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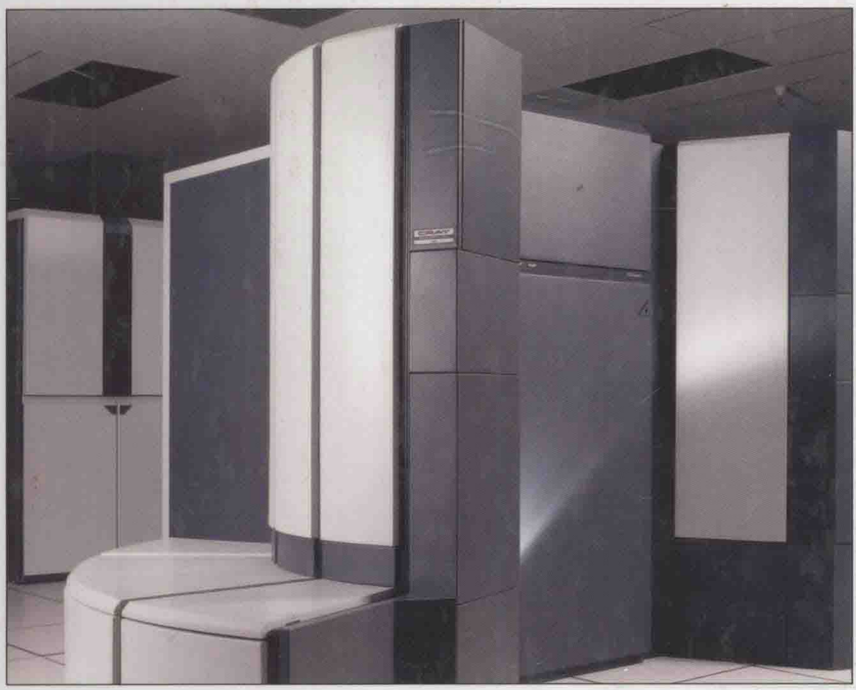

Charting the Future of Cybernetics

Charlene W. Billings & Sean M. Grady

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Facts On File, Inc.

In loving memory of my parents
Alice Labbé Winterer
and
George Emil Winterer

SUPERCOMPUTERS: Charting the Future of Cybernetics, New Edition

This is a new edition of SUPERCOMPUTERS: *Shaping the Future*
by Charlene W. Billings (Facts On File, 1995)

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INTRODUCTION

Supercomputers are very fast, very powerful computers that can perform trillions of mathematical operations in a second—sifting through geological survey data for oil companies that are seeking new deposits, analyzing readings taken during thunderstorms for meteorologists, simulating the forces of a nuclear explosion to test weapons designs and safety without conducting live tests.

Supercomputers also are the most cutting-edge, top-of-the-line computers on the market, and the most expensive ones—a status they have held since the early 1960s. Supercomputers are high-priced machines that require extra care and provide an advanced level of performance that most people do not need. Typical supercomputer customers are government and military agencies, academic institutions, and large corporations. Unlike the personal computers that are found in tens of millions of homes and offices, or the more advanced computers that form the backbone of the Internet, supercomputers have immense amounts of computational power and information storage capacity. Some supercomputer designs have had to include built-in refrigeration systems, while others have immersed their components in a bath of liquid coolant to keep them from overheating.

Though the term *supercomputer* was first used in the 1960s, computer companies such as IBM were building fast mainframe computers (large computers built with sturdy, often room-sized metal frames) as early as the mid-1950s. In a sense, all of the computers of this decade were supercomputers, with each new model designed to be faster and "smarter" than the ones before it. However, supercomputers in the modern sense did not exist until 1964, when the Control Data Corporation brought the CDC 6600—an extremely fast computer designed by supercomputer pioneer Seymour Cray—to market. Its ability to perform 3 million floating-point operations (a type of calculation using decimal fractions) per second made it the fastest computer of its day—and a technological pipsqueak when compared to the supercomputers of today.

The path of development leading up to the supercomputer stretches back to the mid-17th century, when a French mathematician, Blaise Pascal, built a shoebox-sized mechanical counting machine that used cogs and gears to do calculations. Though the counter worked, it was too expensive to produce in great quantities and never became widely successful. Other inventors, though, designed and built various counting and calculating machines of their own over the next few hundred years. The most ambitious of these designs were the Difference Engine and the Analytical Engine, two mechanical, crank-operated computers designed in the mid-19th century by Charles Babbage, a British mathematician. Of the two designs, Babbage thought the analytical engine was the most promising. In his design, the analytical engine had the ability to store information, perform calculations, and retain the results for further operations, abilities that have been perfected in modern computers. Unfortunately, Babbage's plans were too advanced for the technology of Victorian England. Despite working nearly 20 years to translate his design from paper to reality, Babbage was unable to bring his creation to life. Nevertheless, because the functions of his mathematical engines were so close to those of modern computers, he is considered the founding father of computing.

During the 80 or so years following Babbage's attempt to build his complex calculator, other inventors invented or improved machines designed to make communicating easier and office chores less burdensome. Telephones, typewriters, cash registers, practical desktop calculators—these and other machines began appearing in homes and businesses around the world. But the most critical step toward the invention of computers in general, and supercomputers in particular, came in the last decade of the 19th century, when the U.S. Census Bureau used a punch card counting machine to analyze information gathered during the 1890 census. Working by hand, Census Bureau employees had taken 10 years to compile and tabulate the information gathered during the 1880 census; using the punch card counters, bureau employees working on the 1890 census took only two years.

From the time of the 1890 census to the middle of the 20th century, the development of computing technology gradually increased. Scientists in the United States and Europe who were studying the way information flowed through corporations and research institutions theorized that mechanical calculators could speed the process while reducing mistakes. Researchers for office machine companies also suggested building such machines to make doing business easier. And when World War II broke out in 1939, scientists in England began working on electronic code-cracking computers that could decipher the secret messages being relayed to the troops and ships of Nazi Germany.

These machines form the ancestry of supercomputers, which still are being used for many of the same tasks, such as cryptography and high-level accounting, that their predecessors were designed to handle. Just as with their home- and office-based counterparts, supercomputers have decreased in size and cost even as they have increased in computing power. Some computer industry analysts suggest that, with future advances, supercomputing power may be available for about as much money as a midrange personal computer cost in the late 1990s.

The two questions such predictions raise are "What would people use it for?" and "Are the advances needed for this type of supercomputer truly likely to happen?" Unless people use their computers for extremely complicated business or research tasks—such as creating detailed graphic displays or analyzing scientific data—much of the power of a supercomputer would be wasted in the average home or office. And as computer chip designers pack more components into tighter spaces, they are nearing the physical limits of how small electronics can go.

The answer to the first question likely will come from an unexpected source. Indeed, the personal computer, which came into being around 1975, did not catch on with consumers other than hobbyists and game players until almost 1980, when the first small-computer business spreadsheet program, VisiCalc, went into production. Likewise, the computer boom of the 1990s was sparked by the development of the World Wide Web and the Web browser in the late 1980s. These "killer applications," or "killer apps," took the world by surprise when they came out. The same thing may happen if a "killer app" for low-priced supercomputers comes along.

The second question, though, seems to be in the process of being solved. Optical computers that use light instead of electrons, computers that make use of quantum mechanics (a theory of how atoms and subatomic particles behave), and hypercomputers created from linking numerous computers into a computational network are being explored as methods to work around the physical limitations of computing.

Supercomputers: Charting the Future of Cybernetics is a revised and updated edition of *Supercomputers: Shaping the Future*, published in 1995 as part of Facts On File's Science Sourcebooks series. At that time, the field of supercomputing had nearly reached the point where these machines were able to perform 1 trillion floating-point operations per second, or "flops," per day. In fact, many of the companies that made these high-powered computers were building machines that theoretically could perform 2 or 3 trillion flops per second, though these systems did not reach this level of performance in real-world tests. At the end of 2001 the top 17 supercomputers in the world performed at or above the 1 trillion flop, or teraflop, calculation level—the most powerful, the IBM ASCI White computer at the Lawrence Livermore National Laboratory in California, performing nearly seven and a quarter teraflops when tested using a benchmarking program.

During this time, computer scientists and researchers also have figured out a number of ways to gain supercomputer-level performance from less expensive computing systems, including personal computers. These methods have been applied to such tasks as the search for new drugs to combat anthrax, a disease that long has been suggested as a possible weapon of bioterrorism, and which gained renewed attention because of a series of anthrax infections following the September 11, 2001, attacks on the World Trade Center in New York and the Pentagon in Washington, D.C.

This updated edition of *Supercomputers* gives students a good general idea of how the field of high-performance computing affects everyday life, not just the work of scientists and engineers. The following 19 chapters provide a closer look at how the supercomputers of today came to be, describe the makeup of typical supercomputer systems, provide examples of how supercomputers are used, and examine how the limits to future development are being confronted and overcome.

CONTENTS

PART 1

Creating a Calculating Machine

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THE ORIGINAL COMPUTERS

Computers as we know them today are machines: boxes of circuit boards, wires, a few whirring fans, and a series of sockets for gadgets such as monitors and keyboards. This basic design is the same for just about every computer made today, from personal computers (PCs) to the most advanced supercomputers. Even Internet servers—which use fast central processing units (CPUs), large memory circuits, and gigabyte-capacity storage devices to send information from computer to computer over the world's phone lines—contain components that are not much different from those found in PCs.

These days, getting a computer to do more work means opening it up and putting in more memory cards, a more powerful CPU, or a larger hard-disk drive. Before the 1950s, though, getting more work from a computer meant providing better pay, better working conditions, and additional help from other computers. Yes, computers did exist back then; in fact, by the beginning of the 20th century, computers had existed for hundreds of years. They were not machines, however—they were people.

When it first became widely used (in about 1650), the word *computer* meant a person who performed mathematical computations for a living. Many of these human computers worked for banks, counting-houses (forerunners of modern-day accounting firms), trading companies, and other businesses that needed people who were good with numbers. Computers also worked for government agencies, universities, and scientific societies that wanted to prepare specialized numeric tables requiring complex mathematical work, such as almanacs showing the times of sunrise and sunset, or high and low tides.

It was not an ideal way to do business. All those calculations took a lot of time, and double-checking the human computers' output was a tedious process. Worse yet, there were no guarantees that the results of these efforts would be accurate (which, in many cases, they were not). Even though the work was done by men and women who were among the best-educated people of their times, there was a feeling throughout the world that there had to be a better way to do things. The search for this better way led to the creation of modern electronic computers, just as the desire to make basic arithmetic easier for the first human computers led to the development of mathematics.

Calculating by Hand

People who can handle numbers, from simple counting tasks to complex calculations, have been in demand just about as long as nations have existed. Some of the world's earliest writings—found on 5,200-year-old clay tablets from the ancient kingdom of Sumer, in what is now southern Iraq—are bookkeeping records that include tallies of crop yields and livestock produced in the land, of goods traded between cities, and of taxes taken in by the Sumerian kings and their governors. As people in other lands around the world began grouping together in towns, cities, and nations, they also began developing ways to keep track of these facts and figures. In a way, bookkeeping has been a major factor in the development of the world's written languages: The symbols people use today were developed over thousands of years by scribes who were, among other tasks, trying to keep up with the economics of their times.

As merchants expanded their trade to distant lands, their need for scribes who could keep track of this trade expanded as well. As kingdoms grew, their rulers needed people who could accurately keep track of the wealth in the royal treasuries and chart how it was spent on armies, palaces, and civic improvements such as sewers and city walls. Before long, the ability to manage information—collecting it, interpreting it, and sending it quickly to others—became a cornerstone of civilization.

Centuries passed, and people began to develop mathematical systems that went far beyond simple tasks of addition, subtraction, multiplication, and division. Elements of modern algebra, which focuses on general rules of arithmetic rather than operations with specific numbers, have been found in Egyptian scrolls dating back as far as 2,000 B.C. Modern algebra was developed by Greek, Hindu, and Arabic scholars; the word *algebra* comes from the Arabic word *al-jabr*, which means "the reunification."

Geometry—the system of measuring and calculating points, lines, angles, surfaces, and solid objects—probably got its start when ancient land surveyors discovered there were easily identified relationships between the proportions of objects. Scholars in many lands worked out a way to represent these relationships mathematically. This knowledge swiftly found its way into the building trades as architects and master craftsmen started to design mathematically based construction plans. The science of astronomy and the mysticism of astrology both were based on the mathematically predictable motion of the planets and the apparent motion of the Sun and the stars. Even art was seen as a realm in which mathematics played a part, with sculptors calculating ideal proportions for the objects they depicted and painters reproducing the appearance of the real world through use of vanishing points and other tricks of perspective.

Other methods that followed—trigonometry, logarithms, calculus, and further styles of advanced math—were developed by scholars who had the same goals as later computer pioneers: to make it easier to perform the mechanical operations of mathematics. To bring these mathematical systems into being, though, the scholars who created them needed a little help.

Beads, Sticks, and Wheels

People have always used some sort of tool to help them keep track of things. Before the scribes of Sumer came up with their accounting symbols, herders probably used piles of pebbles or notches in tree bark to keep track of how many cattle or sheep they had in their fields. We know this is possible, because modern-day herders across the globe do pretty much the same thing. Even the practice of mixing a few black sheep in a flock of white sheep is a method of keeping track of the flock, with a black sheep acting as a counter for 10 white ones.

Virtually anything could be used as a mathematical memory aid. The quipu, in which knotted strings were used to keep track of numbers such as population counts, was one of the more unusual of these devices.