

# Innovation

**SBIR Topic Number:**

AF04-293

**SBIR Title:**

Computational Fluid Dynamics (CFD) Fuel Injector Design Tool Applicable to High-Pressure, Vitiated Augmentor Flow

**Contract Number:**

FA9101-05-C-0041

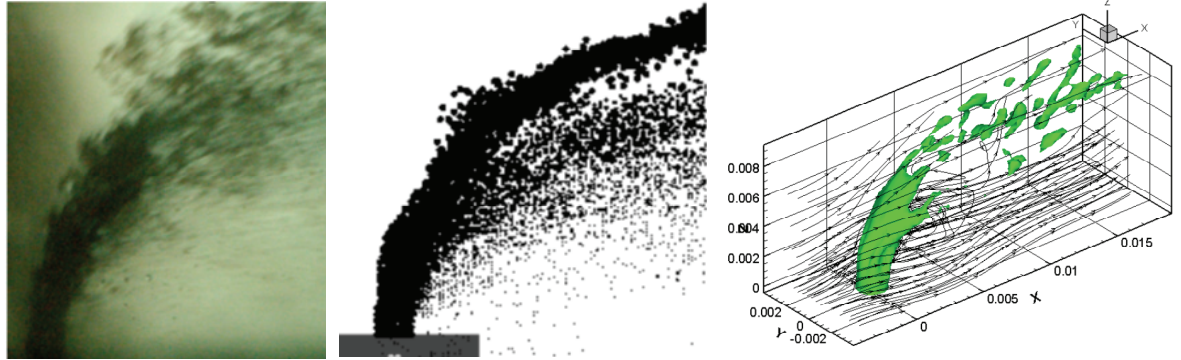
**SBIR Company Name:**

Flow Parametrics, LLC  
Ivoryton, CT

**Technical Project Office:**

Arnold Engineering Development Center (AEDC)  
Arnold AFB, TN

This Air Force SBIR/STTR Innovation Story is an example of Air Force supported SBIR/STTR technology that met topic requirements and has outstanding potential for Air Force and DoD.



Experimental photograph (left); computational fluid dynamics (CFD) simulation (middle); and volume of fluid (VOF) combined with large eddy simulation (LES) of the liquid jet in cross flow (right)

## Design Tool for Fuel Injections in Turbine Engines

- Quality of fuel delivery injection characteristics is crucial to combustion system performance in modern gas turbine engines
- Robust software package provides better liquid fuel boundary conditions and spray characteristics, and provides greater insight into liquid fuel breakup process
- Air Force SBIR funding was used to develop and validate spray droplet breakup and dynamics models for use in a CFD tool
- Experimental datasets allow the Air Force to improve and develop its simulation software

AEDC/2007-116

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## Air Force Requirement

The Air Force and its contractor base utilize experimental data to develop computational fluid dynamics (CFD) models in the design analysis of airframe and engine flowpaths, including turbine engine hot section components. Combustors and augmentors represent special challenges in component design, due to the complex physics of liquid fuel injection, breakup, atomization, evaporation, and combustion, all at high pressures, temperatures, and in a highly turbulent flowfield. Engine operability must be guaranteed at all points in the Mach-altitude flight envelope, including operating points at partial and full augmentation.

Understanding augmentor combustion performance over these wide ranges of conditions is a requirement. In order to achieve this understanding, detailed experimental data of the interaction of a liquid fuel jet and the associated crossflow is needed. This also allows for the validation of physics-based models that can be implemented into CFD flow solvers, which in turn provides an ability to compute, visualize, and understand these complex flows.

## SBIR Technology

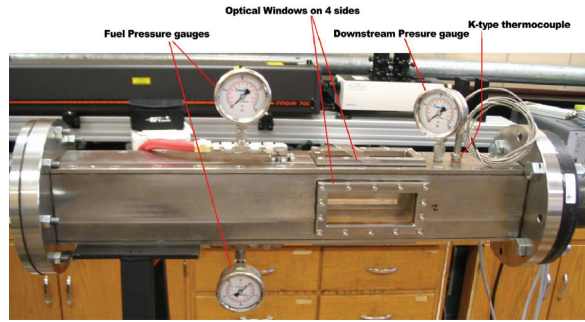
Flow Parametrics, LLC successfully developed a simulation tool that demonstrated the critical components of the computational fuel injection in gas turbine engines using combustion geometries. The physics of liquid fuel injection has been investigated experimentally, analytically, and computationally through a coordinated, multi-faceted program. Detailed experimental data for liquid fuel jets penetrating into a crossflow, the principal fuel injection technique for augmentors, have been acquired and used to develop new physical models for better CFD modeling of augmentors.

These models benefit from highly detailed, optical measurements performed at realistic augmentor operating conditions – a unique accomplishment. The experiments covered a range of orifice diameters and orifice configurations. The cross stream temperatures, pressures and chemical compositions were matched to actual augmentor flight conditions.

## Potential Air Force Application

This program provided experimental datasets of liquid fuel jet(s) at actual augmentor flight conditions. These datasets allow the Air Force to improve and develop its own proprietary simulation software.

A stand alone volume of fluid (VOF) software package was supplied to the Air Force through this program. The benefit of the package is that it can provide better liquid fuel boundary conditions to CFD, provide better spray characterizations, and provide better understanding of the liquid fuel breakup process.



Experimental test rig for liquid jet in cross flow at high temperature and pressure: rig showing optical access port

The technologies developed for liquid fuel injection may be utilized directly by the Air Force, aircraft engine design and manufacturing suppliers, instrumentation developers, and test engineers to investigate and predict augmentor performance in advance of expensive testing in wind tunnels and test rigs. This approach can help eliminate unnecessary tests, optimize the instrumentation layout of tests to be performed, and thereby reduce risk and cost in product development and test programs.

Customers potentially benefiting from the code enhancements include key industrial firms and government agencies such as the U.S. Air Force at the Arnold Engineering Development Center (AEDC) and the Air Force Research Laboratory (AFRL), NASA Glenn Research Center, aircraft engine manufacturers such as Pratt & Whitney and General Electric, major international power generation turbine manufacturers, as well as companies in other industries.

## Company Impact

Robert Ryder, President and Founder of Flow Parametrics, LLC said, "The opportunity to work with the Air Force on a focused project such as this has enabled us to acquire detailed experimental data in one of the most challenging areas, liquid fuel injection into combustion systems at high temperature and pressure. This in turn allows us to provide more accurate software to our customers, beyond what is available in the literature."

Flow Parametrics, LLC develops and markets advanced CFD software, and provides expert consulting and outsourcing services to industry. Its flow solver, FPVortex™ is capable of computing aerodynamics and multi-phase, chemically reacting flows in and around complex geometries, ranging from rocket combustion chambers and gas turbine combustors and augmentors, to ground effects race cars and sailboat hulls and keels.



# SBIR/STTR

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