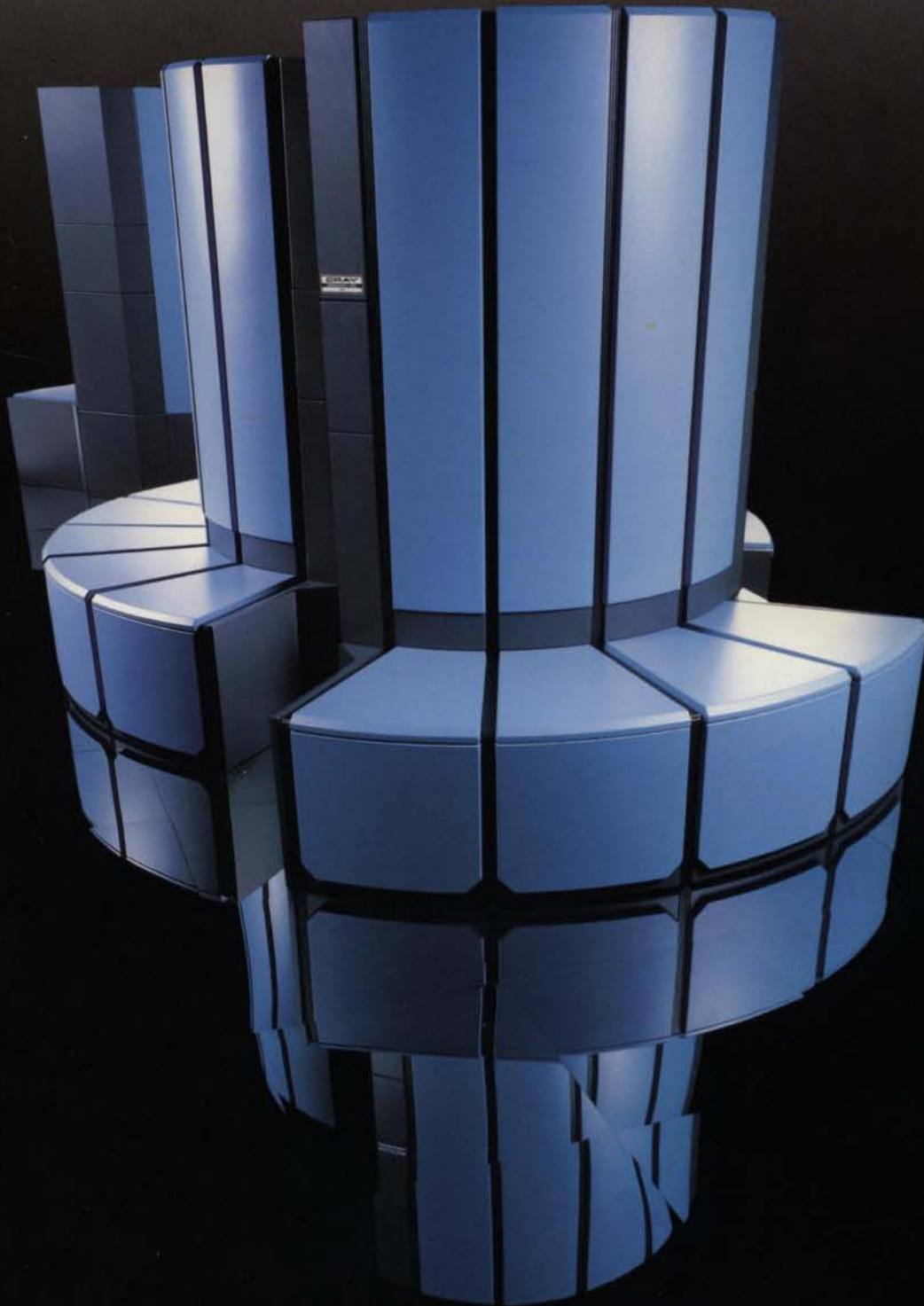


# The Cray Extended Architecture Series of Computer Systems

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**CRAY**

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Cray Research's mission is to develop and market the world's most powerful computer systems. For more than a decade, Cray Research has been the industry leader in large-scale computer systems. The majority of supercomputers installed worldwide are Cray systems. These systems are used in advanced research laboratories and have gained strong acceptance in diverse government, university, and 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. The CRAY-1 computer quickly established itself as the standard for large-scale computer systems; it was the first commercially successful vector processor. 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 routinely by scientists and engineers in a wide variety of disciplines.

The CRAY X-MP series of computer systems was Cray Research's first product line featuring a multiprocessor architecture. The two or four CPUs of the larger CRAY X-MP systems can operate independently and simultaneously on separate jobs for greater system throughput or can be applied in combination to operate jointly on a single job for better program turnaround time. For the first time, multiprocessing and vector processing combined to provide a geometric increase in computational performance over conventional scalar processing techniques.

The CRAY Y-MP computer system, introduced in 1988, extended the CRAY X-MP architecture by providing unsurpassed power for the most demanding computational needs.

Now, Cray Research is pleased to introduce the Extended Architecture series of computer systems. These systems are based on the CRAY Y-MP architecture, offer greater price/performance than the CRAY X-MP series and, with the CRAY Y-MP system, comprise an integrated line of 12 compatible computer systems.

# Introducing the Cray Extended Architecture series of computer systems

Cray Research, the industry leader in large-scale computing, is pleased to provide users with a new choice in supercomputing — the Cray Extended Architecture series of computer systems. The EA series is based on the CRAY Y-MP architecture and builds upon the best features of the field-proven CRAY X-MP series while providing customers with larger memory options and improved price/performance.

The EA series is a broad product family, ranging from entry-level single-processor models to popular two- and four-processor systems all the way up to the powerful eight-processor CRAY Y-MP system.

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

The EA series systems feature large central memories (four million to sixty-four million 64-bit words), enabling users to tackle larger problems with ease. Many of the models in the EA series are field upgradable with regard to number of CPUs and size of memory. The same high-performance software runs on all models of the EA series.



## A universe of applications

Applications for the Extended Architecture series of computer systems range from the subatomic to the celestial. Whether used to compute the charge densities of atoms or to optimize the aerodynamics of spacecraft, Cray EA systems provide scientists and engin-

eers with unique research and problem-solving capabilities.

As the marketplace for supercomputers has grown, Cray Research has provided unequaled hardware performance and flexibility. The range of system configurations in the EA series lets users at all levels of the supercomputing spectrum select systems

that meet their specific needs. In commercial, academic, or government laboratories, in production or research, Cray EA systems adapt easily to the most varied and demanding computational environments.

Customers worldwide enjoy the cost-cutting efficiency and reliable performance that Cray systems provide.

The ability to run realistic models of complex phenomena and to process large data sets quickly make Cray EA systems the standard for computational performance — providing users with their most revealing, precise, and profitable results. The following pages illustrate applications for which Cray systems have proven invaluable.

# CRAY

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

Complementing the power of the EA series is a powerful range of I/O technology managed by the Cray I/O Subsystem (IOS). 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 EA system through two 1000-Mbyte/sec channels, an SSD provides a maximum aggregate transfer rate of 2000 Mbytes/sec. In addition, Cray Research's disk storage units offer high-speed disk storage capacities of up to 20.8 billion bytes (Gbytes) and sustained transfer rates of up to 9.6 Mbytes/sec at the user job level.

A wide variety of applications programs are available for extended architecture systems, helping users solve problems in areas such as reservoir simulation and seismology, aerospace and automotive engineering, nuclear research, graphics and imaging,

and computational chemistry. Thus, scientists and engineers can use extended architecture systems and industry-standard codes to solve a wide range of problems. Additionally, software developed for the CRAY-1 system and earlier CRAY X-MP systems can be run on all models of the Extended Architecture series, thus protecting user software investments.

Cray systems can be integrated easily into a user's existing computer environment. Cray Research offers hardware and software interfaces for many other manufacturers' equipment. EA series systems require a minimum of floor space, occupying just 94 square feet (9 square meters) in the maximum configuration, including the I/O Subsystem and an external SSD solid-state storage device (but excluding electrical and cooling support equipment.)

Cray systems offer the most powerful and cost-effective computing solutions available today for advanced scientific applications — both for experienced supercomputer users with the most demanding computing requirements and for newer users whose research needs now require supercomputer power. The Extended Architecture series 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, Cray systems are evolving to meet users' expanding computing requirements.

### Structural analysis

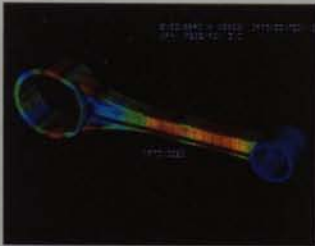
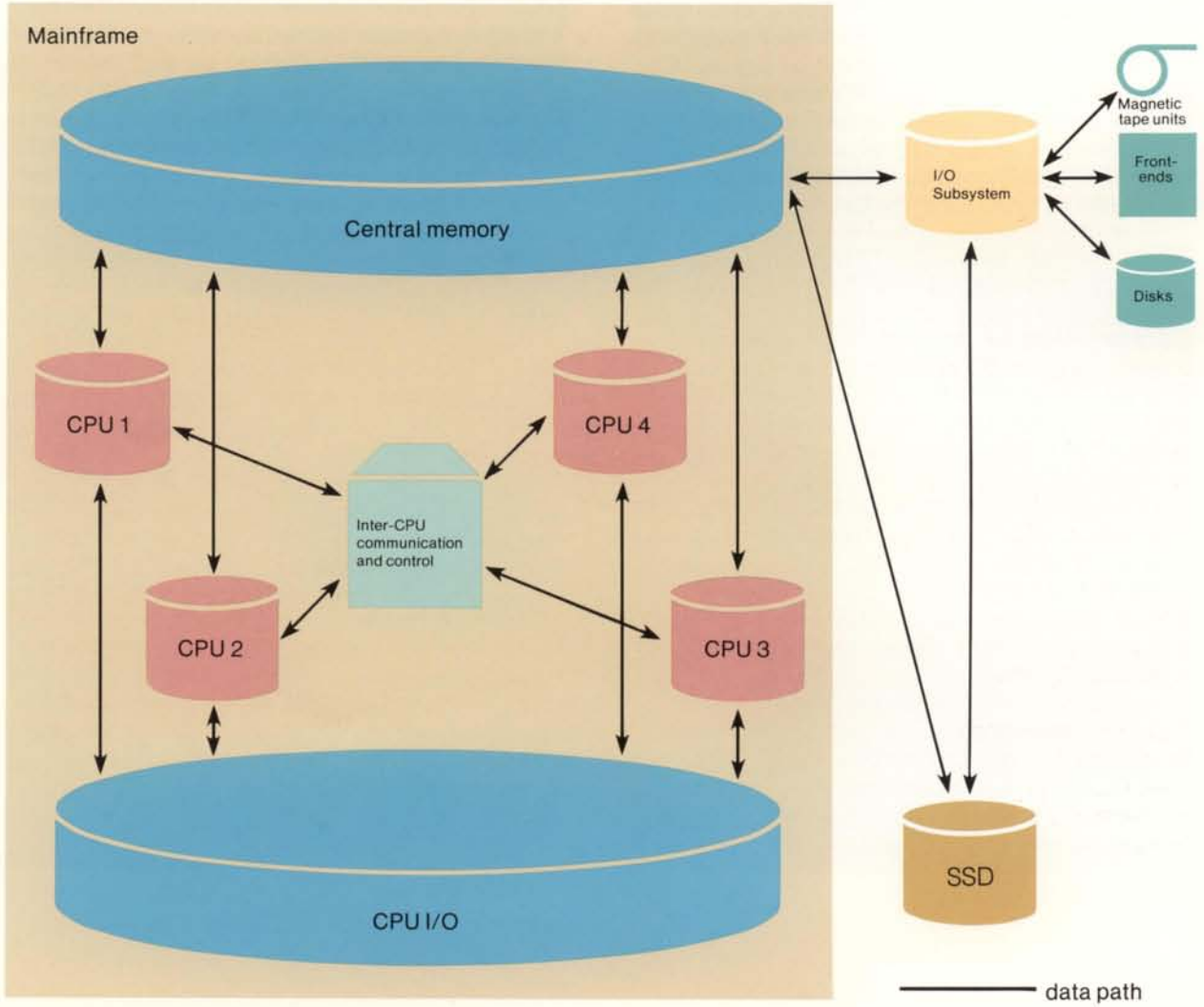
Finite element analysis is a mathematical tool for studying the integrity of physical structures. It enables engineers to simulate the responses of structures to a variety of load and constraint conditions during the design process. Using Cray Extended Architecture

systems, engineers can use finite element analysis to analyze structures too large or complex to be evaluated in any other way, thereby improving engineering efficiency and resulting in more structurally sound and lightweight components.



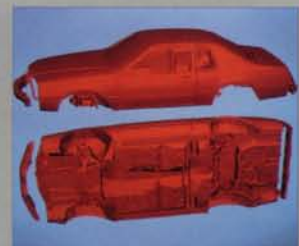
Original (left) and optimized (right) designs for an automobile connecting rod. The analysis revealed an optimized shape that would reduce the weight of the component without compromising its strength. (Courtesy Engineering Design Optimization, Inc., and General Motors Research Laboratories)

## Four-processor Extended Architecture system organization



Model of an automotive differential (left) created on a Cray system with MSC/NASTRAN software and displayed with the MOVIE.BYU graphics package. (Courtesy General Motors Research Laboratories)

(Right) MSC/NASTRAN model of Ford Thunderbird. (Courtesy Ford Motor Company)



# CRAY

# System overview

EA series models are available with one, two, or four processors and with memory sizes of up to 64 million words, while the CRAY Y-MP system offers eight processors and 32 million words of memory.

All Extended Architecture models can run in either CRAY X-MP mode (X-mode) or CRAY Y-MP mode (Y-mode). X-mode uses the instruction set from earlier CRAY X-MP models, while Y-mode uses the

upward-compatible CRAY Y-MP instruction set. This capability allows customers to convert codes run on earlier CRAY X-MP systems to CRAY Y-MP format. The ability to switch between X-mode and Y-mode is software selectable.

The table below lists configuration options for models in the Extended Architecture series.

## Extended Architecture system configuration options

	CRAY Y-MP/8	CRAY X-MP EA/4	CRAY X-MP EA/2	CRAY X-MP EA/1	CRAY X-MP EA/se
<b>Mainframe</b>					
CPUs	8	4	2	1	1
Memory (64-bit words)	32M (bipolar)	16, 32, or 64M	16, 32, or 64M	16, 32, or 64M	4 or 16M
6-Mbyte/sec channels	8	4	4	2 or 4	1
100-Mbyte/sec channels	8	4	2	1 or 2	1 or 2
1000-Mbyte/sec channels	4	1 or 2	1	1	N/A
<b>Solid-state Storage Device</b>					
Memory size (Mwords)	128, 256, or 512	32, 128, 256, or 512	32, 128, 256, or 512	32, 128, 256, or 512	N/A
<b>I/O Subsystem</b>					
	One IOS	Two IOSs			
I/O processors	4	7 or 8	2, 3, or 4	2, 3, or 4	2 or 3
Disk storage units	2 to 24	4 to 48	2-32	2-32	2-8
Magnetic tape channels	1 to 8	2 to 16	1-8	1-8	0-4
Network interfaces	1 to 7	2 to 14	1-7	1-7	1-3
Buffer memory (Mwords)	4 or 8	8, 12, or 16	4, 8, or 32	4, 8, or 32	2, 4, 8, or 32

N/A signifies option is not available on the model.

### 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 Research's Extended Architecture computer

systems enable aircraft designers to evaluate and modify designs faster and more cost effectively than they could by relying solely on wind tunnel tests. In recent years automakers also have begun to enjoy the benefits of aerodynamic testing via super-computer.



Result of Euler calculation performed on a 300,000-grid-element model of an F-15 fighter using the AIRPLANE software package. (Courtesy Antony Jameson and Tim Baker, Princeton University)

## The CRAY X-MP EA/4 systems

CRAY X-MP EA/4 computer systems offer up to ten times greater performance than the original CRAY-1 computer. They are configured with 16, 32, or 64 million 64-bit words of static MOS memory and offer a maximum memory bandwidth 16 times that of the CRAY-1 computer. Models with 32 million words of memory can be field-upgraded to 64-million-word models, and models with 16 million words of memory can be field-upgraded to 32- or 64-million-word models. Central memory has a bank cycle time of 68 nanoseconds and is shared by four identical CPUs with a clock cycle time of 8.5 nanoseconds. Each CRAY X-MP EA/4 mainframe is the familiar 12-column 270° arc chassis and has the same electrical requirements as the CRAY-1 computer and earlier CRAY X-MP computer systems.

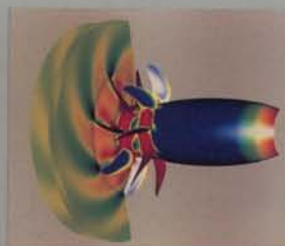
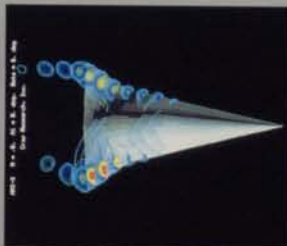
Each of the four CRAY X-MP EA/4 processors has scalar and vector processing capability and can access all of central memory. The CPUs may operate independently on separate jobs or may be organized in any combination to operate jointly on a single job.

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

Cray Research's SSD, in conjunction with the CRAY X-MP EA/4 multiprocessor architecture, enables users to employ existing applications and to develop new algorithms to solve larger and more sophisticated problems in science and engineering — problems that could not be attempted before due to computational or I/O limitations. The field-proven SSD offers up to 512 million words (4096 Mbytes) of very fast random-access secondary MOS memory. An external SSD with 128 million words or more of memory connects to a CRAY X-MP EA/4 system through two very high-speed channels with a maximum aggregate transfer rate of 2000 Mbytes/sec. As an alternative to an external SSD, a 32-million-word or 128-million-word internal SSD can be installed in the IOS cabinet.

Cray Research's DS-40 disk subsystems match the power of the CRAY X-MP EA/4 systems, offering 20.8 Gbyte capacity, sustained transfer rates of 9.6 Mbytes/sec at the user job level, and an average seek time of 16 milliseconds. Cray Research's DD-49 and DD-39 disk drives are also supported.

National Aerospaceplane model showing density contours in cross-flow planes.



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

# CRAY

## The CRAY X-MP EA/2 systems

Field-proven CRAY X-MP EA/2 systems are the most widely installed supercomputers today and, as such, have become the standard in supercomputing. The dual-processor CRAY X-MP EA/2 systems offer up to sixteen times the memory of the original CRAY X-MP/2 systems introduced in 1982. Depending on the application, overall throughput is three to five times that of a CRAY-1 system.

The CRAY X-MP EA/2 systems are available with 16, 32, or 64 million 64-bit words of static MOS shared central memory, providing a maximum memory bandwidth eight times that of the CRAY-1 computer system. Models with 32 million words of memory can be field-upgraded to 64-million-word

models, and models with 16 million words of memory can be field-upgraded to 32- or 64-million-word models. Each CPU has an 8.5-nanosecond clock cycle time and a memory bank cycle time of 68 nanoseconds. Each CRAY X-MP EA/2 mainframe consists of eight vertical columns arranged in a 180° arc. As with the CRAY X-MP EA/4 processors, the CRAY X-MP EA/2 processors can operate independently on different programs or can be harnessed together to operate on a single user program.

CRAY X-MP EA/2 computer systems include the same I/O Subsystem as the CRAY X-MP EA/4 models and can be configured with the same SSD hardware and disk devices. One SSD channel, with a transfer rate of 1000 Mbytes/sec, connects an optional external SSD (128 million words or larger) to the mainframe. As an alternative to an external SSD, a 32-million-word or 128-million-word internal SSD can be installed 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. The large memory and fast processing of Cray Extended Architecture computer systems enable petroleum engineers to perform detailed analyses on these large data sets quickly and cost-effectively, thereby saving the petroleum industry time and money.



Result of prestack depth migration performed with the PREMIG software package.  
(Courtesy GeoQuest International)

## The CRAY X-MP EA/1 systems

CRAY X-MP EA/1 systems combine a single high-performance CPU with 16, 32, or 64 million 64-bit words of static MOS memory. Models with 32 million words of memory can be field-upgraded to 64-million-word models, and models with 16 million words of memory can be field-upgraded to 32- or 64-million-word models. The single-processor CRAY X-MP EA/1 systems are also field upgradable to dual-processor systems, so they provide maximum flexibility as a user's supercomputing needs grow.

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

The upgradable CRAY X-MP EA/1 systems are supported by the same I/O Subsystem as are CRAY X-MP EA/4 systems and CRAY X-MP EA/2 systems. The full range of disk devices and SSD models is available.

The upgradable CRAY X-MP EA/1 systems are appropriate for supercomputer customers requiring high single-processor performance and who want the option of upgrading to a dual-processor system.

## The CRAY X-MP EA/14se and CRAY X-MP EA/116se systems

Two models of the CRAY X-MP EA product line are available for first-time supercomputer users: the CRAY X-MP EA/14se and the CRAY X-MP EA/116se systems. These systems combine a single CRAY X-MP EA CPU with either 4 million or 16 million 64-bit words of static MOS memory. A CRAY X-MP EA/14se system can be upgraded to a CRAY X-MP EA/116se system, but neither can be upgraded to a dual-processor system. The CRAY X-MP EA/14se and CRAY X-MP EA/116se systems are specially packaged and priced to serve both first-time supercomputer users and dedicated project requirements in large-scale computational environments. They support the full range of CRAY X-MP EA software and applications.

In each of these models, the CPU and the I/O Subsystem are contained in six vertical columns arranged in a 135° arc that requires less electrical power than upgradable CRAY X-MP EA/1 systems. Each system supports up to eight disk channels and up to four IBM-compatible tape channels but does not support an SSD connection.

The performance of CRAY X-MP EA/14se and CRAY X-MP EA/116se systems is approximately 80 percent of their upgradable counterparts.

### 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 temperature

and pressure underground, the chemical makeup of the petroleum, and the reservoir's geology. Modeling the interaction of these variables for large volumes of earth requires the computing power Cray Extended Architecture systems provide.



Study of underground microbial injection. Injection pump is at upper left, suction pump at lower right. Color gradient shows varying concentrations of microbes.

CRAY

# Cray Extended Architecture design

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

## Processors

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

Each EA processor offers very fast scalar processing with high-speed processing of long and short vectors. Additionally, multiprocessor models enable users to employ 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.

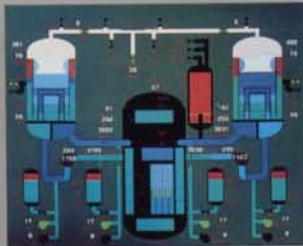
The overall effective performance of each processor executing typical user programs with interspersed scalar and vector codes (usually short vectors) is ensured through fast data flow between scalar and vector functional units, short memory access time for vector and scalar references, and short start-up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

Each 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.

All processors can run in either X-mode or Y-mode.

## Energy research

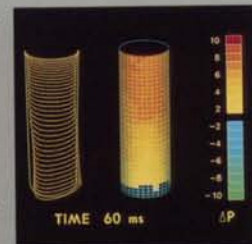
Safety studies of nuclear power plants require the most advanced computer systems available. Only supercomputers such as Cray Research's Extended Architecture systems provide the computing power needed to simulate the intricate fluid flow, heat transfer, and neutronics phenomena



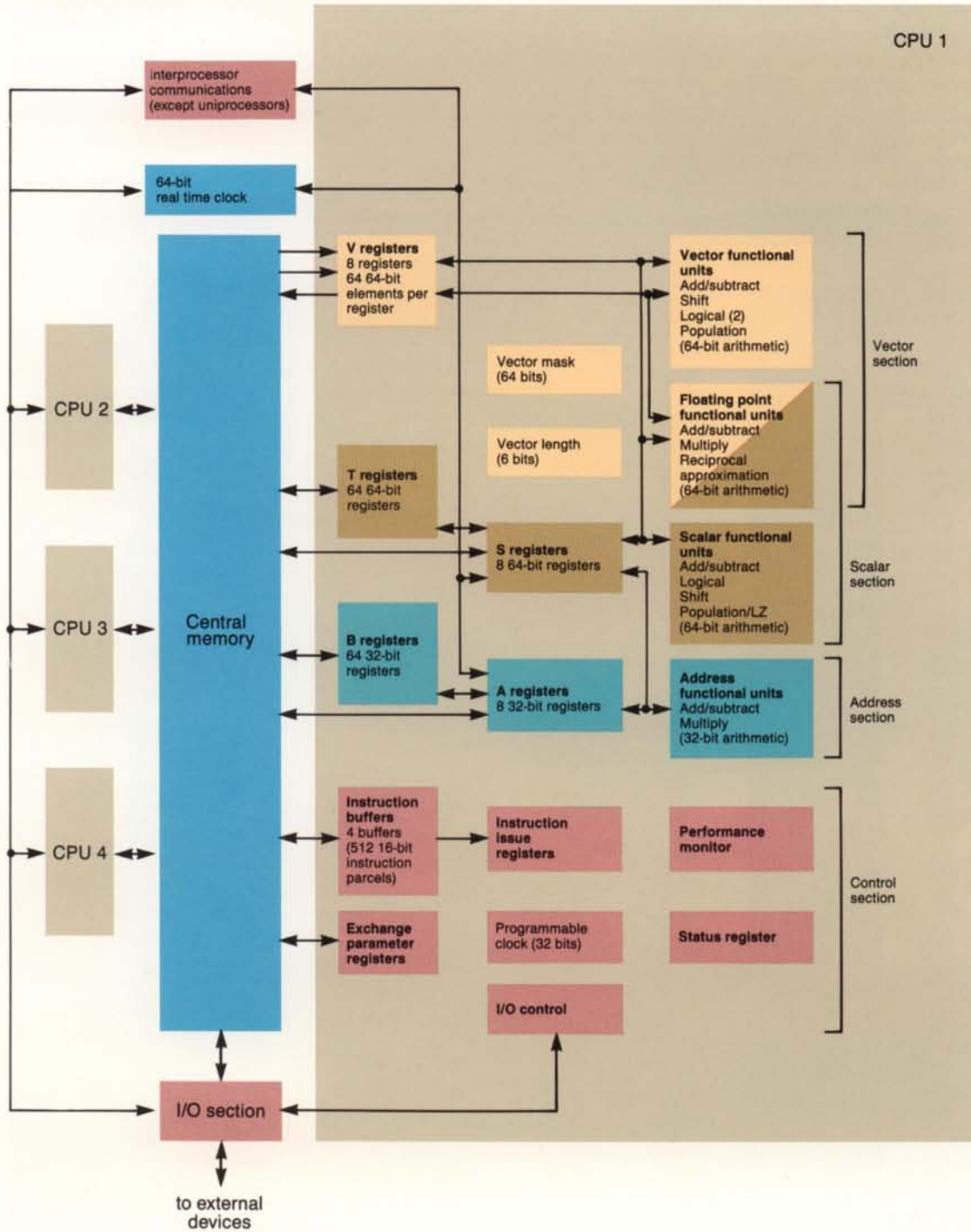
that occur inside nuclear power plants.

Model of a light water nuclear reactor (left) used for thermal hydraulic studies. (Courtesy E. T. Latts, Idaho National Engineering Laboratory)

Cylindrical section of a nuclear reactor core (right) showing calculated pressure field.

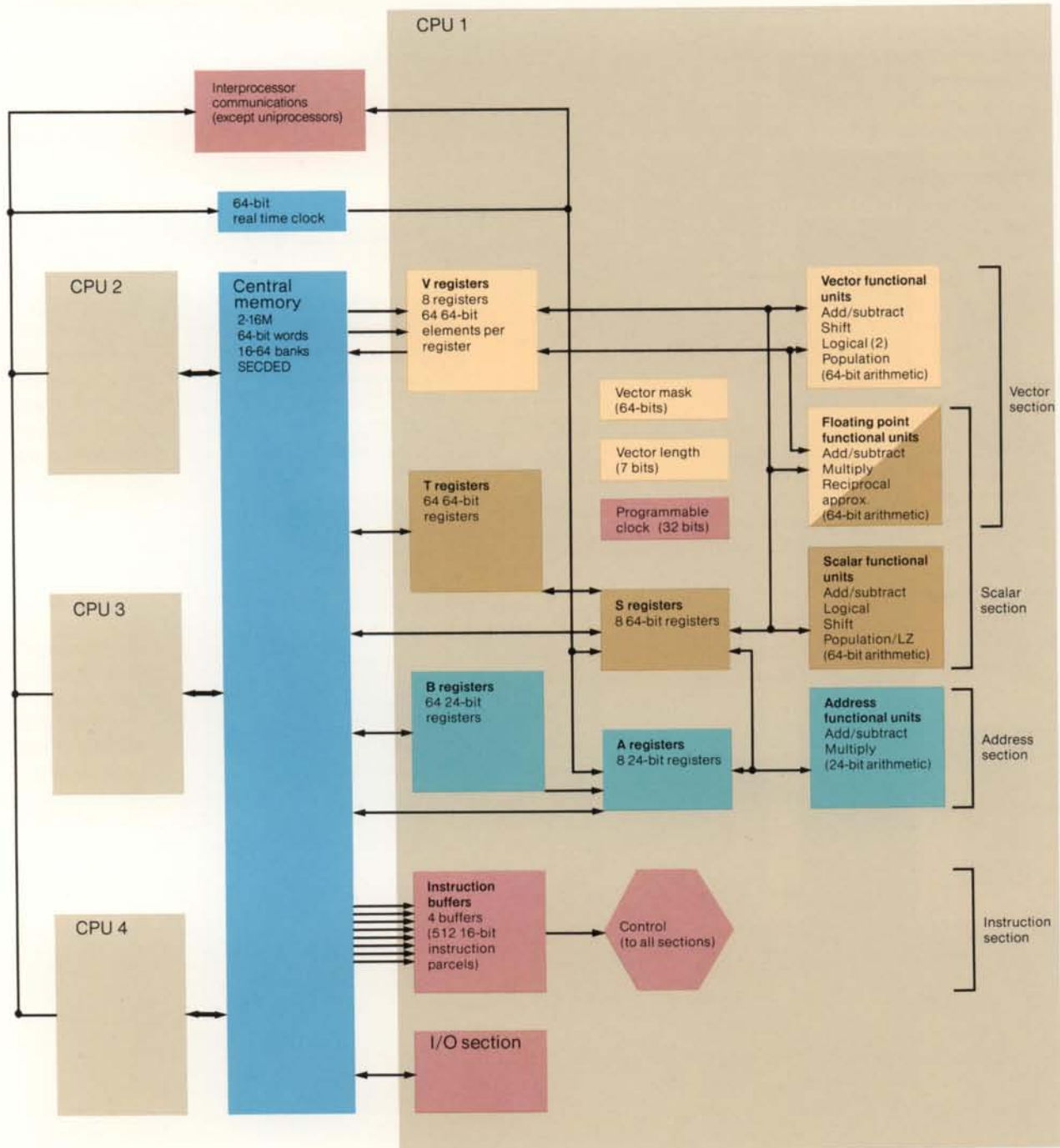


# Four-processor Extended Architecture system block diagram (Y-mode)



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### Four-processor Extended Architecture system block diagram (X-mode)



## Programmable clock

A 32-bit programmable real-time clock that has a frequency equal to the reciprocal of the clock cycle time is a standard feature of the Extended Architecture series of computers. This clock allows the operating system to force interrupts to occur at a particular time or frequency.

## Data structure

The Extended Architecture systems' internal character representation is in ASCII with each 64-bit word able to accommodate eight characters. Scalar integer arithmetic is done in 64-bit 2's complement mode. Floating point numbers (64-bit quantities) consist of a 48-bit signed magnitude binary coefficient and a 15-bit biased exponent. Address arithmetic is done in 32-bit 2's complement mode.

## Central memory

Depending on the model, up to 64 million 64-bit words of directly addressable memory is available with the Extended Architecture 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. Extended Architecture memory features single-bit error correction, double-bit error detection (SECDED) logic.

Multiprocessor Extended Architecture systems share a central memory organized into interleaved memory banks that can be accessed independently and in parallel during each machine clock period. Each 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 system has four times the memory bandwidth of a CRAY-1 system. The multiport memory has built-in conflict resolution hardware to minimize delays and maintain the integrity of simultaneous memory bank references.

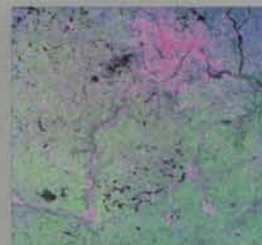
The interleaved multiport memory design, coupled with the short memory cycle time, provides high-performance memory organization with sufficient bandwidth to support high-speed parallel CPU and I/O operations.

### Image processing

Imaging technologies used in satellite surveillance and medical diagnosis often require extensive data processing to create useful images. Cray Research's Extended Architecture computer systems are ideal for rapidly processing the vast amounts of data that such technologies generate.



Magnetic resonance image of a human profile (left) and Thematic Mapper image produced from Landsat data showing an area southwest of Minneapolis-St. Paul, Minnesota.



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### Extended Architecture highlights

- ❑ One processor with 4 or 16 million words of MOS memory on the CRAY X-MP EA/14se and CRAY X-MP EA/116se systems, respectively
- ❑ One, two, or four processors sharing 16, 32, or 64 million words of MOS memory on other systems
- ❑ 8.5-nsec clock cycle on CRAY X-MP EA systems
- ❑ 10.0-nsec clock cycle on CRAY X-MP EA/14se and CRAY X-MP EA/116se systems
- ❑ SECEDED memory protection
- ❑ Four parallel memory ports per processor
- ❑ Flexible hardware chaining for vector operations
- ❑ Gather/scatter and compressed index vector support
- ❑ Flexible processor clustering for multitasking applications
- ❑ Dedicated registers for efficient interprocessor communications and control
- ❑ X-mode and Y-mode instructions

## Multiprocessors and multitasking

The Extended Architecture multiple-CPU configurations have made Cray Research the recognized leader in multiprocessing. They 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 pro-

grams serially executed on a single CPU. Performance improvements are in proportion to the number of tasks that can be made to operate in parallel for the program and the number of CPUs that can be applied to the separate tasks.

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

Customers can expect multitasked applications running on CRAY X-MP EA/2 systems to realize speed increases of 1.8 to 1.9 times over upgradable CRAY X-MP EA/1 model execution times; speed increases of 3.5 to 3.8 times are possible with the CRAY X-MP EA/4 systems.

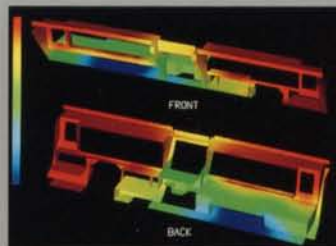
## Input/output processing

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 (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.

### Computational fluid dynamics

Fluid flow characterizes physical processes ranging from a yacht's cleaving the surface of a body of water to the flow of plastic through an injection mold. The equations that describe fluid flow were formulated early in the nineteenth century, but until the

advent of supercomputers, no practical means existed to solve them precisely. Today, Cray Extended Architecture computer systems make possible state-of-the-art fluid flow modeling for studies of coating flows, plastic injection and extrusion, watercraft hydrodynamics, and other applications.



Injection molding simulation of an automobile dashboard created with the C-FLOW software package. Colors correspond to pressure variations as the plastic advances through the mold. (Courtesy Advanced CAE Technology, Inc.)

The I/O Subsystem is an essential part of the extended architecture design and acts as a data distribution point for the mainframe. The IOS handles I/O for many front-end computer systems and peripherals, such as disk units and plug-compatible IBM Series 3420 and 3480 tape subsystems. The IOS includes two to four interconnected I/O processors. Each I/O processor has its own local memory and shares a common buffer memory.

The internal IOS configured with the CRAY X-MP EA/14se and CRAY X-MP EA/116se includes two or three I/O processors.

Buffer memory is secondary solid-state storage, accessible by all of the I/O processors in the IOS. With its 2, 4, 8, or 32 million words (16, 32, 64, or 256 Mbytes) of static MOS memory, depending on model, it provides I/O buffering of data to and from the peripheral devices. It can also be used to store user datasets, thus contributing to faster and more efficient data access by the CPUs.

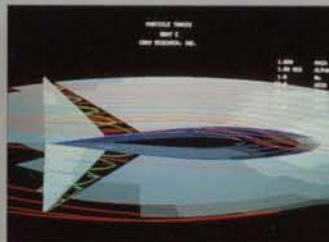
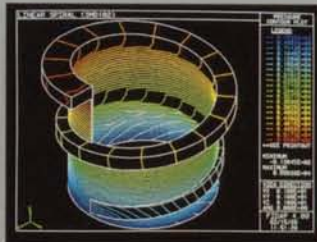
The Extended Architecture series of computer systems support up to three channel types, identified by their maximum transfer rates as 6-Mbyte/sec, 100-Mbyte/sec, and 1000-Mbyte/sec. Depending on the CRAY X-MP EA model, one, two, or four 6-Mbyte/sec channels, one, two, or four 100-Mbyte/sec channels, and one or two 1000-Mbyte/sec channels can be configured on each system. The 6-Mbyte/sec channels pass control information between central memory and the IOS or between central memory and network interfaces. The 100-

Mbyte/sec channels transfer data between central memory and the IOS or between the IOS and the SSD. The 1000-Mbyte/sec channels transfer data between central memory and the SSD.

#### 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
  - Network interface through Cray Research FEI-3 interface and Sun or other workstation
  - Linkage to workstations through Network Systems Corporation (NSC) or similar network adapters
  - Front-end system communication with IBM, CDC, DEC, Honeywell, Data General, and UNISYS computer systems
  - Fiber Optic Link
  - High-speed external channel
- IOS optionally configured with a 32-million-word or 128-million-word SSD in the same cabinet for all but the CRAY X-MP EA/14se and CRAY X-MP EA/116se
- IOS located in the mainframe cabinet for the CRAY X-MP EA/14se and CRAY X-MP EA/116se

Simulation of plastic tube extrusion through a spiral die showing surface pressure contours. Simulation performed with the FIDAP software package. (Courtesy Dennis Coyle, General Electric Co.)



Particle traces over keel and winglets for the yacht *Stars & Stripes*, winner of the 1987 America's Cup.

CRAY

## Peripheral devices

To help customers obtain the maximum benefit from the Extended Architecture systems, Cray Research offers many peripheral devices, including data storage units and communications products.

### Disk storage units

Cray Research's high-density, high-speed disk storage units complement and balance the high computing speeds of Cray systems. The top-of-the-line DS-40 disk subsystem has a capacity of 20.8 Gbytes. The DD-49 and DD-39 disk drives are also supported; both have capacities of 1.2 Gbytes. All these disk units can sustain transfer rates of up to 9.6 Mbytes/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, these disk units provide superior I/O performance.

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.

## Network interfaces

Systems in the Extended Architecture series connect easily to existing computer environments. A major benefit of this networking capability is that the end user has access to a considerably greater computational resource while continuing to work in a familiar environment. Several hardware interfaces are available to integrate Cray systems into customer environments.

The Network Systems Corporation (NSC) HYPER-channel, Computer Network Technology LANlord, and similar network adapters enable Extended Architecture systems to communicate with multiple front-end computer systems.

Digital Equipment Corporation offers a VAX Super-computer Gateway that provides a high-performance direct connection between the Digital VAXcluster environment and EA systems.

The Cray Research HSX-1, a special high-speed external communication channel, provides full duplex point-to-point communication (up to 100 Mbytes/sec) with very fast devices over distances of up to 70 feet (22 meters). Real-time, high-resolution color animation is an example of an application that can make use of this channel.

Cray Research network interfaces (FEIs) compensate for differences in channel widths, word size, logic levels, and control protocols between front-end systems supplied by other manufacturers and Cray systems. Up to three network interfaces can be accommodated by CRAY X-MP EA/14se and CRAY X-MP EA/116se systems, up to seven network interfaces

### Electronic design

The complexity of today's electronic circuitry and competitive pressures for fast design turnaround make design efficiency critical in the electronics industry. To meet these demands, designers of electronic components increasingly use computer-aided design (CAD) methods

that enable them to design and test components by modeling them on a computer. CAD enables designers to modify their designs repeatedly without incurring the expense of building and testing actual parts at each step in the design process. Extended Architecture computer systems are cost-effective tools



for modeling not only logic circuit layout, but also overall system architecture, timing, and design-rule checking.

Model of the electrical field distribution in a high-electron-mobility transistor (HEMT).

can be accommodated by upgradable CRAY X-MP EA systems, and up to fourteen network interfaces can be accommodated by CRAY Y-MP computer systems.

- The Cray Research FEI-1 provides a point-to-point interface at the I/O channel level to a wide variety of computers and workstations, including IBM, CDC, DEC, Data General, UNISYS, and Honeywell Bull.
- The Cray Research fiber optic link allows an FEI-1 to be separated from an Extended Architecture system by distances of up to 1 kilometer (about .6 miles).
- The Cray Research FEI-3 used in conjunction with an Apollo, Sun, Motorola, or IRIS intelligent workstation provides a network interface between EA systems and Ethernet local area networks or other VME devices.

### The SSD storage device

Cray Research's optional SSD solid-state storage device is a very fast random-access device suited for use with Extended Architecture systems. The SSD allows the development of algorithms to solve larger and more sophisticated problems in science and engineering. Note that the SSD is not offered for the CRAY X-MP EA/14se or CRAY X-MP EA/116se computer systems.

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

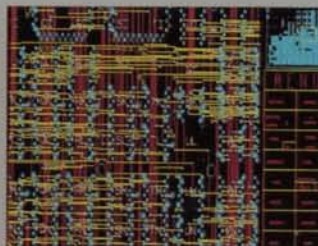
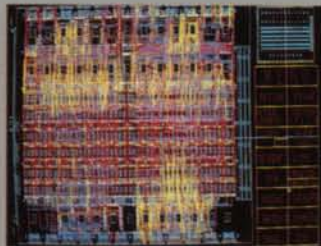
System performance is significantly enhanced by the SSD's exceptionally high transfer rates and short data access times. Up to 512 million words (4096 Mbytes) of rapid-access MOS memory may be configured on an SSD. Transfer rates of 100 to 1000 Mbytes/sec per channel and access times of less than 25 microseconds are achievable between the SSD and an Extended Architecture mainframe. Thus, the SSD offers significant performance improvements on I/O-bound applications.

An SSD in its own stand-alone cabinet is linked to the CRAY X-MP EA/4 systems through two 1000-Mbyte/sec channels and to the CRAY X-MP EA/1 and CRAY X-MP EA/2 models through one 1000-Mbyte/sec channel. An internal SSD is located in the IOS cabinet rather than in a stand-alone cabinet.

#### SSD highlights

- Models available in stand-alone cabinets with 128, 256, or 512 million words (1024 to 4096 Mbytes) of memory
- Internal SSD with 32 million words or 128 million words located in the IOS cabinet
- Support for two 1000-Mbyte/sec channels for linkage to CRAY X-MP EA/4 models or one 1000-Mbyte/sec channel for linkage to CRAY X-MP EA/1 or CRAY X-MP EA/2 models
- SECDED memory protection
- Software support to allow existing programs to use the SSD without program modification

Designs for large printed-circuit boards generated on Cray systems.



**CRAY**

## Physical characteristics

Each mainframe is extremely compact; keeping wire lengths short minimizes signal propagation times. A CRAY X-MP EA/14se or CRAY X-MP EA/116se mainframe consists of six vertical columns arranged in a 135° arc that occupies about 20 square feet (2 square meters) of floor space. A standard CRAY X-MP EA/1 or CRAY X-MP EA/2 mainframe consists of eight vertical columns arranged in a 180° arc that occupies about 26 square feet (2.5 square meters) of floor space. And a CRAY X-MP EA/4 mainframe is composed of 12 vertical columns arranged in a 270° arc requiring just 40 square feet (4 square meters) of floor space.

Unlike the other mainframes, the mainframes for the CRAY X-MP EA/14se and CRAY X-MP EA/116se house the I/O Subsystem (IOS) as well as the CPU and memory. These systems also include an attached power distribution unit that occupies about 7 square feet (0.7 square meters) of floor space and allows easy system installation.

For all upgradable models, the accompanying IOS is housed in a separate cabinet that consists of four vertical columns arranged in a 90° arc occupying 24 square feet (2.3 square meters) of floor space.

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

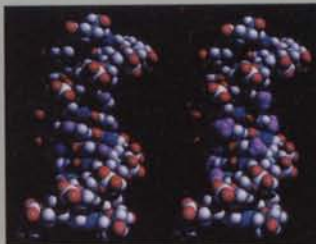
High-speed 2500-macrocell array technology and 16-gate array integrated circuits are used in the CRAY X-MP EA CPUs. These logic circuits, with typical 300- to 400-picosecond propagation delays, enable dense concentration of components. All models in the CRAY X-MP EA series use static MOS memory components.

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.

### Computational chemistry

Computer simulation is an invaluable tool for studying molecular motion, which can occur in a matter of picoseconds (trillionths of a second). Using Extended Architecture 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 Extended Architecture computer systems.



Models of AIDS viral DNA sequence (far left) and anti-AIDS drug (left) with modified DNA structure that binds selectively to the AIDS viral DNA. (Courtesy Frederick Hausheer, National Cancer Institute)

# Software

All Extended Architecture computer systems come with state-of-the-art software including UNICOS, an operating system based primarily on the AT&T UNIX System V Operating System and in part on the Fourth Berkeley Software Distribution (BSD). UNICOS offers a widely accepted program development environment that complements the advanced computational power of Extended Architecture systems. All UNICOS and Fortran software that was developed for earlier CRAY X-MP computer systems runs on Extended Architecture systems, thus protecting user software investments.

The Cray operating system COS is also supported, allowing COS programs developed in the earlier CRAY X-MP environment to use up to 16 million words of memory on an extended architecture system. The Guest Operating System feature of COS allows users to run UNICOS from within COS.

Standard software also includes an automatic scalar optimizing and vectorizing Fortran compiler, automatic scalar optimizing and vectorizing C and Pascal compilers, extensive library routines, program- and file-management utilities, debugging aids, a Cray assembler (CAL), PSL LISP, and a wealth of third-party and public-domain applications.

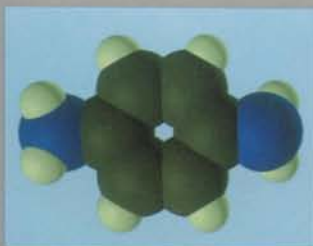
Programs written in one language can call routines written in another language. In addition to the Fortran, C, and Pascal compilers, Ada, Common Lisp, and SIMSCRIPT compilers are under development.

Extended Architecture computer systems are supported by communications software and hardware interfaces to meet a variety of customer connectivity

needs. Included are the TCP/IP protocol, a widely accepted protocol for interconnecting UNIX systems, and Cray proprietary station products. These facilitate connections of Cray supercomputers to workstations and to other vendors' systems and operating software environments (for example IBM MVS and VM, CDC NOS/BE and NOS/VE, and AT&T and BSD UNIX).

## Software summary

- UNICOS, which is based on the AT&T UNIX System V operating system, with enhancements to support the large-scale scientific computer environment
- The Cray operating system COS, which can run UNICOS within the Guest Operating System (GOS)
- A vectorizing Fortran compiler
- An optimized Fortran mathematical and I/O subroutine library
- A scientific subroutine library optimized for Extended Architecture systems
- A multitasking library
- A wide variety of system utilities
- A vectorizing C compiler
- A vectorizing ISO Level 1 Pascal compiler
- CAL, the Cray macro assembler
- Software for connecting to multi-vendor environments
- A wide variety of major application programs



Model of Dupont's Kevlar® aramid fiber (para-diaminobenzene) calculated with the GRADSCF *ab initio* quantum chemistry program. (Courtesy David Dixon, E. I. du Pont de Nemours & Company)

Model of the bacterial enzyme SGPA. Colors designate the protein's various functional groups. (Courtesy Michael James, University of Alberta)



# CRAY

## UNICOS operating system

The UNICOS operating system, which is distributed between central memory and the I/O Subsystem, delivers the full power of Extended Architecture hardware in both an interactive and a batch environment. Significant features of UNICOS include support for asynchronous I/O, improved file system integrity, multiprocessing, and user multitasking. UNICOS efficiently manages high-speed data transfers between Cray systems and peripheral equipment. Standard system software interfaces the Extended Architecture computer systems with other vendors' operating systems and with networks. UNICOS includes a variety of utility programs that assist in program development and maintenance. User programs can be ported easily between UNICOS and other UNIX systems.

UNICOS is based on UNIX System V, an operating system developed by AT&T. In recent years, versions of UNIX have become available on many different computer systems. Like UNIX, UNICOS is written in the C programming language. It contains a small kernel that is accessed through system calls and a large, diverse set of utilities and library programs. Its file system is hierarchical, featuring directories for convenient organization of files.

The UNICOS kernel has been substantially enhanced in many areas, including I/O processing and the handling of very large data files.

The UNICOS system supports both an interactive environment and a batch processing capability to provide for efficient use of the system by large, long-running jobs. The standard UNIX process accounting features have been augmented with accounting

features more appropriate for a supercomputer environment.

Users may initiate asynchronous processes that can communicate with one another. A variety of command-language interpreters (shells) are possible. UNICOS offers the standard AT&T UNIX Bourne shell and the University of California Berkeley 4.3 BSD C shell. Other shells may be created to provide different command interfaces for users.

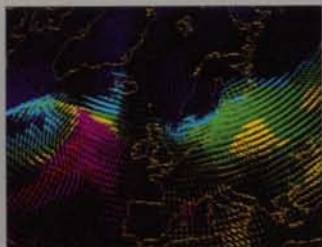
UNICOS provides the classic multiuser environment of UNIX in which information and resources are easily shared. UNICOS provides password protection and file access permissions. A system administrator can create a system profile to provide a customized initial environment for each user. To aid in controlling access to critical files, each user can be assigned to one or more logical groups. Associated with each file in the system is a set of access permissions. The system administrator may specify read, write, and execute restrictions for each file in the system.

The UNICOS tape subsystem enables users to access extensive amounts of data while using the computational power of the Extended Architecture systems for data analysis and large-scale problem solving. Tapes may be accessed by user programs as well as being used for both backing up and restoring user files on-line.

Cray Research has adopted an industry-standard operating system along with industry-standard communications protocols and proprietary software interfaces to other computing systems. This offers users an open system environment that permits access across a wide variety of interconnected computer systems, allowing the user to choose where work

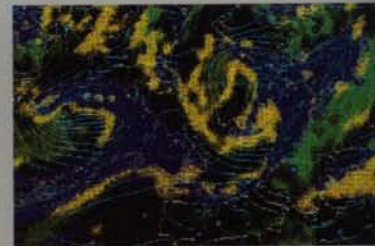
### Weather and climate research

Accurate models of Earth's atmosphere must include variables such as airflow, solar heating, air pressure, and cloud movement. Extended Architecture computer systems enable researchers to run large and complex atmos-



pheric models for weather forecasting and climate research.

Computer maps of Europe and the North Atlantic showing wind speed and wind direction (left) and pressure contours and cloud fields (right). (Courtesy European Centre for Medium-Range Weather Forecasts)



may best be processed. The result is a combination of flexibility and computing power unparalleled in the computer industry.

## COS operating system

Extended Architecture systems also support the COS operating system on up to 16 Mwords of memory, thus protecting users' investments in software developed for earlier CRAY X-MP systems or for CRAY-1 systems. COS, which is primarily batch-oriented, shares several characteristics with UNICOS. It is distributed between central memory and the IOS, and it effectively manages high-speed data transfers between the Cray system and peripheral units. It includes many utility programs that assist in program development and maintenance. As with UNICOS, standard system software interfaces the Cray system with other vendors' operating systems and with networks.

The Guest Operating System (GOS) feature of COS allows users to run both COS and UNICOS concurrently.

## Fortran compilers and libraries

Cray Research offers the CFT77 Fortran compiler for the Extended Architecture series of computer systems. This compiler fully complies with the ANSI standard 3.9-1978 (Fortran 77) and offers a high degree of automatic scalar and vector optimization. It permits maximum portability of programs between different computers and accepts many nonstandard constructs written for other vendors' compilers. Highly optimized (scalar and vector) object code is produced from standard Fortran code; users can program in standard Fortran syntax to access the full power of the Cray system architecture. As a state-

of-the-art Fortran compiler, CFT77 not only generates highly vectorized, optimized, and multitasked code, but also offers array syntax and portability to CRAY Y-MP and CRAY-2 systems as well as to future Cray systems.

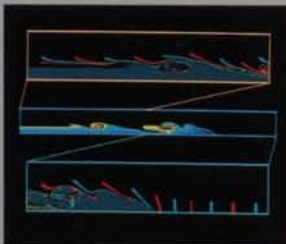
The Cray Fortran compiler CFT, which is supported on Extended Architecture systems in X-mode, was the first Fortran compiler in the industry to automatically vectorize codes, automatically vectorize inner DO loops, and provide scalar optimization without sacrificing high compilation rates.

The compilers and Fortran library offer current Cray customers a high level of source code compatibility by making available on Extended Architecture systems Fortran extensions, compiler directives, and library interfaces that are available on other Cray Research products.

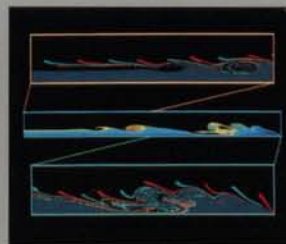
### Fortran compiler features

- ANSI standard compliance
- Automatic optimization of code, including vectorization of DO loops
- Portability of application codes
- Library routines optimized for the Extended Architecture systems
  - Scientific library
  - I/O library
  - Multitasking library

The Fortran library and a library of highly optimized scientific subroutines enable the user to take maximum advantage of the hardware architecture. The I/O library provides the Fortran user with convenient and efficient use of external devices at maximum data rates for large files.



Model of airflow showing the development of wind shear, an atmospheric condition that poses a serious hazard to low-flying aircraft. Similar methods are used to study phenomena ranging from tornado formation to acid rain. (Courtesy Kelvin Droegemeier, University of Oklahoma, and Robert Wilhelmson, University of Illinois.)



CRAY

## Multiprocessing

In conjunction with vectorization and large memory support, a flexible multiprocessing capability provides a major performance boost to large-scale scientific computing. Multiprocessing is a technique whereby an application program is partitioned into independent tasks that can execute in parallel on a Cray computer system. This results in substantial throughput improvements over serially executed programs. The performance improvements are in proportion to the parallelism inherent in the program, the number of tasks that can be constructed for the program, and the number of CPUs that can be applied to these separate tasks.

Three methods of multiprocessing can be used: macrotasking, microtasking, and automatic multitasking. Macrotasking is best suited to programs with larger, longer-running tasks. The user interface to the Extended Architecture macrotasking capability is a set of Fortran-callable subroutines that explicitly defines and synchronizes tasks at the subroutine level. These subroutines are compatible with similar routines available on other Cray products.

Microtasking, the second method of multiprocessing, breaks code into small units that can be executed in parallel on multiple processors. It has proven to be a very effective tool. Microtasking uses a pre-processor to allow programmers to multiprocess the low-level (fine granularity) parallelism found in many existing codes. Extremely fast synchronization allows microtasking's self-scheduling algorithm to make effective use of any available CPU cycles, providing effective load balancing of the system.

Cray Research's CFT77 Fortran compiler will soon provide an initial automatic multitasking capability called "autotasking." It will automatically partition a program into tasks and efficiently use whichever processors are available at any point during the running of the program.

## Pascal

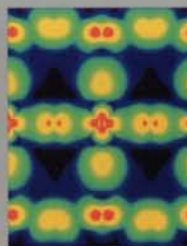
Pascal is a high-level, general-purpose programming language used as the implementation language for the CFT77 compiler and other Cray products. Cray Pascal complies with the ISO Level 1 standard and offers such extensions to the standard as separate compilation of modules, imported and exported variables, and an array syntax.

The optimizing Cray Pascal compiler takes advantage of extended architecture hardware features through both scalar optimization and automatic vectorization of FOR loops. It provides access to Fortran common block variables and uses a common calling sequence that allows Pascal code to call Fortran, C, and CAL routines.

### 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 Extended Architecture computer systems, physicists can experiment on mathematical

models of atomic and subatomic structures. This capability enables physicists to refine their theories faster than would be possible by any other means.



Contour map of the electronic charge around copper and oxygen atoms in the superconductor  $\text{YBa}_2\text{Cu}_3\text{O}_7$ . (Courtesy S. Massidda, Jaejun Yu, A. J. Freeman, Northwestern University; and D. D. Koelling, Argonne National Laboratory)

## C language

C is a high-level programming language used extensively in the creation of the UNICOS operating system and the majority of the utility programs that constitute the system. It is a widely used computer language available on processors ranging from microcomputers to mainframe computers to Cray supercomputers. C is useful for a wide range of applications and system-oriented programs. The availability of C complements the scientific orientation of Fortran. The Cray C compiler performs scalar optimization and vectorizes code automatically.

## Utilities

A set of software tools assists both interactive and batch users in the efficient use of extended architecture systems.

A variety of debugging aids allows users to detect program errors by examining both running programs and program memory dumps. These aids include symbolic interactive debuggers and symbolic post-mortem dump interpreters. Performance aids assist in analyzing program performance and optimizing programs with a minimum of effort.

The *Perftrace* utility, for example, supplies statistics on computer performance for individual program units within a program. The information comes from

the Hardware Performance Monitor, which is standard on Extended Architecture computer systems. Other performance utilities include *Flowtrace*, which prints information on all procedure calls, and *Ftref*, which provides a calling tree and other structural information about a program.

A source code control system tracks modifications to files. This is useful when programs and documentation undergo frequent changes due to development, maintenance, or enhancement. Several text editors offer versatility for users wishing to create and maintain text files. Operational support facilities enable proper management of the system.

Included with each release of UNICOS is on-line documentation in a format familiar to UNIX users and help facilities for quick reference of information.

## CAL

The Cray assembler, CAL, provides a macro assembly language that is especially helpful for tailoring programs to the Extended Architecture series of computer systems and for writing programs requiring hand-optimization.

## Biomedical research

Cray Research's Extended Architecture computer systems provide researchers in biology and medicine with the general-purpose computing capabilities they need. Applications for large-scale computer systems in biomedical research include diagnostic image processing, structural analysis for bio-

mechanical engineering, fluid dynamic analysis for artificial heart design, genetic sequencing, and molecular modeling for pharmaceutical design.



Single frame from a movie of simulated muscle contraction, showing the various components of muscle tissue. (Courtesy Max Schaible, Minnesota Supercomputer Institute)

# CRAY

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## COS migration

The Guest Operating System (GOS) feature of the COS operating system allows users to run both COS and UNICOS concurrently on Extended Architecture systems. A maximum of 16 million words of memory can be dedicated to COS. The Guest Operating System feature is a valuable tool for migrating from COS to UNICOS. A variety of additional migration tools have been created to further ease conversions of Fortran code from COS to UNICOS, COS datasets to UNICOS files, and COS job control language statements to UNICOS commands.

## Networking

The wide array of available networking software products allows users to integrate the Extended Architecture series of computer systems into new or existing computing environments easily.

The TCP/IP networking suite is available on Extended Architecture computer systems running UNICOS, providing flexibility for integrating a Cray system into an open network architecture that supports the TCP/IP protocol suite.

Cray Research also provides station software products that offer access to proprietary protocol implementations (such as SNA, DECnet, and CDCnet) through network interfaces. Station software runs on a variety of systems and workstations to provide the logical connection to Cray Extended Architecture computer systems running UNICOS or COS. Standard Cray station software is available for the following systems: IBM MVS and VM, CDC NOS, NOS/VE, and NOS/BE, DEC VAX/VMS, and a variety of computers and workstations running UNIX. Station software for UNISYS and Honeywell Bull systems is available from third-party vendors.

## Applications

In addition to Cray Research system and application software, a wide variety of third-party and public domain application programs can be run in Cray UNICOS and COS environments. These codes can take immediate advantage of the outstanding performance of the Extended Architecture systems for

### Advanced graphics

The need to analyze and understand the results of simulations performed on Cray systems has made computer graphics itself an important application for Cray systems. This increasingly is the case as researchers attempt to generate motion pictures from their models to

observe the models evolving over time. Translating data from a computer model into such a movie can require as much computing as the creation of the model itself. Cray systems also have been used to generate commercial imagery for the motion picture and advertising industries, and to compute "fly-through" movies of archi-



tectural models that allow a structure to be viewed from any angle and elevation.

Design study for a proposed performing arts theater generated on a Cray computer system.

applications such as computational fluid dynamics, structural analysis, mechanical engineering, nuclear safety, circuit design, seismic processing, image processing, molecular modeling, and artificial intelligence.

Cray Research works closely with third-party software vendors and customers in converting, optimizing, and maintaining application software on Cray computer systems. A comprehensive catalog of available programs is published by the Cray Applications Department.

This application software, teamed with Fortran, C, and Pascal compilers, editors, debuggers, libraries, database management tools, and many other software tools and products, provides users with the software they need to use Cray Extended Architecture systems to their fullest capabilities.

One common supercomputing application is the simulation of physical phenomena — the analysis and prediction of the behavior of physical systems through computer modeling. Large-memory Extended Architecture computer systems offer increased capacity to conduct three-dimensional simulations of a wide variety of problem domains such as weather forecasting, aircraft and automotive design, energy research, reservoir simulation, and seismic analysis. Extended Architecture systems also provide an opportunity to find challenging solutions for applications such as genetic engineering, artificial intelligence, quantum chemistry, and economic modeling. Large-memory Extended Architecture

computer systems offer increased capability to explore new solution techniques or increased problem resolution while yielding very high computation rates. In practical terms, this means that problems considered too costly to solve with earlier supercomputer systems now become economically feasible.

#### Applications

- Advanced graphics
- Applied mathematics
- Artificial intelligence
- Atmospheric and oceanic research
- Circuit simulation and design
- Crashworthiness simulation
- Economic modeling
- Energy research
- Financial modeling
- Fluid dynamics
- Genetic engineering
- Molecular dynamics
- Petroleum exploration and recovery
- Process design
- Quantum chemistry
- Signal and image processing
- Structural analysis
- Weather forecasting

#### New dimensions

Cray computer systems are redefining the state-of-the-art in computational research. Cray systems enable scientists and engineers to solve problems that are beyond the capabilities of conventional mainframe computers. Their balanced, general-purpose capabilities and superior computational per-

formance make Cray systems the tools of choice for total supercomputing solutions.

The applications described here represent well-established uses of Cray computer systems. As these applications undergo further refinement, new applications are being developed. Today, Cray computer systems

are solving complex problems in economic and financial modeling, linear programming, discrete event (battle) simulation, astrophysics, and symbolic processing related to expert systems and artificial intelligence.

Scientists, engineers, and planners in these and other areas are making discoveries,

solving problems, and enhancing productivity through computer modeling on Cray systems. As the future of computational research demands increased computing power, Cray systems will continue to meet the needs of the scientific computing community, and to define the leading edge in advanced scientific computing worldwide.

**CRAY**

## Support and maintenance

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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, hardware engineering and system software support is provided locally and through technical centers throughout the company. Cray Research also provides comprehensive user documentation for both hardware and software products. Technical software training is offered to customers on-site or at Cray regional and corporate training facilities.

Cray Research has extensive experience serving the supercomputer customer — over a decade of experience spanning a wide variety of customers and applications. Professional, responsive support from trained specialists is just part of the service 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 very large-scale integrated circuits in Extended Architecture systems improves hardware reliability by reducing the number of modules, solder units, and interconnect wires necessary. Highly automated assembly of components also contributes to hardware reliability. All components undergo strict inspection and checkout prior to assembly into a system, and all computers undergo rigorous operational and reliability tests prior to shipment.

Preventive maintenance techniques assure that system performance is high; effective and timely maintenance is a routine operation. Diagnostic software quickly isolates any problem that may occur. The faulty system element may then be optionally deconfigured and the system operated in a degraded mode, or the element may be replaced immediately and the system restarted fully configured. All system elements are readily accessible for replacement. Further diagnosis and repair of the faulty element may then be completed off-line.

The Cray service philosophy is to replace system elements on-site, providing minimum system downtime and the highest system availability.

## **About Cray Research, Inc.**

Cray Research was organized in 1972 by Seymour R. Cray, a leading designer of large-scale scientific computers, along with a small group of computer industry associates. The company was formed to design, develop, manufacture, and market large-capacity, high-speed computers.

The first model produced was the CRAY-1 computer system in 1976. This was followed by the CRAY-1S system in 1980, the CRAY X-MP system in 1982, the CRAY-2 system in 1985, and the CRAY Y-MP system in 1988. Each offered a considerable improvement in price/performance over predecessors in its product line. The Extended Architecture series of computer systems continues this tradition of computing excellence from Cray Research.

Cray Extended Architecture computer systems demonstrate Cray's continued commitment to overall performance. Over the years, Cray Research has offered new products such as the DS-40 disk subsystem and the SSD solid-state storage device to complement its computing systems and to continually improve its computational capacity for users.

Cray Research has more experience than any other vendor in producing software for supercomputers. This software assures that your Cray computing system is used to its fullest. From the revolutionary CFT compiler — the first Fortran compiler to automatically vectorize code — to our industry-leading multitasking capability, and to today's UNICOS operating system supported with full-featured ANSI standard Fortran, C, and Pascal compilers, Cray Research develops software that allows users easy access to the computer architecture. In addition, Cray Research's networking software and support for connecting Cray supercomputers into your existing computing environment is unmatched.

Today Cray Research is the world leader in supercomputers, with more than 200 installations worldwide. The company operates manufacturing, research, development, and administrative facilities in Chippewa Falls, Wisconsin and the Minneapolis, Minnesota area. The company has sales and support offices throughout North America and has subsidiary operations in Western Europe and the Far East.



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