The CRAY X-MP Series of Computer Systems

CRAY

For close to a decade, Cray Research has been the industry leader in large-scale computer systems. Today, about 70 percent of all 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 success and experience 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 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 bigger problems while providing better value than any other systems available. Large memory size options allow a wider range of problems to be solved, while 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 today and in the future.

Introducing the CRAY X-MP Series of Computer Systems

Announcing expanded capabilities to serve the needs of a broadening marketplace: the CRAY X-MP Series of Computer Systems. The CRAY X-MP Series now comprises nine models, ranging from a uniprocessor version with one million words of central memory to a top-end system with four processors and a 16-million-word memory. Today's CRAY X-MP line is a field-proven technology; Cray Research introduced the dual-processor CRAY X-MP in 1982 and expanded the series to include one- and four-processor models in 1984.

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 it can apply two or more processors to a single job for better program turnaround time. The combination of multiprocessing and vector processing provides 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 has been developed to ensure easy access to these performance features. The result is that users can realize maximum throughput for a variety of job mixes and programming environments.

A diversity of applications

The spectrum of applications for CRAY X-MP Computer Systems ranges from the subatomic to the celestial. Whether calculating charge densities of atoms or the aerodynamics of spacecraft, CRAY X-MP Computer Systems offer new opportunities for research and discovery.

The CRAY X-MP's many configuration options give users the freedom to tailor systems to meet specific needs. In a business, university or government laboratory, in basic or applied research, Cray systems can be adapted to meet the most varied and demanding computational requirements. As the marketplace for supercomputers has grown in size and diversity, Cray Research has provided new supercomputing performance capabilities.

Applications for Cray systems are well established in numerous high technology fields. The ability to run realistic simulations of complex phenomena and to process enormous amounts of data quickly have made CRAY X-MP systems the standard for securing the most accurate, detailed, enlightening and profitable results. The following pages illustrate real-life applications for which the CRAY X-MP has proven invaluable.

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Each 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 X-MP Series is a new generation of I/O technology. Cray's DD-39 and DD-49 disk drives offer 1200-Megabyte (Mbyte) capacity and very fast sustained transfer rates (9.8 Mbyte/sec for a DD-49, 5.9 Mbyte/sec for a DD-39). In addition, Cray's Solid-state Storage Device (SSD) provides up to 1024 Mbytes of very fast random-access secondary MOS memory. When connected to a four-processor CRAY X-MP through two 1000-Mbyte/sec channels, it provides a maximum aggregate transfer rate of 2000 Mbyte/sec.

A wide variety of applications programs for solving problems in industries such as petroleum, aerospace, automotive, nuclear research and chemistry are available for operation on CRAY X-MP computers. Thus, scientists and engineers can use X-MP systems and industry standard codes to solve a wide range of problems. Additionally, software developed for the CRAY-1 can be run on all models of the CRAY X-MP Series, thus protecting user software investment.

From both a hardware and software standpoint, the CRAY X-MP can be integrated easily into a user's existing computer environment. Hardware and software front-end interfaces for other manufacturers' equipment are available. And the CRAY X-MP requires a minimum of floor space, occupying just 112 square feet (11 square meters) in its maximum configuration, including the Solid-state Storage Device.

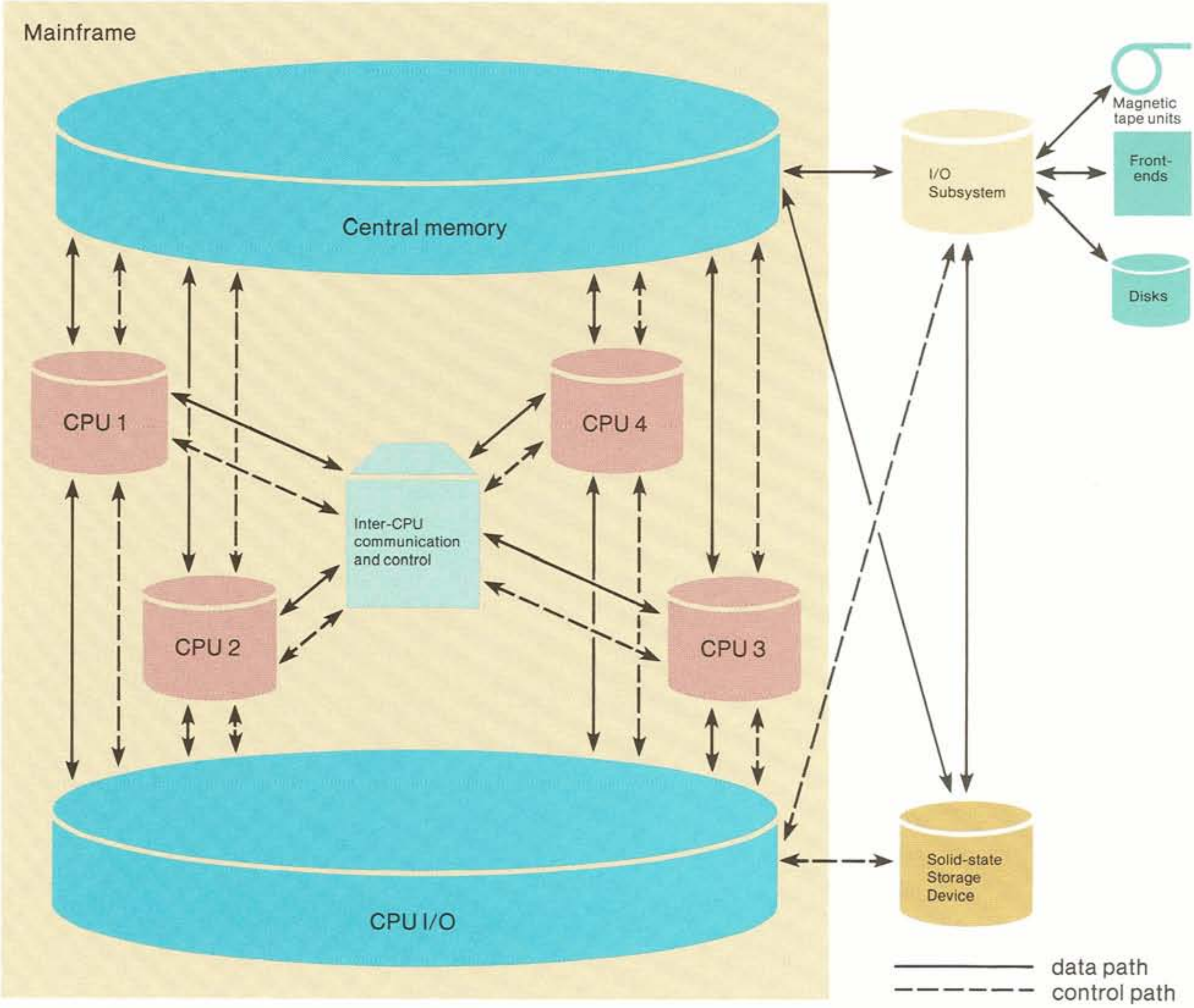
Cray computers offer the most powerful and cost-effective computing solutions available today for advanced scientific applications — both for experienced supercomputer users with the most demanding computing requirements and for newer users whose research needs now require supercomputer power. The CRAY X-MP features one or more powerful CPUs, a very large central memory, exceptionally fast computing speeds and I/O throughput to match. As the supercomputer marketplace broadens, the CRAY X-MP Series of Computer Systems will evolve to meet users' expanding computing requirements.

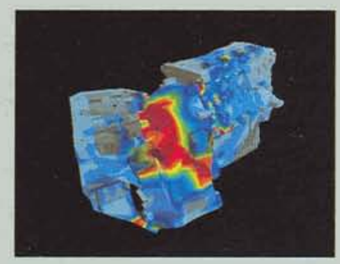
Structural analysis

Finite element analysis is a mathematical method for calculating the effects of temperature- and pressure-related stress on physical structures. The aerospace, automotive and civil engineering industries rely on the method to conduct engineering design and analysis. Using CRAY X-MP systems, scientists 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.

Experimental and computational results of the impact of a nose cone against an angled solid surface. (Left) Actual results and (right) the numerical simulation of this highly nonlinear process. The striking similarity between the two confirms the validity of the computational approach. (Credit: Lawrence Livermore and Sandia National Laboratories.)

CRAY X-MP multiprocessor system organization





Deformed powertrain assembly illustrating strain energy density distribution under first mode of vibration. (Credit: ©1984, Ford Motor Co.)

System overview

Aerodynamic simulation

Airplane designers have long relied on wind tunnel tests to evaluate the aerodynamics of airplanes and airplane sections. But wind tunnel testing requires the time-consuming and costly construction of physical test models. CRAY X-MP supercomputers enable airplane designers to evaluate designs mathematically and to modify designs faster and more cost-effectively than they could by relying solely on wind tunnel tests. In recent years, the auto industry has also begun enjoying the benefits of aerodynamic testing via supercomputer.

(Left) Full model of a Martin-Marietta X24C-10D Lifting Body. (Right) A transverse flow plane (perpendicular to the flight direction) just behind the cockpit. The coloration shows the variation in Mach number. (Far right) Flow plane at the tail of shuttle-like aircraft.

The CRAY X-MP/4 computers

The top-of-the-line CRAY X-MP/4 computer systems offer an order of magnitude greater performance than the original CRAY-1. They are configured with eight or sixteen million 64-bit words of ECL bipolar memory and provide a maximum memory bandwidth 16 times that of the CRAY-1. Central memory has a bank cycle time of 38 nanoseconds (nsec) and is shared by four identical CPUs with a clock cycle time of 9.5 nsec. The X-MP/4 mainframe is the familiar 12-column 270° arc chassis with the same electrical requirements as the CRAY-1.

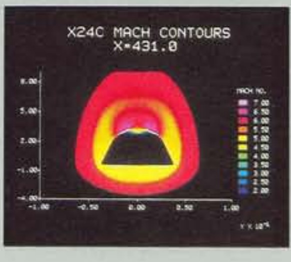
Each of the four CRAY X-MP/4 processors has scalar and vector processing capability and can access all of central memory. The CPUs may operate independently on separate jobs or may be organized in any combination to operate jointly on a single job.

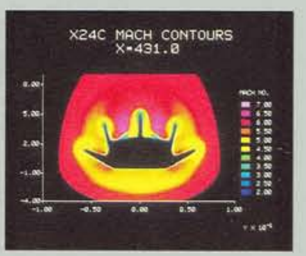
The raw computational power of the CRAY X-MP/4 systems is augmented by the powerful input/output and data-handling capabilities of the CRAY I/O Subsystem (IOS). The IOS is integral to all CRAY X-MP computers and enables fast, efficient data access and processing by the CPUs.

Cray Research's DD-49 disk drive matches the power of the X-MP/4 models, offering 1200-Mbyte capacity, sustained transfer rates of 9.8 Mbyte/sec and very fast access times (2 milliseconds).

In addition to high-capacity, fast access disk technology, the field-proven SSD offers up to 1024 Mbytes of very fast random-access secondary MOS memory. The SSD 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, in conjuction with the 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.

These cross-sections represent three-dimensional airflows as depicted by the Navier-Stokes equations. Their computational requirements make the Navier-Stokes equations the most difficult to solve, but they are also the most accurate. (Credit: W.L. Hankey, S.J. Scherr, J.S. Shang, Air Force Wright Aeronautical Laboratories.)





The CRAY X-MP/2 computers

The field-proven CRAY X-MP/2 models have become the established price and performance leaders in the supercomputer industry. The new 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. Overall throughput is typically three to five times that of a CRAY-1.

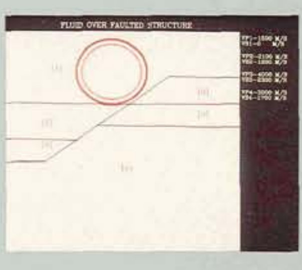
The CRAY X-MP/2 systems are available with four, eight or sixteen million 64-bit words of shared MOS central memory, providing a maximum memory bandwidth four times that of the CRAY-1. Each CPU has a 9.5 nsec clock cycle time and memory bank cycle time of 76 nsec. The CRAY X-MP/2 models consist of eight vertical columns arranged in a 180° arc.

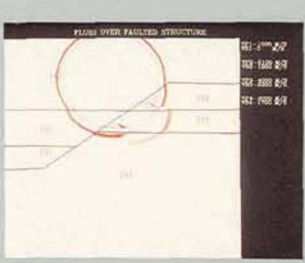
As with the X-MP/4 systems, the CRAY X-MP/2 CPUs can operate independently on different programs or can be harnessed together to operate on a single user program.

CRAY X-MP/2 computers incorporate the same I/O Subsystem and SSD hardware as the X-MP/4 models. One SSD channel, with a total transfer rate of 1000 Mbyte/sec, connects the optional SSD to the mainframe. Typically, the system is configured with DD-49 disk drives.

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 can indicate the presence or absence of 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 systems can perform detailed analyses on these large amounts of data in a timely and cost-effective way, saving petroleum companies time and money.



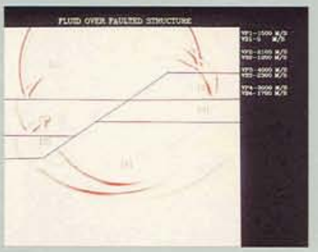


The CRAY X-MP/1 computers

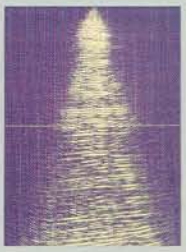
The CRAY X-MP/1 models combine a single CRAY X-MP CPU with one, two, four or eight million 64-bit words of static MOS memory. Memory bandwidth is four times that of the CRAY-1. Single processor CRAY X-MP systems typically provide the user with 1.5 to 2.5 times CRAY-1 power at a comparable cost. The CRAY X-MP/1 CPU has a 9.5 nsec clock cycle time, and a memory bank cycle time of 76 nsec. The X-MP/1 mainframe is a six-column, 135° arc chassis requiring the same electrical power as the X-MP/2.

CRAY X-MP/1 models use the same I/O Subsystem and support the same range of Solid-state Storage Device models as the CRAY X-MP/2 models. Typically, the X-MP/1 is configured with DD-39 disk drives.

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



Color variable density displays of a seismic wave propagation from a fluid through a faulted structure. The full elastic equation was used, demonstrating the conversion of P waves (red) into S waves (blue). (Credit: Dan Kosloff and Moshe Reshef, University of Tel Aviv.)



Common source seismic record after depth migration. It contains 96 traces, each six seconds long and sampled at an interval of four milliseconds, producing a total of 144,000 samples. Hundreds of these records are required to study subsurface geology. (Credit: Geo-Quest International, Inc.)

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. Innovative architecture and technologies built into the CRAY X-MP make such performance a practical reality.

Processors

Each CRAY X-MP processor offers very fast scalar processing with high-speed processing of long and short vectors. Additionally, multiprocessor models enable the user 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 heavy 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.

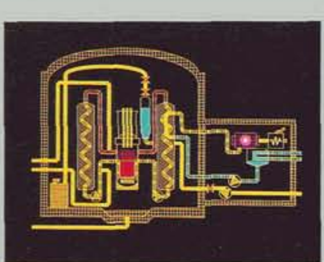
Each X-MP processor also includes instructions for the efficient manipulation of randomly distributed data elements and conditional vector operations. Gather/scatter instructions allow for the vectorization of randomly organized data, and the compressed index instruction allows for the vectorization 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.

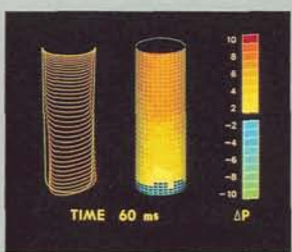
Central memory

Depending on the model, one to sixteen 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 all 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.

Nuclear energy research

Computer simulation of nuclear power plants requires the most advanced computer systems available. Only supercomputers such as the CRAY X-MP provide the computing power needed to simulate the intricate fluid flow, heat transfer and neutronics phenomena that characterize today's nuclear power plants.





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

CRAY X-MP mainframe highlights:

- ☐ Four processors sharing 8 or 16 million words of ECL bipolar memory with the X-MP/4, or
- ☐ Two processors sharing 4, 8 or 16 million words of MOS memory with the X-MP/2, or
- ☐ One processor with 1, 2, 4 or 8 million words of MOS memory, on the X-MP/1
- ☐ 9.5 nsec clock cycle
- ☐ 38 nsec (on X-MP/4) or 76 nsec (on X-MP/1 and X-MP/2) 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 communications and control

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 X-MP processor has four parallel memory ports connected to central memory: two for vector 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. 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 process jobs faster than with single CPUs 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 serially executed programs. Performance improvements are in proportion to the number of tasks that can be constructed 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 CRAY X-MP's extraordinary processing power, 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. (Credit: Arthur J. Freeman, Henri J. F. Jansen, 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 computers can realize speed increases of 1.8 to 1.9 times over single-processor CRAY X-MP 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 has developed hardware that ensures computing power is not held captive by I/O limitations. The architecture of the IOS, 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, 100-Mbyte and 1000-Mbyte channels
- ☐ I/O Subsystem with:
  - Parallel disk streaming capabilities, one controller per disk cabinet
  - I/O buffering for disk- 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

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

Image processing

Earth-imaging satellites, space probes and medical imaging technologies generate tremendous amounts of data. However, the data must often be processed extensively to be useful. The pictures created by digital imaging technology are composed of millions of tiny dots called pixels. Processing the information contained in these pixels in a practical timeframe requires the processing speed of a CRAY X-MP. For everything from scanning the Earth for resources to tracking down deadly tumors, CRAY X-MP systems are ideal for the most sophisticated image processing applications.

Buffer memory is solid-state secondary storage, accessible by all of the I/O processors in the IOS. With its 8, 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 are the DD-39 and DD-49 disk drives, high density (1200-Mbyte) magnetic storage devices. The DD-39 can sustain a data transfer rate of 5.9 Mbyte/sec with an average access time of 18 milliseconds (msec); the DD-49 can sustain a rate of 9.8 Mbyte/sec with an average access time of 16 msec. These disks are the fastest available, and when combined with the data handling and buffering capability of the IOS, they provide unsurpassed I/O performance. From 2 to 32 disk drives can be connected to an I/O Subsystem for up to 38 gigabytes of total disk storage. Typically, DD-49 disks are configured on the CRAY X-MP/4 and CRAY X-MP/2 and DD-39 disks are configured on the CRAY X-MP/1.

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; DD-39 disks may be striped two to five wide.

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

Solid-state Storage Device

The optional Solid-state Storage Device (SSD) is a very fast random-access device suited for use with the CRAY X-MP. The SSD in conjunction with multiprocessor architecture allows the development of algorithms to solve larger and more sophisticated problems in science and engineering.

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

Three Thermatic Mapper images of regions in the Midwest. (Left) An area west of Kansas City, Kansas. (Right) A close-up of the Minneapolis/St. Paul area, and (far right) an area southwest of the Twin Cities.

Each image was produced by Cray Research's CSADIE software on a CRAY X-MP from a 336 million-byte Thermatic Mapper database.

System performance is significantly enhanced by the SSD's exceptionally high transfer rates and short data access times. Up to 1024 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 an 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:

- ☐ Memory size of 256, 512 or 1024 Mbytes
- ☐ Support for:
  - — Two 1000-Mbyte channels for linkage to CRAY X-MP/4
  - — One 1000-Mbyte channel for linkage to CRAY X-MP/1 or X-MP/2
- ☐ SECDED memory protection
- ☐ Software support to allow existing programs to use the SSD without program modification
- ☐ Direct data path (100-Mbyte channel) between SSD and IOS

An 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.

On the CRAY X-MP/4, support is provided to link the SSD to the mainframe via two 1000-Mbyte channels. For linkage to the X-MP/1 and X-MP/2 models, one 1000-Mbyte channel is used.

Physical characteristics

The CRAY X-MP is extremely compact; keeping wire lengths short minimizes signal propagation times. The elegant and compact CRAY X-MP/1 mainframe consists of six vertical columns arranged in a 135° arc that occupies 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 IOS can be positioned up to 19 feet (5.8 meters) from the mainframe.

Graphics

For many supercomputer applications, graphics are needed to display meaningfully the large amounts of data produced. But graphics is itself a unique application. Computer graphics has revolutionized commercial animation. Whether in motion pictures, advertisements or the latest rock video, computer graphics transport viewers to worlds made not of real objects, but of digital information. CRAY X-MP supercomputers provide the speed and memory needed to generate the most complex and convincing visual displays. With Cray systems, animators can create motion picture sequences without using sets or props.

Scene from "The Last Starfighter" motion picture - Gunstar moving through Rylosian clouds. (Credit: Digital Scene Simulation[sm] by Digital Productions, Los Angeles, California, U.S.A. © 1985. All rights reserved.)

System configuration options

	X-MP/1	X-MP/2	X-MP/4
Mainframe			
CPUs	1	2	4
Bipolar memory (64-bit words)	N/A	N/A	8 or 16M
MOS memory (64-bit words)	1, 2, 4 or 8M	4, 8 or 16M	N/A
6-Mbyte channels	2 or 4	4	4
100-Mbyte channels	1 or 2	2	4
1000-Mbyte channels	1	1	2
I/O Subsystem			
I/O processors	2, 3 or 4	2, 3 or 4	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 (Mbytes)	8, 32 or 64	8, 32 or 64	64
Solid-state Storage Device			
Memory size (Mbytes)	256, 512 or 1024	256, 512 or 1024	256, 512 or 1024

N/A signifies option is not available on the model

The optional SSD consists of four columns arranged in a 90° arc occupying 24 square feet (2.3 square meters) and is connected to the mainframe through one or two short aerial bridgeways, depending on model.

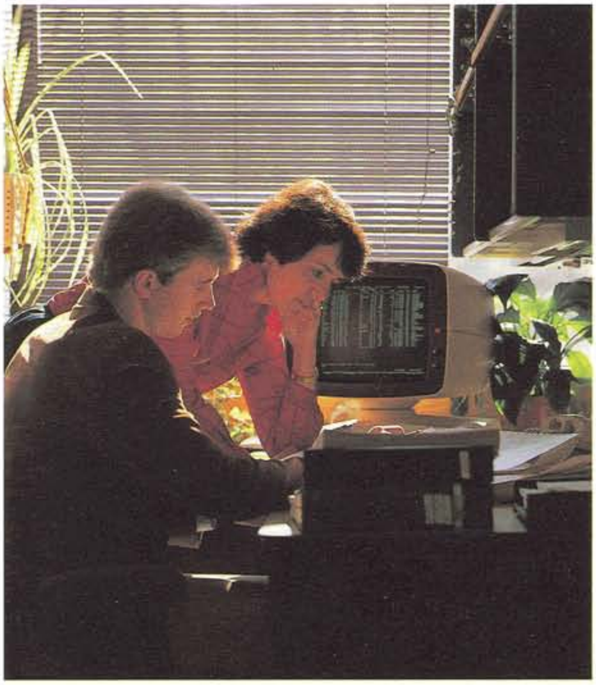
High-speed 16-gate array integrated logic circuits are used in the CRAY X-MP CPUs. These logic circuits, with typical 300 to 400 picosecond propagation delays, are faster and denser than the circuitry used in the CRAY-1. CRAY X-MP/4 memory is composed of ECL bipolar circuits; CRAY X-MP/1 and CRAY X-MP/2 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 cooling maintains the necessary internal system temperature which contributes to high system reliability and minimizes the requirement for expensive room cooling equipment.

A terrain mapping of the San Francisco Bay area developed for real-time emergency assessment. A 7-gigabyte database and a ray-tracing algorithm were used to prepare the image. (Credit: © Patrick Weidhaas, Lawrence Livermore National Laboratory, 1983.)

Characters from "The Adventures of Andre and Wally B" generated on a CRAY X-MP. (Credit: © 1984, Lucasfilm.)

CRAY X-MP software

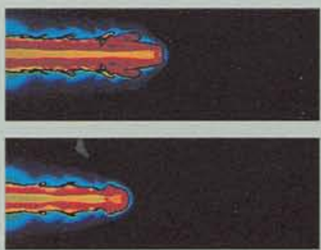


A full range of system and applications software compatible with that provided on the CRAY-1 computer systems is available for the CRAY X-MP systems. This software includes the efficient Cray Operating System (COS), an auto-vectorizing ANSI 78 Cray FORTRAN compiler, extensive FORTRAN and scientific library routines, program and dataset management utilities, debug aids, a selection of compilers, a powerful Cray assembler (CAL) and a wealth of third-party and public-domain application codes.

The operating system, the FORTRAN compiler and library programs are designed to 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.

Computational fluid dynamics

Fluid flow characterizes physical processes ranging from the circulation of gases in the atmosphere to the emission of supersonic jets from galaxies. Although the equations describing fluid physics were identified early in the 19th century, the development of supercomputers made possible the accurate modeling of complex three-dimensional flow fields. Today, CRAY X-MP systems are used for state-of-the-art fluid flow modeling in studies of coating flows, petroleum reservoir simulations and research in the atmospheric and astrophysical sciences.



Evolutionary images of supersonic gas jets boring their way through other gases that are 100 times (left) and 10 times (right) denser. In simulating supersonic gas jets, the combination of color imaging with a Cray system enables one to probe in detail both the dynamics and internal physics of the gas flows. (Credit: Michael Norman, Larry Smarr and Karl-Heinz Winkler.)

The Cray Operating System efficiently delivers the full power of the hardware to both batch and interactive users. The operating system, which is distributed between central memory and the IOS, effectively manages high-speed data transfers between the CRAY X-MP and peripherals such as disks, SSD and on-line magnetic tapes. Standard system software is also offered for interfacing the CRAY X-MP Computer System with other vendor's operating systems and with networks. This is described further under "System Integration". COS also includes a variety of utility programs that assist in program development and maintenance.

Cray's FORTRAN compiler fully meets the ANSI 78 standards while offering a high degree of automatic scalar and vector optimization within these standards. The Cray compiler permits maximum portability of programs between different Cray systems and accepts many nonstandard constructs written for other vendor's compilers. There is no need for using nonstandard vector syntax to produce vectorized object code. The compiler is fully supported by highly optimized FORTRAN and scientific library routines for maximum performance from the CRAY X-MP Series computers.

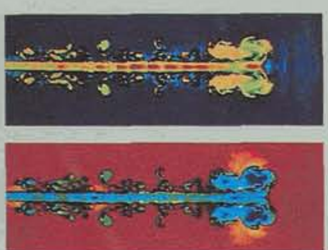
The success of the CRAY-1 stimulated the development of a wide variety of third-party and public domain application programs, which are now available on CRAY X-MP computers. Major applications codes are offered for the CRAY X-MP in fields such as computational fluid dynamics, mechanical engineering, 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 applications software on the CRAY X-MP Series. A comprehensive directory of available programs is published by the Cray Applications Software Library Service.

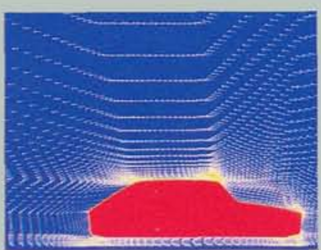
The above-mentioned software teamed with an ISO Level 1 Pascal compiler, a sort package, a C compiler and many other software tools and products, provides users with the software they need to use the CRAY X-MP to its fullest capabilities.

Software highlights:

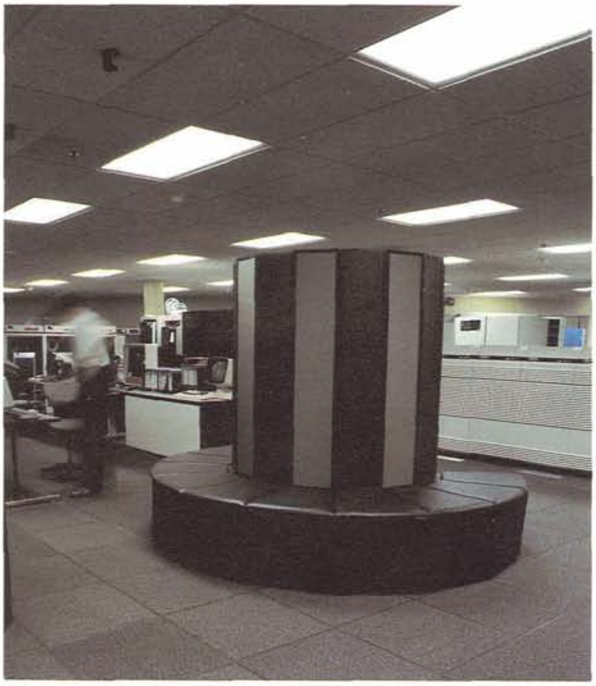
- An efficient multiprogramming and multitasking operating system
- High-performance I/O management
- Versatile system utility programs
- An auto-vectorizing and optimizing ANSI 78 FORTRAN compiler
- Highly optimized scientific libraries
- C compiler
- ISO Level 1 PASCAL
- A sort package
- A wide variety of major application programs



Two-dimensional flow around a fast-back automobile. The image was produced by solving the two-dimensional Navier-Stokes equations.
(Credit: Dornier GmbH, West Germany.)



System integration



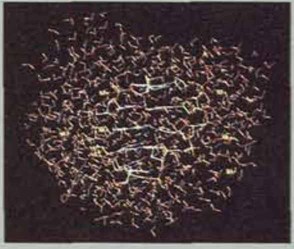
CRAY X-MP Series computers are designed to be connected easily to one or more front-end computer systems. Thus, a CRAY X-MP computer can be added into an existing configuration so that the end user continues to work in a familiar computer environment but now has access to a considerably greater computational resource. Jobs can be submitted from a front-end to the CRAY X-MP for processing and results returned to the user on the originating front-end or optionally to a different front-end. Data can be transferred readily between any front-end system and the X-MP, with data conversion and reformatting handled automatically by software.

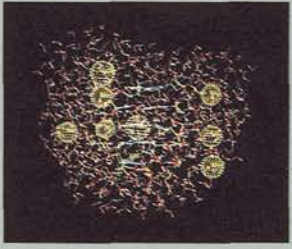
Cray Research offers hardware interfaces that connect the CRAY X-MP I/O Subsystem to a wide variety of front-end equipment, including IBM, CDC, DEC, Data General, Sperry and Honeywell. Additionally, the I/O Subsystem may be connected to one or more Network Systems Corporation HYPERchannel™ adapters for those installations wishing to configure their CRAY X-MP in a high-speed local area network.

Cray Research provides software interface support for a variety of front-end systems. Station software runs on the front-end system and provides the logical connection between other vendors' equipment and CRAY X-MP computers. Standard Cray software is available for the following: IBM MVS and VM, CDC NOS and NOS/BE, DEC VAX/VMS, Data General RDOS and AT&T UNIX™. Station software for Sperry and Honeywell operating systems is currently available from third-party sources.

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 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 millions of atoms long. The detailed and highly iterative mathematics involved in modeling such systems demands the computational capability of the CRAY X-MP.



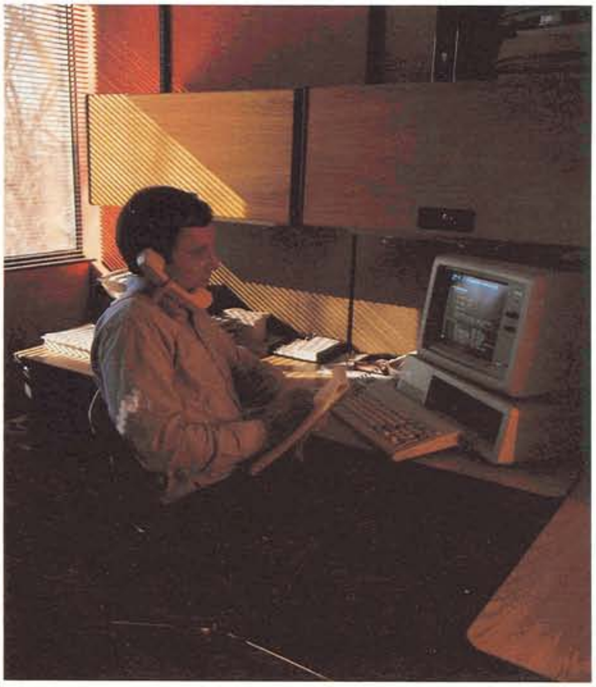


Support and maintenance

Customer support

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 on-site engineering and system software support is provided. Additional assistance is available from technical centers throughout the company.

Cray Research provides comprehensive documentation and offers customer training on-site or at Cray training facilities. Cray Research's responsive customer support program results from extensive accumulated experience in the supercomputer business and from a strong customer orientation.



CRAY X-MP reliability and maintenance

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 X-MP system reliability exceeds that of the CRAY-1. 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 highest system availability.

DNA molecules with water and sodium ions. (Far left) DNA-water-counterion system. (Left) DNA with full surface display of the sodium ions. A 106-picosecond molecular dynamics simulation was performed, and for each step a complicated evaluation of forces involving all 2733 atoms was performed. (Credit: Computer Graphics Laboratory, UCSF.)

Distribution of individual electrons in an oxygen molecule, O_2. One electron has a high probability of being found between the atoms in a "bonding orbital" (far left), while the other electron avoids the region between the atoms representing an "anti-bonding orbital" (left). Near the atomic nuclei, there is a small region where the probability of finding an electron is very high, as illustrated by the spiked regions in the graphs. The power of a CRAY X-MP is required in solving the kind of quantum-mechanical equations used to form these images.

CRAY X-MP design detail

Mainframe

CRAY X-MP single- and multiprocessor systems are designed to offer users outstanding performance on large-scale, compute-intensive and I/O-bound jobs.

CRAY X-MP mainframes consist of six (X-MP/1), eight (X-MP/2) or twelve (X-MP/4) vertical columns arranged in an arc. Power supplies and cooling are clustered around the base and extend outward.

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/216	2	16	32
CRAY X-MP/28	2	8	32
CRAY X-MP/24	2	4	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

Hardware features:

- ☐ 9.5 nsec clock
- ☐ One, two or four CPUs, each with its own computation and control sections
- ☐ Large multiport central memory
- ☐ Memory bank cycle time of 38 nsec on X-MP/4 systems, 76 nsec on X-MP/1 and X-MP/2 models
- ☐ Memory bandwidth of 25-100 gigabits, depending on model
- ☐ I/O section
- ☐ Proven cooling and packaging technologies

A description of the major system components and their functions follows.

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 (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.

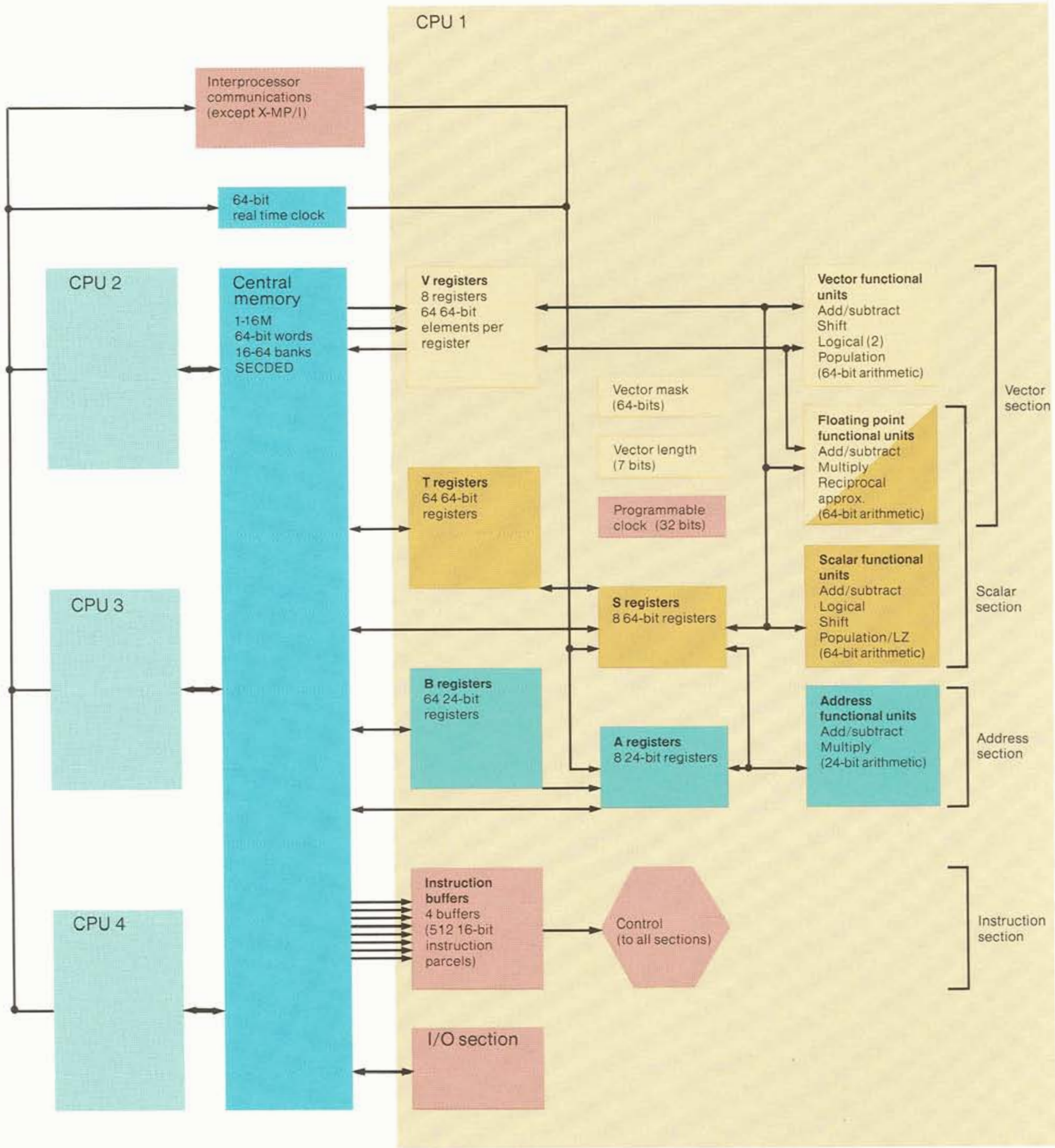
Registers

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
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 four-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 computers 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 for 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, 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.

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Programmable clock
A 32-bit programmable real-time clock that has a frequency of 105 MHz, corresponding to an increment of 9.5 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 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.

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 (see next page). 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 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

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

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.

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 9.5 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.

Central memory

CRAY X-MP central memory can be one, two, four, eight or 16 million words (depending on model). A Cray word is composed of 64 data bits and eight 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 a 9.5 nsec clock period, bank cycle time is 38 nsec on CRAY X-MP/4 computers and 76 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 X-MP computers.

Each processor of the 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

$$A(I) = B(I) + S*C(I)$$

where S is a scalar, B and C are two input vectors, and A is the output vector. The multiple memory access ports on 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 enables memory block transfers to the B, T and V registers in parallel with vector arithmetic operations.

In addition, the CRAY X-MP provides hardware support for vector conditionals. Gather/scatter operations (chainable from other vector memory fetches and stores) and compressed-index generation facilitate and speedup execution of various conditional vector operations realized from ordinary user programs. All CRAY X-MP computers 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 may be equipped with a variety of high-performance channels for communicating with the mainframe, the I/O Subsystem and the Solid-state Storage Device. The latter two devices are high-speed data transfer devices designed to support CRAY X-MP processing speeds.

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

CRAY X-MP computers support three channel types identified by their maximum transfer rates as 6-Mbyte, 100-Mbyte and 1000-Mbyte channels. The table above indicates channel support capabilities on CRAY X-MP systems.

Input/output

I/O Subsystem

The power of the CRAY X-MP 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 X-MP/1 and X-MP/2 systems, and four IOPs are standard on the X-MP/4. 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 I/O processor is always designated as a master processor and is used for communication with all front-end computer systems and for controlling maintenance peripherals. Typically, one or two I/O processors can be used for controlling disk storage units. IOPs are linked to central memory via one or two 100-Mbyte channels.

When there are three or four 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.

IOS buffer memory is a separate independent storage unit composed of 8, 32 or 64 Mbytes of MOS integrated circuits. For an X-MP/4, buffer memory must be 32 Mbytes or larger. The IOPs connect to buffer memory through 100-Mbyte 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. This cabinet may be positioned up to 19 feet (5.8 meters) from the mainframe.

Solid-state Storage Device

The Solid-state Storage Device is available in sizes of 256, 512 or 1024 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.

On the CRAY X-MP/4, the SSD is connected to the mainframe through two 1000-Mbyte channels, while on the X-MP/1 and X-MP/2 systems, this connection is via one 1000-Mbyte channel. SSD memory is fully equipped with SECDED logic.

The SSD cabinet closely resembles the IOS. It is made of four vertical columns arranged in a 90° arc mounted in a bench-like base.

DD-39 and DD-49 disk drives

Cray's very high performance DD-39 and DD-49 magnetic storage disk drives support the data capacity and transfer speed requirements of the largest CRAY X-MP computers. The DD-39 has a capacity of 1200 Mbytes and can sustain a data transfer rate of 5.9 Mbyte/sec. The DD-49 also has a capacity of 1200 Mbytes, however, it can sustain a rate of 9.8 Mbyte/sec.

Up to 32 disk drives may be configured on a CRAY X-MP system. A combination of DD-39 and DD-49 drives may be configured on the same 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 in the CRAY-1, 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 between CRAY X-MP systems and Apollo workstations is via 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.

The CRAY X-MP Series of Computers — a family of supercomputers that offers flexibility for the broad and growing range of science and engineering computational needs at all levels.

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 your local Cray Research sales office.

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