A CRAY RESEARCH, INC. PUBLICATION

CRAY CHANNELS

Volume 4, Number 1

ANNOUNCEMENT!
New CRAY X-MP introduced

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Searching for the 27th Mersenne Prime

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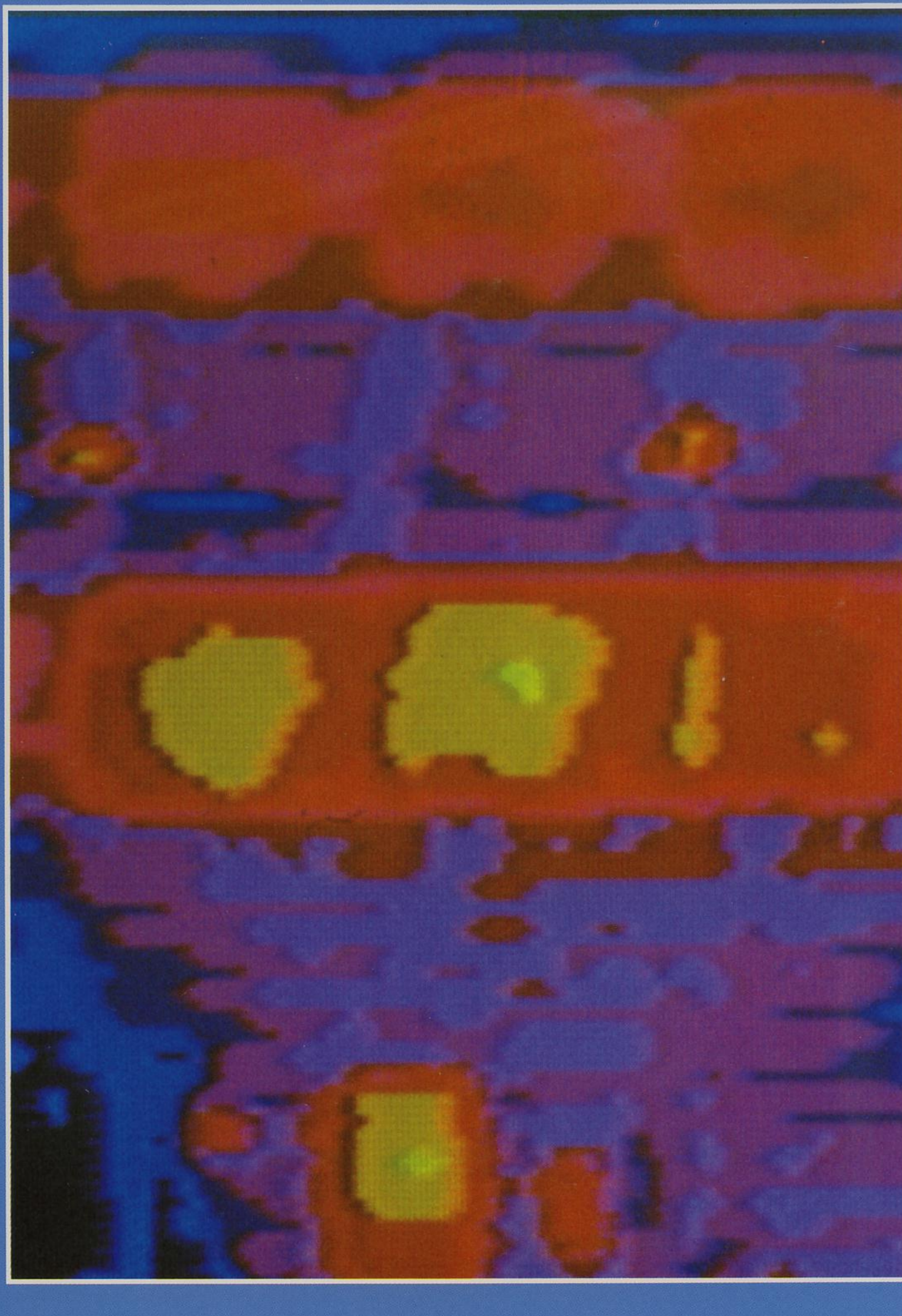


From the editor's desk

New product announcements are always exciting, but it's particularly satisfying to be able to bring you the product introduction contained in this issue of **CRAY CHANNELS.** The new CRAY X-MP Series of Computer Systems is a major computational resource ideal for execution of both multiprocessor jobs and concurrent independent uniprocessor jobs. The X-MP's powerful dual Central Processing Units share a two- or four-million word Central Memory. Also announced was a new Solid-state Storage Device offering exceptionally high transfer rates to users of X-MP or S Series systems.

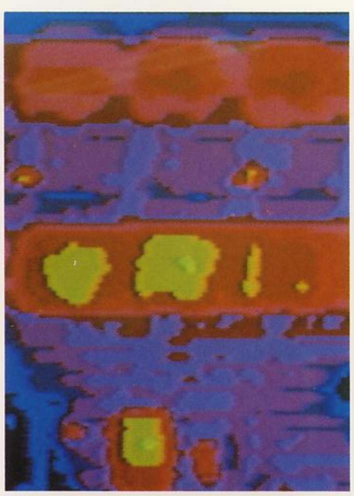
Elsewhere in this issue, Cray's Dave Slowinski recounts his efforts in finding the 27th Mersenne Prime number. And we bring you a pull-out reference detailing the major applications programs available on the CRAY-1. As always, company, user, and applications news fills out the issue.

As if the product announcements contained herein weren't enough, there's one additional introduction that should be made. Carol Smith has joined the **CRAY CHANNELS** staff since our last issue. In future issues, Carol will be reporting on many of the topics you're most interested in. For this issue, she presents the company's history from a tenth-anniversary vantage point.

I hope you enjoy this issue as much as we've enjoyed preparing it for you!

— T.M.B.

About the cover



Infrared scan of a string of chips on a CRAY module board

Cray Research recently purchased a number of infrared thermal imaging units that will aid engineers in completing system reliability checks. These units, which are being used in Chippewa Falls and in the field, enable engineers to rapidly locate components that are running over temperature. They were also used in the research and development of new cooling techniques for Cray Research's newest product, the CRAY X-MP Series. Each "hot spot" on an infrared scan indicates a component that could present problems in the future. By finding these potential problems early, engineers can make precautionary modifications or repairs to maintain CRAY system reliability. This photograph, taken on the color infrared unit located at the company's Chippewa Falls Manufacturing facility, shows strings of chips on a module board being tested. A hot spot indicates a component that most probably will fail in the future.

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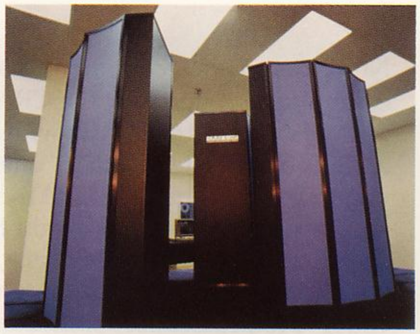

REGULAR COLUMNS

CREDITS

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CRAY CHANNELS is a quarterly publication of Marketing Publications, Cray Research, Inc., P.O. Box 154, Minneapolis, Minnesota 55440. CRAY CHANNELS is intended for users of Cray Research computer systems and others interested in the company and its products.

Requests for copies of CRAY CHANNELS may be addressed to the Marketing Publications Department of Cray Research at the above address. If you have a feature article or news item to submit for publication, please contact the editor of CRAY CHANNELS either by mail or by telephone at (612) 333-5889.

Introducing the CRAY X-MP

Now, Cray Research announces an answer to your expanding computational needs — the CRAY X-MP Series of Computer Systems. The CRAY X-MP, with its major innovations in architecture and technology, offers overall system throughput up to five times that of a CRAY-1 S/1000 CPU, and a maximum burst rate up to eight times that of the CRAY-1 for specific cases. At the same time, software compatibility has been maintained between the CRAY X-MP and the CRAY-1 to protect user software investment.

The CRAY X-MP, with its 9.5 nanosecond clock cycle time, is the fastest general-purpose computer system available today. It is capable of an overall instruction issue rate of more than 200 million instructions per second (MIPS). Computation rates of over 400 million 64-bit floating point operations (MFLOPS) are possible, and combined arithmetic/logical operations can exceed 1,000 million operations per second (MOPS).

CRAY X-MP system overview

The CRAY X-MP Series is a powerful system ideal for execution of multiprocessor jobs and concurrent independent uniprocessor jobs. At the heart of the CRAY X-MP mainframe are two identical Central Processing Units (CPUs), each of which, through various hardware enhancements, is even more powerful than the CRAY-1 uniprocessor. Synchronization of the processors is achieved through clusters of shared registers in the CPU intercommunication section and through Central Memory.

The CRAY X-MP's dual processors share a single bipolar Central Memory of two million or four million words that supports the requirements of large-scale applications. Central Memory is arranged in 32 banks for four-million-word systems and in 16 banks for two-million-word systems. These interleaved memory banks enable extremely high transfer rates through the I/O section and provide low read/write times for vector processing. The CRAY X-MP's short bank cycle time (38 nanoseconds) is well-suited to high-performance scalar and vector applications.

Cray Research's I/O Subsystem, which is an integral part of the CRAY X-MP, also contributes

Series of Computer Systems

to the system's outstanding performance. The I/O Subsystem offers parallel disk drive capabilities, I/O buffering for disk-resident and Buffer Memory-resident datasets, on-line tape handling, and efficient front-end system communication. Up to eight million words of Buffer Memory can be configured on the IOS, enabling faster and more efficient data access and processing by the CPUs.

Complementing the CRAY X-MP and designed with its demanding throughput requirements in mind is the new Cray Research Solid-state Storage Device (SSD). The SSD, with its exceptionally high transfer rates, can be used as a fast-access disk device for large datasets generated and manipulated repetitively by user programs. It can also be used by the system for temporary storage of system programs. The SSD is available with 64, 128, or 256 million bytes of on-line storage. Memories are fully field upgradable from the smallest to the largest size offered.

Accompanying the SSD and enabling its high performance is a broadband channel capable of a maximum burst transfer rate of 10 gigabits per second. Performance improvement factors of 50 to 100 are anticipated over disk units for short random or long sequential transfers. Transferring a million-word dataset requires only about 50 milliseconds, including system overhead. The SSD can also be attached to a CRAY-1 S Series Computer System through the 100 Mbyte/sec channel. Under this condition, significant speedup in I/O can also be achieved.

CRAY X-MP hardware features

Sixteen-gate array integrated circuits are used throughout the CRAY X-MP CPUs. These circuits, which are faster and denser than the circuitry used in the CRAY-1, contribute to a clock cycle time of 9.5 nanoseconds and a memory bank cycle time of 38 nanoseconds. Proven cooling and packaging techniques have also been used on the CRAY X-MP to ensure high system reliability.

The CRAY X-MP's four parallel memory access ports per processor, combined with the improved clock cycle time, means that the CRAY X-MP has over eight times the total usable memory bandwidth of the CRAY-1.

The high performance of the CRAY X-MP is evident in both scalar and vector modes. Scalar performance is improved through the faster clock, short memory access time, and larger instruction buffers, while vector performance is improved through a combination of faster clock, parallel memory ports and hardware automatic 'chaining' features. These new features allow simultaneous memory fetch, arithmetic, and memory store operations in a series of related vector instructions. Either long or short vector operations, characterized by heavy register usage or heavy memory references, use these features to advantage.

CRAY X-MP software features

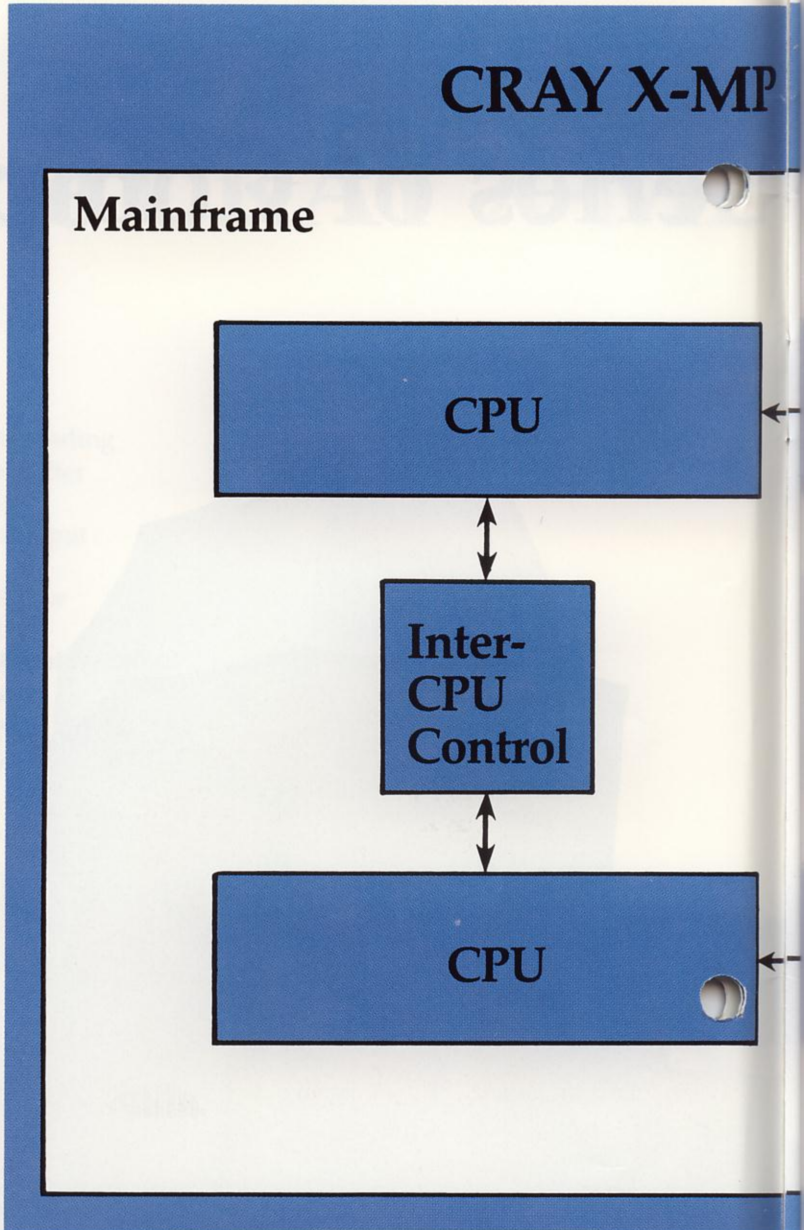
The processing potential of the CRAY X-MP Series has stimulated the development of new system and user software techniques. Cray Research is committed to providing users with full and easy access to the power of the new CRAY X-MP.

The CRAY Operating System (COS), by providing the same user interface to both the CRAY X-MP and the CRAY-1, enables a smooth migration path to the higher capacity CRAY X-MP systems. COS treats the multiple processors of the CRAY X-MP symmetrically; that is, COS and user code may execute on either processor.

New techniques extending the multiprocessing capabilities of the CRAY FORTRAN Compiler (CFT) are also being explored. Furthermore, new software supports the SSD and the IOS Buffer Memory so that to users, these devices appear like disks. Thus, temporary datasets employed by user jobs may reside wholly or partially within the SSD or Buffer Memory, resulting in significant reductions of I/O wait time.

CRAY X-MP physical characteristics

The CRAY X-MP mainframe consists of twelve vertical columns arranged in a 270° arc. Each column houses two chassis holding up to 72 modules. Power and cooling supplies are clustered around the base and extend outward to provide seating for maintenance personnel. The compact mainframe requires just 100 square feet of floor space.



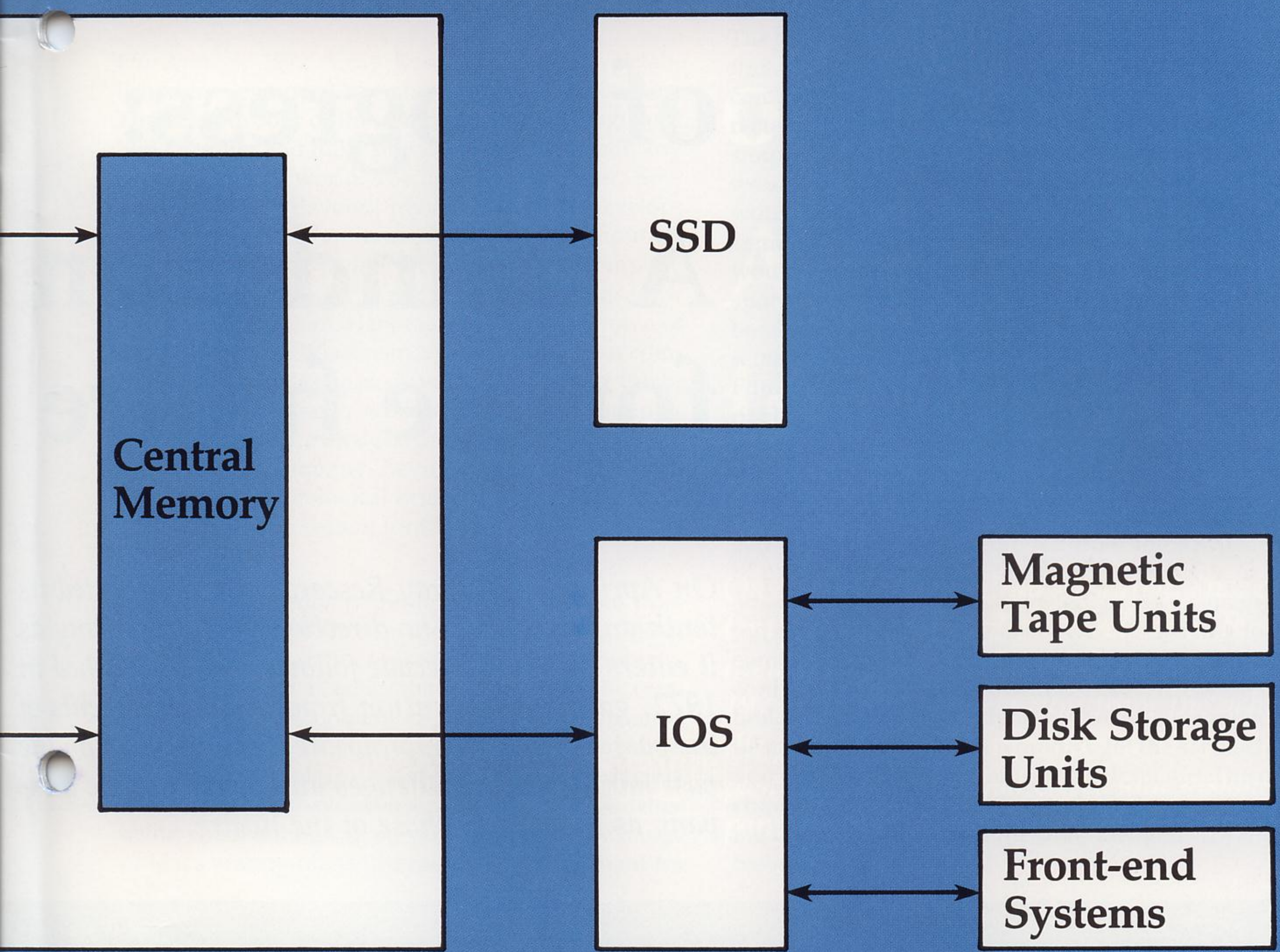
CRAY X-MP availability

The first CRAY X-MP is currently undergoing testing at the Cray Research Development facility in Chippewa Falls, Wisconsin. Upon completion of testing, the system will be moved to the company's Software and Support facility in Mendota Heights, Minnesota, where software development work will continue. During 1983, it is expected that several CRAY X-MPs will be delivered to customer sites. ☐

Highlights

The CRAY X-MP is a powerful computer system ideal for execution of multiprocessor jobs and concurrent independent uniprocessor jobs. With its advanced

overall system organization

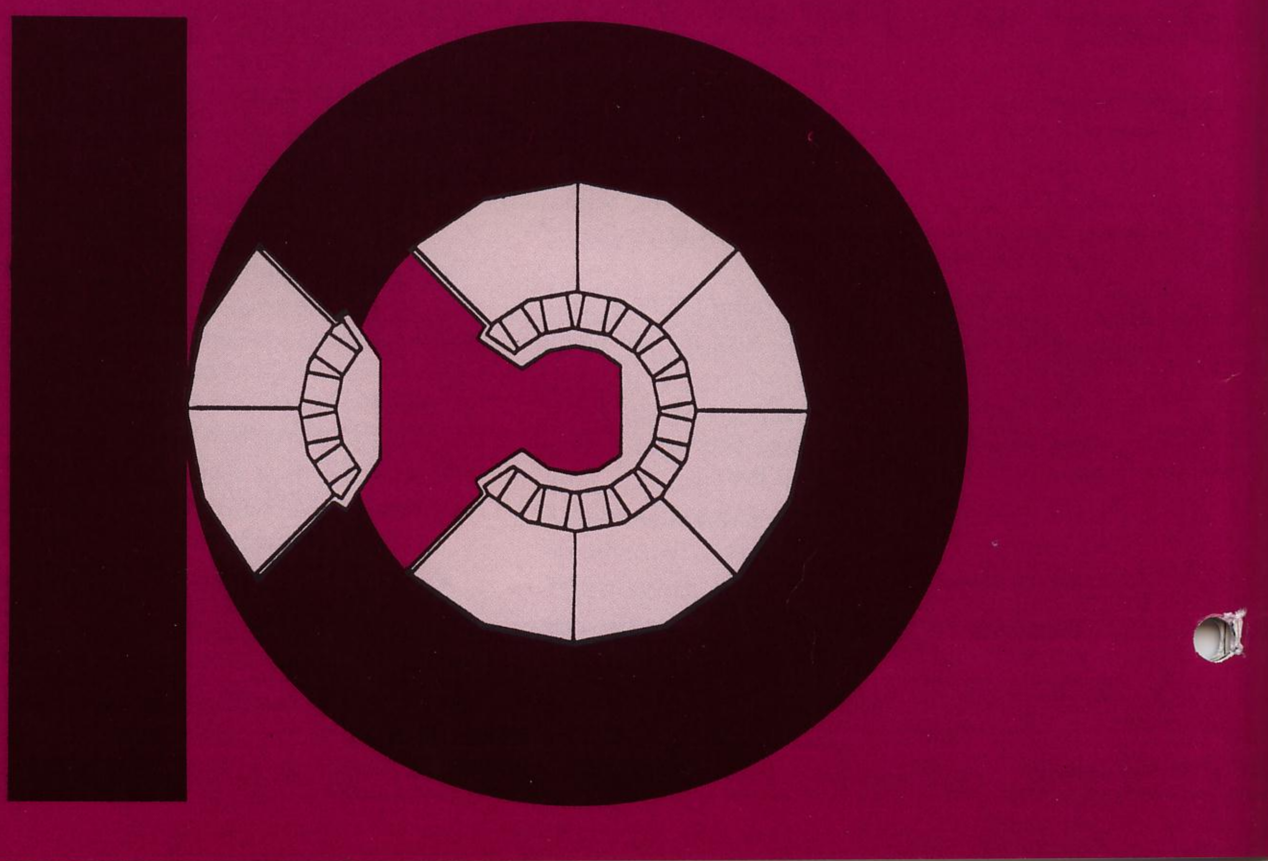


design and improved performance, the CRAY X-MP offers:

- Overall system throughput up to five times that of a CRAY-1 S/1000 CPU on many jobs, with a maximum burst rate of up to eight times that of the CRAY-1 for specific cases
- Two identical Central Processing Units sharing a Central Memory of up to four million 64-bit words
- Four parallel memory access ports per processor providing over eight times the total usable memory bandwidth of the CRAY-1
- Four instruction buffers with a combined capacity of 512 16-bit instruction parcels, twice the capacity of those on the CRAY-1
- Operational registers and functional units that are among the features providing compatibility with the CRAY-1
- Hardware support for partitioning of memory fields into data and program areas
- The new high-performance Solid-state Storage Device (SSD) which, with its transfer rate of up to 10 gigabits/second, can be used as an exceptionally fast-access disk device
- An integral I/O Subsystem that efficiently performs input/output functions between the mainframe, peripheral devices, and the front-end systems and has a sustained transfer rate of 40 Mbytes/second between the mainframe and the I/O Subsystem
- Software that takes advantage of the unique CRAY X-MP hardware features while remaining compatible with that of the CRAY-1
- Compact size — just 100 square feet of floor space required for the mainframe
- Proven component and cooling technologies designed for high reliability

A decade of progress: A foundation for the future

On April 6, 1982, Cray Research, Inc. celebrated its tenth anniversary. The direction of the company as it enters its second decade follows that established in 1972, gaining momentum from the achievements of the past. This is an appropriate time to reflect on the past motivations, challenges and visions of the company as they direct those of the future.



On April 6, 1972, Cray Research, Inc. was established by Seymour Cray and a group of colleagues. The sole purpose of the company was to design and build a larger and more powerful computer than any available in the world. For most of his career, Seymour Cray has devoted his energy to the development of computer systems with massive computing capabilities. Prior to the founding of the company bearing his name, Mr. Cray conducted his research and development in a laboratory in his hometown of Chippewa Falls, Wisconsin. A small number of computer and business associates joined him in establishing the company, while a handful of computer industry investors pledged more than $2.5 million to the fledgling company. Seymour Cray's stellar reputation for technological brilliance and entreprenurial skill was the reason for the enthusiastic support he received.

The tiny new company conducted its operations from an old abandoned shoe factory while construction of a new 9,000 square foot research lab was underway. Cray insisted on a facility that would foster the creativity of his development engineers. He envisioned that it would be "a super-quiet think tank where we will develop a colossal giant computer." The facility was designed to have acoustically perfect rooms while being small enough to encourage the free exchange of ideas among his employees. Cray's penchant for small working environments has continued over the decade as the company has grown and decentralized.

Company goals defined

The young company's goal was the production, within three to four years, of the next generation of supercomputers. Basic guidelines defined by Mr. Cray directed the company toward its achievement. Quite simply, the guidelines stipulated that: 1) All efforts would dedicated to supercomputers; the company would not diversify downward with mainframes designed for a mass market. 2) Development efforts would be assigned to small teams of engineers responsible for a specific task. These engineers would be given the freedom to innovate in an atmosphere removed from day-to-day company operations. 3) Future systems development would result in compatible add-on systems to user's existing systems. Today, ten years later, these guidelines are still integral to the company's philosophy.

Cray's greatest reward from the establishment of the company seems to be derived from the satisfaction of producing computing tools that contribute to the advancement of human knowledge. "The person using the equipment," he once said, "is striving to do something significant. I see myself playing a role of contributing to it by providing a tool. If I were just building another something a little cheaper and a little more cost-effective, I wouldn't get the satisfaction I do out of doing something more dramatic. The machines I've been building have been factors in moving this particular part of the computer industry ahead technically."

1972

Cray Research founded on April 6
Development of world's fastest computer begins
Hallie Lab construction is completed

1973

Software development begins
Cray Research employs 21 people
Development work progresses

Initially, fewer than 100 organizations worldwide were identified as potential users of the anticipated CRAY system. The system was expected to answer the needs of a small segment of the scientific community that required the ability to execute complex vector and scalar calculations to aid in the mathematical simulation of multi-dimensional physical events. Potential applications were seen to include hydro and aerodynamic modeling in addition to seismic and nuclear fission analyses.

Meeting the challenge

Cray determined that both large memory and high speed were key requirements to performing those calculations efficiently. As a result, the new system was designed to contain up to one million words of memory. The arithmetic, control and memory were composed of 1,500 printed circuit modules. It had a clock period of 12.5 nanoseconds and 50 nanosecond memory constructed of 1,024-bit bipolar chips. The system was housed in a semi-cylindrical cabinet just slightly over six feet high and four feet in diameter containing more than 60 miles of wiring. The innovative adaptation of known technologies resulted in the CRAY-1's revolutionary architecture. This architecture is key to its unmatched capabilities. However, Seymour Cray insisted, "There is not much to designing really... I design computers about the same way I design sailboats... for simplicity."

Company offers stock to public

As the first CRAY-1 was nearing completion in 1975, it became apparent that the small company would require additional funding. The $8.6 million raised from 1972 to 1975 had been absorbed by developmental costs. At the behest of Seymour Cray early in 1976, John Rollwagen, the company's newly appointed chief financial officer, made his way to New York to sell the company to the financial community. His objective was to raise $10,000,000 through the sale of shares of stock expected to sell for $16.50 per share.

As luck would have it, March 17, 1976, St. Patrick's day, was the day of the stock offering. All shares were quickly snapped up. Over-the-counter trading showed the stock opening at $24.00 per share, ultimately settling back to about $18.00. It was a stunning performance for a company that had no sales or revenues to its name. The investment community's confidence in Cray Research was attributed to the solid reputation that Seymour Cray had earned for himself over the years and its confidence that his vision would become a reality. With the financial requirements of the company satisfied, Cray Research was able to carry on with the business of bringing its computer to market.

The CRAY-1 steps out

The first CRAY-1 delivered in early March 1976 to Los Alamos National Laboratories (LANL), successfully completed a 180-day testing and evaluation period. In October, LANL reported that the CRAY-1 met every performance criterion they had established. In May 1976, the National Center for Atmospheric Research (NCAR) ordered a CRAY-1 to be de-

1974

Research staff grows as CRAY-1 nears completion

Employee count increases to 30

1975

CRAY-1 introduced

Cray Research personnel increases by 50%

John Rollwagen joins Cray Research

1976

The first CRAY-1 is installed and accepted

Cray Research holds public stock offering

Company brings in its first revenues

livered a year later. By the end of 1976 the company realized its first revenues, about $500,000.

In anticipation of increasing demand for its product, Cray Research began gearing up for further growth. It increased its payroll from 45 in 1975 to 124 in 1976. Efforts focused on enhancing the performance capabilities of the CRAY-1 as related to specific customer needs. One research and development objective was software development. Initial development work culminated with the introduction of the CRAY FORTRAN Compiler (CFT) and CRAY Operating System (COS) in 1977. Seymour Cray began development on the next generation of supercomputers in that same year.

Cray assumes industry leadership

Meanwhile, CRAY-1 system proposals were submitted to and accepted by a number of organizations. Two systems were sold and delivered in 1977 and additional customer commitments covered the production plan for all of 1978. Production goals were stepped up from one machine annually to four. The establishment of a new manufacturing facility in Chippewa Falls, Wisconsin, coupled with doubling the number of employees, made that goal a reality.

As the CRAY-1 gained wider acceptance as the standard of supercomputer excellence, its user base expanded. In 1978 a CRAY-1 was scheduled for delivery to the first commercial user. Tentative commitments were also received by several other commercial organizations involved in aerospace and petrochemical research, structural engineering and automotive design. Sales subsidiaries were established in Japan, West Germany, England and France.

By 1978 Cray Research, Inc. had successfully demonstrated its ability to produce the volume of equipment necessary to honor customer orders. It established its position as the leading supplier of large-scale scientific computers. The company had achieved its primary purpose but would not rest there. Large-scale development efforts continued on CRAY-1 enhancements alongside CRAY-2 development. At the same time the company strove to maintain the small personal working environment out of which the CRAY-1 technology was born.

Software development continued at an accelerated pace through 1978 in recognition of users' increasing software requirements. The demand for applications software for the CRAY-1 also expanded as the customer base grew. Software became recognized as a major component in the further enhancement of CRAY systems.

In 1979 the CRAY-1 S Series of Computer Systems was announced. Its introduction represented an evolution of the CRAY-1 by offering larger memory size and enhanced input/output capabilities. The advent of the CRAY-1/S system reinforced the commitment of Cray Research to be the industry leader of supercomputer development and to ensure compatibility across a family of systems, augmenting the user's total computing power.

Growth and transition

In 1979, the company experienced an extraordinary spurt of growth, reporting revenues of almost $43 million. Overall employment grew by 67%, from 321 to 524. The tremendous growth raised questions about the company's future direction — how its product

1977

CRAY-2 development work begins
Initial CFT and COS software versions are released
Company shows first profits
Cray Research opens its first manufacturing facility

1978

Cray Research plans to manufacture its own circuit boards
CRAY-1 production rate increases to eight machines annually
User base expands to commercial market
Eight CRAY systems installed to date
Mendota Heights facility under construction

1979

CRAY-1 S Series of Computers is announced
Company grows to 524 employees
$8 million profit in this year equals total capitalization for first four years
Cray Research is positioned number five on Inc. 100 roster

line should be defined, how large it should grow, and how quickly. Cray Research, Inc. reiterated its purpose to develop, manufacture, market and install the world's most powerful large-scale scientific computers. To that end, CRAY-1 and CRAY-2 development work was stepped up, while programs were initiated for the development of even more advanced technology. The company determined that ongoing development and support would continue on the CRAY-1 throughout the 1980's.

The second generation appears on the horizon

Development of products less powerful than the CRAY-1 was considered but later rejected. The company expected that, with time, growing numbers of industrial and scientific researchers would require the computing capability available with CRAY-1. Therefore, growth would evolve as users grew into CRAY systems as opposed to the company making less powerful systems to meet the demand of the mass market. Very significant expenditures were allocated to research and development to ensure the maintenance of Cray Research's technological edge.

The company's commitment to research and development resulted in a major technological breakthrough announced late in 1981. The technology is the basis upon which the CRAY-2 system will be built. Seymour Cray applied liquid immersion technology to solve one of the basic problems in computer design, that of cooling. By immersing the computer in a bath of clear inert liquid, cooling is accomplished more efficiently, enabling higher-density packaging of components. The CRAY-2 is expected to be six to twelve times faster than the CRAY-1 and will be very small, occupying about half the space of its predecessor. The first CRAY-2 is expected to be ready for the market by 1985.

In order to spur hardware development on, Seymour Cray stepped down as chairman of Cray Research on November 19, 1981 to devote full-time personal efforts to the CRAY-2 and other design and development work. Seymour Cray remains a director of the company and a member of the executive committee. John Rollwagen has assumed the chairmanship while remaining president and chief executive officer of the company.

In April of this year, Cray Research announced the CRAY X-MP Computer System (see article in this issue). With this introduction, the company remained true to its founding principles, extending Cray Research's leadership in large-scale computer development.

The strength of Cray Research's products is evidenced by the tremendous successes of the past decade. The company has grown from an entrepreneurial venture to a solid company providing the world's most advanced computer systems. CRAY systems have become major computational resources for a select group of scientific users and, more recently, industries heavily involved in complex research.

Cray Research's goals in 1982 remain the same as those of 1972, the development and support of the world's most powerful computers. In 1982 and beyond, the effort to achieve those goals is strengthened by the foundation established over the company's first decade. □

1980

First CRAY-1 installed in petroleum research environment

First CRAY-1/S order received

Number of employees grows to 761

Cray Research stock begins trading on the New York Stock Exchange

1981

CRAY-2 technology announced

Company grows to 1,000 employees

Largest CRAY-1 is installed in petroleum industry

35 CRAY systems installed to date

1982

Company celebrates ten year anniversary

CRAY X-MP Computer Series is announced

Seymour Cray devotes full-time efforts to CRAY-2 development

Major applications software available on the CRAY-1

An extensive array of scientific and engineering applications software packages has become available on the CRAY-1 over the past few years. Following is a "top 50" list of major applications software that is of special importance to customers of Cray Research, Inc. This list is by no means comprehensive; rather, it is designed to provide you with an idea of the variety of software available to CRAY-1 users.

A number of the packages listed are available through the Cray Applications Software Library. For general information on the Library, contact:

David Darling
Cray Research, Inc.
1440 Northland Drive
Mendota Heights, Minnesota 55120

Structural and Thermal Analysis

ANSYS	Swanson Analysis Systems, Inc. P.O. Box 65 Houston, PA 15342 Tel: (412) 746-3304	General purpose structural and thermal analysis
ASASFLOAT **ASASLAUNCH**	Atkins Research and Development Ltd. Woodcote Grove, Ashley Rd., Epsom Surrey KT18 5BW, England Tel: (03727) 26140	Simulation of launch and upending characteristics of large offshore structures
FLOATMOOR	B.W. Oppenheim, Ph.D. and Associates Los Angeles, CA	Static and dynamic analysis of moored vessels
HONDO	Cray Applications Software Library	Linear structural analysis
MARC	Marc Analysis Research Corp. 260 Sheridan Ave., Suite 200 Palo Alto, CA 94306 Tel: (415) 326-7511	General purpose structural analysis with special emphasis on nonlinear problems
MSC/NASTRAN	MacNeal-Schwendler Corp. 7442 N. Figueroa Street Los Angeles, CA 90041 Tel: (213) 254-3456	General purpose structural and thermal analysis
NISA	Engineering Mechanics Research Corp. P.O. Box 696 Troy, MI 48009 Tel: (313) 698-1606	Linear structural and thermal analysis
PAFEC75	Pafec Ltd., Pafec House 40 Broadgate, Beeston Nottingham NG9 2FN, England Pafec Engineering Consultants, Inc. 601 Concord Street Knoxville, TN 37919 Tel: (615) 524-7447	General purpose structural and thermal analysis

PISCES 2DELK	Physics International Company 2700 Merced Street San Leandro, CA 94557 Tel: (415) 357-4610	Complex fluid-structure interaction
SAP4	Cray Applications Software Library	Linear structural analysis
SINDA	Prose, Inc. Malago Cove Plaza Palos Verdes Estates, CA 90274 Tel: (213) 373-8919	Thermal-fluid system analysis
SPACE4	Digital Analysis Consultants, Inc. 7460 Girard Avenue La Jolla, CA 90237 Tel: (714) 759-3373	Linear structural analysis
STAAD III	Research Engineers P.O. Box 2706 Cherry Hill, NJ 08034 Tel: (609) 482-0900	Linear analysis of framed structures

Piping analysis

PIPESD	John A. Blume and Associates, Engineers 120 Jessie Street San Francisco, CA 94105	Static, dynamic, and thermal analysis of 3-D piping systems
SIMFLEX	Peng Engineering 10543 Alcott Drive Houston, TX 77043 Tel: (713) 461-3949	Linear static analysis of 3-D piping systems

Chemical and Petroleum Engineering

BETA II, VBETA, Chemical Flooding Simulator, Combustion Model, Steamflood Model	INTERCOMP Resource Development and Engineering, Inc. 1201 Dairy Ashford, Suite 2000 Houston, TX 77079 Tel: (713) 493-5900	Oil reservoir simulation and oil recovery problems
BOSS, BOSS-AIM, BOSS-COMPOSITIONAL, BOSS-THERMAL	Scientific Software, Inc. 18th Floor, First of Denver Plaza 633 Seventeenth Street, Denver, CO Tel: (303) 571-1111	Oil reservoir simulation
PORES	Operations Research Group AERE, Harwell Didcot, Oxon OX11 0RA, England	Oil reservoir simulation
PROCESS	Simulation Sciences, Inc. 1440 N. Harbor Blvd. Fullerton, CA 92635 Tel: (714) 879-9180	Chemical process simulation
TRITRI	Franlab Consultant, Sophia Antipolis BP 14, Valbonne, France	Oil reservoir simulation

Nuclear Engineering

NUCLIB	Boeing Computer Services	Variety of applications in nuclear engineering and reactor safety analysis
PDQ7	Scientific Computer Simulation, Inc. P.O. Box 114 Moraga, CA 94556 Tel: (415) 376-0629	Neutron diffusion analysis
RELAP4/MOD6	Intermountain Technology, Inc. Idaho Falls, ID	Reactor transient analysis
TRAC-P1A	Cray Applications Software Library	Reactor transient analysis

Electronics Engineering

DRC	NCA Corp. 388 Oakmead Parkway Sunnyvale, CA 94086 Tel: (408) 245-7990	Design rule checking
HSPICE, META-1, META-2, SETREM	Meta-Software, Inc. 841 Stendahl Lane Cupertino, CA 95014 Tel: (408) 245-7990	Circuit simulation
NEMOS	D.P. Kennedy and Associates, Inc. Gainesville, FL	MOS transistor design
SPICE2	Cray Applications Software Library	Circuit simulation

Aerodynamics

FLO27, FLO57	Cray Applications Software Library	Transonic fluid flow simulation

Atomic Physics

GAUSSIAN76	Cray Applications Software Library	Molecular structure simulation

Mathematics and Statistics

AMOSLIB	Cray Applications Software Library	Special functions
NCAR Software Support Library		General mathematics, statistics, and utilities
BCSLIB	Boeing Computer Services	General mathematics and statistics

EISPACK	Cray Research, Inc.	Eigenvalues and eigenfunctions
LINPACK		Linear algebra
Harwell Subroutine Library	Building 8.9, AERE, Harwell Didcot, Oxon OX11 0RA, England Tel: (0235) 24141	General mathematics and statistics
IMSL	IMSL, Inc. 7500 Bellaire Blvd, 6th floor Houston, TX 77036 Tel: (713) 772-1927	General mathematics and statistics
TWODEPEP		2-D partial differential equations
NAG Library	NAG Library Service Coordinator NAG Central Office, 7 Banbury Road Oxford, OX2 6NN, England Tel: (0865) 511245	General mathematics and statistics
SCICONICS	SCICON Service Bureau, England	Linear programming

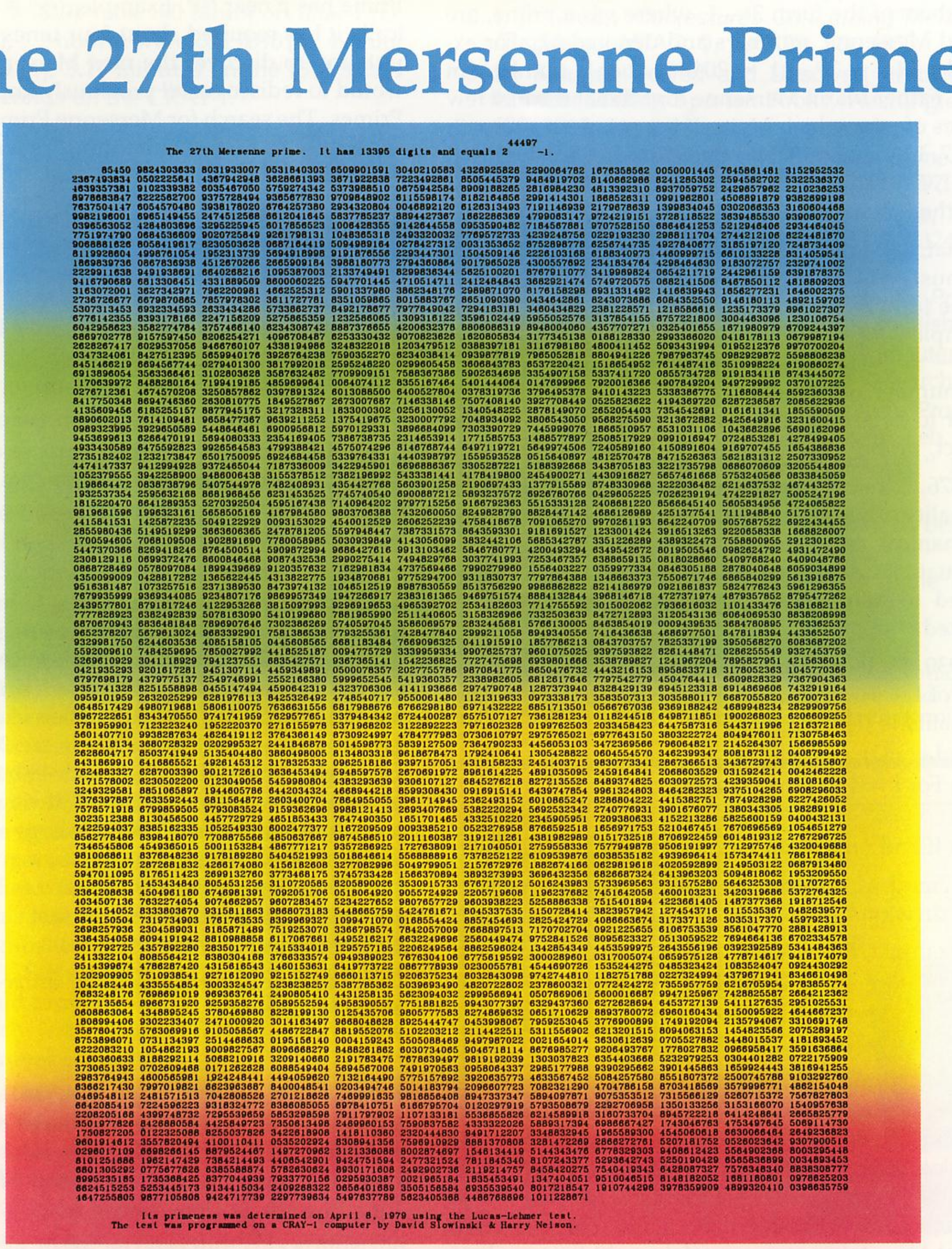
Computer graphics

C-GUL	Atkins Research and Development Ltd. Woodcote Grove, Ashley Rd, Epsom Surrey KT18 5BW, England Tel: (03727) 26140	Graphics support for ASASLAUNCH and ASASFLOAT programs
CPS-1	Radian Corp. 8501 Mo-Pac Blvd. Austin, TX 78776 Tel: (512) 444-0541	3-D surface and contour plotting
DISSPLA	ISSCO 4186 Sorrento Valley Blvd. San Diego, CA 92121 Tel: (714) 452-0170	General plotting and charting
GHOST80	U.K.A.E.A., Culham, England	General plotting and charting
NCAR Graphics Library	Cray Applications Software Library	General plotting and charting

Software tools

RIM-5	Boeing Commercial Airplane Co. P.O. Box 3707, M/S 73-03 Seattle, WA 98124 Tel: (206) 237-2389	Database management
INDEX	Cray Applications Software Library	FORTRAN program directory listing
ROFF		Text processing
TIDY		FORTRAN program reformatting □

Searching for the 27th Mersenne Prime



David Slowinski
Cray Research, Inc.

There seems to be an astounding amount of interest in the world's largest known prime. When Curt Noll and Laura Nickel discovered the twenty-fifth Mersenne Prime, 21701, in October, 1978, the announcement was carried by every major wire service in the United States and even announced by Walter Cronkite on the CBS Evening News.

Historically, the largest known prime has been a Mersenne Prime. What is a Mersenne Prime? How does one search for a large prime?

Numbers of the form 2^p—1, where p is a prime, are called Mersenne numbers and denoted M_p. For example, $M_{11} = 2^{11} - 1 = 2047$ is such a number. In 1644, Father Marin Mersenne found that the first few values of p for which M_p itself is a prime were $p = 2$, 3, 5, 7, 13, 17, and 19. He conjectured, moreover, that for 31, 67, 127, and 257 M_p would be prime and that no other such primes would occur in that range.

Fermat, and later, Euler proved that all factors of any M_p must be of the form $2kp + 1$ and, simultaneously, of the form $8n \pm 1$, where k and n are integers. For example $2047 = 23 \cdot 89 = (2 \cdot 1 \cdot 11 + 1)(2 \cdot 4 \cdot 11 + 1) = (8 \cdot 3 - 1)(8 \cdot 11 + 1)$. This discovery greatly reduces the number of potential factors of M_p and allowed Euler to determine that M_{31} = 2, 147, 483, 647 was, in fact, prime.

In 1876, E. Lucas discovered a fast way to test for the primality of a Mersenne number. Using this test and mechanical calculators, (and scores of ambitious graduate students, no doubt), 61, 89, and 107 were added to Mersenne's list while 67 and 257 were deleted.

In 1930, D. H. Lehmer published an improved version of Lucas' algorithm. The Lucas-Lehmer test for primality is [1]:

(1) Let $u(1) = 4$,

(2) For $i = 1$ to $p - 2$ compute

(3) $u(i + 1) = (u(i)^2 - 2) \bmod M_p$,

(4) If and only if $u(p - 1) = 0$, then M_p is a prime.

The "mod M_p" means to keep only the remainder after division by M_p.

For example, if $p = 5$, $M_p = 2^5 - 1 = 31$, and

$u(2) = (4^2 - 2) \bmod 31 = 14$,

$u(3) = (14^2 - 2) \bmod 31 = 8$,

$u(4) = (8^2 - 2) \bmod 31 = 0$.

This Mersenne number primality test is very cheap to perform compared to testing an arbitrary number of comparable size, but even for this algorithm, the calculation required to test a single M_p increases with p on the order of (p^3) since there are roughly p trips through a loop that takes order (p^2) to compute. Thus, to test M_{2r+1} takes approximately eight times as long as to test M_r with the same process.

The advent of the computer made possible the extension of the list of known Mersenne Primes to 23 entries by 1963. The additions were 521, 607, 1279, 2203, 2281, 3217, 4253, 4423, 9689, 9941, and 11213 [2-4]. Eight years later, M_{19737} was found prime [5] and in 1978, the primacy of M_{21701} was determined [6].

Known Mersenne Primes clearly become more scarce as p increases. D. Gillies conjectured that the number of these primes in an interval $[x. 2x]$ is about two [4]. His conjecture agrees well with the observed frequency of Mersenne Primes and with the Eberhart Conjecture which states that with the vth Mersenne Prime has p near $(\frac{3}{2})^v$. Example, $(\frac{3}{2})^{23} \cong 11223$. Historically it has required about four times as much computation to discover the next Mersenne Prime as it would to rediscover *all* previously known Mersenne Primes. The search for Mersenne Primes has been an accurate measure of computing power for the past two hundred years.

The Lucas-Lehmer test is well suited to scientific computers available today, such as the CRAY-1. With hopes of being mentioned in *Time* magazine, and access to a CRAY-1, the author coded his version of a program to search for a new "World's Largest Prime" in February 1979, using CRAY-1, S/N 11 at Chippewa Falls, Wisconsin, which was undergoing factory checkout.

The CRAY-1 is a large general-purpose computer with "vector" instructions and "vector-chaining" capability [7]. The article on vector processing by P. Johnson gives an introduction to the unique hardware characteristics of the CRAY-1 [8].

My implementation of the Lucas-Lehmer algorithm represents the multiple precision integer as digits, ^{D}, in base, $^B = 2^{24}$, even though the CRAY-1 word size is 64-bits. This choice is because the floating-point-multiply hardware unit returns an exact 48-bit integer product when the operands are 24-bit integers. This is convenient since each such 48-bit product must be summed with many others during the squaring procedure and the 64-bit word is large enough to hold the sum of all partial products for a given sum position. Thus, the carries do not need to be propagated across word boundaries until the very end of the procedure.

The required squaring in (3) of an m-digit multiple precision integer

$$u(i)^2 = \left(\sum_{i=0}^{m-1} D(i) \cdot B^i \right)^2,$$

reduces on the CRAY-1 to a sequence of vector loads, multiplies, shifts, and adds, such that, generally, one load, one multiply, one shift, and one add are all done in a single clock period of 12.5 nanoseconds. (Necessary start-up, storing and loop overhead time results in an overall net rate of 75 million load-multiply-shift-adds per second.)

The mod function at line (3) is also very fast to compute since, for a binary number y, (at most $2p$-bits long), $y \pmod{M_p}$ is simply the sum of the low-order p bits of y and its high-order bits. [It is interesting to note that this special technique for calculating y (mod(base^{power} − 1)) works for all bases. For example 12345678 mod (9999) is 6912, which is 5678 plus 1234.] The mod function calculation consumes very little time relative to squaring $u(i)$.

With this method, the CRAY-1 has a tremendous speed advantage over conventional computers. As an indication of the speed of the CRAY-1, the Lucas-Lehmer test for $p = 8191$ took 100 hours on Illiac-I (D. Wheeler, 1959), 5.2 hours on an IBM 7090 [9], 49 minutes on Illiac-II [4], 3.17 minutes on the IBM 360/91 [5], and ten seconds on the CRAY-1.

The author's program independently discovered the 26th Mersenne Prime, M_{23209}, on February 23, 1979, two weeks (alas) after Noll (sans Nickel). The check for M_{23209} which had taken Noll eight hours forty minutes on a CYBER-174, [10] used less than seven minutes on the CRAY-1. This near success at being the discoverer of a "World's Largest Prime," coupled with the fact that the CRAY-1 seemed to have an enormous advantage over previous computers used, gave impetus to continuing the search for what would be the 27th Mersenne Prime.

Unfortunately, the Eberhart conjecture predicts that the 27th Mersenne Prime would be near $(\frac{3}{2})^{27} \cong 57,000$ and at the rate the program was running, it would need 2,000 hours of CRAY-1 time (commercially available at $7500 per hour) to check that far.

At this time four things happened which combined to bring early success to what could have been a long search. First, a modification to the squaring procedure was contributed by Harry Nelson which cut the computer time needed for performing the Lucas-Lehmer test to less than half that previously required. Second, I obtained a table of Mersenne Numbers in the range $2^{23,000}$ to $2^{50,000}$ which were already known to have divisors less than 2^{37} [11]. This eliminated slightly more than half of those from the list of potential primes. Third, Nelson incorporated the program (with a few modifications) as a portion of a hardware diagnostic routine he was developing for use on CRAY-1, S/N 10 at UCLLL, which meant that the search could properly utilize a good deal of time during the early test period of S/N 10. Fourth, the sequence of primes cooperated.

The result was that after applying the Lucas-Lehmer test to about a thousand numbers, the code determined, on Sunday, April 8th, that $2^{44497} - 1$ is, in fact, the 27th Mersenne Prime.

It seems customary for one who searches for Mersenne Primes to make a conjecture concerning the distribution of Mersenne Primes or the potential divisors of Mersenne numbers [2–4]. In keeping with tradition, the author submits the Slowinski conjecture: There will always be more conjectures concerning Mersenne Primes than there are known Mersenne Primes.

It is rare that a large project is the work of a single person. This project is not an exception. The author would like to acknowledge invaluable assistance and encouragement from many generous people including Harry Nelson, Curt Noll, and Bill Durch. □

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Acknowledgement

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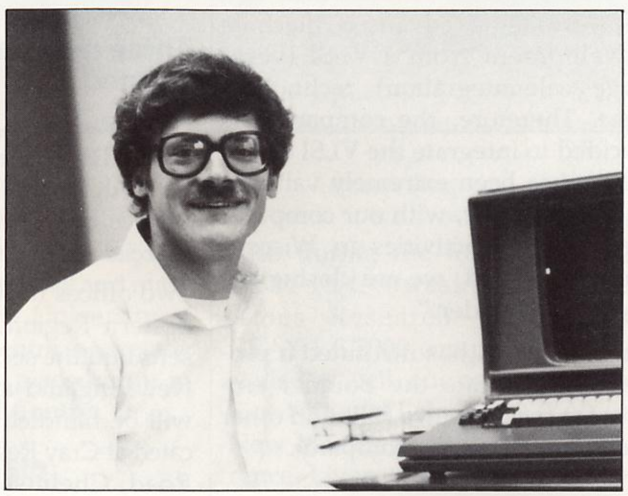


—About the Author—

David Slowinski *began working for Cray Research, Inc. in 1977 as a Development Analyst. While working for Cray, he spent a year and a half at the National Magnetic Fusion Energy Computer Center. Currently, he is a Sr. Programmer Analyst with Steve Chen's Product Development Group located in Chippewa Falls, Wisconsin. He received his B.S. in 1976 from Michigan State University and in 1979 left Cray to attend Michigan State where he received his M.S. in computer science in 1980. He returned to the company in the fall of that same year.*

CORPORATE REGISTER

Cray Laboratories consolidated

On March 19, 1982 Cray Research announced consolidation of its research and development programs at its laboratories in Boulder, Colorado and Chippewa Falls, Wisconsin. The technology developed at Boulder will be transferred to Chippewa Falls and used to augment development of specific programs at that location.

Chairman and President John Rollwagen explained, "Last November the company reached an important decision point when we chose to apply liquid immersion technology to development of the CRAY-2. That decision required redirection of work at the Boulder division which had been pursuing advanced machine development from a VLSI (very-large-scale-integration) technology base. Therefore, the company has decided to integrate the VLSI effort, which has been extremely valuable to the company, with our computer development activities in Wisconsin. As a result, we are closing the facility in Boulder."

Cray Research has instituted a program to relocate the Boulder employees to Chippewa Falls and other locations within the company.

Digital Productions orders a CRAY-1

Cray Research, Inc. announced in March the installation of a CRAY-1 S/1000 computer system at the new Digital Productions facility in Los Angeles, California in the second quarter of 1982.

Digital Productions will use the system to generate image simulation services specializing in high resolution, high scene complexity, color raster graphics. Digital Productions' Computer Scene Simulation services will be marketed to a number of industries including motion picture, television and real estate. The company indicated that the CRAY system will enable it to offer the highest scene complexity available in Computer Scene Simulation. In addition, greater amounts of graphics will be produced in less time than ever before, resulting in lower production costs.

Cray Research Chairman John A. Rollwagen said, "We are excited about this order because it will be the first CRAY system used exclusively for graphics applications."

Three new sales offices opened

Cray Research, Inc. has recently opened three new sales offices in the United States. These offices will service both government and commercial accounts.

Two offices have been set up in the Eastern Region, one in Massachusetts and the second in Georgia. The New England and New York areas will be handled by Ron Beehler located at Cray Research, Inc., 18 North Road, Chelmsford, Massachusetts 01824, telephone (617) 256-9186.

Paul Spivey will manage accounts located in Florida, Georgia, North Carolina, South Carolina, Tennessee, Alabama, Mississippi, Kentucky and Louisiana. He can be contacted at Cray Research, Inc., 4405 Mall Boulevard - Suite 515, Union City, Georgia 30291, telephone (404) 964-5148.

A third office to service the San Francisco Bay area has been established on the west coast in Mountain View, California headed by Bence Gerber. The address and phone number at that location are Cray Research, Inc., 2083 Landings Drive, Mountain View, California 94043, telephone (415) 960-3620.

Rice Lake plant opens

Cray Research, Inc. moved into a new manufacturing facility in Rice Lake, Wisconsin late in March. The 4800 square foot building sits on approximately five acres of land and is now the site for the assembly of electronic modules used in the CRAY-1/S computer systems.

These sophisticated electronic assemblies require an extremely high level of quality workmanship. As Dennis Aney, newly appointed manager of the facility, explained, "We will bring people in slowly and spend as much time as needed to train them properly. Quality output is our primary objective." Eight people will complete training by the end of April. Thereafter, it is expected that three people a month will be hired and trained with emphasis placed on meticulous workmanship.

Chevron orders, receives CRAY-1 system

In February, a CRAY-1 S/2300 computer system was installed at the Chevron Oil Field Research Company in La Habra, California. Chevron plans to use the system for research and development in exploration data processing and petroleum reservoir engineering. Chevron is the fourth petroleum industry firm to install a CRAY supercomputer.

Dr. Richard Field (l.), Director of the University of London Computer Centre, signs contract with Barry Utting and Neil Davenport of Cray Research (U.K.) Ltd.

University of London to purchase CRAY-1

In March 1982, the University of London announced plans to purchase a CRAY-1 S/1000 computer. The system has been leased since April 1981 by the Science and Engineering Research Council (SERC) and located at its Daresbury, Cheshire, U.K. laboratory. Collaboration between the SERC, the University of London and the Computer Board for Universities and Research Councils will enable a purchase option in the SERC's existing leasing agreement to be exercised.

The system will be moved into a new building extension at the University of London Computer Centre in April 1983. The CRAY will then be upgraded by adding memory and mass storage, allowing the University of London Computer Centre to meet the increasing demands placed on it in its role as a National Centre.

Installations update

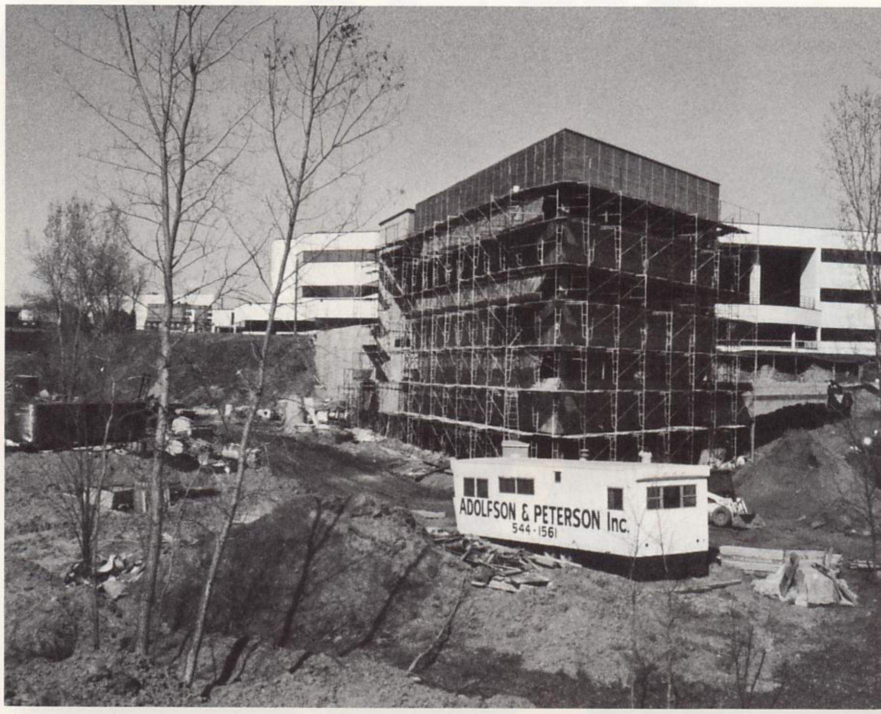
Several CRAY systems were installed during the fourth quarter of 1981 and the first quarter of 1982. In December 1981 a CRAY-1 S/4400 was installed and accepted by Exxon Production Research Company in Houston, Texas.

As planned, Boeing Computer Services installed and accepted its two million word CRAY-1/S system in December 1981.

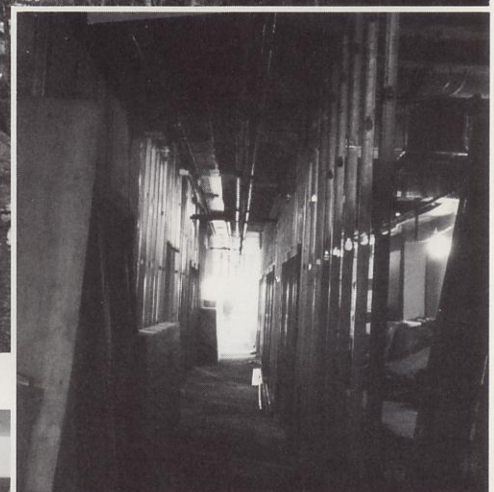
Also during the fourth quarter, a CRAY-1 S/1300 was installed at NASA Ames Research Center. Two CRAY-1 S/2000 computers were installed as well, one going to Los Alamos National Laboratory (LANL) in New Mexico and the other to Lawrence Livermore National Laboratory Computing Center (LCC) in California. The CRAY-1 S/2000 at LANL was upgraded to a four million word system during the first quarter of this year. Both LANL and LCC anticipate the addition of another CRAY system at their respective locations during 1982.

A CRAY-1 S/1000 was installed at Sandia National Laboratories, Albequerque, New Mexico in February.

CORPORATE REGISTER



Construction progresses on Cray Research's Mendota Heights facility addition.



Minnesota facilities expand

In February, senior management and certain Cray Research support staff moved from the Mendota Heights, Minnesota facility to the new corporate headquarters located in downtown Minneapolis. The Mendota Heights facility now houses the software development and marketing support groups. Construction at that facility is underway on a second addition that will provide 30,000 additional square feet of office and computer room space. Margaret Loftus, Vice President, Software Development, acknowledged, "Mendota Heights is now a technical facility housing a homogeneous group consisting primarily of software professionals. This should assist in the smooth flow of operations." The software development and marketing support groups have become increasingly important to Cray Research, as evidenced by the growth of the groups from eight people in 1976 to over 100 today.

When completed, the building will house three CRAY systems including two CRAY-1/S computers and a CRAY X-MP. Front-end systems on site include Data General, Amdahl, Control Data and IBM processors. Completion of the addition is scheduled for the third quarter of 1982.

CRAY-1 to be installed at AERE

Cray Research, Inc. has recently accepted an order for a CRAY-1 S/1000 system to be installed at the Atomic Energy Research Establishment, Harwell in the United Kingdom during the second quarter of 1982. This system will replace the CRAY-1 that has been operating at Harwell since early 1981.

New PCB facility begins production

Construction was completed on the new printed circuit board facility located in Chippewa Falls, Wisconsin this past winter. Production began at the facility in March and is expected to increase steadily as the plant becomes fully staffed. The facility should be operating at capacity by mid-summer.

The original PCB facility opened in 1980 in Chippewa Falls will continue its operations. The addition of this new plant means that virtually all of Cray's PCB needs will satisfied by in-house production.

APPLICATIONS IN DEPTH

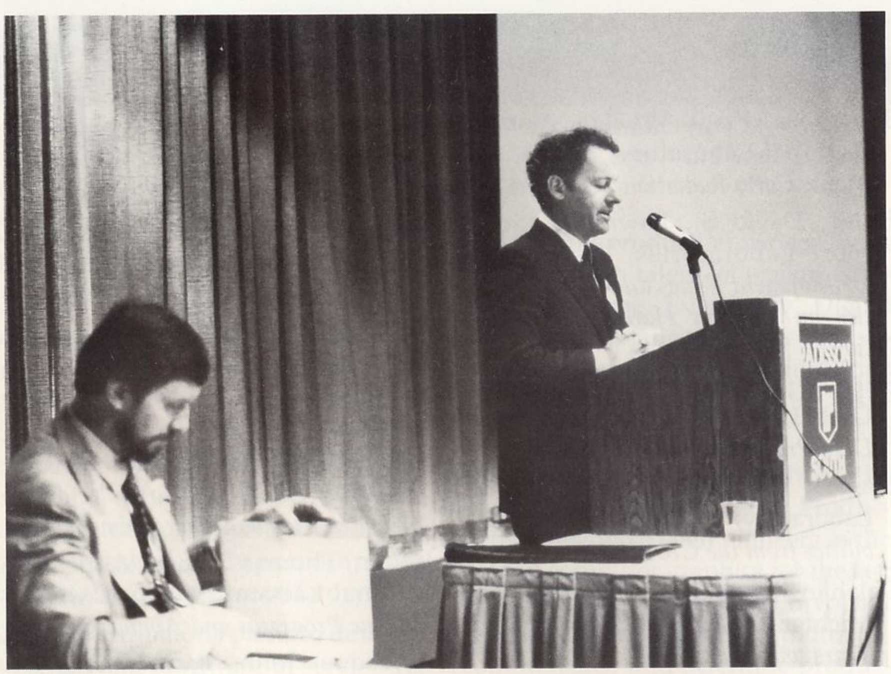
Cray Research sponsors scientists' meeting

The Applications Department of Cray Research recently hosted a symposium in Minneapolis for CRAY-1 users, titled "Science, Engineering, and the CRAY-1." This symposium, which was held April 5-7, included presentations by representatives from a number of applications areas, plus small-group dicussions and numerous opportunities for attendees to meet with others involved in similar work. The symposium drew more than 170 attendees from throughout the U.S., Japan, Germany, France, and the U.K.

A listing of the applications areas represented by symposium attendees gives an idea of the variety of users that Cray Research products attract. In attendance were participants from such industries as: petroleum, electronics, nuclear, aerospace, chemical engineering, and software consulting. Also attending were representatives from government and commercial research laboratories and a number of participants sharing interest in structural analysis.

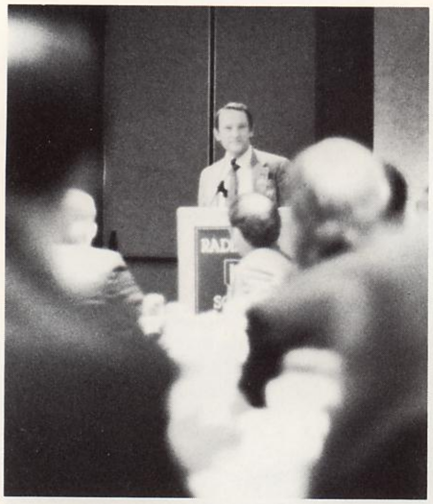
Upon arrival Sunday evening, symposium participants were invited to a get-acquainted hour at the hotel. This first evening provided an opportunity for conference-goers to become acquainted and to begin the informal interchange of ideas and experiences.

The presentations themselves spanned three days, and each evening, related activities were planned. On Monday evening, a group of 80 took a trip to Chippewa Falls, Wisconsin to tour the company's manufacturing facility. Others remained in town to run benchmark programs at the Mendota Heights facility.



John Rollwagen, Chairman and President (r.), and Derek Robb, Manager, Software Applications, open conference on Monday morning.

APPLICATIONS IN DEPTH



Seymour Cray speaks at anniversary banquet.

Tuesday evening, conference attendees were invited to a banquet celebrating the tenth anniversary of the founding of Cray Research. At the banquet, Seymour Cray reminisced about how his work has evolved through the years. John Rollwagen, Chairman of the company, provided a historical perspective, discussing Cray Research's first decade.

Following is an alphabetical listing of symposium presentations:

Anderson, M. Paul, Ford Motor Company, *"Potential for 'Supercomputer' Technology in Automotive Design/Engineering Applications"*

Babrowicz, Frank W., Los Alamos National Laboratory, *"Vectorized Monte Carlo Radiation Transport"*

Bailey, David S., Lawrence Livermore Laboratories, *"Large Code Development Issues and Some Statistics on Current Hardware Utilization"*

Butscher, Werner, Cray Research GmbH, West Germany, *"Seismic Data Processing on the CRAY-1"*

Buzbee, Bill, Los Alamos National Laboratory, *"New Modeling Capabilities from the CRAY-1"*

Calahan, Donald A., University of Michigan, *"Research Summary: Six Years with the CRAY-1"*

Demos, Gary, Digital Productions, *"Computer Scene Simulation"*

Dodson, David S., Boeing Computer Services, *"Improving the Performance of a Sparse Matrix Solver on the CRAY-1"*

Dubois, P., Lawrence Livermore National Laboratories, *"TORANAGA: An ODE Solver for Supercomputers"*

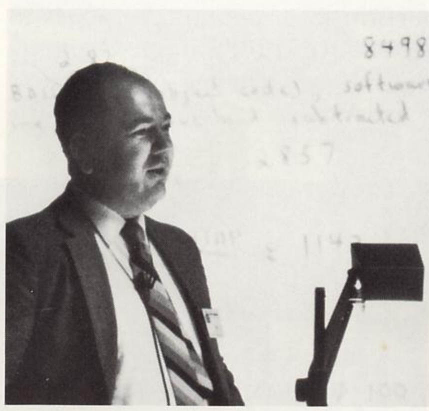
Duff, Iain, AERE Harwell, *"The Solution of Sparse Linear Equations on the CRAY-1"*

Erisman, A.M., Boeing Computer Services, *"BCS Mathematical Software for the CRAY-1"*

Ginsberg, Myron, General Motors Research, *"Some Observations on Evaluation of a CRAY-1 for an Industrial Research Environment"*

Hamilton, C. Hayden, PDA Engineering, *"The Advent of Color Graphics in Engineering Design and Analysis: A Coming Dimension to Pre- and Post-Processing of F.E.M."*

Hankey, W.L., Wright-Patterson Air Force Base, *"Vector Processor and CFD"*



Myron Ginsberg, General Motors Research, discusses the CRAY in an industrial research environment.

Hsiung, Chris, Cray Research, Inc., *"Results on First Order Linear Recurrence Equations"*

Jameson, Antony, Princeton University, *"Solutions to Euler Equations in Two and Three Dimensions"*

Jordan, Thomas L., Los Alamos National Laboratory, *"CALMATH: Some Programs and Applications"*

Levesque, John, Pacific-Sierra Research, *"Helping the CRAY Make You Look Good"*

McCormick, C.W., MacNeal-Schwendler Corporation, *"Performance of MSC/NASTRAN on the CRAY Computer"*

Meyer, Bertrand, Electricite de France, *"Methodology for CRAY Programming"*

Patterson, G.S., Jr., Cray Research, Inc., *"Large-Scale Scientific Simulations"*

Perrott, Ron, Queen's University of Belfast, *"A Parallel Language for the CRAY-1"*

Rogers, J.N., Sandia National Laboratory, *"Fixed Point Vector Implementation of Discrete Event Simulation on the CRAY-1/S"*

Spangenberg, W.H., Los Alamos National Laboratory, *"A Fast Algorithm for Two-Dimensional Data Table Use in Hydrodynamic and Radiative Transport Codes"*

Stringer, James C., Cray Research, Inc., *"Efficiency of D4 Gaussian Elimination on a Vector Computer"*

Swanson, John A., Swanson Analysis Systems, *"Opportunities Provided by Large Computers"*

Wallis, John, Intercomp, *"Reservoir Simulation on the CRAY-1"*

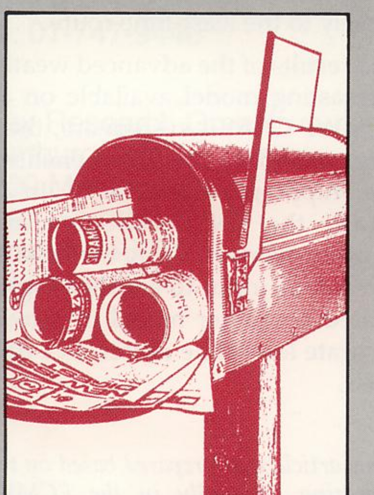
Stu Patterson addresses the future requirements of large-scale scientific processing.

Warnock, Tony T., Cray Research, Inc., *"Some Experiments with Quasi-Random Sequences in Transport Calculations"*

Yu, N.J., Boeing Computer Services, *"Transonic Flow Simulations for 3-D Complex Configurations"*

USER NEWS

An image generated by the Digital Productions Encoding/Filming Program. The scene shown is part of an animated sequence of a flight over a city undergoing a major earthquake.



Computer Scene Simulation at Digital Productions

Digital Productions recently installed a CRAY-1 S/1000 at its offices in Los Angeles, California. The company will use its CRAY-1/S to synthesize realistic-appearing motion pictures of objects described mathematically. The digital synthesis of these pictures is so computationally demanding that supercomputer power was deemed mandatory.

Digital Productions plans to develop software and hardware to service the motion picture and scientific communities. Initially, the company will provide full-production service, with artistic design talent as well as computer expertise. Eventually, Digital Productions plans to license its software and hardware to organizations that require potent computer visualization tools.

Gary Demos and John Whitney, Jr. are co-founders of Digital Productions. They have been pioneers in the field of computer graphics for the last ten years, and have been involved with numerous motion pictures, commercials, and scientific productions. While directing this group, they produced film for the movies

CRAY RESEARCH, INC.

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