Preface

The sixteenth biennial Summer Program of the Center for Turbulence Research was held from June 26 to July 22, 2016. CTR hosted eighty-one participants from thirteen countries, including eighteen U.S. institutions. Thirty-two CTR staff members, including graduate students, postdoctoral fellows and faculty, worked alongside the participants and contributed to forty-four projects spearheaded during the Summer Program. The participants were selected on the basis of high quality of their research proposals and their synergy with current scientific interests of CTR. The role of CTR continues to be that of providing a forum for the fundamental study of multi-physics turbulent flows for engineering analysis.

This proceedings volume contains fourty-four reports, which are divided into five groups: Multi-phase Flows, Combustion, Turbulence and Transition Physics, Large-Eddy Simulation (LES), and Uncertainty Quantification. Preceding each group of papers is a technical overview that summarizes the main technical accomplishments.

The research group on multi-phase flows emphasized phenomena related to particle-laden flows, including the analysis of particle trajectories, electrically charged particles, interaction of flames with particles, and turbulent flows motorized by active matter. Parallel efforts were made in formulating numerical methods for compressible two-phase systems and transcritical high-pressure flows, and in addressing the characteristics of turbulence through porous materials.

Activities related to research on combustion focused on fuel mixing, ignition, turbulent combustion and combustion dynamics. Efforts were made on the subgrid-scale modeling for dispersion of fuel droplets and for molecular-weight fluctuations in gas constants for oxy-combustion systems. Non-premixed reacting turbulent jets were studied using Lagrangian coherent structures, and optimal ignition locations were characterized using adjoint techniques. Reduced descriptions for complex fuels were formulated for turbulent-combustion LES models. A key area of research in the group was that of combustion instabilities and noise, which was studied in the context of both rocket and gas-turbine cumbustors.

The turbulence and transition physics group studied the structure and modeling of transitional boundary layers and wakes, the analysis and control of wall-bounded turbulence, and the mechanisms of noise generation and propagation in turbulent flows. The projects tackled a variety of problems of technical relevance for external and internal aerodynamics, including, for instance, identification and characterization of turbulent spots within fully developed turbulent boundary layers, analysis of compressibility and wall-compliance effects on transitional boundary layers, and control of hypersonic boundary layers along compression corners.

The use of LES methodology continues to flourish in industrial settings and is a subject of great interest and perusal at CTR. The LES group activities led to the study of subgrid scale models, and novel concepts for wall modeling. The activities were supplemented with computations employing wall-modeled LES and new grid generation techniques applied to high-speed flows in complex geometries, including specific applications to external aerodynamics such as the NASA Common Research Model.

The determination of sensitivities and uncertainties in complex flow problems were the main focus of the group working on uncertainty quantification. The activities encompassed three main areas related to the study of sensitivities in high-fidelity flow simulations: the analysis of sensitivity using adjoints, the assessment of the effects of geometrical uncertainties on turbulent flows, and the determination of the epistemic uncertainties induced by assumptions in turbulent transport models.

As in previous years, four weekly tutorials were given during the CTR Summer Program. The topics discussed in the tutorials this year were: "Wall Modeling" by George Park, "High-Pressure Transcritical Flows" by Lluis Jofre-Cruanyes and Daniel Banuti, "Compressible Turbulence" by Ivan Bermejo-Moreno, and "Large-Eddy Simulations for Design" by Sanjeeb Bose.

The participants of the 2016 Summer Program presented their accomplishments on July 22. This final event was attended by several colleagues from industry, academia, and government.

It is our great pleasure to acknowledge sponsorship of the 2016 Summer Program by the US Air Force Office of Scientific Research (AFOSR), National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), the Advanced Simulation and Computing Program of the Department of Energy's National Nuclear Security Administration, and the Office of Naval Research (ONR). The simultaneous commitment of five different federal agencies to funding the 2016 CTR Summer Program underscores the importance of understanding and modeling turbulent flows for addressing outstanding engineering challenges.

This proceedings is dedicated to the memory of John Lumley (1930-2015). John was one of the most influential scholars of turbulent flows in the second half of the twentieth century. He was a member of the first CTR Advisory Committee in 1989 and chaired this committee in 1990. His research in turbulence physics over five decades, particularly in statistical modeling of turbulent flows, and his seminal books inspired many researchers at CTR and throughout the world.

We are grateful to Vi Nguyen and Pamela Nelson Foster for their assistance and efficient organization of the 2016 CTR Summer Program. 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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