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This grant was used by the Center for Fluid Mechanics, Turbulence and Computation of the Division of Applied Mathematics of Brown University for the acquisition of equipment in order to:(1) acquire supercomputing graphics,(2) improve the network infrastructure, (3) acquire a high-capacity, high-bandwidth tape backup/archival system, and (4) modernize the workstation laboratory. The following projects were directly benefited from this acquisition: AFOSR: F49620-94-1-0313, AFOSR: F49620-1-0279, AASERTS: F49620-96-1-0267, F49620-97-1-0185, and F49620-98-1-0315.

Personnel included Prof. G.E. Karniadakis, Professor of Applied Mathematics; the following Post-Docs/Visitors: Dr. S.J. Sherwin (Imperial College), A. Beskok (Univ. of Texas A&M; and the following PhD students: M. Kirby, I. Lomtev, T.C. Warburton, J. Trujillo (US minority) and C. Evangelinos.

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FINAL REPORT
AFOSR number: F49620-97-1-0292
Interactive Graphics for Steering Computing: Applications to Plasma and Fluid Dynamics

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Objectives

This grant was used by the Center of Fluid Mechanics, Turbulence and Computation of the Division of Applied Mathematics of Brown University for the acquisition of equipment in order to: (1) acquire supercomputing graphics, (2) improve the network infrastructure, (3) acquire a high-capacity, high-bandwidth tape backup/archival system, and (4) modernize the workstation laboratory. This upgrade of our current facilities was necessary for the optimum use of local computing resources as well as those available remotely at the DOD Super Computing centers. The acquisitions outlined in this grant particularly enhanced the use of the parallel computer (IBM SP2/24-nodes) we had installed at the Center. The following projects were directly benefited from this acquisition: AFOSR: F49620-94-1-0313, AFOSR: F49620-95-1-0279, (AASERT) F49620-96-1-0267, F49620-97-1-0185, and F49620-98-1-0315.

List of Accomplishments

- Purchase of a 4-processor SGI Origin O2000 with Infinity Reality graphics and of a 6-processor SUN enterprise 5000. Integration of the new multi-processors in the network of the Center for Fluid Mechanics at Brown University using ATM and Gigabit switches.
- Development of interactive preprocessing and postprocessing tools for refinement and visualization on unstructured and hybrid grids.
- Benchmarking of several parallel codes used for AFOSR and other DOD work and optimization of the parallel paradigm on the Origin O2000 NUMA memory architecture.
- Dissimination of expertise across campus, and distribution of the parallel code NEKTAR to several users around the country.

Personnel

- Faculty: G.E. Karniadakis, Professor of Applied Mathematics
- Post-Docs/Visitors: Dr. S.J. Sherwin (Imperial College), A. Beskok (University of Texas A & M).
- PhD Students: M. Kirby, I. Lomtev, T.C. Warburton, J. Trujillo (US minority) and C. Evangelinos.

Publications

1. T.C. Warburton and G.E. Karniadakis, "A Discontinuous Galerkin Method for the Viscous MHD Equations", J. Comp. Phys., submitted.

2. I. Lomtev and G.E. Karniadakis, "A Discontinuous Galerkin Method for the Navier-Stokes equations", Int. J. Num. Meth. Fluids, in press.

3. T.C. Warburton, S.J. Sherwin and G.E. Karniadakis, "Spectral basis functions for 2D hybrid hp elements", SIAM J. Scientific Computing, in press, 1998.

4. I. Lomtev, C.B. Quillen and G.E. Karniadakis, "Spectral/hp methods for viscous compressible flows on unstructured 2D meshes", J. Comp. Phys., vol. 144, p. 325-357, 1998.

5. J. Trujillo, "Effective high-order vorticity-velocity formulation", PhD thesis, Princeton University, 1998 (supervised by the PI).

6. T.C. Warburton, "Spectral/hp Methods on Polymorphic Multi-Domains: Algorithms and Applications", PhD thesis, Brown University, 1998 (supervised by the PI).

7. J. Trujillo and G.E. Karniadakis, "A penalty method for the vorticity-velocity formulation", J. Comp. Phys., accepted, 1998.

8. S.J. Spencer, T.C. Warburton, and G.E. Karniadakis, "Spectral/hp methods for elliptic problems on hybrid grids", Contemporary Mathematics, vol. 218, p. 191-215, 1998.

9. T.C. Warburton, I. Lomtev, M. Kirby, and G.E. Karniadakis, "A discontinuous Galerkin method for the compressible Navier-Stokes equations on hybrid grids", Proc. Tenth Internationa Conference on Finite Elements in Fluids, January 5-8, 1998, Tucson, Arizona, p. 604, Eds. M. Hafez and J.C. Heirich.

10. G.E. Karniadakis and S.J. Sherwin, "Spectral/hp Element Methods for CFD", monograph, Oxford University Press, 1998.

11. G.E. Karniadakis and R.D. Henderson, "Spectral Element Methods for Incompressible Flows", Chapter 29, The Handbook of Fluid Dynamics, edited by R.W. Johnson, CRC Press, 1998.

12. H. Marmanis, Y. Du, C.H. Crawford, and G.E. Karniadakis, "Turbulence control via geometry modifications and electromagnetic fields", Proc. ECCOMAS 98, Athens, Greece, 1998.

13. Ma Xia and G.E. Karniadakis, "The spectrum of the turbulent near-wake: A comparison of DNS and LES", 1st AFOSR Int. Conference on DNS/LES, Ruston, LA, 1997 (invited paper).

14. A. Beskok and G.E. Karniadakis, "Modeling separation in rarefied gas flows", AIAA 97-1783, 4th AIAA Shear Flow Conference, Snowmass Village, CO, 1997.

15. I. Lomtev and G.E. Karniadakis, "A discontinuous spectral/hp element Galerkin method for the Navier-Stokes equations on unstructured grids", Proc. IMACS WC'97, Berlin, Germany, 1997.

16. I. Lomtev and G.E. Karniadakis, "Simulations of viscous supersonic flows on unstructured h-p meshes", AIAA 97-0754, 35th Aerospace Sciences Meeting, Reno, 1997.

17. G.E. Karniadakis and R.D. Henderson, "Spectral Element Methods for Incompressible Flows", CRC Handbook of Fluid Dynamics, Chapter 29, 1998.

18. C.H. Crawford and G.E. Karniadakis, "Reynolds Stress Analysis of EMHD-controlled Wall Turbulence, Part I: Streamwise Forcing", Phys. Fluids, vol. 9(3), 1997.

Interactions/Transitions

The PI will organize the first International conference on Discontinuous Galerkin Methods on May 24-26, in Newport, RI USA. Participants will include several researchers from the AFOSR labs that have expressed strong interest in these new methods. The PI has expanded the computtaional infrastructure of the Division of Applied Mathematics and of Brown University by establishing a new Center on Scientific Computing and Scientific Visualization along with Profs. A. van Dam of Computer Science and G. Guralnik of Physics. The emphasis of activities in the new center is interactive graphics in immersive evironments, which is a continuation of the AFOSR sponsored work.

The PI was invited in the past two years to present the AFOSR-sponsored research at:

- (1998) Cornell Workshop on POD-Galerkin Models for the Dynamics and Control of Complex Flows
- (1998) University of Michigan, Department of Aerospace Engineering
- (1998) AFOSR/Princeton Workshop on Plasma-Assisted Drag Reduction
- (1998) DARPA/NUWC Workshop on Electromagnetic Turbulence Control
- (1998) DOE/Oakridge Workshop on Discontinuous Galerkin Methods for Materials
- (1998) NSF Woskshop on New Computational Challenges
- (1998) AIAA Fluid Dynamics Conference on LES
- (1998) SIAM Annual Meeting/Symposium on MHD
- (1998) ICOSAHOM'98 Symposium on Corner Singularities
- (1998) Japanese Society of Fluid Mechanics 30th Anniversary Symposium
- (1998) University of Tokyo, Department of Mechanical Engineering
- (1998) Turkey Workshop on Industrial and Environmental Applications of DNS/LES
- (1997) University of Rhode Island
- (1997) University of Maryland/CTC
- (1997)University of Cincinnati
- (1997) Worchester Polytechnic Institute
- (1997) Penn State University
- (1997) MHD Conference, Dresden, Germany
- (1997) First AFOSR Conference on DNS/LES
- (1997) ASME micro-Therm Workshop
- (1997) 10th Domain Decomposition Conference

The parallel code NEKTAR and the interactive graphics package has been distributed to more than one dozen Universities and Laboratories. Some of them include Cornell University, Penn State University, University of Wisconsin, Imperial College, North Carolina University, Florida State University, OAK Ridge Labs, Nielsen, Inc. etc. There is limited documentation of the code, which has made this distribution somewhat difficult. However, certain researchers, e.g. Hussaini & Erlebacher at FSU have used NEKTAR extensively in LES of compressible turbulence and have developed new extensions for their applications. In the future we plan the porting of the new developments to the AFOSR codes MACH2 and MACH3.