CMOS Image Sensors: Tech Transfer from Saturn to your Cell Phone

Eric R. Fossum
Thayer School of Engineering at Dartmouth

National Academy of Inventors
2nd Annual Conference, February 22, 2013

CMOS Image Sensors: Tech Transfer

the US Space Program from ~~Saturn~~ to your Cell Phone

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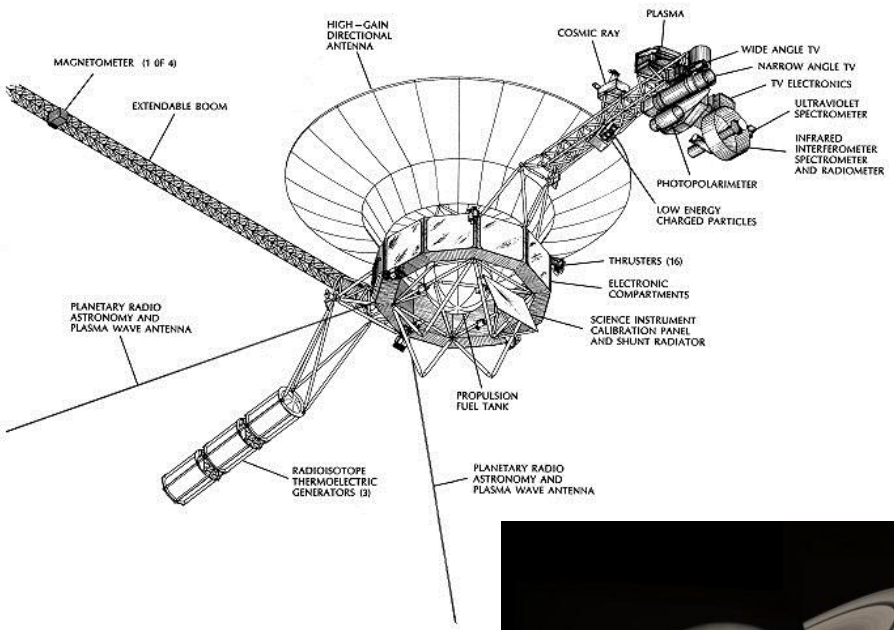
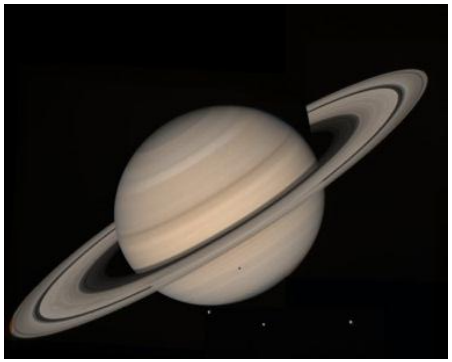
Step 1
“Necessity is the Mother of Invention”

Voyager ISS had vidicon cameras (wide angle and narrow angle)

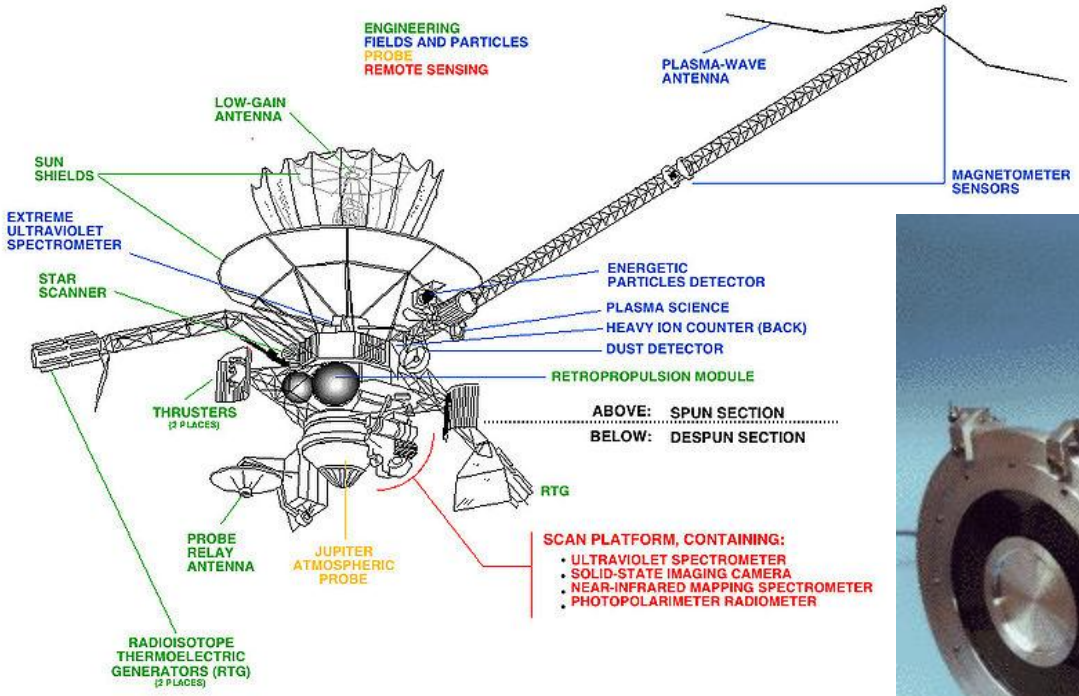
Mass: 38.2 kg
Power (avg): 35.0 W





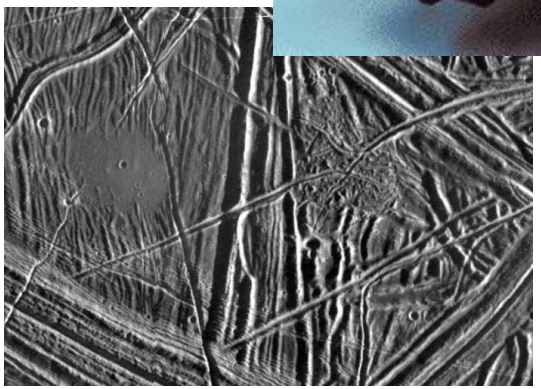
http://nssdc.gsfc.nasa.gov/nmc/experimentDisplay.do?id=1977-084A-01

Galileo SSI had solid-state CCD cameras (wide angle and narrow angle)



Mass: 29.7 kg
Power (avg): 15 W
CCD: 800x800 pixels

Callisto

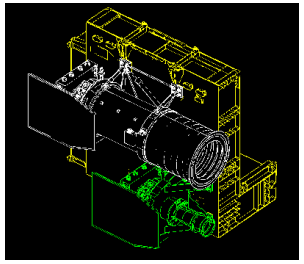


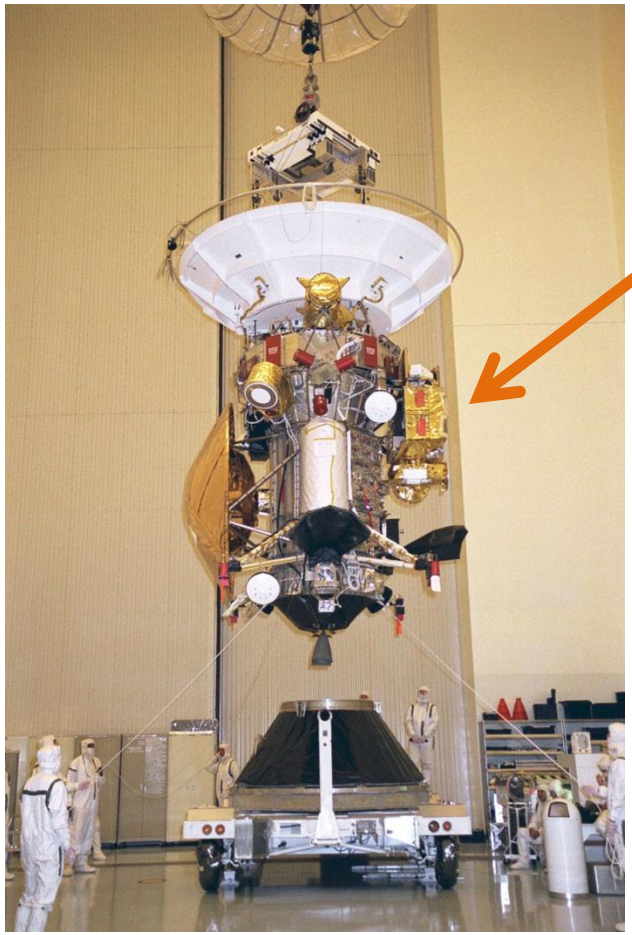
Europa

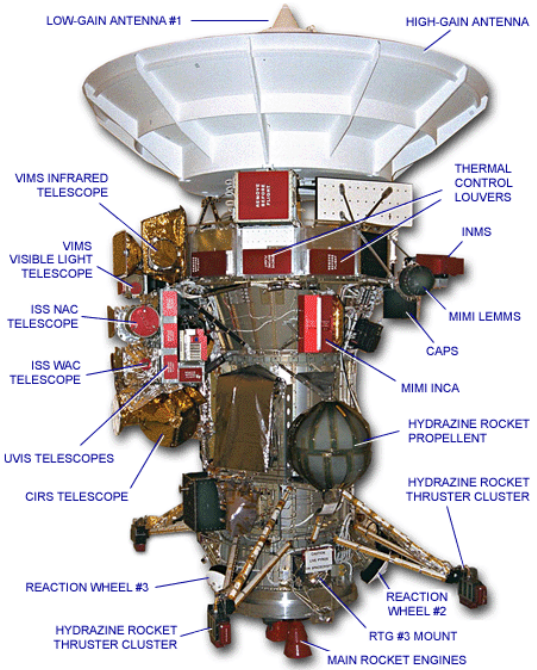
http://en.citizendium.org/wiki/Galileo_Probe

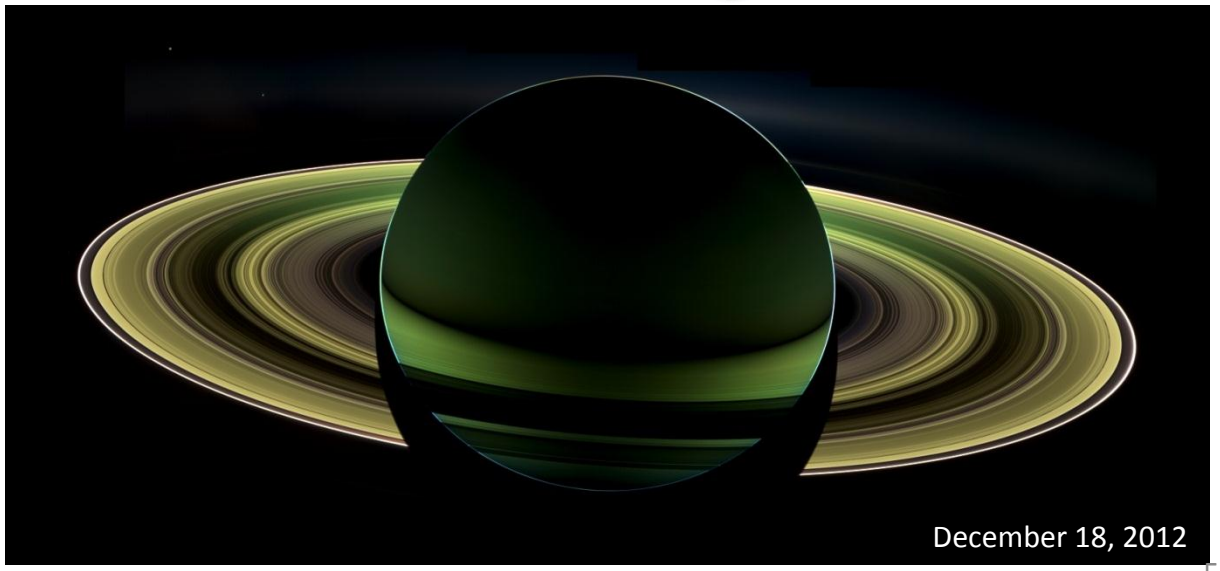
Cassini ISS has solid-state CCD cameras (wide angle and narrow angle)

Mass: 57.83 kg
Power (avg): 30.0 W
CCD: 1024x1024 pixels







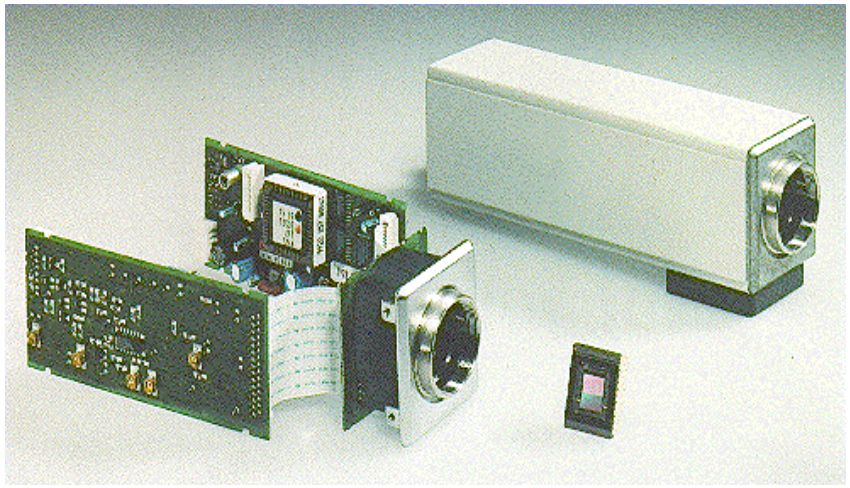


NASA's Administrator Daniel Goldin
"Faster, Better, Cheaper"

Need to Miniaturize Cameras
On Future Spacecraft

Smaller payload mass = Smaller rockets
Smaller payload volume = Less radiation shielding (less mass)
Less power = Smaller power generation on-board

Step 2
Invent a New Technology



CCD cameras have many components and consume significant power.

BUT, the CCD is not amenable to electronics integration

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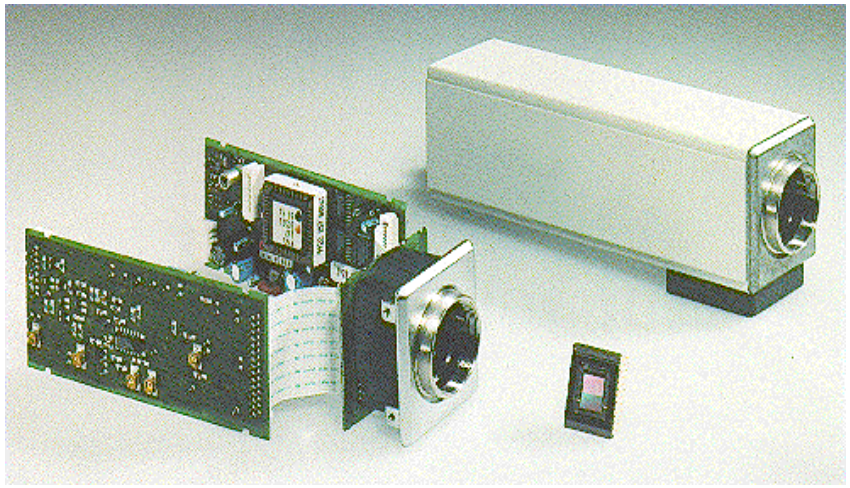

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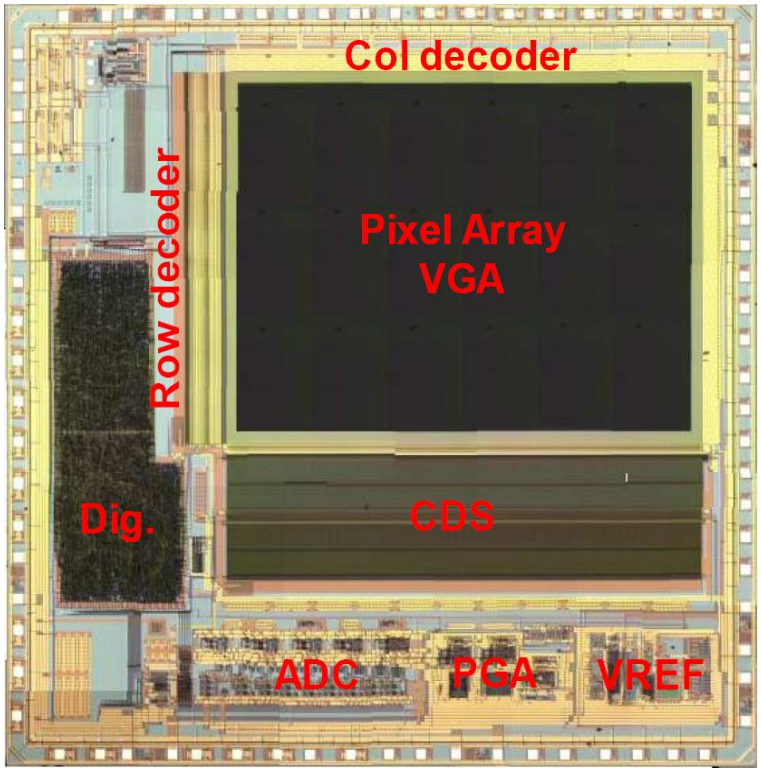
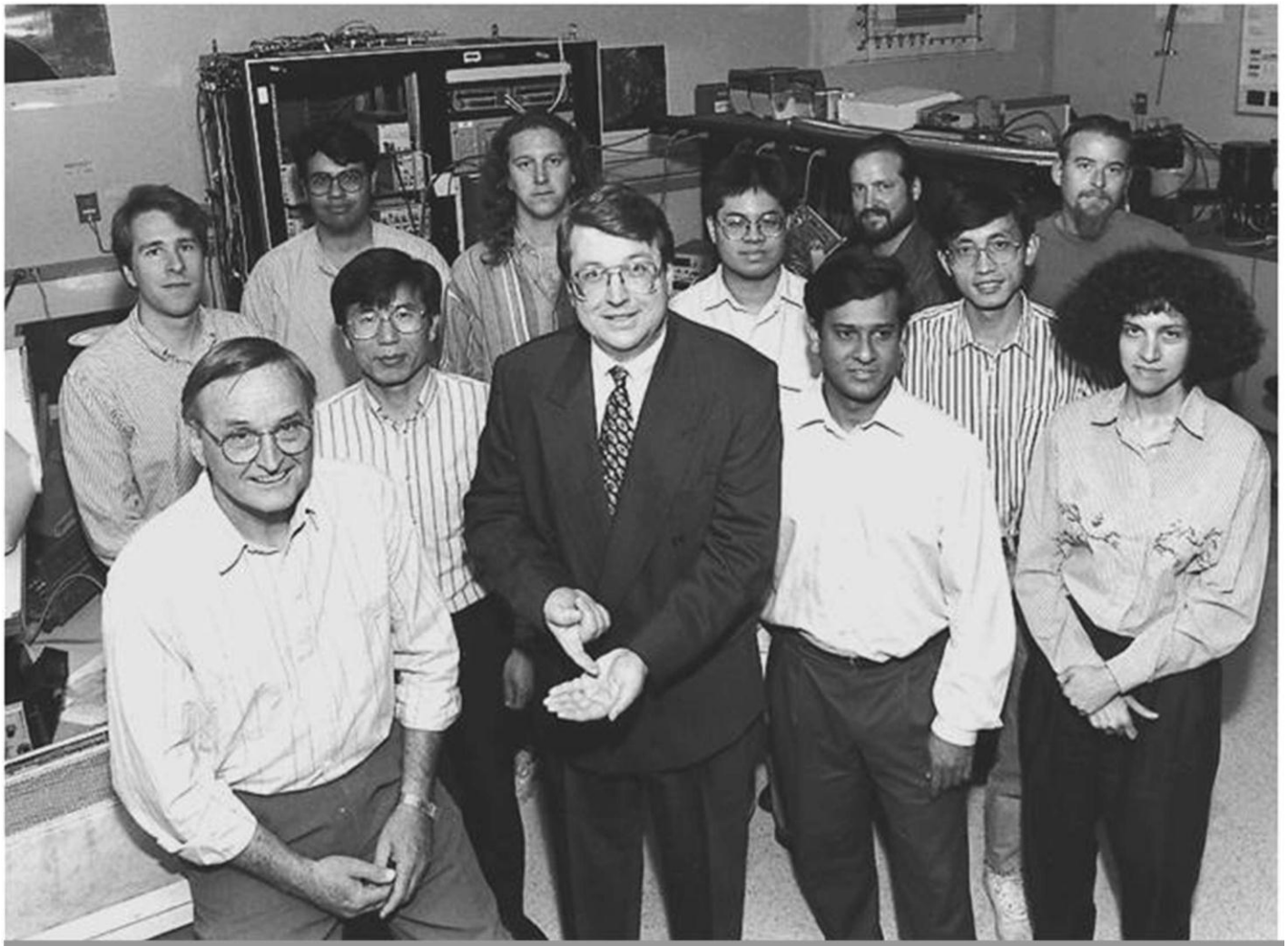


CMOS Active Pixel Sensor
With Intra-Pixel Charge Transfer
Camera-on-a-chip

Most of the JPL Team



Advanced Imager Technology Group, Jet Propulsion Laboratory, California Institute of Technology 1995
Back row: Roger Panicacci, Barmak Mansoorian, Craig Staller, Russell Gee, Peter Jones, John Koehler
Front row: Robert Nixon, Quisup Kim, Eric Fossum, Bedabrata Pain, Zhimin Zhou, Orly Yadid-Pecht

Step 3
Technology Transfer

To fulfill a secondary NASA mission to strengthen US Industry JPL/Caltech signed Technology Cooperation Agreements with

- AT&T Bell Labs
- Kodak
- Schick Technologies (startup)

And other agreements/visits with

- National Semiconductor
- Motorola
- Intel
- EG&G Reticon
- etc.

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$\Rightarrow$ Entrenched industry moves slowly in adopting new technologies so in February 1995 we founded Photobit Corporation to commercialize the CMOS image sensor technology ourselves

Step 4
Get a Lucky Break

Science & Technology

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

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

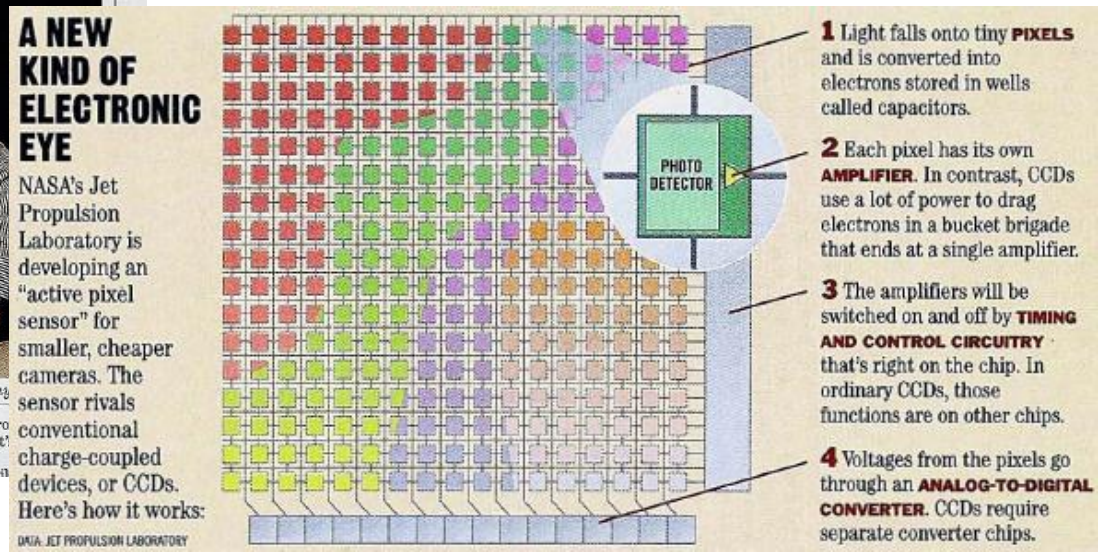
Get ready for the camera-on-a-chip. Since the 1970s, camera makers have dreamed of a one-chip camera containing all the components necessary to take a snapshot or make a movie. With all the smarts on one chip instead of several, designers figure they could make a camera small and cheap enough to open 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

cost much less than CCDs. One chip can incorporate all manner of electronic controls that are usually on multiple chips,

ter for Space Microelectro
gy at JPL. "For them, it'
leapfrog the Japanese."

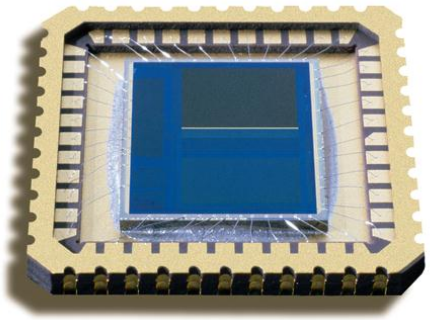


March 6, 1995 Business Week article

Step 5
Perspiration Phase

1995-2001 Photobit grows to about 135 persons

- Self funded with custom-design contracts from private industry
- Important support from SBIR programs (NASA/DoD)
- Later, investment from strategic business partners to develop catalog products



The Photobit Team Circa 2000

Step 6
Miller Time

2001 – Photobit acquired by Micron Technology

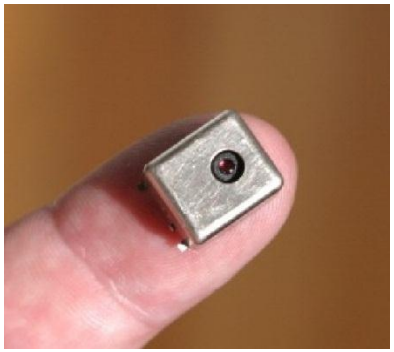
Meanwhile, by 2001 there were many competitors emerging in the CMOS image sensor business due in part to the earlier efforts to promote the transfer the technology.

Examples: Toshiba, ST Micro, Omnivision

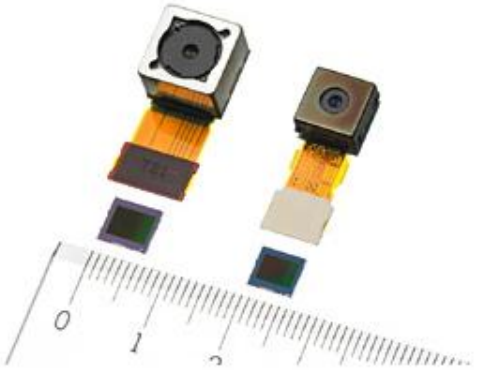
Later, came Sony and Samsung (now #1, #2 in worldwide market)

Step 7
The Technology Has a Life of its Own

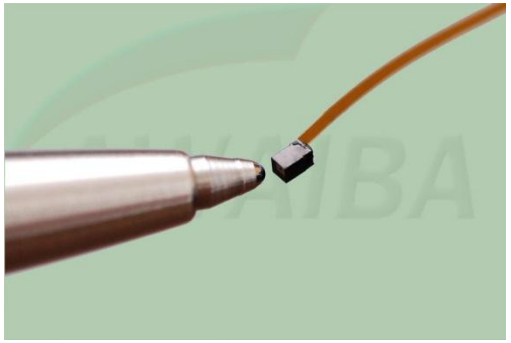
- Today, over 2 billion camera phones are manufactured each year that use the CMOS image sensor technology we invented at JPL, or more than 60 cameras per second, 24/7/52
- Semiconductor sales of CMOS image sensors exceeded $7B in 2012.
- Caltech has successfully enforced its patents against all the major players.
- NASA is now just adopting the technology for use in space.



Siimpel MEMS AF
2 Mpix camera ~2007



16Mpix camera modules
From Sony ~2012



Endoscopy Camera ~2012

New Technology Invariably Brings New Social Issues

Instant communications (e.g. Facebook)

Rapid Social Change (Arab Spring)

Inappropriate use

Visual overload (e.g. Japanese Tsunami)

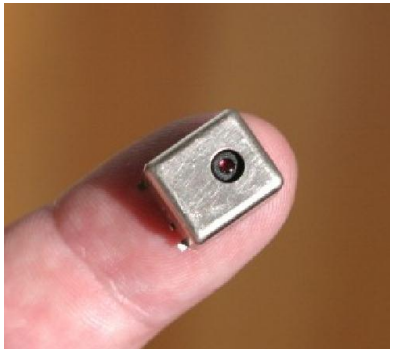
Security v. Privacy

New Weapons

Summary

Invention and Promise

+15 years



From the Voyager Spacecraft

To a Fantastic Voyage