Who Will Build the Next Supercomputer?

NASA wants the United States to fund development of a new supercomputer before Japan can dominate the field

If NASA has its way, one of two U.S. companies may soon start building the world's fastest and most powerful computer. The agency wants to use the computer in aeronautical research and design and estimates its cost at $100 million, which includes funds to defray development costs for the manufacturer and to build a network so that researchers at universities, industries, and government laboratories can use the machine. NASA administrators argue that the government should provide the funds because the market for supercomputers is small and it may be a decade or more before any U.S. company, on its own, makes available a computer as powerful as the one NASA needs. "What is technically feasible and what is feasible from a marketing standpoint are completely different," says William Ballhaus, Jr., the director of astronautics at NASA's Ames Research Center at Moffett Field, California.

As part of its argument for government funds, NASA is pointing out that the Japanese government is supporting four companies which are developing supercomputer technologies. Ballhaus says that representatives from the Japanese computer firms Hitachi and Fujitsu visited Ames Research Center and explained to NASA administrators and researchers that Japan plans to become the world leader in the field of supercomputers. The Japanese said they do not expect to make an enormous amount of money on their supercomputers, but they are building them for their prestige value. Making the world's most powerful computers would help all of their computer sales and should help Japan successfully compete with this country in the computer market. At present, the United States is the major exporter of large scientific computers and uses its control of the market as a political weapon against the Soviet Union.

Japanese representatives also told NASA scientists that Japan plans to make inroads in the field of aeronautics—another high-technology area currently dominated by the United States. Japan's National Aerospace Laboratory is seeking government funds for a supercomputer similar to the one NASA wants to build.

NASA's involvement with supercomputers began a decade ago, when the Ames Research Center offered to give the Illiac IV a home. The Illiac, the largest and most advanced computer of its day, was developed with funds from the Advanced Research Projects Agency of the Department of Defense. It was installed at the University of Illinois in the late 1960's, where it was to have served primarily as a research facility. But because of the student unrest on college campuses at that time, the Defense Department began to worry about the Illiac's safety if it remained at the university.

In the meantime, computer scientists and aeronautical engineers were starting to look to computational fluid dynamics as a way to supplement wind tunnel simulations in the design of aircraft. The idea was to numerically simulate what goes on in wind tunnels and in flight in order to detect some of the errors that occur when wind tunnels alone are used in aeronautical design. Some famous aircraft design errors have been attributed to inadequacies of wind tunnel simulations. For example, the location of shock waves along the wings of the C-141, a military transport, was mispredicted by wind tunnel simulations. When flight-tested the plane tended to nose downward, and its design had to be modified at great expense. NASA scientists argued that they could use the Illiac to avoid such design errors.

The Defense Department agreed to move the Illiac to Ames Research Center, but NASA's experiences with the machine were far from an unqualified success. "Unfortunately, our hopes got ahead of reality. We perceived the Illiac as a computer, not as a research tool, and we oversold what we would be able to do," says Ellis Whiting, who is chief scientist at NASA's Office of Aeronautics and Space Technology in Washington, D.C. The problem with the Illiac was that it was unreliable, Whiting explains.

What researchers at Ames learned from their experience with the Illiac, however, has whetted their appetites for the powerful machine they are now seeking. Most computers were, and still are, designed to operate serially—operations are performed one after the other in sequence. By contrast, the Illiac is a parallel processor—it has 64 separate units that operate in lockstep, executing the same operation 64 times simultaneously. If computer programs can be designed to take advantage of this parallelism, the speedup in computing time can be enormous.

Fortunately, problems in fluid dynamics, which are what concern the Ames researchers, are particularly amenable to parallel processing. They frequently involve large-scale matrix operations in which the computer must perform the same arithmetic procedures over and over millions of times. "What we learned is that at first the problems seem inherently serial. But we found that almost every one of our problems can be specified in a parallel way. We got an opportunity to see the problems from a different perspective. Now we have even gone back and improved the serial programs," Whiting says.

In a major coup, the NASA researchers were able to use the Illiac to solve the complete Navier-Stokes equations describing airflows to a degree that was beyond the power of conventional computers. But neither the Illiac nor any computer now on the market can solve equations representing fluid flows in three dimensions. These are solutions that NASA says are greatly needed in aeronautics research.

Computer designers say that there are two ways to significantly improve the speed of computers. One is to use electronics to minimize the time it takes for signals to travel in the computer. The Japanese government is funding two projects to do this. One company is using gallium arsenide as a semiconductor and another is using Josephson junctions. In this country, IBM has a large research program funded by the Defense Department to study Josephson junctions (*Science*, 18 August 1978, p. 602). There are technical difficulties in using superconducting electronics, however. A Josephson junction computer, for example, must be cooled in liquid helium to a temperature of 4.2 K.

The other way to improve computational speed is to change the way data are organized in computers and the way programming languages are written. This puts more of the onus on the users, but many computer scientists believe it is a wide-open area for vast increases in computational speed and efficiency. It is the approach favored by NASA and the one being taken by Hitachi and Fujitsu and the U.S. firms Burroughs, Control Data Corporation (CDC), and Cray.

Although no U.S. firms are yet planning to combine the use of superconducting electronics and computer architecture, Japan apparently is. According to an article in the October 1980 issue of *Business JAPAN*, the Ministry of Industry and Technology is funding a major effort along this line, with the aim of developing a supercomputer by 1988 that is at least 100 times faster than the one NASA wants. Ballhaus believes, however, that Japan's plans are overly optimistic. "We are not aware of any realistic estimates that the Josephson junction or gallium arsenide technologies will be available for use by 1988," he says.

What NASA says it needs to solve three-dimensional viscous flow equations for complete aircraft and aircraft components is a computer that can sustain a speed of 1 billion operations per second and that has a memory of 240 million words. The Illiac has a speed of 25 million operations per second and a memory of 16 million words. The most powerful computers on today's market are CDC's Cyber 205, which has about 1/12 the speed NASA wants and 1/64 the memory, and the Cray-1S, which has 1/30 the required speed and 1/64 the required memory.

Both CDC and Burroughs Corporation are bidding to make the machine NASA wants, but by somewhat different designs. (According to G. Stuart Patterson, president of Cray Research, Inc., Cray did not bid because it is a small company, with only about 300 employees, and cannot afford to devote the effort needed to make NASA's machine.) Both companies are prohibited by their contracts with NASA from giving details of how they plan to build the computer, so the few details that are available come from NASA officials.

According to Whiting at NASA, Burroughs plans to build a machine with more than 100 processors for doing computations. Each processor would act like a separate computer, but all would share a central memory. The processors would work independently for a certain period, then would be synchronized, then would work independently again. "The problems of handling communications within the machine are horrendous," Whiting says, but not unsolvable. "Both Burroughs and CDC have creative and sophisticated ways of handling data."

The CDC approach to making NASA's supercomputer is to use four pipelines—a method already being used by CDC and by Cray in their large computers. A pipeline, which is similar in concept to an assembly line, can handle a number of equivalent problems at once. For example, if each problem has five steps, the pipeline would start to work on step one of the first problem. Then, at the same time that it moved to step two of the first problem, it would begin work on step one of the second problem, and so on. The process continues until all of the pipeline's processors are working and the pipeline is filled up.

The difficulty with the Burroughs and CDC approaches is that scientists would have to learn to organize their data and define their problems so as to take advantage of the special features of the machines. Recognizing this, CDC offers courses in designing programming languages for their current pipeline machine, the Cyber 205.

Despite the advent of computers like the Cyber 205, it is still not known how ready scientists are to rethink the way they program. This is a crucial point, because NASA says it wants a general-purpose computer which can be used by scientists in many disciplines. According to Peter Lykos, a computational chemist at the Illinois Institute of Technology, chemists, at least, are ready. Lykos, who organized a conference on supercomputers in chemistry, held last summer in Las Vegas, says, "Chemists are willing to adapt their programs to a different computer architecture." Patterson thinks many scientists who work on very large problems are already thinking in terms of parallel computations.

Another question is whether computer designers truly understand the needs of scientists who do large-scale computations. George Michael of Lawrence Livermore Laboratory says, "We have some rather empirical evidence that many don't." He also believes that the users of computers cannot effectively communicate with computer designers to tell them of their needs. Lykos, on the other hand, thinks many computational chemists are ready to talk to computer designers. He recently traveled to Japan, at Hitachi's invitation, and lectured on computational chemistry to that firm's chief computer designer.

Patterson questions whether NASA can get a computer as powerful as the one it wants by 1986. "If they really want a computer that is 40 times as powerful as the Cray-1, I think that's an awful leap forward. They really ought to count on one that is 5 to 10 times as powerful as the Cray-1," he says.

NASA

Wind tunnel test

A three-quarter-scale model of a supersonic fighter is tested at Ames Research Center.

One fluid dynamics expert who is familiar with NASA's proposals, and who wishes not to be named because of his close ties with NASA scientists, argues that, "A machine of that size really could have an impact. If it works. The danger is that the machine could turn out to be just one big albatross." In addition, Cray plans to have a more powerful computer available a few years later than NASA has in mind for its supercomputer. Although it will be four times slower than the machine NASA wants, the one Cray plans will not have been developed with government funds and should cost NASA less. "Frankly, I doubt that a factor of 4 will make a difference," the fluid dynamics expert says.

On the other hand, NASA's plans have been strongly endorsed by the agency's advisory committees and its advisory council, which include representatives of the aeronautics industry and scientists in fields such as weather forecasting and space science, where large-scale computations are the norm.

Of course, it is by no means sure that NASA will get its supercomputer. The agency, Whiting says, has been lobbying for the computer for the past $1^1/_2$ years. Funds for it were not in the 1981 budget, and the moment of truth for NASA will come when the 1982 budget is revealed this month. Whiting is cautiously optimistic, saying, "We made some mistakes in the past and we antagonized some people with our exuberance. This year we did a better job of talking."

—GINA BARI KOLATA