Title: Scale-resolved simulations and analysis strategies for aero-propulsion systems

Abstract: Fluid mechanics of aero-propulsion systems harbor complex phenomena, often requiring experimentally-anchored scale-resolved simulations to study them. Equally important is the use of suitable physics-based and modal-based analysis techniques that enable us to identify and extract key mechanisms that impact system performance and predict potential performance deviations. In this seminar, we discuss this approach in the context of evaluating three systems, associated with aeroacoustics, external and internal aerodynamics. In the first scenario, we utilize large-eddy simulations to evaluate plasma-based actuators to reduce acoustic emissions from rectangular supersonic jets. The simulations and analyses reveal critical variations in coherent structures and their convection velocities induced by the actuators, that provide a first-principles based guidance for noise reduction strategies. The second system analyzed is a mixed-compression supersonic inlet, where modal and stability analyses of the external and internal compression paths elucidate a multi-modal mechanism of boundary layer transition. Further, we identify geometry-based control strategies that can potentially stabilize shock-boundary-layer-interactions in this system, critical to the safety of the flight vehicle. Finally, we present direct numerical simulations and spectral analyses of aerodynamics of hypersonic forebodies, with focus on the thermal loading on the vehicle. A most significant design choice (for a given set of flight conditions) is the nose radius, which impacts the instability dynamics in the boundary layer, resulting in various modal and non-modal paths of transition to turbulence over the fuselage.