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A Descriptive Performance Model of Small, Low Cost, Diskless Beowulf Clusters

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A DESCRIPTIVE PERFORMANCE MODEL OF SMALL, LOW COST, DISKLESS BEOWULF CLUSTERS

by

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ABSTRACT

A DESCRIPTIVE PERFORMANCE MODEL OF SMALL,

LOW COST, DISKLESS BEOWULF CLUSTERS

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Commodity supercomputing clusters known as Beowulf clusters, have become a low cost alternative to traditional supercomputers. Beowulf clusters combine inexpensive computers and specialized software to achieve supercomputing power. The processing nodes in a diskless Beowulf cluster do not have a local hard disk unlike the nodes in most commodity clusters. Research has provided performance information for diskless clusters built with expensive, high performance equipment. Beowulf clusters use commodity off-the-shell hardware, and little information is available about their performance. This research includes the construction of several diskless Beowulf clusters. Using the NAS Parallel Benchmarks, the performance of these clusters was measured. Through analysis of these measurements, a descriptive performance model of diskless Beowulf clusters was produced.

ACKNOWLEDGEMENTS

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Chapter 1

1 INTRODUCTION

1.1 Background

A supercomputer may be defined as a computer that leads the world in processing capacity, particularly in terms of calculations per second. As the demand for greater computer processing capacity continues to increase, traditional serial processors have encountered physical laws that restrict significant speed improvements. The most promising strategy for overcoming these physical limits is to abandon serial processing in favor of parallel processing. Calculations that are well suited to parallel processing include:

- Matrix inversion
- Massive database searches
- Finite element analysis
- Computational Fluid Dynamics (CFD)
- Simulation and Modeling
- Digital Signal Processing (DSP)
- Image Rendering

(Hord, 1999, p. 1).

One parallel processing design growing in popularity is clustered computing. Clustered computing uses multiple computers, typically PCs or scientific workstations interconnected by networking equipment to form what appears to be a single high performance system.

One clustered computing design that has grown in popularity since its introduction is the Beowulf-class cluster. In the summer of 1994, Thomas Sterling and Donald Becker built a clustered computer consisting of sixteen 486-based processors interconnected by dual 10Mbps Ethernet connections. They called their machine Beowulf. This machine achieved instant success and the concept of using commodity off-the-shelf (COTS) systems to satisfy specific computational requirements spread throughout NASA and into the academic and research communities (Sterling, 2002, p. 2). The development effort for this first machine quickly grew into what is now known as the Beowulf Project.

The concept of a clustered computer is straightforward. A clustered computer is a network of computers running special software that allows them to work as a team. The software turns a collection of networked computers into a distributed system. A distributed system consists of multiple processors working together to accomplish a task. The processors communicate over a network in order to share information and resources. The special software of a distributed system presents the user with a single-system image that gives the system its functional characteristics or personality. Hundreds of nodes in a clustered computer may appear to be a single, very powerful machine.

Beowulf clusters are distinguished by their exceptional price/performance ratio. The performance levels of Beowulf clusters are particularly remarkable because they are achieved using inexpensive computers and networking equipment Beowulf clusters represent an inexpensive alternative to the sophisticated, and costly systems normally associated with supercomputers (Vrenios, 2002, p. 11) (Warren, 1997, p. 1372).

The software tools for developing clustered applications depend on the underlying programming model used. Within the Beowulf cluster community, the message passing paradigm has emerged as the standard. The message passing model implements concurrent tasks or processes on each node. Messages passed between these processes enable them to share data and synchronize their operation. The tasks themselves are written in a standard programming language such as C, C++, or Fortran. A library of communication routines is utilized by each task to transfer data to and from tasks running on other nodes in the cluster. Two message passing libraries have emerged as the industry standards: Parallel Virtual Machine (PVM) and Message Passing Interface (MPI) (Sterling, 2002, pp. 8-9).

1.2 Problem Statement

The concept behind clustered systems may be straightforward, but measuring the performance of a cluster is not. The need to measure the performance of a clustered system is far more than curiosity about how fast the system runs. Performance is arguably the central motivation for building a clustered system. This is due to the fact that a cluster is usually built when available PCs are not sufficient for a given task. Thus, the measurement of performance, as well as comparing the performance of various cluster designs, is very important. Many different metrics for Beowulf cluster performance exist. These metrics vary greatly in their practical meaningfulness and ease of measurement. The following list includes some of the metrics currently used to measure cluster performance.

- Speed-up
- Efficiency
- Theoretical Peak Performance
- Application Performance
- Application Run Time

Each of these metrics will be discussed in more detail in the next chapter (Sterling, 2002, pp. 151-155). In addition to these metrics, various benchmarking suites are used to provide more comprehensive information on overall system performance.

Existing research on the performance of Beowulf clusters has focused on systems known as diskfull clusters. In a diskfull cluster, each slave node in the cluster is equipped with a local hard disk for storing the node's operating system, swap space, and other files. Clusters utilizing slave nodes without a local hard disk are known as diskless clusters. The amount of published research describing the performance characteristics of diskless clusters is small compared to the research available on diskfull cluster performance. Most, if not all, of the existing diskless cluster research utilizes high performance commercial networks such as Myrinet™. These commercial networks are very expensive and not classified as commodity off-the-shelf (COTS) equipment appropriate for use in Beowulf cluster construction. By definition, Beowulf clusters are only constructed from COTS equipment and inexpensive software. From available research, it is not clear what the performance characteristics of a diskless Beowulf cluster are, or what factors affect that performance.

1.3 Hypothesis

The benchmarking metrics previously referenced each attempt to predict the performance of a cluster. Unfortunately, the interaction of cluster size, software architecture, network performance, and a variety of hardware performance factors makes diskless cluster performance difficult to predict. The Linpack benchmark, for example, is the unofficial metric used to measure many of the world's most powerful supercomputers. Unfortunately this benchmark estimates the practical performance of many supercomputers to be as much as 30% of the theoretical peak performance. Most parallel applications seldom utilize more than 10% of the theoretical maximum (Bailey, 2002, pp. 154-155). This high margin of error may be significantly reduced if a performance model is developed that considers a variety of hardware configurations and real-world software applications.

This research will identify the effects of various factors on the performance of diskless Beowulf clusters. Benchmarking experiments will be designed around these factors to analyze their effect on performance. The results of these experiments will be used to create a model for describing how these factors affect the overall performance of small diskless Beowulf clusters (up to 16 nodes). By measuring the performance of many different software architectures, and hardware configurations it is expected that a descriptive model that will describe the performance characteristics of small, diskless Beowulf clusters will be produced.

1.4 Justification

The need for affordable, high performance computing is often the motivating force behind building a Beowulf cluster. When the performance of a high-end PC or scientific workstation is not sufficient for a given task, the options are relatively few. When supercomputing capacity is essential to completing computationally large tasks, the solution most often depends on a given budget. Beowulf clusters are able to produce computing power comparable to supercomputers at a fraction of the cost of a traditional supercomputer. Even with the economic advantages of a Beowulf cluster, the question of what equipment is required to achieve a given level of performance remains to be clearly answered. A model that describes diskless cluster performance and can provide information about potential cluster performance is needed. The results of this research will include a descriptive performance model of small, low cost, diskless Beowulf clusters. This model will address the viability of using a diskless Beowulf cluster to achieve high performance computing.

1.5 Methodology

Perhaps the most important objective of analyzing the performance of a Beowulf cluster is to identify the system components that significantly affect performance. Knowing what components affect cluster performance allows enables a cluster administrator to upgrade the system for maximum performance The components known to affect Beowulf cluster performance will be identified through research of existing performance measurement techniques. These components may include network capability, number of slave nodes, software architecture, master and slave node memory, CPU speed, and data storage architecture. Benchmark tests will be selected based on these components, and experiments on different hardware configurations will be performed. The data produced by these experiments will be analyzed to produce a model describing the factors that significantly contribute to the performance of small, diskless Beowulf clusters.

1.6 Assumptions

Most data includes a certain amount of variance, even if all factors that can be controlled are held constant. The operation of computer hardware and software is tightly controlled by system clocks, and defined timing sequences within network communication protocols. It is assumed that variation within the Beowulf clusters used for testing will not be noticeable in the cluster's overall performance. Stated another way, a cluster with the same hardware and software configuration will execute the same task in the same amount of time. This assumption eliminates the need for multiple, identical benchmark tests for each given configuration. Preliminary testing has indicated that benchmark tests run on the same hardware produce the same results with less than three percent deviation. Research related to this assumption has indicated that the difference between each benchmark run should be less than five percent (Wang, 2000, p.4).

1.7 Delimitations

In order to develop a model that will accurately describe the performance of a Beowulf cluster, it is necessary to limit the model to clusters of specified configurations and applications. This research will be strictly limited to Class A benchmark applications provided in the NAS Parallel Benchmark (NPB) suite. The communication network of the cluster will be limited to 10Mbps or 100Mbps Ethernet. MPI (Message Passing Interface) will be the message passing library protocol used for this research. The size of the cluster will be between 1 and 16 diskless nodes. Factors identified to affect cluster performance that cannot be varied will be noted, and held constant if possible.

Chapter 2

2 REVIEW OF LITERATURE

2.1 Supercomputing

Many ways to categorize supercomputers exist. A supercomputer may be categorized based on high availability or high performance. Some supercomputers are categorized by the architecture of their memory system: distributed or shared. Other supercomputers are categorized by how tightly the hardware and software are coupled. In addition, classifications may be used to describe the supercomputer architecture in general. Three general classifications of supercomputers include mainframe computing, metacomputing, and clustered computing.

2.1.1 Mainframe Computing

The category of supercomputers familiar to most people is the mainframe. The most famous engineer of mainframe computers is Seymour Cray. In 1972, Seymour Cray founded Cray Research to design and build the world's highest performance general-purpose supercomputers. The Cray-1 computer became a standard in supercomputing performance when it was introduced in 1976. In 1985 the Cray-2 computer was introduced, and continued to advance supercomputing performance and expectations (Cray Supercomputing, 2002).

The mainframe supercomputer is a tightly coupled system of advanced computing architectures that rely on highly efficient hardware mechanisms to achieve supercomputing capabilities. The high cost and limited number of mainframe manufacturers has led to software that is incompatible with other systems, and therefore very expensive (Sterling, 1997, p. 3). At one time, the mainframe completely dominated the supercomputing market. As networking technology has improved, the mainframe supercomputer has been forced to compete with large numbers of less expensive machines configured to work in parallel. These machines range from throwaway PCs to sophisticated scientific workstations.

2.1.2 Metacomputing

Metacomputing, also called distributed computing, is not as well known by the general public as mainframe computing. Despite its relative obscurity, metacomputing has the capacity to be many times more powerful than any mainframe available. The advent of the Internet has provided metacomputing the resources to create the most powerful supercomputer in the world. A metacomputer is a dynamic environment that has some informal, undedicated pool of compute nodes, each relying on its own operating system. These nodes can join or leave the metacomputing environment at any time, and often do so. In addition to its own operating system, each node requires a software layer (middleware) that transforms the collection of independent nodes into a single, virtual, and coherent machine (Abdennadher, 2002, pp. 1-2).

The most well recognized metacomputing implementation is the SETI@home project. SETI@home is a scientific experiment that utilizes computers connected via the

Internet to assist in the Search for ExtraTerrestrial Intelligence (SETI). Internet users can participate by running a free program that downloads and analyzes radio telescope data. The SETI@home program, like most metacomputing programs, is designed to run as a background process, utilizing unused computing cycles without interfering with the computer's normal operation. The SETI@home project reported over 4 million users in July of 2003 (SETI@Home, 2003).

The combined processing power of SETI enthusiasts has produced what is likely the largest distributed computation problem in existence. The SETI@home project forms one of the largest computational system in existence, and has the capacity of being many times more powerful than the world's top supercomputer (McCallum, 2002). In August of 2003 the SETI@Home project reported a computing power of over 40 Teraflops/sec (SETI@Home, 2003). The unofficial world's fastest computer, the Earth Simulator in Yokohama, Japan, currently reports 35.86 Teraflops/sec (Top500.org, 2003).

The downside to SETI and similar metacomputing projects is that the nodes in the system are not dedicated to an overall system function. The metacomputer control system requests an active node to perform some operation, but the node can refuse the request or, more commonly, delay the request an indeterminate amount of time. This means that portions of a calculation may be assigned, but are not actually completed until weeks later. If a calculation is not completed after a considerable amount of time, the calculation must be reassigned to another node in the system. For some metacomputing applications, individual calculations are not needed within a short amount of time. If the results of a specific calculation are needed in a relatively short amount of time, the metacomputer control system may assign the calculation to several nodes in the system and use the results from the node that completes the task first.

The advantage of metacomputing is that the nodes making up the system can be scattered across the globe, and of many different architectures. Another advantage is that the nodes do not require an active connection to the metacomputing system to perform calculations for the system. The SETI@home project takes advantage of metacomputing technology by relying on PC users who are willing to donate their unused computing power, thus eliminating the need to purchase processing nodes (SETI@Home, 2003).

2.1.3 Clustered Computing

In general terms, a cluster is any collection of independent elements interconnected to produce coordinated and cooperative behavior. A computer cluster is a collection of computers integrated by means of an interconnection network. These computers rely on specialized software for organizing and coordinating parallel computing tasks. Clustering is one technique for achieving significant improvements in overall performance, and reliability. Many research clusters have been implemented in industry and academia, often with proprietary networks and / or custom processing nodes (Sterling, 2002, pp. 1-2).

Commodity clusters are collections of computing nodes that are commercially available systems. The network used to integrate the compute nodes of a commodity cluster is dedicated to the cluster and is commercially available. The network is dedicated in the sense that it is used internal to the cluster and only supports communications between compute nodes that make up the cluster, its host or master node, and possibly satellite nodes responsible for managing mass storage resources. The network hardware of a commodity cluster must not be proprietary to the cluster product of a single vendor, but must be available for the assembly of any cluster. Thus, all components of a commodity cluster can be bought by a third-party systems integrator or the end-user.

Commodity clusters employ software available to the general population. This software can be free, repackaged and distributed for modest cost, or developed by third-party software vendors and commercially marketed. Vendors may use and distribute as part of the commodity cluster their own proprietary software as long as alternate software is available from other vendors that may be employed in its place. Two motivating factors drive and restrict the class of commodity computers: (1) the use of non-specialty parts takes advantage of the marketplace for cost reduction and reliability; and (2) the avoidance of critical, proprietary solutions restricted to a specific cluster project. If these proprietary solutions ever became unavailable, future development would be disrupted (Sterling, 2002, p. 2).

2.2 Beowulf Clusters

The original PC cluster project, also called the Beowulf Project, was started at the Center of Excellence in Space Data and Information Science NASA in early 1994. A Beowulf class cluster is a system that usually consists of one master or server node, and one or more client nodes connected via Ethernet. The master node controls the whole cluster and serves files to the client nodes. The master node is also the cluster's console and gateway to the outside Internet world.

The advantages of a Beowulf-class cluster include:

- The price-to-performance ratio of Beowulf clusters makes them affordable, yet powerful tools.
- Hardware is available from multiple sources leading to low prices and easy maintenance and equipment replacement.
- Software, including the operating system, and parallel programming packages, is freely available to everyone under the GNU General Public License. This means that the source code can be obtained, and modified according to individual needs. In most cases, Beowulf cluster software may be downloaded without cost.
- Vast amounts of free documentation and tutorials on building Beowulf clusters can be found on the Internet
- Software is usually based on established standards in the computer industry

(Laboratory of Statistical and Computational Physics, Academia Sinica, 2002).

A Beowulf cluster has two basic constraints: it must be built from commercially available personal computer (PC) components and support hardware, and it must cost less than a scientific workstation of comparable performance (Vrenios, 2002, p.182). A Beowulf cluster is one of the most affordable clustered computing implementations available. Because Beowulf clusters only use COTS technology, the price-performance ratio of these machines is unmatched by standard supercomputing technology. Beowulf clusters are being used to produce supercomputing capabilities by networking the processing power of inexpensive, COTS computer components (Sterling, 1997, 2).

The master node of a Beowulf cluster utilizes the slave nodes' resources (memory, CPU cycles, etc) through messages transmitted over the network. Special software divides computing tasks into manageable pieces that can be assigned to individual nodes in the cluster. The economic advantage of a Beowulf cluster is that the master node and slave nodes may be inexpensive machines running inexpensive software compared to the expensive and very specialized hardware and software used in most supercomputer systems.

The hardware node is the principle building block of the physical cluster system. Each node has its own local memory and one or more microprocessors providing the computing power of the node and thus the cluster. In addition, each node may have one or more hard disks for local data storage and buffering. Some clusters employ diskless nodes to reduce cost and increase reliability. Diskless nodes can reduce the overall cost of a Beowulf cluster. A diskless cluster requires more network bandwidth for many tasks than a cluster whose compute nodes have local storage. As networking bandwidth continues to increase, the performance of diskless clusters will also improve.

The network of a cluster provides the means for exchanging data among the cluster nodes. Coordinating cluster operation and cluster-wide synchronization depends on a reliable network connection. The network components consist of network interface controllers (NICs), the physical network, and network hubs or switches. Each node contains at least one NIC that is used to transfer data between compute nodes and the physical network. The physical network of a cluster usually consists multiple parallel cables, or optical fibers. Hubs or switches interconnect the physical connections and route network messages and data between them. In the case of diskless nodes, the network is used by the nodes to access their operating system, all application software, and in cases, swap partitions.

The most critical weakness in a Beowulf cluster is that the master node is a single point of failure. If the master fails, so does the entire system. A fault-tolerant solution would detect failure of the master and a back-up server, or if they had the capability, one of the nodes would take over. Because a fault tolerant design adds significant complexity to an already complex configuration, it is only used in systems requiring the highest levels of availability (Vrenios, 2002, p. 121).

2.3 Diskfull vs. Diskless Clusters

The processing nodes of a Beowulf system are normally configured with a local hard disk (diskfull) for storing the node's operating system, application files, and local swap file storage. Processing nodes without a local hard disk are known as diskless nodes. A diskless compute node can be a server, workstation, or PC that resides on a LAN (Local Area Network) and has access to a network file server over the network. A diskless node stores its operating system, application, and data files on a network file server. Diskless nodes can reduce the overall cost of a cluster because a single large-capacity disk drive or storage array is usually less expensive than a disk drive for every node in the cluster. In addition, using diskless nodes can simplify backups and security because all files in the cluster are in one place—the file server.

One major disadvantage of diskless compute nodes is that they are not accessible if the network fails. Another disadvantage of diskless node is that accessing a disk over the network is slower than accessing a local hard disk drive. Perhaps the most costly disadvantage of diskless nodes is that if a diskless node does not have sufficient memory for a given operation, the operation will fail. The cost of this failure could be hours of calculations. If a diskfull node runs out of local memory it accesses swap space located the local hard drive. It is possible with Linux to access remote swap space over NFS (Network File System), but the kernel patch that implements this functionality is only considered experimental.

Depending on the functionality of the node's hardware, administrators can boot a diskless node by various methods, including:

- "Network boot from the BIOS using Preboot Execution Environment (PXE) or Remote Program Load (RPL)
- Network boot from the PROM of the network interface card (NIC)
- Local boot from a disk-on-chip flash device
- Local boot using a removable media device such as a floppy or CD-ROM drive"

(Guler, 2002).

2.3.1 Dell Diskfull vs. Diskless Study

To evaluate the performance of a diskless cluster, Dell conducted a study that compared standard and diskless clusters. The Dell team configured one diskless cluster and one diskfull cluster, to compare their performance and identify which kind of applications are suitable for each configuration. Figure 2-1 shows the clusters' configuration details.

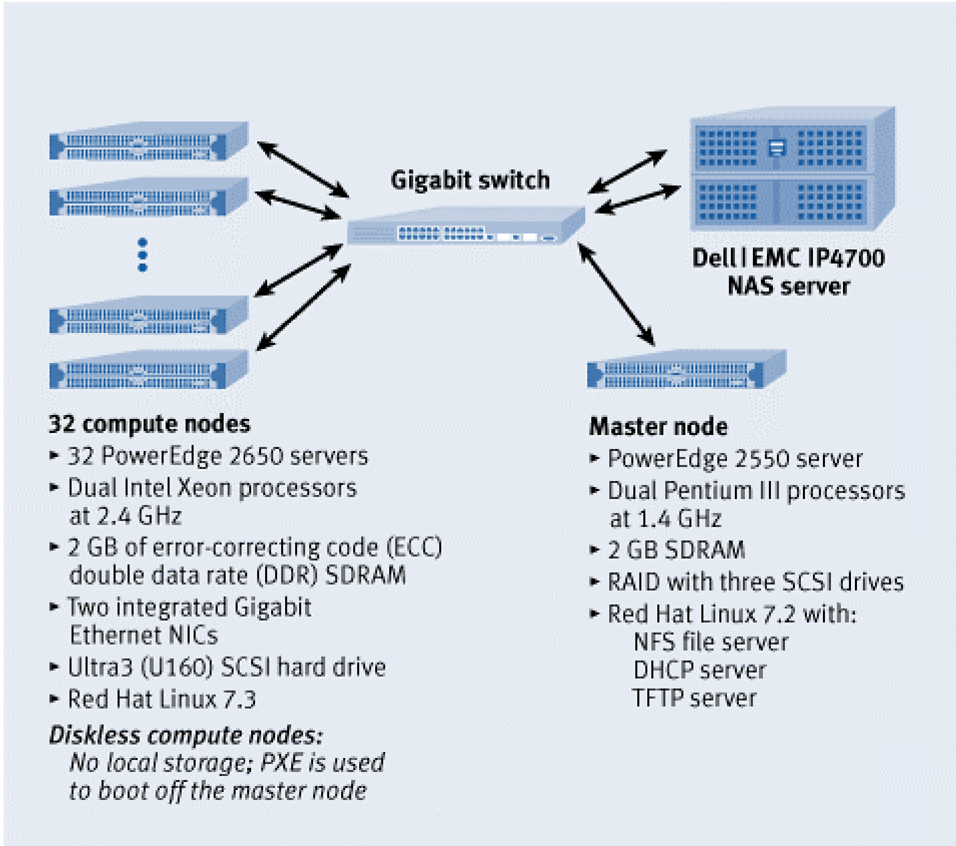

Figure 2-1 Standard and diskless HPC cluster configurations (Guler, 2002).

In the diskless cluster, the hard disks were removed from each compute node. The compute node image was created from the hard disk of one of the diskfull compute nodes. The master node of the diskless cluster was enabled with DHCP (Dynamic Host Configuration Protocol), NFS (Network File System), and TFTP (Trivial File Transfer Protocol) services. The NAS (Network Attached Storage) server managed NFS services of the cluster. All compute nodes and the NAS server were connected through a high-speed, blade-type Foundry Networks® FastIron® II+ Gigabit Ethernet switch. The diskless nodes were configured to boot using PXE. The root file system of the diskless compute nodes physically resided on the NAS server.

The Dell team first used the HINT benchmark to test a single-processor version of the PowerEdge 2650 to identify any performance differences between standard and diskless compute node configurations. Later, the team measured system performance by using the High-Performance Linpack (HPL) benchmark (Guler, 2002). The results of these benchmarks will be discussed to show that the performance of a diskless cluster is comparable to the performance of a diskfull cluster, provided a sufficiently fast network is used.

2.3.2 Testing Performance with the HINT Benchmark

HINT or Hierarchical INTegration is a computer benchmarking tool developed at the Ames Scalable Computing Laboratory . Unlike traditional benchmarks, HINT neither fixes the size of the problem nor the calculation time. HINT uses a measure called QUIPS (QUality Improvement Per Second) to display the speed for a given machine specification and problem size. HINT is scalable and easily portable for a variety of architectures and can be run on anything from a programmable calculator to a supercomputer (*A summary of the HINT benchmark*, 1999).

Two identical compute nodes—one with a hard disk and one without—were benchmarked using the HINT benchmark. The Dell team limited the physical memory usage to 256MB. In Figure 2-2, the results of the two runs are plotted as QUIPS versus memory usage. As Figure 2-2 shows, the diskless and diskfull compute nodes performed almost identically until reaching the physical memory boundary. After that point, the performance of the diskless node dropped more than the performance of the standard node, because the diskless node had to access its swap file on the NAS server, whereas the standard node could swap locally. These results suggest that clusters should not swap over NFS, even if they are using a fast interconnect such as Gigabit Ethernet (Guler, 2002). Based on these results, diskless nodes used in this research will not be provided swap space.

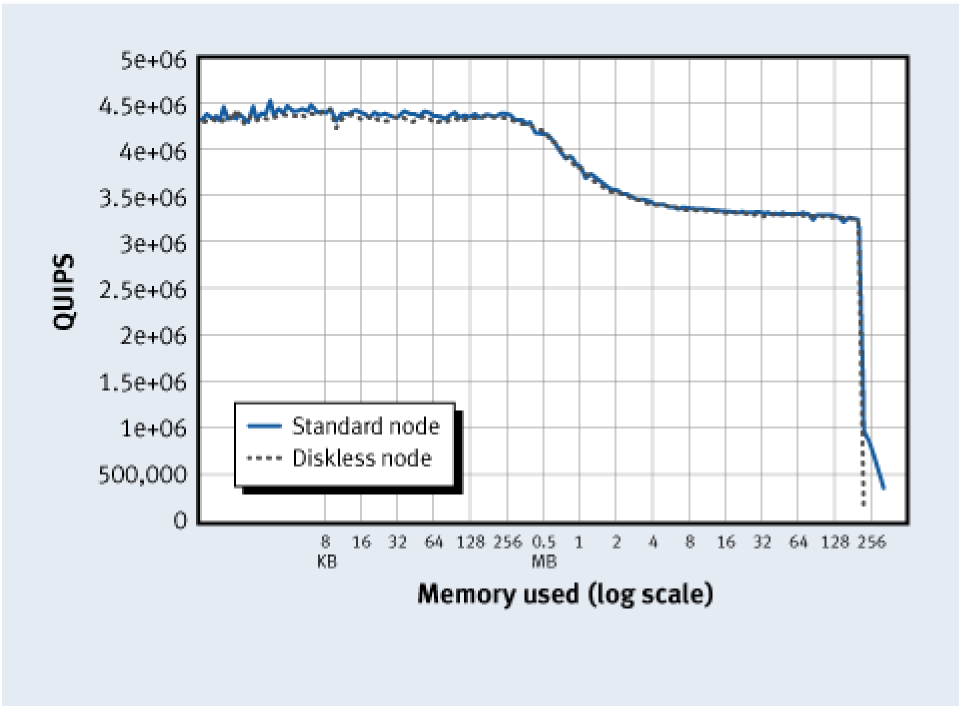

Figure 2-2 HINT performance for a standard and a diskless compute node (Guler, 2002).

2.3.3 Testing Performance with the HPL Benchmark

In addition to the HINT benchmark, the Dell team used the High Performance Linpack (HPL) benchmark to evaluate diskless and diskfull performance. Figure 2-3 displays the performance of single compute nodes with respect to the order of coefficient matrix A. For larger problem sizes, the diskfull node performed approximately five percent better than the diskless node. For smaller problem sizes, the benchmark results were not consistent with the rest of the Dell study, and more study is required to determine accurate performance results (Guler, 2002).

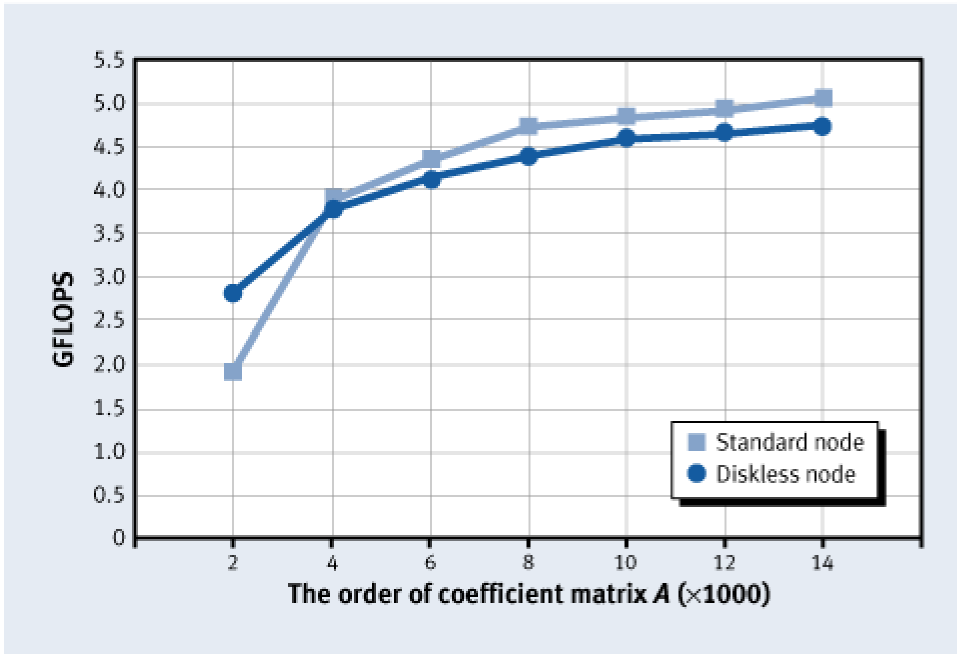

Figure 2-3 HPL performance for a standard and a diskless compute node (Guler, 2002).

The Dell team ran a second HPL benchmark to measure the performance of a midsized cluster. This test allowed the team to determine if scalability issues with the NAS server would limit diskless cluster configurations to small clusters (up to 16 nodes). No scalability, manageability, or operating problems were observed with the diskless clusters containing more than 16 nodes. Figure 2-4 shows the performance results for the diskless cluster and the diskfull cluster. The diskless configuration was found to outperformed the standard cluster configuration by a few Gigaflops (Gflops) (Guler, 2002).

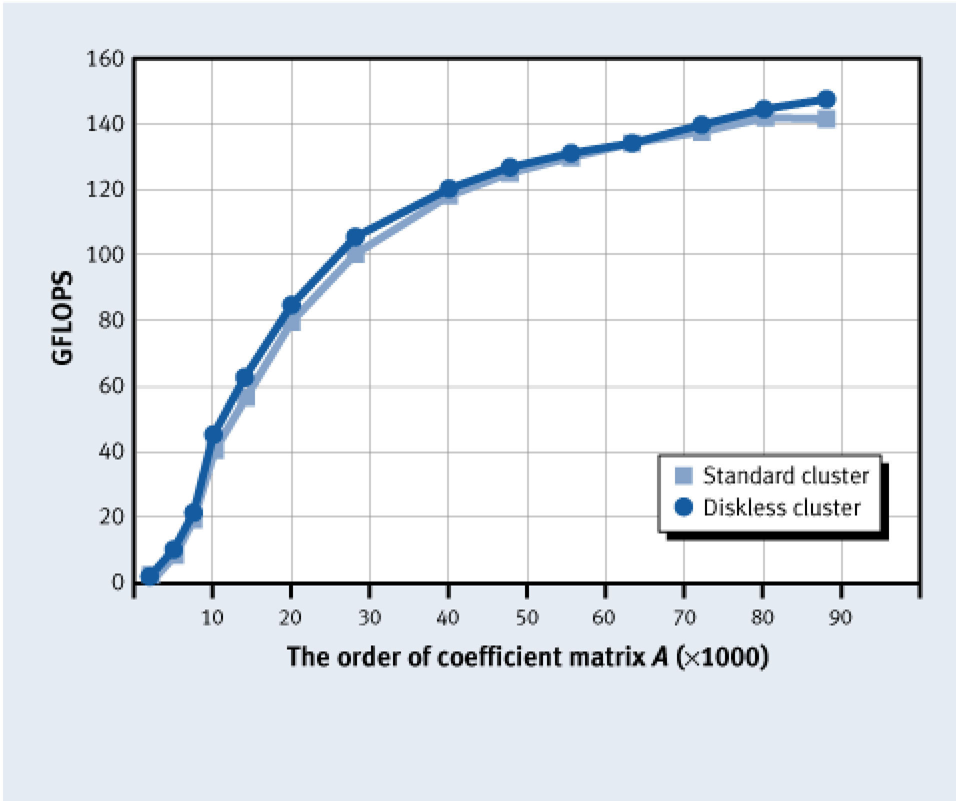

Figure 2-4 HPL performance for midsize standard and diskless clusters (Guler, 2002).

2.3.4 Diskless vs. Diskfull Cluster Conclusions

Diskless clusters have several advantages, and some disadvantages, when compared to diskfull clusters. The Dell study shows that the performance of a diskless cluster suffers most when swapping over the network occurs. However, swapping is an undesirable situation and is not common in most high performance cluster environments. Therefore, the diskless cluster configuration is attractive because of its cost and infrastructure advantages and its comparable performance. In general, the diskless cluster is easier to configure, install, and upgrade than a standard diskfull cluster. It also offers a better price/performance ratio and is more environmentally friendly. By transferring the local storage to a central storage unit, diskless clusters should not suffer a performance penalty as long as a fast interconnect, such as Gigabit Ethernet or the Myricom Myrinet™ technology is used. (Guler, 2002). The Dell study clearly shows that diskless clusters have an advantage over diskfull clusters when a fast network is used.

Dell is one of the many organizations participating in diskless cluster research. These organizations study the performance of diskless clusters, but they do not study diskless Beowulf clusters. The equipment used by Dell and other researchers to study diskless cluster performance is not appropriate for Beowulf clusters because of its high cost. This research will investigate the possibility of using low cost, highly available COTS networking equipment as the communications backbone of a diskless Beowulf cluster.

2.4 Message Passing

"The general architecture of a Beowulf cluster is similar to a distributed memory parallel computer; it consists of multiple nodes that exchange data over a message passing network" (May, 2001, p. 97).

At its most basic level, a Beowulf cluster is designed to make use of several processors at once by passing data between them. The integration of nodes, networks, and software is only one aspect of a cluster. A Beowulf cluster is designed to handle larger data sets and computations than a single processor system. Where one CPU can perform a defined set of computations on a given data set, many processors may be able to provide nearly that much more processing. However the code has to be optimized to utilize the extra processors. This optimization is done through message passing library routines. The slave nodes within a cluster are essentially useless without a means of communicating and cooperating with each other. Two message passing packages are commonly used in Beowulf clusters as well as other parallel computing architectures: Private Virtual Machine (PVM) and Message Passing Interface (MPI). These libraries enable code and data to be passed between the different nodes of a Beowulf cluster (Bookman, 2003, p. 163).

"The key element of the message passing paradigm is not that messages are passed; it is the fact that messages must be passed because the data is not in one place, but rather distributed among the local memory of multiple machines. Data that is not local to a processor cannot be accessed without the active participation of another processor" (Pfisher, 1995, p. 232).

Parallel application software uses an underlying message passage system like PVM or MPI. There are many ways to express parallelism. However, message passing is the most popular and applicable in many cases. Unless an application is specifically written for a cluster environment, it will only work on one CPU. You cannot take applications like Apache or MySql and run them over multiple CPUs in a cluster unless specific parallel source code versions have been created (Eadline, 1999).

2.5 Message Passing Libraries

Private Virtual Machine (PVM) was designed to work on networks of workstations. It has since been adapted for use with other parallel supercomputing architectures. Development of PVM is primarily controlled by its original authors, Jack Dongarra, Al Geist, Bob Manchek, and others. "PVM allows utilization of a network of machines as a single computational resource. PVM is a software package that enables concurrent computing on loosely coupled networks of processing elements. PVM may be implemented on a hardware base consisting of different machine architectures, including single CPU systems, vector machines, and multiprocessors. These computing elements may be interconnected by one or more networks, which may themselves be different" (Hord, 1999, p.186).

Message Passing Interface (MPI) is a well-defined network communications standard, and is supported by many hardware vendors. MPI provides more functionality than PVM and has versions for networks of workstations. Development of MPI is controlled by established standards committees. The goal of the MPI developers is to develop a widely used standard for writing parallel programs. The standard should establish a practical, portable, efficient, and flexible standard for message passing. The development and standardization of MPI involves about 60 people from 40 different organizations. Included in this group are most of the major vendors of parallel computing systems, as well as researchers from academic, government, and commercial sectors.

Two advantages of developing and maintaining a message passing standard are portability and ease-of-use. A well-established message passing standard provides vendors with a clearly defined set of routines they can implement efficiently. By defining a message passing standard, the developers of MPI have been able to improve usability, portability, and scalability (Hord, 1999, pp. 211-212).

There are several free implementations of the MPI standard for distributed memory systems on a variety of platforms. The most comprehensive implementations of

MPI include MPICH (MPI Chameleon), developed at Argonne National Laboratory and Mississippi State University and LAM (Local Area Multicomputer) maintained by the University of Notre Dame. Both implementations are open source and available from various Internet sources. MPICH and LAM are widely used in Beowulf clusters (Deng, 2001, pp 91-108).

In many cases there does not seem to be a compelling reason to choose one message passing library over another. Many developers choose MPI because it is a standard, but PVM is still strongly supported and its development continues (Eadline, 1999). Programs utilizing MPI or PVM are highly portable and function over an inherent shared memory model (Bar, 2002).

The parallel computing benchmarks NAS Parallel Benchmarks (NPB) and Linpack both use MPI. (Eadline, 1999). For this reason and the reasons cited above, The LAM implementation of MPI included in the Redhat 9.0 distribution of Linux was used for this research.

2.6 MOSIX

Beowulf clusters rely on network messages to distribute data and coordinate the function of the cluster. One alternative to the message passing paradigm is to use the Multicomputer Operating System for Unix (MOSIX). MOSIX is a modification to the standard Unix kernel that allows the operating system to treat the cluster as an extended symmetric multi-processor (SMP) machine. Simply stated, MOSIX gives the operating system the ability to assign jobs based on which computer within the cluster has the resources necessary for the task. Because MOSIX introduces remote job processing directly to the kernel, the operating system becomes an integral part of the cluster. Approaching distributed computing in this manner allows jobs to run without submitting them to be executed on a defined set of compute nodes. "The main characteristics of MOSIX include network transparency, autonomy of individual nodes in the cluster, dynamic process migration, automatic load balancing, increased availability, performance, and reliability, and scalability" (Barak, 1993, pp. 2-18).

MOSIX was designed to run on any Intel platform computer as a true adaptive distributed clustering environment. MOSIX can be utilized on a dedicated pool of computers, or on machines that join the cluster during off hours. MOSIX manages the load balancing of the cluster transparently to the user. MOSIX can also be used with the Linux operating system. The most common Linux implementation of MOSIX is found in the openMOSIX Project (Bookman, 2003, p 139).

2.7 Message Passing vs. MOSIX

Two main clustering paradigms exist for the Linux environment: MOSIX (openMOSIX based) and message passing (MPI or PVM based). The message passing paradigm requires parallelization to be explicitly coded through special library routines. In contrast, MOSIX allows the traditional Unix serial programming API to be used (Bar, 2002). The openMOSIX implementation of MOSIX is a clustering technology that offers dynamic and adaptive load balancing through automatic process migration. In process migration, processes that require computing resources not available on the local node are migrated to remote nodes where the resources required are available. Since the openMOSIX technology is built into the Linux kernel, process migration is completely transparent to users and applications (Bar, 2002).

Many parallel programs in their actual form cannot migrate on the MOSIX architecture due to their use of shared memory segments for inter-process communication. However, the openMOSIX dynamic load balancer may still be able to benefit the application, because it will simply migrate away other processes, leaving more CPU power and memory for the parallel code.

The openMOSIX parallel solution offers great advantages for many serial computational problems. The automatic conversion from serial to parallel implementations of the algorithms through the process of migration technology can significantly increase the overall throughput of the cluster. The standard message passing paradigm emerges as the best solution for highly parallel code while the MOSIX approach allows to easily deal with embarrassingly parallel problems (Bar, 2002).

A high bandwidth network improves the performance of most message passing programs, particularly those programs that require large node-to-node communications. Overall, network bandwidth is less important for an openMOSIX platforms dedicated to serial jobs. On the other hand, openMOSIX is far more independent on low latency jobs because of the inter-node load balancing algorithms. (Bar, 2002).

MOSIX offers two significant advantages when compared with the message passing model. Dynamic load balancing across multiple nodes in a cluster is a much more complicated process in the message passing model. Load balancing must be designed as part of a parallel application. With MOSIX, the load balancing just works automatically. Also, MOSIX will run most programs that normally run on Unix / Linux systems. Most programs would require major modifications to run under the message passing model.

The disadvantage of MOSIX is that even with the advanced load balancing capabilities, a MOSIX cluster does not provide the ability to combine node resources to aid in completing a single massive calculation. If none of the nodes in a MOSIX cluster are able to complete a given task working alone, then MOSIX will not change that. MOSIX does not combine resources, it distributes them. If you want your everyday programs to run faster, then MOSIX may provide a good solution. If you have a problem to solve that is too big to run on a single machine, then message passing is the correct choice.

2.8 Beowulf Cluster Software

Beowulf systems deliver an exceptional price/performance ratio for many different applications. They use low cost or no cost software to manage individual nodes and the cluster as a whole. A large portion of the scientific and technical community using Beowulf clusters have employed the Linux open source operating system. Building a Linux cluster is a common solution for budget computing because of the excellent price/performance provided. There are thousands of Linux cluster in use all over the world, and documents on general or particular aspects of cluster setup are readily available.

Commercial providers of Beowulf clusters support the Microsoft Windows operating systems as well as various varieties of Linux and Unix. Regardless of the operating system being used, a Beowulf cluster requires middleware software that allows the nodes of the cluster to function cooperatively. This middleware is available commercially as well as through the open source community.

There are many software packages available that attempt to make the complex configuration of a Beowulf cluster easier. These packages include Open Source Cluster Application Resources (OSCAR), ROCKS, Local Area Multicomputer / Message passing Interface (LAM/MPI), the Linux Utility for cluster Installation (LUI), MAUI and MPICH. In addition to these software packages are cluster operating system distributions intended to provide a turnkey cluster solution. These distributions are usually intended for diskfull clusters, and often require high performance equipment. Among these distributions are OpenSCE, Mandrake's Click, SCYLD Beowulf, and the Linux Terminal Project. These distributions were investigated, but not used to build the clusters required for this research.

2.9 Existing Performance Metrics

Many different metrics for measuring Beowulf cluster performance exist. Some of the most commonly used metrics will be introduced. Using a broad range of metrics will allow users to compare aspects of different application implementations and perhaps provide clues as to how overall performance may be improved.

2.9.1 Speed-up

A useful measure of any multiprocessor implementation of a problem is speed-up. This measure compares the time required to solve the problem on a single processor machine to the time taken to solve the same problem using the parallel implementation.

Speed-up may be defined in terms of the elapsed time taken to complete a given problem as follows:

$$\text{Speed-up (S)} = T(1)/T(N),$$

where T(1) is the run time for a particular program on a single processor and T(N) is the run rime on N processors. Speed-up is also reported as a scalability statistic. A speed-up or scalability figure close to N means that the program scales well. That is, the parallel implementation is very efficient, and the parallel overhead is very low, so that nearly a linear speedup has been achieved. Speed-up statistics can often provide useful information. For example, they can help determine the optimal number of processors for a given application. Speed-up statistics can also be misleading, particularly if cited in the absence of application performance statistics. For example, an impressive speedup statistic may be due to a very low value of T(N), but it may also be due to a large value of T(1) caused by an inefficient one-processor implementation. Researchers commonly note that their speed-up statistics worsen when they accelerate their parallel program through tuning (Bailey, 2002, pp. 152-153) (Chalmers, 1996, p. 80)
(Morse, 1994, pp. 32-42).

2.9.2 Efficiency

The relative efficiency, based on the performance of an application on one processor, can be a useful measure as to what percentage of a processor's time is being spent in useful calculations. This metric helps to determine what the impact of the system overheads are. Relative efficiency can be represented as:

Efficiency = speed-up x 100 / number of processors

(Chalmers, 1996, p. 84) (Morse, 1994, pp. 32-42).

2.9.3 Theoretical Peak Performance

This measurement is the theoretical maximum performance of a system. For scientific applications, theoretical peak performance is defined as the maximum number of floating-point operations per second a system is capable of achieving. Theoretical peak performance is usually calculated as

$$P = N * C * F * R,$$

where P is the performance, N is the number of nodes, C is the number of CPUs per node, F is the number of floating-point operations per clock period, and R is the clock rate, measured in cycles per second. P is typically given in Megaflops (floating-point operations per second) or Gigaflops; abbreviated Mflops and Gflops respectively. For heterogeneous systems, P is calculated as the total of the theoretical peak performance figures for each homogeneous subsystem. The advantage of this metric is that it is very easy to calculate. The disadvantage of this metric is that by definition it is unattainable by ordinary application programs (Bailey, 2002, p. 151).

2.9.4 Application Performance

The statistics for application performance are sometimes given in terms of percentage of theoretical peak performance. Such a measurement is useful for determining the extent to which an application is using the computational power of a system. For example, a low percentage-of-peak measurement may indicate a mismatch between the cluster architecture and the application. The percentage-of-peak metric is not sufficiently informative without additional information. An embarrassingly parallel application can achieve a high percentage-of-peak measurement, but that is not a notable achievement. In general, percentage-of-peak figures beg the question “What percentage-of-peak is a realistic target for a given application?” Without an answer to this question, the percentage-of-peak statistic is not very useful in evaluating a cluster’s performance (Fountain, 1994, pp. 193-197).

The application performance metric is the number of operations performed while executing an application program, divided by the total run time. As with theoretical peak performance, it is typically given in Mflops or Gflops. This metric is a much more meaningful metric than theoretical peak performance, but only if calculated for an application program that closely resembles the program the user intends to run on the system. This metric is harder to use than theoretical peak performance, because the application program must first be ported to the cluster architecture, often a labor intensive and time-consuming task. Another time-consuming and often error-prone task that must be performed is determining the number of floating-point (or integer) operations actually performed by the code. This is a key difficulty since parallel applications are often tuned for optimal performance on the given system. Comparing the application performance results of two systems that are not tuned to the same degree can be misleading. Despite its difficulties, this metric can be very useful if properly applied (Vrenios, 2002, 154-169).

2.9.5 Application Run Time

This metric simply means the total run time for completing a given calculation. One advantage of this statistic is that it does not require the complicated process of determining the number of operations performed. In many ways, application run time is the ultimate metric in the sense that it is the standard performance measurement for applications running on a given system. The disadvantage of this metric is that unless the systems being compared are running identical applications it is difficult to produce meaningful results. The issue of tuning is also a factor with application run time. In comparing performance between two systems, both application implementations must be comparably tuned for the comparison to be accurate (Kuck, 1996, pp. 27-29).

2.10 Supercomputing Performance Benchmark Suites

It has long been a common practice to reduce a given machine's performance to a convenient single number for comparison purposes. Examples include the clock speed, the peak speed, the megaflop of some benchmark, or the arithmetic mean or harmonic mean of the megaflops of a set of benchmarks. The basic hypothesis is that a single number is sufficient to characterize performance, or at least to rank the performance of computing machines. However, on a given system there can be variations in performance by a factor of ten or more from one application to the next. Therefore is it not appropriate to evaluate cluster performance based on a single metric (Kuck, 1996, p. 84).

The code structure of parallel applications significantly influences parallel performance, and data sizes determine which problems can reasonably be solved by

particular systems. Because the structure of parallel applications affects system performance as much or more than the physical system architecture, the hardware and software of parallel systems should be very well matched. It is therefore crucial to use comprehensive performance information from benchmarks representing real applications in the design of a cluster. The process of designing a Beowulf cluster in the light of comprehensive overall performance information can lead to the most effective use of existing machines, and to strategies for improving future systems
(Kuck, 1996, pp. 94-95).

It is clear that no single type of performance measurement is both easily determined and completely informative. In one sense, only one figure of merit matters, as emphasized above: the overall run time for a particular application on a particular system. Overall run time is not easy to determine before a purchase or upgrade decision has to be made. For these reasons many users of cluster systems compare performance using a few standard benchmark programs. The following benchmark programs will be discussed in greater detail later in this chapter:

- TPC Benchmarks
- The Ping-Pong test
- The Perfect Benchmarks
- Livermore Fortran Kernels
- The Linpack benchmark
- The NAS Parallel Benchmark Suite

(Kuck, 1996, pp. 83-91).

The complexity associated with benchmarking parallel systems are compounded over and above those of serial machines. “Particular attention must be paid to questions such as whether data input and output time should be included, how to deal with non-linear effects such as latency, and what to do about scaling results to allow for different sizes of otherwise similar systems” (Fountain, 1994, pp. 207-208).

To be of any value, a benchmark must be carefully designed in terms of the functions it exercises and any constraints on input data. Although a great number of different benchmarks have been proposed, there is little general agreement over their validity (Fountain, 1994, pp. 221-222).

The number of benchmarks that should be used to adequately describe the performance of a cluster depends on the diversity of their structure. Because parallel applications may contain hundreds of thousands (or millions) of instructions, and there are usually many different programs being run on a cluster at any given time, the actual workload of a cluster may include hundreds of millions of instructions. Thus, hundreds of thousands of benchmark program instructions may be necessary to accurately describe a minimal set of all potential performance issues. In principle, one may stop adding new code samples to a benchmark suite when the point is reached at which new samples do not reveal new performance issues, whether comparing multiple systems or isolating problems on a single system.

The number of metrics that should be used to represent the performance of a cluster depends on the performance problems being measured. The overall principle is that enough metrics are needed to distinguish performance among systems that have genuine differences in performance. “The number of metrics used must be sufficient to paint an overall performance picture that is accurate in comparing two machines" (Kuck, 1996, 27-28).

Given the complexity of parallel computer systems and the great variety of applications in their workload, benchmark designers must meet several basic requirements as indicated below:

"Requirements Necessary in Basic Benchmarks

1. Representation of a large, interesting set of computations
2. Reduction in volume of the large set
3. Relatively fast running time
4. Easily portable to many computer systems
5. Minimal human time required to run codes and interpret results
6. Public availability of codes and accurate, replicable results from running them"

(Kuck, 1996, pp. 83-84).

2.10.1 TPC Benchmarks

Many open source benchmarks are available for measuring the performance of a parallel system. Commercial benchmarking suites are available for measuring the performance of most parallel architectures including Beowulf clusters. The most widely used and quoted commercial benchmarks of the Transaction Processing Performance Council (TPC). "The TPC is a consortium of 44 leading hardware and software companies worldwide; it was founded in 1988 to define transaction processing and database tests. The council's TPC Benchmarks A, B, and C are the most popular standard benchmark for determining price/performance in a commercial context. The TPC benchmarks are widely used even though they are large, expensive, and require a significant investment to run" (Pfisher , 1995, p. 342).

2.10.2 Ping–Pong Test

The Ping-Pong test is one of the most widely used measurements performed on cluster systems. Its purpose is to measure the latency and bandwidth of the cluster communications network. The Ping-Pong test includes a number of different tools for testing Transmission Control Protocol (TCP) performance. The MPI communications library is the standard protocol used for the Ping-Pong test (Bailey, 2002, p. 155).

2.10.3 The Perfect Benchmarks

The Perfect Benchmarks were developed by a consortium of supercomputer users and vendors coordinated by the University of Illinois, Urbana-Champaign. They were designed to measure the performance of the overall system, including compilers, on small problems representative of actual supercomputer applications. Using compiler optimizations only, without human intervention, the benchmarks execute at only a few percent of the theoretical parallel peak speed on conventional supercomputers (Schutzer, 1994, p. 161).

2.10.4 Livermore Fortran Kernels

The Livermore Fortran Kernels (LFK) measure the harmonic mean for 24 loops and 3 sizes. Because LFK represents an untuned workload that is hard to parallelize, the results provide a worst-case performance rating (Schutzer, 1994, pp. 161-162).

2.10.5 The Linpack Benchmark

The Linpack Benchmark was developed in the early 1980's when Jack Dongarra began collecting performance results of systems based on their speed in solving a 100 x 100 linear system using Fortran routines. This benchmark is a reasonable way to measure the performance for a single node of a Beowulf-type system (Bailey, 2002, 157).

More recently, Dongarra has released the "highly parallel computing" benchmark. This benchmark was developed for medium-to-large parallel and distributed systems and is now widely used to compare the performance of hundreds of machines. Unlike the basic Linpack benchmark, the scalable version does not specify a matrix size. Instead, the user is invited to solve the largest problem that can reasonably be run on the available system. The Linpack benchmark is the current standard used to benchmark the world's 500 most powerful computers (unofficially). The current list of the world's so-called Top500 computers is maintained at http://www.top500.org (Bailey, 2002, p. 157).

The principal disadvantage of the Linpack Benchmark tools is that they tend to overestimate the performance that real-world scientific application can expect to achieve on a given system. It is common for the Linpack benchmark to achieve 30 percent or more of the theoretical peak performance potential of a system. In contrast, real scientific application code seldom achieves more than 10 percent of the theoretical peak performance on Beowulf systems (Kuck, 1996, pp. 27-30) (Morse, 1994, p. 255).

2.10.6 The NAS Parallel Benchmark Suite

The NAS Parallel Benchmarks programs were developed by NASA's Numerical Aerospace Simulation Systems Division (NAS) for evaluating the performance of parallel systems. The benchmarks are written in Fortran and have been enabled for parallel processing by using embedded calls to MPI routines (Wang, 2000).

The NAS Parallel Benchmark (NPB) suite was designed to typify high-end aeroscience computation. The original NPB included a technical document that specified calculations for each benchmark. The original specification was detailed enough to include how the initial data was to be generated and provide small single-processor code samples. The NPB is a powerful performance suite because it reflects real-world parallel scientific computation to a notably greater degree than most other available benchmarks (Sterling, 2002, p. 156) (Schutzer, 1994, pp. 161-162).

2.11 Review of Literature Conclusions

The configurations that may be used for Beowulf clusters are as varied as the number of applications that can be run on them. The number of performance benchmarking techniques are also numerous. This chapter has summarized the tools and technology needed to assembly and measure the performance of diskless clusters. Using this information, several diskless Beowulf clusters will be constructed and the factors that affect their performance will be identified. Research on parallel benchmarking tools has led to the conclusion that the NAS Parallel Benchmarks should be selected as the benchmarking tool for this research. The NPB suite has the ability to test cluster performance using a wide range of software architectures and problem sizes. A series of benchmarking experiments will be run to collect performance data on low cost, small clusters (1-16 nodes) of various hardware and software configurations. Using parallel programs of different architectures to measure the performance of diskless clusters with different hardware configurations is expected to provide the data required to produce a quality performance model. Extensive research has not revealed that a descriptive performance model of small, diskless Beowulf clusters exists.

Chapter 3

3 RESEARCH PROCEDURES

3.1 Diskless Cluster Construction

A cluster is a group of computers working together toward a common goal. Most clusters require a message passing interface and a job scheduler to allow computers in the cluster to work together. The message passing interface is used to transmit data among nodes in the cluster. The job scheduler takes job requests from user input or other means and schedules them to be run on the number of nodes required (Mississippi Center for Supercomputing Research, 2001). The LAM implementation of MPI was selected to provide the message passing interface and job scheduler services.

By definition, a cluster must consist of at least two nodes, a master and a slave. The master node is the computer that users interact with since it runs the job scheduler. The master node can participate in computational tasks along with slave nodes, but it is not recommended and will not be implemented for this research. Slave nodes respond to the requests of the master node and, in general, do most of the computing. (Mississippi Center for Supercomputing Research, 2001).

Before building the Beowulf clusters used in this research, the hardware resources for cluster node construction were selected. These hardware resources and their performance levels are found in Table 3-1.

Table 3-1 Hardware factors and their performance levels

Hardware Factor	Hardware Performance Levels		
CPU Speed	233MHz	433MHz	1800MHz
Node Memory (RAM)	128MB	256MB	512MB
Network Speed / Routing	10 Mbps Hub	10 Mbps Switch	100 Mbps Switch

It is not necessary for the computers in a cluster to have the same hardware configuration. The only requirement is that the machines share the same architecture. For instance, the cluster should only consist of all Intel machines or all Apple machines, but not a mixture of the two because existing message passing libraries do not account for the difference in endianness. In theory, it is possible to mix architectures when building a cluster by using Java, but there are considerable sacrifices in performance, and overall system administration (Mississippi Center for Supercomputing Research, 2001).

To make the Beowulf clusters in this research as easy as possible to administer, all compute nodes in a given cluster were configured, where possible, with identical hardware. A single set of configuration and operating system files were shared by all nodes in the cluster. Using a disk image shared between all nodes in the cluster makes the software easier to install and maintain than using a separate image for each node (Lindheim, 2000).

3.2 Diskless Node Boot Requirements

For every node in the cluster to use the same disk image, each node is required to perform the following operations as part of its boot process:

1. Load a kernel with built-in network services, network device driver, and NFS-Root capabilities.
2. Automatically obtain the node’s network configuration.
3. Mount a root file system over the network using NFS.
4. Continue loading Linux operating system services by running scripts located under the NFS mounted directory.
5. Start a remote shell server.

After completing each of the above tasks, the node should now be accessible from the master node. The master node can then initiate the cluster middleware on each node.

3.3 Diskless Node Kernel

The purpose of an operating system kernel is to isolate the details of interfacing with computer related hardware from the average user. The kernel provides system calls that give users access system resources without requiring the user to know details about the hardware. For example, if users want to access a file on a hard disk a simple read call to the kernel is all that is required. The kernel will handle hardware interfacing details such as moving the disk R/W head to the correct track, and sector position of the hard disk, and will return the contents of the file to the user. “The Linux kernel is a multi-process, multi-user system. It contains several components such as process management, memory management, file systems, device control, networking, etc. The kernel responds to user’s requests by allocating CPU cycles, RAM, I/O devices, and networking resources” (Laboratory of Statistical and Computational Physics, Academia Sinica, 2002).

Unlike the kernels of most operating systems, the Linux kernel is fully customizable for many different requirements. Powerful kernel configuration tools are available that make the arduous task of rebuilding a kernel a simple matter of selecting the kernel functions desired using a series of menus. The Linux kernel may be customized to be large or small depending on the application. For a diskless node to work, the kernel must allow the following tasks to be accomplished:

1. The node must be able to find its own Ethernet configuration including IP-address, hostname, subnet mask, etc.
2. The node must know the NFS server's IP-address and the path on the NFS server that contains the node's root file system.
3. The node's kernel must be able to mount its root file system over the network using NFS (Kostyrka, 1997).

NFSRoot is a Linux kernel implementation that provides the following functionality:

1. The node's IP-address may be discovered using RARP, BOOTP, or DHCP. The node's Ethernet configuration may also be provided by passing parameters to the kernel using LILO (Linux Loader) or a similar boot loader.
2. The NFS path to mount can also be provided through kernel parameters. If no NFS server is provided, the kernel assumes the server that provided its IP address is also the NFS server. If a path on the NFS server is not provided, the kernel will use the default path of /tftpboot/<IP-address of the node>.
3. To provide NFSRoot functionality the diskless kernel must include the following components:
    a. Network Support (IP kernel level autoconfiguration)

b. RARP support (or BOOTP, or DHCPD)

c. Root file system on NFS.

d. The Ethernet driver for the network card of the compute node

(Kostyrka, 1997).

The diskless kernel used in this research was configured for DHCPD support as a matter of preference. In addition, the Ethernet drivers for all network cards used in the project were compiled into the kernel to allow a single kernel to be used for the project. By default, the kernel identifies the Ethernet card and uses the appropriate driver if it has been included in the kernel. If the required Ethernet driver is not included in the kernel, the diskless node will not complete the boot process over the network, and will search for alternate boot media. The diskless kernel configuration file used for this research can be found in Appendix B.

3.4 Booting a Diskless Node

One of the challenges behind building a diskless cluster is determining how to boot the diskless node's kernel and how to mount the root file system required to initialize the diskless node from a remote server. Since diskless nodes are not equipped with a hard disk, the root file system must be provided by a server through a network connection (Laboratory of Statistical and Computational Physics, Academia Sinica, 2002).

There are at least two methods for booting a diskless node. Each node can boot from its network interface card (NIC) to receive the boot image via DHCP/TFTP, or a suitable kernel may be loaded from a floppy.

One way of booting a compute node without a hard disk is to use a network card with a bootrom. Most network cards use ordinary 28 pin EPROMS. These EPROMS typically come in sizes up to 64kB. For most cards a 32kB EPROM will work. These EPROMS can be programmed using any ordinary EPROM burner.

There are a number of free software packages available for creating a bootrom. Netboot and Etherboot are two of these packages. Netboot is one of the most complete free packages available. Netboot's documentation s very complete and should provide sufficient information for creating a bootrom and booting a computer with it. This documentation as well as the Netboot software maybe found at http://www.han.de/~gero/netboot/

Etherboot is another package for creating a bootrom. Etherboot has a few nice features such as DHCP support. One of the disadvantages of Etherboot is that it uses its own driver format which limits the available network driver support. Another option to Etherboot and Netboot is to use a PXE-compliant boot EPROM (de Goede, 1999) (Gärtner, 2000).

The diskless clusters built for this research all use a standard 1.44Mb floppy disk drive as the initial boot media. The LILO boot loader was installed on a boot floppy and configured to pass special parameters to the kernel that are required for network autoconfiguration and NFSRoot functionality. A boot loader is not required for these features to work properly, but the boot loader provides more flexibility by allowing kernel parameters to be modified without directly modifying and rebuilding kernel source code. The LILO configuration file as well as the script used to build each boot floppy can be found in Appendix B.

3.5 Dynamic Host Configuration Protocol (DHCP)

When a diskless client is powered on, it knows almost nothing about its configuration. It does not know its hostname, since that is established in the boot scripts that run later in the boot process. It has no concept of IP addresses, because it has no hosts file or NIS (Network Information Service) map file to read. The only piece of information it knows for sure is the 48-bit MAC (Media Access Control) address embedded in the hardware of the network interface card. In order to boot, a diskless client must convert its 48-bit MAC address into more useful information such as the boot server IP address, a hostname, an IP address, and the location of its root file system (Stern, 2001, p. 152). RARP, BOOTP, and DHCP are three protocols that can provide the diskless node the network configuration information it needs to complete the boot process.

One of the functions of the master node in a cluster of diskless nodes is to provide each node in the cluster with its network configuration. This was accomplished by configuring the master node as a DHCP server. The DHCP server daemon included in nearly all Linux distributions is well documented with configuration examples in the Linux MAN pages and on multiple Internet sites (Laboratory of Statistical and Computational Physics, Academia Sinica, 2002) The dhcpd.conf file in Appendix B allows the master node to assign nodes in the cluster an IP address as well as a host name.

3.6 Network File System (NFS)

One of the parameters that LILO passed to the kernel was the network location of the master node and the path that contained the diskless node's root file system. A portion of the master node's hard disk was used as the root file system that could be used by each node in the cluster. The NFS (Network File System) protocol was used to "share" this root file system. The master node was configured as a NFS server. The exports file in Appendix A is the configuration file for NFS. The diskless nodes' root file system contains a fstab file that allows each node to access portions of the master node's disk using NFS.

NFS is a distributed file system that provides transparent access to remote disks. NFS allows directories to be remotely accessed by multiple clients over a network. Instead of duplicating common directories on each compute node in a cluster, NFS provides a single copy of the directory that is shared by all systems on the network. To a host running NFS, remote file systems are indistinguishable from local ones. For the user, NFS provides access to a remote system's local storage without having to log in to the system.

NFS imposes a client-server relationship on the hosts that use it. An NFS server is a host that owns one or more file systems and makes them available to certain clients on the network. NFS clients mount file systems from one or more servers. This follows the normal client-server model where the server owns a resource that is used by the client. If NFS has been set up correctly, it should be transparent to the user (Stern, H, 2001, pp. 84-85).

3.7 Diskless over NFS

Diskless clients are probably the most difficult application of NFS. It is a nontrivial matter to get a machine with no local storage to come up as a fully functioning member of the network. Despite the configuration challenges of diskless clients, there are many motivations for using diskless clients:

- “They are quieter than machines with disks.
- They consume less power, and thus generate less heat.
- They are easier to administer, since there is no local copy of the operating system that requires updates.
- When using a fast network media, like 100Mb Ethernet, diskless clients can perform faster if the server is storing the clients data in a disk array. The reason is that client workstations typically have one or two disk spindles, whereas if the client data can be striped across many, usually faster spindles, on the server, the server can provide better response”

(Stern, 2001, p. 147).

During the boot process, a compute node must be able to access a root file system. A root file system is simply a file system that the Linux kernel will mount as ‘/’. The kernel has to be told where to find the root file system; if it cannot find a loadable system image, the kernel halts. The root file system would normally reside on a local hard disk or RAID drive, but a diskless-client must be able to access a root file system located on a network file server. For the clusters used in this research, the NFS server is also the cluster’s master node, but it could be any machine within the cluster. The root file system is needed to store the operating system, applications, configuration information and data. Creating the root file system involves selecting the files necessary for the system to run and making them available to the compute nodes via the network. A root file system must contain everything needed to support a full Linux system. The minimum requirements for a Linux system include:

- The basic file system structure
- A minimum set of directories: /dev, /proc, /bin, /sbin, /etc, /lib, /usr
- A basic set of utilities : sh, ls, cp, mv, etc.
- Minimum set of configuration files: rc, inittab, fstab, etc.
- Devices: /dev/hd*, /del/tty*, /dev/fd0, etc.
- Runtime libraries that provide the basic functions needed by the utilities

The root file system of each a compute node may be located on a RAID disk array, one of the server's local hard disks, a ramdisk, or any other file system that is supported by the diskless node's kernel. Within a diskless cluster, each compute node may have a unique root file system that it accesses on the file server, or many compute nodes may share a single root file system (Laboratory of Statistical and Computational Physics, Academia Sinica, 2002).

Utilities such as ClusterNFS are available that enable many nodes to share significant portions of the same root file system while still utilizing node specific configuration files and other programs to best utilize the node (Warnes, 1999).

3.8 Diskless Node Startup Scripts

Once the diskless nodes are able to access their root file system over NFS, they are able to continue loading the operating system by running operating system setup scripts. A copy of the startup script for the master node was used as a template for the diskless nodes startup script. For a Redhat Linux system, this script is normally located at /etc/rc.d/rc.sysinit. Because the diskless kernel was not configured with all of the capabilities of the master node kernel, portions of the startup script were modified. The modifications made to the master node's rc.sysinit script to make it work for diskless nodes are found in Appendix B.

3.9 Secure Shell (SSH)

Once the diskless node has successfully booted, the master node will need a way to access the node and run programs remotely. Cluster administrators will also want a way of accessing each node in the cluster without physically plugging a monitor and keyboard into it. To provide remote access to each node over the network, SSH was configured to automatically start when each node booted. SSH is secure program that is used to log into another computer.

In order to take advantage of the processing power of the compute nodes in a cluster, the master node must be able to execute programs on each node remotely. SSH allows the master node to remotely execute programs on individual nodes in the cluster. One of the programs that must be executed on each node is the cluster middleware LAM/MPI. In addition to the ability to remotely execute programs, the master node must be able to gain access to each mode without being prompted for a password.

There are two methods to bypass the login password. An entry can either be added to the /etc/hosts.equiv file or to the .rhosts file in each user's home directory. The .rhosts method is preferable because there is one copy in each users directory. /etc/hosts.equiv must be maintained on each node of the cluster, which may lead to an administration headache when users are added or deleted (Eadline, 1999) (Stanford Linear Accelerator Center, 1999).

The most glaring issue with the process of building a Beowulf cluster is the security implications it raises. Allowing root to log in to a node using an insecure shell such as rsh or rlogin is not recommended for most installations. Using /etc/hosts.equiv and other methods to allow logins without supplying a password is usually considered to be security hole. Rsh and rlogin are considered insecure and are being replaced by SSH. For these reasons, is it imperative that, if the master node can be accessed from the Internet, great care is taken to ensure it is secure. If the master node is susceptible to unauthorized access then it is probable that every machine in the cluster is also (Mississippi Center for Supercomputing Research, 2001).

3.10 Local Area Multicomputer (LAM)

"Several implementations of MPI targeting various parallel architectures and operating systems exist. The most common of these implementations are MPICH from Mississippi State University and the Argonne National Laboratory, and LAM from the Ohio State University and the University of Notre Dame. Both of these implementations support the Linux operating system. The performance of these implementations has been compared and LAM is considered to be slightly faster than MPICH. In additional to being faster than MPICH, the internal structure of LAM is simpler than that of MPICH" (Dongarra, 1999, pp. 202-203). For these reasons the LAM implementation of MPI was selected to provide the necessary message passing libraries and the cluster middleware.

LAM (Local Area Multicomputer) is a freeware implementation of MPI that is distributed with most distributions of Linux. LAM provides users not only with the standard MPI libraries routines, but also with several debugging and monitoring tools. The LAM daemon is very powerful for testing and debugging purposes. LAM can provide real time debugging information including deadlock conditions (Radajewski, 1999). Although LAM is specifically intended to be used on heterogeneous clusters of Unix workstations, LAM can be used on a wide variety of Unix-based platforms, ranging from desktop workstations to large supercomputers (LAM/MPI Parallel Computing, 2003).

LAM is a daemon-based implementation of MPI. This means that a process is launched on each machine that will be in the parallel environment. Once all LAM daemons have been launched, LAM is ready to be used. In addition to being daemon based, LAM is a user-based MPI environment, meaning that each user who wishes to use LAM must boot their own LAM environment (LAM/MPI Parallel Computing, 2003).

LAM is considered a stable parallel computing environment; however, the following security factors should be considered when using LAM:

1. "LAM leaves a UNIX domain socket open on each machine in the /tmp directory. This means that if someone breaks into root on one machine, they effectively have root on all machines connected via LAM.
2. There must be some trust mechanism such as .rhost for root, which must allow LAM to be executed on remote nodes. Depending on the local configuration, this may not be secure

3. LAM has never been checked for buffer overflows and other malicious input types of errors.
4. LAM programs are not audited or tracked in any way. This could present a way to execute unauthorized binaries (especially as root)" (LAM/MPI Parallel Computing, 2003).

For these security reasons LAM is insecure and it is unwise to run most LAM binaries as root. Most LAM binaries will quit immediately if root attempts to runs them.

By default, the LAM environment requires that the master node be able to execute remote processes on the compute nodes using RSH (Remote SHell). RSH is a remote shell service that is being replaced by the more secure SSH service. LAM allows the remote shell process to be changed from RSH to SSH or other similar services by setting the environment variable LAMRSH. To use SSH, LAMRSH was set to "ssh –x" (Stanford Linear Accelerator Center, 1999).

3.11 Diskless Beowulf Cluster Configuration Procedure

A summary of the steps required to configure a diskless Beowulf cluster can be found in Figure 3-1. The diskless kernel must be configured for NFSRoot capabilities, and recompiled. The driver for the network interface card as well as network autoconfiguration is also required. Each node in the cluster boots off a floppy disk that has the LILO boot loader installed. LILO is configured to pass parameters to the kernel that tells the kernel to obtain its network configuration using DHCP. LILO also provides the kernel with the network address of the NFS server and the path where the node's root file system can be found. Before the slave node can mount its root file system, it must obtain its network configuration by sending a DHCP request to the master node. The master node is running a DHCP server that provides the IP address and other network configuration information to each slave node. Once the slave node has obtained the necessary networking configuration it can attempt to mount its root file system. A portion of the master node's hard disk has been set aside as the root file system that the slave nodes in the cluster will share. The master node is configured as an NFS server that will allow each slave node to access the diskless root file system over the network. Once this file system has been mounted, the slave nodes can continue to load the Linux operating system by running startup scripts modified to work with the diskless node's kernel. One of the services started by the diskless nodes is an SSH server. SSH allows the diskless node to be remotely accessed by the master node.

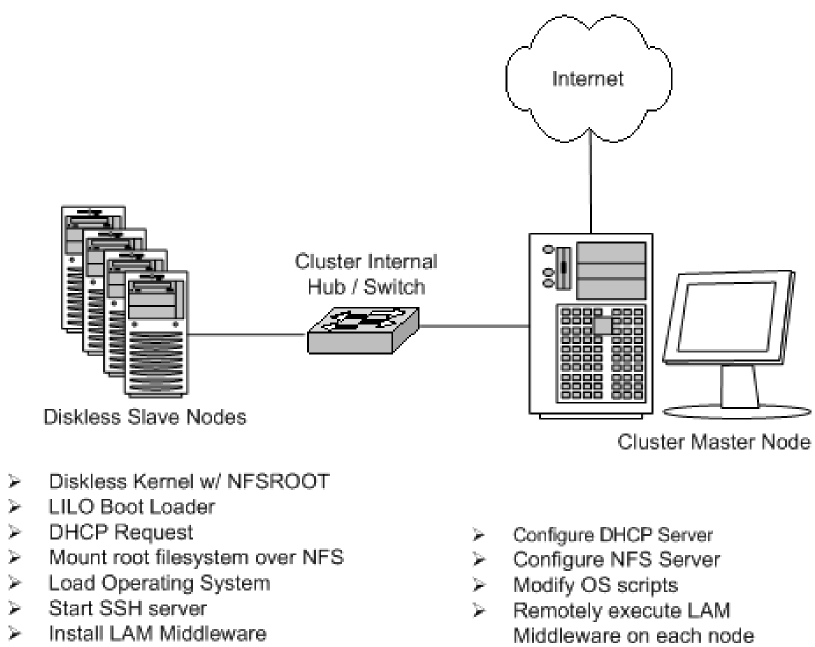

Figure 3-1 Diskless cluster configuration

Once the diskless nodes in the cluster have successfully booted, the master node is able to remotely execute programs. The first program the master node executes is the LAM/MPI middleware daemon. The master node attempts to start the LAM environment on itself and each slave node in the cluster. If the master node is successful in starting the LAM environment, the cluster is up and running. Parallel programs using MPI, like the NPB programs, can now be executed on the cluster.

3.12 The NAS Parallel Benchmark Suite

Researching the available benchmarks used to measure the performance of Beowulf clusters has led to the conclusion that the NAS Parallel Benchmarks provide the necessary tools to test a broad range of parallel computing programs. In addition to being able to test parallel programs of various architectures, the NPB suite also provides performance information for clusters of various sizes. This section will discuss the NPB utilities in detail.

The NPB contains a set of eight benchmark programs. These fall into two broad categories: five relatively simple kernels and three simulated CFD applications. The kernels measure performance on specific functions frequently encountered in computational fluid dynamics and other areas of scientific computing. Specifically they include an embarrassingly parallel computation of pseudo random numbers, a 3D FFT (Fast Fourier Transform) solver, a multigrid solver, a conjugate gradient solver, and an integer sort. The simulated applications are all three-dimensional in nature (Hord, 1999, pp. 64-65). "Benchmarks BT, SP, and LU solve a SD discretization of Navier-Stokes equations using the BT, SP and LU techniques respectively:

$$Ku = r$$

where u and r are 5x1 vectors defined at the points of a 3D rectangular grid and K is a diagonal block matrix of 5x5 blocks. The three benchmarks differ in the factoring of K"

(Frunmkin, 1998). Benchmarks BT, SP, and LU are simulated computational fluid dynamics applications (Bailey, 2002, p. 156).

"The FT benchmark performs FFT of a 3D array, CG solves a sparse system of linear equations by the conjugate gradient method, and MG solves a discrete Poisson problem on a 3D grid by the V-cycle multi-grid algorithm" (Frumkin, 1998).

3.12.1 BT Benchmark

The BT benchmark calculate the Alternating Direction Implicit (ADI) approximate factorization of the operator of the equation:

$$K \simeq BTx \bullet BTy \bullet BTz$$

where *BTx*, *BTy*, and *BTz* are block tridiagonal matrices of 5x5 blocks if the grid points are enumerated in an appropriate direction. The resulting system is then solved by solving the block tridiagonal systems in x-, y-, and z-directions successively. (Frumkin, 1998). The BT benchmark can only be run on a cluster with nodes equal to some number squared.

3.12.2 SP Benchmark

"The SP benchmark uses the Beam-Warming approximate factorization and Pulliam-Chaussee diagonalization of the operator of the following equation and adds fourth-order artificial dissipation:

$$K \simeq T_x \bullet P_x \bullet T_x^{-1} \bullet T_y \bullet P_y \bullet T_y^{-1} \bullet T_z \bullet P_z \bullet T_z^{-1}$$

where T_x, T_y, and T_z are block diagonal matrices of 5x5 blocks, P_x, P_y, and P_z are scalar pentadiagonal matrices. The resulting system then solved by inverting block diagonal matrices T_x, $T_x^{-1} \bullet T_y$, $T_y^{-1} \bullet T_z$ and T_z^{-1} and solving the scalar pentadiagonal systems" (Frumkin, 1998). The SP benchmark can only be run on a cluster with nodes equal to some number squared.

3.12.3 LU Benchmark

"LU implements a version of the SSOR algorithm by splitting of the operator of the equation of below into a product of lower triangular matrix and upper triangular matrix:

$$K \cong \omega (2 - \omega)(D + \omega Y)(I + \omega D^{-1} Z)$$

where ω is a relaxation parameter, D is the main block diagonal of K, Y consists of three sub-block diagonals and Z consists of three super block diagonals. The problem is solved by computing elements of the triangular matrices and solving the lower and the upper triangular system" (Frumkin, 1998). The LU benchmark can only be run on a cluster with nodes equal to some power of two.

3.12.4 FT Benchmark

The FT benchmark implements a Fast Fourier Transformation of a 3D array. "The transformation can be formulated as a matrix vector multiplication as indicated by the following equation:

$$v = (F_m \otimes F_n \otimes F_k)u$$

where u and v are 3D arrays of dimensions (m,n,k) represented as vectors of dimensions m x n x k and F_l, $l=m,n,k$ is an FFT matrix of the order l. In the order l, $A \otimes B$ is a block matrix with blocks $a_{ij}B$ and is called tensor product of A and B. The algorithm is based on factorization of the FFT matrix: where I_l, $l=m,n,k$, is

$$F_m \otimes F_n \otimes F_k = (I_m \otimes I_n \otimes F_k)\,(I_m \otimes F_n \otimes I_k)\,(F_m \otimes I_n \otimes I_k)$$

the identity matrix of the order l. Multiplication of each factor by a vector is equivalent to FFT of the array in one direction, henceforth FT performs FFTs in x-, y-, and z-directions successfully" (Frumkin, 1998). The FT benchmarks tests cluster performance in the presence of an application using massive all-to-all communications (Bailey, 2002, p. 156). The FT benchmark can only be run on a cluster with nodes equal to some power of two.

3.12.5 CG Benchmark

"The CG benchmark is different from the other benchmarks since it works with a large unstructured matrix. CG estimates the largest eigenvalue of a symmetric positive definite sparse matrix by the inverse power method. The core of CG is a solution of a sparse system of linear equations by iterations of the conjugate gradient method. One iteration can be written as follows:

$$q = Ap,\ d = p^T q,$$

$$\alpha = \rho/d,\ z = z + \alpha p,\ \ r = r - \alpha q$$

$$\rho_0 = \rho,\ \rho = r^T r,\ \beta = \rho/\rho_0,\ p = r + \beta p$$

The most computationally expensive operation is the spare matrix vector multiplication

$q = Ap$" (Frumkin, 1998). The CG benchmark measures cluster performance when running an application with irregular communication (Bailey, 2002, p. 156). The CG benchmark can only be run on a cluster with nodes equal to some power of two.

3.12.6 MG Benchmark

"The MG benchmark performs iterations of V-cycle multigrid algorithm for solving a discrete Poisson problem $\nabla u = v$ on a 3D grid with periodic boundary conditions. Each iteration consists of evaluation of the residual:

$$r = v - Au$$

And of the application of the correction:

$$u = u + Mr$$

where M is the V-cycle multigrid operator.

"The V-cycle starts from an approximate solution on the finest grid, computes the residual and projects it onto progressively coarse grids (down subset). On the coarsest grid it computes an approximate solution by smoothing the residual, interpolates the solution onto the finer grid, and computes the residual applies the smoothing on the finer grid (up substep)" (Frumkin, 1998). The MG benchmark tests cluster performance using both large and small packet sizes (Bailey, 2002, p. 156). The MG benchmark can only be run on a cluster with nodes equal to some power of two.

3.12.7 IS Benchmarks

The IS benchmark is a massive integer sort program. This benchmark involves irregular interprocessor transfer of integer data. The IS benchmark can only be run on a cluster with nodes equal to some power of two.

3.12.8 EP Benchmark

The EP benchmark is perhaps the simplest of all parallel benchmarks. The benchmark does little more that generate large amounts of random numbers. Unlike the other benchmarks, the EP benchmark can be run on any number of nodes, each node generating its share of random numbers. The EP benchmark requires almost no interprocessor communication, and, unlike the other benchmarks, its performance is nearly linear as more nodes are thrown at the problem (Bailey, 2002, p. 156).

3.13 NAS Parallel Benchmark Features

The NPB programs contain a number of features that make them easier to use for cluster benchmarking purposes. These features include self-verification, internal timing, multiple problem classes, and performance reporting in Mflop/sec.

Self-verification is contained within the code to determine if each run has completed with the correct results. Internal to each benchmark program are special timing mechanisms. Timing is performed according to the NPB 1.0 specification. When possible, the code is run for one time step and then reinitialized before timing begins to eliminate startup costs associated with demand paging and cache loading. Mflop/sec rates are estimated within the code. These estimates are based on actual operation counts without compiler optimizations to provide more accurate performance reporting (Bailey, 1995).

The NAS Parallel Benchmarks must be compiled for a specific class size and number of processors. While some of the benchmarks may be run successfully on a larger number of processors or smaller grid than those specified at compile time, memory access behavior may be different from that of a code compiled explicitly for that size and number of processors (Bailey, 1995). Table 2 contains the most commonly used class sizes available with the NPB Suite.

Table 3-2 NAS Parallel benchmarks problem definitions (Bailey, 1995).

Benchmark Code		Class A	Class B	Class C
Embarrassingly Parallel (EP)		2^{28}	2^{30}	2^{32}
Multigrid (MG)		256^3	256^3	512^3
Conjugate Gradient (CG)		14,000	75,000	150,000
3-D FFT PDE (FT)		256^2 x 128	512 x 256^2	512^3
Integer Sort (IS)		2^{23}	2^{25}	2^{27}
LU Solver (LU)		64^3	102^3	162^3
Pentadiagonal Solver (SP)		64^3	102^3	162^3
Block Tridiagonal Solver (BT)		64^3	102^3	162^3

For Beowulf systems up to 32 processors, class A problems are appropriate. Class B problems are appropriate for system ups to 128 processors. Class C problems can be used to benchmark clusters with up to 256 processors (Bailey, 2002, p. 157).

3.14 Test Plan

By researching the NAS Parallel Benchmark Suite it was determined that the following class A benchmarks should be run on each available hardware configuration:

- BT and SP benchmarks – run on 1, 4, 9 and 16 nodes
- EP benchmarks – run on 1 – 16 nodes
- CG, FT, IS, LU, and MG benchmarks – run on 1, 4, 8, and 16 nodes

After all benchmarks were completed on diskless nodes with a 233MHz CPU, it became apparent that the amount of memory in each node did not affect performance, as long as there was enough memory. Because the diskless nodes do not have swap space, a parallel program will fail completely if any of the nodes run out of memory. As long as each node has enough memory, the amount of memory was not observed to affect performance as indicated by Figure 3-2. Figure 3-2 contains the results of BT benchmark tests for clusters with 233MHz CPUs.

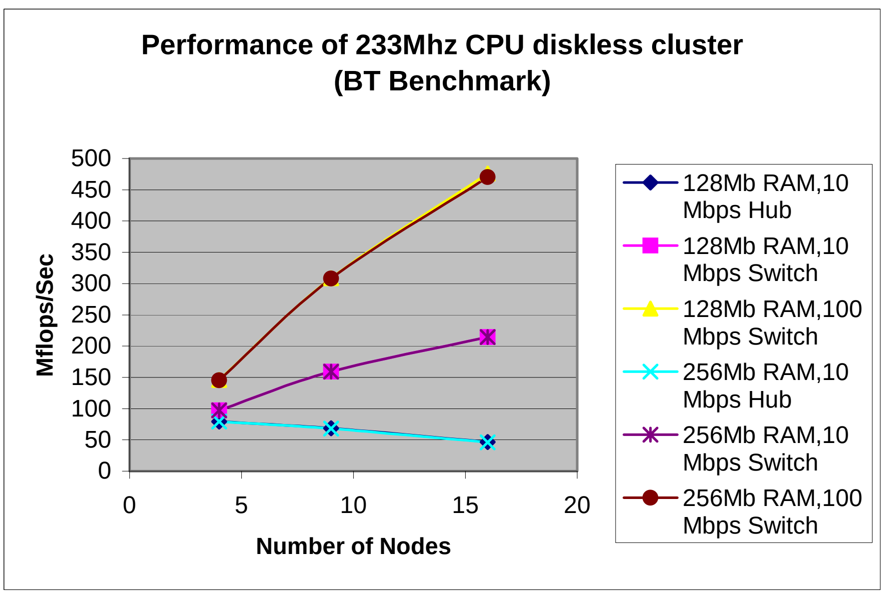

Figure 3-2 Performance of 233Mhz CPU diskless cluster (BT Benchmark)

As Figure 3-2 shows, cluster performance does not change when the amount of memory is changed. This trend was observed for all benchmark tests. The access speed of a nodes memory is expected to have an impact on cluster performance, but equipment was not available to test this factor. Because the amount of RAM each node in the cluster has was shown not to affect performance, future testing did not include RAM as a factor.

Figure 3-2 also indicates that as the number of nodes is increased, performance increases unless a hub is being used. This trend was observed for all benchmarks except the EP benchmark, which requires minimal network communication. The EP benchmark does not adequately represent the normal amount of network traffic expected in a parallel program. The network traffic required to run the EP benchmark is many times less than the network traffic of a real-world parallel application. Figure 3-3 illustrates the performance of a diskless cluster with a 10 Mbps hub for the other seven benchmarks. Notice how increasing the number of nodes in the cluster actually decreases overall performance due to increased network traffic collisions, and retransmission overhead.

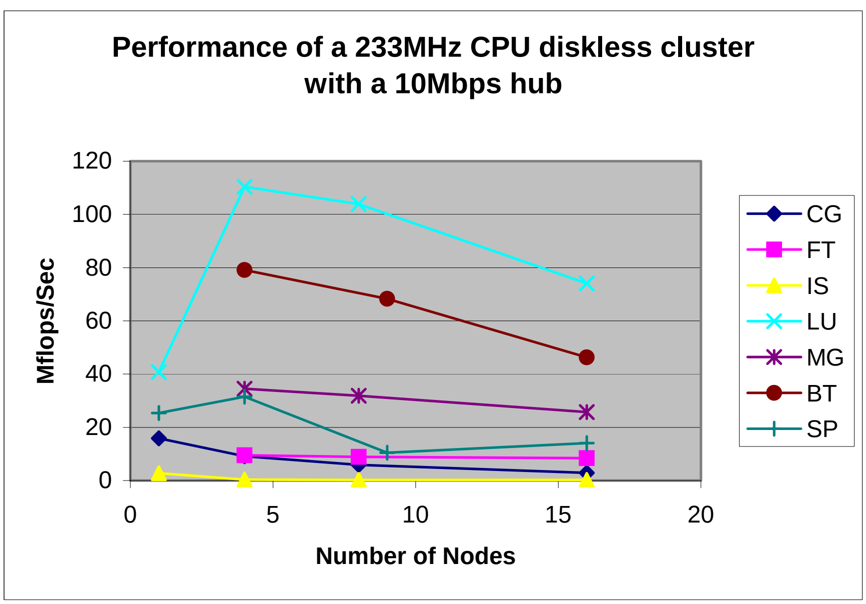

Figure 3-3 Performance of a 233MHz CPU diskless cluster with a 10Mbps hub

The loss of performance observed with a hub strongly indicates that for a diskless cluster to be effective, a switch should be used. For this reason additional testing did not include the 10 Mbps hub. An in-depth discussion of the remaining benchmark results will be included in the next chapter.

Chapter 4

4 DATA ANALYSIS

4.1 Benchmark Performance Analysis

In this chapter the data collected from the diskless Beowulf clusters described in chapter three will be analyzed. The results of this analysis will be used to generate a descriptive model that includes the factors that significantly affect performance and any significant trends that are identified.

Each benchmark in the NAS Parallel Benchmark suite has a different program architecture. Because of this, directly comparing the results of two different benchmarks is not reasonable. Identifying common trends in benchmark results is useful for generalizing the effect of various factors on performance. Analysis of the collected data will attempt to correlate significant trends in performance to one or more factors significantly affecting performance. The data collected is graphically represented in Appendix A. The raw output of each benchmark test is found in Appendix C.

4.2 Parallel Performance

The purpose behind building a Beowulf cluster is clear: use inexpensive hardware and software to obtain performance that is comparable to expensive high-performance systems. Increasing the performance of a Beowulf cluster must be accomplished for the cluster to continuously meet increasing computing demands. Beowulf cluster performance may be increased by adding nodes to the cluster, or by upgrading existing cluster hardware. The performance measured by the EP (Embarrassingly Parallel) benchmark demonstrates how multiple low performance machines can out-perform a single high performance one. This result is expected because the EP benchmark is designed to allow slave nodes to operate independently with minimal network communication.

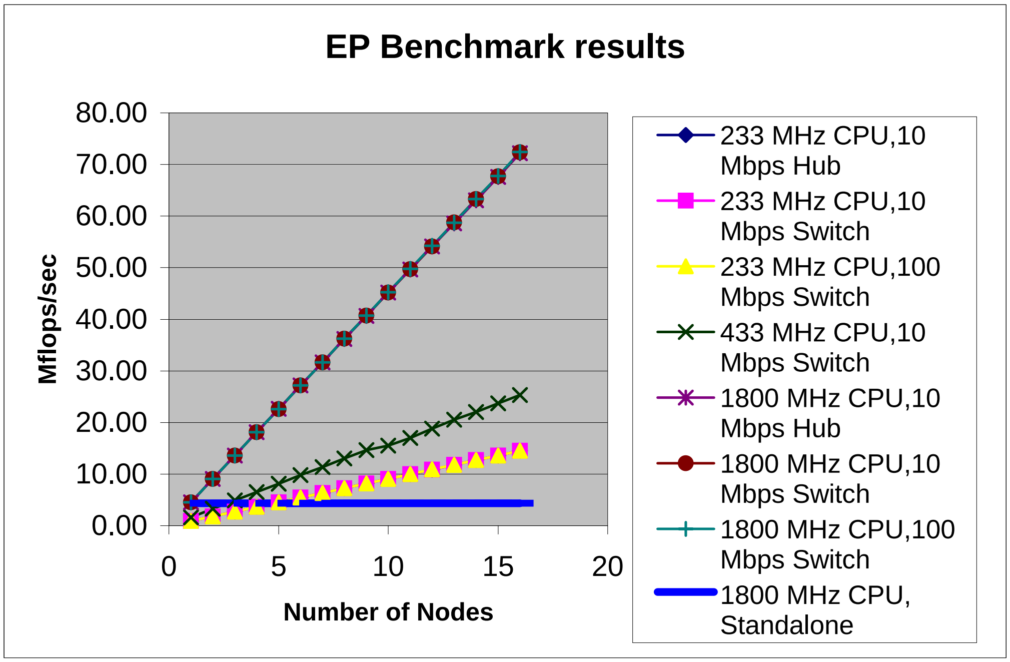

Figure 4-1 EP Benchmark results

Figure 4-1 shows three cluster performance lines. The blue horizontal line represents the performance of a single 1800MHz computer. Notice that the cluster with 233MHz CPUs is able to reach the same performance level as the single 1800MHz computer with approximately five nodes. The cluster with 433MHz CPUs only needs three nodes to match the performance of the 1800MHz machine. This benchmark reports that a 16-node cluster with 233MHz CPUs has approximately the same computing power as a 9-node cluster with 433MHz CPUs, or a 3-node cluster with 1800MHz CPUs. A 16-node cluster with 433MHz CPUs has nearly the same computing power of a 6-node cluster with 1800MHz CPUs. Clearly, the combination of several low performance computers has the potential to outperform a single, high performance machine.

Figure 4-1 illustrates another interesting point about embarrassingly parallel applications. Because the EP benchmark requires minimal network communication, the increase in system performance is nearly linear as nodes are added. The network is not a significant factor in the performance of embarrassingly parallel programs on small, diskless clusters. These results further indicate that node CPU performance is one driving factor in the performance of a cluster running embarrassingly parallel programs.

It should be noted that most useful applications cannot be parallelized to the extent shown by the EP benchmark, As additional nodes are added to the cluster, a nearly linear increase in performance is observed with the EP benchmark. This is the ideal speed-up measurement for a cluster and it is not expected to occur for any of the other benchmarks.

4.3 Local Memory Dependence

The effect of main memory on cluster performance was discussed at the end of the previous chapter. Analysis of the BT benchmarks results indicated that the amount of main memory available to each cluster node does not affect performance. In cases where cluster nodes have sufficient memory to complete the calculations assigned to them, the amount of memory does not appear to affect performance. This was observed for all benchmark programs. Memory access speed is expected to affect cluster performance, but this factor was not tested.

If a cluster node ever runs out of memory, two things can happen: (1) if swap space is available the node will continue the calculations assigned to it, or (2) all calculations the node is participating in will fail. Accessing swap space will always be slower than accessing local memory. A node that is required to access swap space will show a notable decrease in performance. This loss in performance is costly, but it is better than the alternative. A node that runs out of memory, and has no swap space will simply abort the calculations assigned to it. Any data that has not been permanently stored will be lost. A cluster node with insufficient memory and no swap space could result in the loss of hours of calculations. (Duke University Department of Physics, 2003).

As noted in chapter 2, a number of studies have been done on the performance characteristics of diskfull clusters. The Dell study cited in chapter 2 studied the performance of both diskfull and diskless cluster. The high performance diskless nodes in the Dell study has access to swap space over a high performance network. This research focused on the performance of diskless nodes that do not have swap space. As expected, some calculations failed because the nodes did not have enough local memory.

A potential solution to the problem of diskless nodes not having a local hard drive for swap memory is to access swap space over the network. The Dell research cited in chapter 2 concluded that clusters should not swap over NFS, even if they are using a fast interconnect such as Gigabit Ethernet (Guler, 2002). Since the COTS networks currently used in Beowulf clusters do not include fast interconnects such as Gigabit Ethernet, swapping over the network is a computationally expensive solution. Even if advances in COTS networking equipment should make accessing swap space over a network a reasonable solution, the loss in performance caused by swapping can inexpensively be avoided by ensuring that each node in the cluster has sufficient main memory. Analysis of the benchmark data has demonstrated that the amount of memory in a diskless cluster does not significantly affect performance provided each node in the cluster has a sufficient amount.

4.4 Network Effects on Performance

The EP benchmark was determined to be the only parallel program not affected by a slow network. All other benchmark results indicated that network performance is a limiting factor on diskless cluster performance. Even with the 100Mbps switched network, benchmark results indicated a decrease in performance per node as more nodes were added to the cluster. This drop in performance per node is expected since more nodes in a cluster requires more communication overhead and network bandwidth.

Figure 4-2 shows the performance per node measured in Mflops/sec for each benchmark. The ideal performance per node would appear on this graph as a horizontal line. With the exception of the EP benchmark it is clear that the law of diminishing returns applies to diskless cluster performance. Adding nodes to a cluster may increase performance, but the increase will not be as substantial as the performance increase for the previous node added. The more negative the downward slope of the line, the less cluster performance will improve with additional nodes. Once again it should be noted that the reported performance values of each benchmark should not be compared against each other. The overall trend each benchmark is relevant and useful for describing the performance characteristics of the cluster.

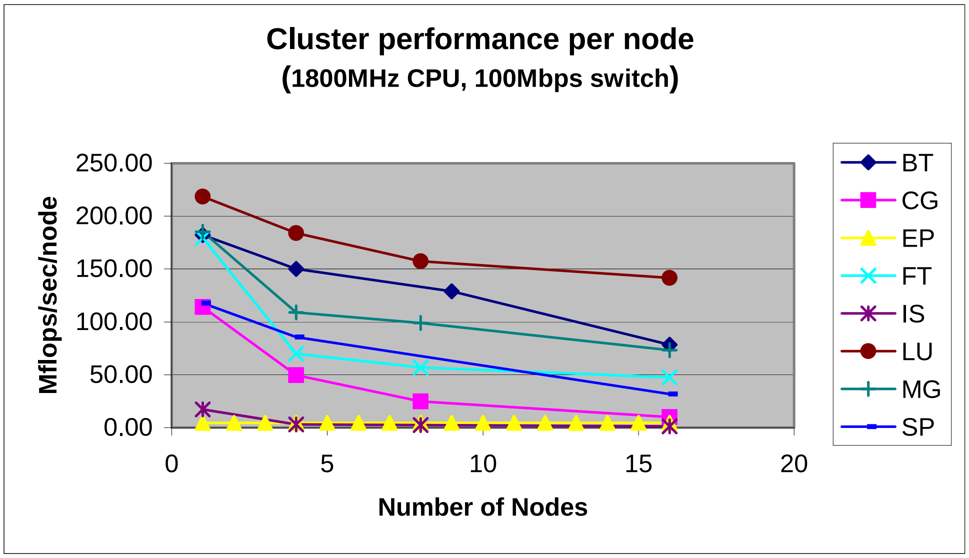

Figure 4-2 Cluster performance per node for a cluster with 1800MHz CPUs, 100Mbps switched network

If the network bandwidth of a cluster is underutilized, performance should increase as nodes are added to the cluster. Figure 4-3 shows the performance of a cluster with 233MHz node CPUs and a 100 Mbps switched network. The lower performance nodes do not require all of the network's available bandwidth. This allows cluster performance to increase without being constrained by the network.

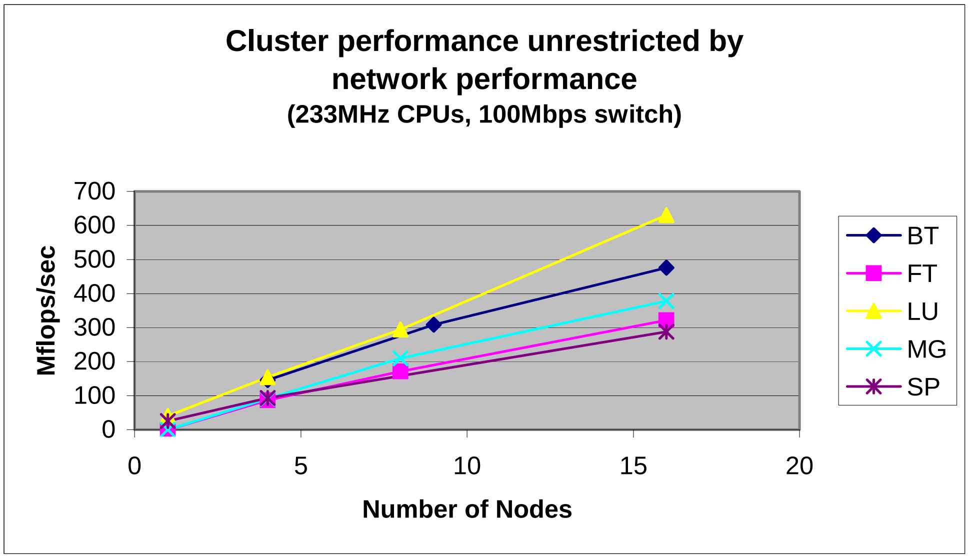

Figure 4-3 Cluster performance unrestricted by network performance

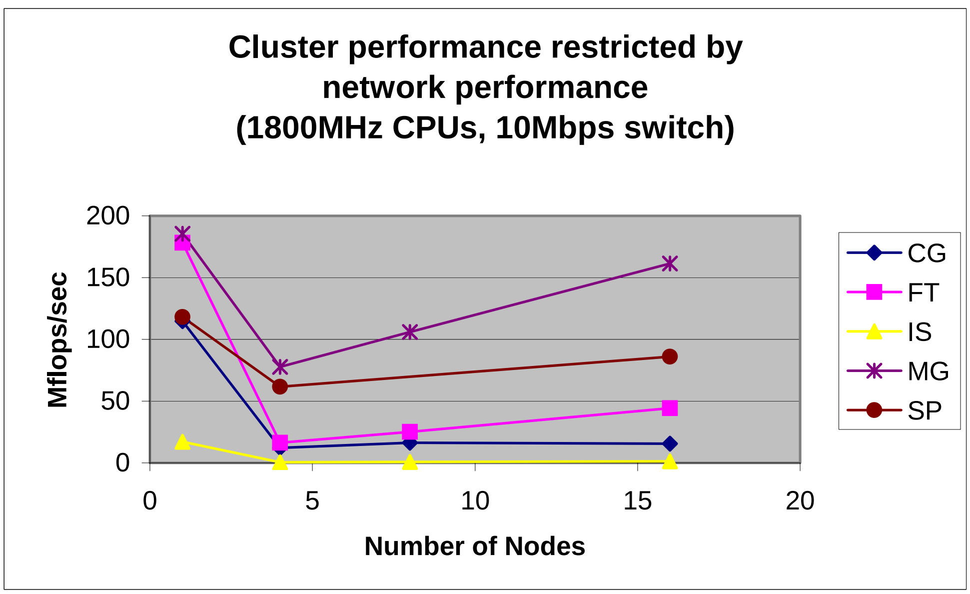

Figure 4-4 Cluster performance restricted by network performance

Contrast the performance increases in Figure 4-3 with a cluster whose performance is restricted by a slower network. Figure 4-4 shows a cluster with 1800MHz nodes and a 10Mbps switch. The higher performance compute nodes require enough bandwidth that the network restricts the increased performance normally achieved by adding nodes to the system. Notice how the cluster performance significantly drops due to the overhead of parallelization and the slow network. For the benchmarks shown, sixteen nodes are not enough to overcome these factors and achieve performance greater than a single node. This is in part due to the fact that additional nodes decrease available network bandwidth and further restricts cluster performance.

4.5 Network Performance and Node CPU Interaction

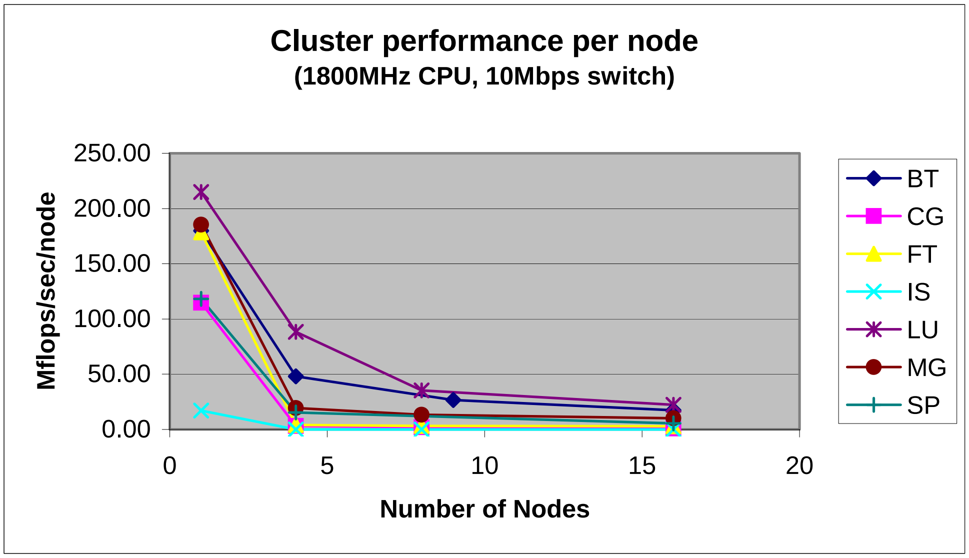

Figure 4-5 Cluster performance per node for a cluster with 1800MHz CPUs, 10Mbps switched network

The number of nodes in a diskless cluster and the network performance are not the only factors that determine the extent which the network will affect overall performance. Figure 4-5 shows the performance per node for the same 1800MHz CPU cluster displayed in Figure 4-2. The difference is that the network in Figure 4-2 is 100 Mbps while the network in Figure 4-5 in only 10 Mbps. Notice how the performance per node drops more dramatically with the 10 Mbps network than the 100 Mbps network. According to Figure 4-5, once the cluster has between four and eight nodes, significant performance will no longer be gained by adding nodes to the cluster. Additional nodes will still improve performance, but adding another 1800MHz computer just to see the cluster's performance increase by approximately 50Mflops is a poor return on investment. The slow network has significantly limited the cluster's performance and future increase in performance through the addition of nodes.

High performance Beowulf clusters with hundreds of nodes would be a waste of money if each additional node only added a few Mflops. This is one of the main reasons most large clusters rely on expensive high performance networks like Gigabit Ethernet, Myrinet™, Quadrics QsNet ™, and Infiniband to achieve network capacities of several hundred megabytes per second.

There is a relationship between the network performance and the CPU performance of the nodes. The combined processing power of the 1800MHz CPUs is able to overload the 10 Mbps switched network. The high performance CPUs have caused the cluster performance per node to drop significantly because of the network's inability to keep up. Figure 4-6 demonstrates the performance per node of a cluster with 233MHz nodes and a 10 Mbps switched network. Although the network is slow, the compute nodes' performance is not enough to completely overpower the network as in Figure 4-5.

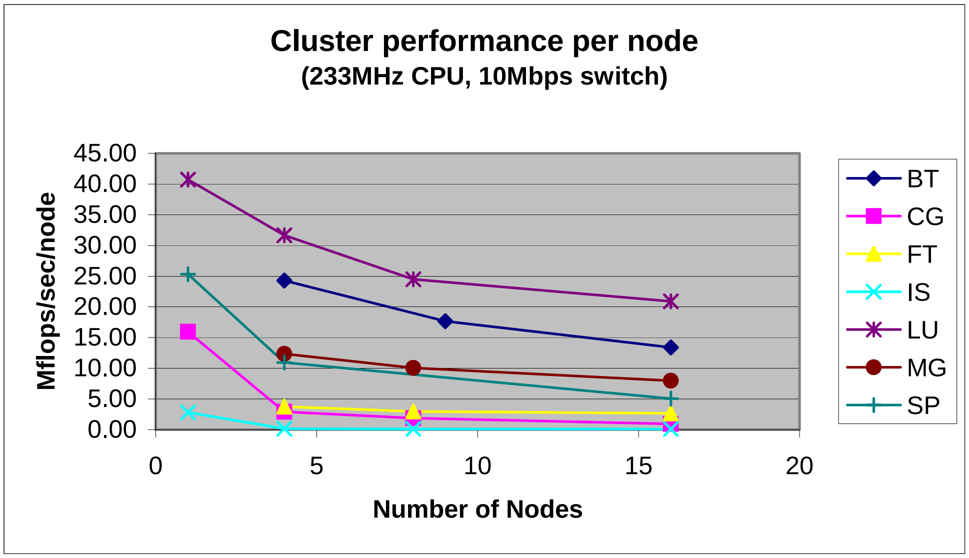

Figure 4-6 Cluster performance per node of a cluster with 233MHz node CPUs and a 10Mbps switch network.

If a slow network can strangle the performance of a cluster with fast node CPUs, then, in some cases, a cluster with slower node CPUs should be able to perform as well or better than a cluster with faster node CPUs. Such a scenario can be found when comparing the performance results of clusters with a 10 Mbps switch network. In Figure 4-7 and 4-8 the MG and FT benchmarks provide effective examples of this scenario.

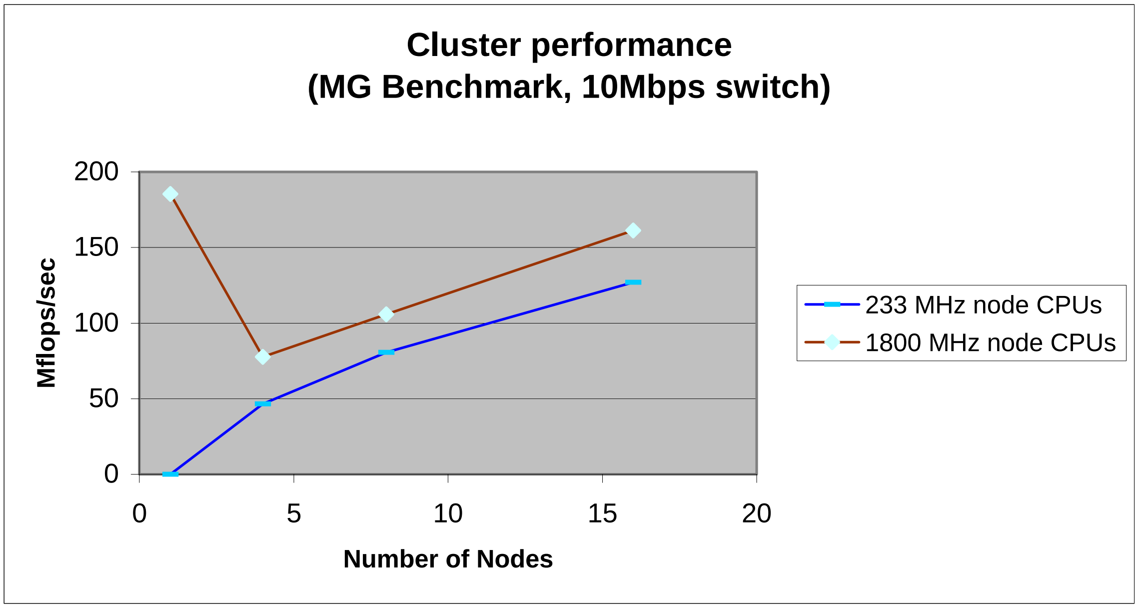

Figure 4-7 MG Benchmark example of low performance node CPUs outperforming high performance node CPUs

The benchmark results in Figures 4-7 and 4-8 illustrate the trend that a cluster with slower node CPUs is able to produce comparable or better performance than a cluster with fast node CPUs, when both clusters have a relatively slow network. The MG benchmark results in Figure 4-7 show that the cluster with 1800MHz CPUs experiences a sharp decline in performance when going from one to four nodes. The cluster with 233MHz CPUs experiences a performance increase that parallels the faster cluster after four nodes. Although the 233MHz CPU cluster does not outperform the first cluster, a cluster of sixteen 233MHz nodes provides roughly the same performance as a cluster with twelve 1800MHz nodes. The processing power of the 1800MHz nodes is being strangled by a slow network.

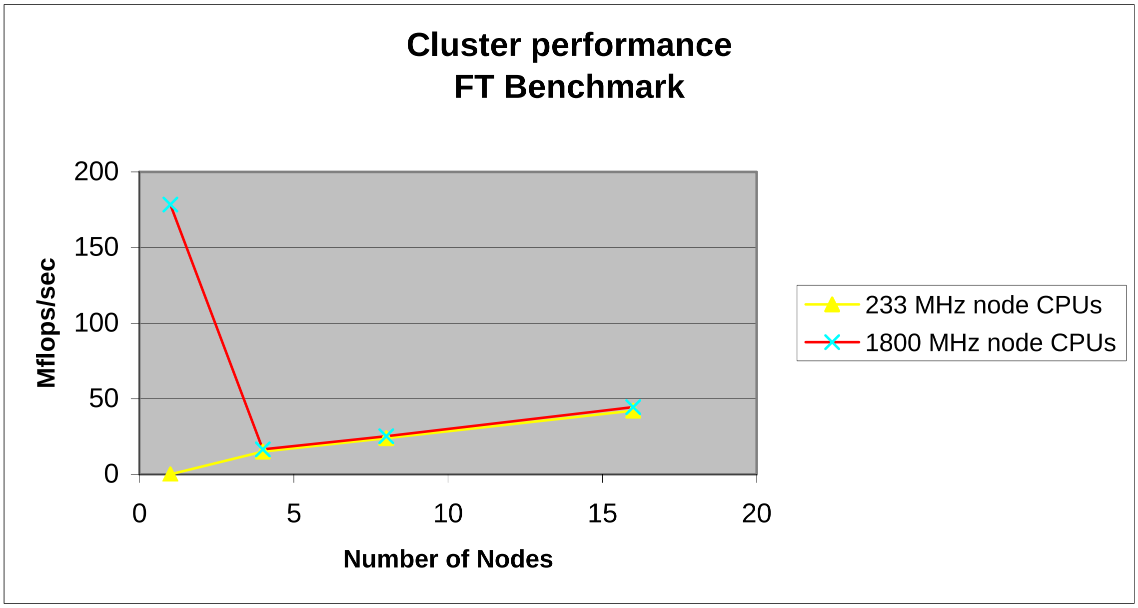

Figure 4-8 FT Benchmark example of low performance node CPUs outperforming high performance node CPUs

The FT benchmark results exhibited a drop in performance for the cluster with 1800MHz nodes that was more severe than the MG results. The performance of both clusters proceed to increase at approximately the same rate after four nodes are added. With a slower 10Mbps switch network, a four-, eight-, or sixteen-node cluster with 233MHz CPUs produced approximately the same performance as a cluster with the same number of 1800MHz CPUs.

A stronger demonstration of the effect of a slow network on cluster performance comes from LU benchmark results. The performance of a cluster with 1800MHz CPUs and a network hub was compared to the performance of a cluster with 233MHz nodes and a 10 Mbps network switch. The compute nodes of the first cluster have a CPU speed over seven times faster than the compute nodes of the second cluster. The network hub and network switch are both 10Mbps. The performance of the 1800MHz CPU cluster experienced a similar loss in performance as the previous two benchmark results, but the similarity ends there. Unlike the other benchmark results, the cluster with 1800MHz CPUs never improved in performance as nodes were added. High performance compute nodes all attempting to push data through a slow network hub at the same time can result in dropped packets, network collisions, and additional network traffic due to retransmission of those packets. In contrast, the cluster with slower 233MHz CPUs did not overload the network and achieved increased performance as compute nodes were added. While the single-node and four-node cluster with 1800MHz nodes had higher performance than the cluster with the same number of 233MHz nodes, the eight- and sixteen-node clusters with 233MHz nodes performed 176% and 443% better than their counterparts. High performance processing nodes require a high performance network to be effective in a clustered environment.

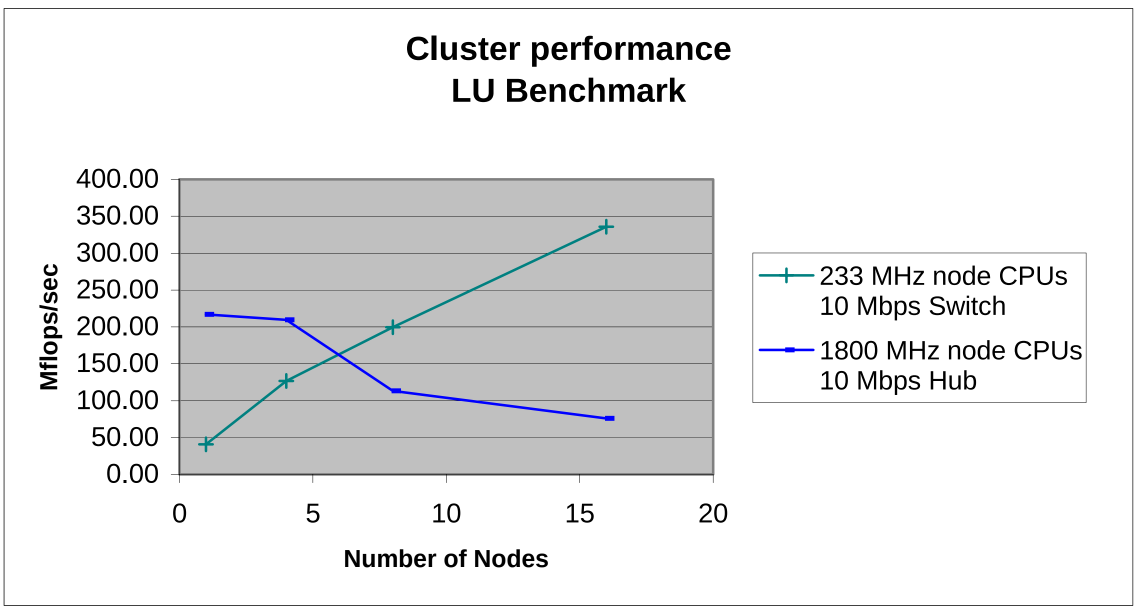

Figure 4-9 LU Benchmark example of low performance node CPUs outperforming high performance node CPUs

The results of these benchmarks lead to an unexpected conclusion. If the node CPUs in a cluster are being upgraded, it is possible that cluster performance may decrease. If this occurs, it is possible that the network is unable to handle the amount of traffic present in the cluster and should be upgraded. When upgrading a cluster, especially a diskless cluster, it is a good practice to upgrade the network until it no longer limits cluster performance before upgrading other parts of the system.

4.6 Embarrassingly Parallel (EP) Application Performance

Cluster performance per node was not significantly affected by a slow network according to the EP benchmark. However, all other benchmarks indicated that a slow network dramatically hindered performance as nodes were added to the system. The sharp decline of performance per node for all benchmarks except EP is illustrated in Figure 4-2. This indicates that even with small diskless clusters, network performance is critical to achieving significant improvements in performance.

The cluster performance per node measured by the EP benchmark appears to be constant in Figure 4-2, but a closer examination of the data shows that this is not the case. Figure 4-10 provides a more detailed picture of the EP performance per node. The graph shows that the performance per node has a general trend of decreasing as nodes are added to the cluster. A statistical analysis of this data provides a least-squares line equation of $P = -0.0008N + 4.5313$ where P is the performance per node and N is the numbers of nodes. The slope of this line indicates that for every node added to the cluster the performance per node, on average, will decrease by 0.0008 Mflops/sec or 800 flops/sec. This calculation was also performed on the EP benchmark results of a cluster with 1800MHz node and a 10 Mbps hub network to see if a slower network would have a greater effect on performance. The performance per node was determined on average to decrease 1800 flops/sec as nodes were added to the cluster.

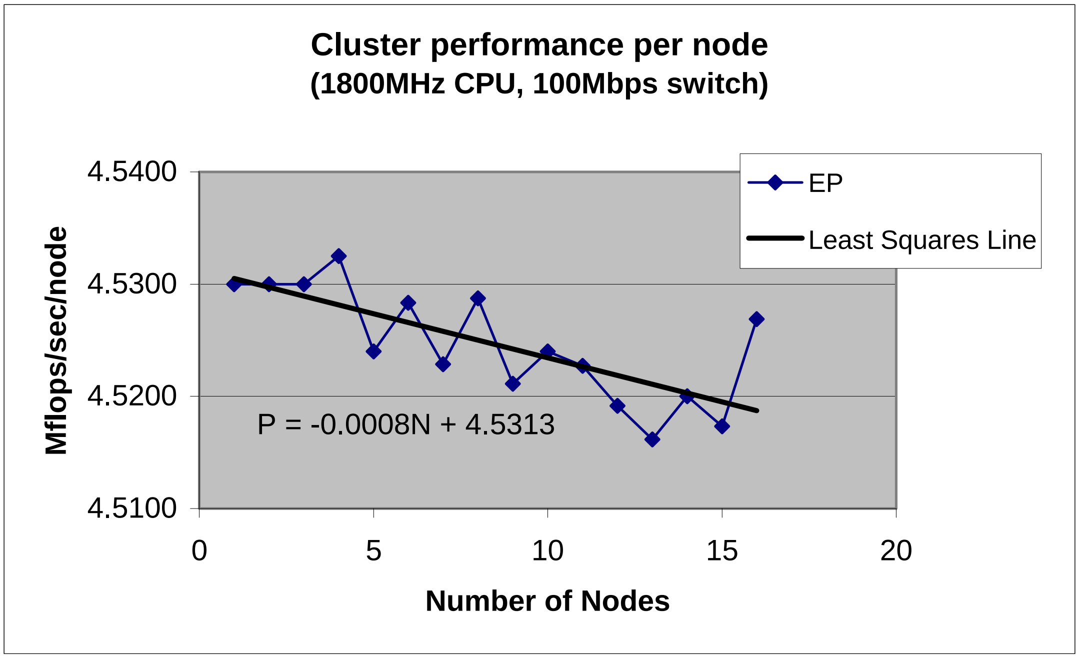

Figure 4-10 Cluster performance per node (EP Benchmark)

Depending on the cluster network, the loss in performance per node measured by the EP benchmark was between 0.018 and 0.040 percent of the average performance gained by additional nodes. Because this loss is so small, it is reasonable to approximate the performance per node measured by the EP benchmark as constant as additional nodes are added to a small, diskless cluster.

Although statistical analysis can be used to approximate the performance per node, the least squares line produced only provides a marginal fit for the data collected. The R-squared value for the regression line fit is 0.8848. This value indicates that approximately 88% of the variance in this data set is explained by the least squares line. One reason for the variability in the graphed data may be the resolution of the EP benchmark. The NAS Parallel Benchmarks only reports performance in increments of .01 Mflops/sec or 10Kflops/sec while the linear regression is approximating a loss in performance per node of 800flops/sec. Therefore, the benchmark may be introducing some of the unaccounted for variance. Random noise in the system may also be affecting the fit of the least squares line. In either case, the greatest distance of any data point from the least squares line is less than 6 Kflops/sec/node, which is not a significant loss in performance given the small cluster size.

4.7 Message Passing Overhead

Whenever designing parallel code, it is important that the question be asked, “Will this problem be completed faster if it is done in parallel?” Not all computational problems are easily parallelized. Some problems are more quickly solved if parallelization is not used. For example, say you wanted to total the value of four numbers. You could parallelize the problem by having two people total two numbers each then report their total to a third person. This third person would then total the numbers given to him and report the results to you. Or you could just add up the numbers yourself and save a lot of time by removing the overhead introduced by multiple conversations. Parallel computing works in a similar manner. The process of parallelizing a problem introduces communications overhead that must be overcome before the problem can be solved faster with multiple machines than with a single computer. Parallelizing a problem usually causes an increase in the time required to solve the problem when the problem being solved is small. The NPB Class A benchmarks are of sufficient size that the parallelizing the problem being solved was not observed to cause a decrease in performance unless a slower network was used.

4.8 Descriptive Performance Model

The following model attempts to describe the performance of low cost, diskless Beowulf clusters. This model identifies factors that affect performance and described performance trends that were observed after extensive benchmark testing.

4.8.1 Factors Affecting Performance

By analyzing cluster performance based on the factors previously described it is possible to produce a general model of diskless Beowulf cluster performance. The factors used to develop this performance model include:

- Compute node main memory
- Network performance including routing and bandwidth
- CPU performance

4.8.1.1 Compute Node Main Memory

Experiments performed to identify the effect of compute node main memory on cluster performance concluded that the amount of memory does not affect cluster performance. This conclusion is valid as long as each node in the cluster has sufficient memory to complete the tasks required of it. The use of a swap partition over the network was determined to be impractical for diskless Beowulf clusters. Therefore, each node must be provided with a sufficient amount of memory.

4.8.1.2 Network Performance

The network was determined to significantly affect the performance of all benchmarks tested except the Embarrassingly Parallel benchmark. Very few useful parallel programs have an embarrassingly parallel architecture, so it is reasonable to concluded that network performance will noticeably affect the performance of a large majority of parallel programs.

Network performance can be described by two factors: routing method, and bandwidth. Overall cluster performance was measured for clusters with a hub. Adding nodes to these clusters did not improve performance. In fact, as more nodes were added to clusters with a hub the overall system performance declined considerably. Clusters with 433MHz CPUs and 1800MHz CPUs were unable to complete the benchmarks tests after more than 24 hours. Using a switch, the same clusters were able to complete all benchmarks within a few hours. A network switch is critical for achieving high performance on a diskless cluster.

The bandwidth of a cluster network was also seen to affect cluster performance. Insufficient network bandwidth can severely limit the performance that additional compute nodes can provide. It some cases, the addition of compute nodes was observed to reduce performance

4.8.1.3 CPU Performance

People often think of computer performance in terms of CPU speed. When greater performance is desired from a computer, a natural solution is to upgrade the CPU. It should be noted that even with a fast network, the sixteen-node cluster with 1800MHz

CPUs was only able to perform approximately 260% better than the sixteen-node cluster with 233MHz CPUs. This is significantly less than 770% better, which would be expected if the CPU clock speeds were directly compared. This result was calculated by averaging the performance increase of all eight benchmarks. If the EP benchmark, which is uncharacteristic of a real-world parallel applications, is removed from the comparison, the cluster with faster CPUs only perform about 230% better.

Perhaps the single most important factor affecting the performance of a diskless Beowulf cluster is network throughput. Diskless clusters depend on network performance for the expensive, yet necessary task of transmitting data between nodes in the cluster. Improving the CPU performance of individual nodes in a cluster with a slow network will not necessarily improve the cluster's performance. It was observed that improving node CPU speeds in a cluster with a slow network can even decrease performance. This leads to the conclusion that when upgrading the performance of a diskless Beowulf cluster, the network infrastructure should be considered in conjunction with the node CPUs.

4.8.2 Performance Model Summary

Analysis of the benchmark data has led to the following model summary for describing the performance of diskless, Beowulf clusters:

- Diskless Beowulf cluster performance is best when the network provides sufficient bandwidth to easily handle the demands placed on it by the cluster nodes.

- Diskless Beowulf clusters can not efficiently use swap space over a network, therefore each node in the cluster must have ample main memory.
- Improved performance of a diskless Beowulf cluster is related directly, but not linearly, to CPU performance provided memory and network bandwidth are sufficient. If either of these factors are not sufficient, then increasing CPU performance can decrease cluster performance
- High-performance CPUs can decrease cluster performance in the presence of a slow network.
- The amount of main memory in a diskless cluster does not affect performance unless it is insufficient
- Insufficient memory in diskless cluster nodes leads to system failure and therefore zero performance.
- A network hub is not appropriate for a diskless Beowulf cluster. A network switch should be employed instead.
- Upgrades to a diskless Beowulf cluster must consider network utilization with other hardware factors.

Chapter 5

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Research Summary

With the inexpensive processing power of commodity off-the-shelf PCs, and the availability of 100Mbps Ethernet, significant low cost benefits can be obtained by combining them to build high performance Beowulf clusters. A Beowulf cluster is a system that usually consists of one master or server node, and one or more client nodes connected via Ethernet. Because Beowulf clusters only use commodity off-the-shelf (COTS) technology, the price-performance ratio of these machines is unmatched by standard supercomputing technology (Sterling, 1997, 2).

Beowulf clusters have many advantages over standard supercomputing technology. The price-performance ratio of Beowulf clusters makes them affordable, yet powerful tools. The low cost hardware used in constructing a Beowulf cluster is available from multiple sources. Beowulf cluster software, including the operating system, and parallel programming packages, is freely available to everyone under the GNU General Public License. This means that the source code can be obtained, used, and modified according to individual needs. In most cases, Beowulf cluster software may be downloaded without cost. Vast amounts of free documentation and tutorials on building Beowulf clusters can be found on the Internet. (Laboratory of Statistical and Computational Physics, Academia Sinica, 2002). In addition to these advantages, Beowulf clusters are well suited to many different applications including massive database searches, finite element analysis, computational fluid dynamics, digital signal processing, and image rendering (Hord, 1999, p. 1).

The drawback of a Beowulf cluster is that problems are not usually solved by calling a support center. Construction and configuration of a Beowulf cluster is often complicated and involves a significant time investment. Instead of a support center, there exists a wealth of information available through FTP sites, web sites, and newsgroups. The information accessible through the Internet was found to be an effective resource for the construction and configuration of the Beowulf clusters used in this research.

The Beowulf clusters in this research were diskless, meaning the slave nodes in the cluster did not have a local hard disk. Instead, they relied on a network accessible drive to store their operating system, applications, and data. Extensive research has concluded that the performance characteristics of Beowulf clusters have been studied for standard diskfull clusters, but very little information is available about the performance of a diskless Beowulf cluster. This research has produced data that was used to identify the factors that affect diskless Beowulf cluster performance.

There are many tools available for benchmarking Beowulf clusters. Researching the available benchmarks used to measure the performance of Beowulf clusters has led to the conclusion that the NAS Parallel Benchmarks (NPB) provide the necessary tools to test a broad range of parallel program architectures. In addition to being able to test parallel programs of various architectures, the NPB suite also provides performance information for clusters of various cluster sizes. The NAS Parallel Benchmark suite was selected to evaluate the performance of the diskless clusters in this research. Analysis of the benchmark results has produced a descriptive model that describes the factors affecting diskless Beowulf cluster performance.

5.2 Conclusions

An analysis of the benchmark results led to the following descriptive performance model for diskless Beowulf clusters:

- Diskless Beowulf cluster performance is best when the network provides sufficient bandwidth to easily handle the demands placed on it by the cluster nodes.
- Diskless Beowulf clusters can not efficiently use swap space over a network, therefore each node in the cluster must have ample main memory.
- Improved performance of a diskless Beowulf cluster is related directly, but not linearly, to CPU performance provided memory and network bandwidth are sufficient. If either of these factors are not sufficient, then increasing CPU performance can decrease cluster performance
- High-performance CPUs can decrease cluster performance in the presence of a slow network.
- The amount of main memory in a diskless cluster does not affect performance unless it is insufficient
- Insufficient memory in diskless cluster nodes leads to system failure and therefore zero performance.
- A network hub is not appropriate for a diskless Beowulf cluster. A network switch should be employed instead.

- Upgrades to a diskless Beowulf cluster must consider network utilization with other hardware factors.

5.3 Recommendations For Future Research

A number of factors known to affect Beowulf cluster performance were not studied. These factors include memory access speed, performance of NFS mounted hardware, various factors affecting master node performance, and network message size. The effect of these factors on cluster performance has been studied for diskfull clusters and in some cases high performance diskless clusters. Existing research was not found to address these factors for low cost diskless clusters. In addition to these factors, research should be conducted that compares the performance of diskfull Beowulf clusters against the performance of diskless Beowulf clusters.

This research has focused on benchmarking Beowulf clusters in which the compute nodes have no hard disk. Removing the hard disk from a cluster's compute nodes has the potential to increase the price / performance ratio of the cluster while reducing noise and power consumption. Modern supercomputing clusters take the idea of removing the compute node's hard disk a step further. The compute nodes in some high performance clusters are completely removed from access to a network drive. The nodes of these supercomputing clusters only have access to secondary media during boot time. Research investigating the performance of a Beowulf cluster of similar configuration should be completed to determine the potential of a low cost cluster that not only has no access to a local hard disk; it has no access to a hard disk whatever.

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7 APPENDIX A

This appendix contains graphical representations of performance results for each benchmark. The output files produced by the NAS Parallel Benchmarks are located in Appendix C if more detail is required.

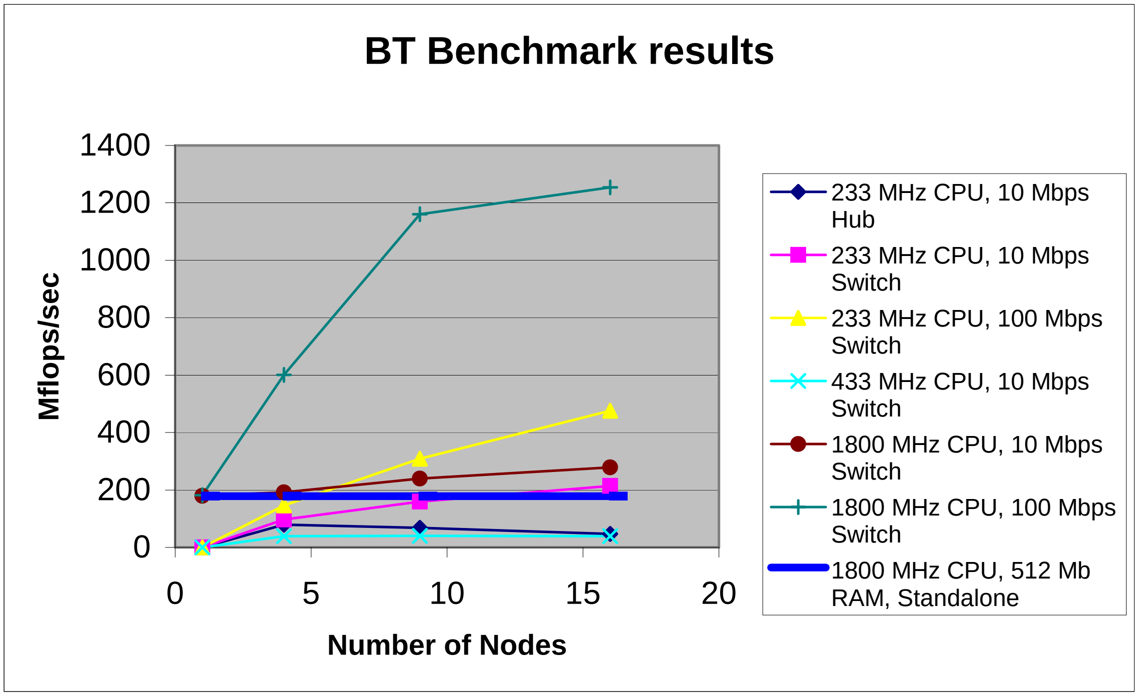

Figure 7-1 BT Benchmark results

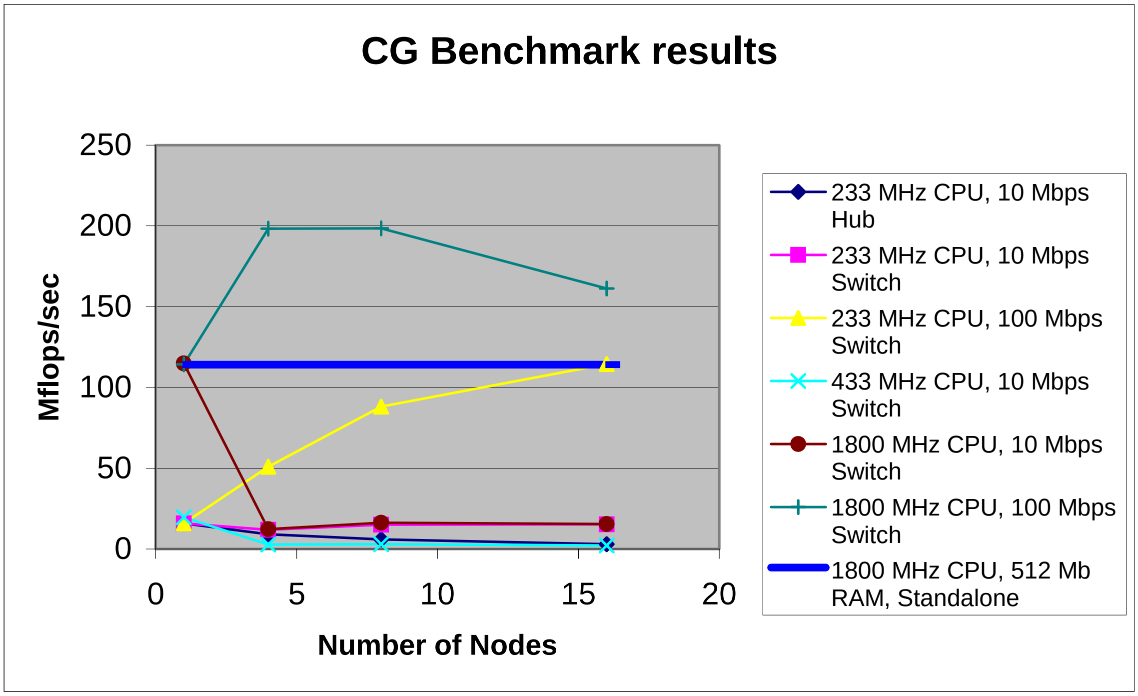

Figure 7-2 CG Benchmark results

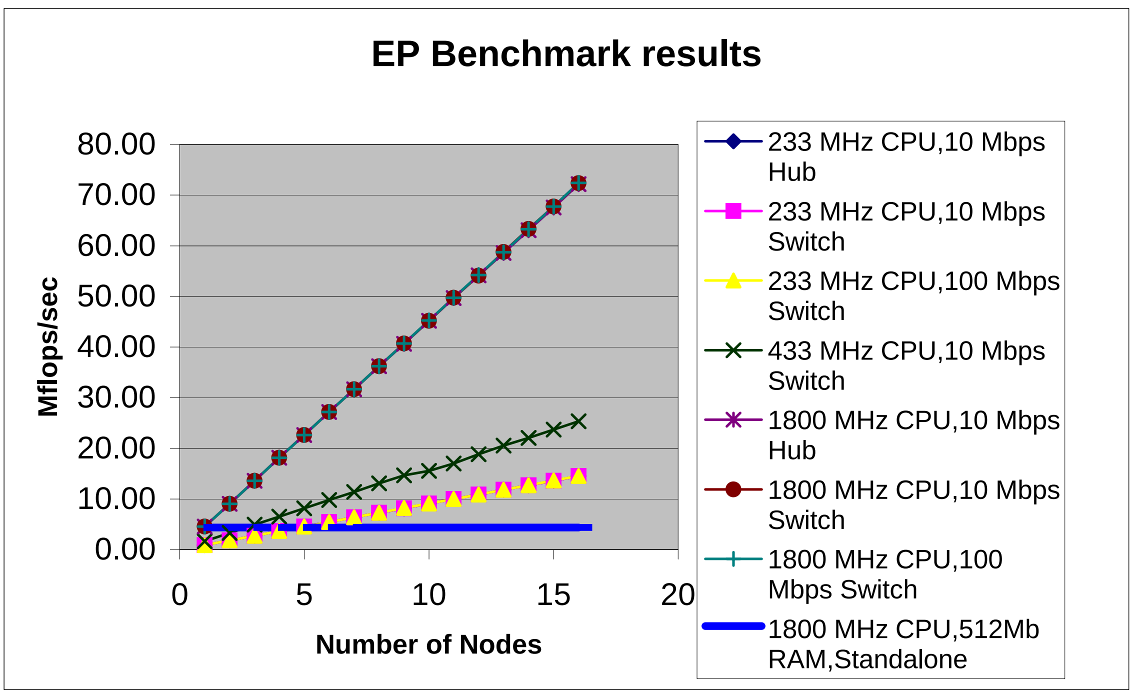

Figure 7-3 EP Benchmark results

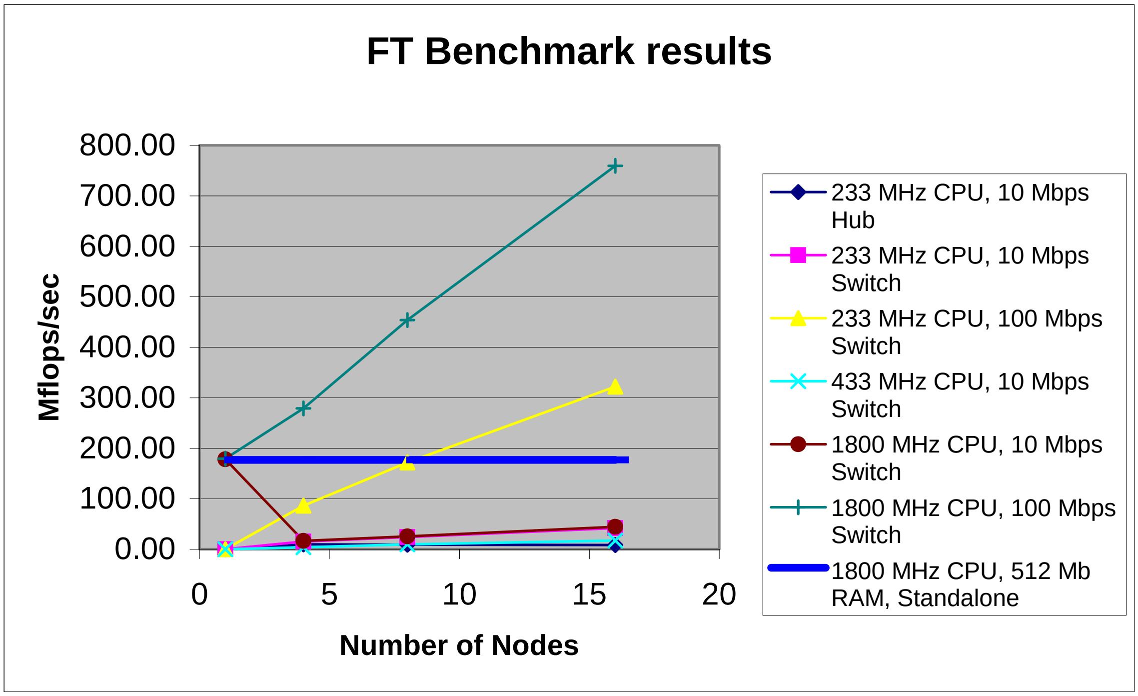

Figure 7-4 FT Benchmark results

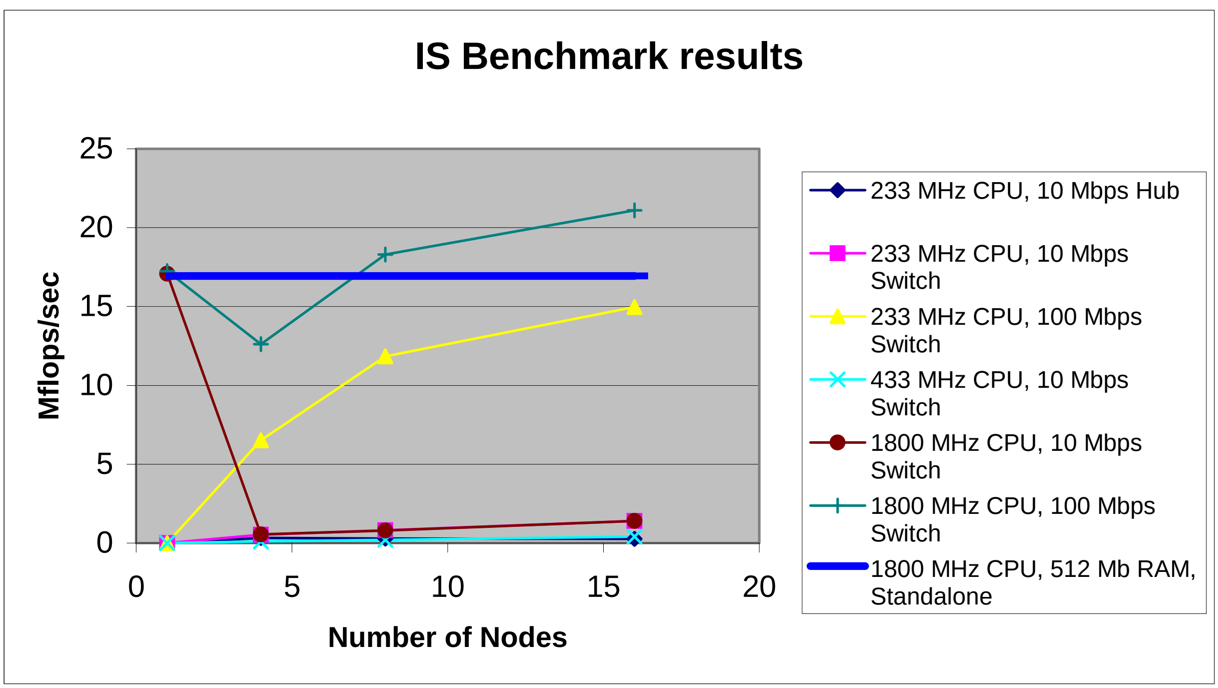

Figure 7-5 IS Benchmark results

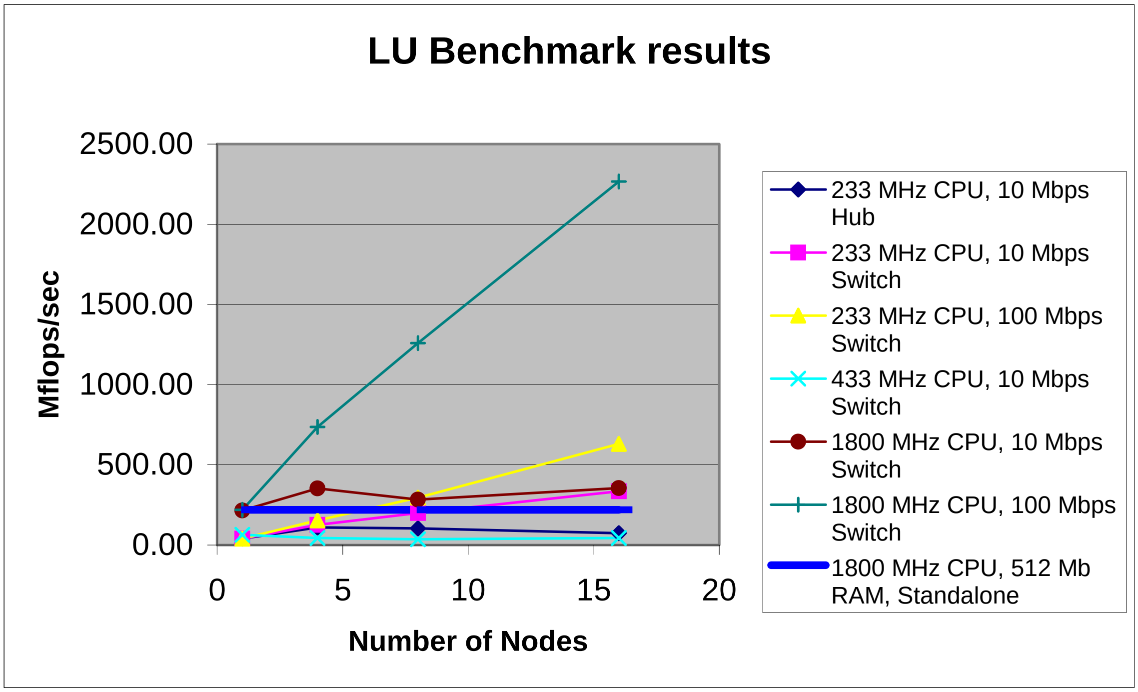

Figure 7-6 LU Benchmark results

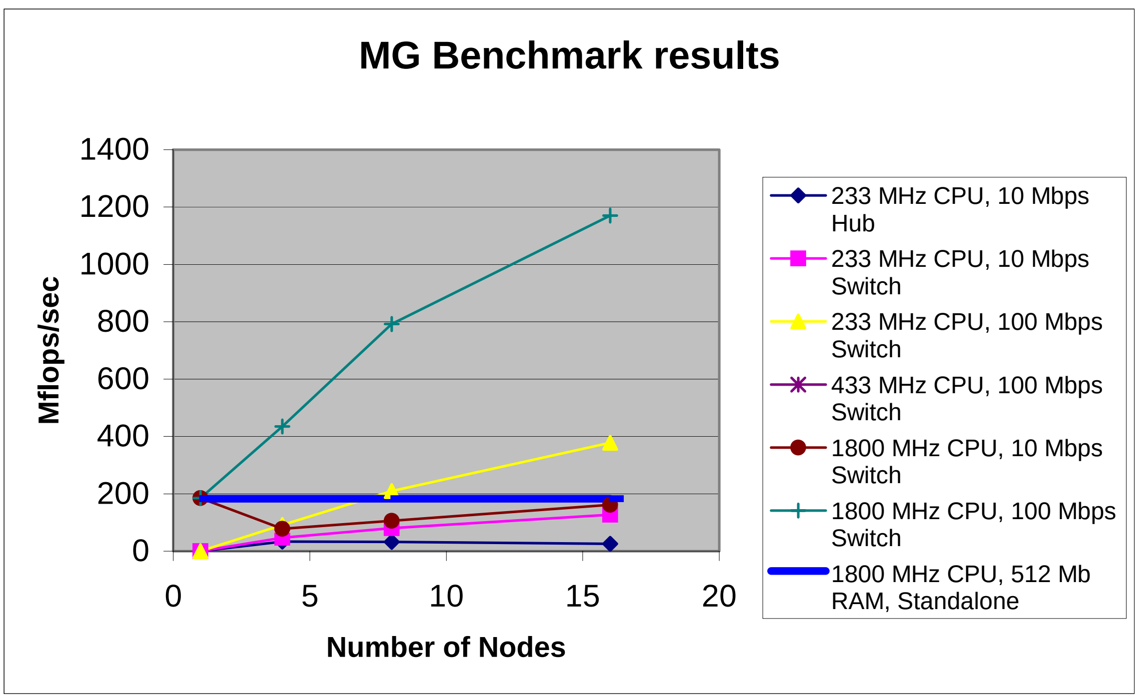

Figure 7-7 MG Benchmark results

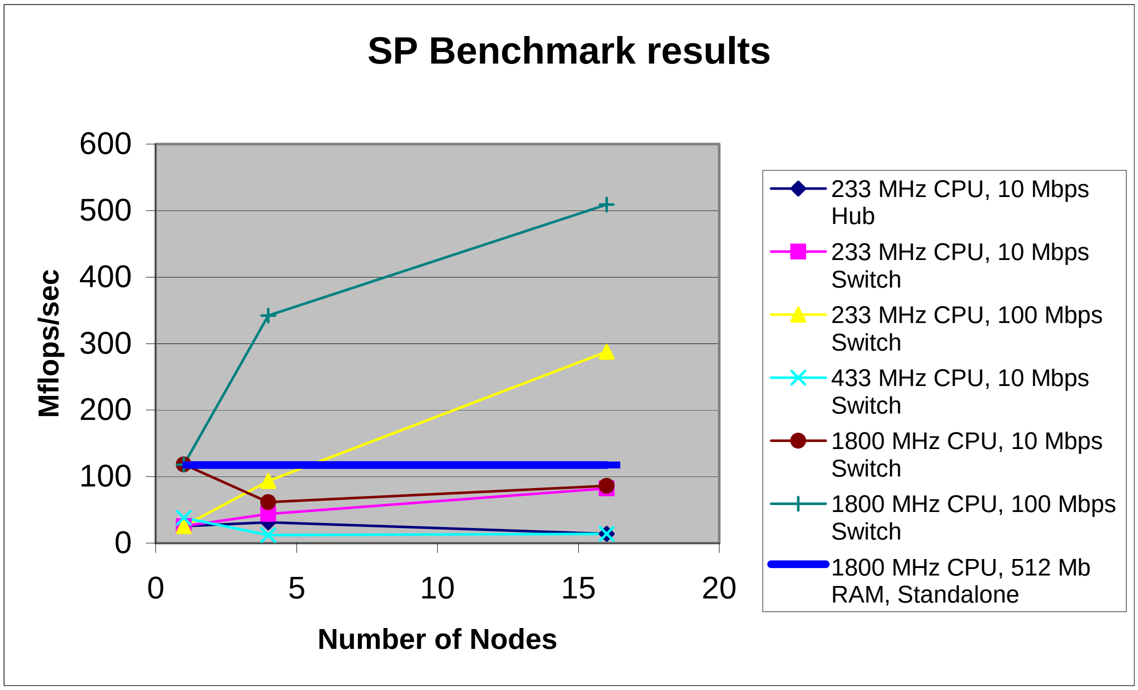

Figure 7-8 SP Benchmark results

8 APPENDIX B

This appendix contains the listings of several configuration files and setup scripts that were used to construct the Beowulf clusters used in this research.

Diskless kernel configuration file

```
#
# Automatically generated make config: don't edit
#
CONFIG_X86=y
# CONFIG_SBUS is not set
CONFIG_UID16=y

#
# Code maturity level options
#
# CONFIG_EXPERIMENTAL is not set

#
# Loadable module support
#
# CONFIG_MODULES is not set

#
# Processor type and features
#
# CONFIG_LOLAT is not set
# CONFIG_M386 is not set
# CONFIG_M486 is not set
CONFIG_M586=y
# CONFIG_M586TSC is not set
# CONFIG_M586MMX is not set
# CONFIG_M686 is not set
# CONFIG_MPENTIUMIII is not set
# CONFIG_MPENTIUM4 is not set
# CONFIG_MK6 is not set
# CONFIG_MK7 is not set
# CONFIG_MELAN is not set
# CONFIG_MCRUSOE is not set
# CONFIG_MWINCHIPC6 is not set
```

```
# CONFIG_MWINCHIP2 is not set
# CONFIG_MWINCHIP3D is not set
# CONFIG_MCYRIXIII is not set
CONFIG_X86_WP_WORKS_OK=y
CONFIG_X86_INVLPG=y
CONFIG_X86_CMPXCHG=y
CONFIG_X86_XADD=y
CONFIG_X86_BSWAP=y
CONFIG_X86_POPAD_OK=y
# CONFIG_RWSEM_GENERIC_SPINLOCK is not set
CONFIG_RWSEM_XCHGADD_ALGORITHM=y
CONFIG_X86_L1_CACHE_SHIFT=5
CONFIG_X86_USE_STRING_486=y
CONFIG_X86_ALIGNMENT_16=y
CONFIG_X86_PPRO_FENCE=y
# CONFIG_X86_F00F_WORKS_OK is not set
# CONFIG_X86_MCE is not set

#
# CPU Frequency scaling
#
# CONFIG_TOSHIBA is not set
# CONFIG_I8K is not set
# CONFIG_MICROCODE is not set
# CONFIG_X86_MSR is not set
# CONFIG_X86_CPUID is not set
# CONFIG_E820_PROC is not set
CONFIG_NOHIGHMEM=y
# CONFIG_HIGHMEM4G is not set
# CONFIG_HIGHMEM64G is not set
# CONFIG_HIGHMEM is not set
# CONFIG_MATH_EMULATION is not set
# CONFIG_MTRR is not set
# CONFIG_SMP is not set
# CONFIG_X86_UP_APIC is not set
# CONFIG_X86_TSC_DISABLE is not set

#
# General setup
#
CONFIG_NET=y
CONFIG_PCI=y
# CONFIG_PCI_GOBIOS is not set
# CONFIG_PCI_GODIRECT is not set
CONFIG_PCI_GOANY=y
CONFIG_PCI_BIOS=y
```

```
CONFIG_PCI_DIRECT=y
# CONFIG_ISA is not set
CONFIG_PCI_NAMES=y
# CONFIG_EISA is not set
# CONFIG_MCA is not set
# CONFIG_HOTPLUG is not set
# CONFIG_PCMCIA is not set
# CONFIG_HOTPLUG_PCI is not set
CONFIG_SYSVIPC=y
# CONFIG_BSD_PROCESS_ACCT is not set
CONFIG_SYSCTL=y
CONFIG_KCORE_ELF=y
# CONFIG_KCORE_AOUT is not set
CONFIG_BINFMT_AOUT=y
CONFIG_BINFMT_ELF=y
CONFIG_BINFMT_MISC=y
CONFIG_PM=y
# CONFIG_APM is not set

#
# Memory Technology Devices (MTD)
#
# CONFIG_MTD is not set

#
# Parallel port support
#
# CONFIG_PARPORT is not set

#
# Plug and Play configuration
#
CONFIG_PNP=y
# CONFIG_ISAPNP is not set

#
# Block devices
#
CONFIG_BLK_DEV_FD=y
# CONFIG_BLK_CPQ_DA is not set
# CONFIG_BLK_CPQ_CISS_DA is not set
# CONFIG_BLK_DEV_DAC960 is not set
# CONFIG_BLK_DEV_LOOP is not set
# CONFIG_BLK_DEV_NBD is not set
# CONFIG_BLK_DEV_RAM is not set
# CONFIG_BLK_STATS is not set
```

```
#
# Multi-device support (RAID and LVM)
#
# CONFIG_MD is not set

#
# Cryptography support (CryptoAPI)
#
# CONFIG_CRYPTO is not set

#
# 128 bit blocksize
#

#
# Networking options
#
CONFIG_PACKET=y
# CONFIG_PACKET_MMAP is not set
# CONFIG_NETLINK_DEV is not set
# CONFIG_NETFILTER is not set
# CONFIG_FILTER is not set
CONFIG_UNIX=y
CONFIG_INET=y
# CONFIG_TUX is not set
CONFIG_IP_MULTICAST=y
# CONFIG_IP_ADVANCED_ROUTER is not set
CONFIG_IP_PNP=y
CONFIG_IP_PNP_DHCP=y
CONFIG_IP_PNP_BOOTP=y
CONFIG_IP_PNP_RARP=y
# CONFIG_NET_IPIP is not set
# CONFIG_NET_IPGRE is not set
# CONFIG_IP_MROUTE is not set
# CONFIG_INET_ECN is not set
# CONFIG_SYN_COOKIES is not set
# CONFIG_VLAN_8021Q is not set

#
#
#
# CONFIG_IPX is not set
# CONFIG_ATALK is not set

#
```

```
# Appletalk devices
#
# CONFIG_DECNET is not set
# CONFIG_BRIDGE is not set

#
# QoS and/or fair queueing
#
# CONFIG_NET_SCHED is not set

#
# Network testing
#
# CONFIG_NET_PKTGEN is not set

#
# Telephony Support
#
# CONFIG_PHONE is not set

#
# ATA/IDE/MFM/RLL support
#
# CONFIG_IDE is not set
# CONFIG_BLK_DEV_IDE_MODES is not set
# CONFIG_BLK_DEV_HD is not set

#
# SCSI support
#
# CONFIG_SCSI is not set

#
# Fusion MPT device support
#
# CONFIG_FUSION_BOOT is not set
# CONFIG_FUSION_ISENSE is not set
# CONFIG_FUSION_CTL is not set
# CONFIG_FUSION_LAN is not set

#
# I2O device support
#
# CONFIG_I2O is not set

#
```

```
# Network device support
#
CONFIG_NETDEVICES=y

#
# ARCnet devices
#
# CONFIG_ARCNET is not set
CONFIG_DUMMY=y
# CONFIG_BONDING is not set
# CONFIG_EQUALIZER is not set
# CONFIG_TUN is not set

#
# Ethernet (10 or 100Mbit)
#
CONFIG_NET_ETHERNET=y
# CONFIG_HAPPYMEAL is not set
# CONFIG_SUNGEM is not set
CONFIG_NET_VENDOR_3COM=y
CONFIG_VORTEX=y
# CONFIG_NET_VENDOR_SMC is not set
# CONFIG_NET_VENDOR_RACAL is not set
# CONFIG_HP100 is not set
# CONFIG_NET_PCI is not set
# CONFIG_NET_POCKET is not set

#
# Ethernet (1000 Mbit)
#
# CONFIG_ACENIC is not set
# CONFIG_DL2K is not set
# CONFIG_E1000 is not set
# CONFIG_NS83820 is not set
# CONFIG_HAMACHI is not set
# CONFIG_R8169 is not set
# CONFIG_SK98LIN is not set
# CONFIG_TIGON3 is not set
# CONFIG_FDDI is not set
# CONFIG_NETCONSOLE is not set
# CONFIG_PPP is not set
# CONFIG_SLIP is not set

#
# Wireless LAN (non-hamradio)
#
```

```
# CONFIG_NET_RADIO is not set

#
# Token Ring devices
#
# CONFIG_TR is not set
# CONFIG_NET_FC is not set

#
# Wan interfaces
#
# CONFIG_WAN is not set

#
# Amateur Radio support
#
# CONFIG_HAMRADIO is not set

#
# IrDA (infrared) support
#
# CONFIG_IRDA is not set

#
# ISDN subsystem
#
# CONFIG_ISDN is not set
# CONFIG_KALLSYMS is not set

#
# Input core support
#
# CONFIG_INPUT is not set
CONFIG_INPUT_MOUSEDEV_SCREEN_X=1024
CONFIG_INPUT_MOUSEDEV_SCREEN_Y=768

#
# Character devices
#
CONFIG_VT=y
# CONFIG_ECC is not set
CONFIG_VT_CONSOLE=y
# CONFIG_SERIAL is not set
# CONFIG_SERIAL_NONSTANDARD is not set
CONFIG_UNIX98_PTYS=y
CONFIG_UNIX98_PTY_COUNT=256
```

```
#
# I2C support
#
# CONFIG_I2C is not set

#
# Mice
#
# CONFIG_BUSMOUSE is not set
# CONFIG_MOUSE is not set

#
# Joysticks
#
# CONFIG_INPUT_GAMEPORT is not set

#
# Input core support is needed for gameports
#

#
# Input core support is needed for joysticks
#
# CONFIG_QIC02_TAPE is not set
# CONFIG_IPMI_HANDLER is not set

#
# Watchdog Cards
#
# CONFIG_WATCHDOG is not set
# CONFIG_SCx200_GPIO is not set
# CONFIG_AMD_RNG is not set
# CONFIG_INTEL_RNG is not set
# CONFIG_AMD_PM768 is not set
# CONFIG_NVRAM is not set
# CONFIG_RTC is not set
# CONFIG_DTLK is not set
# CONFIG_R3964 is not set
# CONFIG_APPLICOM is not set

#
# Ftape, the floppy tape device driver
#
# CONFIG_FTAPE is not set
# CONFIG_AGP is not set
```

```
# CONFIG_DRM is not set
# CONFIG_MWAVE is not set
# CONFIG_BATTERY_GERICOM is not set

#
# Multimedia devices
#
# CONFIG_VIDEO_DEV is not set

#
# Crypto Hardware support
#
# CONFIG_CRYPTO is not set

#
# File systems
#
# CONFIG_QUOTA is not set
# CONFIG_AUTOFS_FS is not set
CONFIG_AUTOFS4_FS=y
# CONFIG_REISERFS_FS is not set
# CONFIG_EXT3_FS is not set
# CONFIG_JBD is not set
# CONFIG_FAT_FS is not set
# CONFIG_CRAMFS is not set
CONFIG_TMPFS=y
CONFIG_RAMFS=y
# CONFIG_ISO9660_FS is not set
# CONFIG_JFS_FS is not set
# CONFIG_MINIX_FS is not set
# CONFIG_VXFS_FS is not set
# CONFIG_NTFS_FS is not set
# CONFIG_HPFS_FS is not set
CONFIG_PROC_FS=y
# CONFIG_DEVPTS_FS is not set
# CONFIG_QNX4FS_FS is not set
# CONFIG_ROMFS_FS is not set
CONFIG_EXT2_FS=y
# CONFIG_SYSV_FS is not set
# CONFIG_UDF_FS is not set
# CONFIG_UFS_FS is not set

#
# Network File Systems
#
# CONFIG_CODA_FS is not set
```

```
CONFIG_NFS_FS=y
# CONFIG_NFS_V3 is not set
CONFIG_ROOT_NFS=y
# CONFIG_NFSD is not set
CONFIG_SUNRPC=y
CONFIG_LOCKD=y
# CONFIG_SMB_FS is not set
# CONFIG_NCP_FS is not set
# CONFIG_ZISOFS_FS is not set

#
# Partition Types
#
# CONFIG_PARTITION_ADVANCED is not set
CONFIG_MSDOS_PARTITION=y
# CONFIG_SMB_NLS is not set
CONFIG_NLS=y

#
# Native Language Support
#
CONFIG_NLS_DEFAULT="iso8859-1"
CONFIG_NLS_CODEPAGE_437=y
# CONFIG_NLS_CODEPAGE_737 is not set
# CONFIG_NLS_CODEPAGE_775 is not set
# CONFIG_NLS_CODEPAGE_850 is not set
# CONFIG_NLS_CODEPAGE_852 is not set
# CONFIG_NLS_CODEPAGE_855 is not set
# CONFIG_NLS_CODEPAGE_857 is not set
# CONFIG_NLS_CODEPAGE_860 is not set
# CONFIG_NLS_CODEPAGE_861 is not set
# CONFIG_NLS_CODEPAGE_862 is not set
# CONFIG_NLS_CODEPAGE_863 is not set
# CONFIG_NLS_CODEPAGE_864 is not set
# CONFIG_NLS_CODEPAGE_865 is not set
# CONFIG_NLS_CODEPAGE_866 is not set
# CONFIG_NLS_CODEPAGE_869 is not set
# CONFIG_NLS_CODEPAGE_936 is not set
# CONFIG_NLS_CODEPAGE_950 is not set
# CONFIG_NLS_CODEPAGE_932 is not set
# CONFIG_NLS_CODEPAGE_949 is not set
# CONFIG_NLS_CODEPAGE_874 is not set
# CONFIG_NLS_ISO8859_8 is not set
# CONFIG_NLS_CODEPAGE_1250 is not set
# CONFIG_NLS_CODEPAGE_1251 is not set
# CONFIG_NLS_ISO8859_1 is not set
```

```
# CONFIG_NLS_ISO8859_2 is not set
# CONFIG_NLS_ISO8859_3 is not set
# CONFIG_NLS_ISO8859_4 is not set
# CONFIG_NLS_ISO8859_5 is not set
# CONFIG_NLS_ISO8859_6 is not set
# CONFIG_NLS_ISO8859_7 is not set
# CONFIG_NLS_ISO8859_9 is not set
# CONFIG_NLS_ISO8859_13 is not set
# CONFIG_NLS_ISO8859_14 is not set
# CONFIG_NLS_ISO8859_15 is not set
# CONFIG_NLS_KOI8_R is not set
# CONFIG_NLS_KOI8_U is not set
# CONFIG_NLS_UTF8 is not set

#
# Console drivers
#
CONFIG_VGA_CONSOLE=y
# CONFIG_VIDEO_SELECT is not set

#
# Sound
#
# CONFIG_SOUND is not set

#
# USB support
#
# CONFIG_USB is not set

#
# Additional device driver support
#
# CONFIG_NET_BROADCOM is not set
# CONFIG_CIPE is not set
# CONFIG_CRYPTO_AEP is not set
# CONFIG_MEGARAC is not set
# CONFIG_FC_QLA2200 is not set
# CONFIG_FC_QLA2300 is not set

#
# Bluetooth support
#
# CONFIG_BLUEZ is not set

#
```

```
# Kernel hacking
#
# CONFIG_DEBUG_KERNEL is not set

#
# Library routines
#
CONFIG_ZLIB_INFLATE=y
CONFIG_ZLIB_DEFLATE=y
```

LILO configuration file

```
boot=/dev/fd0
install=/boot/boot.b
map=/boot/map
read-write
backup=/dev/null
image=/diskless-kernel
label=disklessBoot
root=/dev/nfs
append="nfsroot=/cluster/nodes ip=dhcp"
```

Mknodedisk script file

```
#!/bin/bash
fdformat /dev/fd0H1440
mke2fs /dev/fd0
mount /dev/fd0 /mnt/floppy
rm -rf /mnt/floppy/lost+found
mkdir /mnt/floppy/boot
mkdir /mnt/floppy/dev
cp -R /dev/null /mnt/floppy/dev/
cp -R /dev/fd0 /mnt/floppy/dev/
cp -R /dev/nfs /mnt/floppy/dev/

# if /dev/nfs does not exist use the following to create it:
#	mknod /dev/nfs c 0 255
#

cp /boot/boot.b /mnt/floppy/boot
cp /cluster/config/lilo.diskless.conf /mnt/floppy/
```

```
cp /cluster/nodes/usr/secrc/diskless/arch/i386/boot/bzImage /mnt/floppy/diskless-kernel
lilo -v -c -C lilo.diskless.conf -r /mnt/floppy
umount /mnt/floppy
```

DHCP server configuration file

```
# /etc/dhcpd.conf
ddns-update-style ad-hoc;

subnet 10.10.10.0 netmask 255.255.255.0 {
	range 10.10.10.101 10.10.10.116;
	option broadcast-address 10.10.10.255;

	host tadpole1 {
		hardware ethernet 00:50:04:d6:9a:c8;
		fixed-address 10.10.10.101;
		option host-name "tadpole1";
	}
	host tadpole2 {
		hardware ethernet 00:50:04:d6:99:26;
		fixed-address 10.10.10.102;
		option host-name "tadpole2";
	}
	host tadpole3 {
		hardware ethernet 00:50:04:80:33:dd;
		fixed-address 10.10.10.103;
		option host-name "tadpole3";
	}
	host tadpole4 {
		hardware ethernet 00:50:04:23:d7:85;
		fixed-address 10.10.10.104;
		option host-name "tadpole4";
	}
	host tadpole5 {
		hardware ethernet 00:50:04:72:71:a5;
		fixed-address 10.10.10.105;
		option host-name "tadpole5";
	}
	host tadpole6 {
		hardware ethernet 00:50:04:d6:99:8b;
		fixed-address 10.10.10.106;
		option host-name "tadpole6";
	}
	host tadpole7 {
```

```
        hardware ethernet 00:50:04:72:90:33;
        fixed-address 10.10.10.107;
        option host-name "tadpole7";
}
host tadpole8 {
        hardware ethernet 00:50:04:72:a8:53;
        fixed-address 10.10.10.108;
        option host-name "tadpole8";
}
host tadpole9 {
        hardware ethernet 00:01:02:2c:12:24;
        fixed-address 10.10.10.109;
        option host-name "tadpole9";
}
host tadpole10 {
        hardware ethernet 00:10:5a:d1:0f:bc;
        fixed-address 10.10.10.110;
        option host-name "tadpole10";
}
host tadpole11 {
        hardware ethernet 00:50:04:13:d8:3d;
        fixed-address 10.10.10.111;
        option host-name "tadpole11";
}
host tadpole12 {
        hardware ethernet 00:50:04:a7:77:af;
        fixed-address 10.10.10.112;
        option host-name "tadpole12";
}
host tadpole13 {
        hardware ethernet 00:50:04:d6:9a:6f;
        fixed-address 10.10.10.113;
        option host-name "tadpole13";
}
host tadpole14 {
        hardware ethernet 00:50:04:d6:9a:70;
        fixed-address 10.10.10.114;
        option host-name "tadpole14";
}
host tadpole15 {
        hardware ethernet 00:50:04:d6:94:8a;
        fixed-address 10.10.10.115;
        option host-name "tadpole15";
}
host tadpole16 {
        hardware ethernet 00:50:04:72:6f:c6;
```

```
                fixed-address 10.10.10.116;
                option host-name "tadpole16";
        }

}
```

```
#!/bin/bash
#
# Modified Startup Script for diskless nodes.
# The diskless kernel is limited in that it does not support loadable
# modules and therefore portions of the standard startup script
# for Redhat 9.0 will fail.  These portions have commented out along
# with some sections that are not needed for the simple diskless nodes.
#
# Comment : CRN
#
# /etc/rc.d/rc.sysinit - run once at boot time
#
# Taken in part from Miquel van Smoorenburg's bcheckrc.
#

# Rerun ourselves through initlog
if [ -z "$IN_INITLOG" -a -x /secbin/initlog ]; then
   exec /secbin/initlog $INITLOG_ARGS -r /etc/rc.d/rc.sysinit
fi

# If we're using devfs, start devfsd now - we need the old device names
[ -e /dev/.devfsd -a -x /secbin/devfsd ] && /secbin/devfsd /dev


# The hostname is set by DHCP so we don't want to override it
#HOSTNAME=`/bin/hostname`
if [ -f /etc/secysconfig/network ]; then
   . /etc/secysconfig/network
else
   NETWORKING=no
fi
#if [ -z "$HOSTNAME" -o "$HOSTNAME" = "(none)" ]; then
#    HOSTNAME=localhost
#fi

. /etc/init.d/functions

# Start the graphical boot, if necessary
if [ "$BOOTUP" = "graphical" ]; then
```

```
  if [ -x /usr/bin/rhgb ]; then
     /usr/bin/rhgb
  else
     export BOOTUP=color
  fi
fi

last=0
for i in `LC_ALL=C grep '^[0-9]*.*respawn:/secbin/mingetty' /etc/inittab | sed 's/^.*
tty\([0-9][0-9]*\).*/\1/g'`; do
      > /dev/tty$i
      last=$i
done
if [ $last -gt 0 ]; then
     > /dev/tty$((last+1))
     > /dev/tty$((last+2))
fi

if [ "`/secbin/consoletype`" = "vt" -a -x /secbin/secetsysfont ]; then

   echo -n "Setting default font ($SYSFONT): "
   /secbin/secetsysfont
   if [ $? -eq 0 ]; then
      success
   else
      failure
   fi
   echo ; echo
fi

# Print a text banner.
echo -en $"\t\tWelcome to "
if LC_ALL=C grep -q "Red Hat" /etc/redhat-release ; then
 [ "$BOOTUP" = "color" ] && echo -en "\\033[0;31m"
 echo -en "Red Hat"
 [ "$BOOTUP" = "color" ] && echo -en "\\033[0;39m"
 PRODUCT=`sed "s/Red Hat \(.*\) release.*/\1/" /etc/redhat-release`
 echo " $PRODUCT"
else
 PRODUCT=`sed "s/ release.*//g" /etc/redhat-release`
 echo "$PRODUCT"
fi
if [ "$PROMPT" != "no" ]; then
 echo -en $"\t\tPress 'I' to enter interactive startup."
 echo
 sleep 1
```

```
fi

# Fix console loglevel
/bin/dmesg -n $LOGLEVEL

# Mount /proc (done here so volume labels can work with fsck)
action $"Mounting proc file system: " mount -n -t proc /proc /proc

# Unmount the initrd, if necessary
if LC_ALL=C grep -q /initrd /proc/mounts && ! LC_ALL=C grep -q /initrd/loopfs
/proc/mounts ; then
  if [ -e /initrd/dev/.devfsd ]; then
    umount /initrd/dev
  fi
  action $"Unmounting initrd: " umount /initrd
  /secbin/blockdev --flushbufs /dev/ram0 >/dev/null 2>&1
fi

# Configure kernel parameters
action $"Configuring kernel parameters: " sysctl -e -p /etc/secysctl.conf

# Set the system clock.
ARC=0
SRM=0
UTC=0

if [ -f /etc/secysconfig/clock ]; then
  . /etc/secysconfig/clock

  # convert old style clock config to new values
  if [ "${CLOCKMODE}" = "GMT" ]; then
    UTC=true
  elif [ "${CLOCKMODE}" = "ARC" ]; then
    ARC=true
  fi
fi

CLOCKDEF=""
CLOCKFLAGS="$CLOCKFLAGS --hctosys"

case "$UTC" in
  yes|true)
   CLOCKFLAGS="$CLOCKFLAGS --utc";
   CLOCKDEF="$CLOCKDEF (utc)";
  ;;
  no|false)
```

```
    CLOCKFLAGS="$CLOCKFLAGS --localtime";
    CLOCKDEF="$CLOCKDEF (localtime)";
   ;;
esac

case "$ARC" in
     yes|true)
           CLOCKFLAGS="$CLOCKFLAGS --arc";
           CLOCKDEF="$CLOCKDEF (arc)";
     ;;
esac
case "$SRM" in
     yes|true)
           CLOCKFLAGS="$CLOCKFLAGS --srm";
           CLOCKDEF="$CLOCKDEF (srm)";
     ;;
esac

/secbin/hwclock $CLOCKFLAGS

action $"Setting clock $CLOCKDEF: `date`" date

if [ "`/secbin/consoletype`" = "vt" -a -x /bin/loadkeys ]; then
 KEYTABLE=
 KEYMAP=
 if [ -f /etc/secysconfig/console/default.kmap ]; then
  KEYMAP=/etc/secysconfig/console/default.kmap
 else
  if [ -f /etc/secysconfig/keyboard ]; then
    . /etc/secysconfig/keyboard
  fi
  if [ -n "$KEYTABLE" -a -d "/lib/kbd/keymaps" ]; then
     KEYMAP=$KEYTABLE
  fi
 fi
 if [ -n "$KEYMAP" ]; then
  # Since this takes in/output from stdin/out, we can't use initlog
  if [ -n "$KEYTABLE" ]; then
    echo -n $"Loading default keymap ($KEYTABLE): "
  else
    echo -n $"Loading default keymap: "
  fi
  loadkeys $KEYMAP < /dev/tty0 > /dev/tty0 2>/dev/null && \
     success $"Loading default keymap" || failure $"Loading default keymap"
  echo
 fi
```

fi

The hostname is set by DHCP so we don't want to override it
Set the hostname.
#action $"Setting hostname ${HOSTNAME}: " hostname ${HOSTNAME}

```
############################################################################
# The node kernel does not support modules so skip the USB stuff
# Comment : CRN
#
## Initialize USB controller and HID devices
#usb=0
#if ! LC_ALL=C grep -iq "nousb" /proc/cmdline 2>/dev/null && ! LC_ALL=C grep -q
"usb" /proc/devices 2>/dev/null ; then
#    aliases=`/secbin/modprobe -c | awk '/^alias usb-controller/ { print $3 }'`
#    if [ -n "$aliases" -a "$aliases" != "off" ]; then
#      modprobe usbcore
#      for alias in $aliases ; do
#         [ "$alias" != "off" ] && action $"Initializing USB controller ($alias): " modprobe
$alias
#      done
#      [ $? -eq 0 -a -n "$aliases" ] && usb=1
#    fi
#fi
#
#if ! LC_ALL=C grep -iq "nousb" /proc/cmdline 2>/dev/null && LC_ALL=C grep -q
"usb" /proc/devices 2>/dev/null ; then
#  usb=1
#fi
#
#if [ $usb = 1 -a ! -f /proc/bus/usb/devices ]; then
#    action $"Mounting USB file system: "  mount -t usbdevfs usbdevfs /proc/bus/usb
#fi
#
#needusbstorage=
#if [ $usb = "1" ]; then
#    needusbstorage=`LC_ALL=C grep -e "^I.*Cls=08" /proc/bus/usb/devices
2>/dev/null`
#    LC_ALL=C grep 'hid' /proc/bus/usb/drivers || action $"Initializing USB HID
interface: " modprobe hid 2> /dev/null
#    action $"Initializing USB keyboard: " modprobe keybdev 2> /dev/null
#    action $"Initializing USB mouse: " modprobe mousedev 2> /dev/null
#fi
############################################################################
if [ -f /fastboot ] || LC_ALL=C grep -iq "fastboot" /proc/cmdline 2>/dev/null ; then
        fastboot=yes
```

```
fi

if [ -f /fsckoptions ]; then
	fsckoptions=`cat /fsckoptions`
fi

############################################################################
# nodes will be shutdown uncleanly on a regular basis.
# Remove system integrity checks during boot
# Comment : CRN
#if [ -f /forcefsck ]; then
#	fsckoptions="-f $fsckoptions"
#elif [ -f /.autofsck ]; then
#	echo $"Your system appears to have shut down uncleanly"
#	AUTOFSCK_TIMEOUT=5
#	[ -f /etc/secysconfig/autofsck ] && . /etc/secysconfig/autofsck
#	if [ "$AUTOFSCK_DEF_CHECK" = "yes" ]; then
#		AUTOFSCK_OPT=-f
#	fi
#
#	if [ "$PROMPT" != "no" ]; then
#		if [ "$AUTOFSCK_DEF_CHECK" = "yes" ]; then
#			if /secbin/getkey -c $AUTOFSCK_TIMEOUT -m $"Press N
within %d seconds to not force file system integrity check..." n ; then
#				AUTOFSCK_OPT=
#			fi
#		else
#			if /secbin/getkey -c $AUTOFSCK_TIMEOUT -m $"Press Y
within %d seconds to force file system integrity check..." y ; then
#				AUTOFSCK_OPT=-f
#			fi
#		fi
#		echo
#	else
#		# PROMPT not allowed
#		if [ "$AUTOFSCK_DEF_CHECK" = "yes" ]; then
#			echo $"Forcing file system integrity check due to default setting"
#		else
#			echo $"Not forcing file system integrity check due to default
setting"
#		fi
#	fi
#	fsckoptions="$AUTOFSCK_OPT $fsckoptions"
#fi
############################################################################
if [ "$BOOTUP" = "color" ]; then
```

```
	fsckoptions="-C $fsckoptions"
else
	fsckoptions="-V $fsckoptions"
fi


_RUN_QUOTACHECK=0
ROOTFSTYPE=`awk '/ \/ / && ($3 !~ /rootfs/) { print $3 }' /proc/mounts`
if [ -z "$fastboot" -a "X$ROOTFSTYPE" != "Xnfs" ]; then

      STRING=$"Checking root file system"
	echo $STRING
	initlog -c "fsck -T -a $fsckoptions /"
	rc=$?

	if [ "$rc" = "0" ]; then
		success "$STRING"
		echo
	elif [ "$rc" = "1" ]; then
	      passed "$STRING"
		echo
      fi

      # A return of 2 or higher means there were serious problems.
	if [ $rc -gt 1 ]; then
	      if [ "$BOOTUP" = "graphical" ]; then
		    chvt 1
		fi

		failure "$STRING"
		echo
		echo
		echo $"*** An error occurred during the file system check."
		echo $"*** Dropping you to a shell; the system will reboot"
		echo $"*** when you leave the shell."

	    str=$"(Repair file system)"
		PS1="$str \# # "; export PS1
		sulogin

		echo $"Unmounting file systems"
		umount -a
		mount -n -o remount,ro /
		echo $"Automatic reboot in progress."
		reboot -f
	elif [ "$rc" = "1" ]; then
```

```
                _RUN_QUOTACHECK=1
        fi
fi

# Possibly update quotas if fsck was run on /.
LC_ALL=C grep -E '[[:space:]]+/[[:space:]]+' /etc/fstab | \
   awk '{ print $4 }' | \
   LC_ALL=C grep -q quota
_ROOT_HAS_QUOTA=$?
if [ X"$_RUN_QUOTACHECK" = X1 -a \
   "$_ROOT_HAS_QUOTA" = "0" -a \
   -x /secbin/quotacheck ]; then
        if [ -x /secbin/convertquota ]; then
            if [ -f /quota.user ]; then
                action $"Converting old user quota files: " \
                   /secbin/convertquota -u / && rm -f /quota.user
            fi
            if [ -f /quota.group ]; then
                action $"Converting old group quota files: " \
                   /secbin/convertquota -g / && rm -f /quota.group
            fi
        fi
        action $"Checking root file system quotas: " /secbin/quotacheck -nug /
fi

if [ -x /secbin/isapnp -a -f /etc/isapnp.conf -a ! -f /proc/isapnp ]; then
   # check for arguments passed from kernel
   if ! LC_ALL=C grep -iq nopnp /proc/cmdline >/dev/null 2>&1 ; then
        PNP=yes
   fi
   if [ -n "$PNP" ]; then
        action $"Setting up ISA PNP devices: " /secbin/isapnp /etc/isapnp.conf
   else
        action $"Skipping ISA PNP configuration at users request: " /bin/true
   fi
fi

# Remount the root file system read-write.
state=`awk '/ \/ / && ($3 !~ /rootfs/) { print $4 }' /proc/mounts`
[ "$state" != "rw" ] && \
  action $"Remounting root file system in read-write mode: " mount -n -o remount,rw /

########################################################################
# LVM initialization
#if [ -f /etc/lvmtab -a ! -e /proc/lvm ] ; then
#       modprobe lvm-mod >/dev/null 2>&1
```

```
#fi
#if [ -e /proc/lvm -a -x /secbin/vgchange -a -f /etc/lvmtab ]; then
#       action $"Setting up Logical Volume Management:" /secbin/vgscan &&
/secbin/vgchange -a y
#fi
##########################################################################
# Diskless nodes do not have swap partitions.  Swapping over NFS is possible, but still
# considered experimental.
# Start up swapping.
#action $"Activating swap partitions: " swapon -a -e

# Clear mtab
>/etc/mtab

# Remove stale backups
rm -f /etc/mtab~ /etc/mtab~~

# Enter root, /proc and (potentially) /proc/bus/usb and devfs into mtab.
mount -f /
mount -f /proc
[ -f /proc/bus/usb/devices ] && mount -f -t usbdevfs usbdevfs /proc/bus/usb
[ -e /dev/.devfsd ] && mount -f -t devfs devfs /dev


# The root file system is now read-write, so we can now log
# via syslog() directly..
if [ -n "$IN_INITLOG" ]; then
   IN_INITLOG=
fi

if ! LC_ALL=C grep -iq nomodules /proc/cmdline 2>/dev/null && [ -f /proc/ksyms ];
then
   USEMODULES=y
fi

# The node Kernel does not support modules so this code will fail.
# Comment : CRN
#
# Our modutils don't support it anymore, so we might as well remove
# the preferred link.
#rm -f /lib/modules/preferred /lib/modules/default
#if [ -x /secbin/depmod -a -n "$USEMODULES" ]; then
#    # If they aren't using a recent sane kernel, make a link for them
#    if [ ! -n "`uname -r | LC_ALL=C grep -- "-"`" ]; then
#       ktag="`cat /proc/version`"
#       mtag=`LC_ALL=C grep -l "$ktag" /lib/modules/*/.rhkmvtag 2> /dev/null`
```

```
#       if [ -n "$mtag" ]; then
#          mver=`echo $mtag | sed -e 's,/lib/modules/,,' -e 's,/.rhkmvtag,,' -e 's,[       ].*$,,'`
#       fi
#       if [ -n "$mver" ]; then
#         ln -sf /lib/modules/$mver /lib/modules/default
#       fi
#    fi
#    if [ -L /lib/modules/default ]; then
#          INITLOG_ARGS= action $"Finding module dependencies: " depmod -A default
#    else
#          INITLOG_ARGS= action $"Finding module dependencies: " depmod -A
#    fi
#fi

# tweak isapnp settings if needed.
if [ -n "$PNP" -a  -f /proc/isapnp -a -x /secbin/secndconfig ]; then
    /secbin/secndconfig --mungepnp >/dev/null 2>&1
fi

############################################################################
# The node Kernel does not support modules so this code will fail.
# the nodes don't need sound anyway
# Comment : CRN
#
# Load sound modules if and only if they need persistent DMA buffers
#if LC_ALL=C grep -q "options sound dmabuf=1" /etc/modules.conf 2>/dev/null ; then
#  RETURN=0
#  alias=`/secbin/modprobe -c | awk '/^alias sound / { print $3 }'`
#  if [ -n "$alias" -a "$alias" != "off" ]; then
#      action $"Loading sound module ($alias): " modprobe sound
#      RETURN=$?
#  fi
#  alias=`/secbin/modprobe -c | awk '/^alias sound-slot-0 / { print $3 }'`
#  if [ -n "$alias" -a "$alias" != "off" ]; then
#      action $"Loading sound module ($alias): " modprobe sound-slot-0
#      RETURN=$?
#  fi
#fi
#
#if [ -f /proc/secys/kernel/modprobe ]; then
#   if [ -n "$USEMODULES" ]; then
#       sysctl -w kernel.modprobe="/secbin/modprobe" >/dev/null 2>&1
#       sysctl -w kernel.hotplug="/secbin/hotplug" >/dev/null 2>&1
#   else
#       # We used to set this to NULL, but that causes 'failed to exec' messages"
#       sysctl -w kernel.modprobe="/bin/true" >/dev/null 2>&1
```

```
#       sysctl -w kernel.hotplug="/bin/true" >/dev/null 2>&1
#   fi
#fi
##########################################################################

# Load modules (for backward compatibility with VARs)
if [ -f /etc/rc.modules ]; then
        /etc/rc.modules
fi

##########################################################################
#if [ -f /etc/raidtab ]; then
#       # Add raid devices
#       [ -f /proc/mdstat ] || modprobe md >/dev/null 2>&1
#fi
#if [ -f /etc/raidtab -a -f /proc/mdstat ]; then
#
#       echo -n $"Starting up RAID devices: "
#
#       rc=0
#
#       for i in `awk '{if ($1=="raiddev") print $2}' /etc/raidtab`
#       do
#               RAIDDEV=`basename $i`
#           RAIDSTAT=`LC_ALL=C grep "^$RAIDDEV : active" /proc/mdstat`
#               if [ -z "$RAIDSTAT" ]; then
#                       # First scan the /etc/fstab for the "noauto"-flag
#                       # for this device. If found, skip the initialization
#                       # for it to avoid dropping to a shell on errors.
#                       # If not, try raidstart...if that fails then
#                       # fall back to raidadd, raidrun.  If that
#                       # also fails, then we drop to a shell
#                       RESULT=1
#                       INFSTAB=`LC_ALL=C grep -c "^$i" /etc/fstab`
#                       if [ $INFSTAB -eq 0 ] ; then
#                          RESULT=0
#                          RAIDDEV="$RAIDDEV(skipped)"
#                       fi
#                       NOAUTO=`LC_ALL=C grep "^$i" /etc/fstab | LC_ALL=C grep -
c "noauto"`
#                       if [ $NOAUTO -gt 0 ]; then
#                          RESULT=0
#                          RAIDDEV="$RAIDDEV(skipped)"
#                       fi
#                       if [ $RESULT -gt 0 -a -x /secbin/raidstart ]; then
#                               /secbin/raidstart $i
```

```
#                               RESULT=$?
#                       fi
#                       if [ $RESULT -gt 0 -a -x /secbin/raid0run ]; then
#                               /secbin/raid0run $i
#                               RESULT=$?
#                       fi
#                       if [ $RESULT -gt 0 -a -x /secbin/raidadd -a -x /secbin/raidrun ];
then
#                               /secbin/raidadd $i
#                               /secbin/raidrun $i
#                               RESULT=$?
#                       fi
#                       if [ $RESULT -gt 0 ]; then
#                               rc=1
#                       fi
#                       echo -n "$RAIDDEV "
#               else
#                       echo -n "$RAIDDEV "
#               fi
#       done
#       echo
#
#       # A non-zero return means there were problems.
#       if [ $rc -gt 0 ]; then
#               echo
#               echo
#               echo $"*** An error occurred during the RAID startup"
#               echo $"*** Dropping you to a shell; the system will reboot"
#               echo $"*** when you leave the shell."
#
#               str=$"(RAID Repair)"
#               PS1="$str \# # "; export PS1
#               sulogin
#
#               echo $"Unmounting file systems"
#               umount -a
#               mount -n -o remount,ro /
#               echo $"Automatic reboot in progress."
#               reboot -f
#       fi
#       # LVM initialization, take 2 (it could be on top of RAID)
#       if [ -e /proc/lvm -a -x /secbin/vgchange -a -f /etc/lvmtab ]; then
#               action $"Setting up Logical Volume Management:" /secbin/vgscan &&
/secbin/vgchange -a y
#       fi
#fi
```

```
if [ -x /secbin/devlabel ]; then
	/secbin/devlabel restart
fi

_RUN_QUOTACHECK=0
# Check file systems
if [ -z "$fastboot" ]; then
	STRING=$"Checking file systems"
	echo $STRING
	initlog -c "fsck -T -R -A -a $fsckoptions"
	rc=$?
	if [ "$rc" = "0" ]; then
		success "$STRING"
		echo
	elif [ "$rc" = "1" ]; then
		passed "$STRING"
		echo
	fi

	# A return of 2 or higher means there were serious problems.
	if [ $rc -gt 1 ]; then
		if [ "$BOOTUP" = "graphical" ]; then
			chvt 1
		fi

		failure "$STRING"
		echo
		echo
		echo $"*** An error occurred during the file system check."
		echo $"*** Dropping you to a shell; the system will reboot"
		echo $"*** when you leave the shell."

		str=$"(Repair file system)"
		PS1="$str \# # "; export PS1
		sulogin

		echo $"Unmounting file systems"
		umount -a
		mount -n -o remount,ro /
		echo $"Automatic reboot in progress."
		reboot -f
	elif [ "$rc" = "1" -a -x /secbin/quotacheck ]; then
		_RUN_QUOTACHECK=1
	fi
fi
```

```
# Mount all other file systems (except for NFS and /proc, which is already
# mounted). Contrary to standard usage,
# file systems are NOT unmounted in single user mode.
action $"Mounting local file systems: " mount -a -t nonfs,smbfs,ncpfs -O no_netdev

# check remaining quotas other than root
if [ X"$_RUN_QUOTACHECK" = X1 -a -x /secbin/quotacheck ]; then
        if [ -x /secbin/convertquota ]; then
            # try to convert old quotas
            for mountpt in `awk '$4 ~ /quota/{print $2}' /etc/mtab` ; do
                if [ -f "$mountpt/quota.user" ]; then
                    action $"Converting old user quota files: " \
                    /secbin/convertquota -u $mountpt && \
                        rm -f $mountpt/quota.user
                fi
                if [ -f "$mountpt/quota.group" ]; then
                    action $"Converting old group quota files: " \
                    /secbin/convertquota -g $mountpt && \
                        rm -f $mountpt/quota.group
                fi
            done
        fi
        action $"Checking local file system quotas: " /secbin/quotacheck -aRnug
fi

if [ -x /secbin/quotaon ]; then
    action $"Enabling local file system quotas: " /secbin/quotaon -aug
fi

# Configure machine if necessary.
if [ -f /.unconfigured ]; then
    if [ "$BOOTUP" = "graphical" ]; then
        chvt 1
    fi

    if [ -x /usr/bin/passwd ]; then
        /usr/bin/passwd root
    fi
    if [ -x /usr/secbin/netconfig ]; then
        /usr/secbin/netconfig
    fi
    if [ -x /usr/secbin/timeconfig ]; then
        /usr/secbin/timeconfig
    fi
    if [ -x /usr/secbin/kbdconfig ]; then
```

```
        /usr/secbin/kbdconfig
    fi
    if [ -x /usr/secbin/authconfig ]; then
        /usr/secbin/authconfig --nostart
    fi
    if [ -x /usr/secbin/ntsysv ]; then
        /usr/secbin/ntsysv --level 35
    fi

    # Reread in network configuration data.
    if [ -f /etc/secysconfig/network ]; then
        . /etc/secysconfig/network

        # The hostname is set by DHCP so we don't want to override it
        # Reset the hostname.
        #action $"Resetting hostname ${HOSTNAME}: " hostname ${HOSTNAME}
    fi

    rm -f /.unconfigured
fi

# Clean out /.
rm -f /fastboot /fsckoptions /forcefsck /.autofsck /halt /poweroff

# Do we need (w|u)tmpx files? We don't set them up, but the sysadmin might...
_NEED_XFILES=
[ -f /var/run/utmpx -o -f /var/log/wtmpx ] && _NEED_XFILES=1

# Clean up /var.  I'd use find, but /usr may not be mounted.
for afile in /var/lock/* /var/run/* ; do
        if [ -d "$afile" ]; then
          case "`basename $afile`" in
                news|mon)       ;;
                sudo)
                                rm -f $afile/*/* ;;
                *)              rm -f $afile/* ;;
          esac
        else
          rm -f $afile
        fi
done
rm -f /var/lib/rpm/__db*

# Reset pam_console permissions
[ -x /secbin/pam_console_apply ] && /secbin/pam_console_apply -r
```

```
{
# Clean up utmp/wtmp
>/var/run/utmp
touch /var/log/wtmp
chgrp utmp /var/run/utmp /var/log/wtmp
chmod 0664 /var/run/utmp /var/log/wtmp
if [ -n "$_NEED_XFILES" ]; then
  >/var/run/utmpx
  touch /var/log/wtmpx
  chgrp utmp /var/run/utmpx /var/log/wtmpx
  chmod 0664 /var/run/utmpx /var/log/wtmpx
fi

# Delete X locks
rm -f /tmp/.X*-lock

# Delete VNC & X locks
rm -rf /tmp/.X*-unix

# Delete ICE locks
rm -rf /tmp/.ICE-unix

# Delete Postgres sockets
rm -f /tmp/.s.PGSQL.*

# Now turn on swap in case we swap to files.
swapon -a
action $"Enabling swap space: " /bin/true

# Initialize the serial ports.
if [ -f /etc/rc.serial ]; then
	. /etc/rc.serial
fi

# If a SCSI tape has been detected, load the st module unconditionally
# since many SCSI tapes don't deal well with st being loaded and unloaded
#if [ -f /proc/seccsi/seccsi ] && LC_ALL=C grep -q 'Type:   Sequential-Access'
/proc/seccsi/seccsi 2>/dev/null ; then
#	if LC_ALL=C grep -qv ' 9 st' /proc/devices && [ -n "$USEMODULES" ]; then
#		modprobe st >/dev/null 2>&1
#	fi
#fi

##############################################################################
# Load usb storage here, to match most other things
#if [ -n "$needusbstorage" ]; then
```

```
#         modprobe usb-storage >/dev/null 2>&1
#fi
#
# Ooh, firewire too.
#if ! LC_ALL=C grep -iq "nofirewire" /proc/cmdline 2>/dev/null ; then
#   aliases=`/secbin/modprobe -c | awk '/^alias ieee1394-controller/ { print $3 }'`
#   if [ -n "$aliases" -a "$aliases" != "off" ]; then
#      for alias in $aliases ; do
#         [ "$alias" != "off" ] && action $"Initializing firewire controller ($alias): "
modprobe $alias
#      done
#      LC_ALL=C grep -q "SBP2" /proc/bus/ieee1394/devices 2>/dev/null && modprobe
sbp2 >/dev/null 2>&1
#   fi
#fi
##########################################################################

# If they asked for ide-scsi, load it
#if LC_ALL=C grep -q "ide-scsi" /proc/cmdline ; then
#         modprobe ide-cd >/dev/null 2>&1
#         modprobe ide-scsi >/dev/null 2>&1
#fi


##########################################################################
# The cluster nodes don't have a hard disk -- so skip this
# Comment : CRN
#
#
# Turn on harddisk optimization
# There is only one file /etc/secysconfig/harddisks for all disks
# after installing the hdparm-RPM. If you need different hdparm parameters
# for each of your disks, copy /etc/secysconfig/harddisks to
# /etc/secysconfig/harddiskhda (hdb, hdc...) and modify it.
# Each disk which has no special parameters will use the defaults.
# Each non-disk which has no special parameters will be ignored.
#
#
#disk[0]=s;
#disk[1]=hda;  disk[2]=hdb;  disk[3]=hdc;  disk[4]=hdd;
#disk[5]=hde;  disk[6]=hdf;  disk[7]=hdg;  disk[8]=hdh;
#disk[9]=hdi;  disk[10]=hdj; disk[11]=hdk; disk[12]=hdl;
#disk[13]=hdm; disk[14]=hdn; disk[15]=hdo; disk[16]=hdp;
#disk[17]=hdq; disk[18]=hdr; disk[19]=hds; disk[20]=hdt;
#
#
```

```
#if [ -x /secbin/hdparm ]; then
#   for device in 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20; do
#         unset MULTIPLE_IO USE_DMA EIDE_32BIT LOOKAHEAD
EXTRA_PARAMS
#       if [ -f /etc/secysconfig/harddisk${disk[$device]} ]; then
#               . /etc/secysconfig/harddisk${disk[$device]}
#               HDFLAGS[$device]=
#               if [ -n "$MULTIPLE_IO" ]; then
#                   HDFLAGS[$device]="-q -m$MULTIPLE_IO"
#               fi
#               if [ -n "$USE_DMA" ]; then
#                   HDFLAGS[$device]="${HDFLAGS[$device]} -q -d$USE_DMA"
#               fi
#               if [ -n "$EIDE_32BIT" ]; then
#                   HDFLAGS[$device]="${HDFLAGS[$device]} -q -c$EIDE_32BIT"
#               fi
#               if [ -n "$LOOKAHEAD" ]; then
#                   HDFLAGS[$device]="${HDFLAGS[$device]} -q -A$LOOKAHEAD"
#               fi
#               if [ -n "$EXTRA_PARAMS" ]; then
#                   HDFLAGS[$device]="${HDFLAGS[$device]} $EXTRA_PARAMS"
#               fi
#       else
#               HDFLAGS[$device]="${HDFLAGS[0]}"
#       fi
#       if [ -e "/proc/ide/${disk[$device]}/media" ]; then
#            hdmedia=`cat /proc/ide/${disk[$device]}/media`
#            if [ "$hdmedia" = "disk" -o -f "/etc/secysconfig/harddisk${disk[$device]}" ];
then
#                if [ -n "${HDFLAGS[$device]}" ]; then
#                    action $"Setting hard drive parameters for ${disk[$device]}: "
/secbin/hdparm ${HDFLAGS[$device]} /dev/${disk[$device]}
#                fi
#            fi
#       fi
#   done
#fi

# Boot time profiles. Yes, this should be somewhere else.
if LC_ALL=C grep -q "netprofile=" /proc/cmdline ; then
    cmdline=`cat /proc/cmdline`
    for arg in $cmdline ; do
       if [ "${arg##netprofile=}" != "${arg}" ]; then
          [ -x /usr/secbin/redhat-config-network-cmd ] &&
               /usr/secbin/redhat-config-network-cmd --profile ${arg##netprofile=}
       fi
```

```
    done
fi

# Generate a header that defines the boot kernel.
/secbin/mkkerneldoth

# Adjust symlinks as necessary in /boot to keep system services from
# spewing messages about mismatched System maps and so on.
if [ -L /boot/secystem.map -a -r /boot/secystem.map-`uname -r` -a \
        ! /boot/secystem.map -ef /boot/secystem.map-`uname -r` ]; then
        ln -s -f System.map-`uname -r` /boot/secystem.map
fi
if [ ! -e /boot/secystem.map -a -r /boot/secystem.map-`uname -r` ]; then
        ln -s -f System.map-`uname -r` /boot/secystem.map
fi

# The special Red Hat kernel library symlink must point to the right library
# We need to deal with cases where there is no library, and we need to
# deal with any version numbers that show up.
shopt -s nullglob
for library in /lib/kernel/$(uname -r)/libredhat-kernel.so* ; do
        ln -f $library /lib/
        ldconfig -n /lib/
done
shopt -u nullglob

# Now that we have all of our basic modules loaded and the kernel going,
# let's dump the syslog ring somewhere so we can find it later
dmesg -s 131072 > /var/log/dmesg
# Also keep kernel symbols around in case we need them for debugging
i=5
while [ $i -ge 0 ]; do
        if [ -f /var/log/ksyms.$i ]; then
                mv /var/log/ksyms.$i /var/log/ksyms.$(($i+1))
        fi
        i=$(($i-1))
done

(/bin/date;
 /bin/uname -a;
 /bin/cat /proc/cpuinfo;
 [ -r /proc/modules ] && /bin/cat /proc/modules;
 [ -r /proc/ksyms ] && /bin/cat /proc/ksyms) >/var/log/ksyms.0
# create the crash indicator flag to warn on crashes, offer fsck with timeout
touch /.autofsck
sleep 1
```

```
##############################################################################
# These lines are not needed on the diskless node.
# Comment : CRN
#kill -TERM `/secbin/pidof getkey` >/dev/null 2>&1
#} &
##############################################################################

if [ "$PROMPT" != "no" ]; then
  /secbin/getkey i && touch /var/run/confirm
fi
wait
```

Master Node exports / NFS configuration file

```
/cluster/nodes  *(rw,no_all_squash,no_root_squash)
/cluster/benchmarks/NAS       *(rw,no_all_squash,no_root_squash)
```

Diskless Node fstab file

```
10.10.10.100:/cluster/nodes             /        nfs      defaults        1 1
10.10.10.100:/cluster/benchmarks/NAS        /NAS   nfs      defaults        1 1
none                                    /proc    proc     defaults        0 0
/dev/fd0          /mnt/floppy          auto    noauto,owner,kudzu 0 0
```

LAM/MPI configuration file

```
frog.it.et.byu.edu schedule=no
tadpole1.kermit.it.et.byu.edu
tadpole2.kermit.it.et.byu.edu
tadpole3.kermit.it.et.byu.edu
tadpole4.kermit.it.et.byu.edu
tadpole5.kermit.it.et.byu.edu
tadpole6.kermit.it.et.byu.edu
tadpole7.kermit.it.et.byu.edu
tadpole8.kermit.it.et.byu.edu
tadpole9.kermit.it.et.byu.edu
tadpole10.kermit.it.et.byu.edu
tadpole11.kermit.it.et.byu.edu
```

tadpole12.kermit.it.et.byu.edu
tadpole13.kermit.it.et.byu.edu
tadpole14.kermit.it.et.byu.edu
tadpole15.kermit.it.et.byu.edu
tadpole16.kermit.it.et.byu.edu

NAS build.suite file

```
# config/secuite.def
# This file is used to build several benchmarks with a single command.
# Typing "make suite" in the main directory will build all the benchmarks
# specified in this file.
# Each line of this file contains a benchmark name, class, and number
# of nodes. The name is one of "cg", "is", "ep", mg", "ft", "sp", "bt",
# and "lu".
# The class is one of "S", "W", "S", "B", and "C".
# The number of nodes must be a legal number for a particular
# benchmark. The utility which parses this file is primitive, so
# formatting is inflexible. Separate name/class/number by tabs.
# Comments start with "#" as the first character on a line.
# No blank lines.
#
#
#Class A Benchmark Suite
bt	A	1
bt	A	4
bt	A	9
bt	A	16
cg	A	1
cg	A	4
cg	A	8
cg	A	16
ep	A	1
ep	A	2
ep	A	3
ep	A	4
ep	A	5
ep	A	6
ep	A	7
ep	A	8
ep	A	9
ep	A	10
ep	A	11
ep	A	12
```

ep	A	13
ep	A	14
ep	A	15
ep	A	16
ft	A	1
ft	A	4
ft	A	8
ft	A	16
is	A	1
is	A	4
is	A	8
is	A	16
lu	A	1
lu	A	4
lu	A	8
lu	A	16
mg	A	1
mg	A	4
mg	A	8
mg	A	16
sp	A	1
sp	A	4
sp	A	9
sp	A	16

---

run_A_tests script file

```
#!/bin/bash

echo "Running NPB Class A Benchmarks"
echo "------------------------------"
echo "Running BT Class A - 16 Nodes"
mpirun n1-16 /NAS/bin/bt.A.16 > ./bt.A.16
lamclean

echo "Running CG Class A - 16 Nodes"
mpirun n1-16 /NAS/bin/cg.A.16 > ./cg.A.16
lamclean

echo "Running FT Class A - 16 Nodes"
mpirun n1-16 /NAS/bin/ft.A.16 > ./ft.A.16
lamclean

echo "Running IS Class A - 16 Nodes"
```

```
mpirun n1-16 /NAS/bin/is.A.16 > ./is.A.16
lamclean

echo "Running LU Class A - 16 Nodes"
mpirun n1-16 /NAS/bin/lu.A.16 > ./lu.A.16
lamclean

echo "Running MG Class A - 16 Nodes"
mpirun n1-16 /NAS/bin/mg.A.16 > ./mg.A.16
lamclean

echo "Running SP Class A - 16 Nodes"
mpirun n1-16 /NAS/bin/secp.A.16 > ./secp.A.16
lamclean

echo "Running EP Class A - 16 - 9 Nodes"
mpirun n1-16 /NAS/bin/ep.A.16 > ./ep.A.16
lamclean
mpirun n1-15 /NAS/bin/ep.A.15 > ./ep.A.15
lamclean
mpirun n1-14 /NAS/bin/ep.A.14 > ./ep.A.14
lamclean
mpirun n1-13 /NAS/bin/ep.A.13 > ./ep.A.13
lamclean
mpirun n1-12 /NAS/bin/ep.A.12 > ./ep.A.12
lamclean
mpirun n1-11 /NAS/bin/ep.A.11 > ./ep.A.11
lamclean
mpirun n1-10 /NAS/bin/ep.A.10 > ./ep.A.10
lamclean
mpirun n1-9  /NAS/bin/ep.A.9  > ./ep.A.9
lamclean

echo "Running BT Class A - 9 Nodes"
mpirun n1-9 /NAS/bin/bt.A.9 > ./bt.A.9
lamclean

echo "Running SP Class A - 9 Nodes"
mpirun n1-9 /NAS/bin/secp.A.9 > ./secp.A.9
lamclean

echo "Running CG Class A - 8 Nodes"
mpirun n1-8 /NAS/bin/cg.A.8 > ./cg.A.8
lamclean

echo "Running FT Class A - 8 Nodes"
```

```
mpirun n1-8 /NAS/bin/ft.A.8 > ./ft.A.8
lamclean

echo "Running IS Class A - 8 Nodes"
mpirun n1-8 /NAS/bin/is.A.8 > ./is.A.8
lamclean

echo "Running LU Class A - 8 Nodes"
mpirun n1-8 /NAS/bin/lu.A.8 > ./lu.A.8
lamclean

echo "Running MG Class A - 8 Nodes"
mpirun n1-8 /NAS/bin/mg.A.8 > ./mg.A.8
lamclean

echo "Running EP Class A - 8 - 5 Nodes"
mpirun n1-8 /NAS/bin/ep.A.8 > ./ep.A.8
lamclean
mpirun n1-7 /NAS/bin/ep.A.7 > ./ep.A.7
lamclean
mpirun n1-6 /NAS/bin/ep.A.6 > ./ep.A.6
lamclean
mpirun n1-5 /NAS/bin/ep.A.5 > ./ep.A.5
lamclean

echo "Running BT Class A - 4 Nodes"
mpirun n1-4 /NAS/bin/bt.A.4 > ./bt.A.4
lamclean

echo "Running CG Class A - 4 Nodes"
mpirun n1-4 /NAS/bin/cg.A.4 > ./cg.A.4
lamclean

echo "Running FT Class A - 4 Nodes"
mpirun n1-4 /NAS/bin/ft.A.4 > ./ft.A.4
lamclean

echo "Running IS Class A - 4 Nodes"
mpirun n1-4 /NAS/bin/is.A.4 > ./is.A.4
lamclean

echo "Running LU Class A - 4 Nodes"
mpirun n1-4 /NAS/bin/lu.A.4 > ./lu.A.4
lamclean

echo "Running MG Class A - 4 Nodes"
```

```
mpirun n1-4 /NAS/bin/mg.A.4 > ./mg.A.4
lamclean

echo "Running SP Class A - 4 Nodes"
mpirun n1-4 /NAS/bin/secp.A.4 > ./secp.A.4
lamclean

echo "Running EP Class A - 4 - 1 Nodes"
mpirun n1-4 /NAS/bin/ep.A.4 > ./ep.A.4
lamclean
mpirun n1-3 /NAS/bin/ep.A.3 > ./ep.A.3
lamclean
mpirun n1-2 /NAS/bin/ep.A.2 > ./ep.A.2
lamclean
mpirun n1 /NAS/bin/ep.A.1 > ./ep.A.1
lamclean

echo "Running BT Class A - 1 Node"
mpirun n1 /NAS/bin/bt.A.1 > ./bt.A.1
lamclean

echo "Running CG Class A - 1 Node"
mpirun n1 /NAS/bin/cg.A.1 > ./cg.A.1
lamclean

echo "Running FT Class A - 1 Node"
mpirun n1 /NAS/bin/ft.A.1 > ./ft.A.1
lamclean

echo "Running IS Class A - 1 Node"
mpirun n1 /NAS/bin/is.A.1 > ./is.A.1
lamclean

echo "Running LU Class A - 1 Node"
mpirun n1 /NAS/bin/lu.A.1 > ./lu.A.1
lamclean

echo "Running MG Class A - 1 Node"
mpirun n1 /NAS/bin/mg.A.1 > ./mg.A.1
lamclean

echo "Running SP Class A - 1 Node"
mpirun n1 /NAS/bin/secp.A.1 > ./secp.A.1
lamclean
```

9 APPENDIX C

This appendix contains the performance data generated by the NAS Parallel Benchmark suite categorized by hardware configuration.

Many of the files generated include benchmark progress information. In some cases this information is quite lengthy, and has been removed. In addition to the information listed, each output file provided configuration, and reporting information. This information is identical for each test and is listed below.

```
Compile options:
   MPIF77       = mpif77
   FLINK        = ${MPIF77}
   FMPI_LIB     = -L/usr/lib -lmpi
   FMPI_INC     = -I/usr/include
   FFLAGS       = -O3
   FLINKFLAGS   = (none)
   RAND         = randi8_safe


 Please send the results of this run to:

 NPB Development Team
 Internet: npb@nas.nasa.gov

 If email is not available, send this to:

 MS T27A-1
 NASA Ames Research Center
 Moffett Field, CA  94035-1000

 Fax: 415-604-3957
```

Performance of a single computer with a 1.8GHz CPU, and 512MB RAM

```
NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     1

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
          1 0.1080634671464E+03 0.1080634671464E+03 0.8547806033624E-14
          2 0.1131973090122E+02 0.1131973090122E+02 0.1098479988995E-14
          3 0.2597435451158E+02 0.2597435451158E+02 0.2735554931474E-15
          4 0.2366562254468E+02 0.2366562254468E+02 0.1606297754956E-13
          5 0.2527896321175E+03 0.2527896321175E+03 0.1416646465377E-13
 Comparison of RMS-norms of solution error
          1 0.4234841604053E+01 0.4234841604053E+01 0.2097312019534E-15
          2 0.4439028249700E+00 0.4439028249700E+00 0.1750734785908E-14
          3 0.9669248013635E+00 0.9669248013635E+00 0.1951939943211E-14
          4 0.8830206303977E+00 0.8830206303977E+00 0.2011682149035E-14
          5 0.9737990177083E+01 0.9737990177083E+01 0.1276905978511E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                   941.58
 Total processes =                        1
 Compiled procs  =                        1
 Mop/sec total     =                 178.73
 Mop/sec/process   =                 178.73
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 1

iteration	||r||	zeta
1	0.27827584529972E-12	19.9997581277040
2	0.26160031018478E-14	17.1140495745506
3	0.26714791625944E-14	17.1296668946143
4	0.26473497355311E-14	17.1302113581192
5	0.25962051721040E-14	17.1302338856353
6	0.26115199334372E-14	17.1302349879482
7	0.25993680727334E-14	17.1302350498916
8	0.26120228095637E-14	17.1302350537510
9	0.25450483820989E-14	17.1302350540101
10	0.25904786670248E-14	17.1302350540284
11	0.25506293938445E-14	17.1302350540298
12	0.25257745194192E-14	17.1302350540299
13	0.25415734339777E-14	17.1302350540299
14	0.25063961032389E-14	17.1302350540299
15	0.24842598520619E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 13.11
Total processes = 1
Compiled procs = 1
Mop/sec total = 114.15
Mop/sec/process = 114.15
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 119.3655
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165629841E+03   -1.580732573678431E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   119.37
Total processes =   1
Compiled procs =   1
Mop/sec total   =   4.50
Mop/sec/process   =   4.50
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 1
Processor array : 1x 1
Layout type : 0D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 40.29
Total processes = 1
Compiled procs = 1
Mop/sec total = 177.12
Mop/sec/process = 177.12
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 1

```
  iteration
       1
       2
       3
       4
       5
       6
       7
       8
       9
       10
```

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	4.95
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	16.93
Mop/sec/process	=	16.93
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 1

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.8756130575742E-15
2	0.6340276525969E+02	0.6340276525969E+02	0.1681021481121E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.7287898208366E-15
4	0.1784530116042E+03	0.1784530116042E+03	0.2707542203819E-14
5	0.1838476034946E+04	0.1838476034946E+04	0.1484100990959E-14

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.8299601066640E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.7875436823397E-15
3	0.7347341269877E+01	0.7347341269877E+01	0.4835373161943E-15
4	0.6713922568778E+01	0.6713922568778E+01	0.5291561888607E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.6028759644299E-15

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	541.32
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	220.38
Mop/sec/process	=	220.38
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 1

Initialization time: 12.438 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.692843304701E-16

MG Benchmark Completed.

Class	=	A
Size	=	256x256x256
Iterations	=	4
Time in seconds	=	21.22
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	183.40
Mop/sec/process	=	183.40
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     1

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
         1 0.2479982239930E+01 0.2479982239930E+01 0.6858362315424E-13
         2 0.1127633796437E+01 0.1127633796437E+01 0.2205414189446E-13
         3 0.1502897788877E+01 0.1502897788877E+01 0.5097178881098E-13
         4 0.1421781621169E+01 0.1421781621170E+01 0.3919954724857E-13
         5 0.2129211303514E+01 0.2129211303514E+01 0.1147133988132E-13
Comparison of RMS-norms of solution error
         1 0.1090014029782E-03 0.1090014029782E-03 0.3948832315147E-12
         2 0.3734395176928E-04 0.3734395176928E-04 0.3737982272737E-13
         3 0.5009278540654E-04 0.5009278540654E-04 0.1623290904598E-14
         4 0.4767109393953E-04 0.4767109393953E-04 0.1361760339713E-12
         5 0.1362161339921E-03 0.1362161339921E-03 0.6208351901894E-13
Verification Successful

SP Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      400
Time in seconds =                   723.22
Total processes =                        1
Compiled procs  =                        1
Mop/sec total     =                 117.54
Mop/sec/process   =                 117.54
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

Performance of a cluster with a 10 Mbps network hub and nodes with 233 MHz CPU, and 64MB RAM.

```
NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size:      14000
Iterations:    15
Number of active processes:     4

  iteration           ||r||                 zeta
      1       0.30380719049536E-12    19.9997581277040
      2       0.29763636601233E-14    17.1140495745506
      3       0.30758070039524E-14    17.1296668946143
      4       0.30767836772916E-14    17.1302113581192
      5       0.30362538345620E-14    17.1302338856353
      6       0.30918631267811E-14    17.1302349879482
      7       0.29692461545083E-14    17.1302350498916
      8       0.30136035568592E-14    17.1302350537510
      9       0.30210087485660E-14    17.1302350540101
     10       0.29835949970093E-14    17.1302350540284
     11       0.29536430530910E-14    17.1302350540298
     12       0.29781985872281E-14    17.1302350540299
     13       0.29621143458868E-14    17.1302350540299
     14       0.29849869948111E-14    17.1302350540299
     15       0.29517709020202E-14    17.1302350540299
Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is      0.171302350540E+02
Error is     0.891731133379E-12


CG Benchmark Completed.
Class           =                        A
Size            =                    14000
Iterations      =                       15
Time in seconds =                   164.45
Total processes =                        4
Compiled procs  =                        4
Mop/sec total     =                   9.10
Mop/sec/process   =                   2.27
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- CG Benchmark

 Size:      14000
 Iterations:    15
 Number of active processes:     8

   iteration           ||r||                 zeta
        1       0.26430287941297E-12    19.9997581277040
        2       0.26414813392819E-14    17.1140495745506
        3       0.26266612893876E-14    17.1296668946143
        4       0.26223598758375E-14    17.1302113581192
        5       0.26182783886564E-14    17.1302338856353
        6       0.26288689973095E-14    17.1302349879482
        7       0.25972755600456E-14    17.1302350498916
        8       0.25774519203481E-14    17.1302350537510
        9       0.25550821991349E-14    17.1302350540101
       10       0.25670770323505E-14    17.1302350540284
       11       0.25758028098708E-14    17.1302350540298
       12       0.25113124979678E-14    17.1302350540299
       13       0.25036350044005E-14    17.1302350540299
       14       0.24859657049077E-14    17.1302350540299
       15       0.24631513623583E-14    17.1302350540299
 Benchmark completed
 VERIFICATION SUCCESSFUL
 Zeta is      0.171302350540E+02
 Error is     0.891731133379E-12


 CG Benchmark Completed.
 Class           =                        A
 Size            =                    14000
 Iterations      =                       15
 Time in seconds =                   253.01
 Total processes =                        8
 Compiled procs  =                        8
 Mop/sec total   =                     5.91
 Mop/sec/process =                     0.74
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

```
 NAS Parallel Benchmarks 2.3 -- EP Benchmark

 Number of random numbers generated:    536870912
 Number of active processes:                    1

EP Benchmark Results:

CPU Time =  589.1767
N = 2^   28
No. Gaussian Pairs =     210832767.
Sums =    -4.295875165629841E+03   -1.580732573678431E+04
Counts:
  0      98257395.
  1      93827014.
  2      17611549.
  3       1110028.
  4         26536.
  5           245.
  6             0.
  7             0.
  8             0.
  9             0.


 EP Benchmark Completed.
 Class           =                        A
 Size            =                536870912
 Iterations      =                        0
 Time in seconds =                   589.18
 Total processes =                        1
 Compiled procs  =                        1
 Mop/sec total     =                   0.91
 Mop/sec/process   =                   0.91
 Operation type  = Random numbers generated
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time = 294.6614
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165639063E+03 -1.580732573678573E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 294.66
Total processes = 2
Compiled procs = 1
Mop/sec total = 1.82
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
 NAS Parallel Benchmarks 2.3 -- EP Benchmark

 Number of random numbers generated:    536870912
 Number of active processes:                    3

EP Benchmark Results:

CPU Time =  196.7142
N = 2^   28
No. Gaussian Pairs =     210832767.
Sums =    -4.295875165637473E+03   -1.580732573677940E+04
Counts:
  0      98257395.
  1      93827014.
  2      17611549.
  3       1110028.
  4         26536.
  5           245.
  6             0.
  7             0.
  8             0.
  9             0.


 EP Benchmark Completed.
 Class           =                        A
 Size            =                536870912
 Iterations      =                        0
 Time in seconds =                   196.71
 Total processes =                        3
 Compiled procs  =                        1
 Mop/sec total     =                   2.73
 Mop/sec/process   =                   0.91
 Operation type  = Random numbers generated
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 4

EP Benchmark Results:

CPU Time = 147.2932
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165634618E+03   -1.580732573678638E+04
Counts:
0   98257395.
1   93827014.
2   17611549.
3   1110028.
4   26536.
5   245.
6   0.
7   0.
8   0.
9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   147.29
Total processes =   4
Compiled procs =   4
Mop/sec total   =   3.64
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time = 118.0676
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165631720E+03   -1.580732573678449E+04
Counts:
0   98257395.
1   93827014.
2   17611549.
3   1110028.
4   26536.
5   245.
6   0.
7   0.
8   0.
9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   118.07
Total processes =   5
Compiled procs =   4
Mop/sec total   =   4.55
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 98.4300
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 98.43
Total processes = 6
Compiled procs = 4
Mop/sec total = 5.45
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 84.3051
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 84.31
Total processes = 7
Compiled procs = 7
Mop/sec total = 6.37
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 8

EP Benchmark Results:

CPU Time =   73.7345
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165636284E+03   -1.580732573678494E+04
Counts:
0   98257395.
1   93827014.
2   17611549.
3   1110028.
4   26536.
5   245.
6   0.
7   0.
8   0.
9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   73.73
Total processes =   8
Compiled procs =   7
Mop/sec total   =   7.28
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 9

EP Benchmark Results:

CPU Time =   65.7265
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165630960E+03   -1.580732573678866E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   65.73
Total processes =   9
Compiled procs =   7
Mop/sec total   =   8.17
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time = 59.1098
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632362E+03 -1.580732573678767E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 59.11
Total processes = 10
Compiled procs = 10
Mop/sec total = 9.08
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 11

EP Benchmark Results:

CPU Time =   53.7717
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165632911E+03   -1.580732573678582E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   53.77
Total processes =   11
Compiled procs =   10
Mop/sec total   =   9.98
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time = 49.3049
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633768E+03 -1.580732573678642E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 49.30
Total processes = 12
Compiled procs = 12
Mop/sec total = 10.89
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time =   45.5542
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165628269E+03   -1.580732573678654E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   45.55
Total processes =   13
Compiled procs =   12
Mop/sec total   =   11.79
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time = 42.2564
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635351E+03 -1.580732573678708E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 42.26
Total processes = 14
Compiled procs = 12
Mop/sec total = 12.71
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time = 39.9786
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635445E+03 -1.580732573678607E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	39.98
Total processes	=	15
Compiled procs	=	15
Mop/sec total	=	13.43
Mop/sec/process	=	0.90
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time = 36.9249
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633814E+03 -1.580732573678525E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 36.92
Total processes = 16
Compiled procs = 15
Mop/sec total = 14.54
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :      6
Number of processes :      8
Processor array     :    1x  8
Layout type         :     1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =              256x256x128
Iterations      =                        6
Time in seconds =                   810.89
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                     8.80
Mop/sec/process =                     1.10
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :          6
Number of processes :          16
Processor array     :       1x 16
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =              256x256x128
Iterations      =                        6
Time in seconds =                   884.51
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                     8.07
Mop/sec/process =                     0.50
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 8

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	283.92
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	0.30
Mop/sec/process	=	0.04
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	341.86
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	0.25
Mop/sec/process	=	0.02
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	22 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 1

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.8756130575742E-15
2	0.6340276525969E+02	0.6340276525969E+02	0.1681021481121E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.7287898208366E-15
4	0.1784530116042E+03	0.1784530116042E+03	0.2707542203819E-14
5	0.1838476034946E+04	0.1838476034946E+04	0.1484100990959E-14

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.8299601066640E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.7875436823397E-15
3	0.7347341269877E+01	0.7347341269877E+01	0.4835373161943E-15
4	0.6713922568778E+01	0.6713922568778E+01	0.5291561888607E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.6028759644299E-15

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 250
Time in seconds = 2934.86
Total processes = 1
Compiled procs = 1
Mop/sec total = 40.65
Mop/sec/process = 40.65
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 4

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1415574443078E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.2353430073569E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.1195215306172E-13
4	0.1784530116042E+03	0.1784530116042E+03	0.6370687538397E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1261485842315E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.5928286476171E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1323073386331E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.5802447794332E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.2645780944304E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.1044985005012E-13

Comparison of surface integral

0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00

Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	1079.33
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	110.53
Mop/sec/process	=	27.63
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 8

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

```
  1   0.7790210760669E+03 0.7790210760669E+03 0.1444761544997E-13
  2   0.6340276525969E+02 0.6340276525969E+02 0.5603404937070E-14
  3   0.1949924972729E+03 0.1949924972729E+03 0.9182751742541E-14
  4   0.1784530116042E+03 0.1784530116042E+03 0.1592671884599E-15
  5   0.1838476034946E+04 0.1838476034946E+04 0.1162545776251E-13
```

Comparison of RMS-norms of solution error

```
  1   0.2996408568547E+02 0.2996408568547E+02 0.9485258361874E-15
  2   0.2819457636500E+01 0.2819457636500E+01 0.1354575133624E-13
  3   0.7347341269878E+01 0.7347341269877E+01 0.7132175413867E-14
  4   0.6713922568778E+01 0.6713922568778E+01 0.6614452360759E-15
  5   0.7071531568839E+02 0.7071531568839E+02 0.1225847794341E-13
```

Comparison of surface integral

```
      0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
```

Verification Successful

LU Benchmark Completed.

```
Class           =                        A
Size            =               64x 64x 64
Iterations      =                      250
Time in seconds =                  1149.38
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                   103.79
Mop/sec/process =                    12.97
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 16

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

```
  1   0.7790210760669E+03 0.7790210760669E+03 0.1634477707472E-13
  2   0.6340276525969E+02 0.6340276525969E+02 0.5267200640846E-14
  3   0.1949924972729E+03 0.1949924972729E+03 0.8891235814207E-14
  4   0.1784530116042E+03 0.1784530116042E+03 0.3185343769198E-15
  5   0.1838476034946E+04 0.1838476034946E+04 0.1150178267993E-13
```

Comparison of RMS-norms of solution error

```
  1   0.2996408568547E+02 0.2996408568547E+02 0.4742629180937E-15
  2   0.2819457636500E+01 0.2819457636500E+01 0.1165564649863E-13
  3   0.7347341269878E+01 0.7347341269877E+01 0.6165100781478E-14
  4   0.6713922568778E+01 0.6713922568778E+01 0.1455179519367E-14
  5   0.7071531568839E+02 0.7071531568839E+02 0.1125368466936E-13
```

Comparison of surface integral

```
      0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
```

Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	1611.73
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	74.02
Mop/sec/process	=	4.63
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 16

Initialization time: 67.985 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694838067292E-16

MG Benchmark Completed.

Class	=	A
Size	=	256x256x256
Iterations	=	4
Time in seconds	=	151.53
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	25.69
Mop/sec/process	=	1.61
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400   dt: 0.001500
Number of active processes: 9

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	NAN 0.2479982239930E+01	NAN
2	NAN 0.1127633796437E+01	NAN
3	NAN 0.1502897788877E+01	NAN
4	NAN 0.1421781621170E+01	NAN
5	NAN 0.2129211303514E+01	NAN

Comparison of RMS-norms of solution error

1	NAN 0.1090014029782E-03	NAN
2	NAN 0.3734395176928E-04	NAN
3	NAN 0.5009278540654E-04	NAN
4	NAN 0.4767109393953E-04	NAN
5	NAN 0.1362161339921E-03	NAN

Verification Successful

SP Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   400
Time in seconds =   8087.23
Total processes =   9
Compiled procs =   9
Mop/sec total   =   10.51
Mop/sec/process   =   1.17
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

Performance of a cluster with a 10 Mbps network hub and nodes with 233 MHz CPU, and 128MB RAM.

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     4

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
        1 0.1080634671464E+03 0.1080634671464E+03 0.6706740118690E-14
        2 0.1131973090122E+02 0.1131973090122E+02 0.1569257127136E-14
        3 0.2597435451158E+02 0.2597435451158E+02 0.3692999157490E-14
        4 0.2366562254468E+02 0.2366562254468E+02 0.7355942989988E-14
        5 0.2527896321175E+03 0.2527896321175E+03 0.1574051628196E-13
 Comparison of RMS-norms of solution error
        1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
        2 0.4439028249700E+00 0.4439028249700E+00 0.4126731995354E-14
        3 0.9669248013635E+00 0.9669248013635E+00 0.6085459822952E-14
        4 0.8830206303977E+00 0.8830206303977E+00 0.2137412283349E-14
        5 0.9737990177083E+01 0.9737990177083E+01 0.4560378494683E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =               64x 64x 64
 Iterations      =                      200
 Time in seconds =                  2123.19
 Total processes =                        4
 Compiled procs  =                        4
 Mop/sec total     =                  79.26
 Mop/sec/process   =                  19.82
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              19 Jul 2003
```

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     9

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
       1 0.1080634671464E+03 0.1080634671464E+03 0.6969749535109E-14
       2 0.1131973090122E+02 0.1131973090122E+02 0.2040034265277E-14
       3 0.2597435451158E+02 0.2597435451158E+02 0.5197554369800E-14
       4 0.2366562254468E+02 0.2366562254468E+02 0.6755457847948E-14
       5 0.2527896321175E+03 0.2527896321175E+03 0.1326700658051E-13
 Comparison of RMS-norms of solution error
       1 0.4234841604053E+01 0.4234841604053E+01 0.6291936058601E-15
       2 0.4439028249700E+00 0.4439028249700E+00 0.7127991628339E-14
       3 0.9669248013635E+00 0.9669248013635E+00 0.1148199966595E-14
       4 0.8830206303977E+00 0.8830206303977E+00 0.7543808058880E-15
       5 0.9737990177083E+01 0.9737990177083E+01 0.5837284473195E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                  2462.84
 Total processes =                        9
 Compiled procs  =                        9
 Mop/sec total     =                  68.33
 Mop/sec/process   =                   7.59
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              19 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 200    dt:   0.000800
Number of active processes:    16

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1 0.1080634671464E+03 0.1080634671464E+03 0.7758777784367E-14
      2 0.1131973090122E+02 0.1131973090122E+02 0.3138514254272E-14
      3 0.2597435451158E+02 0.2597435451158E+02 0.5334332116374E-14
      4 0.2366562254468E+02 0.2366562254468E+02 0.1065861127121E-13
      5 0.2527896321175E+03 0.2527896321175E+03 0.1551565176365E-13
Comparison of RMS-norms of solution error
      1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
      2 0.4439028249700E+00 0.4439028249700E+00 0.3001259632985E-14
      3 0.9669248013635E+00 0.9669248013635E+00 0.3329779903125E-14
      4 0.8830206303977E+00 0.8830206303977E+00 0.4149094432384E-14
      5 0.9737990177083E+01 0.9737990177083E+01 0.7661435871068E-14
Verification Successful


BT Benchmark Completed.
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      200
Time in seconds =                  3630.28
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                    46.36
Mop/sec/process =                     2.90
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 1

iteration	||r||	zeta
1	0.27827584529972E-12	19.9997581277040
2	0.26160031018478E-14	17.1140495745506
3	0.26714791625944E-14	17.1296668946143
4	0.26473497355311E-14	17.1302113581192
5	0.25962051721040E-14	17.1302338856353
6	0.26115199334372E-14	17.1302349879482
7	0.25993680727334E-14	17.1302350498916
8	0.26120228095637E-14	17.1302350537510
9	0.25450483820989E-14	17.1302350540101
10	0.25904786670248E-14	17.1302350540284
11	0.25506293938445E-14	17.1302350540298
12	0.25257745194192E-14	17.1302350540299
13	0.25415734339777E-14	17.1302350540299
14	0.25063961032389E-14	17.1302350540299
15	0.24842598520619E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 93.90
Total processes = 1
Compiled procs = 1
Mop/sec total = 15.94
Mop/sec/process = 15.94
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 4

iteration	||r||	zeta
1	0.30380719049536E-12	19.9997581277040
2	0.29763636601233E-14	17.1140495745506
3	0.30758070039524E-14	17.1296668946143
4	0.30767836772916E-14	17.1302113581192
5	0.30362538345620E-14	17.1302338856353
6	0.30918631267811E-14	17.1302349879482
7	0.29692461545083E-14	17.1302350498916
8	0.30136035568592E-14	17.1302350537510
9	0.30210087485660E-14	17.1302350540101
10	0.29835949970093E-14	17.1302350540284
11	0.29536430530910E-14	17.1302350540298
12	0.29781985872281E-14	17.1302350540299
13	0.29621143458868E-14	17.1302350540299
14	0.29849869948111E-14	17.1302350540299
15	0.29517709020202E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 163.38
Total processes = 4
Compiled procs = 4
Mop/sec total = 9.16
Mop/sec/process = 2.29
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 8

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 251.70
Total processes = 8
Compiled procs = 8
Mop/sec total = 5.95
Mop/sec/process = 0.74
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 16

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 515.56
Total processes = 16
Compiled procs = 16
Mop/sec total = 2.90
Mop/sec/process = 0.18
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 587.6175
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165629841E+03 -1.580732573678431E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 587.62
Total processes = 1
Compiled procs = 1
Mop/sec total = 0.91
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time = 295.1406
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165639063E+03 -1.580732573678573E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 295.14
Total processes = 2
Compiled procs = 1
Mop/sec total = 1.82
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 3

EP Benchmark Results:

CPU Time = 196.5423
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165637473E+03 -1.580732573677940E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 196.54
Total processes = 3
Compiled procs = 3
Mop/sec total = 2.73
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
 NAS Parallel Benchmarks 2.3 -- EP Benchmark

 Number of random numbers generated:    536870912
 Number of active processes:                    4

EP Benchmark Results:

CPU Time =  147.3351
N = 2^   28
No. Gaussian Pairs =     210832767.
Sums =    -4.295875165634618E+03   -1.580732573678638E+04
Counts:
  0      98257395.
  1      93827014.
  2      17611549.
  3       1110028.
  4         26536.
  5           245.
  6             0.
  7             0.
  8             0.
  9             0.


 EP Benchmark Completed.
 Class           =                        A
 Size            =                536870912
 Iterations      =                        0
 Time in seconds =                   147.34
 Total processes =                        4
 Compiled procs  =                        4
 Mop/sec total     =                   3.64
 Mop/sec/process   =                   0.91
 Operation type  = Random numbers generated
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time = 118.0530
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165631720E+03   -1.580732573678449E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   118.05
Total processes =   5
Compiled procs =   4
Mop/sec total   =   4.55
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 98.4486
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 98.45
Total processes = 6
Compiled procs = 6
Mop/sec total = 5.45
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 84.3908
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 84.39
Total processes = 7
Compiled procs = 7
Mop/sec total = 6.36
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 8

EP Benchmark Results:

CPU Time = 73.7422
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165636284E+03 -1.580732573678494E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 73.74
Total processes = 8
Compiled procs = 7
Mop/sec total = 7.28
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 9

EP Benchmark Results:

CPU Time = 65.6952
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165630960E+03 -1.580732573678866E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 65.70
Total processes = 9
Compiled procs = 9
Mop/sec total = 8.17
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time =   59.1105
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165632362E+03   -1.580732573678767E+04
Counts:
  0   98257395.
  1   93827014.
  2   17611549.
  3   1110028.
  4   26536.
  5   245.
  6   0.
  7   0.
  8   0.
  9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   59.11
Total processes =   10
Compiled procs =   10
Mop/sec total   =   9.08
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 11

EP Benchmark Results:

CPU Time = 53.7820
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632911E+03 -1.580732573678582E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 53.78
Total processes = 11
Compiled procs = 11
Mop/sec total = 9.98
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time =   49.3214
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165633768E+03   -1.580732573678642E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   49.32
Total processes =   12
Compiled procs =   11
Mop/sec total   =   10.89
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time = 45.5201
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165628269E+03 -1.580732573678654E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 45.52
Total processes = 13
Compiled procs = 13
Mop/sec total = 11.79
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time = 42.2586
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635351E+03 -1.580732573678708E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	42.26
Total processes	=	14
Compiled procs	=	14
Mop/sec total	=	12.70
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time = 39.4687
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635445E+03 -1.580732573678607E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 39.47
Total processes = 15
Compiled procs = 14
Mop/sec total = 13.60
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time = 36.9187
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633814E+03 -1.580732573678525E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	36.92
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	14.54
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 4
Processor array : 1x 4
Layout type : 1D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 754.61
Total processes = 4
Compiled procs = 4
Mop/sec total = 9.46
Mop/sec/process = 2.36
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 8
Processor array : 1x 8
Layout type : 1D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 804.35
Total processes = 8
Compiled procs = 8
Mop/sec total = 8.87
Mop/sec/process = 1.11
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 16
Processor array : 1x 16
Layout type : 1D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 839.54
Total processes = 16
Compiled procs = 16
Mop/sec total = 8.50
Mop/sec/process = 0.53
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 4

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	255.60
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	0.33
Mop/sec/process	=	0.08
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 8

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	284.53
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	0.29
Mop/sec/process	=	0.04
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed
Class = A
Size = 8388608
Iterations = 10
Time in seconds = 328.59
Total processes = 16
Compiled procs = 16
Mop/sec total = 0.26
Mop/sec/process = 0.02
Operation type = keys ranked
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 1

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.8756130575742E-15
2	0.6340276525969E+02	0.6340276525969E+02	0.1681021481121E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.7287898208366E-15
4	0.1784530116042E+03	0.1784530116042E+03	0.2707542203819E-14
5	0.1838476034946E+04	0.1838476034946E+04	0.1484100990959E-14

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.8299601066640E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.7875436823397E-15
3	0.7347341269877E+01	0.7347341269877E+01	0.4835373161943E-15
4	0.6713922568778E+01	0.6713922568778E+01	0.5291561888607E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.6028759644299E-15

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	2931.53
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	40.69
Mop/sec/process	=	40.69
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

```
 NAS Parallel Benchmarks 2.2 -- LU Benchmark

 Size:  64x 64x 64
 Iterations: 250
 Number of processes:     4

Verification being performed for class A
 Accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
        1   0.7790210760669E+03 0.7790210760669E+03 0.1415574443078E-13
        2   0.6340276525969E+02 0.6340276525969E+02 0.2353430073569E-14
        3   0.1949924972729E+03 0.1949924972729E+03 0.1195215306172E-13
        4   0.1784530116042E+03 0.1784530116042E+03 0.6370687538397E-15
        5   0.1838476034946E+04 0.1838476034946E+04 0.1261485842315E-13
 Comparison of RMS-norms of solution error
        1   0.2996408568547E+02 0.2996408568547E+02 0.5928286476171E-15
        2   0.2819457636500E+01 0.2819457636500E+01 0.1323073386331E-13
        3   0.7347341269878E+01 0.7347341269877E+01 0.5802447794332E-14
        4   0.6713922568778E+01 0.6713922568778E+01 0.2645780944304E-15
        5   0.7071531568839E+02 0.7071531568839E+02 0.1044985005012E-13
 Comparison of surface integral
            0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
 Verification Successful


 LU Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      250
 Time in seconds =                  1081.34
 Total processes =                        4
 Compiled procs  =                        4
 Mop/sec total     =                 110.32
 Mop/sec/process   =                  27.58
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 8

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1444761544997E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.5603404937070E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.9182751742541E-14
4	0.1784530116042E+03	0.1784530116042E+03	0.1592671884599E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1162545776251E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.9485258361874E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1354575133624E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.7132175413867E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.6614452360759E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.1225847794341E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	1148.76
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	103.85
Mop/sec/process	=	12.98
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:    16

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1   0.7790210760669E+03 0.7790210760669E+03 0.1634477707472E-13
     2   0.6340276525969E+02 0.6340276525969E+02 0.5267200640846E-14
     3   0.1949924972729E+03 0.1949924972729E+03 0.8891235814207E-14
     4   0.1784530116042E+03 0.1784530116042E+03 0.3185343769198E-15
     5   0.1838476034946E+04 0.1838476034946E+04 0.1150178267993E-13
Comparison of RMS-norms of solution error
     1   0.2996408568547E+02 0.2996408568547E+02 0.4742629180937E-15
     2   0.2819457636500E+01 0.2819457636500E+01 0.1165564649863E-13
     3   0.7347341269878E+01 0.7347341269877E+01 0.6165100781478E-14
     4   0.6713922568778E+01 0.6713922568778E+01 0.1455179519367E-14
     5   0.7071531568839E+02 0.7071531568839E+02 0.1125368466936E-13
Comparison of surface integral
         0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      250
Time in seconds =                  1607.40
Total processes =                       16
Compiled procs  =                       16
Mop/sec total     =                  74.22
Mop/sec/process   =                   4.64
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 4

Initialization time: 51.618 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694334082688E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 114.84
Total processes = 4
Compiled procs = 4
Mop/sec total = 33.89
Mop/sec/process = 8.47
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 8

Initialization time: 53.180 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694952416740E-16

MG Benchmark Completed.

Class	=	A
Size	=	256x256x256
Iterations	=	4
Time in seconds	=	122.20
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	31.85
Mop/sec/process	=	3.98
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 16

Initialization time: 64.421 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694838067292E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 152.04
Total processes = 16
Compiled procs = 8
Mop/sec total = 25.60
Mop/sec/process = 1.60
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     1

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1 0.2479982239930E+01 0.2479982239930E+01 0.6858362315424E-13
     2 0.1127633796437E+01 0.1127633796437E+01 0.2205414189446E-13
     3 0.1502897788877E+01 0.1502897788877E+01 0.5097178881098E-13
     4 0.1421781621169E+01 0.1421781621170E+01 0.3919954724857E-13
     5 0.2129211303514E+01 0.2129211303514E+01 0.1147133988132E-13
Comparison of RMS-norms of solution error
     1 0.1090014029782E-03 0.1090014029782E-03 0.3948832315147E-12
     2 0.3734395176928E-04 0.3734395176928E-04 0.3737982272737E-13
     3 0.5009278540654E-04 0.5009278540654E-04 0.1623290904598E-14
     4 0.4767109393953E-04 0.4767109393953E-04 0.1361760339713E-12
     5 0.1362161339921E-03 0.1362161339921E-03 0.6208351901894E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =               64x 64x 64
Iterations      =                      400
Time in seconds =                  3351.15
Total processes =                        1
Compiled procs  =                        1
Mop/sec total   =                    25.37
Mop/sec/process =                    25.37
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400 dt: 0.001500
Number of active processes: 4

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.2479982239930E+01 0.2479982239930E+01 0.4655807315954E-13
2 0.1127633796437E+01 0.1127633796437E+01 0.3997313218370E-13
3 0.1502897788877E+01 0.1502897788877E+01 0.1654736332415E-13
4 0.1421781621169E+01 0.1421781621170E+01 0.3388964841809E-13
5 0.2129211303514E+01 0.2129211303514E+01 0.1710272491397E-13
Comparison of RMS-norms of solution error
1 0.1090014029782E-03 0.1090014029782E-03 0.3962509001377E-12
2 0.3734395176928E-04 0.3734395176928E-04 0.4663405068414E-13
3 0.5009278540654E-04 0.5009278540654E-04 0.6168505437472E-13
4 0.4767109393954E-04 0.4767109393953E-04 0.1522385515483E-12
5 0.1362161339921E-03 0.1362161339921E-03 0.4795553872937E-13
Verification Successful

SP Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 400
Time in seconds = 2700.65
Total processes = 4
Compiled procs = 4
Mop/sec total = 31.48
Mop/sec/process = 7.87
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     9

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1              NAN 0.2479982239930E+01              NAN
      2              NAN 0.1127633796437E+01              NAN
      3              NAN 0.1502897788877E+01              NAN
      4              NAN 0.1421781621170E+01              NAN
      5              NAN 0.2129211303514E+01              NAN
Comparison of RMS-norms of solution error
      1              NAN 0.1090014029782E-03              NAN
      2              NAN 0.3734395176928E-04              NAN
      3              NAN 0.5009278540654E-04              NAN
      4              NAN 0.4767109393953E-04              NAN
      5              NAN 0.1362161339921E-03              NAN
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      400
Time in seconds =                  8080.47
Total processes =                        9
Compiled procs  =                        9
Mop/sec total   =                    10.52
Mop/sec/process =                     1.17
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400   dt: 0.001500
Number of active processes: 16

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
    1 0.2479982239930E+01 0.2479982239930E+01 0.7861151583476E-13
    2 0.1127633796437E+01 0.1127633796437E+01 0.9451775097624E-14
    3 0.1502897788877E+01 0.1502897788877E+01 0.6707591918895E-13
    4 0.1421781621170E+01 0.1421781621170E+01 0.3123469900284E-14
    5 0.2129211303514E+01 0.2129211303514E+01 0.2356838921071E-13
Comparison of RMS-norms of solution error
    1 0.1090014029782E-03 0.1090014029782E-03 0.3860555522208E-12
    2 0.3734395176928E-04 0.3734395176928E-04 0.3048451562232E-13
    3 0.5009278540654E-04 0.5009278540654E-04 0.1007793103271E-12
    4 0.4767109393954E-04 0.4767109393953E-04 0.1640366839278E-12
    5 0.1362161339921E-03 0.1362161339921E-03 0.2606711856244E-13
Verification Successful

SP Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   400
Time in seconds =   6068.85
Total processes =   16
Compiled procs =   16
Mop/sec total   =   14.01
Mop/sec/process   =   0.88
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

Performance of a cluster with a 10 Mbps network hub and nodes with 233 MHz CPU, and 256MB RAM.

```
NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 200    dt:   0.000800
Number of active processes:     4

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1 0.1080634671464E+03 0.1080634671464E+03 0.6706740118690E-14
      2 0.1131973090122E+02 0.1131973090122E+02 0.1569257127136E-14
      3 0.2597435451158E+02 0.2597435451158E+02 0.3692999157490E-14
      4 0.2366562254468E+02 0.2366562254468E+02 0.7355942989988E-14
      5 0.2527896321175E+03 0.2527896321175E+03 0.1574051628196E-13
Comparison of RMS-norms of solution error
      1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
      2 0.4439028249700E+00 0.4439028249700E+00 0.4126731995354E-14
      3 0.9669248013635E+00 0.9669248013635E+00 0.6085459822952E-14
      4 0.8830206303977E+00 0.8830206303977E+00 0.2137412283349E-14
      5 0.9737990177083E+01 0.9737990177083E+01 0.4560378494683E-14
Verification Successful


BT Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      200
Time in seconds =                  2126.32
Total processes =                        4
Compiled procs  =                        4
Mop/sec total     =                  79.14
Mop/sec/process   =                  19.79
Operation type  =           floating point
Verification    =             SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 200   dt: 0.000800
Number of active processes: 9

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
    1 0.1080634671464E+03 0.1080634671464E+03 0.6969749535109E-14
    2 0.1131973090122E+02 0.1131973090122E+02 0.2040034265277E-14
    3 0.2597435451158E+02 0.2597435451158E+02 0.5197554369800E-14
    4 0.2366562254468E+02 0.2366562254468E+02 0.6755457847948E-14
    5 0.2527896321175E+03 0.2527896321175E+03 0.1326700658051E-13
Comparison of RMS-norms of solution error
    1 0.4234841604053E+01 0.4234841604053E+01 0.6291936058601E-15
    2 0.4439028249700E+00 0.4439028249700E+00 0.7127991628339E-14
    3 0.9669248013635E+00 0.9669248013635E+00 0.1148199966595E-14
    4 0.8830206303977E+00 0.8830206303977E+00 0.7543808058880E-15
    5 0.9737990177083E+01 0.9737990177083E+01 0.5837284473195E-14
Verification Successful

BT Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   200
Time in seconds =   2464.73
Total processes =   9
Compiled procs =   9
Mop/sec total   =   68.28
Mop/sec/process   =   7.59
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:    16

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
       1 0.1080634671464E+03 0.1080634671464E+03 0.7758777784367E-14
       2 0.1131973090122E+02 0.1131973090122E+02 0.3138514254272E-14
       3 0.2597435451158E+02 0.2597435451158E+02 0.5334332116374E-14
       4 0.2366562254468E+02 0.2366562254468E+02 0.1065861127121E-13
       5 0.2527896321175E+03 0.2527896321175E+03 0.1551565176365E-13
 Comparison of RMS-norms of solution error
       1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
       2 0.4439028249700E+00 0.4439028249700E+00 0.3001259632985E-14
       3 0.9669248013635E+00 0.9669248013635E+00 0.3329779903125E-14
       4 0.8830206303977E+00 0.8830206303977E+00 0.4149094432384E-14
       5 0.9737990177083E+01 0.9737990177083E+01 0.7661435871068E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                  3635.49
 Total processes =                       16
 Compiled procs  =                       16
 Mop/sec total     =                  46.29
 Mop/sec/process   =                   2.89
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              24 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 1

iteration	||r||	zeta
1	0.27827584529972E-12	19.9997581277040
2	0.26160031018478E-14	17.1140495745506
3	0.26714791625944E-14	17.1296668946143
4	0.26473497355311E-14	17.1302113581192
5	0.25962051721040E-14	17.1302338856353
6	0.26115199334372E-14	17.1302349879482
7	0.25993680727334E-14	17.1302350498916
8	0.26120228095637E-14	17.1302350537510
9	0.25450483820989E-14	17.1302350540101
10	0.25904786670248E-14	17.1302350540284
11	0.25506293938445E-14	17.1302350540298
12	0.25257745194192E-14	17.1302350540299
13	0.25415734339777E-14	17.1302350540299
14	0.25063961032389E-14	17.1302350540299
15	0.24842598520619E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 94.01
Total processes = 1
Compiled procs = 1
Mop/sec total = 15.92
Mop/sec/process = 15.92
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 4

iteration	||r||	zeta
1	0.30380719049536E-12	19.9997581277040
2	0.29763636601233E-14	17.1140495745506
3	0.30758070039524E-14	17.1296668946143
4	0.30767836772916E-14	17.1302113581192
5	0.30362538345620E-14	17.1302338856353
6	0.30918631267811E-14	17.1302349879482
7	0.29692461545083E-14	17.1302350498916
8	0.30136035568592E-14	17.1302350537510
9	0.30210087485660E-14	17.1302350540101
10	0.29835949970093E-14	17.1302350540284
11	0.29536430530910E-14	17.1302350540298
12	0.29781985872281E-14	17.1302350540299
13	0.29621143458868E-14	17.1302350540299
14	0.29849869948111E-14	17.1302350540299
15	0.29517709020202E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 163.95
Total processes = 4
Compiled procs = 4
Mop/sec total = 9.13
Mop/sec/process = 2.28
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 8

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 252.89
Total processes = 8
Compiled procs = 8
Mop/sec total = 5.92
Mop/sec/process = 0.74
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 16

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 513.84
Total processes = 16
Compiled procs = 16
Mop/sec total = 2.91
Mop/sec/process = 0.18
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 589.7941
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165629841E+03 -1.580732573678431E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 589.79
Total processes = 1
Compiled procs = 1
Mop/sec total = 0.91
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time = 295.1688
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165639063E+03 -1.580732573678573E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	295.17
Total processes	=	2
Compiled procs	=	1
Mop/sec total	=	1.82
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 3

EP Benchmark Results:

CPU Time = 196.7278
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165637473E+03 -1.580732573677940E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 196.73
Total processes = 3
Compiled procs = 1
Mop/sec total = 2.73
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 4

EP Benchmark Results:

CPU Time = 147.6002
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634618E+03 -1.580732573678638E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 147.60
Total processes = 4
Compiled procs = 4
Mop/sec total = 3.64
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time = 118.0491
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165631720E+03 -1.580732573678449E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 118.05
Total processes = 5
Compiled procs = 4
Mop/sec total = 4.55
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 98.4378
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 98.44
Total processes = 6
Compiled procs = 4
Mop/sec total = 5.45
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 84.3256
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 84.33
Total processes = 7
Compiled procs = 7
Mop/sec total = 6.37
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 8

EP Benchmark Results:

CPU Time = 73.8044
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165636284E+03 -1.580732573678494E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	73.80
Total processes	=	8
Compiled procs	=	7
Mop/sec total	=	7.27
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 9

EP Benchmark Results:

CPU Time = 65.6109
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165630960E+03 -1.580732573678866E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 65.61
Total processes = 9
Compiled procs = 7
Mop/sec total = 8.18
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time = 59.1124
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632362E+03 -1.580732573678767E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 59.11
Total processes = 10
Compiled procs = 10
Mop/sec total = 9.08
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 11

EP Benchmark Results:

CPU Time = 53.7263
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632911E+03 -1.580732573678582E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 53.73
Total processes = 11
Compiled procs = 10
Mop/sec total = 9.99
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time = 49.3095
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633768E+03 -1.580732573678642E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 49.31
Total processes = 12
Compiled procs = 12
Mop/sec total = 10.89
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time = 45.5004
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165628269E+03 -1.580732573678654E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	45.50
Total processes	=	13
Compiled procs	=	12
Mop/sec total	=	11.80
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time = 42.2728
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635351E+03 -1.580732573678708E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	42.27
Total processes	=	14
Compiled procs	=	12
Mop/sec total	=	12.70
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time = 39.4574
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635445E+03 -1.580732573678607E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 39.46
Total processes = 15
Compiled procs = 15
Mop/sec total = 13.61
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time = 36.9269
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633814E+03 -1.580732573678525E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 36.93
Total processes = 16
Compiled procs = 15
Mop/sec total = 14.54
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :          6
Number of processes :          4
Processor array     :       1x  4
Layout type         :         1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =              256x256x128
Iterations      =                        6
Time in seconds =                   755.98
Total processes =                        4
Compiled procs  =                        4
Mop/sec total   =                     9.44
Mop/sec/process   =                   2.36
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :           6
Number of processes :           8
Processor array     :       1x  8
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =              256x256x128
Iterations      =                        6
Time in seconds =                   803.26
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                     8.88
Mop/sec/process =                     1.11
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 16
Processor array : 1x 16
Layout type : 1D

T =	1	Checksum =	5.046735008193E+02	5.114047905510E+02
T =	2	Checksum =	5.059412319734E+02	5.098809666433E+02
T =	3	Checksum =	5.069376896287E+02	5.098144042213E+02
T =	4	Checksum =	5.077892868474E+02	5.101336130759E+02
T =	5	Checksum =	5.085233095391E+02	5.104914655194E+02
T =	6	Checksum =	5.091487099959E+02	5.107917842803E+02

Result verification successful
class = A

FT Benchmark Completed.

Class	=	A
Size	=	256x256x128
Iterations	=	6
Time in seconds	=	844.88
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	8.45
Mop/sec/process	=	0.53
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 1

```
 iteration
       1
       2
       3
       4
       5
       6
       7
       8
       9
       10
```

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	29.71
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	2.82
Mop/sec/process	=	2.82
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 4

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	256.53
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	0.33
Mop/sec/process	=	0.08
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	24 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size:  8388608  (class A)
Iterations:   10
Number of processes:     8

  iteration
       1
       2
       3
       4
       5
       6
       7
       8
       9
       10


IS Benchmark Completed
Class           =                        A
Size            =                  8388608
Iterations      =                       10
Time in seconds =                   283.97
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                     0.30
Mop/sec/process =                     0.04
Operation type  =              keys ranked
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	324.29
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	0.26
Mop/sec/process	=	0.02
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	22 Jul 2003

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:     1

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1   0.7790210760669E+03 0.7790210760669E+03 0.8756130575742E-15
     2   0.6340276525969E+02 0.6340276525969E+02 0.1681021481121E-14
     3   0.1949924972729E+03 0.1949924972729E+03 0.7287898208366E-15
     4   0.1784530116042E+03 0.1784530116042E+03 0.2707542203819E-14
     5   0.1838476034946E+04 0.1838476034946E+04 0.1484100990959E-14
Comparison of RMS-norms of solution error
     1   0.2996408568547E+02 0.2996408568547E+02 0.8299601066640E-15
     2   0.2819457636500E+01 0.2819457636500E+01 0.7875436823397E-15
     3   0.7347341269877E+01 0.7347341269877E+01 0.4835373161943E-15
     4   0.6713922568778E+01 0.6713922568778E+01 0.5291561888607E-15
     5   0.7071531568839E+02 0.7071531568839E+02 0.6028759644299E-15
Comparison of surface integral
         0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      250
Time in seconds =                  2930.75
Total processes =                        1
Compiled procs  =                        1
Mop/sec total     =                  40.71
Mop/sec/process   =                  40.71
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 4

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1415574443078E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.2353430073569E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.1195215306172E-13
4	0.1784530116042E+03	0.1784530116042E+03	0.6370687538397E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1261485842315E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.5928286476171E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1323073386331E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.5802447794332E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.2645780944304E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.1044985005012E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	1080.81
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	110.38
Mop/sec/process	=	27.59
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:     8

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1   0.7790210760669E+03 0.7790210760669E+03 0.1444761544997E-13
      2   0.6340276525969E+02 0.6340276525969E+02 0.5603404937070E-14
      3   0.1949924972729E+03 0.1949924972729E+03 0.9182751742541E-14
      4   0.1784530116042E+03 0.1784530116042E+03 0.1592671884599E-15
      5   0.1838476034946E+04 0.1838476034946E+04 0.1162545776251E-13
Comparison of RMS-norms of solution error
      1   0.2996408568547E+02 0.2996408568547E+02 0.9485258361874E-15
      2   0.2819457636500E+01 0.2819457636500E+01 0.1354575133624E-13
      3   0.7347341269878E+01 0.7347341269877E+01 0.7132175413867E-14
      4   0.6713922568778E+01 0.6713922568778E+01 0.6614452360759E-15
      5   0.7071531568839E+02 0.7071531568839E+02 0.1225847794341E-13
Comparison of surface integral
          0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =               64x 64x 64
Iterations      =                      250
Time in seconds =                  1148.98
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                   103.83
Mop/sec/process =                    12.98
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 16

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

```
1  0.7790210760669E+03 0.7790210760669E+03 0.1634477707472E-13
2  0.6340276525969E+02 0.6340276525969E+02 0.5267200640846E-14
3  0.1949924972729E+03 0.1949924972729E+03 0.8891235814207E-14
4  0.1784530116042E+03 0.1784530116042E+03 0.3185343769198E-15
5  0.1838476034946E+04 0.1838476034946E+04 0.1150178267993E-13
```

Comparison of RMS-norms of solution error

```
1  0.2996408568547E+02 0.2996408568547E+02 0.4742629180937E-15
2  0.2819457636500E+01 0.2819457636500E+01 0.1165564649863E-13
3  0.7347341269878E+01 0.7347341269877E+01 0.6165100781478E-14
4  0.6713922568778E+01 0.6713922568778E+01 0.1455179519367E-14
5  0.7071531568839E+02 0.7071531568839E+02 0.1125368466936E-13
```

Comparison of surface integral

```
   0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
```

Verification Successful

LU Benchmark Completed.

```
Class           =   A
Size            =   64x 64x 64
Iterations      =   250
Time in seconds =   1609.63
Total processes =   16
Compiled procs  =   16
Mop/sec total   =   74.11
Mop/sec/process =   4.63
Operation type  =   floating point
Verification    =   SUCCESSFUL
Version         =   2.3
Compile date    =   21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 4

Initialization time: 48.977 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694334082688E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 112.66
Total processes = 4
Compiled procs = 4
Mop/sec total = 34.55
Mop/sec/process = 8.64
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 8

Initialization time: 53.923 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694952416740E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 121.96
Total processes = 8
Compiled procs = 8
Mop/sec total = 31.92
Mop/sec/process = 3.99
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 16

Initialization time: 65.218 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694838067292E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 151.22
Total processes = 16
Compiled procs = 16
Mop/sec total = 25.74
Mop/sec/process = 1.61
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400   dt: 0.001500
Number of active processes: 1

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
    1 0.2479982239930E+01 0.2479982239930E+01 0.6858362315424E-13
    2 0.1127633796437E+01 0.1127633796437E+01 0.2205414189446E-13
    3 0.1502897788877E+01 0.1502897788877E+01 0.5097178881098E-13
    4 0.1421781621169E+01 0.1421781621170E+01 0.3919954724857E-13
    5 0.2129211303514E+01 0.2129211303514E+01 0.1147133988132E-13
Comparison of RMS-norms of solution error
    1 0.1090014029782E-03 0.1090014029782E-03 0.3948832315147E-12
    2 0.3734395176928E-04 0.3734395176928E-04 0.3737982272737E-13
    3 0.5009278540654E-04 0.5009278540654E-04 0.1623290904598E-14
    4 0.4767109393953E-04 0.4767109393953E-04 0.1361760339713E-12
    5 0.1362161339921E-03 0.1362161339921E-03 0.6208351901894E-13
Verification Successful

SP Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   400
Time in seconds =   3351.64
Total processes =   1
Compiled procs =   1
Mop/sec total   =   25.36
Mop/sec/process   =   25.36
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     4

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
    1 0.2479982239930E+01 0.2479982239930E+01 0.4655807315954E-13
    2 0.1127633796437E+01 0.1127633796437E+01 0.3997313218370E-13
    3 0.1502897788877E+01 0.1502897788877E+01 0.1654736332415E-13
    4 0.1421781621169E+01 0.1421781621170E+01 0.3388964841809E-13
    5 0.2129211303514E+01 0.2129211303514E+01 0.1710272491397E-13
Comparison of RMS-norms of solution error
    1 0.1090014029782E-03 0.1090014029782E-03 0.3962509001377E-12
    2 0.3734395176928E-04 0.3734395176928E-04 0.4663405068414E-13
    3 0.5009278540654E-04 0.5009278540654E-04 0.6168505437472E-13
    4 0.4767109393954E-04 0.4767109393953E-04 0.1522385515483E-12
    5 0.1362161339921E-03 0.1362161339921E-03 0.4795553872937E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      400
Time in seconds =                  2695.79
Total processes =                        4
Compiled procs  =                        4
Mop/sec total   =                    31.53
Mop/sec/process =                     7.88
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400 dt: 0.001500
Number of active processes: 9

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	NAN	0.2479982239930E+01	NAN
2	NAN	0.1127633796437E+01	NAN
3	NAN	0.1502897788877E+01	NAN
4	NAN	0.1421781621170E+01	NAN
5	NAN	0.2129211303514E+01	NAN

Comparison of RMS-norms of solution error

1	NAN	0.1090014029782E-03	NAN
2	NAN	0.3734395176928E-04	NAN
3	NAN	0.5009278540654E-04	NAN
4	NAN	0.4767109393953E-04	NAN
5	NAN	0.1362161339921E-03	NAN

Verification Successful

SP Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	400
Time in seconds	=	8083.21
Total processes	=	9
Compiled procs	=	9
Mop/sec total	=	10.52
Mop/sec/process	=	1.17
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:    16

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1 0.2479982239930E+01 0.2479982239930E+01 0.7861151583476E-13
     2 0.1127633796437E+01 0.1127633796437E+01 0.9451775097624E-14
     3 0.1502897788877E+01 0.1502897788877E+01 0.6707591918895E-13
     4 0.1421781621170E+01 0.1421781621170E+01 0.3123469900284E-14
     5 0.2129211303514E+01 0.2129211303514E+01 0.2356838921071E-13
Comparison of RMS-norms of solution error
     1 0.1090014029782E-03 0.1090014029782E-03 0.3860555522208E-12
     2 0.3734395176928E-04 0.3734395176928E-04 0.3048451562232E-13
     3 0.5009278540654E-04 0.5009278540654E-04 0.1007793103271E-12
     4 0.4767109393954E-04 0.4767109393953E-04 0.1640366839278E-12
     5 0.1362161339921E-03 0.1362161339921E-03 0.2606711856244E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      400
Time in seconds =                  6068.61
Total processes =                       16
Compiled procs  =                       16
Mop/sec total     =                  14.01
Mop/sec/process   =                   0.88
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

Performance of a cluster with a 10 Mbps network switch and nodes with 233 MHz CPU, and 64MB RAM.

NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 200 dt: 0.000800
Number of active processes: 9

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.1080634671464E+03 0.1080634671464E+03 0.6969749535109E-14
2 0.1131973090122E+02 0.1131973090122E+02 0.2040034265277E-14
3 0.2597435451158E+02 0.2597435451158E+02 0.5197554369800E-14
4 0.2366562254468E+02 0.2366562254468E+02 0.6755457847948E-14
5 0.2527896321175E+03 0.2527896321175E+03 0.1326700658051E-13
Comparison of RMS-norms of solution error
1 0.4234841604053E+01 0.4234841604053E+01 0.6291936058601E-15
2 0.4439028249700E+00 0.4439028249700E+00 0.7127991628339E-14
3 0.9669248013635E+00 0.9669248013635E+00 0.1148199966595E-14
4 0.8830206303977E+00 0.8830206303977E+00 0.7543808058880E-15
5 0.9737990177083E+01 0.9737990177083E+01 0.5837284473195E-14
Verification Successful

BT Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 200
Time in seconds = 2131.70
Total processes = 9
Compiled procs = 9
Mop/sec total = 78.94
Mop/sec/process = 8.77
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 1

iteration	||r||	zeta
1	0.27827584529972E-12	19.9997581277040
2	0.26160031018478E-14	17.1140495745506
3	0.26714791625944E-14	17.1296668946143
4	0.26473497355311E-14	17.1302113581192
5	0.25962051721040E-14	17.1302338856353
6	0.26115199334372E-14	17.1302349879482
7	0.25993680727334E-14	17.1302350498916
8	0.26120228095637E-14	17.1302350537510
9	0.25450483820989E-14	17.1302350540101
10	0.25904786670248E-14	17.1302350540284
11	0.25506293938445E-14	17.1302350540298
12	0.25257745194192E-14	17.1302350540299
13	0.25415734339777E-14	17.1302350540299
14	0.25063961032389E-14	17.1302350540299
15	0.24842598520619E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 93.95
Total processes = 1
Compiled procs = 1
Mop/sec total = 15.93
Mop/sec/process = 15.93
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 8

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 458.96
Total processes = 8
Compiled procs = 8
Mop/sec total = 3.26
Mop/sec/process = 0.41
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size:      14000
Iterations:    15
Number of active processes:    16

  iteration          ||r||                 zeta
       1       0.26430287941297E-12    19.9997581277040
       2       0.26414813392819E-14    17.1140495745506
       3       0.26266612893876E-14    17.1296668946143
       4       0.26223598758375E-14    17.1302113581192
       5       0.26182783886564E-14    17.1302338856353
       6       0.26288689973095E-14    17.1302349879482
       7       0.25972755600456E-14    17.1302350498916
       8       0.25774519203481E-14    17.1302350537510
       9       0.25550821991349E-14    17.1302350540101
      10       0.25670770323505E-14    17.1302350540284
      11       0.25758028098708E-14    17.1302350540298
      12       0.25113124979678E-14    17.1302350540299
      13       0.25036350044005E-14    17.1302350540299
      14       0.24859657049077E-14    17.1302350540299
      15       0.24631513623583E-14    17.1302350540299
Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is      0.171302350540E+02
Error is     0.891731133379E-12


CG Benchmark Completed.
Class           =                        A
Size            =                    14000
Iterations      =                       15
Time in seconds =                   572.35
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                     2.61
Mop/sec/process =                     0.16
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 589.8275
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165629841E+03 -1.580732573678431E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 589.83
Total processes = 1
Compiled procs = 1
Mop/sec total = 0.91
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time = 294.8042
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165639063E+03 -1.580732573678573E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 294.80
Total processes = 2
Compiled procs = 1
Mop/sec total = 1.82
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 3

EP Benchmark Results:

CPU Time = 196.6669
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165637473E+03 -1.580732573677940E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 196.67
Total processes = 3
Compiled procs = 3
Mop/sec total = 2.73
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 4

EP Benchmark Results:

CPU Time = 147.3235
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634618E+03 -1.580732573678638E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 147.32
Total processes = 4
Compiled procs = 4
Mop/sec total = 3.64
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time = 118.0366
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165631720E+03 -1.580732573678449E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 118.04
Total processes = 5
Compiled procs = 4
Mop/sec total = 4.55
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 98.4360
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 98.44
Total processes = 6
Compiled procs = 6
Mop/sec total = 5.45
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 84.2562
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 84.26
Total processes = 7
Compiled procs = 7
Mop/sec total = 6.37
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 8

EP Benchmark Results:

CPU Time = 73.7954
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165636284E+03 -1.580732573678494E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 73.80
Total processes = 8
Compiled procs = 7
Mop/sec total = 7.28
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 9

EP Benchmark Results:

CPU Time = 65.9710
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165630960E+03 -1.580732573678866E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 65.97
Total processes = 9
Compiled procs = 9
Mop/sec total = 8.14
Mop/sec/process = 0.90
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time = 59.5830
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632362E+03 -1.580732573678767E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 59.58
Total processes = 10
Compiled procs = 10
Mop/sec total = 9.01
Mop/sec/process = 0.90
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 11

EP Benchmark Results:

CPU Time = 54.2826
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632911E+03 -1.580732573678582E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 54.28
Total processes = 11
Compiled procs = 11
Mop/sec total = 9.89
Mop/sec/process = 0.90
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time = 49.8419
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633768E+03 -1.580732573678642E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 49.84
Total processes = 12
Compiled procs = 11
Mop/sec total = 10.77
Mop/sec/process = 0.90
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time = 46.1314
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165628269E+03 -1.580732573678654E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 46.13
Total processes = 13
Compiled procs = 13
Mop/sec total = 11.64
Mop/sec/process = 0.90
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time =   42.8509
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165635351E+03   -1.580732573678708E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   42.85
Total processes =   14
Compiled procs =   14
Mop/sec total   =   12.53
Mop/sec/process   =   0.89
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time = 40.5474
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635445E+03 -1.580732573678607E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 40.55
Total processes = 15
Compiled procs = 14
Mop/sec total = 13.24
Mop/sec/process = 0.88
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time = 38.0074
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633814E+03 -1.580732573678525E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 38.01
Total processes = 16
Compiled procs = 16
Mop/sec total = 14.13
Mop/sec/process = 0.88
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :          6
Number of processes :          8
Processor array     :        1x  8
Layout type         :         1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =             256x256x128
Iterations      =                        6
Time in seconds =                   497.62
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                    14.34
Mop/sec/process =                     1.79
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :          6
Number of processes :         16
Processor array     :       1x 16
Layout type         :         1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =            256x256x128
Iterations      =                        6
Time in seconds =                   332.18
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                    21.48
Mop/sec/process =                     1.34
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 4

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	274.96
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	0.31
Mop/sec/process	=	0.08
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 8

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	209.40
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	0.40
Mop/sec/process	=	0.05
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	172.38
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	0.49
Mop/sec/process	=	0.03
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 1

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.7790210760669E+03 0.7790210760669E+03 0.8756130575742E-15
2 0.6340276525969E+02 0.6340276525969E+02 0.1681021481121E-14
3 0.1949924972729E+03 0.1949924972729E+03 0.7287898208366E-15
4 0.1784530116042E+03 0.1784530116042E+03 0.2707542203819E-14
5 0.1838476034946E+04 0.1838476034946E+04 0.1484100990959E-14
Comparison of RMS-norms of solution error
1 0.2996408568547E+02 0.2996408568547E+02 0.8299601066640E-15
2 0.2819457636500E+01 0.2819457636500E+01 0.7875436823397E-15
3 0.7347341269877E+01 0.7347341269877E+01 0.4835373161943E-15
4 0.6713922568778E+01 0.6713922568778E+01 0.5291561888607E-15
5 0.7071531568839E+02 0.7071531568839E+02 0.6028759644299E-15
Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 250
Time in seconds = 2931.23
Total processes = 1
Compiled procs = 1
Mop/sec total = 40.70
Mop/sec/process = 40.70
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:     4

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
    1  0.7790210760669E+03 0.7790210760669E+03 0.1415574443078E-13
    2  0.6340276525969E+02 0.6340276525969E+02 0.2353430073569E-14
    3  0.1949924972729E+03 0.1949924972729E+03 0.1195215306172E-13
    4  0.1784530116042E+03 0.1784530116042E+03 0.6370687538397E-15
    5  0.1838476034946E+04 0.1838476034946E+04 0.1261485842315E-13
Comparison of RMS-norms of solution error
    1  0.2996408568547E+02 0.2996408568547E+02 0.5928286476171E-15
    2  0.2819457636500E+01 0.2819457636500E+01 0.1323073386331E-13
    3  0.7347341269878E+01 0.7347341269877E+01 0.5802447794332E-14
    4  0.6713922568778E+01 0.6713922568778E+01 0.2645780944304E-15
    5  0.7071531568839E+02 0.7071531568839E+02 0.1044985005012E-13
Comparison of surface integral
       0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      250
Time in seconds =                   911.70
Total processes =                        4
Compiled procs  =                        4
Mop/sec total   =                   130.85
Mop/sec/process =                    32.71
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 8

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1444761544997E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.5603404937070E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.9182751742541E-14
4	0.1784530116042E+03	0.1784530116042E+03	0.1592671884599E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1162545776251E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.9485258361874E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1354575133624E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.7132175413867E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.6614452360759E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.1225847794341E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	1160.86
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	102.77
Mop/sec/process	=	12.85
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 16

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1634477707472E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.5267200640846E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.8891235814207E-14
4	0.1784530116042E+03	0.1784530116042E+03	0.3185343769198E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1150178267993E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.4742629180937E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1165564649863E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.6165100781478E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.1455179519367E-14
5	0.7071531568839E+02	0.7071531568839E+02	0.1125368466936E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	1422.10
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	83.89
Mop/sec/process	=	5.24
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 8

Initialization time: 53.995 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694952416740E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 121.40
Total processes = 8
Compiled procs = 8
Mop/sec total = 32.06
Mop/sec/process = 4.01
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400   dt: 0.001500
Number of active processes: 4

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
    1 0.2479982239930E+01 0.2479982239930E+01 0.4655807315954E-13
    2 0.1127633796437E+01 0.1127633796437E+01 0.3997313218370E-13
    3 0.1502897788877E+01 0.1502897788877E+01 0.1654736332415E-13
    4 0.1421781621169E+01 0.1421781621170E+01 0.3388964841809E-13
    5 0.2129211303514E+01 0.2129211303514E+01 0.1710272491397E-13
Comparison of RMS-norms of solution error
    1 0.1090014029782E-03 0.1090014029782E-03 0.3962509001377E-12
    2 0.3734395176928E-04 0.3734395176928E-04 0.4663405068414E-13
    3 0.5009278540654E-04 0.5009278540654E-04 0.6168505437472E-13
    4 0.4767109393954E-04 0.4767109393953E-04 0.1522385515483E-12
    5 0.1362161339921E-03 0.1362161339921E-03 0.4795553872937E-13
Verification Successful

SP Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   400
Time in seconds =   2966.91
Total processes =   4
Compiled procs =   4
Mop/sec total   =   28.65
Mop/sec/process   =   7.16
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:    16

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1 0.2479982239930E+01 0.2479982239930E+01 0.7861151583476E-13
     2 0.1127633796437E+01 0.1127633796437E+01 0.9451775097624E-14
     3 0.1502897788877E+01 0.1502897788877E+01 0.6707591918895E-13
     4 0.1421781621170E+01 0.1421781621170E+01 0.3123469900284E-14
     5 0.2129211303514E+01 0.2129211303514E+01 0.2356838921071E-13
Comparison of RMS-norms of solution error
     1 0.1090014029782E-03 0.1090014029782E-03 0.3860555522208E-12
     2 0.3734395176928E-04 0.3734395176928E-04 0.3048451562232E-13
     3 0.5009278540654E-04 0.5009278540654E-04 0.1007793103271E-12
     4 0.4767109393954E-04 0.4767109393953E-04 0.1640366839278E-12
     5 0.1362161339921E-03 0.1362161339921E-03 0.2606711856244E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      400
Time in seconds =                  4053.80
Total processes =                       16
Compiled procs  =                       16
Mop/sec total     =                  20.97
Mop/sec/process   =                   1.31
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

Performance of a cluster with a 100 Mbps network switch and nodes with 233 MHz CPU, and 64MB RAM.

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 4

iteration	||r||	zeta
1	0.30380719049536E-12	19.9997581277040
2	0.29763636601233E-14	17.1140495745506
3	0.30758070039524E-14	17.1296668946143
4	0.30767836772916E-14	17.1302113581192
5	0.30362538345620E-14	17.1302338856353
6	0.30918631267811E-14	17.1302349879482
7	0.29692461545083E-14	17.1302350498916
8	0.30136035568592E-14	17.1302350537510
9	0.30210087485660E-14	17.1302350540101
10	0.29835949970093E-14	17.1302350540284
11	0.29536430530910E-14	17.1302350540298
12	0.29781985872281E-14	17.1302350540299
13	0.29621143458868E-14	17.1302350540299
14	0.29849869948111E-14	17.1302350540299
15	0.29517709020202E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 29.65
Total processes = 4
Compiled procs = 4
Mop/sec total = 50.47
Mop/sec/process = 12.62
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 8

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 16.97
Total processes = 8
Compiled procs = 8
Mop/sec total = 88.16
Mop/sec/process = 11.02
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 589.7592
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165629841E+03 -1.580732573678431E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 589.76
Total processes = 1
Compiled procs = 1
Mop/sec total = 0.91
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time = 295.1331
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165639063E+03 -1.580732573678573E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	295.13
Total processes	=	2
Compiled procs	=	1
Mop/sec total	=	1.82
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 3

EP Benchmark Results:

CPU Time = 196.5777
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165637473E+03 -1.580732573677940E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 196.58
Total processes = 3
Compiled procs = 1
Mop/sec total = 2.73
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 4

EP Benchmark Results:

CPU Time = 147.5785
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634618E+03 -1.580732573678638E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 147.58
Total processes = 4
Compiled procs = 4
Mop/sec total = 3.64
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time = 118.0433
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165631720E+03 -1.580732573678449E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 118.04
Total processes = 5
Compiled procs = 4
Mop/sec total = 4.55
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 98.2661
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 98.27
Total processes = 6
Compiled procs = 4
Mop/sec total = 5.46
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time =   84.3120
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165635864E+03   -1.580732573678781E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   84.31
Total processes =   7
Compiled procs =   7
Mop/sec total   =   6.37
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 8

EP Benchmark Results:

CPU Time = 73.7096
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165636284E+03 -1.580732573678494E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 73.71
Total processes = 8
Compiled procs = 7
Mop/sec total = 7.28
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 9

EP Benchmark Results:

CPU Time = 65.5836
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165630960E+03 -1.580732573678866E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 65.58
Total processes = 9
Compiled procs = 7
Mop/sec total = 8.19
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time =   59.0974
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165632362E+03   -1.580732573678767E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   59.10
Total processes =   10
Compiled procs =   10
Mop/sec total   =   9.08
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 11

EP Benchmark Results:

CPU Time = 53.7603
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632911E+03 -1.580732573678582E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 53.76
Total processes = 11
Compiled procs = 10
Mop/sec total = 9.99
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time = 49.2899
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633768E+03 -1.580732573678642E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 49.29
Total processes = 12
Compiled procs = 12
Mop/sec total = 10.89
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time = 45.4621
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165628269E+03 -1.580732573678654E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 45.46
Total processes = 13
Compiled procs = 12
Mop/sec total = 11.81
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time = 42.2449
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635351E+03 -1.580732573678708E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 42.24
Total processes = 14
Compiled procs = 12
Mop/sec total = 12.71
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time = 39.4868
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635445E+03 -1.580732573678607E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 39.49
Total processes = 15
Compiled procs = 15
Mop/sec total = 13.60
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time =   36.9098
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165633814E+03   -1.580732573678525E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   36.91
Total processes =   16
Compiled procs =   15
Mop/sec total   =   14.55
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :         6
Number of processes :         8
Processor array     :       1x  8
Layout type         :        1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =             256x256x128
Iterations      =                        6
Time in seconds =                    43.67
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                   163.42
Mop/sec/process =                    20.43
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 16
Processor array : 1x 16
Layout type : 1D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 21.97
Total processes = 16
Compiled procs = 16
Mop/sec total = 324.82
Mop/sec/process = 20.30
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 8

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class =	A
Size =	8388608
Iterations =	10
Time in seconds =	6.94
Total processes =	8
Compiled procs =	8
Mop/sec total =	12.10
Mop/sec/process =	1.51
Operation type =	keys ranked
Verification =	SUCCESSFUL
Version =	2.3
Compile date =	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	6.00
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	13.99
Mop/sec/process	=	0.87
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	22 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 1

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.8756130575742E-15
2	0.6340276525969E+02	0.6340276525969E+02	0.1681021481121E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.7287898208366E-15
4	0.1784530116042E+03	0.1784530116042E+03	0.2707542203819E-14
5	0.1838476034946E+04	0.1838476034946E+04	0.1484100990959E-14

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.8299601066640E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.7875436823397E-15
3	0.7347341269877E+01	0.7347341269877E+01	0.4835373161943E-15
4	0.6713922568778E+01	0.6713922568778E+01	0.5291561888607E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.6028759644299E-15

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	2935.01
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	40.65
Mop/sec/process	=	40.65
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 4

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1   0.7790210760669E+03 0.7790210760669E+03 0.1415574443078E-13
2   0.6340276525969E+02 0.6340276525969E+02 0.2353430073569E-14
3   0.1949924972729E+03 0.1949924972729E+03 0.1195215306172E-13
4   0.1784530116042E+03 0.1784530116042E+03 0.6370687538397E-15
5   0.1838476034946E+04 0.1838476034946E+04 0.1261485842315E-13
Comparison of RMS-norms of solution error
1   0.2996408568547E+02 0.2996408568547E+02 0.5928286476171E-15
2   0.2819457636500E+01 0.2819457636500E+01 0.1323073386331E-13
3   0.7347341269878E+01 0.7347341269877E+01 0.5802447794332E-14
4   0.6713922568778E+01 0.6713922568778E+01 0.2645780944304E-15
5   0.7071531568839E+02 0.7071531568839E+02 0.1044985005012E-13
Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   250
Time in seconds =   770.49
Total processes =   4
Compiled procs =   4
Mop/sec total   =   154.83
Mop/sec/process   =   38.71
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 8

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1444761544997E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.5603404937070E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.9182751742541E-14
4	0.1784530116042E+03	0.1784530116042E+03	0.1592671884599E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1162545776251E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.9485258361874E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1354575133624E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.7132175413867E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.6614452360759E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.1225847794341E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	402.44
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	296.44
Mop/sec/process	=	37.05
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:    16

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1   0.7790210760669E+03 0.7790210760669E+03 0.1634477707472E-13
     2   0.6340276525969E+02 0.6340276525969E+02 0.5267200640846E-14
     3   0.1949924972729E+03 0.1949924972729E+03 0.8891235814207E-14
     4   0.1784530116042E+03 0.1784530116042E+03 0.3185343769198E-15
     5   0.1838476034946E+04 0.1838476034946E+04 0.1150178267993E-13
Comparison of RMS-norms of solution error
     1   0.2996408568547E+02 0.2996408568547E+02 0.4742629180937E-15
     2   0.2819457636500E+01 0.2819457636500E+01 0.1165564649863E-13
     3   0.7347341269878E+01 0.7347341269877E+01 0.6165100781478E-14
     4   0.6713922568778E+01 0.6713922568778E+01 0.1455179519367E-14
     5   0.7071531568839E+02 0.7071531568839E+02 0.1125368466936E-13
Comparison of surface integral
         0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      250
Time in seconds =                   190.19
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                   627.25
Mop/sec/process =                    39.20
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 16

Initialization time: 5.091 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694838067292E-16

MG Benchmark Completed.

Class	=	A
Size	=	256x256x256
Iterations	=	4
Time in seconds	=	10.20
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	381.63
Mop/sec/process	=	23.85
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     9

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1               NAN 0.2479982239930E+01               NAN
      2               NAN 0.1127633796437E+01               NAN
      3               NAN 0.1502897788877E+01               NAN
      4               NAN 0.1421781621170E+01               NAN
      5               NAN 0.2129211303514E+01               NAN
Comparison of RMS-norms of solution error
      1               NAN 0.1090014029782E-03               NAN
      2               NAN 0.3734395176928E-04               NAN
      3               NAN 0.5009278540654E-04               NAN
      4               NAN 0.4767109393953E-04               NAN
      5               NAN 0.1362161339921E-03               NAN
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      400
Time in seconds =                  5650.12
Total processes =                        9
Compiled procs  =                        9
Mop/sec total     =                  15.05
Mop/sec/process   =                   1.67
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

Performance of a cluster with a 10 Mbps network switch and nodes with 233 MHz CPU, and 128MB RAM.

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     4

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
       1 0.1080634671464E+03 0.1080634671464E+03 0.6706740118690E-14
       2 0.1131973090122E+02 0.1131973090122E+02 0.1569257127136E-14
       3 0.2597435451158E+02 0.2597435451158E+02 0.3692999157490E-14
       4 0.2366562254468E+02 0.2366562254468E+02 0.7355942989988E-14
       5 0.2527896321175E+03 0.2527896321175E+03 0.1574051628196E-13
 Comparison of RMS-norms of solution error
       1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
       2 0.4439028249700E+00 0.4439028249700E+00 0.4126731995354E-14
       3 0.9669248013635E+00 0.9669248013635E+00 0.6085459822952E-14
       4 0.8830206303977E+00 0.8830206303977E+00 0.2137412283349E-14
       5 0.9737990177083E+01 0.9737990177083E+01 0.4560378494683E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                  1728.13
 Total processes =                        4
 Compiled procs  =                        4
 Mop/sec total   =                    97.38
 Mop/sec/process   =                  24.34
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              19 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 200    dt:   0.000800
Number of active processes:     9

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1 0.1080634671464E+03 0.1080634671464E+03 0.6969749535109E-14
      2 0.1131973090122E+02 0.1131973090122E+02 0.2040034265277E-14
      3 0.2597435451158E+02 0.2597435451158E+02 0.5197554369800E-14
      4 0.2366562254468E+02 0.2366562254468E+02 0.6755457847948E-14
      5 0.2527896321175E+03 0.2527896321175E+03 0.1326700658051E-13
Comparison of RMS-norms of solution error
      1 0.4234841604053E+01 0.4234841604053E+01 0.6291936058601E-15
      2 0.4439028249700E+00 0.4439028249700E+00 0.7127991628339E-14
      3 0.9669248013635E+00 0.9669248013635E+00 0.1148199966595E-14
      4 0.8830206303977E+00 0.8830206303977E+00 0.7543808058880E-15
      5 0.9737990177083E+01 0.9737990177083E+01 0.5837284473195E-14
Verification Successful


BT Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      200
Time in seconds =                  1056.18
Total processes =                        9
Compiled procs  =                        9
Mop/sec total   =                   159.33
Mop/sec/process =                    17.70
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 200    dt:   0.000800
Number of active processes:    16

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
       1 0.1080634671464E+03 0.1080634671464E+03 0.7758777784367E-14
       2 0.1131973090122E+02 0.1131973090122E+02 0.3138514254272E-14
       3 0.2597435451158E+02 0.2597435451158E+02 0.5334332116374E-14
       4 0.2366562254468E+02 0.2366562254468E+02 0.1065861127121E-13
       5 0.2527896321175E+03 0.2527896321175E+03 0.1551565176365E-13
Comparison of RMS-norms of solution error
       1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
       2 0.4439028249700E+00 0.4439028249700E+00 0.3001259632985E-14
       3 0.9669248013635E+00 0.9669248013635E+00 0.3329779903125E-14
       4 0.8830206303977E+00 0.8830206303977E+00 0.4149094432384E-14
       5 0.9737990177083E+01 0.9737990177083E+01 0.7661435871068E-14
Verification Successful


BT Benchmark Completed.
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      200
Time in seconds =                   785.26
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                   214.30
Mop/sec/process =                    13.39
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 4

iteration	||r||	zeta
1	0.30380719049536E-12	19.9997581277040
2	0.29763636601233E-14	17.1140495745506
3	0.30758070039524E-14	17.1296668946143
4	0.30767836772916E-14	17.1302113581192
5	0.30362538345620E-14	17.1302338856353
6	0.30918631267811E-14	17.1302349879482
7	0.29692461545083E-14	17.1302350498916
8	0.30136035568592E-14	17.1302350537510
9	0.30210087485660E-14	17.1302350540101
10	0.29835949970093E-14	17.1302350540284
11	0.29536430530910E-14	17.1302350540298
12	0.29781985872281E-14	17.1302350540299
13	0.29621143458868E-14	17.1302350540299
14	0.29849869948111E-14	17.1302350540299
15	0.29517709020202E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 125.22
Total processes = 4
Compiled procs = 4
Mop/sec total = 11.95
Mop/sec/process = 2.99
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 8

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 99.60
Total processes = 8
Compiled procs = 8
Mop/sec total = 15.02
Mop/sec/process = 1.88
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 16

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 97.91
Total processes = 16
Compiled procs = 16
Mop/sec total = 15.28
Mop/sec/process = 0.96
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 589.8346
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165629841E+03 -1.580732573678431E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 589.83
Total processes = 1
Compiled procs = 1
Mop/sec total = 0.91
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time = 294.8639
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165639063E+03 -1.580732573678573E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 294.86
Total processes = 2
Compiled procs = 1
Mop/sec total = 1.82
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 3

EP Benchmark Results:

CPU Time = 196.7263
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165637473E+03 -1.580732573677940E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 196.73
Total processes = 3
Compiled procs = 3
Mop/sec total = 2.73
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 4

EP Benchmark Results:

CPU Time = 147.4726
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634618E+03 -1.580732573678638E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	147.47
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	3.64
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time = 118.0478
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165631720E+03 -1.580732573678449E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 118.05
Total processes = 5
Compiled procs = 4
Mop/sec total = 4.55
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 98.3947
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 98.39
Total processes = 6
Compiled procs = 6
Mop/sec total = 5.46
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 84.4625
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 84.46
Total processes = 7
Compiled procs = 7
Mop/sec total = 6.36
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 8

EP Benchmark Results:

CPU Time = 73.8014
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165636284E+03 -1.580732573678494E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 73.80
Total processes = 8
Compiled procs = 7
Mop/sec total = 7.27
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 9

EP Benchmark Results:

CPU Time =   65.7285
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165630960E+03   -1.580732573678866E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   65.73
Total processes =   9
Compiled procs =   9
Mop/sec total   =   8.17
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time = 59.1019
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632362E+03 -1.580732573678767E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	59.10
Total processes	=	10
Compiled procs	=	10
Mop/sec total	=	9.08
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 11

EP Benchmark Results:

CPU Time =   53.7133
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165632911E+03   -1.580732573678582E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   53.71
Total processes =   11
Compiled procs =   11
Mop/sec total   =   10.00
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time = 49.2991
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633768E+03 -1.580732573678642E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 49.30
Total processes = 12
Compiled procs = 11
Mop/sec total = 10.89
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time =   45.4062
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165628269E+03   -1.580732573678654E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   45.41
Total processes =   13
Compiled procs =   13
Mop/sec total   =   11.82
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time = 42.2356
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635351E+03 -1.580732573678708E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 42.24
Total processes = 14
Compiled procs = 14
Mop/sec total = 12.71
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time =   39.4519
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165635445E+03   -1.580732573678607E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   39.45
Total processes =   15
Compiled procs =   14
Mop/sec total   =   13.61
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time = 36.9063
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633814E+03 -1.580732573678525E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 36.91
Total processes = 16
Compiled procs = 16
Mop/sec total = 14.55
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size              : 256x256x128
Iterations         :          6
Number of processes :          4
Processor array    :      1x  4
Layout type        :         1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class          =                        A
Size           =             256x256x128
Iterations     =                        6
Time in seconds =                   473.74
Total processes =                        4
Compiled procs  =                        4
Mop/sec total     =                  15.06
Mop/sec/process   =                   3.77
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :           6
Number of processes :           8
Processor array     :        1x  8
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =             256x256x128
Iterations      =                        6
Time in seconds =                   298.45
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                    23.91
Mop/sec/process =                     2.99
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 16
Processor array : 1x 16
Layout type : 1D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 169.59
Total processes = 16
Compiled procs = 16
Mop/sec total = 42.08
Mop/sec/process = 2.63
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 4

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	157.43
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	0.53
Mop/sec/process	=	0.13
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 8

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed
Class = A
Size = 8388608
Iterations = 10
Time in seconds = 101.71
Total processes = 8
Compiled procs = 8
Mop/sec total = 0.82
Mop/sec/process = 0.10
Operation type = keys ranked
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	59.71
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	1.40
Mop/sec/process	=	0.09
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

 Size:  64x 64x 64
 Iterations: 250
 Number of processes:     1

Verification being performed for class A
 Accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
        1   0.7790210760669E+03 0.7790210760669E+03 0.8756130575742E-15
        2   0.6340276525969E+02 0.6340276525969E+02 0.1681021481121E-14
        3   0.1949924972729E+03 0.1949924972729E+03 0.7287898208366E-15
        4   0.1784530116042E+03 0.1784530116042E+03 0.2707542203819E-14
        5   0.1838476034946E+04 0.1838476034946E+04 0.1484100990959E-14
 Comparison of RMS-norms of solution error
        1   0.2996408568547E+02 0.2996408568547E+02 0.8299601066640E-15
        2   0.2819457636500E+01 0.2819457636500E+01 0.7875436823397E-15
        3   0.7347341269877E+01 0.7347341269877E+01 0.4835373161943E-15
        4   0.6713922568778E+01 0.6713922568778E+01 0.5291561888607E-15
        5   0.7071531568839E+02 0.7071531568839E+02 0.6028759644299E-15
 Comparison of surface integral
            0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
 Verification Successful


 LU Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      250
 Time in seconds =                  2929.92
 Total processes =                        1
 Compiled procs  =                        1
 Mop/sec total   =                    40.72
 Mop/sec/process =                    40.72
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 4

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1415574443078E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.2353430073569E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.1195215306172E-13
4	0.1784530116042E+03	0.1784530116042E+03	0.6370687538397E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1261485842315E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.5928286476171E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1323073386331E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.5802447794332E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.2645780944304E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.1044985005012E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 250
Time in seconds = 943.20
Total processes = 4
Compiled procs = 4
Mop/sec total = 126.48
Mop/sec/process = 31.62
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 8

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1444761544997E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.5603404937070E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.9182751742541E-14
4	0.1784530116042E+03	0.1784530116042E+03	0.1592671884599E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1162545776251E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.9485258361874E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1354575133624E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.7132175413867E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.6614452360759E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.1225847794341E-13

Comparison of surface integral

0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00

Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	598.39
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	199.36
Mop/sec/process	=	24.92
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 16

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1634477707472E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.5267200640846E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.8891235814207E-14
4	0.1784530116042E+03	0.1784530116042E+03	0.3185343769198E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1150178267993E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.4742629180937E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1165564649863E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.6165100781478E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.1455179519367E-14
5	0.7071531568839E+02	0.7071531568839E+02	0.1125368466936E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	355.12
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	335.93
Mop/sec/process	=	21.00
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 4

Initialization time: 37.484 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694334082688E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 83.71
Total processes = 4
Compiled procs = 4
Mop/sec total = 46.50
Mop/sec/process = 11.62
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 8

Initialization time: 21.790 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694952416740E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 48.26
Total processes = 8
Compiled procs = 8
Mop/sec total = 80.65
Mop/sec/process = 10.08
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256  (class A)
Iterations:   4
Number of processes:    16

Initialization time:         13.260 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is   0.243336530907E-05
Error is     0.694838067292E-16


MG Benchmark Completed.
Class           =                        A
Size            =               256x256x256
Iterations      =                        4
Time in seconds =                    30.63
Total processes =                       16
Compiled procs  =                        8
Mop/sec total   =                   127.07
Mop/sec/process =                     7.94
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

```
 NAS Parallel Benchmarks 2.3 -- SP Benchmark

 No input file inputsp.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 400    dt:   0.001500
 Number of active processes:     1

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
       1 0.2479982239930E+01 0.2479982239930E+01 0.6858362315424E-13
       2 0.1127633796437E+01 0.1127633796437E+01 0.2205414189446E-13
       3 0.1502897788877E+01 0.1502897788877E+01 0.5097178881098E-13
       4 0.1421781621169E+01 0.1421781621170E+01 0.3919954724857E-13
       5 0.2129211303514E+01 0.2129211303514E+01 0.1147133988132E-13
 Comparison of RMS-norms of solution error
       1 0.1090014029782E-03 0.1090014029782E-03 0.3948832315147E-12
       2 0.3734395176928E-04 0.3734395176928E-04 0.3737982272737E-13
       3 0.5009278540654E-04 0.5009278540654E-04 0.1623290904598E-14
       4 0.4767109393953E-04 0.4767109393953E-04 0.1361760339713E-12
       5 0.1362161339921E-03 0.1362161339921E-03 0.6208351901894E-13
 Verification Successful


 SP Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      400
 Time in seconds =                  3351.56
 Total processes =                        1
 Compiled procs  =                        1
 Mop/sec total   =                    25.36
 Mop/sec/process =                    25.36
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400 dt: 0.001500
Number of active processes: 4

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.2479982239930E+01 0.2479982239930E+01 0.4655807315954E-13
2 0.1127633796437E+01 0.1127633796437E+01 0.3997313218370E-13
3 0.1502897788877E+01 0.1502897788877E+01 0.1654736332415E-13
4 0.1421781621169E+01 0.1421781621170E+01 0.3388964841809E-13
5 0.2129211303514E+01 0.2129211303514E+01 0.1710272491397E-13
Comparison of RMS-norms of solution error
1 0.1090014029782E-03 0.1090014029782E-03 0.3962509001377E-12
2 0.3734395176928E-04 0.3734395176928E-04 0.4663405068414E-13
3 0.5009278540654E-04 0.5009278540654E-04 0.6168505437472E-13
4 0.4767109393954E-04 0.4767109393953E-04 0.1522385515483E-12
5 0.1362161339921E-03 0.1362161339921E-03 0.4795553872937E-13
Verification Successful

SP Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 400
Time in seconds = 1947.25
Total processes = 4
Compiled procs = 4
Mop/sec total = 43.66
Mop/sec/process = 10.91
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     9

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1              NAN 0.2479982239930E+01              NAN
      2              NAN 0.1127633796437E+01              NAN
      3              NAN 0.1502897788877E+01              NAN
      4              NAN 0.1421781621170E+01              NAN
      5              NAN 0.2129211303514E+01              NAN
Comparison of RMS-norms of solution error
      1              NAN 0.1090014029782E-03              NAN
      2              NAN 0.3734395176928E-04              NAN
      3              NAN 0.5009278540654E-04              NAN
      4              NAN 0.4767109393953E-04              NAN
      5              NAN 0.1362161339921E-03              NAN
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      400
Time in seconds =                  6306.88
Total processes =                        9
Compiled procs  =                        9
Mop/sec total   =                    13.48
Mop/sec/process =                     1.50
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400   dt: 0.001500
Number of active processes: 16

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

```
1 0.2479982239930E+01 0.2479982239930E+01 0.7861151583476E-13
2 0.1127633796437E+01 0.1127633796437E+01 0.9451775097624E-14
3 0.1502897788877E+01 0.1502897788877E+01 0.6707591918895E-13
4 0.1421781621170E+01 0.1421781621170E+01 0.3123469900284E-14
5 0.2129211303514E+01 0.2129211303514E+01 0.2356838921071E-13
```

Comparison of RMS-norms of solution error

```
1 0.1090014029782E-03 0.1090014029782E-03 0.3860555522208E-12
2 0.3734395176928E-04 0.3734395176928E-04 0.3048451562232E-13
3 0.5009278540654E-04 0.5009278540654E-04 0.1007793103271E-12
4 0.4767109393954E-04 0.4767109393953E-04 0.1640366839278E-12
5 0.1362161339921E-03 0.1362161339921E-03 0.2606711856244E-13
```

Verification Successful

SP Benchmark Completed.

```
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      400
Time in seconds =                  1035.45
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                    82.10
Mop/sec/process =                     5.13
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

Performance of a cluster with a 100 Mbps network switch and nodes with 233 MHz CPU, and 128MB RAM.

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     4

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
       1 0.1080634671464E+03 0.1080634671464E+03 0.6706740118690E-14
       2 0.1131973090122E+02 0.1131973090122E+02 0.1569257127136E-14
       3 0.2597435451158E+02 0.2597435451158E+02 0.3692999157490E-14
       4 0.2366562254468E+02 0.2366562254468E+02 0.7355942989988E-14
       5 0.2527896321175E+03 0.2527896321175E+03 0.1574051628196E-13
 Comparison of RMS-norms of solution error
       1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
       2 0.4439028249700E+00 0.4439028249700E+00 0.4126731995354E-14
       3 0.9669248013635E+00 0.9669248013635E+00 0.6085459822952E-14
       4 0.8830206303977E+00 0.8830206303977E+00 0.2137412283349E-14
       5 0.9737990177083E+01 0.9737990177083E+01 0.4560378494683E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =                64x 64x 64
 Iterations      =                      200
 Time in seconds =                  1154.23
 Total processes =                        4
 Compiled procs  =                        4
 Mop/sec total   =                   145.80
 Mop/sec/process =                    36.45
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              19 Jul 2003
```

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     9

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
       1 0.1080634671464E+03 0.1080634671464E+03 0.6969749535109E-14
       2 0.1131973090122E+02 0.1131973090122E+02 0.2040034265277E-14
       3 0.2597435451158E+02 0.2597435451158E+02 0.5197554369800E-14
       4 0.2366562254468E+02 0.2366562254468E+02 0.6755457847948E-14
       5 0.2527896321175E+03 0.2527896321175E+03 0.1326700658051E-13
 Comparison of RMS-norms of solution error
       1 0.4234841604053E+01 0.4234841604053E+01 0.6291936058601E-15
       2 0.4439028249700E+00 0.4439028249700E+00 0.7127991628339E-14
       3 0.9669248013635E+00 0.9669248013635E+00 0.1148199966595E-14
       4 0.8830206303977E+00 0.8830206303977E+00 0.7543808058880E-15
       5 0.9737990177083E+01 0.9737990177083E+01 0.5837284473195E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                   545.44
 Total processes =                        9
 Compiled procs  =                        9
 Mop/sec total     =                 308.53
 Mop/sec/process   =                  34.28
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              19 Jul 2003
```

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:    16

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
      1 0.1080634671464E+03 0.1080634671464E+03 0.7758777784367E-14
      2 0.1131973090122E+02 0.1131973090122E+02 0.3138514254272E-14
      3 0.2597435451158E+02 0.2597435451158E+02 0.5334332116374E-14
      4 0.2366562254468E+02 0.2366562254468E+02 0.1065861127121E-13
      5 0.2527896321175E+03 0.2527896321175E+03 0.1551565176365E-13
 Comparison of RMS-norms of solution error
      1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
      2 0.4439028249700E+00 0.4439028249700E+00 0.3001259632985E-14
      3 0.9669248013635E+00 0.9669248013635E+00 0.3329779903125E-14
      4 0.8830206303977E+00 0.8830206303977E+00 0.4149094432384E-14
      5 0.9737990177083E+01 0.9737990177083E+01 0.7661435871068E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                   353.48
 Total processes =                       16
 Compiled procs  =                       16
 Mop/sec total   =                   476.08
 Mop/sec/process   =                  29.76
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              24 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 1

iteration	||r||	zeta
1	0.27827584529972E-12	19.9997581277040
2	0.26160031018478E-14	17.1140495745506
3	0.26714791625944E-14	17.1296668946143
4	0.26473497355311E-14	17.1302113581192
5	0.25962051721040E-14	17.1302338856353
6	0.26115199334372E-14	17.1302349879482
7	0.25993680727334E-14	17.1302350498916
8	0.26120228095637E-14	17.1302350537510
9	0.25450483820989E-14	17.1302350540101
10	0.25904786670248E-14	17.1302350540284
11	0.25506293938445E-14	17.1302350540298
12	0.25257745194192E-14	17.1302350540299
13	0.25415734339777E-14	17.1302350540299
14	0.25063961032389E-14	17.1302350540299
15	0.24842598520619E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 93.91
Total processes = 1
Compiled procs = 1
Mop/sec total = 15.94
Mop/sec/process = 15.94
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 4

iteration	||r||	zeta
1	0.30380719049536E-12	19.9997581277040
2	0.29763636601233E-14	17.1140495745506
3	0.30758070039524E-14	17.1296668946143
4	0.30767836772916E-14	17.1302113581192
5	0.30362538345620E-14	17.1302338856353
6	0.30918631267811E-14	17.1302349879482
7	0.29692461545083E-14	17.1302350498916
8	0.30136035568592E-14	17.1302350537510
9	0.30210087485660E-14	17.1302350540101
10	0.29835949970093E-14	17.1302350540284
11	0.29536430530910E-14	17.1302350540298
12	0.29781985872281E-14	17.1302350540299
13	0.29621143458868E-14	17.1302350540299
14	0.29849869948111E-14	17.1302350540299
15	0.29517709020202E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 29.37
Total processes = 4
Compiled procs = 4
Mop/sec total = 50.96
Mop/sec/process = 12.74
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 8

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 16.99
Total processes = 8
Compiled procs = 8
Mop/sec total = 88.08
Mop/sec/process = 11.01
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 16

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 13.06
Total processes = 16
Compiled procs = 16
Mop/sec total = 114.59
Mop/sec/process = 7.16
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 588.0414
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165629841E+03 -1.580732573678431E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 588.04
Total processes = 1
Compiled procs = 1
Mop/sec total = 0.91
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time = 294.3693
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165639063E+03 -1.580732573678573E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 294.37
Total processes = 2
Compiled procs = 1
Mop/sec total = 1.82
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 3

EP Benchmark Results:

CPU Time = 196.2118
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165637473E+03 -1.580732573677940E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 196.21
Total processes = 3
Compiled procs = 3
Mop/sec total = 2.74
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 4

EP Benchmark Results:

CPU Time = 147.4471
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165634618E+03   -1.580732573678638E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   147.45
Total processes =   4
Compiled procs =   4
Mop/sec total   =   3.64
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time = 118.0398
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165631720E+03 -1.580732573678449E+04
Counts:

```
 0     98257395.
 1     93827014.
 2     17611549.
 3      1110028.
 4        26536.
 5          245.
 6            0.
 7            0.
 8            0.
 9            0.
```

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 118.04
Total processes = 5
Compiled procs = 4
Mop/sec total = 4.55
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 98.4385
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 98.44
Total processes = 6
Compiled procs = 6
Mop/sec total = 5.45
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 84.3988
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 84.40
Total processes = 7
Compiled procs = 7
Mop/sec total = 6.36
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 8

EP Benchmark Results:

CPU Time = 73.7954
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165636284E+03 -1.580732573678494E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 73.80
Total processes = 8
Compiled procs = 7
Mop/sec total = 7.28
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 9

EP Benchmark Results:

CPU Time = 65.5781
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165630960E+03 -1.580732573678866E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	65.58
Total processes	=	9
Compiled procs	=	9
Mop/sec total	=	8.19
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time = 59.0446
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632362E+03 -1.580732573678767E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 59.04
Total processes = 10
Compiled procs = 10
Mop/sec total = 9.09
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 11

EP Benchmark Results:

CPU Time = 53.6782
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632911E+03 -1.580732573678582E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 53.68
Total processes = 11
Compiled procs = 11
Mop/sec total = 10.00
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time = 49.2607
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633768E+03 -1.580732573678642E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 49.26
Total processes = 12
Compiled procs = 11
Mop/sec total = 10.90
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time = 45.4664
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165628269E+03 -1.580732573678654E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 45.47
Total processes = 13
Compiled procs = 13
Mop/sec total = 11.81
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time = 42.2375
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635351E+03 -1.580732573678708E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 42.24
Total processes = 14
Compiled procs = 14
Mop/sec total = 12.71
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time = 39.4278
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635445E+03 -1.580732573678607E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 39.43
Total processes = 15
Compiled procs = 14
Mop/sec total = 13.62
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time = 36.9078
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633814E+03 -1.580732573678525E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 36.91
Total processes = 16
Compiled procs = 16
Mop/sec total = 14.55
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :           6
Number of processes :           4
Processor array     :         1x  4
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =              256x256x128
Iterations      =                        6
Time in seconds =                    82.64
Total processes =                        4
Compiled procs  =                        4
Mop/sec total   =                    86.36
Mop/sec/process =                    21.59
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :           6
Number of processes :           8
Processor array     :        1x  8
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =             256x256x128
Iterations      =                        6
Time in seconds =                    41.58
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                   171.65
Mop/sec/process =                    21.46
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- FT Benchmark

```
No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :       6
Number of processes :      16
Processor array     :    1x 16
Layout type         :      1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =             256x256x128
Iterations      =                        6
Time in seconds =                    22.15
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                   322.24
Mop/sec/process =                    20.14
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 4

```
  iteration
       1
       2
       3
       4
       5
       6
       7
       8
       9
       10
```

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	12.86
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	6.52
Mop/sec/process	=	1.63
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 8

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	7.09
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	11.83
Mop/sec/process	=	1.48
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	5.61
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	14.96
Mop/sec/process	=	0.94
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	19 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 1

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
    1   0.7790210760669E+03 0.7790210760669E+03 0.8756130575742E-15
    2   0.6340276525969E+02 0.6340276525969E+02 0.1681021481121E-14
    3   0.1949924972729E+03 0.1949924972729E+03 0.7287898208366E-15
    4   0.1784530116042E+03 0.1784530116042E+03 0.2707542203819E-14
    5   0.1838476034946E+04 0.1838476034946E+04 0.1484100990959E-14
Comparison of RMS-norms of solution error
    1   0.2996408568547E+02 0.2996408568547E+02 0.8299601066640E-15
    2   0.2819457636500E+01 0.2819457636500E+01 0.7875436823397E-15
    3   0.7347341269877E+01 0.7347341269877E+01 0.4835373161943E-15
    4   0.6713922568778E+01 0.6713922568778E+01 0.5291561888607E-15
    5   0.7071531568839E+02 0.7071531568839E+02 0.6028759644299E-15
Comparison of surface integral
        0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   250
Time in seconds =   2931.87
Total processes =   1
Compiled procs =   1
Mop/sec total   =   40.69
Mop/sec/process   =   40.69
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:     4

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
    1   0.7790210760669E+03 0.7790210760669E+03 0.1415574443078E-13
    2   0.6340276525969E+02 0.6340276525969E+02 0.2353430073569E-14
    3   0.1949924972729E+03 0.1949924972729E+03 0.1195215306172E-13
    4   0.1784530116042E+03 0.1784530116042E+03 0.6370687538397E-15
    5   0.1838476034946E+04 0.1838476034946E+04 0.1261485842315E-13
Comparison of RMS-norms of solution error
    1   0.2996408568547E+02 0.2996408568547E+02 0.5928286476171E-15
    2   0.2819457636500E+01 0.2819457636500E+01 0.1323073386331E-13
    3   0.7347341269878E+01 0.7347341269877E+01 0.5802447794332E-14
    4   0.6713922568778E+01 0.6713922568778E+01 0.2645780944304E-15
    5   0.7071531568839E+02 0.7071531568839E+02 0.1044985005012E-13
Comparison of surface integral
        0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      250
Time in seconds =                   774.17
Total processes =                        4
Compiled procs  =                        4
Mop/sec total     =                 154.10
Mop/sec/process   =                  38.52
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:     8

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1   0.7790210760669E+03 0.7790210760669E+03 0.1444761544997E-13
     2   0.6340276525969E+02 0.6340276525969E+02 0.5603404937070E-14
     3   0.1949924972729E+03 0.1949924972729E+03 0.9182751742541E-14
     4   0.1784530116042E+03 0.1784530116042E+03 0.1592671884599E-15
     5   0.1838476034946E+04 0.1838476034946E+04 0.1162545776251E-13
Comparison of RMS-norms of solution error
     1   0.2996408568547E+02 0.2996408568547E+02 0.9485258361874E-15
     2   0.2819457636500E+01 0.2819457636500E+01 0.1354575133624E-13
     3   0.7347341269878E+01 0.7347341269877E+01 0.7132175413867E-14
     4   0.6713922568778E+01 0.6713922568778E+01 0.6614452360759E-15
     5   0.7071531568839E+02 0.7071531568839E+02 0.1225847794341E-13
Comparison of surface integral
         0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      250
Time in seconds =                   404.63
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                   294.83
Mop/sec/process =                    36.85
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 16

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

```
 1   0.7790210760669E+03 0.7790210760669E+03 0.1634477707472E-13
 2   0.6340276525969E+02 0.6340276525969E+02 0.5267200640846E-14
 3   0.1949924972729E+03 0.1949924972729E+03 0.8891235814207E-14
 4   0.1784530116042E+03 0.1784530116042E+03 0.3185343769198E-15
 5   0.1838476034946E+04 0.1838476034946E+04 0.1150178267993E-13
```

Comparison of RMS-norms of solution error

```
 1   0.2996408568547E+02 0.2996408568547E+02 0.4742629180937E-15
 2   0.2819457636500E+01 0.2819457636500E+01 0.1165564649863E-13
 3   0.7347341269878E+01 0.7347341269877E+01 0.6165100781478E-14
 4   0.6713922568778E+01 0.6713922568778E+01 0.1455179519367E-14
 5   0.7071531568839E+02 0.7071531568839E+02 0.1125368466936E-13
```

Comparison of surface integral

```
     0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
```

Verification Successful

LU Benchmark Completed.

```
Class            =                    A
Size             =              64x 64x 64
Iterations       =                   250
Time in seconds  =                189.32
Total processes  =                    16
Compiled procs   =                    16
Mop/sec total    =                630.14
Mop/sec/process  =                 39.38
Operation type   =        floating point
Verification     =            SUCCESSFUL
Version          =                   2.3
Compile date     =           19 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 4

Initialization time: 19.951 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694334082688E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 42.69
Total processes = 4
Compiled procs = 4
Mop/sec total = 91.18
Mop/sec/process = 22.80
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 8

Initialization time: 9.393 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is   0.243336530907E-05
Error is   0.694952416740E-16

MG Benchmark Completed.
Class   =   A
Size   =   256x256x256
Iterations   =   4
Time in seconds =   18.55
Total processes =   8
Compiled procs =   8
Mop/sec total   =   209.82
Mop/sec/process   =   26.23
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   19 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 16

Initialization time: 5.159 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694838067292E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 10.28
Total processes = 16
Compiled procs = 8
Mop/sec total = 378.46
Mop/sec/process = 23.65
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
 NAS Parallel Benchmarks 2.3 -- SP Benchmark

 No input file inputsp.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 400    dt:   0.001500
 Number of active processes:     1

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
      1 0.2479982239930E+01 0.2479982239930E+01 0.6858362315424E-13
      2 0.1127633796437E+01 0.1127633796437E+01 0.2205414189446E-13
      3 0.1502897788877E+01 0.1502897788877E+01 0.5097178881098E-13
      4 0.1421781621169E+01 0.1421781621170E+01 0.3919954724857E-13
      5 0.2129211303514E+01 0.2129211303514E+01 0.1147133988132E-13
 Comparison of RMS-norms of solution error
      1 0.1090014029782E-03 0.1090014029782E-03 0.3948832315147E-12
      2 0.3734395176928E-04 0.3734395176928E-04 0.3737982272737E-13
      3 0.5009278540654E-04 0.5009278540654E-04 0.1623290904598E-14
      4 0.4767109393953E-04 0.4767109393953E-04 0.1361760339713E-12
      5 0.1362161339921E-03 0.1362161339921E-03 0.6208351901894E-13
 Verification Successful


 SP Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      400
 Time in seconds =                  3354.06
 Total processes =                        1
 Compiled procs  =                        1
 Mop/sec total   =                    25.35
 Mop/sec/process =                    25.35
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              19 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400 dt: 0.001500
Number of active processes: 4

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.2479982239930E+01 0.2479982239930E+01 0.4655807315954E-13
2 0.1127633796437E+01 0.1127633796437E+01 0.3997313218370E-13
3 0.1502897788877E+01 0.1502897788877E+01 0.1654736332415E-13
4 0.1421781621169E+01 0.1421781621170E+01 0.3388964841809E-13
5 0.2129211303514E+01 0.2129211303514E+01 0.1710272491397E-13
Comparison of RMS-norms of solution error
1 0.1090014029782E-03 0.1090014029782E-03 0.3962509001377E-12
2 0.3734395176928E-04 0.3734395176928E-04 0.4663405068414E-13
3 0.5009278540654E-04 0.5009278540654E-04 0.6168505437472E-13
4 0.4767109393954E-04 0.4767109393953E-04 0.1522385515483E-12
5 0.1362161339921E-03 0.1362161339921E-03 0.4795553872937E-13
Verification Successful

SP Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 400
Time in seconds = 911.56
Total processes = 4
Compiled procs = 4
Mop/sec total = 93.26
Mop/sec/process = 23.31
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 19 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     9

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1              NAN 0.2479982239930E+01              NAN
     2              NAN 0.1127633796437E+01              NAN
     3              NAN 0.1502897788877E+01              NAN
     4              NAN 0.1421781621170E+01              NAN
     5              NAN 0.2129211303514E+01              NAN
Comparison of RMS-norms of solution error
     1              NAN 0.1090014029782E-03              NAN
     2              NAN 0.3734395176928E-04              NAN
     3              NAN 0.5009278540654E-04              NAN
     4              NAN 0.4767109393953E-04              NAN
     5              NAN 0.1362161339921E-03              NAN
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      400
Time in seconds =                  5650.62
Total processes =                        9
Compiled procs  =                        9
Mop/sec total   =                    15.04
Mop/sec/process =                     1.67
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:    16

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1 0.2479982239930E+01 0.2479982239930E+01 0.7861151583476E-13
      2 0.1127633796437E+01 0.1127633796437E+01 0.9451775097624E-14
      3 0.1502897788877E+01 0.1502897788877E+01 0.6707591918895E-13
      4 0.1421781621170E+01 0.1421781621170E+01 0.3123469900284E-14
      5 0.2129211303514E+01 0.2129211303514E+01 0.2356838921071E-13
Comparison of RMS-norms of solution error
      1 0.1090014029782E-03 0.1090014029782E-03 0.3860555522208E-12
      2 0.3734395176928E-04 0.3734395176928E-04 0.3048451562232E-13
      3 0.5009278540654E-04 0.5009278540654E-04 0.1007793103271E-12
      4 0.4767109393954E-04 0.4767109393953E-04 0.1640366839278E-12
      5 0.1362161339921E-03 0.1362161339921E-03 0.2606711856244E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      400
Time in seconds =                   295.48
Total processes =                       16
Compiled procs  =                       16
Mop/sec total     =                 287.70
Mop/sec/process   =                  17.98
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              19 Jul 2003
```

Performance of a cluster with a 10 Mbps network switch and nodes with 233 MHz CPU, and 256MB RAM.

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     4

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
       1 0.1080634671464E+03 0.1080634671464E+03 0.6706740118690E-14
       2 0.1131973090122E+02 0.1131973090122E+02 0.1569257127136E-14
       3 0.2597435451158E+02 0.2597435451158E+02 0.3692999157490E-14
       4 0.2366562254468E+02 0.2366562254468E+02 0.7355942989988E-14
       5 0.2527896321175E+03 0.2527896321175E+03 0.1574051628196E-13
 Comparison of RMS-norms of solution error
       1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
       2 0.4439028249700E+00 0.4439028249700E+00 0.4126731995354E-14
       3 0.9669248013635E+00 0.9669248013635E+00 0.6085459822952E-14
       4 0.8830206303977E+00 0.8830206303977E+00 0.2137412283349E-14
       5 0.9737990177083E+01 0.9737990177083E+01 0.4560378494683E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                  1732.31
 Total processes =                        4
 Compiled procs  =                        4
 Mop/sec total     =                  97.14
 Mop/sec/process   =                  24.29
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              24 Jul 2003
```

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     9

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
        1 0.1080634671464E+03 0.1080634671464E+03 0.6969749535109E-14
        2 0.1131973090122E+02 0.1131973090122E+02 0.2040034265277E-14
        3 0.2597435451158E+02 0.2597435451158E+02 0.5197554369800E-14
        4 0.2366562254468E+02 0.2366562254468E+02 0.6755457847948E-14
        5 0.2527896321175E+03 0.2527896321175E+03 0.1326700658051E-13
 Comparison of RMS-norms of solution error
        1 0.4234841604053E+01 0.4234841604053E+01 0.6291936058601E-15
        2 0.4439028249700E+00 0.4439028249700E+00 0.7127991628339E-14
        3 0.9669248013635E+00 0.9669248013635E+00 0.1148199966595E-14
        4 0.8830206303977E+00 0.8830206303977E+00 0.7543808058880E-15
        5 0.9737990177083E+01 0.9737990177083E+01 0.5837284473195E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                  1056.65
 Total processes =                        9
 Compiled procs  =                        9
 Mop/sec total     =                 159.26
 Mop/sec/process   =                  17.70
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 200    dt:   0.000800
Number of active processes:    16

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
    1 0.1080634671464E+03 0.1080634671464E+03 0.7758777784367E-14
    2 0.1131973090122E+02 0.1131973090122E+02 0.3138514254272E-14
    3 0.2597435451158E+02 0.2597435451158E+02 0.5334332116374E-14
    4 0.2366562254468E+02 0.2366562254468E+02 0.1065861127121E-13
    5 0.2527896321175E+03 0.2527896321175E+03 0.1551565176365E-13
Comparison of RMS-norms of solution error
    1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
    2 0.4439028249700E+00 0.4439028249700E+00 0.3001259632985E-14
    3 0.9669248013635E+00 0.9669248013635E+00 0.3329779903125E-14
    4 0.8830206303977E+00 0.8830206303977E+00 0.4149094432384E-14
    5 0.9737990177083E+01 0.9737990177083E+01 0.7661435871068E-14
Verification Successful


BT Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      200
Time in seconds =                   785.51
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                   214.24
Mop/sec/process =                    13.39
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 1

iteration	||r||	zeta
1	0.27827584529972E-12	19.9997581277040
2	0.26160031018478E-14	17.1140495745506
3	0.26714791625944E-14	17.1296668946143
4	0.26473497355311E-14	17.1302113581192
5	0.25962051721040E-14	17.1302338856353
6	0.26115199334372E-14	17.1302349879482
7	0.25993680727334E-14	17.1302350498916
8	0.26120228095637E-14	17.1302350537510
9	0.25450483820989E-14	17.1302350540101
10	0.25904786670248E-14	17.1302350540284
11	0.25506293938445E-14	17.1302350540298
12	0.25257745194192E-14	17.1302350540299
13	0.25415734339777E-14	17.1302350540299
14	0.25063961032389E-14	17.1302350540299
15	0.24842598520619E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 93.94
Total processes = 1
Compiled procs = 1
Mop/sec total = 15.93
Mop/sec/process = 15.93
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 4

iteration	||r||	zeta
1	0.30380719049536E-12	19.9997581277040
2	0.29763636601233E-14	17.1140495745506
3	0.30758070039524E-14	17.1296668946143
4	0.30767836772916E-14	17.1302113581192
5	0.30362538345620E-14	17.1302338856353
6	0.30918631267811E-14	17.1302349879482
7	0.29692461545083E-14	17.1302350498916
8	0.30136035568592E-14	17.1302350537510
9	0.30210087485660E-14	17.1302350540101
10	0.29835949970093E-14	17.1302350540284
11	0.29536430530910E-14	17.1302350540298
12	0.29781985872281E-14	17.1302350540299
13	0.29621143458868E-14	17.1302350540299
14	0.29849869948111E-14	17.1302350540299
15	0.29517709020202E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 129.00
Total processes = 4
Compiled procs = 4
Mop/sec total = 11.60
Mop/sec/process = 2.90
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 8

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 99.32
Total processes = 8
Compiled procs = 8
Mop/sec total = 15.07
Mop/sec/process = 1.88
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 16

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 99.10
Total processes = 16
Compiled procs = 16
Mop/sec total = 15.10
Mop/sec/process = 0.94
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 588.0135
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165629841E+03 -1.580732573678431E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 588.01
Total processes = 1
Compiled procs = 1
Mop/sec total = 0.91
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time = 294.9604
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165639063E+03   -1.580732573678573E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   294.96
Total processes =   2
Compiled procs =   1
Mop/sec total   =   1.82
Mop/sec/process =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 3

EP Benchmark Results:

CPU Time = 196.1480
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165637473E+03 -1.580732573677940E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 196.15
Total processes = 3
Compiled procs = 1
Mop/sec total = 2.74
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 4

EP Benchmark Results:

CPU Time = 147.5878
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634618E+03 -1.580732573678638E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 147.59
Total processes = 4
Compiled procs = 4
Mop/sec total = 3.64
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time = 118.0434
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165631720E+03 -1.580732573678449E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 118.04
Total processes = 5
Compiled procs = 4
Mop/sec total = 4.55
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 98.4524
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	98.45
Total processes	=	6
Compiled procs	=	4
Mop/sec total	=	5.45
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 84.3398
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 84.34
Total processes = 7
Compiled procs = 7
Mop/sec total = 6.37
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 8

EP Benchmark Results:

CPU Time =   73.8011
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165636284E+03   -1.580732573678494E+04
Counts:

```
 0      98257395.
 1      93827014.
 2      17611549.
 3       1110028.
 4         26536.
 5           245.
 6             0.
 7             0.
 8             0.
 9             0.
```

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   73.80
Total processes =   8
Compiled procs =   7
Mop/sec total   =   7.27
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 9

EP Benchmark Results:

CPU Time = 65.5898
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165630960E+03 -1.580732573678866E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 65.59
Total processes = 9
Compiled procs = 7
Mop/sec total = 8.19
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time = 59.1018
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632362E+03 -1.580732573678767E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	59.10
Total processes	=	10
Compiled procs	=	10
Mop/sec total	=	9.08
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 11

EP Benchmark Results:

CPU Time = 53.7731
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632911E+03 -1.580732573678582E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 53.77
Total processes = 11
Compiled procs = 10
Mop/sec total = 9.98
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time = 49.3076
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633768E+03 -1.580732573678642E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 49.31
Total processes = 12
Compiled procs = 12
Mop/sec total = 10.89
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time = 45.4141
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165628269E+03 -1.580732573678654E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 45.41
Total processes = 13
Compiled procs = 12
Mop/sec total = 11.82
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time = 42.2452
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635351E+03 -1.580732573678708E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	42.25
Total processes	=	14
Compiled procs	=	12
Mop/sec total	=	12.71
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time =   39.4289
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165635445E+03   -1.580732573678607E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   39.43
Total processes =   15
Compiled procs =   15
Mop/sec total   =   13.62
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time =   36.9120
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165633814E+03   -1.580732573678525E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   36.91
Total processes =   16
Compiled procs =   15
Mop/sec total   =   14.54
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :           6
Number of processes :           4
Processor array     :        1x  4
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =              256x256x128
Iterations      =                        6
Time in seconds =                   475.69
Total processes =                        4
Compiled procs  =                        4
Mop/sec total   =                    15.00
Mop/sec/process =                     3.75
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 8
Processor array : 1x 8
Layout type : 1D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 298.94
Total processes = 8
Compiled procs = 8
Mop/sec total = 23.87
Mop/sec/process = 2.98
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :           6
Number of processes :          16
Processor array     :       1x 16
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =              256x256x128
Iterations      =                        6
Time in seconds =                   168.54
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                    42.34
Mop/sec/process =                     2.65
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size:  8388608  (class A)
Iterations:   10
Number of processes:     1

  iteration
       1
       2
       3
       4
       5
       6
       7
       8
       9
       10


IS Benchmark Completed
Class           =                        A
Size            =                  8388608
Iterations      =                       10
Time in seconds =                    29.72
Total processes =                        1
Compiled procs  =                        1
Mop/sec total     =                   2.82
Mop/sec/process   =                   2.82
Operation type  =              keys ranked
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 4

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	156.56
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	0.54
Mop/sec/process	=	0.13
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	24 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 8

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	101.26
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	0.83
Mop/sec/process	=	0.10
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

```
  iteration
       1
       2
       3
       4
       5
       6
       7
       8
       9
       10
```

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	59.18
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	1.42
Mop/sec/process	=	0.09
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	22 Jul 2003

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

 Size:  64x 64x 64
 Iterations: 250
 Number of processes:     1

Verification being performed for class A
 Accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
        1   0.7790210760669E+03 0.7790210760669E+03 0.8756130575742E-15
        2   0.6340276525969E+02 0.6340276525969E+02 0.1681021481121E-14
        3   0.1949924972729E+03 0.1949924972729E+03 0.7287898208366E-15
        4   0.1784530116042E+03 0.1784530116042E+03 0.2707542203819E-14
        5   0.1838476034946E+04 0.1838476034946E+04 0.1484100990959E-14
 Comparison of RMS-norms of solution error
        1   0.2996408568547E+02 0.2996408568547E+02 0.8299601066640E-15
        2   0.2819457636500E+01 0.2819457636500E+01 0.7875436823397E-15
        3   0.7347341269877E+01 0.7347341269877E+01 0.4835373161943E-15
        4   0.6713922568778E+01 0.6713922568778E+01 0.5291561888607E-15
        5   0.7071531568839E+02 0.7071531568839E+02 0.6028759644299E-15
 Comparison of surface integral
            0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
 Verification Successful


 LU Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      250
 Time in seconds =                  2929.80
 Total processes =                        1
 Compiled procs  =                        1
 Mop/sec total   =                    40.72
 Mop/sec/process =                    40.72
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 4

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
    1   0.7790210760669E+03 0.7790210760669E+03 0.1415574443078E-13
    2   0.6340276525969E+02 0.6340276525969E+02 0.2353430073569E-14
    3   0.1949924972729E+03 0.1949924972729E+03 0.1195215306172E-13
    4   0.1784530116042E+03 0.1784530116042E+03 0.6370687538397E-15
    5   0.1838476034946E+04 0.1838476034946E+04 0.1261485842315E-13
Comparison of RMS-norms of solution error
    1   0.2996408568547E+02 0.2996408568547E+02 0.5928286476171E-15
    2   0.2819457636500E+01 0.2819457636500E+01 0.1323073386331E-13
    3   0.7347341269878E+01 0.7347341269877E+01 0.5802447794332E-14
    4   0.6713922568778E+01 0.6713922568778E+01 0.2645780944304E-15
    5   0.7071531568839E+02 0.7071531568839E+02 0.1044985005012E-13
Comparison of surface integral
        0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   250
Time in seconds =   942.23
Total processes =   4
Compiled procs =   4
Mop/sec total   =   126.61
Mop/sec/process   =   31.65
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

```
 NAS Parallel Benchmarks 2.2 -- LU Benchmark

 Size:  64x 64x 64
 Iterations: 250
 Number of processes:     8

 Verification being performed for class A
 Accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
           1   0.7790210760669E+03 0.7790210760669E+03 0.1444761544997E-13
           2   0.6340276525969E+02 0.6340276525969E+02 0.5603404937070E-14
           3   0.1949924972729E+03 0.1949924972729E+03 0.9182751742541E-14
           4   0.1784530116042E+03 0.1784530116042E+03 0.1592671884599E-15
           5   0.1838476034946E+04 0.1838476034946E+04 0.1162545776251E-13
 Comparison of RMS-norms of solution error
           1   0.2996408568547E+02 0.2996408568547E+02 0.9485258361874E-15
           2   0.2819457636500E+01 0.2819457636500E+01 0.1354575133624E-13
           3   0.7347341269878E+01 0.7347341269877E+01 0.7132175413867E-14
           4   0.6713922568778E+01 0.6713922568778E+01 0.6614452360759E-15
           5   0.7071531568839E+02 0.7071531568839E+02 0.1225847794341E-13
 Comparison of surface integral
               0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
 Verification Successful


 LU Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      250
 Time in seconds =                   608.57
 Total processes =                        8
 Compiled procs  =                        8
 Mop/sec total   =                   196.03
 Mop/sec/process =                    24.50
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:    16

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
    1   0.7790210760669E+03 0.7790210760669E+03 0.1634477707472E-13
    2   0.6340276525969E+02 0.6340276525969E+02 0.5267200640846E-14
    3   0.1949924972729E+03 0.1949924972729E+03 0.8891235814207E-14
    4   0.1784530116042E+03 0.1784530116042E+03 0.3185343769198E-15
    5   0.1838476034946E+04 0.1838476034946E+04 0.1150178267993E-13
Comparison of RMS-norms of solution error
    1   0.2996408568547E+02 0.2996408568547E+02 0.4742629180937E-15
    2   0.2819457636500E+01 0.2819457636500E+01 0.1165564649863E-13
    3   0.7347341269878E+01 0.7347341269877E+01 0.6165100781478E-14
    4   0.6713922568778E+01 0.6713922568778E+01 0.1455179519367E-14
    5   0.7071531568839E+02 0.7071531568839E+02 0.1125368466936E-13
Comparison of surface integral
        0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =                 64x 64x 64
Iterations      =                      250
Time in seconds =                   356.54
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                   334.60
Mop/sec/process =                    20.91
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 4

Initialization time: 35.123 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694334082688E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 78.90
Total processes = 4
Compiled procs = 4
Mop/sec total = 49.33
Mop/sec/process = 12.33
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 8

Initialization time: 21.659 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694952416740E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 48.25
Total processes = 8
Compiled procs = 8
Mop/sec total = 80.67
Mop/sec/process = 10.08
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 16

Initialization time: 13.484 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694838067292E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 30.53
Total processes = 16
Compiled procs = 16
Mop/sec total = 127.49
Mop/sec/process = 7.97
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
 NAS Parallel Benchmarks 2.3 -- SP Benchmark

 No input file inputsp.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 400    dt:   0.001500
 Number of active processes:     1

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
       1 0.2479982239930E+01 0.2479982239930E+01 0.6858362315424E-13
       2 0.1127633796437E+01 0.1127633796437E+01 0.2205414189446E-13
       3 0.1502897788877E+01 0.1502897788877E+01 0.5097178881098E-13
       4 0.1421781621169E+01 0.1421781621170E+01 0.3919954724857E-13
       5 0.2129211303514E+01 0.2129211303514E+01 0.1147133988132E-13
 Comparison of RMS-norms of solution error
       1 0.1090014029782E-03 0.1090014029782E-03 0.3948832315147E-12
       2 0.3734395176928E-04 0.3734395176928E-04 0.3737982272737E-13
       3 0.5009278540654E-04 0.5009278540654E-04 0.1623290904598E-14
       4 0.4767109393953E-04 0.4767109393953E-04 0.1361760339713E-12
       5 0.1362161339921E-03 0.1362161339921E-03 0.6208351901894E-13
 Verification Successful


 SP Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      400
 Time in seconds =                  3354.43
 Total processes =                        1
 Compiled procs  =                        1
 Mop/sec total     =                  25.34
 Mop/sec/process   =                  25.34
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     4

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1 0.2479982239930E+01 0.2479982239930E+01 0.4655807315954E-13
     2 0.1127633796437E+01 0.1127633796437E+01 0.3997313218370E-13
     3 0.1502897788877E+01 0.1502897788877E+01 0.1654736332415E-13
     4 0.1421781621169E+01 0.1421781621170E+01 0.3388964841809E-13
     5 0.2129211303514E+01 0.2129211303514E+01 0.1710272491397E-13
Comparison of RMS-norms of solution error
     1 0.1090014029782E-03 0.1090014029782E-03 0.3962509001377E-12
     2 0.3734395176928E-04 0.3734395176928E-04 0.4663405068414E-13
     3 0.5009278540654E-04 0.5009278540654E-04 0.6168505437472E-13
     4 0.4767109393954E-04 0.4767109393953E-04 0.1522385515483E-12
     5 0.1362161339921E-03 0.1362161339921E-03 0.4795553872937E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      400
Time in seconds =                  1937.71
Total processes =                        4
Compiled procs  =                        4
Mop/sec total     =                  43.87
Mop/sec/process   =                  10.97
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

```
 NAS Parallel Benchmarks 2.3 -- SP Benchmark

 No input file inputsp.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 400    dt:   0.001500
 Number of active processes:     9

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
        1               NAN 0.2479982239930E+01               NAN
        2               NAN 0.1127633796437E+01               NAN
        3               NAN 0.1502897788877E+01               NAN
        4               NAN 0.1421781621170E+01               NAN
        5               NAN 0.2129211303514E+01               NAN
 Comparison of RMS-norms of solution error
        1               NAN 0.1090014029782E-03               NAN
        2               NAN 0.3734395176928E-04               NAN
        3               NAN 0.5009278540654E-04               NAN
        4               NAN 0.4767109393953E-04               NAN
        5               NAN 0.1362161339921E-03               NAN
 Verification Successful


 SP Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      400
 Time in seconds =                  6320.40
 Total processes =                        9
 Compiled procs  =                        9
 Mop/sec total   =                    13.45
 Mop/sec/process =                     1.49
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:    16

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1 0.2479982239930E+01 0.2479982239930E+01 0.7861151583476E-13
      2 0.1127633796437E+01 0.1127633796437E+01 0.9451775097624E-14
      3 0.1502897788877E+01 0.1502897788877E+01 0.6707591918895E-13
      4 0.1421781621170E+01 0.1421781621170E+01 0.3123469900284E-14
      5 0.2129211303514E+01 0.2129211303514E+01 0.2356838921071E-13
Comparison of RMS-norms of solution error
      1 0.1090014029782E-03 0.1090014029782E-03 0.3860555522208E-12
      2 0.3734395176928E-04 0.3734395176928E-04 0.3048451562232E-13
      3 0.5009278540654E-04 0.5009278540654E-04 0.1007793103271E-12
      4 0.4767109393954E-04 0.4767109393953E-04 0.1640366839278E-12
      5 0.1362161339921E-03 0.1362161339921E-03 0.2606711856244E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      400
Time in seconds =                  1045.55
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                    81.31
Mop/sec/process =                     5.08
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

Performance of a cluster with a 100 Mbps network switch and nodes with 233 MHz CPU, and 256MB RAM.

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     4

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
       1 0.1080634671464E+03 0.1080634671464E+03 0.6706740118690E-14
       2 0.1131973090122E+02 0.1131973090122E+02 0.1569257127136E-14
       3 0.2597435451158E+02 0.2597435451158E+02 0.3692999157490E-14
       4 0.2366562254468E+02 0.2366562254468E+02 0.7355942989988E-14
       5 0.2527896321175E+03 0.2527896321175E+03 0.1574051628196E-13
 Comparison of RMS-norms of solution error
       1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
       2 0.4439028249700E+00 0.4439028249700E+00 0.4126731995354E-14
       3 0.9669248013635E+00 0.9669248013635E+00 0.6085459822952E-14
       4 0.8830206303977E+00 0.8830206303977E+00 0.2137412283349E-14
       5 0.9737990177083E+01 0.9737990177083E+01 0.4560378494683E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =               64x 64x 64
 Iterations      =                      200
 Time in seconds =                  1158.05
 Total processes =                        4
 Compiled procs  =                        4
 Mop/sec total   =                   145.32
 Mop/sec/process   =                  36.33
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              24 Jul 2003
```

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     9

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
        1 0.1080634671464E+03 0.1080634671464E+03 0.6969749535109E-14
        2 0.1131973090122E+02 0.1131973090122E+02 0.2040034265277E-14
        3 0.2597435451158E+02 0.2597435451158E+02 0.5197554369800E-14
        4 0.2366562254468E+02 0.2366562254468E+02 0.6755457847948E-14
        5 0.2527896321175E+03 0.2527896321175E+03 0.1326700658051E-13
 Comparison of RMS-norms of solution error
        1 0.4234841604053E+01 0.4234841604053E+01 0.6291936058601E-15
        2 0.4439028249700E+00 0.4439028249700E+00 0.7127991628339E-14
        3 0.9669248013635E+00 0.9669248013635E+00 0.1148199966595E-14
        4 0.8830206303977E+00 0.8830206303977E+00 0.7543808058880E-15
        5 0.9737990177083E+01 0.9737990177083E+01 0.5837284473195E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                   546.60
 Total processes =                        9
 Compiled procs  =                        9
 Mop/sec total   =                   307.88
 Mop/sec/process =                    34.21
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 200 dt: 0.000800
Number of active processes: 16

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.1080634671464E+03 0.1080634671464E+03 0.7758777784367E-14
2 0.1131973090122E+02 0.1131973090122E+02 0.3138514254272E-14
3 0.2597435451158E+02 0.2597435451158E+02 0.5334332116374E-14
4 0.2366562254468E+02 0.2366562254468E+02 0.1065861127121E-13
5 0.2527896321175E+03 0.2527896321175E+03 0.1551565176365E-13
Comparison of RMS-norms of solution error
1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
2 0.4439028249700E+00 0.4439028249700E+00 0.3001259632985E-14
3 0.9669248013635E+00 0.9669248013635E+00 0.3329779903125E-14
4 0.8830206303977E+00 0.8830206303977E+00 0.4149094432384E-14
5 0.9737990177083E+01 0.9737990177083E+01 0.7661435871068E-14
Verification Successful

BT Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 200
Time in seconds = 357.49
Total processes = 16
Compiled procs = 16
Mop/sec total = 470.73
Mop/sec/process = 29.42
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 1

iteration	||r||	zeta
1	0.27827584529972E-12	19.9997581277040
2	0.26160031018478E-14	17.1140495745506
3	0.26714791625944E-14	17.1296668946143
4	0.26473497355311E-14	17.1302113581192
5	0.25962051721040E-14	17.1302338856353
6	0.26115199334372E-14	17.1302349879482
7	0.25993680727334E-14	17.1302350498916
8	0.26120228095637E-14	17.1302350537510
9	0.25450483820989E-14	17.1302350540101
10	0.25904786670248E-14	17.1302350540284
11	0.25506293938445E-14	17.1302350540298
12	0.25257745194192E-14	17.1302350540299
13	0.25415734339777E-14	17.1302350540299
14	0.25063961032389E-14	17.1302350540299
15	0.24842598520619E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 93.92
Total processes = 1
Compiled procs = 1
Mop/sec total = 15.93
Mop/sec/process = 15.93
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 4

iteration	||r||	zeta
1	0.30380719049536E-12	19.9997581277040
2	0.29763636601233E-14	17.1140495745506
3	0.30758070039524E-14	17.1296668946143
4	0.30767836772916E-14	17.1302113581192
5	0.30362538345620E-14	17.1302338856353
6	0.30918631267811E-14	17.1302349879482
7	0.29692461545083E-14	17.1302350498916
8	0.30136035568592E-14	17.1302350537510
9	0.30210087485660E-14	17.1302350540101
10	0.29835949970093E-14	17.1302350540284
11	0.29536430530910E-14	17.1302350540298
12	0.29781985872281E-14	17.1302350540299
13	0.29621143458868E-14	17.1302350540299
14	0.29849869948111E-14	17.1302350540299
15	0.29517709020202E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 29.87
Total processes = 4
Compiled procs = 4
Mop/sec total = 50.10
Mop/sec/process = 12.52
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size:      14000
Iterations:    15
Number of active processes:     8

  iteration           ||r||                 zeta
       1       0.26430287941297E-12    19.9997581277040
       2       0.26414813392819E-14    17.1140495745506
       3       0.26266612893876E-14    17.1296668946143
       4       0.26223598758375E-14    17.1302113581192
       5       0.26182783886564E-14    17.1302338856353
       6       0.26288689973095E-14    17.1302349879482
       7       0.25972755600456E-14    17.1302350498916
       8       0.25774519203481E-14    17.1302350537510
       9       0.25550821991349E-14    17.1302350540101
      10       0.25670770323505E-14    17.1302350540284
      11       0.25758028098708E-14    17.1302350540298
      12       0.25113124979678E-14    17.1302350540299
      13       0.25036350044005E-14    17.1302350540299
      14       0.24859657049077E-14    17.1302350540299
      15       0.24631513623583E-14    17.1302350540299
Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is      0.171302350540E+02
Error is     0.891731133379E-12


CG Benchmark Completed.
Class           =                        A
Size            =                    14000
Iterations      =                       15
Time in seconds =                    16.89
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                    88.59
Mop/sec/process =                    11.07
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 16

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 12.64
Total processes = 16
Compiled procs = 16
Mop/sec total = 118.40
Mop/sec/process = 7.40
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 590.3174
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165629841E+03   -1.580732573678431E+04
Counts:
  0   98257395.
  1   93827014.
  2   17611549.
  3   1110028.
  4   26536.
  5   245.
  6   0.
  7   0.
  8   0.
  9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   590.32
Total processes =   1
Compiled procs =   1
Mop/sec total   =   0.91
Mop/sec/process =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time = 295.1624
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165639063E+03 -1.580732573678573E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 295.16
Total processes = 2
Compiled procs = 1
Mop/sec total = 1.82
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 3

EP Benchmark Results:

CPU Time = 196.7246
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165637473E+03   -1.580732573677940E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   196.72
Total processes =   3
Compiled procs =   1
Mop/sec total   =   2.73
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 4

EP Benchmark Results:

CPU Time = 147.5788
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634618E+03 -1.580732573678638E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 147.58
Total processes = 4
Compiled procs = 4
Mop/sec total = 3.64
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time = 118.1903
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165631720E+03   -1.580732573678449E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   118.19
Total processes =   5
Compiled procs =   4
Mop/sec total   =   4.54
Mop/sec/process   =   0.91
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 98.4426
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 98.44
Total processes = 6
Compiled procs = 4
Mop/sec total = 5.45
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 84.3224
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	84.32
Total processes	=	7
Compiled procs	=	7
Mop/sec total	=	6.37
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 8

EP Benchmark Results:

CPU Time = 73.7931
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165636284E+03 -1.580732573678494E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 73.79
Total processes = 8
Compiled procs = 7
Mop/sec total = 7.28
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 9

EP Benchmark Results:

CPU Time = 65.7209
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165630960E+03 -1.580732573678866E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 65.72
Total processes = 9
Compiled procs = 7
Mop/sec total = 8.17
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time = 59.1012
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632362E+03 -1.580732573678767E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 59.10
Total processes = 10
Compiled procs = 10
Mop/sec total = 9.08
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
 NAS Parallel Benchmarks 2.3 -- EP Benchmark

 Number of random numbers generated:    536870912
 Number of active processes:                  11

EP Benchmark Results:

CPU Time =   53.7655
N = 2^   28
No. Gaussian Pairs =     210832767.
Sums =    -4.295875165632911E+03   -1.580732573678582E+04
Counts:
  0      98257395.
  1      93827014.
  2      17611549.
  3       1110028.
  4         26536.
  5           245.
  6             0.
  7             0.
  8             0.
  9             0.


 EP Benchmark Completed.
 Class           =                        A
 Size            =                536870912
 Iterations      =                        0
 Time in seconds =                    53.77
 Total processes =                       11
 Compiled procs  =                       10
 Mop/sec total   =                     9.99
 Mop/sec/process =                     0.91
 Operation type  = Random numbers generated
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time = 49.2966
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633768E+03 -1.580732573678642E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 49.30
Total processes = 12
Compiled procs = 12
Mop/sec total = 10.89
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time = 45.5433
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165628269E+03 -1.580732573678654E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 45.54
Total processes = 13
Compiled procs = 12
Mop/sec total = 11.79
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time = 42.2386
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635351E+03 -1.580732573678708E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	42.24
Total processes	=	14
Compiled procs	=	12
Mop/sec total	=	12.71
Mop/sec/process	=	0.91
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time = 39.4890
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635445E+03 -1.580732573678607E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 39.49
Total processes = 15
Compiled procs = 15
Mop/sec total = 13.60
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time = 36.9068
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633814E+03 -1.580732573678525E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 36.91
Total processes = 16
Compiled procs = 15
Mop/sec total = 14.55
Mop/sec/process = 0.91
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 4
Processor array : 1x 4
Layout type : 1D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 81.90
Total processes = 4
Compiled procs = 4
Mop/sec total = 87.13
Mop/sec/process = 21.78
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :           6
Number of processes :           8
Processor array     :       1x  8
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =              256x256x128
Iterations      =                        6
Time in seconds =                    41.76
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                   170.88
Mop/sec/process =                    21.36
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 16
Processor array : 1x 16
Layout type : 1D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 22.07
Total processes = 16
Compiled procs = 16
Mop/sec total = 323.36
Mop/sec/process = 20.21
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 1

```
  iteration
       1
       2
       3
       4
       5
       6
       7
       8
       9
       10
```

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	29.72
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	2.82
Mop/sec/process	=	2.82
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 4

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	13.19
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	6.36
Mop/sec/process	=	1.59
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	24 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 8

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	6.87
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	12.21
Mop/sec/process	=	1.53
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

```
  iteration
       1
       2
       3
       4
       5
       6
       7
       8
       9
       10
```

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	5.74
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	14.63
Mop/sec/process	=	0.91
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	22 Jul 2003

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:     1

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1   0.7790210760669E+03 0.7790210760669E+03 0.8756130575742E-15
     2   0.6340276525969E+02 0.6340276525969E+02 0.1681021481121E-14
     3   0.1949924972729E+03 0.1949924972729E+03 0.7287898208366E-15
     4   0.1784530116042E+03 0.1784530116042E+03 0.2707542203819E-14
     5   0.1838476034946E+04 0.1838476034946E+04 0.1484100990959E-14
Comparison of RMS-norms of solution error
     1   0.2996408568547E+02 0.2996408568547E+02 0.8299601066640E-15
     2   0.2819457636500E+01 0.2819457636500E+01 0.7875436823397E-15
     3   0.7347341269877E+01 0.7347341269877E+01 0.4835373161943E-15
     4   0.6713922568778E+01 0.6713922568778E+01 0.5291561888607E-15
     5   0.7071531568839E+02 0.7071531568839E+02 0.6028759644299E-15
Comparison of surface integral
         0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      250
Time in seconds =                  2930.70
Total processes =                        1
Compiled procs  =                        1
Mop/sec total   =                    40.71
Mop/sec/process =                    40.71
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 4

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1   0.7790210760669E+03 0.7790210760669E+03 0.1415574443078E-13
2   0.6340276525969E+02 0.6340276525969E+02 0.2353430073569E-14
3   0.1949924972729E+03 0.1949924972729E+03 0.1195215306172E-13
4   0.1784530116042E+03 0.1784530116042E+03 0.6370687538397E-15
5   0.1838476034946E+04 0.1838476034946E+04 0.1261485842315E-13
Comparison of RMS-norms of solution error
1   0.2996408568547E+02 0.2996408568547E+02 0.5928286476171E-15
2   0.2819457636500E+01 0.2819457636500E+01 0.1323073386331E-13
3   0.7347341269878E+01 0.7347341269877E+01 0.5802447794332E-14
4   0.6713922568778E+01 0.6713922568778E+01 0.2645780944304E-15
5   0.7071531568839E+02 0.7071531568839E+02 0.1044985005012E-13
Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   250
Time in seconds =   773.92
Total processes =   4
Compiled procs =   4
Mop/sec total   =   154.15
Mop/sec/process   =   38.54
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 8

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1444761544997E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.5603404937070E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.9182751742541E-14
4	0.1784530116042E+03	0.1784530116042E+03	0.1592671884599E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1162545776251E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.9485258361874E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1354575133624E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.7132175413867E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.6614452360759E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.1225847794341E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 250
Time in seconds = 378.66
Total processes = 8
Compiled procs = 8
Mop/sec total = 315.05
Mop/sec/process = 39.38
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 16

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1634477707472E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.5267200640846E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.8891235814207E-14
4	0.1784530116042E+03	0.1784530116042E+03	0.3185343769198E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1150178267993E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.4742629180937E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1165564649863E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.6165100781478E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.1455179519367E-14
5	0.7071531568839E+02	0.7071531568839E+02	0.1125368466936E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   250
Time in seconds =   186.31
Total processes =   16
Compiled procs =   16
Mop/sec total   =   640.31
Mop/sec/process   =   40.02
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 4

Initialization time: 19.108 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is   0.243336530907E-05
Error is   0.694334082688E-16

MG Benchmark Completed.
Class   =   A
Size   =   256x256x256
Iterations   =   4
Time in seconds =   40.18
Total processes =   4
Compiled procs =   4
Mop/sec total   =   96.86
Mop/sec/process   =   24.22
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 8

Initialization time: 9.337 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694952416740E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 18.52
Total processes = 8
Compiled procs = 8
Mop/sec total = 210.19
Mop/sec/process = 26.27
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 16

Initialization time: 5.091 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694838067292E-16

MG Benchmark Completed.

Class	=	A
Size	=	256x256x256
Iterations	=	4
Time in seconds	=	9.98
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	389.92
Mop/sec/process	=	24.37
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     1

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1 0.2479982239930E+01 0.2479982239930E+01 0.6858362315424E-13
     2 0.1127633796437E+01 0.1127633796437E+01 0.2205414189446E-13
     3 0.1502897788877E+01 0.1502897788877E+01 0.5097178881098E-13
     4 0.1421781621169E+01 0.1421781621170E+01 0.3919954724857E-13
     5 0.2129211303514E+01 0.2129211303514E+01 0.1147133988132E-13
Comparison of RMS-norms of solution error
     1 0.1090014029782E-03 0.1090014029782E-03 0.3948832315147E-12
     2 0.3734395176928E-04 0.3734395176928E-04 0.3737982272737E-13
     3 0.5009278540654E-04 0.5009278540654E-04 0.1623290904598E-14
     4 0.4767109393953E-04 0.4767109393953E-04 0.1361760339713E-12
     5 0.1362161339921E-03 0.1362161339921E-03 0.6208351901894E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      400
Time in seconds =                  3352.84
Total processes =                        1
Compiled procs  =                        1
Mop/sec total   =                    25.35
Mop/sec/process =                    25.35
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     4

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1 0.2479982239930E+01 0.2479982239930E+01 0.4655807315954E-13
      2 0.1127633796437E+01 0.1127633796437E+01 0.3997313218370E-13
      3 0.1502897788877E+01 0.1502897788877E+01 0.1654736332415E-13
      4 0.1421781621169E+01 0.1421781621170E+01 0.3388964841809E-13
      5 0.2129211303514E+01 0.2129211303514E+01 0.1710272491397E-13
Comparison of RMS-norms of solution error
      1 0.1090014029782E-03 0.1090014029782E-03 0.3962509001377E-12
      2 0.3734395176928E-04 0.3734395176928E-04 0.4663405068414E-13
      3 0.5009278540654E-04 0.5009278540654E-04 0.6168505437472E-13
      4 0.4767109393954E-04 0.4767109393953E-04 0.1522385515483E-12
      5 0.1362161339921E-03 0.1362161339921E-03 0.4795553872937E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      400
Time in seconds =                   913.91
Total processes =                        4
Compiled procs  =                        4
Mop/sec total     =                  93.02
Mop/sec/process   =                  23.25
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     9

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1            NAN 0.2479982239930E+01          NAN
      2            NAN 0.1127633796437E+01          NAN
      3            NAN 0.1502897788877E+01          NAN
      4            NAN 0.1421781621170E+01          NAN
      5            NAN 0.2129211303514E+01          NAN
Comparison of RMS-norms of solution error
      1            NAN 0.1090014029782E-03          NAN
      2            NAN 0.3734395176928E-04          NAN
      3            NAN 0.5009278540654E-04          NAN
      4            NAN 0.4767109393953E-04          NAN
      5            NAN 0.1362161339921E-03          NAN
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =              64x 64x 64
Iterations      =                      400
Time in seconds =                  5650.74
Total processes =                        9
Compiled procs  =                        9
Mop/sec total   =                    15.04
Mop/sec/process =                     1.67
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
 NAS Parallel Benchmarks 2.3 -- SP Benchmark

 No input file inputsp.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 400    dt:   0.001500
 Number of active processes:    16

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
       1 0.2479982239930E+01 0.2479982239930E+01 0.7861151583476E-13
       2 0.1127633796437E+01 0.1127633796437E+01 0.9451775097624E-14
       3 0.1502897788877E+01 0.1502897788877E+01 0.6707591918895E-13
       4 0.1421781621170E+01 0.1421781621170E+01 0.3123469900284E-14
       5 0.2129211303514E+01 0.2129211303514E+01 0.2356838921071E-13
 Comparison of RMS-norms of solution error
       1 0.1090014029782E-03 0.1090014029782E-03 0.3860555522208E-12
       2 0.3734395176928E-04 0.3734395176928E-04 0.3048451562232E-13
       3 0.5009278540654E-04 0.5009278540654E-04 0.1007793103271E-12
       4 0.4767109393954E-04 0.4767109393953E-04 0.1640366839278E-12
       5 0.1362161339921E-03 0.1362161339921E-03 0.2606711856244E-13
 Verification Successful


 SP Benchmark Completed.
 Class           =                        A
 Size            =              64x 64x 64
 Iterations      =                      400
 Time in seconds =                   293.95
 Total processes =                       16
 Compiled procs  =                       16
 Mop/sec total     =                 289.20
 Mop/sec/process   =                  18.07
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              24 Jul 2003
```

Performance of a cluster with a 10 Mbps network switch and nodes with 433 MHz CPU, and 128MB RAM.

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     4

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
       1 0.1080634671464E+03 0.1080634671464E+03 0.4208150662707E-14
       2 0.1131973090123E+02 0.1131973090122E+02 0.8957319681692E-12
       3 0.2597435451158E+02 0.2597435451158E+02 0.7933109301274E-14
       4 0.2366562254468E+02 0.2366562254468E+02 0.1486200726549E-13
       5 0.2527896321175E+03 0.2527896321175E+03 0.1810159372426E-13
 Comparison of RMS-norms of solution error
       1 0.4234841604052E+01 0.4234841604053E+01 0.1677849615627E-14
       2 0.4439028249702E+00 0.4439028249700E+00 0.4376836964769E-12
       3 0.9669248013635E+00 0.9669248013635E+00 0.3444599899784E-14
       4 0.8830206303977E+00 0.8830206303977E+00 0.1885952014720E-14
       5 0.9737990177083E+01 0.9737990177083E+01 0.1824151397873E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                  4349.00
 Total processes =                        4
 Compiled procs  =                        4
 Mop/sec total   =                    38.70
 Mop/sec/process =                     9.67
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              24 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 200    dt:   0.000800
Number of active processes:     9

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
       1 0.1080634671464E+03 0.1080634671464E+03 0.6969749535109E-14
       2 0.1131973090122E+02 0.1131973090122E+02 0.2040034265277E-14
       3 0.2597435451158E+02 0.2597435451158E+02 0.5197554369800E-14
       4 0.2366562254468E+02 0.2366562254468E+02 0.6755457847948E-14
       5 0.2527896321175E+03 0.2527896321175E+03 0.1326700658051E-13
Comparison of RMS-norms of solution error
       1 0.4234841604053E+01 0.4234841604053E+01 0.6291936058601E-15
       2 0.4439028249700E+00 0.4439028249700E+00 0.7127991628339E-14
       3 0.9669248013635E+00 0.9669248013635E+00 0.1148199966595E-14
       4 0.8830206303977E+00 0.8830206303977E+00 0.7543808058880E-15
       5 0.9737990177083E+01 0.9737990177083E+01 0.5837284473195E-14
Verification Successful


BT Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      200
Time in seconds =                  4174.06
Total processes =                        9
Compiled procs  =                        9
Mop/sec total     =                  40.32
Mop/sec/process   =                   4.48
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 200    dt:   0.000800
Number of active processes:    16

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1 0.1080634671464E+03 0.1080634671464E+03 0.7758777784367E-14
      2 0.1131973090122E+02 0.1131973090122E+02 0.3138514254272E-14
      3 0.2597435451158E+02 0.2597435451158E+02 0.5334332116374E-14
      4 0.2366562254468E+02 0.2366562254468E+02 0.1065861127121E-13
      5 0.2527896321175E+03 0.2527896321175E+03 0.1551565176365E-13
Comparison of RMS-norms of solution error
      1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
      2 0.4439028249700E+00 0.4439028249700E+00 0.3001259632985E-14
      3 0.9669248013635E+00 0.9669248013635E+00 0.3329779903125E-14
      4 0.8830206303977E+00 0.8830206303977E+00 0.4149094432384E-14
      5 0.9737990177083E+01 0.9737990177083E+01 0.7661435871068E-14
Verification Successful


BT Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      200
Time in seconds =                  4263.76
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                    39.47
Mop/sec/process =                     2.47
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 1

iteration	||r||	zeta
1	0.27827584529972E-12	19.9997581277040
2	0.26160031018478E-14	17.1140495745506
3	0.26714791625944E-14	17.1296668946143
4	0.26473497355311E-14	17.1302113581192
5	0.25962051721040E-14	17.1302338856353
6	0.26115199334372E-14	17.1302349879482
7	0.25993680727334E-14	17.1302350498916
8	0.26120228095637E-14	17.1302350537510
9	0.25450483820989E-14	17.1302350540101
10	0.25904786670248E-14	17.1302350540284
11	0.25506293938445E-14	17.1302350540298
12	0.25257745194192E-14	17.1302350540299
13	0.25415734339777E-14	17.1302350540299
14	0.25063961032389E-14	17.1302350540299
15	0.24842598520619E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 76.40
Total processes = 1
Compiled procs = 1
Mop/sec total = 19.59
Mop/sec/process = 19.59
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 4

iteration	||r||	zeta
1	0.30380719049536E-12	19.9997581277040
2	0.29763636601233E-14	17.1140495745506
3	0.30758070039524E-14	17.1296668946143
4	0.30767836772916E-14	17.1302113581192
5	0.30362538345620E-14	17.1302338856353
6	0.30918631267811E-14	17.1302349879482
7	0.29692461545083E-14	17.1302350498916
8	0.30136035568592E-14	17.1302350537510
9	0.30210087485660E-14	17.1302350540101
10	0.29835949970093E-14	17.1302350540284
11	0.29536430530910E-14	17.1302350540298
12	0.29781985872281E-14	17.1302350540299
13	0.29621143458868E-14	17.1302350540299
14	0.29849869948111E-14	17.1302350540299
15	0.29517709020202E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 529.58
Total processes = 4
Compiled procs = 4
Mop/sec total = 2.83
Mop/sec/process = 0.71
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 8

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 496.59
Total processes = 8
Compiled procs = 8
Mop/sec total = 3.01
Mop/sec/process = 0.38
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 16

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 693.48
Total processes = 16
Compiled procs = 16
Mop/sec total = 2.16
Mop/sec/process = 0.13
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 328.8152
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165629841E+03 -1.580732573678431E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 328.82
Total processes = 1
Compiled procs = 1
Mop/sec total = 1.63
Mop/sec/process = 1.63
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time = 164.4325
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165639063E+03 -1.580732573678573E+04
Counts:

```
 0     98257395.
 1     93827014.
 2     17611549.
 3      1110028.
 4        26536.
 5          245.
 6            0.
 7            0.
 8            0.
 9            0.
```

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 164.43
Total processes = 2
Compiled procs = 1
Mop/sec total = 3.26
Mop/sec/process = 1.63
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 3

EP Benchmark Results:

CPU Time = 109.6526
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165637473E+03 -1.580732573677940E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 109.65
Total processes = 3
Compiled procs = 1
Mop/sec total = 4.90
Mop/sec/process = 1.63
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 4

EP Benchmark Results:

CPU Time =   82.2257
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165634618E+03   -1.580732573678638E+04
Counts:

```
 0     98257395.
 1     93827014.
 2     17611549.
 3      1110028.
 4        26536.
 5          245.
 6            0.
 7            0.
 8            0.
 9            0.
```

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   82.23
Total processes =   4
Compiled procs =   4
Mop/sec total   =   6.53
Mop/sec/process   =   1.63
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time = 65.8249
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165631720E+03 -1.580732573678449E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 65.82
Total processes = 5
Compiled procs = 4
Mop/sec total = 8.16
Mop/sec/process = 1.63
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 54.8441
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 54.84
Total processes = 6
Compiled procs = 4
Mop/sec total = 9.79
Mop/sec/process = 1.63
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 47.2547
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 47.25
Total processes = 7
Compiled procs = 7
Mop/sec total = 11.36
Mop/sec/process = 1.62
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 8

EP Benchmark Results:

CPU Time = 41.1183
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165636284E+03 -1.580732573678494E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 41.12
Total processes = 8
Compiled procs = 7
Mop/sec total = 13.06
Mop/sec/process = 1.63
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 9

EP Benchmark Results:

CPU Time = 36.6116
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165630960E+03 -1.580732573678866E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 36.61
Total processes = 9
Compiled procs = 7
Mop/sec total = 14.66
Mop/sec/process = 1.63
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time = 34.5414
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632362E+03 -1.580732573678767E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 34.54
Total processes = 10
Compiled procs = 10
Mop/sec total = 15.54
Mop/sec/process = 1.55
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 11

EP Benchmark Results:

CPU Time = 31.5633
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632911E+03 -1.580732573678582E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 31.56
Total processes = 11
Compiled procs = 10
Mop/sec total = 17.01
Mop/sec/process = 1.55
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time =   28.5264
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165633768E+03   -1.580732573678642E+04
Counts:
0   98257395.
1   93827014.
2   17611549.
3   1110028.
4   26536.
5   245.
6   0.
7   0.
8   0.
9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   28.53
Total processes =   12
Compiled procs =   12
Mop/sec total   =   18.82
Mop/sec/process   =   1.57
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time = 26.1502
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165628269E+03 -1.580732573678654E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 26.15
Total processes = 13
Compiled procs = 12
Mop/sec total = 20.53
Mop/sec/process = 1.58
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time = 24.3349
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635351E+03 -1.580732573678708E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	24.33
Total processes	=	14
Compiled procs	=	12
Mop/sec total	=	22.06
Mop/sec/process	=	1.58
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time = 22.6349
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635445E+03 -1.580732573678607E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 22.63
Total processes = 15
Compiled procs = 15
Mop/sec total = 23.72
Mop/sec/process = 1.58
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time =   21.1803
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165633814E+03   -1.580732573678525E+04
Counts:
0   98257395.
1   93827014.
2   17611549.
3   1110028.
4   26536.
5   245.
6   0.
7   0.
8   0.
9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   21.18
Total processes =   16
Compiled procs =   15
Mop/sec total   =   25.35
Mop/sec/process   =   1.58
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 4
Processor array : 1x 4
Layout type : 1D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 1948.90
Total processes = 4
Compiled procs = 4
Mop/sec total = 3.66
Mop/sec/process = 0.92
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :           6
Number of processes :           8
Processor array     :       1x  8
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =              256x256x128
Iterations      =                        6
Time in seconds =                   753.15
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                     9.48
Mop/sec/process =                     1.18
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :           6
Number of processes :          16
Processor array     :       1x 16
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =              256x256x128
Iterations      =                        6
Time in seconds =                   411.42
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                    17.35
Mop/sec/process =                     1.08
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 4

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed
Class = A
Size = 8388608
Iterations = 10
Time in seconds = 810.64
Total processes = 4
Compiled procs = 4
Mop/sec total = 0.10
Mop/sec/process = 0.03
Operation type = keys ranked
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 8

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	408.42
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	0.21
Mop/sec/process	=	0.03
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

```
 iteration
      1
      2
      3
      4
      5
      6
      7
      8
      9
      10
```

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	208.82
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	0.40
Mop/sec/process	=	0.03
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	22 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 1

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.8756130575742E-15
2	0.6340276525969E+02	0.6340276525969E+02	0.1681021481121E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.7287898208366E-15
4	0.1784530116042E+03	0.1784530116042E+03	0.2707542203819E-14
5	0.1838476034946E+04	0.1838476034946E+04	0.1484100990959E-14

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.8299601066640E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.7875436823397E-15
3	0.7347341269877E+01	0.7347341269877E+01	0.4835373161943E-15
4	0.6713922568778E+01	0.6713922568778E+01	0.5291561888607E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.6028759644299E-15

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	1894.53
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	62.97
Mop/sec/process	=	62.97
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 4

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1   0.7790210760669E+03 0.7790210760669E+03 0.1415574443078E-13
2   0.6340276525969E+02 0.6340276525969E+02 0.2353430073569E-14
3   0.1949924972729E+03 0.1949924972729E+03 0.1195215306172E-13
4   0.1784530116042E+03 0.1784530116042E+03 0.6370687538397E-15
5   0.1838476034946E+04 0.1838476034946E+04 0.1261485842315E-13
Comparison of RMS-norms of solution error
1   0.2996408568547E+02 0.2996408568547E+02 0.5928286476171E-15
2   0.2819457636500E+01 0.2819457636500E+01 0.1323073386331E-13
3   0.7347341269878E+01 0.7347341269877E+01 0.5802447794332E-14
4   0.6713922568778E+01 0.6713922568778E+01 0.2645780944304E-15
5   0.7071531568839E+02 0.7071531568839E+02 0.1044985005012E-13
Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   250
Time in seconds =   2680.18
Total processes =   4
Compiled procs =   4
Mop/sec total   =   44.51
Mop/sec/process   =   11.13
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:     8

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1   0.7790210760669E+03 0.7790210760669E+03 0.1444761544997E-13
      2   0.6340276525969E+02 0.6340276525969E+02 0.5603404937070E-14
      3   0.1949924972729E+03 0.1949924972729E+03 0.9182751742541E-14
      4   0.1784530116042E+03 0.1784530116042E+03 0.1592671884599E-15
      5   0.1838476034946E+04 0.1838476034946E+04 0.1162545776251E-13
Comparison of RMS-norms of solution error
      1   0.2996408568547E+02 0.2996408568547E+02 0.9485258361874E-15
      2   0.2819457636500E+01 0.2819457636500E+01 0.1354575133624E-13
      3   0.7347341269878E+01 0.7347341269877E+01 0.7132175413867E-14
      4   0.6713922568778E+01 0.6713922568778E+01 0.6614452360759E-15
      5   0.7071531568839E+02 0.7071531568839E+02 0.1225847794341E-13
Comparison of surface integral
          0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =               64x 64x 64
Iterations      =                      250
Time in seconds =                  3350.66
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                    35.60
Mop/sec/process =                     4.45
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 16

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

```
   1   0.7790210760669E+03 0.7790210760669E+03 0.1634477707472E-13
   2   0.6340276525969E+02 0.6340276525969E+02 0.5267200640846E-14
   3   0.1949924972729E+03 0.1949924972729E+03 0.8891235814207E-14
   4   0.1784530116042E+03 0.1784530116042E+03 0.3185343769198E-15
   5   0.1838476034946E+04 0.1838476034946E+04 0.1150178267993E-13
```

Comparison of RMS-norms of solution error

```
   1   0.2996408568547E+02 0.2996408568547E+02 0.4742629180937E-15
   2   0.2819457636500E+01 0.2819457636500E+01 0.1165564649863E-13
   3   0.7347341269878E+01 0.7347341269877E+01 0.6165100781478E-14
   4   0.6713922568778E+01 0.6713922568778E+01 0.1455179519367E-14
   5   0.7071531568839E+02 0.7071531568839E+02 0.1125368466936E-13
```

Comparison of surface integral

```
       0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
```

Verification Successful

LU Benchmark Completed.

```
Class           =                A
Size            =          64x 64x 64
Iterations      =              250
Time in seconds =            2668.93
Total processes =               16
Compiled procs  =               16
Mop/sec total   =             44.70
Mop/sec/process =              2.79
Operation type  =       floating point
Verification    =         SUCCESSFUL
Version         =              2.3
Compile date    =         21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 4

Initialization time: 177.300 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694334082688E-16

MG Benchmark Completed.

Class	=	A
Size	=	256x256x256
Iterations	=	4
Time in seconds	=	386.18
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	10.08
Mop/sec/process	=	2.52
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 8

Initialization time: 144.380 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694952416740E-16

MG Benchmark Completed.

Class	=	A
Size	=	256x256x256
Iterations	=	4
Time in seconds	=	326.50
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	11.92
Mop/sec/process	=	1.49
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 16

Initialization time: 96.780 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336531671E-05
Error is 0.771338017330E-14

MG Benchmark Completed.

Class	=	A
Size	=	256x256x256
Iterations	=	4
Time in seconds	=	193.85
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	20.08
Mop/sec/process	=	1.25
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400 dt: 0.001500
Number of active processes: 1

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.2479982239930E+01 0.2479982239930E+01 0.6858362315424E-13
2 0.1127633796437E+01 0.1127633796437E+01 0.2205414189446E-13
3 0.1502897788877E+01 0.1502897788877E+01 0.5097178881098E-13
4 0.1421781621169E+01 0.1421781621170E+01 0.3919954724857E-13
5 0.2129211303514E+01 0.2129211303514E+01 0.1147133988132E-13
Comparison of RMS-norms of solution error
1 0.1090014029782E-03 0.1090014029782E-03 0.3948832315147E-12
2 0.3734395176928E-04 0.3734395176928E-04 0.3737982272737E-13
3 0.5009278540654E-04 0.5009278540654E-04 0.1623290904598E-14
4 0.4767109393953E-04 0.4767109393953E-04 0.1361760339713E-12
5 0.1362161339921E-03 0.1362161339921E-03 0.6208351901894E-13
Verification Successful

SP Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 400
Time in seconds = 2233.28
Total processes = 1
Compiled procs = 1
Mop/sec total = 38.07
Mop/sec/process = 38.07
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400   dt: 0.001500
Number of active processes: 4

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.2479982239930E+01 0.2479982239930E+01 0.4655807315954E-13
2 0.1127633796437E+01 0.1127633796437E+01 0.3997313218370E-13
3 0.1502897788877E+01 0.1502897788877E+01 0.1654736332415E-13
4 0.1421781621169E+01 0.1421781621170E+01 0.3388964841809E-13
5 0.2129211303514E+01 0.2129211303514E+01 0.1710272491397E-13
Comparison of RMS-norms of solution error
1 0.1090014029782E-03 0.1090014029782E-03 0.3962509001377E-12
2 0.3734395176928E-04 0.3734395176928E-04 0.4663405068414E-13
3 0.5009278540654E-04 0.5009278540654E-04 0.6168505437472E-13
4 0.4767109393954E-04 0.4767109393953E-04 0.1522385515483E-12
5 0.1362161339921E-03 0.1362161339921E-03 0.4795553872937E-13
Verification Successful

SP Benchmark Completed.
Class   =   A
Size   =   64x 64x 64
Iterations   =   400
Time in seconds =   7125.85
Total processes =   4
Compiled procs =   4
Mop/sec total   =   11.93
Mop/sec/process   =   2.98
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   24 Jul 2003

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400 dt: 0.001500
Number of active processes: 9

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	NAN	0.2479982239930E+01	NAN
2	NAN	0.1127633796437E+01	NAN
3	NAN	0.1502897788877E+01	NAN
4	NAN	0.1421781621170E+01	NAN
5	NAN	0.2129211303514E+01	NAN

Comparison of RMS-norms of solution error

1	NAN	0.1090014029782E-03	NAN
2	NAN	0.3734395176928E-04	NAN
3	NAN	0.5009278540654E-04	NAN
4	NAN	0.4767109393953E-04	NAN
5	NAN	0.1362161339921E-03	NAN

Verification Successful

SP Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	400
Time in seconds	=	8453.03
Total processes	=	9
Compiled procs	=	9
Mop/sec total	=	10.06
Mop/sec/process	=	1.12
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400 dt: 0.001500
Number of active processes: 16

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.2479982239930E+01 0.2479982239930E+01 0.7861151583476E-13
2 0.1127633796437E+01 0.1127633796437E+01 0.9451775097624E-14
3 0.1502897788877E+01 0.1502897788877E+01 0.6707591918895E-13
4 0.1421781621170E+01 0.1421781621170E+01 0.3123469900284E-14
5 0.2129211303514E+01 0.2129211303514E+01 0.2356838921071E-13
Comparison of RMS-norms of solution error
1 0.1090014029782E-03 0.1090014029782E-03 0.3860555522208E-12
2 0.3734395176928E-04 0.3734395176928E-04 0.3048451562232E-13
3 0.5009278540654E-04 0.5009278540654E-04 0.1007793103271E-12
4 0.4767109393954E-04 0.4767109393953E-04 0.1640366839278E-12
5 0.1362161339921E-03 0.1362161339921E-03 0.2606711856244E-13
Verification Successful

SP Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 400
Time in seconds = 6162.95
Total processes = 16
Compiled procs = 16
Mop/sec total = 13.79
Mop/sec/process = 0.86
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

Performance of a cluster with a 10 Mbps network switch and nodes with 1800 MHz CPU, and 512MB RAM.

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     1

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
        1 0.1080634671464E+03 0.1080634671464E+03 0.8547806033624E-14
        2 0.1131973090122E+02 0.1131973090122E+02 0.1098479988995E-14
        3 0.2597435451158E+02 0.2597435451158E+02 0.2735554931474E-15
        4 0.2366562254468E+02 0.2366562254468E+02 0.1606297754956E-13
        5 0.2527896321175E+03 0.2527896321175E+03 0.1416646465377E-13
 Comparison of RMS-norms of solution error
        1 0.4234841604053E+01 0.4234841604053E+01 0.2097312019534E-15
        2 0.4439028249700E+00 0.4439028249700E+00 0.1750734785908E-14
        3 0.9669248013635E+00 0.9669248013635E+00 0.1951939943211E-14
        4 0.8830206303977E+00 0.8830206303977E+00 0.2011682149035E-14
        5 0.9737990177083E+01 0.9737990177083E+01 0.1276905978511E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                   936.10
 Total processes =                        1
 Compiled procs  =                        1
 Mop/sec total     =                 179.77
 Mop/sec/process   =                 179.77
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 200    dt:   0.000800
Number of active processes:     4

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
       1 0.1080634671464E+03 0.1080634671464E+03 0.6706740118690E-14
       2 0.1131973090122E+02 0.1131973090122E+02 0.1569257127136E-14
       3 0.2597435451158E+02 0.2597435451158E+02 0.3692999157490E-14
       4 0.2366562254468E+02 0.2366562254468E+02 0.7355942989988E-14
       5 0.2527896321175E+03 0.2527896321175E+03 0.1574051628196E-13
Comparison of RMS-norms of solution error
       1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
       2 0.4439028249700E+00 0.4439028249700E+00 0.4126731995354E-14
       3 0.9669248013635E+00 0.9669248013635E+00 0.6085459822952E-14
       4 0.8830206303977E+00 0.8830206303977E+00 0.2137412283349E-14
       5 0.9737990177083E+01 0.9737990177083E+01 0.4560378494683E-14
Verification Successful


BT Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      200
Time in seconds =                   877.51
Total processes =                        4
Compiled procs  =                        4
Mop/sec total   =                   191.78
Mop/sec/process =                    47.94
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 200   dt: 0.000800
Number of active processes: 9

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.1080634671464E+03 0.1080634671464E+03 0.6969749535109E-14
2 0.1131973090122E+02 0.1131973090122E+02 0.2040034265277E-14
3 0.2597435451158E+02 0.2597435451158E+02 0.5197554369800E-14
4 0.2366562254468E+02 0.2366562254468E+02 0.6755457847948E-14
5 0.2527896321175E+03 0.2527896321175E+03 0.1326700658051E-13
Comparison of RMS-norms of solution error
1 0.4234841604053E+01 0.4234841604053E+01 0.6291936058601E-15
2 0.4439028249700E+00 0.4439028249700E+00 0.7127991628339E-14
3 0.9669248013635E+00 0.9669248013635E+00 0.1148199966595E-14
4 0.8830206303977E+00 0.8830206303977E+00 0.7543808058880E-15
5 0.9737990177083E+01 0.9737990177083E+01 0.5837284473195E-14
Verification Successful

BT Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 200
Time in seconds = 703.67
Total processes = 9
Compiled procs = 9
Mop/sec total = 239.15
Mop/sec/process = 26.57
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 200   dt: 0.000800
Number of active processes: 16

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.1080634671464E+03 0.1080634671464E+03 0.7758777784367E-14
2 0.1131973090122E+02 0.1131973090122E+02 0.3138514254272E-14
3 0.2597435451158E+02 0.2597435451158E+02 0.5334332116374E-14
4 0.2366562254468E+02 0.2366562254468E+02 0.1065861127121E-13
5 0.2527896321175E+03 0.2527896321175E+03 0.1551565176365E-13
Comparison of RMS-norms of solution error
1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
2 0.4439028249700E+00 0.4439028249700E+00 0.3001259632985E-14
3 0.9669248013635E+00 0.9669248013635E+00 0.3329779903125E-14
4 0.8830206303977E+00 0.8830206303977E+00 0.4149094432384E-14
5 0.9737990177083E+01 0.9737990177083E+01 0.7661435871068E-14
Verification Successful

BT Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 200
Time in seconds = 604.44
Total processes = 16
Compiled procs = 16
Mop/sec total = 278.41
Mop/sec/process = 17.40
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 07 Aug 2003

```
NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size:      14000
Iterations:    15
Number of active processes:     1

  iteration           ||r||                 zeta
        1       0.27827584529972E-12    19.9997581277040
        2       0.26160031018478E-14    17.1140495745506
        3       0.26714791625944E-14    17.1296668946143
        4       0.26473497355311E-14    17.1302113581192
        5       0.25962051721040E-14    17.1302338856353
        6       0.26115199334372E-14    17.1302349879482
        7       0.25993680727334E-14    17.1302350498916
        8       0.26120228095637E-14    17.1302350537510
        9       0.25450483820989E-14    17.1302350540101
       10       0.25904786670248E-14    17.1302350540284
       11       0.25506293938445E-14    17.1302350540298
       12       0.25257745194192E-14    17.1302350540299
       13       0.25415734339777E-14    17.1302350540299
       14       0.25063961032389E-14    17.1302350540299
       15       0.24842598520619E-14    17.1302350540299
Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is      0.171302350540E+02
Error is     0.891731133379E-12


CG Benchmark Completed.
Class           =                        A
Size            =                    14000
Iterations      =                       15
Time in seconds =                    13.03
Total processes =                        1
Compiled procs  =                        1
Mop/sec total   =                   114.85
Mop/sec/process =                   114.85
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 4

iteration	||r||	zeta
1	0.30380719049536E-12	19.9997581277040
2	0.29763636601233E-14	17.1140495745506
3	0.30758070039524E-14	17.1296668946143
4	0.30767836772916E-14	17.1302113581192
5	0.30362538345620E-14	17.1302338856353
6	0.30918631267811E-14	17.1302349879482
7	0.29692461545083E-14	17.1302350498916
8	0.30136035568592E-14	17.1302350537510
9	0.30210087485660E-14	17.1302350540101
10	0.29835949970093E-14	17.1302350540284
11	0.29536430530910E-14	17.1302350540298
12	0.29781985872281E-14	17.1302350540299
13	0.29621143458868E-14	17.1302350540299
14	0.29849869948111E-14	17.1302350540299
15	0.29517709020202E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 121.97
Total processes = 4
Compiled procs = 4
Mop/sec total = 12.27
Mop/sec/process = 3.07
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 8

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 91.69
Total processes = 8
Compiled procs = 8
Mop/sec total = 16.32
Mop/sec/process = 2.04
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 16

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 96.38
Total processes = 16
Compiled procs = 16
Mop/sec total = 15.53
Mop/sec/process = 0.97
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 118.5056
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165629841E+03 -1.580732573678431E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 118.51
Total processes = 1
Compiled procs = 1
Mop/sec total = 4.53
Mop/sec/process = 4.53
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time =   59.2273
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165639063E+03   -1.580732573678573E+04
Counts:
0   98257395.
1   93827014.
2   17611549.
3   1110028.
4   26536.
5   245.
6   0.
7   0.
8   0.
9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   59.23
Total processes =   2
Compiled procs =   1
Mop/sec total   =   9.06
Mop/sec/process   =   4.53
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 3

EP Benchmark Results:

CPU Time =   39.5187
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165637473E+03   -1.580732573677940E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   39.52
Total processes =   3
Compiled procs =   1
Mop/sec total   =   13.59
Mop/sec/process   =   4.53
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 4

EP Benchmark Results:

CPU Time =   29.6302
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165634618E+03   -1.580732573678638E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   29.63
Total processes =   4
Compiled procs =   4
Mop/sec total   =   18.12
Mop/sec/process =   4.53
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time =   23.7310
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165631720E+03   -1.580732573678449E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   23.73
Total processes =   5
Compiled procs =   4
Mop/sec total   =   22.62
Mop/sec/process =   4.52
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 19.7585
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 19.76
Total processes = 6
Compiled procs = 4
Mop/sec total = 27.17
Mop/sec/process = 4.53
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 16.9522
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	16.95
Total processes	=	7
Compiled procs	=	7
Mop/sec total	=	31.67
Mop/sec/process	=	4.52
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time =   16.9522
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165635864E+03   -1.580732573678781E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   16.95
Total processes =   7
Compiled procs =   7
Mop/sec total   =   31.67
Mop/sec/process   =   4.52
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 16.9522
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 16.95
Total processes = 7
Compiled procs = 7
Mop/sec total = 31.67
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time = 11.8749
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632362E+03 -1.580732573678767E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 11.87
Total processes = 10
Compiled procs = 10
Mop/sec total = 45.21
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 11

EP Benchmark Results:

CPU Time = 10.7958
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632911E+03 -1.580732573678582E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.

Class	=	A
Size	=	536870912
Iterations	=	0
Time in seconds	=	10.80
Total processes	=	11
Compiled procs	=	10
Mop/sec total	=	49.73
Mop/sec/process	=	4.52
Operation type	=	Random numbers generated
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time =   9.9212
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165633768E+03   -1.580732573678642E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   9.92
Total processes =   12
Compiled procs =   12
Mop/sec total   =   54.11
Mop/sec/process   =   4.51
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time = 9.1386
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165628269E+03 -1.580732573678654E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 9.14
Total processes = 13
Compiled procs = 12
Mop/sec total = 58.75
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time = 8.4822
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635351E+03 -1.580732573678708E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 8.48
Total processes = 14
Compiled procs = 12
Mop/sec total = 63.29
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time = 7.9273
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635445E+03 -1.580732573678607E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 7.93
Total processes = 15
Compiled procs = 15
Mop/sec total = 67.72
Mop/sec/process = 4.51
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time = 7.4214
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633814E+03 -1.580732573678525E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 7.42
Total processes = 16
Compiled procs = 15
Mop/sec total = 72.34
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 1
Processor array : 1x 1
Layout type : 0D

T =	1	Checksum =	5.046735008193E+02	5.114047905510E+02
T =	2	Checksum =	5.059412319734E+02	5.098809666433E+02
T =	3	Checksum =	5.069376896287E+02	5.098144042213E+02
T =	4	Checksum =	5.077892868474E+02	5.101336130759E+02
T =	5	Checksum =	5.085233095391E+02	5.104914655194E+02
T =	6	Checksum =	5.091487099959E+02	5.107917842803E+02

Result verification successful
class = A

FT Benchmark Completed.

Class	=	A
Size	=	256x256x128
Iterations	=	6
Time in seconds	=	40.02
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	178.33
Mop/sec/process	=	178.33
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size             : 256x256x128
Iterations        :       6
Number of processes :       4
Processor array    :     1x  4
Layout type       :       1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class          =                   A
Size           =          256x256x128
Iterations      =                  6
Time in seconds =              434.24
Total processes =                  4
Compiled procs  =                  4
Mop/sec total    =              16.43
Mop/sec/process   =              4.11
Operation type  =       floating point
Verification    =          SUCCESSFUL
Version         =                2.3
Compile date    =         21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 8
Processor array : 1x 8
Layout type : 1D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 283.23
Total processes = 8
Compiled procs = 8
Mop/sec total = 25.20
Mop/sec/process = 3.15
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size : 256x256x128
Iterations : 6
Number of processes : 16
Processor array : 1x 16
Layout type : 1D
T = 1 Checksum = 5.046735008193E+02 5.114047905510E+02
T = 2 Checksum = 5.059412319734E+02 5.098809666433E+02
T = 3 Checksum = 5.069376896287E+02 5.098144042213E+02
T = 4 Checksum = 5.077892868474E+02 5.101336130759E+02
T = 5 Checksum = 5.085233095391E+02 5.104914655194E+02
T = 6 Checksum = 5.091487099959E+02 5.107917842803E+02
Result verification successful
class = A

FT Benchmark Completed.
Class = A
Size = 256x256x128
Iterations = 6
Time in seconds = 160.89
Total processes = 16
Compiled procs = 16
Mop/sec total = 44.36
Mop/sec/process = 2.77
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 1

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	4.92
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	17.07
Mop/sec/process	=	17.07
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :           6
Number of processes :           4
Processor array     :       1x  4
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =              256x256x128
Iterations      =                        6
Time in seconds =                   434.24
Total processes =                        4
Compiled procs  =                        4
Mop/sec total   =                    16.43
Mop/sec/process =                     4.11
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size              : 256x256x128
Iterations        :           6
Number of processes :          8
Processor array   :       1x  8
Layout type       :         1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =             256x256x128
Iterations      =                        6
Time in seconds =                   283.23
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                    25.20
Mop/sec/process =                     3.15
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- FT Benchmark

No input file inputft.data. Using compiled defaults
Size                : 256x256x128
Iterations          :           6
Number of processes :          16
Processor array     :       1x 16
Layout type         :          1D
T =    1     Checksum =    5.046735008193E+02    5.114047905510E+02
T =    2     Checksum =    5.059412319734E+02    5.098809666433E+02
T =    3     Checksum =    5.069376896287E+02    5.098144042213E+02
T =    4     Checksum =    5.077892868474E+02    5.101336130759E+02
T =    5     Checksum =    5.085233095391E+02    5.104914655194E+02
T =    6     Checksum =    5.091487099959E+02    5.107917842803E+02
Result verification successful
class = A


FT Benchmark Completed.
Class           =                        A
Size            =             256x256x128
Iterations      =                        6
Time in seconds =                   160.89
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                    44.36
Mop/sec/process =                     2.77
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 1

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	4.92
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	17.07
Mop/sec/process	=	17.07
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 4

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed
Class = A
Size = 8388608
Iterations = 10
Time in seconds = 154.56
Total processes = 4
Compiled procs = 4
Mop/sec total = 0.54
Mop/sec/process = 0.14
Operation type = keys ranked
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 8

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	104.70
Total processes	=	8
Compiled procs	=	8
Mop/sec total	=	0.80
Mop/sec/process	=	0.10
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	60.13
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	1.40
Mop/sec/process	=	0.09
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	22 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 1

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

```
1  0.7790210760669E+03 0.7790210760669E+03 0.8756130575742E-15
2  0.6340276525969E+02 0.6340276525969E+02 0.1681021481121E-14
3  0.1949924972729E+03 0.1949924972729E+03 0.7287898208366E-15
4  0.1784530116042E+03 0.1784530116042E+03 0.2707542203819E-14
5  0.1838476034946E+04 0.1838476034946E+04 0.1484100990959E-14
```

Comparison of RMS-norms of solution error

```
1  0.2996408568547E+02 0.2996408568547E+02 0.8299601066640E-15
2  0.2819457636500E+01 0.2819457636500E+01 0.7875436823397E-15
3  0.7347341269877E+01 0.7347341269877E+01 0.4835373161943E-15
4  0.6713922568778E+01 0.6713922568778E+01 0.5291561888607E-15
5  0.7071531568839E+02 0.7071531568839E+02 0.6028759644299E-15
```

Comparison of surface integral

```
   0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
```

Verification Successful

LU Benchmark Completed.

```
Class           =            A
Size            =     64x 64x 64
Iterations      =          250
Time in seconds =        554.63
Total processes =            1
Compiled procs  =            1
Mop/sec total   =        215.09
Mop/sec/process =        215.09
Operation type  =  floating point
Verification    =    SUCCESSFUL
Version         =          2.3
Compile date    =   21 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 4

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1415574443078E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.2353430073569E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.1195215306172E-13
4	0.1784530116042E+03	0.1784530116042E+03	0.6370687538397E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1261485842315E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.5928286476171E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1323073386331E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.5802447794332E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.2645780944304E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.1044985005012E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	337.82
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	353.13
Mop/sec/process	=	88.28
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:     8

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1   0.7790210760669E+03 0.7790210760669E+03 0.1444761544997E-13
      2   0.6340276525969E+02 0.6340276525969E+02 0.5603404937070E-14
      3   0.1949924972729E+03 0.1949924972729E+03 0.9182751742541E-14
      4   0.1784530116042E+03 0.1784530116042E+03 0.1592671884599E-15
      5   0.1838476034946E+04 0.1838476034946E+04 0.1162545776251E-13
Comparison of RMS-norms of solution error
      1   0.2996408568547E+02 0.2996408568547E+02 0.9485258361874E-15
      2   0.2819457636500E+01 0.2819457636500E+01 0.1354575133624E-13
      3   0.7347341269878E+01 0.7347341269877E+01 0.7132175413867E-14
      4   0.6713922568778E+01 0.6713922568778E+01 0.6614452360759E-15
      5   0.7071531568839E+02 0.7071531568839E+02 0.1225847794341E-13
Comparison of surface integral
          0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =               64x 64x 64
Iterations      =                      250
Time in seconds =                   421.83
Total processes =                        8
Compiled procs  =                        8
Mop/sec total   =                   282.81
Mop/sec/process =                    35.35
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 16

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1634477707472E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.5267200640846E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.8891235814207E-14
4	0.1784530116042E+03	0.1784530116042E+03	0.3185343769198E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1150178267993E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.4742629180937E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1165564649863E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.6165100781478E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.1455179519367E-14
5	0.7071531568839E+02	0.7071531568839E+02	0.1125368466936E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	335.90
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	355.15
Mop/sec/process	=	22.20
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 1

Initialization time: 12.322 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.692843304701E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 20.99
Total processes = 1
Compiled procs = 1
Mop/sec total = 185.44
Mop/sec/process = 185.44
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 4

Initialization time: 21.820 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694334082688E-16

MG Benchmark Completed.

Class	=	A
Size	=	256x256x256
Iterations	=	4
Time in seconds	=	50.16
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	77.60
Mop/sec/process	=	19.40
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 8

Initialization time: 15.667 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694952416740E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 36.78
Total processes = 8
Compiled procs = 8
Mop/sec total = 105.83
Mop/sec/process = 13.23
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 16

Initialization time: 10.262 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694838067292E-16

MG Benchmark Completed.

Class	=	A
Size	=	256x256x256
Iterations	=	4
Time in seconds	=	24.13
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	161.30
Mop/sec/process	=	10.08
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

 No input file inputsp.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 400    dt:   0.001500
 Number of active processes:     1

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
      1 0.2479982239930E+01 0.2479982239930E+01 0.6858362315424E-13
      2 0.1127633796437E+01 0.1127633796437E+01 0.2205414189446E-13
      3 0.1502897788877E+01 0.1502897788877E+01 0.5097178881098E-13
      4 0.1421781621169E+01 0.1421781621170E+01 0.3919954724857E-13
      5 0.2129211303514E+01 0.2129211303514E+01 0.1147133988132E-13
 Comparison of RMS-norms of solution error
      1 0.1090014029782E-03 0.1090014029782E-03 0.3948832315147E-12
      2 0.3734395176928E-04 0.3734395176928E-04 0.3737982272737E-13
      3 0.5009278540654E-04 0.5009278540654E-04 0.1623290904598E-14
      4 0.4767109393953E-04 0.4767109393953E-04 0.1361760339713E-12
      5 0.1362161339921E-03 0.1362161339921E-03 0.6208351901894E-13
 Verification Successful


 SP Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      400
 Time in seconds =                   719.48
 Total processes =                        1
 Compiled procs  =                        1
 Mop/sec total   =                   118.16
 Mop/sec/process =                   118.16
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     4

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
     1 0.2479982239930E+01 0.2479982239930E+01 0.4655807315954E-13
     2 0.1127633796437E+01 0.1127633796437E+01 0.3997313218370E-13
     3 0.1502897788877E+01 0.1502897788877E+01 0.1654736332415E-13
     4 0.1421781621169E+01 0.1421781621170E+01 0.3388964841809E-13
     5 0.2129211303514E+01 0.2129211303514E+01 0.1710272491397E-13
Comparison of RMS-norms of solution error
     1 0.1090014029782E-03 0.1090014029782E-03 0.3962509001377E-12
     2 0.3734395176928E-04 0.3734395176928E-04 0.4663405068414E-13
     3 0.5009278540654E-04 0.5009278540654E-04 0.6168505437472E-13
     4 0.4767109393954E-04 0.4767109393953E-04 0.1522385515483E-12
     5 0.1362161339921E-03 0.1362161339921E-03 0.4795553872937E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =               64x 64x 64
Iterations      =                      400
Time in seconds =                  1377.96
Total processes =                        4
Compiled procs  =                        4
Mop/sec total   =                    61.69
Mop/sec/process =                    15.42
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400   dt: 0.001500
Number of active processes: 9

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	NAN	0.2479982239930E+01	NAN
2	NAN	0.1127633796437E+01	NAN
3	NAN	0.1502897788877E+01	NAN
4	NAN	0.1421781621170E+01	NAN
5	NAN	0.2129211303514E+01	NAN

Comparison of RMS-norms of solution error

1	NAN	0.1090014029782E-03	NAN
2	NAN	0.3734395176928E-04	NAN
3	NAN	0.5009278540654E-04	NAN
4	NAN	0.4767109393953E-04	NAN
5	NAN	0.1362161339921E-03	NAN

Verification Successful

SP Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	400
Time in seconds	=	7557.11
Total processes	=	9
Compiled procs	=	9
Mop/sec total	=	11.25
Mop/sec/process	=	1.25
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:    16

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1 0.2479982239930E+01 0.2479982239930E+01 0.7861151583476E-13
      2 0.1127633796437E+01 0.1127633796437E+01 0.9451775097624E-14
      3 0.1502897788877E+01 0.1502897788877E+01 0.6707591918895E-13
      4 0.1421781621170E+01 0.1421781621170E+01 0.3123469900284E-14
      5 0.2129211303514E+01 0.2129211303514E+01 0.2356838921071E-13
Comparison of RMS-norms of solution error
      1 0.1090014029782E-03 0.1090014029782E-03 0.3860555522208E-12
      2 0.3734395176928E-04 0.3734395176928E-04 0.3048451562232E-13
      3 0.5009278540654E-04 0.5009278540654E-04 0.1007793103271E-12
      4 0.4767109393954E-04 0.4767109393953E-04 0.1640366839278E-12
      5 0.1362161339921E-03 0.1362161339921E-03 0.2606711856244E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      400
Time in seconds =                   987.32
Total processes =                       16
Compiled procs  =                       16
Mop/sec total     =                  86.10
Mop/sec/process   =                   5.38
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

Performance of a cluster with a 100Mbps network switch and nodes with 1800 MHz CPU, and 512MB RAM.

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     1

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
        1 0.1080634671464E+03 0.1080634671464E+03 0.8547806033624E-14
        2 0.1131973090122E+02 0.1131973090122E+02 0.1098479988995E-14
        3 0.2597435451158E+02 0.2597435451158E+02 0.2735554931474E-15
        4 0.2366562254468E+02 0.2366562254468E+02 0.1606297754956E-13
        5 0.2527896321175E+03 0.2527896321175E+03 0.1416646465377E-13
 Comparison of RMS-norms of solution error
        1 0.4234841604053E+01 0.4234841604053E+01 0.2097312019534E-15
        2 0.4439028249700E+00 0.4439028249700E+00 0.1750734785908E-14
        3 0.9669248013635E+00 0.9669248013635E+00 0.1951939943211E-14
        4 0.8830206303977E+00 0.8830206303977E+00 0.2011682149035E-14
        5 0.9737990177083E+01 0.9737990177083E+01 0.1276905978511E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =              64x 64x 64
 Iterations      =                      200
 Time in seconds =                   923.96
 Total processes =                        1
 Compiled procs  =                        1
 Mop/sec total     =                 182.13
 Mop/sec/process   =                 182.13
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

```
 NAS Parallel Benchmarks 2.3 -- BT Benchmark

 No input file inputbt.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 200    dt:   0.000800
 Number of active processes:     4

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
        1 0.1080634671464E+03 0.1080634671464E+03 0.6706740118690E-14
        2 0.1131973090122E+02 0.1131973090122E+02 0.1569257127136E-14
        3 0.2597435451158E+02 0.2597435451158E+02 0.3692999157490E-14
        4 0.2366562254468E+02 0.2366562254468E+02 0.7355942989988E-14
        5 0.2527896321175E+03 0.2527896321175E+03 0.1574051628196E-13
 Comparison of RMS-norms of solution error
        1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
        2 0.4439028249700E+00 0.4439028249700E+00 0.4126731995354E-14
        3 0.9669248013635E+00 0.9669248013635E+00 0.6085459822952E-14
        4 0.8830206303977E+00 0.8830206303977E+00 0.2137412283349E-14
        5 0.9737990177083E+01 0.9737990177083E+01 0.4560378494683E-14
 Verification Successful


 BT Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      200
 Time in seconds =                   280.01
 Total processes =                        4
 Compiled procs  =                        4
 Mop/sec total   =                   600.99
 Mop/sec/process   =                 150.25
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              24 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 200    dt:   0.000800
Number of active processes:     9

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
    1 0.1080634671464E+03 0.1080634671464E+03 0.6969749535109E-14
    2 0.1131973090122E+02 0.1131973090122E+02 0.2040034265277E-14
    3 0.2597435451158E+02 0.2597435451158E+02 0.5197554369800E-14
    4 0.2366562254468E+02 0.2366562254468E+02 0.6755457847948E-14
    5 0.2527896321175E+03 0.2527896321175E+03 0.1326700658051E-13
Comparison of RMS-norms of solution error
    1 0.4234841604053E+01 0.4234841604053E+01 0.6291936058601E-15
    2 0.4439028249700E+00 0.4439028249700E+00 0.7127991628339E-14
    3 0.9669248013635E+00 0.9669248013635E+00 0.1148199966595E-14
    4 0.8830206303977E+00 0.8830206303977E+00 0.7543808058880E-15
    5 0.9737990177083E+01 0.9737990177083E+01 0.5837284473195E-14
Verification Successful


BT Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      200
Time in seconds =                   144.99
Total processes =                        9
Compiled procs  =                        9
Mop/sec total   =                  1160.65
Mop/sec/process =                   128.96
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- BT Benchmark

No input file inputbt.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 200    dt:   0.000800
Number of active processes:    16

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1 0.1080634671464E+03 0.1080634671464E+03 0.7758777784367E-14
      2 0.1131973090122E+02 0.1131973090122E+02 0.3138514254272E-14
      3 0.2597435451158E+02 0.2597435451158E+02 0.5334332116374E-14
      4 0.2366562254468E+02 0.2366562254468E+02 0.1065861127121E-13
      5 0.2527896321175E+03 0.2527896321175E+03 0.1551565176365E-13
Comparison of RMS-norms of solution error
      1 0.4234841604053E+01 0.4234841604053E+01 0.1258387211720E-14
      2 0.4439028249700E+00 0.4439028249700E+00 0.3001259632985E-14
      3 0.9669248013635E+00 0.9669248013635E+00 0.3329779903125E-14
      4 0.8830206303977E+00 0.8830206303977E+00 0.4149094432384E-14
      5 0.9737990177083E+01 0.9737990177083E+01 0.7661435871068E-14
Verification Successful


BT Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      200
Time in seconds =                   134.25
Total processes =                       16
Compiled procs  =                       16
Mop/sec total   =                  1253.49
Mop/sec/process =                    78.34
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              07 Aug 2003
```

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 1

iteration	||r||	zeta
1	0.27827584529972E-12	19.9997581277040
2	0.26160031018478E-14	17.1140495745506
3	0.26714791625944E-14	17.1296668946143
4	0.26473497355311E-14	17.1302113581192
5	0.25962051721040E-14	17.1302338856353
6	0.26115199334372E-14	17.1302349879482
7	0.25993680727334E-14	17.1302350498916
8	0.26120228095637E-14	17.1302350537510
9	0.25450483820989E-14	17.1302350540101
10	0.25904786670248E-14	17.1302350540284
11	0.25506293938445E-14	17.1302350540298
12	0.25257745194192E-14	17.1302350540299
13	0.25415734339777E-14	17.1302350540299
14	0.25063961032389E-14	17.1302350540299
15	0.24842598520619E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 13.04
Total processes = 1
Compiled procs = 1
Mop/sec total = 114.75
Mop/sec/process = 114.75
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 4

iteration	||r||	zeta
1	0.30380719049536E-12	19.9997581277040
2	0.29763636601233E-14	17.1140495745506
3	0.30758070039524E-14	17.1296668946143
4	0.30767836772916E-14	17.1302113581192
5	0.30362538345620E-14	17.1302338856353
6	0.30918631267811E-14	17.1302349879482
7	0.29692461545083E-14	17.1302350498916
8	0.30136035568592E-14	17.1302350537510
9	0.30210087485660E-14	17.1302350540101
10	0.29835949970093E-14	17.1302350540284
11	0.29536430530910E-14	17.1302350540298
12	0.29781985872281E-14	17.1302350540299
13	0.29621143458868E-14	17.1302350540299
14	0.29849869948111E-14	17.1302350540299
15	0.29517709020202E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 7.55
Total processes = 4
Compiled procs = 4
Mop/sec total = 198.29
Mop/sec/process = 49.57
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 8

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 7.54
Total processes = 8
Compiled procs = 8
Mop/sec total = 198.47
Mop/sec/process = 24.81
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- CG Benchmark

Size: 14000
Iterations: 15
Number of active processes: 16

iteration	||r||	zeta
1	0.26430287941297E-12	19.9997581277040
2	0.26414813392819E-14	17.1140495745506
3	0.26266612893876E-14	17.1296668946143
4	0.26223598758375E-14	17.1302113581192
5	0.26182783886564E-14	17.1302338856353
6	0.26288689973095E-14	17.1302349879482
7	0.25972755600456E-14	17.1302350498916
8	0.25774519203481E-14	17.1302350537510
9	0.25550821991349E-14	17.1302350540101
10	0.25670770323505E-14	17.1302350540284
11	0.25758028098708E-14	17.1302350540298
12	0.25113124979678E-14	17.1302350540299
13	0.25036350044005E-14	17.1302350540299
14	0.24859657049077E-14	17.1302350540299
15	0.24631513623583E-14	17.1302350540299

Benchmark completed
VERIFICATION SUCCESSFUL
Zeta is 0.171302350540E+02
Error is 0.891731133379E-12

CG Benchmark Completed.
Class = A
Size = 14000
Iterations = 15
Time in seconds = 9.28
Total processes = 16
Compiled procs = 16
Mop/sec total = 161.18
Mop/sec/process = 10.07
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 1

EP Benchmark Results:

CPU Time = 118.4528
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165629841E+03   -1.580732573678431E+04
Counts:
 0   98257395.
 1   93827014.
 2   17611549.
 3   1110028.
 4   26536.
 5   245.
 6   0.
 7   0.
 8   0.
 9   0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   118.45
Total processes =   1
Compiled procs =   1
Mop/sec total   =   4.53
Mop/sec/process   =   4.53
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 2

EP Benchmark Results:

CPU Time = 59.2454
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165639063E+03 -1.580732573678573E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 59.25
Total processes = 2
Compiled procs = 1
Mop/sec total = 9.06
Mop/sec/process = 4.53
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 3

EP Benchmark Results:

CPU Time = 39.5002
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165637473E+03 -1.580732573677940E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 39.50
Total processes = 3
Compiled procs = 1
Mop/sec total = 13.59
Mop/sec/process = 4.53
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
 NAS Parallel Benchmarks 2.3 -- EP Benchmark

 Number of random numbers generated:    536870912
 Number of active processes:                    4

EP Benchmark Results:

CPU Time =   29.6165
N = 2^   28
No. Gaussian Pairs =     210832767.
Sums =    -4.295875165634618E+03   -1.580732573678638E+04
Counts:
  0      98257395.
  1      93827014.
  2      17611549.
  3       1110028.
  4         26536.
  5           245.
  6             0.
  7             0.
  8             0.
  9             0.


 EP Benchmark Completed.
 Class           =                        A
 Size            =                536870912
 Iterations      =                        0
 Time in seconds =                    29.62
 Total processes =                        4
 Compiled procs  =                        4
 Mop/sec total   =                    18.13
 Mop/sec/process =                     4.53
 Operation type  = Random numbers generated
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 5

EP Benchmark Results:

CPU Time = 23.7306
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165631720E+03 -1.580732573678449E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 23.73
Total processes = 5
Compiled procs = 4
Mop/sec total = 22.62
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 6

EP Benchmark Results:

CPU Time = 19.7620
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165634690E+03 -1.580732573678302E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 19.76
Total processes = 6
Compiled procs = 4
Mop/sec total = 27.17
Mop/sec/process = 4.53
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 7

EP Benchmark Results:

CPU Time = 16.9575
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635864E+03 -1.580732573678781E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 16.96
Total processes = 7
Compiled procs = 7
Mop/sec total = 31.66
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 8

EP Benchmark Results:

CPU Time = 14.8165
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165636284E+03 -1.580732573678494E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 14.82
Total processes = 8
Compiled procs = 7
Mop/sec total = 36.23
Mop/sec/process = 4.53
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 9

EP Benchmark Results:

CPU Time = 13.1950
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165630960E+03 -1.580732573678866E+04
Counts:
0 98257395.
1 93827014.
2 17611549.
3 1110028.
4 26536.
5 245.
6 0.
7 0.
8 0.
9 0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 13.20
Total processes = 9
Compiled procs = 7
Mop/sec total = 40.69
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 10

EP Benchmark Results:

CPU Time = 11.8680
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632362E+03 -1.580732573678767E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 11.87
Total processes = 10
Compiled procs = 10
Mop/sec total = 45.24
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 11

EP Benchmark Results:

CPU Time = 10.7917
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165632911E+03 -1.580732573678582E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 10.79
Total processes = 11
Compiled procs = 10
Mop/sec total = 49.75
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 12

EP Benchmark Results:

CPU Time = 9.8991
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633768E+03 -1.580732573678642E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 9.90
Total processes = 12
Compiled procs = 12
Mop/sec total = 54.23
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 13

EP Benchmark Results:

CPU Time =   9.1439
N = 2^   28
No. Gaussian Pairs =   210832767.
Sums =   -4.295875165628269E+03   -1.580732573678654E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class   =   A
Size   =   536870912
Iterations   =   0
Time in seconds =   9.14
Total processes =   13
Compiled procs =   12
Mop/sec total   =   58.71
Mop/sec/process   =   4.52
Operation type = Random numbers generated
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 14

EP Benchmark Results:

CPU Time = 8.4839
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635351E+03 -1.580732573678708E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 8.48
Total processes = 14
Compiled procs = 12
Mop/sec total = 63.28
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 15

EP Benchmark Results:

CPU Time = 7.9236
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165635445E+03 -1.580732573678607E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 7.92
Total processes = 15
Compiled procs = 15
Mop/sec total = 67.76
Mop/sec/process = 4.52
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

NAS Parallel Benchmarks 2.3 -- EP Benchmark

Number of random numbers generated: 536870912
Number of active processes: 16

EP Benchmark Results:

CPU Time = 7.4122
N = 2^ 28
No. Gaussian Pairs = 210832767.
Sums = -4.295875165633814E+03 -1.580732573678525E+04
Counts:

0	98257395.
1	93827014.
2	17611549.
3	1110028.
4	26536.
5	245.
6	0.
7	0.
8	0.
9	0.

EP Benchmark Completed.
Class = A
Size = 536870912
Iterations = 0
Time in seconds = 7.41
Total processes = 16
Compiled procs = 15
Mop/sec total = 72.43
Mop/sec/process = 4.53
Operation type = Random numbers generated
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size:  8388608  (class A)
Iterations:   10
Number of processes:     1

  iteration
       1
       2
       3
       4
       5
       6
       7
       8
       9
       10


IS Benchmark Completed
Class           =                        A
Size            =                  8388608
Iterations      =                       10
Time in seconds =                     4.86
Total processes =                        1
Compiled procs  =                        1
Mop/sec total   =                    17.25
Mop/sec/process =                    17.25
Operation type  =              keys ranked
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 4

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	6.64
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	12.62
Mop/sec/process	=	3.16
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	24 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 8

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class =	A
Size =	8388608
Iterations =	10
Time in seconds =	4.59
Total processes =	8
Compiled procs =	8
Mop/sec total =	18.29
Mop/sec/process =	2.29
Operation type =	keys ranked
Verification =	SUCCESSFUL
Version =	2.3
Compile date =	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- IS Benchmark

Size: 8388608 (class A)
Iterations: 10
Number of processes: 16

iteration
1
2
3
4
5
6
7
8
9
10

IS Benchmark Completed

Class	=	A
Size	=	8388608
Iterations	=	10
Time in seconds	=	3.97
Total processes	=	16
Compiled procs	=	16
Mop/sec total	=	21.11
Mop/sec/process	=	1.32
Operation type	=	keys ranked
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	22 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 1

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.8756130575742E-15
2	0.6340276525969E+02	0.6340276525969E+02	0.1681021481121E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.7287898208366E-15
4	0.1784530116042E+03	0.1784530116042E+03	0.2707542203819E-14
5	0.1838476034946E+04	0.1838476034946E+04	0.1484100990959E-14

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.8299601066640E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.7875436823397E-15
3	0.7347341269877E+01	0.7347341269877E+01	0.4835373161943E-15
4	0.6713922568778E+01	0.6713922568778E+01	0.5291561888607E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.6028759644299E-15

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	545.89
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	218.54
Mop/sec/process	=	218.54
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 4

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

1	0.7790210760669E+03	0.7790210760669E+03	0.1415574443078E-13
2	0.6340276525969E+02	0.6340276525969E+02	0.2353430073569E-14
3	0.1949924972729E+03	0.1949924972729E+03	0.1195215306172E-13
4	0.1784530116042E+03	0.1784530116042E+03	0.6370687538397E-15
5	0.1838476034946E+04	0.1838476034946E+04	0.1261485842315E-13

Comparison of RMS-norms of solution error

1	0.2996408568547E+02	0.2996408568547E+02	0.5928286476171E-15
2	0.2819457636500E+01	0.2819457636500E+01	0.1323073386331E-13
3	0.7347341269878E+01	0.7347341269877E+01	0.5802447794332E-14
4	0.6713922568778E+01	0.6713922568778E+01	0.2645780944304E-15
5	0.7071531568839E+02	0.7071531568839E+02	0.1044985005012E-13

Comparison of surface integral
0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
Verification Successful

LU Benchmark Completed.

Class	=	A
Size	=	64x 64x 64
Iterations	=	250
Time in seconds	=	162.17
Total processes	=	4
Compiled procs	=	4
Mop/sec total	=	735.64
Mop/sec/process	=	183.91
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size: 64x 64x 64
Iterations: 250
Number of processes: 8

Verification being performed for class A
Accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual

```
 1   0.7790210760669E+03 0.7790210760669E+03 0.1444761544997E-13
 2   0.6340276525969E+02 0.6340276525969E+02 0.5603404937070E-14
 3   0.1949924972729E+03 0.1949924972729E+03 0.9182751742541E-14
 4   0.1784530116042E+03 0.1784530116042E+03 0.1592671884599E-15
 5   0.1838476034946E+04 0.1838476034946E+04 0.1162545776251E-13
```

Comparison of RMS-norms of solution error

```
 1   0.2996408568547E+02 0.2996408568547E+02 0.9485258361874E-15
 2   0.2819457636500E+01 0.2819457636500E+01 0.1354575133624E-13
 3   0.7347341269878E+01 0.7347341269877E+01 0.7132175413867E-14
 4   0.6713922568778E+01 0.6713922568778E+01 0.6614452360759E-15
 5   0.7071531568839E+02 0.7071531568839E+02 0.1225847794341E-13
```

Comparison of surface integral

```
     0.2603092560489E+02 0.2603092560489E+02 0.0000000000000E+00
```

Verification Successful

LU Benchmark Completed.

```
Class            =           A
Size             =    64x 64x 64
Iterations       =         250
Time in seconds  =       94.72
Total processes  =           8
Compiled procs   =           8
Mop/sec total    =     1259.50
Mop/sec/process  =      157.44
Operation type   =  floating point
Verification     =   SUCCESSFUL
Version          =         2.3
Compile date     =   21 Jul 2003
```

```
NAS Parallel Benchmarks 2.2 -- LU Benchmark

Size:  64x 64x 64
Iterations: 250
Number of processes:    16

Verification being performed for class A
Accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
       1   0.7790210760669E+03 0.7790210760669E+03 0.1634477707472E-13
       2   0.6340276525969E+02 0.6340276525969E+02 0.5267200640846E-14
       3   0.1949924972729E+03 0.1949924972729E+03 0.8891235814207E-14
       4   0.1784530116042E+03 0.1784530116042E+03 0.3185343769198E-15
       5   0.1838476034946E+04 0.1838476034946E+04 0.1150178267993E-13
Comparison of RMS-norms of solution error
       1   0.2996408568547E+02 0.2996408568547E+02 0.4742629180937E-15
       2   0.2819457636500E+01 0.2819457636500E+01 0.1165564649863E-13
       3   0.7347341269878E+01 0.7347341269877E+01 0.6165100781478E-14
       4   0.6713922568778E+01 0.6713922568778E+01 0.1455179519367E-14
       5   0.7071531568839E+02 0.7071531568839E+02 0.1125368466936E-13
Comparison of surface integral
           0.2603092560489E+02 0.2603092560489E+02 0.1364804975715E-15
Verification Successful


LU Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      250
Time in seconds =                    52.64
Total processes =                       16
Compiled procs  =                       16
Mop/sec total     =                2266.33
Mop/sec/process   =                 141.65
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              21 Jul 2003
```

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 1

Initialization time: 12.327 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.692843304701E-16

MG Benchmark Completed.

Class	=	A
Size	=	256x256x256
Iterations	=	4
Time in seconds	=	21.01
Total processes	=	1
Compiled procs	=	1
Mop/sec total	=	185.25
Mop/sec/process	=	185.25
Operation type	=	floating point
Verification	=	SUCCESSFUL
Version	=	2.3
Compile date	=	21 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 4

Initialization time: 4.537 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694334082688E-16

MG Benchmark Completed.
Class = A
Size = 256x256x256
Iterations = 4
Time in seconds = 8.94
Total processes = 4
Compiled procs = 4
Mop/sec total = 435.43
Mop/sec/process = 108.86
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 8

Initialization time: 2.630 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is 0.243336530907E-05
Error is 0.694952416740E-16

MG Benchmark Completed.

Class =	A
Size =	256x256x256
Iterations =	4
Time in seconds =	4.91
Total processes =	8
Compiled procs =	8
Mop/sec total =	792.33
Mop/sec/process =	99.04
Operation type =	floating point
Verification =	SUCCESSFUL
Version =	2.3
Compile date =	24 Jul 2003

NAS Parallel Benchmarks 2.3 -- MG Benchmark

No input file. Using compiled defaults
Size: 256x256x256 (class A)
Iterations: 4
Number of processes: 16

Initialization time: 1.863 seconds

Benchmark completed
VERIFICATION SUCCESSFUL
L2 Norm is   0.243336530907E-05
Error is   0.694838067292E-16

MG Benchmark Completed.
Class   =   A
Size   =   256x256x256
Iterations   =   4
Time in seconds =   3.33
Total processes =   16
Compiled procs =   16
Mop/sec total   =   1170.35
Mop/sec/process   =   73.15
Operation type =   floating point
Verification   =   SUCCESSFUL
Version   =   2.3
Compile date   =   21 Jul 2003

NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size: 64x 64x 64
Iterations: 400 dt: 0.001500
Number of active processes: 1

Verification being performed for class A
accuracy setting for epsilon = 0.1000000000000E-07
Comparison of RMS-norms of residual
1 0.2479982239930E+01 0.2479982239930E+01 0.6858362315424E-13
2 0.1127633796437E+01 0.1127633796437E+01 0.2205414189446E-13
3 0.1502897788877E+01 0.1502897788877E+01 0.5097178881098E-13
4 0.1421781621169E+01 0.1421781621170E+01 0.3919954724857E-13
5 0.2129211303514E+01 0.2129211303514E+01 0.1147133988132E-13
Comparison of RMS-norms of solution error
1 0.1090014029782E-03 0.1090014029782E-03 0.3948832315147E-12
2 0.3734395176928E-04 0.3734395176928E-04 0.3737982272737E-13
3 0.5009278540654E-04 0.5009278540654E-04 0.1623290904598E-14
4 0.4767109393953E-04 0.4767109393953E-04 0.1361760339713E-12
5 0.1362161339921E-03 0.1362161339921E-03 0.6208351901894E-13
Verification Successful

SP Benchmark Completed.
Class = A
Size = 64x 64x 64
Iterations = 400
Time in seconds = 721.89
Total processes = 1
Compiled procs = 1
Mop/sec total = 117.76
Mop/sec/process = 117.76
Operation type = floating point
Verification = SUCCESSFUL
Version = 2.3
Compile date = 21 Jul 2003

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:     4

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1 0.2479982239930E+01 0.2479982239930E+01 0.4655807315954E-13
      2 0.1127633796437E+01 0.1127633796437E+01 0.3997313218370E-13
      3 0.1502897788877E+01 0.1502897788877E+01 0.1654736332415E-13
      4 0.1421781621169E+01 0.1421781621170E+01 0.3388964841809E-13
      5 0.2129211303514E+01 0.2129211303514E+01 0.1710272491397E-13
Comparison of RMS-norms of solution error
      1 0.1090014029782E-03 0.1090014029782E-03 0.3962509001377E-12
      2 0.3734395176928E-04 0.3734395176928E-04 0.4663405068414E-13
      3 0.5009278540654E-04 0.5009278540654E-04 0.6168505437472E-13
      4 0.4767109393954E-04 0.4767109393953E-04 0.1522385515483E-12
      5 0.1362161339921E-03 0.1362161339921E-03 0.4795553872937E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      400
Time in seconds =                   248.40
Total processes =                        4
Compiled procs  =                        4
Mop/sec total     =                 342.23
Mop/sec/process   =                  85.56
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```

```
 NAS Parallel Benchmarks 2.3 -- SP Benchmark

 No input file inputsp.data. Using compiled defaults
 Size:  64x 64x 64
 Iterations: 400    dt:   0.001500
 Number of active processes:     9

Verification being performed for class A
 accuracy setting for epsilon =  0.1000000000000E-07
 Comparison of RMS-norms of residual
        1               NAN 0.2479982239930E+01               NAN
        2               NAN 0.1127633796437E+01               NAN
        3               NAN 0.1502897788877E+01               NAN
        4               NAN 0.1421781621170E+01               NAN
        5               NAN 0.2129211303514E+01               NAN
 Comparison of RMS-norms of solution error
        1               NAN 0.1090014029782E-03               NAN
        2               NAN 0.3734395176928E-04               NAN
        3               NAN 0.5009278540654E-04               NAN
        4               NAN 0.4767109393953E-04               NAN
        5               NAN 0.1362161339921E-03               NAN
 Verification Successful


 SP Benchmark Completed.
 Class           =                        A
 Size            =             64x 64x 64
 Iterations      =                      400
 Time in seconds =                  6867.47
 Total processes =                        9
 Compiled procs  =                        9
 Mop/sec total   =                    12.38
 Mop/sec/process =                     1.38
 Operation type  =           floating point
 Verification    =               SUCCESSFUL
 Version         =                      2.3
 Compile date    =              21 Jul 2003
```

```
NAS Parallel Benchmarks 2.3 -- SP Benchmark

No input file inputsp.data. Using compiled defaults
Size:  64x 64x 64
Iterations: 400    dt:   0.001500
Number of active processes:    16

Verification being performed for class A
accuracy setting for epsilon =  0.1000000000000E-07
Comparison of RMS-norms of residual
      1 0.2479982239930E+01 0.2479982239930E+01 0.7861151583476E-13
      2 0.1127633796437E+01 0.1127633796437E+01 0.9451775097624E-14
      3 0.1502897788877E+01 0.1502897788877E+01 0.6707591918895E-13
      4 0.1421781621170E+01 0.1421781621170E+01 0.3123469900284E-14
      5 0.2129211303514E+01 0.2129211303514E+01 0.2356838921071E-13
Comparison of RMS-norms of solution error
      1 0.1090014029782E-03 0.1090014029782E-03 0.3860555522208E-12
      2 0.3734395176928E-04 0.3734395176928E-04 0.3048451562232E-13
      3 0.5009278540654E-04 0.5009278540654E-04 0.1007793103271E-12
      4 0.4767109393954E-04 0.4767109393953E-04 0.1640366839278E-12
      5 0.1362161339921E-03 0.1362161339921E-03 0.2606711856244E-13
Verification Successful


SP Benchmark Completed.
Class           =                        A
Size            =             64x 64x 64
Iterations      =                      400
Time in seconds =                   166.97
Total processes =                       16
Compiled procs  =                       16
Mop/sec total     =                 509.13
Mop/sec/process   =                  31.82
Operation type  =           floating point
Verification    =               SUCCESSFUL
Version         =                      2.3
Compile date    =              24 Jul 2003
```