Ph.D. DISSERTATION DEFENSE

Candidate:	Ben Segall
Degree:	Doctor of Philosophy
School/Department:	Mechanical Engineering
Date:	5/1/2026
Time/Location:	2:30 PM Gateway South 216
Title:	Hypersonic Turbulent Boundary Layer Statistics
Chairperson:	Dr. Nicholaus Parziale, Department of Mechanical Engineering, SES
Committee Members:	Dr. Kevin Connington, Department of Mechanical Engineering, SES Dr. Muhammad Hajj, Department of Civil, Environmental and Ocean Engineering, SES Dr. Jason Rabinovitch, Department of Mechanical Engineering, SES

ABSTRACT

A physical understanding of supersonic and hypersonic turbulence is essential for the design of high-speed vehicles, as quantities such as aerodynamic drag and heat transfer directly influence vehicle performance and survivability. Non-intrusive flow diagnostic techniques, such as krypton tagging velocimetry (KTV) and acetone tagging velocimetry (ATV), enable measurement of these turbulent quantities without disturbing the flow field.

Experiments were performed in the Stevens Shock Tunnel to obtain streamwise and wall-normal velocity fluctuation profiles in Mach 6 turbulent boundary layers over a hollow-cylinder–flare test article under varying conditions, including free-flight enthalpy. Surface measurements of heat transfer and wall shear stress were used to characterize boundary conditions and support validation of the optical diagnostics.

A novel technique was developed to measure wall-normal velocity fluctuations using a single inclined laser line, enabling access to quantities that are difficult to capture with existing diagnostics.

The measured turbulence profiles are compared with experimental and computational studies from the literature to assess the validity of Morkovin's hypothesis, which relates compressible turbulent flows to their incompressible counterparts. The results show favorable agreement with theoretical and direct numerical simulation trends for streamwise fluctuations and capture the expected behavior of wall-normal fluctuations, where previous measurement techniques have exhibited discrepancies.

These findings provide new experimental evidence supporting Morkovin's hypothesis in hypersonic turbulent boundary layers and improve the characterization of turbulence structure in high-speed flows, contributing to the development and validation of turbulence models for hypersonic applications.