BEYOND BAR CHARTS AND CAD: PC GRAPHICS GROWS UP/84

CFCs—FACING THE MUSIC ON THE OZONE LAYER CRISIS/92

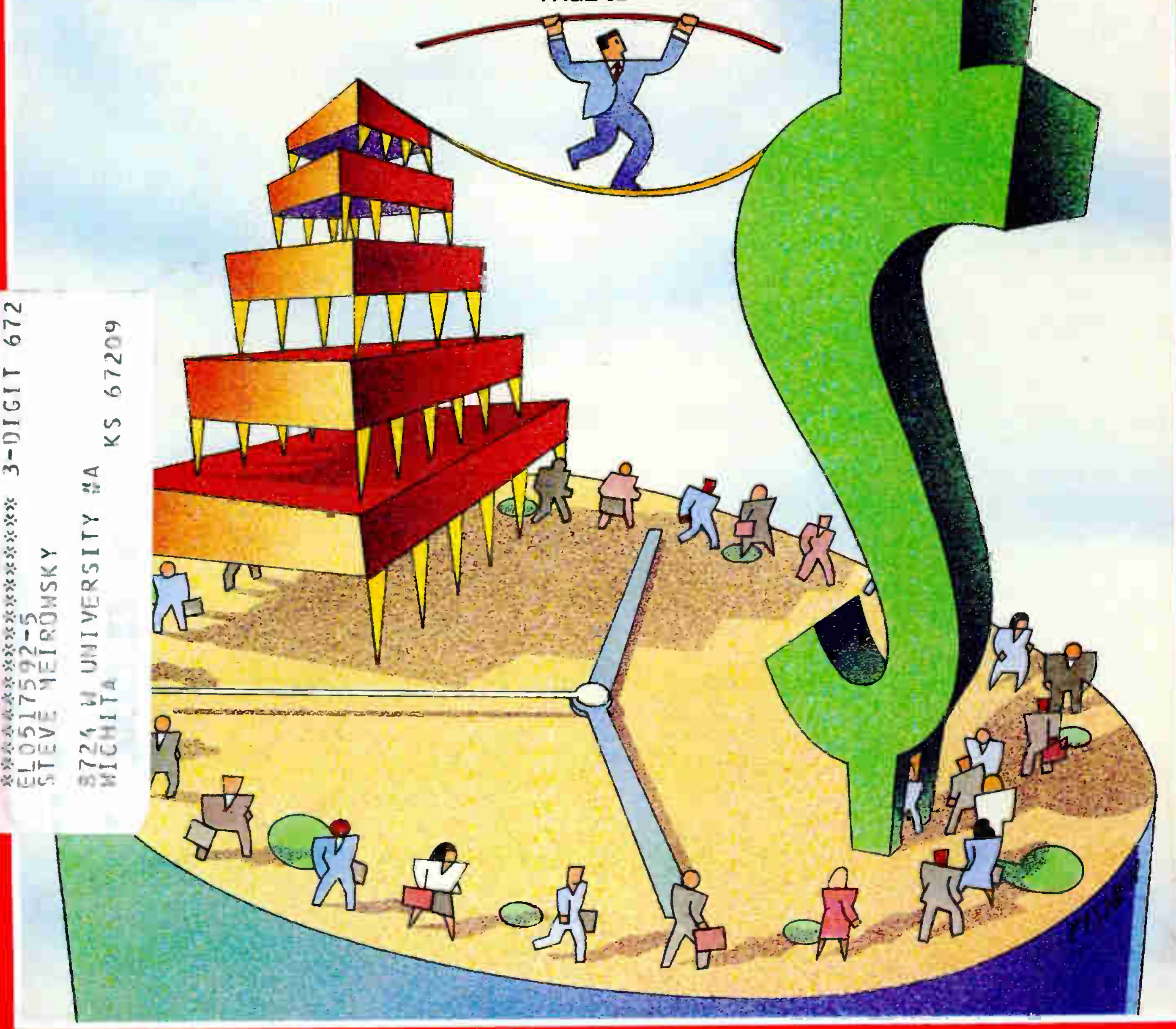
A VNU BUSINESS PUBLICATION IN U.S. $6.00 APRIL 1989

Electronics

TIME TO MARKET

QUICK-TURN CHIP STRATEGIES HELP SYSTEM MAKERS HIT CRITICAL MARKET WINDOWS

PAGE 62



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Circle 14

20-2021

UPPING THE ANTE

Is 'time to market' another American foible, or is it really nature's way of doing business?

One recent accrual of facts may prove to be uncomfortable for orthodox followers of the doctrine of "Getting there firstes' with the mostes'," at least as it applies to the development and marketing of microchip-based systems. As you'll find documented on p. 62 of this issue, the marketing scoresheet increasingly seems to indicate that firstes', once achieved, may render mostes' unnecessary and irrelevant. Put another way, it appears that without firstes', you can forget about mostes'.

Anyway, you get the picture. At least you will after reading Senior Editor Bernie Cole's examination of how and why a new breed of ASIC "minifabs" may soon become a common, critical element in the marketing strategies of system houses that are used to winning when the chips are down.

The celebration of market-churning, competitive ingenuity has become a reflex in this business, but let's not take anything for granted. It would not be hard to find certain astute and hard-minded businessmen, say, in Europe and Asia, who would identify the quick-turn minifab as a typical symptom of the American fetish for innovation that is, above all, a chaotic force in the marketplace. After all, they will remind you, a product's "maturity" is usually defined as that period during which profit is most likely to flow. Whether they are technically right or wrong isn't the issue. Unfortunately for them, they seem not to be on the side of God and the Harvard Business School.

The same hard-minded businessmen, of course, were only too eager to satisfy the American market's whims when it involved no more than changing a die or two, reformatting an assembly line, and recruiting low-cost labor. The money and time—read that as risk—involved in setting up semiconductor fabrication facilities is something else again.

It is perhaps a good thing that Karl Marx so vehemently despised the idea of market churning. Thanks to him there are some alternative markets available where products do tend to have long life cycles. Very long.

Yet another international dichotomy surfaced recently, as various countries weighed in on the question of atmospheric damage as a result of the industrial use of CFC compounds. As Washington bureau chief Tobias Naegele's investigation into this subject points out (p. 92), major U. S. electronics manufacturers are toeing the line on plans for the inevitable replacement of CFCs—at whatever cost. Some of their counterparts in developing countries, however, say that the idea of globally imposing remedial standards is unfair and will head off economic development.

Fair or not, until somebody learns how to contain ozone damage within the borders of its country of origin, there's only one sky and we have to fix it.

ROBIN NELSON

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NEWSLETTERS

FEATURES

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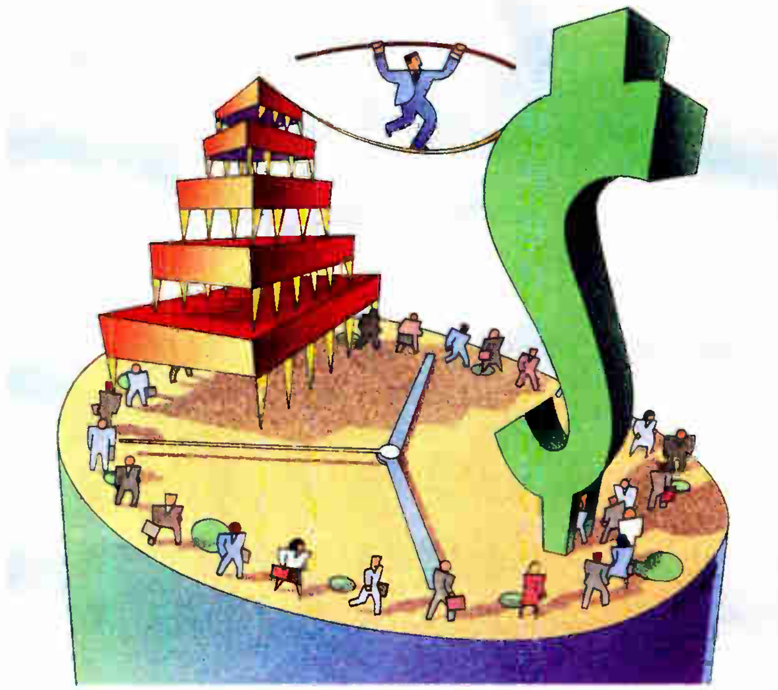

PAGE 62

WORLDWIDE NEWS ANALYSIS

COMPANIES TO WATCH

PEOPLE TO WATCH

DEPARTMENTS

ISDN S-transceiver

ISDN S-transceiver + data link controller

ISDN S-transceiver/ extended performance

ISDN Integrated Data protocol controller

ISDN high level serial controller

ISDN Ping pong transceiver

It takes to make a

ISDN U-transceiver (4B/3T + 2B/1Q)

ISDN U-transceiver (4B/3T + 2B/1Q)

ISDN Quad data link controller

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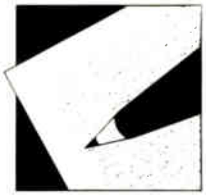
Circle 65

LETTER FROM PITTSBURGH

A RUST BELT CITY TAKES ON NEW SHEEN AS AN AI HUB

PITTSBURGH



Spring has come to Pittsburgh. But the swaths of color in Steel Town, U. S. A. come from more than just daffodils, tulips, and crocuses. The tender buds of a knowledge-based economy are painting the landscape, too. The high-tech formula mixes residues of the city's heritage of the century-old heavy industry with the cutting-edge technologies of today.

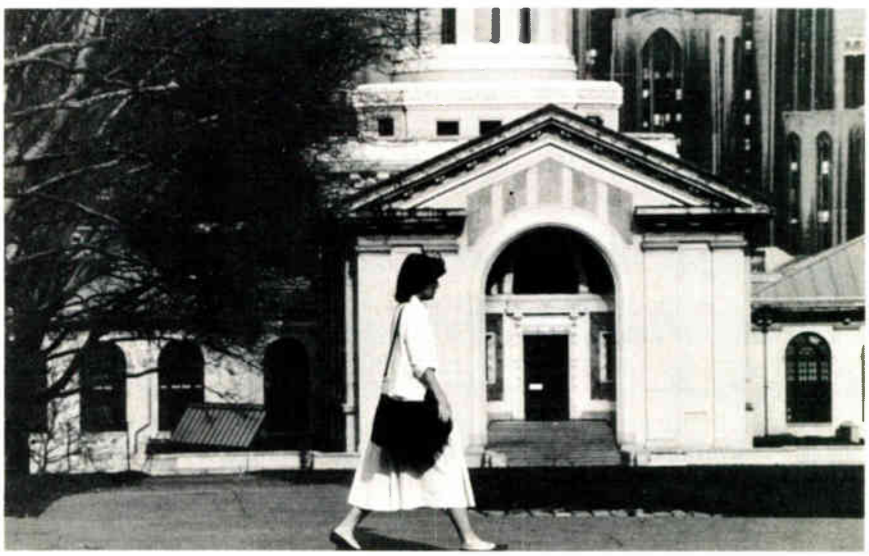
The city is vying for leadership in specific areas of software development, process control, advanced materials, instrumentation, and medical electronics. Artificial intelligence, in particular, is alive, well, and multiplying in Pittsburgh. Typical of what is happening on the AI front is the Intelligent Technology Group Inc. A couple of years ago two top managers left the Carnegie Group Inc. to form the new company, which specializes in AI enhancements of financial software. Intelligent Technology has been growing by leaps and bounds ever since, through internal growth and acquisitions.

Significantly, spin-offs are not the only AI action in Pittsburgh. Just last month, American Cimflex Inc., a factory-automation innovator, acquired Teknowledge of Palo Alto, Calif. Teknowledge was one of the original AI "gang of four" that included the Carnegie Group, Inference Corp. of Los Angeles, and Intellicorp of Menlo Park, Calif. Although the corporate headquarters of Cimflex Teknowledge will be in Pittsburgh, most Teknowledge personnel will stay on the West Coast. Still, Pittsburgh probably ranks right at the top as a pool of AI talent.

"I'd guess that between 400 and 500 people are working in AI in the Pittsburgh area, believe it or not," says Charles Buenzli, Cimflex Teknowledge's vice president of AI technology. Besides the obvious AI companies, many large firms in Pittsburgh, including some of the dozen Fortune 500 companies based there, have in-house AI operations.

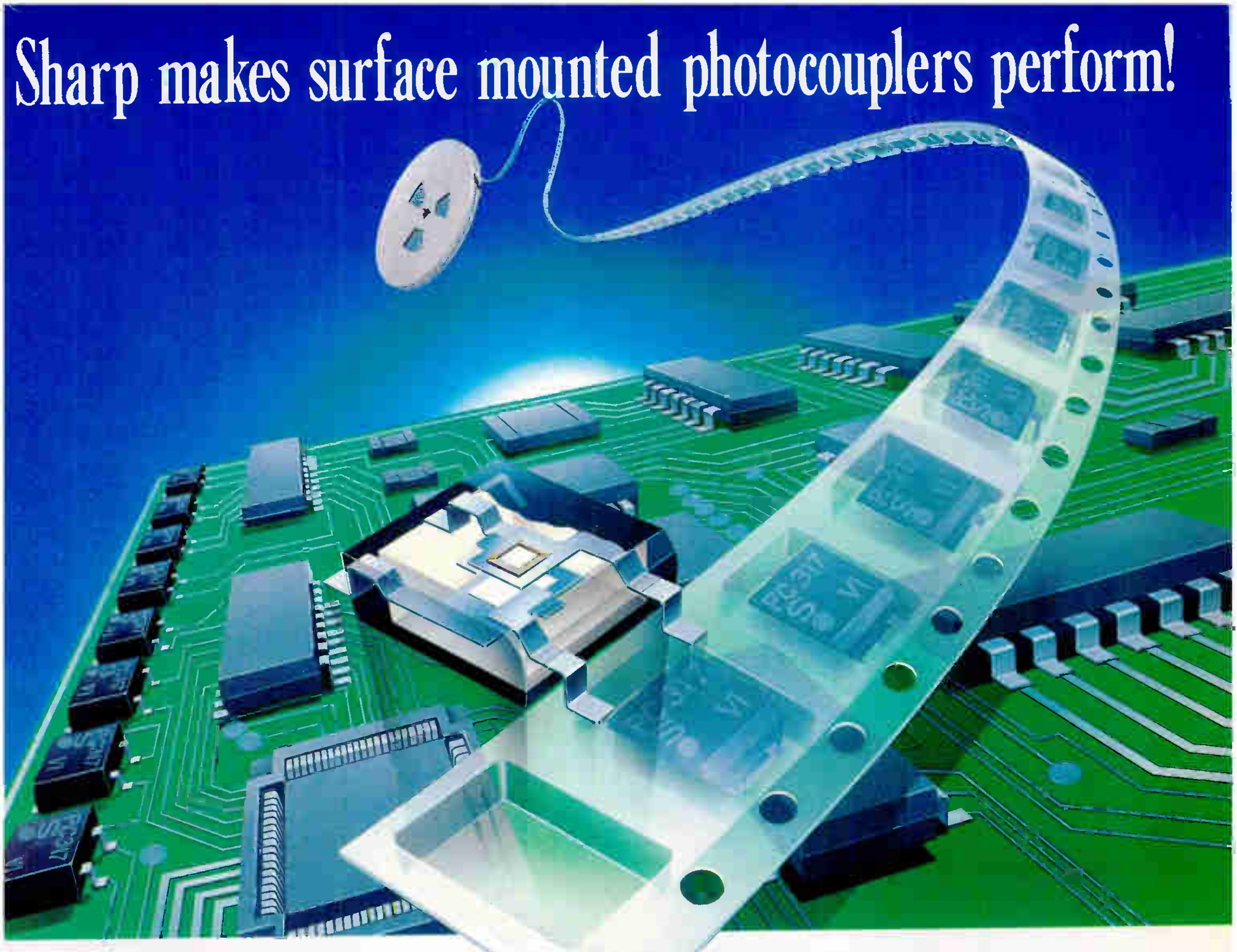
Process control is also going high-tech as the city's corporate infrastructure, created by steel, railroad, and coal barons, adapts itself to the age of computers, software, and silicon. "There has always been a lot of manufacturing know-how here," says Tim Parks, executive director of the Pittsburgh High Technology Council, "and that is being married to software for the process-control industry."

That manufacturing bent also makes materials research a major sector. Labs at schools such as Carnegie Mellon University and the University of Pittsburgh and corporations such as Alcoa, PPG, and USX have spawned several companies specializing in advanced materials. One such leader is II VI Corp., named for its focus on combining the elements in the second and sixth columns of the periodic chart into compounds for CO_2 lasers. Besides growing epitaxial layers of zinc selenide, II VI has been growing profits at a rate of 30% per year, says president Francis Kramer. Among the infrastruture advantages in the area, he says, are advanced testing laboratories, a "real solid work force with a good work ethic," and



Carnegie Mellon University is the city's chief technology incubator, turning out a stream of technical PhDs in artificial intelligence, computer science, and CAD/CAM.

Sharp makes surface mounted photocouplers perform!

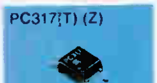


Surface mounting of photocouplers is important for reducing the size of many types of systems. But providing high performance in a smaller package required innovative packaging technology.

Sharp's Double Transfer Mold structure delivers high isolation voltages in DIPs, and it is crucial for providing high isolation voltage in mini-flat packages. Sharp's PC300 series of phototransistor output photocouplers and phototriacs deliver this performance in super-compact packages ideal for 100% surface mount systems.

Look for Sharp to continue their innovation in optoelectronics with the PC400 series, which will incorporate OPIC* functions inside the mini flat pack, increasing the integration of I/O functions. Call Sharp today if your system needs this kind of performance.

* OPIC is a trademark of Sharp and stands for Optical IC. It has a light detecting element and peripheral circuits integrated onto one chip. This innovative technology was developed by combining Sharp's advanced optoelectronics and IC technology.



PC317(T) (Z)
4.4X3 6X2.0mm

PC3D17
4.4X7.83X2.0mm

PC3Q17
4.4X16.29X2.0mm

S11MS1(A),(B)
4.4X3.6X2 0mm

SHARP SURFACE MOUNTED PHOTOCOUPLERS

● **Mini-flat , opaque package type PC300 Series**

Model No.	Features	Main Applications
PC317/PC317T/PC317Z	Viso: 2.5kVrms	Various fields
PC314/PC314T/PC314Z	AC input response Viso. 2.5kVrms	Telephones Programmable controllers
PC315/PC315T/PC315Z	High sensitivity CTR: 600% Viso: 2.5kVrms	Programmable controllers Electronic home appliances
PC316/PC316T/PC316Z	High collector-emitter voltage V_{CEO}: 120V Viso: 2.5kVrms	Telephones Programmable controllers FA equipment

*1 PC***, PC***T:Tape packaged products PC***Z:Sleeve packaged products
*2 In addition to the above, multi-channel types (2ch 4ch) are also available

● **Mini-flat package, OPIC type PC400 Series (Under development)**

Model No.	Features	Main Applications
PC400/PC400T/PC400Z	Viso: 3.75kVrms	Computer peripherals
PC401/PC401T/PC401Z	Viso: 3.75kVrms	Computer peripherals
PC410/PC410T/PC410Z	High speed (10Mbit/sec) Viso: 2.5kVrms	Computer peripherals
PC417/PC417T/PC417Z	High speed (1Mbit/sec) Viso: 2.5kVrms	Computer peripherals
PC452/PC452T/PC452Z	High collector-emitter voltage V_{CEO}: 300V, Viso: 2.5kVrms	Telephones

*3 PC*** PC***T:Tape packaged products PC***Z: Sleeve packaged products
*4 Package size 4 4X3.6X2.6mm

● **Mini-flat package, phototriac couplers S11MS/21MS Series**

Model No.	Power supply line	Features	Main Applications
S11MS1/S11MS1A S11MS1B	100V	Super compact, Viso. 2 5kVrms	For triggering of solid state relay
S21MS1/S21MS1A/S21MS1B	200V	Super compact, Viso. 2 5kVrms	For triggering of solid state relay
S11MS2/S11MS2A/S11MS2B	100V	Super compact, Viso. 2.5kVrms Built-in zero-cross circuit	For triggering of solid state relay
S21MS2/S21MS2A/S21MS2B	200V	Super compact, Viso: 2.5kVrms Built-in zero-cross circuit	For triggering of solid state relay

*5 S**MS*A, S**MS*B:Tape packaged products S**MS*:Sleeve packaged products

SHARP

Circle 45

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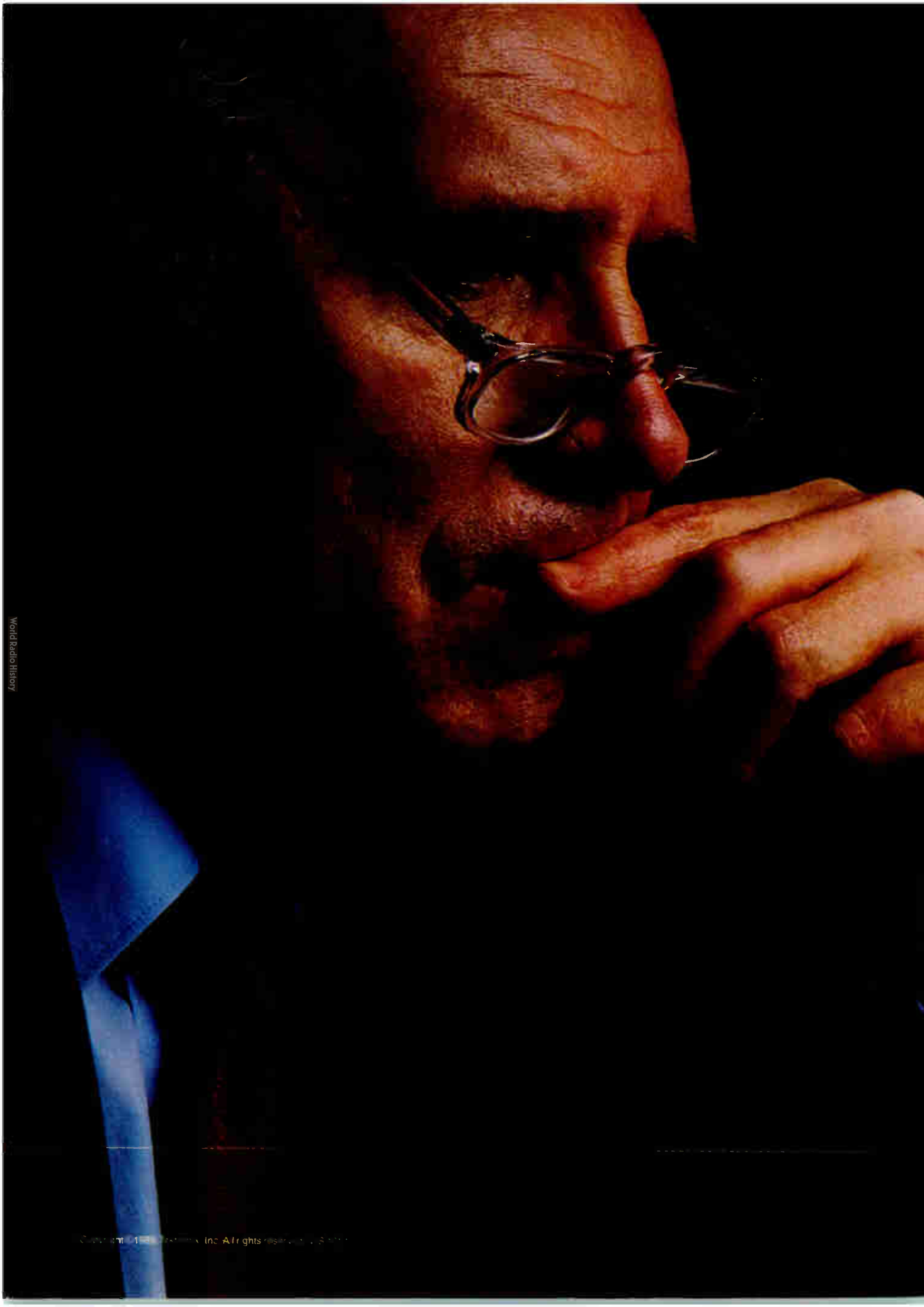

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For more information about the Vista Series VLSI Logic Test Systems, **call (800) 635-8774. In Oregon, dial 239-0266.**

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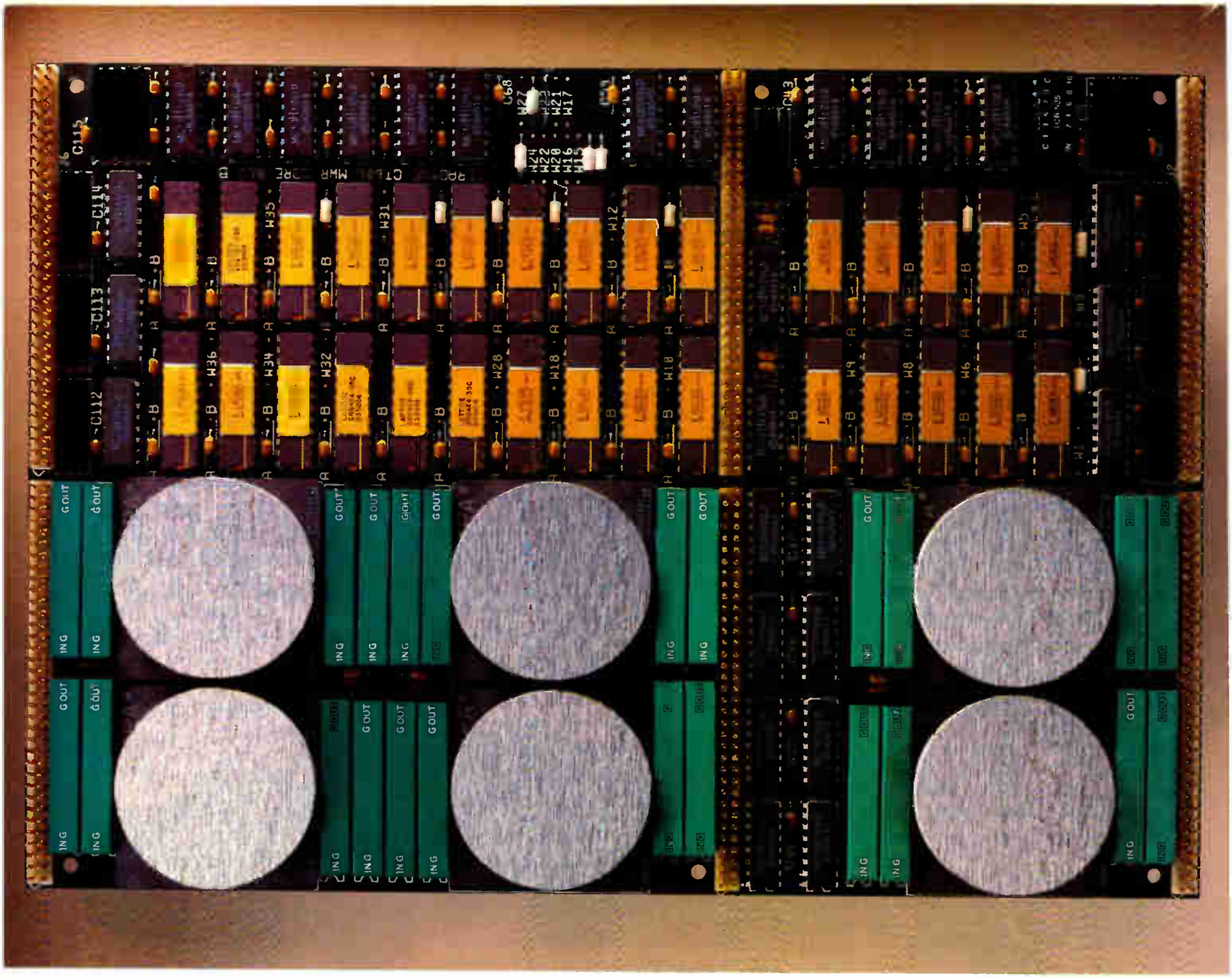

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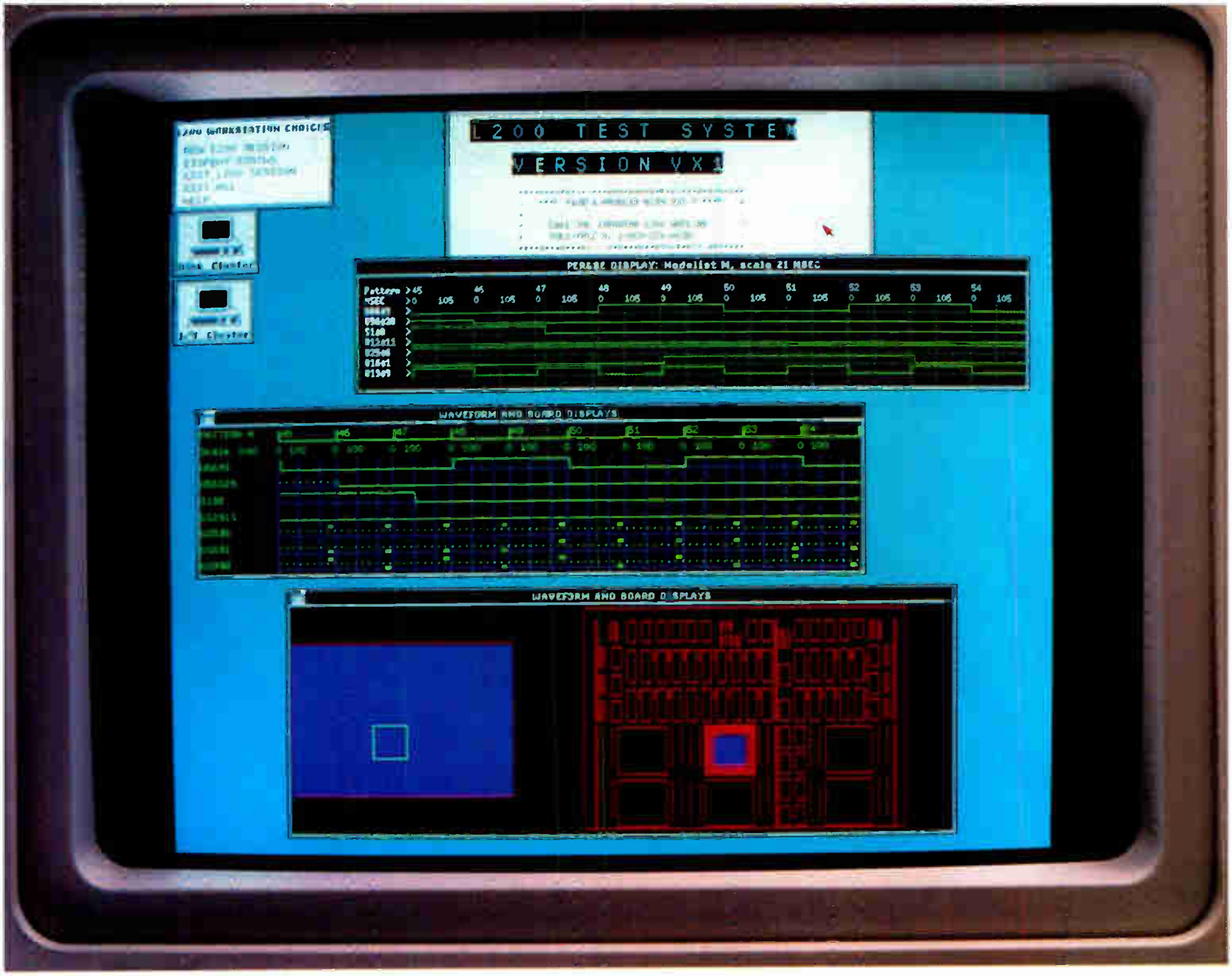
And the L200 hits test signal timing precisely. With up to 32 timing sets for drive phases and test windows. Its 250 ps programming resolution with zero dead time puts signal edges right where you want them.

Divide and conquer.
VLSI/VHSIC boards demand large, complex test programs. But the L200's distributed computer architecture simplifies matters.

Testing is controlled by a VAX computer. It sends tasks to specialized processors for rapid deployment of analog, digital, and memory tests.



here's a simple plan of attack.

Programmers will appreciate clustered VAX workstations. Graphics, like waveforms and shmoo plots, make heavy debug and analysis light work.

Simulation and other tactics.

High-powered software tools tailor L200 test development to modern design techniques and test strategies. Precisely the caliber of tools you need to get tests up and running fast.

	Test Channels	Maximum Pattern Rate	Channel Skew
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L293	576	80 MHz	±1.5 ns
L280vx	1152	10 MHz	±10 ns
L210vx	576	10 MHz	±10 ns

L200 VLSI board test systems are the performance leaders.

Take our LASAR simulator. It works closely with the L200 for both cluster and board-level testing. LASAR accurately predicts VLSI circuit responses and reports test program fault coverage.

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Circle 3

ELECTRONICS NEWSLETTER

WILL JESSI OPEN ITS DOORS TO U. S. COMPANIES?

Jessi, the $4.5 billion Joint European Submicron Silicon project designed to make Europe independent of American and Japanese semiconductor technology by the mid-1990s [*Electronics,* September 1988, p. 52], is open to taking on non-European partners, and one likely candidate is IBM Corp. Although it hasn't officially applied to become a member, IBM Deutschland GmbH, the U. S. computer maker's German subsidiary, is said to be interested in signing on. "They are welcome on board," says a spokesman for Philips International NV of the Netherlands. The Dutch giant, along with the French-Italian combine SGS-Thomson Microelectronics and West Germany's Siemens AG, is one of Europe's big-three semiconductor makers taking part in Jessi. Some industry analysts, who consider complete European independence of U. S. technology an elusive goal, think that an IBM partnership in Jessi may help European firms gain entry into Sematech, the U. S. semiconductor initiative. "But so far Sematech has kept itself isolated from non-American firms," the Philips spokesman says. □

FINALLY: A RELATIONAL DATA-BASE MANAGEMENT SYSTEM WITH BUILT-IN SECURITY

Sybase Inc. has unleashed the first data-base management system to offer government users multiple security levels, so that top-secret, classified, and unclassified information can all be safely stored in the same data base. Unlike other approaches, which sought to superimpose security software shells over an existing DBMS, Sybase built its system from the ground up, says Richard Scheffer, director of marketing at the Emeryville, Calif., company. As a result, the Secure SQL Server incorporates the security features in the operating system, minimizing the performance penalties usually associated with adding computer security features, Scheffer says. "There is some performance overhead," he admits, "but we've kept it to a minimum." The Secure SQL Server is designed to meet the National Computer Security Center's B1 security level, which permits the system to restrict data access based on user identity or by security tags assigned to the data itself. Initial systems, priced from $20,000 to $200,000, will run on Unix-based VAX systems from Digital Equipment Corp. A more secure B2-level system, running on "bare hardware" without the Unix operating system, will be available next year. □

NEW DENSE INTERCONNECT TECHNIQUE GOES CIVILIAN

Makers of computers and other commercial equipment are getting a crack at using new and very dense multilayer interconnect technology previously offered primarily to aerospace and defense contractors to drastically shrink the size of their products. Reductions of 10 : 1 are common, with one board for a U. S. Air Force contract cut to 300 in.^{3} from 6,000 in.^{3}, according to William D. Baker, president of UniStructure Inc. The Irvine, Calif., company was founded in 1986 and developed for aerospace and defense customers an interconnect technology based on liquid organic dielectrics, photolithography processing, and additive metalization. Baker recently joined UniStructure from Rockwell International's nearby Semiconductor Products Division, where he was executive vice president. He is concentrating on offering the technology to the commercial equipment field because interconnection improvements lag behind the size reductions continually coming down the pike on the chip side. While the UniStructure approach is more expensive than conventional methods in the beginning, it can yield important manufacturing cost reductions of 30% to 40% due to smaller sizes, says Baker. It also yields improved performance, he claims. Several large firms are well along in evaluating the technique, he says. Others are looking into another dense-packaging approach, multichip modules (see p. 106). □

ELECTRONICS NEWSLETTER

80386 AND 486 OS/2 SOFTWARE KITS TO APPEAR THIS YEAR

The importance of OS/2 software is growing almost daily—some industry watchers believe IBM Corp. will introduce the operating system on computers based on Intel Corp.'s 80386 and 80486 to compete directly with Apple Computer Inc.'s Macintosh. So developers are anxiously awaiting 386 and 486 versions of OS/2 from its creator, Microsoft Corp. in Redmond, Wash. Now the waiting seems to be coming to an end. Microsoft has been promising an OS/2 software developer's kit supporting the 386 for 1989, and a source close to the company says there will definitely be a kit supporting the just-introduced 80486, too (see p. 27). There are four new instructions on the 80486, and they will be accommodated in the kit. It will be announced at the Spring Comdex show in Chicago April 10 to 13, and begin shipping by autumn. OS/2 application software will begin appearing in 1990. □

ENCORE ACQUIRES GOULD'S COMPUTER OPERATIONS

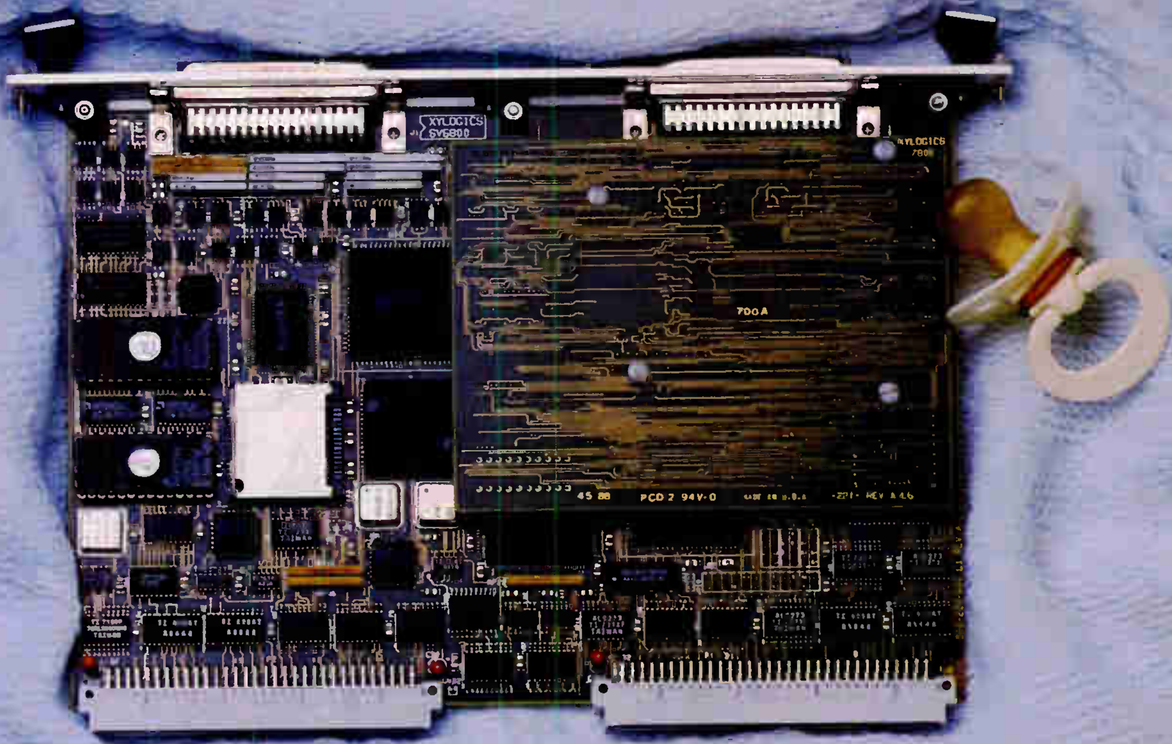
In an unusual move intended to provide substantially greater critical mass for both organizations, Encore Computer Systems Corp., the Marlboro, Mass., manufacturer of parallel-processing systems, is acquiring the much larger Gould/Computer Systems Inc. of Fort Lauderdale, Fla., from Nippon Mining Co. Ltd.—and Gould is providing $140 million of the purchase price. Encore had 1988 revenue of $34.4 million and has had five consecutive profitable quarters. Gould/Computer Systems revenues were approximately $225 million last year. The resulting company, with total revenue of $250 million to $275 million, will probably retain the Encore name. It melds two organizations with strong credentials—and substantial installed bases—in technical computing, including software development, academic time sharing, artificial intelligence, image processing, and simulation. □

EAST GERMANY'S TECHNOLOGICAL FEAT: 1-MBIT DRAMs

East Germany's ability to develop and build high-density memories has industry analysts shaking their heads. Not only will pilot production of 1-Mbit dynamic random-access memories be started this year by the optical equipment and electronics producer VEB Carl Zeiss Jena, but the company plans to develop 4-Mbit DRAMs as well. The 1-Mbit parts, the Eastern bloc's first, uses 1-μm CMOS technology and sport a 50-ns fast-page-mode access time. The 58 mm^2 chips come in a standard 18-pin package and are compatible with similar devices from Toshiba, Siemens, and Texas Instruments. The development of the 1-Mbit part and its 256-Kbit predecessor accounted for most of the $7.6 billion that the East German government allocated to microelectronics R&D during the past several years. West European industry analysts consider it a feat that a small country like East Germany—it's no bigger than Kansas and has just 17 million people—can muster the financial and technological clout needed to develop high-density memory chips, and do it without access to Western technology. □

NEED DRAMs? HERE'S ONE WAY TO GET THEM

If the shortage of dynamic random-access memories is abating, a band of armed robbers in California's Orange County hasn't heard about it. Over the past six months, at least five companies have been hit in late-night robberies, with the memory chips as the main target. The biggest haul was at Western Digital Corp. in Irvine, where two bandits forced an unarmed security guard to open a storage area and took some $100,000 worth of DRAMs, according to authorities. The armed robberies are a new development in the DRAM shortage, they say, with previous thefts largely being inside jobs. □



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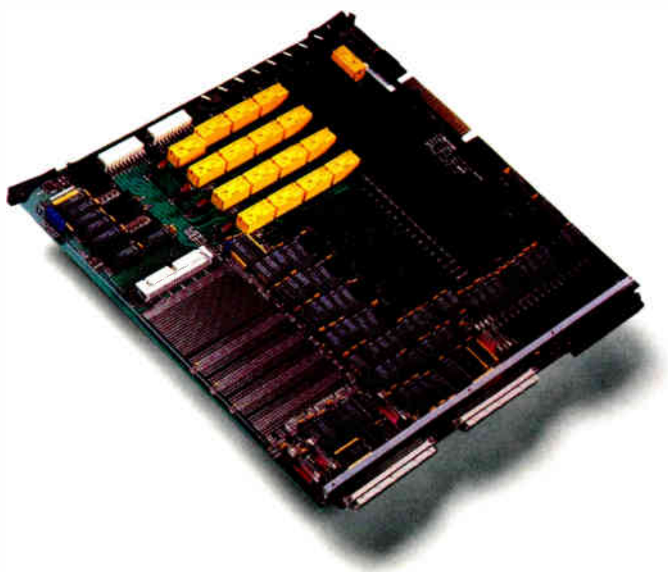
A GENTLE REMINDER ON THE IMPORTANCE OF LOOKING AROUND.



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To appreciate its performance fully, it's only fair to judge the 8000 by comparable systems: those costing much more.

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The 8000 is the only combinational tester with 2,048 fully-hybrid, non-multiplexed test points. Each node has a driver/receiver behind it; each can be used for either functional or in-circuit testing. All of which helps reduce the

cost of programming and implementing engineering changes.

The 8000's digital test subsystem truly warrants the term "high performance," with 10 MHz pattern rate, 8Kx4 RAM per node, programmable slew rates and 10ns programmable edge placement.

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Polarity	Positive and negative
Energy storage capacitor	150pF ±10%
Discharge resister	150Ω ±5%
Charging resister	100MΩ ±10%
Rise time of the discharge current	5ns ±30% at 4kV
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PRODUCTS TO WATCH

DATA TRANSLATION DELIVERS REAL-TIME FRAME GRABBING FOR THE PS/2

Real-time image capture for desktop publishing and scientific image processing has arrived for IBM Corp.'s Personal System/2. The vehicle is Data Translation Inc.'s QuickCapture frame-grabber card and interface software. The Marlboro, Mass., company claims it got to market first by designing a custom chip to solve the size and power problems posed by the PS/2 and its Micro Channel architecture. Images can be displayed on any RS-170 RGB analog monitor, with 256 shades of gray, or in 256 colors when using an available look-up table that applies false colors to monochrome images. Display resolution is 640 by 480 pixels. After capture, images can be exported to TIFF, PCX, or DT-IRIS files for use in other software programs such as Bioscan Inc.'s Optimas for scientific image processing. QuickCapture sells for $2,595 and is available now. □

NCR GOES AFTER THE ETHERNET MARKET WITH A 32-BIT CONTROLLER CHIP

Ethernet chip makers will be up against a formidable new competitor when NCR Corp. unveils two ICs this month: a 32-bit Ethernet controller and a twisted-pair transceiver. NCR claims its 92C28 is the first single-chip Ethernet controller to support both 16- and 32-bit data transfers. In the 16-bit mode, it provides about 20% better data throughput than popular 16-bit Ethernet chips while providing twice the performance in a 32-bit mode, say spokesmen at the company's Microelectronics Division in Fort Collins, Colo. The 92C28 also supports new IEEE 802.3 standards for layer management. The NCR 92C02 transceiver chip also meets draft standards developed by the IEEE's 10BaseT committee for unshielded, twisted-pair phone lines. Both chips are available in sample form this month, with production set for June. In 5,000-unit quantities, the 92C28 sells for $35, while the 92C02 is priced at about $15. □

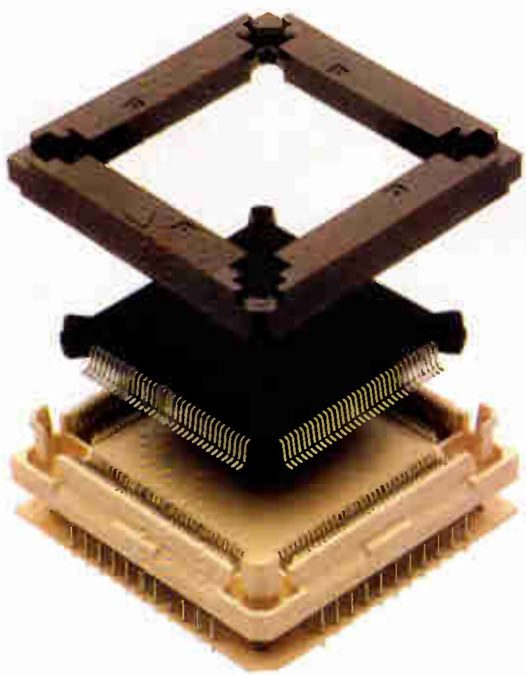
CIPRICO OFFERS A BOARD-LEVEL CONTROLLER OPTION FOR MULTIPLE-DISK SYSTEMS

Original-equipment manufacturers who need to control multiple disk drives can now add standard-interface, board-level products to their list of options. Ciprico Inc.'s Rimfire 6600 parallel disk-array controllers are the first board-level products to use the SCSI-2 host interface, claims the Plymouth, Minn., company. The Rimfire 6600 controls up to five industry-standard ESDI drives connected in parallel. In a typical five-drive configuration, four drives store data and the fifth is a parity drive that stores information that can be used to recover data and continue operation if one of the four data drives fails. The parity information can also be used to regenerate data on a drive replacing a failed drive. The mean-time data availability of the five-drive array can exceed the life expectancy of most computer systems. Customer shipments of the Rimfire 6600 will begin in August. The single-piece price for OEMs is $5,995. □

ROCKWELL'S 2,400-BIT/S MODEM CUTS CHIP COUNT AND POWER REQUIREMENTS

Makers of modem cards for laptop computers can cut chip count on their products and attain less than half the power consumption of present solutions with Rockwell International's RC224AT 2,400-bit/s modem chip. Based on the Newport Beach, Calif., company's MicroDSP CMOS microcontroller, the RC224AT is fabricated in a 1.6-μm CMOS process. It implements the CCITT V.22bis standard and replaces the six components needed in previous solutions. Besides delivering its power savings with a 305-mW operating mode and 37-mW standby mode, the device incorporates on-chip a built-in UART, a serial interface, and a complete AT command set. Available now, the RC224AT costs $28 each in 10,000-unit quantities. □

One small step for PQFPs. One giant step for service



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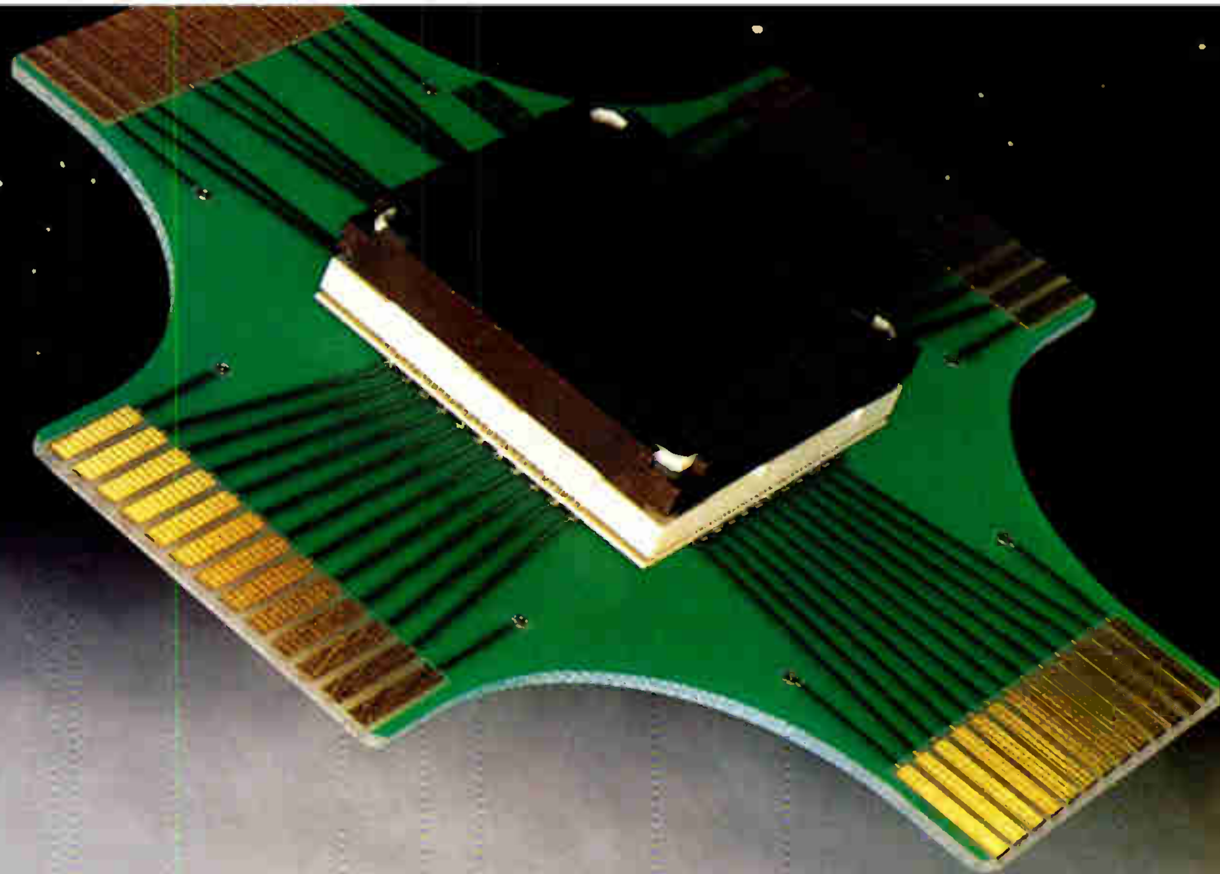

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For technical literature and more information, call the AMP Product Information Center at 1-800-522-6752 and ask about Micro-Pitch Sockets. AMP Incorporated, Harrisburg, PA 17105-3608.

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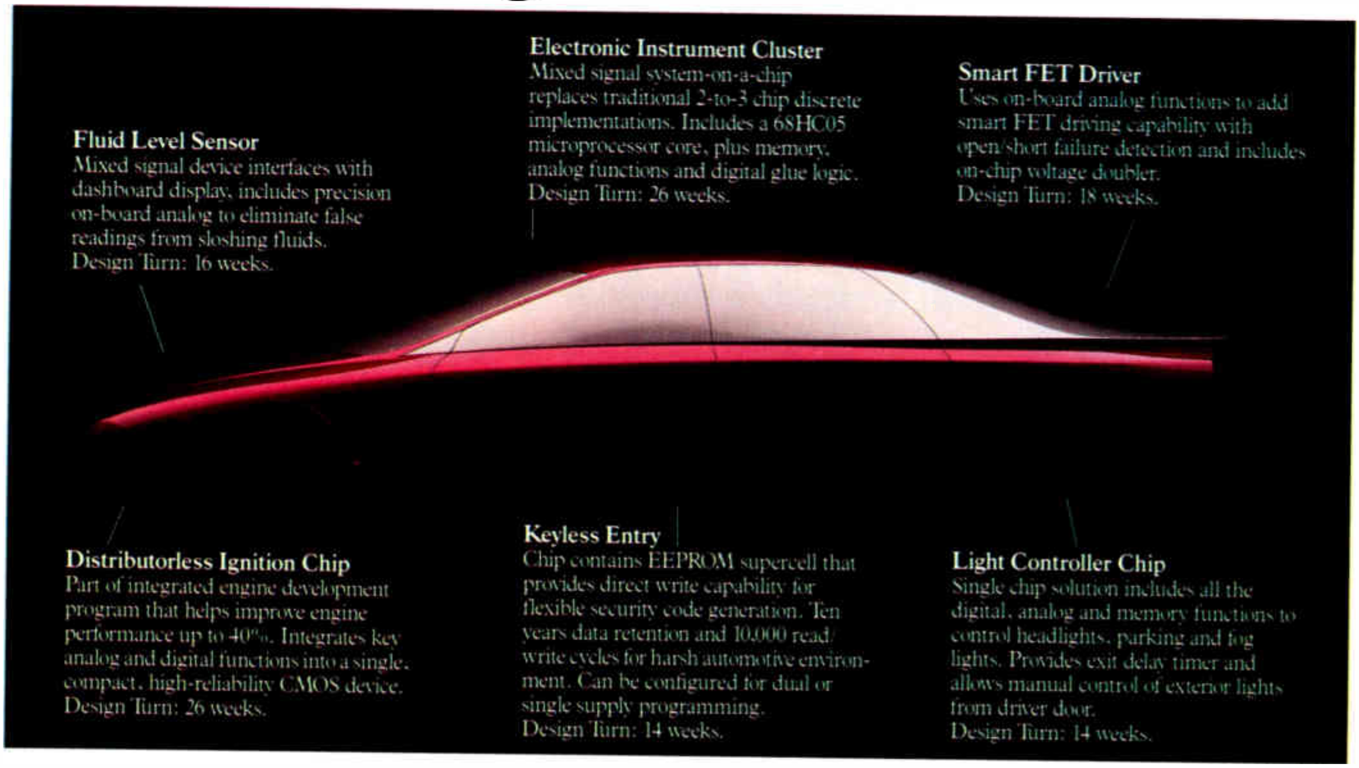

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Creating value

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Electronics

THEY'RE FASTER, THEY'RE DENSER, AND THEY'RE HERE: 80486 AND 68040 DEBUT

Intel and Motorola microprocessors promise new power for desktop computing

SAN JOSE, CALIF.

They're here. The eagerly awaited next-generation microprocessor chips from the two titans—Intel and Motorola—are about to square off in the unending war of the complex-instruction-set computer processors. The new combatants are the 80486 from Intel Corp. of Santa Clara, Calif., and the 68040 from Motorola Inc. of Austin, Texas. Intel will roll out the 80486 in Chicago at the Spring Comdex show April 10 to 13 even as Motorola representatives travel the country telling customers about the 68040's architecture.

The market for the chips is enormous and growing. By 1992, $1.6 billion worth of 32-bit CISC microprocessors will be sold, predicts Dean McCarren, an analyst at In-Stat Inc. of Scottsdale, Ariz., against $684 million in 1989. Driving the growth is an insatiable demand for desktop computers. Another analyst, William Lempesis of Dataquest Inc. in San Jose, estimates that worldwide shipments of DOS-based machines hit 11.6 million units in 1988, 26% more than the 9.2 million shipped in 1987. Though the 1989 growth rate will be slower, he says, it will still represent a sizable and growing market.

The new contenders for that market have much in common. In fact, Michael Slater, editor and publisher of the industry newsletter *Microprocessor Report*, believes that there is no major difference between them. Both chips are faster and denser than their predecessors—the 80486 two to four times as speedy, the 68040 three times as fast. Both are completely binary-compatible with the previous models. And both integrate more functions on-chip than the earlier parts, adding cache and a floating-point processor. Compatibility with the 80386 and the 68030 means that the installed base of software will work on new systems built with the higher-performance chips. But taking full advantage of this higher performance means waiting for more powerful operating systems.

THIS YEAR. Intel's Claude Leglise, director of marketing at the Microcomputer Division, says the 80486, in 25- and 33-MHz versions, will be in production this year and will cost $950. Today's 33-MHz 80386 sells for $367. Sources close to Motorola say that pricing and availability of the 68040 will be announced in the third quarter, along with more detailed specifications such as clock speed and cache size.

To a great extent, the design of both processors is dictated by the vast installed base of hardware and software. The chips must provide a significant performance boost over the previous generation yet be completely binary-compatible to gain market acceptance. Part of the performance boost can be credited to the latest 1-μm CMOS manufacturing processes used. But the architectures help too.

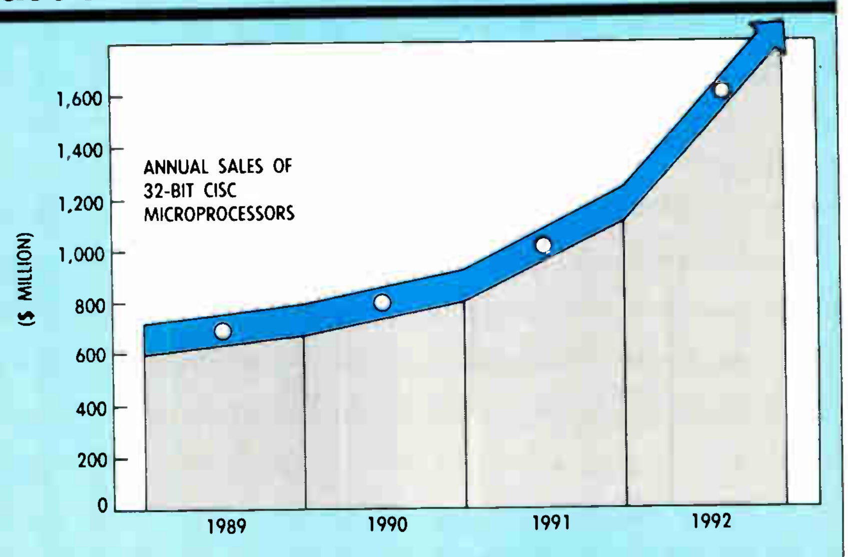
In designing the 80486, Intel used reduced-instruction-set-computing techniques, such as reducing clocks per instruction. "We evaluated the 386 compilers to determine which instructions were being used more frequently," says Leglise. "We improved the microarchitecture of the [new] chip so that instructions such as Add, Substract, Load, and Store all execute in one clock cycle."

The 80486 sports 8 Kbytes of instruction and data cache, sufficient for most systems built with the 25- or 33-MHz chips, he says. With most DOS and OS/2 applications, the user will experience a hit rate on the order of 92%, says Bill Rash, Intel's marketing manager for advanced 32-bit microprocessors. Intel also squeezed in a floating-point coprocessor that is binary-compatible with the 80386's floating-point processor. Like the 68040, the 80486 has an on-board memory-management unit equivalent to Intel's 80385 MMU. Its proven 1-μm process permitted Intel to jam a million transistors on-chip and make the new elements possible.

FEWER CLOCKS. For the 68040, there also is much more pipelining so that the average number of clocks per instruction will drop, says Slater. The chip boasts more parallelism—the bus controller, for example, runs in parallel with the central processing unit. "Now the 68040 CPU can be accessing the data or instruction cache while the bus controller is fetching new data and instructions from random-access memory," says Jack Browne, director of marketing at Motorola. On-board cache memory is also boosted with such features as the four-way associative cache. This provides a higher hit rate than other cache implementations.

The Motorola part—at 500 mils on a side slightly larger than the 300-mil 68030—houses 1.2 million transistors, says

CISC SALES ARE LOOKING UP



SOURCE: INSTAT INC.

Browne. Its floating-point unit conforms with IEEE-754 and is compatible with Motorola's 68882 floating-point math coprocessor. Also, the chip's integral MMU supports demand-page and real-time operating systems, and large cache.

Besides providing the same single-processor functionality, both companies seem to be eyeing multiprocessor applications. Both chips sport new hardware mechanisms dedicated to multiprocessing, such as multiple cache coherency. With so many similarities and so few differences, the chips might as well be twins. "The main difference between them is that the 80486 runs DOS [the operating system for IBM Corp. PCs] and the 68040 runs [Apple Computer Inc.'s] Macintosh OS," says Slater.

SOFTWARE WALL. But operating-system software is the burden a processor must bear, and nowhere is that more true than for the 80486 and DOS. "DOS software is constrained by the 1-Mbyte total addressing range of the 8088," the class of microprocessors for which DOS was written, says Slater. "Of this, the user can access only 640 Kbytes because of the way IBM divided up the address space—a crippling limitation." This segmented address space is a nightmare for software developers. The 80386 gets rid of these limitations in native mode, but DOS does not run in native mode on the 80386—it runs DOS programs in 8086 mode. Thus, the DOS operating system is inadequate even for the 80386—and will certainly be inadequate for the 80486.

IBM will bring up the OS/2 operating system on 80386- and 80486-based systems and use this to compete more directly with the Macintosh, predicts John Rossi, vice president at the investment firm of Alex Brown & Sons in San Francisco.

Actually, though, the Macintosh is in no better position to take advantage of the 68040 than the PC is with the 80486, says Dataquest's Lempesis. The Macintosh isn't even making full use of the 68030, since its operating system does not have true multitasking capability, though Apple is working on this.

Nevertheless, buyers are putting down good money for PCs with higher-performance CPUs, and there is no sign that they will stop. When systems containing the 80486 and 68040 begin appearing on the market—late this year and early in 1990 for the 80486—the asking price is likely to be high. Browne predicts 68040-based systems will sell for $7,000 to $15,000. And analyst McCarren of In-Stat believes an 80486 system will go for just under $10,000.

Such price tags will likely attract only power users and those with network-server applications. But they offer desktop PCs every bit as powerful and functional as Unix-based engineering work stations. *–Jonah McLeod*

MEMORIES

U. S. RETURNS TO DRAMS—SLOWLY AND CAREFULLY

WASHINGTON

DRAMs—you can't live with them and you can't live without them.

U. S. semiconductor companies bailed out of the dynamic random-access-memory business in the mid-1980s because of sharp price competition and outright dumping by foreign manufacturers. They couldn't live—indeed, stay alive—making DRAMs. But their customers, whose appetites for memory kept growing, couldn't live without them.

Buyers say they were "held hostage" by foreign suppliers throughout the DRAM shortage of 1987 and 1988, and bemoan the loss of domestic DRAM suppliers. Now, sobered and strengthened by their trials, the two groups are working together in an effort to reestablish large-scale DRAM manufacturing in the U. S.

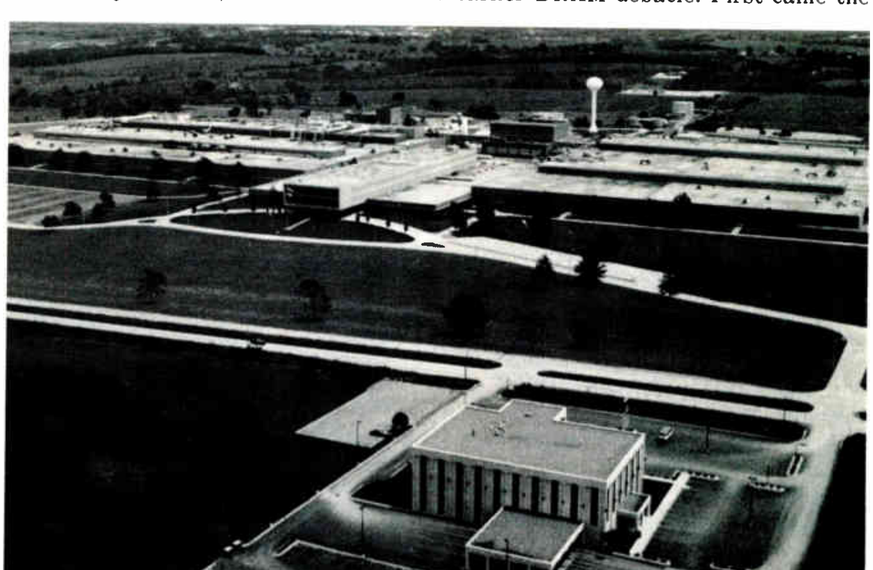
It all came together in March. Within weeks of each other, the Semiconductor Industry Association and the American Electronics Association announced efforts to encourage U. S.-based DRAM production; a California startup called Alliance Semiconductor Corp. announced it would be manufacturing 1-Mbit DRAMs in volume later this year at a fab leased from AT&T Co.; Micron Technology Corp. announced it would double its DRAM capacity by mid-1990; and Motorola Inc. declared that its new fabrication line is now cranking out production quantities of 1-Mbit chips in Mesa, Ariz.

Why now? Industry insiders say that everything finally clicked after nearly two years of behind-the-scenes negotiations. Early in March, the SIA board of directors said it would develop a plan and structure for the formation of cooperative ventures for large-scale DRAM production, and encourage their formation. Less than two weeks later, the AEA and SIA together issued a letter inviting interested member companies to step forward. The groups say they expect at least one and perhaps as many as three DRAM-building alliances to be formed.

PRICE CRASH? But not everyone is tickled by the prospects of a sudden boost in worldwide DRAM manufacturing capacity. "There's plenty of fear out there that DRAM prices are going to come crashing down precipitously," says Michael Gumport, an analyst with Drexel Burnham Lambert who follows the DRAM market. The spot-market cost of a 1-Mbit DRAM held steady at around $18 for for the last two quarters, he says, and he predicts a gradual slide to about $15 in June and $11 by the end of the summer. Production costs are about $4 to $5 per chip, he says, providing a comfortable profit margin.

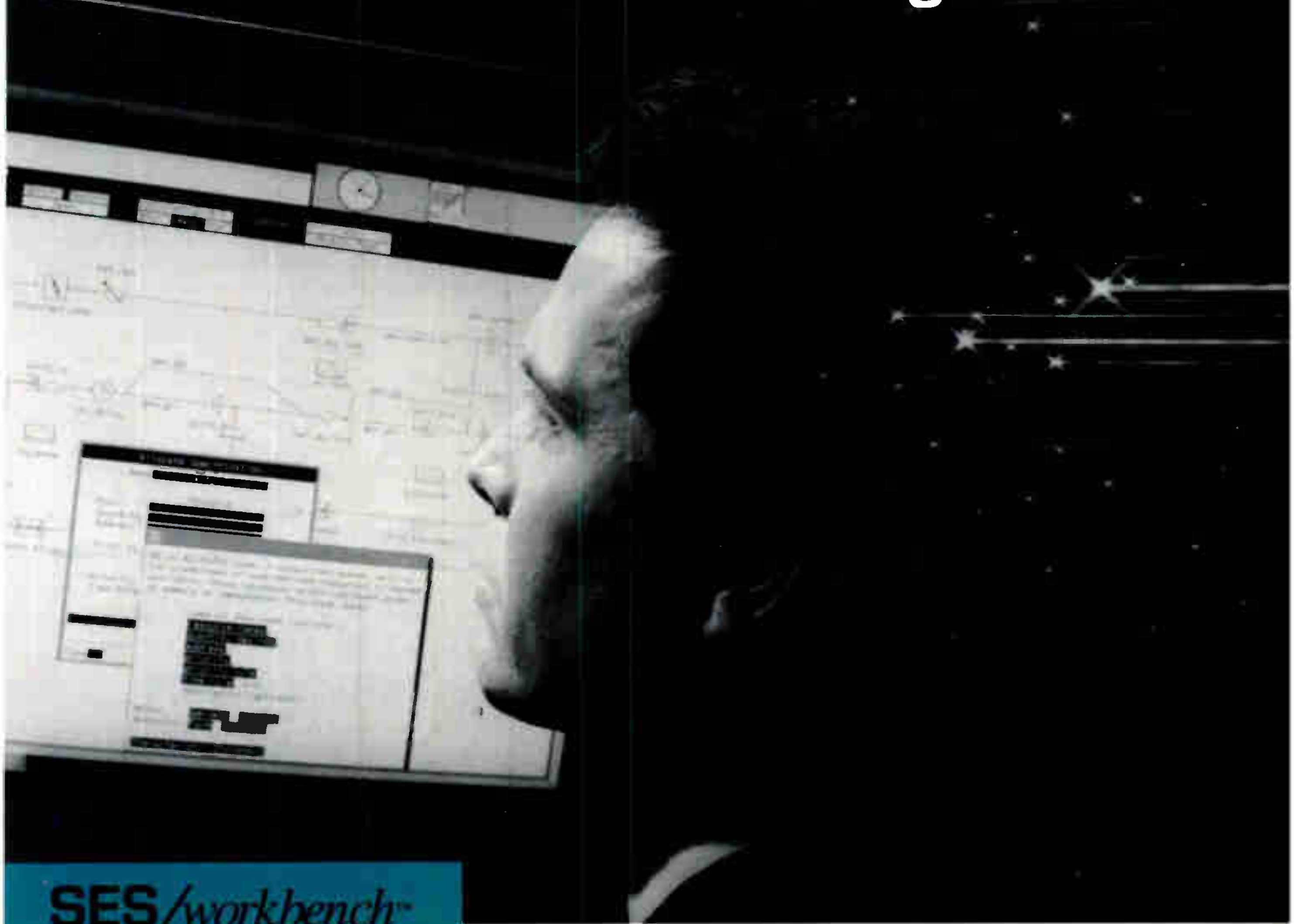
But if capacity were to suddenly balloon, that margin could grow slimmer, making it that much more difficult for startups or new joint ventures to come on stream without losing their shirts. "It would be late to get in now," Gumport says. The time to plan a return was a year to two years ago, he adds, and unless a company already has designs and a facility in hand, it's going to miss the boat.

The chip makers say it took two years to get the DRAM effort under way because they needed that time to recover from the earlier DRAM debacle. First came the



Alliance Semiconductor plans to begin producing 1-Mbit DRAMs in this Lee's Summit, Mo., facility, which it is leasing from AT&T Co.'s Kansas City Works.

A Testbed For The Imagination



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fights: with the Japanese over implementation of the Semiconductor Trade Accord of 1986; in Congress and at the Pentagon for the money to establish Sematech, the chip-manufacturing technology consortium; and with the AEA over the fair-market-value pricing scheme used by the Commerce Department to regulate pricing for Japanese DRAMs.

For their part, the systems companies that weathered the DRAM shortage found out what scarcity can do to their bottom lines. Many are still smarting over having to pay sharply higher prices for memories. And they are especially worried about having to buy DRAMs from the same giant, vertically integrated Japanese firms they are competing with on the systems level.

It will take more than an industry agreement to get DRAM production going again, of course. For one thing, the new allies will have to cough up some very serious money: experts estimate that a single world-class 1-Mbit DRAM fab would cost $250 million. A 4-Mbit line could cost $100 million more.

So far, Motorola is the only one of a crew of major U. S. chip makers that dropped out of DRAM manufacturing to return. The company opened its Arizona fab, called Mos 6, in December and ramped up to production levels only last month. A plant at East Kilbride, Scotland, will also serve the U. S. market. Adam F. Cuhney, a financial analyst at Kidder Peabody & Co. in San Francisco, projects Motorola will crank out between 4 million and 5 million 1-Mbit DRAMs at the U. S. plant. Motorola confirms these figures.

AT&T is returning in a different way. The company is leasing about 130,000 square feet of space in its chip plant near Kansas City, Mo.—including two Class 10 clean rooms idled since February 1987 when AT&T halted production of 1-Mbit DRAMs—to Alliance Semiconductor of San Jose, Calif. Alliance plans to start producing high-performance 64-Kbit static RAMs there this month. As the fab gets up and running, says company president and cofounder N. Damodar Reddy, it will switch over to 1-Mbit DRAMs in the second half of the year.

NO HELP. Despite all the talk around the industry about reestablishing a U. S. DRAM presence, Alliance hasn't gotten any help from other chip firms or from systems companies. Reddy says he tried hard last fall to raise venture capital from a variety of Silicon Valley chip makers and chip consumers to build a DRAM fab, to no avail. In the end, he turned to a trio of unlikely saviors: AT&T, to lease its facility, and the Missouri state government and Hallmark Cards for money.

Drexel Burnham's Gumport says this kind of opportunistic approach by a smaller company is "a more logical approach" than the cooperative ventures being explored by the trade groups. "The leaders aren't all that eager to cooperate with the have-nots," he says. "I think it will be tough to get the full support that you'll need to make that kind of venture work." But Alliance will also have a tough time of it: "I think they're running about a year late" compared with the company's original plan, he says. "It's yet to be seen whether they can ramp up production for a reasonable cost."

Meanwhile, Micron Technology and Texas Instruments Inc., the only two chip-making mainstays not to halt U. S. DRAM production, have been adding capacity. Micron is building a third fab that will eventually double its total DRAM capacity. The Boise, Idaho, company plans an 18-month ramp-up to full production. TI, which last year doubled the capacity of its Dallas DRAM facility, expects to spend at least $756 million on equipment in 1989. *–Tobias Naegele*

MEMORIES

SIMTEK REVIVES SNOS FOR NONVOLATILITY

COLORADO SPRINGS

There's a new contender in the race for leadership in the 1990s in nonvolatile semiconductor memory chips. Actually, it's an old technology warhorse that most prognosticators long ago scratched from the running.

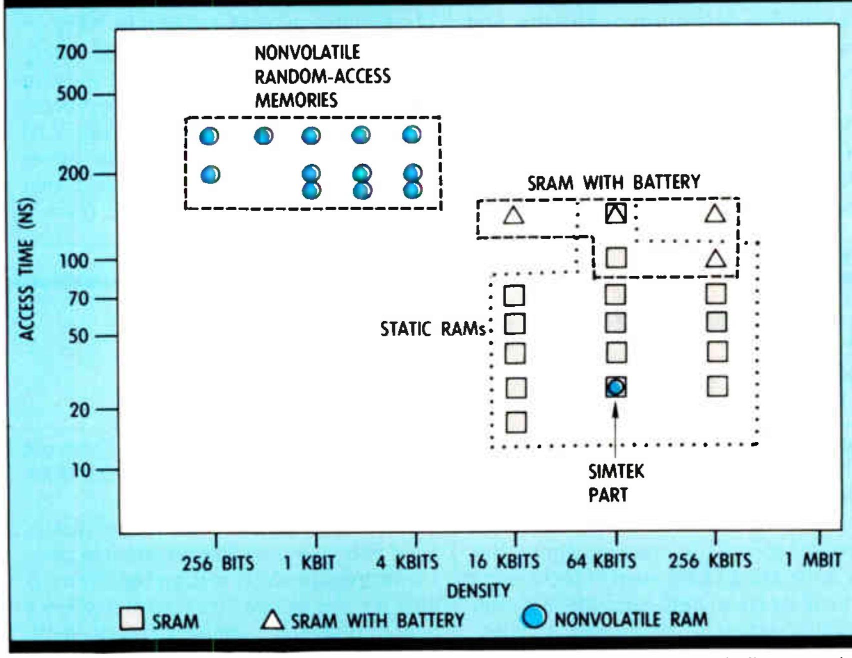
But if two-year-old Simtek Corp. in Colorado Springs can deliver on its business plan, industry watchers may want to reexamine their betting cards. And they might want to pay particular attention to the technology that has been variously known over the years as MNOS, SNOS, and SONOS, among other monikers.

Those acronyms stand for metal or silicon-nitride-oxide semiconductor technology, which has been widely used since the 1970s in small, nonvolatile rewriteable memories for applications like odometers, TV tuners, and other consumer gear. Indeed, according to some reports, 80% to 85% of all nonvolatile memory chips produced in Japan are built in the nitride-based multiple dielectric structures. And because of its natural radiation hardness, the technology has always been a favorite of the U. S. military.

But the MNOS and SNOS processes have historically suffered from yield and reliability problems. In the commercial markets for high-density parts, the technology lost out in the 1980s to more directly CMOS-compatible floating-gate electrically erasable programmable read-only-memory technologies.

Now, thanks to improved cell designs and advances in uniform nitride deposition

IN FAST, DENSE COMPANY



The SNOS technology that Simtek is pushing can be used to implement nonvolatile memories that compare favorably with other parts in access times and density.

techniques in recent years, Simtek, for one, believes that SNOS holds potential inherent advantages over floating-gate-based nonvolatile chip technology. As mainstream nonvolatile chip densities move to 1 Mbit and beyond, "we're making our bets on nitride," says Richard L. Petritz, Simtek's chairman and chief executive officer. The company is now seeing first silicon on two SNOS devices.

Petritz, a well-known semiconductor memory veteran, established Mostek Corp. as a venture capitalist and was that company's first president. He next founded Inmos International plc, with British government funding. Then, in May 1987, he cofounded Simtek with Gary Derbenwick, with the help of minority Japanese funding from Nippon Steel Corp. Derbenwick is Simtek's president.

DEJA VU. "Mostek made an impressive market in the dynamic random-access-memory business, and Inmos did very well in static RAMs and was one of the pioneers in sophisticated fast SRAM design," Petritz says. "And I look at Simtek as potentially being that kind of company. Our business plan is built around my and Gary's feeling that the next great area for expansion in the semiconductor business is nonvolatile memory."

There are plenty of skeptics, of course. But if Simtek is right, it could make SNOS a serious contender not only in nonvolatile memory devices, but for use in microprocessors and logic chips as well. It's a technology that many see becoming increasingly important as the next decade unfolds, although the competition will be heavy [*Electronics*, March 1989, p. 80].

Simtek hopes to roll out two new SNOS memory chips by the end of this year that feature impressive nonvolatile performance and density. One—a 64-Kbit nonvolatile SRAM—boasts access times as low as 35 ns, compared with around 150 ns on today's fastest commercially available parts.

The other Simtek chip—a full-function 256-Kbit EEPROM—matches the 70-ns access times of the fastest parts of this type available today and leaves the bulk of 256-Kbit EEPROMs in the dust.

Unlike some floating-gate-based parts, both Simtek chips are 5-V-only devices. (Internal 15-V programming voltages are generated on-chip.) Both are also expected to match or exceed nonvolatile floating-gate devices in key characteristics such as retention, endurance, and reliability, Petritz says.

SOME UNCONVINCED. Simtek is sure to meet plenty of skepticism. "There are a lot of people who have looked into SNOS and given it up. It's not new, and if it was easily manufacturable, it would still be in use," says Krish Panu, director of marketing for Xicor Inc. in Milpitas, Calif.

Xicor is the industry leader in low-density 256-to-4-bit nonvolatile RAMs. It recently began offering samples of a full-function 1-Mbit EEPROM built in a thick-oxide, triple-polysilicon, floating-gate-cell process. Access times on the dense Xicor part are 250 ns, and the chip sells for $995. Xicor also offers a 256-Kbit EEPROM in the same technology that features 120-ns access times and sells for $70 to $80 in volume [*Electronics*, May 12, 1986, p. 30].

SNOS and MNOS processes must overcome yield and reliability problems

Nevertheless, a small but growing number of chip houses are taking renewed interest in SNOS. Japan's Hitachi Ltd., for one, offers both 64- and 256-Kbit SNOS EEPROM parts commercially, though they are not as fast as the planned Simtek 256-Kbit chip. Microchip Technology Inc. in Chandler, Ariz., has "started to look at SNOS for a 256-Kbit EEPROM," says marketing vice president Rahul Sud, after earlier scrapping the technology in favor of a floating-gate-based 256-Kbit EEPROM. The latter chip, which only recently came out in sample form, offers 150-ns access times.

At Simtek, engineers note that the quick access times on their first two designs actually owe more to clever circuit design than to the underlying SNOS. But as parts get denser and device geometries shrink, the nitride technology has advantages that they believe will become more and more important.

Unlike floating-gate parts—which store charge in a continuous conduction band on a polysilicon gate between two insulating oxide layers—an SNOS memory cell stores electrons in traps on a nitride insulator. This means that an SNOS cell is not susceptible to catastrophic blow-out, as are floating-gate-based cells. These can lose all their charge through a pinhole in an oxide, says Klauss Dimmler, project manager for Simtek's 256-Kbit EEPROM design.

SNOS also enjoys a related advantage in testability, he contends. "It's impossible to predict exactly when [a floating-gate part] is going to blow." But by using the same kind of margin-mode testing commonly done on DRAMs and SRAMs, "you can be 100% certain that an SNOS device will last in the field for as long as you've tested it for," Dimmler says.

SMALLER CELLS. Another SNOS advantage is relatively small cells, according to Petritz. The company won't provide cell or chip dimensions for its first two parts, the STK 28C256-70 EEPROM and the STK 10C68A nonvolatile SRAM. But for comparable design rules, Dimmler says, Simtek memory-cell sizes are "pretty much halfway between" those of flash and conventional full-feature floating-gate EEPROM parts.

The first two Simtek parts are designed with conservative 1.9-μm geometries, but the technology is easily scalable, adds Petritz. "We see no problems in going to 1 Mbit, 4 Mbits, and on up."

One thing that remains to be seen is whether the Simtek technology is manufacturable at yields high enough to make it cost-competitive. Simtek is using Orbit Semiconductor Inc. in Sunnyvale, Calif., as a foundry for prototype circuits, and company executives say they've seen good results on first-run silicon delivered last month. Petritz says Simtek hopes to build its own "minifab" for development and limited production in a few years.

Simtek also hopes to close by the end of June "a modest-size" second round of funding with U. S. venture-capital firms, Petritz says. One of them is Centennial Funds in Denver, where general partner Mark Dubovoy says his firm is "very interested. We've had a number of sanity checks, and people seem to be getting more and more confident that the process and design are sound and will work. And if you believe that, then it becomes an execution game. I think they've got a shot at it." *–Wesley R. Iversen*

NETWORKS

A NEW LOOK FOR FIBER: PLASTIC REPLACES GLASS

YONKERS, N. Y.

Fiber-optic Ethernet was long considered a costly solution appropriate only for local-area networks that need a high degree of security or noise immunity. But now it's getting an infusion of technology that will let these nets compete on a cost-per-node basis with unshielded, twisted-pair telephone wiring.

Fiber's new look results from three parallel developments. First, the Yonkers laboratory of Codenoll Technology Corp. has fabricated fast, light-emitting diodes powerful enough to drive a passive Ethernet hub that splits signals optically. This passive-hub technology eliminates the need for electronic components in the hub and that, in turn, delivers significant cost savings, says Steve Anderson, Codenoll's engineering vice president for component technology.

Second, costs can be further reduced by using plastic fiber instead of glass as the transmission medium, and strides are being made in bringing plastic technology up to snuff. Besides being less expensive than glass cable—and copper, too—plastic fiber saves on installation costs because of its easy-to-handle connectors, says Anderson. Third, the final set of questions surrounding a fiber Ethernet standard should be resolved by the IEEE 10BaseT committee this year.

But don't expect an avalanche of plastic-fiber Ethernet installations anytime soon. Commercial products will not become available for one or two years, says Frederick Scholl, Codenoll's senior vice president. When they do, Scholl expects an installed plastic-fiber system based on a passive-star topology to cost 30% to 50% less on a per-node basis than the twisted-pair competition. Installed twisted-pair prices now are \$500 to \$700 per node, depending on the vendor and number of nodes.

Codenoll's biggest breakthrough is its red-light, edge-emitting LED display. Fabricated of layers of aluminum-gallium-indium phosphide and gallium arsenide, the LED emits light from its edge rather than its surface. This configuration makes lightwave coupling to the plastic fiber easier. The LED's 100 μW of power is enough to drive a passive-star, plastic-fiber system without amplification in the hub. Just as important, says Anderson, the device's switching time is 5 ns, against 20 to 50 ns for other LEDs powerful enough to drive passive-hub, plastic LANs. The device must switch that fast in order to deliver Ethernet's 10-Mbit/s data-transmission speed.

Even though "we've shown that plastic fiber can be used at high switching speed and power," says Anderson, the company is not ready to start churning out production volumes. Fine-tuning is also needed for the lightwave coupler in the hub, says Scholl. But both technologies are well along the development path.

The main remaining challenge is to extend the maximum distance between hub and node to the 100 meters offered by twisted-pair Ethernets. This is not now possible because of the high attenuation factor of plastic fiber. Codenoll is already running an 80-m Ethernet, and small improvements in any one of a number of areas—including cable attenuation and receiver sensitivity—will make the 100-m radius a reality, according to Anderson. The technology would support at least seven nodes per hub.

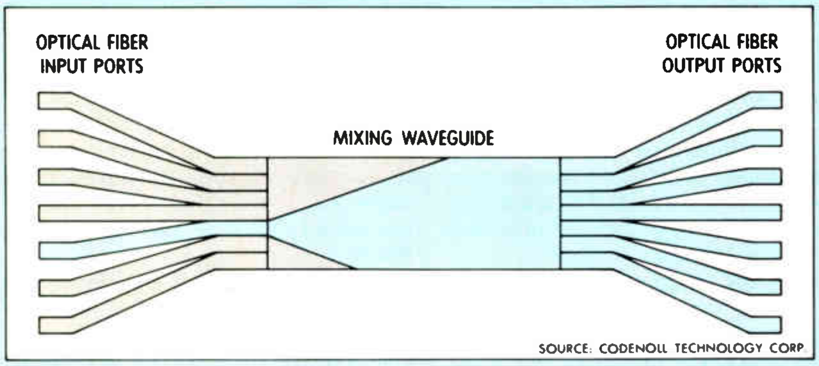
Still, even after the plastic-fiber technology problems are solved, not everyone is bullish about the technology's prospects. "The electricians who deal with wiring plants are very comfortable with using twisted-pair, but they have an uncertainty factor—a fear factor—with fiber," says Albert Bender, chairman of FiberCom Inc. in Roanoke, Va. "Even if they are equal in cost, I think twisted-pair would win all ties."

VOTE COMING. On the standards front, the IEEE subcommittee formulating the specification for Ethernet running on fiber-optic cable should have a draft ready for a vote by November, says Doug Ruby, director of marketing for Chipcom Corp. The Waltham, Mass., company is a proponent of an active-star topology, for which the 10BaseT committee will recommend standards. It will also set standards for the passive-star topology.

Although the passive-star topology has the advantage of eliminating electronics in the hub, it also has a down side, says Ruby. In particular, it requires that Ethernet's collision-detection function—the means of sensing that two messages have been simultaneously received—must be implemented at each node. The active star, on the other hand, implements collision-detection in the hub. This is a more cost-effective solution, says Ruby, because the cost of collision-detection electronics is shared by the nodes connected to the hub.

Like FiberCom, Chipcom is shying away from head-to-head competition between plastic fiber and twisted-pair Ethernet. "Glass is there for a reason," Ruby says, noting that its low power attenuation translates into greater run lengths and more nodes than can be achieved with copper-based transmission media. "We see the market growing really quickly," he says, "but for large networks, not small ones." *–Jack Shandle*

MIXING ROD-STAR COUPLER



All-optical devices, such as Codenoll's mixing-rod star coupler, cut Ethernet costs by eliminating electronics in the hub.

Circle 63 on reader service card →

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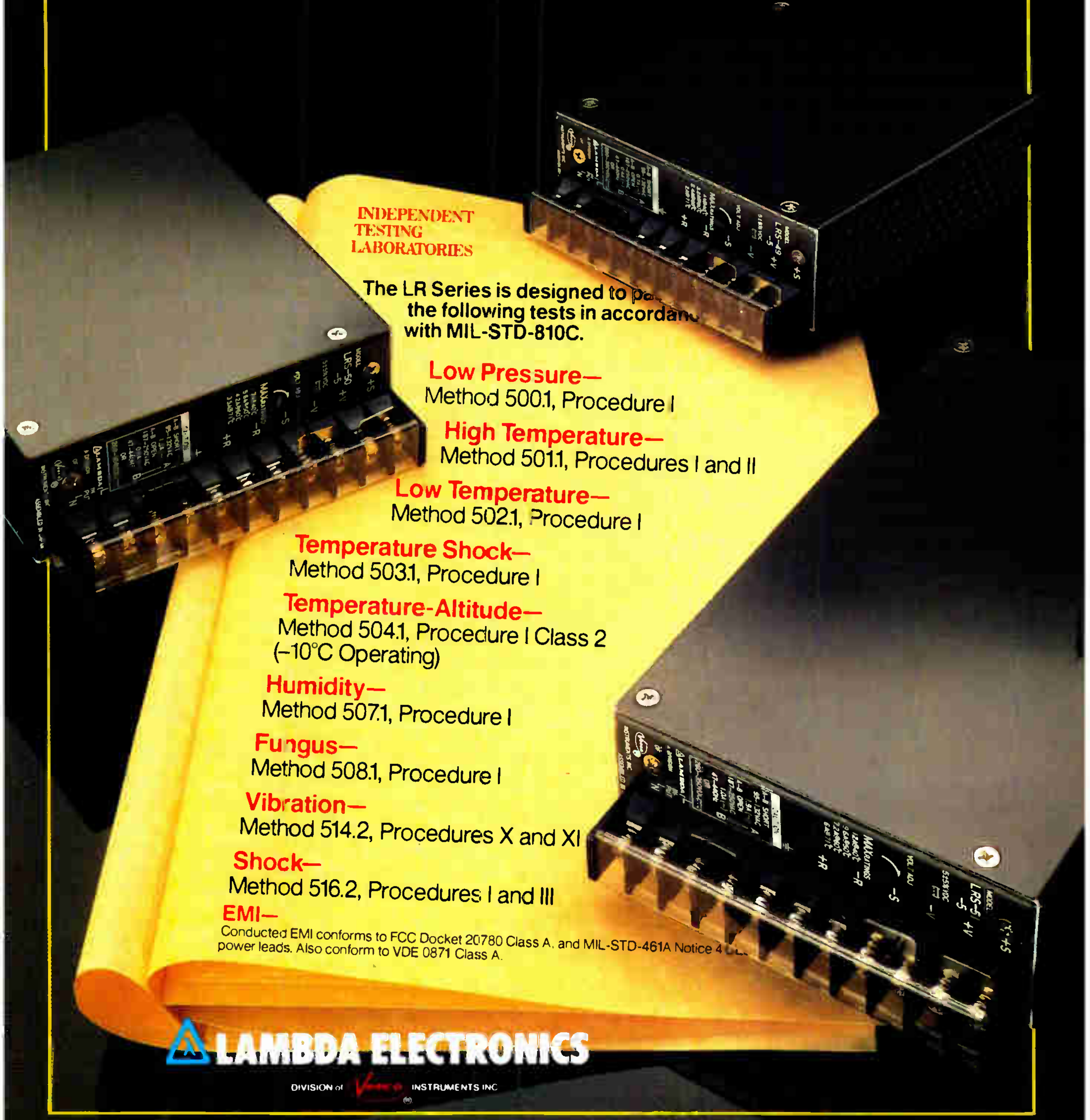

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Low Pressure (Method 500.1 Procedure I)
Units are operated in a chamber simulating 15,000 feet altitude and are operated and checked after one hour. Units are exposed for one hour prior to check.

High Temperature (Method 501.1 Procedure I & II)
Units are operated and checked at + 71°C after 48 hours exposure to this temperature.

Units are also subjected to three 12 hour high temperature cycles between + 49°C and + 71°C. After the third cycle, units are checked at + 71°C ambient.

Low Temperature (Method 502.1 Procedure I)
Units are subjected to − 57°C for 24 hours. Temperature is then increased to 0°C and the units are operationally checked.

Temperature Shock (Method 503.1 Procedure I)
Units are transferred between two chambers, one at − 57°C, the other at + 71°C. Units remain in each chamber for four hours. After twenty-four hours, the units are allowed to return to ambient conditions when a check is carried out.

Temperature — Altitude (Method 504.1 Procedure I Class 2)
Units are put through the following cycle in accordance with this test.

Step	Temperature	Altitude	Unit operation
1a	+ 25°C	40,000 ft.	Non operating
1b	− 62°C	Site	Non operating
2	0°C	Site	Operating
3	0°C	10,000 ft.	Operating
4	− 10°C	Site	Operating
5	+ 25°C	Site	Operating
6	+ 85°C	Site	Non operating
7	+ 55°C	Site	Operating
8	+ 71°C	Site	Operating
10	+ 52°C	10,000 ft.	Operating
11	+ 68°C	10,000 ft.	Operating

Humidity (Method 507.1 Procedure I)
Prior to starting the test period, chamber temperature is maintained between + 20 and + 38°C (+ 58° and + 100°F) with uncontrolled humidity. During the first two hour period, the temperature is gradually raised to + 65°C. This temperature is maintained during the next 6 hour period. During the following 16 hour period, the temperature is gradually reduced to + 30°C. This 24 hour period constitutes 1 cycle. This cycle is repeated 10 times (240 hours) with relative humidity maintained at 95% throughout all cycles. At the conclusion of the 240 hours of test, and while units are still at 30°C and 95% relative humidity, the units are operationally checked.

Fungus Proofing (Method 508.1 Procedure I)
Units are exposed to the spore cultures of the specified fungus species in an environment capable of encouraging fungus growth. At end of test, units must not show signs of fungus growth, deterioration or corrosion.

Vibration (Method 514.2 Procedures X & XI)
Units are secured to the test machine by their normal mounting means and subjected to simple harmonic motion with an amplitude of 1.0 inch (double amplitude) or 1.5g at frequencies from 5Hz to 200Hz. An operational check is then carried out.

Packaged units are placed on a bounce machine and bounced 2.0 inches at 284 rpm for three hours (thirty minutes on each face). Units are tested and inspected for evidence of physical change.

Shock (Method 516.2 Procedures I & III)
Units are secured to the shock machine by their normal mountings and subjected to 18 half-sine, 11 millisecond, 15g shock pulses. An operational check is carried out afterwards.

Units are also tested for crash safety. Again units are secured to the shock machine by their normal mountings but this time subjected to twelve half-sine shocks of 30g with 11 millisecond duration. The mounting attachments are then checked for failure or hazard.

Conducted Interference (MIL-STD-461A)
Units were tested according to the procedures laid down under MIL-STD-461A Notice 4 CE04 for conducted EMI. The units were found to conform with either output grounded. LRS power supplies also meet VDE 0871 Class A and FCC Docket 20780 Class A.

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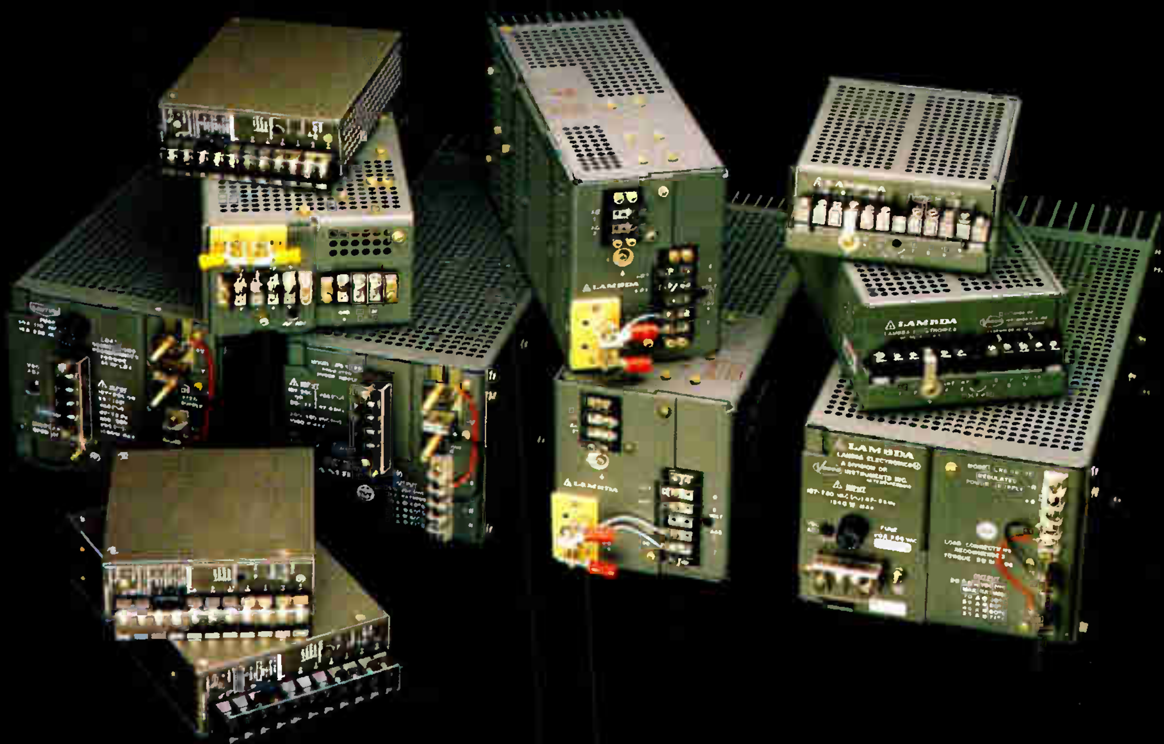

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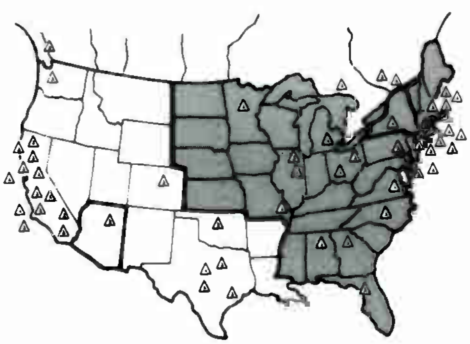

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2V ±5% ADJ.	4.0	3.2	2.4	2.0	1 1/2 × 4 17/32 × 4 23/32	$ 158	$ 150	**LRS-49-2**
	7.0	5.6	4.2	3.5	1 1/2 × 4 17/32 × 5 15/32	200	190	**LRS-50-2**
	12.0	9.6	7.2	6.0	1 11/16 × 4 17/32 × 7 13/64	252	240	**LRS-51-2**
	15.0	13.7	11.1	5.9	2 × 4 7/8 × 6 1/4	324	308	**LRS-52-2**
	25.0	21.5	17.5	10.0	2 3/8 × 4 7/8 × 8 1/2	441	420	**LRS-53-2**
	40.0	34.0	27.5	19.5	3 × 4 7/8 × 11	541	515	**LRS-54-2**
	60.0	51.0	41.0	30.0	3 3/4 × 4 7/8 × 10 1/2	688	655	**LRS-55-2**
	90.0	77.0	61.0	45.0	4 7/16 × 4 7/8 × 11 1/2	853	812	**LRS-56-2**
	130.0	110.0	90.0	68.0	5 × 4 7/8 × 12	1118	1064	**LRS-57-2**
	180.0	147.0	120.0	83.0	5 1/2 × 4 7/8 × 13 1/8	1353	1288	**LRS-58-2**
	250.0	200.0	165.0	125.0	6 5/8 × 4 7/8 × 13 25/32	1647	1568	**LRS-59-2**
5V ±5% ADJ.	4.0	3.2	2.4	2.0	1 1/2 × 4 17/32 × 4 23/32	158	150	**LRS-49-5**
	7.0	5.6	4.2	3.5	1 1/2 × 4 17/32 × 5 15/32	200	190	**LRS-50-5**
	12.0	9.6	7.2	6.0	1 11/16 × 4 17/32 × 7 13/64	252	240	**LRS-51-5**
	15.0	13.7	11.1	5.9	2 × 4 7/8 × 6 1/4	289	275	**LRS-52-5**
	25.0	21.5	17.5	10.0	2 3/8 × 4 7/8 × 8 1/2	394	375	**LRS-53-5**
	40.0	34.0	27.5	19.5	3 × 4 7/8 × 11	483	460	**LRS-54-5**
	60.0	51.0	41.0	30.0	3 3/4 × 4 7/8 × 10 1/2	615	585	**LRS-55-5**
	90.0	77.0	61.0	45.0	4 7/16 × 4 7/8 × 11 1/2	762	725	**LRS-56-5**
	130.0	110.0	90.0	68.0	5 × 4 7/8 × 12	998	950	**LRS-57-5**
	180.0	147.0	120.0	83.0	5 1/2 × 4 7/8 × 13 1/8	1208	1150	**LRS-58-5**
	250.0	200.0	165.0	125.0	6 5/8 × 4 7/8 × 13 25/32	1470	1400	**LRS-59-5**
6V ±5% ADJ.	3.3	2.6	2.0	1.7	1 1/2 × 4 17/32 × 4 23/32	158	150	**LRS-49-6**
	6.0	4.8	3.6	3.0	1 1/2 × 4 17/32 × 5 15/32	200	190	**LRS-50-6**
	10.0	8.0	6.0	5.0	1 11/16 × 4 17/32 × 7 13/64	252	240	**LRS-51-6**
	13.5	12.2	9.9	5.2	2 × 4 7/8 × 6 1/4	289	275	**LRS-52-6**
	21.0	18.5	16.0	8.3	2 3/8 × 4 7/8 × 8 1/2	394	375	**LRS-53-6**
	35.0	31.0	24.0	17.0	3 × 4 7/8 × 11	483	460	**LRS-54-6**
	52.0	44.0	36.0	26.0	3 3/4 × 4 7/8 × 10 1/2	615	585	**LRS-55-6**
	80.0	69.0	54.0	39.0	4 7/16 × 4 7/8 × 11 1/2	762	725	**LRS-56-6**
	110.0	93.0	76.0	58.0	5 × 4 7/8 × 12	998	950	**LRS-57-6**
	150.0	123.0	100.0	70.0	5 1/2 × 4 7/8 × 13 1/8	1208	1150	**LRS-58-6**
	210.0	170.0	140.0	105.0	6 5/8 × 4 7/8 × 13 25/32	1470	1400	**LRS-59-6**
12V ±5% ADJ.	1.7	1.4	1.0	0.9	1 1/2 × 4 17/32 × 4 23/32	158	150	**LRS-49-12**
	3.0	2.4	1.8	1.5	1 1/2 × 4 17/32 × 5 15/32	200	190	**LRS-50-12**
	5.2	4.1	3.1	2.6	1 11/16 × 4 17/32 × 7 13/64	252	240	**LRS-51-12**
	7.8	6.8	4.9	2.3	2 × 4 7/8 × 6 1/4	289	275	**LRS-52-12**
	12.5	11.2	9.6	7.2	2 3/8 × 4 7/8 × 8 1/2	394	375	**LRS-53-12**
	22.0	18.5	15.0	10.0	3 × 4 7/8 × 11	483	460	**LRS-54-12**
	30.0	26.0	22.0	16.0	3 3/4 × 4 7/8 × 10 1/2	615	585	**LRS-55-12**
	47.0	41.0	34.0	21.9	4 7/16 × 4 7/8 × 11 1/2	762	725	**LRS-56-12**
	65.0	58.0	48.0	34.0	5 × 4 7/8 × 12	998	950	**LRS-57-12**
	84.0	69.0	56.0	40.0	5 1/2 × 4 7/8 × 13 1/8	1208	1150	**LRS-58-12**
	110.0	92.0	74.0	53.0	6 5/8 × 4 7/8 × 13 25/32	1470	1400	**LRS-59-12**
15V ±5% ADJ.	1.4	1.1	0.8	0.7	1 1/2 × 4 17/32 × 4 23/32	158	150	**LRS-49-15**
	2.6	2.0	1.6	1.3	1 1/2 × 4 17/32 × 5 15/32	200	190	**LRS-50-15**
	4.2	3.3	2.5	2.1	1 11/16 × 4 17/32 × 7 13/64	252	240	**LRS-51-15**
	6.4	5.6	4.0	1.9	2 × 4 7/8 × 6 1/4	289	275	**LRS-52-15**
	10.0	9.0	7.7	5.8	2 3/8 × 4 7/8 × 8 1/2	394	375	**LRS-53-15**
	18.0	15.0	12.0	8.0	3 × 4 7/8 × 11	483	460	**LRS-54-15**
	25.0	22.0	19.0	13.0	3 3/4 × 4 7/8 × 10 1/2	615	585	**LRS-55-15**
	38.0	33.0	28.0	17.9	4 7/16 × 4 7/8 × 11 1/2	762	725	**LRS-56-15**
	52.0	46.0	38.0	27.0	5 × 4 7/8 × 12	998	950	**LRS-57-15**
	68.0	56.0	45.5	32.0	5 1/2 × 4 7/8 × 13 1/8	1208	1150	**LRS-58-15**
	90.0	75.0	60.0	43.0	6 5/8 × 4 7/8 × 13 25/32	1470	1400	**LRS-59-15**

LR SERIES Switching Power Supplies

SINGLE OUTPUT

	MAX CURRENT AT OPERATING TEMPERATURE OF (A) 40°C	50°C	60°C	71°C	DIMENSIONS (inches)	PRICE QTY. 1	PRICE QTY. 10	MODEL
20V ±5% ADJ.	1.0	0;8	0.6	0.5	1 1/2 × 4 17/32 × 4 23/32	$ 158	$ 150	LRS-49-20
	2.1	1.7	1.3	1.0	1 1/2 × 4 17/32 × 5 15/32	200	190	LRS-50-20
	3.5	2.8	2.1	1.7	1 11/16 × 4 17/32 × 7 13/64	252	240	LRS-51-20
	4.9	4.3	3.0	1.5	2 × 4 7/8 × 6 1/4	289	275	LR5-52-20
	7.7	6.9	5.9	4.5	2 3/8 × 4 7/8 × 8 1/2	394	375	LRS-53-20
	13.5	11.5	8.5	5.5	3 × 4 7/8 × 11	483	460	LR5-54-20
	19.0	16.5	14.0	10.0	3 3/4 × 4 7/8 × 10 1/2	615	585	LR5-55-20
	29.5	27.0	22.0	13.8	4 7/16 × 4 7/8 × 11 1/2	762	725	LRS-56-20
	40.0	36.0	30.0	21.0	5 × 4 7/8 × 12	998	950	LRS-57-20
	52.0	43.0	35.0	24.5	5 1/2 × 4 7/8 × 13 1/8	1208	1150	LRS-58-20
	70.0	58.0	46.0	33.0	6 5/8 × 4 7/8 × 13 25/32	1470	1400	LRS-59-20
24V ±5% ADJ.	0.9	0.7	0.5	0.5	1 1/2 × 4 17/32 × 4 23/32	158	150	LR5-49-24
	1.8	1.4	1.1	0.9	1 1/2 × 4 17/32 × 5 15/32	200	190	LR5-50-24
	3.0	2.4	1.8	1.5	1 11/16 × 4 17/32 × 7 13/64	252	240	LRS-51-24
	4.1	3.6	2.6	1.2	2 × 4 7/8 × 6 1/4	289	275	LRS-52-24
	6.5	5.8	5.0	3.8	2 3/8 × 4 7/8 × 8 1/2	394	375	LRS-53-24
	11.5	9.5	7.5	4.5	3 × 4 7/8 × 11	483	460	LRS-54-24
	16.0	14.0	12.0	8.0	3 3/4 × 4 7/8 × 10 1/2	615	585	LRS-55-24
	25.0	22.5	18.5	11.6	4 7/16 × 4 7/8 × 11 1/2	762	725	LRS-56-24
	33.5	29.0	24.0	17.0	5 × 4 7/8 × 12	998	950	LR5-57-24
	44.0	36.0	29.5	20.5	5 1/2 × 4 7/8 × 13 1/8	1208	1150	LRS-58-24
	60.0	50.0	40.0	28.0	6 5/8 × 4 7/8 × 13 25/32	1470	1400	LRS-59-24
28V ±5% ADJ.	0.7	0.6	0.4	0.4	1 1/2 × 4 17/32 × 4 23/32	158	150	LRS-49-28
	1.6	1.3	1.0	0.8	1 1/2 × 4 17/32 × 5 15/32	200	190	LRS-50-28
	2.5	2.0	1.5	1.2	1 11/16 × 4 17/32 × 7 13/64	252	240	LRS-51-28
	3.5	3.1	2.2	1.1	2 × 4 7/8 × 6 1/4	289	275	LRS-52-28
	5.7	5.1	4.4	3.3	2 3/8 × 4 7/8 × 8 1/2	394	375	LRS-53-28
	9.5	8.5	6.5	4.0	3 × 4 7/8 × 11	483	460	LRS-54-28
	14.0	12.0	10.0	7.0	3 3/4 × 4 7/8 × 10 1/2	615	585	LRS-55-28
	22.0	20.0	16.0	10.0	4 7/16 × 4 7/8 × 11 1/2	762	725	LRS-56-28
	29.0	25.5	21.0	15.0	5 × 4 7/8 × 12	998	950	LRS-57-28
	38.0	31.0	25.5	17.5	5 1/2 × 4 7/8 × 13 1/8	1208	1150	LRS-58-28
	52.0	43.0	34.0	24.0	6 5/8 × 4 7/8 × 13 25/32	1470	1400	LRS-59-28
48V ±5% ADJ.	0.4	0.3	0.2	0.2	1 1/2 × 4 17/32 × 4 23/32	158	150	LRS-49-48
	0.9	0.7	0.5	0.4	1 1/2 × 4 17/32 × 5 15/32	200	190	LRS-50-48
	1.5	1.2	0.9	0.7	1 11/16 × 4 17/32 × 7 13/64	252	240	LR5-51-48
	2.0	1.7	1.2	0.6	2 × 4 7/8 × 6 1/4	289	275	LRS-52-48
	3.3	2.8	2.4	1.8	2 3/8 × 4 7/8 × 8 1/2	394	375	LRS-53-48
	5.8	5.1	3.6	2.3	3 × 4 7/8 × 11	483	460	LRS-54-48
	8.2	7.2	6.2	4.2	3 3/4 × 4 7/8 × 10 1/2	615	585	LRS-55-48
	13.0	12.0	9.5	6.0	4 7/16 × 4 7/8 × 11 1/2	762	725	LRS-56-48
	17.5	15.5	12.5	9.0	5 × 4 7/8 × 12	998	950	LRS-57-48
	22.5	18.5	15.0	10.5	5 1/2 × 4 7/8 × 13 1/8	1208	1150	LRS-58-48
	31.0	26.0	21.0	15.0	6 5/8 × 4 7/8 × 13 25/32	1470	1400	LRS-59-48

MRS SERIES FILTERS

MODEL	COMPATIBLE POWER SUPPLIES	DIMENSIONS (Inches)	WEIGHT (Lbs.)	PRICE QTY. 1	PRICE QTY. 10
MRS-53	LRS-52, 52M, LRS-53, 53M	1 15/16 × 1 13/16 × 1 5/8	.6	$63	$60
MRS-54	LRS-54	3 1/8 × 15/16 × 1 7/16	1	69	65
MRS-55	LRS-55	3 1/8 × 15/16 × 1 7/16	1	74	70

*Contact factory for 48V special filters.

Ripple and Noise Specification with Output Filter

Output Voltage	Ripple RMS	Ripple PK-PK
LR (with MRS Filter)		
2, 5, 6 Volt Models	2mV	12mV
12, 15, 20, 24, 28 Volt Models	4mV	20mV

LR SERIES

Specifications

DC OUTPUT
Voltage range shown in tables.

REGULATED VOLTAGE

regulation, line .... 0.1% from 95 to 132VAC. 95 to 132VAC or 187 to 265VAC on LRS-49, 50, 51, 57, 58 and "M" option models. 187 to 265VAC on LRS-59 and "V" option models.

regulation, load .... 0.1% from no load to full load.

ripple and noise .... 10mV RMS, 35mV pk-pk for 2V models of LRS-49, 50, 51 and all 5V and 6V models. (25mV pk-pk for all other 2V models).
15mV RMS, 100mV pk-pk for 12V through 28V models.
35mV RMS, 150mV pk-pk for 48V models.

temperature coefficient .... 0.03%/°C.

remote programming resistance .... 1000Ω/volt.

remote programming voltage .... volt per volt.

AC INPUT

line .... 95 to 132VAC, 47-440Hz.
95 to 132VAC or 187 to 265VAC (user selectable), 47-440Hz on LRS-49, 50, 51, 57, 58 and "M" option models. 187 to 265VAC, 47-440Hz on LRS-59 only.

power .... LRS-49: 30 watts maximum.
LRS-50: 51.5 watts maximum.
LRS-51: 96 watts maximum.
LRS-52: 137 watts maximum.
LRS-53: 225 watts maximum.
LRS-54: 380 watts maximum.
LRS-55: 515 watts maximum.
LRS-56: 819 watts maximum.
LRS-57: 1100 watts maximum.
LRS-58: 1350 watts maximum.
LRS-59: 1900 watts maximum.

DC INPUT
145VDC ± 10%. (260 to 370VDC for LRS-49, 50, 51, 57, 58, 59 and "M" and "V" option models.)

EFFICIENCY
50% min for 2V model of LRS-49. 55% min for all other 2V models. 65% min for 5V and 6V models of LRS-49. 67% min. for 5V and 6V models of LRS-52. 66% min for 12V and 15V models of LRS-49. 68% min for 5V and 6V models of LRS-50. 70% min for 5V through 15V models of LRS-53, 54; 12V and 15V models of LRS-50; 20V through 48V models of LRS-49. 73% min on 5V and 6V models of LRS-51; 20V through 48V models of LRS-50. 75% min for 5V and 6V models of LRS-55, 56; 5V through 15V models of LRS-57, 58, 59; 12V and 15V models of LRS-51; 12V through 20V models of LRS-52; 20V through 48V models of LRS-53, 54. 77% min for 12V through 20V models of LRS-55, 56. 78% min for 20V through 48V models of LRS-51; 24V through 48V models of LRS-52. 80% min for 20V through 48V models of LRS-57, 58, 59; 24V through 48V models of LRS-55, 56.

OVERSHOOT
No overshoot at turn-on, turn-off or power failure.

OPERATING TEMPERATURE RANGE
Continuous duty −10°C to +71°C with suitable derating above 40°C. Guaranteed turn-on at −20°C.

STORAGE TEMPERATURE RANGE
−55°C to +85°C.

OVERLOAD PROTECTION

ELECTRICAL
External overload protection, automatic electronic current limiting circuit limits the output current to a preset value, thereby providing protection for the load as well as the power supply.

THERMAL
Self-resetting thermostat.

FUSING
Line fuse removes the power supply from the line if a short occurs in the input circuitry.

OVERVOLTAGE PROTECTION
Overvoltage protection is standard on all models. If output voltage increases above a preset level, inverter drive is removed.

COOLING
All units are convection cooled. No fans or blowers are needed.

IN-RUSH LIMITING
The turn-on in-rush current will not exceed 40 amps peak from a cold start. (13 amps on LRS-49, 50. 19 amps on LRS-51. 50 amps on LRS-57, 58, 59.)

DC OUTPUT CONTROLS
Simple screwdriver adjustment over the entire voltage range.

INPUT AND OUTPUT CONNECTIONS
All input, output, sensing, and remote on/off connections for LRS-49, 50, 51, 52 and LRS-53 are made through barrier strip terminals. All input, sensing and remote on/off connections for LRS-54, LRS-55, LRS-56, LRS-57, LRS-58 and LRS-59 are made through barrier strip terminals. DC output connection is made through heavy duty threaded bus bars.

MOUNTING
Two mounting surfaces and two mounting positions on LRS-52, 53, 54. One mounting surface and one mounting position on LRS-49, 50, 51, 55, 56, 57, 58, 59.

POWER FAILURE
2V, 5V and 6V models will remain within regulation limits for at least 16.7 msec. after loss of AC power when operating at full load, V_O max, and 105VAC input at 60Hz. (105 or 210VAC for LRS-49, 50, 51, 57, 58 and "M" option models. 210VAC at 60Hz for LRS-59.)

REMOTE SENSING
Provision is made for remote sensing to eliminate the effects of power output lead resistance on DC regulation.

REMOTE TURN-ON/TURN-OFF
Provision is made for digitally controlled remote turn-on, turn-off (TTL Compatible).

FUNGUS PROOFING
All units are inherently fungi inert.

MILITARY SPECIFICATIONS
The LR Series is built in Lambda factories to quality and inspection procedures which are similar to MIL-I-45208. The LRS-49, 50 and 51 are pending approval of environmental testing. The remainder of the series has passed environmental testing in accordance with MIL-STD-810C.

1) Low Pressure — Method 500.1, Procedure I.
2) High Temperature — Method 501.1, Procedures I and II.
3) Low Temperature — Method 502.1, Procedure I.
4) Temperature Shock — Method 503.1, Procedure I.
5) Temperature-Altitude — Method 504.1, Procedure I. Class 2 (−10°C Operating).
6) Humidity — Method 507.1, Procedure I.
7) Fungus — Method 508.1, Procedure I.
8) Vibration — Method 514.2, Procedures X and XI.
9) Shock — Method 516.2, Procedures I and III.

EMI
Conducted EMI conforms to FCC Docket 20780 Class A, and MIL-STD-461A Notice 4 CEO4 for power leads. LRS-57, LRS-58, LRS-59, and "M" and "V" option models also conform to VDE 0871 Class A.

PHYSICAL DATA

Package Model	Lbs. Net	Lbs. Ship	Size Inches
LRS-49	1 3/8	2 3/8	1 1/2 × 4 17/32 × 4 23/32
LRS-50	1 1/2	2 1/2	1 1/2 × 4 17/32 × 5 15/32
LRS-51	2	3	1 11/16 × 4 17/32 × 7 13/64
LRS-52	2 1/4	3 1/4	2 × 4 7/8 × 6 1/4
LRS-53	3 1/4	4 1/4	2 3/8 × 4 7/8 × 8 1/2
LRS-54	6 1/2	7 1/2	3 × 4 7/8 × 11
LRS-55	7	8 1/2	3 3/4 × 4 7/8 × 10 1/2
LRS-56	8 1/2	10	4 7/16 × 4 7/8 × 11 1/2
LRS-57	10 1/2	12	5 × 4 7/8 × 12
LRS-58	12 1/2	14	5 1/2 × 4 7/8 × 13 1/8
LRS-59	16 1/2	19	6 5/8 × 4 7/8 × 13 25/32

OPTIONS

AC Input

Add Suffix[1]	For Operation at:	Price
−V (LRS-55, 56 only)	185 to 265VAC 47-440Hz	12%
−M (LRS-52, 53, 54 only)	95 to 132VAC or 187 to 265VAC, 47-440Hz (customer selectable)	12%

[1] Add Suffix after package number, i.e.: LRS-55V-5, LRS-52M-5.

ACCESSORIES
Rack Adapters (LRA-14, LRA-15, LRA-17) and cable system available.

FINISH
Grey, Fed. Std. 595, No. 26081.

GUARANTEED FOR 5 YEARS
Five year guarantee includes labor as well as parts. Guarantee applies to operation at full published specifications at end of 5 years.

UL/CSA
UL Recognized. CSA Certified. LRS-49, 50, 51, 57, 58, 59 under evaluation.

TUV LICENSED
110/220 and 220 input versions. LRS-49, 50, 51 under evaluation.

A WAY TO EASE REMOTE-CONTROL PANIC

FREIBURG, WEST GERMANY

Imagine this: a TV remote-control unit, about the size and shape of a ballpoint pen, that puts a menu and a cursor on the screen, allowing the user to select dozens of receiver functions with just one key. And by simply sweeping the unit across the screen, the viewer can set receiver parameters such as brightness, contrast, volume, and balance.

That's not just a pipe dream. It's a concept for which the ITT Semiconductors Group is now developing chips. The outfit will demonstrate the remote-control unit during the Radio and Television Show in West Berlin Aug. 25 to Sept. 3, and set makers should have the first receivers and remote controllers using the chips on the market next year.

Moreover, the system is suited to the coming age of high-definition TV and its promise of a gradual marriage of the personal computer and the TV [*Electronics*, March 1989, p. 70].

NEW GENERATION. "It could be the first of a new generation of remote-control tools replacing the mouse and similar devices," says Sönke Mehrgardt, director of concept engineering and business development at Intermetall GmbH, the group's subsidiary in Freiburg, West Germany, where the chips are being readied.

The ITT concept applies not just to TV sets but wherever equipment is controlled from a monitor—that is, in a man-machine interface, where a cursor and a menu provide visual communication between the display and its operator. The system is superior to the mouse controller used for many personal computers because it is wireless; and it is faster than the key-driven cursor most commonly used to control PC screens.

The idea behind the controller, according to ITT, is to make it easier to work today's feature-laden TV sets. Operating some of the high-end models, particularly those being sold in Europe, can rank right up there with flying a small plane. In some of these sophisticated units, the viewer has to contend with a checklist of options including videotext, teletext, satellite reception and descrambling, and picture freeze and zoom. There may be as many as 20 video and stereo standards, and nine or so picture-in-picture insets. And that's all in addition to the standard TV functions—brightness, contrast, volume, and the like.

Unit controls features from windows to sound, and could replace the mouse

The upshot of all this complexity is remote-control units festooned with as many as 50 keys. Some European TV-set makers have even reluctantly decided not to add features to their new models, in the fear that additional bells and whistles would make controlling the sets still more difficult.

For its part, ITT is taking this problem so seriously that it has set up a human-interface design group whose aim is to facilitate equipment control. "We must make system operation simpler, and one way to do that is to take the complexity out of the human-operated controller and put it into on-chip software," Mehrgardt says. With the new controller, ITT appears to have done that.

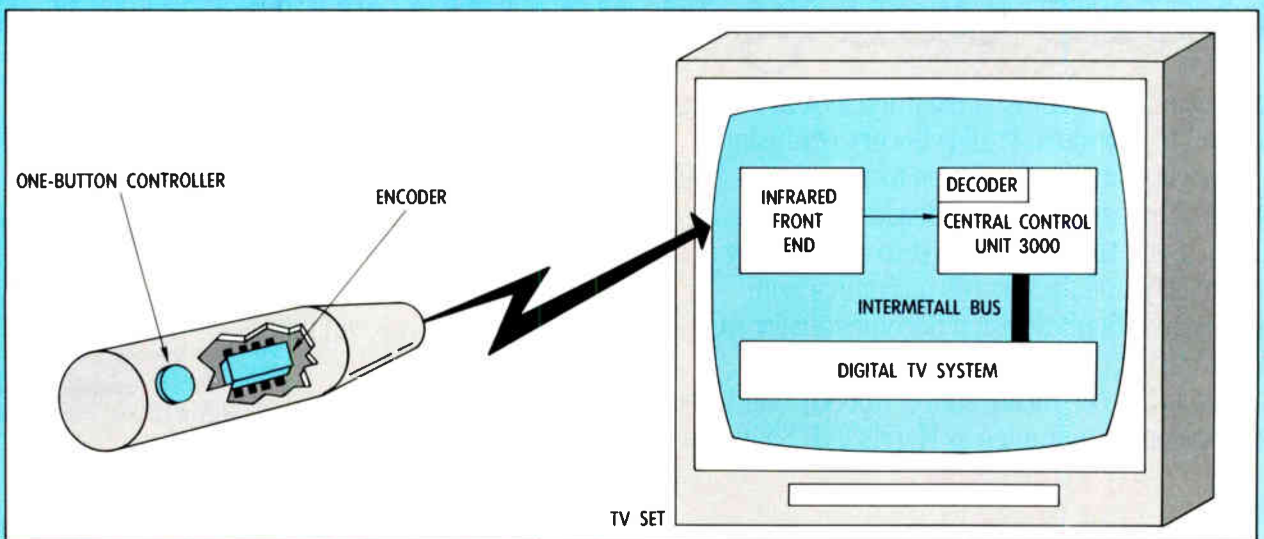
PIECE OF CAKE. Working the new remote controller is child's play: press the key and the screen displays a menu. This may be a horizontal bar divided into several sections, each marked with a channel number. Press the key again and move the cursor to the appropriate section to turn on the desired channel.

Another menu lists the set's special functions—videotext, freeze and zoom, picture-in-picture insets, and others. Again, pointing the cursor to the section in question and pressing the button picks the one wanted. With the cursor it's also possible to move picture insets to any spot on the screen.

Setting the receiver parameters is just as simple: move the cursor to, say, Contrast on the menu, press the key, and a bar will appear on the screen. Then, sweeping the remote controller from left to right across the screen gradually changes the bar's color shade from light to dark, indicating that the receiver's contrast parameter is moving from low to high. In effect, the user controls the adjustment simply by moving his hand.

In principle, just one key will suffice. But some TV-set manufacturers may choose to fit the controller with one or more additional keys for specific channels or often-used functions. More than one

A NEW LOOK IN REMOTE CONTROL



key won't add to circuit complexity, Mehrgardt says.

For remote control, each channel number, receiver function, and parameter selected has its own code, which is digitally enshrouded in the sequence of infrared pulses coming from the control unit. The directional information—which indicates the controller's sweep direction across the screen—is contained in the signals' varying amplitudes.

At the receiver, an IR amplifier boosts this double-modulated signal stream from microvolt to volt levels and feeds it to a microcontroller for real-time processing. The digital and directional data are decoded and finally used to execute the function picked out on the menu to set the receiver to the desired level of contrast, volume, balance, brightness, and so on.

The microcontroller is Intermetall's CCU3000, a 35-mm^2 CMOS chip using 1.5-μm technology. Besides decoding, the chip handles timer, watchdog, and interrupt functions, digital-to-analog and analog-to-digital conversion, and a host of other tasks.

At the heart of the chip is a 65C02 central-processing unit, which performs 5 million operations/s. Because it employs a functionally unchanged 65C02 core, the controller can use program-development systems that are already on the market, including emulators and high-level language compilers. *–John Gosch*

INDUSTRIAL

LIGHTS, SOUND, ACTION: PLANT CONTROL GETS GLITZY

DES MOINES, IOWA

A set of tools for developing software that combines audio, video, and graphics could soon make a big splash in industrial computing. Called RAVE, which stands for Real-time Audio/Video Environment, the tool set should help slash the time and cost it takes to develop sophisticated interfaces for real-time factory process-control systems and for commercial applications like automated teller machines and point-of-sale equipment.

Developed by Microware Systems Corp. in Des Moines, RAVE lets software developers mix high-quality digital sound, still and moving video, and computer-generated graphics in a single system. Microware thinks an ideal application would be simulated control panels—replicas of actual control panels that are displayed on a screen, complete with moving dials and meters, the sound of switches closing and machinery moving. If RAVE lives up to Microware's expectations, the impact could be far-reaching. "We're trying to advance the standards by which man-machine interfaces are judged," says Andy Ball, Microware's vice president of marketing.

The tools run on top of OS-9, Microware's real-time operating system for Motorola Inc. 68000 microprocessors. OS-9 is already available from about 75% of U. S. VMEbus board vendors, is used on 90% of all VME systems in Japan, and is widely used on a number of industrial buses, Ball says. He predicts a number of major vendors of central-processing-unit boards will port RAVE to their systems within a few months after the package is available May 15.

Microware developed the RAVE technology for use in Compact Disk Interactive, the format for a consumer product that merges digital sound with video and computer-generated graphics. Every CD-I player will include an OS-9 operating system, which means potential big business for Microware. But CD-I has been slow to emerge; although it was introduced three years ago, the first players and disks are not expected to reach the market until the second half of this year.

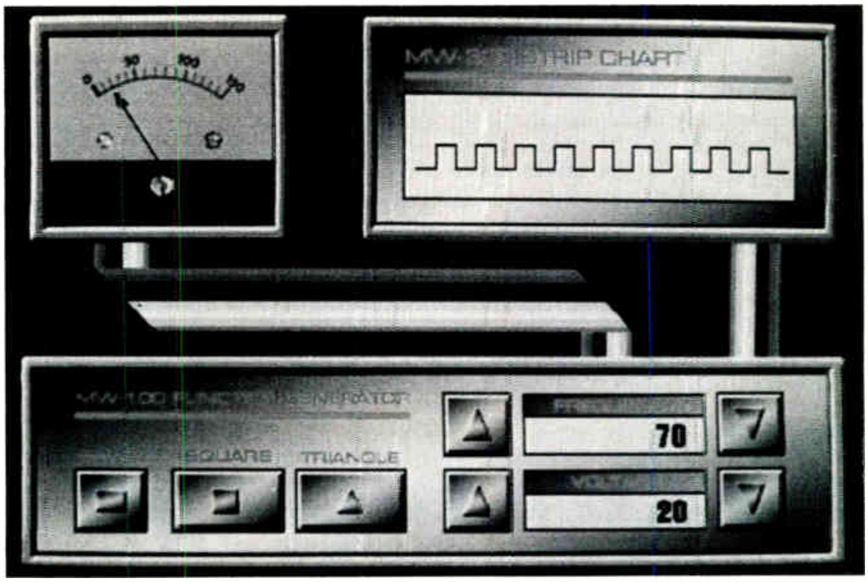
Microware, in the meantime, started looking for other applications for RAVE. "We realized that this was an ideal type

of interface for our primary market in industrial control," says Todd Earles, Microware's manager for multimedia products. Indeed, so suited is it to these applications that the technology might have been designed for process control and embedded systems from the beginning. The package includes a set of software tools that allows systems integrators to quickly and cheaply develop custom audio/video control systems for a variety of equipment types without writing a single line of code. Once an interface is developed, RAVE automatically generates all of the audio, video, and related C source codes that are necessary for a run-time environment.

In the factory, RAVE interfaces will typically run on video touch screens. Ball thinks the technology should prove popular with nontechnical factory personnel, who are often uncomfortable with more conventional monitor and keyboard-type interfaces. "One of the great things about RAVE is that by combining audio with the video, you can give the user confirmative feedback that can really raise his confidence level." A worker turning off a valve might hear the sound of a valve closing, for example, or he might get spoken confirmation that it has closed.

One outsider who shares Microware's enthusiasm is Tim Elsmore, cofounder at Tecma Microsystems Inc. The San Diego startup is developing a VMEbus audio/video controller board for RAVE applications. Elsmore says the board will be available in July, priced between $1,500 and $2,000 in single-unit quantities. "This audio/video interactive stuff is the wave of the future," Elsmore says. "We've already seen glimpses of it in factory automation, where people are starting to use video-interactive touch screens."

But until now, Elsmore says, factory graphics interfaces have made little, if any, use of audio feedback beyond nondescriptive beeps and buzzes. And for existing factory systems, "in every case, a systems integrator had to define and write his own package, because there's been no standard environment for audio/video work," he says. "If Microware is successful, this will cut development time for interactive graphics interfaces down from something



The RAVE factory-control scheme from Microware Systems lets software developers mix high-quality digital sound, still and moving video, and computer-generated graphics.

like two years to six months."

Ball goes even further, claiming that typical RAVE development time could be one sixth that required today. What's more, he says, a RAVE interface can run on much simpler hardware than current factory human-machine interfaces, which typically require powerful graphics processors and other exotic gear. "You can use a simple bit-mapped video controller, as cheap as you can go, and RAVE will work just fine. And you can also use a very simple audio controller." That means that hardware for RAVE can be built for 50% to 75% less than that required for today's video factory interfaces, Ball says.

The RAVE package will be offered in three separate modules. Audio, video, keyboard, and mouse drivers are provided. So are drawing and block-copy primitives, which supplement a library of stock video images of more than 40 different types of commonly used controls and indicators, ranging from push buttons and slide bars to strip-chart and numeric readout indicators. RAVE developers can also produce digitized images of actual controls using a video camera. Images created, called up, or captured can be modified using RAVE's paint-box graphics package. RAVE's audio tools similarly allow developers to capture or create, edit, and play back audio segments, including voice messages or recorded sounds. Audio may be input from any external source, such as a microphone or cassette, or loaded from a disk.

In single-unit quantities, a RAVE development package will cost $1,470. Board vendors that need only the drivers and other software necessary to make their products RAVE-compatible can get volume pricing of the tool set at "well under $200 per copy," Ball says. *–Wesley R. Iversen*

SEMICONDUCTORS

NATIONAL IS STAKING OUT OFFICE IMAGING

SANTA CLARA, CALIF.

National Semiconductor Corp. is staking out a position as the dominant supplier of embedded processors for office-imaging hardware, from laser printers to fax machines and copiers. The Santa Clara company introduced late last month the second in a family of processors spun off from its Series 32000 of 32-bit microprocessors.

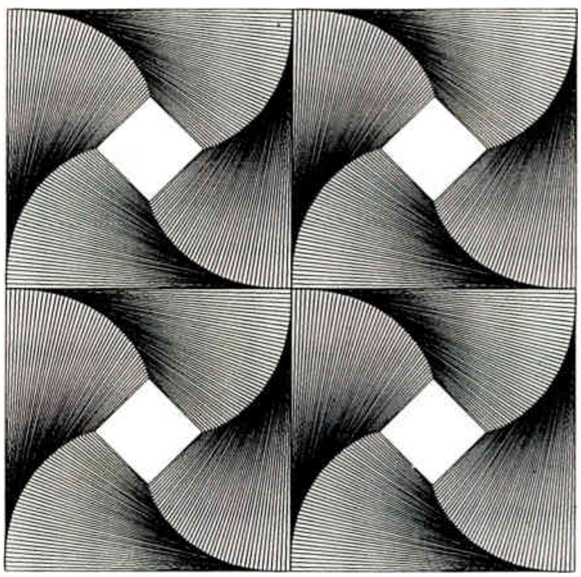
The new device, the NS32GX32, is a processor with an application-specific instruction set tailored to execute Postscript commands and other image-specific tasks. It is aimed at high-end laser-printer applications, along with a variety of office-peripheral jobs in applications such as scanners, copiers, and facsimile systems. Eventually, National thinks, it could be used in next-generation imaging peripherals that combine all of these functions.

The NS32GX32 complements the first processor in the family, the NS32CG16, which was introduced in 1987 and is intended for use in low-end laser printers. The new chip can help power large-scale laser printers, capable of printing from eight to 80 pages per minute; the NS32CG16 works with smaller, personal printers that run at two to eight ppm.

Coupled with National's relationship with Japan's Canon—National provides the embedded processors for all Canon's laser-printer engines, which represent almost three-quarters of the laser-printer engines sold worldwide—the introduction of the new processor gives National a solid position covering the full range of office-imaging applications.

By contrast, most of the other companies selling embedded processors for imaging are concentrating on page printers, a class comprising both laser and ink-jet printers, says Giora Yaron, vice president of the microprocessor product group at National. Their reasons for doing so are obvious: the printers represented 95% of all sales of 32-bit processors for the office-imaging market in 1988, according to Dataquest Inc., a San Jose, Calif., market-research firm. Moreover, Dataquest expects sales in this category to grow rapidly, zooming from $13.4 million last year to $175.6 million in 1993.

But National is taking a longer view, Yaron says. "When you look a little closer at the imaging segment of the office-peripherals market, what you find is that the share for page printers will constitute less than 50% of the total sales" in the not-so-distant future, he says. By 1993, scanner sales are expected to grow fivefold, to 15% of the overall market. In the same time frame, fax-machine sales will grow tenfold, accounting for 10% of the market. So it makes more sense, Yaron believes, for National to develop a product line that it can sell to all these segments of the office-peripherals market.



With the NS32GX32, this line drawing can be executed in just 640 ms. With the NS32CG16, the job takes 5,003 ms.

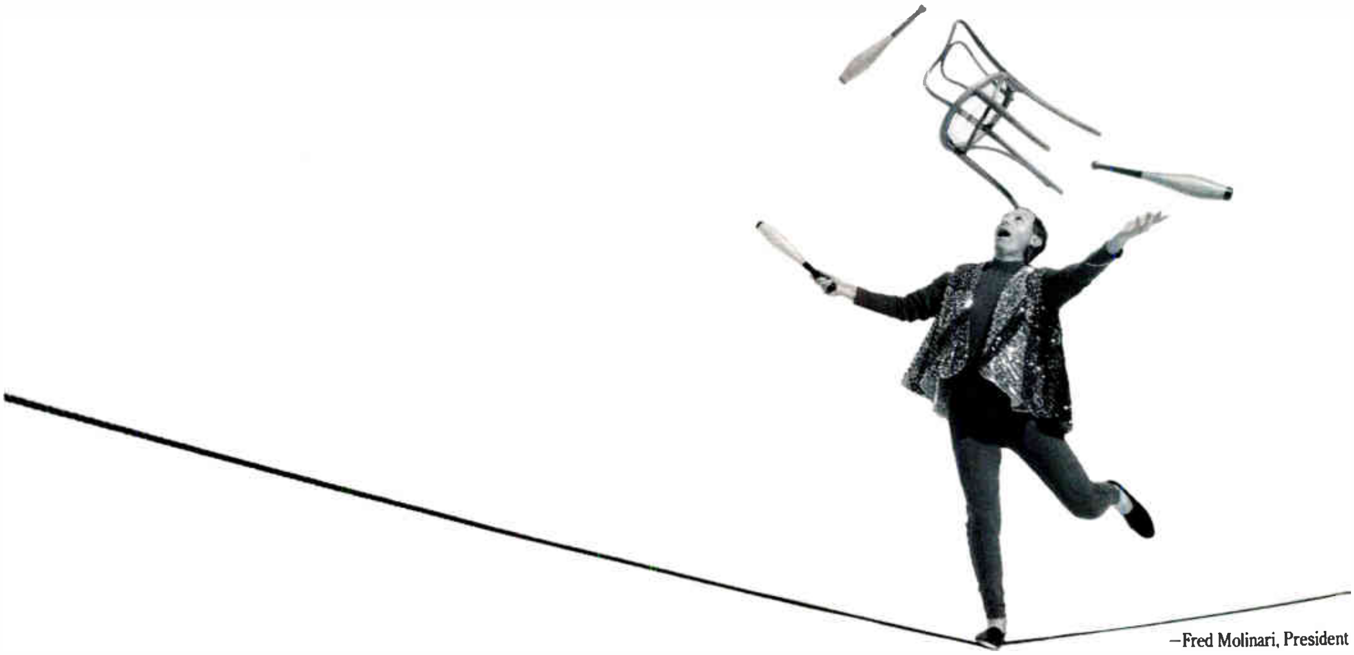
The common thread in all those applications is the use of bit-mapped graphics to capture, draw, store, and transmit digital representations of images. That's why National was able to so easily adapt its general-purpose processors, the Series 32000, to office imaging—the firm merely had to add instructions specific to bit-mapped graphics manipulation to the 32000's instruction set.

In addition, National then incorporated a number of image-processing functions on the chip. For example, the 32GX32 includes logic for bit-block-transfer functions such as line-drawing primitives. Moreover, the chip also carries instructions for implementing one- and two-dimensional data-compression algorithms. These include the modified Huffman code, which is required to meet Group III facsimile standards.

The 32GX32 also incorporates on-chip a two-way set-associative data cache. In conjunction with special stack instructions, this feature gives the designer an extremely powerful engine for processing page-description languages such as Postscript, according to Yaron.

Then too, the one device also incorporates a number of features that generally have been implemented off the chip. Among them are an oscillator, logic for direct memory access, and interface logic for use with external slave microcontrollers. Finally, the device embodies logic to support an optional external bit-block-transfer accelerator.

A high-speed bus boasts internal bandwidth of 240 Mbytes/s and external bandwidth of 96 Mbytes/s. Running at clock rates up to 30 MHz, the chip has a real-time interrupt response of only 1.23 μs and can do context switching in just 3.6 μs, Yaron says. *–Bernard C. Cole*



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Circle 9

WORK STATIONS

HOW DEC AND DG WILL GIVE SUN A RUN FOR ITS MONEY

WESTBORO, MASS.

In their effort to overtake Sun Microsystems Inc. in the work-station race, longtime rivals Digital Equipment Corp. and Data General Corp. are harkening to an old adage: if you can't beat 'em, join 'em. Both DEC and Data General have embraced reduced-instruction-set computing for a new line of work stations, and both have augmented their proprietary operating systems with AT&T Co.'s Unix. Sun, of course, has long championed both RISC and Unix in its work stations.

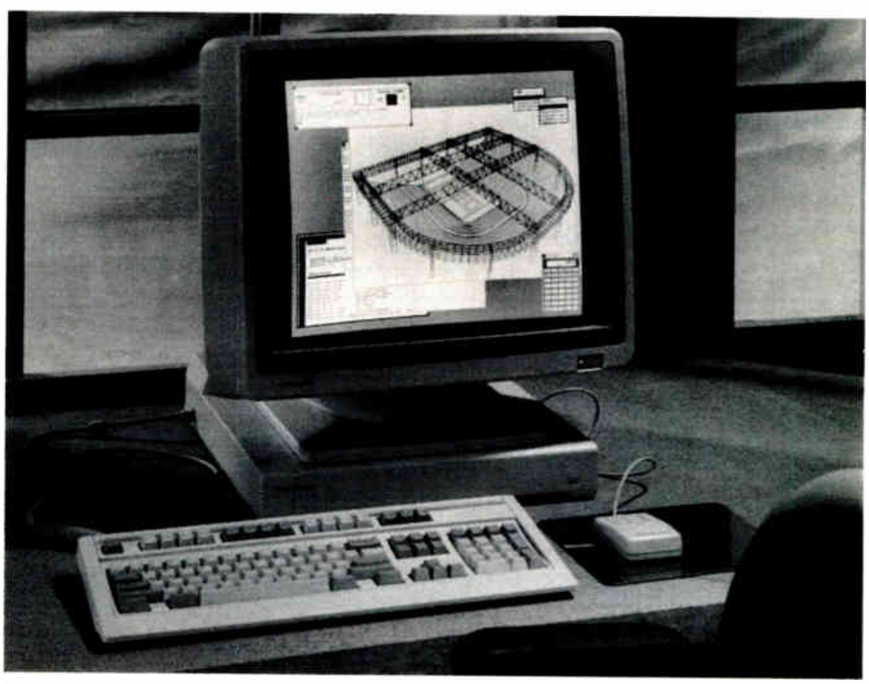
DEC got onto the track first, but Data General soon was running hard and threatening to catch up [*Electronics*, March 1989, p. 15]. The DEC RISC-based work stations, introduced by the Maynard, Mass., computer giant in January, set a new price/performance standard for such systems at the time: $850 per million instructions/s for a 14-mips unit priced at $11,900 [*Electronics*, February 1989, p. 49]. But Data General, in Westboro, Mass., promptly toppled that mark by coming in at less than $500/mips with a 17-mips work station selling for $7,450.

The adoption of RISC-based platforms designed for the Unix operating system, although anticipated by analysts, is a major shift into open systems for both companies. Until now, each had relied mainly on computers built with proprietary architectures to run proprietary operating systems. The obvious reason for the move is that despite their traditional strengths in minicomputers, both companies are scrambling to catch up to Sun, the acknowledged work-station leader.

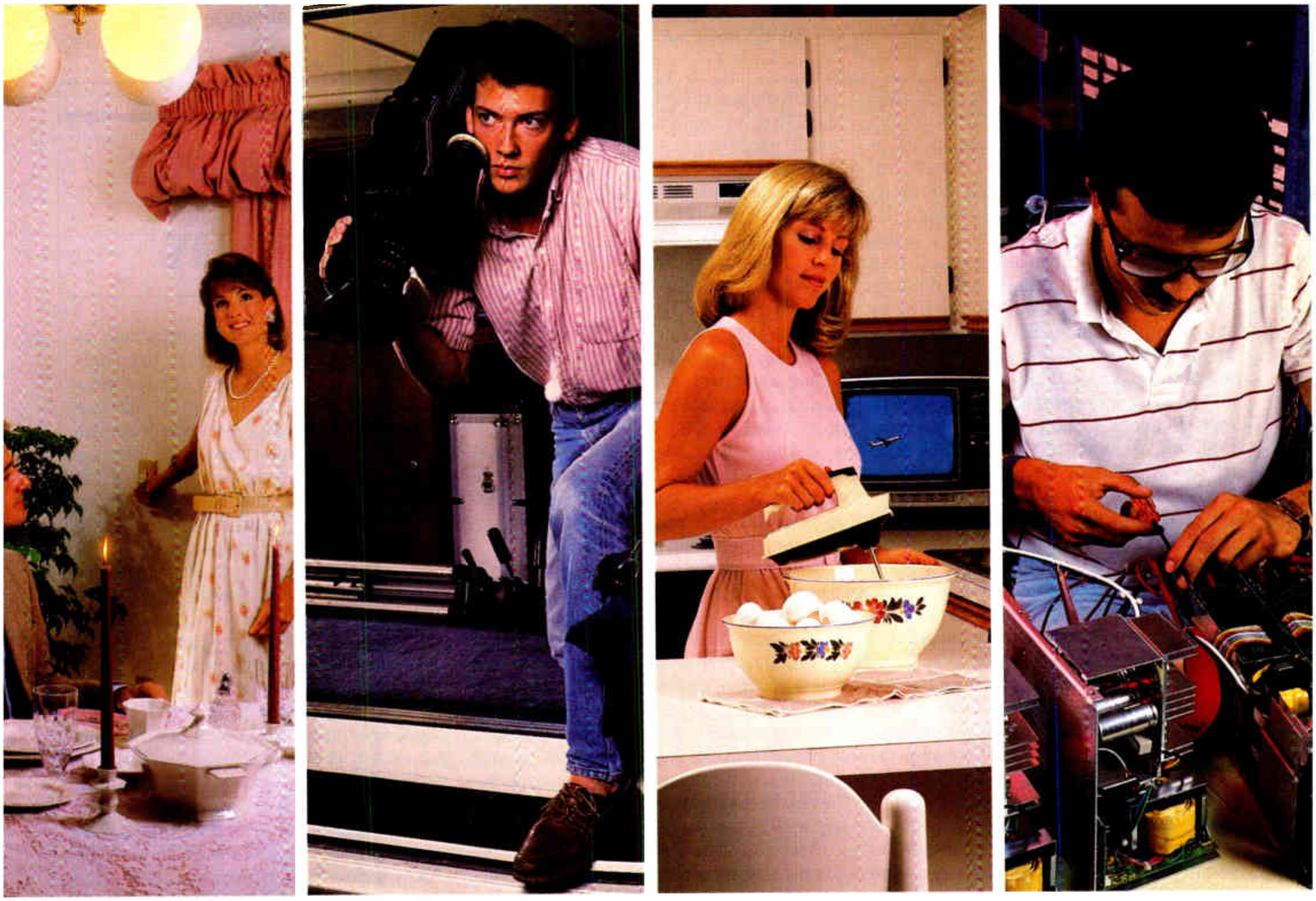
The gospel according to DEC had previously been that VAX hardware running DEC's VMS operating system was all customers needed, from the desktop to the corporate mainframe. Similarly, Data General had long relied for growth on its MV/Eclipse architecture running the company's Advanced Operating System. Each firm will continue to support and expand its proprietary family, but both are committing heavily to RISC-based Unix systems, tacitly admitting that, at least when it comes to work stations, the old standbys aren't going to give them the kind of robust growth they would like.

Both are late starters in the RISC race, however, where Sun is well established with its Sparc architecture. Sun has the largest market share in work stations overall and especially in technical work stations. DEC is moving fast—Vicki Brown, senior analyst at International Data Corp., Framingham, Mass., an authority on work stations, estimates that the company finished second only to Sun in 1988 work-station units shipped, displacing Apollo Computer Inc. of Chelmsford, Mass.

Data General thinks it can gain ground, too. Its new RISC products are among the first to employ Motorola Inc.'s



Data General enters the market for RISC work stations with this 17-mips machine, built around the Motorola 88000 and selling for the same price as a personal computer.



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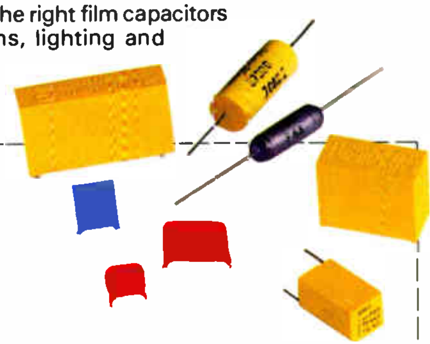

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88000 CMOS microprocessor. (DEC uses the R2000 processor from MIPS Computer Systems Inc. in Sunnyvale, Calif.) Herbert Osher, Data General's director of product marketing, says his company chose the 88000 for several reasons. He maintains that the 88000 embodies "a better system-design concept in that it's a complete unit, with integer and floating-point processors on one chip, and cache and memory management on another."

UPWARD MOBILITY. Further, Osher says the 88000 is more easily upwardly scalable to drive larger systems without software headaches than other RISC chips. Finally, "We also thought it was important to have an emitter-coupled-logic implementation of the chip to build a broad range of high-performance systems." Data General is designing the ECL version of the 88000 for Motorola; it will deliver 100 mips when it debuts in 1991.

For now, however, Data General is content with the 17 to 20 mips the CMOS chips rack up in Dhrystone performance, Osher says. That's because the first target market is the midrange niche served by PC-like work stations, not the high-performance Sun and Apollo technical systems. Because Data General hadn't seriously dented this market, "we don't have a work-station business to protect, so we can be as aggressive as possible" in pricing the systems, Osher says. The $7,450 price applies to a diskless, monochrome-monitor work station having 4 Mbytes of memory and built around a 16.7-MHz version of the 88000.

The Data General family also has four other versions of the work station with monochrome or color monitors, disk drives, more memory, and/or a 20-MHz 88000. There are also two servers, ranging in price from $52,000 to $90,000, depending on memory.

IDC's Vicki Brown says Data General has indeed got "absolutely the best price/performance ratio in a work station today. They've beaten DEC. Unfortunately, price/performance may not be enough for Data General to succeed in the market. My main concern is that they may not be able to penetrate sufficiently outside their own installed base. They're very late getting into work stations; it may be too late for them ever to be perceived as a major player."

Data General claims it's in for the duration. When he introduced the initial RISC family members, Edson de Castro, Data General's president, said: "The technologies we're showing . . . are a first important step in a multiyear process to implement a distributed applications architecture permitting applications to be distributed over a wide range of open hardware and communication platforms."

Another analyst, however, says that for Data General it could be a very long haul indeed. "It might take a year or more for both Data General and Digital to develop significant momentum" for their RISC work stations, says Mark Stahlman, a research analyst who follows the work-station market for Sanford C. Bernstein & Co. Inc., New York. It will take the two companies that long, he believes, to make up for the lag in developing application software.

And Stahlman isn't convinced that Data General will be able to deliver sustained performance in the 17-to-20-mips range. He believes 10 to 13 mips will be more likely. Finally, he points out that the price for a useful work station—including a color monitor, 8 Mbytes of memory, and an 80-Mbyte hard-disk drive—will probably come in at about $17,000.

"It's still an interesting product at that price, even at 13 mips," Stahlman says. "However, the software question is still a bit cloudy. The competitive impact of a product like this may take a year to determine." *–Lawrence Curran*

MILITARY

THE PENTAGON'S PAPER PURGE IS UNDER WAY

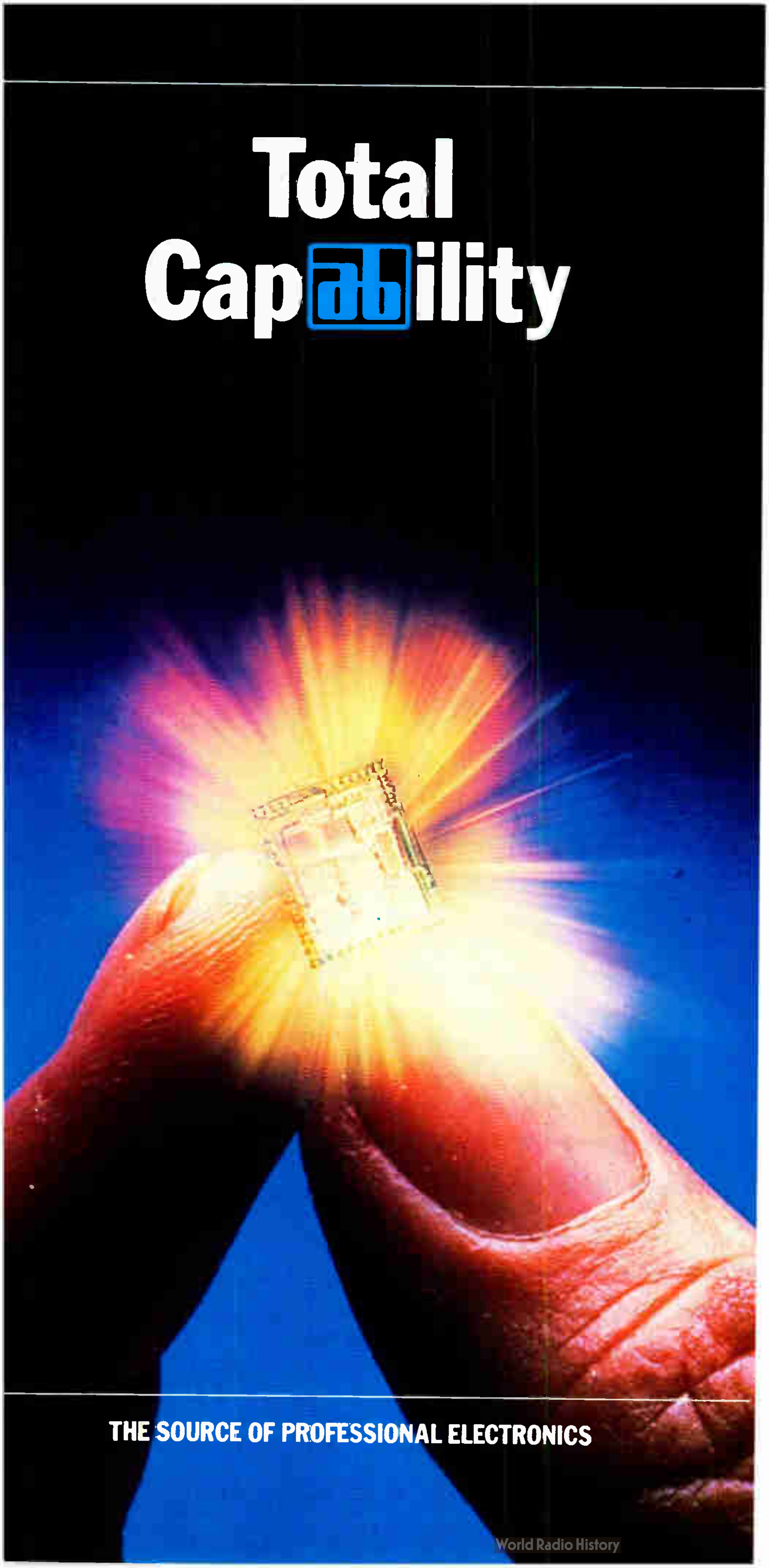
WASHINGTON

The Defense Department is turning up the pressure to get industry to comply with its Computer-Aided Logistics Support standards. Now four years old, this push to convert weapon-system documentation from paper to the more pliable electronic form is moving further out of the test phase and into the realm of everyday contracting. "Companies without CALS capabilities will not win contracts," says Paul R. Cataldo, director of integrated logistic support policy for the Navy. "It's that simple."

That goes for the Army and Air Force as well. All three services are now proving out the CALS concept on their highest-profile weapons programs. Among these are the Navy's A-12 Advanced Tactical Aircraft and its SSN-21 Sea Wolf Attack Submarine; the Army's LHX Lightweight Attack Helicopter; and the Air Force's Advanced Tactical Fighter and V-22 Osprey Tilt-Rotor Aircraft. Indeed, the Navy's Sea Wolf program this winter demonstrated one of CALS' biggest benefits for the first time: it transferred design drawings in digital form from Newport News, Va., which is running the submarine program, to Groton, Conn., where Electric Boat Co. is building it.

But the multibillion-dollar CALS program is not without its struggles, technical and otherwise, and supporters fear that tight military budgets in the next few years could slow it down. "Technologies that don't shoot—that don't kill people—will have a hard time competing" for

Circle 217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funding in the current constrained budget environment, says Alfredo Campo, the Army's assistant deputy for logistics. "The benefits of CALS have to be translated right to the soldier. If we can't do that, we won't get a penny for it."

The Pentagon needs money to add data-processing equipment that can handle the increase in incoming data. It also needs to develop data bases and networks that will allow it to freely exchange data between its own computers and those belonging to its contractors.

Those benefits revolve around combat readiness and quick, easy repair. One of the greatest hopes for CALS is that it can reduce the monstrous amounts of paper documentation that are carried aboard ships and aircraft so that, should a system or component break down, instructions for finding and replacing the faulty part are aboard. But paper is hard to keep track of, hard to update, and enormously heavy. Some estimate, for example, that if the paper documentation were removed from the average Navy ship and replaced with magnetic or optical media, the vessel could sit up to 3 in. higher in the water. That would make it faster, permit it to carry additional equipment, or both. A 9,600-ton cruiser carries as much as 26 tons of documentation in its hull.

Likewise, the Air Force hopes to shed the weight of the paper documentation from its cargo planes. Digitizing technical orders that remain with the C-17 cargo aircraft in flight will save 1,000 lbs of on-board weight, says Mary K. Cronin, director of plans and programs in the Air Force's Product Assurance and Acquisition Logistics Office in Washington.

The DOD plans to have all its data-interchange standards in place by 1992, when all contracts will require CALS as a matter of course. However, officials are satisfied for now with a commitment from contractors that they will implement CALS data-exchange standards where applicable as soon as the standards become available.

Implementing and paying for CALS in new weapons systems will be relatively easy. "CALS costs will be built into the cost of the program," says Michael McGrath, director of the Pentagon's centralized CALS Policy Office in Washington. But paying for them in existing programs may be much harder, he says, because in requiring the paper-to-digital switch, CALS will cost more up front.

EATING PROFITS? Also, since most of the cost savings CALS promises are not realized until the acquisition and maintenance phases of a program's life, contractors fear that these savings to the Pentagon will eat into profit margins they had been counting on to offset investments made early in the program.

"There is little incentive on the part of a contractor to reduce his profit base," McGrath says. So "in existing weapons systems we're looking at incentive programs, such as the Industrial Modification Incentive Program or Value Engineering—programs that were developed for other purposes but that can be used here." These programs typically permit a contractor to share in the savings created by making changes in contract specifications [*Electronics*, August 1988, p. 31].

Overall, however, industry is ready and willing to embrace CALS, and a variety of industry groups have invested in developing the necessary technologies and standards to bring the project to fruition. These include PDES Inc., a consortium of defense contractors that is developing the Product Data Exchange Specification, and computer-graphics companies that must create standard computer-screen formats that can be supported in a range of hardware and software environments. Even the Commerce Department is getting in on the act through its Na-

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tional Institute of Standards and Technology (formerly the National Bureau of Standards), which is developing a PDES test bed to test emerging standards in a real manufacturing environment.

Industry, in fact, may be even more excited about the prospects presented by CALS than the military. Company managers see CALS as a driver, pushing electronic data interchange, or EDI, past its current level as a purchasing and ordering tool [*Electronics*, February 1989, p. 126] and into the design environment, where it can be used to trim time to market and become a valuable competitive tool. "In the long term, adoption of CALS won't be used to gain a competitive advantage," says Paul Perchersky, MIS director at defense electronics specialist E-Systems Inc., Dallas. "It will be used to protect yourself from being put at a competitive disadvantage." *–Tobias Naegele*

SIMULATION

NEW TOOLS AID SIMULATION AT THE PC-BOARD LEVEL

SAN JOSE, CALIF.

Designers of printed-circuit boards increasingly are looking to follow the lead established by designers of application-specific integrated circuits—they want to simulate the operation of their boards before they actually build them. Until recently, board-level simulation has been held back by the lack of effective tools, particularly those capable of modeling. But now that situation is beginning to change.

The latest instrument to emerge for board designers is a general-purpose hardware modeler from Logic Modeling Systems Inc. that works with any simulator, whether it's a commercial or a proprietary system. The hardware simulator reinforces an increasing number of behavioral software models with new debugging features in the board designer's arsenal—models that are likely to soon be described in a standard language, VHDL. Joining the new simulation tools will be related design aids like the ASIC emulator from Quickturn Systems, which enables designers to emulate ASICs in a prototype system early in the design cycle. The Quickturn system can also be used in a simulation environment, where it functions as an accelerator.

A hardware simulator, software models, and an ASIC tool aid designers

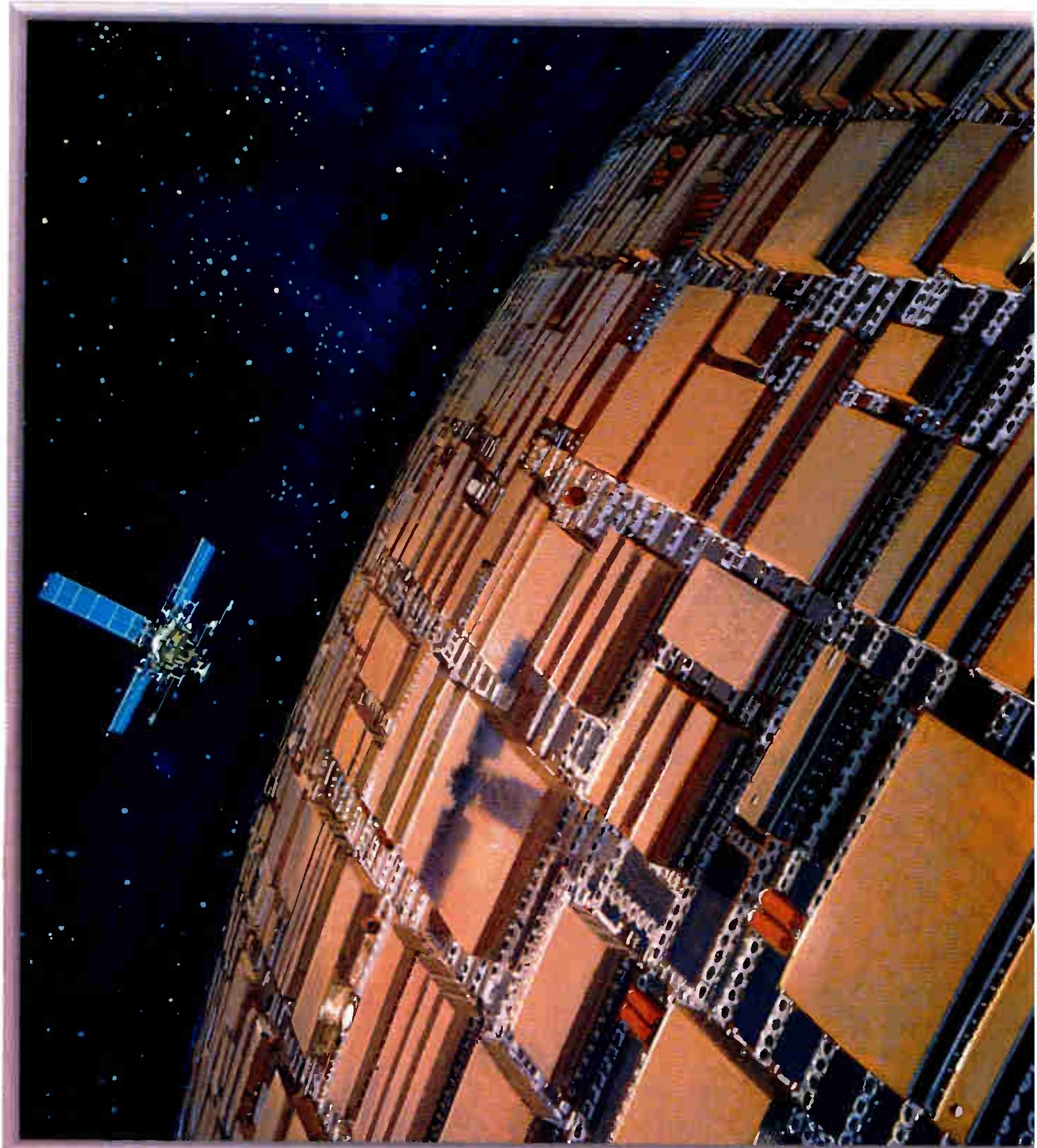
The market for simulation in general is booming. The digital simulation market will be worth $290.5 million this year, according to Cindy Thames, vice president at The Technology Research Group in Boston, and the analog simulation market will be worth $100 million. She predicts that both will more than double by 1992, with digital reaching $586.7 million and analog, $288.5 million. "Board-level simulation still represents a relatively small percent of the total simulation market," coming in at around 5%, she says. "But it's growing."

Logic Modeling Systems' LM1000 is sure to propel this growth. It is the first networked hardware modeler that has been tightly integrated with most of the popular simulators running on industry-standard platforms, says L. Curtis Widdoes Jr., founder, president, and chief executive officer of the San Jose company. This is important, since designers use simulators from more than one vendor of computer-aided-engineering systems.

Software provided with the LM1000 transparently connects the modeler to any commercially available simulator running on any work station, locally or over a network. Also, the system can be easily programmed to work with any in-house simulator now available. By contrast, a proprietary hardware modeler from a CAE company supports only that firm's simulator and hardware platforms. "You can also use the LM1000 hardware modeler to model ASICs," says Holly Stump, director of marketing at Logic Modeling. "You can replace the gate-level description of the chip with the chip itself, and speed up the simulation considerably."

One reason the hardware modeler will facilitate board-level simulation is that it gives instant availability of models of all the devices that designers might want to wire onto their boards. In the past, designers performing board-level simulation never had all the models they needed and had to write some models themselves. Logic Automation Inc. of Beaverton, Ore., is in the business of developing such models. It has more than 4,000 models in its SmartModels library, which costs $9,900 annually (see p. 122).

Software models offer debugging facilities that are not available on a hardware modeler. For example, Logic Automation announced last month the introduction of SmartModel Windows, which enables designers to look inside a model during simulation. "With Windows, you can access internal registers of the device being modeled," says Robert Hunter, the company's vice president of marketing. "You



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THE $500 MILLION QUESTION: WILL CONGRESS FUND HDTV DEVELOPMENT...

The hottest thing on Capitol Hill these days is high-definition TV. Saying that HDTV development is vital to U. S. competitiveness in world markets, Rep. Don Ritter (R., Pa.) introduced a bill last month that would provide up to $500 million over the next five years to assist U. S. industry in meeting the challenge of Japanese and European competitors. The HDTV Competitiveness Act of 1989 also would make the R&D tax credit, now scheduled to be phased out of the tax code at the end of this year, permanent when used to invest in HDTV-related research. Moreover, the bill would open up antitrust restrictions to encourage cooperative R&D among major industrial players; and it would give the Commerce Department broad authority to establish programs to help industry develop and commercialize HDTV technology, including "special assistance for pilot [manufacturing] projects." The bill is now under the review of four House committees, but don't look for instant action. The average bill takes almost 20 months to wend its way through Congress. ☐

...AND WILL THE BUSH ADMINISTRATION SUPPORT SUCH FUNDING?

Developing a U. S. presence in HDTV is a "top priority" at the Commerce Department, says Commerce Secretary Robert A. Mosbacher; in fact, "there is nothing at this point that has a higher priority." As the President's point man for HDTV policy, Mosbacher is heading an interagency Economic Policy Council that "is now studying what the government's role should be in advanced TV." But he stops short of supporting federal financing of HDTV-technology ventures, insisting that "I have not made up my mind on government participation." Instead, he says, industry should be encouraged to make the investments on its own, with government aid limited to removing legal barriers that might be blocking the establishment of cooperative research ventures. In the meantime, however, Mosbacher will have his hands full trying to mediate a dispute over the U. S. stand on a worldwide production standard for HDTV. The State Department, which controls all international agreements, is holding steady to its 1985 decision to back Japan's 1,125-line, 60-Hz MUSE production standard, despite warnings from critics who say that decision was based on a now-faulty premise—that a single worldwide production standard could be found. Since Europe and Japan have already vowed to go different ways, these critics say, the U. S. should think twice before committing to MUSE. ☐

DARPA MAY BOOST HDTV FUNDING PAST $30 MILLION

In yet another HDTV development, the Defense Advanced Research Projects Agency wants to boost funding for HDTV research significantly beyond the $30 million set aside for it last fall, says Craig Fields, Darpa's deputy director for research. Fields also suggests that other money, collected from other defense and nondefense agencies, may be pooled to help fund HDTV research in the next several years. Darpa was swamped with 87 HDTV proposals in late February in response to a request for advanced-TV research ideas. Subjects ranged from transmission systems and displays to sophisticated microelectronics. Given the quality of the proposals, Fields says, the U. S. not only has a chance to compete on a worldwide scale in HDTV, it "certainly has the opportunity of winning as well." Darpa plans to categorize the proposals—which came from 73 U. S. companies plus the American subsidiaries of Sony Corp. of Japan and Philips International NV of the Netherlands—and assemble them "into a cohesive program," Fields says. Darpa will seek to forge industry alliances to create a program larger in scale than many had originally thought possible. And it's not "shutting the door" on future HDTV proposals; the agency will continue to support such research "for years," he says. ☐

WASHINGTON INSIDER

NOW IT WILL BE EASIER TO SELL RAD-HARD CHIPS OVERSEAS

The Defense Department is loosening up export restrictions for radiation-hardened integrated circuits, chips that are designed to withstand the harsh radiation environments of outer space and those near-nuclear explosions. The new rules reverse an order, implemented in 1985, that "effectively dried up our rad-hard markets overseas," says Joe Tirado, manager of strategic marketing for military programs at Harris Corp.'s Semiconductor Sector. Those rules banned the export of any chips capable of withstanding total-dose radiation over 100 kilorads—just about all rad-hard and rad-tolerant chips. "Companies, and not just Harris, lost millions of dollars in sales," says Tirado, whose division is the world's largest supplier of rad-hard circuitry. The Pentagon's new rules, written with input from industry and slated for release this month, permit the sale of circuits with total-dose hardness up to 500 kilorads to members of the North Atlantic Treaty Organization, Japan, and Australia. The main restriction is that the chips can't exceed three other hardness parameters: for dose-rate upset, neutron radiation, and single-event upset. The new regulations also set export policy for chips that meet only some of these characteristics and for parts that, while not designed to be rad-hard, exhibit significant radiation tolerance nonetheless for total dose, dose-rate-upset, and single-event-upset radiation. □

ELECTRONIC TECHNOLOGIES TOP THE PENTAGON'S 'CRITICAL' LIST

How dependent on electronics has the Defense Department become? Very dependent: 17 of the 22 technologies it lists as "critical" to the long-term security of the U. S. are electronics-related. The list, the latest in a series of government and industry-funded reports aimed at identifying "key," "critical," and "essential" technologies for Pentagon investment and nurturing, identifies a broad mix of technologies ranging from semiconductor manufacturing know-how to software producibility; from the development of fiber-optic technology to robotics, parallel computing, phased-array radars, and passive sensors, which can detect an enemy threat without emitting a telltale signature of their own. But the report is just the beginning of what is likely to be a long, drawn-out debate between Congress and the Pentagon over how well the Pentagon is managing its technology initiatives. Sen. Jeff Bingaman (D., N. M.), chairman of the Defense Industry and Technology Subcommittee of the Senate Armed Services Committee, says he's not sure the Pentagon is managing its research funds as well or as efficiently as possible, and he plans hearings this month to press the military and industry on the list's credibility. □

THE AEA SAYS THE JAPANESE FSX PROJECT IS A 'BAD DEAL'

The U. S. should scrap its deal to provide the Japanese with vital F-16 aircraft technology because it will accelerate Japan's penetration of the U. S. market for advanced avionics, says J. Richard Iverson, president of the American Electronics Association. "If you look at the FSX from the electronics point of view, it's a bad deal," he says. The deal would provide Japan with the F-16's basic airframe and engines, but not the electronic technology that makes up about 40% of the aircraft. Iverson says AEA members are worried that the Japanese will not just develop their own avionics suite for the FSX—one that would include, among other advanced features, a high-power modular phased-array radar—but that they will then try to use that advanced technology to compete against U. S. makers in future U. S. avionics programs. "There's no darned American electronics in that airplane," Iverson says, adding that he thinks the Japanese should buy at least some of their airborne electronics from the U. S. Japan figures to spend about $4 billion on electronics for the FSX over the life of the program. □

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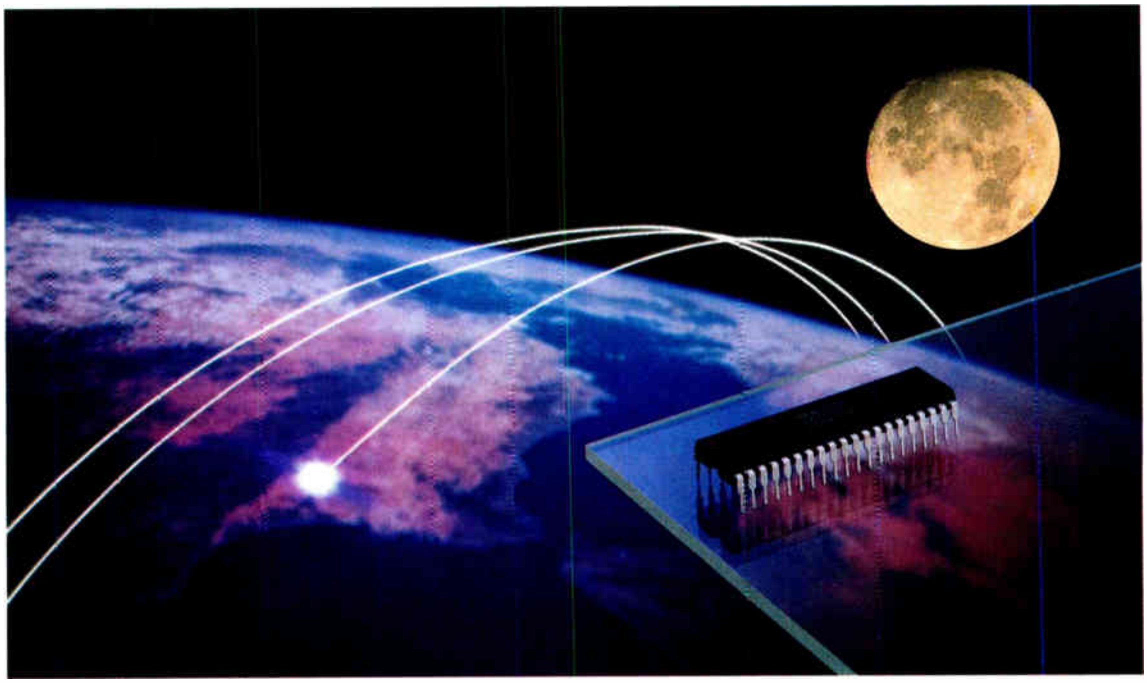

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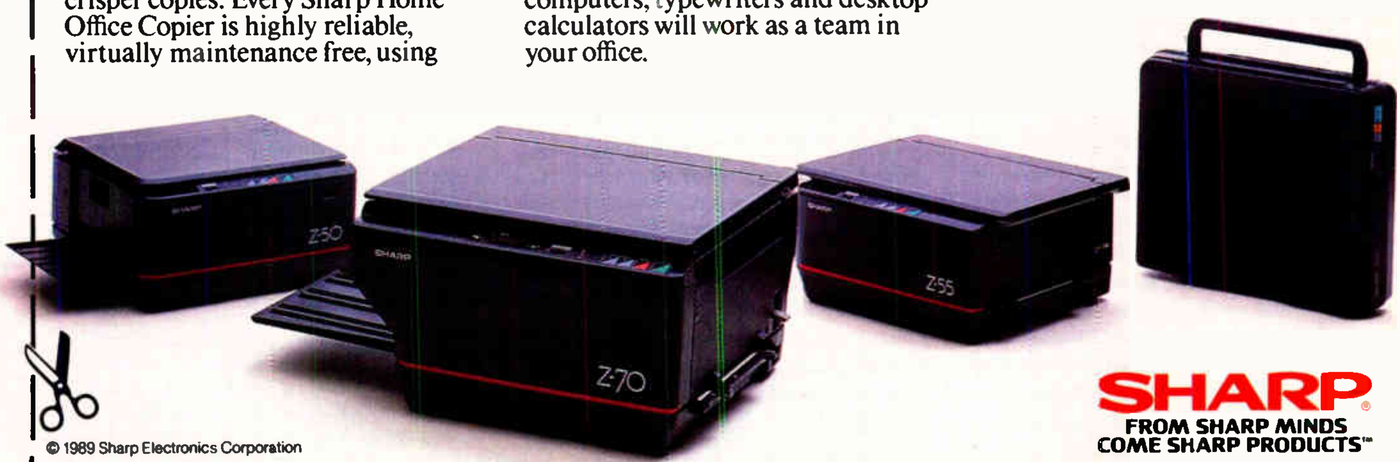

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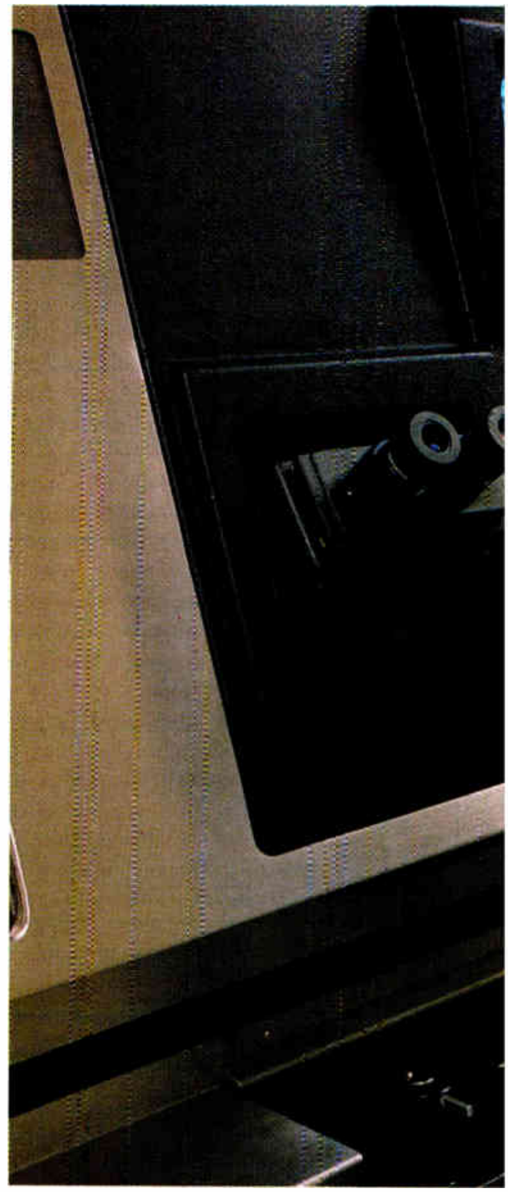
Circle 12

BY BERNARD C. COLE

Getting to the market on time

How new quick-turnaround strategies and technologies for ASICs are helping OEMs hit critical market windows



An important new way of looking at the chip market is emerging that affects strategies across the board, from systems designers and original-equipment manufacturers to chip designers and semiconductor makers. The time-honored "learning curve" approach to market domination is giving way to the more compelling view through a market "window of opportunity." In short, it is becoming clear that market dominance is achieved not by the company that comes in with the lowest-cost product, but usually by the one who gets there first.

As recognition of the central strategic importance of time to market has grown, OEMs have worked harder and worked smarter to spot windows of market opportunity in advance. Computer-aided engineering tools can help turn concepts into designs in ever shorter times, and application-specific integrated-circuit technologies like gate arrays have been nurtured to create shortcuts to silicon implementations of those designs.

But that delay between completed design and silicon in hand is still too long and too nerve-wracking. If the chips that emerge from the foundry (or captive fabrication line) don't work as intended, the schedule for product introduction is generally set back a month to six weeks or more. Budgets go up in smoke. Careers are on the line.

This type of pressure is changing the chip industry. Fab lines are being designed in new ways to shorten the silicon-turnaround time—in fact, they're being designed from the ground up with turnaround as the central driving force. And new kinds of equipment are adding a new twist to the process: now the design errors that halt a project in its tracks can be fixed on silicon. It's like white-wiring a chip: lasers and ion beams can cut away interconnect and lay in new wires. This way a run of working prototypes can be rushed to market while the chip masks are fixed and a new batch of silicon is run off. The six-week delay disaster is erased.

For the few commodity semiconductor products such as dynamic random-access memories, low- to medium-speed static RAMs, erasable programmable read-only memories, and standard logic at the small- and medium-scale-integration levels, the learning-curve chip-production strategies still apply. But to a growing number of OEMs who are turning to ASICs based on gate arrays and cell-based methodologies, it is the ability to hit the opening of the market window that is most important.

And the ASIC segment continues to grow fast. The projections of Integrated Circuit Engineering Corp., a market-research firm in Scottsdale, Ariz., say that by 1992, nearly one out of every four dollars spent on ICs (23.9%) will be for some type of ASIC device. For the ASIC manufacturers and their customers, the key to success in this marketplace is not so much the ability to produce the lowest-cost circuit or even the one with the top performance; the key is to turn around

Fixing first-cut silicon to get prototypes out the door fast is possible with equipment like this holographic inspection system from Insystems

designs and get into production fast.

As a result, there has been a radical shift from traditional high-volume, high-capital-cost "maxifab" production lines appropriate for commodity chips to a new generation of lower-cost "minifabs" oriented toward quick turnaround of prototypes and low-volume production. This growing quick-turn environment is also creating market opportunities for startups with new types of equipment that will allow semiconductor makers—and ultimately OEM users of ASICs—to get finished prototypes in days or hours.

"What we have here is a revolution in the making," says G. Dan Hutcheson, executive vice president of VLSI Research Inc., San Jose, Calif. It is a revolution that OEMs must watch closely, because many of the technologies and methods involved can be applied at the system house as well as at the fab line.

In the high-volume, commodity environment, the learning-curve strategy, put to work so successfully by Japanese semiconductor companies, assumes that certain future improvements in the technology and the ability to manufacture using them will result in lower prices and eventual market penetration. Aggressive chip makers, mostly Japanese, plot the predicted learning curve and drop prices prematurely to the predicted low prices, hauling in the customers and cornering the bulk of the market share, making up for losses early in the lifetime of a product with profits.

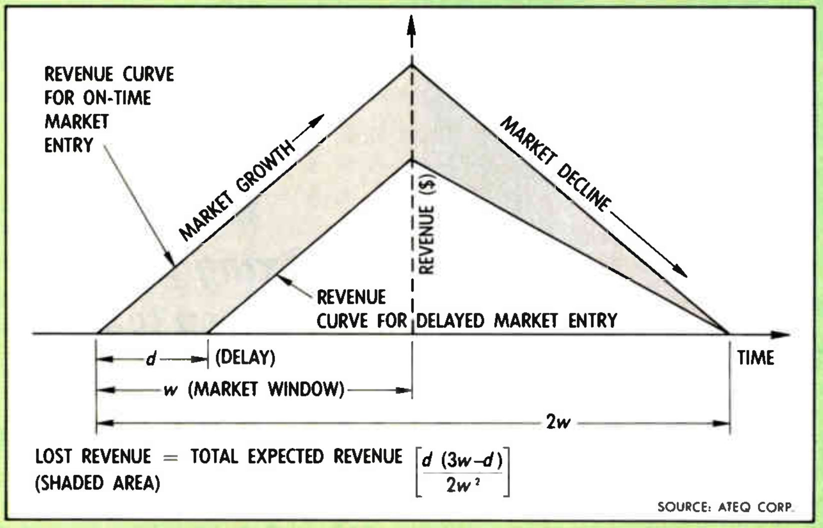
Ten years of improvements in CAD have allowed development of application-specific gate arrays and cell-based custom and semicustom circuits in weeks rather than months, and of application-specific standard products—niche products—at the VLSI level in months rather than years. Riding on this progress, OEMs have found that the learning curve no longer applies. Product lifetimes have eroded too far. OEMs are concentrating on getting to market first and following up the initial product with variations targeted to very specific market needs to hold and expand market share.

The market time for a typical electronics-based product has dropped to about two years. New products must be introduced every 12 to 18 months, on average, to maintain continuity. In some areas, such as personal computers, the product lifetime is as little as a year or less, and the introduction-opportunity window (usually defined as the first half of a product's lifetime) a matter of no more than six months.

CAD tools have reduced development times to something like the same order as the product lifetime, says William McClean, manager of market research at ICE. So to hit critical market windows, development of a second generation of product must begin before that of the first is finished, and the third generation must start just as development of the first-generation product is ending. System developers can ill afford any lengthening of these cycles, he says.

According to a model developed by Mi-

CALCULATING THE LOSSES OF LATENESS



Revenue lost in being late to market (by a length of time equivalent to *d*, for delay) is shown in the shaded area of this model, which was developed by Ateq Corp.

chael Keeger, strategic marketing manager of Ateq Corp., Beaverton, Ore., the revenue loss due to missing a market-window target can be very significant. In the figure above, the uppermost curve represents the growth and decline of revenue from a typical product when introduced at the start of the appropriate market window. The curve below it represents the likely revenue curve for a delayed introduction. The shaded area in between represents the total revenue lost due to the delay in product introduction for the second case. For example, he says, if a product should have generated $10 million when the market window was hit perfectly, and the window is 18 months long, then a delay of one month would cause a revenue loss of $820,000.

More is lost than just revenue, adds James Schoeffel, product marketing manager at Ateq. "There is a significantly greater likelihood that competitors with similar or alternative products will establish and maintain relative market share throughout the product life cycle," he says. Even when the delayed product is superior in performance, he says, there may be production-ramp and learning-curve limitations that prevent a company from achieving high enough production volumes and low enough system costs in the remaining market window.

This analysis is supported by similar studies by ICE, which indicate that a product with a market lifetime of two years will experience as much as a 12% revenue loss if introduction is delayed by as little as two months and as much as 32% if it is delayed six months. Products with longer lifetimes are not immune, either. According to ICE, a six-month delay on a product with a five-year life span is

New fab lines—called 'minifabs'—are being set up for fast, economical small-lot production

likely to result in a 15% loss in revenue.

No wonder, then, that time to market is becoming the buzzword in American industry. A recent survey of 50 major U. S. companies by Kaiser Associates, a Vienna, Va., consulting firm, found that practically all put top priority on strategies that improved their ability to get to market fast. And for companies basing their products on critical electronic components, this is especially true. When three to four revisions are required to develop a gate array or standard-cell circuit, says Ateq's Schoeffel, every week that can be shaved from the prototype turnaround time can accelerate overall product development by a month. And once the circuit has been debugged and passed approval, he adds, similar savings can be achieved by the speed with which it moves into volume production. Also important is tightly matching output to the just-in-time schedules of the OEM for which it is being designed.

CAD layout tools have improved a hundredfold over the last five to 10 years, reducing the effort required from hundreds to tens of man-years. Simulation tools cut the number of revisions by a half to a quarter, says Conrad dell'Oca, vice president of research and development at ASIC maker LSI Logic Corp., San Jose. But, he says, there's considerable room for improvement in production. "As difficult as it was to develop such tools and design methodologies," he says, "the more difficult road lies ahead, [that of] eliminating the production bottlenecks."

The bottlenecks have always been there, says Hutcheson of VLSI Research, it was just that the delay added to the total turnaround was small compared to that required originally in the design of the chips. "Now this equation has been turned on its head," he says.

The problem facing manufacturers of gate arrays and cell-based custom and semicustom circuits is that the traditional "maxifab" methodologies are built for economies of scale and learning-curve cost reductions instead of time to market. Oriented as they are toward the fabrication of a single product line, says Hutcheson, maxifabs for such products as DRAMs require investments of $150 million to $200 million per line. Two- to three-year life cycles or more are required. To justify the cost, product runs must be aimed at the highest volume possible, in the millions of units per month.

In such an environment, the smaller production runs for prototypes (10 devices or under) and even volume production (up to 1,000) get tied up in bottlenecks waiting for the high-volume runs to be completed. And the equipment, oriented toward runs of multiple wafers and maximum utilization to reduce cost, is not flexible enough. The machines can't be modified quickly every time a new part is run through.

ASIC manufacturers face a totally different production environment, with well over a hundred different device types using over 50 different process-flow variations. Most devices will have only one or two wafer lots being built, says Franc deWeeger, president of Advantage Technology Corp., Sunnyvale, Calif., and some, especially in the prototype stage, no more than one wafer. A handful of parts, on the other hand, will be in high-volume production, anywhere from tens to hundreds of wafers and thousands of dice per month, constituting 30% to 40% of the company's output.

As a result, rather than depend on the excess capacity of the the maxifab lines for their ASICs and niche-oriented standard products, many U. S. manufacturers are turning to alternative production techniques. From a handful of such facilities a few years ago, about 200 ASIC-oriented minifabs have been built out of a total of 600 or so fab facilities worldwide, says James Feldhan, vice president of Instat Corp. in Scottsdale. He expects the trend to continue, with minifabs growing from about 10% of the total in 1987 to as high as 20% by 1990. Of the companies joining this trend, the smaller number are traditional semiconductor houses, including Fujitsu, Motorola, National Semiconductor, NEC, Texas Instruments, and Toshiba.

Large manufacturers are handling the problem with so-called "fabs within fabs"—special equipment and personnel oriented toward small-volume and prototype production of ASICs, says Hutcheson. Also, says McClean of ICE, many companies, particularly the Japanese, are focusing on parts, mainly gate arrays, that can be fabricated more like commodity devices, with master slices produced in volume. Typical of this approach is that taken by Fujitsu Ltd., which produces undefined gate-array wafers in high volume on maxifab lines in Japan. These are then shifted as needed to the company's ASIC line in Gresham, Wash., where the last two or three layers of customized metalization are added.

For even tighter turnaround times for prototypes and small-volume production of completed designs, most ASIC companies and standard-product startups targeting smaller-volume niche markets have opted for the new minifab approach. Costing much less than maxifabs—in the neighborhood of $20 million to $50 million—such facilities handle single-wafer processing and small production runs of many products on a single line. To achieve this, the fabrication line is modular, with tiny equipment islands scattered throughout the plant and designed for maximum flexibility. Among those opting for this approach are Dallas Semiconductor, Harris Semiconductor, LSI Logic, Paradigm, Silicon Systems, VLSI Technology, and Western Digital. And TI, in addition to its DRAM-derived ASIC fab line, is investigating the minifab approach with a pilot line for military parts [*Electronics*, January 1989, p. 27].

MINIFAB. More typical of the current state of the art is VLSI Technology's new minifab, a 40,000-ft² Class 1 facility in San Antonio, Texas. "The quick-turn objective means production cycles that are no more than 1.5 times the theoretical minimum cycle time," says Jack Satich, vice president of technology at the San Jose, Calif.-based firm. By contrast, he says, present-generation fab lines using traditional technologies have a production cycle anywhere from 3 to 10 times as long as that theoretical minimum. The company believes that before the end of the year it will be able to turn around a completely tested prototype of a cell-based semicustom circuit in 10 days. With gate-array-based designs, Satich says, turnaround time should be even shorter.

Key to this speed is inventory control, via "demand-pull" production methodology, in which an operation can accept, or pull, inventory from a previous process

GETTING PROTOTYPES IN HOURS, NOT WEEKS

Good news, designers: the focused ion-beam systems that are just becoming available produce fully functional prototypes of custom, semicustom, and standard circuits in hours rather than weeks. First out are wafer- and chip-modification systems from Micrion Corp., Beverley, Mass., and Seiko Instruments Inc., Tokyo.

Using a focused beam of gallium ions, these systems let users alter chips three ways. They can remove existing metal interconnections to isolate one part of a circuit. They can add new metal interconnections to rewire a circuit. And they can generate new contact areas, so that voltage measurements can be made to monitor the electrical performance of a circuit under actual operating conditions.

Almost every new integrated circuit goes through one or more iterations before its final configuration is determined, particularly the more complex circuits such as VLSI microprocessors, memories, and application-specific ICs. When an error is found, a designer of high-density parts (100,000 gates and up) has had until now only two options. He could cut wires with a mechanical probe or a laser, or he could go through the complete mask/fabrication cycle all over again.

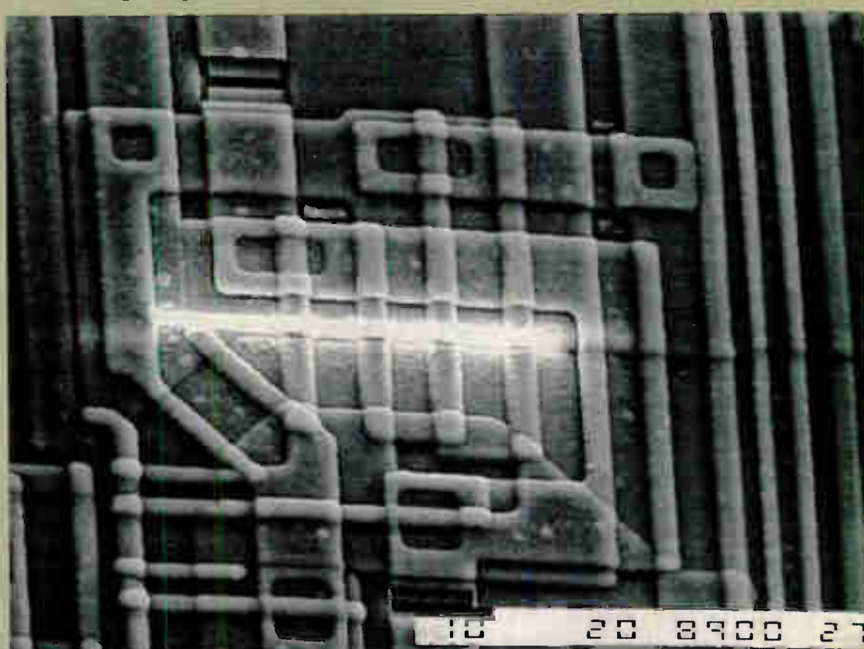
Both of these time-honored approaches have limitations. Mechanical probes can only be used on geometries of 2 to 3 μm or larger, ruling them out for advanced VLSI. Laser techniques can cut or add lines as small as 1 μm, but only by means of thermal ablation. This process requires high temperatures, frequently causing heat damage to surrounding sections of the IC.

If the designer opts for the mask/fab cycle, he must first go back to the computer-aided-design system, modify the mask patterns necessary to reconnect the circuit as desired, make new masks, and then run a new lot of wafers. Depending on the factory priorities at the time, this can take as much as a few days to a week for laser-based systems and up to 10 weeks for traditional fabrication techniques. An additional disadvantage is added cost and wastage: existing wafers must be thrown out and new ones produced.

With a focused-ion-beam IC-development system, all these problems vanish. Changes can be made in a matter of hours on the existing wafers, using gallium ion beams that can be focused as small as 0.1 μm and accelerated to an energy of no more than 25,000 V.

Positioned by control signals, where the beam strikes the circuit, the ions selectively remove material by the highly controlled process of sputtering. This lets the system make ultraprecise cuts of metal lines, with virtually no increase in temperature and therefore no damage to the surrounding circuit areas. Because of the small size of the cutting beam, cuts as small as 0.5 μm can be made on circuit features which are themselves positioned as close as 0.5 μm apart.

To form new interconnects, the same focused beam can selectively deposit metals such as tungsten. If a metal-carrying gas such as tungsten carbonyl or tungsten hexafluoride is present at the surface of the circuit, the ion beam will decompose the gas. This leaves a metal deposit, providing high-quality, high-conductivity interconnections. *–B. C. C.*



Micrion's ion-beam chip-modification system can cut through metal interconnect and isolation layers, as shown, and add new wiring to a circuit as well.

step when the operation can accommodate it. The standard method is the push-through approach, which is oriented toward achieving as high an output as possible. While the idea is to push materials through to the next stage as quickly as possible to increase throughput, Satich says, this approach can often hide manufacturing problems due to queuing of inventory in front of a work station from the previous one. It's not unusual for a push-through fab to have a six-to-eight-week cycle for a product that takes just a few days to make.

Demand-pull systems handle small lot sizes more easily. They also make it easier to decrease setup times on equipment for different types of devices. And because they eliminate inventory queues, it quickly becomes clear when a piece of equipment is down or when a circuit is receiving a lot of rework.

To implement the demand-pull scheme, VLSI Technology has chosen equipment to support single-wafer processing instead of processing wafers in batches. This accommodates the small ASIC lot sizes, typically four to six wafers per lot. In such a scheme, steps that require processing one wafer at a time can proceed at their own pace, says Satich, while, for example, plasma etchers, which need to accumulate a number of wafers before commencing operation, do not introduce delays due to batching.

Lot delays are also minimized by organizing the equipment around work cells, each of which represents a logical segment of a process flow. This means the next piece of processing equipment for any wafer lot is logically placed close by. It's not specific to a particular process flow; rather, it is generic and adaptable to a variety of processes. In traditional semiconductor processing schemes, by contrast, equipment is organized into work groups according to function: one bay for coating, one for exposure, another for etching. Such an organization requires transporting lots between areas, and this causes delays and more difficulty in inventory management.

Laser and ion-beam techniques could ultimately change the complexion of the industry

Although designed originally for the quick-turn needs of ASICs, such a production philosophy is also being used to build standard products targeted at high-performance niche markets, says Satich. At LSI Logic, for example, the same production line is used for making ASICs, semistandard, and standard products. And at VLSI Technology, Satich says, the application-specfic SRAM-based products are being fabricated on the line.

On another front, equipment and software startups have a number of offerings in the works to make ASIC manufacturing faster. The new equipment—including laser-based systems for fabricating gate arrays and focused-ion-beam chip and wafer modification systems—may ultimately make it possible to move the prototyping stage of the process out to the OEM user's facility, says Hutcheson of VLSI Research.

Such systems will catch design and fabrication errors early, notes William McMakin, vice president of marketing at Micrion Corp., Beverley, Mass. They will also allow engineering changes early in the product-development cycle, and "the earlier such changes can be made, the less they cost and the shorter the overall development time," he says.

This is corroborated by a recent ICE study, which indicates that a major reason for long design cycles is an excessive number of engineering changes. The earlier changes can be made, ICE says, the lower the cost and the greater the impact they have on improving performance.

Focused-ion-beam systems, meanwhile, are just arriving in the U. S., though they have been available for at least a year in Japan. The two main manufacturers are Micrion and Seiko Instruments Inc. of Tokyo (see p. 65), both of which are gearing up for a major push in the U. S.

One type of complementary quick-turnaround fabrication tool is the laser-based direct-write system [*Electronics*, Nov. 12, 1987, p. 69], varying forms of which are being developed by Elron Electronic Industries, Lasarray, and Lasa Industries. These machines are aimed at developing semicustom designs based on specially prepared gate-array wafers. Such systems, now priced in the $1 million to $4 million range, should reach $17 million in annual sales by 1992, says Hutcheson.

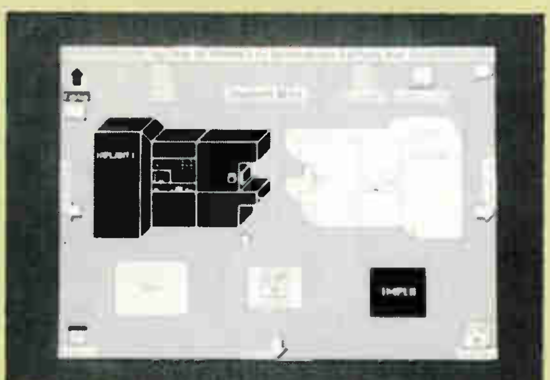
A key stumbling block is the technology's ability to produce working circuits with sufficiently high yield and reliability. Even a few errors in the cutting or additive steps could ruin the entire circuit. At National, engineers are grappling with the problem by linking the Lasa additive system to the Seiko fo-

CIM SOFTWARE CAN SIMPLIFY ASIC MANUFACTURING

As chip makers push for more efficient fabrication of application-specific integrated circuits, their colleagues in software are marching right along with them. There's heavy competition among software houses to develop computer-integrated-manufacturing programs to support the ASIC effort.

It took the emergence of application-specific gate arrays and standard cells to drive the development of sophisticated computer-aided-design tools; so too the quick-turn requirements of a new generation of ASIC minifab lines are driving the development of CIM software.

The demands placed on a CIM system are substantially different for ASICs than for high-volume standard parts, says G. Dan Hutcheson, executive vice president at VLSI Research Corp., San Jose, Calif. In a commodity environment, with a given rate of wafer production using similar numbers of processing steps, the transaction rate and data-base size are likely to be much smaller, he says. Also, an ASIC fab needs much more flexibility in its CIM system. Vast numbers of parts, masks, inventories, and processes must be easily defined, tracked, and controlled.



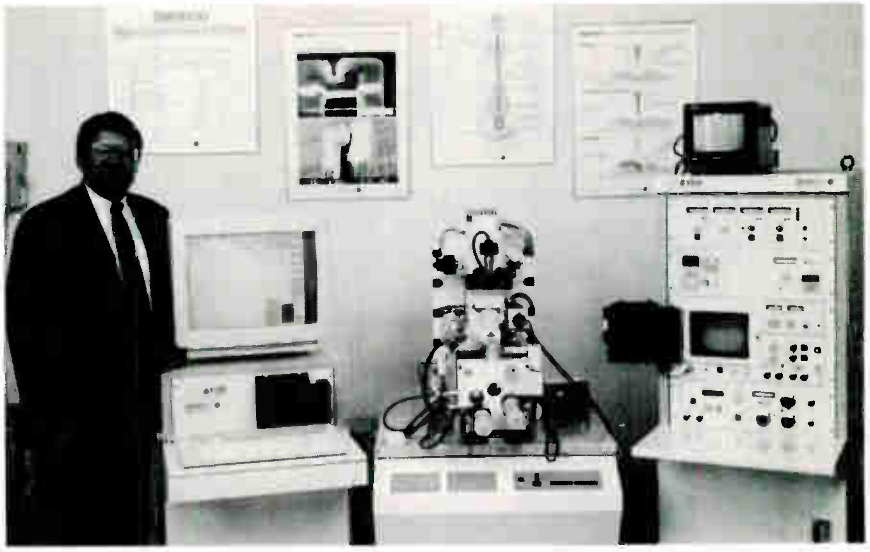
Promis's factoryTop software lets managers see a segment of the factory floor or step back for an overall view.

This is no easy task. The short lead times, the mixture of varying market windows, and the OEMs' demand for just-in-time deliveries make scheduling and balancing products in the line complex. Also, the great number of ASIC products and processes result in even larger numbers of specifications, most of which require sign-off procedures and engineering-change control. With the thousands of masks and hundreds of specs and settings, the opportunities for error are many.

The demand for CIM software to meet these many requirements has emerged so quickly within the semiconductor industry that companies cused-ion-beam modification system, says Ronald Kovacs, manager of in-situ processing. Circuits developed on the Lasa system could be evaluated and, if faulty, modified by the Seiko unit. The modified prototypes could be delivered to the customer on schedule, he says, while at the same time the circuit could be analyzed to eliminate the problem.

Another quick-turn option is the ASIC-fabrication service built around a proprietary e-beam direct-write manufacturing technology from United Silicon Structures, a San Jose subsidiary of European Silicon Structures. Where current e-beam and laser-based direct-write approaches are aimed at replacing the last two masked metalization layers in gate-array processing, the United Silicon service uses the e-beam as an all-layer direct-write tool to implement standard-cell circuits, says vice president of marketing Jacques Castaillac. Design is done with the firm's e-beam-optimized Solo family of design tools.

Another piece of the puzzle under examination at National is technology for pinpointing defects on chips produced on the laser machines or by standard means, so that they can be fixed by the ion-beam and laser systems. Kovacs says the chip maker is evaluating a number of advanced wafer-inspection systems, such as the Model 8600 holographic-based system from Insystems Inc. of San Jose. The promise, he says, "is that the improvement in yield early in the prototyping stage could reduce overall development costs by several orders of magnitude, more than offsetting the capital-equipment investment." If such equipment proves out, he says, it could radically change the way both semicustom and standard chips are produced. "It would reduce the need to develop a dedicated fab line or a fab within a fab totally oriented toward quick-turn production," he says. "It would allow semiconductor manufacturers to retain the economies of scale associated with traditional high-volume fabrication lines, while at the same time meeting the increasingly fast-turnaround requirements of OEMs."



B. K. Marya, president of Catalyst Semiconductor, says the Seiko Instruments ion-beam chip-modification system Catalyst is using should "cut turnaround time by at least 14 weeks."

In the longer run, says Dan Dooley, president of Lasa Industries Inc., San Jose, the entire complexion of the semiconductor industry could be transformed. "With such equipment, distributors would have a more effective way back into the loop, incorporating such systems into their already existing network of design centers," he says. Such systems would also further spur the development of startups, who in the initial phases could create prototypes without dependence on a foundry or ASIC house. And as for OEM users of ASICs, says Dooley, such equipment could bring a much larger portion of product development back under their direct control.

"Because of the rapidly narrowing market window for new products, OEMs have moved to just-in-time strategies to survive," he says. "As a result, they have been forced to reverse a decades-old tradition of working with a wide number of suppliers. Instead, they thin out the number of vendors, working exclusively with one or two ASIC or semiconductor firms." By taking over prototyping, OEMs could go back to the original multiple-supplier approach, using ASIC or semiconductor houses only for the fabrication of production volumes. □

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have not had the time to develop proprietary tools. Then too, doing it themselves would be costly and time-consuming: insiders say it would take at least $10 million and hundreds of man-years. To fill the gap, a number of commercial packages have been developed by companies such as Cameo Systems, Consilium, Hewlett- Packard, Promis Systems, and Qronos Technology.

"What we are seeing is an increasing vertical integration of the product-development and manufacturing process from chip to system," says Hutcheson. "What the Japanese are achieving institutionally with their semiconductor operations as integral parts of a much larger systems company, U. S. companies are achieving through standard sets of hardware and software tools."

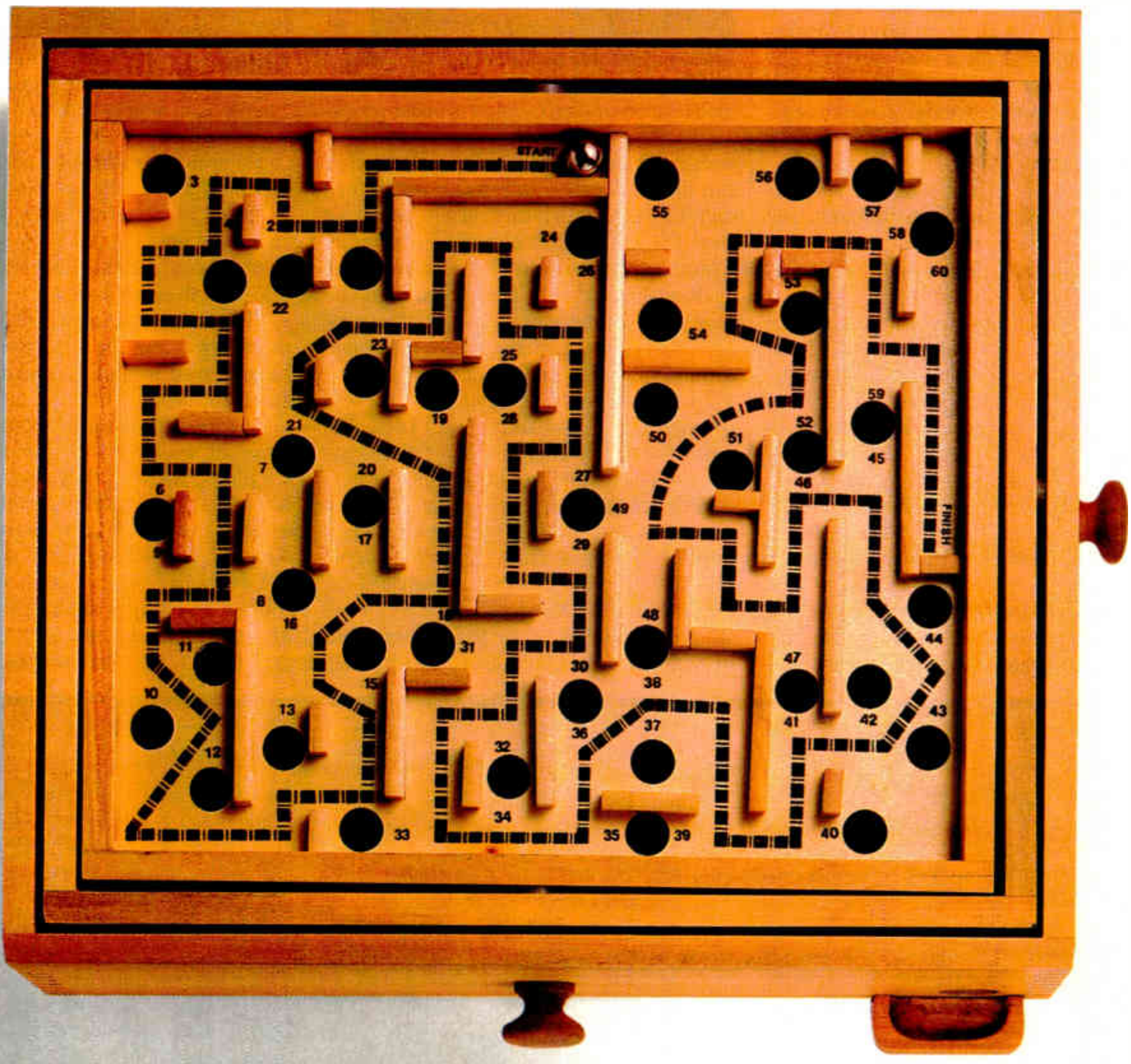
With a de facto standard in CAD tools and some common hardware platforms, he says, "half the job of vertical integration has been achieved." And the new breed of sophisticated CIM tools goes a long way toward nailing down the other half, in Hutcheson's opinion.

Although the competition is still stiff, a consensus of sorts seems to be emerging on a de facto standard. Industry players are divided between Promis from Promis Systems Corp., Santa Clara, Calif., and Comets from Consilium Inc. of San Jose. In the Promis camp are an impressive number of heavy-hitters: Analog Devices, AT&T Technology, Bendix, Bosch, Ferranti/Plessey, IBM, Intel, LSI Logic, McDonnell Douglas, Silicon Systems, Texas Instruments, and VLSI Technology Inc. The latter two companies also use the Consilium system, along with Signetics and Xerox.

On the hardware side, most CIM packages use Digital Equipment Corp.'s family of computers for hard-core number crunching. For the front-end user interface, where the CAD world has settled on the IBM Corp. PC family, no such standard has emerged in CIM.

In a bid for that title, Promis has developed factoryTop, a front-end interface that runs on Apple Computer Inc.'s Macintosh. It's connected to the Promis Factory Management System through direct asynchronous links—DECnet, Ethernet or AppleTalk packets via Ethernet. The system relies on the Mac's object-oriented, mouse-driven graphic interface to let line managers quickly and easily window in on an activity in a particular area of the factory or take an overall view of the entire factory floor, says Ray Potwora, director of marketing. Initial versions of the product will be introduced late in May at the Semicon/West show in San Mateo, Calif. *–B. C. C.*

The traditional approach to IC design.



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DSP winners. The 32-bit parts are the flagships of product lines aimed at a market that's growing at a heady 35.5% compounded annual growth rate, according to the Information Network, a market-research group based in San Francisco.

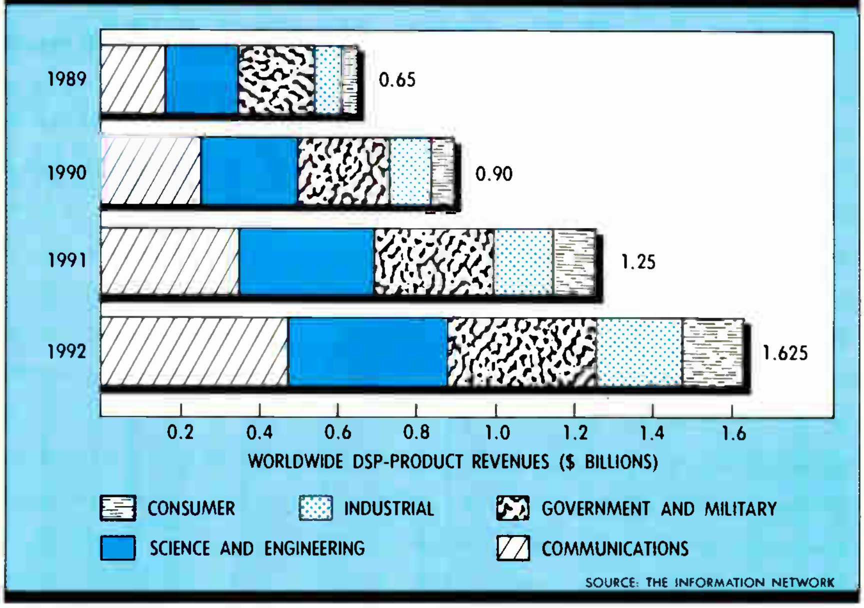
This year, the firm expects the market to be worth $650 million, growing to $1.625 billion by 1992. The smaller market segments broken out in the Information Network's studies will grow the fastest, it predicts. Communications, industrial, and consumer DSP markets grow at 40.5%, 47%, and 56.4% annual rates, respectively—above the industry average. The science and engineering segment and the government and military segment, though larger, will grow more slowly, at 30.7% and 25%, respectively.

The old timer in the 32-bit floating-point DSP market is AT&T Co., which introduced an n-MOS chip in 1984. The first supplier to hit the market with a CMOS chip, however, was NEC Corp. of Tokyo. The μPD77230 began shipping in 1987, finding applications as a codec in telecommunications switching systems, according to George Wang, DSP product line manager at NEC Microelectronics Inc., a NEC subsidiary in Mountain View, Calif. The chip's 150-ns cycle time allowed it to outperform the slower and more power-hungry AT&T n-MOS chip, which could post only a 250-ns cycle time.

In April 1988, Texas Instruments Inc., Dallas, rolled out the TMS320C30, implemented in 1-μm CMOS technology. It set a new performance mark for 32-bit floating-point DSPs with a 60-ns, single-cycle execution time, claims Michael Hames, DSP product manager for TI in Houston. Four times faster than the AT&T device, the chip could crank out 33 million floating-point operations/s. In comparison, a system-level product that's popular for signal-processing work, the M64/60 mid-range supercomputer from Floating Point Systems Inc. in Beaverton, Ore., has a peak performance rating of 38 megaflops and a price tag of $475,000.

AT&T responded with a version of its 32-bit floating-point chip, called the DSP32C, that is implemented in the company's advanced 0.9-μm CMOS technology. The chip is three times faster than its n-MOS progenitor, but still slightly slow-

SMALL DSP MARKETS GROW FAST



BEYOND DSPs: EASY PROGRAMMING AND 10 GIGAFLOPS TOO

When Oryx Corp. conceived the idea for its Super Signal Processor computer, a machine that can run at 10 billion floating-point operations/s, the Paramus, N. J., company knew the task would be incomplete until the hardware was matched with a software-development tool tailored to the needs of the signal-processing market.

"Signal-processing design engineers always start off with a flow graph of their application," says Greg Paret, Oryx's manager for software development. "Our system lets them program directly from a flow graph." Instead of drawing a flowchart on paper and then farming out the programming to a software company specializing in a high-level language such as Fortran, Oryx's Flowgraph Editor lets designers draw diagrams on a Sun Microsystems Inc. work station. The software takes charge from there. Using a library of more than 135 primitive functions such as fast Fourier transforms and the like, it creates a program that delivers assembly-language efficiency.

Oryx's bright idea pays dividends in both development time and program execution. By eliminating the intermediate step of high-level programming, the application can be completed in days instead of weeks, says chief technical officer John Hiller. And since the program runs in assembly language—which is downloaded to the SSP's node controllers—program execution is not bogged down by a host computer's input/output bandwidth or by high-level language execution that degrades performance.

Users draw diagrams that pull in routines from a DSP library

Working in assembly language delivers 90% of the SSP's peak processing power to the application, says Hiller. In contrast, Fortran-coded programs limit the machine to about 20% of its peak. The SSP will find users in military/aerospace applications such as radar, sonar, and very high-end image processing. Both laboratory and rugged versions are available. A 32-bit floating-point, coarse-grain parallel processor, the SSP features a modular architecture [*Electronics*, March, 1989, p. 43]. Each arithmetic node delivers 160 megaflops, and nodes can be added as processing needs grow.

A useful way to grasp the Flowgraph Editor's power, says Paret, is to think of it as a schematic-capture editor and library editor rolled into one. In signal processing, he adds, the two functions cannot be handled separately, since "you're defining and using the library functions simultaneously." Basically, the software takes care of all the complex bookkeeping needed to create an application.

The diagram drawn on the work-station screen consists of two types of blocks: tasks and queues. Tasks are the algorithms that the designer strings together to process data in his application. Queues represent the lines seen between the blocks in a flowchart. They have more significance in the Flowgraph Editor system, because the signal-processing designer must specify limitations on the data—such as queue size—and destination. A window pops up querying the designer for parameters, including the number of elements in the matrix and thresholds. Thresholds are important, says Paret, because the "task" must know when to stop filling the matrix with data. Among the other parameters are er than the TI part at an 80-ns cycle time and a peak 28-megaflops computation rate. NEC also plans to announce a new chip, another 32-bit CMOS part, later this year. Wang says its cycle time will be below 100 ns.

The companies already on the market are about to get some powerful competition. They are also about to get some competition on a different level, where a criterion other than sheer performance will be introduced as a measure of a 32-bit DSP's appeal.

Two companies have announced they are rolling out 32-bit DSPs, Fujitsu Microelectronics Inc. of San Jose, Calif., and Motorola Inc. in Austin, Texas. A third company, Analog Devices in Norwood, Mass., says it plans to introduce a 32-bit DSP by the end of this year.

The Fujitsu chip, the MB86232, is comparable in performance to the NEC chip. In addition, says Paul McGuire, a Fujitsu product marketing engineer, "It has a microcoded divide routine that takes 27 cycles or 2 µs to run. Other chips require the applications developer to write a divide routine, which takes at least twice as long to execute as the microcoded divide instruction on the 86232." Motorola's parts, the 96000 family, will perform slightly better than TI's device—40 megaflops compared with 33. Few details of the Analog Devices chip are available yet.

But all three will offer something the earlier 32-bit DSPs don't: compatibility with the IEEE's 754-1985 floating-point standard. This could turn out to be a crucial weapon in the DSP battle. "Not being IEEE-compatible turns off users who want to replace an application running on an array processor with a board containing a 32-bit floating-point DSP chip," says Michael Drumm, vice president of international sales and marketing at Sky Computer Inc. in Lowell, Mass. "Most array processors are IEEE-compatible."

Analog Devices, Fujitsu, and Motorola are rolling out DSPs with IEEE-754 compatibility

Besides making it easier to design a board to replace a processor, compatibility with the IEEE standard can significantly improve a DSP's performance. "Other DSP chips must perform a conversion to achieve IEEE compatibility," says Bobby Saffari, central applications engineer at Fujitsu. The performance hit is heavy because the conversion takes place at run time. "TI's own documents say that it takes 12 words or 18 cycles to convert an IEEE-745-compatible variable into a form acceptable to the C30. The conversion of a C30 variable into IEEE format takes 15 words or 14 to 21 cycles."

Not surprisingly, the chip makers with non-IEEE-compatible DSPs argue that compliance is not all that important. TI, for example, admits that the C30 is not bit-for-bit compatible with the IEEE specification, and executing the conversion during run time does cut down the chip's performance by something like 30%. The AT&T and NEC chips require a conversion, too, but suffer less. Each executes one instruction to convert from the chip's internal floating-point format to the IEEE format. "But IEEE compatibility is not a big issue," TI's Hames contends, "because DSPs are designed into embedded systems. IEEE becomes an issue when tying it to another system with an IEEE data base."

Not so, says Analog Device's David Fair. A lot of the applications in which 32-bit floating-point processors will serve will require IEEE compatibility. Workstation math coprocessors all adhere to the standard. Building a graphics subsystem with a DSP processor that does not meet the standard would not be practical.

Beyond the question of specific applications, the issue of IEEE compatibility will complicate the already complex task of developing software for 32-bit DSPs. The chips need programs that can do what heretofore had been systems-level work.

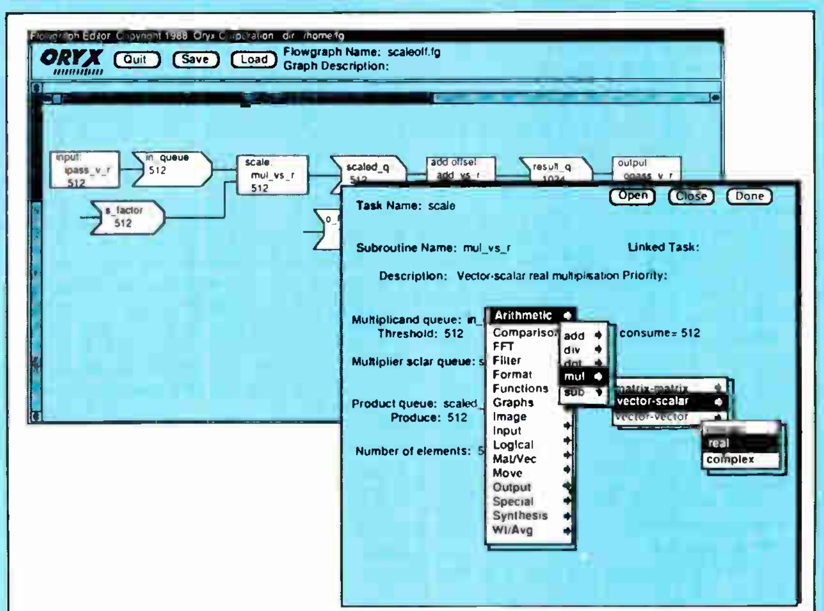
Previous generations of DSPs performed relatively simple application tasks. "The DSP chip simply performed a repetitive task, regardless of the nature of the signal it received," says David Wong, president of Spectron Microsys-

"offsets" and "consume amounts." Offsets delimit portions of the data so that submatrices can be operated on independently. Consume amounts specify how much data is to be used and how much is to be discarded.

By moving through nested menus, the designer specifies the arithmetic operations of data types such as integer, real, or complex numbers. "We have a fairly deep hierarchy of pop-up screens," says Paret—at least four deep, depending on the operation's complexity.

In addition to blocks defining tasks, there are four types of queues: first-in first-out, which operate conceptually as data collectors and repositories; constant sources, which are basically used to store coefficients and scale functions; graphical input/output; and storage. Graphical input/output queues are symbolic representations of flow graphs that have already been created. "It is basically a name-substitution system," says Paret. A designer may have created a small flow graph to perform a function, for example, and will call it through the graphical queues. Storage queues, he says, "are the proverbial bit buckets—a place to throw data you don't need." *–Jack Shandle*

FROM FLOWCHART TO EXECUTION IN ONE STEP



SOURCE: ORYX CORP.

A typical Flowgraph Editor screen displays task and queue blocks configured as a flow chart. The enlarged window (inset) shows the nested functions used for each task.

tems Inc. in Santa Barbara, Calif. "For example, a digital filter, modem, or voice-synthesis system performs the same function continuously."

But the new level of applications means that the processor must change its operation depending on the content of the incoming signal. Not only does this require decision-making capability in the DSP's instruction set, it also requires many more algorithms operating in real time.

REAL-TIME NEED. In speech recognition, for example, a DSP accepts input data, performs data compression, and stores the result in memory, a repetitive function. But the recognizer back-end software acquires the data from memory, performs dynamic programming, segmentation, and even search operations, and then makes decisions based on the outcome of this processing. Since the software tasks performing this back-end operation are not synchronous with incoming data, the DSP needs a multitasking real-time operating system.

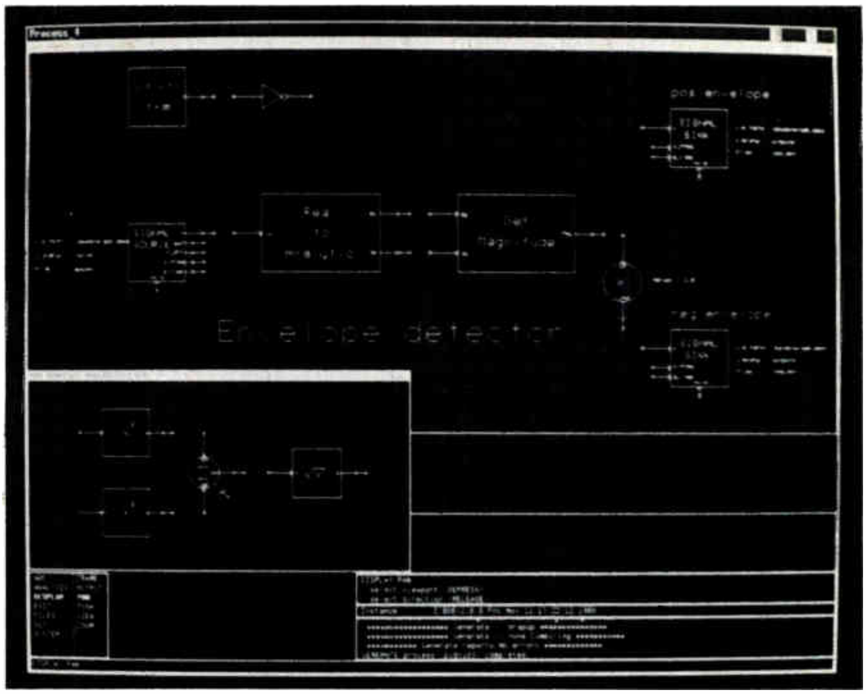
In addition, "DSP chips are operating more and more in a multiprocessing environment, in which a DSP might be required to talk to a host CPU," Wong says. In a multiprocessor system performing sophisticated speech processing, each DSP chip could be testing out 50 to 100 different hypotheses. The outcome of evaluating one hypotheses on one processor could affect the outcome of another DSP's evaluation. In such a system, each processor must have a means of communicating with another in order to synchronize operations.

To create the programs that can handle such applications, designers and programmers are turning to a wide array of sophisticated tools. Among them are high-level languages, powerful software-development environments, and advanced debugging techniques.

Besides accommodating the more complex programming that developers are taking on, high-level languages can cut the time it takes to create programs and hence the time it takes to get a DSP-based system to market. To meet demand, DSP vendors are providing high-level compilers, mostly for the C language.

In addition, software development, once carried out primarily on personal computers, is now being done on work stations and larger computer systems as well, and then ported down into the prototype DSP system. The Signal Processing Worksystem from Comdisco Resources Inc. in San Francisco, for example, combines a graphics editor and a library of basic DSP functions.

Using it, a software developer does not need to write code. Instead, he describes a system by using building blocks and configures each block so that it contains the desired operating characteristics. The system then automatically produces assembly code for a specific DSP chip.



Comdisco's Worksystem lets a system developer work with building blocks that he configures to represent operating characteristics of a DSP-based system.

Comdisco claims Worksystem achieves significant productivity gains. Using the system, says Michael Walsh, senior vice president at Comdisco, a designer cut the time it took to develop a 2,400-baud modem to four months from the eight months it would have taken without it.

A similar graphics-oriented tool from Burr-Brown Corp. in Tucson, Ariz., called DSPlayXL, allows the designer to build DSP algorithms by drawing and then connecting blocks on a PC display screen. The blocks represent different DSP operations. To create a block, the software produces a menu on the screen. Once completed, the design can be downloaded into the AT&T DSP32C chip.

Designers are looking for tools to build far more advanced DSP systems

Because both the Comdisco and Burr-Brown tools have graphics capability, the designer using either one of them can view a signal moving through his design just as if it were a piece of signal-conditioning hardware.

TI is providing its own development system, the XDS 1000, as well as a real-time operating system called SPOX. SPOX includes facilities for the interprocess communications needed to implement systems where multiple DSPs are working nonsynchronously. Comdisco also runs SPOX on its Worksystem.

Creating the software is only the first, if the most difficult, step in DSP system design. The next step is to download the software to a prototype system for debugging. Hardware tools for doing so generally are built around the same kind of test systems used for testing microprocessor-based designs, with an in-circuit emulator that provides a view of the DSP operating in the target system.

Motorola, for one, will supply an application-development system including such tools to support its forthcoming chip. It comes with a host development system, a development module containing the DSP chip, and boards for sending analog signals into the DSP chip and routing them off it.

Taking another tack, Fujitsu has developed a special flat-pack version of the surface-mount MB86232 that actually fits into the final applications hardware being developed. On the back of the package are 64 pins in an 8-by-8 array, which tie to test points inside the DSP. The package was developed to allow the designer to debug systems built with surface-mounted devices. It lets the designer probe input and output pins as well as internal nodes of the DSP, so he can watch its internal operation to see how the algorithm is running during program execution.

Third-party vendors, such as Burr-Brown and Spectrum Signal Processing Inc. of Burnaby in British Columbia are getting into the act, too. Both sell products to facilitate prototyping, including DSP processor boards and analog I/O boards. Spectrum's twist is an added high-speed real-time bus that links the I/O and DSP boards plugged into a PC chassis. □

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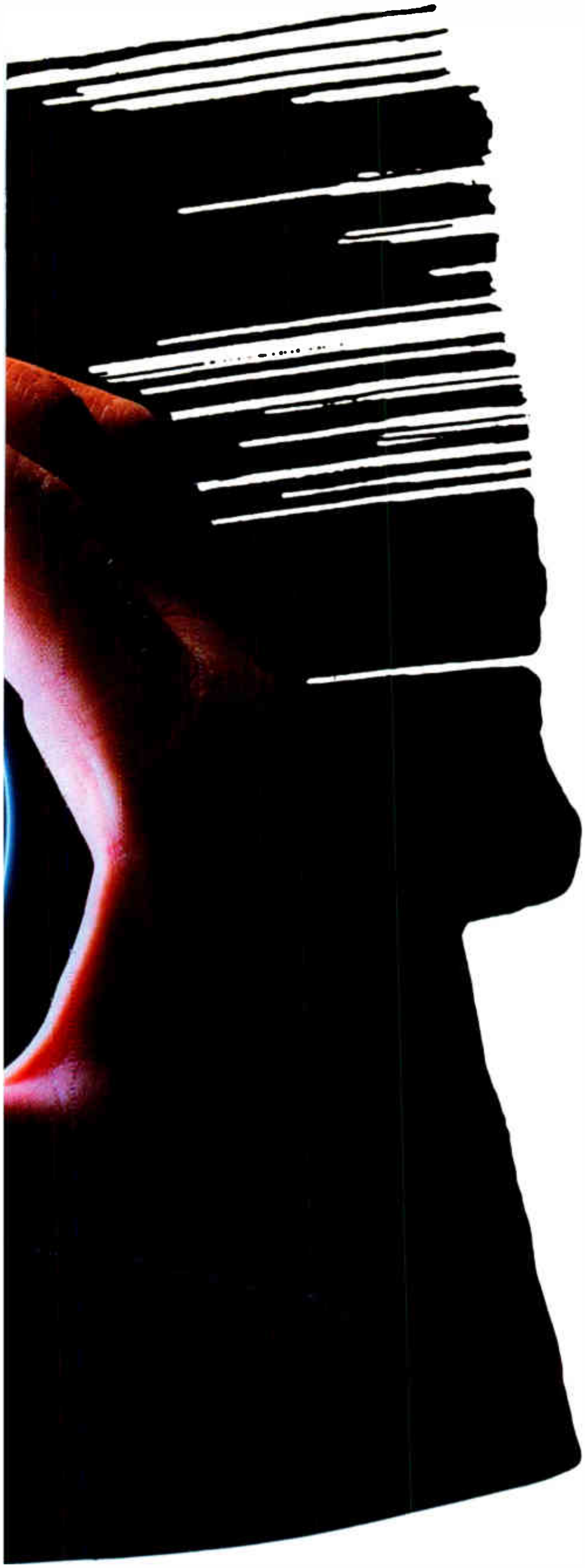

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Eratosthenes

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Circle 55

SIGNAL PROCESSORS OPEN UP NEW TERRITORY IN COMMUNICATIONS

With prices falling and programming easier, DSPs are motoring into the mainstream

by Jack Shandle

DSP

Digital signal processors are bustin' out all over the communications scene, thanks to lower prices, easy-to-use development systems, and a growing need to harness the multiply-and-accumulate function that DSPs were born to run.

Wherever there's a complex algorithm to be calculated, there's usually a DSP for the job. The high-performance 9,600-bit/s modems conforming to the CCITT V.32 standard could not be built for less than $1,000 without them. Sophisticated algorithms central to speech-recognition technology cannot be executed fast enough by conventional microprocessors, so designers have turned to DSPs. Other hot new DSP areas include cellular radio phones, video teleconferencing, and multiplexing four voice conversations on leased 64-Kbit/s lines that formerly could carry only one.

As a result of all this activity, the market for general-purpose, programmable DSP processors—as opposed to the building-block chips that execute selected DSP functions—is forecast to grow from $140 million in 1988 to $250 million by 1990, according to Dataquest Inc., the San Jose, Calif., market researchers. What's more, that nearly 40% annual growth rate takes into account significant price rollbacks as competition stiffens and production lines gear up, says David Fair, DSP product-line manager for Analog Devices Inc. in Norwood, Mass. Even AT&T Microelectronics has declared itself a combatant in the price wars. In January it brought out a plastic-package version of its DSP32, slashing prices for the 32-bit device to $49 each—a 65% decrease. AT&T also reduced the price of its DSP16 to $25.20 each, a cut of nearly 50%.

SOFTWARE IS TOUGH. Invented at AT&T Bell Laboratories less than a decade ago for use in central-office switches, DSPs have motored their way into the mainstream despite formidable difficulty in writing software for them. This hurdle is being overcome with new assembler/debugger development systems that make programming almost a breeze from such companies as Ariel Corp. of Highland Park, N. J. (see p. 81).

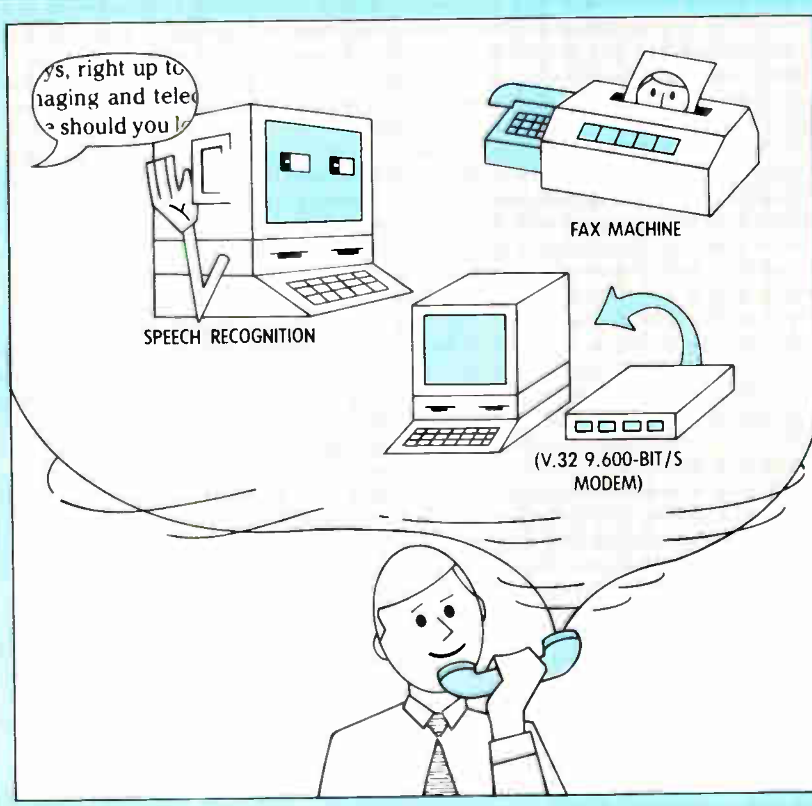
Another technology limit was in peripheral circuitry: the lack of an analog-to-digital converter that delivers true 16-bit resolution. Of critical importance here is Motorola Inc.'s introduction last month of a single-chip ADC that delivers true 16-bit resolution and 96-dB dynamic range. Based on sigma-delta approximation techniques, the 56ADC runs off a single 5-V power supply, eliminating the need for a dc-dc converter. Delta-sigma techniques do away with the anti-aliasing filters and automatic gain control devices needed in multiple-chip solutions. The upshot is a 15 : 1 reduction in board space to implement the function, an order-of-magnitude price reduction (the part costs $50), and a system that does not have to be trimmed with potentiometers, says Motorola's Garth Hillman, DSP strategic applications manager in Austin, Texas.

Although DSPs find applications in many areas outside communications, it is still their home base. "There's going to be a big demand for fast, lean, and mean integer-DSP chips that are easy to program," says Analog Devices' Fair. Selection criteria begin with the decision to go with integer or floating-point DSPs, says Jim Flynn, an applications engineer at AT&T Microelectronics in Holmdel, N. J.

For the vast majority of communications applications, both types deliver adequate performance. Architecturally, the difference is in the arithmetic logic unit: the ALUs in floating-point chips are larger and more complex. Mostly for that reason, integer chips are less expensive, a difference that shows up even with AT&T's new pricing: the floating-point DSP32, at $49, costs about 40% more than the fixed-point DSP16.

But that extra circuitry makes float-

DSPs: RIDING A WHIRLWIND



ing-point chips easier to program, says Flynn. Integer arithmetic requires the programmer to keep track of where the decimal point should be; so although they execute instructions faster, there are usually more instructions to execute because of decimal-shifting deficiencies. Because floating-point chips can handle much larger numbers, their dynamic range is greater: up to 1,500 dB for the DSP32, compared with 80 to 96 dB for integer chips. Power-dissipation considerations, on the other hand, give the edge to integer parts, which are usually CMOS. AT&T's DSP16 consumes 350 mW, for example, compared with 2 W (2,000 mW) for the n-MOS DSP32. Typical power consumption for the CMOS version of the 32-bit device—the DSP32C—is still a hefty 800 mW. Power consumption is particularly important in portable equipment such as cellular radio-phones.

The spectrum of DSP applications ranges from the low-end conventional modems used in facsimile machines to the hyperfast requirements of radar and sonar. An important performance indicator is the cycle time for a multiply-and-accumulate operation, says Nick Birch, product marketing engineer for Inmos Ltd. in Bristol, UK. Ordinary microprocessors attain minimum cycle times of 1 μs and can handle low-end communications applications such as 2,400 bit/s modems, he says. Dedicated DSP chips, with cycle times as fast as 50 ns, cover most of the remaining applications, such as V.32 modems, speech processing, and voice multiplexing. For higher-performance applications, special-purpose chips incorporating DSP functions, such as Inmos's A100, are the devices of choice.

Speech-recognition technology is hurtling ahead thanks to the sophistication supplied by DSPs. At its Columbus, Ohio, facility, AT&T Systems Division is developing a speech-recognition box using the DSP32 that will hook into a private-branch exchange and conduct highly structured conversations with callers. For the time being, at least, the technology is aimed at catalog mail-order sales. "The customer will phone in and talk to a computer," says Flynn. "The DSP will recognize what questions you're asking and respond with the correct answers."

Another DSP application tied directly to conventional phone service is the 9,600-bit/s V.32 modem. It was a designer's nightmare only a few years ago, largely for two reasons, says Jay Blazensky, product marketing manager for Digicom Systems Inc., Milpitas, Calif.

Where there's a complex algorithm to calculate, there's usually a DSP for the job

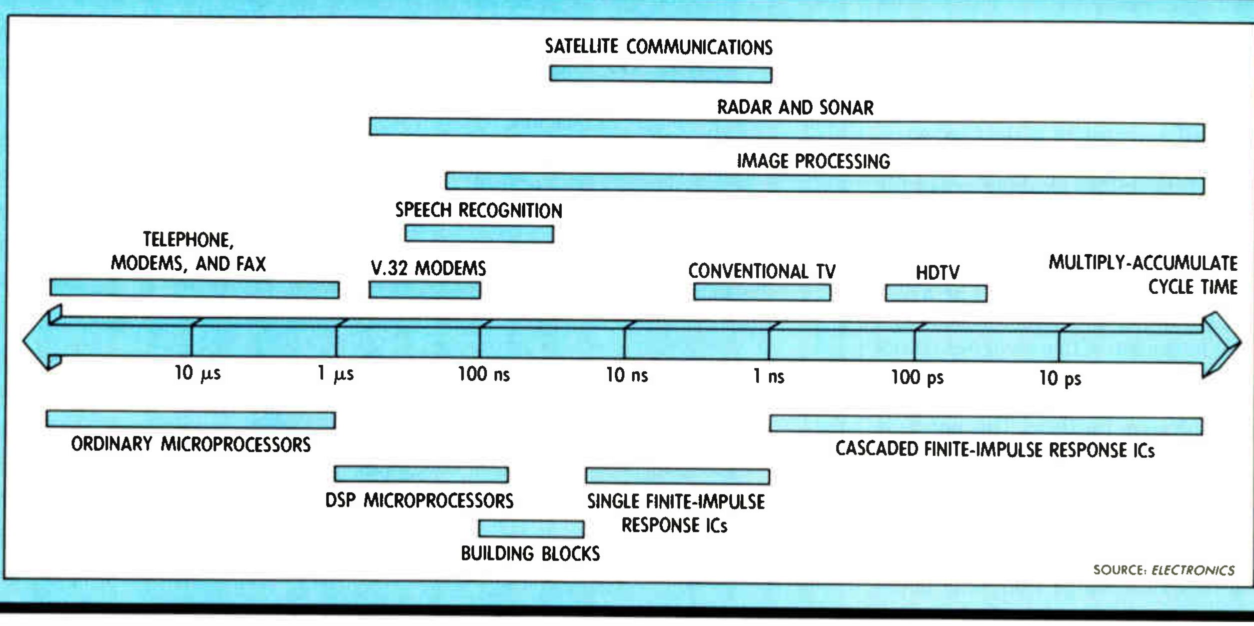
First, while transmitting in full-duplex mode at 2,400 bits/s can be accomplished by using split-band technology—transmitting over one band and receiving in another—the total bandwidth available on a phone line is insufficient for full duplex at 9,600 bits/s. That speed can only be handled by having the transmit and receive bands overlap. This calls for echo cancellation, which necessitates adaptive filtering using DSPs. And second, the 9,600 bits/s are still being sent at a 2,400-baud rate, a feat that requires sending four bits in each baud interval. Two modulation techniques have been developed to do this—quadrature amplitude modulation and trellis-coded modulation. Both are based on algorithms that require DSPs to run in real time.

Digicom Systems chose Analog Devices' ADSP-2100 for its modem. "The ADSP-2100 allowed us to use just one DSP instead of two," to handle both echo cancellation and adaptive filtering, says Blazensky. "It was mostly a matter of speed and resolution. The chip has 24-bit data lines where most of the others have 16 bits; and it lets you fetch, multiply, and accumulate in a single 125-ns cycle." Cutting the number of DSPs per modem also trims the number of peripheral chips, and by knocking off a few high-end features, its $795 price tag is well below the $1,500 to $1,700 charged by the competition.

Besides the telecommunications-switching applications for which DSPs were invented, one of the earliest volume applications was in facsimile machines, where the devices function as modems. But the present generation of facsimile is already pushing the performance limits of the last generation of DSPs, says Tim Litch, telecom DSP marketing manager for Texas Instruments Inc. in Austin.

"The Group IV facsimile machines have sophisticated data-compression requirements," he says, "but even beyond that, they call for a better image." While conventional facsimile could always handle text quite well, Group IV fax machines produce sophisticated gray-scale images, which means higher-performance image compression. DSP processors such as TI's recently introduced TMS320C30—which runs twice as fast as the company's 320C25 and has a more robust instruction set—will carry fax technology into the new generation. "Opting

DSPs: A SPECTRUM OF APPLICATIONS



SOURCE: *ELECTRONICS*

to use two C25s or one C30 depends on time-to-market considerations and price," says Litch. Right now, TI has not ramped C30 production and it costs two or three times what a C25 does. As with all chips, the price will fall as production rises, and Litch sees the transition to C30s as the chip of choice coming in the mid-1990s.

While companies such as Digicom and facsimile makers use DSPs to send data over voice lines, Pacific Communication Sciences Inc. in San Diego is hitching its wagon to a different star: sending voice over 64-Kbit/s leased digital data lines and 1.54-Mbit/s T1 lines. Tariffs on these lines have been in a free-fall since the Bell Operating Companies realized their value, says Philip Wilson, Pacific Communication's vice president for voice products.

FOUR FOR ONE. The company's algorithms for adaptive transform coding deliver a four-times multiplexing factor—they send four conversations over the 64-Kbit/s line that could carry only one without voice compression. "We can now do it in a consumer product in real time with DSPs," Wilson says. The algorithms, executed by TI's TMS320C25, analyze the analog voice input in the frequency domain, where redundant information is removed. "On each C25, we can put two channels at 16 Kbits/s plus two echo cancelers, and that's a significant advantage," says Wilson. Pre-DSP implementation would have required solutions costing more than $1,000, he says, but with DSPs in the $25 to $50 range, the cost is closer to $100.

In one of the more exotic applications, GE Government Services is using Inmos DSPs in a drug-trafficking radar system being developed for the U. S. Customs Service. The pulse-compression radar system will be suspended from a tethered aerostat, with a maximum of 1.5 kW of power being transmitted via the tether. But pulse compression yields a resolution that otherwise would have required 3 mW of input power, says Jim Houyouse, senior engineer at GE's Melbourne, Fla., operation. The radar can pinpoint an object to within about a twentieth of a mile. Each of six correlators, or processors, in the radar contains 18 Inmos A100s.

"We would have had a tough time building it without the A100s," says Houyouse. "Weight and power consumption are important. If we couldn't have put it inside the airborne system, we would have needed telemetry equipment capable of handling 100 Mbits/s of telemetry. With the pulse compression, we need 1 Mbit/s." To get high average power, says Houyouse, requires a very long pulse—in this case 150 µs long—that is compressed at a ratio of 200 : 1.

DSPs come into play because of their high-speed multiply-accumulate capability, and the Inmos A100 proved especially appealing because of its pipeline-processing, dual-register architecture.

The key pulse-compression algorithm has both real and imaginary coefficients, says Houyouse, and the dual registers allow designers to switch registers on alternate cycles to handle these two components. Pipelined processing is needed because of the real-time requirements of radar signal processing.

Europe is well ahead of the U. S. in cellular technology generally and digital cellular phones in particular. In this application, a battery of daunting problems besets even the most powerful DSP, says Hamid Alikhan, DSP consultant with Orbitel Mobile Communications Ltd., Hampshire, UK. That's especially true for companies working on a system generically known as Groupe Special Mobile, after the committee that wrote the specifications. The question being asked in European design labs is, can a cost-effective VLSI solution be designed, developed, and put into production before the project's 1991 target date? Orbitel demonstrated a prototype last summer, for example, but it occupied a standard 19-in. rack that was 4 ft high. To be commercially acceptable, the same functionality must be crammed into a holdable phone at a target cost of $350.

The time-division-multiple-access technology chosen for the GSM has a time slot between 600 and 650 µs, which requires very accurate synchronization of the network so the right speech packets are reassembled into a coherent conversation. The fact that the phones are most often moving places a further demand on the DSP—that the call be handed off from one cell to the next within 1 or 2 µs. Still another problem is the task of filtering out echoes—a job DSPs do well. The algorithms for handling such multipath distortion are jealously guarded by equipment makers.

Additional reporting by Peter Fletcher

NOW, A POWERFUL DSP SOURCE DEBUGGER

As digital signal processors push deeper into the mainstream and attract more applications developers, the programming aids available to designers are keeping pace. The latest is Ariel Corp.'s powerful debugging package for Motorola Inc.'s 24-bit 56001 DSP chip.

The BUG-56 breaks new ground in several areas for DSP tools. For starters, instead of the conventional line-by-line display of the program, the system is menu-driven and offers extensive on-line help screens. It also offers symbolic debugging, which is the Highland Park, N. J., company's answer to the problem of code addresses changing every time the code is reassembled.

BUG-56 lets program developers put symbols and labels on specific parts of the program, according to Anthony Agnello, Ariel's president. The symbols can be used as operands: for example, developers can begin single-stepping through their code by typing the label "begin" instead of typing in the physical address of the code line.

Until now, no one has taken on the task of developing a full-featured debugger, says Agnello, because the market has been too small to justify the cost. But Agnello joins many other market watchers in predicting rapid growth in DSPs.

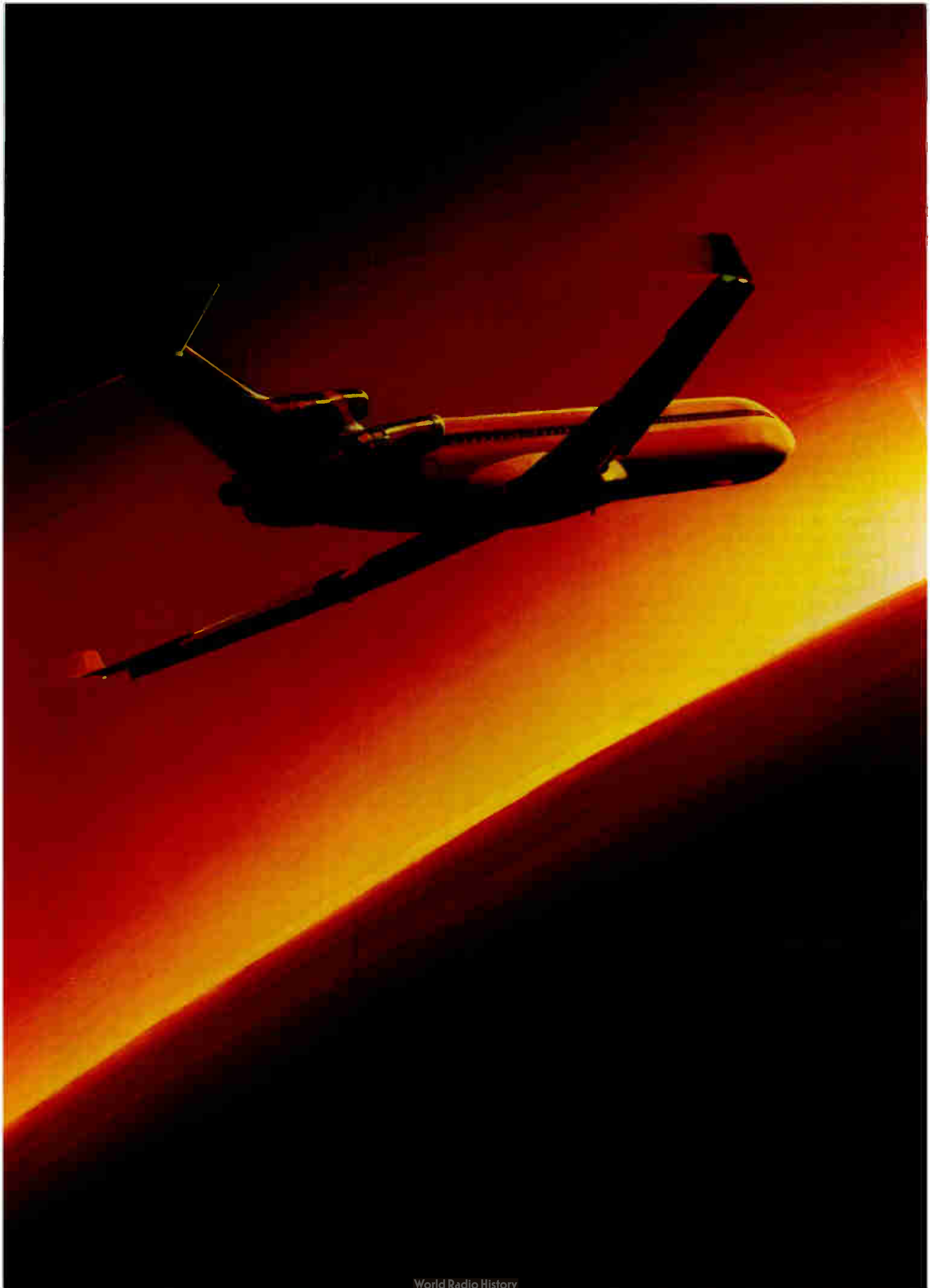
Texas Instruments Inc. started the move toward programmable DSPs, he says, and Motorola Inc. has upped the ante with its easy-to-use 56001. "Motorola wants to be a major player, and its chips are being designed to be close to a general-purpose processor," says Agnello. Namely, they use peripherals, a robust instruction set, parallelism, and a wider instruction word than competing products.

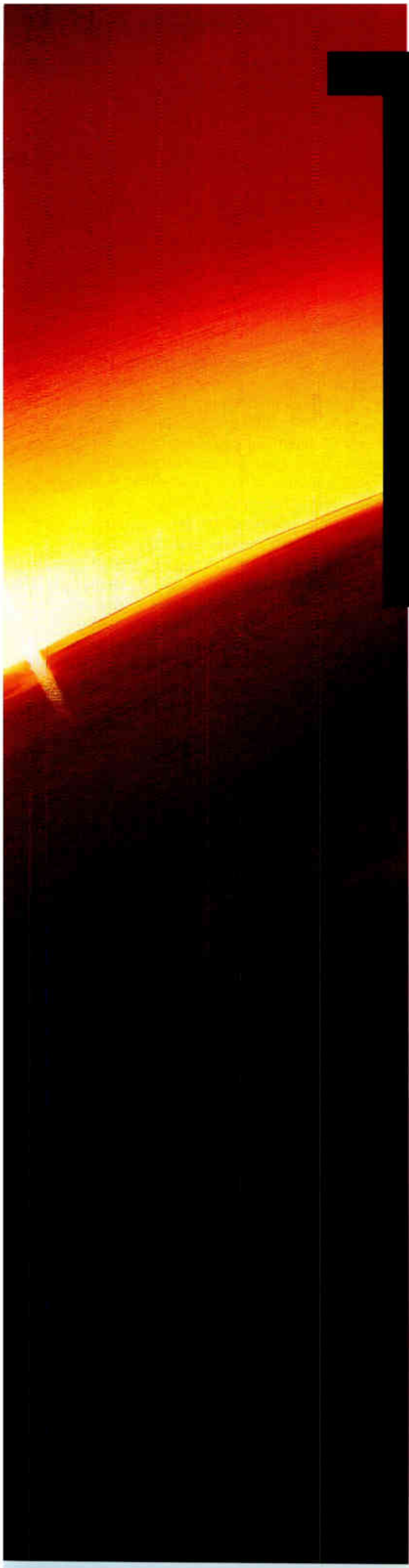
Ariel also offers a development-product line for TI's DSPs but has not yet fielded a high-end debugger for them. Ariel products run on IBM Corp. Personal Computers and Hewlett-Packard Co. work stations.

Comprised of 40,000 lines of source code written in C, BUG-56 runs the user's code on the chip itself, which permits debugging under full-speed operation. It also provides the ability to test the program against interrupts. "In the real world, the analog-to-digital converter is constantly interrupting the code, and you need to have complete control over interrupts," says Agnello.

Another interesting feature that is specific to DSP program development is the ability to hear the audio signals or view the video signals that the processor is manipulating. One more unique trait is that the BUG-56 provides hooks to MS-DOS, allowing the 56001 to perform operations that usually run on the PC. For example, files can be opened for reading, writing, or appending.

Debugging settings, such as breakpoints and traces, are automatically maintained in a configuration file. This saves the developer's time, says Agnello, by eliminating the need for repeatedly entering and exiting the debugger to access the settings. Finally, Ariel built support for two monitors into the program. Typically, one monitor will display the assembly code and registers while the other displays the high-level source code. This lets developers single-step through the program and watch the source code and registers change. *–J. S.*





PC GRAPHICS

MAINSTREAM MARKETS—BIG ONES—ARE HEATING UP; ONE KEY IS PHOTOREALISM

BY TOM MANUEL

Graphics uses of personal computers are growing up. Desktop machines can now be used for a galaxy of sophisticated applications as leading-edge technology pushes the quality of PC graphics to the level of hand-drawn and photographed images. Major mainstream applications beyond the familiar computer-aided design and business-presentation graphics are catching on fast and could contribute heavily to the growth of the PC and graphics-peripherals industries. Systems for desktop publishing, business-form production, fashion design, advertising, and medical imaging, among others, target millions of potential new users.

"The big buzzword today is photorealism," says Jon Peddie, who heads the consulting firm of Jon Peddie Associates in Oakland, Calif. Photorealistic image rendering on PCs takes cheap, abundant, internal memory and external storage; plentiful and inexpensive computer cycles; and high-resolution screens and printers. These pieces are rapidly falling into place.

The one element that's missing so far is affordable printing technology that can keep up with the graphics PCs can produce. "Today, people use color printers to do an in-house proof to see whether they like a particular graphic," says Joe Grossmann, vice president for product development at Enabling Technologies Inc. in Chicago. "But for the copies, that they take to the outside. My guess is, though, that within two years, we'll see high-quality printers that people will have at their desks." They should be priced between $2,000 and $3,000, Grossman says. He also expects to see some new color printers priced at around $10,000 that could produce the kind of production-quality graphics that people now get from an outside print house.

The processors, though, are already here. "Things are coming together now, if you include the work-station type of personal computers, such as those from Hewlett-Packard, Silicon Graphics, and Sun," Peddie says. "And in a couple of years, with the 80486 and the N10 [Intel Corp.'s new 80860 microprocessor] combination, we will have photorealism on Intel processors as well."

Also available now are high-resolution displays. MegaScan Technology Inc., for example, a Gibsonia, Pa., company, makes monitor subsystems consisting of very high-resolution monitors and the supporting frame buffers and display processors. The MegaScan UHR-2007 monitor, for example, features 200 dots/in. with 8 bits of gray scale. At 2,560 by 2,048 pixels on a 19-in. screen, it's the highest-resolution gray-scale display available, showing images of a quality exceeding that of 35-mm film. Another monitor from MegaScan, the UHR-3000, sets the resolution record for a 1-bit monochrome monitor at 4,096 by 3,300 pixels and 300 dots/in. It displays document pages exactly as they will be printed by a laser printer, at the same size and with the same resolution.

MegaScan is aiming at two main markets with the UHR-2007, says Kevin L. Gonor, the company's vice president of sales and marketing. One is satellite imaging, which takes in a range of applica-

A drawing package from ModaCAD for the fashion industry consists of software modules that automate every aspect of apparel manufacture, from drawing board to sewing room.

GEM Artline is a general-purpose drawing package from Digital Research Corp. that gives artists and designers in a wide range of businesses a variety of tools to work with.

tions. The second is medical imaging for digital X-rays and magnetic resonance imaging. The monitor makes it possible to build, in real time, digital radiology systems that doctors can use for diagnosis right off the screen. Because the image is in digital form, various views can be displayed at will and the images can be transmitted over communications links to 300-dot/in. monitors at other locations. "It is a breakthrough in diagnostic imaging, and it also eliminates the storage of film," says Gonor. Pushed by its medical-imaging users, the company is working on a 12-bit gray-scale monitor that will provide even more detail; it should be introduced next year.

The UHR-3000 is aimed at PC-based document storage and retrieval and desktop publishing. In the former, old, crumbling paper documents can be scanned, restored or enhanced, then stored forever for display at a quality equal to the original when it was new. In the latter, the operators can see a page of text on the screen exactly as it will appear in print.

Desktop publishing, in fact, is probably the hottest area for PC-based graphics. The worldwide desktop publishing market—including software and hardware and encompassing both the Apple Computer Inc. Macintosh and the IBM Corp. PC and its compatibles—will grow from $2.3 billion last year to $10.1 billion in 1992, according to the market research firm Dataquest Inc. in San Jose, Calif.

Among the companies tapping into the market is Sigma Designs Inc. The Fremont, Calif., company's SilverView is the first 21-in. gray-scale monitor for the Macintosh II. It provides nearly 16 by 12 in. of display area, which means it can display full pages and even double-page spreads. In the color arena, one of the newest monitor subsystems is a 1,600-by-1,200-pixel monitor from the Computer Graphics Division of Lundy Electronics & Systems Inc. in Glen Head, N. Y. The Lundy 1612 is the highest-resolution display system on the market for IBM PCs and compatibles, the company says.

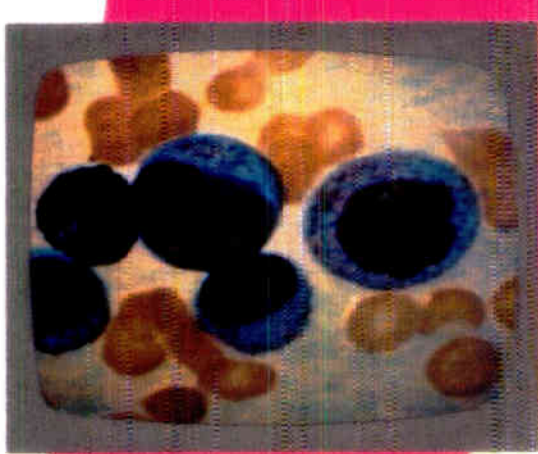
One of the key requirements for desktop publishing, assuming clear text has been achieved, is the production of high-quality pictures. One method for producing such pictures is to scan and digitize photographs and then change and retouch them electronically.

A typical product used for such work is the Digital Darkroom software package for the Macintosh from Silicon Beach Software in San Diego. The company is probably the leader in the field of gray-scale image processing, at least in the lower and middle ranges of the market. Since it was introduced last August, about 10,000 copies of the Digital Darkroom package have been sold at $295 each. The software automates 90% of the process of retouching through macro commands, or "macro-level technology," as opposed to pixel-level manipulation at the high end. A typical application involves removing a person or object from a picture and having the software adjust the gray scale so it matches, thus making the photo look natural.

Silicon Beach intends to follow the Digital Darkroom with another product, the Supercard, which is scheduled for introduction this month. Among other things, it will enable designers to write their own graphics applications for Apple machines. The company claims that the $195 Supercard outperforms Apple's very popular Hypercard, which it resembles.

Desktop publishing is not the only application that requires production or reproduction of high-quality artwork, of course. So do advertising, interior design, and fashion design, to name a few. For all of them, software is available that provides drawing capabilities plus a library of existing art—so-called "clip art"—that can be used as it is, combined, or otherwise modified. Programs exist for both Macintosh and IBM and compatible PCs. Among them are Illustrator, from Adobe; Freehand, from Aldus; Artline, from Digital Research; Designer, from Micrografx; and many others. Paint and draw graphics programs for personal computers represent a significant PC market segment. Dataquest pegs this market at 901,000 units and $220 million in 1987; and 1.1 million

Medical imaging systems convert laboratory data into a series of images that help doctors make diagnoses and prescribe treatments.



600-by-800-pixel resolution now. But Armitage expects that within 18 months, 1,024-by-1024-pixel resolution will become the standard.

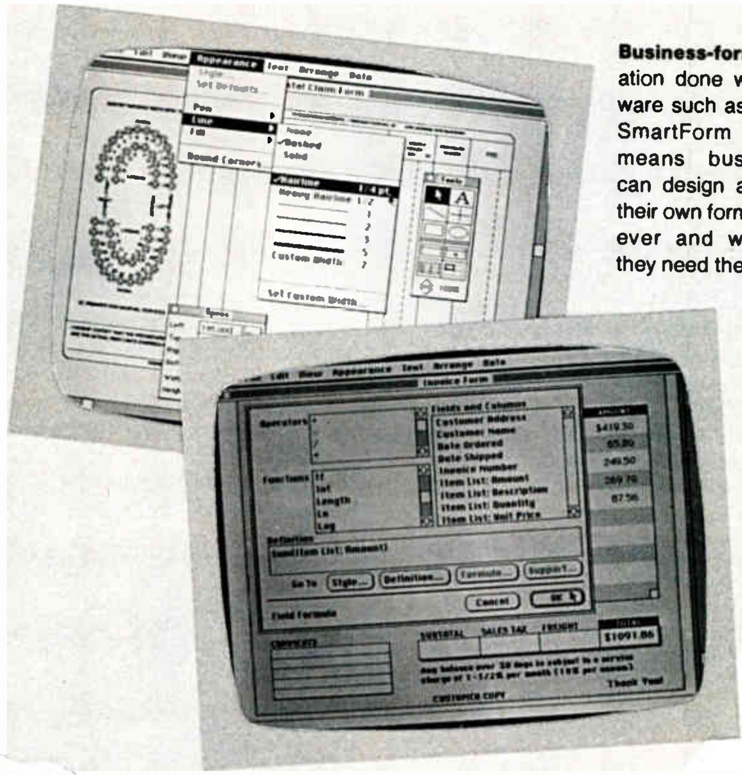
Armitage says he's also excited about the prospects for availability of Intel's 80486 by the end of the year. But he's got some concerns about the need to move to an operating system beyond MS-DOS—be it OS-2 or something else—to tap the hardware's full power. "The one thing we can't really do on PCs right now with large images is real-time panning, real-time zooming, and real-time 3-d rotation," Armitage says. "But the faster coprocessors and the faster graphics boards are going to let us do that."

The technology pushing PC graphics extends beyond processors and memory. More sophisticated data-acquisition and imaging boards, for example, are making a wealth of new applications possible. For example, one company that supplies such boards, Data Translation Inc. in Marlboro, Mass., sells products that support two vastly different kinds of systems. One involves medical imaging for diagnosis and treatment of kidney stones and gallstones; the other encompasses sophisticated before-and-after graphics being used by hair stylists.

Data Translation's customer for the medical application is an equipment supplier to the medical profession whose name the company declines to reveal. Its system—which has been approved for use by the federal Food and Drug Administration—is about the size of an average refrigerator, according to Bernadette Morrissey-Golas, product marketing manager for scientific image processing at Data Translation. The system processor that's used is an IBM PC AT-compatible computer.

Data Translation provides a DT 2808 data-acquisition board, DT2851 monochrome frame-grabber board, and DT2858 coprocessor board for the PC. The data-acquisition board is linked either to an X-ray camera or ultrasound sensor to acquire and convert the analog signals for use by the frame grabber. The frame grabber captures and stores the images, assisting a radiologist in determining the location and dimensions of a patient's kidney stone or gallstone.

But instead of the conventional procedure of having the radiologist send a written report to the patient's physician, which may take days, the physician can receive the processed images almost immediately for evaluation if his PC is equipped with a frame grabber, too. Then if the patient and doctor decide to bombard a kidney stone with ultrasound, the imaging system can also be used to determine if the stone has been pulverized. Morrissey-Golas says her customer's system is in use in hospitals in Louisiana, Minnesota, Nebraska, and Texas.



Business-form generation done with software such as Claris's SmartForm series means businesses can design and print their own forms whenever and wherever they need them.

In sharp contrast to the medical system, another Data Translation customer in Coral Springs, Fla., uses a Macintosh II equipped with the company's DT2270 Color Capture color frame-grabber board to preview hair-styling and other cosmetic changes. The company is called Combputer Images Inc., which sells or leases the equipment to hair-styling outlets for use in helping clients decide what changes, if any, they want to make in their appearance.

The frame-grabber board captures the subject's current image from an NTSC-type video camera linked to the Mac II. Then the stylist can apply to that image a variety of other hair styles and colors retrieved by the system from a digitized library stored in an associated video recorder, which is also driven by the frame-grabber board. The customer gets a good idea of how his or her hair will look before it's actually cut or colored.

Another emerging application is the design and production of business forms. By producing their own forms, companies no longer have to worry about stocking and distributing reams of paper forms. New forms and new versions of old forms can be quickly produced as they are needed. They can also be distributed over a company network and printed at remote locations to serve the needs of local divisions or offices. Companion programs can help users fill out of the forms on the computer as well.

Controlling a business tool as commonplace as a form can help an organization save a significant amount of money. The market for PC-forms software, as a result, is starting to take off. In 1987, the PC-forms products market was 127,000 units, worth about $50 million, according to Dataquest. The market research firm expects the 1988 market will end up having accounted for 237,000 units, worth $94 million, and it predicts that the 1989 market will come to 350,000 units worth $138 million.

PC forms-production packages are now available from a half dozen or so firms. Claris Corp., the Mountain View, Calif., Macintosh software company, has a major offering in its SmartForm Series products. Similar packages are available from a number of other companies including Delrina Technology (Per:FORM), Channelmark (Power Up FormsFile), Creative Laser Systems (Create!Form), Megahaus (MegaForm), Shana Enterprises (FastForms), Adobe Systems' Spectrum Digital Systems subsidiary (TrueForm), FormWorx (FormWorx), Softview (FormSystem), and Acius (4thDimension).

Most of these include a form-filling-out program as well as design and production software. The software division of Antic Publishing Inc. offers Flexform templates, a library of forms to be used with Claris SmartForms, that reduce the time it takes to design and lay out computerized forms.

Additional reporting by Larry Waller, Wesley R. Iversen, and Lawrence Curran

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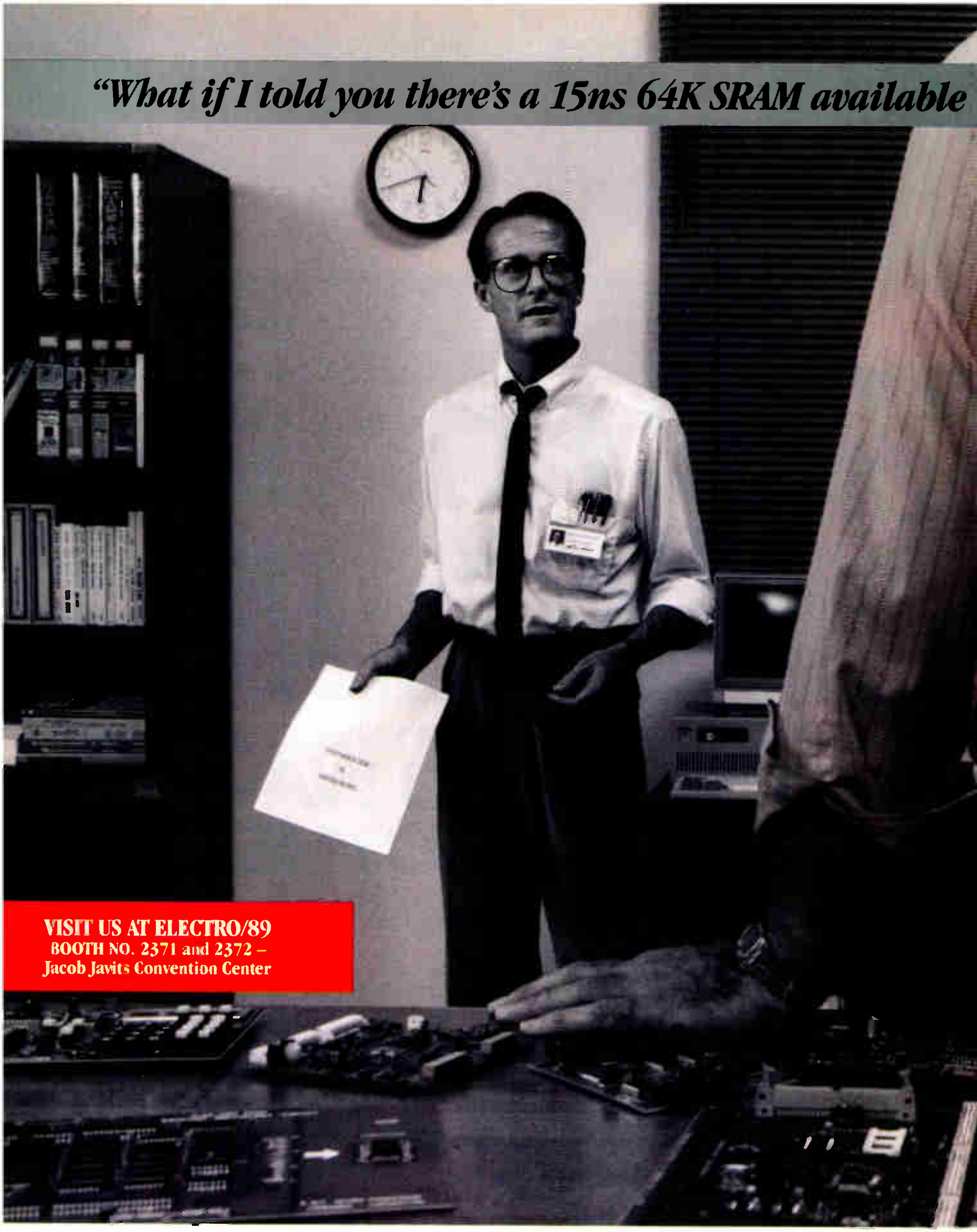

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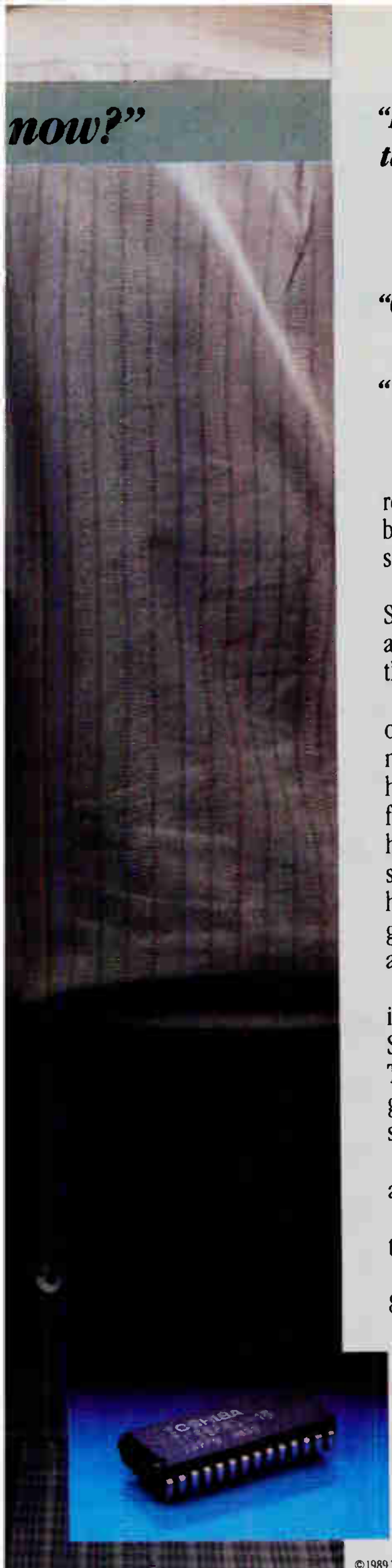

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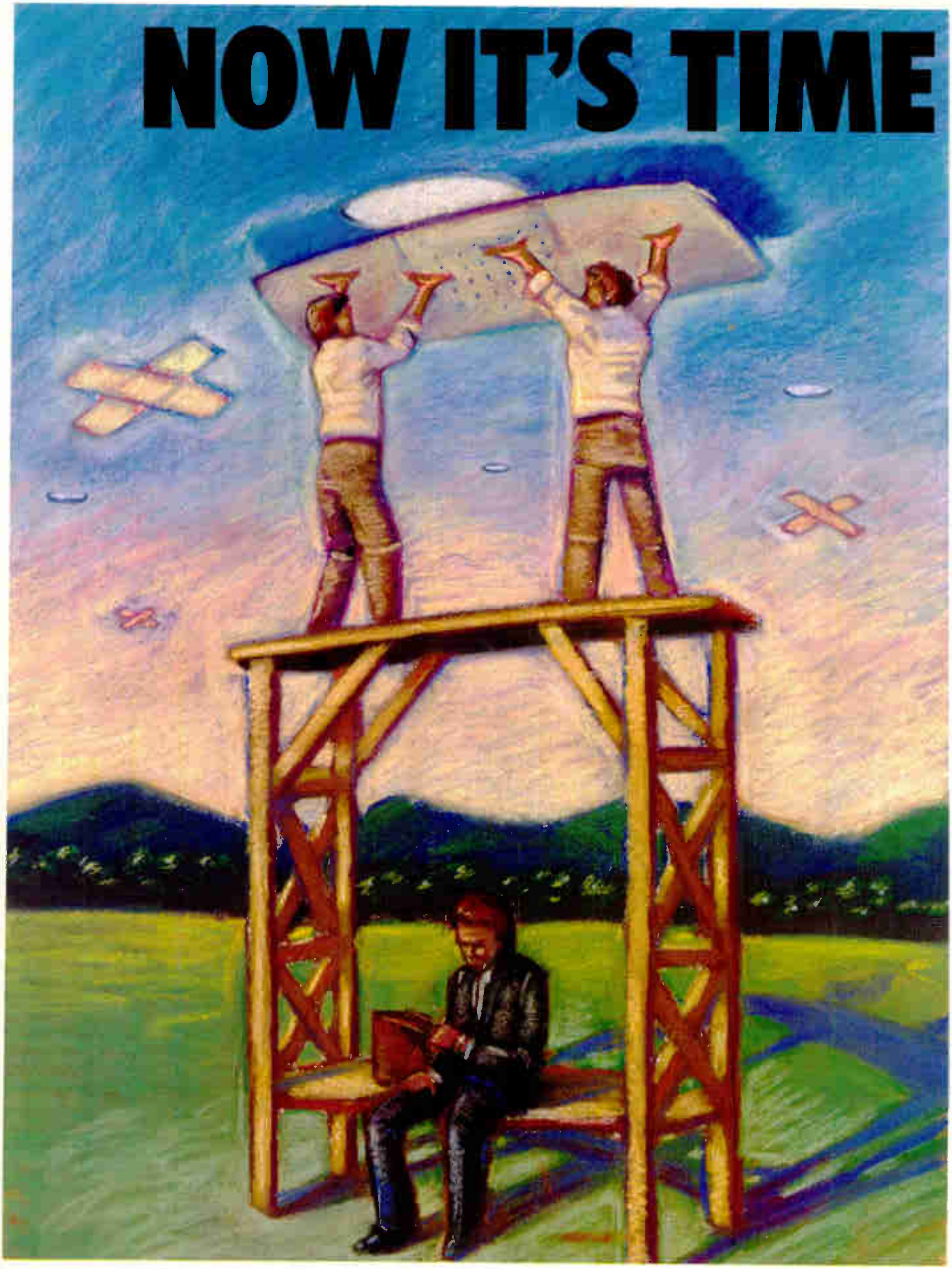


TO FIX THE SKY

by Tobias Naegele

From IC firms to computer makers, the electronics industry is scrambling for options to replace the chemical CFC

In the annals of electronics history, 1988 may go down as the year the industry woke up to the fact that it was helping to burn a hole in the sky.

Chlorofluorocarbons, or CFCs, were the wonder chemicals of the 1980s: nontoxic to workers and seemingly harmless to the environment. Electronics companies fell in love with them, incorporating the chemicals in the manufacturing processes of everything from computer disk assemblies and circuit boards to optical fiber and semiconductors. It seemed too good to believe, electronics executives recall. And it was.

Scientists now say CFCs are responsible for the deterioration of the Earth's stratospheric ozone, a layer of triple-atom oxygen molecules that filters out the sun's harmful ultraviolet rays, preventing skin cancer, crop damage, and other environmental hazards. The giant "ozone hole" that now appears each winter over Antarctica has been blamed on CFCs. And a new report, just released by the National Aeronautics and Space Administration and the National Oceanographic and Atmospheric Administration, claims that high concentrations of ozone-depleting chlorine compounds in the Arctic stratosphere threaten the ozone over the North Pole as well.

Although scientists have been warning of the possibility of ozone depletion for years, the hard evidence startled governments and businesses alike. The Montreal Protocol, an international treaty signed last year by the U. S., the Soviet Union, the European Community, Japan, and eight other nations, will limit CFC sales to 1986 levels as of July of this year. That's 15% to 20% less than was consumed in 1988, says Robert L. Cohen, business manager of Du Pont Co.'s Electronics Department. "So the freeze is really a cutback." Du Pont is the world's largest producer of CFCs.

The protocol calls for a further 20% reduction July 1, 1993 and for an overall 50% cutback from 1986 levels by mid-1999. Still further cutbacks are expected. Last month the 12-member EC and Canada announced they would no longer use or make CFCs after the end of the century. Shortly afterwards, President Bush said the U. S. would follow suit. And experts now expect the Montreal Protocol's limitations to be revised in the next year or two, cutting back to 5% to 15% of 1986 levels by the end of the century.

Du Pont, in fact, is so sure that further limits will cripple the CFC business by then that Cohen says, "our policy is to withdraw from manufacturing CFCs entirely" by the turn of the century. "There are no buts in there," he adds. "We're going to do it."

ACTION NOW. "Many people see the protocol as the last word," says Cheryl Russell, director of environmental and occupational health at the American Electronics Association. "It's not. The restrictions are going to be tightened." And the hunt for alternatives, which include terpenes, water-based detergent solutions, conservation, and a broad-based search for new solvent chemicals, will take years, she says. "People need to take action and they need to take action now," Russell says. "If they don't, one day they'll wake up and have to pay 100% more for the CFCs they're using, and the next day they won't be able to buy them at all."

Electronics manufacturers are by no means the biggest consumers of CFCs—40% of the estimated 720 million lbs of CFCs produced in 1986 were used as refrigerants and 28% in various forms of foam, such as fast-food packaging, cushions, and insulation. But electronics still represents a significant 12% chunk of the market. All told, the industry consumed on the order of 95 million lbs of CFCs in 1988, at a cost of around $128 million. "For electronics companies, the problem is huge," says an executive at IBM Corp., the industry's largest CFC user, with an annual worldwide consumption of nearly 11 million lbs. "We use CFCs in virtually every product we make."

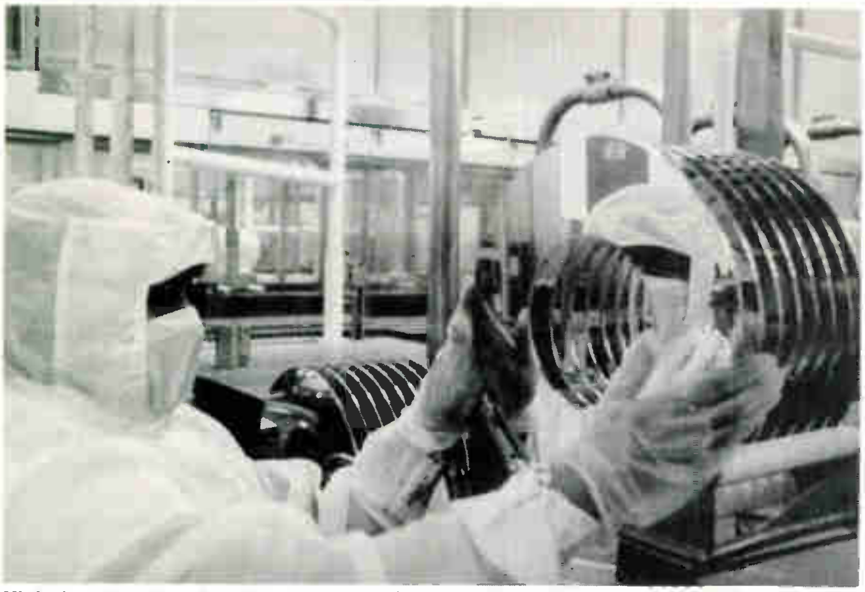
Furthermore, the way CFCs are used in the electronics industry often involves free release of the chemicals into the atmosphere, thus constituting a particularly "dirty" application. CFCs in refrigeration systems are at least inside sealed tanks and plumbing. That's why electronics firms stand to gain so much from conservation—catching the CFCs and recycling them.

CFCs were first developed 56 years ago for refrigeration. Chemically inert by nature, they are a class of organic gases and liquids composed of a carbon backbone with chlorine and other halogens—usually fluorine or bromine—attached to that backbone.

The chemicals, specifically CFC-113, one of nearly a dozen CFC compounds, were first used in electronics in the late 1950s and were used only sparingly through the 1970s. But when surface-mount technology came into vogue in the 1980s, the use of CFC-113 rocketed. The new circuit boards were tough to clean, and manufacturers quickly learned that no available solvent had as much to offer as the CFCs, which were nontoxic, apparently environmentally safe, easy to evaporate, and very, very clean. The chemicals also posed no destructive risk to the product.

Along the way, the military caught on, essentially mandating in its specifications that CFCs be used to clean a vast array of military products. That endorsement, many experts say, may have encouraged companies to use the chemicals in commercial processes so that they could meet military specs without running separate manufacturing lines. In fact, some observers credit mil-specs with driving as much as 40% to 50% of

Illustration: Mark Braught



High-density disk-drive plants such as this one, at IBM's San Jose, Calif., facility, are major CFC consumers. IBM is exploring water-based detergent solutions as a replacement.

the electronics industry's CFC use. The Pentagon, in conjunction with electronics firms and the U. S. Environmental Protection Agency, is trying to address this issue (see p. 96).

Now, having grown addicted to the chemicals, the electronics industry is looking for another way. It won't be easy. The variety of applications for which CFCs are used is so large that even Du Pont executives don't really know how and where their chemicals are being employed. But with production limits already set, companies will have to work fast.

In addition to the upcoming limits set by the Montreal Protocol, there is an additional threat to supplies posed by the CFC makers themselves. The protocol only limits their total output, leaving them free to make whichever CFCs they choose within those limits. So automakers, for example, whose car air conditioners account for more than 25% of total CFC consumption in the U. S., may have more pull than the electronics consumers relying on CFC-113.

That has electronics users fearful that shortages could arise, forcing prices way up and taking money away from their efforts to find replacements. Du Pont's Cohen admits that "it is conceivable that some CFCs will become more scarce than others."

Two other hidden threats are local legislation and a move afoot in Congress to tax "windfall profits" on CFCs if artificial shortages lead to unusual price hikes. CFC manufacturers fear such a tax, which they consider "counterproductive." They say any excess profits are needed to offset the huge investment they're being forced to shoulder to develop and manufacture alternatives. Congressional sources counter, however, that artificially high prices could serve as a disincentive in the search for alternatives, allowing companies to earn substantially higher profits from reduced operations.

Local governments are also drawing heat from the chemical and electronics industries for their efforts to get into the CFC regulating game. The worry here is that individual governments will ban or limit CFC use before companies are able to find out everything they need to know to choose an alternative. Rhode Island, for example, last year passed legislation intended to ban the sale of all goods containing or made with CFCs. The law, which remains on the books, is premature and unenforceable, says F. A. "Tony" Vogelsberg Jr., an environmental manager at Du Pont headquarters in Wilmington, Del.

"You can't just go out and ban everything that uses CFCs in its manufacture," says Vogelsberg. "We're talking about cars, video-cassette recorders, TVs, computers, houses—because of their insulation—almost everything. We're not opposed to legislation," he

AT IBM, FIRE AND WATER ARE REPLACING CFCs

IBM Corp. consumed 11 million pounds of chlorofluorocarbons in 1987, an amount representing almost 12% of the entire electronics industry's consumption. "We are, without doubt, the biggest electronics user of CFCs in the world," says a company executive.

And what part of the company uses the most? Probably its massive disk-drive assembly and manufacturing facility in San Jose, Calif. The plant absorbs roughly 2.75 million pounds of CFCs a year, representing about 25% of IBM's worldwide use. Cutting down is difficult, but IBM has had moderate success: CFC use declined 20% in 1988 from 1987's level, and executives expect to boost the savings to 30% this year, thanks to a combination of conservation and process changes.

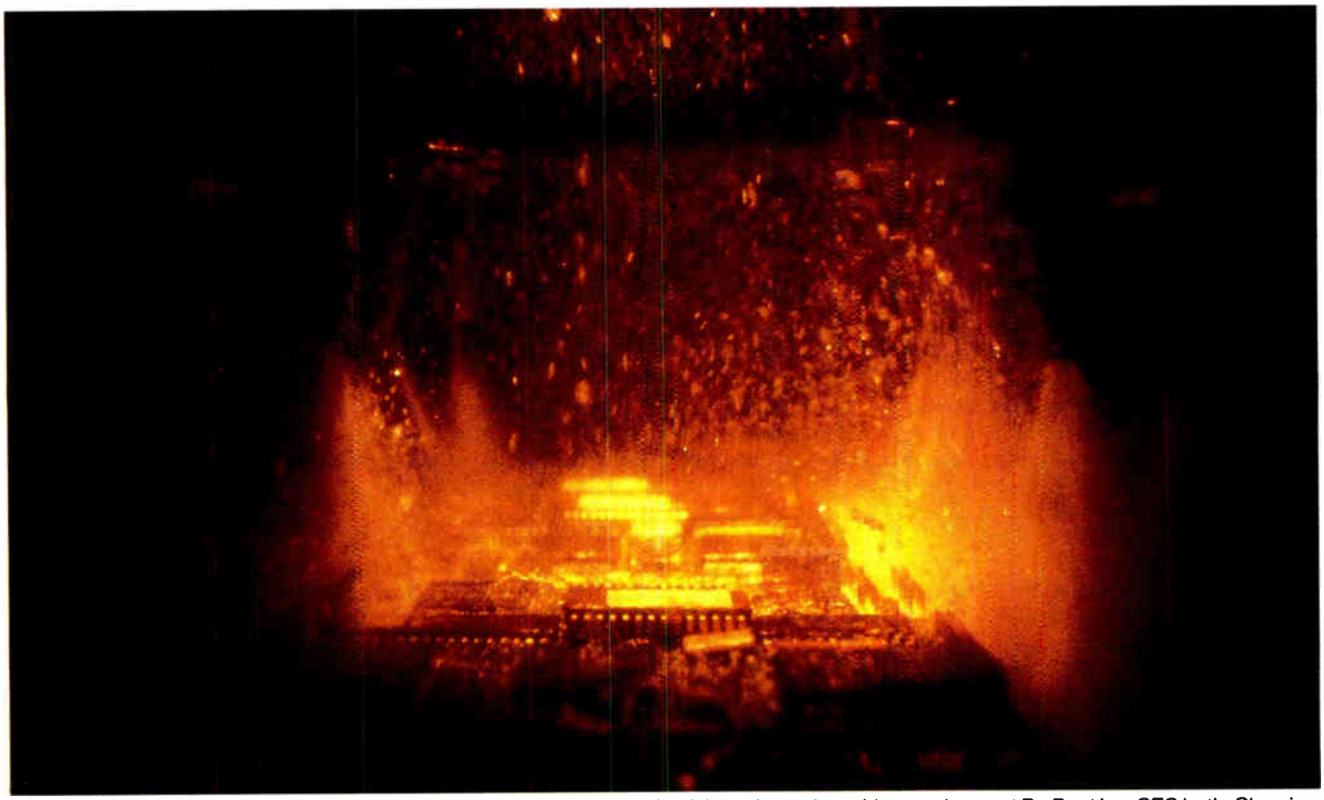
The company began with simple solutions, says June J. Andersen, the plant's project manager for environmental assessment. Its first project was to find ways to conserve CFCs and to control emissions. It resulted in new cleaning systems that have "every known way of conserving and controlling" the chemicals used to clean its complex head-disk assemblies. IBM enclosed the systems to trap evaporating gases and installed facilities for cleaning and reusing the chemicals.

Those changes helped a little, Andersen says, but not enough. The next project was much bigger: finding steps in the manufacturing process where CFCs could be replaced with water-based detergent solutions. This remedy is "limited to applications where you have compatible materials," Andersen says. For example, most magnetic materials cannot be washed in water because it degrades performance. Also, very small or complex geometries, such as the read/write heads for disk drives, can't be cleaned in water, primarily because water's high molecular surface tension hinders cleaning and drying in such small spaces. Since either failure can render an expensive part useless, other solutions will have to be found, she says.

Not all parts, however, are so sensitive. Some are washable in highly purified water and detergent solutions and where possible, IBM has tried to make the switch. "We are able to wash head-arm suspensions in water-based processes" in some cases, says Andersen. Elsewhere, the Armonk, N. Y.-based firm has found a way to use hot water and air to replace the CFCs it once used to dry damp disk substrates before the magnetic material is applied. Since the process is cheaper than the CFC-based system it replaces, the company will end up with identical quality and save money too.

But Andersen is quick to point out that what's good for IBM isn't necessarily good for everybody. "Yes, changing to water-based processes saves us money," she says. "But we already have a water-purification plant [to make the purified water these jobs require] and a waste-water treatment plant [to clean the detergent from the water afterwards]. Not many others can afford to have these kinds of facilities on their own." *—T. N.*

Electronics companies consumed 95 million lbs of CFCs in 1988, or about 12% of the U. S. total



The biggest electronics users of CFCs are manufacturers of printed-circuit boards, such as this one shown at Du Pont in a CFC bath. Cleaning boards and assemblies accounts for 40% of the industry's consumption, and alternatives may be hard to find.

adds. "We just want to make sure that what [state governments] do pass is reasonable and enforceable."

California and the Canadian provinces of Ontario and British Columbia have all begun efforts to impose restrictions on CFC use, despite criticism from those who say that unless this issue is worked out on a global basis, the dangers of ozone depletion will remain. "The stratosphere can't tell the difference between CFCs from California and CFCs from Taiwan," says Michael R. Harris, market development manager for alternate fluorocarbons at ICI Americas Inc., the Wilmington, Del., subsidiary of UK chemical giant ICI Ltd. "This has to be addressed as a global problem, not a local one." That means getting compliance from Taiwan, the two Koreas, India, and other recently industrialized countries that have not signed the Montreal Protocol.

But local governments persist. A bill currently moving its way through the California state senate, for example, seeks to give the state's Air Board the authority to monitor the development of CFC replacements. Once it has determined that an alternative solvent is available for a given application, the Air Board would be able to outlaw the use of CFCs for that particular job.

That kind of regulation has many in the electronics industry worried. "Let's not go racing in to use some other chemicals before we're really sure that we know everything there is to know about them," says the AEA's Russell. "One of the reasons we switched to CFCs in the first place was that we felt they were safer. Some of the other chemicals we used before CFCs raised questions later about cancer and other health risks." She says the industry fears that, if the issue is rushed, it may be forced to use solvents that could be "extremely hazardous" to workers' personal health. "That just does not seem like the way to go," she says.

Another wrinkle is that unlike other industries, where CFC use is straightforward and consistent from one application to the next, electronics manufacturers use the chemicals in such a huge variety of applications that finding substitutes is a shockingly difficult task. Even officials at Du Pont and ICI admit that finding replacements will be more difficult and take considerably longer than for many other industries, because of the wide variety of CFC uses and the high sensitivity of the parts they clean. Simply put, solutions that work for Tektronix's cathode-ray tubes are not likely to work for Motorola's printed-circuit boards, IBM's computer disk drives, AT&T's optical fibers, or Intel's semiconductors.

So the search for alternatives will be a long, hard road, with every user fighting for solutions to his own unique problems. Many circuit-board makers, for example, are turning to terpenes—naturally occurring solvents that are derived primarily from citrus rinds and forest products, such as wood pulp—to clean their boards. But these solvents are too harsh for IBM's purposes, says the Armonk, N. Y., company, which uses CFC-113 to clean and dry its high-density disk drives. Instead, the company has found a 30% savings by switching, where possible, to water-based cleaning methods (see p. 94). And virtually all electronics companies are finding that by conserving, they can reduce their CFC use by as much as 25% or more, according to the EPA.

Still other pc-board alternatives involve switching to cleaner, so-called low-solids fluxes or using chlorinated solvents. The latter solution has already caught on in Europe and Japan, but it worries U. S. environmental officials because of the concern "that if it has chlorine in it, it must be bad," says Harris of ICI. His company is marketing Propaklone, an alcohol-and-trichloroethane mixture that it says works well in surface-mount applications. The chemical requires somewhat more careful handling than CFCs, he says, but is a far lesser danger to the ozone layer.

If any one alternative has captured wider attention than the others, it has to be the terpenes, which seem to have comparable cleaning capabilities to the CFCs. And the terpene that has attracted the most attention is Bioact EC-7, a mixed product made from several natural and synthetic terpenes—including one produced from orange and lemon rinds—specifically for cleaning pc boards. EC-7 was developed by Petroferm Inc., a small, privately held company in Fernandina Beach, Fla., which markets it jointly with Alpha Metals Inc., a Jersey City, N. J., supplier of solder and solder-related materials.

Their largest customer so far: AT&T Co., which has cautiously embraced the chemical and is now using it in limited quantities at three U. S. plants. Other companies, including Texas Instruments Inc. and Japan's NEC Corp., are using it, too, though in far more moderate amounts. But AT&T executives, who say that pc-board cleaning accounts for about 25% of the company's annual CFC consumption, are not ready to abandon other technologies in their search for alternative solvents. In fact, the company has just begun offering commercially the AT&T Low Solids Fluxer, which allows it to use a non-CFC cleaning process at several of its pc-board manufacturing facilities.

AT&T's use of EC-7 is still "not major," says David Chittick, AT&T's vice president for environmental and safety engineering. And he says it's not likely to become major any time soon, because it requires a more complicated two-step cleaning process than the one-step cleaning provided by CFCs. EC-7 also necessitates entirely different equipment from the CFC vapor-phase cleaners that AT&T and most other companies currently use.

Other drawbacks to EC-7 are more troubling. Some say the chemical is too harsh for many applications. Others suggest that it may be too expensive. And still others worry that terpenes may not be as environmentally safe as Petroferm would like people to believe. They worry that the chemical may turn out to be more toxic than now believed, and that terpenes, which are long-lived and robust, pose special waste-management problems that may be difficult to address for companies that depend on municipal sewer authorities. Finally, some critics of the chemical note that, with a fairly low flash point of around 117°F, terpenes may pose a fire hazard when sprayed and could even be explosive.

Petroferm president and chief executive officer William R. Galloway Jr. readily admits that EC-7 may be more difficult to handle than CFCs. But he also states unequivocally that the risks it poses are far less severe than "the risk of letting all those CFCs float up into the atmosphere and burn a hole in the ceiling." As to cost, he says he sees no rea-

CFC ALTERNATIVES

Alternative	Date Available	Years to Penetrate Market	Estimated Reduction Potential
Terpenes/Aqueous Cleaners	NOW	5	50%
CFC-113 Azeotropes (including Freon SMT)	NOW	4	12%
Conservation	NOW	1	25%
HCFC-123	1992	10	3%
Other solutions in development	?	?	10%

SOURCE: U.S. Environmental Protection Agency & *ELECTRONICS*

ONCE PART OF THE PROBLEM, DOD BECOMES PART OF THE SOLUTION

One of the biggest reasons electronics firms use chlorofluorocarbons to clean their circuit boards, disks, and other equipment can be summed up in two words: military specifications.

The Defense Department requires its contractors and their suppliers to choose their solvents from a short list that includes some alcohol-based cleaners and CFC-113. They allow no other solvents without special permission, and because of the long delays involved in getting such approval, few, if any, companies make the effort. As a result, many firms now use CFC-113 exclusively on all their product lines in order to avoid widely varying process changes between military and commercial products.

"As much as 40% to 50% of the [use of] CFCs in electronics today is driven by military requirements," says Joseph Felty, process engineering manager in electro-optical systems for Texas Instruments Inc. in Dallas. And that's regardless of whether or not the end product is destined for military use. "What happened was, the spec became a de facto world standard. It's a badge of quality."

But the badge is beginning to tarnish. Deputy Secretary of Defense William H. Taft IV issued a directive in mid-February ordering defense agencies and services to seek ways to cut down on CFC use. The directive established a Pentagon role in the funding of research-and-development activities to search for replacements. But perhaps more importantly, it also sets a department-wide policy to "review and modify military specifications to permit use of new processes, techniques, or chemicals" to replace CFCs.

Some work is already under way. In conjunction with the U. S. Environmental Protection Agency and industry, the DOD has launched a joint program to find acceptable alternatives to CFC-113 in printed-circuit-board applications. Code-named "China Lake" because much of the initial work has been done at the DOD's Electronics Manufacturing and Productivity Facility near China Lake, Calif., the project is aimed at quantifying "how clean is clean," says Felty of TI.

The China Lake team, which includes staff engineers and managers from AT&T, IBM, Northern Telecom, and other companies in addition to EPA and DOD officials, has so far produced a benchmark test card designed to mimic the variety of features and components that might be found on a typical military circuit design. The card includes both large-pin-count surface-mounted devices and through-hole wired components. Initial test boards were processed through standard vapor-phase solder-reflow processes, batch degreasers, and wave fluxers and soldering systems. They were compiled in early March, and the group is beginning to test alternative solvents.

"In the long run," says Felty, "we'll need new chemicals. But right now there are a lot of chemicals that will suffice. They may require more or different equipment, but they will work." —*T. N.*

son why he should be helping electronics manufacturers cut their costs while offering a solution to their problem. "We're not selling this product on the basis of price," he says. "The fact is, there isn't another commercially proven alternative [to CFCs] available. We're going to charge what we can."

The specter of increased costs for CFCs or other chemicals, coupled with the lack of many proven alternatives, has put the initial emphasis at most companies on a very simple concept: conservation. Northern Telecom Ltd., which consumed about 2.2 million lbs of CFCs annually in 1986 and 1987, almost exclusively for cleaning circuit boards, began to address the issue when the Montreal Protocol was signed in January 1988. The Canadian telecommunications giant implemented a conservation plan in July, and "by October, we had achieved a 30% reduction in CFC use," says Art Fitzgerald, director of environmental affairs at the company's corporate headquarters in Toronto. "By year's end, we were up to a 40% reduction."

That comes as no surprise to Du Pont's Cohen, who says that his company has long been trying to encourage conservation and better use habits—to no avail. "We've been telling customers for years that they could conserve and save money, but I guess there just wasn't any incentive, until now."

Northern Telecom's story of waste-not, want-not economics should also leave the company somewhat richer for its effort. Fitzgerald says he estimates the savings will equal at least $600,000 a year, and probably more. And so far, almost all of the savings has been from simply being more careful in the handling of the chemicals themselves, making sure cleaning tanks are covered and leak-free, for example.

Conservation is also a thrust on Capitol Hill, says an aide to Sen. John H. Chafee (R-R. I.), who has introduced a bill to severely limit the production and use of CFCs and other chlorine-based chemicals with ozone-depleting potential. "We're going to press for much more recycling at the very least," the aide says. "We should not be freely venting these chemicals into the atmosphere."

Northern Telecom has also benefited from using Freon SMT, "an interim solution," according to Cohen of Du Pont, which manufactures the material. Freon SMT is a CFC azeotrope that reduces the amount of CFC-113 in cleaning machines by about 25%. It was developed for cleaning solder flux off pc boards assembled using chips in surface-mount packages, and Northern Telecom and other companies have made the switch as an interim move to cut down on emissions. ICI also offers a variety of CFC-113 derivatives and azeotropes for electronics users under its Arklone brand name.

ICI and Du Pont are working on other alternative chemicals as well. Cohen says Du Pont is set to announce a pair of new chemicals that may be useful some day but are still "at least three years away." It will take that long, he says, to determine if the market wants the chemicals and whether it is worth building the plants necessary to make them. One is a semi-aqueous solution that, like Bioact EC-7, requires a two-step process beginning with a bath or spray and finishing with a water rinse. The other is based on HCFC—that's hydrochlorofluorocarbon—technology, a chemical that is far less damaging to stratospheric ozone.

Every solution helps a little bit. But executives at larger firms are saying that all the solutions in the world will do little good if they're kept in a vacuum. Much as electronics companies are pushing government to address the whole CFC-ozone issue on a global scale, they realize that their own CFC challenge needs to be tackled as an industry-wide problem if it is to be licked at all. The largest companies depend so much on smaller vendors, they say, that unless these smaller players get a helping hand, the larger ones will, in the end, pay the price.

Conservation has had its successes: Northern Telecom cut CFC use 40% in a year

"What the industry needs," says one IBM executive, "is technology transfer. We need to find a way, on a continuing basis, to get the word out. The recognition is there now, from both producers and users, that this stuff won't be around after [the year] 2000, except perhaps for some specialized uses. Now we've got to get down to the issue of finding replacements."

Yet the EPA, which many electronics-industry spokesmen say should be taking a lead role in technology transfer, is often criticized as not being helpful enough. "The EPA has not been as good as it should be in this issue," says Terry McManus, manager of corporate environmental affairs at Intel Corp. in Scottsdale, Ariz. "They need to play a role, put on seminars, produce documents on success stories and substitutes. You don't see enough of that."

IBM has become a leader in seeking a solution to its massive CFC requirements, and Big Blue is doing its part to share the progress it has made using aqueous cleaning and other techniques. Executives hint that further developments, in particular a possible replacement for some surface-mount pc-board applications, may be announced shortly. IBM is viewing the CFC issue as one of strategic importance, and is trying to assist its vendors and other smaller companies to overcome their dependence on CFCs. June J. Andersen, project manager for environmental assessment at IBM's Environmental Department in San Jose, Calif., says the company is also publishing papers on its replacement research in order to reach the broader electronics community.

That, most experts say, is essential. The largest companies—IBM, AT&T, and Digital Equipment Corp., for example—were quick to recognize that CFC supplies might be cut off or diminished in the 1990s, and they have been pursuing alternatives and working on conservation methods for several years. But the vast majority of U. S. electronics firms are not capable of setting aside man power, money, and equipment to tackle what they see as a chemical or environmental, rather than a technological, problem.

"Almost 80% of our members are small companies," says the AEA's Russell. "These firms don't have the money to hire environmental experts. What we need is technology transfer." To further that aim, the AEA sponsored a two-day seminar on the CFC problem in Santa Clara, Calif., late in February, and last fall the University of California at Los Angeles also held a meeting on finding CFC alternatives.

While IBM has taken on a major role in looking out for the little guy, its motives are not purely altruistic. One of the biggest reasons for proselytizing aqueous cleaning is that, since parts must be cleaned more than once as they undergo various steps in the assembly process, consistency in cleaning methodology is vital. "If the vendor uses water-based cutting fluids [to reduce friction when machining a part], then we can use water-based cleaning later on," Andersen says. "There really is a chain among all the vendors, from the most basic parts all the way up to our finished [product]. We're all in this together." □

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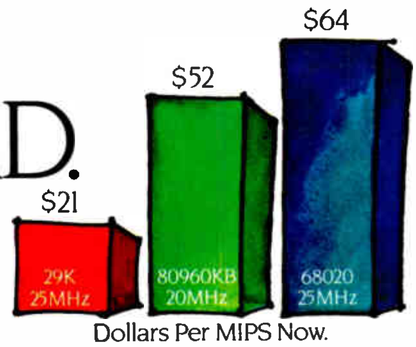

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HIGH-TECH MARKETING: A BALANCING ACT BETWEEN STYLE AND SUBSTANCE

How do you grab the industry's attention and get across complex ideas at the same time?

by Larry Waller

One of Retix Corp.'s best-selling products has more to do with graphic design than electronic design. The medium: ink on paper. The price: $15. The aim: to make comprehensible the mind-boggling intricacies of the Open Systems Interconnect data-communications protocol and, not coincidentally, to boost Retix's role in the OSI hardware and software market.

The product is a colorful poster depicting the seven-layer complications of the OSI models and protocols in all their incredible detail. The Santa Monica, Calif., company has printed 40,000 copies so far, and the end is not in sight: chairman of the board Andy De Mari says orders are coming in so fast that Retix may end up distributing 400,000 by the time it's through.

What's more, he's convinced that without the poster, Retix would have been hard put to duplicate its fast-growth record: sales should top $40 million this year. "It gives us visibility and a unique symbol," he says.

The Retix poster is one example of a successful solution to the perennial head-scratcher that technology managers face. Whether at a multinational giant or a modest startup, they must find a way to propel their products or services—or their companies' names—out of the crowd. They must promote new ideas, educate an audience about technologies it doesn't understand, or change outside perceptions, sometimes radically. And they must do it in a tumultuous environment where competitors worldwide are all striving for the same thing.

The fox is Edgecore, the stallion Motorola in this updated Aesop's fable that's aimed at marketing VMEbus boards

Pulling it off successfully requires starting with the right stuff—a demonstrably superior product that leapfrogs rivals and hits prospective customers squarely where they live. The best examples are already part of industry folklore: Intel Corp.'s family of microprocessors, Apple Computer Inc.'s machines, especially the Macintosh, and a handful of others. At that lofty level, many industry observers would place Apple founder Steve Jobs's NeXT machine; its blockbuster debut last October has given Jobs a chance to repeat his Apple success, some say.

But the great bulk of the industry doesn't have the superstar pizzazz—or, often, the advertising budget—to command such widespread attention. Especially for small firms, it's tough just to get enough visibility and name recognition for the sales staff to get its foot in the customers' door.

Despite the difficulty of the challenge, though, a few small companies—Retix among them—have mounted successful efforts to catapult themselves and their products into industry consciousness. Their accomplishments are all the more remarkable because they are promoting new or difficult technologies, such as fuzzy logic or the complex, poorly understood OSI, both of which need far more detailed explanations, even among technicians, than familiar subjects like microprocessors and computers. In this category, run-of-the-mill promotional techniques that depend on announcements, press conferences, and word of mouth seldom are effective.

The trick is to come up with a fresh marketing slant that has enough sizzle to grab attention and gets across complex or subtle ideas at the same time. The problem is by no means a new one—the advertising business has been grappling with it for many a year. But the task is especially hard in the high-technology arena, as any executive who has been charged with the job will confirm.

Carrying it out successfully represents nothing less than "the heart of marketing technology," says Stanley Michelson of the Los Angeles advertising firm bearing his name. A veteran marketing executive who directs campaigns for a host of high-tech clients, Michelson most admires work that can "dramatize things in nontechnical terms." The prospective audience is receptive to this approach as long at "it maintains technical integrity too," he says.

That's why the Retix poster works so well. First distributed in 1985, the year the company was founded, it offers a high level of technical detail in an accessible, graphically appealing way. Retix has used the poster as a springboard to gain prominence as a hardware leader in OSI networks and bridges, along with the software that ties them together. The poster is anything but a happy accident; it was created with this intent in mind, says De Mari.

Retix's founding coincided with the debut of the international standards, whose protocols require reams of paper to explain completely, even to specialists. As De Mari recalls, he and cofounder John

Stephensen, the senior vice president for technology and strategic marketing, decided to devise a graphic presentation of "an architecture very difficult to understand in the complexity of its relationships." They boiled down the voluminous OSI specifications, using smooth ellipses for the graphic blocks rather than harsh triangles or rectangles.

From the base of giving "something useful to the telecommunications community," the poster carrying Retix's name in its lower left-hand corner can today be found on walls in engineering facilities throughout the world. The poster's complexity actually works in the company's favor, says Stephensen. When equipment designers view the maze of OSI requirements, he says, they think, "Maybe we need Retix to guide us through."

De Mari believes that as the new gear incorporating OSI gets into end-user hands, demand for the poster will grow. The company gives the poster away to companies in its target customer group and sells it to anyone outside of that niche. Surprisingly enough, some 75 such over-the-transom requests come in for the poster every month, and no one has complained yet about the $15 price tag.

Just as a poster has helped Retix gain an edge in OSI, so a demonstration program similar to a video game is the tool being used by another company specializing in an arcane technology. Togai Infralogic Inc., an Irvine, Calif., startup, faces the daunting task of trying to explain fuzzy logic.

The firm has gotten up a good head of steam by introducing a compiler for this form of logic, which in effect adds "maybe" to standard logic's "yes" and "no" options. A dedicated processor is due out within several months [*Electronics*, March 1989, p. 102]. But fuzzy logic is still so little known that even the research scientists and designers of expert systems who are the prime potential users are mostly in the dark. The question was, "What can we come up with that will educate them to what fuzzy logic can and can't do?" says Carl C. Perkins, Togai's vice president for business development.

Togai's answer is an interactive demonstration program for personal computers, which the company whipped up in the course of a few weeks and delivered to prospects who were calling for information last February. It gives a knowledgeable person the tools to solve a particular real-time control problem.

The idea, says Perkins, was to "give them something interesting, but more important, something they can do themselves. If you can get their attention, you've hooked them." He says the feedback is encouraging so far, but more time must pass before interest translates into sales. The company kept costs for this promotion tool at a minimum by doing all

GIVING IT ONE BIG PUSH: APPLE AND '1984'

Many of the best promotions work well on a small scale—within small budgets and with a narrowly focused audience. But sometimes a company needs to get a clear new message across to a huge audience. Such was the case for Apple Computer Inc.'s Macintosh, whose debut in the middle of the 1984 Super Bowl represented a whole new kind of promotion strategy: "event marketing."

The company's famous "1984" commercial established the Mac as a new kind of personal computer, different from IBM Corp.'s PCs. It launched the product that gained Apple a role in corporate computing, a machine that eventually would make possible a whole new role for the personal computer: desktop publishing. Considering just how successful the advertising campaign was, it seems astonishing in retrospect that the commercial almost didn't run.

Back in 1983, Apple faced an uncertain future. Sales of the Apple II were softening, the Apple III was selling poorly, and an ambitious new machine, the Lisa, had flopped. The company had a lot riding on the Macintosh.

The ad established the Macintosh as a different kind of computer

Apple's management felt it had to persuade potential customers that the new computer was radically different from the PC. The Mac actually was radically different, with its icon-based user interface and a mouse controlling its operation. It was designed to be far easier to use than a PC.

But every personal-computer maker claimed his machine was easy to use, says Fred Goldberg, vice chairman of Chiat/Day in San Francisco, Apple's advertising agency at the time. IBM had mounted brilliant ad campaigns starring a Charlie Chaplin-like character; the ads and the character were exceedingly friendly, and they made it seem as if the PC must be friendly, too.

So the promotion for the Mac somehow had to portray the Apple machine as something dramatically apart from the PC. Chiat/Day came up with a simple, highly effective tactic. It would not attempt to differentiate between the Mac and the PC. Instead, it would dramatize the difference between Apple and IBM.

The ad worked beyond Chiat/Day or Apple's wildest dreams. It aired only once, during the broadcast of Super Bowl XVIII in early 1984. Taking advantage of the implications in "1984," it set up a scene with overtones of George Orwell's novel. In a large hall, row upon row of figures, identically dressed in drab garb, stare with blank eyes at a huge screen, waiting for Big Brother to speak. Suddenly, a young woman in colorful athletic attire bursts into the hall, running toward the screen. As she comes close, she flings a hammer and smashes the screen and the image of Big Brother.

To anyone who knew anything about Apple and IBM, the implications were unmistakable. Apple was the champion of the daring, the unconventional. IBM epitomized the tyranny of a colossal corporation, the grinding effects of conformity. The ad didn't need to actually mention IBM or its PC.

The 60-second spot was a sensation. The day after it ran, Goldberg says, a survey showed it was scoring 79% in viewer recall—that is, 79% of 38.8 million households watching the Super Bowl remembered it. The impact was heightened as word of the commercial spread. Evening news shows reran the commercial, breeding more attention. The fact that the commercial ran only once during the game added to its mystique.

The single showing, however, was a fluke. For that matter, the fact that the commercial aired at all was something of a fluke.

Chiat/Day had originally purchased three time slots during the Super Bowl. Then Apple's board of directors got a look at the commercial. They hated it, for reasons that remain unarticulated. Perhaps the attack on corporate drabness hit a nerve. In any case, they demanded that it be yanked.

Chiat/Day successfully sold two of the time slots, but it couldn't unload the third. Rather than eat the cost of a unused slot, Apple's management overruled the board.

The storm of media attention created by the commercial blew away any doubts Apple might have had about its propriety. The sales helped, too. The day after the Super Bowl, Apple sold $3.5 million worth of computers in six hours, Goldberg says. In 90 days, it sold $155 million worth.

The Macintosh promotion didn't end with the "1984" commercial. The day after the Super Bowl, Apple started running another TV ad in which someone drops all the manuals needed to use the IBM PC, then drops the one small Macintosh manual. Print ads filled out the promotion campaign.

The momentum begun by the campaign is still building. In 1984, Apple had $1.516 billion in net sales. John Rossi, an analyst in the San Francisco office of the investment firm of Alex. Brown & Sons, expects it to have net sales of $5.3 billion this year. For Apple, 1984 was a very good year. *–Jonah McLeod* the work internally. Perkins thinks the universe of potential users presently numbers about 500, but could pick up as the technology takes off. So a more sophisticated (but not interactive) version of the demonstation is in the works for videotape presentation.

If Togai's marketing tool is high-tech, Edgecore Computer Inc.'s is decidedly low-tech. Last year the Scottsdale, Ariz., company embraced Aesop's Fables as its main communications vehicle when the usual methods failed to get its story across clearly.

Edgecore is a supplier of top-end VMEbus boards that offer compatibility with Motorola 68000-series processors at a higher performance level. But the burden of explaining what former marketing executive Pam Mayer calls largely "intangible concepts" proved tough. Such issues as product breadth, upward software compatibility, a single architecture for all needs, close association with Motorola Inc., and staying out of competition with its OEM customers did not lend themselves to a conventional marketing framework, she recalls.

Company president Phillips Smith happened to be leafing through a collection of the classic fables when the proverbial light bulb flashed above his head. "It was incredible the way they hit on the issues," he says. The race between the hare and the tortoise, for example, has direct meaning for users who are contemplating the raw speed of reduced-instruction-set computers instead of the complex-instruction-set architecture of the Edgecore boards. Then there's the wisdom of an alliance between the fox (Edgecore) who climbs on the back of the stallion (Motorola) to pluck fruit off the higher branches of the tree.

Edgecore kicked off its Aesop's program a year ago by mailing off a book of the fables along with a flyer discussing some "timeless truisms" about computers, giving the company twist. It followed up with four individual tales, one every few weeks, along with a calender-poster for 1989. The fables came with appealing illustrations and a low-key Edgecore tie-in woven in at the end.

To give engineers a handle on what fuzzy logic can and can't do, Togai distributes tnis house-produced "video game."

Response from the 600 potential buyers targeted by the direct-mail effort has been greater than expected, says Mayer. Follow-up research showed that the recipients remembered details. As a result, awareness of Edgecore and its products shot up, so salespeople had an entree. The campaign cost $80,000, but the firm believes that spending many times that amount in standard advertising would not have gotten similar results.

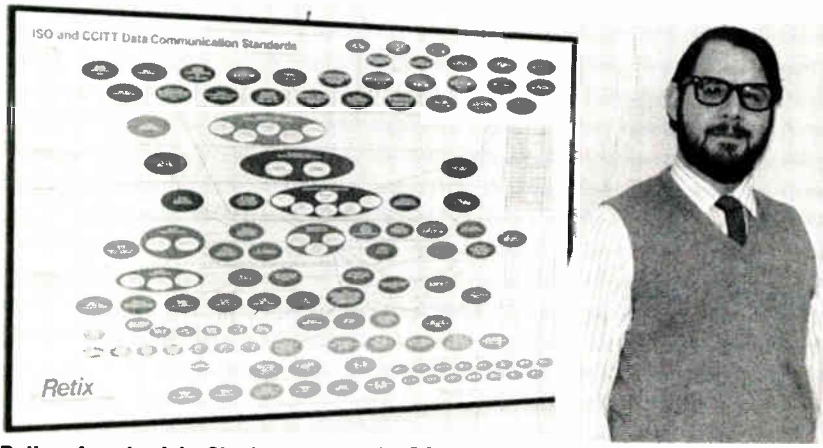
Of course, marketing hits like these are matched by any number of misses—ideas or products that disappeared without a trace. For example, IBM Corp. sunk some $100 million into its PC Jr., complete with a slick Charlie Chaplinesque advertising campaign. Lotus Development Corp. couldn't get its Symphony package off the ground; and even the acknowledged master, Apple, had to withdraw its Lisa computer. Basic product inadequacies or poor market targeting were the culprits, and heavy investments in clever promotion and advertising programs could not save them.

Even some very innovative efforts with sound products behind them can stumble and fall. A prime example is the Dumb Terminal, sold by a division of Lear Siegler Inc. in the late 1970s. The meteoric success of its marketing campaign catapulted the Anaheim, Calif., division into a spot as the leading independent supplier of this equipment. The idea originated in an agency brainstorming session when a staff member remarked, "How can we sell this thing? It's so dumb it doesn't do anything." But later on, when terminals became a commodity item facing major foreign competition, the established reputation of the Dumb Terminal couldn't save it. Lear Siegler sold the division some years ago, before the company itself disappeared in a leveraged buyout.

Failures of this type come as no surprise to consultant Regis McKenna, whose Palo Alto, Calif., firm guided Intel and Apple in their formative days. "Flashy sales and marketing techniques can work with consumer [products], but not for technology firms," he says bluntly. Glitzy approaches cannot replace solid steps taken for business reasons. Both Intel and Apple designed their first products in close cooperation with heavyweight customers, then built momentum on the strength of these relationships. Building and exploiting this "reference structure," as McKenna terms it, is the key to the success of startups.

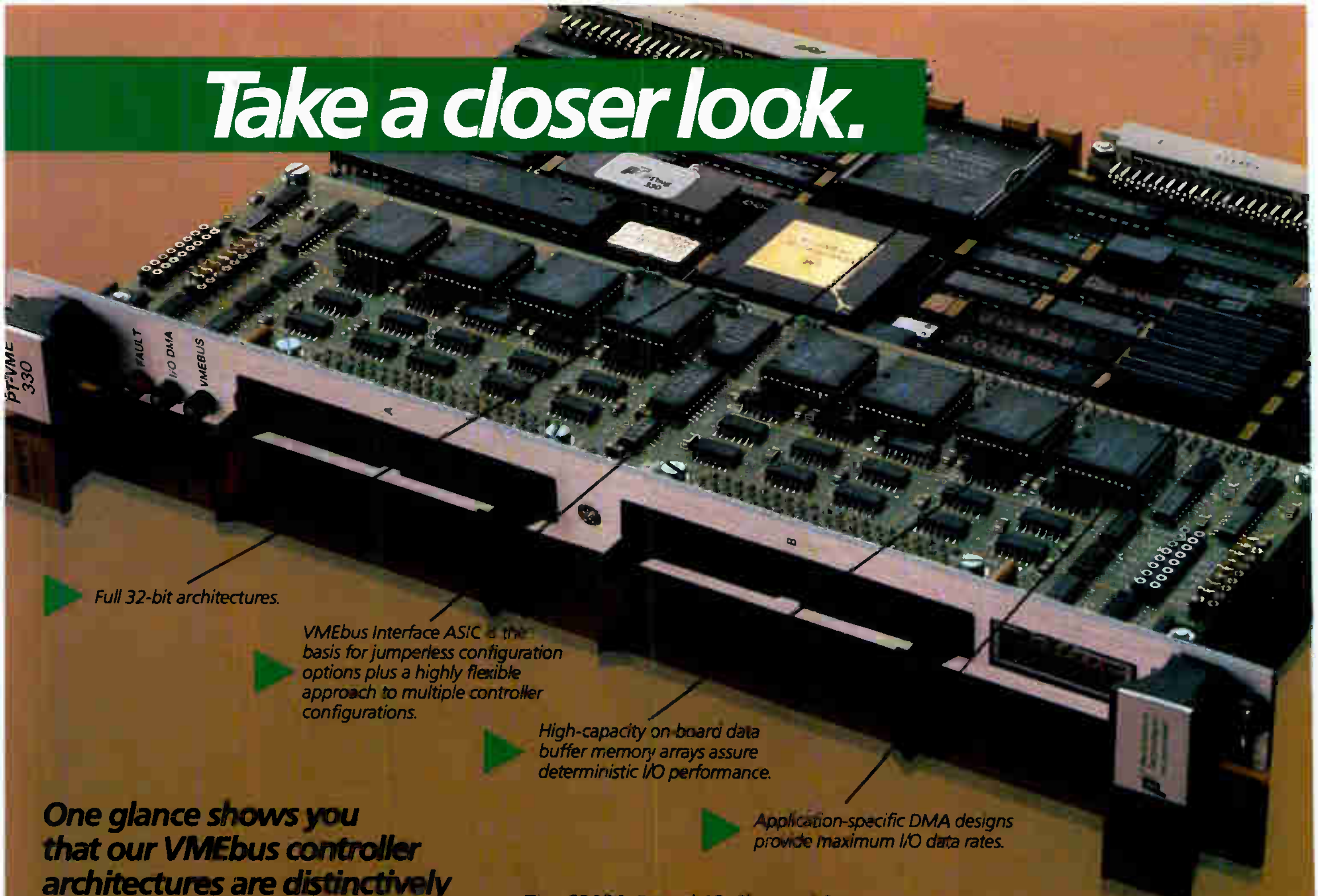
The brilliant marketing idea is then built upon this solid base, he says. That's why he predicts that Jobs's NeXT will be so successful in its target market, high-level education. Of course, Jobs has star quality, and that can't hurt. But, says McKenna, his preparatory spadework is a textbook case of touching all the bases. For example, he says, Jobs brought Stanford and Carnegie-Mellon University representatives onto his board; he forged an alliance with IBM to share the NeXT interface; he recruited third-party software writers; he attracted financier H. Ross Perot as an investor; and he set up beta-test sites at top schools.

It seems to have worked. "We came as unbelievers and left as converts," says computer-industry expert Richard A. Shaffer, editor and publisher of the authoritative *Technologic Computer Letter*. Shaffer admits he was initially skeptical of the hype surrounding the NeXT debut. Now he predicts it will repeat Apple's success, due in no small part to the power of the ideas driving Jobs. "He is a great salesman of dreams," says Shaffer, "and dreams are what America buys." □



Retix cofounder John Stephensen says the OSI poster's aim was to give "something useful to the telecommunications community." In return, Retix got a springboard to OSI prominence.

Take a closer look.



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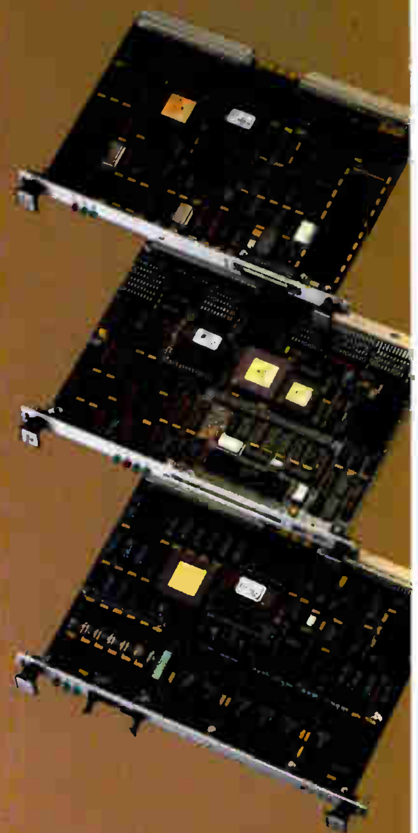

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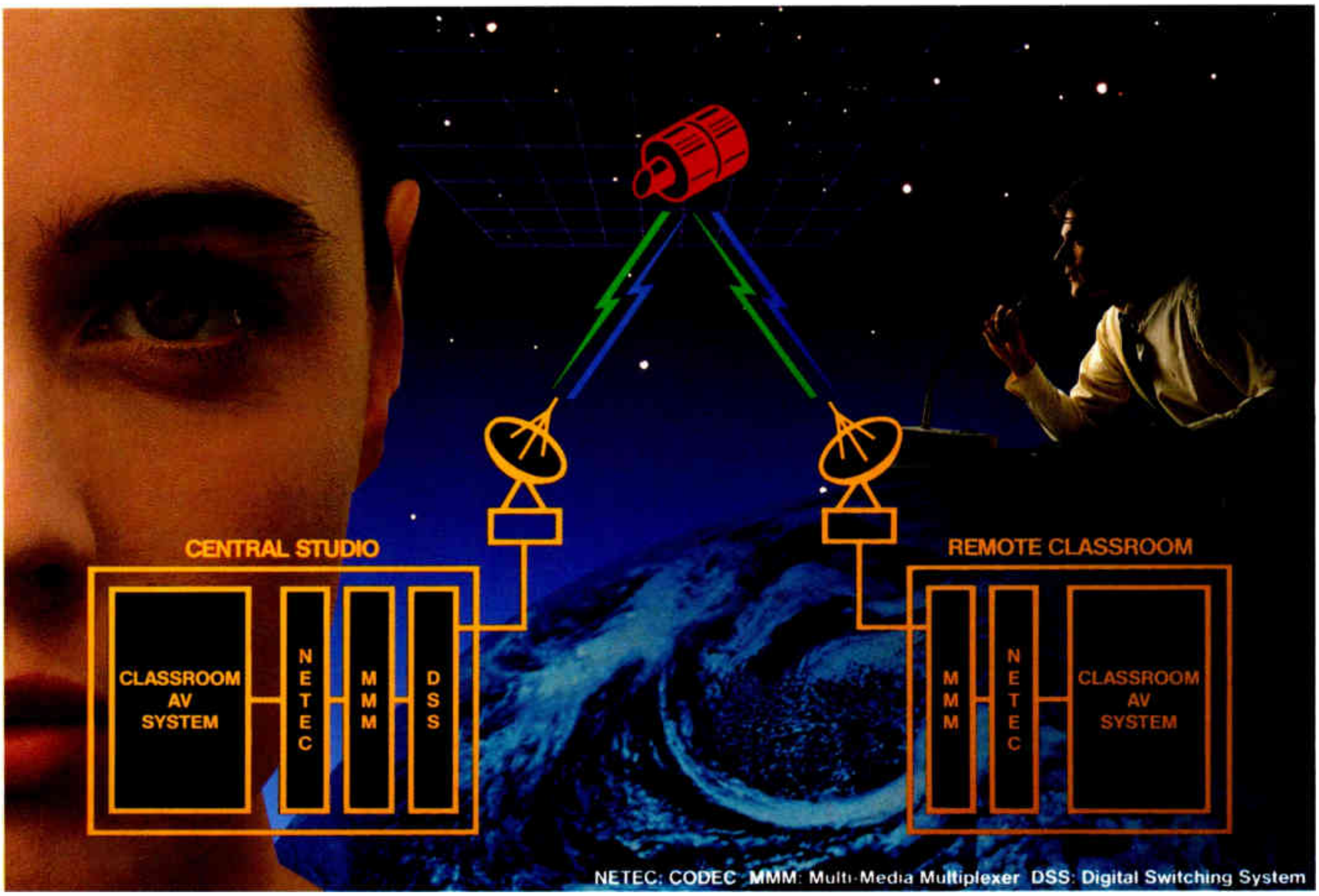

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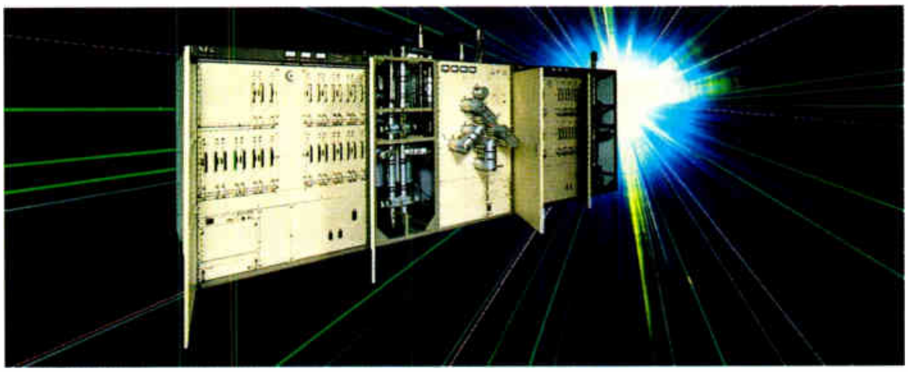


VAST LIBRARY SYSTEM FOR CHINA.

NEC is supplying a large-scale information system to the National Library of China (NLC) in Beijing. With over 14 million volumes in its collection, the NLC is one of the world's largest libraries.

The library system for the People's Republic of China consists of two mainframes for database management and 270 personal computers for terminal applications. The system will handle 56 languages and allow retrieval of millions of books in each language by category and author listing.

The NLC and NEC are jointly developing Chinese-language software for the system. The software will meet China's new national standard of 32,000 characters. The library system will be in full-scale operation in mid-1991.

Since the NLC is one of China's academic centers, it will use the system in the future as the core of a network linking thousands of libraries around the country.

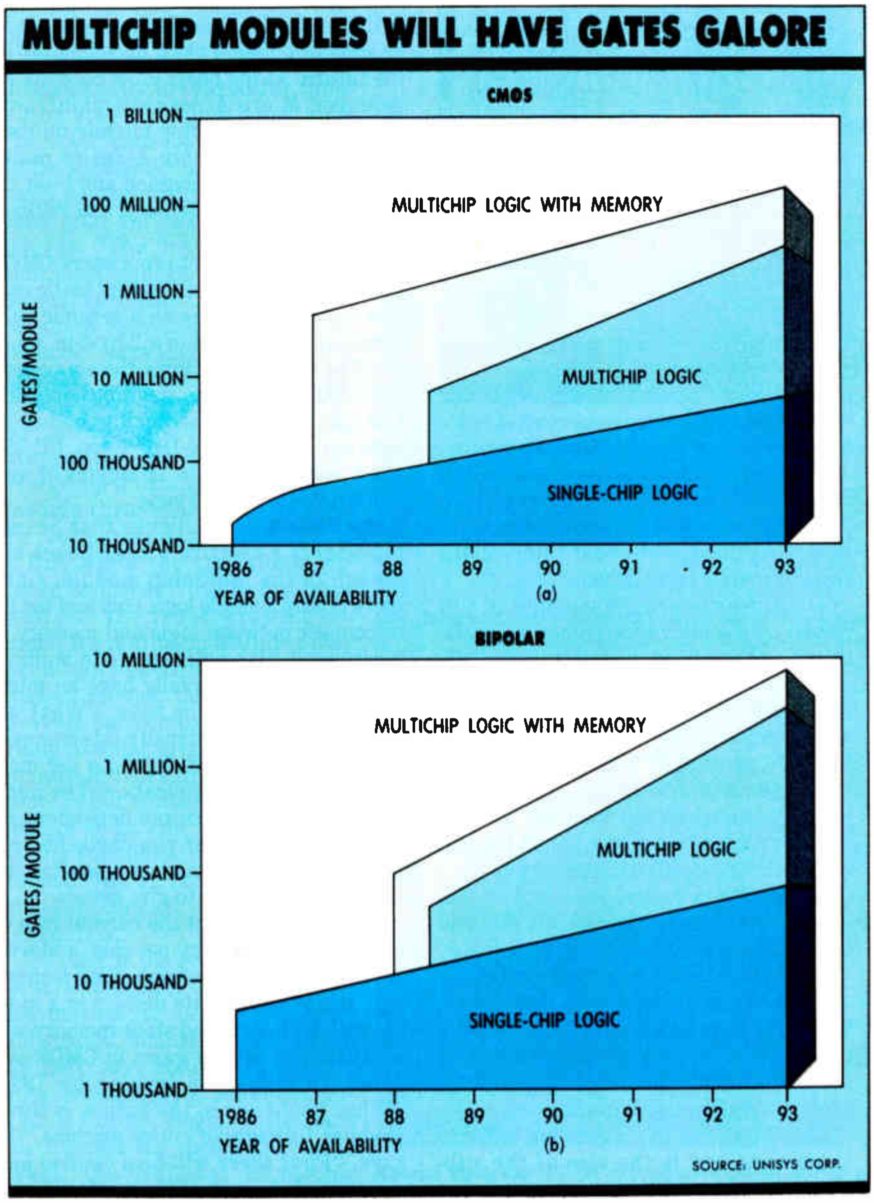
NEC

an entire single processor. Of course, you can then couple several of them together to form a multiprocessor."

Also investigating multichip modules is the Microelectronics and Computer Technology Corp., the cooperative research consortium in Austin, Texas. The group has an active packaging and interconnect program for nine shareholders exploring three interrelated research thrusts: bonding and assembly, interconnect technology, and multichip-system technology. The multichip-system effort, headed by manager Dennis Herrell, is aimed at applying techniques developed in the other two areas to multichip modules.

According to Herrell, the bonding and assembly group is concentrating on high-density TAB techniques for bare dice on silicon or ceramic substrates and pc boards. The interconnect group, meanwhile, is developing a very high-density copper-polyimide technology. "It's not thin film," Herrell says. "We call it medium film, where we build up layers of interconnect over an insulator on a substrate, usually silicon or alumina. We start off with a 4-in. wafer, build up layers of copper and polyimide to form the interconnect, and attach the chips with TAB techniques to get very high density," he says.

Line width is nominally 15 μm on a 50-μm pitch. "We can go substantially less than that, but we've found that's about optimum for controlling characteristic impedance, keeping dc losses to a minimum, and keeping crosstalk between lines acceptable," he says. "With a 2-mil pitch we get density of 500 lines/in. One x-and-y-layer pair gives us more interconnectivity than IBM achieves with its 44-layer ceramic modules," which are used in the company's 3090 machines.



The CMOS logic-gate density available in modules will reach 100 million gates by 1993 (a); bipolar modules will show similar density growth on a smaller scale (b).

With this kind of density, controlled impedance interconnections with x and y wiring can be fabricated for off-chip rise times as fast as 200 to 300 ps and chip I/O densities that typically have required 10 to 20 layers in pc boards or multilayer ceramic technology.

TEN MILLION GATES. Herrell's group is also concerned with other techniques that have to be brought to the modules, such as cooling, power distribution and regulation, and connecting to the outside world. Its major goal "is to put together a suite of packaging and interconnect technologies that will enable [the shareholders], in the 1992-to-1993 time frame, to assemble a 10-million-gate processor with a 3-ns cycle time and manufacture it for $1,000," excluding the cost of manufacturing the chips. Such a coup would "open the door to developing a computer work station for about $10,000 or $15,000 that will outperform anything that exists at the present moment—including the Cray 3, the NEC SXT, or the ETA[10] supercomputers," Herrell says.

This is no pie-in-the-sky notion. Engineers estimate that by the 1990s, multichip-module technology could lead to the production of a 10-million-gate machine, assembled from 100 chips with 100,000 gates apiece. Depending on the design of the system, each of these chips would require between 500 and 1,000 I/Os. Assuming silicon coverage of 33%, and chips 1 cm square, they forecast a requirement of 40 in.^{2} of high-density interconnect area. They anticipate that, of the $1,000 module cost, $400 will be for the manufacture of the interconnect, or $10/in.^{2}.

A program very similar to MCC's but focused entirely on silicon as a substrate is under way in Great Britain. Called the Research Initiative into Silicon Hybrids, or RISH, it is one of a series of collaborative precompetitive projects called National Electronics Research Initiatives open to British companies and funded jointly by industry and the government's Department of Trade and Industry. RISH was started in 1986 with a projected life of three to five years.

Like MCC, the RISH effort is aiming for a tool box of technologies and processes from which the collaborating companies can select those most appropriate for their applications. At the Malvern laboratories where the work is being pursued, researchers have developed both copper/polyimide and aluminum/polyimide metal/dielectric processes. Copper gives a 60% improvement in line length for a given geometry and can also be plated, says John Bailey, a staff member of Mars Electronics International assigned to RISH, who described the RISH work at Nepcon West last month. But the copper/polyimide interface must be protected with barrier layers to prevent diffusion of the copper into the polyimide, he says. As

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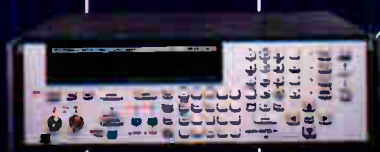

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a result, Bailey believes the relatively simple processing of aluminum/polyimide systems is a more attractive option.

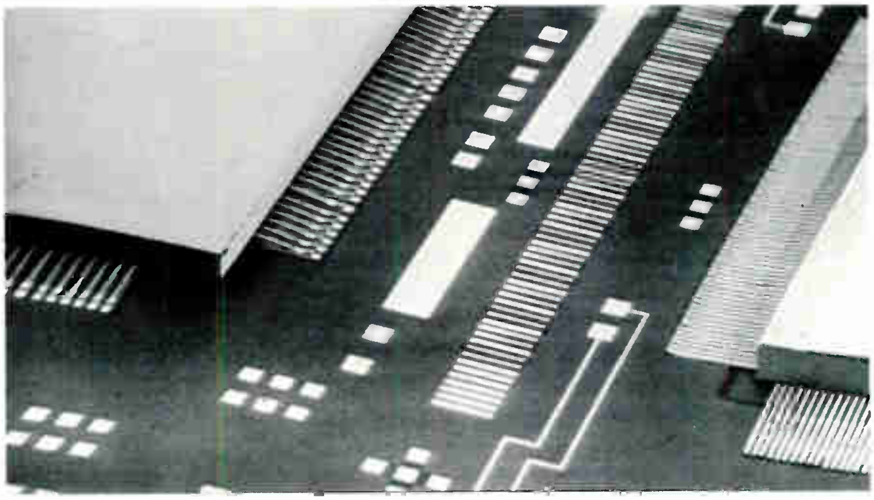
Bailey points out that silicon multichip modules have their own characteristics and therefore their own requirements in a computer-aided-engineering system. Being in competition, to some extent, with pc-board makers, layout and mask designers need equivalent automatic placement and routing facilities. Thermal modeling is also important.

The CAE requirements, Bailey says, therefore include a pc-board-type routing algorithm that will accommodate feature resolutions down to 0.1 μm on a module of 10 by 10 cm, and the ability to generate data in a form suitable for IC mask making. No such system exists commercially at this time. At RISH, engineers have written custom software that interfaces a conventional pc-board layout system and a full custom-IC layout system to meet these requirements. They have also included a thermal modeling program.

RISH engineers favor solder reflow, or flip-chip, technology for die attachment. As they see it, the technology can exceed interconnection requirements for the foreseeable future. Also, this approach makes devices less prone to lead damage and allows them to be tested without pad damage. Then, too, alignment is not a critical issue with flip-chips.

Meanwhile, at Rockwell International's Autonetics Electronic Systems Division in Anaheim, Calif., multichip-module technology has been used to design and develop a dual-1750A-processor system to be used in an automatic target-recognition scheme. The objective was both higher packing density and improved performance, says Jim Spear, an R&D engineering manager for the program.

Capable of running at 40 MHz, the module has chips laid down on a silicon substrate with four layers of aluminum interconnect insulated by 6-to-10-μm polymer dielectric layers. A total of 140 components, including resistors and capacitors, are placed on a substrate 2 to 2½ in. square. Line width is 1 mil. In addition to two single-chip 1750 chips from Performance Semiconductor, the prototype contains 512 Kbytes of RAM, 16 Kbytes of electrically erasable programmable read-only memory, and serial and parallel ports.



On MCC's multichip substrate, two silicon chips are bonded face down to a copper/polyimide substrate using gold-to-gold single-point outer-lead bonding.

100 MIPS. Spear is aiming at larger substrates with 3 or 3½ in. square of active interconnect. His goal is to place 60 to 90 ICs, including reduced-instruction-set-computer processors and digital signal processors. "We're looking to get processors with 100 million operations/s on a single wafer by the end of this fiscal year," he says. Such designs are targeted for ground- and space-station-based interceptor systems. In addition, they will be used in miniaturization of the Global Positioning System being developed at Rockwell's Cedar Rapids, Iowa, facility.

The role of semiconductor suppliers may ultimately be pivotal in the further development of multichip modules as a mainstream packaging technology. So far, some system builders say, the merchant chip makers have shown little enthusiasm for supplying bare chips prepared for TAB or solder-bumped (flip-chip) assembly. "There is certainly a reluctance on the part of chip manufacturers to ship bare chips to any customers other than the large OEMs, like IBM, Digital Equipment, or Hewlett-Packard," says PCK Technology's Messner. Joy at Unisys agrees. "One concern I have is that most of the semiconductor industry is not pursuing [multichip modules] and thinking how they are going to ship their products in the future," he says, "unless they are part of a captive operation."

Messner believes that multichip mod-

TESTING THE MODULES REMAINS A THORNY PROBLEM

Getting the cost down is a major goal for all the players in multichip-module technology, and one of the big contributors to cost is testing. "Testing is a real bitch," says Clyde Loftahl, national sales manager at Advanced Packaging Systems in San Jose, Calif. "There is no commercial equipment available, so you have to cobble things up."

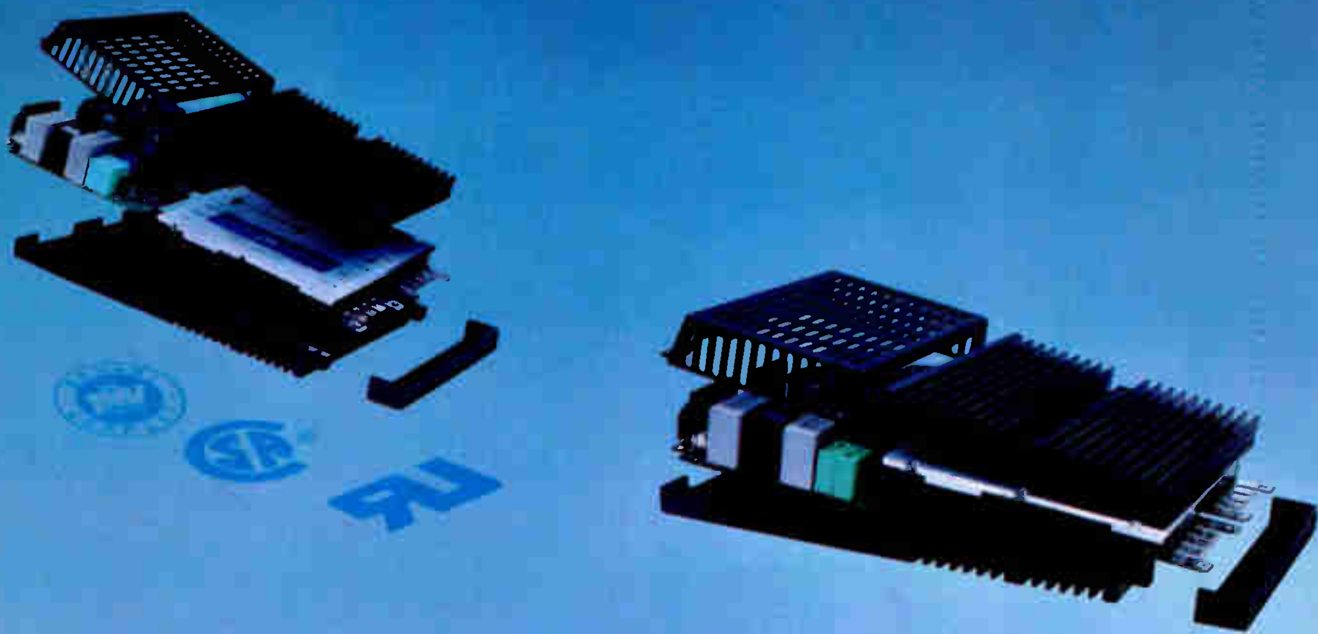
The typical bed-of-nails or computer-controlled mechanical probes used in chip testing are too slow for high-density multichip-module interconnects, says Dennis Herrell, manager of the Microelectronics and Computer Technology Corp.'s multichip-module research group in Austin, Texas. So his group is exploring the use of electron beams for this purpose.

The technique is similar to the e-beam method used for probing digital integrated circuits. "We vector an e-beam to a chip pad, where a chip is to be connected, turn on the beam, and charge up that net to, say, 10 V in 100 μs," he says. "Other points in the net are then interrogated with the beam to determine their voltage level, and if there is integrity, an open or a short." The system is now a laboratory model, but Herrell hopes to bring it to a point where an outside vendor can produce it as a manufacturing tool.

However, functional testing of a module after the chips are in place is extremely difficult. "Functional testing of complex systems is a very important issue and needs a lot of attention here and elsewhere," Herrell says. The more complex the system, the more important it is "to adopt built-in test techniques or standards that enable us to test the interconnects with chips in place."

At Rockwell International's Autonetics Electronics Systems Division in Anaheim, Calif., test patterns for a continuity check are taken off the data base generated by the Cadnetix Corp. autorouting equipment that generates the interconnect pattern on the substrate. The substrate is placed on a numerically controlled table controlled by the test tape and given an automatic continuity test. But this approach depends heavily on the vendor's ability to ship good chips, and the firm works very closely with vendors to assure that this is done.

Loftahl says that even though testing is "a laborious process right now," things are bound to improve. He says a lot of his customers are working very hard at developing software for testing. *–S. W.*



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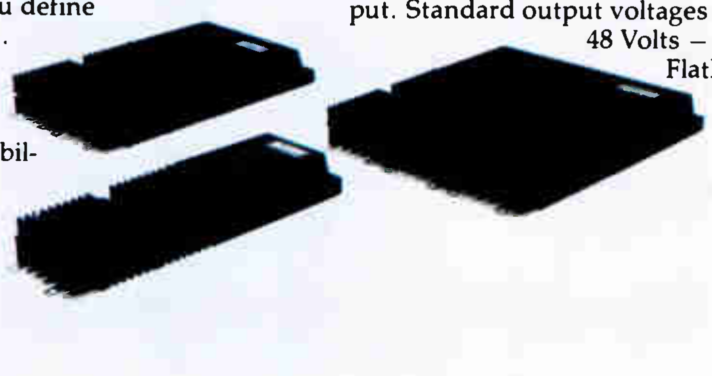

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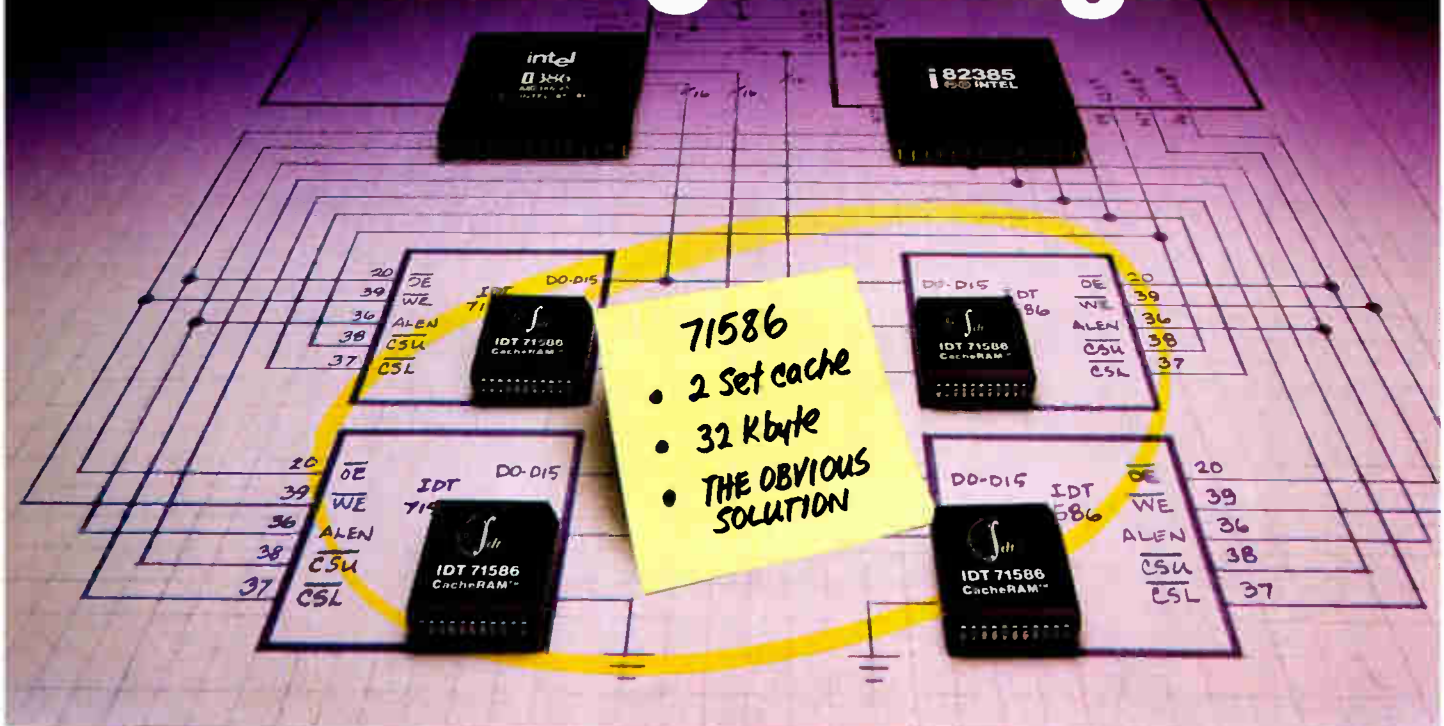

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DO U. S. FIRMS WEAR CULTURAL BLINDERS?

Little use is made of engineers with experience in Japan

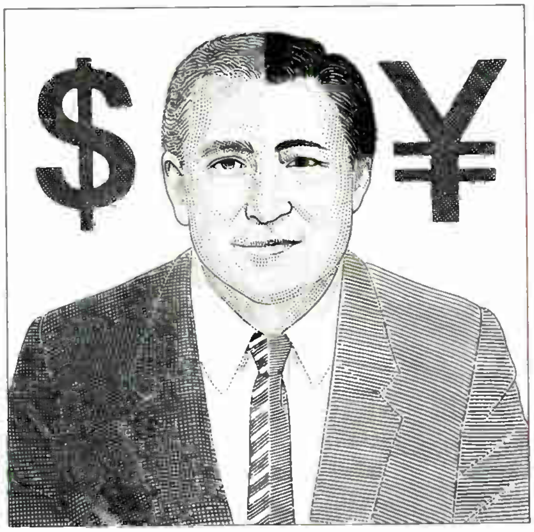
Like the Victorian English, American businessmen spanned the globe after World War II, dominating foreign economies with the world's best goods and services. It didn't matter that these Americans rarely spoke the native tongues of their host countries; they spoke English, and expected to be understood. And if they weren't, they just spoke louder and slower.

Now the tables have turned. Not only does the world speak English—and very well, thank you—but Japanese and European business people now know how to do business on American soil, on American terms, and have been wildly successful. They have learned that understanding your foreign competitor is the first and maybe only way to turn him into a customer, while many U. S. businesses just keep talking louder and slower.

But change is coming. Officials at the National Science Foundation, the American Electronics Association, and the Massachusetts Institute of Technology—which all fund transfer programs that send U. S. engineers to work in Japan for up to a year—say there is a growing awareness in U. S. businesses that engineers with insight into and experience with Japanese language, culture, and business methods offer invaluable expertise. But while businesses finally have begun to recognize the value of such personnel, they "haven't always known how to use them effectively," says Richard Samuels, director of the MIT-Japan Science and Technology Program.

That, say engineers who have been through these programs, is an understatement. They complain that in many cases they received only modest interest from U. S. companies after returning from work at Japanese corporate or university labs, and that, once hired, their skills were underutilized. "Professionally speaking, it hasn't had much impact," says Douglas W. Browning, an assistant professor at Georgia Tech's School of Electrical Engineering, of his experience in the AEA Japan Research Fellowship Program five years ago.

That's not just because he went to work in academia either, says Cheryl Fields, manager of education science policy at the AEA. "The Fellows [who have gone to work in industry] have had mixed feelings about how they've been used in the past," she says.



Why is interest so low? Possibly because most large companies are now trying to replace the "international" divisions they established in the 1960s and 1970s to coordinate their overseas sales with more streamlined and autonomous regional management, says Pat J. Canavan, vice president and corporate director of human resources at Motorola Inc. "We came to the conclusion a couple of years ago that our real limiting factor in expanding in Japan was not technology or limited investment capital, but in people who knew that marketplace and who knew how we do business here," he says.

But Motorola has tried to address the issue not by hiring Americans with Japanese experience—although it is a sponsor for the MIT program, the most extensive Japan-study program for U. S. engineers—but by finding Japanese who know the U. S. That includes recruiting Japanese students in the U. S. who might want to work in North America for a while before going home to Japan; Japanese-Americans; and native Japanese. "The cost of expatriating Americans to Japan is prohibitive," he says. "We try to avoid that."

So are these students wasting their time? Absolutely not, he says. "Maybe in the short term those skills and experiences aren't going to be used, but don't worry—in the long run, they'll be tremendously valuable."

Indeed, there have been some successes. Anderson E. Howard, now a microwave-circuit designer with Hewlett-Packard Co.'s Network Measurement Division in Santa Rosa, Calif., says his bosses are "drawing on my Japan experiences right now" by seeking him out to help translate Japanese research papers and technical literature. Howard spent eight months working at NEC Corp. as an AEA Fellow in 1984 and 1985, before returning to the U. S. and a job at HP. When pressed, however, Howard admits that his knowledge of Japanese is underutilized.

"There's a lot of technical information from Japan that could be useful here [in the U. S.]," he says. "In Japan, there's a hysteria about learning English and most engineers are relatively fluent. But people here who can't read [something] just ignore it. American companies suffer because of that." Now, with Japanese research and engineering getting more respect for innovation, interest in Japan is rising among students. MIT, which sent only 50 students in the last four years, will send at least 40 in 1990, Samuels says.

Is corporate interest keeping pace? That's hard to say: most companies are looking for specific kinds of technology know-how or experience, Samuels points out, and only a very few can afford to hire simply for potential. The big ones can, however, and that's what led AT&T Co. to hire AEA Fellow Peter W. Wolniansky after he returned from a year in Japan working for Sony Corp. Although Wolniansky had been working on magneto-optic technology—something of little interest to AT&T, which was seeking personnel to work on modems—the overseas experience caught the eye of Gaston A. Arredondo, supervisor of data-products systems engineering. "Right now, we don't make much use of Peter's experience," he admits. "But we will. It's an experience with potential." □

by Tobias Naegele

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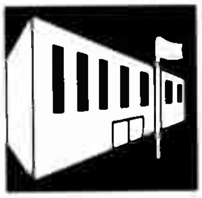
COMPANIES TO WATCH

CONCURRENT IS SITTING PRETTY AFTER AN UNCONVENTIONAL BUYOUT

The deal with Masscomp places it at the top of the real-time computing heap



TINTON FALLS, N. J.

Jim Sims is smiling—even though after a 16-year streak of profits, his company, Concurrent Computer Corp., showed its first loss in February. Red ink is likely to illuminate the balance sheet for the current quarter, ended in March, as well, say stock-market analysts.

So why is Jim Sims smiling? Only Concurrent's accountants know for sure, and it has plenty to do with tax laws, financial wizardry, and, most of all, carving out a dominant position in the $1.5 billion-and-growing market for standards-based real-time computing systems.

It all started last October, when rival Massachusetts Computer Corp. of Westford, Mass., bought all of Concurrent's stock for $20 a share. But this was no ordinary takeover. Masscomp, with only one third the sales volume of Concurrent, appeared to be a minnow eating a whale. What's more, Concurrent chipped in to help Masscomp buy it, contributing $77 million in cash and raising the remainder of the $247 million sale price from three venture-capital firms and a junk-bond offering.

One analyst characterizes this unconventional deal as an unusual version of a leveraged buyout. What it adds up to is a big tax savings for the newly merged company, still named Concurrent and still based in Tinton Falls. The firm will be "in a no-tax position in the U. S. for the next three to five years," says Sims, who remains chairman, president, and chief operating officer.

Once the financial hocus-pocus fades into history, says Sims, the merger's real significance will be evident. The deal makes the new $400 million Concurrent the world's largest corporation dedicated solely to real-time computing. It defines real-time systems as those with guaranteed response times between 1 s and 1 µs, depending on the application. The firm offers a full line of real-time products, ranging from a $10,000 board-level computer to a $1 million parallel-processing system.

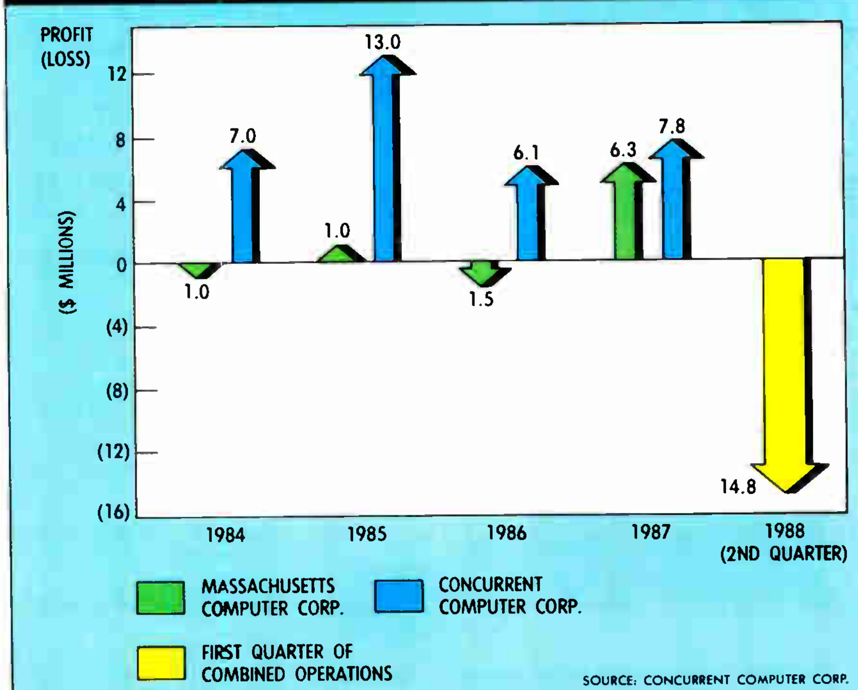
Teaming with Masscomp helps Concurrent nail down the standards-based share of this market. Over its eight years of business, Masscomp has enhanced AT&T Co.'s Unix operating system to run in real-time; its Real-Time Unix can run on a VMEbus system with guaranteed responses of 10 ms. Sims's two-year goal is to "use Unix to solve the entire spectrum of applications. One more generation of standards-based hardware, which is now in development, will let us do that. The trick is to get the software there at the same time."

Negotiations for the merger started in April 1988. Tax laws dictated that Masscomp buy Concurrent for cash, so all of Concurrent's assets were recorded as expenses. For example, $50 million in inventory, which was already paid for, was shown as an expense on the books, even though no money changed hands. The same principle applied to other assets and the "good will" expense that accounts for the difference between the purchase price and the market value. The tax break comes from the fact that over the next decade, all the expenses that were entered twice on the books will be depreciated on the corporate income-tax return.

Although the unusual nature of the deal plunged the new Concurrent into a deficit for its second quarter, Jeffrey Canin, an analyst for Hambrecht & Quist in San Francisco, sees it turning a profit in its fiscal fourth quarter, ending in June. Canin expects Concurrent to show a loss for fiscal 1989 but says it has sufficient revenue from ongoing business to pay off its debt without much strain.

Canin also thinks heading toward standards-based real-time computing is the right strategy. "It's one thing to know that the company covers the full spectrum of price/performance with its products," he says, "but it's even more important for them to migrate to a single standard operating system." Indeed, Sims has put Concurrent squarely in the standards-making battleground. The company announced its first enhancements at

WHEN A LOSS IS NOT A LOSS



the Unix trade show, Uniforum, in San Francisco in February. Concurrent is a voting member of the Posix IEEE 1003.4 real-time and X3H3 committees. It's also a member of the VXI standards group, Unix International Inc., and the Open Software Foundation. Still, Sims has pledged to support its existing customer base for proprietary systems—and to continue the stream of enhancements.

Among its products is the Series 3200 hardware and OS/32 software, which dominates the flight-simulation applications market, where under-10-μs responses must be guaranteed. Other high-end real-time applications of 1 ms and below include process simulation and network control (10 to 100 μs), and telemetry control and seismic analysis (1 ms to 100 μs). Masscomp's midrange real-time forte has been process control and industrial automation (1 to 10 ms), plus medical diagnosis and laboratory automation (10 to 100 ms). Concurrent also has a market presence in on-line transaction-processing.

Market watcher Dataquest Inc. of San Jose, Calif., estimates the all-inclusive real-time computing market at $6.8 billion, and Sims sees Concurrent competing for a $1.5 billion segment. In the future, he says, no one knows how high it could go. "Every year we find new applications—people who want to go from batch processing to on-line real time," he says. "There's no way to estimate what the growth rate is there." *–Jack Shandle*

KEEPING U. S. EXPERTISE AT HOME

EDEN PRAIRIE, MINN.

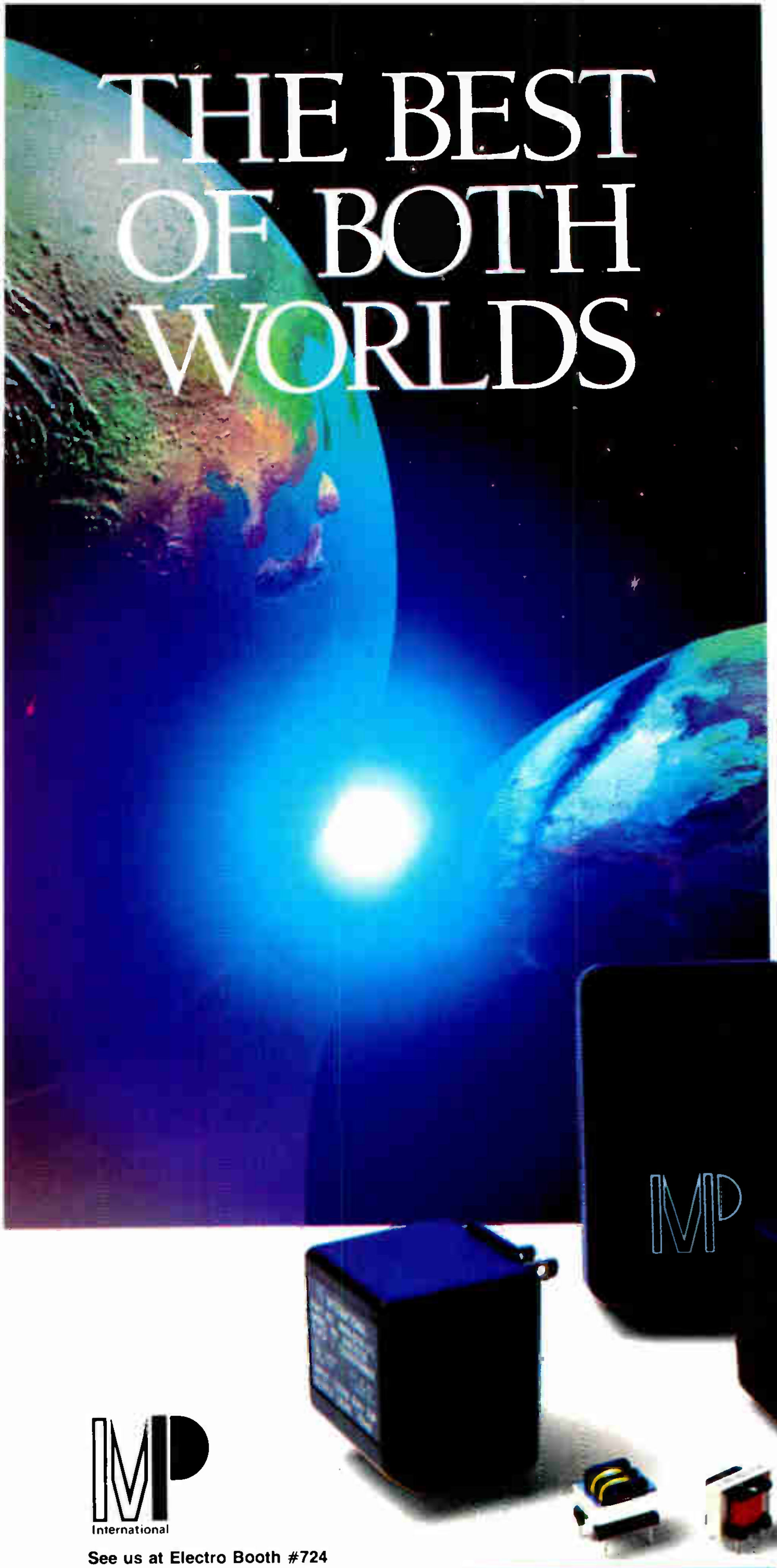
By now it's a truism that foreign competitors often make better commercial use of U. S. technology than American companies do. But an Eden Prairie firm is doing its part to change that. Teltech Inc. hopes to become a force in the information-services industry while also helping keep U. S. technical expertise at home.

Teltech offers a unique on-line technical-information service that can quickly put scientists and engineers in person-to-person contact with U. S. authorities in any of about 1,400 scientific areas. It also provides computerized literature searches that are done interactively by phone, with the client following along on his personal computer screen. And the services are available to U. S. and Canadian clients only.

"It's our [U. S.] knowledge, and we ought to be using it for our benefit," says Joe Schuster, Teltech's founder and president. Foreign firms "come over here and we give them our technology, and what we don't give them, they steal. And then they end up beating us over the head with it. And I don't think that's right," he says.

WIDE BASE. The expertise that Teltech provides comes from a data base of some 5,600 experts in a wide variety of technical fields, who are available on short notice to answer questions. Some have been recruited from major U. S. universities, national laboratories, and consulting firms; others are recently retired technical professionals. All have signed nondisclosure agreements with Teltech. Some states and universities offer similar, but more limited, expert-network systems, "but there's not anybody even close to what we're doing," says Schuster.

The system works like this: using their PCs plus software provided by Teltech, subscribers punch in key words to get the names of up to eight authorities in a given field, from a basic data base of 1,000 experts. Biographies and phone numbers are flashed on the screen. If that doesn't turn the trick, a call to Teltech will produce a



search for qualified names among the remaining 4,600 experts.

In all, about 45% of Teltech's specialists have electronics expertise, in fields ranging from hybrid-circuit technology and printed-circuit-board repair to device reliability, surface-mount technology, and analog-circuit design. Another 25% specialize in related areas. "We offer help to an engineer when he's forced to go outside the core of his expertise," says Ron Helgeson, a Teltech vice president.

And that can save lots of time, says James Mandelert, a systems engineer for Cray Research Inc. in Chippewa Falls, Wis. "We had a situation last year where we needed some questions answered about national electrical codes," he says. "It had to do with motor controls. We were trying to do some clever packaging, and I needed some rule definitions clarified." Teltech connected him to "a couple of people who actually had a hand in writing the code." In the course of two 20-minute conversations, he says, he got the information he needed.

Teltech was founded in 1984 but has been on-line nationally only since early 1987. It boasts a list of about 340 corporate subscribers, Helgeson says, from startups to big-name companies. Among them, besides Cray, are Amdahl, Bell & Howell, Computervision, Digital Equipment, Hewlett-Packard, Honeywell, McDonnell Douglas, and Perkin-Elmer.

For an annual fee, subscribers get unlimited use of the literature search, the expert network, or both. First-year fees are based on a firm's annual revenues and number of technical personnel, and can range from $6,000 to $15,000 for the combination service. Fees for succeeding years are adjusted upward or downward based on usage, Helgeson says.

KEY TO SUCCESS. Schuster, 56, says he got the idea for Teltech after many years of running his own small business—Minnesota Valley Engineering, a maker of cryogenic dewers and containers. In Schuster's days the firm was competing against much larger, more heavily financed competition. But it succeeded because "we systematically went around and found experts in each phase of technology that was important to us. I thought that maybe the process could be formalized, and that maybe one could make a business doing that."

So far, the formula appears to be working. The company, which is privately held, anticipated revenue of $3.1 million in the year that ended in February, says Helgeson, against $1.4 million the previous year. Teltech should be profitable by September, he says, and revenue should double to $6 million for the year ending in February 1990. *–Wesley R. Iversen*

HOW ONE FIRM IS RACKING UP 100% GROWTH

BEAVERTON, ORE.

The list of companies that can grow at a rate of better than 100% annually is a short one. Now, add Logic Automation Inc. to the lineup. Founded in 1984 as a software consulting company, Logic Automation pioneered the business of selling board-level behavioral models, for which it is the leading vendor.

Three developments occurred in the company's short life to allow it to grow to the point where it anticipates $15 million in sales in 1989, say sources close to the Beaverton company.

First, Logic Automation has attracted large semiconductor companies willing to fund the cost of creating behavioral models for entire families of integrated cir-

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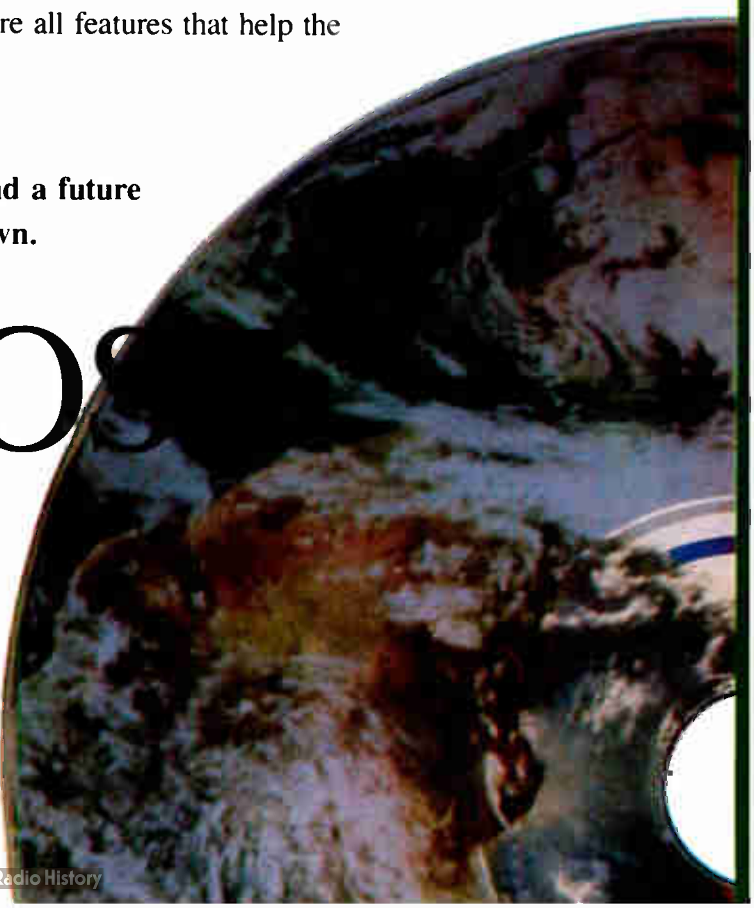

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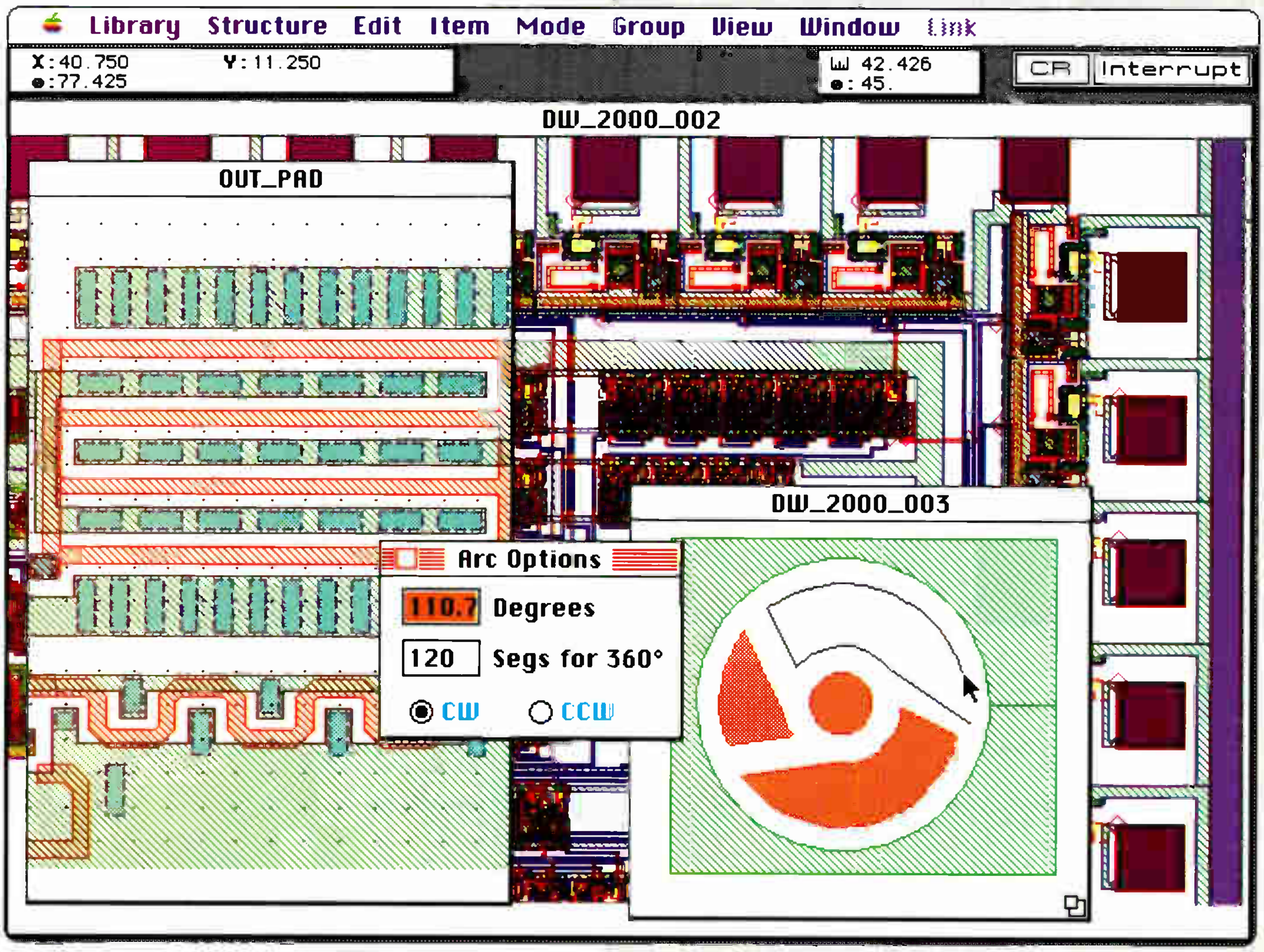

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Circle 25

cuits. Second, it developed a subscription service that greatly simplifies sales, distribution, and support of the models. And third, the company devised a software technique that allows it to automatically transport an entire library of models to any hardware platform quickly.

But as every MBA knows, building a company involves more than just executing the right moves at the right time; there also must be a growing market and demand for the product. In this regard, Logic Automation is sitting atop a growing pile of money.

When the company started, only a handful of designers in a handful of companies were simulating board designs. Even today, only 10% or so of board designs are being simulated, says Cindy Thames, vice president of The Technology Research Group in Boston.

But that should change significantly over the next five years. One major semiconductor company surveyed its customers and found that 95% aimed to provide 100% board-level simulation by 1990, says Richard H. Drew, general partner at Olympic Venture Partners in Portland, an early investor in Logic Automation.

Logic Automation executives credit Advanced Micro Devices Inc., Sunnyvale, Calif., and Analog Devices Inc., Norwood, Mass., for giving it a boost early on by ordering behavioral models for their ICs. "These two firms provided us data, test vectors, and then started paying for the R&D to develop the models," says Robert Hunter, Logic Automation's vice president of marketing. Then, in 1988, Texas Instruments Inc. entered a multiyear agreement under which the Dallas company will finance the development of models for a library of 15,000 TI chips. Logic Automation can then provide the models to its customers.

SUBSCRIBE. But the key source of revenue for the company is selling models to designers. This creates a logistical headache as the number of models in the library increases. The solution: yearly subscriptions to the entire library, which eliminates elaborate record keeping to keep track of individual models for individual customers. Anytime a model changes, every subscriber gets updated.

"Our subscription service came into being in 1986," says Hunter. "The idea came from a customer, British Telecom. They wanted some way to get everything in our library. So long as the subscription cost is reasonable, the broader class of users would prefer to have an entire library rather than buy individual models. Today, for less than $10,000 you get every model in the library." The library provides a growing revenue stream; "we have better than 95% renewal rate on our subscriptions," says Hunter.

The one other requirement that a buyer has for a company selling models is to get models for its particular simulator and work station. It must support all the commercially available simulators from companies such as Daisy, HHB Cadat, and Mentor as well as customers' proprietary simulators.

The cost of making the entire library work with each simulator and of porting the libraries to each of the various hardware platforms would make it impractical if all this work had to be done by hand. "At Logic Automation, we developed a technology to write behavioral models once and translate them to other target simulators, work stations, etc.," says Hunter. "When an operating system goes through a change or when a CAE vendor upgrades his simulator, all we have to do is recompile the model library and send out a free copy to the customer."

This translation capability is one of the reasons the company has attracted major chip makers. "Semiconductor companies have tried to do their own model libraries, but they lack the intermediate format that Logic Automation has to provide models for the wide variety of simulators currently on the market," Drew explains.

The company, which started on its own financing, received its first round of funding in November 1985—$1.5 million from Olympic Venture Partners and Hambrecht & Quist Inc. It received a second round worth $4.75 million a year later. These were followed by Sutter Hill Ventures, Mohr-Davidow Ventures, and Merrill, Pickard, Anderson & Eyre. "Bill Lattin came on board as president at the time and played a major role in second-round financing," says Hunter.

"Today the company is cash-positive and does not need another round of financing," says Drew. At the same time, the customer base continues to grow. And with each paying its annual $10,000 subscription fee, the system is paving the way for Logic Automation's continued growth. *–Jonah McLeod*

MAKING THE MOVE FROM ACADEMIA TO INDUSTRY

AACHEN, WEST GERMANY

There's much about Aixtron GmbH that's unusual for a German company. Founded in 1983 in a town right where West Germany, Belgium, and Holland meet, this maker of vapor-phase-epitaxy equipment owes its existence to the transfer of technology from academia to industry in a country where everybody talks about it but few do it.

Not only that, but the company's founders left the safety of the university environment for the challenge of the rough-and-tumble business world. The route for most German scientists is straight into the gentle and contemplative world of corporate research.

But what's most exceptional is that within four years of its three-man startup phase, Aixtron has propelled itself into the No. 1 position in its field, leaving behind well-established U. S. and British competitors. Aixtron ventured across the Atlantic last year and across the Pacific into the Far East this year.

It all started in the 1970s at Aachen's prestigious Technical University, where Meino Heyen, then an electronics researcher, and physicist Holger Jürgensen were working with metal-organic vapor-phase epitaxy, or MOVPE. With MOVPE, extremely thin films of III-V semiconductor compounds such as gallium arsenide and indium phosphide are grown by the reaction of the gaseous compounds and hydrides on a heated substrate.

GALLIUM ARSENIDE. The technique—it's also suitable for II-VI compounds made, for example, of mercury, cadmium, and tellurium—is crucial for preparing GaAs wafers. They are used for optoelectronic devices, from light-emitting diodes to laser-based transmitting and receiving elements, as well as for high-speed logic circuits and superconductors.

Spotting a demand for MOVPE equipment, the two researchers readied the technique for industrial use and set up shop in late 1983 to build and sell the apparatus. The three founders, including Heinrich Schumann, who handles finances, combined the French for Aachen, Aix-la-Chapelle, and electronics to come up with the name Aixtron.

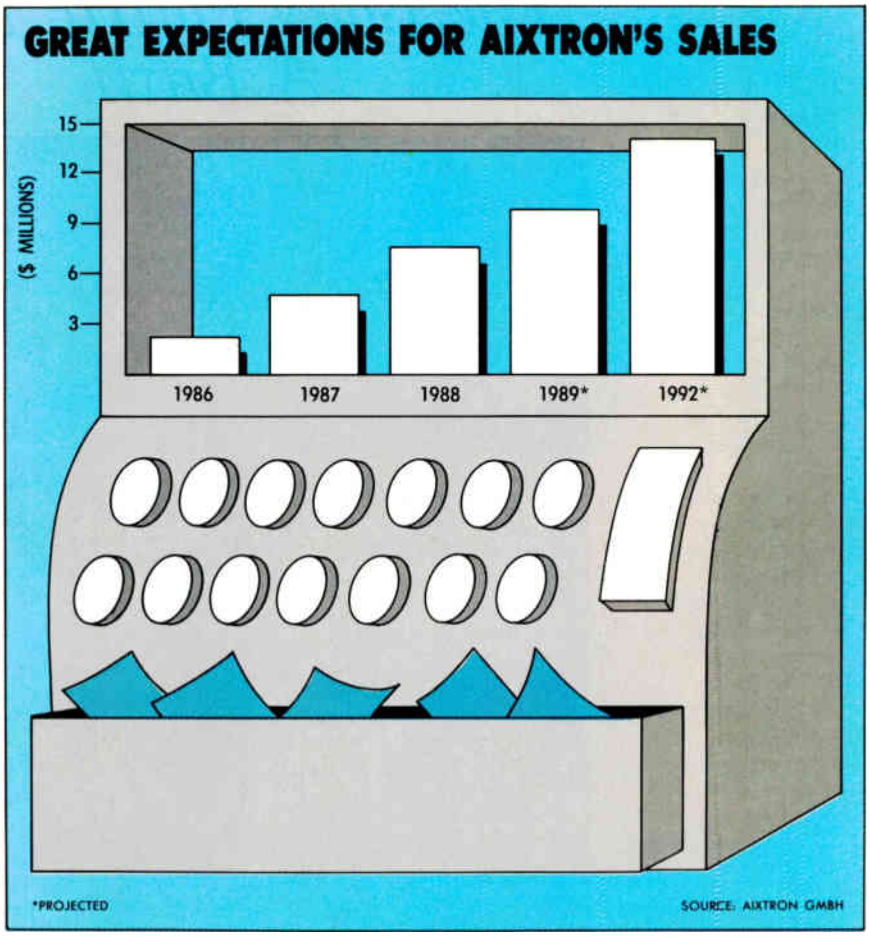
Until recently, big chip makers built epitaxy equipment for optoelectronic devices largely on their own. The disadvantage, though, is cost. That disadvantage is compounded by the need to hire highly qualified people to control the intricacies of depositing films as thin as one atomic layer. In these processes, the gas concen-

Circle 213

tration must be held to ±0.1%, temperatures to ±0.2°C, and pressures to better than 1 torr. With Aixtron's apparatus, these parameters are controlled from a process computer, and the layer-deposition program runs automatically.

Aixtron has done remarkably well with its MOVPE systems. On the average, the year-to-year sales increases more than doubled from 1984 through 1987. Business surged a hefty 50% last year to reach $7.5 million, and for 1989 Heyen expects sales to shoot up another 30%. He predicts that in 1992 the company will chalk up $14 million worth of business. At the same time, Aixtron's staff has been growing dramatically, from the three founders to 45 people last year. Floor space during that period increased, too, from 600 ft² to 9,000 ft².

CUTTING IN. This growth, Heyen says, comes not only from a customer base broadened by smaller chip makers moving into optoelectronics, but also at the expense of Aixtron's competitors—Cambridge Instruments and Thomas Swan of the UK, and Emcore, Spire, and CVD of the U. S.—which are also selling computer-controlled MOVPE systems. But while competitors' sales have slowed, Aixtron has catapulted into the spot of being the world's top producer as of 1987. And it has remained there ever since: last year, company leaders figure, Aixtron had 70% to 80% of a European market amounting



to approximately $5.6 million.

Heyen and Jürgensen say that tight control of process tolerances is their equipment's edge. And that, they say, can be credited to the know-how they've acquired at Aachen's Technical University, a world center in III-V compound re-

$280,000 to $560,000, depending on the number of gases they can handle. The prices are steep, but to most customers cost is secondary, Heyen says. The accurate process control counts more.

Now the company is taking that accu-

year. The company is negotiating to establish sales outlets in Taiwan, South Korea, and Australia.

Heyen is optimistic, particularly about the optoelectronics market's growth potential. Some forecasters foresee sales

ers, it triples to 360,000 gallons. For 4-Mbit DRAMs, this volume is expected to increase at least fourfold.

The Athens solution to these problems is a chemical reprocessing and management system that not only reduces chemical consumption and disposal by 97%, but also reduces by 100 times per mask level the defects big enough to cause damage. The new technology uses and reprocesses chemicals 20 times purer than the ultrapure bottled versions now on the market, Scott says. It cuts ionic contaminants to a level more than 50 times lower than the standards established by the Semiconductor Equipment Materials Institute—fewer than 100 parts per billion.

CONTINUAL REUSE. The first step in the Athens approach is to refine commodity acids to a state about 30% purer than the best now offered. The chemicals then go into noncontaminating containers, which are shipped to the semiconductor plant. At the plant, the containers are locked into the reprocessor equipment. The chip maker's participation essentially ends at that point. "Instead of the chemicals being carried into and out of the wafer-fab operation," Scott says, "there is continual repurification and reuse of the chemicals."

The reprocessor equipment contains proprietary chemical equipment, analytical instruments, and a microprocessor that controls its operation, monitors instruments, and interfaces with the fab-line host computer, which downloads process parameters to it. An on-line trace-impurity analyzer monitors contamination to the acid solution.

The volume of the acid bath is continuously maintained, instead of being periodically dumped and refilled. The only additional chemicals needed after startup are those necessary to make up for the small amount lost during the recleaning and through removal of wafers from the bath. The system regenerates oxidants in order to maintain a constant level of concentration.

The approach evidently has won the approval of the semiconductor industry. Besides the help Athens had in developing its system, it has recruited as its president Donald Brooks, ex-president of Fairchild Semiconductor and before that an executive at Texas Instruments Inc. Also, it initially attracted $15 million in venture capital, then moved quickly into the black. Sales this fiscal year should reach $4.5 million; next year, they should reach $10 million. *–Bernard C. Cole*

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Circle 49

PEOPLE TO WATCH

KIELY'S CHALLENGE: GUIDING A STARTUP IN A NEW COMPUTER TECHNOLOGY

The president of Prisma will help create a system—perhaps the first—based on GaAs

COLORADO SPRINGS

Just about a year ago, Steve Kiely took a big step. After 21 years on the fast track in technical management at IBM Corp. and Prime Computer Inc., he cast his lot with a startup. Now, as president and chief executive officer of Prisma Inc., Kiely believes he's in a strong position to catch what could be the next big wave in technical computing.

Last month Prisma wrapped up $8.25 million in its second round of venture-capital financing, clearing the way for Kiely's primary challenge. He must manage the final development and introduction of what could be the industry's first major computing system to be based on gallium arsenide circuitry. Targeting general-purpose technical computing, the Colorado Springs company expects to ship what it's calling a real-time scalar machine to the first beta site by late this year. The unit combines the inherent speed advantages of GaAs with a supercomputer-style architecture and an open-system approach based on Sun Microsystems Inc.'s Sparc reduced-instruction-set computer architecture.

The result will be a system priced in the same $1 million range as top-end computers from firms like Data General, Digital Equipment, and Prime, Kiely says. But the Prisma machine will deliver about 10 times better performance, with peak operating rates of 250 million instructions per second and sustained rates of 150 mips. The first Prisma system is scheduled to ship in early 1990.

The 43-year-old New York City native took the top Prisma spot last April, after three years as vice president for systems marketing and development at Prime in Natick, Mass. The Prime stint followed an 18-year career at IBM, where Kiely started as a systems programmer at the firm's Kingston, N. Y., development lab in 1967 and ended as the Kingston site's general manager in 1985.

All that experience notwithstanding, when Kiely moved to the small firm he found some gaps in his training. "Talking to venture capitalists is something that IBM or Prime don't give you experience for, so Steve came up a learning curve on that," says Paul J. Kirby, general partner at Hill, Carman, Kirby, & Washing in Boulder, Colo., Prisma's lead venture capitalist. On the technical side, though, there were no gaps. "He was the youngest lab manager in IBM's history and the youngest site general manager at Kingston," says Kirby. "He had all of IBM's technical and scientific computing under him. And when he left IBM for Prime, he broadened his experience." Kiely earned his undergraduate degree in math from Fairfield University in Fairfield, Conn. In 1983, he picked up a master's in business administration from Stanford University.

With Prisma, the opportunity outweighed any qualms Kiely may have had about moving to a startup. "The computer industry hasn't seen a major shift in technology in a long time, and going to GaAs over silicon is a very dramatic step," he says. "In the technical markets, there's a shift toward open and distributed computing that is pretty clear and noticeable, and I think it creates exactly the right environment for a company like ours to get started: we can do what the customer wants in a way nobody else can."

"Going to GaAs over silicon is a very dramatic step" for the computer industry, says Kiely at Prisma.

Kiely sees particular opportunity in computer-aided design and other engineering applications, where there's a growing base of Sparc software. He also sees the military using the Prisma system for high-performance real-time applications in command, control, communications, and intelligence.

Prisma's GaAs expertise comes from company cofounder Philip Gerskovich, who was once head of electrical engineering for Cray Research Inc.'s Advanced Research Project. As such, he was heavily involved in work on the Cray-3, a top-end GaAs-based vector-processing supercomputer the company expects to introduce around year's end [*Electronics*, December 1988, p. 32].

If Minneapolis-based Cray meets its plan, the Cray-3 could beat out the Prisma machine as the first commercially available GaAs-based system. But even if it does, the $20 million Cray-3 is aimed at an entirely different market than the VAX-class, open-systems, technical-computing niche Prisma is going after. In that arena, Kiely expects Prisma to have the market to itself for about two years.

The Prisma president concedes the technical risk in bringing new and unproven GaAs technology to market. But work on the Prisma machine, which will rely on GaAs devices from Gigabit Logic Inc. of Newbury Park, Calif., is running on schedule so far, he says. Yields on the 100-to-200-gate chips developed early in the effort are running so high that "we made the decision last summer to sprinkle in some 1,000-gate devices, because it's clearly achievable," Kiely says.

If Prisma meets its plan, the payoff could be big time, Kiely says, given the sheer size of the technical-computing market and the change toward open and distributed environments Sun pioneered. "If things go well, this could be a billion-dollar company" within five to 10 years, Kiely says. "To say that I'm excited is an understatement." *–Wesley R. Iversen*

ADJUSTING THE FOCUS AT TROUBLED WAVETEK

SAN DIEGO

The task handed to C. Fredrick Sehnert as president and chief executive at Wavetek Corp. represents one of the classic management tests in the electronics industry. Put in the form of a question, it is this: Can an executive noted for marketing expertise turn around a company built on technology and product engineering when that company gets into trouble? The answer: It depends.

That's the challenge Sehnert, 57, faced when Wavetek directors named him to the post last July. He was the miracle worker everyone expected to deal with mounting troubles. Unrealistic growth plans gone awry, along with the prospect of big losses, set the stage, recalls David M. Goodman, a director at the company for 20 years. "When the crises came, we looked at Sehnert," he says.

Board members had already seen Sehnert's talents during his eight-year stint as a director. "I guess they knew me pretty well," he says. But the biggest attraction was Sehnert's proven track record in devising effective ways of selling products. Most recently, Sehnert headed a privately held firm, Software Products International Inc., also in San Diego, that develops and markets business packages for microcomputers.

Previously, he ran several consulting companies that specialized in product planning and marketing. In the 1970s, he directed marketing for four test and measurement divisions at instrumentation heavyweight Tektronix Inc. of Beaverton, Ore. And before that, he served as board chairman and CEO at Kratos Inc., San Diego, an analog instrument maker.

Insiders agree that this record adds up to a background that's perfectly suited for Wavetek, which has strong entries in T&M equipment but needs to do a better job of bringing them to customers. "Fred has a good feel for matching technology to market needs and trends," says an associate of many years.

While the longer-term need at Wavetek calls for new approaches for more effective marketing, the deteriorating situation when Sehnert stepped in demanded strong medicine immediately. "It's been a real busy time," he says about his first six months. The company had overstretched itself trying to do too much, so "we retrenched and the company was restructured, reorganized, and refocused."

Sehnert helped Wavetek "retrench, restructure, reorganize, and refocus." Now can he turn the instrument maker's financial picture around?

To cut expenses during restructuring, Wavetek trimmed about 20% of its personnel, reducing the ranks to about 1,000. Product lines were cut back too, including one featuring an advanced open-architecture system composed of building-block modules for test instrumentation that would have been a pacesetter for the business. But "it was too big a technical challenge, so we tapered it back," says Sehnert. While such measures were needed, they were also costly, and they put the company deeply into the red with a $7.6 million loss last year.

CULTURE. But some other moves to revamp the company best display Sehnert's thinking, which is nothing less than "to alter the Wavetek culture," he says. His rationale stems from the drastic changes in the T&M business since the advent of the microprocessor. It has essentially made test and measurement equipment into data-acquisition systems that generate reports. "The classical bench-testing market is flat and half the test engineers are now sitting at a screen designing firmware or software," Sehnert says.

The result is product design and production cycles that move faster than ever, and Wavetek, which grossed $84 million in 1988, has to be streamlined to keep pace. Sehnert intends to make its smaller size an advantage. It will be able to respond faster to customers than can bigger rivals, such as Tektronix and Hewlett-Packard Co. of Palo Alto, Calif. In practical terms, it means reorganizing Wavetek around its two primary businesses, T&M and signal-analysis instrumentation for cable TV. By tightening the focus, management can allocate company resources more efficiently and the staff can work more closely with customers.

That's Sehnert's goal, at any rate, and the basic changes have been put into place. All the Wavetek CEO will promise for now is that financial returns will improve over last year's. Whether or not even better things are in the offing depends on more than doing a better job. Though he is not predicting one at the moment, a recession would severely crimp the improvement timetable, for example, and Sehnert is as nervous on this score as any of his peers. *–Larry Waller*

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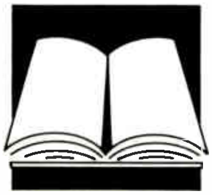
BOOK REVIEW

TECHNOLOGY CAN'T BE MANAGED IN A VACUUM

MANAGING TECHNOLOGY:
The Strategic View
by Lowell W. Steele
New York: McGraw-Hill, $39.50



Lowell Steele has been an active participant in corporate strategic planning from the early 1970s, when the term became a favorite managerial buzzword. Now that it's an accepted—if somewhat misunderstood—survival technique, he is more than qualified to write a book on the subject.

Since most of Steele's time has been spent at General Electric Co., where he rose to the position of staff executive for technology planning, his book generally deals with technology's impact on strategic planning in a large company with an extensive and diverse product line. That perspective tends to leave the entrepreneurial reader out in the cold for chapters at a time, but Steele's main themes apply to even the most modest enterprise.

Simply put, Steele advocates a systems approach to technology planning, based on the belief that technology cannot be managed in a vacuum. It has already become the key determinant of corporate survival: those who do not innovate fall by the wayside. While few would argue with that premise, Steele focuses on implications that are less obvious. In his view, a systems approach to technology management means that all the areas of the corporation must be in constant change. Innovation cannot be limited to the research laboratory. It must thread its way through sales, purchasing, and, most important, manufacturing.

RENEWING THE CULTURE. He contends that the ways of doing things that have worked in the past—in other words, a company's corporate organization and culture—all need to be renewed periodically. The best example of this, says Steele, is the tension between operational management, which is responsible for turning out a cost-competitive, quality-controlled product, and technology management, which is characterized by an atmosphere of ambiguity and uncertainty. No one knows where the next "better idea" is coming from, except that it will be born in a research lab. Operational managers dote on redundancy and predictability. Technology managers live in a world where "saying 'no' to innovation is generally right, but totally ignoring it is disaster," says Steele.

Such tension is valuable, however, as long as it is resolved through what Steele calls information technology. Rooted in accounting, it essentially calls for an enterprise-wide, integrated information system that can be mobilized to illuminate the impact of any course of action from all viewpoints, including operations, finance, and human resources.

The role of management is to evaluate the data. Despite its arcane nature, technology can be managed by nontechnologists if they learn to ask sensible questions that are dictated by knowing the process of successful innovation. One key indicator is market share for a product. Managers must also be able to identify technologists they can trust. "Judging people has always been a key ingredient of managerial success," Steele says. The final, crucial skill is selling the new idea to the boss. This requires knowing the customer's prejudices—in this case, top management's—and in being absolutely certain that the technology in question is truly responsive to the corporation's needs at the time. *–Jack Shandle*

From A to Z—barely

To the editor: Thanks to *Electronics* and Wesley Iversen for the article on HDTV ["U. S. gropes for unity on HDTV," *Electronics*, March 1989, p. 70]. To this comprehensive article I would like to add two additional points about the subject.

Your presentation shows a lack of technical depth in the specific area of TV technology. The reason is that the Zenith proposal for the new standards was barely mentioned, while the Philips and Thomson proposals were presented in some depth.

Anyone who participated in the week-long presentations of Systems Subcommittee WP-1 that were held in Virginia during November of last year knows that the Zenith proposal is distinguished by its elegance and simplicity. In addition, the engineering depth shown in the Zenith presentations—particularly in the areas of cochannel and adjacent-channel interference—made a profound impression on the assemblage of those who are schooled in the art of television. This proposal is clearly an important one in any discussion of a U. S. standard.

Secondly, the author does not identify the source of the divergence in views of the companies moving in and around HDTV. Consumer electronics has historically been a blue-collar opportunity. TV's appeal has been to the sensory responses of audio and video, and moves in the areas of entertainment and games. Computers, on the other hand, are a white-collar development and move in the dimensions of the mind and the acquisition and manipulation of knowledge. The truth is that the computer world has been singularly unsuccessful to date in attracting the blue-collar audience that TV enjoys; that is, videotext.

These are vastly different worlds, and the "groping for unity" that is occurring in the U. S. can be traced basically to these different approaches.

Albert L. Kelsch
Hollister, Calif.

Taiwan topics

To the editor: I read with interest "The timing was just right for Taiwan silicon foundry" [*Electronics*, October 1988, p. 169], about Taiwan Semiconductor Manufacturing Co. There are several inaccuracies that I would like to take this opportunity to correct.

First, the article states that "along with a handful of Taiwanese companies, which together own the remaining 25% of Taiwan Semiconductor, [they] set up a fab and recruited Morris Chang . . . ." The investors did not set up a fab and then recruit me. What happened was the Republic of China's government requested my proposal to set up an IC company, I proposed the idea of establishing it as a pure foundry, made it the charter of Taiwan Semiconductor, recruited the investors with the help of the government, and then set up the fab.

Second, it says, "The Taiwanese government, [Chang] says, was primarily interested in creating a manufacturing facility for these design houses—profit was secondary." On the contrary, the government deliberately holds less than 50% of the shares of the company so that it can operate as an independent private company. Combined, private investors (who are, of course, strongly profit-motivated) hold the controlling share of Taiwan Semiconductor.

Finally, the article predicts that revenue for 1988 "will be in excess of $30 million." I wish the statement were true, but you have overstated our revenue. However, we are in a steep ramp and expect your number to be closer to our 1989 revenue.

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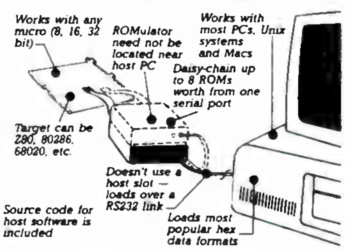

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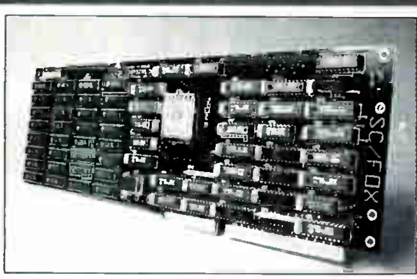

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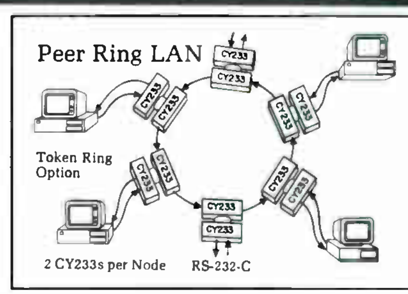

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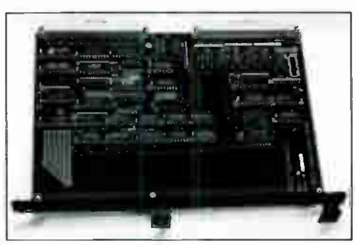

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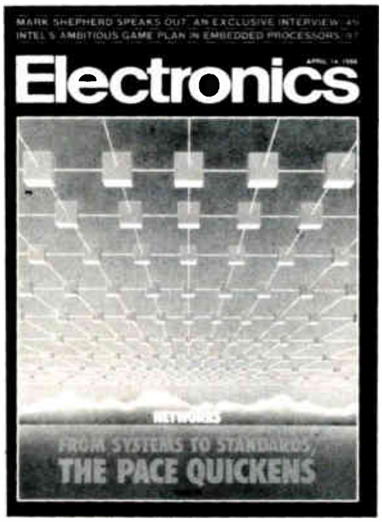
UPDATE: EVERYTHING'S COMING UP ROSES FOR ISDN

The rosy market prospects forecast a year ago for communications equipment that provide global connectivity through compliance with international standards are every bit as bright for 1989. Last year, London-based BIS Mackintosh Ltd. predicted a 34% growth rate for such equipment [*Electronics*, April 14, 1988, p. 75]; and this year, analysts and industry executives see no reason to revise these views. BIS Mackintosh made its forecast on the basis of a 1988 survey, which found that electronics-industry managers were particularly bullish on the prospects of three standards and protocol sets: the integrated services digital network, which integrates voice and data on the same phone service; the Open Systems Interconnect; and the International Telegraph and Telecommunications Consultative Committee's X.400 electronic-mail protocols, which are also incorporated in the International Standards Organization OSI recommendations.



Market prospects are bright for communications gear that provides global connectivity

For ISDN, market prospects look brighter than ever, despite the slow pace of standards bodies. ISDN should start up a steep growth curve worldwide in 1992 and 1993, says Gerald Clare, manager of BIS Mackintosh's Systems Division. During those two years, many potential ISDN users—mostly midsize companies and large corporations—will be thinking about replacing their private-branch-exchange equipment, which has a life cycle of about seven years. During the mid-1980s, says Clare, there was a worldwide boom in sales of a new breed of digital PBXs. Since ISDN provides the vast majority of PBX services, users can avoid the capital expense of purchasing a new PBX by switching to ISDN.

Just as important is a change in attitude about information technology generally, says Clare. "People are learning to use information technology in an aggressive way in leading-edge companies," he says. "ISDN, with its new bag of tricks, is something that is very interesting to them now, because they see it as a way of becoming more competitive."

In the U. S., ISDN took giant strides in 1988, says Walt Lahti, director of research for In-Stat Inc., Scottsdale, Ariz. As standards affecting chip design have firmed up during CCITT deliberations, chip makers have inundated the market with products. Meanwhile, the number of phone lines capable of implementing ISDN has grown much faster than In-Stat's projections, says Lahti. While In-Stat estimated that a minimum of 3,000 ISDN lines would be installed by the end of 1988, Lahti now believes the number is closer to 30,000. Moreover, AT&T has shipped central office switches capable of implementing another 200,000 ISDN lines.

Chip makers and telecom-systems manufacturers, recognizing that the complexity of fielding an ISDN product line is too much to take on alone, are teaming up in joint marketing efforts. The list of ISDN chips grows almost daily, but among the more important, says Lahti, is the two-chip set to be jointly marketed by AT&T Co. and Intel Corp. that implements the U interface in ISDN's primary-rate service. Standards for the U interface were the last to firm up, and AT&T and Intel's tandem marketing of the same chip set adds credibility to the solution. Other major strategic ISDN partnerships include Motorola and Northern Telecom; Siemens and Advanced Micro Devices; and National Semiconductor and SGS/Thomson.

Of all the standards mentioned as potential market movers by BIS Mackintosh a year ago, the OSI protocols have now taken center stage. "There used to be skepticism about the commitment of vendors to field a full range of OSI products," says Joe Forgione, product marketing director for distributed systems and communications at Data General Corp., Westboro, Mass. "Two years ago, vendors, including ourselves, had promised products but still had little or nothing to sell. Now we're starting to see real products with real delivery times." Digital Equipment Corp., Hewlett-Packard Co., and others also have OSI products.

Meanwhile, the "first major, practical applications-level OSI products"—namely, implementations of the X.400 electronic-messaging protocols—have demonstrated the usefulness of the standard, says Forgione. By allowing electronic mail systems to talk to one another, X.400 has proven the value of standards in giving customers a competitive edge. "1989 will be the turning point for OSI," says Forgione. "We're seeing OSI being deployed as real-world products—as opposed to demonstrations on trade-show floors."

Another strong market mover for OSI is the U. S. government. Through its Government Open System Interconnect Protocol, the federal bureaucracy has mandated OSI as the communications standard in all government procurements after August 1990, says John Stephensen, senior vice president for technology and marketing at Retix Corp., a Santa Monica, Calif., leader in OSI software. While Retix once sold almost exclusively to OEMs, he adds, "this year, we see a change—end users are starting to purchase OSI products, X.400 in particular." He predicts a big boom in 1992, "when major corporations will begin using OSI as their major means of communications."

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