United States General Accounting Office

GAO

Testimony

For Release
on Delivery
Expected at
2:00 p.m. EST
Tuesday
March 5, 1991

Supercomputing in Industry

Statement for the record by
Jack L. Brock, Jr., Director, Government
Information and Financial Management Issues
Information Management and Technology Division

Before the
Subcommittee on Science, Technology, and Space
Committee on Commerce, Science, and Transportation
United States Senate

Messrs. Chairman and Members of the Committee and Subcommittee:

I am pleased to submit this statement for the record, as part of the Committee's hearing on the proposed High Performance Computing Act of 1991. The information contained in this statement reflects the work that GAO has conducted to date on its review of how industries are using supercomputers to improve productivity, reduce costs, and develop new products. At your request, this work has focused on four specific industries--oil, aerospace, automobile, and pharmaceutical/chemical--and was limited to determining how these industries use supercomputers and to citing reported benefits.

We developed this material through an extensive review of published documents and through interviews with knowledgeable representatives within the selected industries. In some cases, our access to proprietary information was restricted. Since this statement for the record reports on work still in progress, it may not fully characterize industry use of supercomputers, or the full benefits likely to accrue from such use.

BACKGROUND

A supercomputer, by its most basic definition, is the most powerful computer available at a given time. While the term supercomputer does not refer to a particular design or type of computer, the basic design philosophy emphasizes vector or parallel processing,[1] aimed at

---

[1] Vector processing provides the capability of operating on arrays, or vectors, of information simultaneously. With parallel processing, multiple parts of a program are executed concurrently. Massively parallel supercomputers are currently defined as those having over 1,000 processors.

achieving high levels of calculation very rapidly. Current supercomputers, ranging in cost from $1 million to $30 million, are capable of performing hundreds of millions or even billions of calculations each second. Computations requiring many hours or days on more conventional computers may be accomplished in a few minutes or seconds on a supercomputer.

The unique computational power of supercomputers makes it possible to find solutions to critical scientific and engineering problems that cannot be dealt with satisfactorily by theoretical, analytical, or experimental means. Scientists and engineers in many fields--including aerospace, petroleum exploration, automobile design and testing, chemistry, materials science, and electronics--emphasize the value of supercomputers in solving complex problems. Much of this work centers around scientific visualization, a technique allowing researchers to plot masses of raw data in three dimensions to create visual images of objects or systems under study. This enables researchers to model abstract data, allowing them to "see" and thus comprehend more readily what the data reveal.

While still relatively limited in use, the number of supercomputers has risen dramatically over the last decade. In the early 1980s, most of the 20 to 30 supercomputers in existence were operated by government agencies for such purposes as weapons research and weather modeling. Today about 280 supercomputers[2] are in use worldwide. Government (including

[2] This figure includes only high-end supercomputers such as those manufactured by Cray Research, Inc. Including International Business Machines (IBM) mainframes with vector facilities would about double this number.

defense-related industry) remains the largest user, although private industry has been the fastest growing user segment for the past few years and is projected to remain so.

The industries we are examining enjoy a reputation for using supercomputers to solve complex problems for which solutions might otherwise be unattainable. Additionally, they represent the largest group of supercomputer users. Over one-half of the 280 supercomputers in operation are being used for oil exploration; aerospace modeling, testing, and development; automotive testing and design; and chemical and pharmaceutical applications.

THE OIL INDUSTRY

The oil industry uses supercomputers to better determine the location of oil reservoirs and to maximize the recovery of oil from those reservoirs. Such applications have become increasingly important because of the low probability of discovering large oil fields in the continental United States. New oil fields are often small, hard to find, and located in harsh environments making exploration and production difficult. The oil industry uses two key supercomputer applications, seismic data processing and reservoir simulation, to aid in oil exploration and production. These applications have saved money and increased oil production.

Seismic data processing increases the probability of determining where oil reservoirs are located by analyzing large volumes of seismic data[3] and producing two- and three-dimensional images of subsurface geology. Through the study of these images, geologists can better understand the characteristics of the area, and determine the probability of oil being present. More accurately locating oil reservoirs is important because the average cost of drilling a well is estimated at about $5.5 million and can reach as high as $50 million. Under the best of circumstances, most test wells do not result in enough oil to make drilling cost-effective. Thus, avoiding drilling one dry well can save millions of dollars. The industry representatives who agreed to share cost estimates with us said that supercomputer use in seismic data processing reduces the number of dry wells drilled by about 10 percent, at a savings of hundreds of millions of dollars over the last 5 years.

Reservoir simulation is used to increase the amount of oil that can be extracted from a reservoir. Petroleum reservoirs are accumulations of oil, water, and gas within the pores of rocks, located up to several miles beneath the earth's surface. Reservoir modeling predicts the flow of fluids in a reservoir so geologists can better determine how oil should be extracted. Atlantic Richfield and Company (ARCO) representatives estimate that reservoir simulation used for the oil field at Prudhoe Bay, Alaska--the largest in production in the United States--has resulted in increased oil production worth billions of dollars.

---

[3] Seismic data are gathered by using sound-recording devices to measure the speed at which vibrations travel through the earth.

THE AEROSPACE INDUSTRY

Engineers and researchers also use supercomputers to design, develop, and test aerospace vehicles and related equipment. In particular, computational fluid dynamics, which is dependent upon supercomputing, enables engineers to simulate the flow of air and fluid around proposed design shapes and then modify designs accordingly. The simulations performed using this application are valuable in eliminating some of the traditional wind tunnel tests used in evaluating the aerodynamics of airplanes. Wind tunnels are expensive to build and maintain, require costly construction of physical models, and cannot reliably detect certain airflow phenomena. Supercomputer-based design has thus resulted in significant time and cost savings, as well as better designs, for the aerospace industry.

Lockheed Aerospace used computational fluid dynamics on a supercomputer to develop a computer model of the Advanced Tactical Fighter for the U.S. Air Force. By using this approach, Lockheed was able to display a full-vehicle computer model of the fighter after approximately 5 hours of supercomputer processing time. This approach allowed Lockheed to reduce the amount of wind-tunnel testing by 80 hours, resulting in savings of about half a million dollars.

The Boeing Aircraft Company used a Cray 1S-2000 supercomputer to redesign the 17-year old 737-200 aircraft in the early 1980s. Aiming to create a more fuel-efficient plane, Boeing decided to make the body design longer and replace the engines with larger but more efficient models. To determine the appropriate placement of these new engines, Boeing used the supercomputer to simulate a wind-tunnel test. The results of this simulation--which were much more detailed than would have been available from an actual wind-tunnel test--allowed the engineers to solve the engine placement problem and create a more fuel-efficient aircraft.

THE AUTOMOBILE INDUSTRY

Automobile manufacturers have been using supercomputers increasingly since 1985 as a design tool to make cars safer, lighter, more economical, and better built. Further, the use of supercomputers has allowed the automobile industry to achieve these design improvements at significant savings.

One supercomputer application receiving increasing interest is automobile crash-simulation. To meet federally mandated crash-worthiness requirements, the automobile industry crashes large numbers of pre-prototype vehicles head-on at 30 miles per hour into rigid barriers. Vehicles for such tests can cost from $225,000 to $750,000 each. Crash simulation using supercomputers provides more precise engineering information, however, than is typically available from actually crashing vehicles. In addition, using supercomputers to perform this type of structural analysis reduces the number of actual crash tests required by 20 to 30 percent, saving the companies millions of dollars each year. Simulations such as this were not practical prior to the development of vector supercomputing because of the volume and complexity of data involved.

Automobile companies credit supercomputers with improving automobile design in other ways as well. For example, Chrysler Corporation engineers use linear analysis and weight optimization software on a Cray X-MP supercomputer to improve the design of its vehicles. The resulting designs--which, according to a Chrysler representative, would not have been practical without a supercomputer--will allow Chrysler to achieve an annual reduction of about $3 million in the cost of raw materials for manufacturing its automobiles. In addition, one automobile's body was made 10 percent more rigid (which will improve ride and handling) and 11 percent lighter (which will improve fuel efficiency). According to the Chrysler representative, this is typical of improvements that are being achieved through the use of its supercomputer.

THE CHEMICAL AND PHARMACEUTICAL INDUSTRIES

Supercomputers play a growing role in the chemical and pharmaceutical industries, although their use is still in its infancy. From computer-assisted molecular design to synthetic materials research, companies in these fields increasingly rely on supercomputers to study critical design parameters and more quickly and accurately interpret and refine experimental results. Industry representative told us that, as a result, the use of supercomputing will result in new discoveries that may not have been possible otherwise.

The pharmaceutical industry is beginning to use supercomputers as a research tool in developing new drugs. Development of a new drug may require up to 30,000 compounds being synthesized and screened, at a cost of about $5,000 per synthesis. As such, up to $150 million, before clinical testing and other costs, may be invested in discovering a new drug, according to an E.I. du Pont de Nemours and Company representative. Scientists can now eliminate some of this testing by using simulation on a supercomputer. The supercomputer analyzes and interprets complex data obtained from experimental measurements. Then, using workstations, scientists can construct three-dimensional models of the large, complex human proteins and enzymes on the computer screen and rotate these images to gain clues regarding biological activity and reactions to various potential drugs.

Computer simulations are also being used in the chemical industry to replace or enhance more traditional laboratory measurements. Du Pont is currently working to develop replacements for chlorofluorocarbons, compounds used as coolants for refrigerators and air conditioners, and as cleansing agents for electronic equipment. These compounds are generally thought to contribute to the ozone depletion of the atmosphere and are being phased out. Du Pont is designing a new process to produce substitute compounds in a safe and cost-effective manner. These substitutes will be more reactive in the atmosphere and subject to faster decomposition. Du Pont is using a supercomputer to calculate the thermodynamic data needed for developing the process. These calculations can be completed by the supercomputer in a matter of days, at an approximate cost of $2,000 to $5,000. Previously, such tests--using experimental measurements conducted in a laboratory--would require up to 3 months to conduct, at a cost of about $50,000. Both the cost and time required would substantially limit the amount of testing done.

BARRIERS TO GREATER USE OF SUPERCOMPUTERS

These examples demonstrate the significant advantages in terms of cost savings, product improvements, and competitive opportunity that can be realized through supercomputer use. However, such use is still concentrated in only a few industries. Our industry contacts identified significant, interrelated barriers that individually or collectively, limit more widespread use of supercomputers.

Cost. Supercomputers are expensive. A supercomputer's cost of between $1 million and $30 million does not include the cost of software development, maintenance, or trained staff.

Cultural resistance. Simulation on supercomputers can not only reduce the physical testing, measurement, and experimentation, but can provide information that cannot otherwise be attained. For many scientists and managers this represents a dramatic break with past training, experience, generally accepted methods, or common doctrine. For some, such a major shift in research methodology is difficult to accept. These new methods are simply resisted or ignored.

Lack of application software. Supercomputers can be difficult to use. For many industry applications, reliable software has not yet been developed. This is particularly true for massively parallel supercomputers.

Lack of trained scientists in supercomputing. Between 1970 and 1985, university students and professors performed little of their research on supercomputers. For 15 years, industry hired students from universities who did not bring supercomputing skills and attitudes into their jobs. Now, as a result, many high-level scientists, engineers, and managers in industry have little or no knowledge of supercomputing.

In conclusion, our work to date suggests that the use of supercomputers has made substantial contributions in key U.S. industries. While our statement has referred to benefits related to cost reduction and time savings, we believe that supercomputers will increasingly be used to gain substantive competitive advantage. Supercomputers offer the potential--still largely untapped--to develop new and better products more quickly. This potential is just beginning to be explored, as are ways around the barriers that prevent supercomputers from being more fully exploited.