Aerodynamic modeling of high Reynolds number flows, while mature in many ways, suffers dramatic inaccuracies in complex cases such as separating flows. Turbulence and transition models are themselves incomplete representations of the full physics and require quantitative insights from theory, fully-resolved simulations, and experiments. While experiments are often considered the standard against which to judge models, significant challenges exist in measuring the true boundary conditions present in any given study. These challenges have led many to suspect that unknown and uncertain experimental boundary conditions play a substantial role in the discrepancies between simulation and experimental results.

Our team has focused on conducting combined experimental and computational studies with an emphasis on the stringent demands of computational model validation. In the talk, the philosophy of validation studies will be discussed, with insights from two studies conducted at Virginia Tech. A study already completed on an unsteady transitional airfoil flow (Figure 1) supported the development of a new implementation of transitional modeling for delayed detached eddy simulation. A new study of low Mach number, high Reynolds number flow of a plane turbulent boundary layer over bumps (Figure 2) is also underway with the goal to produce detailed experimental data sets of smooth wall flows with various levels of separation that, for the first time, meet the most exacting requirements of CFD validation as per Oberkampf and Smith (2017, ASME Journal of VV & UQ). To attain this goal, an intensive research program has begun that brings together experts in experiments, computations and CFD validation. This effort will involve detailed measurements and calculations needed for full uncertainty quantification, experimental configuration design, and extensive documentation of the flow boundary conditions and boundary condition sensitivities. Key results from these studies will be presented, in addition to descriptions of future efforts for obtaining new validation data for use by the turbulence modeling community.

Figure 1. Unsteady flow over airfoil.  
Figure 2. New wall-mounted bump case.
Prof. Todd Lowe leads a research team focused on the aerodynamics and aeroacoustics of propulsion inlets and exhausts with advanced capabilities in laser-based optical diagnostics. His fundamental contributions have provided insights for understanding turbulence transport and noise in turbulent shear flows, with much recent work focused on the impact of large-scale turbulence on supersonic jet noise. His instrumentation research has resulted in several notable impacts, including fluorescent particle velocimetry for very near wall flow measurement, 250 kHz planar Doppler velocimetry and new interpretations of the particle lag effects on supersonic turbulent boundary layer statistics. He is co-inventor of two US utility patents, with two additional patents pending, and has authored publications in the areas of advanced diagnostics for fluid dynamics, turbulent shear flow and jet noise physics, propulsion and power, and signal processing. He is the Co-Director of the Advanced Propulsion and Power Laboratory at Virginia Tech and currently leads a team of undergraduate and graduate student researchers, a research scientist and a laboratory engineer. Prior to returning to Virginia Tech as a faculty member in late 2010, he was V.P. for Research and Development at AUR, Inc., a small business focused on laser diagnostics research and development.