A CRAY RESEARCH, INC. PUBLICATION

CRAY CHANNELS

Volume 6, Number 2

FEATURE ARTICLES:

Cray computers and engineering analysis

Steps toward supercomputing

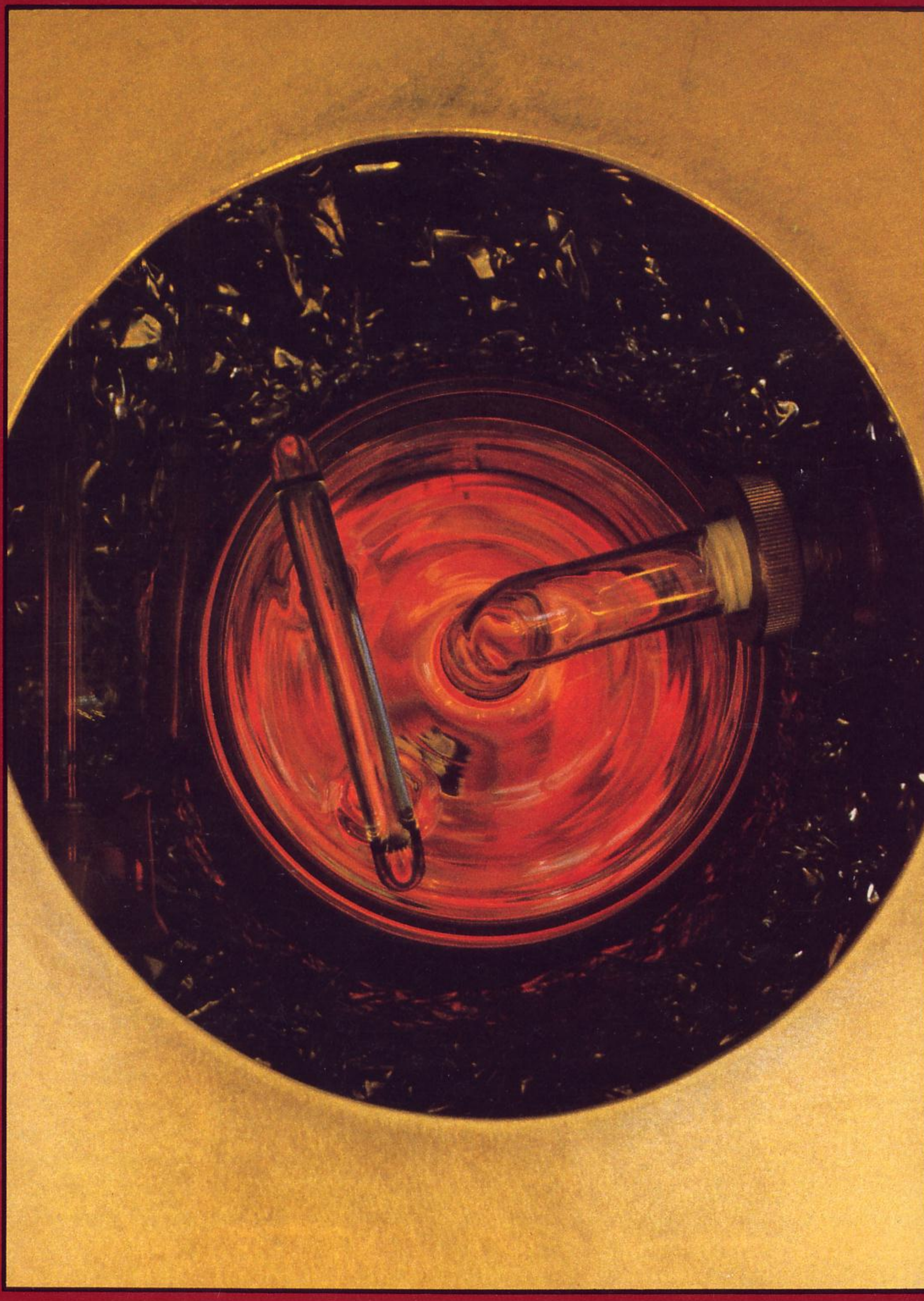
Computer simulation of natural phenomena

Building blocks of CAD

DEPARTMENTS:

Corporate register

Applications in depth



IN THIS ISSUE

The concept of replacing and augmenting traditional experimental engineering with computer simulation is becoming much more common. For years, research labs have used large computers to simulate the most complex physical systems such as weather forecasting, geophysical and nuclear research. Today, industrial laboratories are harnessing supercomputer power to solve the largest product development challenges.

This issue of CRAY CHANNELS focuses on different uses of CRAY computer power in engineering. The impact of supercomputing can be quite dramatic. Technology developments in newer industries now can be tackled with the supercomputing tool, while older industries that have lost momentum over the past few decades gain a new perspective on development potential.

Much of the new development activity employs computer simulation of physical events, thus replacing the need for extensive physical modeling. The make-and-break engineering philosophy is losing its footing to computer simulation. This is only one more area in which the technological/information revolution is making its mark. Along with the many technological innovations ranging from telecommunications to robotics, CRAY supercomputers and computer simulation, provide tremendous opportunity for industrial development and discovery in the years ahead.

On the cover an annealing furnace used at Cray Research's Advanced Research Projects Development Center is shown. The furnace is used to subject gallium arsenide wafers to high temperature treatment after ion implantation. The furnace is made of quartz tubing to accommodate temperatures that range between 800°-900° C.

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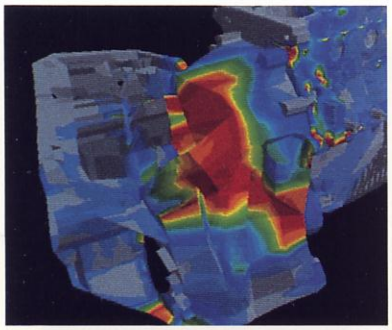

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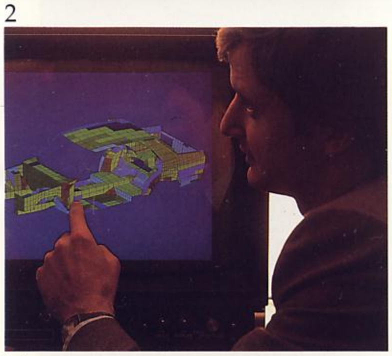

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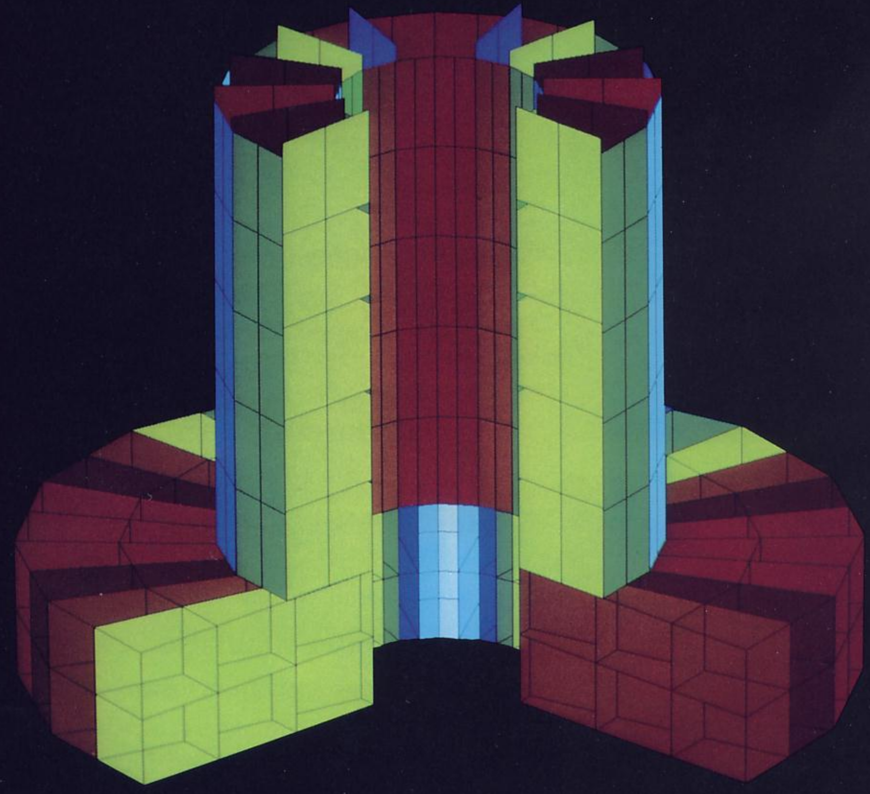
CRAY CHANNELS is a quarterly publication of Cray Research, Inc., 608 Second Avenue South, Minneapolis, MN 55402. It is intended for users of Cray computer systems and others interested in the company and its products. Subscription requests, feature story ideas and news items submitted to the editor at the above address are welcomed.



Cray computers and engineering analysis

Large-scale computing power, in combination with advances in structural mechanics, is dramatically affecting the way industries that develop very sophisticated products do business. In the past few years, the cost of supercomputing has come down, while the ease of use has increased. Consequently, major industrial engineering organizations around the country are beginning to integrate supercomputers into their development shops. Supercomputers are becoming necessary for several reasons. Major industries such as aerospace, automotive and energy development are facing new challenges. Nowadays, competition is much stiffer and customers demand efficient, high-quality products. Moreover, the lead-time to develop better products is getting longer and product life cycles are getting shorter. Faster engineering turnaround, design optimization, increasing productivity and reducing extensive prototype testing are among the major objectives of today's engineering management.

Today, there is a need for product parts and systems to undergo comprehensive analysis prior to specifying the actual configuration or developing a prototype. Engineering analysis involves detailed simulation of the behavior of structures under a wide variety of operating conditions, typically involving structural analysis using the finite element method. An extension of the analysis phase involves the activities of computer-aided engineering (CAE), which encompasses not only analysis, but comprehensive geometric modeling, design, drafting and testing. All of these activities are dependent on sufficient computer power.

Engineering methods in transition

In the past, a common solution to growing computing needs has been to add more computers with the same capability. It is fairly simple: the hardware capabilities are known, users are comfortable with the systems, software is already in place, and costs can easily be justified. Just roll the computer in, plug it in and connect the terminals. There are no drastic changes. And that's just it — nothing really changes. There are probably more users on the system, but their level of productivity as well as the sophistication of analyses that can be conducted is about the same. Chances are users still have to wait overnight to get results for larger problems and still cannot run large simulations or many non-linear analyses.

Industries involved in manufacturing complex products find that sufficient computing power cannot be effectively provided by the type of equipment in place today. There is a vacuum in computer power with regard to the large analysis and simulation work — a vacuum that supercomputing is beginning to fill. The aerospace, automotive, petroleum and energy development industries are among those that can realize the most dramatic and cost-effective results from the use of supercomputers. The growing number of CRAY systems installed in such companies attests to the recognition of the role supercomputing can play.

Keeping structural analysis functions in mind, this article investigates CRAY characteristics useful in mechanical engineering applications, looks at work that CRAY systems are doing in a variety of industries and then looks at how supercomputer systems fit into the engineering environment.

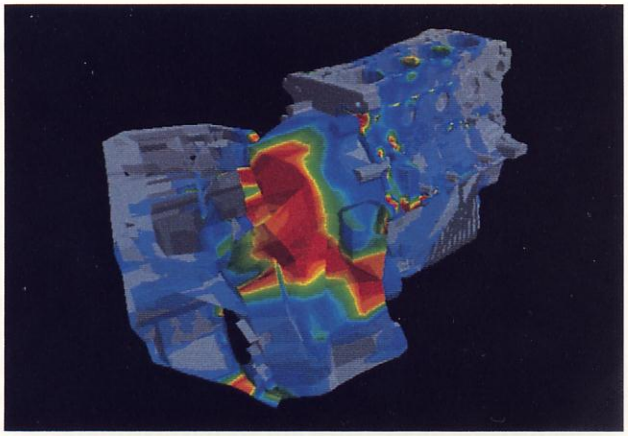
CRAY computing for engineering analysis

What is it that makes CRAY computers a good tool for structural analysis? To answer that question, perhaps one should first look at computing performance requirements for such problems.

Structural analysis problems typically rely on the finite element method for solution. Detailed finite element models are structured with many degrees-of-freedom, and thus display a corresponding need to solve large systems of equations. Furthermore, the use of iterative design optimization techniques calls for multiple passes through matrix equation solvers, requiring extremely fast computers with high levels of parallelism. Large geometries and 3-D structures consume more computer resources than less sophisticated structures. Large problems dictate the need for large central memory, and because the size of many large problems exceeds central memory capacity, highly effective I/O is needed to ensure solid performance.[1]

The basic characteristic of the CRAY making it suitable for structural analysis problems is extremely fast computing. The CRAY X-MP internal clock ticks every 9.5 nanoseconds (nsec); this compares with other mainframe clock cycles that hover around 100 nsec.

Cray computers also incorporate very high performance vector and scalar processing. For the many applications exhibiting a moderate to high degree of parallelism, CRAY power is most efficient. Vector processing, which enables a single instruction to perform the same operation on many elements of



Ford Motor Company analyzes the dynamic behavior of powertrain assemblies. Stress analysis was carried out on an engine block to determine the effect of impact forces in rail car shipment. A 3-D powertrain assembly finite element model was constructed, normal mode analysis was performed with MSC/NASTRAN, results were postprocessed with MOVIE.BYU. Presentation of the dynamic results was achieved with color-coded strain energy density animations of the first two eigensolutions. The image above of the deformed shape illustrates strain energy density distribution under 1st mode of vibration.

the problem, is a major feature of the CRAY. A prime example of such a vector application is the large stiffness matrix inversion and subsequent matrix multiplication required to determine the set of displacements in a structural analysis problem. The solution phases of many finite element problems can execute an order of magnitude faster on a CRAY-1 than on a large mainframe, and about two times faster than that on CRAY X-MP multiprocessor systems.

The significance of fast scalar processing cannot be over-emphasized because certain portions of numerical problems are sequential by nature. For instance, the generation of elements comprising a stiffness matrix involves almost pure scalar processing.

Dr. Basu Mukherji, Manager of Applications Support at Boeing Computer Services, provided the following observations of CRAY performance at a software conference in October 1983: "Getting good performance out of a vector computer with a finite element program is difficult because so many finite element operations are scalar or short vector type, rather than long vector operations. For example, if half the analysis can be speeded up by a factor of 20 by vectorization and the other half has no speed increase because it consists of primarily scalar operations, the overall run time can only be speeded up by about a factor of two. Fortunately, the CRAY has excellent scalar performance, so conversion to the CRAY will result in a major speed improvement even with relatively little vectorization."

CRAY computers' large memory is an important characteristic that makes them suitable for structural analysis problems. The systems may be configured with up to four million 64-bit words. The CRAY's large, fast, real memory allows 3-D geometrically complex finite element problems to be solved entirely in central memory.

The value of large memory becomes evident in other comments by Dr. Makherji at the same conference: "In one case, the problem would not run on the Cyber (760) but ran through without a hitch on the CRAY. The problem could have been restructured and the computer reconfigured so that it could be run on the Cyber, but it did not seem to be a worthwhile exercise.....(On the CRAY), the solution times generally improved by a factor of more than six. The overall CPU time improved by an average of about five."

Because structural analysis problems can be very large and iterative, the availability of high-capacity, fast-access, secondary storage on a computer system is also important. Again, CRAY computers are unsurpassed in the speed and capacity of their secondary storage devices. Recognizing that overall performance is only as good as the weakest link in the system, Cray Research developed a special hardware device called the I/O Subsystem (IOS) to manage I/O traffic in and out of the system. It connects to the mainframe via very high-speed channels, through to the disk storage and front-end systems.

In addition, a very powerful peripheral secondary storage device is configurable with up to 32 million 64-bit words on CRAY systems. The Solid-state Storage Device (SSD) functions as a very high-speed disk and connects to the mainframe through extremely high-speed channels. The speed of this device may be appreciated from the fact that a one-million word file is transferred between the CRAY X-MP and SSD in only 6.4 milliseconds. MacNeal Schwendler Corp., originators of MSC/NASTRAN, has reported I/O performance improvement factors of 23:1 with the use of the I/O Subsystem and SSD. [2] Figure 1 illustrates a basic CRAY computer configuration including the IOS and SSD connections.

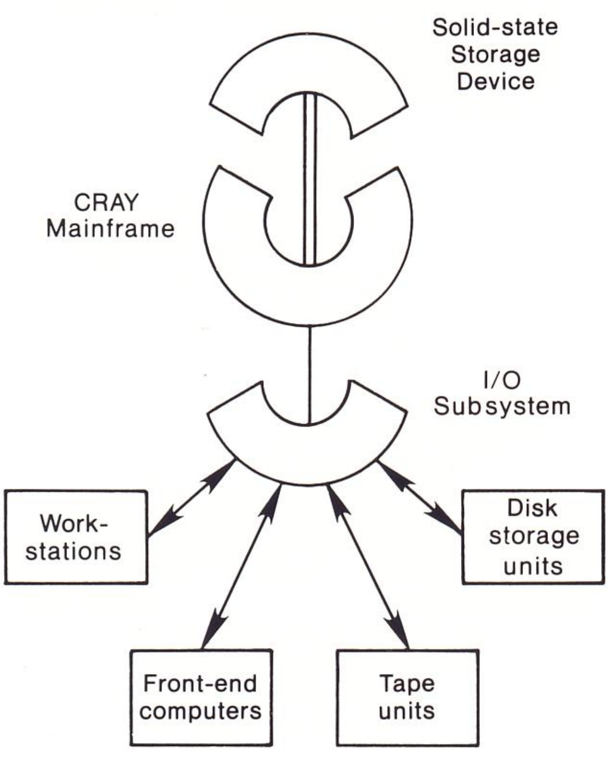


Figure 1. A CRAY computer system.

A full library of Cray-developed systems software makes hardware capabilities readily accessible to the user. The CRAY FORTRAN Compiler is an advanced auto-vectorizing compiler that conforms to the ANSI '78 standard. The benefits of vector processing are easily realized with the compiler. A Boeing user commented, "It has been our experience that programs can be converted to the CRAY with relatively little difficulty if they are written in a reasonable approximation to FORTRAN 77."

FEM applications programs on the CRAY

Many finite element programs have been developed to take advantage of the CRAY's outstanding problem solving capabilities. Cray Research supports customers and third-party vendors in converting codes for operation on the CRAY. As a result, popular programs including MSC/NASTRAN, COSMIC/NASTRAN, ANSYS, MARC and ABAQUS are running on CRAYs around the world. (See page 21 for more information about available structural analysis programs.)

In aerospace

Aircraft design problems are among the most computationally expensive in any industry. In addition to aerodynamics considerations, engineers in aerospace face structural integrity challenges. More and more aerospace structural analysis problems are being solved on CRAY computers.

Grumman Aerospace Corporation (GAC) recently purchased a CRAY-1 M/2200, after having used CRAY computers at service bureau centers for some time. Robert Winter, a Senior Staff Scientist for GAC, explained what importance supercomputing has in development work: "In many nonlinear structural dynamics problems we are limited by the computer's speed and the size of core memory. For nonlinear transient problems with plasticity and large deflections involving as many as several thousand separate time increments, available compute power can be a real stumbling block. We run problems of this size in battle damage analysis for aircraft, and crash analysis for aircraft and automobile designs."

Winter added, "Even if computation time is only reduced by a factor of two with the CRAY, substantial gains have been made when one considers that computation time for a complex problem is de-

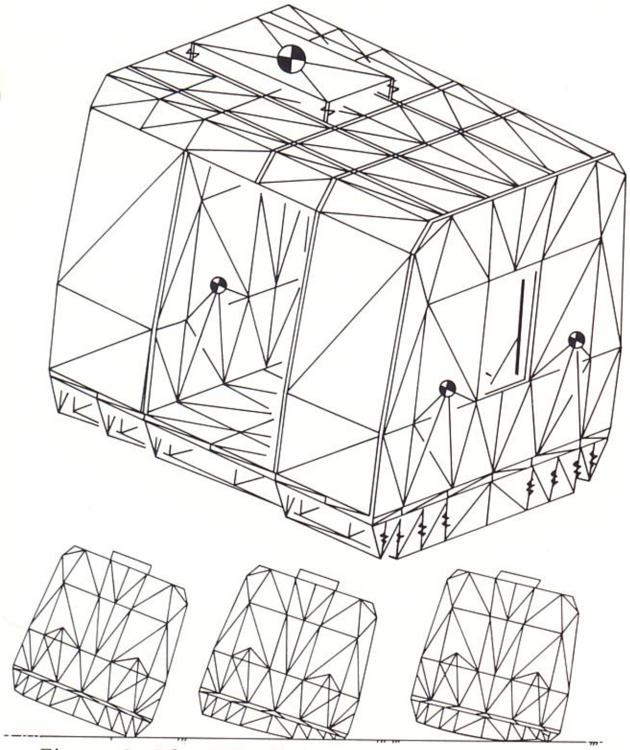


Figure 2. The 3-D finite element model illustrates a helicopter cabin. The cabin is made entirely of nonmetallic graphite glass Kevlar reinforced laminants. The second series of images shows the cabin deformations viewed from the front, with a 20° roll attitude.

creased from two weeks to one (running one CPU hour per night with restart). I expect that we will see greater performance improvements than that with our CRAY, but we can justify the system on that kind of turnaround time reduction alone." Figure 2 illustrates the type of analyses Grumman will conduct on the CRAY.

Linear problems, although not quite as complex, still benefit from supercomputing. Michael L. Russo, Engineering Analyst, also from Grumman, used a CRAY-1 in the analysis of flutter on the Navy's F-14A aircraft. Russo wished to identify aircraft flutter parameters from flight data corrupted by process and measurement noise. The data had been acquired by transducers onboard the aircraft and telemetered to a ground station for digitization. Typical flutter models contain 10 to 50 first-order differential equations and require up to 250,000 64-bit words of central memory. Software evaluation runs using 90 seconds of data sampled at 250 Hz, required up to 1.5 hours of CRAY CPU time.

Why use the CRAY for this problem? Mike Russo explained, "The analysis is computationally intensive, requiring multiple passes through the test data for final convergence to a linear math model representing the aeroelastic behavior of the aircraft. Other computers simply could not handle the computations. The CRAY gave us a 25-time speed-up over (one large-scale mainframe) and a 12-time speed-up over (another large mainframe)."

Dr. Basu Mukherji, Manager of Applications Support for Boeing Computer Services, endorsed the experiences of the Grumman researchers, commenting on the value of the CRAY in addressing finite element problems: "The CRAY is unique because of its capability to handle very large problems in a routine manner. Trying to solve large problems on a small computer is frustrating. We don't have to waste time trying to coordinate and babysit large jobs when they are running on the CRAY."

For energy systems development

Westinghouse's Advanced Energy Systems Division, involved in nuclear reactor development, successfully combines its advanced applications software with supercomputer power in the structural mechanics group. Very large 3-D and complex nonlinear problems that simply weren't practical a few years ago are solved with ease using CRAY computing power, as the following examples indicate.

Bill Woodward, of the structural mechanics group of Westinghouse's Advanced Energy Systems Division discussed a recent analysis he performed with the CRAY. The three-dimensional linear analysis was performed to determine the elastic load controlled stresses in a Liquid Metal Fast Breeder Reactor (LMFBR) superheater steam head due to internal pressure and nozzle loads. The stress distribution in the area between the outlet pipe and the manway was a region of special interest. The structure is illustrated in Figure 3. The 3-D model contained 1565 20-node brick elements and had a total of 24,783 DOF. The maximum wavefront was 858. The Westinghouse WECAN structural analysis code solved the problem on the CRAY. The total CRAY CPU time for solution of this very large problem was less than 26 minutes.

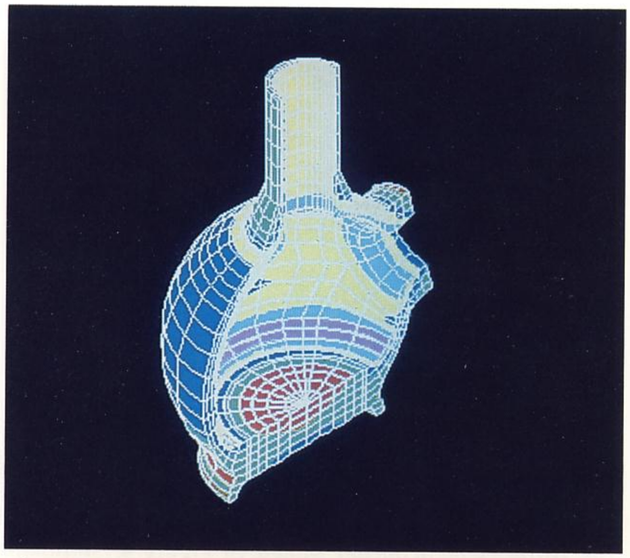


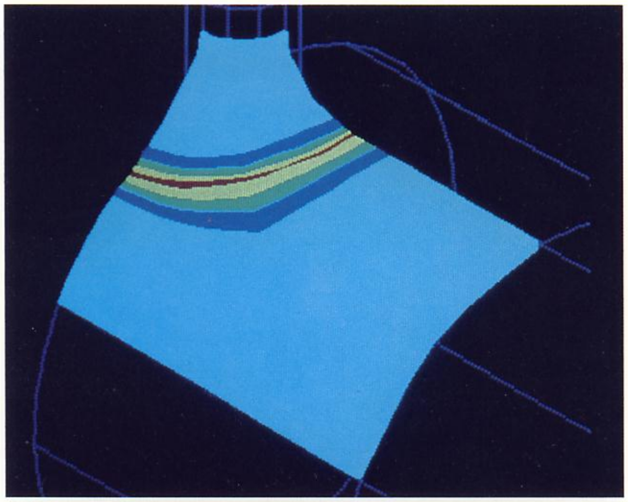
Figure 3. illustrates the superheater steam head analysis results. The analytical solution was obtained with the Westinghouse finite element program, WECAN. The 3-D model was generated using the Westinghouse-developed pre- and post-processing program FIGURES-II.

Bill Woodward commented, "What's really interesting is that three-dimensional analyses are now being performed routinely. Large problems just weren't practical on a routine basis before because of both the computing time and cost. We are solving very large problems very quickly and they are very tractable."

Aspi Dhalla, another member of the structural mechanics group at the Advanced Energy Systems Division, explained that he is performing state-of-the-art weld shrinkage effects evaluation and relaxation of weld residual stresses using the CRAY in combination with ABAQUS, a structural analysis code. He recently completed a three-dimensional elastic-plastic-creep analysis of an inlet nozzle welded to the cylinder of a heat exchanger operating at an elevated temperature of 1100°F.

The model for the nonlinear problem included three planes of symmetry to generate a finite element mesh consisting of 324 tri-quadratic solid elements and 5,673 total DOF with a wavefront of 285 DOF. In the analysis, the nozzle was subjected to 450 psi internal pressure with a creep hold time of 3000 hours at 1100°F. To evaluate the weld shrinkage effects at the nozzle-cylinder intersection, different material properties were specified to simulate a gradual variation of material properties between the weld and the base metal. The analysis was performed over a two-month period in 25 discrete steps using the restart capability of ABAQUS. Seven CRAY CPU hours were required. The as-built geometry of the inlet nozzle is illustrated below in Figure 4.

Dhalla commented, "This particular analysis of a prototypic welded structural component of a LMFBR was the first of its kind ever performed. The CRAY can handle this type of problem because of its large core memory. The analysis itself could have been run on a smaller machine but the I/O requirements would have been very high. In addition, the wall clock time and cost involved would have made it prohibitive."



The finite element model shown in Figure 4. simulates the as-built geometry of an inlet nozzle welded to the cylinder of a heat exchanger in a LMFBR plant. The analysis was performed with the ABAQUS finite element program. The 3-D model was generated with FIGURES-II.

Automotive design work

Automobile design and development is one area where it is felt that CRAY systems can have tremendous impact. For some time, CRAY computers have been used by different automotive companies for structural analysis problems. Recently the first CRAY computer was installed at an automobile manufacturer — General Motors.

A service-bureau CRAY user in the automotive industry offers some insight into the merits of supercomputing in his field. He feels the benefit of a CRAY in a production environment is felt directly in reducing design turnaround lead-time. Conservatively, he estimates that 12 months can be cut from the design cycle using the CRAY for structural analysis. "In order to stay competitive, it is necessary to conduct more exacting analyses. Japan is moving that way, as are other car manufacturers." He went on to say that one may spend the same amount of money computing with the CRAY as with smaller systems, but results will be available much faster. "Our problems can be very large — up to 20 or 30 thousand DOF and can require 40 to 50 runs, primarily because of the nonlinear nature of the problems," he said. "If we had a CRAY-1 in-house right now, we could fill it up."

Cray Research is able to provide benchmark data from tests run for auto companies at the company's facility in Mendota Heights. Automotive structural analysis problems performed with MSC/NASTRAN on the CRAY-1 S/2400 and CRAY X-MP/24 at Cray Research in Mendota Heights were compared with problem execution on an IBM 3081. The example problems and the performance ratios that follow in Figure 5 are typical of computing time reductions being realized with CRAY computers.

Total clock time was measured for performance of the third problem on the CRAY X-MP. I/O time for the job on the CRAY X-MP when writing to DD-29 disks added another 161 seconds; total job execution time, including system overhead was 339 seconds. With the SSD, I/O time was 47 seconds.

You have just read of how supercomputing impacts engineering shop operations. With continuing trends toward structural optimization and nonlinear analysis, computers that effectively address finite element analysis will help increase engineering productivity.

Integrated systems approach

A truly effective engineering environment calls for far more than just superlative computing power. A

Problem	IBM 3081*	CRAY-1/S*	CRAY-1/S IBM ratio	CRAY X-MP*+	CRAY X-MP IBM ratio
Dynamic *(13,000 DOF)*	5940	760	7.82	509	11.67
Static *(25,000 DOF)*	13,800	1420	9.72	900	15.33
Static *(13,000 DOF)*	1811	260	6.68	161	11.25

** in CPU seconds*
+ single processor performance

Figure 5. Automotive structural analysis benchmark data.

fine balance of sufficient computer power, database management, integrated applications software, interactivity and user friendliness are equally important. CRAY systems effectively address the difficult design and analysis problems that encumber smaller computers, but the CRAY is not a standalone computer. It must communicate with other mainframes or superminicomputers, and ultimately with engineering graphics workstations and user terminals to function effectively.

The first step in integrating a CRAY into a computerized engineering environment requires the use of front-end interfaces provided by Cray Research. These interfaces are available for many manufacturers equipment including IBM, DEC, CDC, Data General and Sperry. The interfaces form the hardware link to the CRAY by compensating for differences in channel widths, word size, logic levels, and control protocols between the CRAY and other systems.

In addition, Cray also offers station packages to provide full software support for communications between the CRAY and front-end systems. Using station software, a user has immediate access to the CRAY in either batch or interactive mode. Communications support is also provided for a wide range of graphics devices that may be attached to the front-end computer.

The result of these developments is that the supercomputer becomes the focus for large multi-user workloads. It performs analysis — structural, thermal and kinematic — and handles the complex geometrical calculations in design applications for which rapid turnaround is critical. Quite simply, it takes over those tasks that, in a large user environment can swamp traditional mainframes.

Conclusion

The solutions to the challenges imposed by the marketplace are not easy. To stay profitable, industries, especially large manufacturing industries, are making significant changes in their development operations. Engineering shops are being called upon to improve products, to reduce development costs and to decrease development time. Supercomputers are helping them achieve these objectives. That is why CRAY systems are being added into more and more engineering shops today. □

Footnotes

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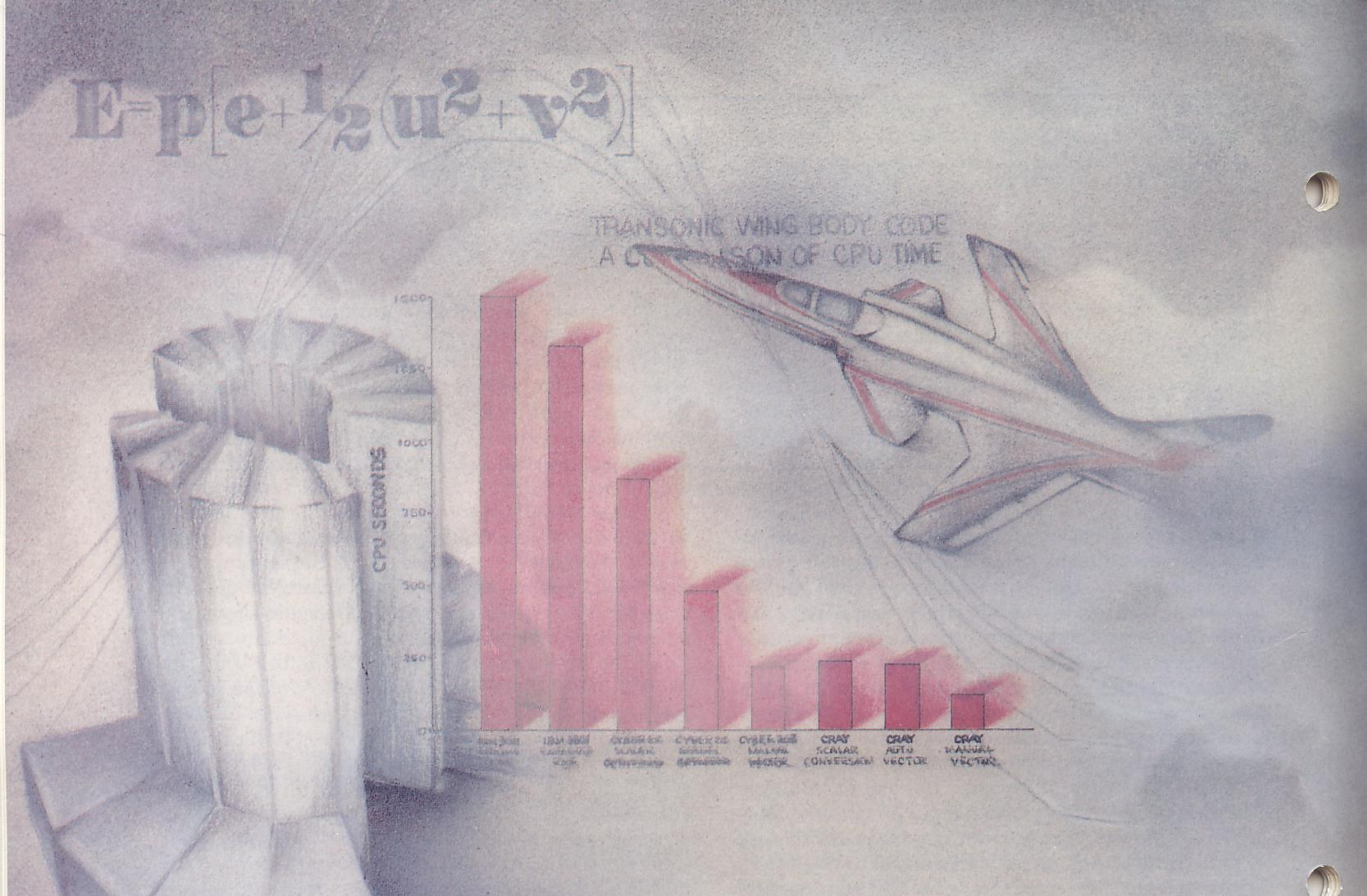


Steps toward supercomputing

Paul Muzio, Grumman Aerospace Corporation

Grumman Aerospace Corporation, a major force in the aerospace industry, is heavily involved in the development and manufacture of aircraft. The company conducted a thorough study to determine how to address it's burgeoning computing requirements. After considerable deliberation, Grumman decided that a CRAY computer would ease the computing burden. A CRAY-1/M was installed in late 1983. Paul Muzio, Assistant to the Director - Information Processing, Information Resource Management, offered the following reflections on the supercomputer installation. We thought that many of our readers could appreciate Grumman's experiences related here that lead to the installation of a CRAY.

In the past, Grumman Aerospace Corporation (GAC) relied primarily on IBM mainframes for its engineering and scientific computing resources. For the most part, the users were content with the systems — they were familiar with the hardware and software, and were unwilling to change. On the other hand, they weren't really happy with the available capacity. Users felt that management was not providing sufficient computing resources. Jobs took too long to complete. Large jobs could, at best, be serviced overnight and in many cases had to be segmented and run over a period of days or weeks.

The GAC Information Resource Management Department decided to look at the available computing opportunities. We looked for a product with substantial compute power — at least an order of magnitude greater than an IBM 3033, a product that was easy to use, a product for which a substantial amount of commercial software was available and a product that would fit into our computational environment.

There were several reasons that GAC began to look at supercomputer alternatives. Enhancing engineering productivity, for the reasons described above, was paramount. Rapid turnaround, multiple design options and increasing dependency on analysis techniques were trends fast becoming a fact of life.

But beyond that, we felt that in order to continue to be competitive with the rest of the industry, we would have to boost our computing resources. It was decided that, for the long term, the additional CPU cycles provided with a supercomputer would substantially enhance our ability to remain competitive.

Not only that, we found the supercomputer compared more than favorably with the large-scale mainframe in the cost-effectiveness category. The chart below tells the tale.

	Large-scale computer	Supercomputer
Total system cost	$2,500,000	$6,300,000
Performance	5.0 MIPS (2.5 MFLOP)	30 MFLOP
Cost/Performance	$1.00/FLOP	0.21/FLOP

In April 1982, a member of our Research and Development Center and I attended the Cray Technical Symposium held in Minneapolis. Making a long story short, the chain of events and discussions that took place on that trip were an abbreviated version of the process that eventually led to the installation of the CRAY at GAC.

The research user, eager to learn about CRAY systems was, nonetheless, apprehensive. We discussed the merits and demerits of the CRAY vis a vis our traditional computing environment en route to Minneapolis. The researcher invariably retreated to the position, "It sounds good, but wouldn't we be better off just getting another IBM mainframe?"

By the end of the conference the researcher's comment was, "It sounds good, but wouldn't we be better off getting a couple of IBM mainframes?" Before answering the question we decided to access the CRAY at the University of Minnesota. After running on the CRAY for a few weeks, the user was convinced that a supercomputer might just be a worthwhile alternative.

Jobs that took 48 minutes of CPU time on an IBM 3033 and were turned around overnight, ran in two minutes on the CRAY and were turned around in five to ten minutes. From then on, the machine sold itself. In our performance comparisons we saw performance improvements ranging from 12 to 60 times on our aerodynamic programs, and 8 to 17 times improvement on our structural analysis codes. Ilia iacta est.

Well, it wasn't quite that simple. We did look at a number of other products such as array processors and the Cyber 205, and they did have their proponents, but on the basis of overall performance, growth potential, ease of use, compatibility with the aerospace industry computing needs, compatibility with our own mode of operation and software availability, the CRAY won hands down. It really was no contest. The recommendation was made and accepted that the CRAY would become Grumman's primary analytical engineering computing resource. Our CRAY-1 M/2200 was installed in December 1983.

I would just like to comment on the discussion in the press about supercomputers and software compatibility. I think most of the comments are nonsense. Sure, it would be nice to have a machine that would run everything, but what is really important is to have a machine that runs the most important engineering and scientific software easily and rapidly. The CRAY does that.

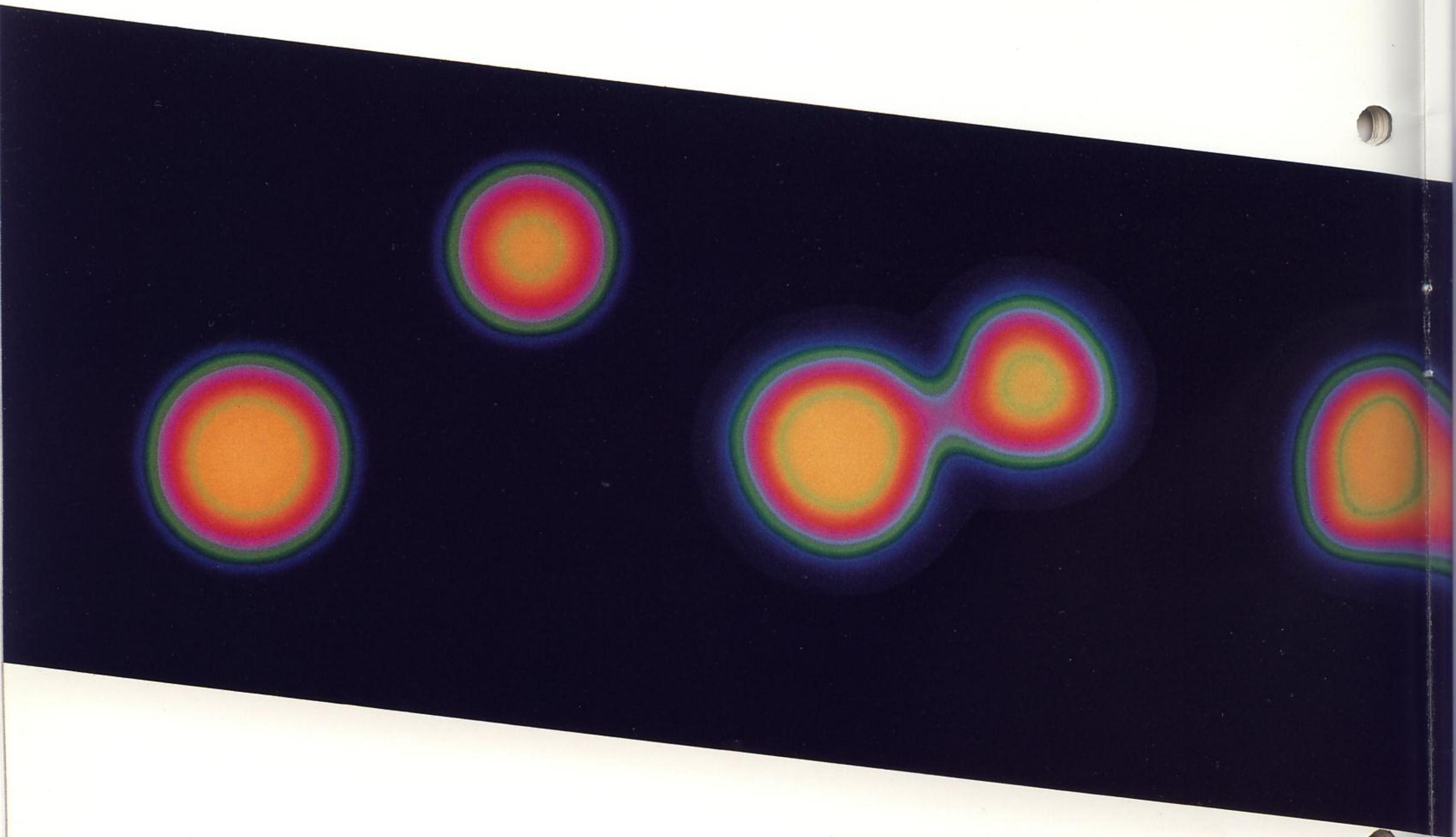
The system has an excellent FORTRAN 77 compiler, and well over a hundred commercially available application programs. Cray Research has shown real commitment to ensuring that commercial software is converted to run on its computers — software that is important to our industry. In fact, as a result of the CRAY, GAC is re-evaluating its software libraries and bringing packages into the computing environment that had not been considered previously. A good example is PATRAN, another is Historian.

The purpose of the CRAY acquisition at Grumman was to provide our users with substantially greater computational and I/O throughput capability across the board, especially in the aerodynamics, nonlinear structural analysis and image processing applications areas. We expect that the CRAY will be used for linear structural analysis, circuit design and propulsion studies.

Right now, Boppe's Transonic Wing Code, a major Grumman aerodynamic code using finite difference methods, is running on the CRAY about 12 times faster than it did on an IBM 3033. Other aerodynamic codes such as Antony Jameson's FLO 47, Grumman-developed CANTATA and Boeing's PANAIR have been or are being transported to the CRAY. DYCAST, a software program developed for helicopter crash analysis, was implemented on the CRAY with the assistance of the Cray Applications Department. The program is one of the most advanced in the industry.

GAC has been and continues to be a major user of CADAM and CATIA. Two- and three-dimensional wire-frame and solid modeling has been and will continue to be important in our design process. PATRAN is installed on the CRAY and will be used heavily in conjunction with CATIA for our aerodynamic and structural analysis work. The new system means we will be placing more emphasis on graphics for pre-analysis data preparation and post-analysis data presentations.

Yes, there have been a few difficulties in working the CRAY computer, but the system has and will continue to have a major impact on Grumman's approach to development. The system has forced us to re-examine information processing techniques. □



Computer simulation of natural phenomena

In developing his Theory of Relativity, Albert Einstein coined the term "thought experiment" to refer to the simple mental tests he applied — tests he could not apply physically because they involved motion at speeds near that of light. Computer simulation of natural phenomena takes Einstein's thought experiments a step further, enabling experimentation through numerical methods at the computational level.

Just what is computer simulation? Why is it valuable? And what does it say about future requirements for advanced computational facilities such as the CRAY? This article defines computer simulation and explores its characteristics in principle and practice.

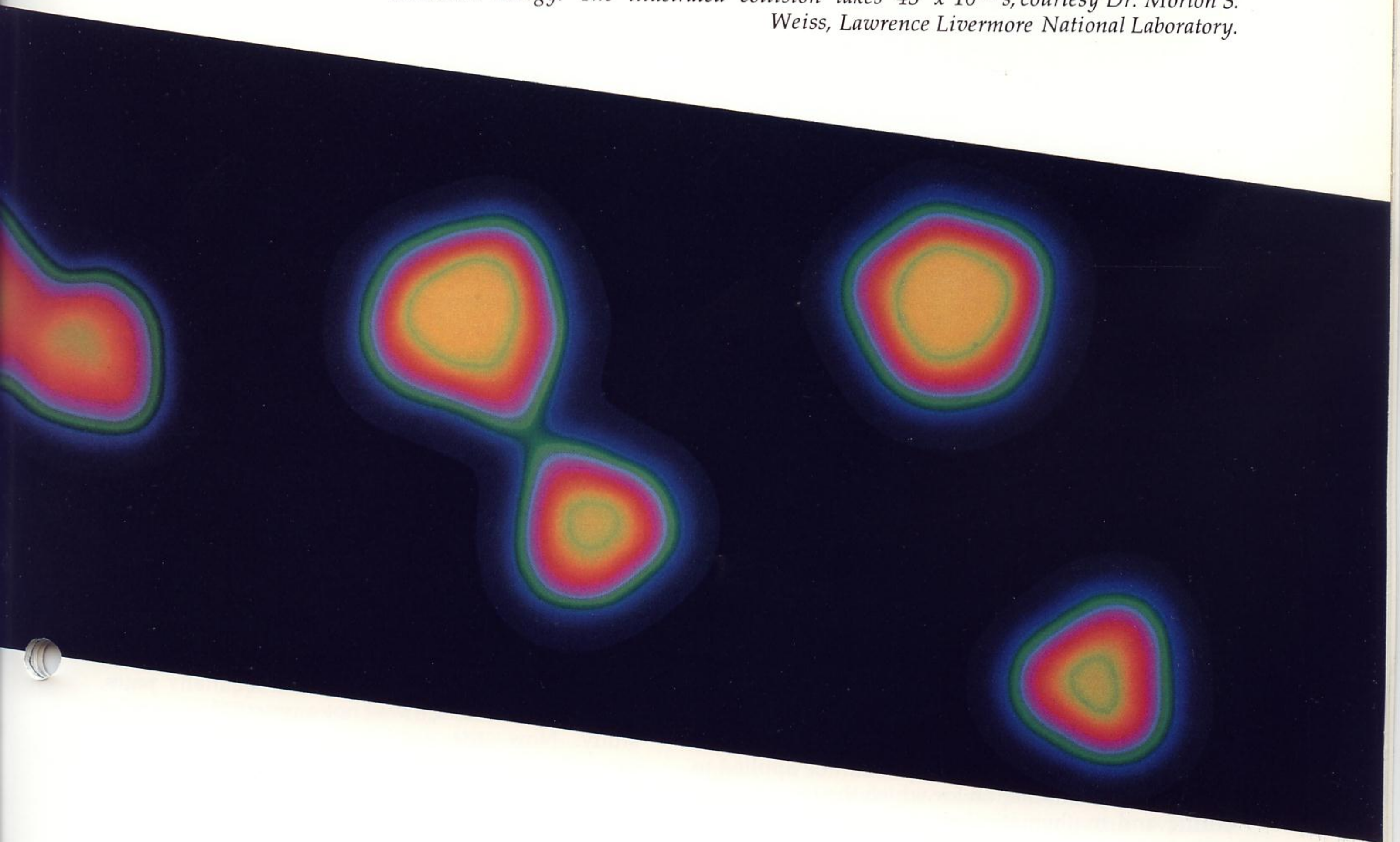
Some background

Computer simulation (also known as computer modeling, forecasting, design analysis, and prediction) involves the mathematical mimicking of real-world processes. Large-scale computer power allows researchers to study complexity in models that is not otherwise tractable, and allows scientists to study phenomena that are difficult to study experimentally.

Over the past 40 years, companies and other organizations that would not have considered the advantages of numerical techniques and supercomputers are using them in increasing numbers. Can anyone imagine a large corporation, let alone most laboratories, harnessing the power of a MANIAC I in the 1940s? Yet today, supercomputers are being used by many engineering and research laboratories in both corporate and government sectors.

Application areas using supercomputer power include mechanical structural analysis, modeling of seismic data, petroleum reservoir modeling, aerodynamics and weather modeling, to name a few. Hidden in this seemingly diverse list of uses is an important and interesting commonality. Most of these application areas replace and augment experimental, theoretical and analytical techniques with computer simulation.

Computer generated images representing krypton-86 and lanthanum-139 colliding nearly head on at the same bombardment energy. The illustrated collision takes 45 x 10^{-22} s, courtesy Dr. Morton S. Weiss, Lawrence Livermore National Laboratory.



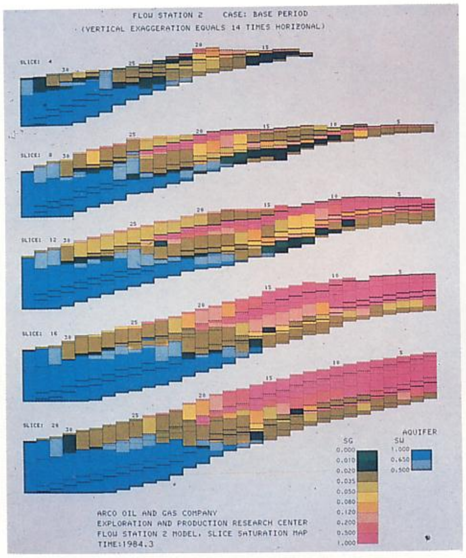
The benefits provided by computer simulation vary from discipline to discipline. In some cases, computer modeling is simply the most cost-effective approach. In other cases, it may be the *only* approach. Sometimes, computer simulation provides a safe way to perform an unsafe experiment. Quite often, it can save time and enable better design optimization because a wider range of design alternatives may be tested than is possible using more traditional methods.

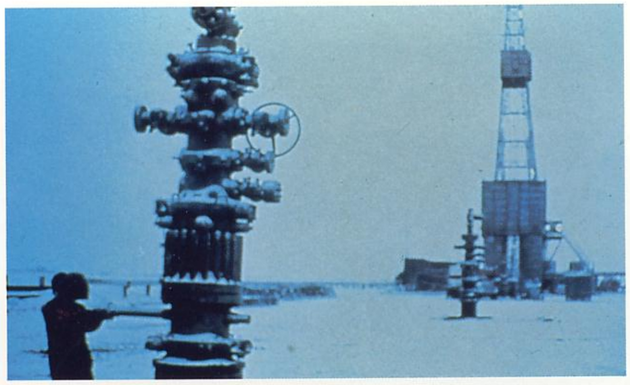
From physical models to compute testing

Computational aerodynamics promises substantial savings to manufacturers, operators and passengers of modern commercial aircraft. The traditional approach in aircraft design has been to build physical models and test them in large experimental facilities called wind tunnels. As you might imagine, these physical models are expensive to construct and wind tunnels are costly to build and operate. Although they provide an important final verification function, computational aerodynamicist Dr. Antony Jameson remarks, "It makes no more sense to blindly construct dozens of wind tunnel models than it does to build a dozen Verrazano bridges and wait to see which one will fall down first." With computer simulation, aircraft design optimization is more likely as computational testing allows easier and cheaper design evaluation than is possible with wind tunnel testing.

Simulation on a large or small scale

In some cases, computer simulation is the *only* possible way to study a complex physical phenomenon. Some physical processes are too small to be observed directly, or they take place too quickly. Such is the case with the simulation of nuclear collisions. On the other hand, some processes are too large or remote or take place too slowly to be studied directly. An example of this is the development of a petroleum reservoir, where many different methods of extraction are possible. The petroleum engineer has the difficult task of determining which extraction method will maximize recovery over time. The alternative to computer simulation is to observe and record a production history for ten cubic miles of earth, perhaps, on the North Slope of Alaska, for 30 years — almost a career undertaking!





ARCO Oil and Gas Company uses its CRAY-1 for reservoir simulation. The simulation model at left depicts simulations of the eastern portion of the Prudhoe Bay Oil Reservoir. The photograph above shows a scene from the Kuparuk field also on the north slope of Alaska near Prudhoe Bay.

Making observation safe

Numerical simulation also provides a safe way to perform unsafe experiments. Suppose, for example, that you wanted to determine the response of a nuclear reactor to a massive loss of coolant liquid. Obviously, conducting a real experiment is much too dangerous and costly to attempt. On the other hand, the computational experiment is safe and relatively inexpensive, and the various stages of the process can be studied in detail once the experiment has begun.

Computer simulation principles

In principle, computer simulation can be applied to any natural phenomenon for which the required scientific and mathematical principles and computer techniques are established and understood. These key elements are schematically illustrated in Figure 1.

The scientific and mathematical principles of many of today's most important problems were established years ago. For example, the Navier-Stokes equations, used in aerodynamic simulations, and generally considered to be the fundamental representation of the physics of generalized fluid flow, were established in 1827. And the Schrodinger equation, which is the basic formulation of problems in nuclear, atomic and molecular physics, was established in 1926.

The numerical methods for solving the problems describing the physical phenomena have been known for decades. But the equations are very complex. Today there is a need to devise streamlined algorithms. Although the mathematics for these phenomena have been understood for many years, numerical simulation was not a practical method of study. Now, the availability of computers, and powerful ones at that, have made computer simulation a practical reality.

Clearly, computer simulation is complex and the pitfalls are many. Therefore, the results of single computational experiments should be validated against the results of the corresponding real-world process, as with the nose cone test shown in the photographs on the next page. But once the technique and method is verified, computer simulation provides

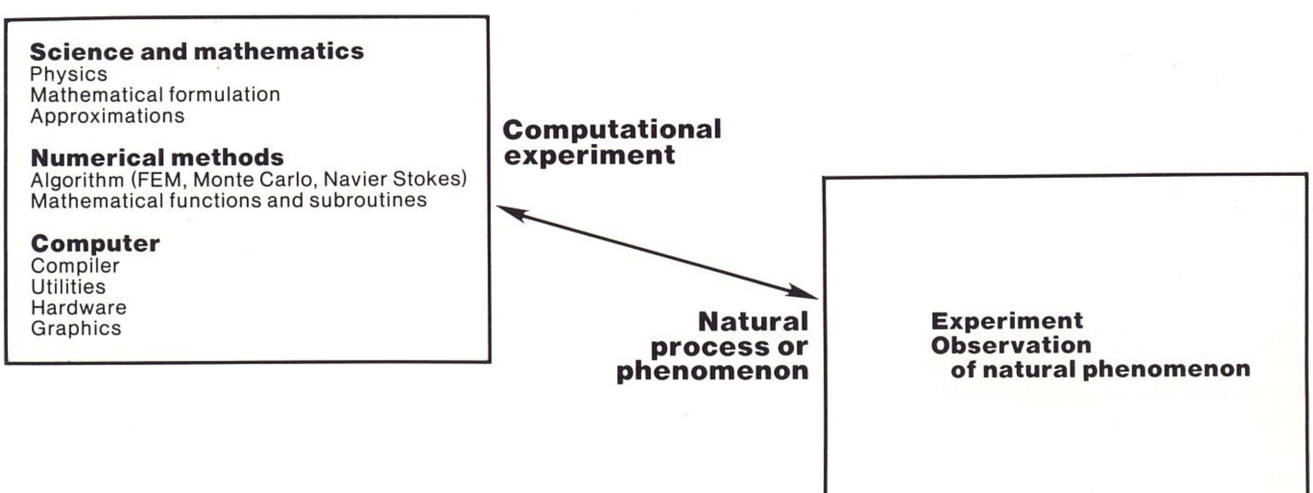
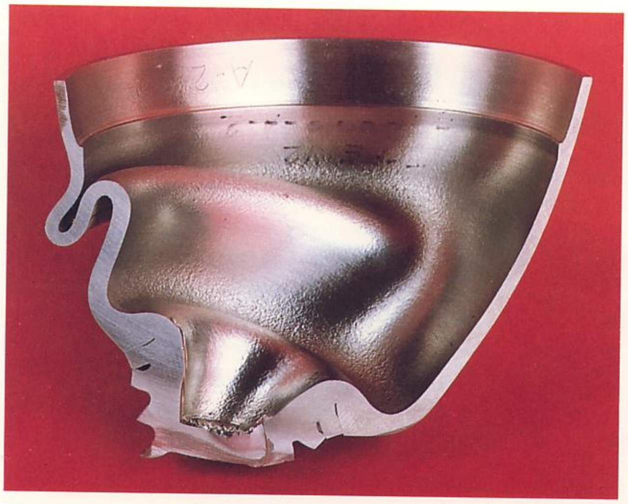
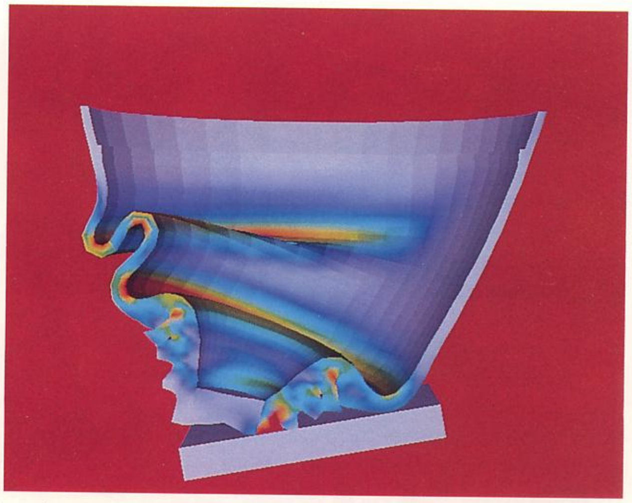


Figure 1. Key elements of computer simulation.

The nose cone shown at left represents a cooperative effort between Lawrence Livermore and Sandia National Laboratories. The photo at left is of the experiment in which the test nose cone was impacted at an angle on a solid surface. The picture at right shows the results of numerical simulation of this highly nonlinear process executed on a CRAY. The two techniques produced remarkably similar results indicating the validity of the computational approach. As a result, nose cone redesigns can be completed in a few days via supercomputer, saving valuable time!

an opportunity to do many experiments more quickly, at a reduced cost and possibly, to conduct experiments inaccessible via traditional methods.

Computer simulation in practice

The requirements for advanced computational facilities in computer simulation can be huge. The availability of a few powerful systems has only served to whet the appetite of the world's scientists and engineers. The reasons for this can be illustrated with a simple mathematical inequality:

$$AM \leq P.$$

In this expression, A represents the accuracy of the mathematical model of the phenomenon being studied. The fewer approximations that are made to the exact or "ab initio" representation, the higher the value of A. For the "ab initio" calculation of a nuclear interaction, A is very large. On the other hand, for typical aerodynamic simulations of a wing at subsonic speeds, A is quite low. The mathematical representation is highly approximate but quite adequate for simple geometries (a wing) at subsonic speeds.

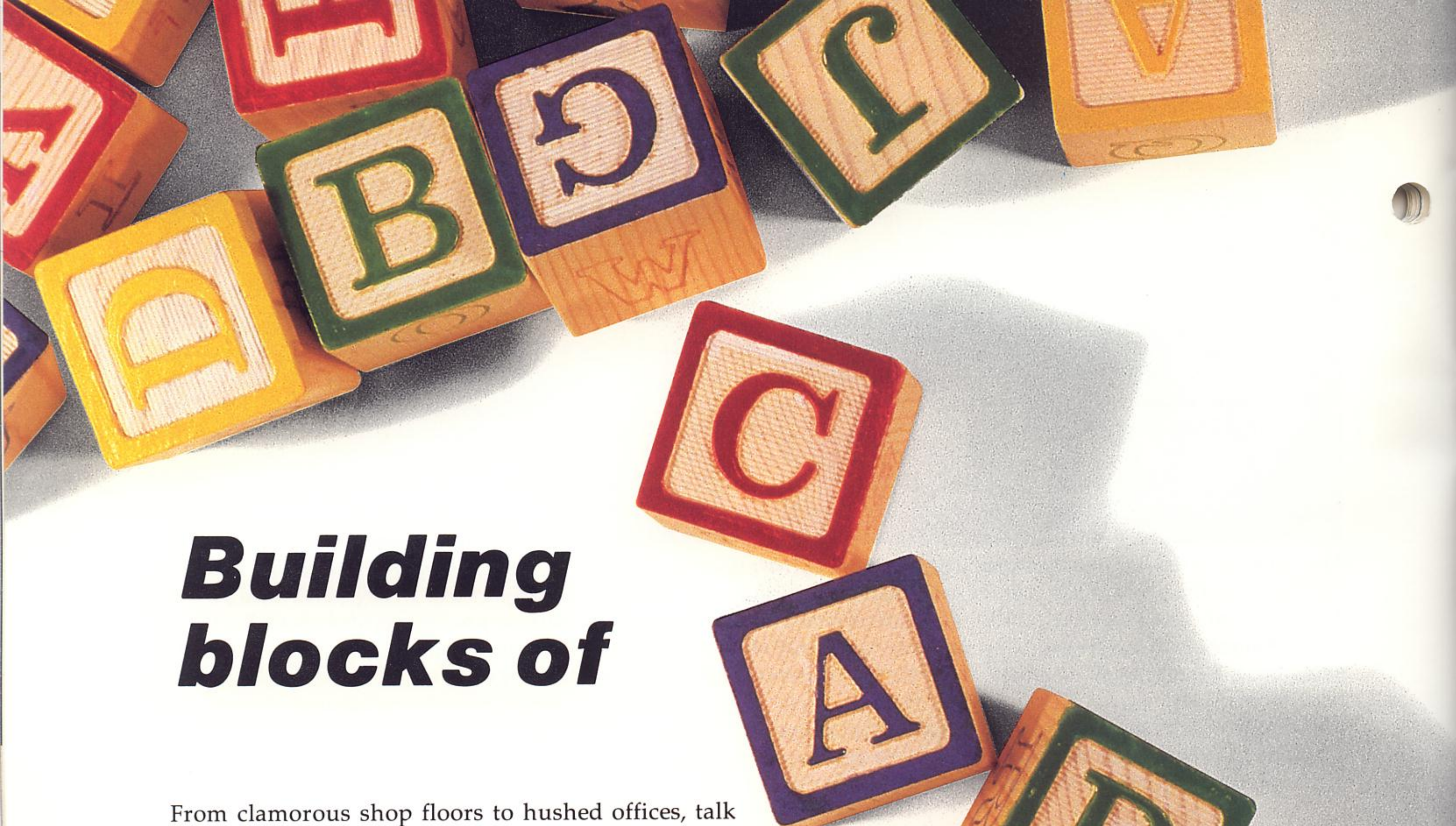
The term M represents the scale of the model being considered. This term takes into account the geometric complexity, dimensionality (1-, 2- or 3-D), the required spatial and/or temporal resolution (number of elements) and other factors which describe the relative scale of the process being simulated. For simulation of an aircraft wing alone, M is relatively small; for simulation of a full aircraft in detail, M is large.

Of course, the units of A and M are arbitrary and relative, but we can say with certainty that the product of A and M must be less than or equal to P, the available computer power. Because of this constraint, the scientist or engineer must often sacrifice either the model complexity or the mathematical accuracy of a simulation experiment.

CRAY computer systems have increased P by factors of 5, 10 or even 100 over other computers presently used for simulation. But this added capability has served to spark the creative imaginations of scientists and engineers, many of whom can envision computer experiments that require factors of 100 or 1000 over present computational capabilities. They do this by improving the mathematical representation, increasing the spatial or temporal resolution or adding to the model. The goal, of course, is the most accurate possible simulation of the phenomenon of interest given the available computer power.

The demand for more compute capacity for modeling and analysis is insatiable. Ongoing development in supercomputing will undoubtedly help ease the burden placed on computational facilities. Additionally, it is imperative that numerical research yield more efficient algorithms for solution of the mathematical formulas. Research in mathematics, physics, chemistry and engineering will certainly result in more accurate and less expensive approximation to the mathematical representations of physical phenomena. However, these efforts may barely keep pace with the growing need for high performance computer systems coming from computer simulation applications alone.

The term supercomputer has been defined as "a system that is only one generation behind the computing requirements of leading edge efforts in science and engineering." Considering that both substantial improvements in mathematical accuracy (A) and increases in model complexity and resolution (M) are needed in many application areas, this definition of a supercomputer will remain true for the foreseeable future. □



Building blocks of

From clamorous shop floors to hushed offices, talk of computer-aided design and manufacturing (CAD/CAM) buzzes. And why not? This technology is leading us through a second industrial revolution as the century draws to an end. Dramatic changes are being made in all phases of product design and manufacturing, primarily as a result of computers. Today, CAD systems are increasing engineers' productivity two to ten times, while enabling them to produce better product designs than ever before. Over the past 20 years, CAD systems have become indispensible in virtually all thriving red-blooded manufacturing companies.

Technology developments of the 60's and 70's made the computer a welcome partner in product development and manufacture. Computers became more affordable and easy to use, while software for a variety of engineering applications became prolific. CAD/CAM continues to infiltrate design and manufacturing shops at remarkable rates — in 1980, CAD/CAM system expenditures were about $1 billion and by 1987 they are expected to be $7 billion. Together, mechanical and electronic design and analysis account for about 75% of all CAD/CAM applications, mechanical CAD/CAM alone comprises more than 50% of that total.

The supercomputer fit

Today, supercomputers are finding their way into engineering shops because they efficiently handle certain CAD functions such as analysis, modeling and design. Structural analysis requirements can be very demanding, and are becoming more so. In certain environments, supercomputers are sometimes the only practical computing tool for structural analysis problems.

CRAY systems are are part of engineering shops involved in designing and analyzing complex products such as aircraft and automobiles. Traditionally, their processing compute power has been reserved for the sophisticated structural analysis and simulation tasks in these industries. Now, CRAY computers are beginning to share in computer modeling responsibilities also.

CAD/CAM defined

While CAD/CAM means different things to different people, a good general definition is: CAD/CAM is the direct application of specialized hardware and/or software to product engineering and manufacturing operations. The main objective of CAD is to produce a definition of the part or system to be produced through computerized design and analysis. CAM translates the product definition into tangible goods via computer-controlled manufacturing processes.

A key concept of CAD/CAM is that the functions of design and manufacturing are not only computerized, but that they are tied together through a shared database. The successful integration of various engineering disciplines is an important concept built into CAD systems. Information generated by engineers in the CAD database becomes the starting point for the production people to determine process plans.

An important advanced CAD/CAM capability is numerical control (NC) programming. Numeric data identified during CAD is drawn upon to establish computer programs in the CAM phase. Because information is stored and transferred by computer systems, instead of on paper, data going from one group to another is more reliable and is available more quickly. Beyond NC control, CAM includes the areas of production process and planning, group technology, material and production control, numerical control and robotics.

Most of the discussion in this article will focus on CAD. Figure 1 illustrates an integrated CAD/CAM system.

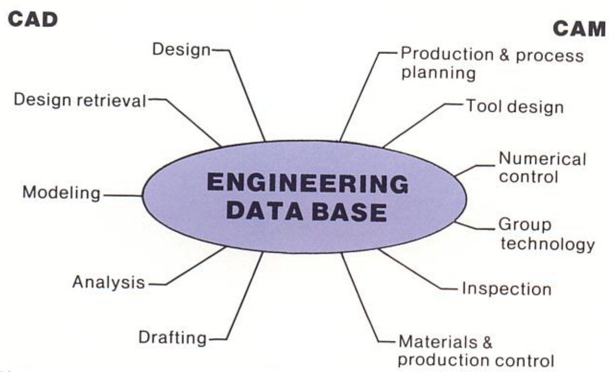


Figure 1. Integrated CAD/CAM system.

CAD and engineering

Let's get back to the basics. How does CAD relate to engineering? What are the computer functions, and where do computers like the CRAY fit?

The engineering process that a product goes through from the original idea to manufacturing can be broken down into the five classic phases illustrated in Figure 2. Keep in mind that not all CAD systems may perform all of these functions. In fact, some may perform only a few of them while others may go through steps that are not even represented below. However, the process outlined here provides a good idea of engineering steps.

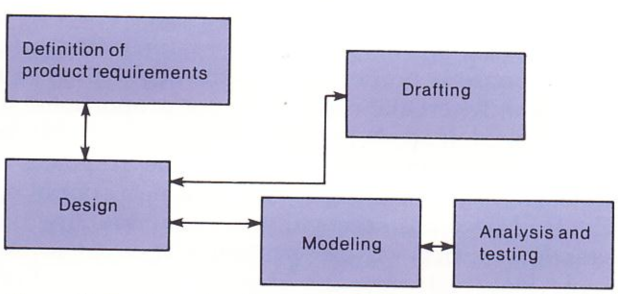


Figure 2. Engineering functions.

Definition of product requirements

The first step in designing a product is to determine the product requirements, addressing areas such as performance specifications, styling, cost, reliability and safety. The product's size, weight, tolerances and strength will also be defined. These requirements will then be passed on to an engineering group to develop the design solution that satisfies the greatest number of requirements.

Design

The design function is the first step in which a CAD system comes into play, with the computer and an interactive graphics terminal replacing the engineer's drafting table. Typically, design and modeling activities in a large company are conducted by geographically dispersed project groups that have access to local minicomputer CAD systems. These systems generally offer good interactive facilities.

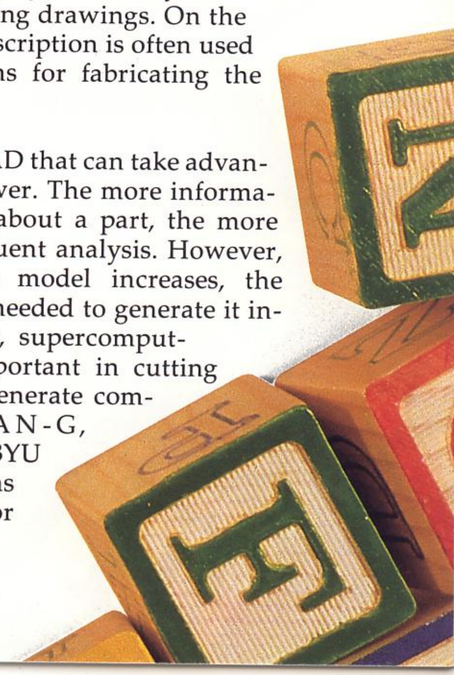
To design a part, an engineer draws directly onto the terminal screen. The data can be entered into the system by using an input tablet, an alphanumeric terminal, or in some cases, by a stylus that writes directly on the screen itself. The computer automatically converts the graphic representation of the part into a geometric model that is mathematically described and stored in the database. A very important aspect of the design process is the retrieval of old designs. Once drawings are created on a computer, they are stored on the system and can be accessed by the user over and over again. This is an area in which CAD techniques bring major productivity increases. From here, a product design moves into the modeling phase.

Modeling

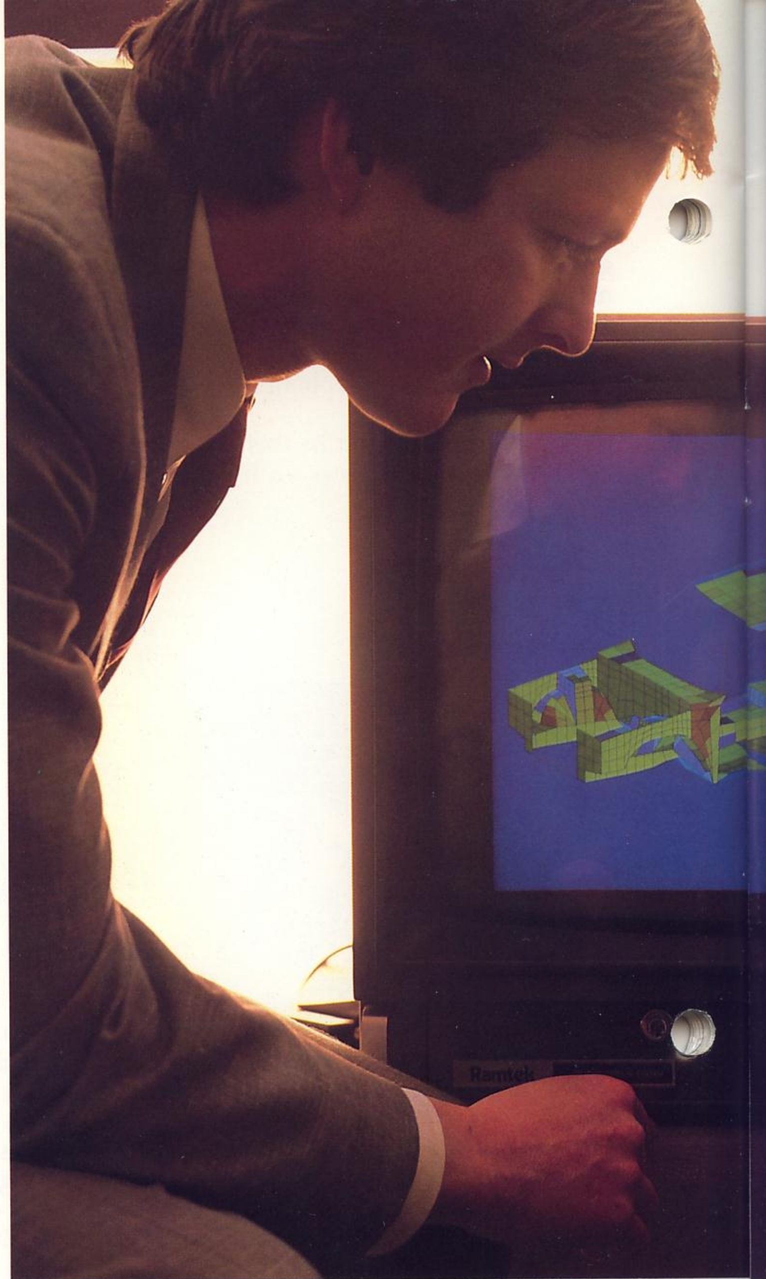
The geometric model is considered to be one of the most important elements of CAD because it is the starting point for so many other design functions. Modeling takes the geometric data from the design phase and formats the information in a way that becomes useful in analysis. The data specified in the analytical model may vary depending on the characteristics being scrutinized. Kinematic analysis may require different information from thermal analysis, and so on.

The geometry serves as input in the creation of a finite element model for analysis, or may serve as input for the final engineering drawings. On the CAM side, the geometric description is often used to generate NC instructions for fabricating the part.

Modeling is one phase of CAD that can take advantage of supercomputing power. The more information a model can provide about a part, the more useful the results of subsequent analysis. However, as the complexity of the model increases, the amount of compute power needed to generate it increases geometrically. Thus, supercomputers like the CRAY are important in cutting down the time needed to generate complex models. PATRAN-G, ROMULUS and MOVIE.BYU are three modeling programs that have been converted for operation on CRAYs.

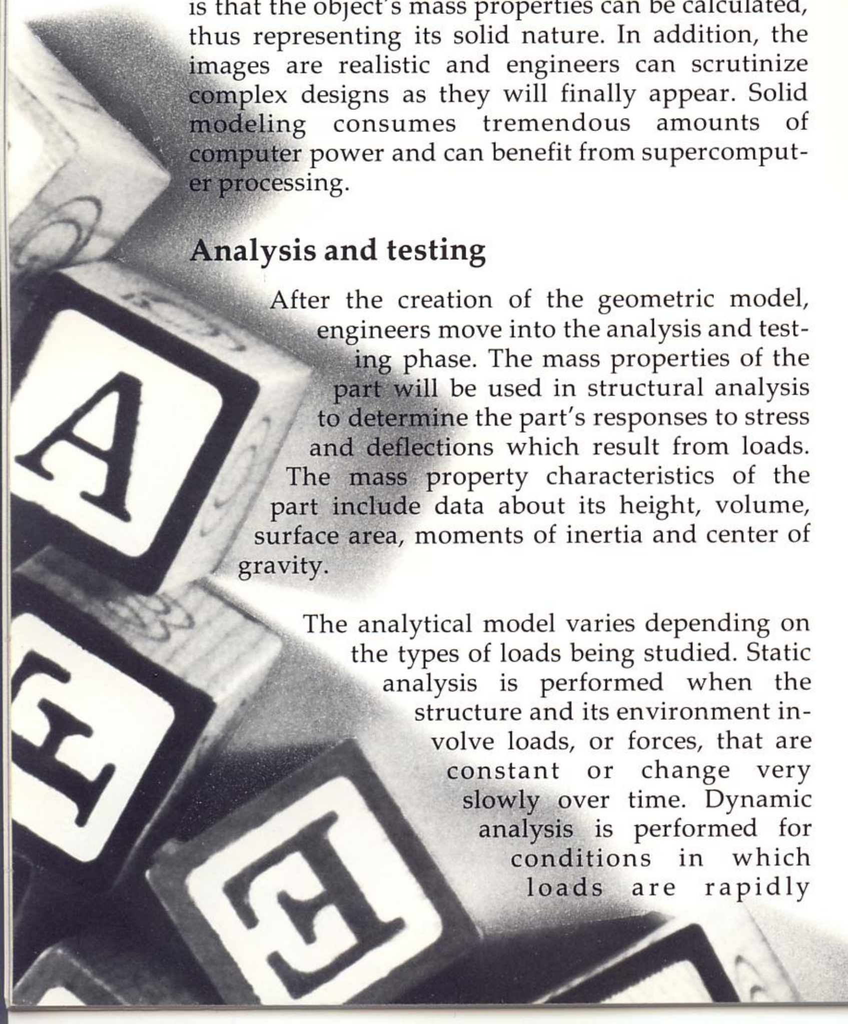


There are several modeling techniques. Today, most modeling is done with wire frames that represent part shapes with interconnected line elements that appear as stick figures. Wire-frame models consume little computer time and memory, but the amount of information they convey about the part is somewhat limited. For instance, information about the part's surface is not available, and it is not possible to distinguish surfaces from the interior, although this information is contained in the database.



The surface model is a more advanced model that overcomes some of the limitations of wire frames by precisely defining the part geometry. Engineers build surface models from a menu of surface features such as planes and cylinders that are stored in the computer. Using hidden-line removal techniques, surface models can appear solid, but they cannot represent the solid nature of the part. For example, determining whether the model is actually a thin piece of metal or a thick solid structure may be very difficult.

The most advanced geometric model is the 3-D solid model, which provides a complete unambiguous description of a solid object. Solid models may be created by using a surface image to define the boundary of a mass in the computer, or may use combinations of basic geometric shapes to compose complex shapes. That is, cubes, spheres, or other geometric primitives are used to describe a model in much the same way that building blocks are used to make up larger structures. A major advantage of solid models is that the object's mass properties can be calculated, thus representing its solid nature. In addition, the images are realistic and engineers can scrutinize complex designs as they will finally appear. Solid modeling consumes tremendous amounts of computer power and can benefit from supercomputer processing.



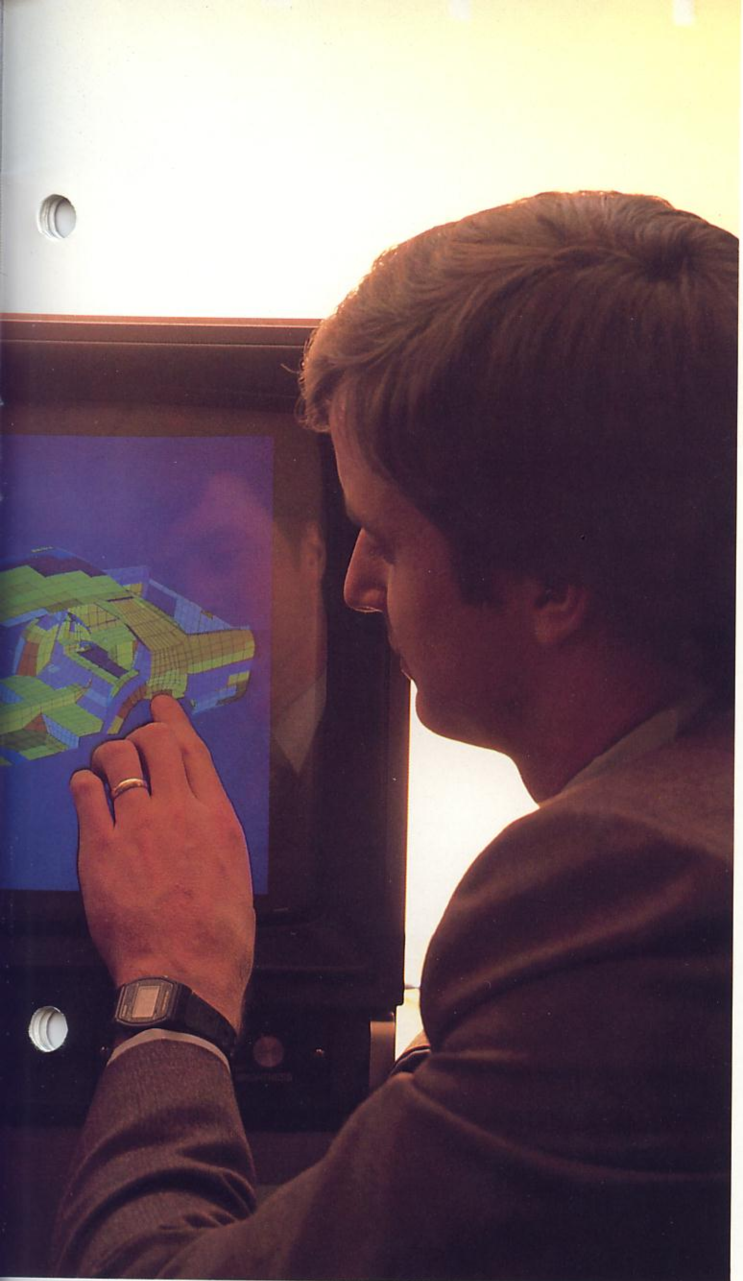
Analysis and testing

After the creation of the geometric model, engineers move into the analysis and testing phase. The mass properties of the part will be used in structural analysis to determine the part's responses to stress and deflections which result from loads. The mass property characteristics of the part include data about its height, volume, surface area, moments of inertia and center of gravity.

The analytical model varies depending on the types of loads being studied. Static analysis is performed when the structure and its environment involve loads, or forces, that are constant or change very slowly over time. Dynamic analysis is performed for conditions in which loads are rapidly applied, or vary over time. Air turbulence around an aircraft is an example of a dynamic load.

Another distinction made in structural analysis is whether the results of loading are *linear,* meaning the response is proportional to the applied load, or *nonlinear,* where the response is not proportional to the applied load. When the response is linear in nature, the load is doubled and the response is doubled. When responses are nonlinear, doubling the load does not necessarily result in doubling the reaction — nor will the structure respond in the same way each time the identical load is applied. Nonlinear problems require much more computation than do linear problems because they require much finer meshes.

Structural analysis is the most classic engineering function for which supercomputer power is used. Generally, structural analysis programs run three to ten times faster on the CRAY than on other mainframes. Consequently, complex problems in



CAD that were not even considered a few years ago, can now be solved in a timely economic manner on the CRAY. In addition, routine structural analysis problems can be handled so quickly that many more design iterations can be studied, usually leading to a better design.

Finite element method

One of the most powerful and widely used structural analysis techniques is the finite element method (FEM). For all practical purposes, FEM is impossible without the use of computers because problems can easily involve tens of thousands of simultaneous equations.

In integrated CAD systems, the user can call up a geometric model of the part, automatically creating the elements and nodes used to create the finite element model. Once the part is modeled, the user can specify loads and perform an analysis with FEM programs.

When analysis is completed, graphics post-processing techniques are used to convert the numeric solution into graphics presentation form for easy evaluation. Output data may illustrate the effects of heat on an object, or illustrate deformation in a crash analysis. Any number of effects may be solved for and displayed, and depending on the acceptablity of the outcome, the model may be modified and re-analyzed until the results are satisfactory.

Computer-aided engineering

Beyond structural analysis of product parts, engineers may attempt to determine the performance of an entire product. This phase of CAD is referred to as computer-aided-engineering (CAE) and is considered to be an advancement within CAD. Today, CAE comprises about 3% of all CAD efforts, by 1987, that figure is expected to grow to 20%.

An entire structure is mathematically represented as a system model synthesized from components analyzed earlier and, possibly, a historical database. Once the system model is created, it is analyzed with data representing loads and other effects that it might encounter in reality. For instance, if a car were being analyzed, one might want to simulate it crashing into a wall. The computer would predict the car's performance in such a crash.

System simulation takes the place of prototype tests. Large and complex structures can be cost-effectively analyzed via computer simulation. Industries such as automotive, aerospace, heavy machinery, and heavy construction are among those aggressively implementing CAE. With new car design lead-times standing at about 60 months, and new aircraft designs taking about seven years, cutting design cycle time can save millions — to say nothing of the savings in materials and operating costs. Not only that, but the product designs are better.

The complex analyses and computer simulations associated with CAE are compute-intensive and can overwhelm the largest computers in an engineering shop. For engineering design problems involving large complex products, CRAY supercomputers offer very unique job throughput opportunities. Whereas many large computing problems can force engineers to wait for hours and days for results, or perhaps discourage them from running their problems at all, CRAY computers help decrease turnaround in the CAE process.

Drafting

When the final design is determined, detailed hard copy drawings are produced by plotting different views of the geometric model previously created and stored in the computer memory. Most CAD systems allow the production of detail and assembly drawings from design information as a byproduct of the original geometry. The drawings are required by

manufacturing to plan, fabricate and assemble a final product. Computer-aided drafting offers a two- to six-fold increase in drafting productivity for most applications.

Summary

In summary, the objective of computer-aided design is to produce the optimum product design. This results in improved product quality, increased productivity and decreased engineering and manufacturing costs. CAD systems minimize or eliminate many tedious engineering tasks, while supercomputers integrated into CAD environments augment knowledge of products prior to manufacturing. No wonder CAD technology is changing the engineering and manufacturing industries the world over. □

LLNL describes the finite-element method

Before a computer program can calculate a structure's response to applied forces, it must be provided with a mathematical description of the object. Simple mathematical formulas usually are not sufficient for this because they fit regular geometrical shapes only and cannot allow for major distortions.

Instead, the structure being represented must be divided into a large number of elements; the location of each element is specified in terms of a coordinate system. This process is called discretizing. Then, the computer program can calculate how the applied forces affect each element and how each element affects its adjacent neighbors. A master calculation summarizing all the individual calculations describes the affect on the whole structrue.

Elements are shaped somewhat like bricks, and their shapes are defined by the positions of their corners (called nodes). Elements must be quite small to map out the entire structure without seriously distorting either its geometry, the temperature, pressure and other gradients inside it. However, the smaller the elements are, the more there are, and the more complicated, time-consuming and expensive the calculation is.

To obtain a complete picture, the calculation must follow a structure's response to the applied forces through time. Thus, the time-step factor is an important consideration in generating a finite element mesh. The program calculates how each element affects its neighbors, but only its adjacent neighbors. Hence, the program must be limited to calculating in time intervals so short that no disturbance in any one element can propagate beyond its adjacent neighbors.

This sounds simple, but in practice it is quite complicated. A disturbance travels at the speed of sound, and this speed varies as a function of the temperature and density of the material. Even if the elements are all the same size at the start, once the structure begins to deform, some elements may be squashed or stretched. Sound can cross a thin element much more quickly than a thick one. Therefore, the program must search through all the elements, find the one in which the sound transit time is the shortest, and make the time step for the next calculation less than this minimum transit time. Obviously, it is possible for the time-step size to become very small, with the result that the calculation will require many time steps and a great deal of computer time.

Acknowledgement

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New versions of COS, CFT released

Version 1.13 of the standard Cray Operating System (COS) and Cray FORTRAN Compiler (CFT) was released recently. The 1.13 release provides many new capabilities and significantly improves system performance. (Note: CFT 1.12 revision level was skipped in order to bring the current CFT and COS revision levels back into agreement.)

At the top of the list of release features in 1.13 is the implementation of multitasking. This feature allows a single user job to create multiple tasks that can execute simultaneously in the multiple CPUs of the CRAY X-MP. With the new version of COS, the CPU no longer executes user jobs as such, but rather executes user tasks within a user job. A CRAY X-MP site may elect to support multiple tasks per job (a CRAY-1 site may not), and these tasks are then doled out to the CPUs as the job progresses.

Also for multiple-processor systems, CFT now optionally generates code that uses a run-time stack. The stack-based code generated by CFT is reentrant and suitable for use in a multitasking environment.

Another major feature in 1.13 is disk striping, which groups disks together to improve I/O performance. A striped disk group consists of two to seven disk units on an I/O Subsystem that are treated as a single logical device by the operating system.

Mass storage devices may now be configured as controlled devices; sectors of a controlled device used by a job must be declared on the JOB control statement. New library routines allow conversion of disk and tape datasets to and from CDC record and block format. New macros allow users to position tape datasets and recover tape jobs after a system interruption.

The CFT instruction scheduler has been completely rewritten for 1.13. The new scheduler generates more efficient code that catches chain slot time reliably, considers functional unit and memory busy times and resolves register path conflicts. Scalar instructions are scheduled more efficiently and scalars are bottom loaded by default (although a control option can disable this).

A control statement option allows users to improve the execution speed of FORTRAN programs by causing CFT to allocate local scalar variables to B and T registers instead of memory. Certain one-line DO-loops are now recognized by CFT and replaced with library routine calls. A number of CFT intrinsic functions have been vectorized, and others have been changed to generate improved code. Gather load and scatter store have also been added, thereby enhancing CFT's vectorization capabilities. Scalar and vector versions of a population count parity intrinsic function are now available.

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CFT now issues informative messages explaining the reason for dependencies found in DO-loops. This additional information should assist users in coverting these DO-loops into vectorizable versions.

A series of Cray performance tests showed that the FORTRAN compiler version 1.13 generates code that executes an average of 10% faster than that generated by CFT version 1.11. Of course, the amount of improvement depends on the nature of the program.

NASA orders first CRAY-2

In April Cray Research announced that the National Aeronautic and Space Administration ordered Cray systems, including the new CRAY-2 product.

The CRAY-2 will be installed by the Numerical Aerodynamics Simulation (NAS) Program at the NASA-Ames Research Center in the third quarter of 1985. It will be at the center of a new National Facility being developed by NASA for the numerical simulation of advanced aerodynamic designs. NASA's CRAY-2 will have 64 million words of MOS memory. As part of the same order, a CRAY-1/M will be installed in the third quarter of 1984, interim to receipt of the CRAY-2.

Developed under the direction of Seymour Cray, the company's founder, the CRAY-2 is a four-processor system with a large central memory. It's three-dimensional circuit modules are cooled by being immersed in an inert liquid.

The CRAY-2 employs a UNIX-based operating system, a departure from the operating system used in the CRAY X-MP and CRAY-1/M. CRAY-2 performance is expected to be six to twelve times that of a CRAY-1. John Rollwagen, Cray's chairman, said the company expects to install two more CRAY-2 systems, both in 1985.

Italian universities order CRAY-1/M

A consortium of 13 Italian universities recently joined together to order a CRAY-1 M/2200 computer system. The consortium, called CINECA, will install the system at its data processing center in Casalecchio Di Reno, Bologna, in the third quarter of 1984, pending approval of an export license.

CINECA was formed to supply computing services to member universities and to outside universities and industrial organizations throughout Italy. CINECA's 13 members include the Universities of Trento, Udine, Trieste, Padova, Venezia, Ferrara, Bologna, Modena, Parma, Ancona, Siena, Firenze and Catania. The new CRAY-1/M will be used for basic scientific research.

U.K. seismic contractor orders CRAY

In April, Cray Research announced that Merlin Profilers Limited ordered a CRAY-1 S/1300. The system is scheduled to be installed during the third quarter of 1984 at Merlin Profilers' facility in Woking, England, pending approval of an export license.

Merlin Profilers is a European seismic contractor, offering worldwide seismic services to the oil and gas exploration industry. Paul Blundell, Managing Director of the company, noted that, "The CRAY will allow us to offer advanced processing of high density data needed for current exploration in the North Sea and elsewhere."

In a reciprocal arrangement, Merlin has offered Cray Research the use of its advanced seismic software package.

Boeing orders second CRAY

Boeing Computer Services Co. (BCS) ordered a second CRAY-1/S computer in May. The one-million-word system was installed at BCS headquarters in Bellevue, Washington. BCS installed its first CRAY-1 in 1981.

Boeing Computer Services is a division of Boeing Company that offers a broad range of computer services to customers in the United States, Canada and Great Britain.

CRAY-1/M at Mobil

Mobil Exploration and Producing Services, Inc. (MEPSI) recently ordered a CRAY-1 M/2300. The system is to be installed at MEPSI's facility in Dallas, Texas.

Cray R&D remains tops

Cray Research's investment in research and development traditionally has been among the highest in industry, and 1982 (the most recent year's figures available) was no exception. In Business Week's comparison of 765 companies (the March 21, 1984 issue), Cray Research once again was listed first in R&D dollars spent per employee (at $20,958) and fourth in spending as a percent of sales (at 20.1%). To put these numbers in perspective, the averages for the computer industry were $5,321 and 7.0%, respectively. The all-industry composite figures came in at $2,645 and 2.4%, respectively.

Cray Research is committed to spending approximately 15% per year in its engineering and development efforts. This commitment is based on a belief that a heavy emphasis in these areas is imperative as the computer industry becomes increasingly competitive.

Now you might say, it's not what you have, but how you use it. Rest assured that Cray's investment in R&D, together with the efforts of many talented development employees, should help preserve the company's reputation as the industry leader.

APPLICATIONS IN DEPTH

Structures codes on the CRAY

What good is a supercomputer without software that matters? What good is the software without sufficient power to drive it? The answer to both these questions is: "Nothing." So that's why Cray Research has made sure that software programs that matter in mechanical analysis have been and continue to be converted and optimized for operation on CRAY computers.

Cray encourages third party vendors to implement and develop CRAY versions of their software — many have done so. Virtually all of the most popular finite element programs are available for operation on CRAY systems.

Brief synopses of some of the most widely used structural analysis programs are given here. Our selection is in no way exhaustive, and does not indicate any preference by Cray Research for these programs. Those interested in a comprehensive listing and description of the structural analysis programs on the CRAY should contact: Applications Department, Cray Research, Inc., 1440 Northland Drive, Mendota Heights, MN 55120; telephone: (612) 452-6650.

And now, onto a description of the programs:

ABAQUS, a relative newcomer in the structural analysis field, has been developed by Hibbitt, Karlsson and Sorensen, Inc. It is an advanced finite element code for structural and heat transfer analysis that includes nonlinear effects, dominating the overall program design. Typical industry segments and applications are: crashworthiness studies, sheet buckling and suspension components, analysis of risers, pipelines and platforms and soil mechanics, pipe whip, thermal shock, fracture mechanics and concrete containment analysis.

The program has general modeling capabilities (2- and 3-D continua, beams, shells, trusses, cables, gaps, etc.) and a large library of materials (isotropic and anisotropic elasticity, hyperelasticity, hypoelasticity, metal plasticity, visco-plasticity, soils plasticity and crushing). The code has a broad range of procedures including static and dynamic stress, transient and steady-state heat transfer, fully coupled temperature/stress, large eigenproblem solution, Riks method for unstable post-buckling response, impact solution, etc. All response history procedures offer automatic time step solution.

More information about ABAQUS can be obtained by contacting: Hibbitt, Karlsson, and Sorensen, Inc., 35 S. Angell St., Providence, RI, 02906, telephone: (401) 861-0820.

ANSYS is a large-scale general purpose program for finite element analysis of several classes of engineering problems. In the area of structural analysis, ANSYS checks for elasticity, plasticity, creep, swelling and small and large deflections. It has both linear and nonlinear capabilities in the structural and heat transfer areas. The program may be applied to a large number of structures, including two- and three-dimensional shells and solids. The nonlinear options in ANSYS include geometric nonlinearity, nonlinear material behavior and special nonlinear elements such as gaps and interfaces.

For more information contact: Swanson Analysis Systems, Inc., P.O. Box 65, Houston, PA 15342; telephone: (412) 746-3304.

ASAS is a general purpose finite element system for linear stress, steady-state heat conduction, and natural frequency analysis. The code is designed to allow analysis of a wide range of structures and solid bodies under a variety of loading and support conditions. ASAS capabilities include: a range of 50-plus elements, graphic data checking and display of deflected shapes and vibrational modes and well-defined interfaces to meet post-processing requirements.

Additional information about ASAS may be obtained by contacting: Atkins Research and Development Ltd., Woodcote Grove, Ashely Road, Epsom, Surrey, DT18 5BW, ENGLAND; telephone: 011-44-3727-26140. In the United States contact: W. E. Atkins, Inc., 7763 San Felipe, Suite 202, Houston, TX 77035; telephone: (713) 785-0124.

COSMIC NASTRAN is a general purpose finite element program for structural analysis. Structural elements provide for the specific representation of the more common types of construction, including rods, beams, shear panels, plates and shells of revolution. More general structures can be analyzed by using combinations of these elements and by the use of "general" elements. Control systems, aerodynamic transfer functions, and other non-structural features can be incorporated into the structural analysis problem by the user.

The range of analysis that can be performed with COSMIC/NASTRAN includes static response to concentrated or distributed loads, thermal expansion, and enforced deformation; dynamic response to transient loads, steady-state sinusoidal loads and random excitation; determination of real and complex eigenvalues for use in vibration analysis; and dynamic and elastic stability analysis.

COSMIC/NASTRAN is supported by RPK Corporation, P.O. Box 6585, Athens, GA 30604; telephone: (404) 548-1212.

MARC is a general purpose finite element system providing capabilities for solving a wide range of structural analysis problems. The system includes a library of elements and a selection of material behaviors, both linear and nonlinear. MARC can be used for linear elastic analysis of 2- and 3-D solids, shells and beams, and for applications in which nonlinear material and geometric effects dominate and must be included in conjunction with sophisticated geometric modeling.

MARC is offered by Marc Analysis Research Corporation, 260 Sheridan Ave., Suite 200, Palo Alto, CA 94306; telephone: (415) 326-7511.

MSC/NASTRAN, is one of the most popular general purpose finite element programs for structural analysis of complex structures. The program's capabilities include static and dynamic analysis, material and geometric nonlinearity, heat transfer, aeroelasticity, acoustics and electromagnetism analysis. Additional features include an extensive list of structural elements; automatic generation of several types of loads, including gravity loads and loads induced by thermal strains; plots of deformed and undeformed structures; and the choice of alternative methods of analysis, including either direct or modal formulations of dynamic problems. A significant number of CRAY sites use MSC/NASTRAN, including several service bureaus, aerospace, and government laboratories.

For more information regarding MSC/NASTRAN contact MacNeal Schwendler Corporation, 815 Colorado Blvd., Los Angeles, CA 90041; telephone: (213) 258-9111.

PAFEC75, Version 3.4 is the latest in the PAFEC (Program for Automatic Finite Element Calculations) suite. The system is a suite of FORTRAN subroutines capable of solving a wide range of static and dynamic structural problems using the finite element method. Modeling facilities are provided by a library of over 80 elements for use in 1-, 2- or 3-D. These include beams, springs, masses, plates, shells, bricks and wedge elements. Calculations include steady-state and transient temperature predictions, plasticity, creep, harmonic and transient dynamic responses, and certain cases of large displacement problems.

Additional information about the package can be obtained by contacting Pafec Ltd., Pafec House, Strelley Hall, Main Street, Strelley Nottingham NG8 6PE, ENGLAND; telephone: 011-44-602-292291.

WECAN is a general purpose finite element program that is used for structural analysis in disciplines such as civil engineering and nuclear development. The system has been developed over a 16-year period at the Westinghouse Research and Development Center and is supported for operation on the company's CRAY computers.

It has a wide range of capabilities including static elastic and inelastic analysis, steady-state heat conduction, steady-state hydraulic analysis, standard and reduced modal analysis, harmonic response analysis, dynamic transient analysis and linear buckling analysis.

Those interested in time-sharing or leasing WECAN on CRAY systems should contact: Albert S. Harsch, Westinghouse Electric Corporation, AST Advanced Mechanical Services, Pittsburgh, PA 15235; telephone: (412) 824-9100.

Kinematic analysis on the CRAY

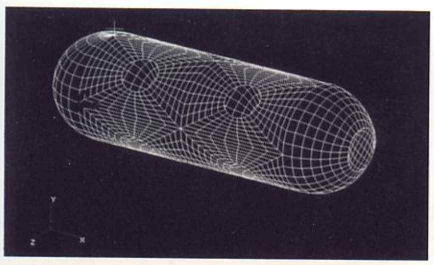
Kinematic analysis programs are converted for operation on CRAY computers. One code currently available is AMP3D-ADAMS, which performs kinematic and dynamic analysis of spatial mechanisms. The analysis is completely automatic and the designer is only required to provide basic physical data such as masses, inertias, dimensions, and driving forces. This information is communicated to the program as simple input language. Multi-degree of freedom systems with large geometric displacements are accommodated by the system.

Persons interested in additional information about AMP3D-ADAMS should contact: Mechanical Dynamics, Inc., 555 South Forest, Ann Arbor, MI 48104; telephone: (313) 994-6065.

Powerful design tool on the CRAY

The availability of PDA/PATRAN-G brings a powerful modeling complement to the broad collection of analytical programs on the CRAY. Computationally-intense geometric modeling tasks found in mechanical engineering applications can now take advantage of the sophisticated solid modeling capabilities of PATRAN on the CRAY. The combination of the two provides very strong modeling, design analysis and evaluation capabilities for engineers and analysts in many disciplines.

PDA/PATRAN-G allows the creation of a continuous solid model, independent of the analysis model. Thus, the PATRAN-G user can develop multiple analysis models optimized for the specific analysis type, all from a single consistent geometric model. Extensive use of construction, viewing and editing features have been integrated into a single package, providing friendly interface for design analysis modeling and evaluation. Effective color graphics implementation assures understanding and confidence for



The 3-D wire-frame model above was analyzed with NASTRAN and modeled with PATRAN.

the user. Accurate calculations for lengths, areas, volumes, weight and mass property parameters are available as well as interfaces to finite element, finite difference and CAD/CAM programs.

PATRAN is available from PDA Engineering, 1560 Brookhollow Drive, Santa Ana, CA 92705-5475; telephone: (714) 556-2800, or from the Applications Department, Cray Research Inc., 1440 Northland Drive, Mendota Heights, MN 55120.

Images with CSADIE

CSADIE is a file-oriented software system for the manipulation of digital image data converted for operation on the CRAY. CSADIE supplies routines for a wide variety of commonly used image operations. In addition, a user is provided with an input/output package to facilitate design of new procedures. By using a standardized I/O system, CSADIE frees the user from many complex programming tasks and at the same time guarantees the integrity of image files. CSADIE started life at Los Alamos National Laboratory. In its first incarnation, it was known as the Los Alamos Digital Image Enhancement System — LADIES. But eventually the program came to be known as SADIE.

CSADIE is implemented as a FORTRAN callable subroutine library. A large number of application subroutines are provided, each making use of a standard I/O interface. Both signal processing and image analysis applications are supported. Routines may be assembled together to create programs usable by persons having little or no familiarity with the CSADIE system itself.

Alternately, it is possible to write complex FORTRAN programs which still take advantage of the facilities provided by CSADIE. If desired, such programs are easily accessible to other users by adding them to the CSADIE library.

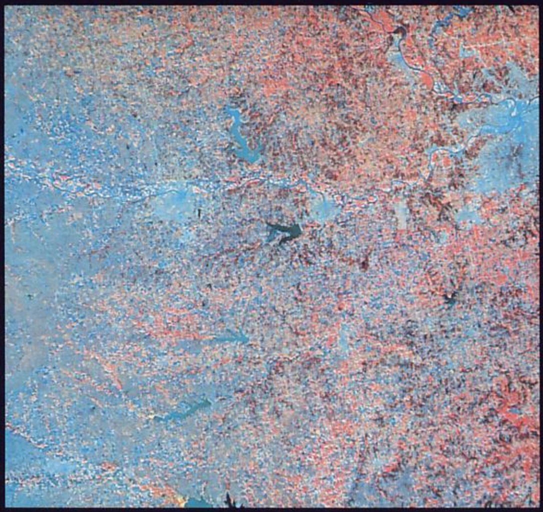
The CSADIE library is organized into two sections. The first is composed of procedures which process entire images. If these operations meet the user's needs, then the procedures in the second section may be ignored. Use of the first section requires little knowledge of FORTRAN or the internal workings of CSADIE. The second section is composed of subroutines which operate on individual image lines. These routines provide the user with access to the system's I/O operations and allow great flexibility in the implementation of new computational procedures. Use of this section requires experience with FORTRAN and a greater understanding of the structure and operation of CSADIE.

CSADIE is designed specifically for use on CRAY computers. The most important consequence of this design criteria is that mathematical operations are done in floating point arithmetic. As a result, CSADIE uses a real number representation for image values. A distinct advantage of this representation is that truncation induced quantization error is more easily avoided. In addition, area and perimeter calculations are computed with extreme accuracy and many primitive operations are vectorized. The system monitors image attributes in its own internal database, eliminating the need for the user to keep track of image parameters such as size and max-and-min. Other CRAY-design considerations deal mostly with I/O handling.

CSADIE provides for processing of FORTRAN subroutines in the spatial and frequence domains. The spatial routines include picture IN/OUT routines, image expansion and compression, median filtering, grid, histogram and printer plots. The frequence routines include two-dimensional filtering of bandpass, convolution and power spectrum computations.

CSADIE execution on the CRAY compares very favorably with similar execution on other systems. In comparing execution time with a VAX 11/780, one oil company user realized a performance improvement of 120:1. Cray Research suggests, however, that typical performance improvements will range from 30: to 60:1.

Recently, 300 Mbytes of data comprising thematic mapper landsat images of 7168 x 5968 elements with seven bands on three 6250 bpi tapes were read onto disk by a



This Thematic Mapper (TM) image shows a 5K x 5K square image displayed on a 1K x 1K raster terminal. Topeka, Kansas is found in the center of the image, Lawrence, Kansas is visable to the right, and Kansas City is at the far right. The red component of the image is spectral Band 4, green as Band 3 and blue as Band 2. Perry Lake located northeast of Topeka is visable. North end of the lake is lighter blue in color due to sedimentation in the water.

The TM image is a close-up in full resolution of a 1K x 1K picture of Topeka, Kansas in Bands 4, 3 and 2. Each pixel is taken directly from the original 336 Mbyte TM database of 7 band 7168 x 5968 images. The image shows detail of the river including the number of bridges crossing it. Traffic interchanges and housing cul-de-sacs are also visable with the 30-meter per pixel resolution.

CRAY X-MP in 7.5 minutes on a production system. Typical time for the same operation on a supermini-computer is 1.5 hours.

Those interested in additional information about CSADIE should contact: Applications Department, Cray Research, Inc. 1440 Northland Drive, Mendota Heights, MN 55120; telephone: (612) 452-6650.

SIGGRAPH in Minneapolis

July 23-27, 1984 will be a good time to be in Minneapolis, and not just because the weather should be good. For five days, computer graphics experts from all corners of the world will meet in Minneapolis, MN for SIGGRAPH '84.

The week's agenda includes panel discussions, courses, presentations and an art exhibit. A high point of the session promises to the expected presentation of the first computer-generated Omnimax film. Several individuals from around the country have created computer graphics film vignettes that are being compiled into a film collage. If the project is completed on schedule, it will be shown at the Science Museum of Minnesota Omnitheater in Saint Paul. Among other data processing equipment manufacturers, Cray Research has donated computing resources for the generation of this film.

Among the topics covered in the course schedule are: CAD, solid modeling, medical and biological applications for computer graphics and image synthesis. Among the topics covered in paper presentations are engineering and medical applications of computer graphics, modeling, visible surface algorithms, interactive systems and graphics standards.

The session is being held in cooperation with the IEEE Technical Committee on Computer Graphics, Eurographics, the Minnesota College of Art and Design, the University of Minnesota, the Science Museum of Minnesota and the Institute for Media Arts. Those interested in additional information about SIGGRAPH '84 should contact Lynn Valastyan, Conference Office, 111 East Wacker Drive, Chicago, Ill. 60601; telephone: (312) 644-6610.

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