Smile and say,

GENIUS

NASA and DoD SBIRs fuel the development of camera-on-a-chip

When he took office in 1992, NASA Administrator Dan Goldin shook up the agency's status quo by adopting an approach he called "faster, better, cheaper." The program pushed for an increase in the number of research missions while keeping total costs the same, a shorter mission timescale that spanned years instead of decades, and more opportunities for innovation.

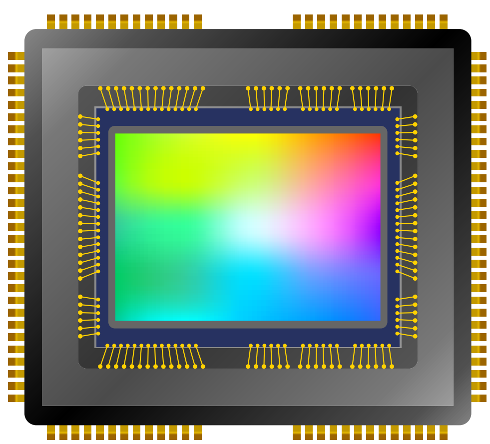
This coincided with a need from the NASA Jet Propulsion Laboratory (JPL) in Pasadena, Califronia, to enable charge-coupled device (CCD) image sensors—a technology used in digital camera systems—on future interplanetary spacecraft.

An engineer at JPL, Eric Fossum, began brainstorming ways to improve upon CCDs, which had certain drawbacks. For one, the cameras were large and heavy, which made them less than ideal for space applications. More importantly, operating inefficiencies plagued CCD cameras to the point where they required significant power to run.

"I recognized there were some shortcomings with CCDs in general, and I thought an active pixel sensor approach—which was an idea that already existed, of putting a transistor inside every pixel—would be very useful for NASA applications," said Fossum. "But it was an older idea that was also known not to work particularly well, and CCDs were still better at the time."

In 1993, Fossum, along with his JPL colleagues Sabrina Kemeny and Sunetra Mendis, succeeded in developing a new type of image sensor technology that boasted smaller size, lower cost, and greater power efficiency compared to CCDs. Their invention, the complementary metal oxide semiconductor (CMOS) active pixel sensor with intra-pixel charge transfer, led to the creation of a camera-on-a-chip—which can be found in just about every smartphone, digital camera, and computer today.

"The reason our invention became so successful was that it had a couple of clear advantages over the incumbent CCD technology. The number one reason was power—it basically used 5 to



With early help from SBIR contracts, CMOS sensors revolutionized imaging technology.

10 times less power than CCD," said Kemeny. "One of the reasons it was invented in the first place was for space missions, where every little bit of power savings makes a huge difference. But that power savings is also what enabled cameras to be able to live inside our cell phones."

In 1995, Kemeny and some of her colleagues left JPL to found a spin-off company based on CMOS technology called Photobit. Fossum, her husband at the time and co-founder, joined her a year later. After securing the license agreement from NASA, they received early funding from the Small Business Innovation Research (SBIR) program. Photobit won two NASA SBIR awards to start in 1996, followed by multiple SBIR awards from the Department of Defense (DoD).

Today, CMOS image sensors appear in just about every smart phone, digital camera, security system, and newer-model vehicle.

They credit the SBIR program funding with helping to get Photobit product research and development off the ground. Kemeny also notes that the DoD SBIR awards pushed Photobit's engineers to go further with the technology for specialized military applications.

For instance, an SBIR award from the Army funded the development of high-resolution, high-speed, low-power image sensors for recording the details of missile launches on test ranges. As a result, the company created CMOS image sensors with speeds greater than 500 frames per second and electronic shuttering capability that could freeze even the fastest motion to create high quality images. Photobit also used an SBIR award from DARPA to develop a micro-sized, micro-power CMOS sensor that led to a swallowable pill-camera for noninvasive medical imaging of the gastrointestinal system.

"The DoD projects really pushed the science in ways that the military needed, like for extremely high-speed cameras and ultra high-resolution sensors," Kemeny said.

The main difference between CCD and CMOS image sensors lies in the way they transfer charge. An image sensor is divided into pixels that contain both a photodetector to collect light and readout electronics to transfer the information. Each pixel can be thought of as a bucket that collects a certain number of photoelectrons depending on the light intensity that strikes it. A CCD works by repeatedly dumping those photoelectrons into the neighboring pixel's bucket until they reach the end of the line, at which point the total charge is recorded and amplified.

This "bucket brigade" method of charge transfer works surprisingly well. However, CCD operation requires lots of power, and a CCD system needs camera control chips in addition to the image sensor chip, which contributes to its large size. The CMOS image sensor does away with the bucket brigade method altogether by inserting a transistor in each pixel. This way, every pixel records and amplifies its charge directly without having to pass it to a neighbor.

CMOS systems used far less power than CCDs, in a smaller form factor, and they were cheaper to manufacture at the time. Fossum and Kemeny's invention became known as a "camera-on-a-chip," since it reduced the number of chips needed for image acquisition from five or more to only one.

Today, CMOS image sensors appear in just about every smart phone, digital camera, security system, and newer-model vehicle. They are by far the most utilized image sensor technology, capturing all but a few percentages of image sensor unit sales.

"I always knew it had the potential to be huge," said Fossum.

Photobit Corp. (Micron Technology) • Pasadena, CA (Boise, ID)

Modernization Priority: Microelectronics

SBIR contract: DAAD07-98-C-0105 • Agency: Army • Topic: A96-106, Ultra High Resolution CMOS APS Camera

SBIR contract: DAAH01-98-C-R184 • Agency: DARPA • Topic: SB962-070, Micropower Microdot CMOS APS Image Sensor SBIR contract: F33615-99-C-1400 • Agency: MDA • Topic: BMDO97-003, Visible CMOS Imager with Ultra High Dynamic Range