The CRAY X-MP Series of Computer Systems

CRAY

For more than a decade, Cray Research has been the industry leader in large-scale computer systems. Today, about two-thirds of the supercomputers installed worldwide are Cray systems. They are used in advanced scientific and research laboratories around the world and have gained strong acceptance in diverse industrial environments. No other manufacturer has Cray Research's breadth of experience and success in supercomputer development.

The company's initial product, the CRAY-1 computer system, was first installed in 1976 and quickly became the standard for large-scale scientific computers — and the first commercially successful vector processor. For some time previously, the potential advantages of vector processing had been understood, but effective practical implementation had eluded computer architects. The CRAY-1 system broke that barrier, and today vectorization techniques are used commonly by scientists and engineers in a wide variety of disciplines.

The field-proven CRAY X-MP computer systems now offer significantly more power to solve new and larger problems while providing better value than any other systems available. Large memory size options allow a wider range of problems to be solved, while the system's innovative multiprocessor design provides practical opportunities to exploit multitasking, the next dimension of parallel processing beyond vectorization. Once again, Cray Research has moved supercomputing forward, offering new levels of hardware performance and software techniques to serve the needs of scientists and engineers.

Introducing the enhanced CRAY X-MP series of computer systems

The CRAY X-MP series of computer systems represents the evolution of field-proven technologies into the widest selection of supercomputers available today. The eleven models of the CRAY X-MP series combine one to four processors with two million to 16 million 64-bit words of memory, and many models are field upgradable with regard to number of central processing units (CPUs) and size of memory. The same high-performance software runs on all models of the series.

The CRAY X-MP multiprocessor configurations allow users to employ multiprogramming, multiprocessing, and multitasking techniques. The multiple CPUs may operate independently and simultaneously on separate jobs for greater system throughput or may be applied in any combination to operate jointly on a single job for better program turnaround time. Multiprocessing and vector processing combine to provide a geometric increase in computational performance over conventional scalar processing techniques.

The CRAY X-MP system design is carefully balanced to deliver optimum overall performance. Fast long and short vector processing is balanced with high-speed scalar processing, and both are supported by powerful input/output capabilities. Each CPU also offers gather/scatter and compressed index vector instructions, which allow for the vectorized processing of randomly organized data, which previously was performed by scalar processing. Cray Research software ensures easy access to these performance features. This means users can realize maximum throughput for a variety of job mixes and programming environments.

A universe of applications

Proven applications for CRAY X-MP computer systems range from the subatomic to the celestial. Whether used to find the charge densities of atoms or to optimize the aerodynamics of spacecraft, CRAY X-MP systems provide scientists and engineers with unique opportunities for exploration and discovery.

As the marketplace for supercomputers has grown in size and diversity, Cray Research has provided unequaled hardware flexibility. The range of CRAY X-MP system configurations allows users to tailor systems to their specific needs. In commercial, academic, or government laboratories, in production or research, CRAY X-MP computer systems easily adapt to the most varied and demanding computational requirements.

Customers throughout the world enjoy the cost-cutting efficiency and reliable performance provided by Cray computer systems. The ability to run realistic models of complex phenomena and process enormous amounts of data quickly have made CRAY X-MP computer systems the standard in computational performance — providing users with their most accurate, enlightening, and profitable results. The following pages illustrate real-world applications for which CRAY X-MP computer systems have proved invaluable.

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Complementing the power of the CRAY X-MP series is a powerful range of I/O technology managed by the I/O Subsystem. Cray Research's SSD solid-state storage device provides up to 512 million words (4096 Mbytes) of very fast random-access secondary MOS memory. When connected to a four-processor CRAY X-MP system through two 1000-Mbyte/sec channels, an SSD provides a maximum aggregate transfer rate of 2000 Mbytes/sec. In addition, Cray Research's DD-49 and DD-39 disk drives offer 1200-Mbyte capacity and very fast sustained transfer rates.

A wide variety of application programs are available for CRAY X-MP systems, helping users solve problems in areas such as reservoir simulation and seismology, aerospace and automotive engineering, nuclear research, graphics and imaging, and computational chemistry. Thus, scientists and engineers can use CRAY X-MP systems and industry-standard codes to solve a wide range of problems. Additionally, software developed for the CRAY-1 system can be run on all models of the CRAY X-MP series, thus protecting user software investments.

CRAY X-MP systems can be integrated easily into a user's existing computer environment. Cray Research offers hardware and software front-end interfaces for many other manufacturers' equipment. And the CRAY X-MP system requires a minimum of floor space, occupying just 90 square feet (9 square meters) in its maximum configuration, including the SSD storage device (but excluding electrical and cooling support equipment).

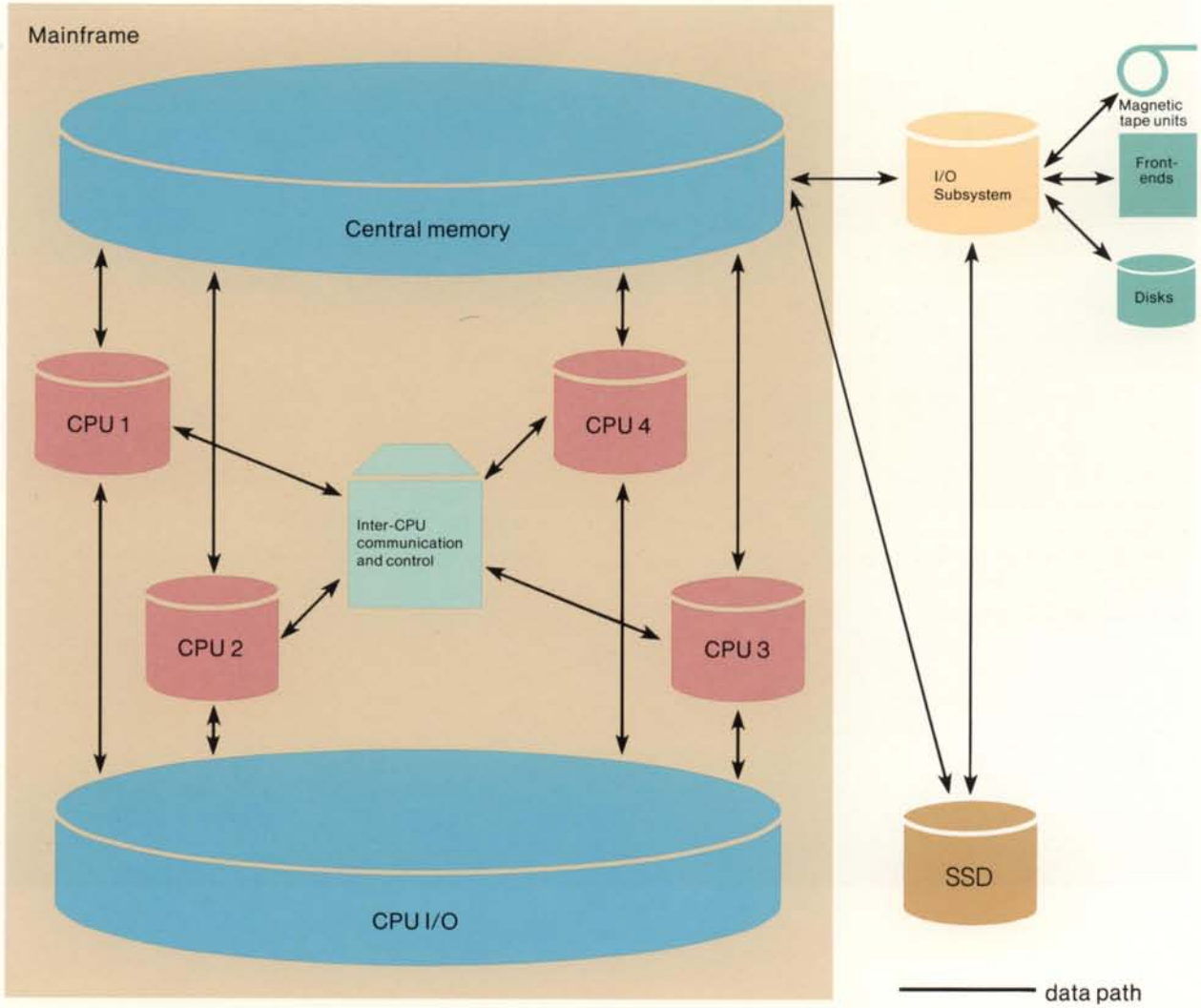
Cray systems offer the most powerful and cost-effective computing solutions available today for advanced scientific applications — both for experienced supercomputer users with the most demanding computing requirements and for newer users whose research needs now require supercomputer power. The CRAY X-MP systems feature one, two, or four powerful CPUs, very large central memories, exceptionally fast computing speeds, and I/O throughput to match. As the supercomputer marketplace broadens, the CRAY X-MP series of computer systems is evolving to meet users' expanding computing requirements.

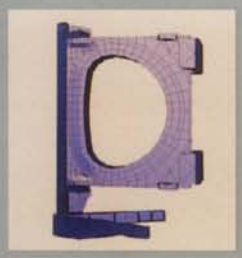
Structural analysis

Finite element analysis (FEA) is a mathematical method for calculating the effect of stress on physical structures. The aerospace, automotive, civil engineering, and other industries rely on FEA to conduct engineering design and analysis. Using CRAY X-MP systems, engineers can rapidly evaluate structures too large or complex to be analyzed adequately any other way. The result is improved engineering efficiency and more structurally sound and lightweight components.

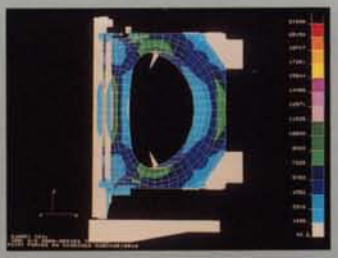
(Left) A 40-ton superconducting electromagnet for use in fusion energy research. A structural analysis was conducted to help set operating levels for a facility housing an array of six such coils. (Right) Solid model of one coil created on a CRAY X-MP computer system with the graphics program MOVIE.BYU.

CRAY X-MP multiprocessor system organization





(Left) A model of the entire six-coil array created by rotating the single-coil model about a vertical axis. (Right) Display of stress contours resulting from calculated magnetic forces. (All images courtesy Martin Marietta Energy Systems, Inc.)



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System overview

Aerodynamic simulation

Aircraft designers have long relied on wind tunnel tests to evaluate the aerodynamics of aircraft and aircraft sections. But wind tunnel testing requires the time-consuming and costly construction of physical test models. CRAY X-MP computer systems enable aircraft designers to evaluate and modify their designs faster and more cost-effectively than they could by relying solely on wind tunnel tests. In recent years auto-makers have also begun to enjoy the benefits of aerodynamic testing via supercomputer.

Cross-section of a three-dimensional airflow about a shuttle-like aircraft as depicted by the Navier-Stokes equations. Computational requirements make the Navier-Stokes equations the most difficult to solve, but they are also the most accurate. (Courtesy W.L. Hankey, S.J. Scherr, and J.S. Shang, Air Force Wright Aeronautical Laboratories)

The CRAY X-MP/4 systems

The top-of-the-line CRAY X-MP/4 computer systems offer an order of magnitude greater performance than the original CRAY-1 computer. They are configured with 4, 8, or 16 million 64-bit words of ECL bipolar memory and offer a maximum memory bandwidth 16 times that of the CRAY-1 computer. Central memory has a bank cycle time of 34 nsec and is shared by four identical CPUs with a clock cycle time of 8.5 nsec. Each CRAY X-MP/4 mainframe is the familiar 12-column 270° arc chassis and has the same electrical requirements as the CRAY-1 computer.

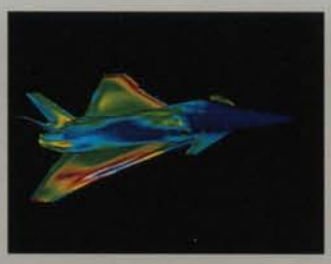
Each of the four CRAY X-MP/4 processors has scalar and vector processing capability and can access all of central memory. The CPUs may operate independently on separate jobs or may be organized in any combination to operate jointly on a single job.

The raw computational power of the CRAY X-MP/4 systems is augmented by the powerful input/output and data-handling capabilities of the Cray I/O Subsystem (IOS). The IOS is integral to all CRAY X-MP systems and enables fast, efficient data access and processing by the CPUs.

Cray Research's SSD, in conjuction with the CRAY X-MP/4 multiprocessor architecture, enables users to fully exploit existing applications and to develop new algorithms to solve larger and more sophisticated problems in science and engineering — problems that could not be attempted before due to computational or I/O limitations. The field-proven SSD offers up to 512 million words (4096 Mbytes) of very fast random-access secondary MOS memory. An SSD with 64 million words or more of memory connects to a CRAY X-MP/4 system through two very high-speed channels with a maximum aggregate transfer rate of 2000 Mbytes/sec, while the SSD with 32 million words of memory is located in the IOS cabinet.

Cray Research's DD-49 disk drives match the power of the CRAY X-MP/4 systems, offering 1200-Mbyte capacity, sustained transfer rates of 9.6 Mbytes/sec at the user job level, and very fast seek times (average 16 milliseconds).

Pressure contours calculated for a European fighter aircraft configuration, with blue indicating low pressure and red indicating high pressure. (Courtesy Albrecht Eberle, Messerschmitt-Boelkow-Blohm)



Calculated pressure field radiated by an unducted fan engine. Computer simulation can accelerate the design of more powerful and efficient aircraft propulsion systems. (Courtesy John J. Adamczyk, NASA Lewis Research Center)

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The CRAY X-MP/2 systems

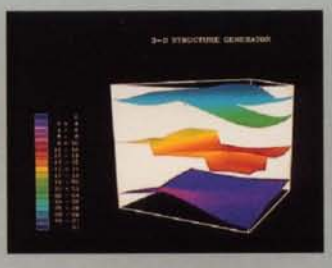
The field-proven CRAY X-MP/2 systems are the most widely installed supercomputers today and, as such, have become the standard in supercomputing. The dual-processor CRAY X-MP/2 systems offer up to four times the memory and require only half the electrical power of the original CRAY X-MP/2 systems introduced in 1982. Overall throughput is typically three to five times that of a CRAY-1 system.

The CRAY X-MP/2 systems are available with 2, 4, 8, or 16 million 64-bit words of shared MOS central memory, providing a maximum memory bandwidth four times that of the CRAY-1. Each CPU has an 8.5 nsec clock cycle time and a memory bank cycle time of 68 nsec. Each CRAY X-MP/2 mainframe consists of eight vertical columns arranged in a 180° arc. As with the CRAY X-MP/4 CPUs, the CRAY X-MP/2 processors can operate independently on different programs or can be harnessed together to operate on a single user program.

CRAY X-MP/2 computers incorporate the same I/O Subsystem as the CRAY X-MP/4 models and can be configured with the same SSD hardware and DD-49 disk drives. One SSD channel, with a transfer rate of 1000 Mbytes/sec, connects the optional SSD (64 million words or larger) to the mainframe; the SSD with 32 million words of memory is located in the IOS cabinet.

Geological exploration

Inducing a shock in the ground and recording sound waves reflected back to the surface is a method scientists use to "see" underground structures. The method is called reflection seismology and is used to locate petroleum and other resource deposits. However, the amount of data needed to profile a large volume of earth accurately can be immense, and the required analyses are staggeringly complex. CRAY X-MP computer systems can perform detailed analyses on these large amounts of data in a timely and cost-effective manner, saving the petroleum industry time and money.



Output from a three-dimensional structure generator used for seismic data migration and modeling. The generator runs on Cray computer systems and includes surface fitting, unconformities, and faults.

The CRAY X-MP/1 systems

The field upgradable CRAY X-MP/1 systems combine a single high-performance CPU with 4, 8, or 16 million 64-bit words of static MOS memory. And because they are field upgradable to dual-processor systems, they provide flexibility as a user's supercomputing needs grow.

The field upgradable models of the CRAY X-MP/1 system provide 1.5 to 2.5 times the overall throughput of a CRAY-1 system. The single CPU of the CRAY X-MP/1 systems has an 8.5-nsec clock cycle time and a 68-nsec memory bank cycle time. Memory bandwith is four times that of the original CRAY-1 computer. The mainframe has the same physical appearance and electrical requirements as the CRAY X-MP/2 computer systems.

The upgradable CRAY X-MP/1 systems are supported by the same I/O Subsystem as other systems in the CRAY X-MP series. Typically, DD-49 disk drives are configured on these systems, and the full range of SSD models are available.

The CRAY X-MP/1 systems are appropriate for supercomputer customers requiring high single-processor performance with the added advantage of future growth potential.

Reservoir simulation

Petroleum companies often use fluid injection to mobilize oil trapped underground and push it to the surface. The procedure typically involves pumping in water or water plus a surfactant. But to determine precisely the best strategy for a particular reservoir, engineers must consider the underground temperature and pressure, the chemical makeup of the petroleum, and the reservoir's geology. Modeling the interactions of these variables for large volumes of earth requires the massive computing power of CRAY X-MP computer systems.

Study of underground microbial injection conducted on a CRAY X-MP computer system. Injection pump is at upper left, suction pump at lower right. Color gradient shows varying concentrations of microbes. The simulation is of an actual case using microbes to clean contaminated petroleum.

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The CRAY X-MP/14se system

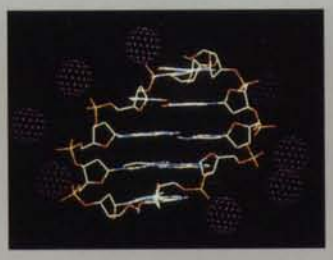
An exciting new CRAY X-MP model, the CRAY X-MP/14se, is now available. This entry-level system combines a single CRAY X-MP CPU with four million 64-bit words of static MOS memory. The CRAY X-MP/14se has been specially packaged and priced to serve both first-time supercomputer users and dedicated project requirements in large-scale computational environments. This new model offers true supercomputer performance and supports the full range of CRAY X-MP software and applications.

The CRAY X-MP/14se CPU and I/O Subsystem are contained in six vertical columns arranged in a 135° arc that requires less electrical power than an upgradable CRAY X-MP/1 system. The system supports up to eight DD-39 disk drives and up to 16 IBM-compatible tape drives but does not support an SSD connection.

The performance of a CRAY X-MP/14se is approximately 80 percent of the upgradable model of the CRAY X-MP/14 system.

Molecular science

Computer simulation is an invaluable tool for studying molecular motion, which can occur in a matter of picoseconds (trillionths of a second). Using CRAY X-MP computer systems, scientists can simulate atomic and molecular events and gain insight into chemical reaction rates, catalytic mechanisms, properties of synthetic polymers, and the shapes of biological molecules thousands of atoms long. The detailed and highly iterative mathematics involved in such modeling demands the computational capabilities of CRAY X-MP computer systems.



(Left) Image of DNA section with sodium ions generated from data produced on a CRAY X-MP system. (Right) A scorpion neurotoxin protein. The interactions of nearly 1000 protein and solvent atoms were computed on a CRAY X-MP system with the program CHARMM and displayed with HYDRA. (Right image courtesy Christopher Haydock, Mayo Foundation)

CRAY X-MP design

The CRAY X-MP series design combines high-speed scalar and vector processing with multiple processors, large and fast memories, and high-performance I/O. The result is exceptional speed and high overall system throughput in a balanced and practical computing solution.

Processors

Within the computation section of each CPU are operating registers, functional units, and an instruction control network — hardware elements that cooperate in executing sequences of instructions. The instruction control network makes all decisions related to instruction issue as well as coordinating the three types of processing within each CPU (vector, scalar, and address). Each of the processing modes has its associated registers and functional units. For multiple-processor CRAY X-MP models, the interprocessor communications section coordinates processing between CPUs and shared central memory.

Each CRAY X-MP processor offers very fast scalar processing with high-speed processing of long and short vectors. Additionally, multiprocessor models enable users to exploit the extra dimension of multitasking.

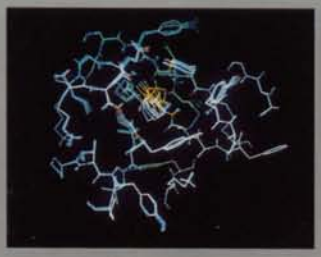
The scalar performance of each processor is attributable to its fast clock cycle, short memory access times, and large instruction buffers. Vector performance is supported by the fast clock, parallel memory ports, and flexible hardware chaining. These features allow simultaneous execution of memory fetches, arithmetic operations, and memory stores in a series of linked vector operations. As a result, the processor design provides high-speed and balanced vector processing capabilities for short and long vectors characterized by heavy register-to-register or memory-to-memory vector operations.

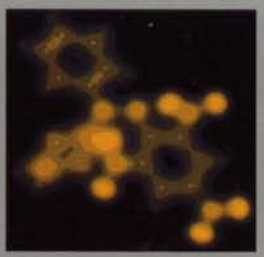
The overall effective performance of each processor executing typical user programs with interspersed scalar and vector codes (usually short vectors) is ensured through fast data flow between scalar and vector functional units, short memory access time for vector and scalar references, and short start-up time for both scalar and vector operations. As a result, CRAY X-MP computers offer high performance using an ANSI standard Fortran compiler, without the need for hand-coding or algorithm restructuring. On all models, a second vector logical unit is used to provide twice the execution speed of bit-level logical operations in each CPU.

Each CRAY X-MP processor also includes instructions for the efficient manipulation of randomly distributed data elements and conditional vector operations. Gather/scatter instructions allow for the vectorization of randomly organized data, and the compressed index instruction allows for the vectorization of unpredictable conditional operations. With these features, CPU performance can be improved by a factor of five for program segments dependent on the manipulation of sparse matrices.

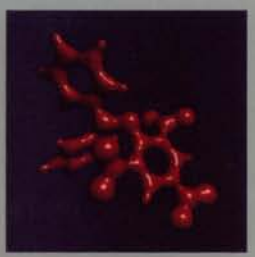
Programmable clock

A 32-bit programmable real-time clock that has a frequency equal to the reciprocal of the clock cycle time is a standard feature of the CRAY X-MP series computers. This clock allows the operating system

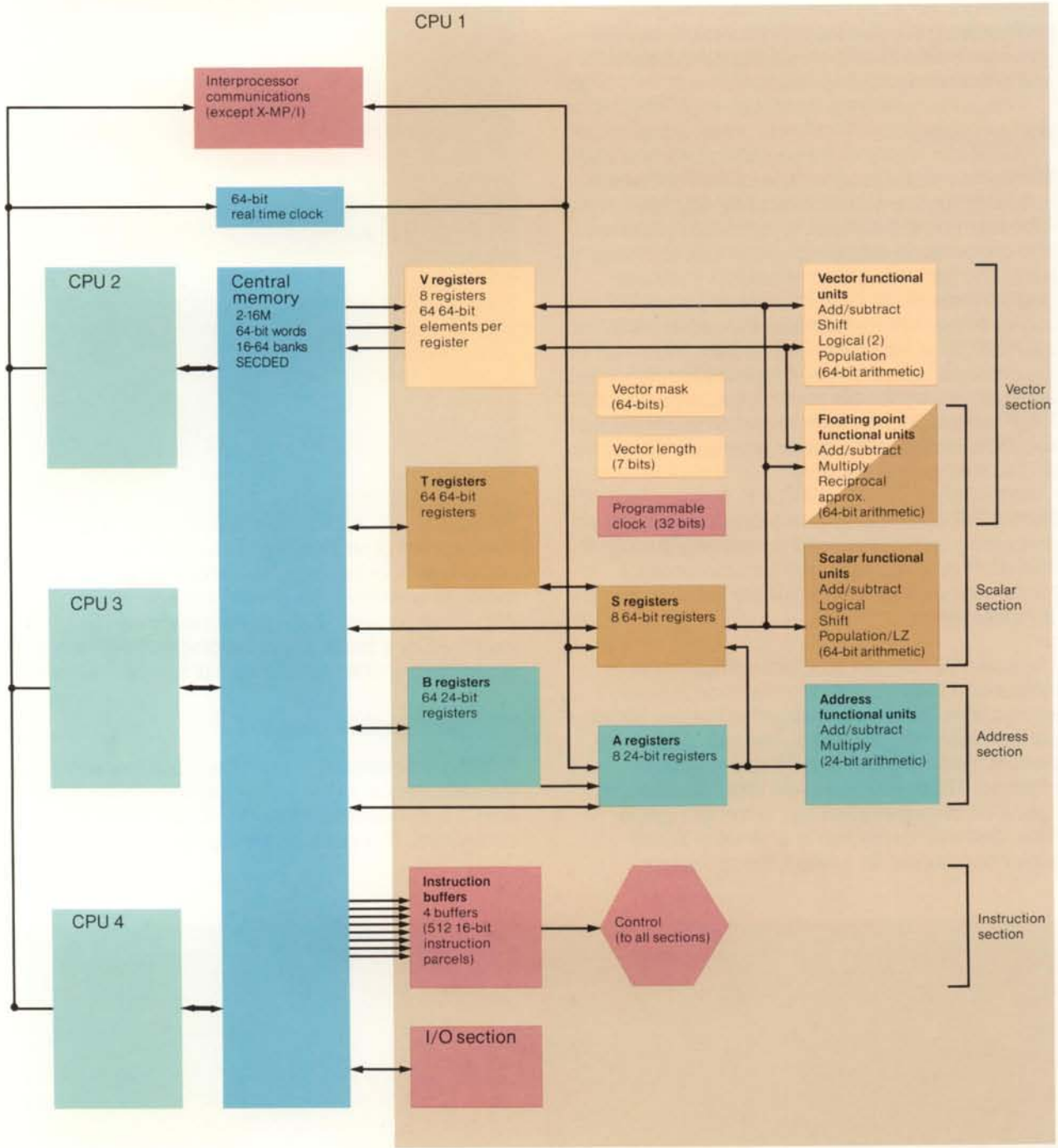




(Left) Color-coded contour map showing the electronic charge density of the DPPH molecule calculated on a CRAY X-MP computer system. (Right) The calculated three-dimensional structure of the same molecule. The surface connects points in space having a given electron density.



CRAY X-MP system organization



to force interrupts to occur at a particular time or frequency.

Data structure

CRAY X-MP system internal character representation is in ASCII with each 64-bit word able to accommodate eight characters. All integer arithmetic is performed in 24-bit or 64-bit 2's complement mode. Floating point numbers (64-bit quantities) consist of a 48-bit signed magnitude binary coefficient and a 15-bit biased exponent.

Central memory

Depending on the model, up to 16 million 64-bit words of directly addressable memory is available with the CRAY X-MP series. Options for field-upgrade of memory are available on most models. The large memory sizes enable users to solve larger problems than before without the need for out-of-memory techniques. CRAY X-MP memory features single-bit error correction, double-bit error detection (SECDED) logic.

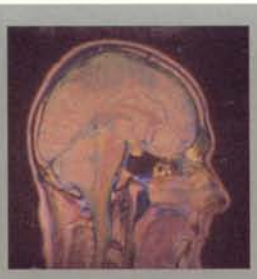
The CRAY X-MP multiprocessor systems share a central memory organized in interleaved memory banks that can be accessed independently and in parallel during each machine clock period. Each CRAY X-MP processor has four parallel memory ports connected to central memory: two for vector and scalar fetches, one for result store, and one for independent I/O operations. Thus, each processor of a CRAY X-MP system has four times the memory bandwidth of a CRAY-1 system. The multiport memory has built-in conflict resolution hardware to minimize delays and maintain the integrity of simultaneous memory bank references.

CRAY X-MP mainframe highlights

- ☐ Four processors sharing 4, 8, or 16 million words of ECL bipolar memory on the CRAY X-MP/4 systems, or
- ☐ Two processors sharing 2, 4, 8, or 16 million words of MOS memory on the CRAY X-MP/2 systems, or
- ☐ One processor (upgradable to two processors) with 4, 8, or 16 million words of MOS memory on the upgradable CRAY X-MP/1 systems, or
- ☐ One processor with 4 million words of MOS memory on the CRAY X-MP/14se system
- ☐ 8.5 nsec clock cycle on all models except the CRAY X-MP/14se system
- ☐ SECDED memory protection
- ☐ Four parallel memory ports per processor
- ☐ Flexible hardware chaining for vector operations
- ☐ Second vector logical unit
- ☐ Gather/scatter and compressed index vector support
- ☐ Flexible processor clustering for multitasking applications
- ☐ Dedicated registers for efficient interprocessor communication and control

Image processing

Imaging technologies used in satellite surveillance and medical diagnosis often require extensive data processing to create useful images. CRAY X-MP computer systems are ideal for rapidly processing the vast amounts of data that such technologies generate.



(Left) Magnetic resonance image of a human profile processed with the aid of a CRAY X-MP computer system. (Right) Thematic Mapper image processed on a CRAY X-MP computer system. This Landsat photograph shows an area southwest of Minneapolis-St. Paul, Minnesota.

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The interleaved multiport memory design, coupled with the short memory cycle time, provides high-performance memory organization with sufficient bandwidth to support high-speed parallel CPU and I/O operations.

Multiprocessors and multitasking

The CRAY X-MP multiple-CPU configurations have made Cray Research the recognized leader in multiprocessing. They continue to offer users the opportunity to decrease turnaround time over single-CPU performance by using either multiprocessing or multitasking techniques.

Multiprocessing allows several programs to be executed concurrently on multiple CPUs of a single mainframe. Multitasking is a feature that allows two or more parts of a program (tasks) to be executed in parallel sharing a common memory space, resulting in substantial throughput improvements over programs serially executed on a single CPU. Performance improvements are in proportion to the number of tasks that can be made to operate in parallel for the program and the number of CPUs that can be applied to the separate tasks.

When executing in multitasking mode, all processors are identical and symmetrical in their programming functions; no CPU is dedicated to any one function. Any number of processors (a cluster) can be dynamically assigned to perform multiple tasks of a single job. In order to provide flexible and efficient multitasking capabilities, special hardware and software features have been built into the systems. These features allow one or more processors to access shared memory or high-speed registers for rapid communication and data transmission between CPUs. All of these capabilities are made available through library routines which can be accessed from Fortran. In addition, hardware provides built-in detection of deadlocks within a cluster of processors.

Experience shows that multitasked applications running on CRAY X-MP/2 systems can realize speed increases of 1.8 to 1.9 times over upgradable CRAY X-MP/1 system execution times; speed increases of 3.5 to 3.8 times have been achieved with the CRAY X-MP/4 systems.

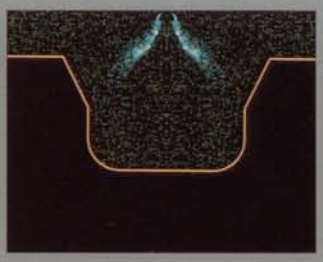
Input/output processing

For super-scale problems requiring extensive data handling, Cray Research has developed hardware that ensures computing power is not held captive by I/O limitations. The architecture of the I/O Subsystem, with its parallel data paths and direct access to main memory, results in a very high I/O bandwidth with a minimum of interference to computation.

The I/O Subsystem (IOS) is an integral part of the CRAY X-MP design and acts as a data distribution point for the mainframe. The IOS handles I/O for a variety of front-end computer systems and peripherals such as disk units and plug-compatible IBM

Computational fluid dynamics

Fluid flow characterizes physical processes ranging from the circulation of gases in the atmosphere to the flow of fuel in auto engines. The equations describing fluid physics were identified early in the nineteenth century, but until the advent of supercomputers, no practical means existed to solve them precisely. Today, CRAY X-MP computer systems make possible state-of-the-art fluid flow modeling for studies of coating flows, automotive and aircraft engine fuel flows, and research in the atmospheric and astrophysical sciences.



Simulation of a direct-injection stratified charge combustion chamber showing the injected fuel spray just prior to ignition. Automakers use computer simulations such as this to help design more fuel-efficient engines.

Input/output highlights

- ☐ 6-Mbyte/sec, 100-Mbyte/sec, and 1000-Mbyte/sec channels
- ☐ I/O Subsystem with:
  - — Parallel disk streaming capabilities, one controller per disk cabinet
  - — I/O buffering for disk-resident and tape-resident datasets
  - — Software support for parallel disk striping
  - — Buffer-memory-resident datasets
  - — High-performance disk drives
  - — High-performance on-line tape handling
  - — Front-end system communication with IBM, CDC, DEC, Honeywell, Data General, and Sperry computer systems
  - — Linkage to workstations such as Apollo and Sun via Network Systems Corporation (NSC) or similar network adapters
  - — Fiber optic link
  - — High-speed external channel
- ☐ IOS optionally configured with a 32-million-word SSD in the same cabinet for all but the CRAY X-MP/14se
- ☐ IOS located in the mainframe cabinet for the CRAY X-MP/14se

Series 3420 and 3480 tape subsystems. Depending on the model, the IOS includes two to four interconnected I/O processors. Each I/O processor has its own local memory and shares a common buffer memory. For all but the CRAY X-MP/14se, one or two additional I/O processors may be configured.

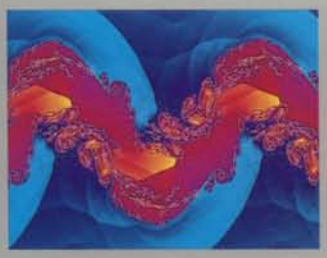
Buffer memory is solid-state secondary storage accessible by all of the I/O processors in the IOS. With its 2, 4, or 8 million words (16, 32, or 64 Mbytes) of static MOS memory, depending on model, it provides I/O buffering of data to and from the peripheral devices. It can also be used to store user datasets, thus contributing to faster and more efficient data access by the CPUs.

The CRAY X-MP systems support up to three channel types, identified by their maximum transfer rates as 6-Mbyte/sec, 100-Mbyte/sec, and 1000-Mbyte/sec. Depending on the CRAY X-MP model, one, two or four 6-Mbyte/sec channels and one, two, or four 100-Mbyte/sec channels are connected to each system. The 100-Mbyte/sec channels are available for transferring data between the IOS and central memory and/or to the SSD.

Disk drives

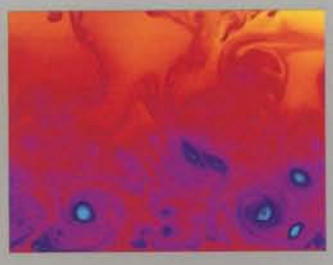
Complementing and balancing CRAY X-MP computing speeds are the DD-49 and DD-39 disk drives, high-density (1200-Mbyte) magnetic storage devices. These disks can sustain transfer rates of 9.6 or 5.9 Mbytes/sec at the user job level with an average seek time of 16 or 18 msec, respectively. When combined with the data handling and buffering capability of the IOS, these disks provide unsurpassed I/O performance.

DD-49 disk drives are typically configured on CRAY X-MP systems other than the CRAY X-MP/14se. For the CRAY X-MP/14se, DD-39 disk drives are standard.



(Left) Simulation showing the instability of a two-dimensional supersonic jet. The jet is traveling at Mach 2 through an ambient gas ten times denser than the jet itself. The image contains nearly 320,000 computational zones, three-fourths of which were generated from symmetry constraints. (Right) Simulation of compressible convection.

An initially unstable equilibrium is shown readjusting so that heat transport is by fluid motion rather than by thermal conduction. Results obtained using the Piecewise-Parabolic Method (PPM) on a CRAY X-MP computer system. (Images this page courtesy Paul Woodward, University of Minnesota. Color schemes by David Helder. © 1985.)



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Effective disk transfer rates can be increased further by the use of optional disk striping techniques. When specified, striping causes system software to distribute a single user dataset across two to five disk drives, depending on the device type. Successive disk blocks are allocated cyclically across the drives and consecutive blocks can thus be accessed in parallel. The resultant I/O performance improvements are in proportion to the number of disk drives used.

Front-end interfaces

CRAY X-MP computers are interfaced to front-end computer systems through the I/O Subsystem. Up to seven front-end interfaces can be accommodated by all but the CRAY X-MP/14se, for which three is the maximum.

Cray Research currently provides front-end interface support for IBM, CDC, DEC, Sperry, and Honeywell systems. Front-end interfaces compensate for differences in channel widths, word size, logic levels, and control protocols between other manufacturers' equipment and the CRAY X-MP system. Users may also elect to use Network Systems Corporation or similar channel adapters in place of one of the front-end interfaces, thus enabling connectivity to many systems.

Fiber optic link

Cray Research's fiber optic link allows a front-end interface to be separated from the CRAY X-MP by distances up to .621 miles (1000 meters) and provides complete electrical separation of the connected devices.

HSX-1 high-speed external channel

The HSX-1, a special high-speed external communications channel, is also available for interfacing very fast devices to the CRAY X-MP system. The HSX-1 provides full duplex point-to-point communication at rates up to 100 Mbytes/sec over distances of up to 70 feet (22 meters). High-speed graphics support is an example of how this channel can be used. Few devices exist today capable of handling the high-speed transfer rates offered by this channel.

The SSD storage device

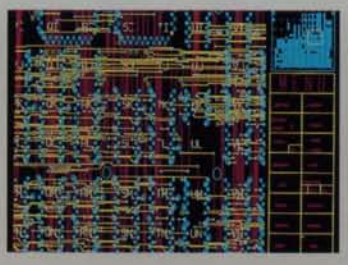
The optional SSD solid-state storage device is a very fast random-access device suited for use with the CRAY X-MP computers. The SSD allows the development of algorithms to solve larger and more sophisticated problems in science and engineering. Note that the SSD is not offered for the CRAY X-MP/14se computer systems.

The SSD is used for large prestaged or intermediate files generated and manipulated repeatedly by user programs. Datasets may be assigned to the SSD by a single control statement without modification of the user program.

System performance is significantly enhanced by the SSD's exceptionally high transfer rates and short data access times. Up to 512 million words (4096 Mbytes) of rapid-access MOS memory may be configured on an SSD. Transfer rates of 100 to 1000 Mbytes/sec per channel and access times of

Electronic design

The complexity of today's electronic circuitry and demands for fast turnaround require the best computational tools for new circuit design. CRAY X-MP computer systems are effective for modeling not only logic circuit layout, but also overall system architecture, timing, and design-rule checking. CRAY X-MP computer systems used for circuit design enable engineers to modify designs repeatedly without incurring the expense of building and testing actual components at each step in the design process.



Design for a large printed circuit board modeled on a Cray supercomputer. Cray computer systems provide the processing speed and memory size engineers need to design the most complex electronic components cost-effectively.

SSD highlights

- Models available in stand-alone cabinets with 64, 128, 256, or 512 million words (512 to 4096 Mbytes) of memory
- SSD with 32 million words located in the IOS cabinet
- Support for two 1000-Mbyte/sec channels for linkage to CRAY X-MP/4 models or one 1000-Mbyte/sec channel for linkage to CRAY X-MP/1 or X-MP/2 models
- SECDED memory protection
- Software support to allow existing programs to use the SSD without program modification
- Direct data path (100-Mbyte/sec channel) between SSD and IOS

less than 25 microseconds are achievable between the SSD and a CRAY X-MP mainframe. Thus, the SSD offers significant performance improvements on I/O-bound applications.

Any SSD in its own stand-alone cabinet is linked to the CRAY X-MP/4 systems via two 1000-Mbyte/sec channels and to the CRAY X-MP/1 and CRAY X-MP/2 models via one 1000-Mbyte/sec channel. The 32-million-word model of the SSD is located in the IOS cabinet rather than in its own stand-alone cabinet.

The SSD can also be connected to the I/O Subsystem. This connection enables data to be transferred between the IOS and the SSD directly, without passing through central memory.

Physical characteristics

Each CRAY X-MP mainframe is extremely compact; keeping wire lengths short minimizes signal propagation times. A CRAY X-MP/14se mainframe consists of six vertical columns arranged in a 135° arc that occupies about 20 square feet (2 square meters) of floor space. A standard CRAY X-MP/1 or CRAY X-MP/2 mainframe consists of eight vertical columns arranged in a 180° arc that occupies about 26 square feet (2.5 square meters) of floor space. And a CRAY X-MP/4 mainframe is composed of 12 vertical columns arranged in a 270° arc requiring just 40 square feet (4 square meters) of floor space.

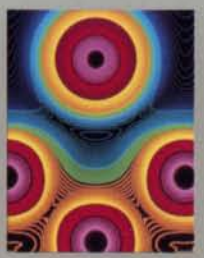
Unlike the other mainframes, the mainframe for the CRAY X-MP/14se houses the IOS as well as the CPU and memory. For all but the CRAY X-MP/14se, the accompanying I/O Subsystem is housed in a separate cabinet that consists of four vertical columns arranged in a 90° arc occupying 24 square feet (2.3 square meters) of floor space.

The optional stand-alone SSD (64 million words or larger) consists of four columns arranged in a 90° arc occupying 24 square feet (2.3 square meters) of floor space. It is connected to the mainframe through one or two short aerial bridgeways, depending on model.

High-speed 16-gate array integrated logic circuits are used in the CRAY X-MP CPUs. These logic circuits, with typical 300- to 400-picosecond propagation delays, are faster and denser than the

Computational physics

In certain fields of physics, such as quantum chromodynamics and condensed matter physics, experimentation is difficult if not impossible. But by tapping the extraordinary processing power of CRAY X-MP computer systems, physicists can experiment on mathematical models of atomic and subatomic structures and thus refine their theories faster than would be possible by any other means.



Charge density contours for an atomic overlayer of cesium on tungsten. Using a Cray system for computation and graphics generation, physicists have investigated the electronic structures of these materials and obtained results impossible to determine analytically. (Courtesy Arthur J. Freeman, Henri J. F. Jansen, and Erich Wimmer, Northwestern University)

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System configuration options

	CRAY X-MP/4	CRAY X-MP/2	CRAY X-MP/1	CRAY X-MP/14se
Mainframe				
CPUs	4	2	1	1
Bipolar memory (64-bit words)	4, 8, or 16M	N/A	N/A	N/A
MOS memory (64-bit words)	N/A	2, 4, 8, or 16M	4, 8, or 16M	4M
6-Mbyte/sec channels	4	4	2 or 4	1
100-Mbyte/sec channels	4	2	1 or 2	1 or 2
1000-Mbyte/sec channels	2	1	1	N/A
Solid-state Storage Device				
Memory size (Mwords)	32, 64, 128 256, or 512	32, 64, 128 256, or 512	32, 64 128 256, or 512	N/A
I/O Subsystem				
I/O processors	2 or 4*	2, 3, or 4	2, 3, or 4	2
Disk storage units	2-32	2-32	2-32	2-8
Magnetic tape channels	1-8	1-8	1-8	0-4
Front-end interfaces	1-7	1-7	1-7	1-3
Buffer memory (Mwords)	4 or 8**	4 or 8	4 or 8	2, 4, or 8***

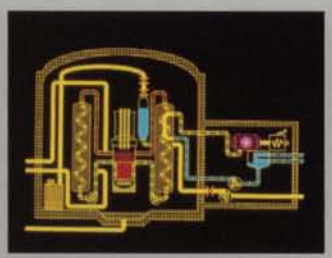
* Two I/O processors are standard on CRAY X-MP/44 and four are standard on larger CRAY X-MP/4 models
** 4 million words of buffer memory on CRAY X-MP/44; 8 million words on larger CRAY X-MP/4 models
*** 2 MW standard
N/A signifies option is not available on the model

circuitry used in the CRAY-1 system. CRAY X-MP/4 memory is composed of ECL bipolar circuits; CRAY X-MP/14se, CRAY X-MP/1 and X-MP/2 memory is composed of static MOS components.

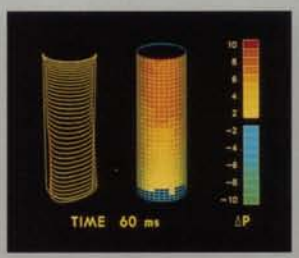
The dense concentration of components requires special cooling techniques to overcome the accompanying problems of heat dissipation. A proven, patented cooling system using liquid refrigerant maintains the necessary internal system temperature, contributing to high system reliability and minimizing the need for expensive room cooling equipment.

Nuclear energy research

Safety studies of nuclear power plants require the most advanced computer systems available. Only super-computers such as CRAY X-MP systems provide the computing power needed to simulate the intricate fluid flow, heat transfer, and neutronics phenomena that occur inside nuclear power plants.



(Left) A pressurized water reactor. The reactor core, primary and secondary heat exchange loops, and containment system are shown. (Right) A cylindrical section of a nuclear reactor core with a calculated three-dimensional pressure field. The color scale indicates the vertical pressure drop (ΔP).



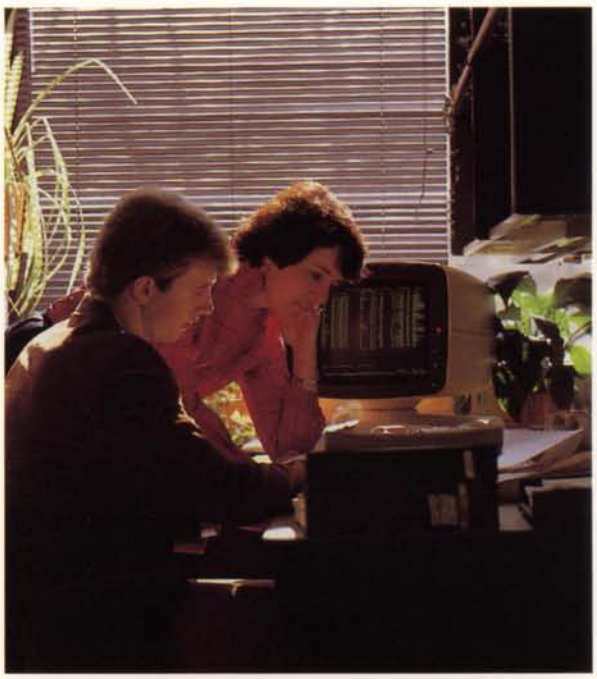
CRAY X-MP software

A full range of software is available for the CRAY X-MP systems, including two Cray proprietary operating systems, COS and UNICOS. UNICOS, based on AT&T's UNIX System V, is available as either a stand-alone operating system or as a guest operating system running concurrently with COS. Cray Research also offers automatic vectorizing ANSI 78 Cray Fortran compilers, extensive Fortran and scientific library routines, program and dataset management utilities, debugging aids, C and Pascal compilers, a powerful Cray assembler (CAL), a wide range of connectivity software, and a wealth of third-party and public domain application codes.

The operating systems, Cray Fortran compilers, and library programs allow users to take advantage of the vectorizing and multiprocessing features of the CRAY X-MP systems.

Cray operating systems

The Cray operating systems, COS and UNICOS, efficiently deliver the full power of the hardware in either an interactive or a batch environment. The Cray operating system is distributed between central memory and the I/O Subsystem. It effectively manages high-speed data transfers between the CRAY X-MP computer and peripherals such as disks, the SSD, and on-line magnetic tapes. Standard system software is also offered for interfacing the CRAY X-MP computer system with other vendors' operating systems and with networks. This is described further later in this section. Each Cray operating system also includes a variety of utility programs that assist in program development and maintenance. UNICOS also offers portability for the CRAY-2 computer systems.

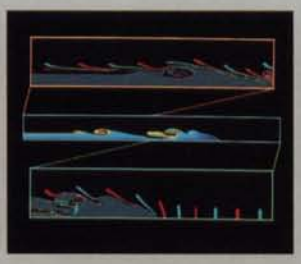


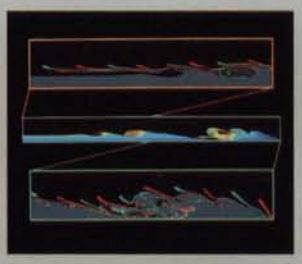
Fortran

Cray Research offers two Fortran compilers for CRAY X-MP systems: CFT and CFT77. Both compilers fully meet the ANSI 78 standards while offering a high degree of automatic scalar and vector optimization. Both permit maximum portability of programs between different Cray systems and accept many nonstandard constructs written for other vendors' compilers. Vectorized object code is produced from standard Fortran code; users need not program nonstandard vector syntax to use the full power of the CRAY X-MP system architecture.

Weather and climate research

Accurate models of the Earth's atmosphere must include variables such as airflow, solar heating, air pressure, and cloud movement. CRAY X-MP systems enable researchers to run the largest and most complex atmospheric models for weather forecasting and climate research.





A Cray system computed these images of an airflow model that shows the development of wind shear, a serious threat to low-flying aircraft. Similar methods are used to study phenomena ranging from tornado formation to acid rain. (Courtesy Kelvin Droegemeier, University of Oklahoma, and Robert Wilhelmson, University of Illinois.)

The compilers are fully supported by highly optimized mathematical and scientific library routines for maximum performance from the CRAY X-MP series of computer systems. CFT77 also offers array syntax, improved performance, and portability to the CRAY-2 and future Cray systems.

Multitasking

CFT and CFT77 both provide multitasking, which is a technique whereby an application program can be partitioned into independent tasks that can execute in parallel on a multiprocessor CRAY X-MP system. Two methods can be used: Fortran-callable subroutines to explicitly define and synchronize tasks at the subroutine level, or a Fortran preprocessor to identify DO loops whose independent iterations may be dispatched to separate processors.

The first method (macrotasking) is best suited to programs with larger, longer-running tasks. The second method (microtasking) is beneficial for programs with shorter running tasks. Later releases of CFT77 will provide automatic multitasking.

Connectivity

CRAY X-MP systems are designed to be connected easily to an existing customer computer environment. A major benefit of this connectivity is that the end user has access to a considerably greater computational resource while continuing to work in a familiar computer environment.

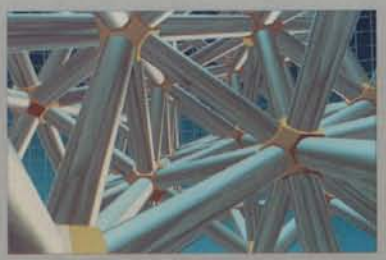
Cray Research offers hardware interfaces that connect the CRAY X-MP system to a wide variety of computers and workstations, including IBM, CDC, DEC, Data General, Sperry, and Honeywell. Additionally, systems may be connected with Network Systems Corporation HYPERchannel adapters or similar channel adapters. The TCP/IP networking suite is available on CRAY X-MP computer systems running UNICOS, providing additional flexibility for integrating a CRAY X-MP system into an open network architecture.

Cray Research also provides software interface support for a variety of other vendors' systems. Station software runs on these systems or workstations and provides the logical connection to CRAY X-MP computers running either COS or UNICOS.

Standard Cray station software is available for the following systems: IBM MVS and VM, CDC NOS and NOS/BE, DEC VAX/VMS, Data General RDOS, Apollo AEGIS, and Bull ROS. UNIX station software is supported for a variety of computers and workstations. In addition, station software for Sperry and Honeywell operating systems is currently available from third-party sources. Cray Research provides additional support with SUPERLINK, a high-performance integrated support processor that transports large amounts of sequential data between the IBM MVS environment and COS.

Advanced graphics

For many supercomputer applications, graphics are needed to help give meaning to the large amounts of data produced. But computer graphics is itself a unique application and one that is revolutionizing commercial animation. Whether in motion pictures, advertisements, or the latest rock video, graphics transport viewers to fantastic worlds built entirely of digital information. CRAY X-MP computer systems can quickly perform the calculations needed to generate the most complex and convincing scenes, eliminating costly sets and props.



Software highlights

- ☐ COS and UNICOS, two powerful operating systems
- ☐ State-of-the-art programming environment for Fortran and other language applications:
  - — Easily accessible performance features (multitasking, vector and scalar processing, I/O, large memory support via SSD)
  - — Optimization tools
  - — Maintenance aids
- ☐ Versatile system utility programs
- ☐ A vectorizing C compiler
- ☐ A vectorizing ISO Level 1 Pascal compiler
- ☐ A wide variety of major application programs
- ☐ Software for connecting CRAY X-MP systems into multi-vendor environments

Thus, the user can access a CRAY X-MP system easily. Data can be transferred between any supported system and the CRAY X-MP system. In many cases, data conversion and reformatting are handled automatically by software. The user can work interactively on a CRAY X-MP system or submit a job to the CRAY X-MP system for processing and have results returned to the originating system or optionally to a different system.

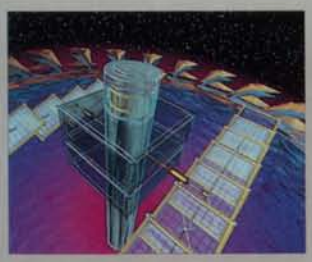
CRAY X-MP systems are supported by communications software and hardware interfaces to meet a variety of customer needs. They can readily join existing environments as a partner in a multi-vendor computing facility.

Application programs

In addition to Cray Research system and application software, a wide variety of third-party and public domain application programs are available for the CRAY X-MP systems. Major application codes are offered for the CRAY X-MP computer series in fields such as computational fluid dynamics, structural analysis, mechanical engineering, nuclear safety, circuit design, seismic processing, image processing, molecular modeling, and artificial intelligence.

Cray Research provides support for the ongoing process of converting and maintaining application software on the CRAY X-MP computer systems. A comprehensive catalog of available programs is published by the Cray Applications Software Library Service.

The above-mentioned software, teamed with an ISO Level 1 Pascal compiler, a sort package, a C compiler, and many other software tools and products, provides users with the software they need to use a CRAY X-MP system to its fullest capabilities.



Computer-generated images produced for television advertisements. These images were produced on a CRAY X-MP computer system at Digital Productions. (Digital Scene Simulation (sm) by Digital Productions, Los Angeles, CA. © 1985. All rights reserved.)

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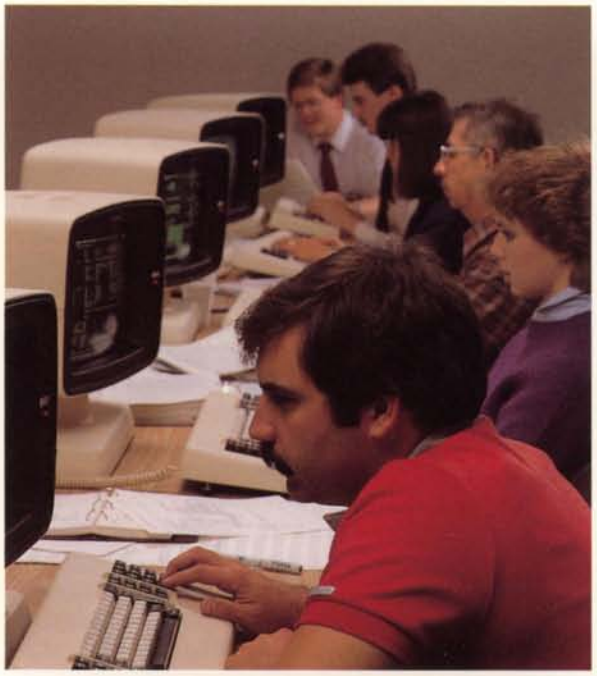
Support and maintenance



Cray Research has developed a comprehensive array of support services to meet customer needs. From pre-installation site planning through the life of the installation, ongoing engineering and system software support is provided locally and through technical centers throughout the company. Cray Research also provides comprehensive documentation and offers customer training on-site or at Cray training facilities.

Cray Research has extensive experience serving the supercomputer customer — over a decade of experience spanning a wide variety of customers and applications. Professional, responsive support from trained specialists is just part of the commitment that Cray Research makes to every customer.

Cray Research recognizes the need for high system reliability while maintaining a high level of performance. The use of higher-density integrated circuits, an overall higher level of component integration, and an increased cooling capacity all ensure that CRAY X-MP system reliability exceeds that of the CRAY-1 system. Components used in CRAY X-MP computers undergo strict inspection and checkout prior to assembly into a system. All CRAY X-MP series computers undergo rigorous operational and reliability tests prior to shipment.

Preventive maintenance techniques identify potential problems before they affect system performance. Diagnostics can be invoked locally at the customer's site or remotely by Cray Research technical support personnel. The Cray maintenance philosophy is to repair and replace modules on-site with minimum system downtime and the highest system availability.

New dimensions

CRAY X-MP computer systems are redefining the state-of-the-art in computational research. Using CRAY X-MP systems, scientists and engineers are solving problems beyond the capabilities of conventional mainframe computers. Cray systems are balanced, general-purpose computing systems that provide researchers in many disciplines with the speed and memory they need to solve leading-edge problems.

The applications described here represent well-established uses of Cray systems. As these applications continue to be refined, many new ones are being developed. Today, CRAY X-MP computer systems are solving complex problems in economic modeling, linear programming, discrete event (battle) simulation, astrophysics, and symbolic processing related to expert systems and artificial intelligence.

Scientists, engineers, and planners in these and many other areas are making discoveries, solving problems, and enhancing productivity through computer modeling. CRAY X-MP computer systems enable users to handle the largest and most complex problems that are solvable today. The capabilities they provide have made Cray systems the standard tools for high-speed scientific computing.

CRAY

The CRAY X-MP series of computer systems — a family of supercomputers that offers flexibility for the broad and growing computational needs of science and engineering.

State-of-the-art technology, outstanding price/performance, flexible and balanced system design, and a commitment to customer support with the resources to provide it — these are the reasons that Cray Research computer systems remain the large-scale computational tool of choice the world over.

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