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HPCC Applications Development and Technology Transfer to Industry

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Abstract

HPCC technologies may be broadly defined as high performance communication networks, massively parallel processing systems, and the technical expertise for using these systems. A gap currently exists between the national HPCC community and industry. For HPCC technology development to continue, and ultimately succeed in the marketplace, industry must adopt and use this technology. Both technical–software development, and sociotechnical–industry's view of HPCC technology as difficult to use must be addressed. Transfer of HPCC technologies to industry must be linked to the technical and business objectives of a company. InfoMall, a new program at the Northeast Parallel Architectures Center, is designed to provide "one stop shopping" for enabling HPCC technologies and business partnerships.

1 Introduction

High performance computing and communications (HPCC) represents a revolutionary new technology promising great benefits to a broad range of economic sectors from manufacturing, to health care, and home entertainment. The High Performance Computing Act of 1991 and the High Performance Computing and Communications (HPCC) initiative of 1992 established the leading national program designed to drive the development of HPCC technologies [12]. However, a gap currently exists between HPCC Grand Challenge teams working to build and implement advanced computational techniques in scientific simulation, and the mainstream scientific computing community who would be willing to give up significant performance gains (two to perhaps five times) in order to have automatic parallelism and portability between machine architectures [24, 25]. More important than the differences within the national scientific computing community is the gap between the HPCC community and industry. For HPCC technology development to continue, and ultimately to succeed in the marketplace, industry must adopt and use this technology.

HPCC technology is now set to pass conventional vector based supercomputers in performance capability. High performance computing is currently a small part of the computer technology market, but is predicted by the Commerce Department to have a worldwide economic impact of $100 Billion by the year 2000. Improvements in technological areas such as software, and changes in industry's perception of the effort required to use HPCC systems are needed to support industry adoption of HPCC technology. HPCC technology can be regarded as a technical success–we expect to soon see performance improvements two orders of magnitude over that of conventional supercomputers, making TeraFLOPS computing capability available in the near term [24]. But this impressive technical accomplishment does not ensure market or commercial success, industry must find HPCC useful and be able to do something new with this technology. As with any new technology, pushing HPCC technology out of the research lab is not effective. Opportunities for HPCC technology in industry must be linked to ap-

plications representing the technical and business objectives of a company. Applications play a role in this process through technology integration, demonstrating results, and defining where future improvements are required. Integrating HPCC technologies includes hardware and software systems, and approaches for using these systems (e.g., algorithms, optimization). Demonstration of benefits includes applying this technology on a scale that is interesting to industry to illustrate the potential rewards, as well as the risks associated with a transition to new technology (e.g., a large scale stock market pricing experiment, software issues and performance of a parallel pricing model [16, 17]. HPCC developers also use applications to define where improvements in future systems are needed, such as the applications benchmark suite used in the FortranD/High Performance Fortran compiler development effort [15].

Technical obstacles such as software limitations, and sociotechnical obstacles such as industry's view of HPCC as difficult to use currently limit the development of HPCC applications in industry. Evaluating and linking developing technologies, then applying them to large scale problems in industry and science is the central mission of the Northeast Parallel Architectures Center (NPAC). Our approach is based on three year's experience with our ACTION industry outreach program [9], and an ongoing survey of industry [8] to identify opportunities for exploiting HPCC technologies. We recently re-focused our activities within ACTION to define InfoMall [**?**], a new program which combines enabling technologies– networks, high performance computing, software, and expertise in using these systems with a deployment strategy based on technology partnerships among small software businesses, medium sized corporations, institutions and public agencies, and high technology partners. Analogous to a retail shopping mall, InfoMall provides "one stop shopping" for enabling technologies and business partnerships.

2 The role of applications

2.1 Academic vs. industry applications

Current experience with parallel computing systems, and development of parallel computing applications is mainly centered in academic and research centers, rather than industry. Differences between academic, and industry or government application codes illustrate why adopting a new computing technology is more easily accomplished in an academic environment. Academic codes are typically one to ten thousand lines long, while industry and government codes can approach one million lines of code. Converting smaller sequential codes to run on parallel systems is obviously an easier task than converting a much larger code, but there are other contributing factors. The life span of an academic code is often one to two years, while an industrial code may have a life span of decades. The original developers of industry codes, those who best understand the details of the code, are usually no longer on the project team that continues to maintain and use the code. At some point in this evolution, the code itself comes to represent knowledge of the industry problem. Due to the differences in size and life span, the design goals of an academic application are quite different from an industry application. The academic researcher, for example a graduate student, will tend to emphasize performance in developing a code, while sacrificing portability and ease of programming or implementation effort required. In contrast, an industry research team working to maintain and upgrade a very large code over one to two decades (maintenance is estimated to account for 70% of costs in a software project) will tend to trade performance for ease of implementation effort, portability, and scalability to future machines [8, 24].

2.2 HPCC Grand Challenge applications

Building on research in academic and government research centers, the 1992 High Performance Computing and Communication (HPCC) Presidential Initiative added new impetus to HPCC technology development. The federal HPCC program is designed to support a set of Grand Challenge applications which require TeraFLOP performance, and are important to the mission of eleven federal agencies including ARPA, DOD, DOE, ED, EPA, NASA, HHS/NIH, DOC/NIST, DOC/NOAA, NSA, and NSF. Collectively, these agencies contribute to national mission areas such as energy, space, health, defense, environment, weather, and basic science and technology [12]. As a driver of new technology, this set of Grand Challenge applications strains the limits of present day HPCC systems, and provides design criteria for HPCC technology developers to address in future systems. A subset of the federal agencies listed above support an annual workshop on Grand Challenge applications and software technologies to define requirements for future technology development in areas such as programming paradigms, development tools, integration environments, and algorithms [24, 25].

2.3 Grand Challenge program approach

Within the Grand Challenge community, there is a clear consensus that the present software environment inadequately supports development of high performance computing applications. It is also clear that applications development will play a central role in the planned evolution of HPCC systems from research to commercial systems. Two general approaches related to software and application development were identified in the 1992 Grand Challenge workshop [24]. First, a gradual or incremental approach to software development is needed in the short term to ease the burden of programming HPCC systems. Second, increased communication among individual researchers and between research centers should be used to build some early successes in applying HPCC technology in industry.

A gradual or incremental approach to developing modest software tools for near term use by application scientists is favored over more comprehensive and sophisticated approaches that necessarily take longer to produce. In the short term, the focus must be on immediate practical considerations that help link user application problems with machine functionality. In the longer term, program support facilities are desired that include more comprehensive compile time tools for code migration and dependency analysis, and runtime tools supporting user selection of system capabilities according to cost/performance criteria.

Currently, users of HPCC systems tend to have a high level of experience and expertise in computation, though not necessarily in parallel computing. The HPCC Grand Challenge application teams are a good example of this group of early users. Currently, parallel programming might be seen as a collaboration between sophisticated users and system software. In general, users must work hard to achieve results on HPCC systems. An evolutionary trend is envisioned by leaders of the HPCC research community that includes broadening the user base through educational programs, while improvements in software development make HPCC systems more readily accessible.

To better exploit the current investment in high performance computing software, and to speed the adoption of standards for critical software components, such as compilers, or message passing libraries, increased communication among researchers is needed. Increased communication between developers of HPCC technology at different centers or using different machine architectures is planned through development of software templates. A template scheme is seen as an alternative to proprietary software products that tend be either too general and therefore inefficient, or too machine specific. Templates should convey a software solution to a problem, be fully documented, and easily modified by other users for their specific purposes and system implementation. Software templates are viewed as a medium for communicating algorithms and codes, and for disseminating this information among the research community in the near term [24].

2.4 Obstacles to technology transfer

HPCC technology is now in position to bypass conventional supercomputing technology in performance, but performance alone is not sufficient to entice application scientists to make the transition from conventional to HPCC based supercomputing. Application scientists need solutions to their problems and require an efficiently used high performance computing environment. Both technical and social obstacles currently limit the transition from conventional to HPCC supercomputers. This transition requires a paradigm shift in algorithms, programming models, and management of system resources. Software is considered the key technical obstacle to developing high performance computing applications [24]. While performance of scalable HPCC systems matches the demand of Grand Challenge applications, a poor fit between technology and application problems remains. Important software issues include standardization in programming models, management, portability, and scalability across architectures. Compile-time and runtime tools are needed to analyze data accesses and modify arrays in a code. Simple migration tools, especially those built around industry standard technologies such as the High Performance Fortran compiler could take some of the burden in developing parallel code off the user. Run-time tools are needed that provide an ability to instrument code, support parallel debuggers, and manage memory.

In addition to technical obstacles, which mainly concern software, there are also important social obstacles to HPCC development. Grand challenge application problems are well suited to TeraFLOP performance, but there are gaps between groups within the science community. Many domain scientists do not consider computational science as "real science". In the computer science community, applications are considered by many to present only unimportant details that should be abstracted from the problem in order to conduct research. Within industry, a widely held view of parallel computing is that it is too difficult to use. A national research effort is underway to improve par-

allel software, for example a data parallel High Performance Fortran standard was recently established [15] but Fortran90 may already be too complex for technical management in industry, creating another gap between industry management and young technical staff [23]. In some industries, there are strong incentives for conducting business according to long established patterns. The evolution of technology–telephones, stock ticker, and computers has had a strong impact on the stock market industry, yet this complex, information driven system converges on people who carry out long established and profitable roles dating to 1900 [4]. In mature industries, strategic innovations are almost certain to require extensive change in all operations of the business, but senior executives may be unable or unwilling to accept the risk associated with this change [11]. HPCC vendors recognize this obstacle and now market network connected workstations as parallel systems. This approach reduces the risk of investing in a new technology, takes advantage of user familiarity with current workstation technology, and follows an evolutionary path from personal computer to workstation to workstation systems. There are of course technical issues favoring this approach as well, including advances in network switching technology and the ability to use the latest workstation processor technology as nodes in a network connected workstation system.

2.5 Software integration as a Grand Challenge

In the Grand Challenge Application Workshop of May, 1993, system integration was identified as an important software issue, particularly among multidisciplinary project teams. Even within a single application program, a single programming paradigm is not considered sufficient. A hierarchy of software models was proposed. This hierarchy could include a high level system integration software layer (e.g., AVS [1], HPC++ [2], FortranM [7]) coordinating large grain functional parallel modules containing data parallel modules. Support for mixing C++ and Fortran programming languages, and calling message passing code from data parallel code was recommended. Constructing application software codes from modular components was clearly defined as an important approach.

Integration of multidisciplinary and heterogeneous application problems is directly relevant to industry. We believe that an important class of problems in industry will require integration of databases, simulation, visualization, interfaces, and decision support. A modular approach, combining the best available technology components, and support for incremental optimization of the overall framework is needed. This modular approach is used in the NASA Ames numerical propulsion software system (NPSS) design environment.

2.6 HPCC applications in industry

Numerical computation has long been the dominate supercomputing application. This is reflected in the set of approximately 30 Grand Challenge problems, which emphasize scientific simulation applications in physics, chemistry, biology, climate and environmental modeling. The HPCC program and its emphasis on scientific simulation has motivated development of both hardware and software, and sophisticated approaches for using these systems. However, applications of HPCC technologies in industry do not directly follow from the scientific achievements of the HPCC program. Given the growing complexity of the Grand Challenge applications in terms of system integration requirements, multidisciplinary applications, and heterogeneous computing, there is a trend emerging toward a modular system framework that encompasses databases, numerical computation, and visualization. This framework defines a model for HPCC applications in industry. As part of our ACTION industry outreach program, we conduct an ongoing survey to identify new industries, as well as new opportunities in existing industries that can use HPCC technologies. We have identified large scale information processing, and commercial examples of military communications, command, control, and intelligence applications as extremely promising application areas [8]. These new applications in industry are likely to require a diverse number of functions such as information processing, numerical computation, interactive system control, and visualization, each optimized for a specific function, and coordinated by system level software.

US industrial competitiveness, and the ability to compete in global economic markets is a growing national concern. While the HPCC program is the leading national program driving development of new HPCC technologies, the HPCC program does not include a technology transfer component. Concern over the state of nation's capability in science and technology is decades old [18], and the lack of a technology transfer program in 1993 illustrates that our federal science agenda is not closely linked to commercial and industrial use of research. Implicit in the HPCC program is a goal of wide dissemination of the results of the HPCC science teams. While it is likely that the

results of this program will flow freely through the scientific research community, these results are not likely to flow easily into industry and production.

The US is the current leader in HPCC technology development, but this does not ensure that the US will be the first to put HPCC technology into large scale industrial use. For example, the display technology used in laptop computers, cockpit displays, and medical imaging systems was developed in the US, but nearly one hundred percent of commercial production market is now in Japan [6]. There is also increasing emphasis on making both the national science agenda [5], and the HPCC program in particular [14] more responsive to the needs of industry. These recommendations include re-directing basic research funds toward applied research programs, vigorous pursuit of federal laboratory and industry collaborations, and strengthened industry input into the HPCC program. Closer ties between the federal HPCC research program and industry are necessary, and applications research linking HPCC development with industry may help to bridge this gap.

3 Technology integration and deployment in industry

As an extension of our ACTION industry outreach program at the Northeast Parallel Architectures Center, we established a new program, InfoMall [?], designed to support HPCC technologies integration, and deployment of these technologies through partnerships with small software businesses and corporate technology partners. Analogous to a retail shopping mall which offers a broad range of consumer products in a single location, InfoMall offers "one stop shopping" for enabling HPCC technologies and business partnerships.

High Performance Computing and Communications (HPCC) systems combining high speed networks, computers, databases, and graphics will have tremendous impact in economic sectors from manufacturing to home entertainment. As these powerful new systems are linked with rapidly expanding data and information sources such as electronic libraries, online manufacturing databases, and interactive video, new information products will emerge. For example, we expect to see electronic medical charts, scientific simulation in the classroom, and a broad range of network based service industries including long distance collaboration and teaching.

NPAC's InfoMall program combines several components, including: the NYNET [19] Gigabit network with parallel computing systems; high technology partners who work with small software businesses; access to hardware, software, and approaches for using these systems; integration of information technologies and businesses; traditional incentives for start-ups and small business support; and finally, links to large HPCC system producers and HPCC product consumers.

Applications are central to our strategy for developing InfoMall. We expect that applications important to InfoMall will come from diverse areas such as geographic information systems, health care, and home entertainment. These applications will likely require: multiple system components supported by expertise from multiple disciplines; wide area or network based computing; optimization of tradeoffs in alternative solutions to a problem; a large scale information storage, processing, and transfer component; visualization; and sophisticated user interfaces. InfoMall products will typically require integration of a number of enabling HPCC technologies, including telecommunication networks, MPP systems, databases, compilers, communication libraries, integration software, High Performance Fortran, parallel and distributed runtime tools, and virtual reality. We consider the methodology for integrating these technologies as an enabling technology. Linking related technologies to build the data, computational, and information systems of the future requires more software, larger databases, larger codes, and integrated components. Aerospace design provides a good example of an application relevant to InfoMall–structural analysis, fluid flow, mesh generation, a modular approach, and system integration are some of the elements required to solve this problem.

The two main components of InfoMall are technology integration and deployment in the business community. We combine basic enabling technologies such as telecommunication networks, and high performance computing systems, and work with teams of small software businesses and high technology partners, to develop new products for industry, and public institutions. For example, we are developing a flood forecast model for the Eastern Lake Ontario basin for a water resource management agency to use in making the difficult tradeoff decisions between competing uses of water in the region (hydropower, recreation, landowners, wetland protection). This system combines databases, hydrological modeling, optimization techniques, visualization and user interfaces. The requirements of such a system come from the water management agency that must ultimately use this in-

formation system–for example, non-computer experts must be able to dynamically control the modeling system, adjust model parameters according to alternative resource allocation plans, and understand probabilistic results that are displayed graphically. The set of HPCC technologies–databases, networks, high performance computers, and software comes from our InfoMall partners including telecommunications and computing vendors, commercial software companies, and our partners in the national research community. The commercialized product, in this case the software running on PCs connecting agencies and public groups with the flood forecast information system, will be produced by a group of small software businesses.

The immediate goal of InfoMall is to enable HPCC software development, and accelerate the transfer of HPCC technologies to industry. Developing software and systems on a state of the art telecommunications and computing infrastructure will allow teams of small businesses (including small groups from large corporations) to develop new information products, create markets for HPCC vendors, and create new jobs.

As InfoMall products require integration of a number of enabling HPCC technologies, we will develop modular teams of small software businesses to work as a "virtual corporation". An individual company may internally have the best approach to a particular technology, but flexibly defined InfoMall partnerships will have the most competitive technologies available over a broader range. For example, if a software product required integration of a design object database, a sophisticated visualization system, and a novel optimization methodology, InfoMall will bring together perhaps four individual small businesses to form the appropriate virtual corporation for this product. This approach to linking small businesses according to project requirements will allow us to compete favorably with larger but less dynamic corporations, and innovative but smaller high technology businesses.

As a mechanism for accelerating HPCC technology transfer to industry, we view InfoMall as a "full-service" technology center. The Northeast Parallel Architectures Center is connected to the leading computer science and technology R&D centers allowing us to bring the best technology available nationally into local economic communities. Our approach is to mix commercial technologies available today with future technologies under development. For example, we are using commercially available AVS software as an integration environment for a financial modeling system [3], and Oracle parallel database software to develop projects in environmental modeling and geographic information systems, medical information systems, and marketing of bank services. Future technologies include heterogeneous computing systems made up of high speed workstations, clusters of workstations, and dedicated MPP systems. Where gaps in available technologies occur, we will develop new technologies such as the FortranD/High Performance Fortran Compiler [15].

Just as a shopping mall offers a broad range of consumer products for retail sale, InfoMall "stocks" information technologies such as different types of networks and computers, software and approaches for using these systems. Similar to the need for a large anchor store in a shopping mall, InfoMall requires high technology corporate partners that help us to create the technology infrastructure to support "virtual corporations" of small software businesses. We require the support of telecommunications and computing vendors, and in return, help to create new markets for these vendors. We propose InfoMall as a pragmatic approach to developing the National Information Infrastructure (NII) for industry.

In our approach to creating an InfoMall technology center, we emphasize the confluence of many competing technologies and develop multiple approaches. A technology that is commercially available today may be the best approach for a given application, but a stronger approach is to combine the best current technology with developing technologies. For example we will combine the workstation based database module in the GRASS [13] Geographic Information System with parallel Oracle [20, 21, 22] software running on an NCube2 to model the effects of acid deposition in the Adirondack region of New York State. To support an "online enterprise", for example the health care and manufacturing industries where an outdated but extensive database system must run side by side with a new technology, we must integrate new and old applications and systems. Putting revolutionary new technologies to work in industry raises a number of implementation issues. There is no easy upgrade path from existing applications to future HPCC applications, and software must often be written from scratch. One small company will not have all of the necessary technologies and facilities. For these reasons, we designed InfoMall to provide generic technologies for a broad range applications within a "full service" technology center. A unique strength of NPAC is our capability to provide the technical expertise needed integrate multiple HPCC technologies.

The "virtual corporation" concept in InfoMall is based on small business entrepreneurs who develop

products, medium sized companies who purchase products and define product requirements, and large technology corporations who supply the system infrastructure. InfoMall helps small software businesses by providing technology R&D that is usually only available to large corporations, enabling a small business to compete for Small Business Innovative Research grants. Medium sized corporations, and public institutions such as city school districts define the requirements, and provide a market for InfoMall products. For example, hospitals and related health care facilities will soon rely on network connections, and multimedia software running on workstations rather than courier services to transmit patient medical records and laboratory results. School systems will be able to run interactive simulations of the global ecosystem over network connections to a regional information "superhighway". High technology corporate partners providing the necessary telecommunications and high performance computing infrastructure for InfoMall will have new and expanded markets for their products.

4 Summary

We expect to see innovative information products emerge on the market in a broad range of economic sectors. Particular areas which we find promising include Geographic Information Systems for environmental and city planning applications, health care information systems aimed at cost control and improved diagnostic capability, and "edutainment" applications making use of modern virtual reality technology and HPCC simulations in the home and classroom.

A gap currently exists between the national HPCC community and industry. Technology transfer to industry is essential for continued development of HPCC technologies, and increased competitiveness of US industry in the global market.

We have established InfoMall at the Northeast Parallel Architectures Center to accelerate transfer of HPCC technologies in our local economy. InfoMall is based on a concept of gathering, evaluating, and integrating information technologies used and supported by small software businesses, and proactively creating partnerships. These partnerships will team members of InfoMall to directly target economic development, creation of jobs, and HPCC software products. In this sense, InfoMall is a "full-service" technology center–we not only offer software, but development and integration support of enabling technologies and applications.

References

[1] *AVS User's Guide*, Stardent Computer, 6 New England Tech Center, 521 Virginia Road, Concord, MA.

[2] M. Chandy and C. Kesselman, "Compositional C++: Compositional Parallel Programming," California Institute Technology Technical Report CS-TR-92-13, 1992.

[3] G. Cheng, K. Mills, and G. Fox, "An Interactive Visualization Environment for Financial Modeling on Heterogeneous Computing Systems," The Sixth SIAM Conference on Parallel Processing for Scientific Computing, March 22-24, 1993, Norfolk, Virginia. SIAM Activity Group on Supercomputing, 1993.

[4] V. Coates, "Technology and US Stock Markets, Social and Institutional Change," *Technological Forecasting and Social Change*, 41, 1-12, 1992.

[5] J. Duga and W. Fisher, "Battelle's R&D Forecast," "Probable R&D Expenditures in 1993," "Forecast and Analysis," Battelle Memorial Institute, Columbus, OH, Dec., 1992. (20 p.)

[6] R. Florida, and D. Browdy. "The Invention That Got Away," *The Journal of Technology Transfer*, 16:2, 303-322. 1991.

[7] I. Foster and K. M. Chandy, "Fortran M: A Language for Modular Parallel Programming," Preprint MCS-P237-0992, Mathematics and Computer Science Division, Argonne National Laboratory, Argonne, Ill., 1992.

[8] G. Fox, "Parallel Computing in Industry: An Initial Survey," Technical Report, Syracuse Center for Computational Science-302, Center for Research on Parallel Computation-TR92219, July 1992.

[9] G. Fox, "ACTION-New York State: Technology Transfer Program of the Northeast Parallel Architectures Center," Talk 92H, Presentation to the ACTION Industrial Advisory Committee, SCCS 303, May 11, 1992.

[10] G. Fox, "InfoMall White Paper," Northeast Parallel Architectures Center at Syracuse University, Syracuse, NY 13244-4100, May 10, 1993. (6 p.)

[11] G. Frontini and P. Richardson. "Design and Demonstration: The Key to Industrial Innovation," *Sloan Management Review*, Summer 1984: 39-49.

[12] "Grand Challenges 1993: High Performance Computing and Communications," The FY 1993 US Research and Development Program, Walter Massey, Chair. A Report by the Committee on Physical, Mathematical, and Engineering Sciences, Federal Coordinating Council for Science, Engineering, and Technology Committee, Office of Science and Technology Policy, 1993. (68 p.)

[13] M. Shapiro, J. Westervelt, D. Gerdes, M. Larson, and K. Brownfield. *GRASS 4.0 Programmer's Manual*, U.S. Army Construction Engineering Research Laboratory, USA-CERL P.O. Box 4005, Champaign, IL 61824-4005. Dec., 1992.

[14] *High Performance Computing and Communications Week*, King Communications Group, Inc., 627 National Press Building, Washington, D.C. 20045. Thursday, May 20, 1993.

[15] "High Performance Fortran Language Specification," High Performance Fortran Forum, May 3, 1993, Version 1.0. 184 pp. Copyright Rice University, Houston, Texas. Available by anonymous ftp at minerva/npac.syr.edu HPFF/hpf-v10-final.ps

[16] K. Mills, G. Cheng, M. Vinson, S. Ranka, and G. Fox. "Software Issues and Performance of a Parallel Model for Stock Option Pricing," Syracuse Center for Computational Science Technical Report-273b. *The Fifth Australian Supercomputing Conference*, Royal Melbourne Institute of Technology and The University of Melbourne, December 7–9, 1992.

[17] K. Mills, M. Vinson, and G. Cheng. "A Large Scale Comparison of Option Pricing Models with Historical Market Data," Syracuse Center for Computational Science Technical Report-260. *The Fourth Symposium on the Frontiers of Massively Parallel Computation*, McClean, Virginia, IEEE Computer Society and NASA Goddard Space Flight Center, October 19-21, 1992.

[18] *University-Industry Research Relationships*, Selected Studies, National Science Board, 1983. (295 p.)

[19] Stephen G. McDermott, Walter Johnston, Ben Ware, Geoffrey C. Fox, M. Stuart Lynn, Malvin H. Kalos, and John A. Graniero, "NYNET: A High-Performance Distributed Computing Corridor," White paper to New York State, Northeast Parallel Architectures Center at Syracuse University, Syracuse NY 13244-4100, January 6, 1993.

[20] *ORACLE7 Server Concepts Manual* ORACLE Corporation, 500 Oracle Parkway, Box 659413, Redwood Shores, CA 94065.

[21] M. Podgorny, S. Costicoglou, and K. Mills, "Parallel Database Technology and the Status of ORACLE 7," Technical Report SCCS-373, NPAC, Nov. 1992.

[22] S. Costicoglou, and M. Podgorny, "Performance Evaluation of the ORACLE Parallel Server v6.2 on nCUBE2," Technical Report SCCS-489, NPAC, May 24, 1993.

[23] RCI North American Annual Member Executive Conference on Technology Transfer, December 2–3, 1992, Herndon, Virginia. RCI, Ltd. Worldwide Headquarters, 1301 East 79th Street, Suite 200, Minneapolis, MN 55425.

[24] "The Workshop on System Software and Tools for High-Performance Computing Environments", L. Holcomb, Workshop Chair. April 14–16, 1992. Pasadena, CA. (225 p.)

[25] "Workshop on Grand Challenge Applications and Software Technology". May 4-6, 1993. Hyatt Regency Hotel, Pittsburgh, PA.