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 CRAY X-MP Series of Computer Systems

Announcing new levels of supercomputing price/performance to serve the needs of a broadening marketplace: the CRAY X-MP series of computer systems. Today's CRAY X-MP systems represent the evolution of field-proven technologies in use since 1982. First introduced with a 9.5 nsec CPU clock cycle time, the series now features an 8.5 nsec clock. From an exceptional entry-level system with one powerful processor and one million words of central memory to a top-end system with four processors and 16 million words of memory, the 11 models of the CRAY X-MP series of computer systems offer users the broadest range of configuration options available today.

The flexible CRAY X-MP multiprocessor configurations allow users to employ multiprogramming, multiprocessing, and multitasking techniques. The multiple-processor architecture can be used to process many different jobs simultaneously for greater system throughput, or to apply two or more processors to 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. Cray Research software ensures easy access to these performance features. That 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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Each CRAY X-MP CPU offers gather/scatter and compressed index vector instructions. These instructions allow for the vectorized processing of randomly organized data, which previously was performed by scalar processing.

Complementing the power of the CRAY X-MP series is a powerful range of I/O technology. 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, it provides a maximum aggregate transfer rate of 2000 Mbyte/sec. In addition, Cray Research's DD-49 disk drive offers 1200-Mbyte capacity and a very fast sustained transfer rate.

A wide variety of application programs for solving problems in industries such as petroleum, aerospace, automotive, nuclear research, and chemistry are available for operation on CRAY X-MP systems. 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 users' software investments.

CRAY X-MP systems can be integrated easily into existing computer environments. 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 112 square feet (11 square meters) in its maximum configuration, including the SSD storage device.

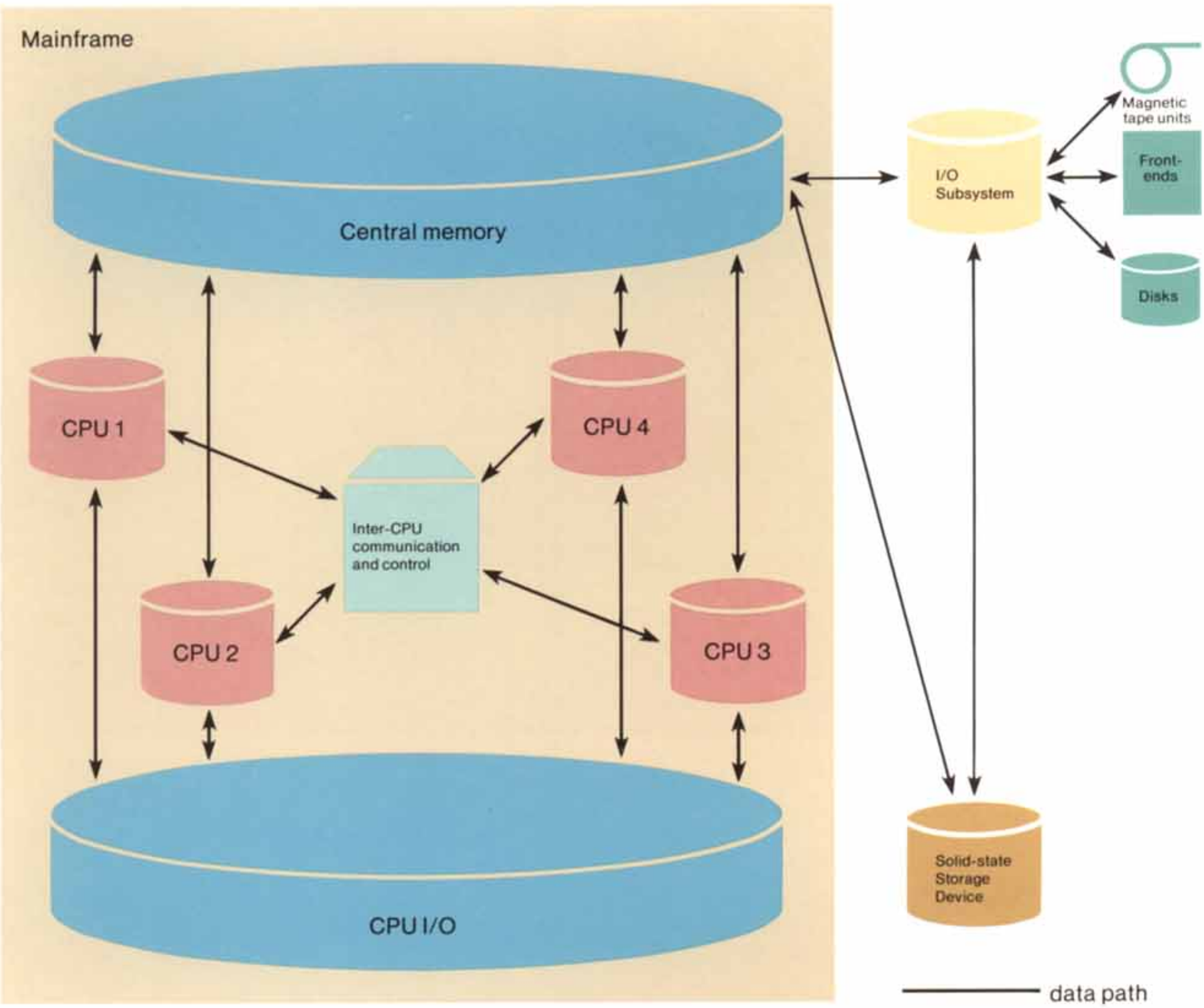
Cray systems offer the most powerful and cost-effective computing solutions available today for advanced scientific applications — both for experienced supercomputer users with the most demanding computing requirements and for newer users whose research needs now require supercomputer power. The CRAY 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.

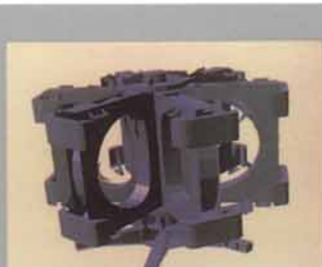
Structural analysis

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.

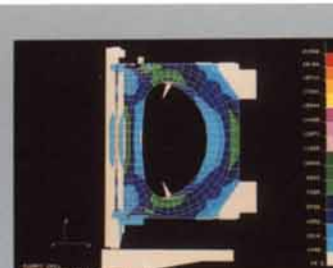
(Left) A 40-ton superconducting electromagnet for use in fusion energy research. A structural analysis was conducted to help set operating levels for a facility housing an array of six such coils. (Right) Solid model of one coil created on a CRAY X-MP computer system with the graphics program MOVIE.BYU.

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.)



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 automakers 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. The CRAY X-MP/4 mainframe is the familiar 12-column 270° arc chassis with the same electrical requirements as the CRAY-1 computer.

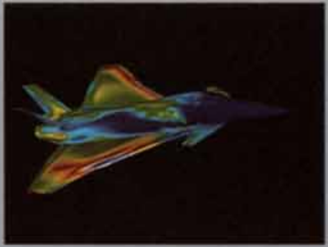
Each of the four CRAY X-MP/4 processors has scalar and vector processing capability and can access all of central memory. The CPUs may operate independently on separate jobs or be organized in any combination to operate jointly on a single job.

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.

In addition to high-capacity, fast access disk technology, 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 the CRAY X-MP/4 systems through two very high-speed channels with a maximum aggregate transfer rate of 2000 Mbyte/sec; the SSD with 32 million words of memory is located in the IOS cabinet. The SSD, in conjunction 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.

Cray Research's DD-49 disk drive matches the power of the CRAY X-MP/4 models, offering 1200-Mbyte capacity, sustained transfer rates of 9.6 Mbyte/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)

The CRAY X-MP/2 systems

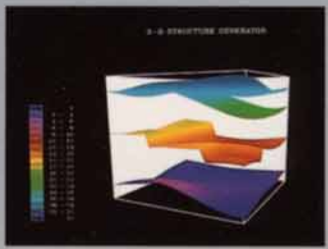
The field-proven CRAY X-MP/2 models have become the established price and performance leaders in the supercomputer industry. Today's CRAY X-MP dual-processor systems offer up to four times the memory and require only half the electrical power of the original CRAY X-MP/2 systems introduced in 1982. Overall 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 memory bank cycle time of 68 nsec. The CRAY X-MP/2 models consist 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, DD-49 disk drives, and SSD hardware as the CRAY X-MP/4 models. One SSD channel, with a total transfer rate of 1000 Mbyte/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 CRAY X-MP/1 models combine a single CRAY X-MP CPU with 1, 2, 4, or 8 million 64-bit words of static MOS memory. Memory bandwidth is four times that of the CRAY-1 computer. Single-processor CRAY X-MP systems typically provide the user with 1.5 to 2.5 times CRAY-1 power at a comparable cost. The CRAY X-MP/1 CPU has an 8.5 nsec clock cycle time and a 68 nsec memory bank cycle time. The CRAY X-MP/1 mainframe is a six-column, 135° arc chassis requiring the same electrical power as the CRAY X-MP/2 computer.

CRAY X-MP/1 models use the same I/O Subsystem and DD-49 disk drives as the larger CRAY X-MP systems and support the same range of SSD models.

With the availability of a wide range of application software and superior price/performance characteristics, the entry-level CRAY X-MP/1 systems are particularly appropriate for the first-time supercomputer customer.

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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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

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 the 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.

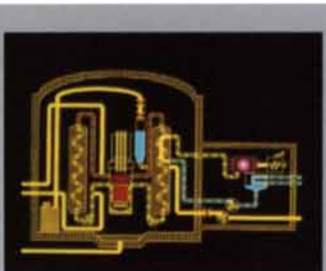
Central memory

Depending on the model, 1 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.

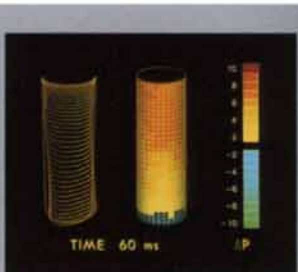
The CRAY X-MP multiprocessor systems share a central memory organized in interleaved memory banks that can be accessed independently and in

Nuclear energy research

Safety studies of nuclear power plants require the most advanced computer systems available. Only supercomputers 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 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 with 1, 2, 4, or 8 million words of MOS memory on the CRAY X-MP/1 systems
- ☐ 8.5 nsec clock cycle
- ☐ 34 nsec (on CRAY X-MP/4 models) or 68 nsec (on CRAY X-MP/1 and CRAY X-MP/2 models) memory bank cycle time
- ☐ 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

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. Ensuring high efficiency, the multiport memory has built-in conflict resolution hardware to minimize delays and maintain the integrity of simultaneous memory references to the same memory bank.

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

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.

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)

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 CRAY X-MP/1 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.

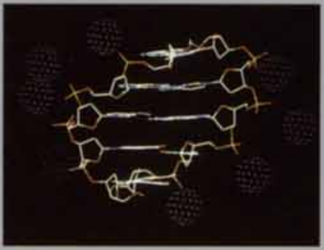
Input/output highlights:

- ☐ 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) network adapters
- ☐ IOS can be configured with a 32-million-word SSD in the same cabinet

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

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)

IBM Series 3420 and 3480 tape subsystems. The IOS includes two, three, or four interconnected I/O processors, each with its own local memory, and a common buffer memory.

Buffer memory is solid-state secondary storage, accessible by all of the I/O processors in the IOS. With its 4 or 8 million words (32 or 64 Mbytes) of static MOS memory, 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.

Complementing and balancing CRAY X-MP computing speeds is the DD-49 disk drive, a high density (1200-Mbyte) magnetic storage device. The DD-49 disk can sustain a transfer rate of 9.6 Mbyte/sec at the user job level with an average seek time of 16 msec. When combined with the data handling and buffering capability of the IOS, the DD-49 provides unsurpassed I/O performance. From 2 to 32 disk drives can be connected to an IOS for up to 38 gigabytes of total disk storage.

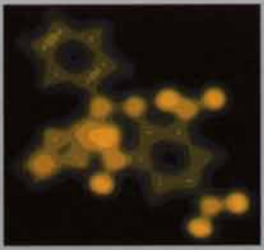
Effective disk transfer rates can be increased further by the use of optional disk striping techniques. When specified, striping causes system software to distribute a single user dataset across two to five disk drives, depending on the device type. Successive disk blocks are allocated cyclically across 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. DD-49 disks may be striped two or three wide.

The CRAY X-MP system supports 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, 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.

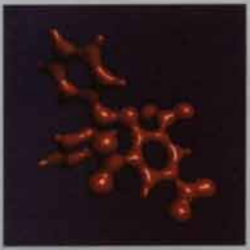
The SSD storage device

The optional SSD solid-state storage device is a very fast random-access device suited for use with the CRAY X-MP systems. The SSD allows the development of algorithms to solve larger and more sophisticated problems in science and engineering.

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



(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.



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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 Mbyte/sec per channel and access times of less than 25 microseconds are achievable between the SSD and a CRAY X-MP mainframe. The SSD offers significant potential for performance improvement on I/O-bound applications, and thus allows users to develop new algorithms that would not otherwise be practical with traditional disk I/O.

SSD highlights:

- ☐ Standalone models available with 64, 128, 256, or 512 million words (512 to 4096 Mbytes) of memory; SSD with 32 million words is 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

The standalone SSD (64 million words or larger) is linked to the CRAY X-MP/4 systems via two 1000-Mbyte/sec channels and to the CRAY X-MP/1 and 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 a separate unit.

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

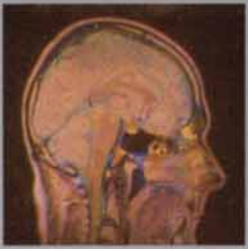
Each CRAY X-MP mainframe is extremely compact; keeping wire lengths short minimizes signal propagation times. A CRAY X-MP/1 mainframe consists of six vertical columns arranged in a 135° arc that occupies only 32 square feet (3 square meters) of floor space. A CRAY X-MP/2 model consists of eight vertical columns arranged in a 180° arc that occupies 43 square feet (4 square meters) of floor space. And a CRAY X-MP/4 system is composed of 12 vertical columns arranged in a 270° arc and requires just 64 square feet (6 square meters) of floor space.

The accompanying I/O Subsystem is composed of four vertical columns in a 90° arc and occupies 24 square feet (2.3 square meters) of floor space.

The optional standalone 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. The 32-million-word SSD is located in the IOS cabinet.

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.

System configuration options

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

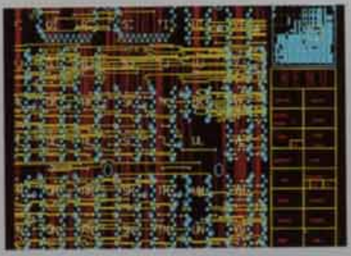
* Two I/O processors on CRAY X-MP/44; four on larger CRAY X-MP/4 models
** 4 million words of buffer memory on CRAY X-MP/44; 8 million words on larger CRAY X-MP/4 models
N/A signifies option is not available on the model

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 circuitry used in the CRAY-1 system. CRAY X-MP/4 memory is composed of ECL bipolar circuits; 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.

Electronic design

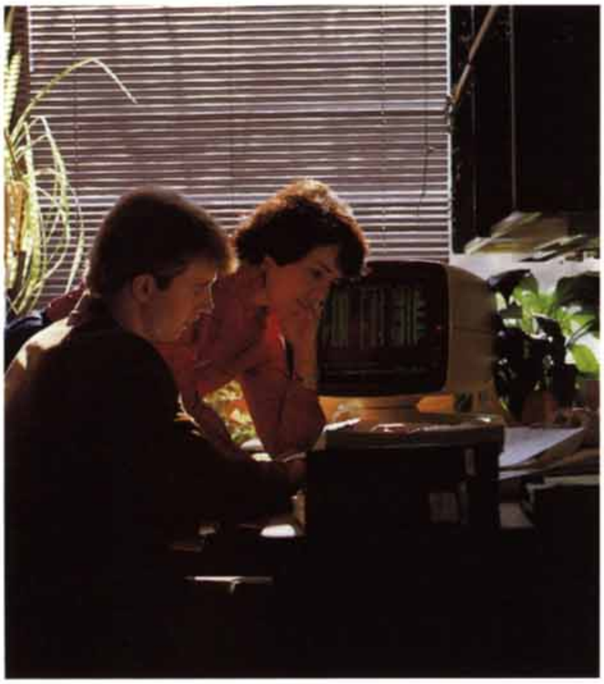
The complexity of today's electronic circuitry and demands for fast turnaround require the best computational tools for new circuit design. CRAY X-MP computer systems are effective for modeling not only logic circuit layout, but also overall system architecture, timing, and design-rule checking. CRAY 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.

CRAY

CRAY X-MP software



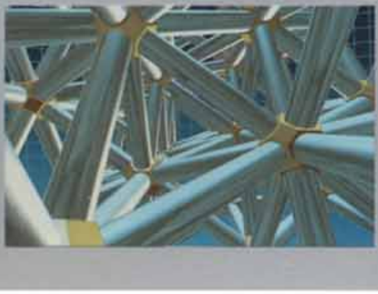
A full range of system and application software compatible with that provided on the CRAY-1 computer systems is available for the CRAY X-MP systems. This software includes two Cray proprietary operating systems, COS and UNICOS. UNICOS, based on AT&T's UNIX System V, is available as either a standalone 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, Pascal, and LISP compilers, a powerful Cray assembler (CAL), and a wealth of third-party and public-domain application codes.

Cray operating systems efficiently deliver the full power of the hardware to both batch and interactive users. Either Cray operating system is distributed between central memory and the I/O Subsystem and 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 on page 16. Each Cray operating system also includes a variety of utility programs that assist in program development and maintenance.

Cray Research offers two FORTRAN compilers for CRAY X-MP systems, CFT and CFT77. CFT fully meets the ANSI 78 standards while offering a high degree of automatic scalar and vector optimization. CFT permits maximum portability of programs between different Cray systems and accepts many

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.



nonstandard constructs written for other vendors' compilers. There is no need for using nonstandard vector syntax to produce vectorized object code. The compiler is fully supported by highly optimized mathematical and scientific library routines for maximum performance from the CRAY X-MP computer series. A new Cray FORTRAN compiler, CFT77, offers array syntax, improved scalar performance, and portability to the CRAY-2 and future Cray systems. Later CFT77 releases will expand the capabilities of automatic vectorizing and provide automatic multitasking.

The operating systems, Cray FORTRAN compilers, and library programs allow users to take advantage of the vectorizing, multiprocessing, and multitasking features of the CRAY X-MP systems. Multitasking 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 large tasks running with dedicated processors. The second method (microtasking) is beneficial for programs with any size tasks running in either a dedicated or a production environment.

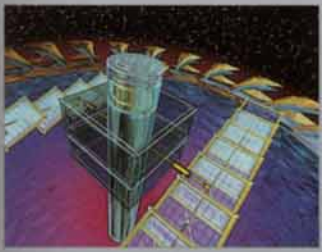
In addition to Cray Research system and application software, a wide variety of third-party and public domain application programs are available for the CRAY X-MP computers. Major application codes are offered for the CRAY X-MP computer series in fields such as computational fluid dynamics, structural 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.

Software highlights:

- ☐ COS and UNICOS, two efficient multiprogramming and multitasking 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
- ☐ C compiler
- ☐ ISO Level 1 Pascal
- ☐ A wide variety of major application programs



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.)

System integration

CRAY X-MP systems are designed to be connected easily to a customer's existing 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 IOS to a wide variety of computers and workstations, including IBM, CDC, DEC, Data General, Sperry, and Honeywell. Additionally, the IOS may be connected to one or more Network Systems Corporation HYPERchannel adapters to configure the CRAY X-MP system in a high-speed local area network. Further, 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.

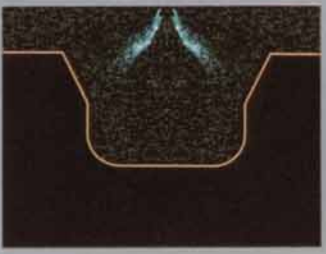
Cray Research also provides software interface support for a variety of other vendors' systems. Station software runs on these systems or workstations and provides the logical connection to CRAY X-MP computers. Standard Cray station software is available for the following systems: IBM MVS and VM, CDC NOS and NOS/BE, DEC VAX/VMS, Data General RDOS, AT&T UNIX, Apollo DOMAIN, and Sun Microsystems workstations. Cray Research provides additional support with SUPERLINK/ISP, a high-performance integrated support processor that transports large amounts of sequential data between the IBM MVS environment and COS. In addition, station software for Sperry and Honeywell operating systems is currently available from third-party sources.

Thus, the user can access a CRAY X-MP system easily. Data can be transferred readily between any supported system and the CRAY X-MP system, with data conversion and reformatting 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.

Supported by communications software and hardware interfaces to meet a variety of customer needs, CRAY X-MP systems can readily join existing environments as a partner in a multivendor computing facility.

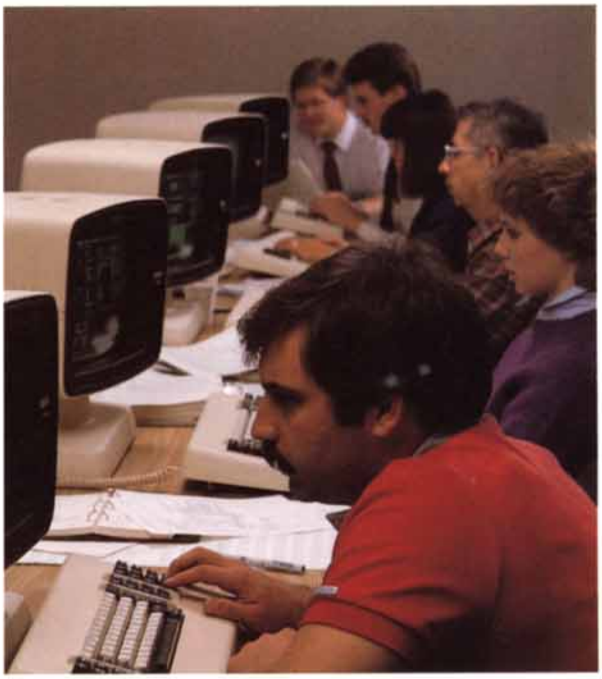
Computational fluid dynamics

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.

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 on-site. Additional assistance is available from technical centers throughout the company. Cray Research also provides comprehensive documentation and offers customer training on-site or at Cray training facilities.

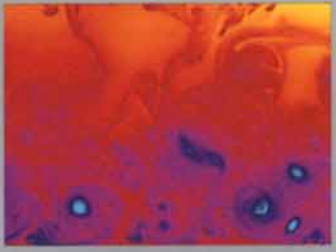
Cray Research has extensive experience serving the supercomputer customer — over a decade of experience spanning a wide variety of users and applications. Professional, responsive support from trained specialists is just part of the commitment that Cray Research makes to every customer.

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.

(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.)



CRAY

CRAY X-MP design detail

Mainframe

CRAY X-MP single- and multi-processor systems are designed to offer users outstanding performance on large-scale, compute-intensive and I/O-bound jobs. Mainframes consist of six (CRAY X-MP/1), eight (CRAY X-MP/2), or twelve (CRAY X-MP/4) vertical columns arranged in an arc. Power supplies and cooling are clustered around the base and extend outward. A description of the major system components and their functions follows.

Hardware features:

- ☐ 8.5 nsec clock
- ☐ One, two or four CPUs, each with its own computation and control sections
- ☐ Large multiport central memory
- ☐ Memory bank cycle time of 34 nsec on CRAY X-MP/4 systems or 68 nsec on CRAY X-MP/1 and X-MP/2 models
- ☐ Memory bandwidth of 25-100 gigabits/sec, depending on model
- ☐ I/O section
- ☐ Proven cooling and packaging technologies

Model	Number of CPUs	Memory size (millions of 64-bit words)	Number of banks
CRAY X-MP/416	4	16	64
CRAY X-MP/48	4	8	32
CRAY X-MP/44	4	4	32
CRAY X-MP/216	2	16	32
CRAY X-MP/28	2	8	32
CRAY X-MP/24	2	4	16
CRAY X-MP/22	2	2	16
CRAY X-MP/18	1	8	32
CRAY X-MP/14	1	4	16
CRAY X-MP/12	1	2	16
CRAY X-MP/11	1	1	16

CPU computation section

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.

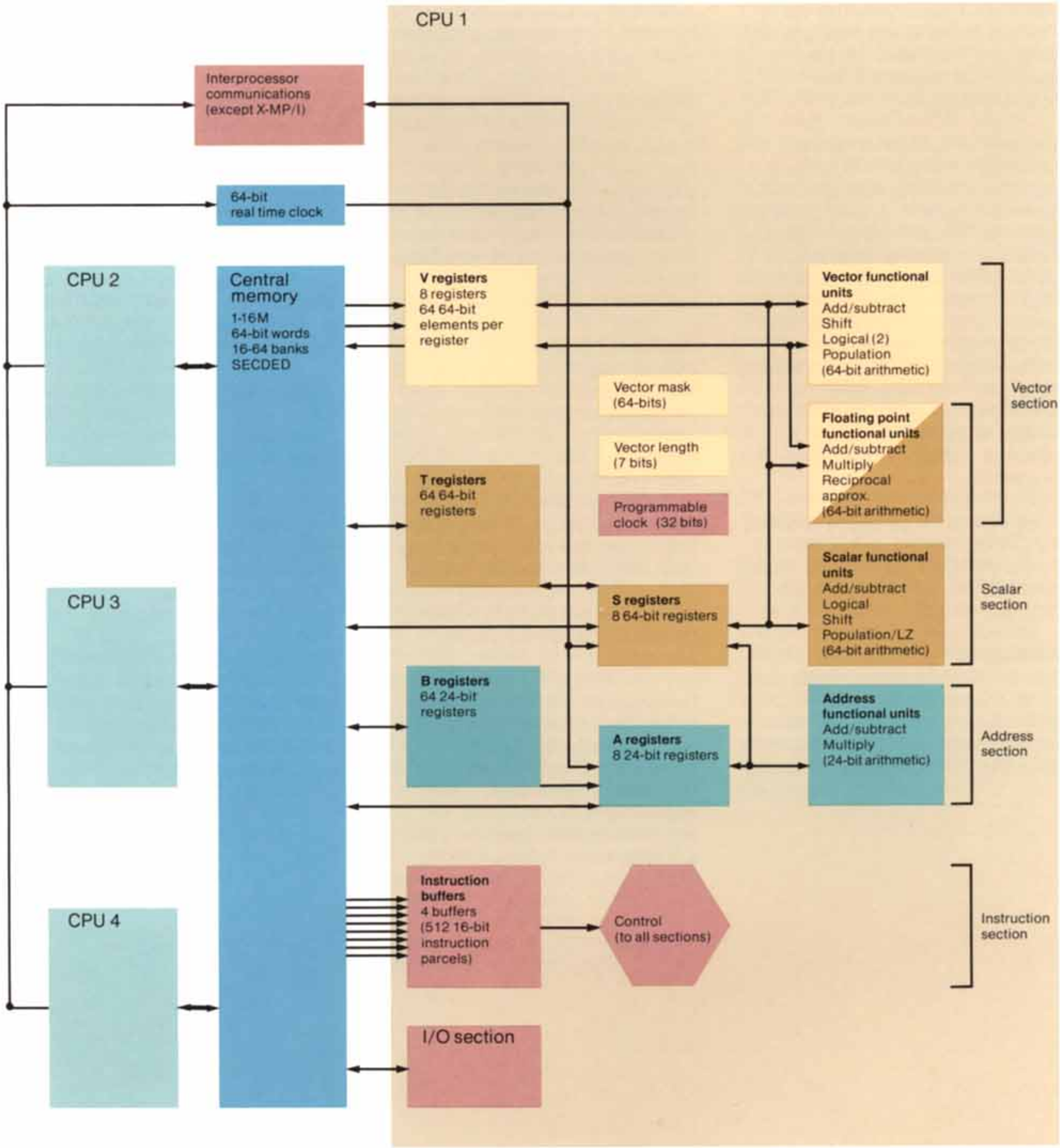
The block diagram of a CRAY X-MP/4 mainframe (opposite page) illustrates the relationship of the registers to the functional units, instruction buffers, I/O channel control registers, interprocessor communications section, and memory. For multiple-processor CRAY X-MP models, the interprocessor communications section coordinates processing between CPUs, and central memory is shared.

Registers

The basic set of programmable registers is composed of eight 24-bit address (A) registers, sixty-four 24-bit intermediate address (B) registers, eight 64-bit scalar (S) registers, sixty-four 64-bit scalar-save (T) registers, and eight 64-element (4096-bit) vector (V) registers with 64 bits per element.

The 24-bit A registers are generally used for addressing and counting operations. Associated with them are 64 B registers, also 24 bits wide. Since the transfer between an A and a B register takes only one clock period, the B registers assume the role of data cache, storing information for fast access without tying up the A registers for relatively long periods.

CRAY X-MP system organization



The 64-bit S registers are used for floating-point, logical, and some integer and character operations. The 64-bit T registers act as cache memory for the S registers. Typically, the B and T registers are used for storing local variables within subroutines.

Each of the eight V registers is actually a set of sixty-four 64-bit registers. The V registers are used for vector operations. Successive elements from a V register enter a functional unit in successive clock periods. The effective length of a vector register for any operation is controlled by a program selectable vector length (VL) register. The vector employed in any calculation need not contain exactly 64 elements. A vector mask (VM) register allows for the logical selection of particular elements of a vector.

In addition to the operating registers, the CPU contains a variety of auxiliary and control registers. These generally are not accessible to a programmer.

Addressing
Instructions that reference data do so on a word basis. Branch instructions, on the other hand, reference parcels within words; the lower two bits of an address identify the location of an instruction parcel in a word. Significantly, the destination of a jump can be any instruction parcel in a 4-million-word instruction segment; word alignment is not required.

The expanded addressing capability in the 8- and 16-million-word systems is accomplished by using 24-bit direct word addressing of data elements while retaining 24-bit parcel addressing for instruction references. In addition, there is a mode that allows the execution of a program that is compatible with conventional 22-bit data addressing.

Hardware supports separation of memory segments for each user's data and program, thus facilitating concurrent programming.

Instruction set
The comprehensive CRAY X-MP instruction set features over 100 operation codes and provides for both scalar and vector processing. Most instructions occupy 16 bits (one parcel); certain branch instructions and memory reference operations occupy 32 bits (two parcels).

Floating-point instructions provide for addition, subtraction, multiplication, and reciprocal approximation. The reciprocal approximation instruction enables CRAY X-MP systems to have a completely segmented divide operation using a floating-point divide algorithm.

Integer addition, subtraction, and multiplication are provided for by the hardware. An integer multiply operation produces a 24-bit result; an addition or subtraction produces either a 24-bit or a 64-bit result. An integer divide is accomplished through a software algorithm using floating-point hardware.

The instruction set includes Boolean operations for OR, AND, exclusive OR, and a mask-controlled merge operation. Shift operations allow for the manipulation of 64-bit or 128-bit operands to produce a 64-bit result. Similar 64-bit arithmetic capability is provided for both scalar and vector processing.

A programmer may index throughout memory in either scalar or vector processing mode. This full indexing capability allows matrix operations in vector mode to be performed on rows, columns, and diagonals and, in general, on any set of data that is stored in memory with regular spacing between elements — with no performance degradation relative to sequentially stored data elements. With gather/scatter, a vector of indices may be used to reference a random pattern of data in memory. Additionally, a compressed or dense index may be generated containing only those items that correspond to some testable condition.

Instructions for population, parity, and leading zero counts (scalar only) return bit counts based on register contents.

Programmable clock
A 32-bit programmable real-time clock that has a frequency of 117.6 MHz, corresponding to an increment of 8.5 nsec, is a standard feature of CRAY X-MP series computers. This clock allows the operating system 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 signed magnitude binary coefficient and a biased exponent. The unbiased exponent range is:

2^{-20000_8} to 2^{+17777_8},

or approximately

10^{-2466} to 10^{+2466}.

An exponent greater than or equal to 2^{+20000_8} is recognized as an overflow condition and causes an interrupt if floating point interrupts are enabled. An exponent less than 2^{-20000} creates an underflow condition and is detected by the floating-point functional units.

Functional units
Instructions other than simple transmit or control operations are performed by hardware elements known as functional units. Each functional unit specializes in implementing algorithms for a specific portion of the instruction set and operates independently of the other units. A functional unit performs its operation in a fixed time called the functional unit time. No delays are possible once the operands have been delivered to a functional unit.

All functional units have one-clock-period segmentation. As a result, information arriving at or moving within the unit is captured and held in a new set of functional unit registers at the end of every clock period. New pairs of operands can thus enter the functional unit each clock period even though the unit may require more than one clock period to complete the calculation.

Functional units can operate concurrently so that, in addition to the benefits of pipelining (each unit can be driven at a result rate of one per clock period), there is also parallelism across the units.

The functional units can be thought of as forming four groups: address, scalar, vector, and floating-point. The first three groups act in conjunction with one of the three primary register types to support address, scalar, and vector modes of processing. The fourth group, floating-point, can support either scalar or vector operations and accepts operands from or delivers results to scalar or vector registers accordingly.

The exchange sequence
Instruction issue is terminated by the hardware upon detection of an interrupt condition. All memory bank and functional unit activity is allowed to finish. To switch execution in order to handle the interrupt, the CRAY X-MP computer executes an exchange sequence. This causes program parameters for the next program to be exchanged with current information in the operating registers. Each program in the system has associated with it a 16-word block called an exchange package containing the parameters used in its execution sequence. Only the address and scalar registers are maintained in a program's exchange package. Exchange sequences may be initiated automatically upon occurrence of an interrupt condition or may be initiated voluntarily by the software.

CPU intercommunication section
The CRAY X-MP CPU intercommunication section, present on CRAY X-MP multiprocessor systems, comprises five (CRAY X-MP/4) or three (CRAY X-MP/2) clusters of shared registers for interprocessor communication and synchronization. Each cluster of shared registers consists of eight 24-bit shared address (SB) registers, eight 64-bit shared scalar (ST) registers, and thirty-two one-bit synchronization (SM) registers.

CRAY X-MP CPU functional units

	Register usage	Time in clock periods
Address functional units		
Addition	A	2
Multiplication	A	4
Scalar functional units		
Addition	S	3
Shift-single	S	2
Shift-double	S	3
Logical	S	1
Population, parity, and leading zero	S	3 or 4
Vector functional units		
Addition	V	3
Shift	V	3 or 4
Full vector logical	V	2
Second vector logical	V	4
Population, parity	V	5
Floating-point functional units		
Addition	S and V	6
Multiplication	S and V	7
Reciprocal approximation	S and V	14

Under operating system control, a cluster may be allocated to zero, one, two, three, or four processors, depending on system configuration. The cluster may be accessed by any processor to which it is allocated in either user or system (monitor) mode. Any processor in monitor mode can interrupt any other and cause it to switch from user to monitor mode. Additionally, each processor in a cluster can asynchronously perform scalar or vector operations dictated by user programs. The hardware also provides built-in detection of system deadlock within the cluster.

Real-time clock
Programs can be precisely timed with a 64-bit real-time clock shared by the processors that increments once each 8.5 nsec.

CPU control section
Each CRAY X-MP CPU contains its own control section. Within each of these are four instruction buffers, each with 128 16-bit instruction parcels, twice the capacity of the CRAY-1 instruction buffer. The instruction buffers of each CPU are loaded from memory at the burst rate of eight words per clock period.

The contents of the exchange package are augmented to include cluster and processor numbers. Increased data protection is also made possible through a separate memory field for user programs and data. Exchange sequences occur at the rate of two words per clock period on the CRAY X-MP computer.

Central memory

CRAY X-MP central memory can be 1, 2, 4, 8, or 16 million words (depending on model). A Cray word is composed of 64 data bits and eight parity check bits. Central memory is shared by the CPUs on multiprocessor systems and is arranged in interleaved banks. The interleaved memory banks enable extremely high transfer rates through the I/O section and provide low read/write times for vector processing. All banks can be accessed independently and in parallel during each machine clock period. Based on an 8.5 nsec clock period, bank cycle time is 34 nsec on CRAY X-MP/4 computers and 68 nsec on CRAY X-MP/1 and X-MP/2 MOS memory models. The table on page 18 indicates memory size and banking arrangements for CRAY X-MP computers.

Each processor of the CRAY X-MP product line has four parallel memory ports: three for vector and scalar operations and one for I/O. The multiport memory has built-in conflict resolution hardware to minimize delays and maintain the integrity of all memory references to the same bank at the same time.

All CRAY X-MP models provide a flexible hardware chaining mechanism for vector processing. This feature enables a result vector to be used at any time as an operand in a succeeding operation. Also, vector chaining to and from memory is possible.

Consider the vector triad operation

$$A(I) = B(I) + S \star C(I)$$

where S is a scalar, B and C are two input vectors, and A is the output vector. The multiple memory access ports on CRAY X-MP systems enable two operands to be read and one to be written simultaneously. Thus, the reads of B and C, the multiply, the add, and the write into A will all chain together and execute in parallel. In general, the CRAY X-MP computer enables memory block transfers to the B, T, and V registers in parallel with vector arithmetic operations.

In addition, the CRAY X-MP system provides hardware support for vector conditionals. Gather/scatter operations (chainable from other vector memory fetches and stores) and compressed-index generation facilitate and speed execution of various conditional vector operations realized from ordinary user programs. All CRAY X-MP systems allow execution of two vector logical operations of the same type at the same time.

Input/output section

The I/O section of the CRAY X-MP system may be equipped with a variety of high-performance channels for communicating with the mainframe, the I/O Subsystem, and the SSD. The latter two devices are high-speed data transfer devices designed to support CRAY X-MP processing speeds.

Model	Channel type		
	1000-Mbyte/sec	100-Mbyte/sec	6-Mbyte/sec
CRAY X-MP/4	2	2	8
CRAY X-MP/2	1	2	8
CRAY X-MP/1	1	1 or 2	8

CRAY X-MP computers support three channel types identified by their maximum transfer rates as 6-Mbyte/sec, 100-Mbyte/sec, and 1000-Mbyte/sec channels. The table above indicates channel support capabilities on CRAY X-MP systems. The 1000-Mbyte/sec channels are used for SSD connections, the 100-Mbyte/sec channels are used for IOS connections, and the 6-Mbyte/sec channels are used for network and front-end connections.

Input/output

I/O Subsystem

The power of the CRAY X-MP system is enhanced by the I/O Subsystem (IOS). The IOS, with its multiple I/O processors (IOPs), acts as a data concentrator and data distribution point for the CRAY X-MP mainframe. A minimum of two IOPs is configured on CRAY X-MP/1 and X-MP/2 systems, and four IOPs are standard on the CRAY X-MP/4 systems. A maximum of four IOPs is possible on all CRAY X-MP computer systems. The IOS handles I/O for a variety of front-end computer systems and for peripherals such as disk units and magnetic tape units. A direct-access path is also available between the IOS and the SSD.

One IOP is always designated as master processor and is used for communication with all front-end computer systems and for controlling maintenance peripherals. Typically, one or two IOPs can be used for controlling disk storage units. IOPs are linked to central memory via one or two 100-Mbyte/sec channels.

When there are three or more I/O processors in an IOS, one can be designated for block multiplexer control. The block multiplexer IOP supports many concurrent data streams, and up to 48 tape units at a time may be configured and active. The tape units supported are IBM-compatible 9-track, 200 IPS, 1600/6250 BPI devices and IBM Series 3480 tape cartridge subsystems. They are connected to the IOP by one to eight block multiplexer channels. The block multiplexer channels operate at 1.5 Mbyte/sec or optionally at 3.0 Mbyte/sec (data streaming model).

IOS buffer memory is a separate independent storage unit composed of 4 or 8 million words of MOS integrated circuits. For a CRAY X-MP/4 system, buffer memory is 8 million words. The IOPs connect to buffer memory through 100-Mbyte/sec ports. Buffer memory is SECDED-protected and is field-upgradable.

The I/O Subsystem IOPs, buffer memory, and controllers are mounted in four columns arranged in a 90° arc with power supplies hidden by benchlike extensions arranged around the outside of the base.

SSD storage device

The SSD is available in sizes of 32, 64, 128, 256, or 512 million words (256 to 4096 Mbytes) of on-line storage. Memory is made of MOS semiconductors and is fully field-upgradable. The SSD is used as an exceptionally fast-access disk device. Datasets are identical to those on disk storage, providing portability and flexibility. Storage on the SSD is allocated as with disk storage; just one job control language statement is required for each dataset assigned to the SSD. Software features allow for SSD resource management including automatic overflow to disk, if required. User data access time can be as little as 25 microseconds. The standalone SSD (64 million words or larger) is linked to the CRAY X-MP/4 systems via two 1000-Mbyte/sec channels and to the CRAY X-MP/1 and X-MP/2 models via one 1000-Mbyte/sec channel. Its cabinet closely resembles the IOS; it consists of four vertical columns arranged in a 90° arc mounted in a bench-like base. The SSD with 32 million words of memory is located in the IOS cabinet. SSD memory is fully equipped with SECDED logic.

DD-49 disk drive

Cray's very high performance DD-49 magnetic storage disk drive supports the data capacity and transfer speed requirements of the CRAY X-MP systems. The DD-49 has a capacity of 1200 Mbytes and can sustain a data transfer rate of 9.6 Mbyte/sec at the user job level. Up to 32 disk drives may be configured on a CRAY X-MP system.

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, identical to those used on the CRAY-1 system, can be accommodated. Users may also elect to supply Network Systems Corporation (NSC) channel adapters in place of one of the front-end interfaces, thus enabling interfacing to many systems. The hardware connection to Sun Microsystems and Apollo workstations is via the NSC HYPERchannel.

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. As an option, a 3-Mbyte/sec fiber optic link is available for any front-end interface to provide front-end connections up to one kilometer distant (.621 miles) and complete electrical separation from the Cray system.

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.

The equipment specifications contained in this brochure and the availability of said equipment are subject to change without notice. For the latest information, contact the nearest Cray Research sales office.

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