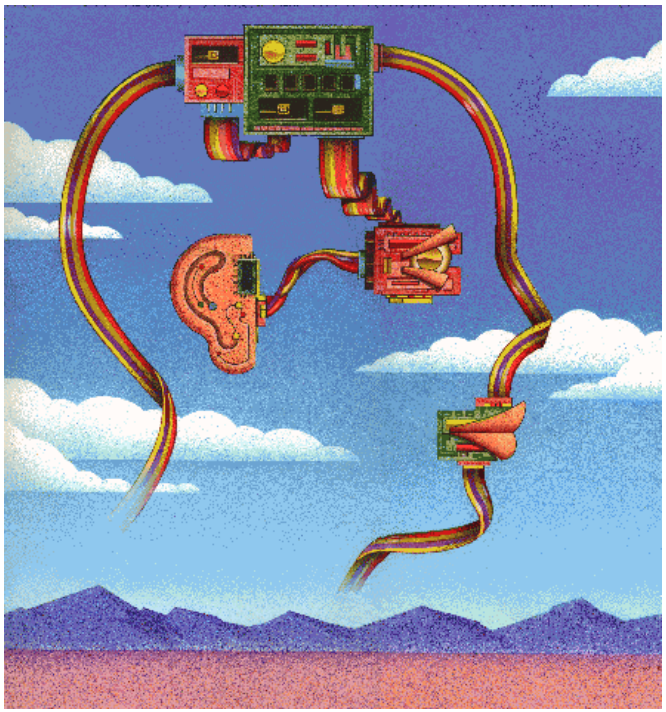

Making a Chip that Sees

a.k.a. Introduction to VLSI Systems

Andreas G. Andreou

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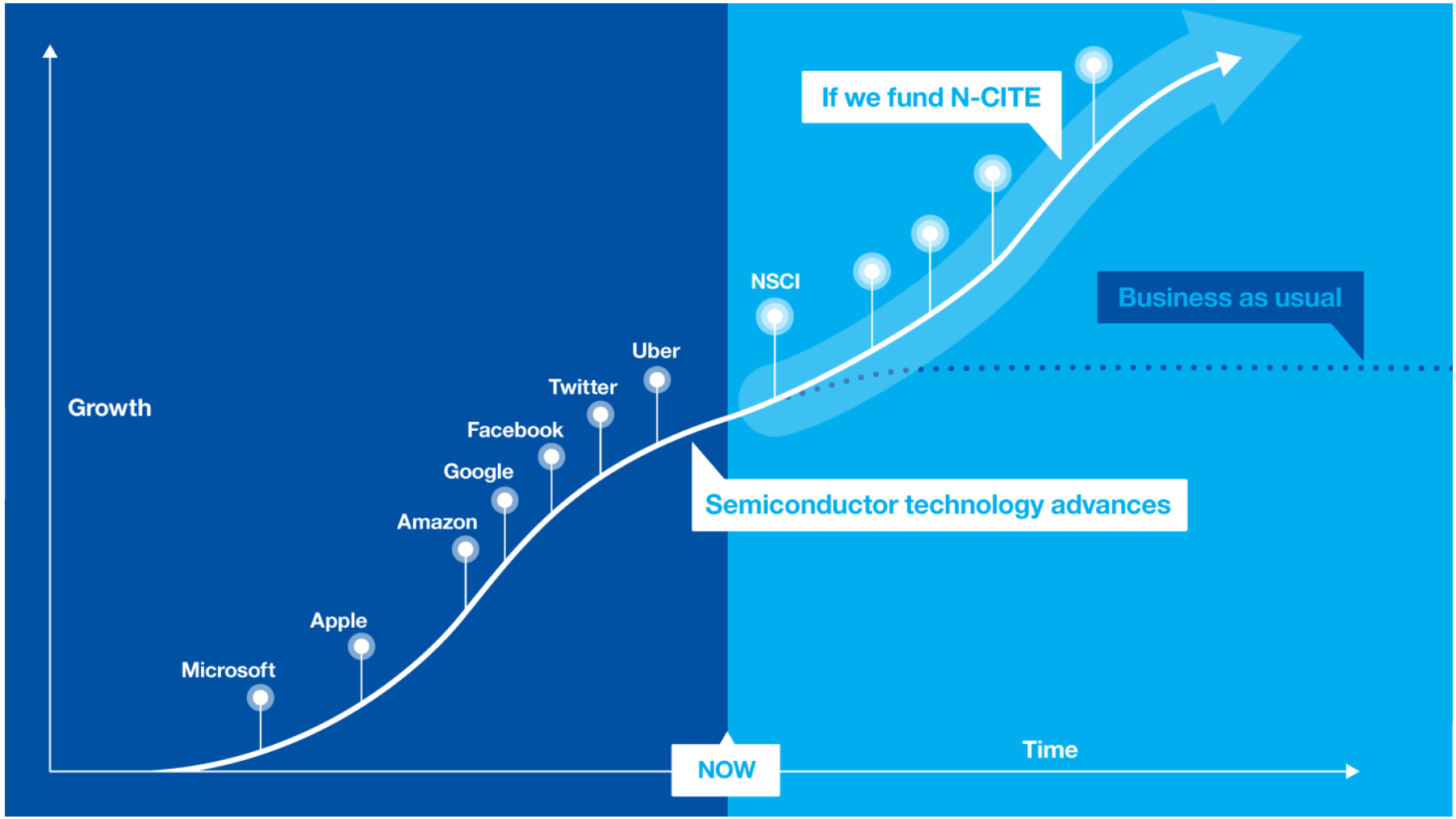
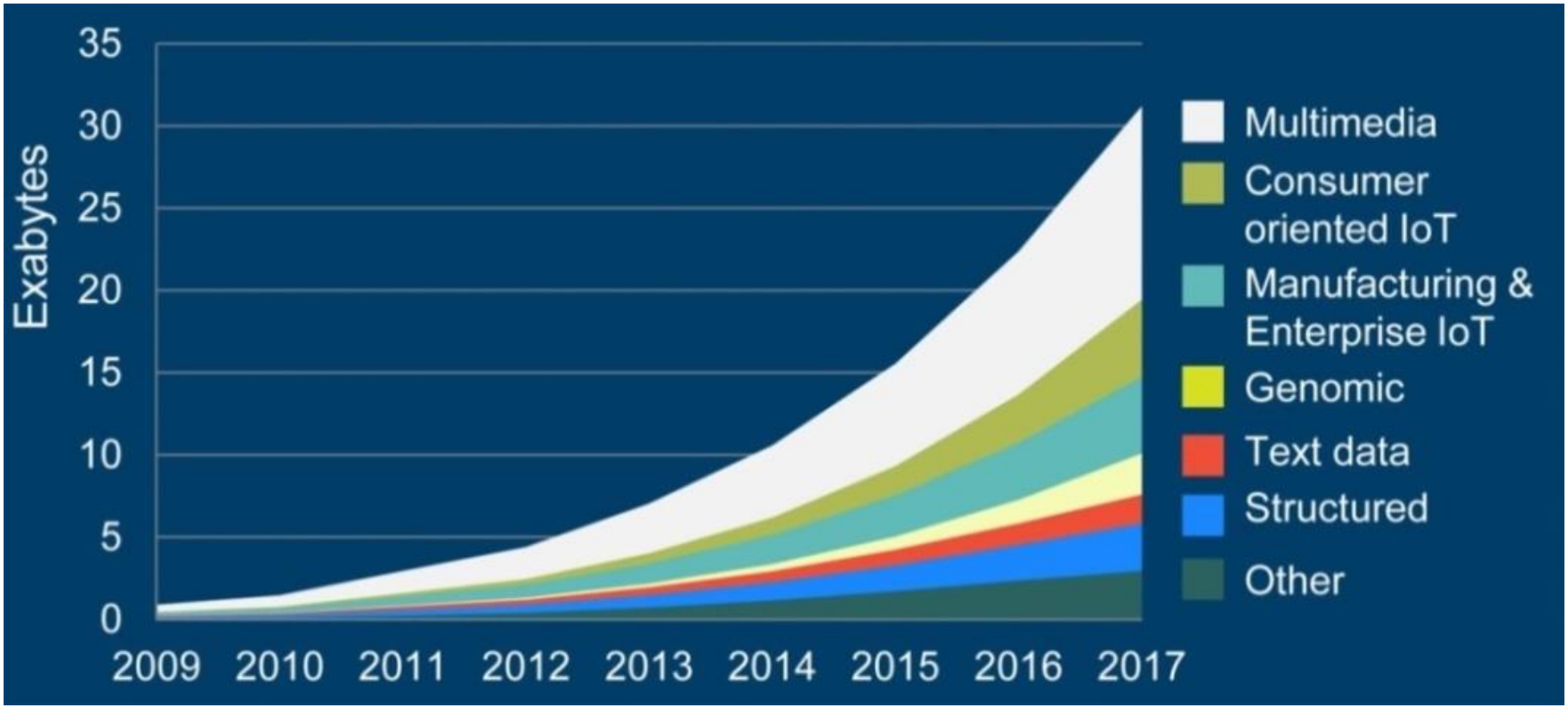
Electrical and Computer Engineering
Center for Language and Speech Processing
Johns Hopkins University
http://www.ece.jhu.edu/faculty/andreou/AGA/index.htm

economic growth depends on chips



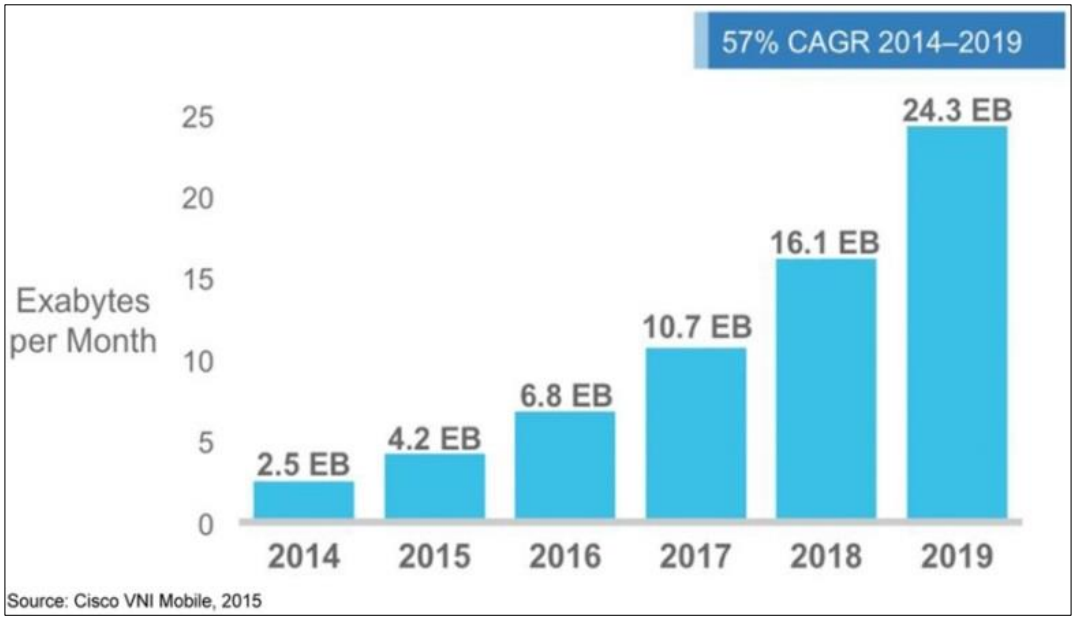
Rebooting the IT Revolution: A Call to Action, SRC, Sept 2015

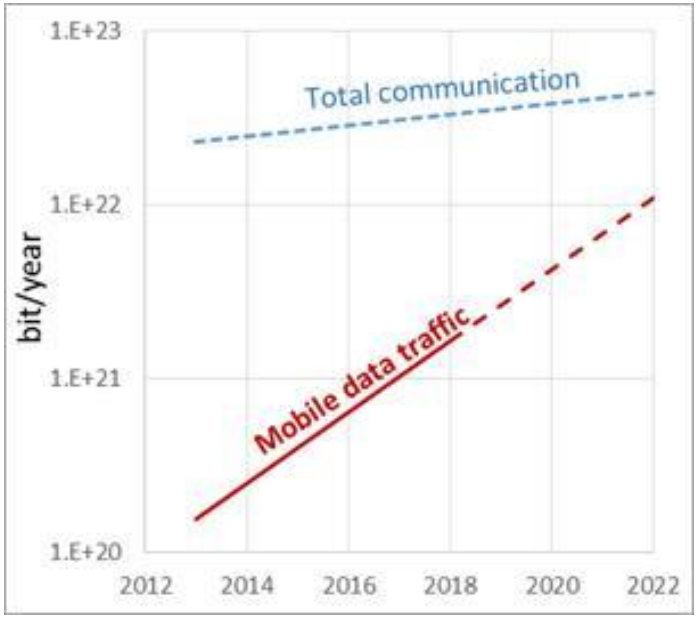
BigData growth



Rebooting the IT Revolution: A Call to Action, SRC, Sept 2015

mobile data growth





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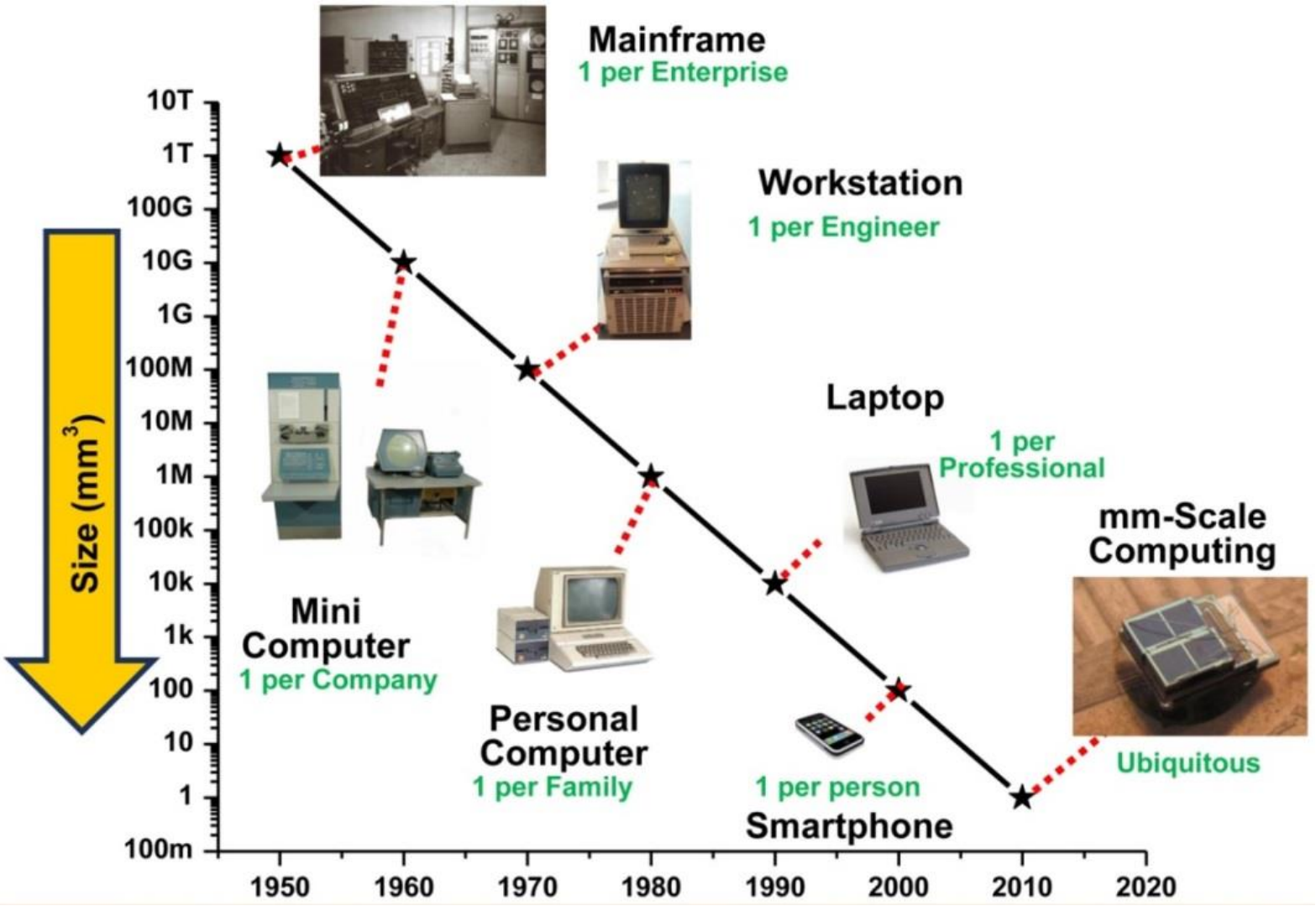
computer size



Rebooting the IT Revolution: A Call to Action, SRC, Sept 2015

computers and the brain

Mammalian Brains vs Computers

Parallel distributed architecture

Low power (25W), small footprint (1 liter)

Asynchronous (no global clock)

Analog computing,
Digital communication

Integrated memory and Computation

Intelligence via Learning thru BBE interactions

Composed of noisy components and operates at low speeds (< 10 Hz)

Spontaneously active

Serial architecture

High power (100MW),
Large footprint (40M liters)

Synchronous (global clock)

Digital computing and communication

Memory and Computation are clearly separated

Intelligence via programmed algorithms/rules

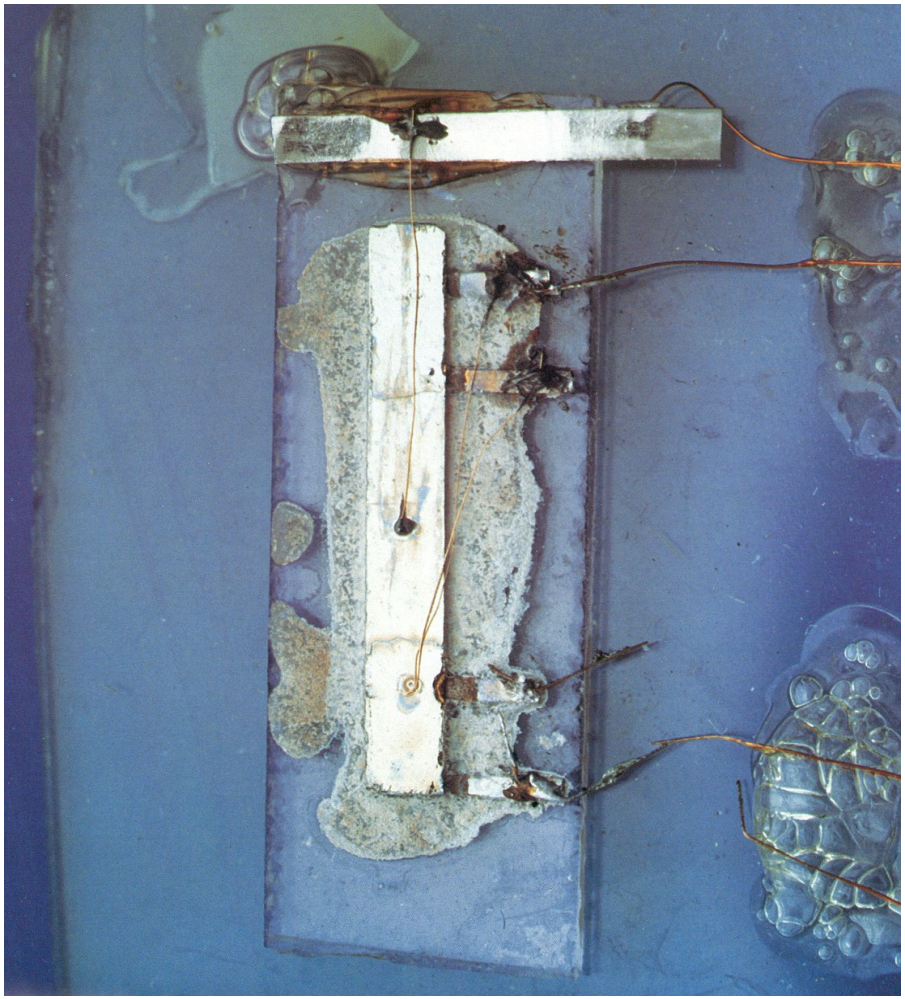
Precision in components and operates
at very high speeds (GHz)

No activity unless instructed

Rebooting the IT Revolution: A Call to Action, SRC, Sept 2015

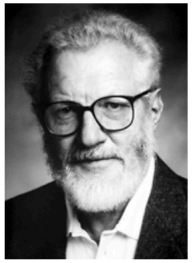
Back in the 50s

Jack Kilby, Texas Instruments,
Phase Shift Oscillator (1958)

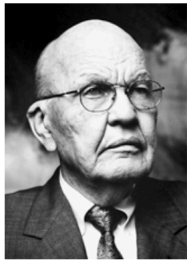


The Nobel Prize in Physics 2000

Zhores I. Alferov
Prize share: 1/4



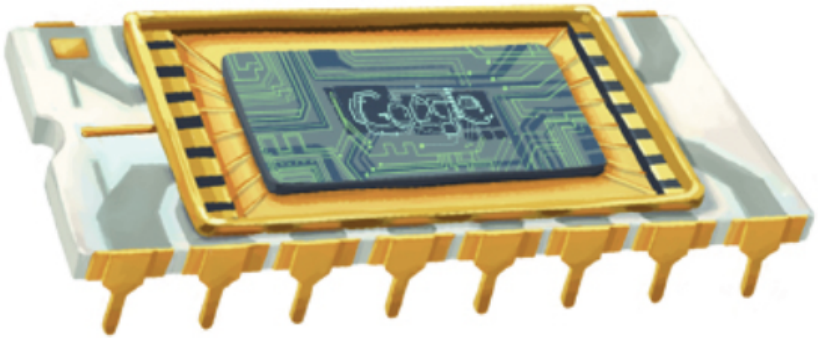
Herbert Kroemer
Prize share: 1/4



Jack S. Kilby
Prize share: 1/2

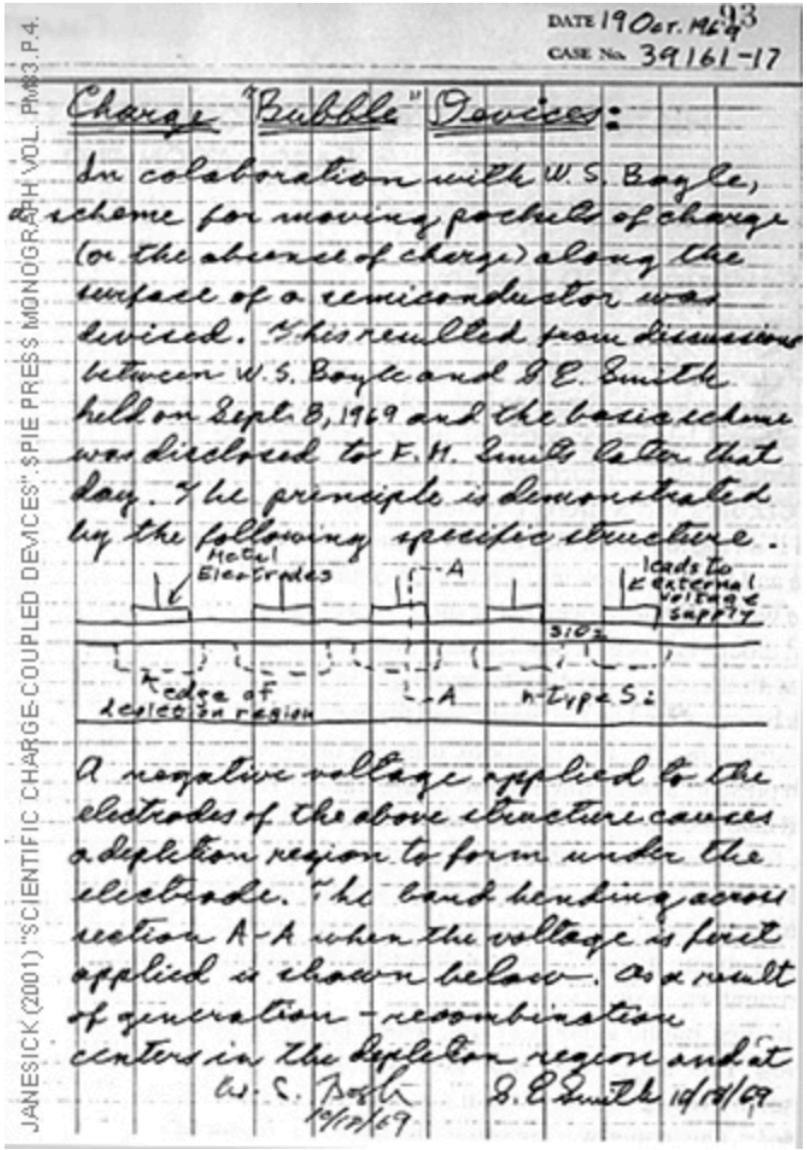
The Nobel Prize in Physics 2000 was awarded *"for basic work on information and communication technology"* with one half jointly to Zhores I. Alferov and Herbert Kroemer *"for developing semiconductor heterostructures used in high-speed- and opto-electronics"* and the other half to Jack S. Kilby *"for his part in the invention of the integrated circuit"*.

Robert Noyce, Fairchild/Intel
Integrated Circuit (1959)



Google Doodle December 12, 2011

Back in the 70s



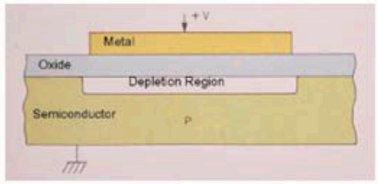
The Nobel Prize in Physics 2009

Photo: U. Montan
Charles Kuen Kao
Prize share: 1/2

Photo: U. Montan
Willard S. Boyle
Prize share: 1/4

Photo: U. Montan
George E. Smith
Prize share: 1/4

The Nobel Prize in Physics 2009 was divided, one half awarded to Charles Kuen Kao *"for groundbreaking achievements concerning the transmission of light in fibers for optical communication"*, the other half jointly to Willard S. Boyle and George E. Smith *"for the invention of an imaging semiconductor circuit - the CCD sensor"*.



Scientific background on the Nobel prize in Physics 2009

Moore's law

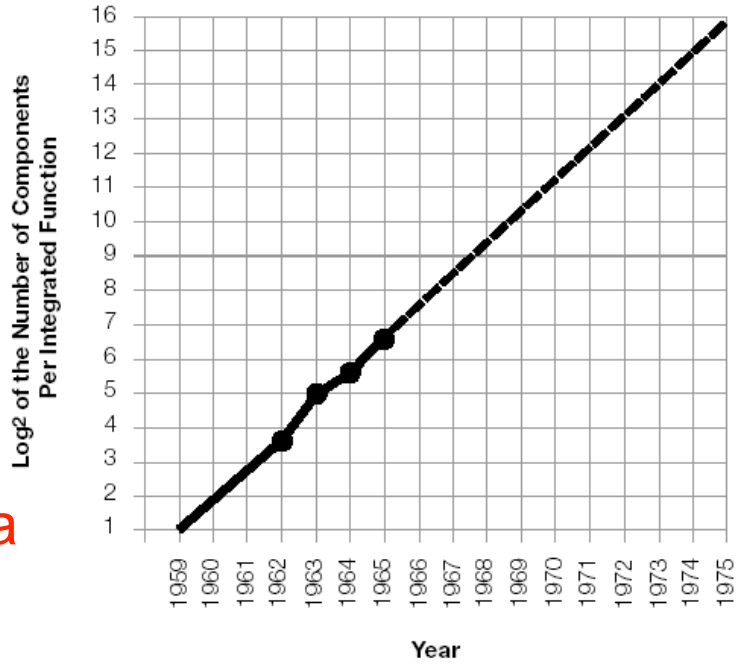
Cramming more components onto integrated circuits

With unit cost falling as the number of components per circuit rises, by 1975 economics may dictate squeezing as many as 65,000 components on a single silicon chip

By Gordon E. Moore

Electronics, Volume 38, Number 8, April 19, 1965

Snapdragon S4 1Billion



1. More transistors per unit silicon area
2. Lower energy costs for computation

80s-90s: the heydays of CAD and foundry design

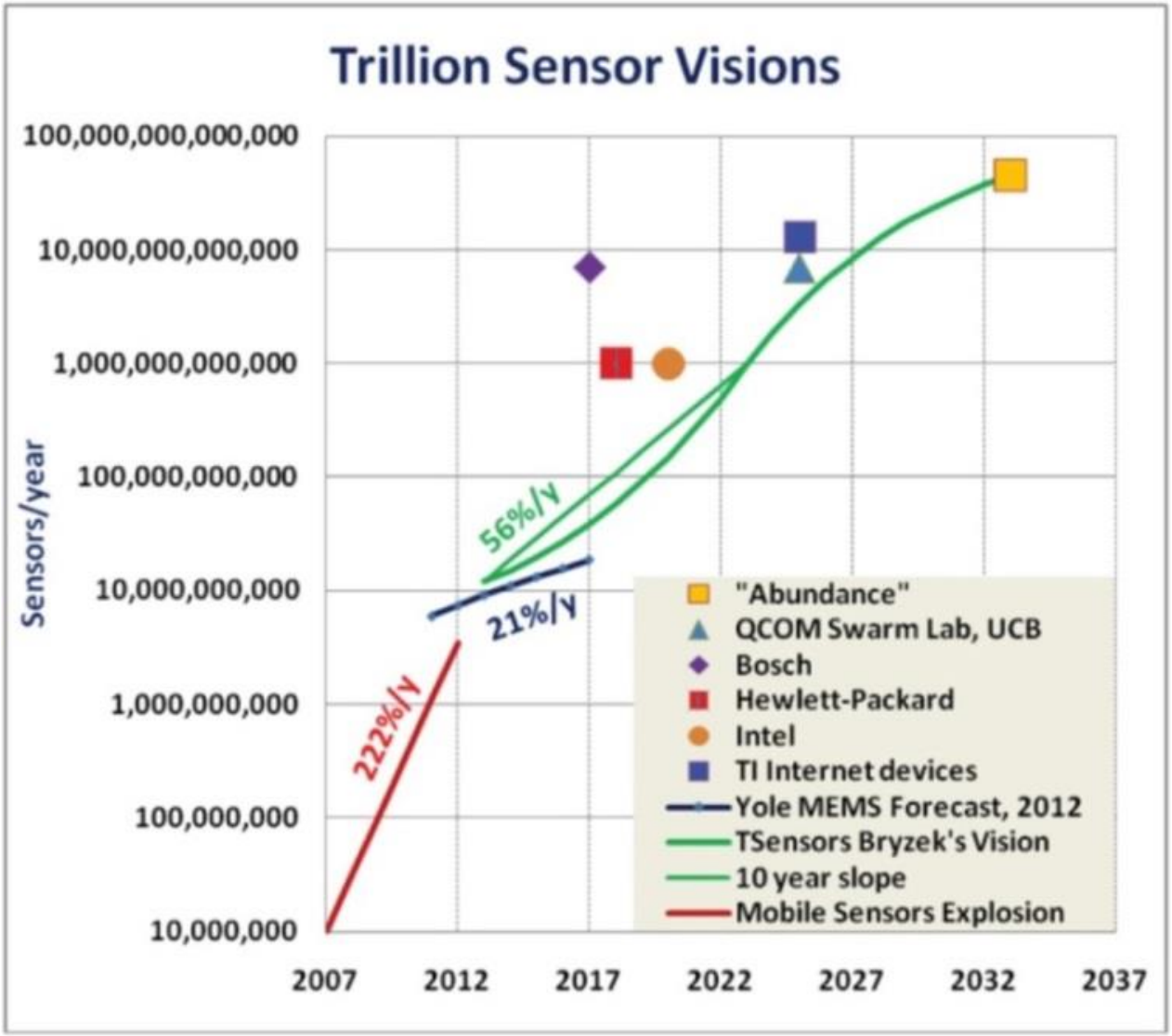
So how do fabricate our own chips?

http://www.mosis.org/

Key idea: Use a number of different manufacturers to contribute manufacturing capacity to multiuser projects.

- ON Semiconductor 500 nanometer CMOS
- TSMC 180, 130, 90, 65, 45, 28 nanometer CMOS
- GF 180, 130, 55, 45 nanometer BiCMOS
- IBM 45 nanometer SOI CMOS!

sensors growth



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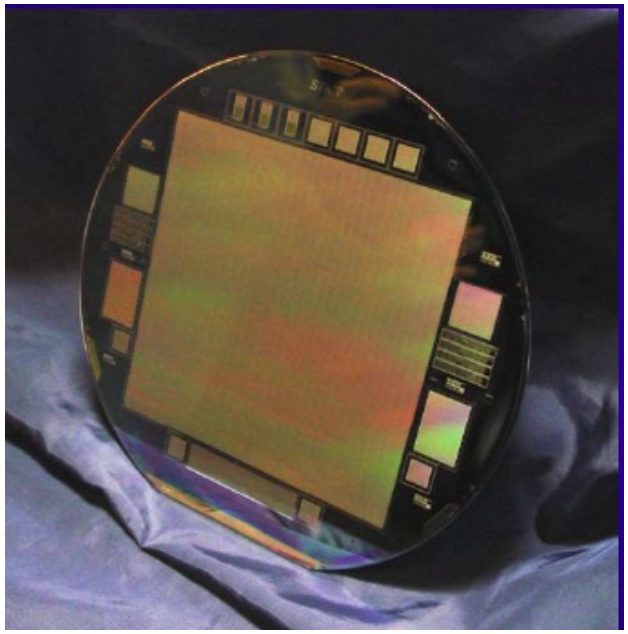
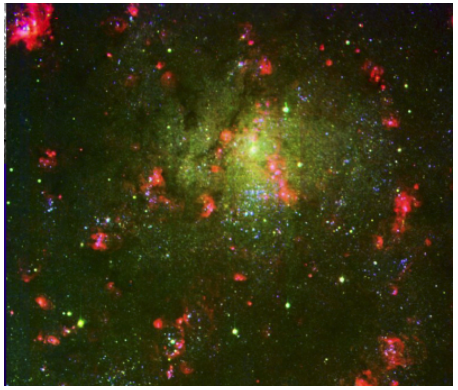
Late 90s CCD to CMOS: the paradigm shift in camera technologies



CCD state of the art

Full 6 inch wafer
111,000,000 pixels
1 frame per second!



$10,000,000

Semiconductor Technology Associates

CMOS APS Cameras

1,200,000 / 8,000,000 pixels

$1 / $15

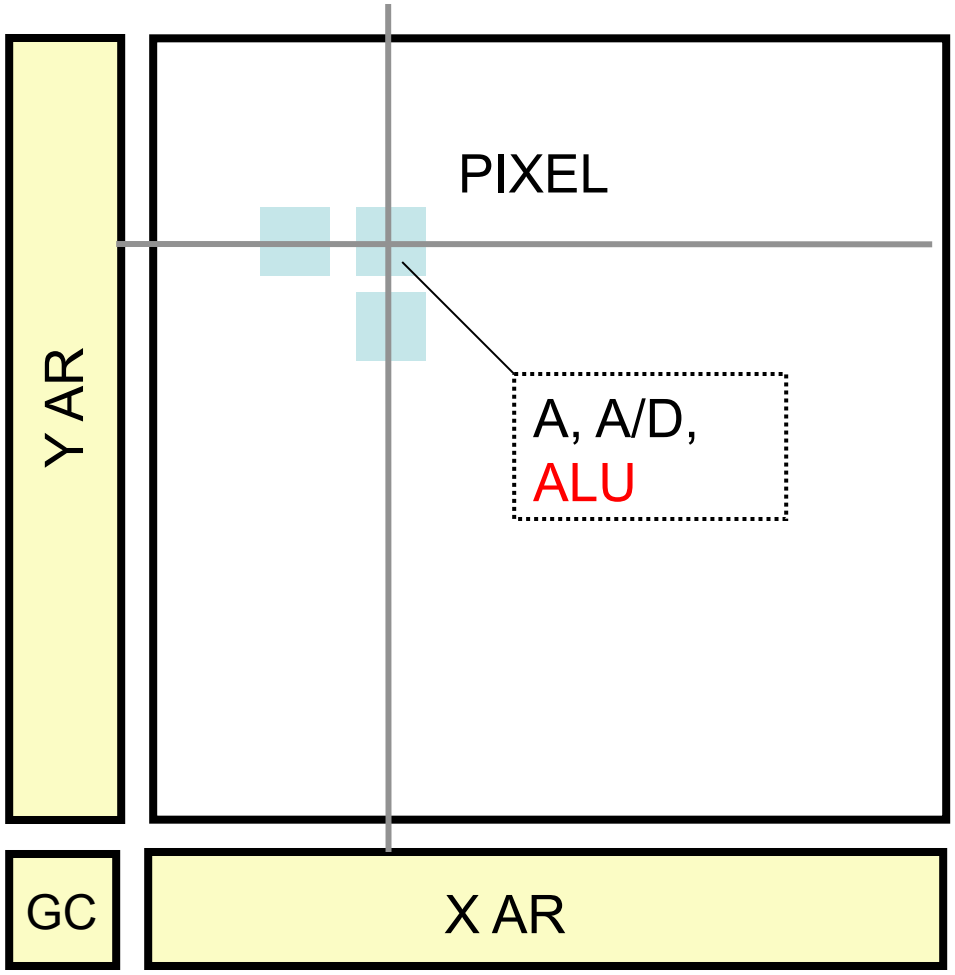
20,000,000 pixels

$200

120,000,000 pixels

$ 1,000,000

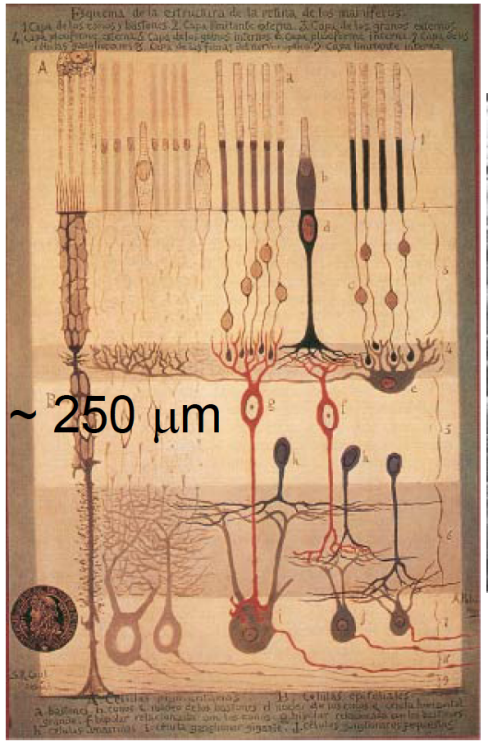
CMOS-APS and digital



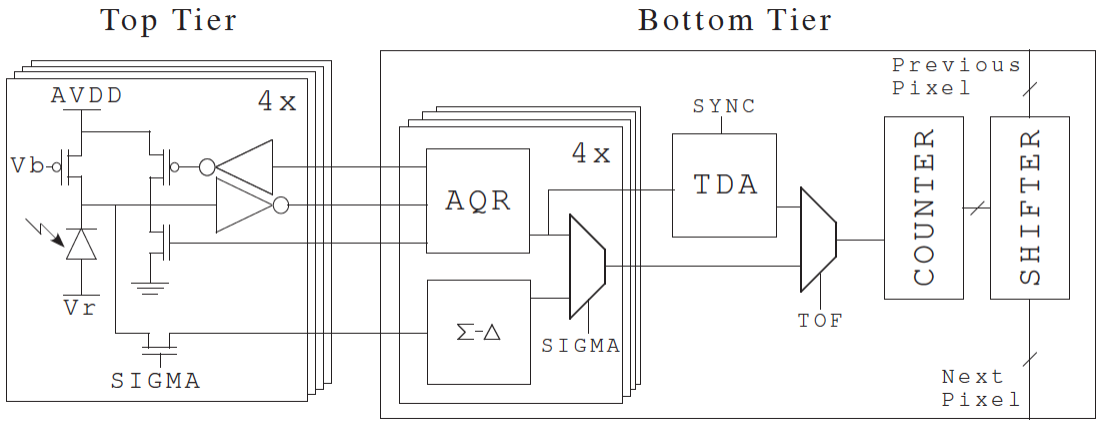
Pixel:
amplification (A)
quantization (A/D)
local asynchronous integration
gain and offset correction

Periphery:
column intensity accumulator (CAC)
global intensity accumulator (GAC)
asynchronous readout (AR)
global control (GC)

combining silicon rods and cones in a single pixel, with event based asynchronous readout



Santiago Ramon y Cajal



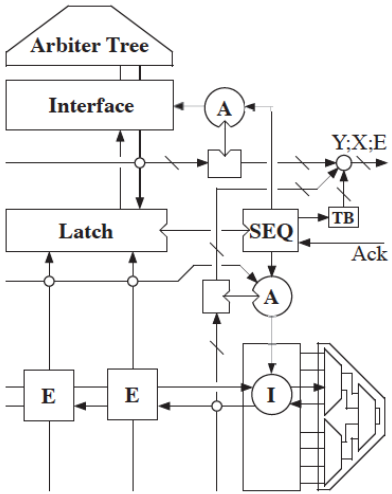
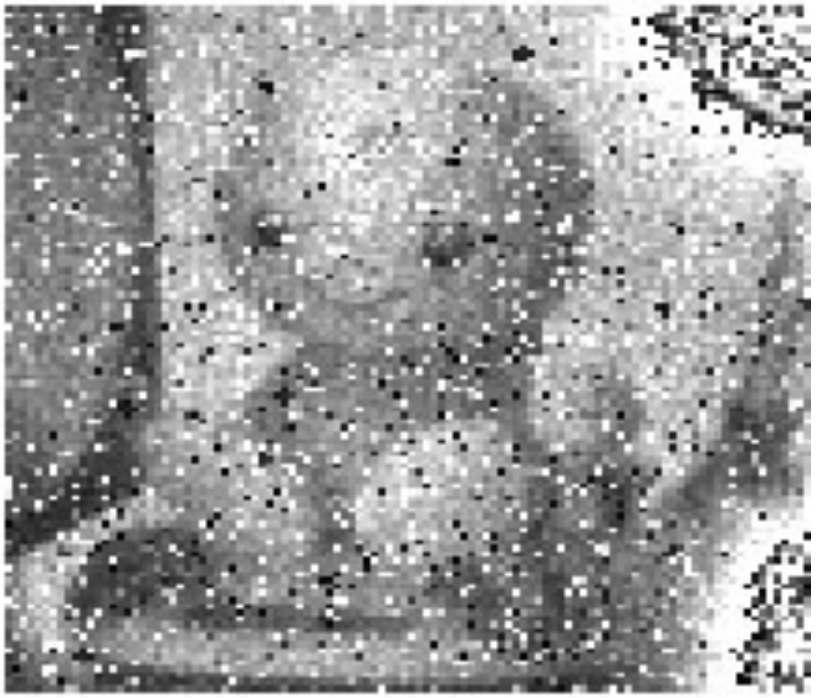
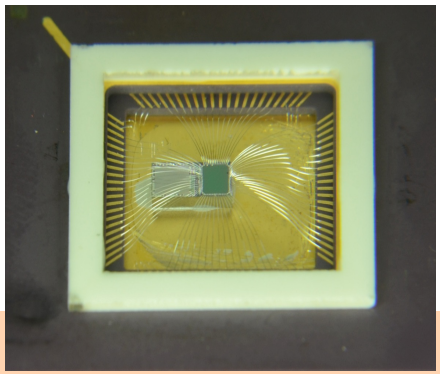


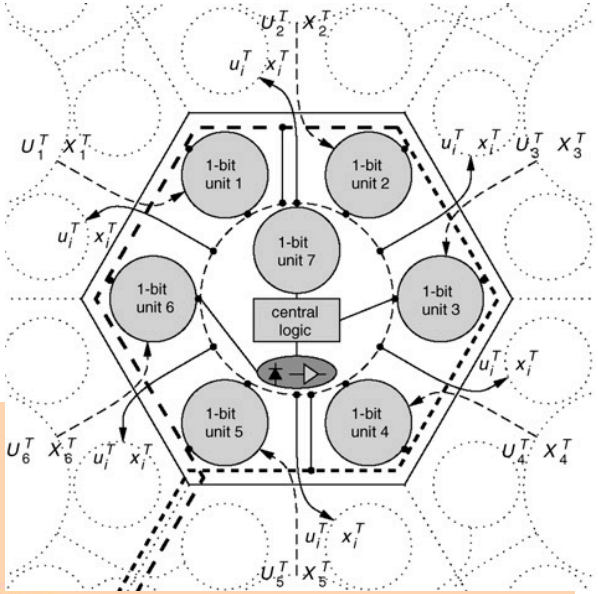
Fig. 5. Asynchronous Readout Architecture The selected row's events are readout in parallel and transmitted in a single packet—row address (Y), column address(es) (X), and tailword (E, generated by TB).

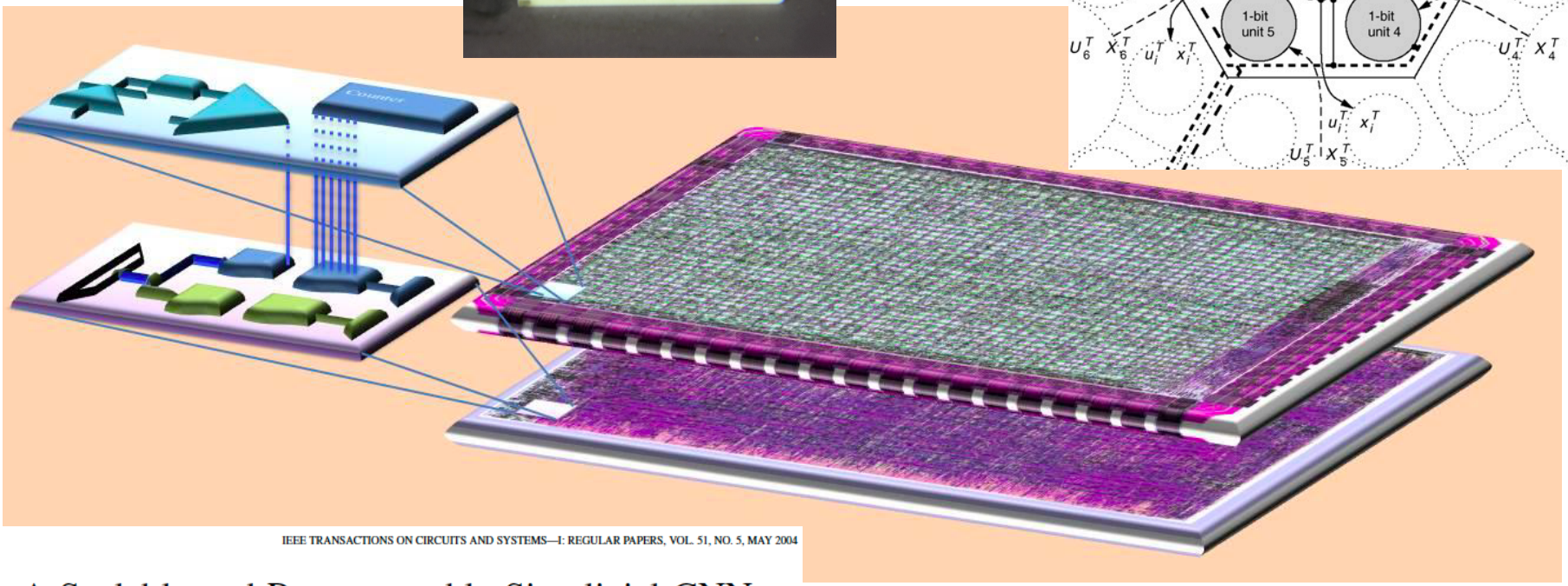
unpublished results from first silicon (Tezzaron 130nm 3D-CMOS)



Multivariate Function Approximator Chip in 3D CMOS





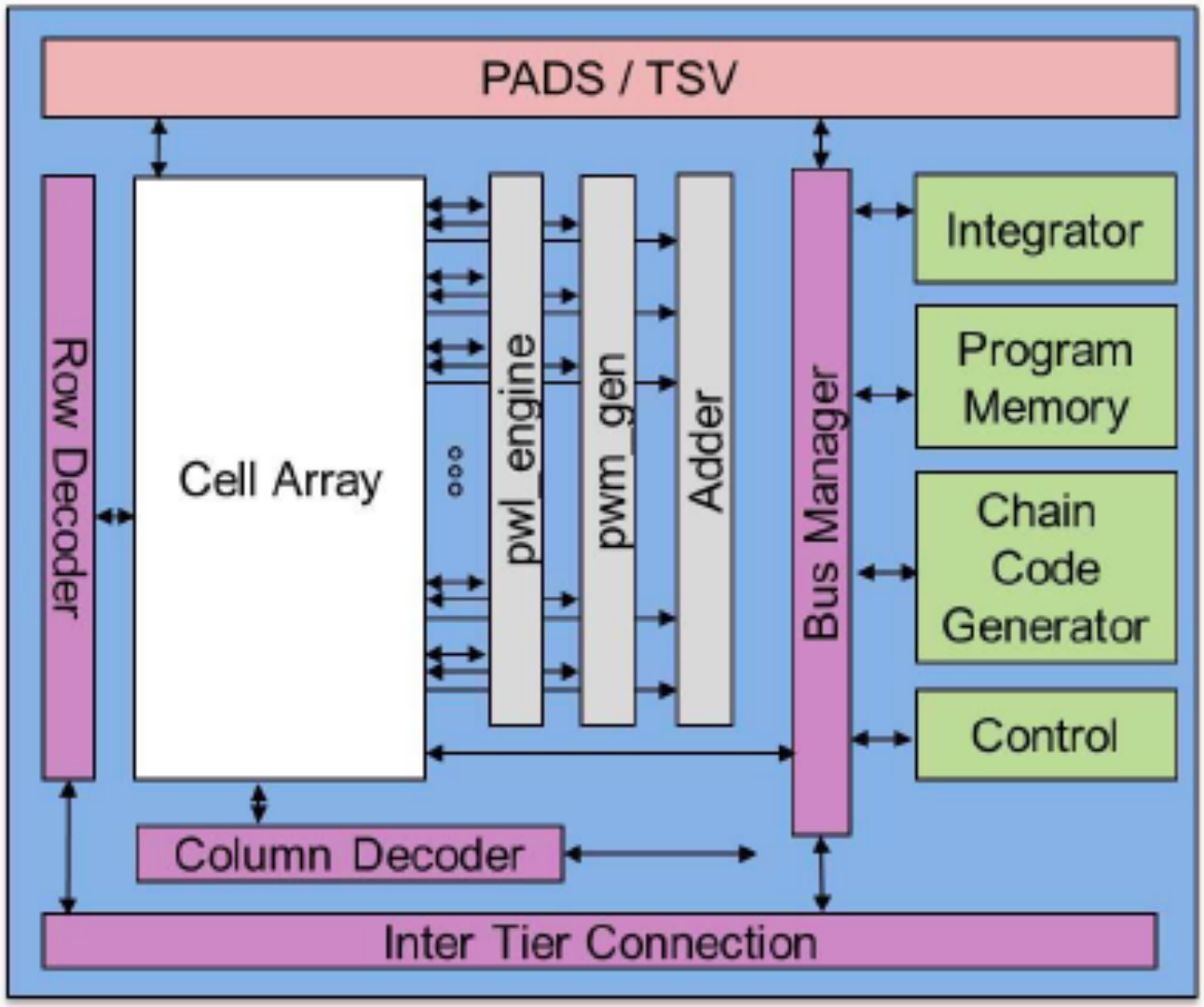


IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS—I: REGULAR PAPERS, VOL. 51, NO. 5, MAY 2004

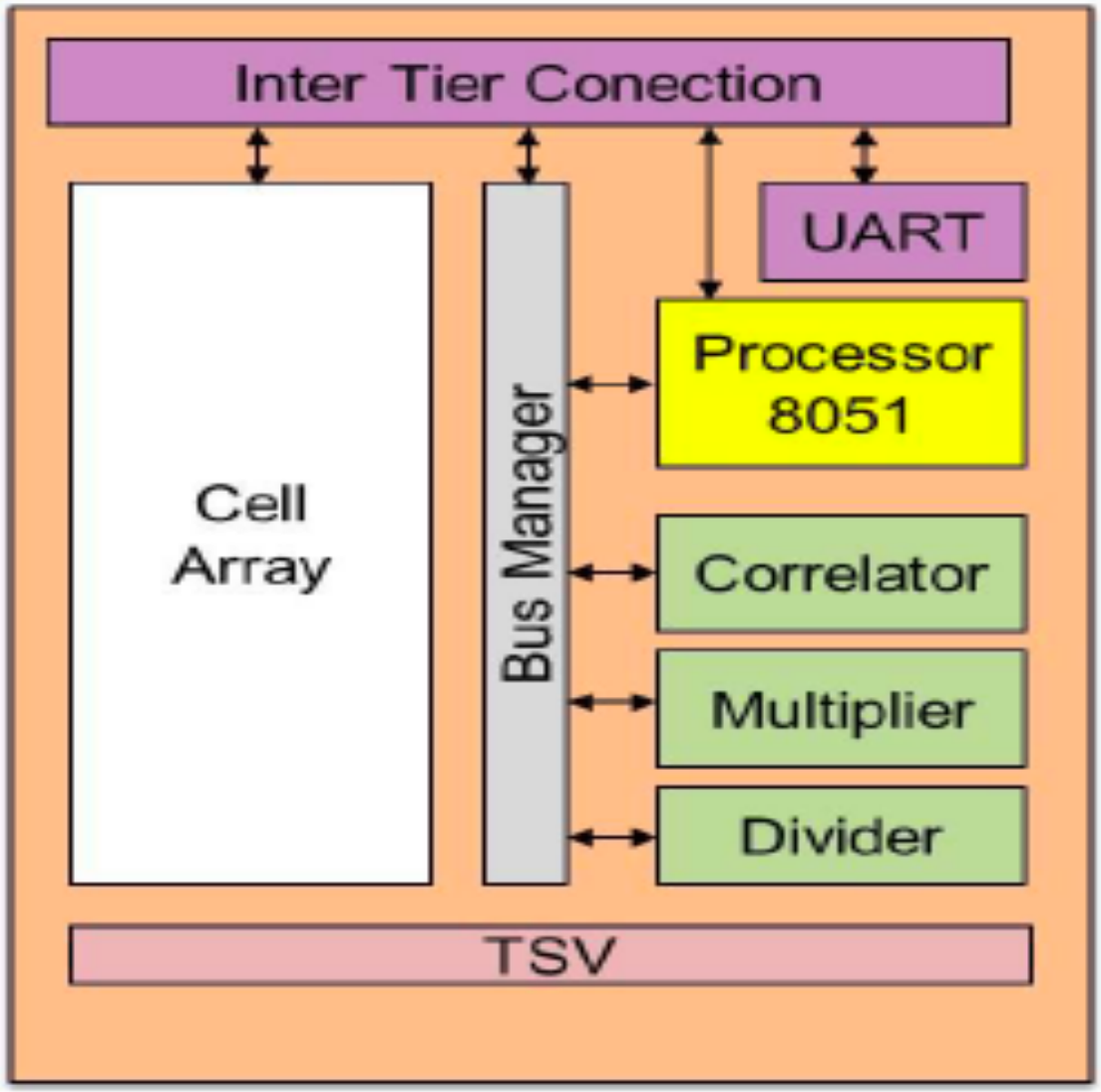
A Scalable and Programmable Simplicial CNN Digital Pixel Processor Architecture

Pablo S. Mandolesi, *Member, IEEE*, Pedro Julián, *Member, IEEE*, and Andreas G. Andreou, *Member, IEEE*

Tezzaron 3D-CMOS Tier 1:



Tezzaron 3D-CMOS Tier 2:



unpublished results from first silicon

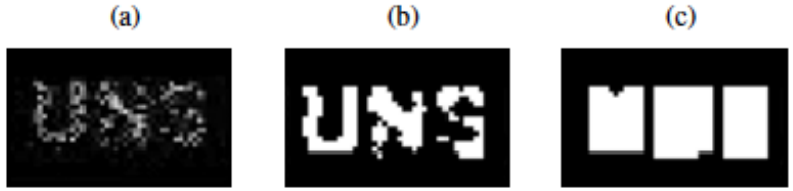


TABLE IV: a) Captured image b)Binarization c)Block recognition

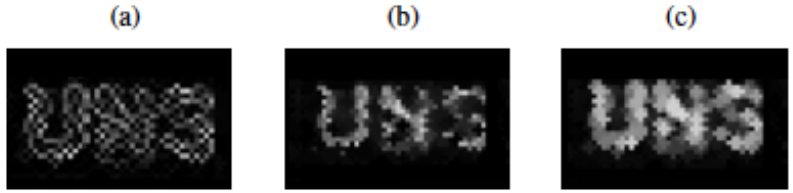


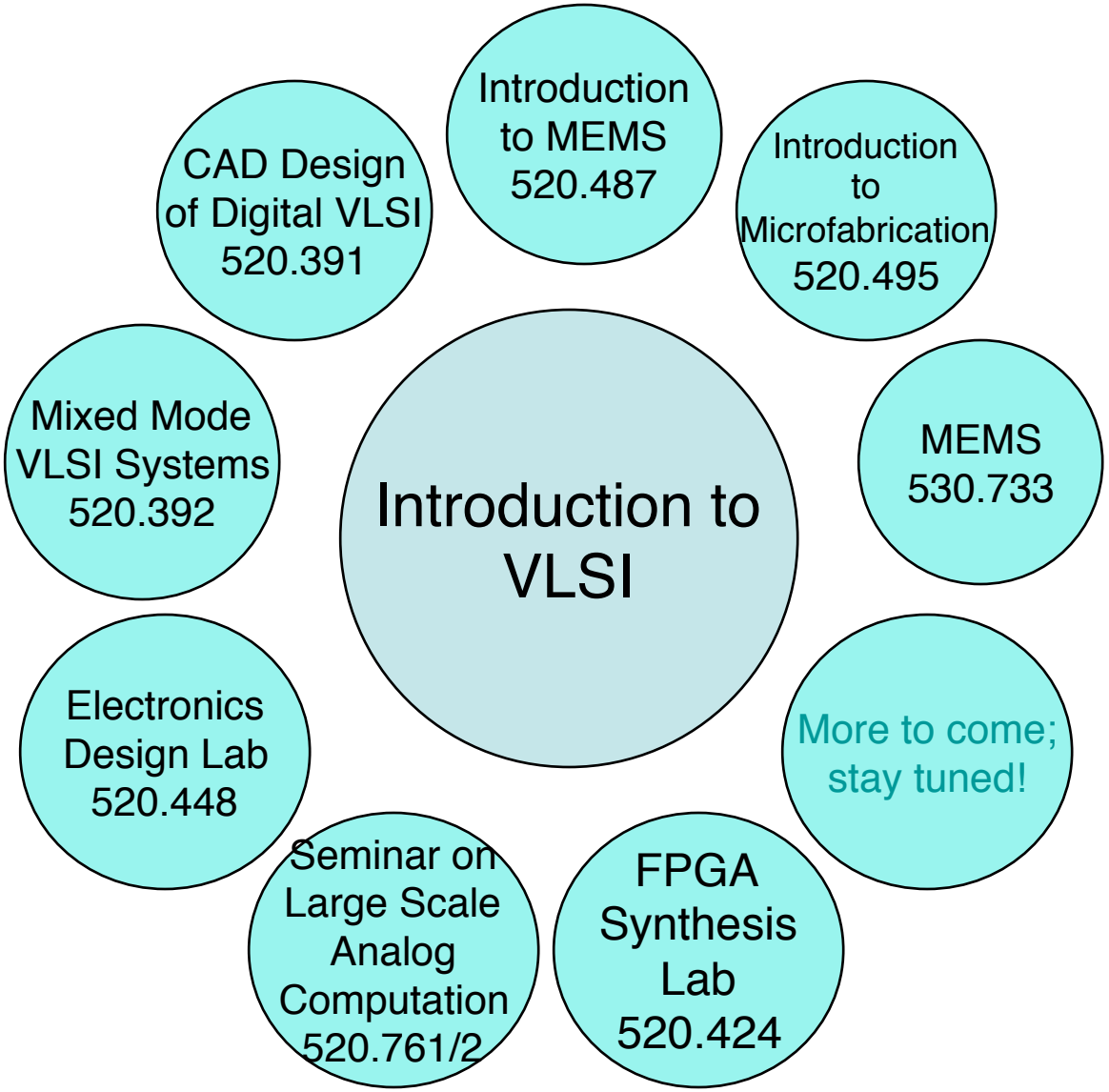
TABLE V: a)Border recognition b)Median Filter c)Dilation

Parameter	Value
Technology	130nm
Die Size	2x2.5mm^2
Cell Size	25x25 μm^2
Resolution	48×32
Photodiode Type	n+/p-Subtrate
Power Supply	1.5V

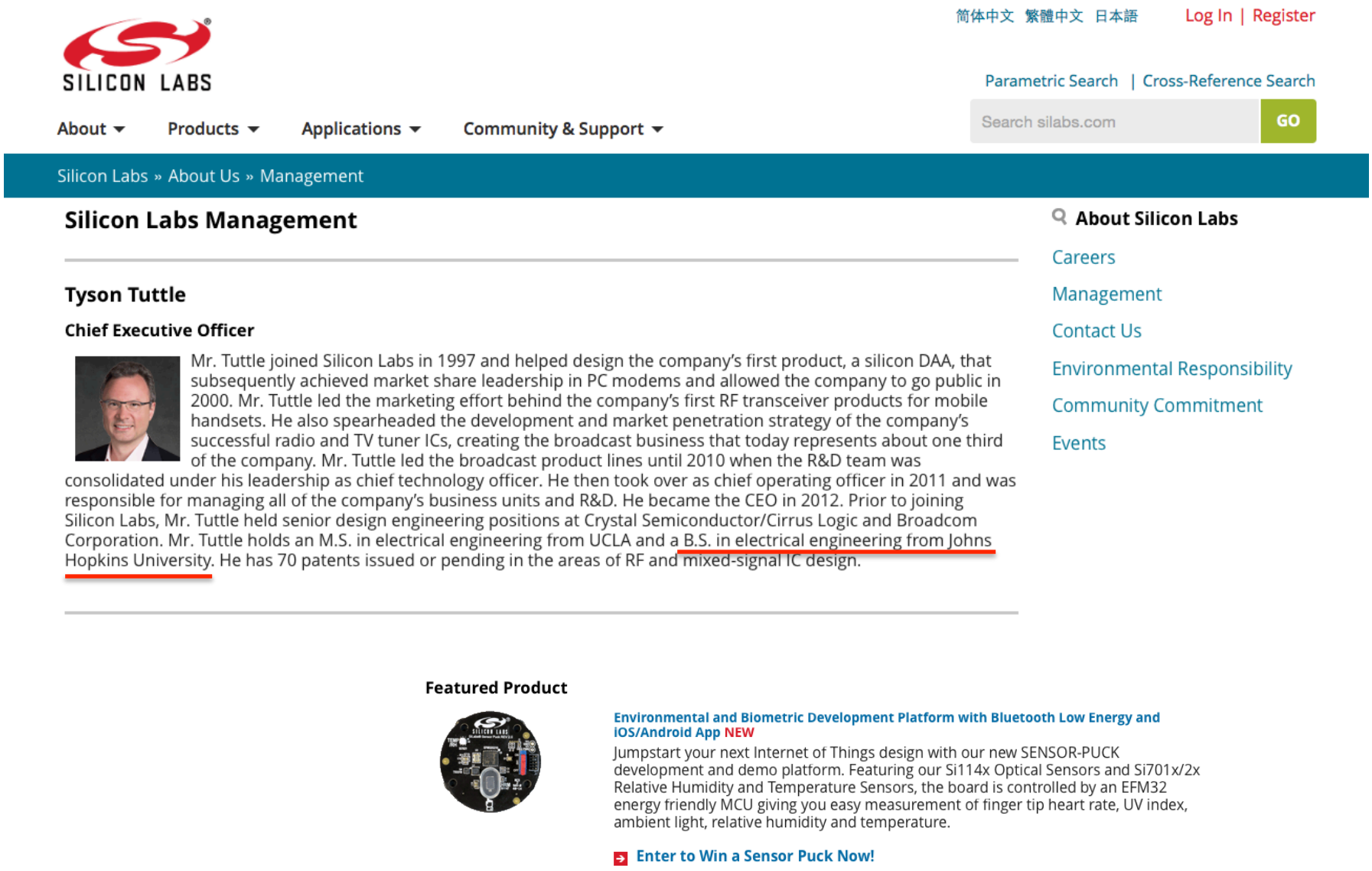
Example: Counting objects in an image, by using a bounding box and erosion without figure elimination.

```
%Capture Image
:BOUNDING
 LOAD FUNCTION_F(Bounding)
 LOAD FUNCTION_G(Zeros)
 Conf = "00000001" ;Border="0", Nei=+, FoG=OR
 CNNProcess(CNN, Conf)
 WAIT until CNNProcess end
 LOAD Counter_on_U
IF image_X = image_U
 goto REDUCE
else
 LOAD Counter_on_X
 goto BOUNDING
end
:REDUCE
repeat 24
 LOAD FUNCTION_F(Point_Reduction)
 LOAD FUNCTION_G(Zeros)
 Conf = "00000001" ;Border="0", Nei=+, FoG=OR
 CNNProcess(CNN, Conf)
 WAIT until CNNProcess end
 LOAD Counter_on_X
end
%Count all the pixels
RST Integrator
for ind=0:47
 COL = ind
 INTEGRATE
end
SELBUSOUT (INTEGER)
```

520.216 and her friends



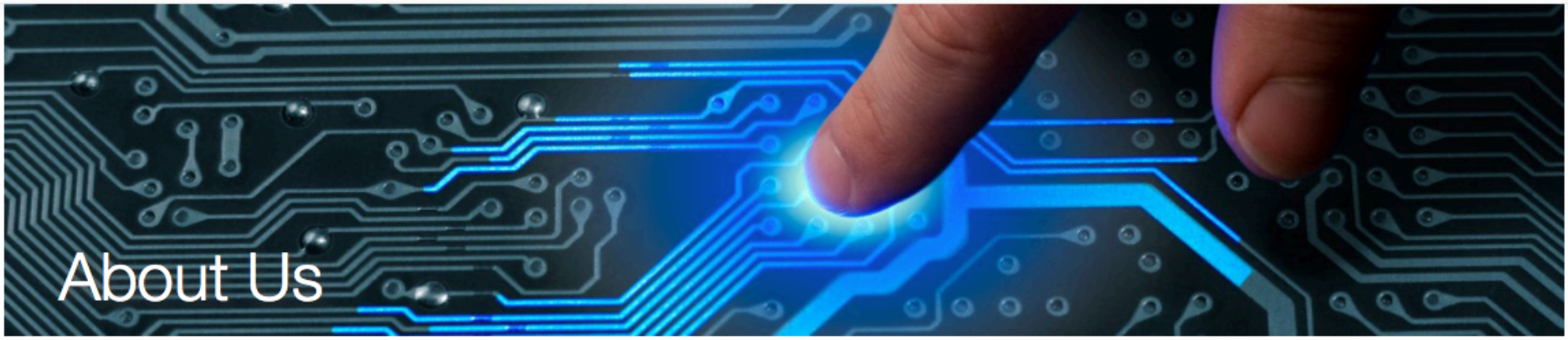
Life after Intro VLSI course (I)



Life after 520.216 (II)

analogix
Bring Vision to Life

Solutions Products Technologies About Us News & Media Search



Kewei Yang

Chairman and CEO

Throughout his career, Kewei Yang has focused on high-speed analog and mixed-signal design. Before co-founding Analogix, he was vice-president of engineering at Mindspeed, a division of Conexant, where he directed the company's development of high-speed transceivers and switch fabric ICs. He came to Conexant via its acquisition of HotRail, where he served as chief scientist. He also served as a lead designer at Rendition, a graphics chip company, and at Hewlett-Packard in the Computer Technology Lab.

Yang has a B.S. degree in electrical engineering from Tsinghua University and an M.S. degree in electrical engineering and Ph.D. from Johns Hopkins University.

Life after intro VLSI (III)

This could be you!

CEO of Johns Hopkins on the Chip

Johns Hopkins on the chip: microsystems and cognitive machines for sustainable, affordable, personalised medicine and healthcare

A.G. Andreou

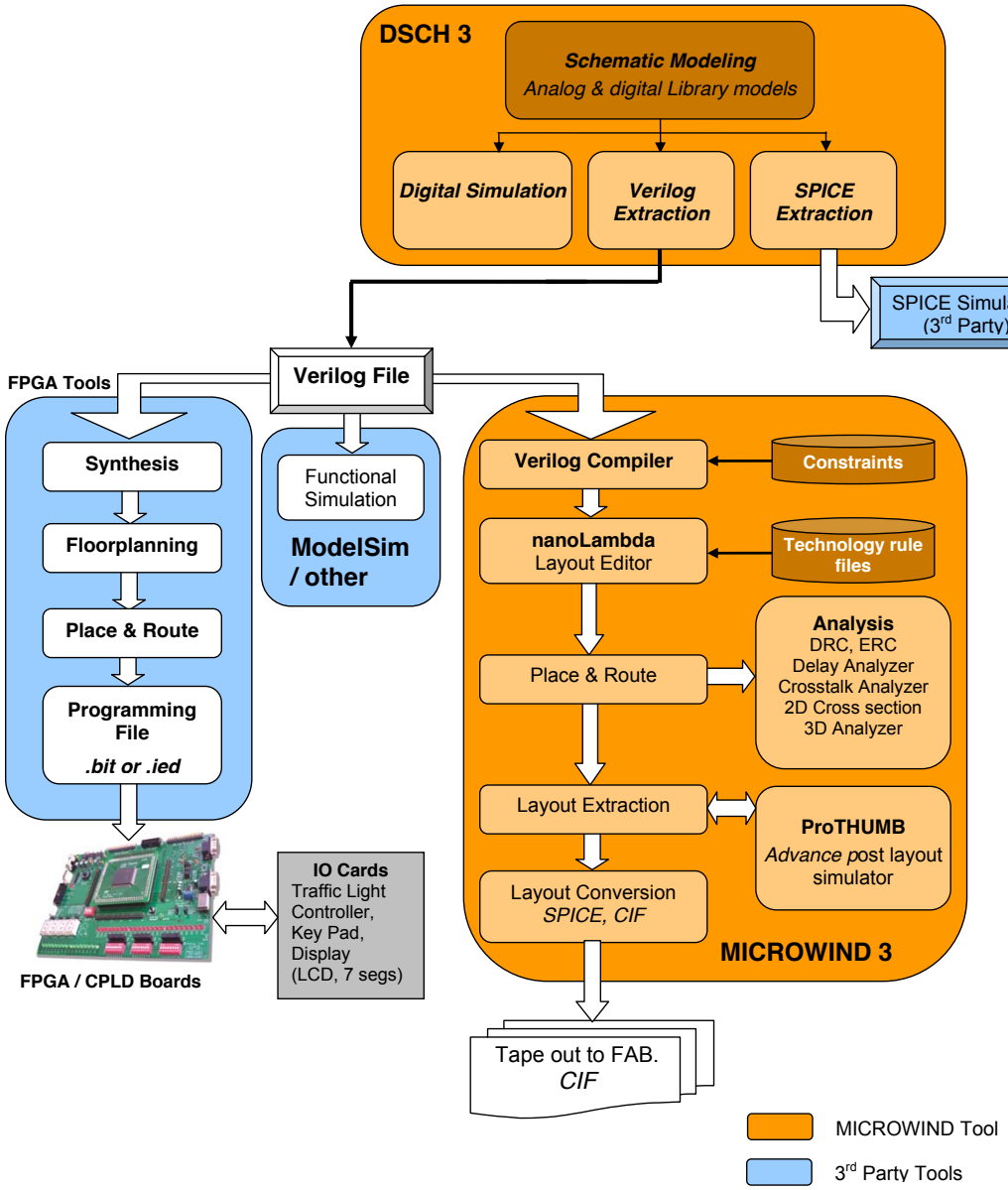
Semiconductor technology is contributing to the advancement of bio-technology, medicine and healthcare delivery in ways that it was never envisioned – from chip micro-arrays, to scientific grade CMOS imagers and ion sensing arrays to implantable prosthesis. This exponential growth of sensory microsystems has led to an exponential growth of data. Cognitive machines, i.e. advanced computer architectures and algorithms, are carefully co-designed to extract knowledge from such health data making rational decisions and recommendations for therapies. Nano, micro and macro robotics driven by sophisticated algorithms interface to the human body at different levels and scales, from nano-scale molecules to micron-scale cells to networks and all the way to the scale of organisms. The present era is one where semiconductor technology and the 'chip' is the foundation of sustainable and affordable personalised medicine and healthcare delivery.

Class Objectives

520.216 will teach you you how to go from a simple idea to a system, a CMOS camera chip. You will do analysis, design and finally layout and simulation and fabricate your own chip!

Emphasis is in physical design principles.

Computer Aided Design Tools



http://www.microwind.net