Preface

The ninth Summer Program of the Center for Turbulence Research was held during the period July 29th – August 23rd, 2002. The increase in number of participants, noted in the Preface to the Proceedings of the 2000 Program, continues: this year there were 50 participants from ten countries, and 30 hosts from Stanford and NASA-Ames.

This Proceedings volume contains 32 papers that span a wide range of topics and an enormous range of physical scales. The papers have been divided into seven groups: Acoustics, RANS modeling, Combustion, Large-eddy simulation (LES), LES Numerics, Stratified Flows, and Fundamentals, In several cases, a paper could have fitted in more than one group so the classification is somewhat arbitrary.

Combustion has been a topic of interest at CTR for many years. New advances are noted, with chemistry models increasing in realism as available computing power has increased. A related topic, essential to combustion of liquid fuels or pulverized solids, is the behavior of sprays. A newly appearing sub-grid stress model for mono-disperse particles is shown to be important. The paper by Selle *et al.* merits special attention because it demonstrates how the basic research work done at CTR over the years is now being applied to real-life problems, in this case, the burner of an existing gas-turbine combustor. Calculations were done using large-eddy simulation and a combustion model, on an unstructured grid fitted to this extremely complicated geometry. CTR's work on LES for combustors has attracted a great deal of attention from the leading companies in the gas turbine industry, because simpler methods of predicting turbulence, mixing and combustion are unable to deal satisfactorily with this very important problem, while direct numerical simulation of the exact Navier-Stokes equations (DNS) is impossibly expensive at full-scale Reynolds number.

In **aero-acoustics**, Large-eddy simulation is emerging as a cost-effective prediction technique, while DNS continues to be a powerful method for answering basic questions about noise production by turbulence that could not possibly be answered by experiments. Reynolds-averaged turbulence models in Navier-Stokes codes (**RANS**) provide the standard technique for turbulence prediction in industry. One of the papers in this group relates to traditional RANS-model calculations, and the other is a comparison of RANS, DNS and Detached-Eddy Simulation (DES, which treats regions near a solid surface by RANS and regions further from the surface, in particular separated regions, by LES).

Work on large-eddy simulation comprised a large part of the Summer Program activities, and in these Proceedings the papers on LES are divided into two sections. The first is on **Large-eddy Simulation** proper, with an emphasis on subgrid-scale modeling. Accurate subgrid-scale modeling near solid surfaces – or the development of alternative near-wall treatments –is a prerequisite for the application of LES to flows with separation. The papers in this group deal both with new concepts and with detailed analysis of existing ones. The **LES Numerics** group addressed worked on numerical issues for LES in complex geometries. New numerical schemes such as the discontinuous Galerkin method, and new computational paradigms are being introduced to build LES codes. This is another trend indicating that LES is moving out of the proof-of-concept stage, to become part of the application tools for engineering analysis.

The **Fundamentals** group is composed of papers that address specific issues. The wall modeling effort in this group is of particular importance for LES modeling as a practical engineering tool. NASA's increased interest in Earth Science is motivating CTR's renewed attention to **Stratified Flows** and geophysical flows. Two of the papers in this section are on idealized flows; while the third presents a simulation of the flow in the Adriatic Sea. This last paper demonstrates one of the advantages of simulations; that one can, for heuristic purposes, add spurious terms to the equations or use artificial boundary conditions to test and improve understanding. In this case, the bathymetry of the Mid-Adriatic Pit is modified to demonstrate the cause of the current along its northern flank.

Optimization and the closely-related topic of airflow control are two important objectives in aerospace research. An outstanding demonstration of what can be achieved by applying optimization theory is the paper by Mohammadi on sonic boom minimization.

More detailed summaries of the accomplishments of each group can be found in the overviews that precede the grouped papers. This year four review tutorials were given: *Concepts for Analyzing the Structure of Complex Flows* (Julian Hunt), *LES on Unstructured meshes* (Krishnan Mahesh), *Computational Acoustics* (Sanjiva Lele), and *Turbulent Combustion* (Norbert Peters/Heinz Pitsch). The final presentation of research accomplishments on August 23rd was attended by a number of colleagues from universities, government agencies and industry. Early reports on some of the projects were presented at the Fifty-first Meeting of the Division of Fluid Dynamics of the American Physical Society in Dallas, TX, November 24th-26th, 2002.

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