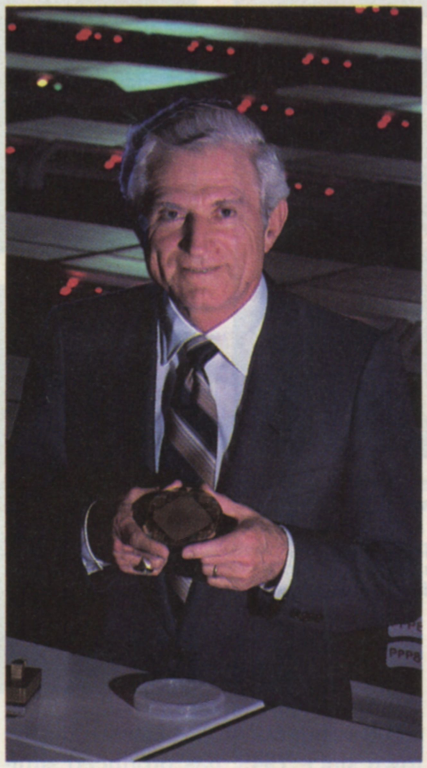
KING OF COMPUTER DESIGN

Gene Amdahl Builds the Most Powerful Number Cruncher Ever

BY JOHN SEDGWICK

For three months in the winter of 1980, Gene Amdahl, the computer-industry genius, lay flat in bed, wracked by back spasms. "If I made the slightest wrong movement," he recalls, "I almost had to scream." Rather than take painkillers, the hardy Amdahl had his own method for dealing with his discomfort: He retreated into the seemingly limitless reaches of his mind.

In truth, he had a lot to think about. The main architect of IBM's trailblazing 360 family of computers during the sixties, he had gone on to challenge the computer giant in the seventies by starting his own firm, Amdahl Corp., to produce a top-of-the-line mainframe. He resents any implication that in going after his former employer he was biting the hand that fed him. "IBM hired me because I knew about computers," he proclaims, "and I was the fountainhead of a lot of their product line. I want that to come out clearly here! IBM did not give me what I have. IBM hired me to get what I had."



Gene Amdahl holds his Trilogy wafer. It does the work of 100 ordinary chips, yet it measures only four inches in diameter.

Either way, the Amdahl machine succeeded fabulously, capturing nearly a quarter of IBM's market in 1977 and establishing a whole new industry that made IBM-compatible computer equipment. But to raise money for what was then the most expensive start-up in computer-manufacturing history, Gene had had to sell so much of his firm to investors that he ended up in 1979 in the frustrating position of being almost powerless in the company that bore his name. That's when the back problems started.

Amdahl pondered his plight as he lay in bed. Once more, he was determined to break out with a new computer, this one faster and more powerful than anything on the market. But how? IBM and his own firm had expanded the capacity of their biggest mainframes by strapping them together in pairs. Because of the complications attendant on dividing tasks between two machines, however, such pairing was a stopgap measure; a new technological breakthrough was needed to maintain the simplicity of one all-powerful machine. But what was this breakthrough to be?

By the time his back healed, Gene had seen the solution. He would expand mainframe capacity by shrinking the fundamental technology further than anyone had thought possible. Hoping to make that solution a reality, in September 1980 he severed his ties with Amdahl to establish a new company called Trilogy Systems Corp. With himself as chairman and his son Carlton, who has since left the company, as vice-chairman, the company has amassed a staggering $230 million from such major electronics firms, and potential users of the technology, as Digital Equipment and the Sperry Corp. He has hired a staff of 480, many of them stars at their former companies, who have had to adjust to being satellites at Trilogy. He has built a manufacturing plant in Ireland and a corporate headquarters in Cupertino, in the heart of California's Silicon Valley. All of this to develop a new and spectacularly complex technology that other firms had explored but only Amdahl deemed workable. That technology is called wafer-scale integration.

Other large mainframe manufacturers, including Amdahl, had expanded internal capacity by increasing the number of the familiar dime-size silicon chips. The largest

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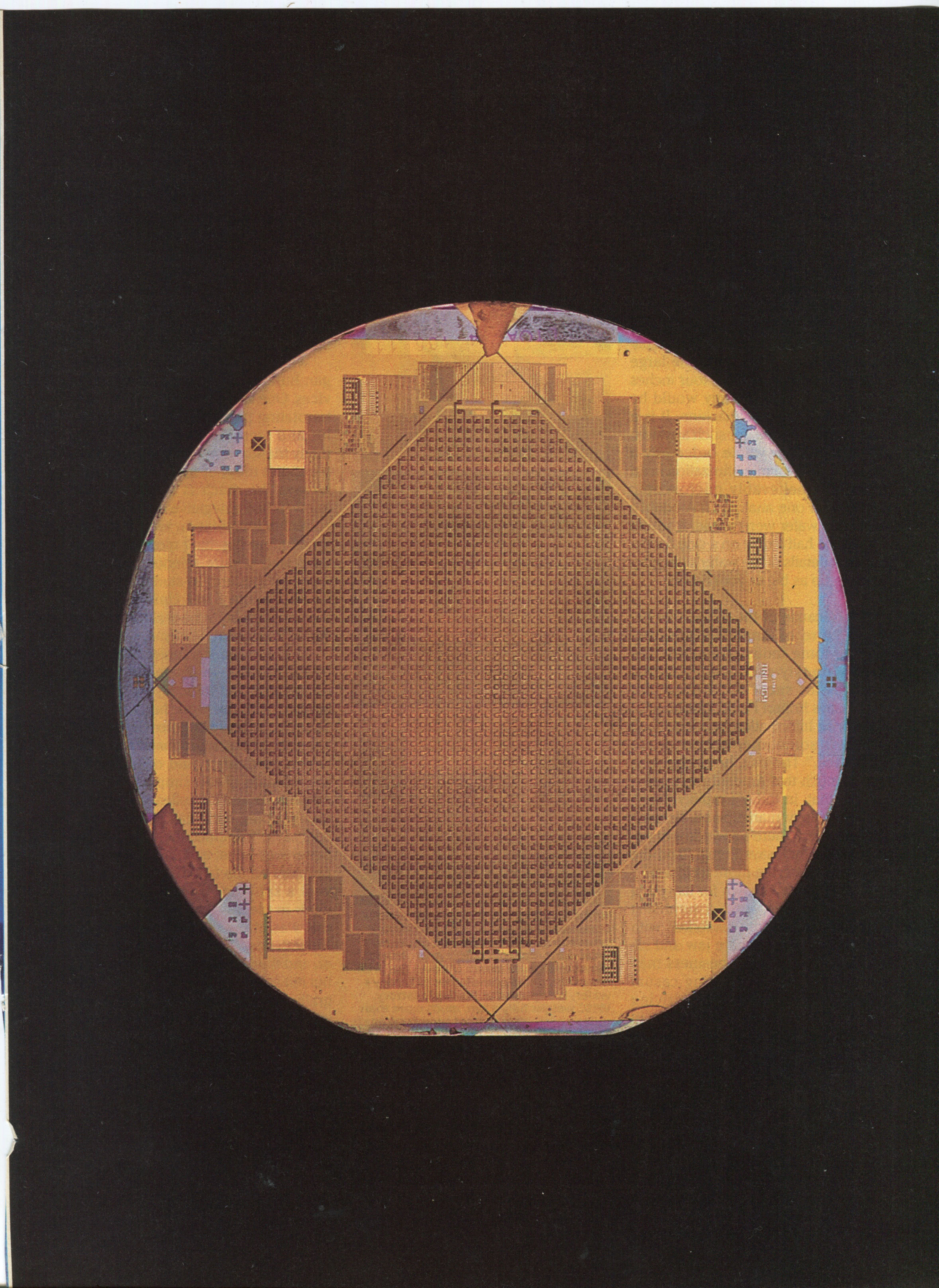
PHOTOGRAPHS BY STEVE SMITH/WHEELER PICTURES

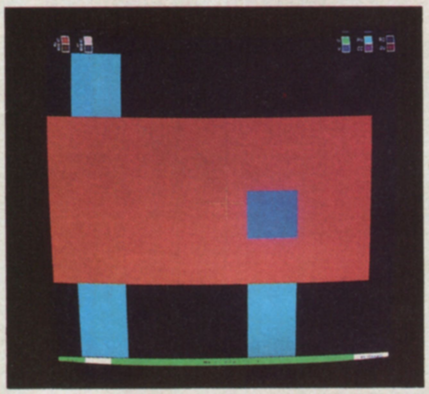


computers packed in several thousand of them. Inside each chip, the information was processed rapidly, but delays were building up in transit from one chip to another. Further, as the number of soldered interconnections grew, the chances for breakdowns increased.

But Amdahl reasoned that he could speed up the machine and reduce its downtime by compressing the circuitry of 100 little chips onto one large wafer, 20 layers thick and four inches in diameter. This prodigy would be the brain of his new machine. It is a breathtaking notion, for such a system dictates another whole order—by a factor of 100—of miniaturization in an already unbelievably microscopic process. In one analogy, if Amdahl's proposed wafer were a field, it would have to be half a mile on a side for the smallest details of the wafer's circuitry to show up as big as your thumb.

Because of the audacious nature of Amdahl's mission, some industry analysts are frankly skeptical about his chances for success. "He's a pioneer," says Robert Fertig, president of Enterprise Information Systems, "and pioneers sometimes get arrows in their back." The risk, he explains, is not so much that Amdahl can't pull it off, but that, in today's rapidly evolving technology marketplace, he can't do it in time. "There's a window of opportunity here," says Fertig, "and the longer he takes, the more it closes."

In an industry known for its young bucks, Amdahl is, at 62, a surprising anomaly He is a trim six-footer, with flinty blue eyes, a square jaw and silver hair. Others in the business may show their flair by wearing casual clothes, drinking beer and driving sports cars; Amdahl dresses nattily in well-tailored suits, is a wine connoisseur (although he can rarely bring himself to purchase his most expensive favorites), takes his Lutheran faith seriously and drives a Rolls-Royce Silver Shadow II.



While handling the Trilogy wafer, under ultraviolet-free yellow light, technicians (above, top, and on opposite page) must wear dustproof coveralls, eye protectors, gloves and gauze masks. (Above) The WISC computer, great-grandfather of Trilogy's wafer, is displayed at Amdahl's factory. WISC weighs fully a ton, much more than today's computers, whose capacity is much greater than WISC's. (Above, center) A magnified view of the wafer's circuitry. The computer has the capacity to enlarge small areas to make the wafers legible.

For all his formidable reputation, Amdahl has a surprisingly gentle manner, a soft, slightly quavering voice and a taste for his secretary's chocolate-chip cookies—all of which suggests a certain boyish timidity that is definitely not the case. When the conversation turns to a sore subject like his nemesis, IBM, the volume and clarity of his voice rise. "We're trying to fight back at IBM on every level we can," he declares, fixing me with a hard look. "It's not only in our interest, it is in the interest of the whole world. IBM is greedy and voracious. It has done more to smother the electronics industry throughout the world than any other company."

This would-be giant killer grew up on a farm near Flandreau, South Dakota. "That world seems unrelated to this world," he says wistfully.

While still in his teens, Amdahl began building fairly sophisticated devices. One was a helicopter with "contrarotating propellers" to control the lift and steering. It didn't win him many friends around Flandreau. "People didn't think of me as a prodigy," he says, "so much as a dreamer. You know, it had a negative cast to it."

As his imagination took flight, he found himself getting more and more interested in pure science, and he finally left the farm to study physics at South Dakota State University and then in graduate school at the University of Wisconsin, Madison.

At Wisconsin, his subject was theoretical physics—a discipline that for minuteness and intricacy is, he feels, kindred with the work he is doing at Trilogy. Attempting to determine whether or not a proposed force between particles could describe the bound state of the simplest particle nucleus, he and his colleagues spent a month doing hand calculations. Amdahl says, "I decided there had to be a better way." Just as if this were some problem on the farm, he set out to invent a solution. He had done some work in electronics in the Navy, but that was about it for formal training. Nevertheless, he designed a computer, and then headed a team to build it, but left before WISC—Wisconsin Integrally Synchronized Computer—was completed. Amdahl now describes it as a one-ton version of a calculator, but by the standards of the time it was extraordinary. As soon as he got his Ph.D. in 1952, he was hired by IBM.

Today the WISC stands on proud display at the gleaming Trilogy headquarters in California. It's a towering array of tubes, switches and dials that offers dramatic proof of how far the computer industry and Gene Amdahl have come. So outmoded is it, in fact, that the WISC served for a time as the backstop for a pistol range before it was recovered and shipped to Trilogy. Despite its battering during

Continued on page 84

PHOTOGRAPHS BY STEVE SMITH/WHEELER PICTURES

SNAPSHOTS

Continued from page 53

cable release, which lets you hold down the shutter button without jiggling anything.

Pick a location that is as free as possible from nearby lights. Focus the camera on infinity, aim it at, say, the Big Dipper or Orion, set the shutter to B or T and open the diaphragm to the lowest f-number.

In a big city or on moonlit nights, the sky is so bright that it will fog the film when exposures run longer than a few minutes, or even less if you're using one of the new 1000-speed films. Under dark country skies, however, you can expose a lot longer, hours in many cases. For your first efforts, make a guess and bracket your exposures liberally; take careful notes so you can figure out what works.

The Earth's rotation will cause stars to move through the field of view during the exposure, sometimes giving spectacular results. Each star will leave a streak, or trail, on the film whenever the exposure runs more than about 15 seconds. Pointing the camera south gives horizontal trails, pointing east or west gives trails that slant to the horizon. Aiming due north yields circular trails as the stars arc around Polaris, the polestar. A long exposure shows that Polaris's trail is also circular, proof that it doesn't lie exactly at the celestial pole.

Experiment with different lenses; wide-angles will take in lots of sky and perhaps include an interesting bit of foreground, while telephotos let you reach out to frame the moon and a bright planet together. To know what photo-worthy celestial events are coming, read magazines such as *Astronomy* and *Sky & Telescope.*

On July 27, for example, the southern Delta Aquarid meteor shower reaches peak activity in the predawn hours. The meteor streaks will appear to radiate outward from the constellation Aquarius in the southern sky at about 15 meteors per hour. Use a wide-angle lens, pointed south, and make your exposures as long as conditions allow.

The moon will be overtaking several planets during August. It passes Saturn on the third and the thirty-first, Mars on the fourth, Jupiter on the seventh and Venus on the twenty-eighth. The conjunctions, as they are called, are photographed best with telephoto lenses—use anything from an 80 mm to a 1,000 mm or more, depending on how close the grouping is.

If you want to capture pinpoint star images, not streaks of light, piggyback your camera on a telescope with an equatorial mounting and a clock drive, which allow for the Earth's rotation. Your exposure times are limited as before, but the photos will now begin to look like star-atlas plates.

Taking photos through the telescope is the most difficult part of astrophotography. It involves extra expenditure of both time and money. You'll need to buy an accessory called an adapter to attach the camera to the telescope's focuser, a separate guide telescope with an illuminated cross-hair eyepiece to monitor your exposures, and an electric drive-rate corrector to adjust any variations in tracking.

For photographing faint nebulas and galaxies, you need the full rig listed above. But if all you want is a moon or a sun photo, you can get by with just the telescope and camera-to-scope adapter. For the moon, set the exposure according to the camera's meter and bracket plenty. Black and white is the best, since the moon has little color. Solar shots require an additional over-the-aperture sun filter—use whatever the scope manufacturer recommends—but the same procedure holds.

For Further Reading

For complete instructions on through-the-telescope photography, head for the library. Look for: *Skyshooting,* R. N. Mayall and M. W. Mayall, Dover, 1968; *Astronomical Photography at the Telescope,* T. Rackham, Faber & Faber, 1972; *Outer Space Photography,* H. E. Paul, Amphoto, 1976. During the past five years, new cameras, films and filters have revolutionized the field. For information on them, try *Astrophotography,* B. Gordon, [self-published], 1983, and *The Hidden Sun,* J. Lowenthal, Avon, 1984.

Each step in astrophotography is more exacting than the previous one, so don't worry if you find you're botching a good many shots. Just take lots of notes—and persevere. ■

Each summer we will publish a special section covering the latest in amateur astronomy. Look for one next August.

PHOTOGRAPH BY JACK B. MARLING

A 10-minute exposure through a 24-inch scope gave this image of globular cluster M22.

COMPUTER KING

Continued from page 44

the ordeal by firearms, the machine still works.

The WISC is one of the few soulful elements I came across at headquarters; otherwise, performance is the company's only measure. A sprawling, award-winning structure of glass and concrete, Trilogy's building itself seems a Hollywood set for The Corporation. Closed-circuit TV cameras scan the grounds for intruders; inside, visitors—myself included—must be accompanied everywhere. Obviously, this is serious business. The place is a spaceship, bound for the future.

Inside the Engine Room

If that is so, the data-processing center on the ground floor is the spaceship's engine room. It provides the raw computing power for the hundreds of scheming minds at terminals upstairs. The center covers 10,000 square feet and is crammed with over a hundred blue and white data processors, all of them churning away—running equations, drawing graphs, plotting circuitry—like so many washing machines thrashing at some vast but invisible pile of laundry.

Down the hall from the processing center I came upon the photolithography center. There technicians in space-suitlike coveralls work in a special darkroom, lit only by ultraviolet-free yellow light, to "print" the circuitry design on silicon wafers. Glass "masks" bearing the design's image, which has been generated by a sophisticated piece of technology called a MEBES (for Manufacturing Electron Beam Exposure System), are the "negatives" in the process. The "paper" is the silicon wafers, which have been treated with a special "emulsion" called photoresist that changes its chemistry when exposed to ultraviolet light. Consequently, when the wafer is exposed to the ultraviolet, the masks leave the original design on the wafer by protecting the photoresist from the light. Technicians then "develop" this image by bathing the wafer in an acid that etches the photoresist where it has been softened by its exposure to the ultraviolet, leaving the design behind.

Four inches in diameter, the finished wafer has the two-and-a-half-inch-square chip mounted in its center. The chip has the brainpower of thousands of WISCs. It has no moving parts, no wheels or cogs, but it is able to channel electricity about its length and breadth in exceedingly useful ways. Think of the chip as the California highway system, with the electrical pulses as miniature automobiles, and you have a pretty good idea of what goes on inside it. And where are all these cars going? They are going to the transistors, where the real work of the chip is done.

In an analogy suggested in Katherine Davis Fishman's *The Computer Establishment,* the transistors can best be thought of as a series of mailboxes, each containing an item of data or a command. The circuits link them together to complete the computer user's business. To perform a simple bit of addition, for example, the computer program would direct our little automobile to pick up one number from mailbox 21, fetch another from mailbox 47, add them at mailbox 51 and store the sum in mailbox 63.

There is an art, then, to determining how best to lay out the transistors, all 800,000 of them, and the connecting circuitry. It is, in fact, an art not so different from that of a highway engineer. On the chip, there are strips of prime real estate, thick with heavily used transistors, and barren territory holding only a few little-used ones. To connect them all, there are fast routes and slow. The chip's designers plot this all out from scratch, making calculations based on general convenience and efficiency. Designers of the conventional silicon chip have done all this before, with one important exception. On a conventional silicon chip, there was only room for one city. With the Trilogy chip there is room for an entire state. And that explains its appeal: It pulls vast reaches of functional territory into a system of communications that is tightly meshed—and previously inconceivable.

The designers of the new wafer—the highway engineers—sit upstairs. One team works at ComputerVision CAD (computer-assisted design) screens mapping the most efficient routes for the circuitry. On one screen, a woman was working with fairly broad strokes that seemed to contradict the wafer's heralded complexity. When I asked where that bit of circuitry fitted in, she pointed to a long chart, roughly 3 feet by 12, that was so thick with lines it could have been a wiring diagram of the Empire State Building. Her work fitted into a smudgy black dot two-thirds of the way along. Yet the diagram itself represented merely half a centimeter of one layer of the final wafer.

A Computerless Office

Unlike practically everyone else in the company, Gene has no computer in his office, and he needs none. He admits to having a calculator in his briefcase but says he rarely bothers with it. "What do people do at terminals?" he asks. "They enter a lot of information into a data base or write letters. My secretary takes dictation for me, which is easier." And he doesn't have much use for a computer data base either, since he can keep all the information he needs in his head. "What I really do," he says, "is think a great deal. Equations are real things to me. They aren't just letters linked together with operations symbols. They are geometric concepts, and when I am thinking about them, I see points in motion. I can see the graph."

And all the equations lead to the wafer that he saw with such clarity in those three bedridden months in 1980. Its shape, for example, is dictated by the marketplace, which is making increasing demands for high-end computers. Just as the invention of the light bulb required more powerful electrical generators, so the emergence of the desktop computer has put severe strains on the massive mainframes that store and process the information that executives in banks, insurance companies, airlines and oil companies access so nimbly. Amdahl says the computer workload is increasing by 50 percent a year.

With wafer-scale integration, Amdahl has a shot at taking a good chunk of the market. Because the wafer will pack such a wallop, the surrounding computer can be small, covering just 15 square feet, the size of a conventional photocopier, as well as be fast and cheap. He hopes to undercut IBM's mainframe price by as much as 40 percent, even though one of his own machines will cost $5 million. He hopes its size will be 90 percent smaller than the standard and its power consumption 50 percent less. Yet he also hopes to increase its output to 30 million instructions per second, or MIPS—30 percent more than two of IBM's biggest combined.

More important still, Amdahl's computer could be reliable—a key factor for companies that can lose business every time their computer crashes. Because the wafer is so big, there is room to pack it with extra circuitry and special diagnostic systems. If the diagnostics show a circuit has failed, they can call up another one to replace it. In a way, Amdahl prefers not to think of his computer as a machine at all but as a "living organism." Like organisms, it can tolerate imperfections in its parts. If a part is flawed, it can be replaced automatically without bringing the whole system down with it. In an organism, cells may die but the being as a whole lives on. Such self-healing is widespread in Amdahl's new computer, from the microprocessors, which ride on the machine to monitor its computations and to direct recalculations when errors are detected, through the extra 1,750-watt power supplies that kick in if an original unit fails.

> Amdahl prefers not to think of his new wafer as a machine at all. Rather, he thinks of it as a "living organism."

Redundancy is such an important factor in the machine that it accounts for the company name, Trilogy. While one wag speculated it stood for the father, the son and the entrepreneurial spirit, the truth is it refers to three identical logic systems: three to guarantee that one will always work. It is on the resulting increased reliability that the company is pinning many of its hopes for success. Amdahl expects his Trilogy to run smoothly for 30 months, and some calculations have shown it could well hold up for 75.

As might be expected, however, the development of this fabulous new machine has not proceeded with all the smooth and sinuous predictability of a sine curve. It's a monstrous task, for Trilogy is essentially building its computer from scratch. "The only raw material we have to get is sand," Carl Amdahl once said. "Just dump a load on our receiving dock, and we'll do the rest."

Assembling the Pieces

In the short run, however, all manner of problems have cropped up, not the least of them the assembly of the wafer itself. The company had attacked the wafer section by section and layer by layer. What they hadn't quite considered was what would happen when they put all the pieces of this layer cake together. As the technicians assembled the wafer package, a number of bizarre phenomena became apparent. Some parts corroded, others grew needlelike filaments of metal that shorted out circuits, and, most dramatic of all, still others shot out coils of metal that looked like miniature springs. The problem, it turned out, was that two of the metal layers, capping the top and bottom of the wafer, were of different electrical potential, and they caused a batterylike action that produced all the havoc. In the race against the clock, that one mistake lost them three months.

Meanwhile, the pace of technological development outside the company continues briskly along. Having been burned by Amdahl once, IBM is not planning to let him burn them again. It has reportedly set up two task forces to counter his initiative. Between the trouble with the wafer's metalization and an earlier 140-day delay when unseasonable rains slowed construction of company headquarters, Amdahl has already had to move his expected delivery date from late 1984 to 1987. The later it goes, the more likely IBM is to come up with its own machine or, just as bad from Trilogy's viewpoint, to change its system software to ruin Amdahl's hopes for compatibility with the IBM line.

On the frontiers of high technology, the casualty rate is enormous. But Gene Amdahl is not one to get ruffled. Passing down the long corridors of Trilogy, he takes remarkably long strides. They have gotten him from a farm in South Dakota to Silicon Valley. And they will get him through this as well. "We don't know which of several courses we're going to take, but we plan to continue with the computer," he said after the last postponement of the delivery date. At press time, however, Trilogy announced that "as a result of a comprehensive review of its computer development program," it would drop the mainframe computer but continue with its giant chip. ■