Phase 2 Project Summary

Firm: MetroLaser, Inc.
Contract Number: NNX11CA51C
Project Title: A Novel, Portable, Projection, Focusing Schlieren System

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Identification and Significance of Innovation:
The schlieren technique has been used for flow diagnostics in wind tunnels since the beginning of aerospace research due to its ability to make airflows – especially shock waves and turbulence – visible. Convection currents in air can also be visualized, which makes schlieren useful for many aerospace and commercial applications. A drawback of current schlieren systems is that they require exact alignment between a pair of widely separated mirrors, which limits portability. This is problematic in wind tunnel facilities, since experiments are frequently installed only to be torn down shortly afterwards. If a facility is not already equipped for schlieren imaging, the procurement process is often time consuming. In this project, we developed a focusing schlieren camera system (schlierenscope) that is easier to align and more versatile than existing schlieren systems. The system projects a background grid upon a reflective screen, and an image of the background grid is focused on a cutoff grid to produce the schlieren effect. Alignment between the screen and the schlierenscope is not critical, which simplifies the setup. All elements that require precise alignment are contained within the schlierenscope body, which allows a portable instrument. Large fields of view are possible.

Technical Objectives and Work Plan:
The primary objective of this project was to build portable, adjustable schlierenscopes that could be used to obtain high-speed schlieren images and video of airflows that are of interest to the aerospace community. Key features were the ability to look at different fields of view, and selectively focus on limited depths of two-dimensional slices of a flow. A second objective of this project was to develop a design for a commercial schlieren instrument that could be used as a tool for government, corporate, and university research laboratories specializing in aerodynamics, ventilation, and heat transfer. We achieved these objectives by building projection focusing schlieren systems that used lens and grid designs. Two different prototypes were constructed. The first system placed the CCD sensor at the primary image plane of the main lens, which restricted the field of view but eliminated several lenses that aberrated the images. This system was demonstrated at the 15 cm x 15 cm Supersonic Wind Tunnel. The second system used condenser lenses to relay the images to a CCD sensor at a secondary image plane, which increased the field of view at the expense of image quality. This system was demonstrated at the Nozzle Acoustic Test Rig.

Technical Accomplishments:
We built two portable schlierenscopes, both of which used strobes to freeze motion with a 1 microsecond flash and captured images with 11 Megapixel CCD cameras. The first system was compact and produced detailed images of shock waves and air jets. The sensitivity was sufficient to observe shock waves in a low pressure chamber (Pressure = 15 torr) with a 6” diameter field of view. This system is capable of visualizing fields of view up to 14.5” wide by 9.5” high, which is larger than commercially available classical schlieren systems. The second system was larger but also capable of visualizing larger fields of view, and its contrast could be adjusted using remotely controlled motorized actuators. A field of view of 30” x 20” was demonstrated at the Nozzle Acoustic Test Rig, and larger fields of view are possible if the screen size and working distance are increased. Both systems are portable enough to be shipped cross-country, wheeled into position on a small cart, and installed in a facility in a few hours. The portability and large field of view make it possible to apply the schlieren technique to cases where it was previously impractical.

NASA Application(s):
Applications exist in all forms of research and development associated with flow fields where schlieren viewing could be useful, including aero-optics, flow control, drag, boundary layer transition, and flow separation. The proposed developments will enhance ground-test facility capability. Ideal applications exist in facilities where large, fixed schlieren systems are impractical. Facilities with windows can be

problematic due to reflections of the projected light by the windows, but the large field of view and portability of the systems make them ideal for free jet facilities.

Non-NASA Commercial Application(s):
The refraction of light by density gradients in air and other gases is a ubiquitous phenomenon that can be exploited to visualize air flows. Density gradients are produced by plumes of hot and cold air, fumes from volatile organic compounds, and jets of compressed air. Commercial applications include characterization of air flows in commercial kitchen ventilation systems, refrigerated display cases, industrial blowers, air knives, and hair dryers. The large field of view is advantageous in many of these applications. These applications do not typically require short exposures, so the cost of the system can be reduced by using inexpensive light emitting diodes and digital SLR cameras with video capability.

Name and Address of Principal Investigator:
Dr. Drew L'Esperance, MetroLaser, Inc., 22941 Mill Creek Drive, Laguna Hills, CA, 92653-1215

Name and Address of Offeror:
MetroLaser, Inc., 22941 Mill Creek Drive, Laguna Hills, California 92653-1215