The CRAY-2 Series of Computer Systems

CRAY

Cray Research's mission is to develop and market the most powerful computer systems available. Cray Research has been the industry leader in large-scale computer systems for more than a decade. Today, the majority of supercomputers installed worldwide are Cray systems. These systems are used in advanced research laboratories around the world and have gained strong acceptance in diverse government 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 and was soon recognized as 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 computer system broke that barrier and today vectorization techniques are used commonly by scientists and engineers in a wide variety of disciplines.

With its significant innovations in architecture and technology, the CRAY-2 series of computer systems sets the standard for the next generation of supercomputers. The large memory and high performance of the CRAY-2 series allow users to solve problems in many areas of science, engineering, and mathematical modeling that cannot be solved with any other computer.

Introducing the CRAY-2 series of computer systems

The CRAY-2 series of computer systems sets the standard for the next generation of supercomputers. Each of the four models of the CRAY-2 series is characterized by a large common memory, two or four background processors, a clock cycle of 4.1 nanoseconds (4.1 billionths of a second), and liquid immersion cooling. The CRAY-2 systems offer effective throughput up to twelve times that of the CRAY-1 computer system and run an operating system based on the increasingly popular UNIX operating system.

The CRAY-2 computer systems use the most advanced technology available. The compact CRAY-2 mainframe is immersed in a fluorocarbon liquid that dissipates the heat generated by the densely packed electronic components. The logic and memory circuits are contained in eight-layer, three-dimensional modules. Both logic and memory circuits are constructed of high-density, high-speed silicon chips.

The CRAY-2 mainframe contains either two or four independent background processors, each more powerful than a CRAY-1 computer. Featuring a clock cycle time of 4.1 nanoseconds — faster than any other computer system available — each of these processors offers exceptional scalar and vector processing capabilities. The background processors can operate independently on separate jobs or concurrently on a single problem. The high-speed local memory integral to each background processor is available for temporary storage of vector and scalar data.

Common memory is one of the most important features of the CRAY-2 series. It consists of up to 256 million 64-bit words, randomly accessible from any of the background processors and from any of the high-speed and common data channels. Common memory is arranged in 64 or 128 interleaved banks, divided evenly among four quadrants. All memory access is performed automatically by the hardware. Any user may use all or part of this memory.

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In conventional memory-limited computer systems, I/O wait times for large problems that use out-of-memory storage run into hours. The large common memory of the CRAY-2 computer systems enables many of these problems to be handled in a fraction of the time.

Cray Research offers high-speed disk drives and tape support to accommodate user mass storage needs. Hardware interface support allows CRAY-2 systems to be connected to a wide variety of front-end systems and external networks.

Control of network access equipment and high-speed disk and tape drives is integral to the CRAY-2 mainframe hardware. A single foreground processor coordinates the data flow between the system common memory and all external devices across high-speed I/O channels. The synchronous operation of the foreground processor with the background processors and the external devices provides a significant increase in data throughput.

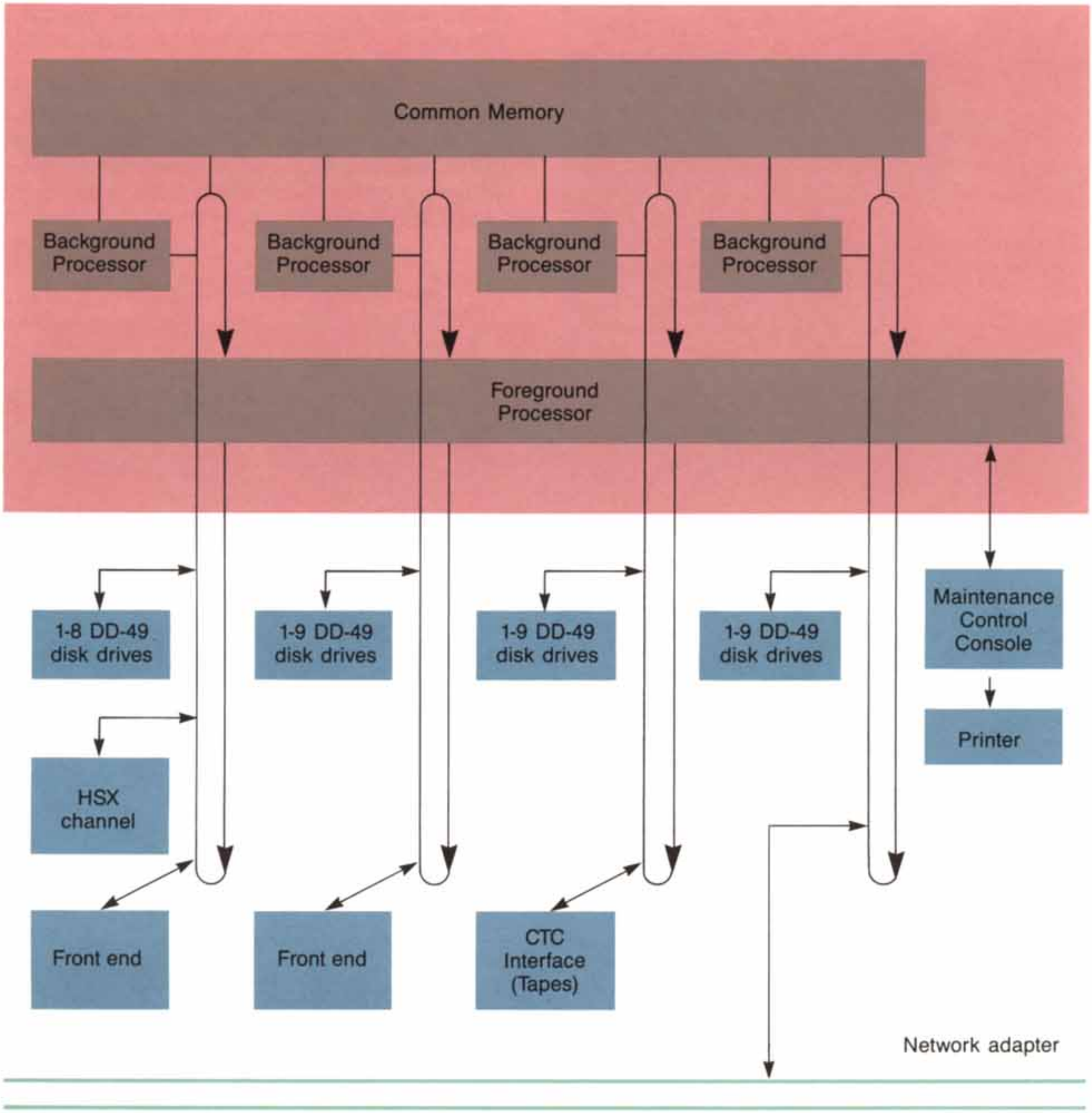
To complement the CRAY-2 architecture, Cray Research has developed an interactive operating system, UNICOS, based on AT&T's UNIX System V operating system. UNICOS is supported by two Fortran compilers: CFT2, which is based on CFT, the field-proven Cray Research Fortran compiler; and CFT77, which represents the leading edge in compiler development.

The CRAY-2 computer systems represent a major advance in large-scale computing. The combination of two or four high-speed background processors, a high-speed local memory, a huge common memory, an extremely powerful I/O capability, and a comprehensive software product offers unsurpassed and balanced performance for the user.

Features of the CRAY-2 series of computer systems

- ☐ Extremely large directly addressable common memory
- ☐ Fastest cycle time available in a computer system (4.1 nsec)
- ☐ Scalar and vector processing combined with multiprocessing
- ☐ Integral foreground processsor
- ☐ High-speed I/O
- ☐ Use of high density memory chips and extremely fast silicon logic chips
- ☐ Liquid immersion cooling
- ☐ UNICOS, an operating system based on industry recognized AT&T UNIX System V
- ☐ Two automatic vectorizing Fortran compilers

Sample CRAY-2 four-processor system configuration



The CRAY-2 computer systems

The CRAY-2 systems are available in four different models that allow users to tailor the system to meet specific needs.

The original CRAY-2 computer system with four background processors and 256 million words of common memory has been upgraded with a faster dynamic random-access memory (DRAM) chip and with pseudobanking, which allows faster memory access and reduces interprocessor memory contention.

An even faster memory CRAY-2 model combines four processors with 128 million words of static random-access memory (SRAM). The faster chip cycle time and the elimination of the need for refreshing memory improves typical throughput on this model by 15 to 25 percent over comparable DRAM CRAY-2 systems.

For users requiring less total throughput, two-processor CRAY-2 systems are available with 64 or 128 million words of SRAM common memory. These systems offer the same per-processor throughput as the four-processor SRAM CRAY-2 system at a reduced cost.

CRAY-2 system configuration options

Background processors	2	2	4	4
SRAM MOS common memory (64-bit words)	64M	128M	128M	N/A
DRAM MOS common memory (64-bit words)	N/A	N/A	N/A	256M
Disk storage units	4-18	4-18	4-36	4-36
6- or 12-Mbyte/sec channels	2-8	2-8	4-16	4-16
Magnetic tape channels	0-8	0-8	0-16	0-16
100-Mbyte/sec channels	0-4	0-4	0-8	0-8

Physical characteristics

The CRAY-2 mainframe is elegant in appearance as well as in architecture. The memory, computer logic, and DC power supplies are integrated into a compact mainframe composed of 14 vertical columns arranged in a 300° arc.

The upper part of each column contains a stack of 24 modules and the lower part contains power supplies for the system. Total cabinet height, including the power supplies, is 45 inches, and the diameter of the mainframe is 53 inches. Thus, the "footprint" of the mainframe is 16 square feet of floor space.

An inert fluorocarbon liquid circulates in the mainframe cabinet in direct contact with the integrated circuit packages and power supplies. This liquid immersion cooling technology allows for the small size of the CRAY-2 mainframe.

Physical characteristics

- ☐ Occupies 16 sq ft of floor space
- ☐ Stands 45 inches high; diameter is 53 inches
- ☐ Weighs 5500 pounds
- ☐ 14 columns arranged in a 300° arc
- ☐ Liquid immersion cooling
- ☐ Uses 16-gate array logic chips
- ☐ Three-dimensional modules
- ☐ Up to 336 pluggable modules
- ☐ Up to 195 KW power consumption
- ☐ 400 Hz power from motor generators
- ☐ Chilled water heat exchange

Architecture and design

In addition to the cooling technology, the CRAY-2 computer systems' extremely high processing rates are achieved by a balanced integration of scalar and vector capabilities and a large common memory in a multiprocessing environment.

The significant architectural components of the CRAY-2 computer systems include either two or four identical background processors, up to 256 million 64-bit words of common memory, a foreground processor, and a maintenance control console.

Each background processor contains registers and functional units to perform both vector and scalar operations. The single foreground processor supervises the background processors, while the large common memory complements the processors and provides architectural balance, thus assuring extremely high throughput rates.

On-site maintenance is performed via the maintenance control console.

Background processors

Each background processor consists of a computation section, a control section, and a high-speed local memory. The computation section performs arithmetic and logical calculations. These operations and the other functions of a background processor are coordinated through the control section. Local memory is used to temporarily store scalar and vector data during computations. Each local memory is 16,384 64-bit words.

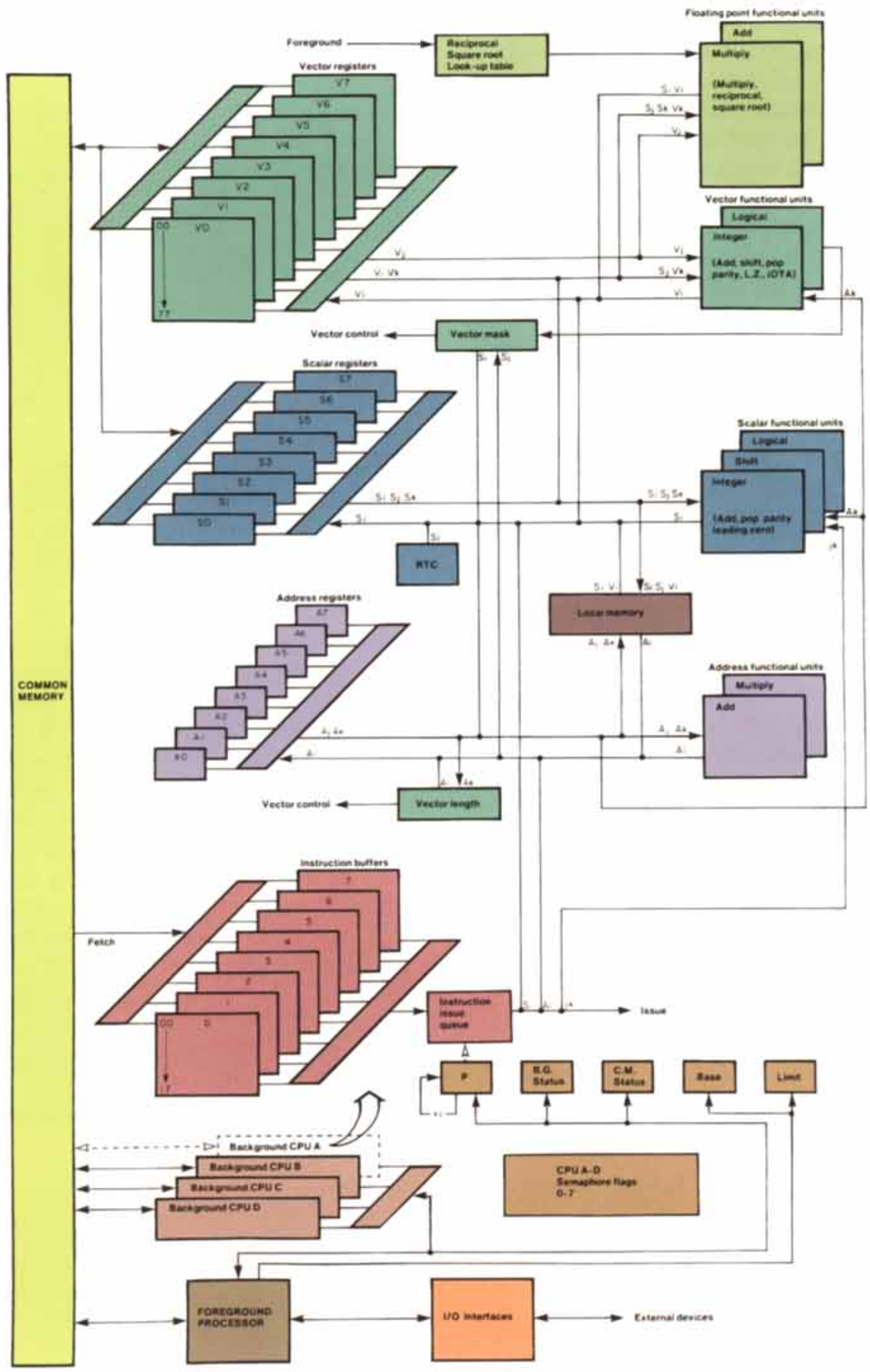
Control and data paths for one background processor are shown in the block diagram (opposite page).

Computation section
The computation section contains registers and functional units that are associated with address, scalar, and vector processing. Two integer arithmetic functional units are employed in address processing. Three functional units are dedicated solely to scalar processing, and two floating point functional units are shared with vector operations. Two functional units are dedicated to vector operations, and allow CRAY-2 systems to issue one result per clock period in vector mode.

Computation section characteristics

- ☐ Twos complement integer and signed magnitude floating-point arithmetic
- ☐ Address and arithmetic registers
  - Eight 32-bit address (A) registers
  - Eight 64-bit scalar (S) registers
  - Eight 64-element vector (V) registers; 64 bits per element
- ☐ Address functional units
  - Add/subtract
  - Multiply
- ☐ Scalar functional units
  - Shift
  - Logical
  - Integer
    - Add/subtract
    - Population/parity
    - Leading zero count
- ☐ Vector functional units
  - Logical
  - Integer
    - Shift
    - Add/subtract
    - Population/parity
    - Leading zero count
    - Compressed iota
- ☐ Floating-point functional units
  - Add/subtract
  - Multiply/reciprocal/square root
- ☐ Scatter and gather vector operations to and from common memory

CRAY-2 four-processor system organization



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Local memory

Each background processor contains 16,384 64-bit words of local memory. Local memory is treated as a register file to hold scalar operands during computation. It may also be used for temporary storage of vector segments where these segments are used more than once in a computation. Local memory accesses take four clock periods, and can overlap accesses to common memory. CRAY-2 local memory replaces the B and T registers on the CRAY-1 computer and is readily available to perform user tasks, such as small matrix manipulation.

Local memory characteristics

- ☐ 16,384 64-bit words
- ☐ Holds scalar and vector operands during computation
- ☐ Temporary storage of vector segments
- ☐ Four-clock-period access time
- ☐ Overlapping register accesses with common memory accesses
- ☐ Replaces CRAY-1 B and T registers

Control section

Each background processor contains an identical independent control section of registers and instruction buffers for instruction issue and control.

Control section characteristics

- ☐ Eight instruction buffers
- ☐ 128 basic instruction codes
- ☐ 32-bit Program Address register
- ☐ 32-bit Base Address register
- ☐ 32-bit Limit Address register
- ☐ 64-bit real-time clock
- ☐ Eight Semaphore flags to provide interlocks for common memory access
- ☐ 32-bit Status register

Each background processor has a 64-bit real-time clock. These clocks and the foreground processor 32-bit real-time clock are synchronized at system start-up and are advanced by one count in each clock period.

Background processor intercommunication

Synchronization of two or more background processors cooperating on a single job is achieved through use of one of the eight Semaphore flags shared by the background processors. These flags are one-bit registers providing interlocks for common access to shared memory fields. A background processor is assigned access to one Semaphore flag by a field in the Status register. The background processor has instructions to test and branch, set and clear a Semaphore flag.

Common memory

One of the primary technological advantages of the CRAY-2 computer systems is their extremely large directly addressable common memories. The CRAY-2 series of computer systems offers up to 256 million words of common memory, the largest of any commercially available computer system. Such a large common memory allows the individual user to run programs that would be impractical to run on any other system; it also enhances multiprogramming by allowing more than an order of magnitude increase in the number of jobs that can reside concurrently in memory (that is, that can be multiprogrammed). Common memory is arranged in four quadrants of 16 or 32 banks each, for a total of 64 or 128 interleaved banks, depending on model. Pseudo-banking improves throughput on the DRAM system by effectively reducing wait times and conflicts.

Memory on the CRAY-2 computer systems is composed of either static or dynamic random-access memory (SRAM or DRAM) metal oxide semiconductor (MOS) chips. The DRAM system is available with 256 million words of common memory. The SRAM systems, with 64 or 128 million words of common memory, show performance improvements of 10 to 40 percent over comparable DRAM systems for two reasons: the faster raw chip speed, and the reduced memory contention that SRAM provides.

Common memory characteristics

- ☐ Up to 256 million words
- ☐ 64 data bits, 8 error correction bits per word
- ☐ Up to 128 banks
- ☐ Either SRAM or DRAM MOS memory technology

Foreground processor and I/O processors

For problems requiring extensive data handling, Cray Research has developed hardware that ensures that the computing power of the CRAY-2 systems is not held captive by I/O limitations.

The foreground processor supervises overall system activity among the foreground processor, background processors, common memory, and peripheral controllers. System communication occurs through two or four high-speed synchronous data channels.

Firmware control programs for normal system operation and a set of diagnostic routines for system maintenance are integral to the foreground processor.

Control circuitry for external devices is also located within the CRAY-2 mainframe.

Foreground communication channels

The foreground processor is connected to either two or four 4-Gbit/sec communication channels. These channels link the background processors, foreground processor, peripheral controllers, and common memory. Each channel connects one background processor, one group of peripheral controllers, one common memory port, and the foreground processor. Data traffic travels directly between controllers and common memory.

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Disk drives

Complementing and balancing CRAY-2 computing speeds are the DD-49 disk drives, high-density (1200-Mbyte) magnetic storage devices. A maximum of 36 disk drives can be configured on four-processor systems and 18 on two-processor models. These disks can sustain transfer rates of 9.6 Mbytes/sec at the user job level with an average seek time of 16 msec.

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 file across two or more drives. 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.

Cray Tape Controller (CTC)

The optional Cray Tape Controller (CTC) enables a CRAY-2 system to interconnect with one or more IBM 3480 Magnetic Tape Subsystems. The CTC is based on VMEbus hardware and interfaces to the CRAY-2 system through a 12-Mbyte/sec channel. Using the CTC, the CRAY-2 system can provide up to four IBM-compatible tape streaming channels. Up to eight tape streaming channels can be configured on a two-processor CTC model and up to 16 on a four-processor CTC model. The CTC can be separated from the CRAY-2 system by up to 50 feet and from the IBM tape controller by up to 400 feet.

The IBM 3480 Magnetic Tape Subsystem uses 200-Mbyte tape cartridges and can sustain a data transfer rate (reading and writing) of 2.5 Mbytes/sec when configured on a CRAY-2 system. A CTC with two streaming channels can sustain an aggregate data transfer rate (reading and writing) of up to 5 Mbytes/sec.

Front-end interfaces

CRAY-2 computer systems may be interfaced to a variety of front-end computer systems. Up to 16 front-end interfaces can be accommodated in a point-to-point configuration. An unlimited number of systems can be connected to the CRAY-2 system using commercially available bus networks.

Cray Research currently provides front-end interface support for IBM, CDC, and DEC systems. Front-end interfaces compensate for differences in channel widths, word size, logic levels, and control protocols between other manufacturers' equipment and a CRAY-2 computer system.

Fiber optic link

Cray Research's fiber optic link allows a front-end interface to be separated from a CRAY-2 computer system by distances up to .621 miles (1000 meters) and provides complete electrical separation of the connected devices.

HSX-1 high-speed external channel

The HSX-1, a special high-speed external communications channel, is also available for interfacing very fast devices to a CRAY-2 computer system. The HSX-1 provides full duplex point-to-point communication at rates up to 100 Mbytes/sec over distances of up to 70 feet (22 meters). The HSX-1 can be used to connect multiple CRAY-2 systems and to connect a CRAY-2 system with a CRAY X-MP system. High-speed graphics support is another example of how this channel can be used.

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CRAY-2 technology

Technological innovations on the CRAY-2 computer systems include liquid immersion cooling and eight-layer, three-dimensional modules.

Liquid immersion cooling

Effective cooling techniques are central to the design of high-speed computational systems. Densely packed components result in shorter signal paths, thus contributing to higher speeds. Traditionally, the tradeoff has been lower reliability due to increased operating temperatures, but this is no longer a limitation. The liquid immersion cooling technology used by the CRAY-2 computer systems is a breakthrough in the design of cooling systems for large-scale computers. It places the cooling medium in direct contact with the components to be cooled, thus efficiently reducing and stabilizing the operating temperature and increasing system reliability. The coolant flows through the module circuit boards at a velocity of one inch per second and is in direct contact with the integrated circuit packages and power supplies.

The coolant used in the CRAY-2 systems is a colorless, odorless, inert fluorocarbon fluid. It is nontoxic and nonflammable and has high dielectric (insulating) properties. It also has high thermal stability and outstanding heat transfer properties.

Liquid immersion cooling characteristics

- ☐ A key to densely packed electronics
- ☐ "Valveless" cooling system
  - 250-gallon closed system
  - Room temperature cooling ranges
  - Accompanying reservoir
  - Shell and tube heat exchangers
- ☐ Chilled water cooling
- ☐ Fluorocarbon fluid
  - Colorless and odorless
  - Inert: nontoxic and nonflammable
  - High insulating properties
  - High thermal stability
  - High heat transfer capacity

Module technology design

The CRAY-2 hardware is constructed of synchronous networks of binary circuits. These circuits are packaged in up to 336 pluggable modules, each of which contains approximately 750 integrated circuit packages. Total integrated circuit population in the largest CRAY-2 system is approximately 240,000 chips, nearly 75,000 of which are memory.

The pluggable modules are three-dimensional structures with an 8 x 8 x 12 array of circuit packages. Eight printed circuit boards form the module structure. Circuit interconnections are made in all three dimensions within the module. Each module measures 1 x 4 x 8 inches, weighs 2 pounds, consists of approximately 40 percent integrated circuits by volume, and consumes 300 to 500 watts of power.

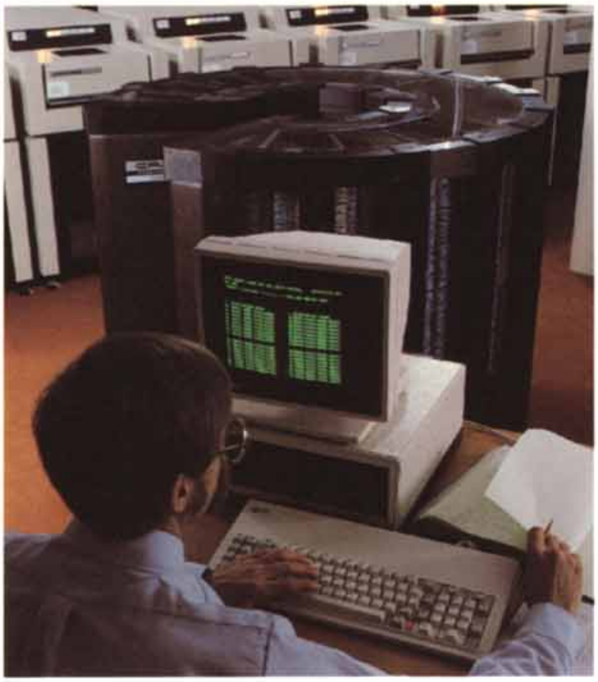
CRAY-2 common memory consists of either 64 or 128 memory banks with up to two million words per bank; each memory bank occupies a circuit module. CRAY-2 logic networks are constructed of 16-gate array integrated circuits packaged in three-dimensional structures.

Reliability

The immersion cooling technology used in the CRAY-2 systems contributes significantly to system reliability. All components rapidly dissipate heat to the fluid, thus preventing high chip temperatures. These chip temperatures are substantially lower than those achieved by other types of cooling and result in significantly reduced chip failure rates. Efficient heat dissipation also prevents destructive thermal shocks that might result from large temperature differentials and fluctuations.

In addition, a fifteen-to-one decrease in module count per CPU and a ten-to-one reduction in memory module count from the CRAY-1 computer system enhance failure isolation, producing a corresponding increase in maintenance efficiency.

CRAY-2 software



Cray Research has made a major commitment to the development of a comprehensive user environment through an aggressive software development program.

The CRAY-2 computer systems come with state-of-the-art software including UNICOS, an operating system based on AT&T UNIX System V. UNICOS offers a widely accepted program development environment joined with the advanced computational power of the CRAY-2 computer systems.

Software includes a choice of two automatic vectorizing Fortran compilers, C and Pascal compilers, extensive Fortran and scientific library routines, program- and file-management utilities, debugging aids, a powerful Cray assembler (CAL), and a wealth of third-party and public-domain application codes.

CRAY-2 systems are also supported by communications software and hardware interfaces to meet a variety of customer connectivity needs; included are TCP/IP protocols, the popular choice for interconnecting UNIX systems.

UNICOS operating system

The Cray operating system, UNICOS, delivers the full power of the hardware in either an interactive or a batch environment. UNICOS efficiently manages high-speed data transfers between the CRAY-2 supercomputers and peripheral equipment. Standard system software is also offered for interfacing the CRAY-2 computer systems with other vendors' operating systems and networks. UNICOS includes a variety of utility programs that assist in program development and maintenance. User programs can be ported easily between CRAY-2 systems and CRAY X-MP computer systems or other UNIX systems.

UNICOS is based on UNIX System V, an operating system developed by AT&T Bell Laboratories. In recent years, versions of UNIX have become available on many different computer systems. UNICOS is written in a high-level language called C and 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 and a simple file model for convenience and efficiency.

The kernel is the heart of the system. It has a simple, well-constructed, and clean structure with short and efficient control paths. It supports a small number of system call primitives that library and application programs can use together to perform more complex tasks.

The kernel of UNICOS has been substantially enhanced in the areas of I/O processing and in the efficient use of very large data files. Other significant enhancements include support for asynchronous I/O, improved file system reliability, multiprocessing, and user multitasking.

The UNICOS system is oriented toward an interactive environment. A batch processing capability has been provided for efficient use of the system by large, long-running jobs. UNICOS batch processing capability is based on the Network Queuing System (NQS), which allows users to submit, terminate, monitor, and — within limits — control batch jobs submitted to the system. NQS supports multiple job classes based on resource requirements, such as maximum time limit and maximum memory required. The standard UNIX process accounting features have been augmented with accounting features more appropriate for a supercomputer environment requiring batch processing capabilities.

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 4.2 BSD C shell. Other shells may be created to provide different command interfaces for users.

UNICOS supports high-level languages (including Fortran, C, and Pascal). Cray Research has adopted industry-standard protocols and an industry-standard operating system in order to offer users a generic environment across a wide range of interconnected computer systems. The result is a combination of flexibility and computing power unparalleled in the computer industry.

CRAY-2 Fortran compilers and libraries

Cray Research offers two Fortran compilers for the CRAY-2 computer systems: CFT Version 2 (CFT2) and CFT77. Both compilers offer a high degree of automatic scalar and vector optimization. Both permit maximum portability of programs between different Cray systems and accept a number of nonstandard constructs written for other vendors' compilers. Vectorized object code is produced from standard Fortran code; users need not program nonstandard vector syntax to use the full power of the CRAY-2 system architecture.

The CRAY-2 Fortran compiler, CFT2, is based on CFT, the highly successful CRAY-1 compiler that was the first in the industry to automatically vectorize codes. CFT2 automatically vectorizes inner DO-loops, provides program optimization, and exploits many of the unique features of the CRAY-2 architecture. It does this without sacrificing high compilation rates. Later releases of CFT2 will offer full ANSI 1978 compliance.

CFT77 is a state-of-the-art compiler that fully complies with the ANSI 1978 standard. CFT77 generates highly vectorized and optimized code. CFT77 also offers array syntax and portability to the CRAY X-MP and future Cray systems.

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

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.

Fortran compiler features

- ☐ ANSI standard compliance with CFT77
- ☐ Automatic optimization of code
  - Vectorizes DO loops
  - Uses local memory
- ☐ Portability of application codes is a primary goal
- ☐ Library routines
  - Scientific library
  - I/O library
  - Multitasking library

Multitasking

In conjunction with vectorization and large memory support, a flexible multitasking capability provides a major performance step in large-scale scientific computing.

Multitasking is a technique whereby an application program can be partitioned into independent tasks that can execute in parallel on a CRAY-2 computer system. This results in substantial throughput improvements over serially executed programs. The performance improvements are in proportion to the number of tasks that can be constructed for the program and the number of background processors that can be applied to these separate tasks.

Two methods can be used: macrotasking and microtasking. Macrotasking, which is available on CRAY-2 systems today, is best suited to programs with larger, longer-running tasks. The user interface to the CRAY-2 macrotasking capability is a set of Fortran-callable subroutines that explicitly define and synchronize tasks at the subroutine level. These subroutines are compatible with similar routines available on other Cray products.

Microtasking, the second method for multitasking, is under development for the CRAY-2 systems. Microtasking is available on the CRAY X-MP systems today and has proven to be a very effective parallel processing tool. Even short-duration tasks that can be multiprocessed have shown improved performance using microtasking.

Later releases of CFT77 will also provide for automatic multitasking.

C language

The C programming language is a high-level language used extensively in the creation of the UNICOS operating system and the majority of the utility programs that comprise the system. It is a modern computer language that is available on processors ranging from microcomputers to mainframe computers and now 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. An automatic vectorizing version of the C compiler is under development.

Pascal

Pascal is a high-level, general-purpose programming language used as the implementation language for the CFT77 compiler, the CAL Version 2 assembler, and various 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 CRAY-2 hardware features through automatic vectorization of FOR loops, instruction scheduling, and use of local memory. It provides access to Fortran common block variables and uses a common calling sequence that allows Pascal code to call Fortran and CAL routines.

Utilities

A set of software tools assist both interactive and batch users in the efficient use of the CRAY-2 systems.

A variety of debugging aids allow users to detect program errors by examining both running programs and program memory dumps. Supported debugging aids include symbolic interactive debuggers and symbolic postmortem dump interpreters.

Performance aids assist in analyzing program performance and optimizing programs with a minimum of effort.

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

A set of migration tools have been created to simplify conversion of Fortran code, datasets, and JCL commands from the Cray Research Operating System (COS) to UNICOS on the CRAY-2 systems.

Included with each release are on-line documentation and help facilities for quick reference of information.

CAL

The CRAY-2 Assembler, CAL Version 2, provides a powerful macro assembly language that is especially helpful for tailoring programs to the architecture of the CRAY-2 systems and for writing programs requiring hand-optimization to the hardware. CAL for the CRAY-2 computer systems uses an instruction syntax and macro capability that is similar to the CRAY-1 assembler.

Connectivity

CRAY-2 systems are designed to be connected easily to an existing customer computer environment. A major benefit of this connectivity is that the end user has access to a considerably greater computational resource while continuing to work in a familiar computer environment.

Cray Research offers hardware interfaces that connect a CRAY-2 system to a wide variety of computers and workstations, including IBM, CDC, and DEC. Additionally, systems may be connected with Network Systems Corporation HYPERchannel adapters or similar channel adapters.

The TCP/IP networking suite is available on CRAY-2 computer systems running UNICOS, providing additional flexibility for integrating a CRAY-2 system into an open network architecture.

Cray Research provides software interface support for a variety of other vendors' systems through station software. This station software runs on a variety of systems or workstations and provides the logical connection to CRAY-2 computer systems running UNICOS. Standard Cray station software is available for the following systems: IBM MVS and VM, CDC NOS and NOS/BE, DEC VAX/VMS, and a variety of computers and workstations running UNIX. Thus, the user can access a CRAY-2 system easily. Data can be transferred between any supported system and the CRAY-2 system. In many cases, data conversion and reformatting are handled automatically by software. The user can work interactively on a CRAY-2 system for processing and have results returned to the originating system or optionally to a different system.

CRAY-2 systems are supported by communications software and hardware interfaces to meet a variety of customer needs. They can readily join existing environments as partners in a multi-vendor computing facility.

Software summary

- ☐ UNICOS, the CRAY-2 operating system, which is based on the proven UNIX System V and enhanced to support both batch and interactive processing in a large-scale scientific computer environment
- ☐ Two vectorizing Fortran compilers (CFT2 and CFT77)
- ☐ A C language compiler
- ☐ An optimized Fortran mathematical and I/O subroutine library
- ☐ A scientific subroutine library optimized for the CRAY-2 computer systems
- ☐ A multitasking library that allows partitioning of an application into concurrently executing tasks
- ☐ A wide variety of system utilities to support the needs of interactive and batch processing
- ☐ A vectorizing Pascal compiler that complies with the ISO Level 1 standard
- ☐ CAL, the Cray macro assembler, which provides access to all CRAY-2 instructions
- ☐ Software for connecting CRAY-2 systems into multi-vendor environments
- ☐ A wide variety of major application programs

Applications

The CRAY-2 computer systems provide balanced performance for computationally intensive large-scale applications. Over 400 application programs are available for Cray systems, and many of these are available on the CRAY-2 systems today. Conversion of additional application programs for use on CRAY-2 systems is an ongoing effort.

Generating solutions to many important problem classes depends heavily on the number of data points that can be considered and the number of computations that can be performed. The CRAY-2 computer systems provide substantial increases over their predecessors with respect to the number of data points that can be handled. Researchers and engineers realistically can apply CRAY-2 computer systems to problems previously considered computationally intractable, as well as solving more commonplace problems faster and with greater accuracy.

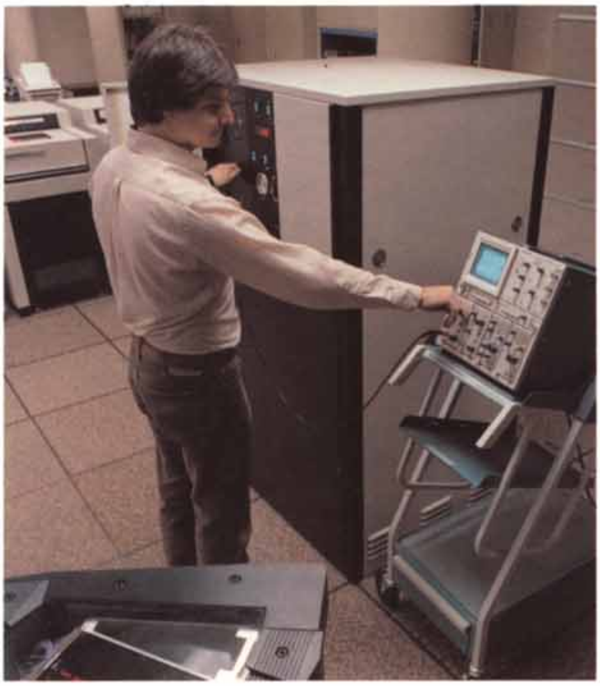
One such application is the simulation of physical phenomena — the analysis and prediction of the behavior of physical systems through computer modeling. Such simulation is common in weather forecasting, aircraft and automotive design, energy research, geophysical research, and seismic analysis. The CRAY-2 computer systems open the door to true three-dimensional simulation in a wide variety of problem domains. They also offer a challenging opportunity to find new solutions to applications in such fields as genetic engineering, artificial intelligence, quantum chemistry, and economic modeling.

The CRAY-2 computer systems offer dramatic improvements in throughput via the balanced exploitation of large memory, fast vector and scalar computation rates, and multiprocessing. Problems with previously prohibitive I/O requirements can now fit in memory. Vectorization and multiprocessing promote very high computation rates. In practical terms, this means that problems previously considered large-scale become medium- or even small-scale on the CRAY-2 computer systems. And problems previously considered unsolvable or too costly to solve become solvable and economically feasible.

Applications

- ☐ Fluid dynamics
- ☐ Circuit simulation and design
- ☐ Structural analysis
- ☐ Energy research
- ☐ Weather forecasting
- ☐ Atmospheric and oceanic research
- ☐ Quantum chemistry
- ☐ Artificial intelligence
- ☐ Genetic engineering
- ☐ Signal image processing
- ☐ Molecular dynamics
- ☐ Petroleum exploration and extraction
- ☐ Process design
- ☐ Economic modeling

Support and maintenance



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

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

Cray Research recognizes the need for high system reliability while maintaining a high level of performance. The use of higher-density integrated circuits and an overall higher level of component integration teamed with liquid immersion cooling enhances CRAY-2 system reliability. Components used in CRAY-2 computer systems undergo strict inspection and checkout prior to assembly into a system. All CRAY-2 computer systems undergo rigorous operational and reliability tests prior to shipment.

Preventive maintenance techniques ensure that system performance is high; effective and timely maintenance is a routine operation. Diagnostic software quickly isolates any problem that may occur and the fluid coolant is quickly pumped into the reservoir adjacent to the mainframe. Once the repair is made, the front panel is reinstalled and the fluid quickly returned to the mainframe. The entire operation requires only a few minutes.

Offering advanced architecture, advanced technology, and advanced software, the CRAY-2 computer systems clearly lead the industry in large-scale computing. The CRAY-2 computer systems offer the fastest processor clock cycle (4.1 nanoseconds), the largest memory (up to 256 million words), and two or four processors. Each processor will operate in scalar and vector mode. The multiple processors may operate independently and simultaneously on separate jobs for greater system throughput or may be applied in any combination to operate jointly on a single job for better program turnaround time. The CRAY-2 computer systems lead the industry in computer architecture by using some of the fastest and most dense components available packaged in three-dimensional modules immersed in liquid coolant. The CRAY-2 computer systems offer a recognized and accepted operating system tailored to the needs of large-scale computers. Two Fortran compilers and a number of extensions to the operating system automatically take advantage of the system architecture and promote efficient use of the system.

About Cray Research

Cray Research, Inc. 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.

Mr. Cray has been a leading architect of large scientific computers for more than 30 years. From 1957 to 1968, he served as a director of Control Data Corporation (CDC) and was a senior vice president at the time of his resignation in early 1972. At CDC, he was the principal architect in the design and development of the CDC 1604, 6600, and 7600 computer systems. Prior to his association with CDC, Mr. Cray was employed at the Univac Division of Sperry Rand Corporation and its predecessor companies, Engineering Research Associates and Remington Rand. Mr. Cray has been the principal designer and developer of both the CRAY-1 and CRAY-2 computer systems.

Today Cray Research is the world leader in supercomputers, with well over 175 supercomputers installed 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 subsidiary operations in Western Europe and the Far East.

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