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13. ABSTRACT *(Maximum 200 words)*

Grant # F49620-97-1-0123 was a DURIP equipment Grant in support of ongoing research in high-order numerical methods at Brown University. This work entails both fundamental and applied research in high-order approximation methods (e.g., Essentially Non-Oscillatory (ENO) schemes, spectral, and spectral element methods) for compressible and incompressible flow simulations, electromagnetic scattering, and image processing, as well as fundamental and applied work in algorithms for high-performance parallel computers. The goal of the DURIP proposal was to improve the computer infrastructure to provide adequate storage for multiple three-dimensional data sets, to facilitate the migration of data to and from remote HPC sites as well as data movement amongst local disk farms and graphics engines, and provide fast workstations for data interrogation, visualization and video imaging.

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Final Technical Report for AFOSR Grant # F49620-97-1-0123

Equipment for Visualization of Transient Flow Simulations

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Technical Objectives

Grant # F49620-97-1-0123 was a DURIP equipment Grant in support of ongoing research in high-order numerical methods at Brown University. The equipment is to enhance research in high-order numerical methods and high-performance computing currently supported under AFOSR Grant F49620-96-1-0150, *High-order accuracy methods for long time integrations* (P.I. - Gottlieb, Co-PI's - Fischer, Shu; annual funding level, $517K). This work entails both fundamental and applied research in high-order approximation methods (e.g., Essentially Non-Oscillatory (ENO) schemes, spectral, and spectral element methods) for compressible and incompressible flow simulations, electromagnetic scattering, and image processing, as well as fundamental and applied work in algorithms for high-performance parallel computers. Fluid dynamics applications include shock enhanced fuel-air mixing for scram-jet engines and the study of fuel-air mixing in bluff body flameholders, as well as two- and three-dimensional heat transfer and transition studies. Computational magnetics applications include volume scattering, wave-guides, and micro-wave electronics. Because the application problems are transient and/or three-dimensional, and involve a broad range of scales, their interpretation in the post-processing stage necessitates the manipulation of large data sets. The goal of the DURIP proposal was to improve the computer infrastructure to provide adequate storage for multiple three-dimensional data sets, to facilitate the migration of data to and from remote HPC sites as well as data movement amongst local disk farms and graphics engines, and provide fast workstations for data interrogation, visualization and video imaging.

Equipment Purchased

Qty.	Item.	total
1	SGI Octane	34,700
2	SGI O2's	24,500
1	4xR10K upgrade to SGI Onyx	34,400
12	Sun Ultra 1/170	79,000
4	Sun Ultra 30	31,000
1	HP Color Laser Jet 5M	4,700
4	256 Mb memory kits for SGI O2's	4,080
2	256 Mb memory kits for SGI Octane	2,040
12	128 Mb memory kits for Sun Ultra 30	4,800
22	128 Mb memory kit for Ultra 170 E	7,600
2	Sparc Storage Array	35,400
2	Sun Jukebox storage module	8,940
50	40 Gb tapes	3,900
1	400 Gb 8 mm storage lib.	11,700
1	Terabyte Enterprise tape lib.	38,000
8	Seagate 9 Gigabyte Cheetah Disk Drvs.	7,200
1	RAID Disk Encl. w/ 4 power suppl.	3,200
4	Sun Gigabit Eth. switch	21,000
1	Cisc. Sys. Multimode Fiber PAM & LtStrm Carrier Module	3,200
1	Cisc. Cat. 5000 Chassis	1,797
1	Cisc. Cat. 5000 pwr. supply	1,197
2	Cisc. Cat. 5000 dual AC pwr. supply option	2,394
1	Cisc. Cat. 5000 Supervisor Engine-TX	4,197
1	Cisc. Cat. 5000 ATM LANE Mod., Dual Phy 2 MM SC Ports	5,997
1	Cisc. Cat. 5000 10/100 Base TX Fast ether. sw. module	5,997
1	Cisc. Cat. 5001 Smartnet maintenance	2,000
1	Cisco WS-X2818	1,497
	Total	384,436

The equipment purchased included a 4-processor upgrade to a 1 Gbyte SGI Onyx graphics workstation, twelve Sun Ultra-170 workstations, four Sun Ultra-30 workstations, an SGI Octane and two SGI O2 workstations. The original proposal called for a more significant upgrade to the SGI Onyx (including Infinite Reality Graphics). However, it was felt that the price/performance of the new Sun workstations was significantly better than what was available at the time from SGI. We therefore decided to improve the performance of the Onyx by providing the Sun's as alternative computation/graphics engines to the researchers involved, thus freeing the Onyx for large-memory and graphics only applications.

Technical Accomplishments

Local computational performance

The Sun workstations have provided an enormous increase in computational performance for graduate students, post-docs and faculty supported under AFOSR Grant F49620-96-1-0150. The Ultra workstations have been used by students working on high-order Essentially Non-Oscillatory (ENO) schemes for hyperbolic problems and by students and post-doctoral fellows working on spectral methods methods for electro-magnetic and flow simulations.

Flow Visualization

We primarily use flow visualization as a tool rather than undertake development of visualization software. For computationally intensive problems the Sun Ultra-10's and Ultra-30's significantly outperform our SGI Onyx. User demand has consequently shifted to the Ultras, freeing the Onyx for large memory applications and video production. We use both Ultras and SGI's for image rendering, i.e., translation of three-dimensional grid-based data into two-dimensional pixel images. For video production, these pixel images are then loaded into the 1 Gbyte Onyx, played back at speed, and downloaded onto VHS tape.

With the equipment acquired under this award, we have been able to visualize transient three-dimensional flow fields at transitional Reynolds numbers. The simulations were performed on a remote-site 512-node Intel Paragon and rendered into video images locally. Because we're able to visualize the simulations at speed, it is now possible to follow the dynamical evolution of vortex structures which were previously unseen. In particular, we have discovered new components in the vortex structures arising from the interaction of a flat-plate boundary layer with a hemispherical roughness element which, to our knowledge, have not been observed experimentally. Other applications include problems three-dimensional convective heat transfer and shock induced combustion.

Computational Electromagnetics

Post-processing and visualization of data sets for these problems is computationally intensive due to the need for computation of near- to far-field transformations. These must be done via high-order interpolation because of the highly-oscillatory solutions. The acquisition of multiple Sun Ultra-170s has greatly reduced turnaround time for researchers working on this problem. Application areas for this work include wave-guides, volume scattering problems, and micro-wave electronics.

Publications

This is a one-year equipment grant which primarily addresses infrastructure improvements for scientific computing in the Applied Mathematics Division at Brown and as such does not support individual researchers. However, it has been instrumental in facilitating the thesis work of Henry Tufo, Baolin Yang, Sigal Gottlieb, Chun-Hao Teng, Changing Hu, and Julie Mullen, and is to be cited in the following theses and related follow on papers.

[1] H. M. Tufo, "Algorithms for large-scale parallel simulation of unsteady incompressible flow in three-dimensional complex geometries" Thesis, Division of Applied Mathematics, (1998).

[2] J. S. Mullen, "Large-eddy simulation of incompressible flows in complex geometries" Thesis, Division of Applied Mathematics, (in preparation).