Department of the Navy SBIR/STTR Transition Program

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Topic # N20A-T022
Measurements of Wall-Shear-Stress Distribution in Hypersonic Flows
Engineering and Scientific Innovations, Inc.

WHO

SYSCOM: ONR

Sponsoring Program: Office of Naval Research - Hypersonics D&I Program

Transition Target: DOD Aerodynamic Testing Labs/Commercial Contractors

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Other Transition Opportunities: Hypersonic Vehicle Developers Requiring Non-Intrusive Flow Analysis



Image courtesy of Engineering and Scientific Innovations, Inc. 2023

Notes: Image Description: Artistic rendering depicting Surface Shear-Stress Distribution using Liquid Crystals on a Navy Fighter Jet

LC: Liquid Crystal
SSSLC MS: Shear Stress Sensitive Liquid Crystal Measurement System
CFD: Computation Fluid Dynamics
DOD: Department of Defense
D&I: Discovery & Invention
ESI: Engineering and Scientific Innovations, Inc.

WHAT

Operational Need and Improvement: A full understanding of the aerodynamic nuances and fluid dynamics that affect air vehicles and weapons systems is critical to ensure maximum efficacy and efficiency. Currently, aerodynamic design relies heavily on CFD analysis with little, to no, reliable experimental surface shear stress data to validate it. A non-intrusive, full-field shear stress measurement system utilizing precisely-calibrated Shear Stress Sensitive Liquid Crystals would not only enable the validation of CFD design work but would also unlock an entirely new and reliable method of visualizing and measuring surface shear-stress, even in flows of the hypersonic regime.

Specifications Required: The Office of Naval Research put forth a solicitation requesting a non-intrusive method of measuring wall-shear-stress distributions in hypersonic ground test facilities, in an area of 5mm x 5mm, be it flat or curved, within 1ms, in temperatures reaching 395K and in a range of varying pressures up to M=5, be developed.

Technology Developed: Currently, ESI's Liquid Crystal technology is capable of collecting and analyzing shear stress information from surfaces of spatial resolutions 1mmx1mm or better, within a temporal resolution of mere microseconds, in temperatures up to 330K and at pressures as low as 0.01 psiA (M=4). Furthermore, a comprehensive, computer-controlled LC Calibration system, with user-friendly interfacing, easily and precisely calibrates LCs via rotational rig and spectrographic/camera visualization for full-field shear stress analysis, including shear stress contour determination, have been developed. A Mach 4 wind tunnel has been constructed and the shear stress around 3-dimensional surface mounted bodies (circular cavities & protrusions) analyzed. But we aren't stopping there, improvements are continuously being made, parameters expanded and further advancements continually being worked towards.

Warfighter Value: This technology will allow for the accurate measurement of wall-shear-stress which is paramount to predicting the characteristics of boundary layers and the performance of hypersonic vehicles. In addition, the availability of wall-shear-stress distribution measurements in hypersonic ground test facilities is highly valuable to improve and validate the computational tools needed to extrapolate ground test measurements to flight conditions. Developments implemented via the Shear Stress Sensitive Liquid Crystal Measurement System (SSSLCMS) data will create ever-lasting, systemic trickle-down effects that will improve vehicle performance and reduce cost.

WHEN

Contract Number: N68335-22-C-0844 **Ending on:** Nov 14, 2025

Milestone	Risk Level	Measure of Success	Ending TRL	Date
Demonstrate the ability to non-intrusively indicate changes in surface shear stress using shear stress sensitive Liquid Crystals on a flat plate at Mach 3.5	N/A	Images of shear stress were acquired and clearly demonstrated regions of low shear stress and flow separation	3	1st QTR FY22
CFD design of a Mach 4 and Mach 5 wind tunnel.	N/A	Simulations complete	4	3rd QTR FY22
Mechanical design of the Mach 4 wind tunnel.	N/A	Tunnel fabricated & documented.	8	2nd QTR FY23
Custom made Liquid Crystal - shear stress calibration rig designed and fabricated.	Low	Rig operational and positive viscosity measurements being confirmed	5	4th QTR FY23
Liquid crystal analysis software	Low	Using previous images an acquisition and analysis program was developed	6	4th QTR FY23
Shear stress sensitive Liquid Crystals are	Low	Boundary Layer shear stress	6	1st

HOW

Projected Business Model: ESI and its Shear Stress Sensitive Liquid Crystal Measurement System, will provide accurate quantitative shear stress measurements for our clients. This service based model will include LC calibration, experimental setup, and image processing.

Company Objectives: Provide both an innovative low cost testing service, as well as offer turn-key products to our DOD and commercial clients.

Potential Commercial Applications: Sikorsky has shown an interest in using ESI's LC technology to study the airflow over helicopter rotors. Other clients include any researcher concerned with experimental shear measurements in flow ranging from subsonic to supersonics and into the hypersonic flow regime.

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