

COMBUSTION WEBINAR

*Can Turbulent Combustion Models be Both
Computationally Efficient and Generally Applicable?*

Speaker: Michael Mueller, Princeton University

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Biography: Michael E. Mueller is an Associate Professor and Director of Graduate Studies in the Department of Mechanical and Aerospace Engineering at Princeton University. Since 2020, he is also jointly appointed as a Faculty Researcher at the National Renewable Energy Laboratory. He received a BS degree in mechanical engineering from The University of Texas at Austin in 2007, a MS degree in mechanical engineering from Stanford University in 2009, and a PhD degree in mechanical engineering from Stanford University in 2012. His research interests encompass computational modeling of multi-physics turbulent reacting flows with applications to energy and propulsion, principally combustion with emerging thrusts in offshore wind and fusion, as well as broader areas of computational and data sciences including uncertainty quantification, numerical algorithms, and data-based modeling and algorithms. He has been recognized through the Young Investigator Program of the Army Research Office, with a Research Excellence Award from The Combustion Institute, with the Early Career Combustion Investigator Award of the United States Sections of The Combustion Institute, and as an Associate Fellow of the American Institute of Aeronautics and Astronautics. He currently serves as Associate Editor of the Journal of Engineering for Gas Turbines and Power and serves on the Editorial Board of Combustion and Flame.

Abstract: Turbulent combustion models generally fall into one of two classes. In the first class of models, no attempt is made to reduce the dimensionality of the thermochemical state-space, and these “brute-force” models solve transport equations for every chemical species so are very general but extremely computationally expensive. Conversely, in the second class of models, the dimensionality of the thermochemical state-space is reduced by a priori projecting the thermochemical state onto a very low-dimensional manifold by presuming that combustion occurs in a single asymptotic mode so are very computationally efficient but lack generality and are not applicable to “multi-modal” combustion. In this lecture, a new modeling framework will be presented that breaks this fundamental trade-off, leading to a very general turbulent combustion model that is also computationally efficient. On the theoretical front, two-dimensional manifold equations are derived starting from thermodynamic considerations to describe general “multi-modal” combustion and rely on a new generalized progress variable. On the computational front, rather than precomputing and pretabulating solutions to the two-dimensional manifold equations, which would require excessive preprocessing effort and intractable memory requirements, a new framework termed In-Situ Adaptive Manifolds (ISAM) has been developed in which these solutions are computed ‘on-the-fly’ and stored for efficient reuse using In-Situ Adaptive Tabulation (ISAT). This new modeling framework is applied with LES to a turbulent lifted jet flame and is demonstrated to be as computationally efficient as traditional “uni-modal” manifold-based models yet general enough to provide a complete description of the “multi-modal” stabilization mechanism..

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