2010-11 Mechanical Engineering Distinguished Seminar Series
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TURBULENCE AND STOCHASTICITY IN HIGH-SPEED REACTIVE FLOWS

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Abstract: There have been many discussions of turbulence and the fact that it is a stochastic process. There have been significantly fewer discussions of what this means in a practical sense of predictability and the consequences for risk assessment. Now we have begun to address these issues as they arise in chemically reactive flows, in which there are multiple interacting stochastic processes, including flow instabilities, turbulence, many interactions between shocks, flames, and vortices, and the resulting formation of ignition centers (hot spots). The specific flow that allows us to focus on these issues is the evolution of an initially laminar flame propagating down a channel filled with a series of obstacles. As this system evolves, it undergoes flow transitions from subsonic to supersonic, as it simultaneously undergoes transitions among combustion states from a laminar to a turbulent flame, and then possibly to a detonation. This is illustrated visually by movies made from a multidimensional, compressible, unsteady, deterministic solution of the Navier-Stokes equations. In the process of analyzing the dynamic events portrayed in the movie, we have found several surprising properties of the evolving turbulence. For example, the turbulence in the flow deviates critically from Kolmogorov, equilibrium turbulence, and a leading shock couples to a turbulent flame in what appears to be a metastable flame-shock complex. We suggest ways in which such properties affect the transitions observed, and how the system can be viewed in terms of multiply interacting stochastic processes. The movies are also related to events observed in the large-scale detonation-tube experiments at Lake Lynn Experimental Mines.

Biography: Dr. Elaine S. Oran is the Senior Scientist for Reactive Flow Physics at the Naval Research Laboratory (NRL). She received an A.B. in chemistry and physics from Bryn Mawr College, both a M.Ph. in Physics and a Ph.D. in Engineering and Applied Science from Yale University, and Honorary Doctorates from L'Ecole Centrale de Lyon and Leeds University. At NRL, she is responsible for carrying out theoretical and computational research on the fluid and molecular properties of complex dynamic systems. Active research topics include: chemically reactive flows, turbulence, numerical analysis, high-performance computing and parallel architectures, shocks and shock interactions, rarefied gases, and microfluidics, with applications to combustion, propulsion, astrophysical explosions, and micro-sensor design. In addition to her position at NRL, she is currently an adjunct professor of Aerospace Engineering at the University of Michigan and a visiting professor at Leeds University. She is a member of the NAE and a Fellow of AIAA, APS, and SIAM.

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