1994's GANGBUSTER PROFITS FIRST FULL-YEAR RESULTS FOR 900 COMPANIES

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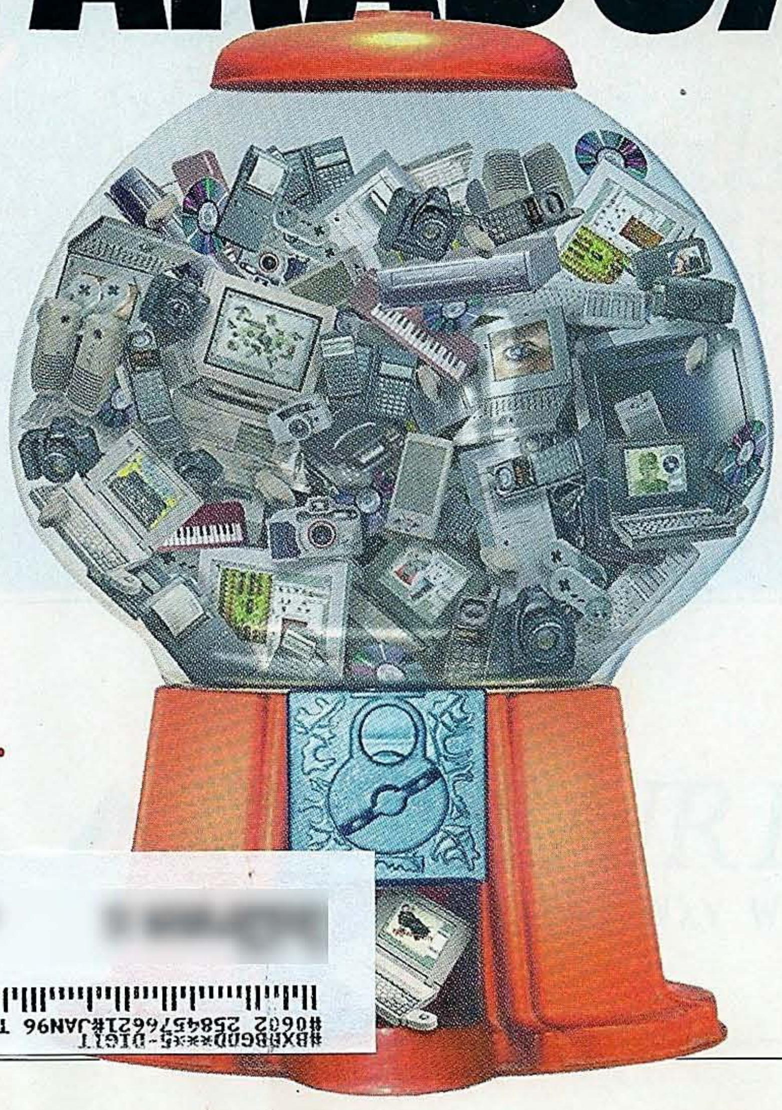
THE TECHNOLOGY PARADOX

Cellular phones are giveaways. Software comes free. Laptops have the power of mainframes.



As high technology becomes dirt cheap, producers must find new ways to prosper. They have.

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INVENTIONS

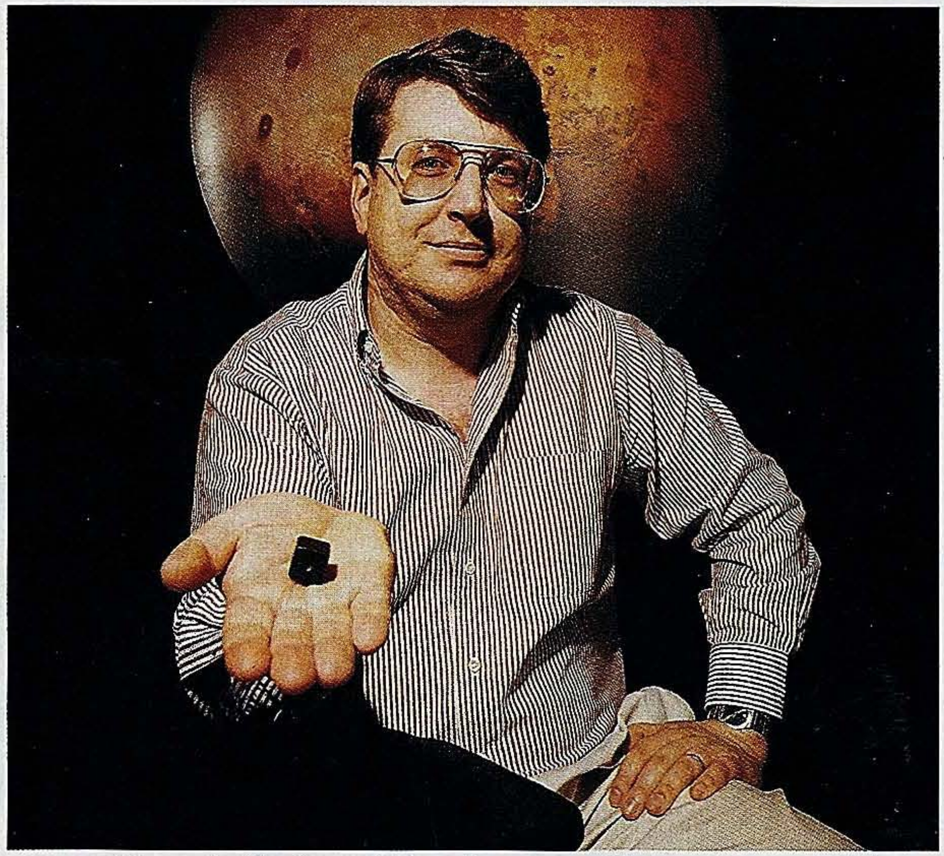
NASA'S TINY CAMERA HAS A WIDE-ANGLE FUTURE

It may still be in the lab, but the latest advance in capturing images has very bright prospects, indeed

Get ready for the camera-on-a-chip. Since the 1970s, camera makers have dreamed of a one-chip camera containing all the components necessary to take a snapshot or make a movie. With all the smarts on one chip instead of several, designers figure they could make a camera small and cheap enough to open vast new markets for everything from dolls that "see" to rear-bumper cameras that would help drivers back up.

Such devices are impractical with today's standard electronic image sensor. It's called a CCD, for charge-coupled device, and it's at the heart of every fax machine and camcorder. Japanese powerhouses such as Sony, Matsushita, and NEC churn out millions a year. CCDs offer good image quality. But they are costly, power-hungry, and—with the accessory chips they require—bulky.

TEAMWORK. Now, the one-chip dream appears on the verge of being fulfilled, thanks to three inventors from NASA's Jet Propulsion Laboratory at California Institute of Technology in Pasadena. The leader is Eric R. Fossum, 37, who was recruited in 1990 from an associate professorship at Columbia University to beef up JPL's image-sensing effort. His co-inventors are a former student now at AT&T Corp., Sunetra K. Mendis, 30, and Fossum's wife, Sabrina E. Kemeny, 37, who took maternity leave from JPL in November and started a company—Photobit—to exploit the concept. Photobit is designing custom sensors based on the invention, while Fossum continues to lead a team of eight at JPL focused on advancing the technology.



FOSSUM: *The project leader and his co-inventors will share in any royalties*

AMY ETRA

Their device, a type of "active pixel sensor," has more in common with a computer chip than with a conventional CCD. Since it's made on standard semiconductor production lines, it taps into enormous economies of scale and should cost much less than CCDs. One chip can incorporate all manner of electronic controls that are usually on multiple chips, from timing circuits to zoom and anti-jitter controls. By consolidating many functions and reading images in a more efficient way, it requires one-hundredth the power of a CCD-based system. And the chip does its own conversion from analog to digital for output on computer monitors or disk storage. About all it needs is a power source and a lens to focus light on it.

Fossum says several U. S. companies are negotiating with JPL on licensing the technology, but he isn't naming names. The chip offers fresh opportunities in imaging to companies that have been stymied by the high barriers to entering CCD production. "American industry is definitely interested," says Carl A. Kukkonen, director of the Center for Space Microelectronics Technology at JPL. "For them, it's a chance to leapfrog the Japanese."

AT&T, for one, would like to take the first jump. Long interested in low-cost cameras for video telephones, it has already collaborated with JPL to build two prototype arrays. A CCD costs a modest $20, but other components bring the system cost to $140, says Bryan D. Ackland, head of the VLSI Systems Research Dept. at AT&T Bell Laboratories in Holmdel, N.J. By putting everything on one chip, says Ackland, "what we're trying to do is build the entire camera subsystem for $20." At that price, every personal computer could come with a built-in videoconference feature, just as many multimedia PCs come outfitted with speakerphones today.

Bell Labs' interest in active pixel sensors is especially impressive because

Since the device can be manufactured on standard semiconductor production lines, it will allow enormous economies of scale

Bell Labs invented the CCD 25 years ago. Researchers knew then that they could cover a chip with light-sensitive areas called pixels, or picture elements. Each pixel captures photons and turns them into electrons in proportion to the brightness of the light. What was needed was a way to retrieve signals from the pixels. Running a wire to each pixel would have covered the chip with metal, making it opaque. So Bell Labs came up with a clever way of using electrodes with voltage differentials to drag the electrons from one pixel to the next, bucket-brigade style, until the entire row was at the edge of the chip, where the buckets were amplified and read out as a voltage level.

Those CCD chips, though, needed ultrapure silicon; like an old string of Christmas tree lights, a single defect would darken an entire row of pixels. They consumed lots of power. And they required a custom-manufacturing process. The Japanese mastered the process and virtually took over the industry when they put CCDs into mass production for camcorders.

A PIXEL'S PROGRESS. Meanwhile, JPL—pressed by NASA to come up with small cameras for satellites—was struggling to figure out how to cram control circuitry into the alien environment of CCD chips. "At the end of 1992, we simply turned the problem around," says Fossum. They stopped using the CCD as a platform and instead dropped thousands of micro-CCDs onto a chip that was more like a computer circuit. Within six months, they had their first working chips.

Advances in chipmaking allowed JPL to wire each pixel—the idea Bell Labs had long before rejected. Today chipmakers can etch metal lines less than a micron wide, a tenth of the thickness of 25 years ago, creating all kinds of spare room on the chip. "We asked ourselves, 'what other things can we put in the pixel?'" Fossum says. They put an amplifier in each one, along with circuits that allowed each pixel to be read out individually for features such as panning and zooming. Now they're integrating other functions, such as timing, control, and analog-to-digital conversion.

Fossum's team hopes to build a complete digital video camera the size of a plastic gambling die (see mock-up in photo). And it also has a $1.5 million contract from the Pentagon's Advanced Research Projects Agency to build a wireless camera, complete with battery and antenna, all in a one-inch cube. You send it a radio pulse to take a picture, and the camera beams the picture back.

The JPL team isn't alone. A company in Edinburgh, Scotland, VLSI Vision Ltd., has already come up with a chip that incorporates all of the digital circuitry. But without amplifiers in each pixel, that chip's resolution is only good enough for sorting parts on factory lines or for home security systems. Closer to JPL's approach is the work of NHK, Japan's national broadcasting company. Fumihiko Ando, a senior research engineer at NHK Science & Technical Research Laboratories, claims that NHK's "Amplified MOS Imager" has many of the same advantages of JPL's, including speed, but is more workable because it uses smaller pixels. He has already built a prototype that reels in 360 frames a second—enough to capture every seam stitch on an incoming fastball or the locomotion of a water strider bug.

Researchers at Eastman Kodak Co., the biggest producer of CCDs in the U.S., are also skeptical of JPL's approach, questioning whether active pixel sensors can deliver sufficient quality.

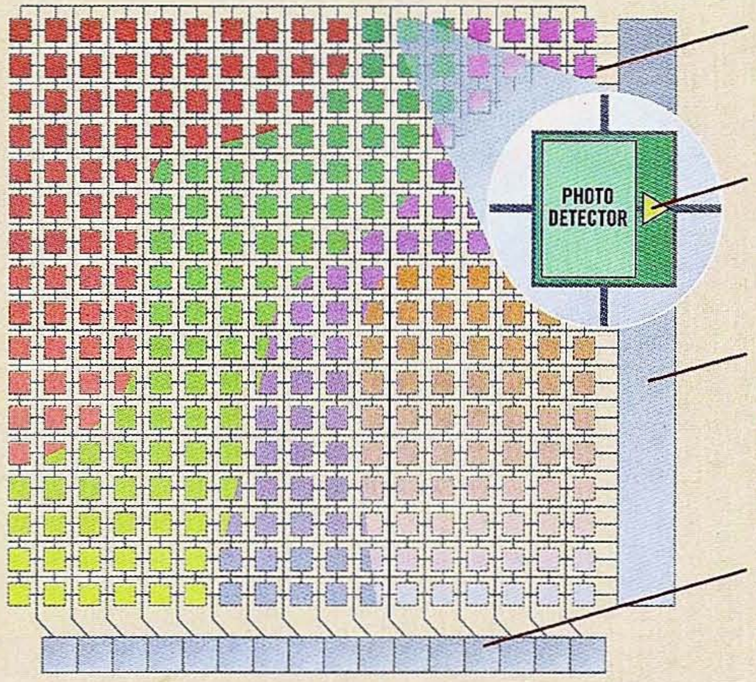
To be sure, JPL's active pixel sensor isn't yet ready to replace conventional video cameras or still digital cameras in fields where image quality is essential—its images are still a bit "noisier" and can't match the resolution of those produced by a CCD camera. NHK's Ando figures that he's three to five years away from matching the CCD in resolution. Fossum says that because JPL's pixels are bigger than NHK's, he's more like five years away. Meanwhile, JPL is aiming the technology at new markets where small size and low power-consumption are critical, such as toys, portable video phones, video baby monitors, and document imaging. Even if the active pixel sensor got no further than that, it would be a coup for a threesome who saw cameras in a different light.

By Larry Armstrong in Pasadena, Calif., with Larry Holyoke in Tokyo

A NEW KIND OF ELECTRONIC EYE

NASA's Jet Propulsion Laboratory is developing an "active pixel sensor" for smaller, cheaper cameras. The sensor rivals conventional charge-coupled devices, or CCDs. Here's how it works:

DATA: JET PROPULSION LABORATORY



1 Light falls onto tiny **PIXELS** and is converted into electrons stored in wells called capacitors.

2 Each pixel has its own **AMPLIFIER.** In contrast, CCDs use a lot of power to drag electrons in a bucket brigade that ends at a single amplifier.

3 The amplifiers will be switched on and off by **TIMING AND CONTROL CIRCUITRY** that's right on the chip. In ordinary CCDs, those functions are on other chips.

4 Voltages from the pixels go through an **ANALOG-TO-DIGITAL CONVERTER.** CCDs require separate converter chips.

LISA KNOUSE BRAIMAN/BW