Preface

The fifteenth biennial Summer Program of the Center for Turbulence Research was held during the period of July 6 to August 1, 2014. CTR hosted seventy-five participants from nine countries. In addition, twenty-six CTR staff members facilitated and contributed to the Summer Program projects. The projects encompassed broad areas of research on multi-physics effects in turbulent flows. As in the past, the participants were selected based on their research proposals and the current scientific interests of CTR. The role of CTR continues to be that of providing a forum for the study of turbulence physics and other multi-scale phenomena for engineering analysis.

This proceedings volume contains forty-seven reports, which are divided into six groups: Particle-Laden Flows, Two-Phase Flows, Combustion, Jet Noise, Transition and Turbulence, and Large-Eddy Simulation (LES) methodologies. Each group of papers is preceded by a brief technical overview that summarizes their main accomplishments.

There is a renewed interest in particle-laden flows at Stanford motivated by the recently awarded Predictive Science Academic Alliance Program (PSAAP-II). The overarching physical problem of PSAAP-II is the study of solar-power collectors involving particle-to-gas energy transfer enabled by thermal radiation. The group dedicated to this topic emphasized phenomena related to two-way inter-phase coupling, including studies of finite particle-size and thermal-radiation effects on turbulence statistics and particle settling rates, along with characterizations of the onset of incipient motion of particles embedded in turbulent boundary layers. Parallel efforts were made in formulation of subgrid-scale models for particle dispersion.

The research group on two-phase flows focused on the fundamental topic of inter-phase dynamics in turbulent flows. Their efforts involved the characterization and subgrid-scale modeling of turbulence-interphase interactions, including algorithmic identifications of resulting features such as droplets and ligaments. In addition, several predictive simulations were carried out for specific engineering applications, such as diesel injectors and transcritical dynamics of fuel jets in propulsion systems, as well as liquid-layered wall interactions with wiping air jets for industrial coating processes.

In response to stringent regulations being imposed on the operation of combustion systems, the combustion group dedicated efforts to formulating and testing reduced-order models for soot and nitrogen-oxide emissions. These investigations were performed in parallel with analyses of the onset and development of thermoacoustic instabilities in combustion engines, which motivated the deployment of adjoint methods and uncertainty-quantification frameworks for chemically-reacting flows. A key area of research in the group was that of fundamental analysis on flame dynamics for its potential in subgrid-scale modeling of turbulent combustion, which included studies of limiting conditions for stabilization of edge flames in turbulent co-flows, and the description of inter-scale transfer of energy in turbulent deflagrations.

Activities related to research on jet noise revolved around the utilization of computational aeroacoustics to understand fundamental physical phenomena related to noise propagation from aircraft engines. In particular, ground-breaking LES computations were performed by the jet-noise group that highlighted the importance of modeling the interior of the exhaust nozzle for the correct prediction of the far-field sound levels. The LES database was also used for characterization of wave-packet dynamics. In addition, and in connection with combustion-generated noise, the group used dynamic-mode decomposition techniques to dissect the physics responsible for sound generation in transonic high-pressure turbine stages.

The transition and turbulence group studied controlling mechanisms and physical factors central to transition in a number of configurations of interest to external and internal aerodynamics. For instance, direct numerical simulations were used to characterize transition in boundary layers over swept wings, as well as shock-wave interactions with boundary layers over compliant walls. Furthermore, drag reduction was investigated in the context of wall-bounded turbulent flows, by considering both superhydrophobic surfaces and acoustic-impedance wall boundary conditions. In parallel efforts, shape-optimization algorithms of turbine blades were developed to minimize turbulent heat transfer in conjunction with reduced-order models that serve as primers for physics-based subgrid-scale models of wall-bounded turbulence.

The use of LES methodology is currently flourishing in industry and continues to be a central subject of interest at CTR. The LES group undertook projects that led to improved numerical methods and new considerations for subgrid-scale modeling. The activities were supplemented with LES computations that considered roughness models in turbulent boundary layers and wall-modeled LES of high-speed flows, including specific applications in turbomachinery.

An important feature that has become a tradition of the CTR Summer Programs are the four weekly tutorials. In the 2014 Summer Program, the topics discussed in the tutorials were: “Low-Order Models and Jet Noise” by Tim Colonius, “Radiation Modeling” by Iain Boyd, “Particle-Laden Turbulent Flows” by Said Elghobashi, and “Combustion Instabilities” by Matthew Juniper.

The participants of the 2014 Summer Program presented their accomplishments on August 1. This final event was attended by several colleagues from industry, academia, and government. At the concluding banquet, a tribute was given to honor Dr. Richard W. Watson of Lawrence Livermore National Laboratory for his vision and leadership in guiding the Stanford team in the Advanced Simulation and Computing Program (ASC) of the Department of Energy. He helped transform the research culture at CTR by infusing a National Laboratory perspective in the university environment, thus making possible the integrated simulation of multi-disciplinary complex engineering systems.

It is our great pleasure to acknowledge sponsorship of the 2014 Summer Program by the US Air Force Office of Scientific Research (AFOSR), National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), and the Advanced Simulation and Computing program of the Department of Energy’s National Nuclear Security Administration. It is particularly gratifying that five distinct programs within the US Air Force Office of Scientific Research pulled their resources together to become the major supporter of the 2014 Summer Program, highlighting the importance of understanding turbulent flows in broad areas of aerospace sciences and engineering.

Many thanks are due to Vi Nguyen and Rika Bosmans for their assistance and efficient organization of the 2014 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/publications.html`

Parviz Moin
Javier Urzay