Preface

This volume contains the 2019 Annual Research Briefs summarizing the research activities at the Center for Turbulence Research (CTR) in its thirty-third year of operation. The primary objectives of CTR are the investigation and understanding of fundamental aspects of turbulent flows, and the development of physics-based models and predictive tools for multi-scale engineering analysis. The core strategy that CTR employs to pursue these objectives is to bring together key individuals in research fields related to multi-physics turbulent flows, and to provide them with a scientifically vibrant platform where they find encouragement to address diverse and challenging problems in turbulence.

Last year, CTR hosted eighteen resident Postdoctoral Fellows. The CTR roster for 2019 is provided in the Appendix. Also listed are the members of the CTR Steering Committee, which meets quarterly to act on fellowship applications.

The investigations reported in this volume have been supported by several government organizations: the Department of Energy through the Advanced Simulation and Computing (ASC) Program and the INCITE Program, the Air Force Office of Scientific Research (AFOSR), the Office of Naval Research (ONR), and the National Aeronautics and Space Administration (NASA).

The twenty-nine reports contained in this volume cover a wide range of subjects related to multi-physics turbulent flows. The briefs are organized into six sections as follows. The first group of research briefs is devoted to wall-modeled large-eddy simulation (WMLES). The first report includes prediction of the lift characteristics (including maximum lift) of a realistic aircraft in landing configuration. This demonstration of the efficacy of WMLES in terms of both accuracy and time to solution represents the attainment of a long-awaited milestone in the utility of LES in engineering analysis and design. Additional investigations that utilize and evaluate WMLES comprise studies on non-equilibrium and separated turbulent boundary layers, prediction of peak heat transfer in transition to turbulence and modeling of thermochemical processes in hypersonic boundary layers, and prediction of supersonic jet screech from complex nozzle configurations.

Hydrodynamic stability theory has also been key at CTR to predict laminar to turbulent transition in high speed boundary layers and to gain quantitative insights into the mechanics of fully developed turbulent flows. The next group of four reports is devoted to the stability of supersonic jets, efficient numerical algorithm for capturing the evolution and receptivity to flow disturbances in boundary layers, and characterization of optimal distortion of the liquid-gas interface in a liquid jet. This study naturally leads to the third topical group covering studies on multi-phase and particle laden flows. The studies in the multi-phase group include investigation of air-bubbles breakup in water, relevant for marine and naval applications, and novel formulations for the diffuse-interface method for computation of two-phase flows. For particle-laden flows, a numerical method for radiation transport is introduced, and a data-driven approach is demonstrated for determining important dimensionless parameters in irradiated flows. The last two briefs provide a quantitative improvement of predictive capabilities within the framework of the PSAAP-II program.

The fourth topical group is devoted to fundamental scientific questions in canonical turbulent flows. Briefs on topics of interest here include a novel frame-invariant definition of coherent structures and an alternative view of the inter-scale energy transfer which portrays a universal picture of the energy cascade. The research briefs on wall turbulence cover a wide range of subtopics ranging from the introduction of non-linear tools for the analysis of transitional boundary layers, alternative decomposition of the skin friction in physically meaningful contributions, the temporal characterization of extreme dissipation events, and the extension of the minimal flow unit for the logarithmic layer as a simplified testbed to unveil the dynamics of wall turbulence.

Topics on numerical methods and uncertainty quantification are considered in the fifth group of research briefs, followed by investigations of reacting flows and electrokinetics effects. Novel numerical approaches are introduced for elasto-plastic deformations in multi-materials and for the simulation of flows in trans- and supercritical conditions. The two subsequent briefs are devoted to the modeling of uncertainties in variable density flows and multi-material mixing. The sixth group of briefs revisits and extends the modeling of multi-mode combustion, combustor noise, and electroconvective instabilities in ion-selective membranes, the latter is important for the purification of brackish water.

The volume concludes with three additional briefs. The first two explore preliminary ideas in emerging technologies for the prediction and modeling of turbulent flows, namely, quantum computing and artificial intelligence. The last brief offers a short perspective on the historical developments of Orr-Sommerfeld solvers.

It is a great pleasure to thank Pamela Nelson Foster and Vi Nguyen for their help on the day to day management of CTR. This volume is available online, including color versions of the figures in the reports, at the CTR website: `http://ctr.stanford.edu`.

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