Air Force SBIR/STTR

Transition

Air Force SBIR/STTR Transition Story

An example of Air Force supported SBIR/STTR technology that has been transitioned into an Air Force or other DoD system or subsystem or used by Air Force test ranges and facilities or maintenance depots.

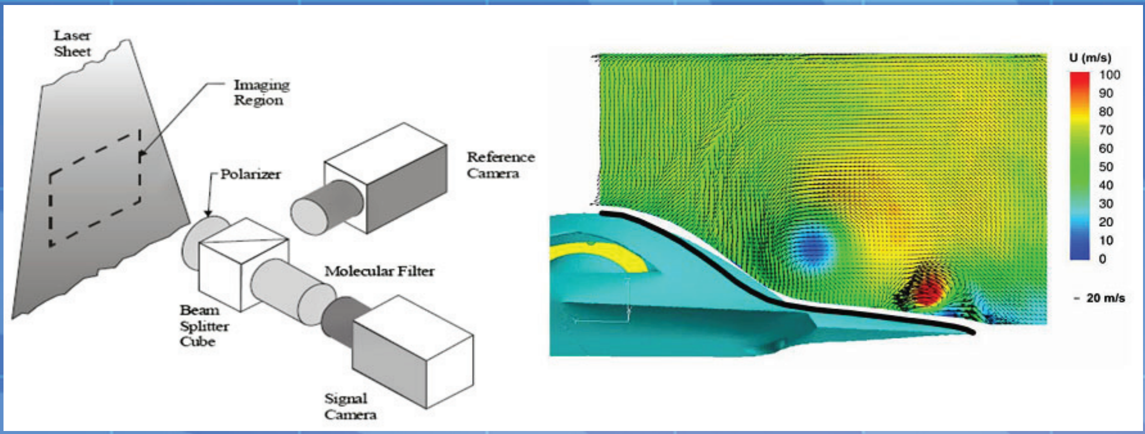
SBIR Topic Number:
AF97-146

SBIR Title:
Global Diagnostic System for Unsteady Flow Fields

Contract Number:
F33615-98-C-3001

SBIR Company Name:
Innovative Scientific Solutions, Inc., Dayton, OH

Technical Project Office:
AFRL Air Vehicles Directorate, Wright-Patterson AFB, OH



Left: Basic components of the FRS velocimetry system; Right: Flow field above the wing of a Boeing Unmanned Combat Air Vehicle (UCAV) model (shown in light blue)

Development of Filtered Rayleigh Scattering Velocimetry for Wind Tunnel Applications

- New technologies are required to understand unsteady aerodynamic flow phenomena and to perform nonintrusive detailed quantitative measurements of the variables in order to validate computational fluid dynamics models
- Innovative Scientific Solutions, Inc. (ISSI) developed a Filtered Rayleigh Scattering (FRS) velocimetry system based on the Doppler shift phenomenon that nonintrusively measures flow velocities in wind tunnels
- In order to measure the Doppler shift with a conventional camera, ISSI developed iodine cells such that the relative intensity of the light transmitted to the camera measures the particle, and therefore flow, velocity
- Iodine cells have been sold to AFRL's Propulsion Directorate, the Air Force Institute of Technology, Sandia National Laboratories, NASA, Texas and Auburn Universities, and the Keck Observatory in Hawaii

Commercialization Pilot Program Series

RBO-11-139

SBIR Requirement

Substantive progress in flight vehicle design depends on understanding and exploiting unsteady flow phenomena. Wind tunnel tests require detailed quantitative measurements of flow variables (velocity, pressure, density, temperature) throughout the flow field to understand the flow phenomena and to validate computational fluid dynamics models. Since probes inserted into the wind tunnel may disturb the flow, these data must be taken by nonintrusive means. Furthermore, to allow detailed investigation of unsteady flow fields, these methods must allow simultaneous measurements on entire planes or volumes in the flow field. Current methods face limitations because of the amount of data that must be acquired at high speeds; they also have limited dynamic range. A new method is required to overcome these limitations.

SBIR Technology

Innovative Scientific Solutions, Inc. (ISSI) developed a Filtered Rayleigh Scattering (FRS) system that measures flow velocities based on the Doppler shift phenomenon. A laser and optics system is used to generate a "light sheet" in the flow region of interest, as shown in the component diagram on the previous page. Light in the sheet is scattered by microscopic particles in the flow. The frequency of the scattered light is shifted as a function of a particle's velocity. In order to measure the Doppler shift with a conventional camera, a technique was required to transform this shift in light frequency into a calibrated change in light intensity. To achieve this transformation, ISSI developed special purpose optical cells (shown below) filled with iodine gas that function as molecular light filters. Specifically, the amount of light absorbed by the iodine cell depends on the frequency of the light. Since the absorption characteristics are stable and precisely calibrated, the relative intensity of the light transmitted to the camera measures the particle, and therefore flow, velocity.

Key technical challenges in the iodine cell development included:

- Achieving very steep filter characteristics so that small differences in light frequency are converted into measurable differences in intensity.

ISSI Iodine Cell

- Ensuring that only gaseous iodine is contained within the cells (starved cells) so the number density does not change with temperature.
- Incorporating nitrogen broadening to allow the cells to be tuned to the particle velocity range of interest.
- Achieving the above characteristics, then permanently sealing the cells and incorporating a temperature control system to ensure long-term, stable usage.

The development and commercialization of these cells represented one of the primary technical breakthroughs accomplished by ISSI under this SBIR project.

A variety of FRS velocimetry experiments were completed in the Subsonic Aerodynamic Research Laboratory wind tunnel of the AFRL Air Vehicles Directorate. One of the most interesting conducted flow measurements on a model of the Boeing Unmanned Combat Air Vehicle (UCAV). The figure on the right on the previous page shows the flow velocities in a plane perpendicular to the model and located behind the point where the wing joins the fuselage. Both inboard and outboard vortex structures, generated by the leading edge of the UCAV wing, are clearly visible.

Transition Impact

After the conclusion of this SBIR project, a complete FRS system was purchased by the Air Force Institute of Technology for use in their wind tunnel and other flow research facilities. More than 50 iodine cells have been sold to notable customers such as the Air Force Institute of Technology, the AFRL Propulsion Directorate, Sandia National Laboratories, NASA, the University of Texas, Auburn University, and the Keck Observatory in Hawaii.

Company Impact

Applications of molecular-filtered Rayleigh scattering go beyond flow measurements in wind tunnels. This technology has been used by ISSI and others to measure temperature fields in a variety of combustion environments, gas concentrations and mixing in jet flows, and to simultaneously measure multiple flow properties such as pressure, density, temperature, and velocity. In addition, iodine cells have application with other spectroscopic techniques such as Raman and Brillouin scattering, or wherever one can take advantage of the large number of stable absorption lines afforded by starved iodine cell technology. Ultimately, technology developed under this SBIR has led to more than $2.8M in new business for ISSI.

Air Force SBIR Program
AFRL/XP
1864 4th Street
Wright-Patterson AFB OH 45433

AF SBIR/STTR Program Manager: Augustine Vu
AF CPP Program Manager: Richard Flake
Website: www.afsbirsttr.com
Comm: (800) 222-0336
Fax: (937) 255-2219
e-mail: afrl.xppn.dl.sbir.hq@wpafb.af.mil