student will be trained, with daily hands-on mentoring from a graduate student and faculty advisor. Depending upon the student’s strengths and interests, the student will be able to choose one of two routes. *Route 1) materials synthesis, testing and characterization:* here, emphasis will be on the materials science, chemistry and physics of the interactions between the materials and their environments. *Route 2) experimental development and materials testing*: emphasis is on developing tribometer (a friction and wear measurement apparatus) capabilities, including the ongoing design of a) ultrahigh vacuum tribometer, b) a tribometer that will be deployed for automated operation on the internationals space station, c) extreme temperature capabilities. Research requires the ability to design and control an experiment, analyze and document results and report discoveries for publications and patents.