AFRL CALL FOR RESEARCH

1. Research Title: *High-fidelity simulations to characterize the physics of plasma-based low-speed flow control*

2. Individual Sponsor:

Dr. Miguel Visbal, AFRL/RQAC,
AFRL/RQAC Bldg 146, Room 225
2210 Eighth Street
WPAFB, OH 45433
Miguel.Visbal@wpafb.af.mil

3. Academic Area/Field and Education Level: Engineering Physics, Applied Physics, Mechanical Engineering, Aerospace Engineering (MS and/or Ph.D. level)

4. Objectives: The proposed thesis topic aims to employ direct and large-eddy simulations to identify and optimize the main mechanisms through which different plasma-based flow control devices influence low speed flows.

5. Description: In recent years, a variety of plasma-based actuators has been successfully employed to control low speed flows. Among the canonical configurations studied are flows past airfoils, cylinders and humps, in each of which substantial reduction or elimination of flow separation has been demonstrated. Results to date suggest that the observations cannot be explained by simple mechanisms, but rather result from a complex combination of events. Until recently, the primary plasma device employed for low-speed flow control was the Dielectric Barrier Discharge (DBD) actuator, comprised of an exposed and a submerged electrode separated by a dielectric, and typically excited by a high-voltage AC signal (~ 10 kV, 10 kHz). Extensive experimental and computational results have led to an evolving consensus on the main mechanism that explains the observations: at reasonable Reynolds numbers, the exerted unsteady force field, often encapsulated in a duty cycle to facilitate a flow-sensitive Strouhal number, excites hydrodynamic instabilities and induces transition to turbulence, enhancing mixing and thus facilitating reattachment or eliminating separation. Details of the instability remain poorly understood however because of the complicated nature of the basic state of the separated flow. Recent observations with other actuators however, bring into question the force-based nature of the presently accepted explanation. In particular, nano-second pulsed actuators (with the same basic dielectric barrier configuration), have been shown experimentally to be as effective as conventional DBDs, but are known to primarily generate heat with no significant directed force output. Microwave-excited surface metal strips have also exhibited an energy (as opposed to momentum) based effect, even in low-speed flow. Such actuators therefore are potentially highly attractive, since they are less sensitive to orientation, more scalable because of their dynamic range of excitation and as preliminary experiments show, can be employed for high-speed (supersonic and hypersonic) flow control as well. The maturity of advanced methodologies coupled to readily available high-performance computing systems provides a unique opportunity to explore the principal physics issues through high-fidelity simulations. To this end, this thesis will derive a more complete understanding of how these actuators interact with the three-dimensional flow field, with a comprehensive effort using high-fidelity three-dimensional simulations based on the full Navier-Stokes equations (DNS/LES). The analysis will first employ available and anticipated experimental results to verify and validate the methodology. The capability will then be employed to understand the development of coherent structures induced by the actuators, and the manner in which these interact with the flow field. The results will also be employed to deduce the hydrodynamic stability characteristics of the basic state. This understanding will then be leveraged to optimize the actuation by proposing and testing the most appropriate excitation characteristics (frequency and actuator location).

6. Research Classification/Restrictions: This research falls under the 6.1 basic research classification.

7. Eligible Research Institutions:

[X] Universities (DAGSI) [] AFIT [] USAFA