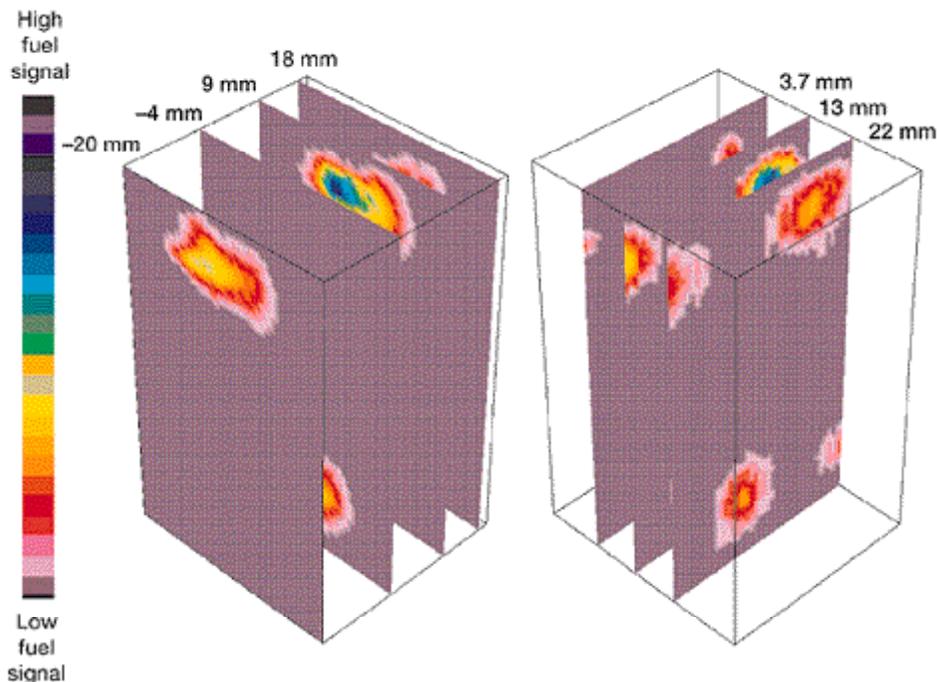


Three-Dimensional Measurements of Fuel Distribution in High-Pressure, High-Temperature, Next-Generation Aviation Gas Turbine Combustors

In our world-class, optically accessible combustion facility at the NASA Lewis Research Center, we have developed the unique capability of making three-dimensional fuel-distribution measurements of aviation gas turbine fuel injectors at actual operating conditions. These measurements are made in situ at the actual operating temperatures and pressures using the JP-grade fuels of candidate next-generation advanced aircraft engines for the High Speed Research (HSR) and Advanced Subsonics Technology (AST) programs.

The inlet temperature and pressure ranges used thus far are 300 to 1100 °F and 80 to 250 psia. With these data, we can obtain the injector spray angles, the fuel mass distributions of liquid and vapor, the degree of fuel vaporization, and the degree to which fuel has been consumed. The data have been used to diagnose the performance of injectors designed both in-house and by major U.S. engine manufacturers and to design new fuel injectors with overall engine performance goals of increased efficiency and reduced environmental impact. Mie scattering is used to visualize the liquid fuel, and laser-induced fluorescence is used to visualize both liquid and fuel vapor.

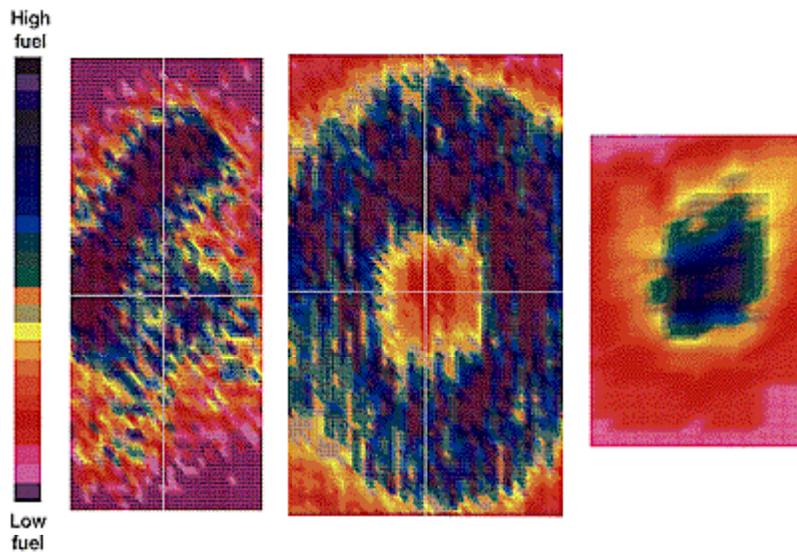


Fuel distribution visualized via PLIF. Inlet temperature, 980 °F; inlet pressure, 212 psia;

equivalence ratio, 0.42. Left: Raw fuel PLIF images in the z-y plane. Right: Composite PLIF fuel images in the x-y plane.

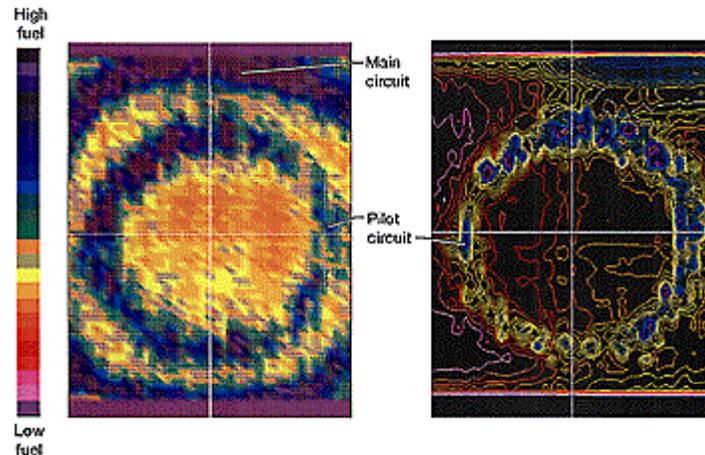
The preceding figure is an example of the process used to produce a three-dimensional flowfield. Measurements were made by taking a spatial sequence (typically with 1-mm spacing) of two-dimensional, planar, laser-induced fluorescence (PLIF) or Mie-scattering digital images. These raw images were taken in planes parallel to the flow axis, z . Then, they were processed by placing them in a three-dimensional grid, as demonstrated by the PLIF image on the left. A three-dimensional composite image was generated by interpolating between the points within the grid. The resulting image can be viewed from any perspective. The image on the right shows selected composite PLIF cross-sectional (x - y plane) images. Each segment of the linear color bar represents approximately 4 percent of the signal. The lowest signal is shown at the bottom of the scale.

Cross-sectional composites provide an important assessment of fuel injector patterns, which are used to assess the radial symmetry produced by an injector. The next figure uses PLIF to show the patterns of three fuel injectors approximately 10-mm downstream from their respective exit planes. Using these composite views makes it easier to determine if an injector is performing as designed.



Fuel patterns via fluorescence approximately 10-mm downstream from three concept fuel injectors at various temperatures, pressures, and equivalence ratios.

The final figure compares the resultant PLIF (left) and planar Mie-scattering (right) patterns for a fuel injector at a downstream distance, z , of 14 mm. The injector has two fuel circuits, a pilot and a main, whose distributions are obvious from the fuel PLIF composite. The Mie-scattering image shows only the fuel distribution arising from the pilot circuit, thereby indicating that the fuel from the main circuit is in the vapor phase. The combination of the two measurement techniques allows us to assess the degree of fuel vaporization.



Comparison of Mie-scattering and fuel PLIF images shows that the main circuit produces vapor whereas the pilot circuit produces liquid. Inlet temperature, 768 °F; inlet pressure, 232 psia; equivalence ratio, 0.304; downstream distance, z, 14 mm. Left: Fuel PLIF image. Right: Mie-scattering image.

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