The simulations of underwater implosion, aerodynamics of flexible flapping-wing micro air vehicles, and high-G maneuver of fighter aircraft share the common challenge of computing flow-structure interactions in highly nonlinear multi-material domains. Indeed, the implosive collapse of a submerged, gas-filled structure and its subsequent effect on the structural integrity of a near-by system is a transient, high-speed, multi-phase inviscid flow-structure interaction problem characterized by ultrahigh compressions, shock waves, large structural displacements and deformations, self-contact, and possibly the initiation and propagation of cracks in the structure. Bio-inspired micro air vehicles operate in the lower Reynolds number regime and tend to have light weight flexible flapping wings. Their unsteady and turbulent aerodynamics are closely linked to their structural dynamics which features large motions and deformations, and their flight characteristics are affected by environmental factors such as wind gust. Fighter aircraft operate in the higher Reynolds number regime. They perform aggressive high-G maneuvers characterized by high angles of attack, and turbulent viscous flows driven by large structural motions. This lecture will present a robust, multi-disciplinary, computational framework for the numerical simulation of all of these highly nonlinear flow-structure interaction problems characterized by multi-material domains. It will discuss its mathematical properties, and highlight its potential with the analysis of material failure driven by multi-phase flow-structure interaction, the simulation of the thrust generation of flexible flapping wings at low Reynolds numbers, and the determination of the roll damping effect on high-speed aircraft maneuvers.

Charbel Farhat is the Vivian Church Hoff Professor of Aircraft Structures, Chairman of the Department of Aeronautics and Astronautics, and Director of the Army High Performance Computing Research Center at Stanford University. He is designated as an ISI Highly Cited Author in Engineering by the Institute for Science Information Web of Knowledge, Thomson Scientific Company. He was knighted by the Prime Minister of France in the Order of Academic Palms and awarded the Medal of Chevalier dans l’Ordre des Palmes Académiques. He is also the recipient of many other academic distinctions including the Lifetime Achievement Award from ASME, the Structures, Structural Dynamics and Materials Award from AIAA, the John von Neumann Medal, Computational and Applied Sciences Award, and R. H. Gallagher Special Achievement Award from USACM, the Gordon Bell Prize and Sidney Fernbach Award from IEEE, the Computational Mechanics Award from IACM, and the Modeling and Simulation Award from DoD. He is a Member of the National Academy of Engineering and a Fellow of AIAA, ASME, IACM, SIAM, USACM, and WIF. He is Editor of the International Journal for Numerical Methods in Engineering and the International Journal for Numerical Methods in Fluids. He also serves on the United States Bureau of Industry and Security’s Emerging Technology and Research Advisory Committee at the Department of Commerce.