# Preface

This report contains the 2001 Annual Progress Reports of the postdoctoral fellows and visiting scholars of the Center for Turbulence Research. In 2001 CTR sponsored 15 resident Postdoctoral Fellows, 7 Research Associates and 3 Senior Research Fellows, hosted 7 visiting scholars and many shorter-term visitors, and supported 6 doctoral students. Most of the doctoral students engaged in turbulence research at CTR are supported by the U.S Office of Naval Research or the Air Force Office of Scientific Research.

CTR is closely associated with the Stanford multidepartmental Center for Integrated Turbulence Simulations (CITS), funded by the Department of Energy's Accelerated Strategic Computing Initiative (ASCI). The aim of the CITS program is to compute the complete flow through an aircraft gas turbine engine. The combustion chamber is the most critical region: it is typically of very complicated geometrical shape, and the fuel is introduced as a spray of droplets which must disperse and vaporize before burning. The first paper in this volume describes large-eddy simulation of the air flow in a real aircraft gas turbine combustor, and there are several papers relevant to the crucial problem of spray combustion.

The two most noticeable features of this year's reports are the application of large-eddy simulation (LES) to a wide range of practical problems, and the continued broadening of the Center's interests, especially in natural phenomena: the Center's alphabet could start with Astrophysics, Buckyballs and Cacti. The diversification of interests has brought with it an increasing number of contacts with industry and with other branches of the natural sciences and life sciences.

The papers fall into seven groups: in order, these are: large-eddy simulation; combustion and hypersonics; sprays and particles; control and optimization; molecular dynamics; instability, acoustics and turbulence structure; and Reynolds-averaged turbulence models (RANS models). Many papers could be included in more than one group, so the groups are not explicitly labeled in the Contents. The common theme, of course, is that these are computer-intensive problems.

As is recognized in the aircraft-engine industry, large-eddy simulation is becoming a powerful engineering tool for predicting internal flows and mixing in real propulsion systems, where Reynolds numbers are low (compared to those in external aerodynamics) and the flow can be separated and highly unsteady. These flow conditions are difficult to capture with RANS models, but can be accurately predicted by LES because they are dominated by large-scale motions. The problem of economically computing high-Reynolds-number attached or separating flows remains. Here all eddies are small, and if the LES is carried right down to the surface then either the mesh has to be so fine that the calculation reduces to DNS, or the sub-grid-scale model has to carry most of the Reynolds stresses and the calculation effectively reduces to RANS. The first one is impossibly expensive and the other is likely to compromise accuracy. Since the day of widespread industrial use of LES has not yet arrived, CTR continues to support work on Reynolds- averaged models.

Combustion is a long-standing interest at CTR, and the work has received a boost from the appointment of Prof. Norbert Peters to the Department of Mechanical Engineering. Much of our work is supported by NASA's Ultra Efficient Engine Technology (UEET) Program. Hypersonic flow with real-gas effects shares many of the problems of combustion, and is also an ongoing interest of NASA.

The importance of spray dynamics in combustion of liquid fuels has been mentioned above: the behavior of particle- laden flows in general is of very wide engineering interest. A special case of particle-laden flow is the long-standing mystery of liquid flow with a suspension of long-chain polymer molecules: spectacular reductions in flow resistance can be achieved but the mechanism is still controversial.

Control and optimization, of turbulent flow or of other systems, is another long-standing interest at CTR, and again is relevant to many branches of engineering.

Molecular dynamics, far though it is from CTR's original interests, is a fast-developing field involving very intensive computing.

Instability problems are closely related to control problems, notably in the case of combustion. Instability of laminar flows is yet another problem that is yielding to intensive computing in the form of DNS. The phenomenological relation between the earlier stages hydrodynamic instability and final, fully-developed turbulence may not be very close, but the computational problems are virtually identical. Aeroacoustics and turbulence structure are the original interests of CTR, and basic research on these topics is still the foundation of improved models, whether the sub-grid-scale models of LES or the traditional RANS models used in industry.

We are grateful to Professor Peter Bradshaw for his thorough technical editing of the reports in this volume. We welcome Peter's participation in CTR in this capacity and his increased interactions with the CTR research staff.

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This volume, like other CTR progress-report volumes, is available as a .pdf file on the Web at http://ctr.stanford.edu