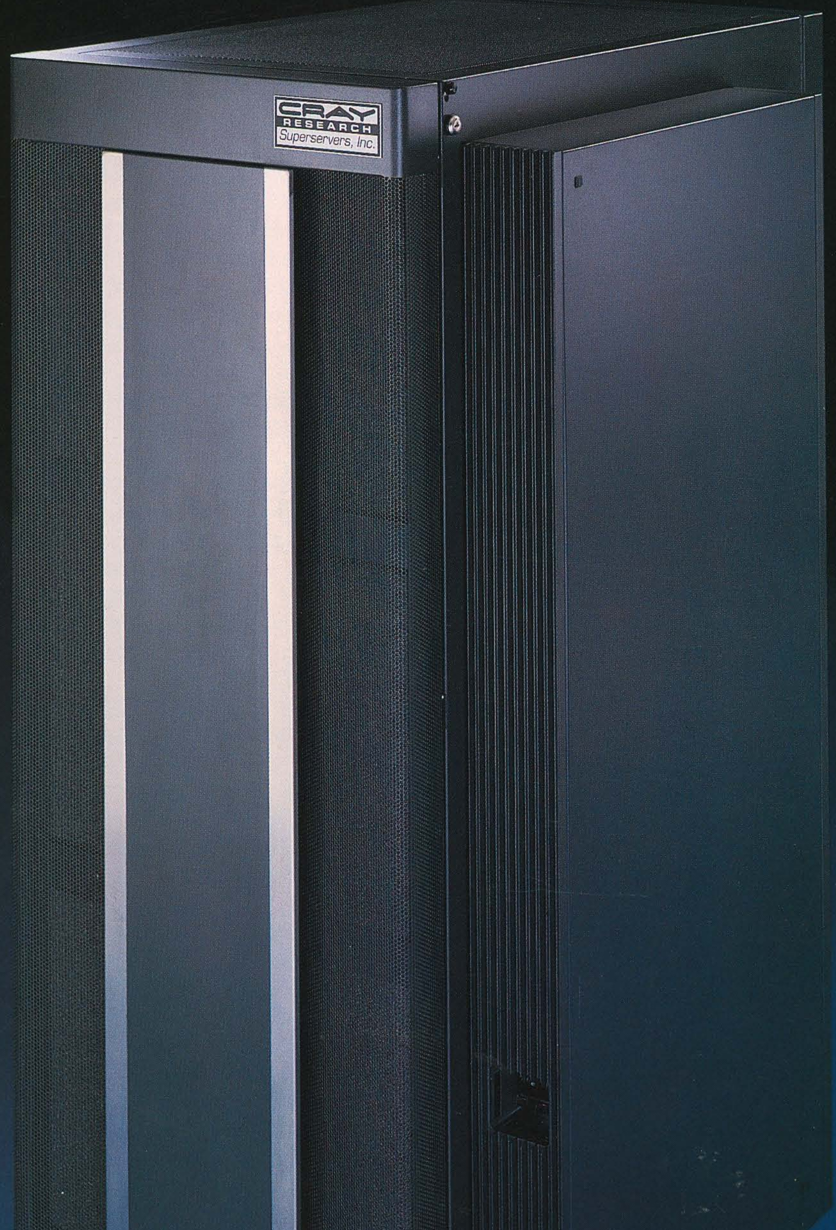
Seamless production parallelism in a heterogeneous network

The CRAY APP Shared-Memory Parallel Processing System



CRAY RESEARCH, INC.

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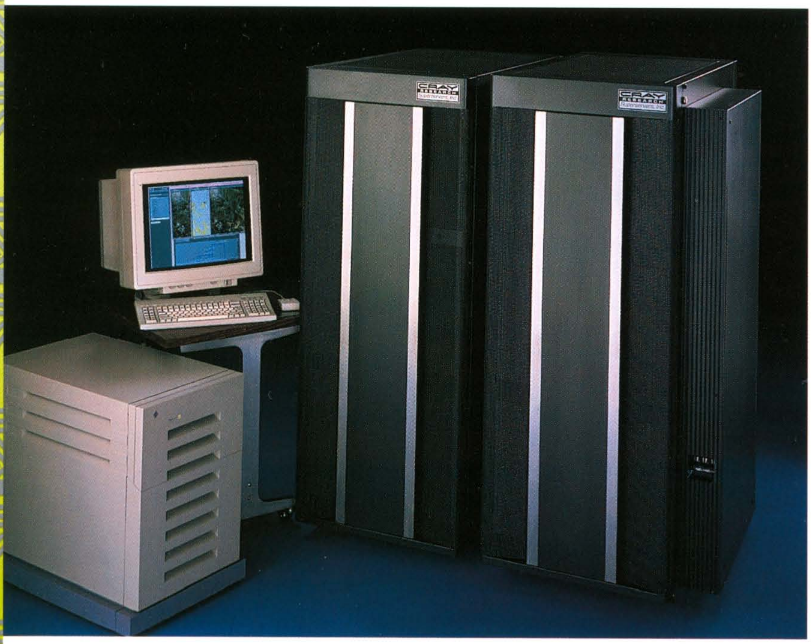


A clustered APP system is the ultimate accelerator for SPARC networks.

Cray Research is the worldwide leader in high performance computing systems.

Today, Cray Research offers the richest set of state-of-the-art software and hardware products in complementary technologies. These include compiler systems, end-user applications, libraries, visualization tools, networking software, and storage management facilities for parallel vector supercomputers, superservers, and massively parallel systems.

Cray Research products offer the ease of use, ease of access, and interoperability that can only be found in a seamless network environment.

The CRAY APP shared memory parallel system sets a new standard for the integration of complementary parallel systems in today's heterogeneous networks.

Solving challenging scientific and industrial problems

The CRAY APP system is designed to provide high performance and to be cost-effective for compute-intensive algorithms and applications found in a wide range of scientific and technical problems.

Cray Research's CRAY APP system offers unmatched price/performance combined with ease of use and the familiar look and feel of the most popular workstations in the world. Using standard Fortran and compiler directives, in some cases sustained performance of over one GFLOPS has been achieved by experienced programmers on average codes in one workday!

Maximizing productivity in a production environment

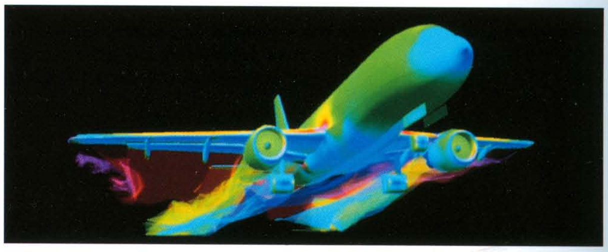
The CRAY APP system is ideally suited for production environments with compute-intensive applications such as

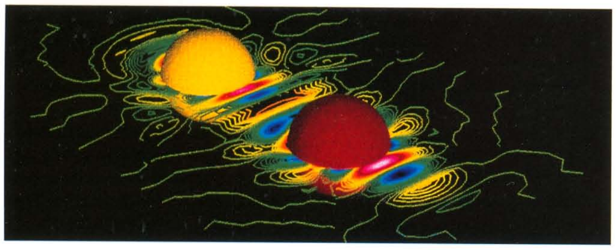
- ☐ signal processing
- ☐ image processing
- ☐ 3-D seismic processing
- ☐ visualization
- ☐ computational chemistry
- ☐ financial modeling
- ☐ design engineering
- ☐ electromagnetics

Delivered performance over a wide range of problems

The CRAY APP system is a cost-effective true shared-memory, multiple-instruction multiple-data (MIMD) compute server designed to provide delivered performance to users running production applications. The most important aspect of an architecture is its immediate usability and future expansion. The CRAY APP system provides just that, because it fits seamlessly into any SPARC network. As a result, the CRAY APP system delivers far more value to customers in low-cost parallel processing systems than other systems in its class.

Airliner in ground effect. Image shows surface pressure distribution and wakes behind the aircraft.





Scattered electrical fields around a double sphere at one instant of time. As time passes, the scattered fields bounce back and forth between the spheres. These field computations are used to obtain radar cross section (RCS) information and for code validation.

Architecture and implementation

The CRAY APP system module is a multiple-bus/crossbar parallel processor designed to accelerate a variety of applications. The CRAY APP system module can be configured with up to 84 processing elements and up to 1 Gbyte of shared memory.

One of the most cost-effective methods to connect many processors is to put them on a common bus. One of the most efficient ways to achieve high performance is to use a crossbar to connect processors to a multi-ported shared memory. The CRAY APP system's innovative architecture offers the advantages of both. The CRAY APP system contains seven buses that are connected to a local shared memory via an eight-by-eight crossbar. While the system concept allows wider crossbars, the eight-by-eight crossbar was chosen to achieve compact physical packaging and system economy. Memory size ranges from 32 Mbytes to 1 Gbyte. Each path operates at 160 Mbytes/s and can accommodate up to 12 microprocessors. Processor buses are equipped with special hardware to assist in bus utilization and process synchronization.

Efficiency and economy in one package

Efficiency and economy extend to the CRAY APP system's physical size and cooling power requirements. Because the CRAY APP system module is air-cooled, it can be installed easily and is cost effective to operate. Its compact size (27''x62''x43'') makes an efficient use of space.

High-performance processing

With up to 84 processors and a peak performance of up to 3.3 GFLOPS (64 bits) and 6.7 GFLOPS (32 bits), each CRAY APP system module delivers excellent raw performance, unmatched price/performance, and provides ease of programming with autoparallelizing C and Fortran compilers in a UNIX environment. Up to 12 CRAY APP system modules can be used in a clustered APP system with up to 8 Gbytes of global shared memory.

High-performance I/O

High-speed direct HIPPI and VME connections allow the CRAY APP system to exchange data with other devices and processors. Standard disk I/O to the UNIX file system is fully supported.

Shared memory parallel processing

Utilizing a flat shared-memory architecture, fast static random access memory (SRAM), and hardware-assisted parallel support (patent pending), the CRAY APP system offers excellent efficiency in

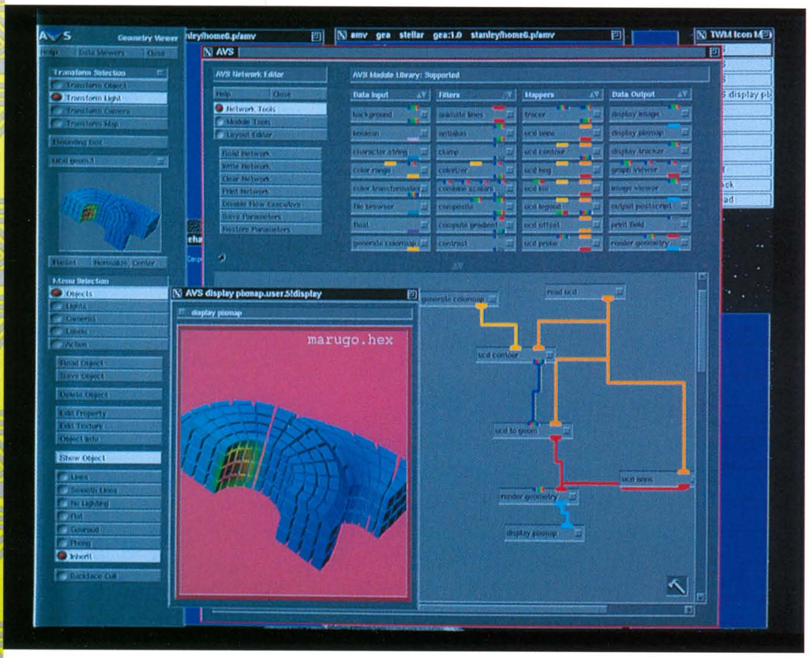
- ☐ memory latency,
- ☐ critical sections,
- ☐ parallel region start-up, and
- ☐ barrier synchronization

that you have come to expect only from Cray Research parallel systems. These translate directly to high efficiency and effective compiled performance.

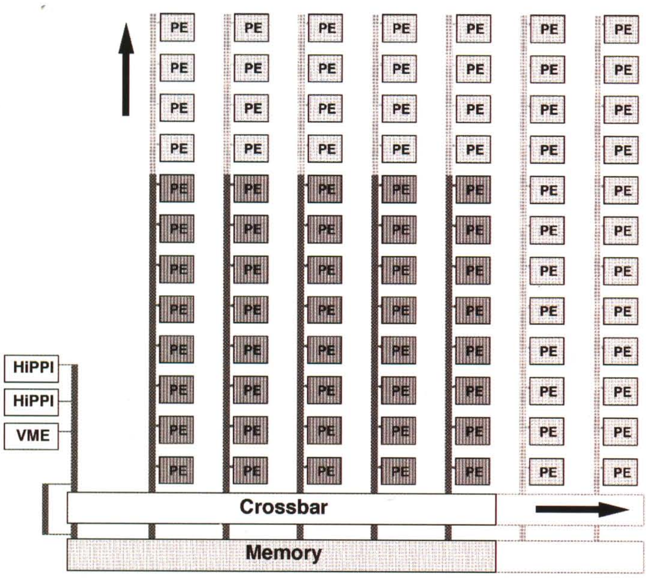
Ideal for production environments

The CRAY APP system brings parallel processing to the production environment with features such as

- ☐ high-performance processing
- ☐ high-performance I/O
- ☐ true shared memory
- ☐ ease of programming
- ☐ seamless integration with scalar processing, vector processing, and storage management technologies
- ☐ affordable fully configured systems
- ☐ low cost operation



Scientific data enhancement using the AVS visualization system. AVS provides a visual point-and-click interface to computing modules on both the workstation and the Cray Research system.



Architecture of a single CRAY APP system module

Multi-user UNIX operating system

The CRAY APP multi-user microkernel is designed and tuned for optimal performance and throughput on a multithreaded parallel application job mix. It manages processors, lightweight threads, process stacks, exceptions, I/O, and supports TCP/IP, RPC, the X Window System, and virtually all of the system services available on the SPARC processor, including Solaris system calls. The client SPARC processor acts as the I/O processor for the CRAY APP system. Standard disk I/O to the UNIX file system is fully supported.

Client/server operation

In addition to supporting complete applications running on the CRAY APP system, the microkernel also manages user jobs in a client/server mode. Compiler directives for interprocess communication are used to split an application so that the server portion running on the CRAY APP system is in live communication with the client portion running on a SPARC processor. The client can, in turn, communicate with other encapsulated software modules running on other processors on the network.

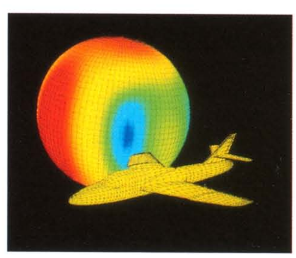
Unified executable

To support the client/server model, the CRAY APP system is integrated into a single compiler system that has the capability of generating code for the SPARC processor and the CRAY S-MP vector processor.

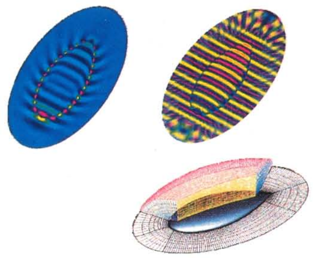
It is possible to create a single "unified" executable image that has subroutines running on the CRAY APP system or on the CRAY S-MP system in either scalar mode (on the SPARC processors) or vector mode (on the vector processor).

Parallelizing compilers

The CRAY APP system can be programmed in ANSI standard Fortran or C. Optimization techniques have been built into the CRAY APP system architecture. The compilers perform local, loop, and global optimizations, including vectorization, locality optimization, and software pipelining. Parallelism is detected automatically



Radar cross section (RCS) of a military aircraft. Red indicates regions of high RCS and blue indicates low RCS.



Almond-shaped targets are used as scatterers to predict the Radar cross section (RCS) of low-observable shapes. The figure shows scattered electrical fields (top left) and total electrical fields (top right) at one instant of time. The bottom right figure shows the multizone grid arrangement used for calculation.

by the compilers or is specified via standard Cray Research microtasking directives. Many of the parallel/vector programming and optimization techniques used in programming the CRAY Y-MP system are also appropriate for the CRAY APP system. A complete set of debugging and profiling tools with standard graphical user interfaces is also available.

Optimized open math library

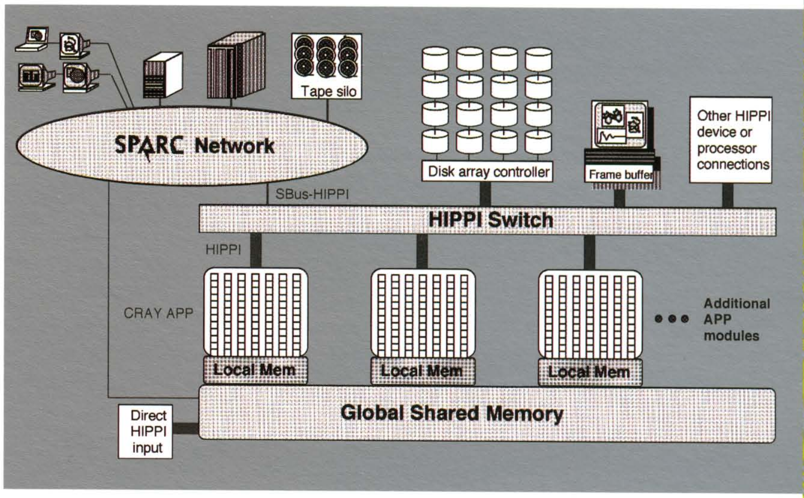
For many widely used algorithms, Cray Research offers CRSmath, an extensive set of optimized mathematical subroutines. CRSmath is openly available for licensed use. The standard Cray Research scientific library, LIBSCI, is also supported.

Clustered CRAY APP system

For applications that can take advantage of higher scalability, a clustered CRAY APP system can be configured with a global shared memory of up to 8 Gbytes and a HIPPI switch for direct external communication. For example, a clustered CRAY APP system with 12 CRAY APP system modules provides 1008 processors, a peak performance of 80 GFLOPS (32 bit), and up to 20 Gbytes of aggregate memory.

Application-driven design

Today, creating a usable parallel system is not simply a matter of choosing a microprocessor or a routing network or deciding on a desired level of scalability. It is the result of balanced hardware design driven by an understanding of system software, compiler systems, and application software.



A clustered CRAY APP system provides scalability, a global shared memory, and direct HIPPI connections.

The design of the CRAY APP system is based on a crossbar routing network, flat shared memory, high I/O rates, and moderate scalability. It is driven by state-of-the-art compiler technologies, efficient hardware-assisted system software, and an extensive analysis of large compute-intensive applications.

For an 84-processor CRAY APP system:

Maximum memory latency	0.15µs
Maximum critical section	53µs
Maximum parallel region overhead	37µs
Maximum barrier synchronization	29µs

Signal and image processing

Large signal and image processing applications in areas such as radar, sonar, speech processing, or image enhancement can take advantage of the CRAY APP architecture. The CRAY APP system can also be used for non-numerical applications such as character searching.

Key algorithms, such as one- or multidimensional convolutions or mixed-radix fast Fourier transforms perform efficiently and exhibit near linear speedup on the CRAY APP system. With this system, Cray Research sets a new level of price/performance for large signal processing applications.

3-D seismic migration

3-D seismic applications such as the Kirchhoff, phase shift, or the ω-χ migrations run efficiently on the CRAY APP system. For example, a 4000 x 500 seismic record can be migrated down 2000 depths in under one minute.

The CRAY APP system brings 3-D analysis within reach of the typical user, achieving outstanding performance at costs normally associated with 2-D analysis.

Visualization

Visualization algorithms such as surface and volume rendering, radiosity, and ray tracing are well suited to the CRAY APP system. Together with its direct HIPPI channel, the CRAY APP system can provide real-time animation capability as well as easy-to-use computational power.

The CRAY APP system has been integrated with Advanced Visualization System (AVS) software running on the SPARC network, executing the compute-intensive modules of AVS.

84-processor CRAY APP system

Sample customer applications with performance over 1 GFLOPS

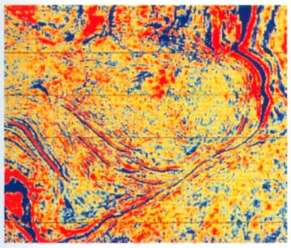
Sonar processing	2.3 GFLOPS
Image processing	1.2 GFLOPS
Image processing	1.1 GFLOPS
Radar processing	2.0 GFLOPS
3-D Kirchhoff migration	1.1 GFLOPS
3-D seismic processing	1.0 GFLOPS
Options evaluation	2.0 GFLOPS
Portfolio optimization	1.3 GFLOPS

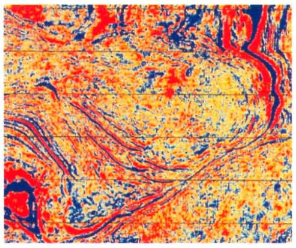
Sample algorithm kernels with performance over 1 GFLOPS

2-D convolution, s.p.*	2.1 GFLOPS
2-D complex FFT, s.p.	1.1 GFLOPS
Matrix solve, d.p.**	1.3 GFLOPS
Triangular matrix update, d.p.	1.1 GFLOPS
Vector logarithm, d.p.	1.3 GFLOPS
Vector exponential, d.p.	1.3 GFLOPS
Vector sine, d.p.	1.1 GFLOPS
Vector cosine, d.p.	1.1 GFLOPS

* s.p. denotes 32-bit (single-precision) arithmetic
** d.p. denotes 64-bit (double-precision) arithmetic

Charge polarization in a folate molecule upon binding to the enzyme dihydrofolate reductase (DHFR). The red surface depicts regions of increased charge density; the blue surface depicts reduced density.





Three-dimensional (3-D) seismic data migration. This computationally intensive process enables researchers to view geological structures for possible deposits of petroleum and natural gas.

Computational chemistry

Applications in computational chemistry that can take advantage of the power of the CRAY APP system include molecular mechanics, Monte Carlo, and molecular dynamics simulation techniques applied to large systems such as polymers or proteins. Other examples include protein crystallography and emerging *ab initio* methods such as the pseudo-spectral generalized valence bond.

The CRAY APP system provides the computational chemist with the compute power and ease of use to study complex models at an affordable price.

Financial modeling

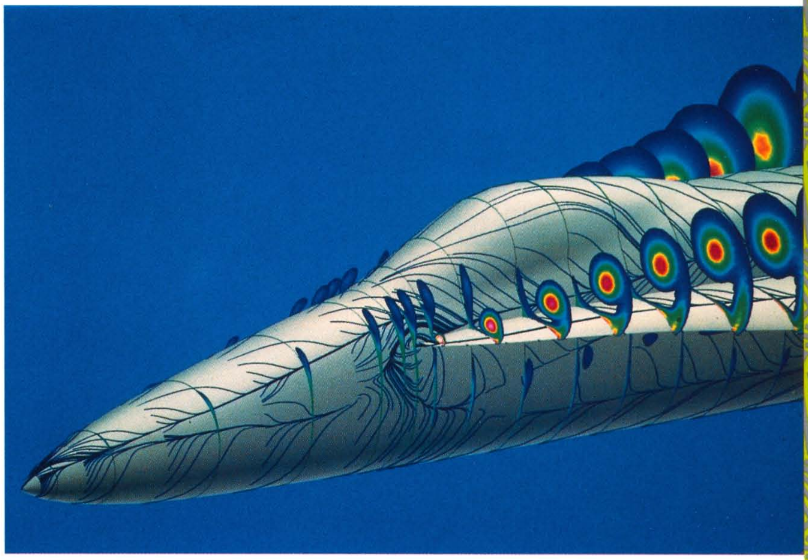
In the financial modeling and investment banking area, the inherent parallelism and compute intensity of applications such as portfolio optimization, Monte Carlo simulations, collateralized mortgage obligations, and foreign exchange result in excellent performance on the CRAY APP system.

The CRAY APP system's ability to integrate with existing SPARC networks allows it to be used quickly and seamlessly, minimizing programming costs and making parallel technologies available to the trading floor as well as the research department.

Electromagnetics

The CRAY APP system tackles compute-intensive electromagnetic applications with its exceptional power in complex arithmetic. It uses HIPPI I/O for fast data exchange and out-of-core matrix calculations.

Using a single CRAY APP system module, sustained performance of over 1 GFLOPS is achieved on large out-of-core linear equation solvers. In addition, the important "matrix fill" operation for large radar cross section applications achieves near linear speedup on the CRAY APP system.



Laminar, compressible flow over the forebody and strake of an F-18 at a high angle of attack (30°) typical of a high-g maneuver (Mach 0.3).

Design engineering

Among highly parallel computers, the CRAY APP system is one of the most effective for design engineering applications. Examples of suitable applications include 3-D analysis of transonic flow, turbine engineering, 3-D mesh generation, boundary element methods, heat transfer, and durability assessment.

An emerging technique in design engineering is interactive application steering where preprocessing, analysis, and postprocessing are combined in a visual interactively controlled session. Used as a network compute server in a client/server mode, the CRAY APP system is an effective enabling tool for this model.

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The product specifications contained in this brochure and the availability of the products are subject to change without notice. For the latest informaion, contact your Cray Research representative.

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