Future of Computing and What Do We Do When We Get There?

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Moore's Law Origins

April 19, 1965

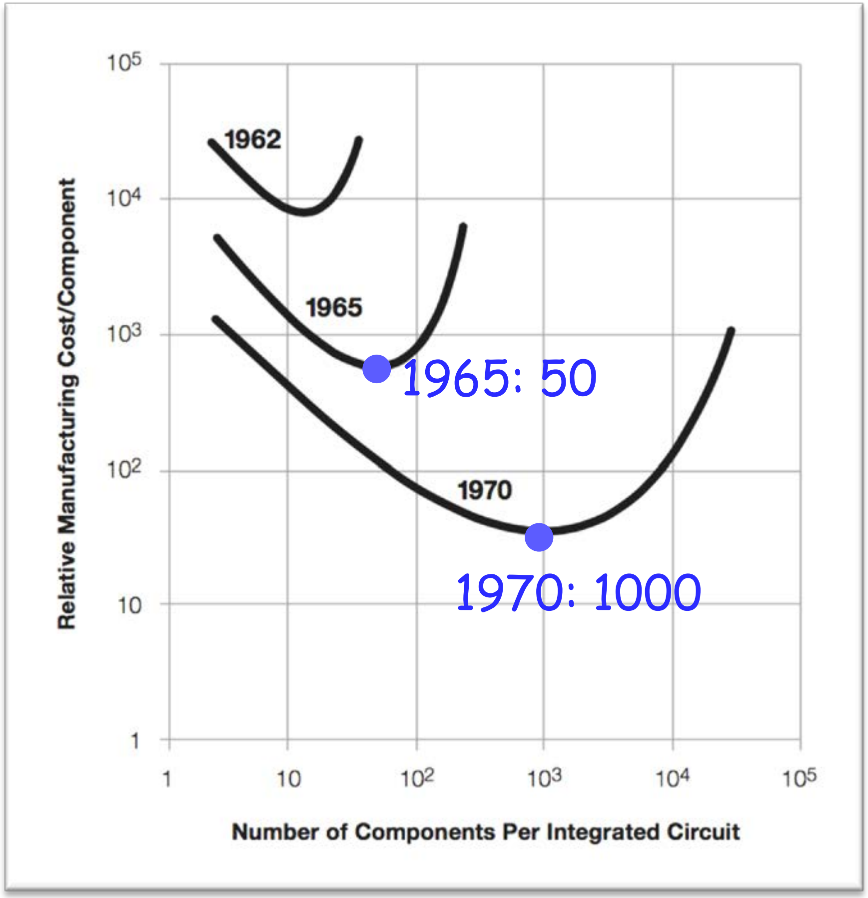
Cramming more components onto integrated circuits

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

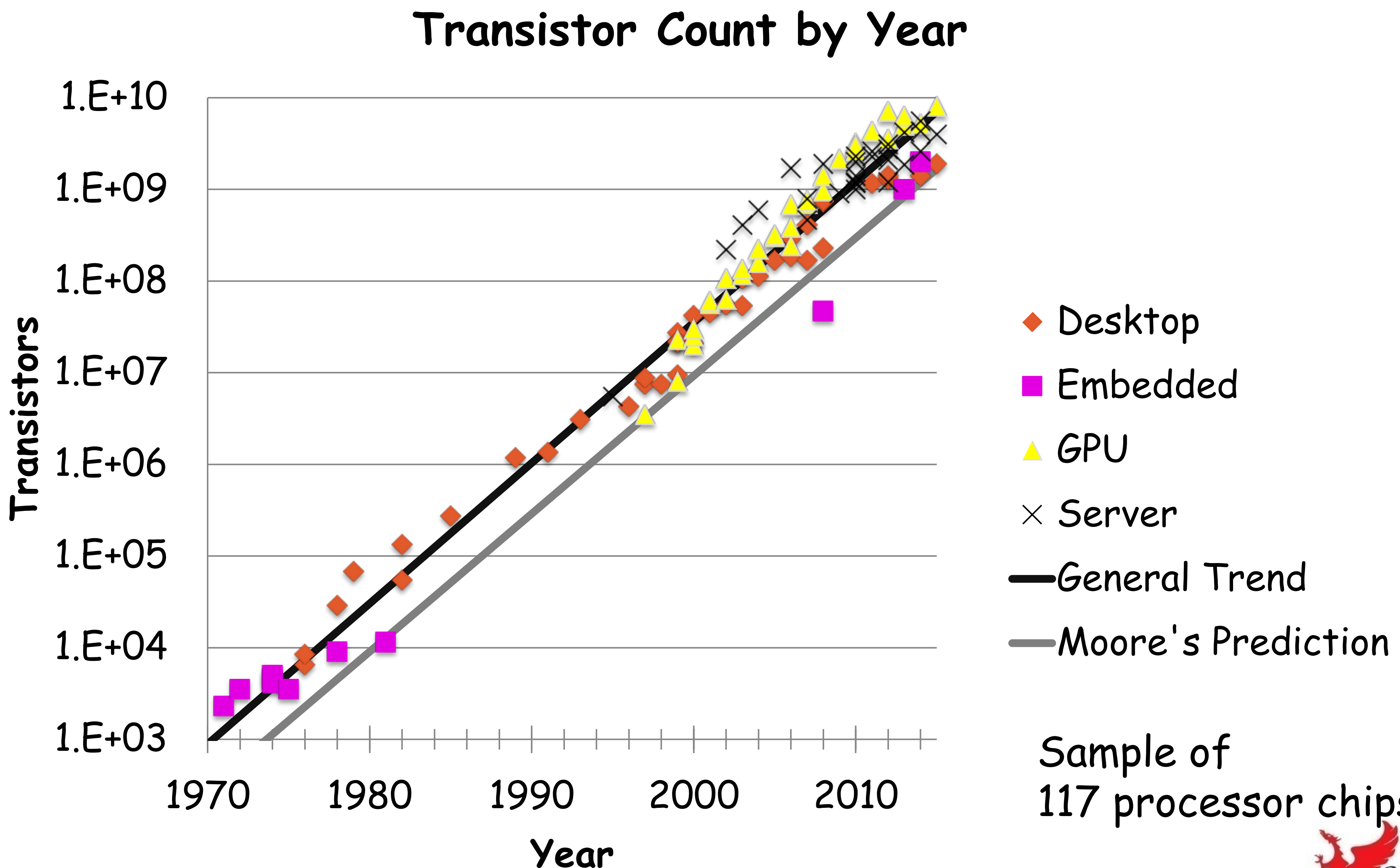
Director, Research and Development Laboratories, Fairchild Semiconductor division of Fairchild Camera and Instrument Corp.

Moore's Law Origins



- Moore's Thesis
  - Minimize price per device
  - Optimum number of devices / chip increasing 2x / year
- Later
  - 2x / 2 years
  - "Moore's Prediction"

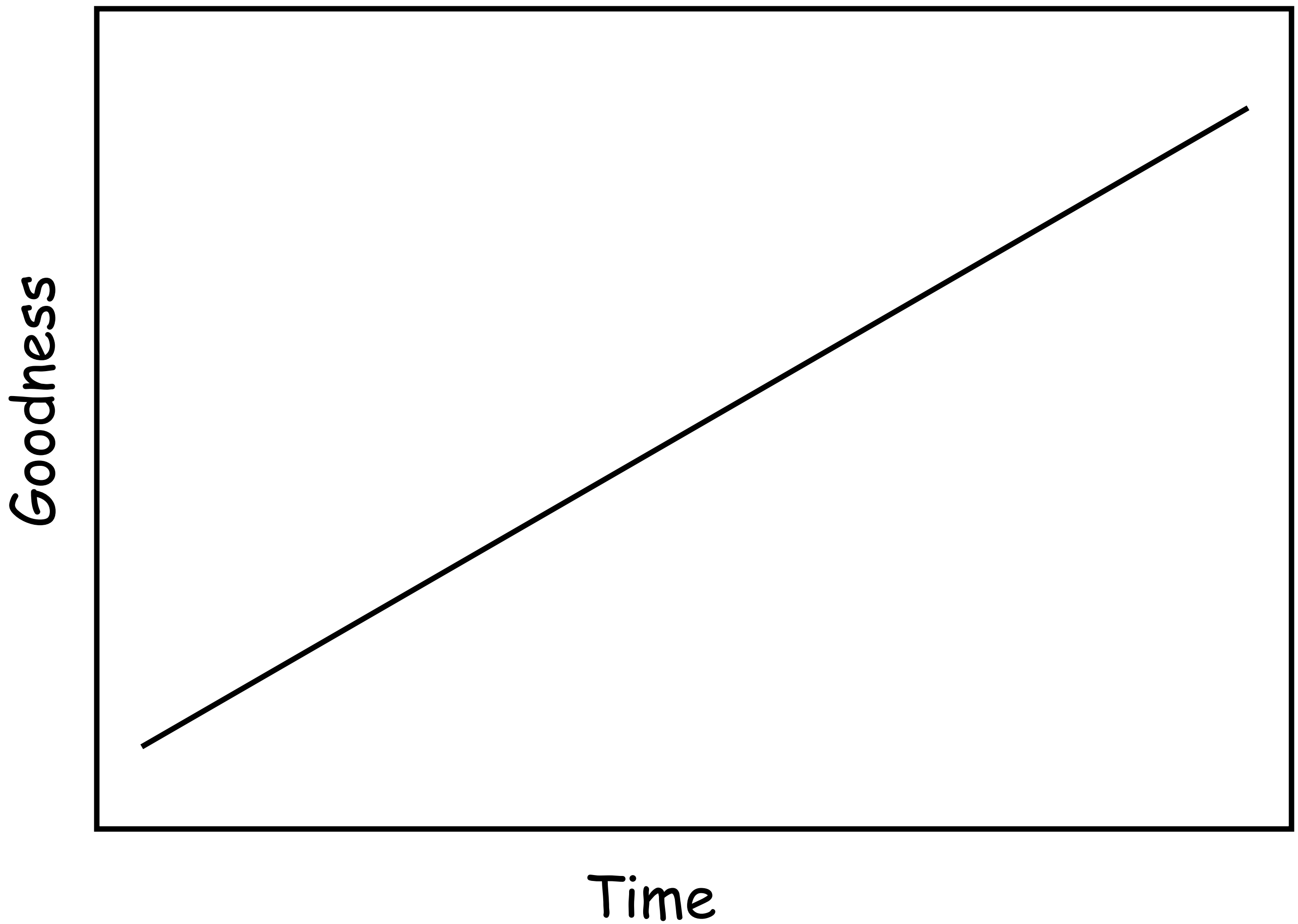
Moore's Law: 50 Years



Sample of
117 processor chips

© Bryant

Moore's Law



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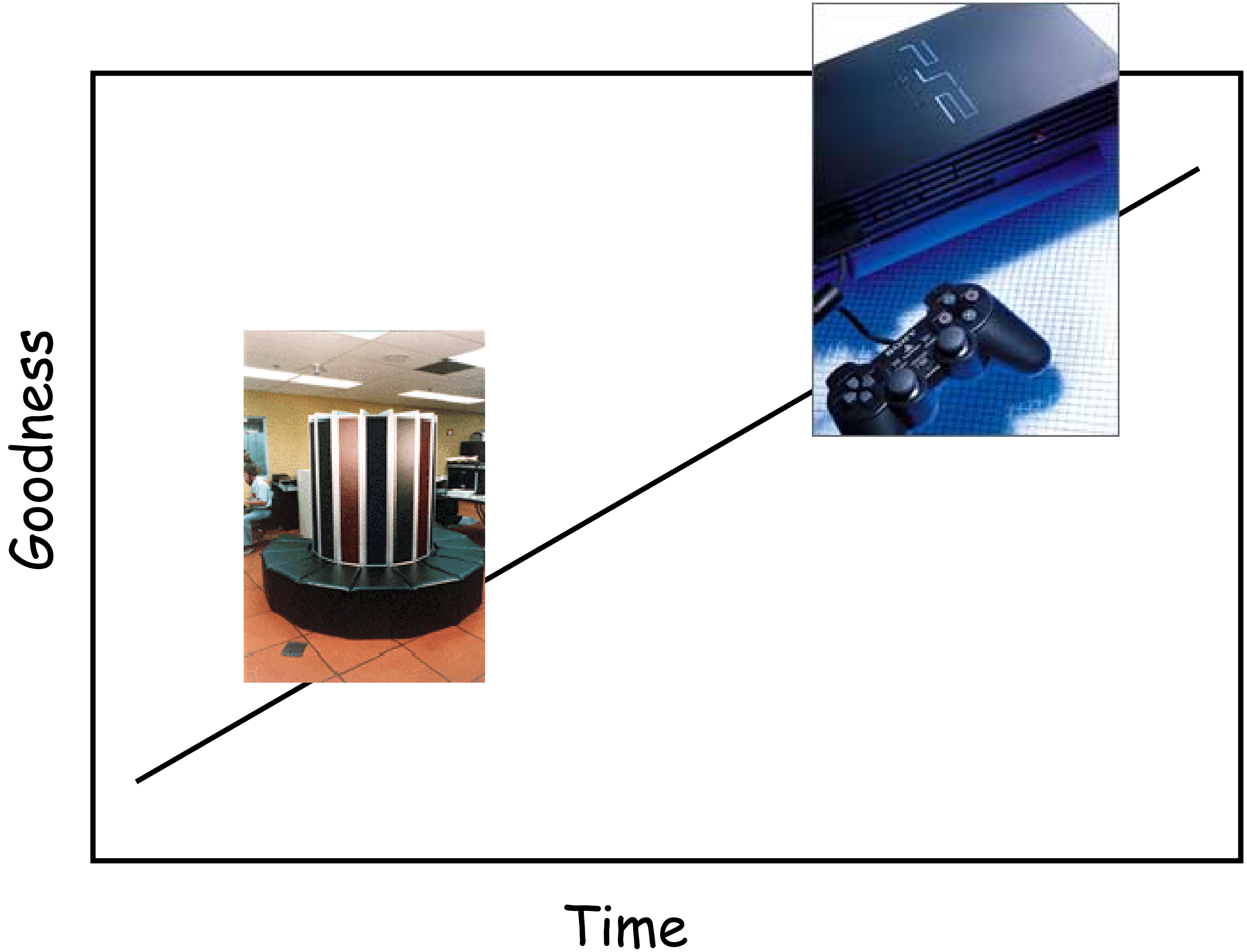
Moore's Law



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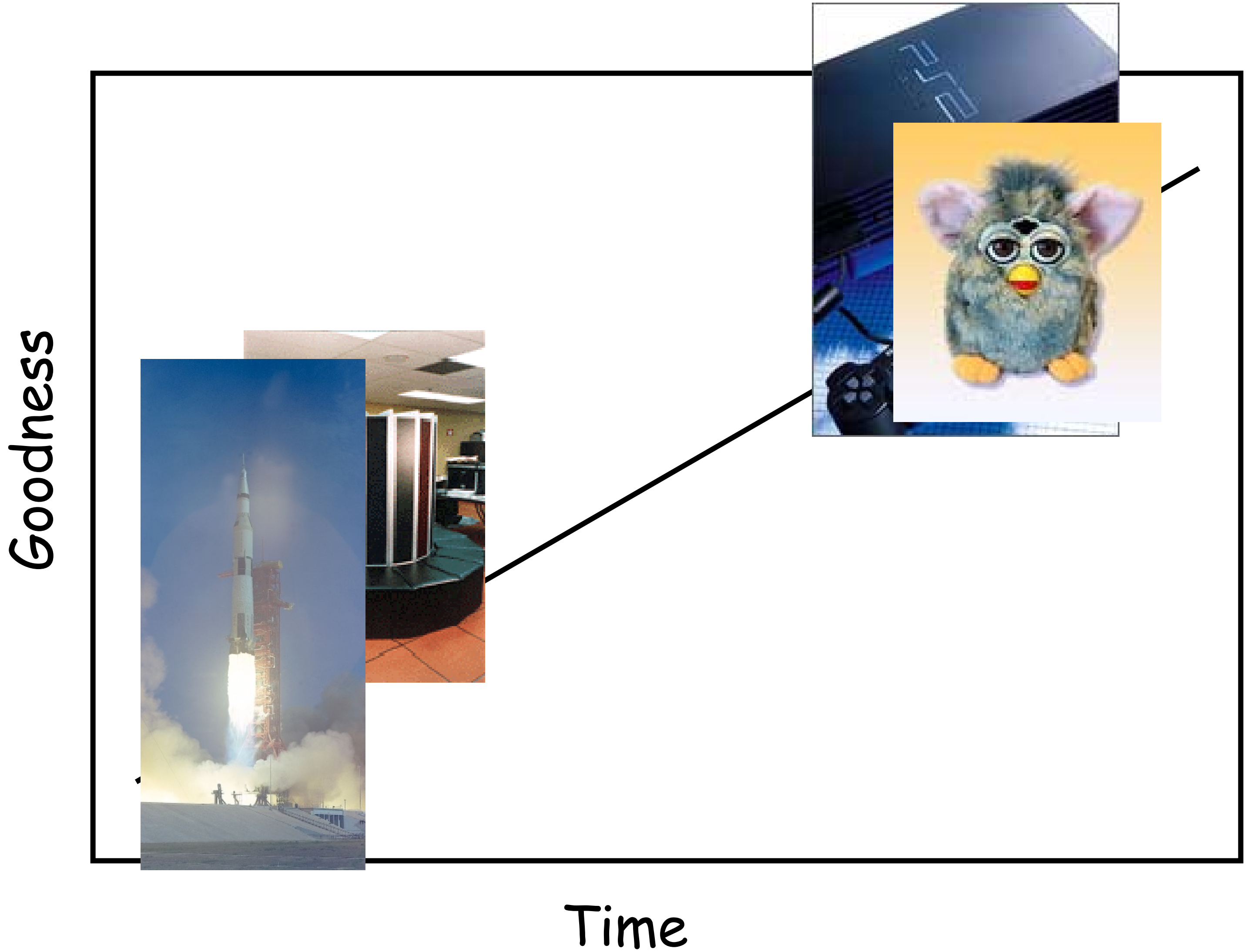
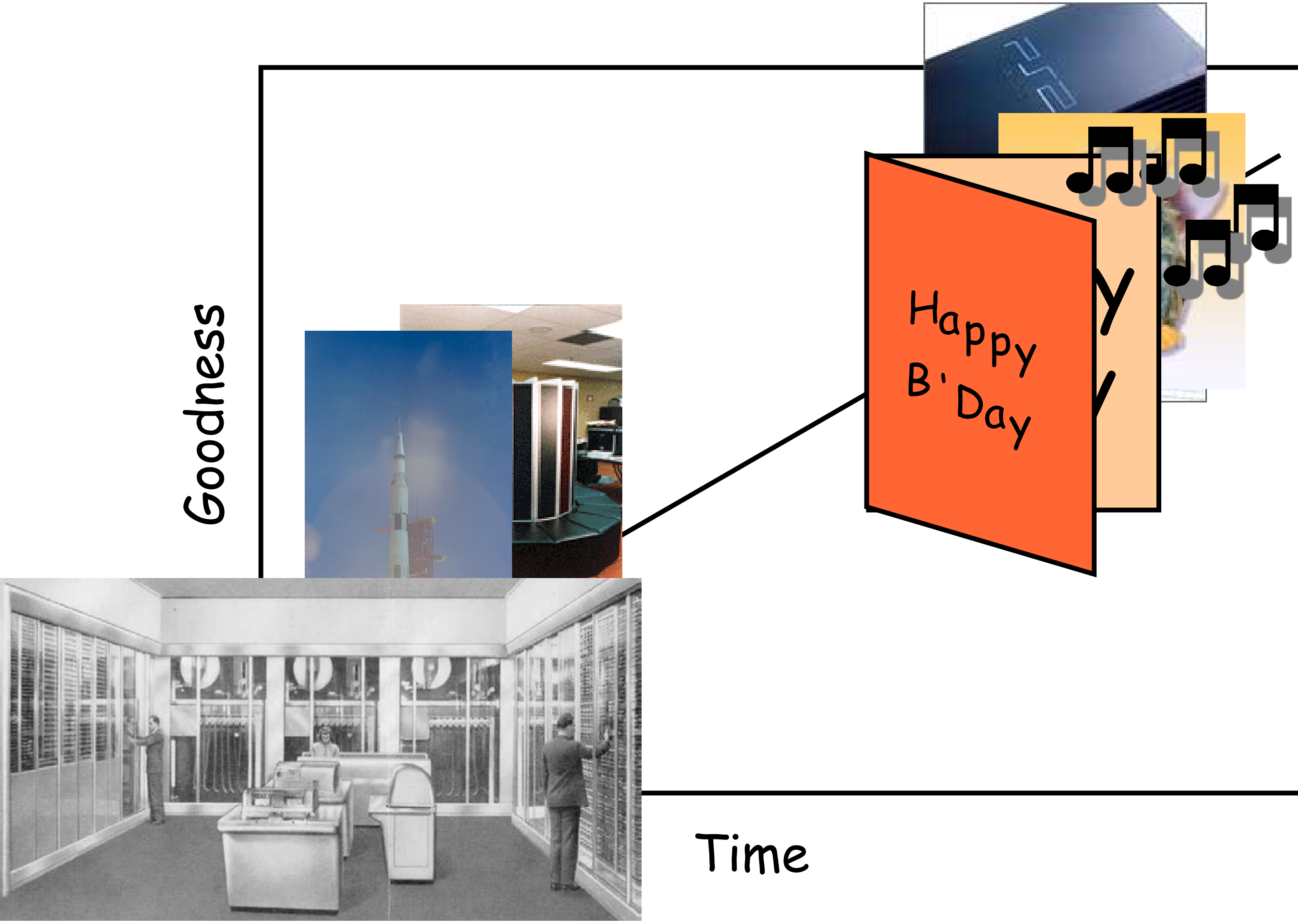
Moore's Law

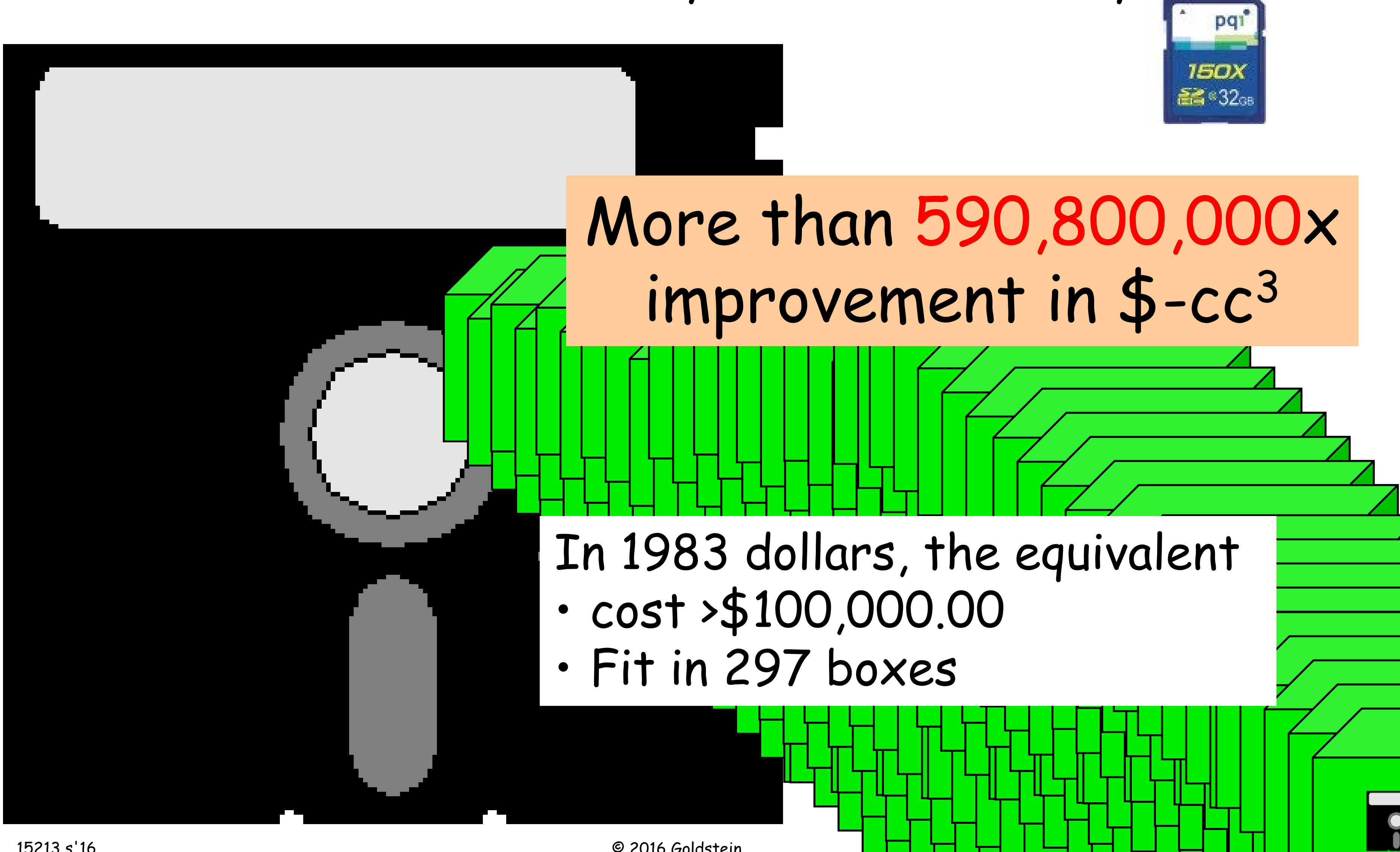


Moore's Law



More on Moore's Law

You can buy this for $10 today.



More than 590,800,000x improvement in \$-cc^3

In 1983 dollars, the equivalent
- cost >$100,000.00
- Fit in 297 boxes

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Eniac → PS/4

- How much would enough Eniac's weigh to equal 2.8Kg of PS/4 computing?

=

?

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Eniac → PS/4

- How much woul gh Eniac's weigh to equal 2.8Kg c 4 comp g?

Alternatively, **more** than all the buildings in Pittsburgh!

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Eniac → PS/4

- From 1946 to 2014

	Eniac	PS/4	Improvement
Ops/sec	5×10^3	2×10^{10}	10^6
Cos			
Pow			
Vol			
Weight	2.7×10^5 Kg	2.8 Kg	10^5

An improvement of
10^{24} ops/sec-\$-Kg-m^3-W

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Understanding Exponentials

- Key to future forcasting
- Very Very hard for humans to do

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Understanding Exponentials

- Key to future forcasting
- Very Very hard for humans to do
- Example: Kasparov Vs. Deep Blue
  - 1989: Kasparov destroys deep blue
  - 1996: Deep Blue wins one game
  - 1997: Deep Blue wins tournament

Understanding Exponentials

- Key to future forcasting
- Very Very hard for humans to do
- Example: Kasparov Vs. Deep Blue
  - 1989: Kasparov destroys deep blue
  - 1996: Deep Blue wins one game
  - 1997: Deep Blue wins tournament
- Particularly hard in the beginning

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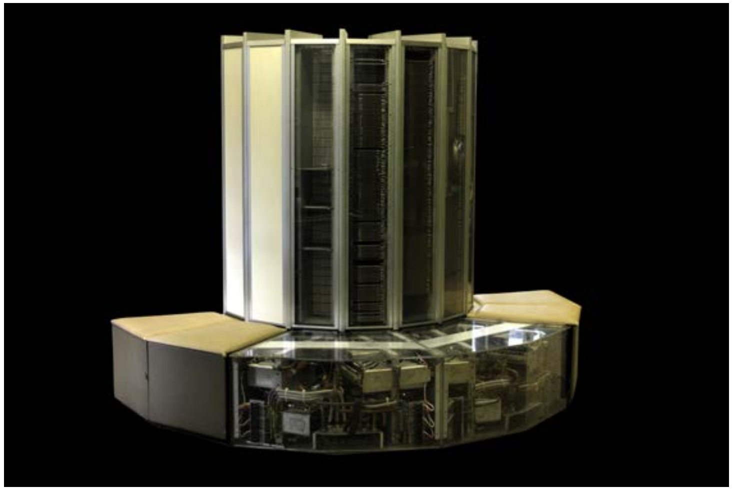
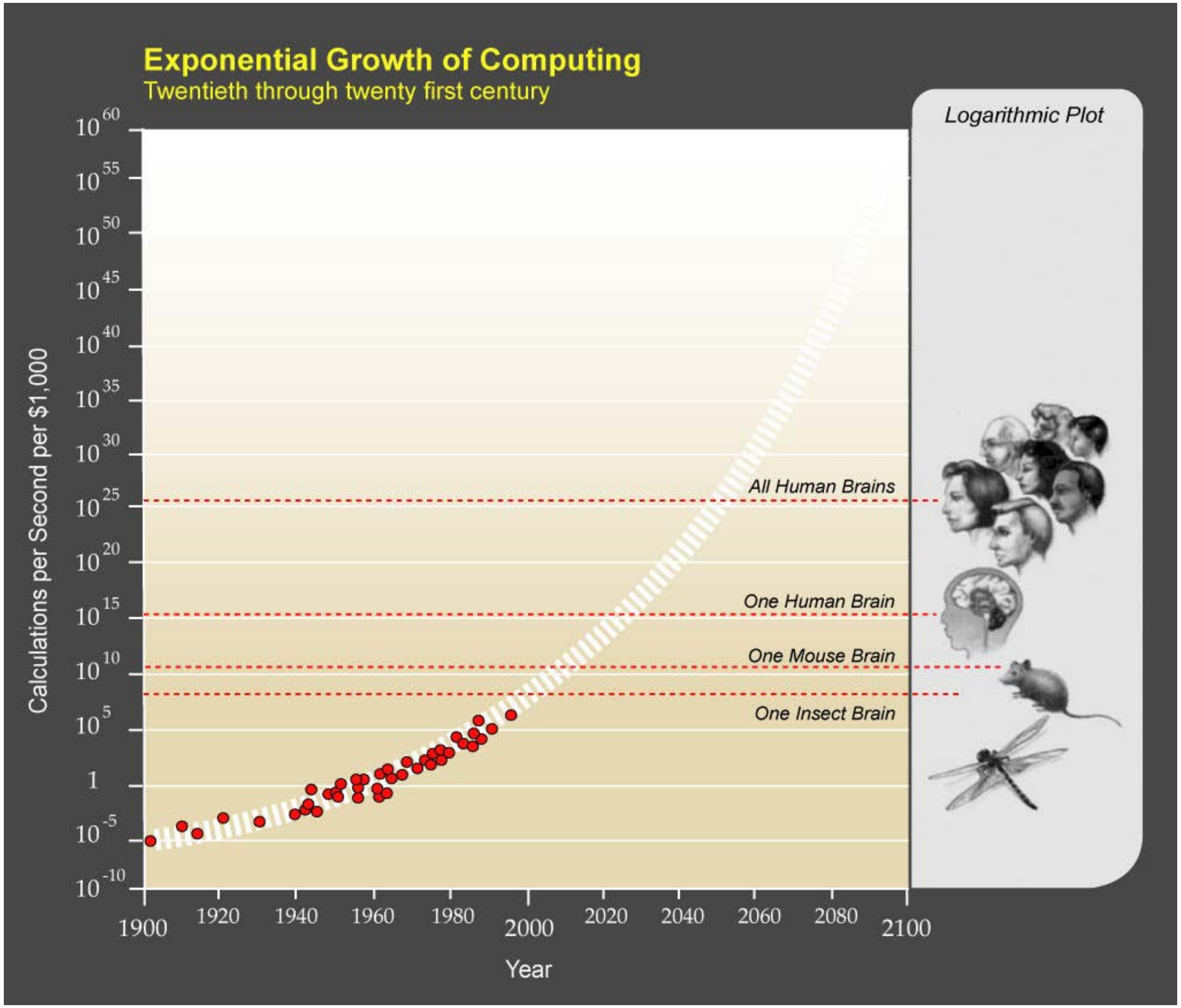
What Moore's Law Has Meant



- 1976 Cray 1
  - 250 M Ops/second
  - ~170,000 chips
  - 0.5B transistors
  - 5,000 kg, 115 KW
  - $9M
  - 80 manufactured
- 2014 iPhone 6
  - > 4 B Ops/second
  - ~10 chips
  - > 3B transistors
  - 120 g, < 5 W
  - $649
  - 10 million sold in first 3 days

What Moore's Law Could Mean



Kurzweil, *The Singularity is Near*, 2005

What Moore's Law Could Mean

- 2015 Consumer Product

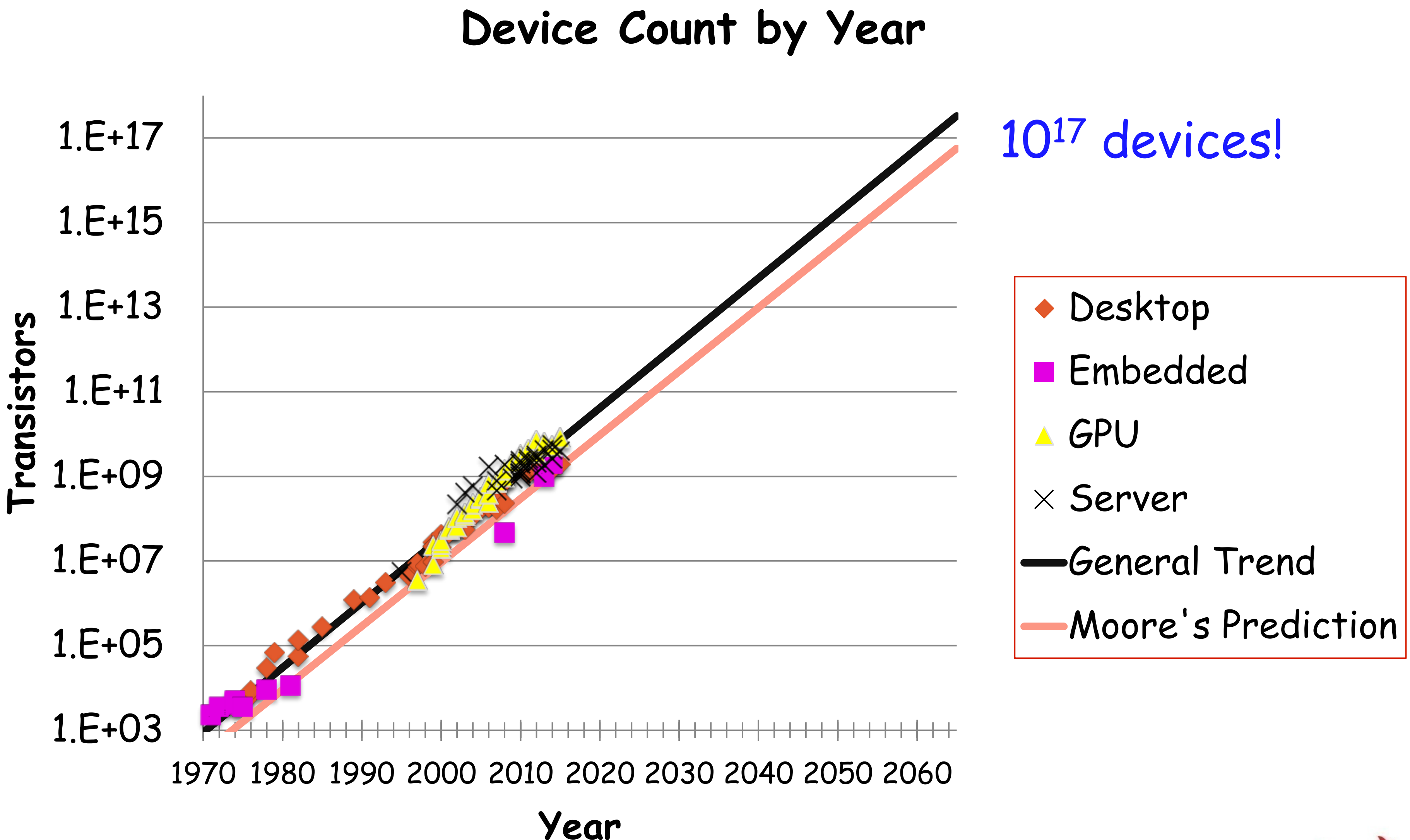
- 2065 Consumer Product

  - Portable
  - Low power
  - Will drive markets & innovation

Requirements for Future Technology

- Must be suitable for portable, low-power operation
  - Consumer products
  - Internet of Things components
  - Not cryogenic, not quantum
- Must be inexpensive to manufacture
  - Comparable to current semiconductor technology
    - $O(1)$ cost to make chip with $O(N)$ devices
- Need not be based on transistors
  - Memristors, carbon nanotubes, DNA transcription, ...
  - Possibly new models of computation
  - But, still want lots of devices in an integrated system

Moore's Law: 100 Years

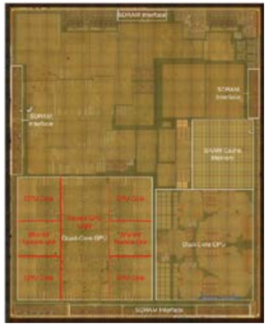


10^{17} devices!

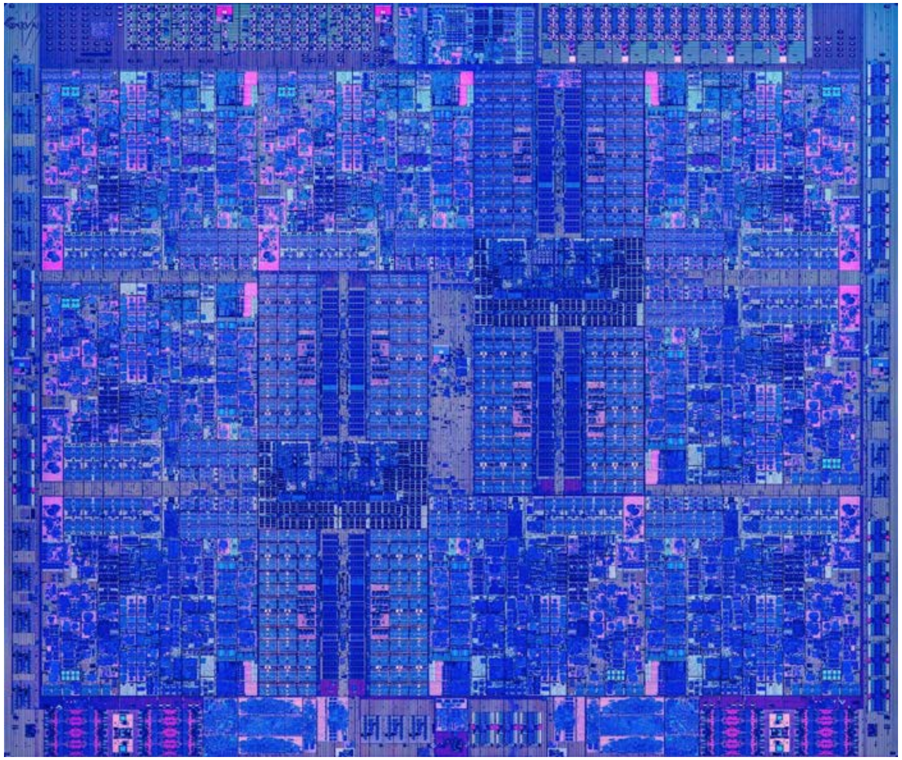
Chips Have Gotten Bigger

Intel 4004
1970
2,300 transistors
12 mm^2

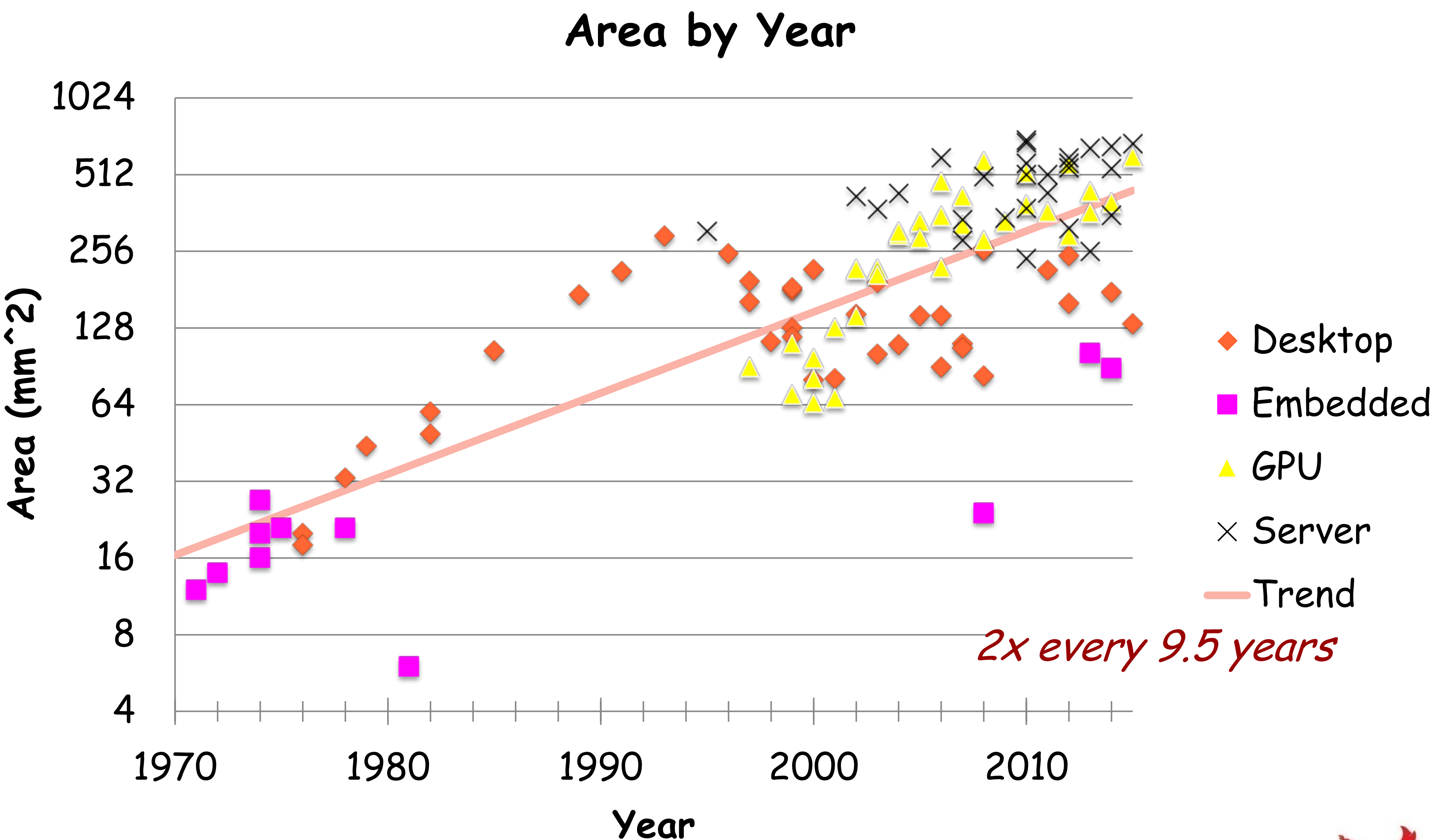
Apple A8
2014
2 B transistors
89 mm^2



IBM z13
205
4 B transistors
678 mm^2



Chip Size Trend



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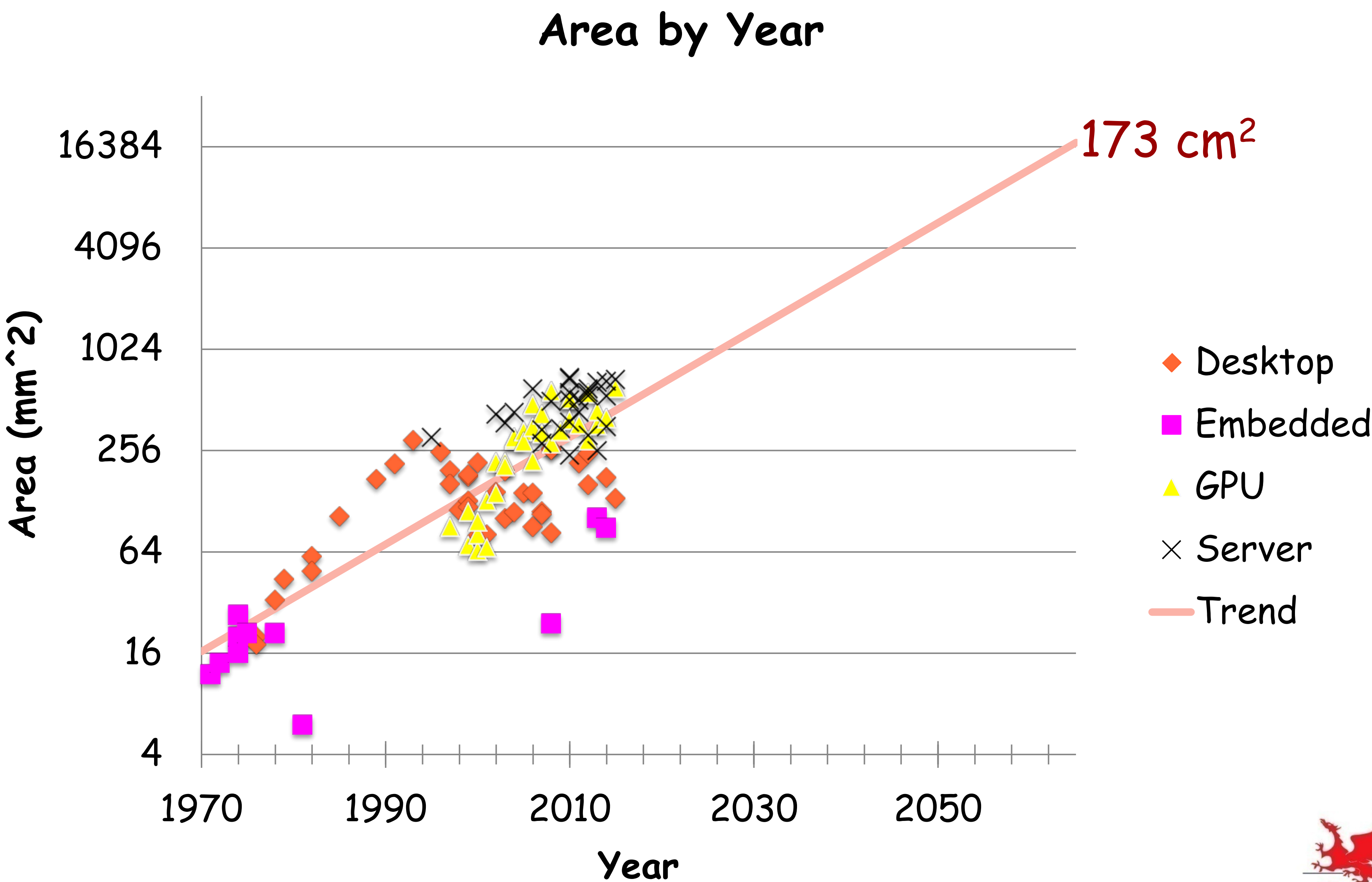
Chip Size Extrapolation



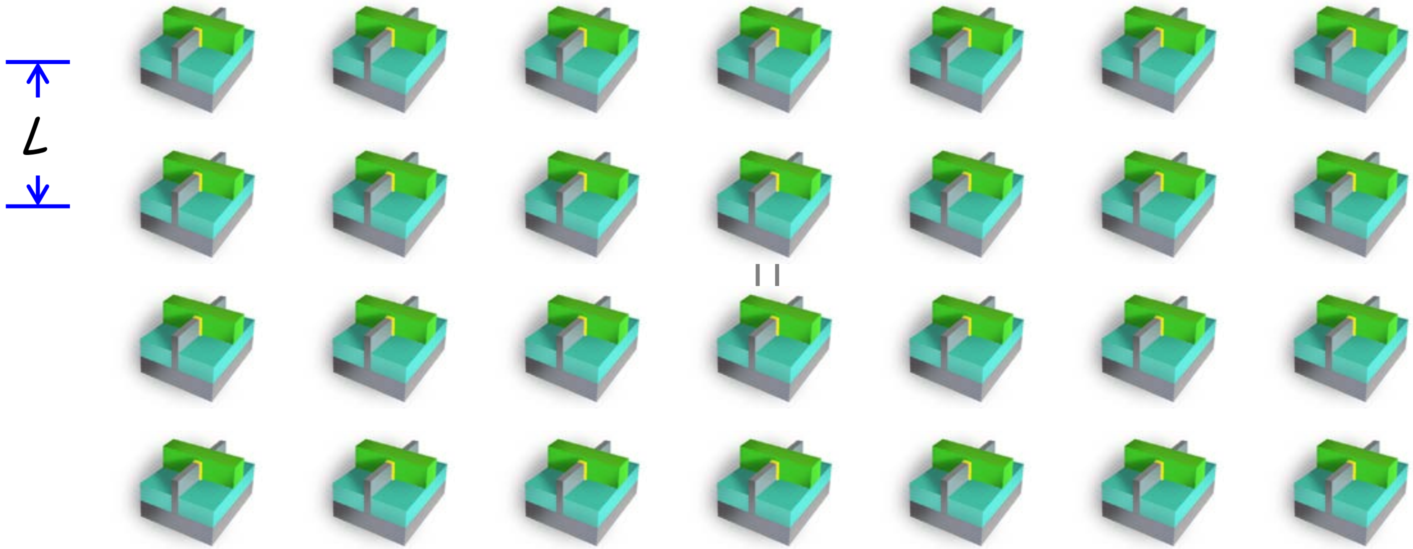
Extrapolation: The iPhone 31s

Apple A59
2065
10^{17} transistors
173 cm^2

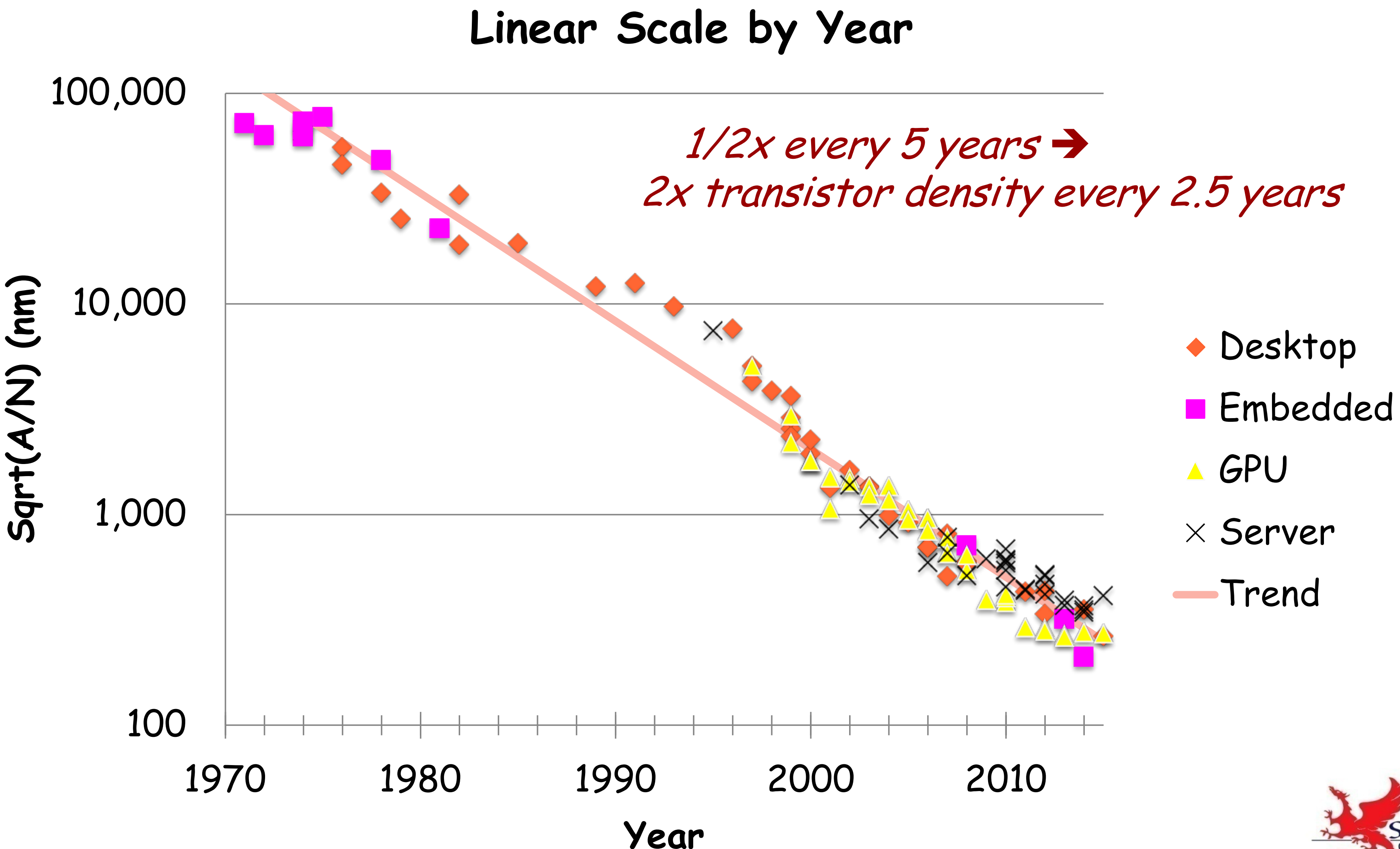
Transistors Have Gotten Smaller

- Area A
- N devices
- Linear Scale L

$$L = \sqrt{A / N}$$



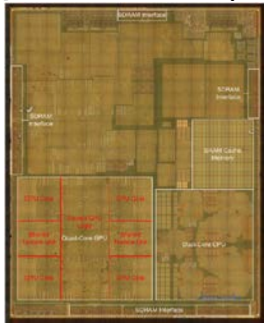
Linear Scaling Trend



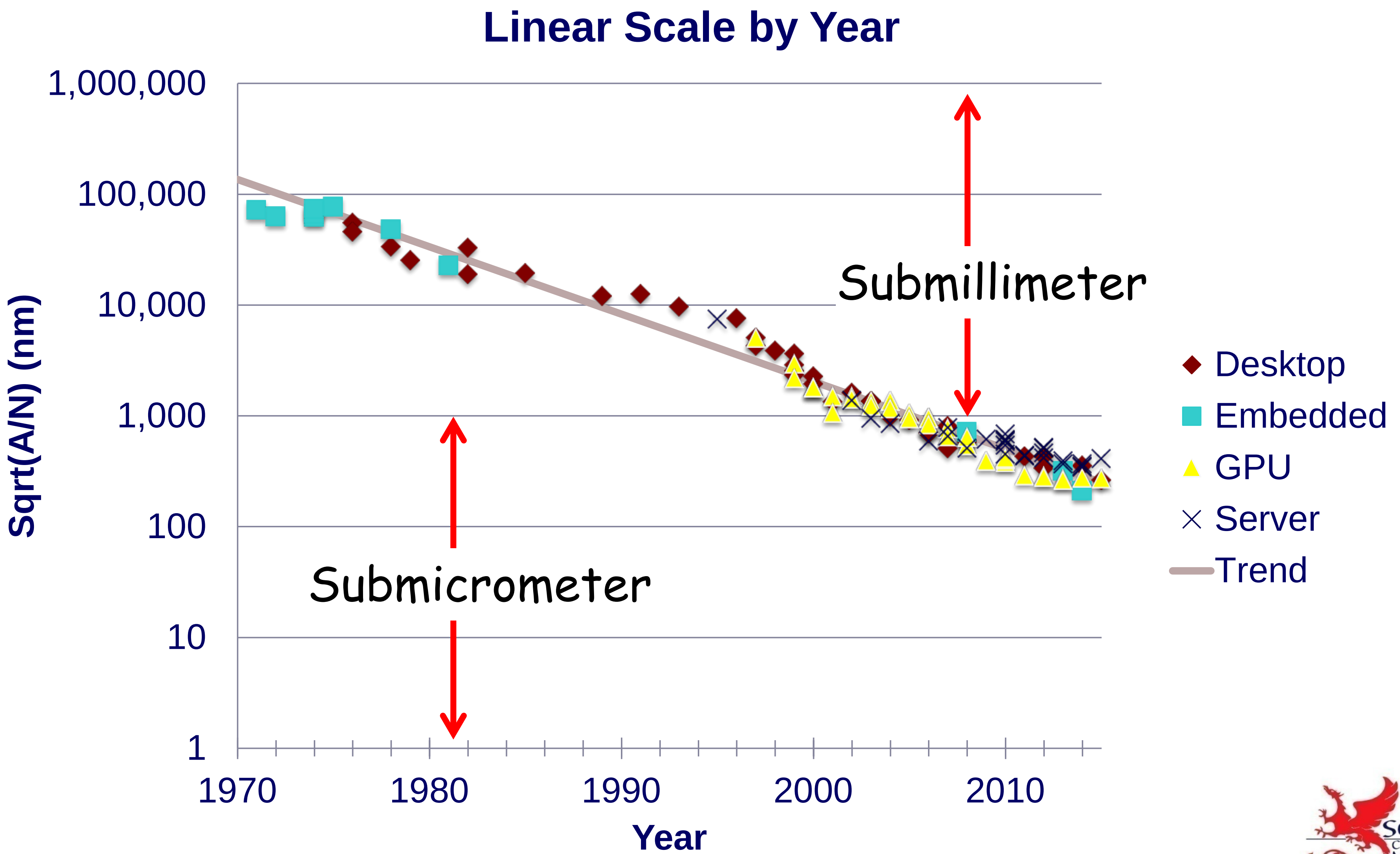
Decreasing Feature Sizes

Intel 4004
1970
2,300 transistors
L = 72,000 nm

Apple A8
2014
2 B transistors
L = 211 nm



Linear Scaling Trend

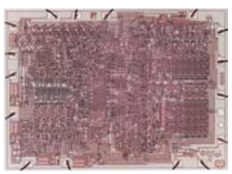


Submillimeter Dimensions

10^{-3} 1 millimeter (mm)

500µm: Length of amoeba

10^{-4}



72µm: Intel 4004 linear scale

50µm: Average size of cell in human body

10^{-5}

10µm: Thickness of sheet of plastic food wrap

5µm: Spider silk thickness

2µm: E coli bacterium length

10^{-6} 1 micrometer (µm)

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Submicrometer Dimensions

10^{-6} 1 micrometer (µm)

400-700nm: Visible light wavelengths

211nm: Apple A8 linear scale

10^{-7}

30nm: Minimum cooking oil smoke particle diameter

10^{-8}

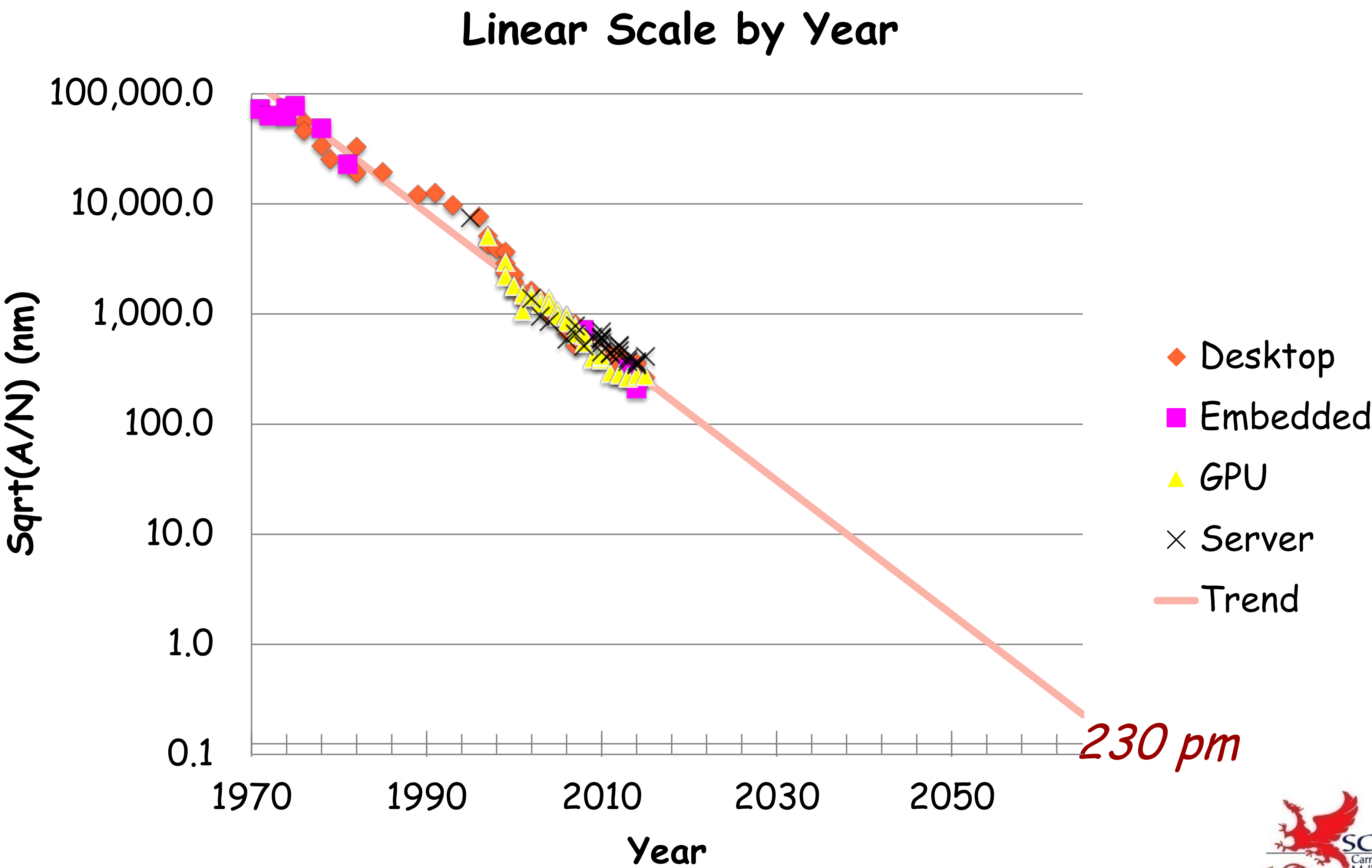
9nm: Cell membrane thickness

2nm: DNA helix diameter

10^{-9} 1 nanometer (nm)

1nm: Carbon nanotube diameter

Linear Scaling Extrapolation

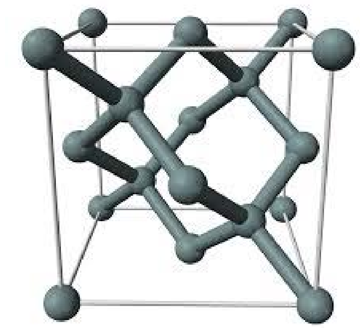


Subnanometer Dimensions

10^{-9} 1 nanometer (nm)

1nm: Carbon nanotube diameter

543pm: Silicon crystal lattice spacing

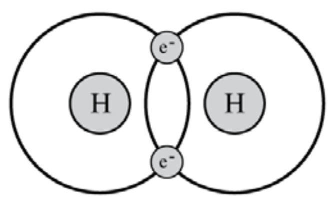


230pm: 2065 linear scale projection

10^{-10}

74pm: Spacing between atoms in hydrogen molecule

53pm: Electron-proton spacing in hydrogen (Bohr radius)



10^{-11}

2.4pm: Electron wavelength (Compton wavelength)

10^{-12} 1 picometer (pm)

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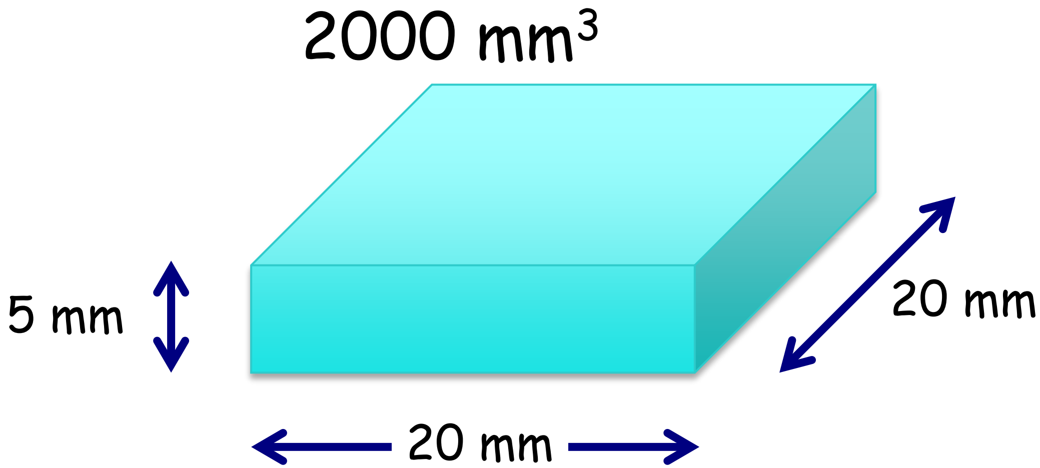
Reaching 2065 Goal

- Target
  - 10^{17} devices
  - 400 mm^2
  - L = 63 pm

Is this possible?

Not with today's tech!

Fabricating in 3 Dimensions



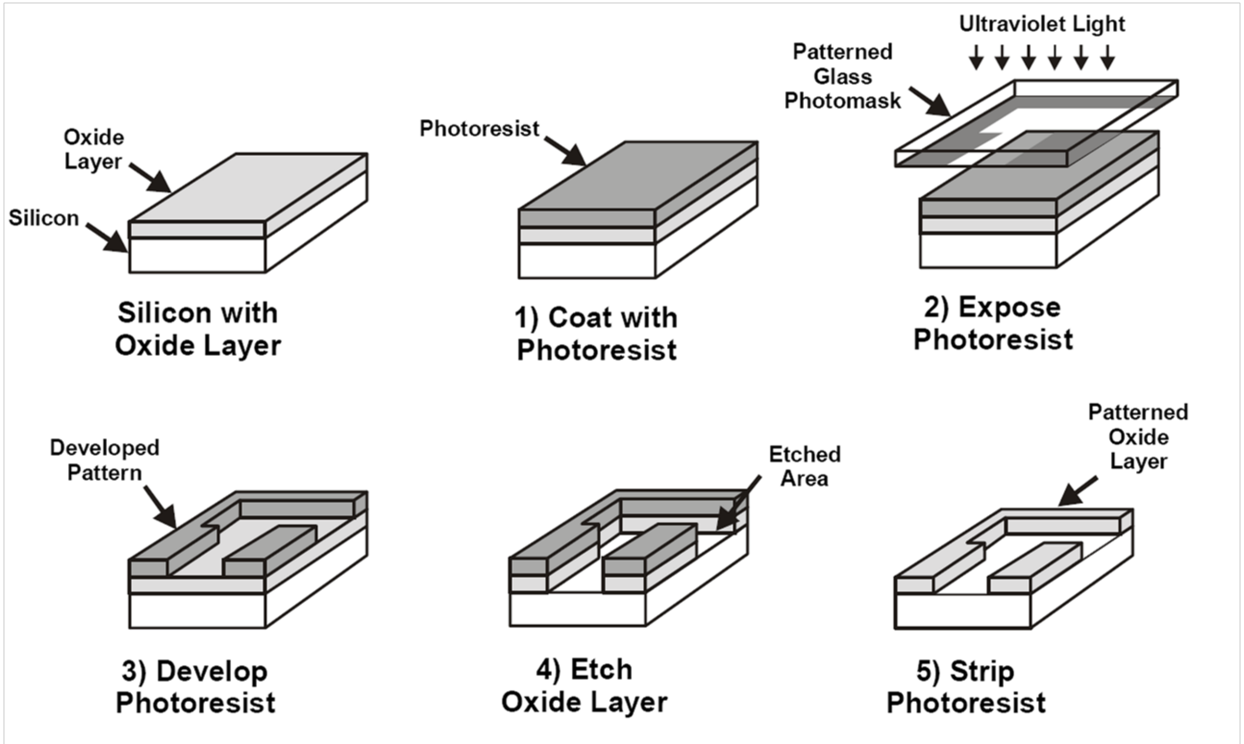
- Parameters
  - 10^{17} devices
  - 100,000 logical layers
    - Each 50 nm thick
    - ~1,000,000 physical layers
      - To provide wiring and isolation
  - L = 20 nm
    - 10x smaller than today

2065 mm^3

3D Fabrication Challenges

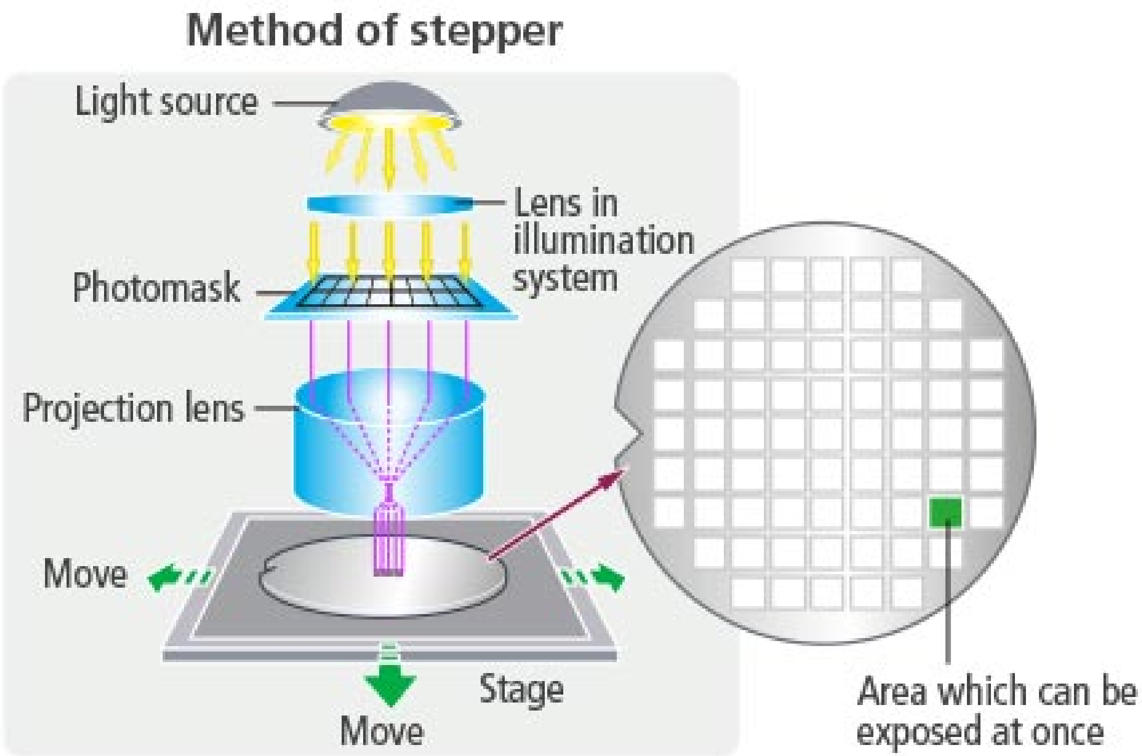
- Yield
  - How to avoid or tolerate flaws
- Cost
  - High cost of lithography
- Power
  - Keep power consumption within acceptable limits
  - Limited energy available
  - Limited ability to dissipate heat

Photolithography



- Pattern entire chip in one step
- Modern chips require ~60 lithography steps
- Fabricate *N* transistor system with O(1) steps

Fabrication Costs



- Stepper
  - Most expensive equipment in fabrication facility
  - Rate limiting process step
    - 18s / wafer
  - Expose 858 mm^2 per step
    - 1.2% of chip area

Fabrication Economics

- Currently
  - Fixed number of lithography steps
  - Manufacturing cost \$10–\$20 / chip
    - Including amortization of facility
- Fabricating 1,000,000 physical layers
  - Cannot do lithography on every step
- Options
  - Chemical self assembly
    - Devices generate themselves via chemical processes
  - Pattern multiple layers at once

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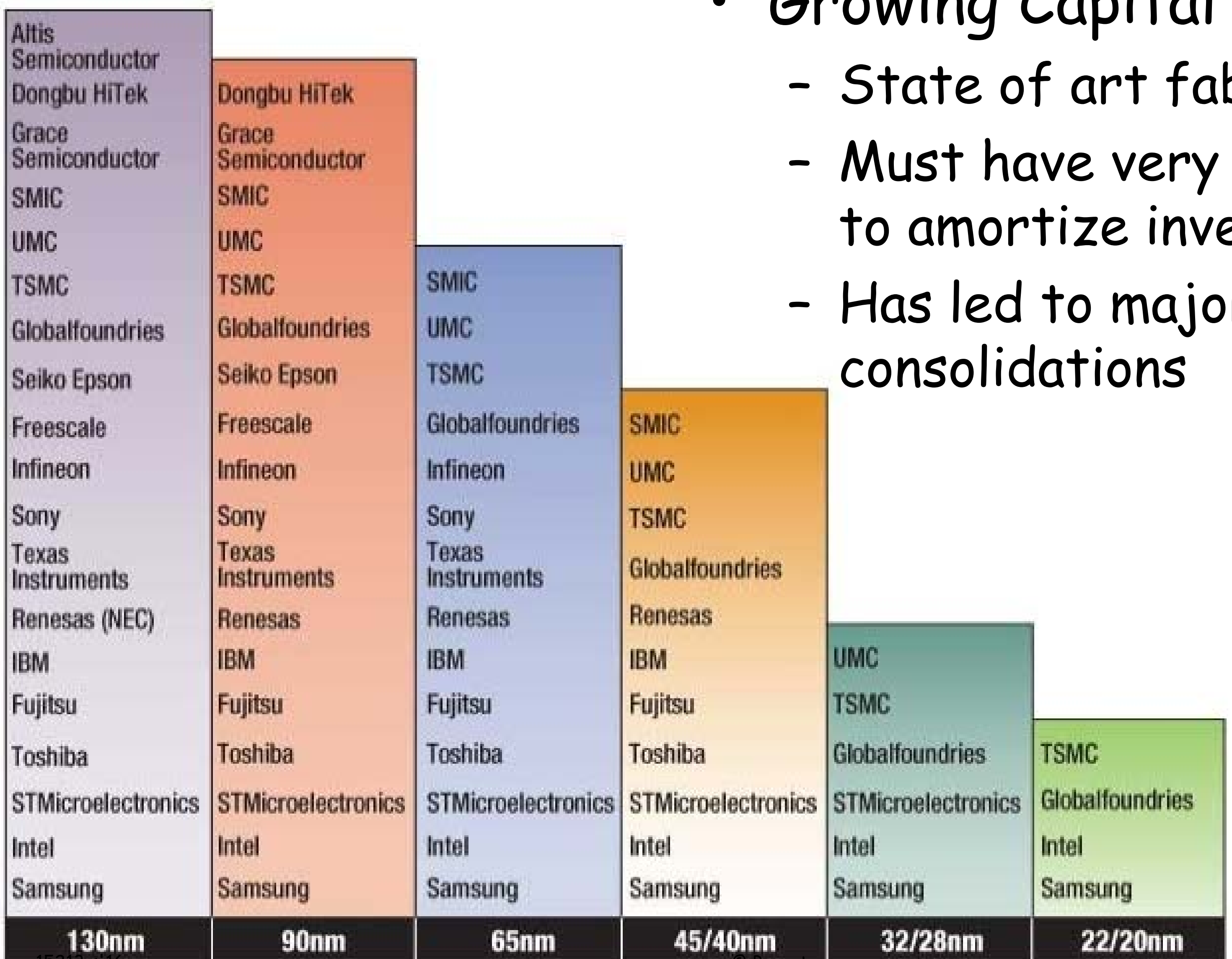
Meeting Power Constraints

- 2 B transistors
- 2 GHz operation
- 1—5 W

Can we increase number of devices by 500,000x without increasing power requirement?

- 64 B neurons
- 100 Hz operation
- 15—25 W
  - Liquid cooling
  - Up to 25% body's total energy consumption

Challenges to Moore's Law: Economic



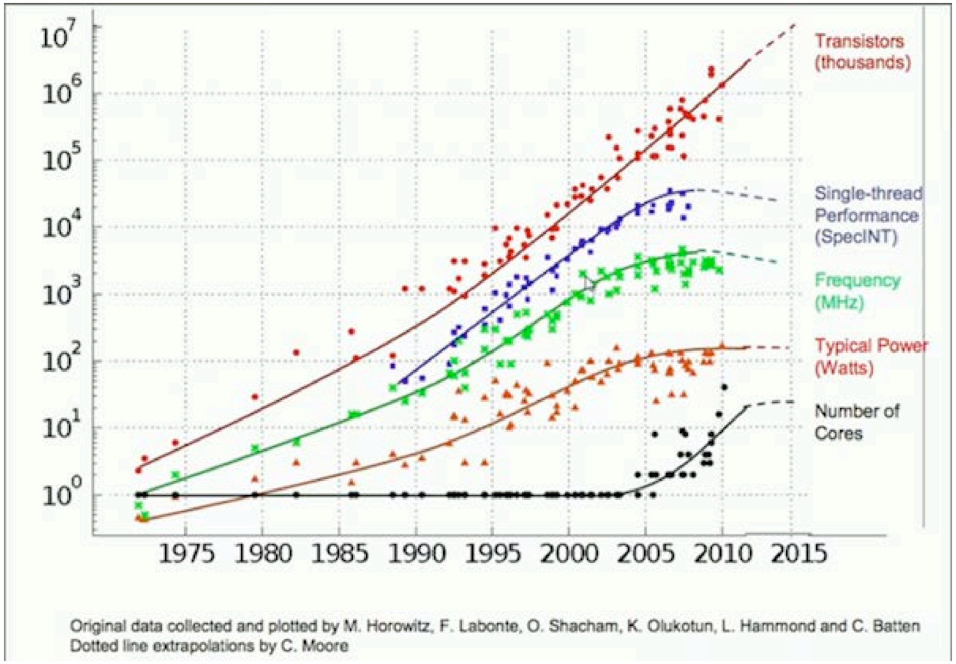
- Growing Capital Costs
  - State of art fab line ~$20B
  - Must have very high volumes to amortize investment
  - Has led to major consolidations

Dennard Scaling

- Due to Robert Dennard, IBM, 1974
- Quantifies benefits of Moore's Law

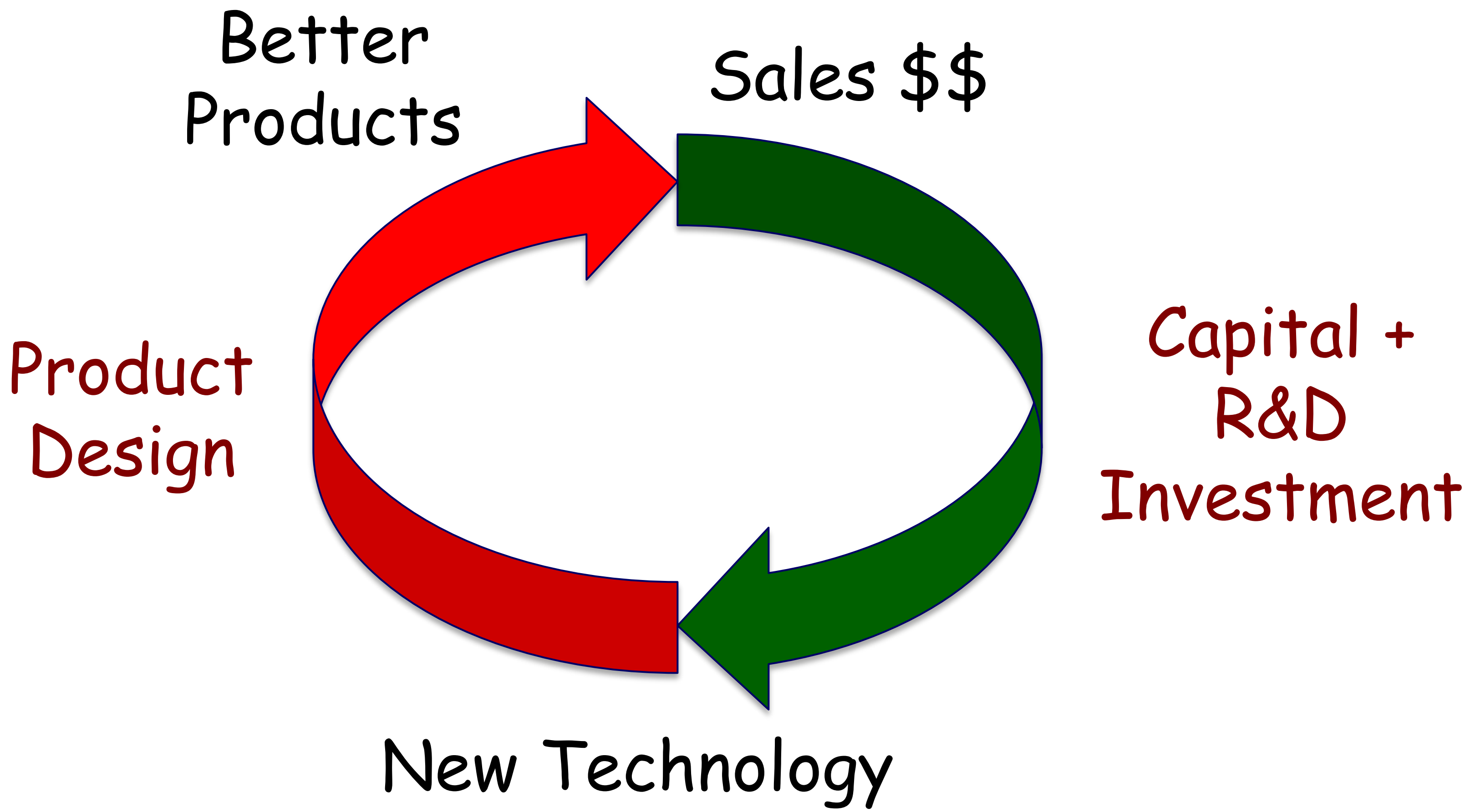
- How to shrink an IC Process
  - Reduce horizontal and vertical dimensions by k
  - Reduce voltage by k
- Outcomes
  - Devices / chip increase by k^2
  - Clock frequency increases by k
  - Power / chip constant
- Significance
  - Increased capacity and performance
  - No increase in power

End of Dennard Scaling



- What Happened?
  - Can't drop voltage below ~1V
  - Reached limit of power / chip in 2004
  - More logic on chip (Moore's Law), but can't make them run faster
    - Response has been to increase cores / chip

Moore's Law Economics



Consumer products sustain the $300B semiconductor industry

Will it all continue?

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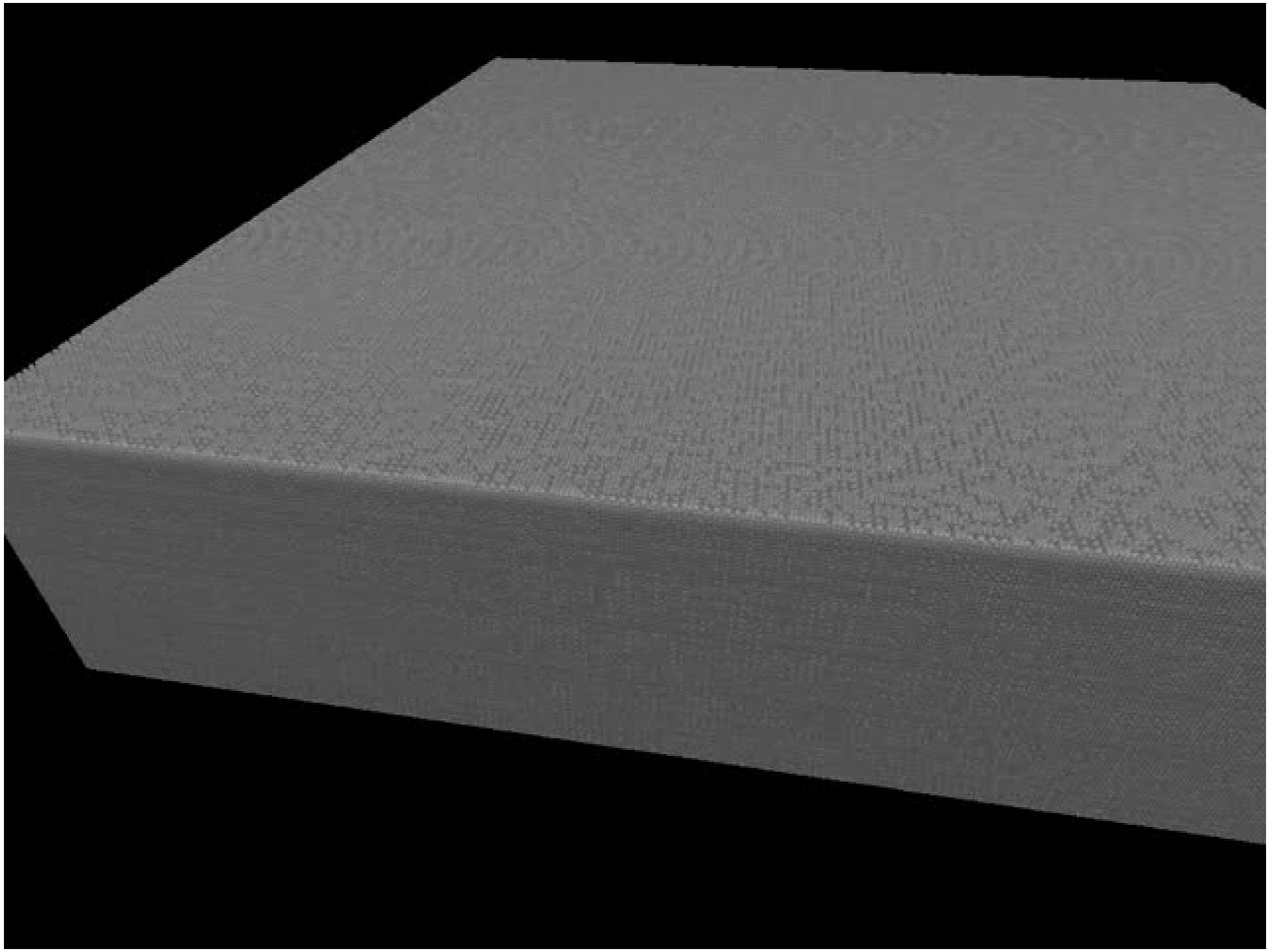
Software



Simulation of 10 million "robots"

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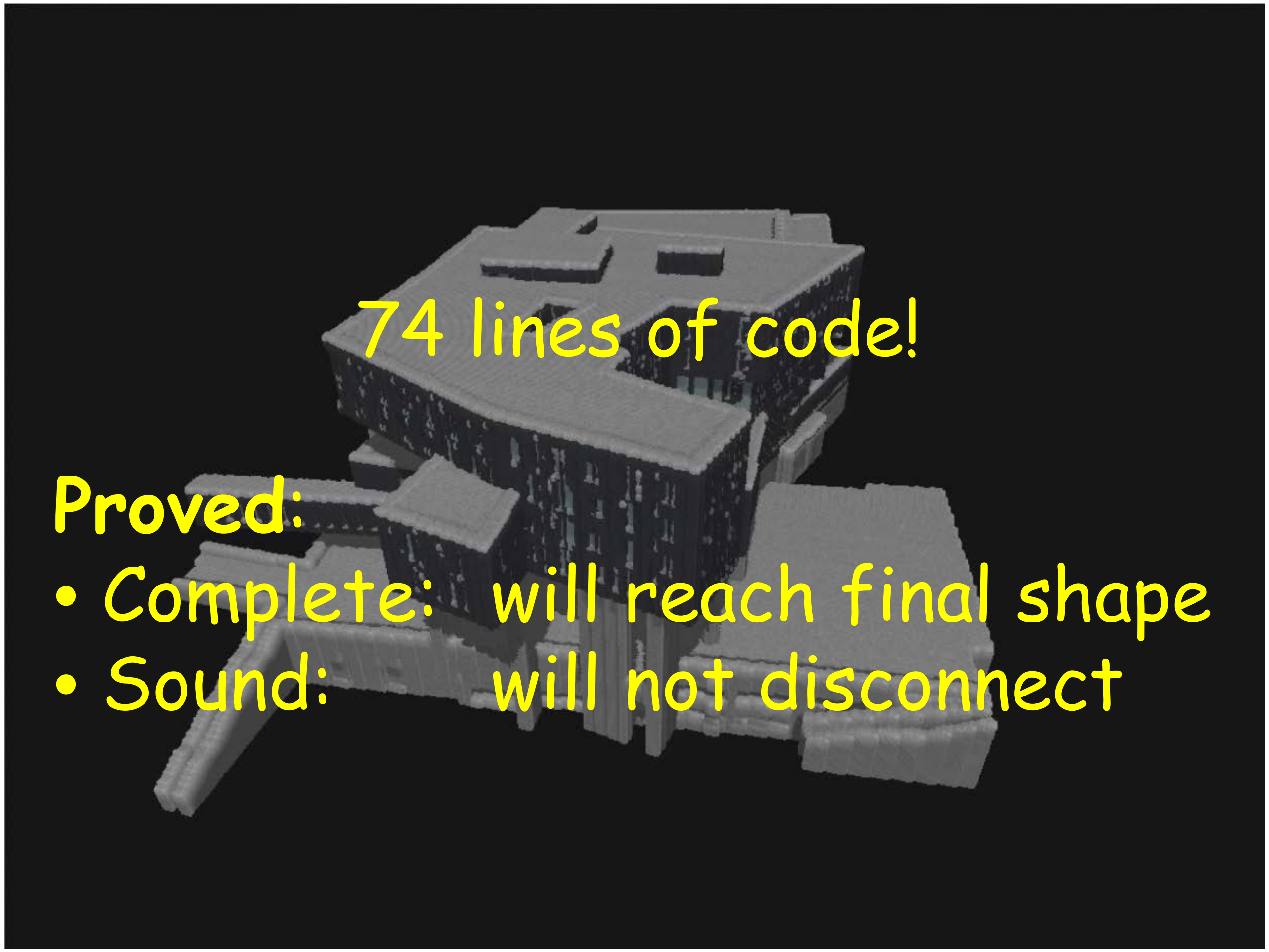
Software


74 lines of code!
Proved:
• Complete: will reach final shape
• Sound: will not disconnect

Insatiable Demand for Computing

- Programmable matter?
- Simulating life
- Many many more

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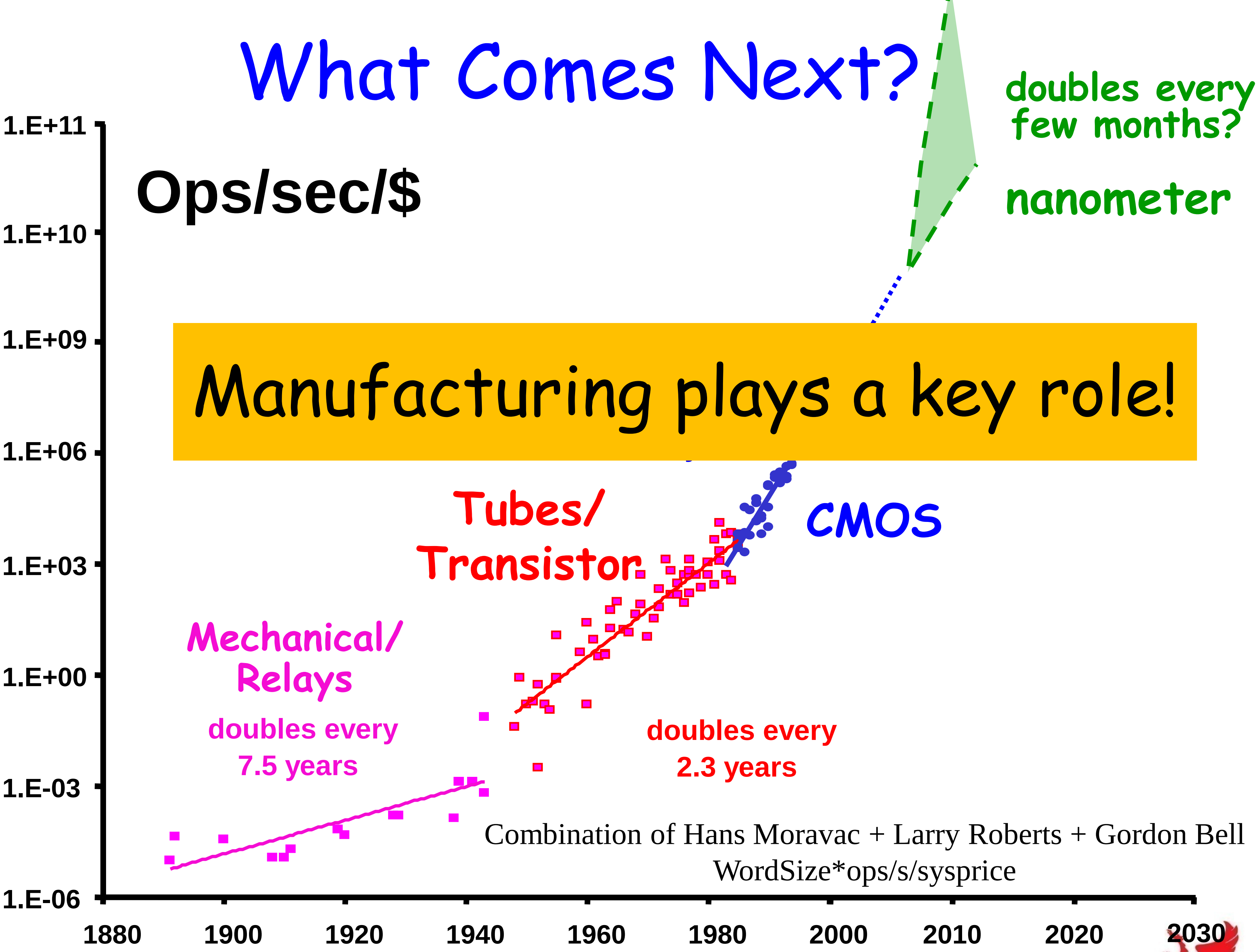
What Comes Next?



From Gray Turing Award Lecture

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Next Time

- How we might fabricate chips with 10^23 components
- What impact this might have
- Other technology trends

- Societal impact
- Potential solutions

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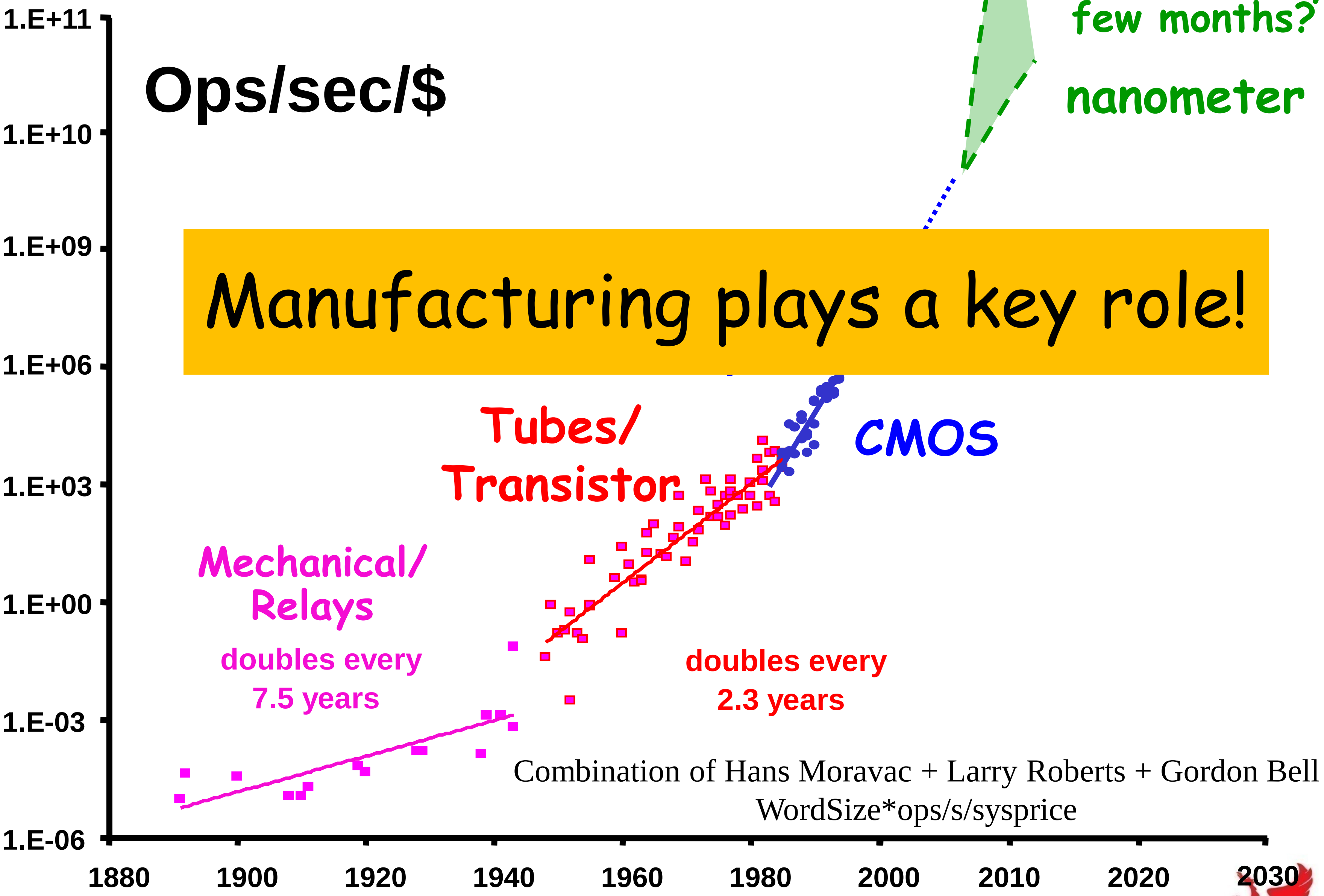
What Comes Next?



Manufacturing plays a key role!

From Gray Turing Award Lecture

Technology Shifts

- Size of Devices
  - $\Rightarrow$ Inches to Microns to Nanometers
- Type of Interconnect
  - $\Rightarrow$ Rods to Lithowires to Nanowires
- Method of Fabrication
  - $\Rightarrow$ Hammers to Light to Self-Assembly
- Largest Sustainable System
  - $\Rightarrow$ 10^1 to 10^8 to 10^{12}
- Reliability
  - $\Rightarrow$ Bad to Excellent to Unknown

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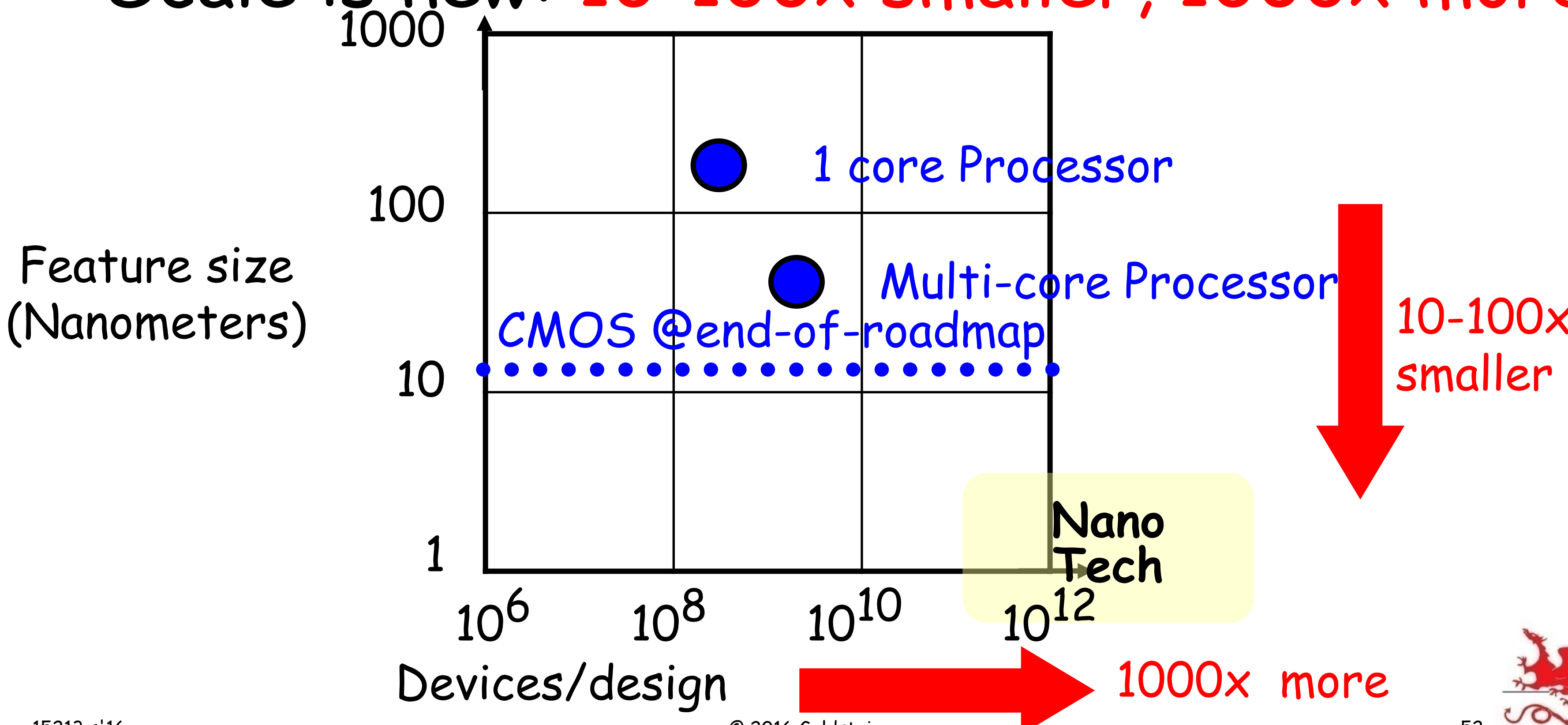
On the cusp of Major Technology Change

- Devices
  - *very* small & numerous
  - Novel characteristics
- Scale is new: 10-100x smaller, 1000x more



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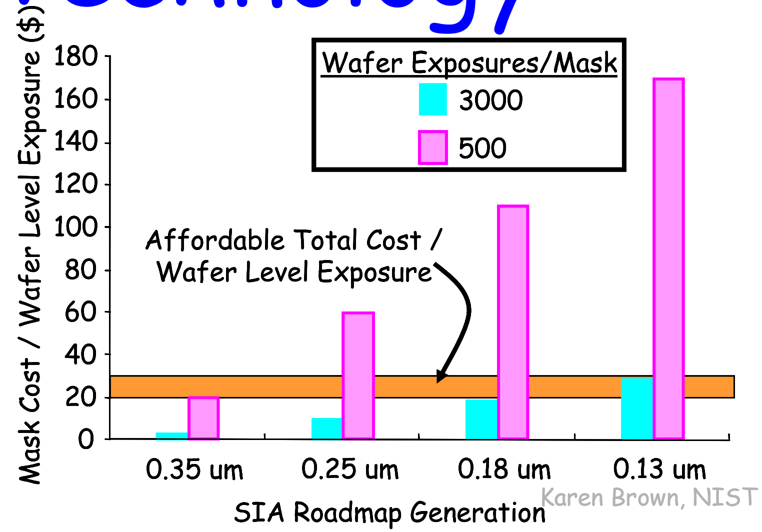
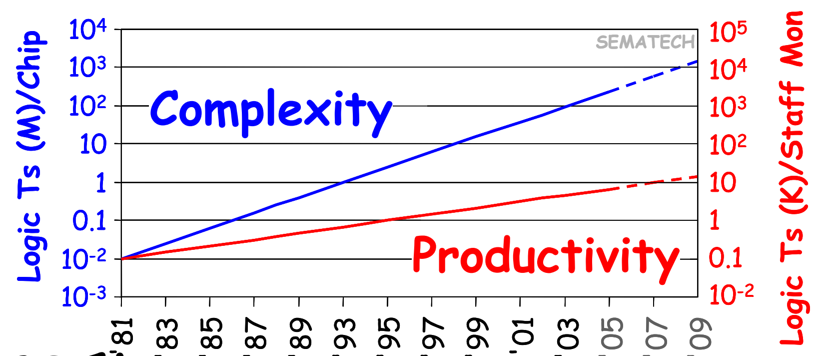
Independent of Technology

As we scale down:

- Devices become
  - more variable
  - more faulty (defects & faults
  - numerous
- Fabrication becomes
  - More expensive
  - More constrained
- Design becomes
  - More complicated
  - More expensive





Requires:

- Defect tolerant architectures
- Higher level specification
- Universal substrate

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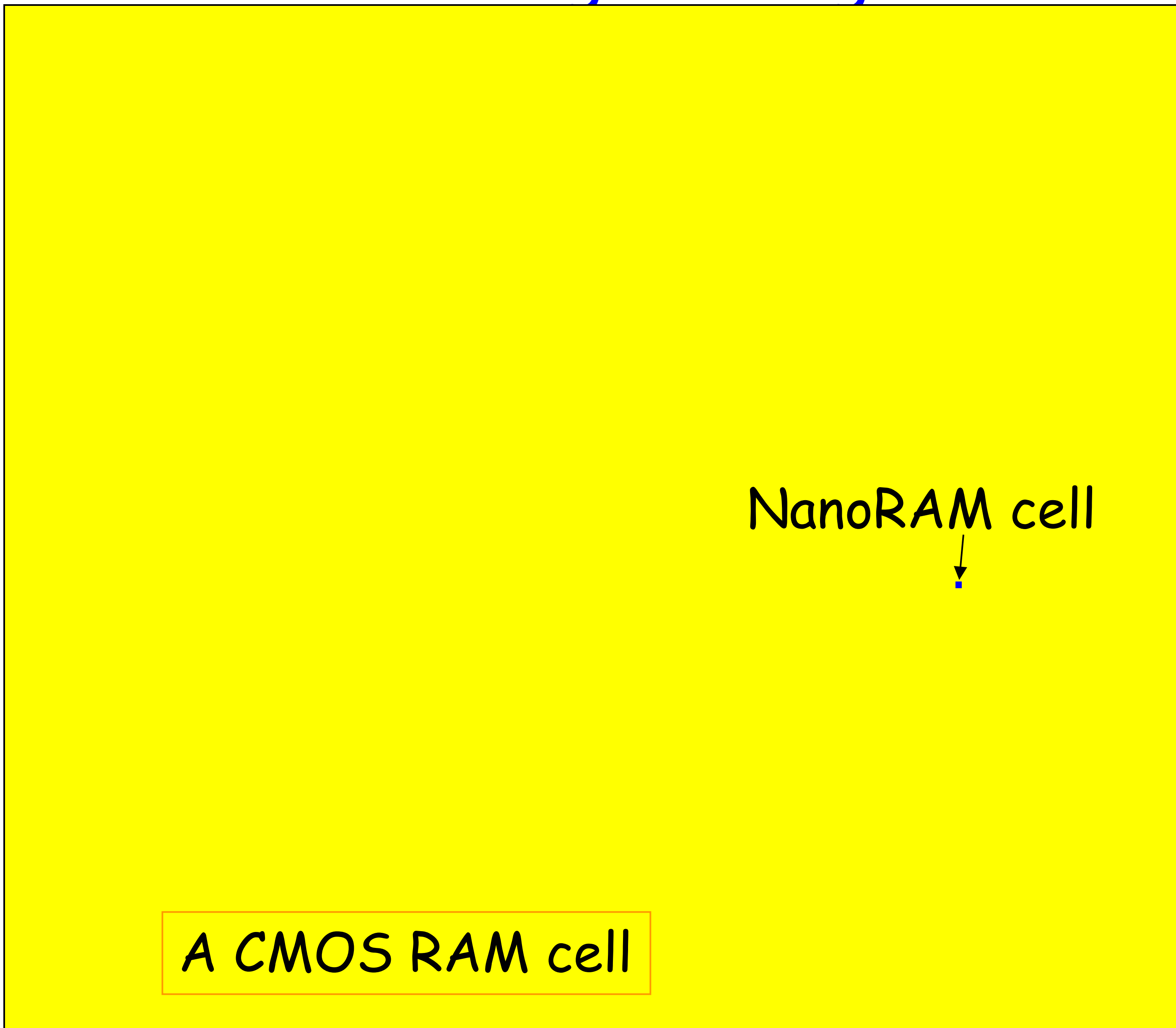
Manufacturing Paradigm Shift Required



nents
components

ufacture
anufacture
up assembly

ales down
d variability
unctionality
connectivity

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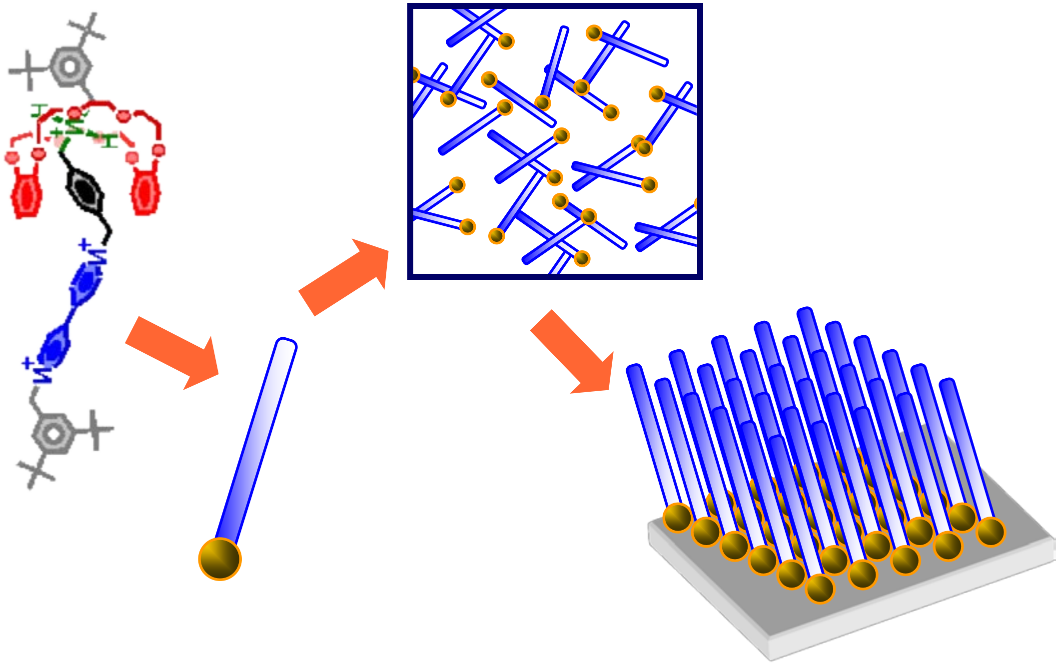
Building a Computing Crystal



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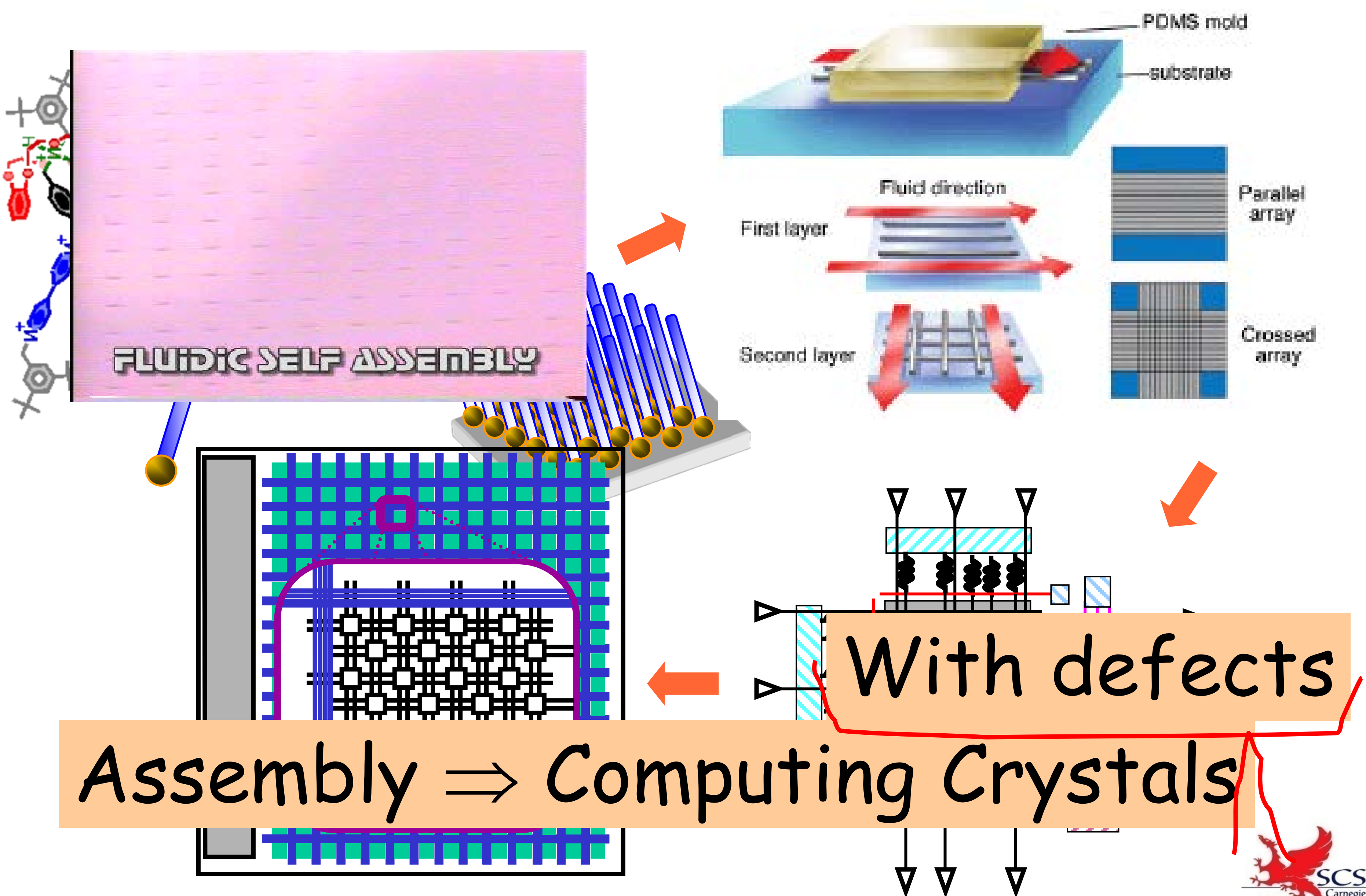
Building a Computing Crystal



Assembly ⇒ Computing Crystals

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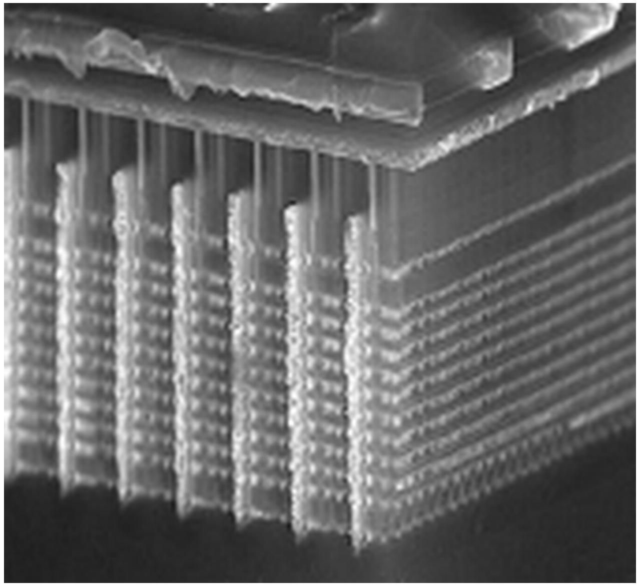
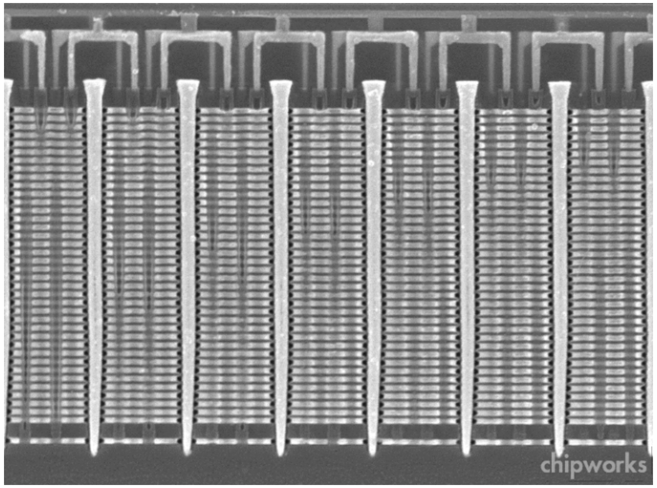
Samsung V-Nand Flash Example





- Build up layers of unpatterned material
- Then use lithography to slice, drill, etch, and deposit material across all layers
- ~30 total masking steps
- Up to 48 layers of memory cells
- Exploits particular structure of flash memory circuits

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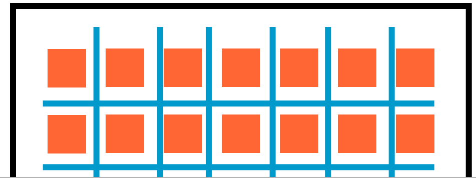
Continuing the Trend



Tradeoff complexity (and precision) at manufacturing time for complexity at compilation time.

Complex fixed chip
+
Program

Regular, tileable structures
+
Configuration

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Defect Tolerant Architectures

- Features:
  - Regular topology
  - Homogenous resources
  - Fine-grained?
  - Post-fabrication modification
- Example from today: DRAM
  - Requires external device for testing
  - Requires external device for repair
- Logic? FPGA

Key is redundancy

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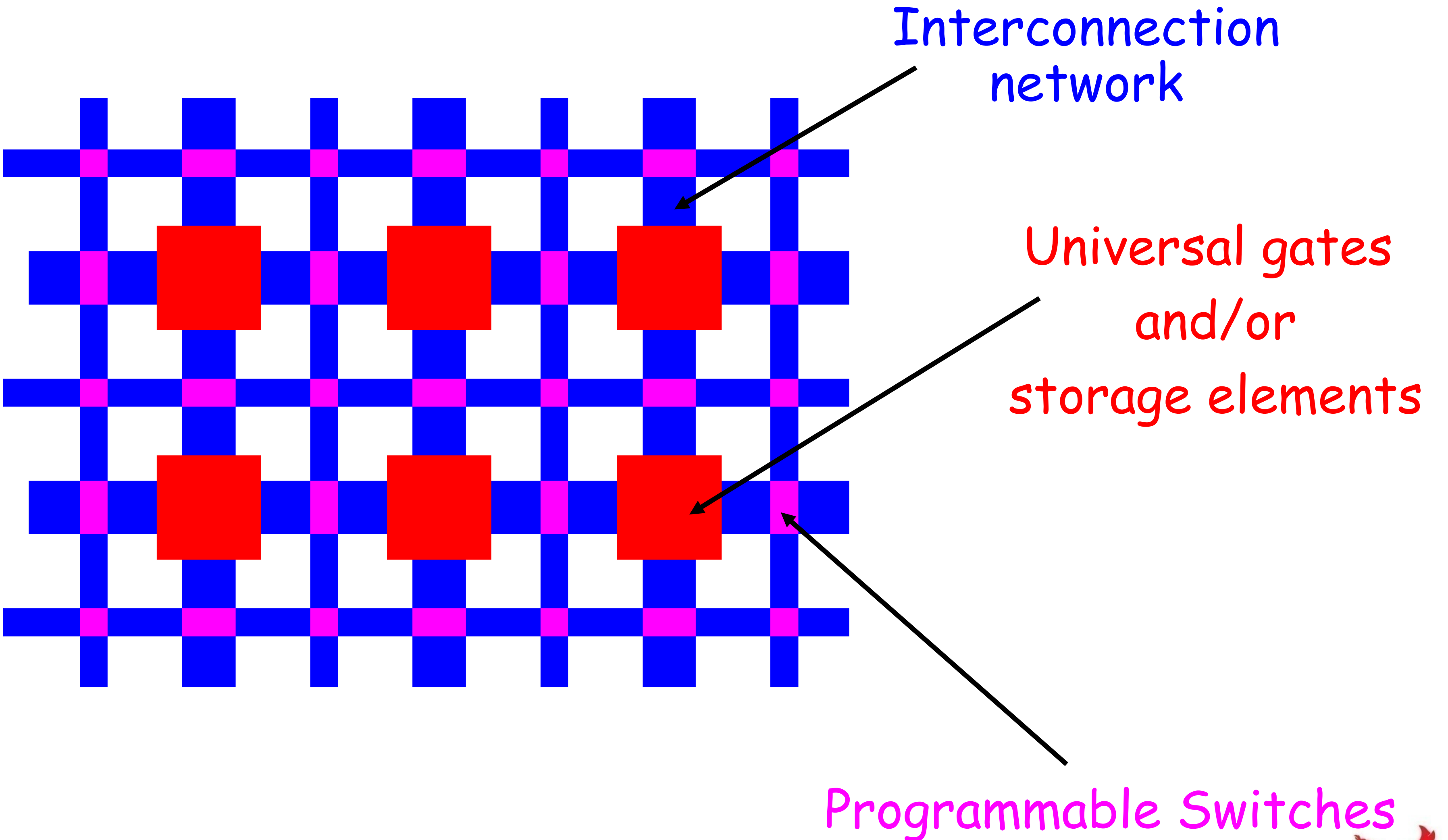
FPGA



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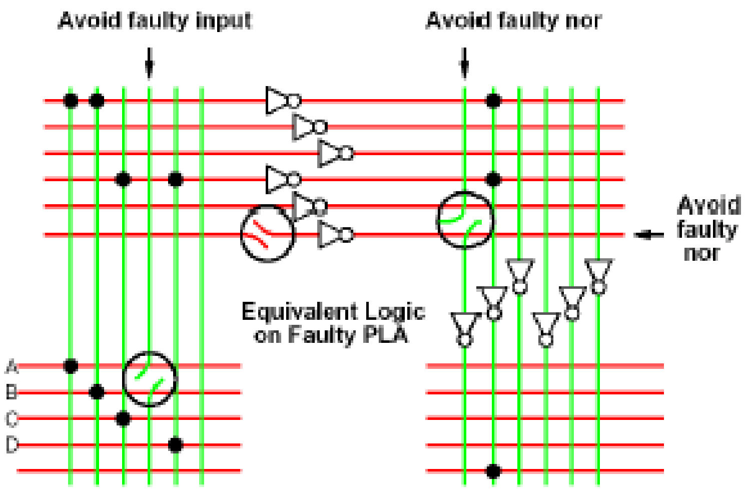
Defect Tolerant Architecture

- Extra devices, wires, and post-processing to route around defective elements
- New circuit techniques
- Radical architectures to exploit
  - Randomness
  - Reconfigurability
  - Plentiful resources
- New testing approaches



CalTech

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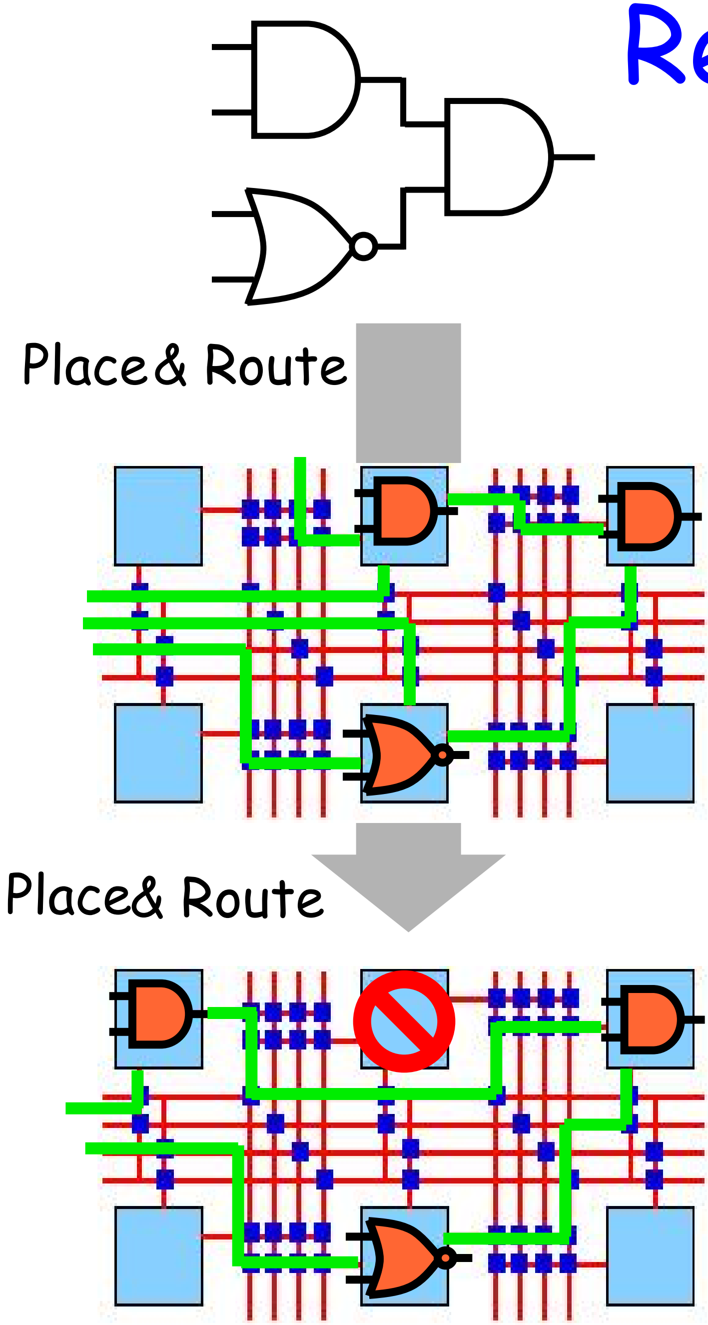
Reconfigurability & DFT



- FPGA computing fabric
  - Regular
  - periodic
  - Fine-grained
  - Homogenous
- programs $\Rightarrow$ circuits
- Aides defect tolerance

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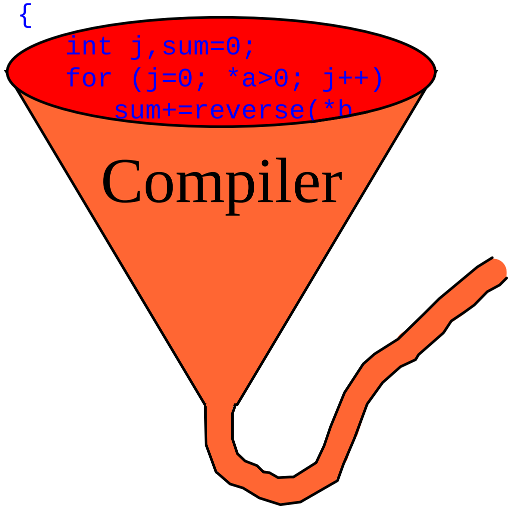
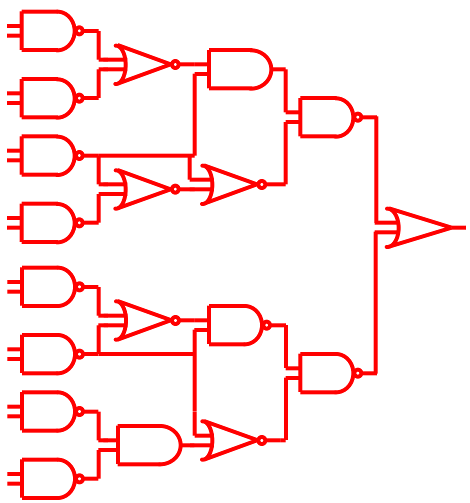
Reconfigurable Computing

General-Purpose

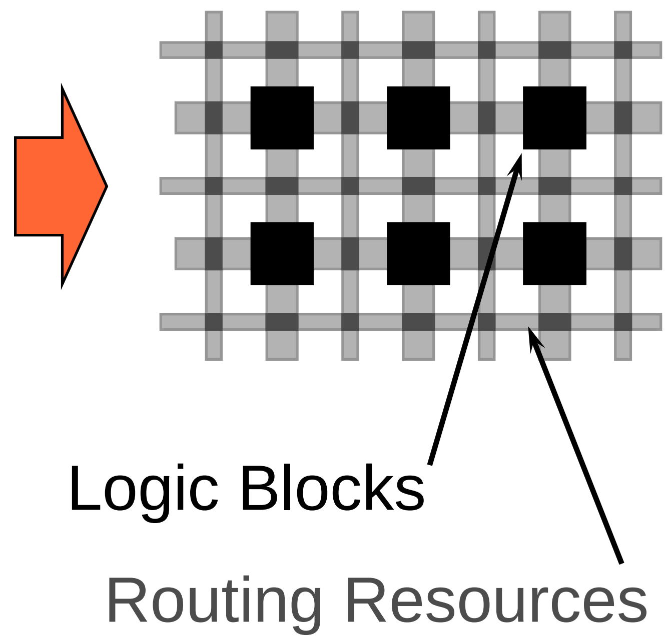
```
int reverse(int x)
{
   int k,r=0;
   for (k=0; k<64; k++)
      r |= x&1;
      x = x >> 1;
      r = r << 1;
   }
}
int func(int* a,int *b)
{
   int j,sum=0;
   for (j=0; *a>0; j++)
      sum+=reverse(*b
```



Custom Hardware



General-Purpose Custom Hardware



Advantages of Reconfigurable

- Flexibility of a processor
- Performance of custom hardware

Near

You have to

- Store and
- Address

the configuration

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SCS Carnegie Mellon School of Computer Science

Advantages of Reconfigurable

- Flexibility of a processor
- Performance of custom hardware
  - Reduce time to market
  - Reduce design cost
  - Built-in dynamic fault tolerance
  - Built-in self test
  - Low Power

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Sources of Performance

- Exploit multiple levels of parallelism
  - MIMD, SIMD
  - ILP
  - Pipeline
  - bit-level
- Custom function units
  - Custom sizes
  - Specialized functions
- Improved memory performance
- Data dependent hardware generation

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Pause for a second

- 50 more years of Moore's law?
  - Probably not in Si, but …
- Probably need new architectures, etc.

- But, so far,

Necessity is the mother of invention

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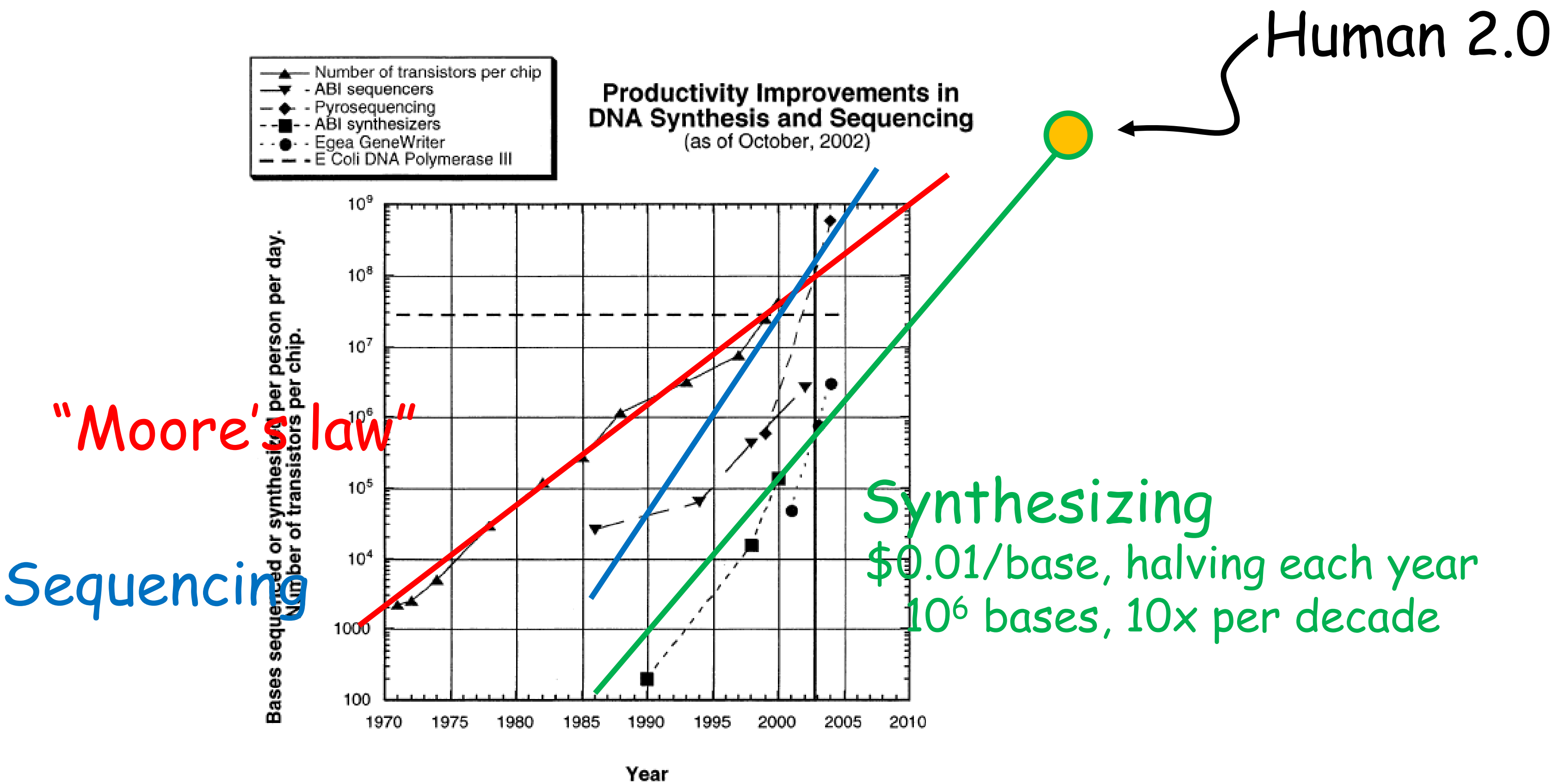
Exponentials Abound



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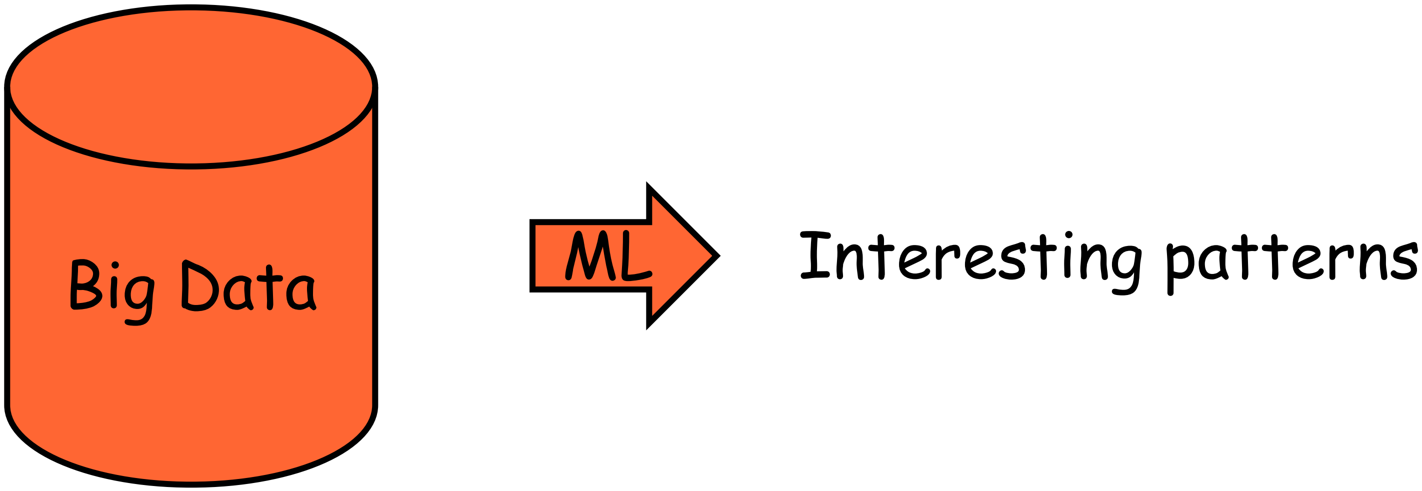
Big Data can look like AI



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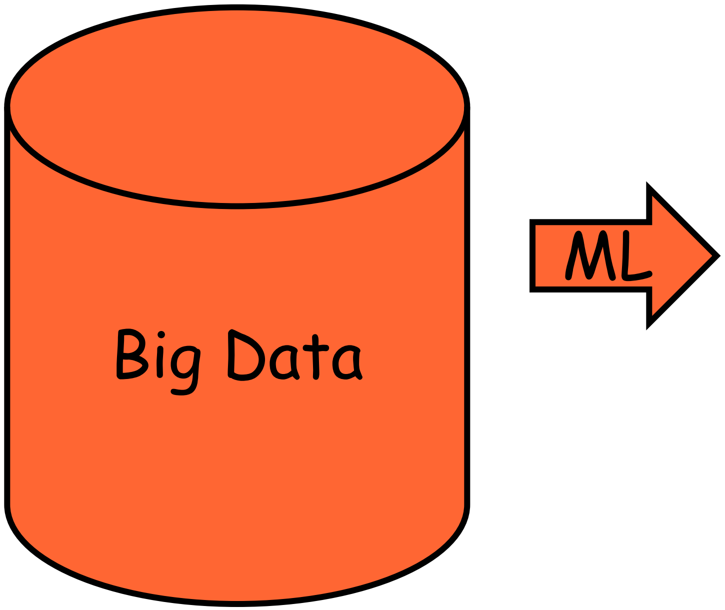
Big Data can look like AI



More
Interesting patterns

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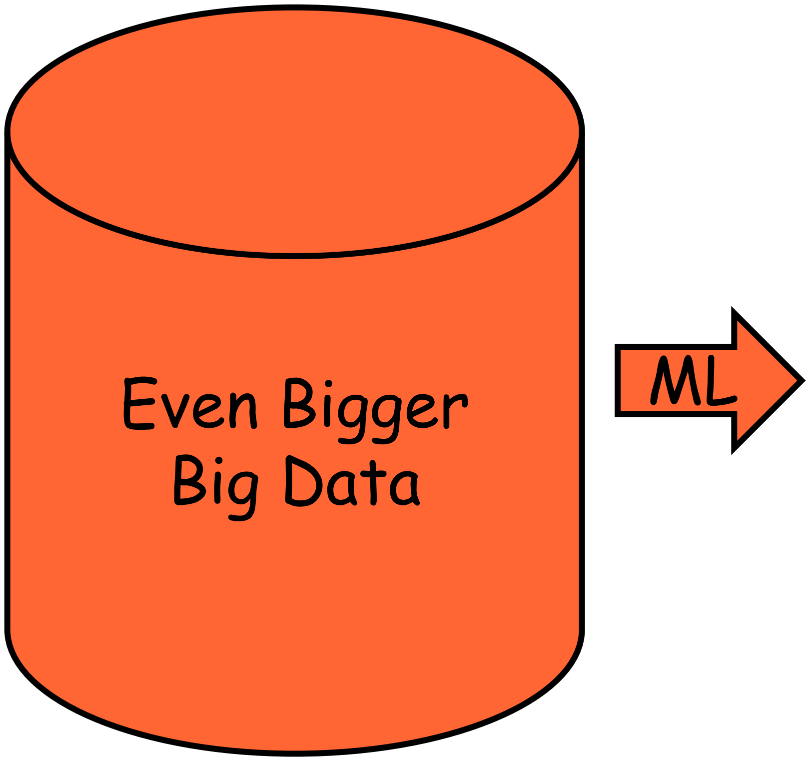
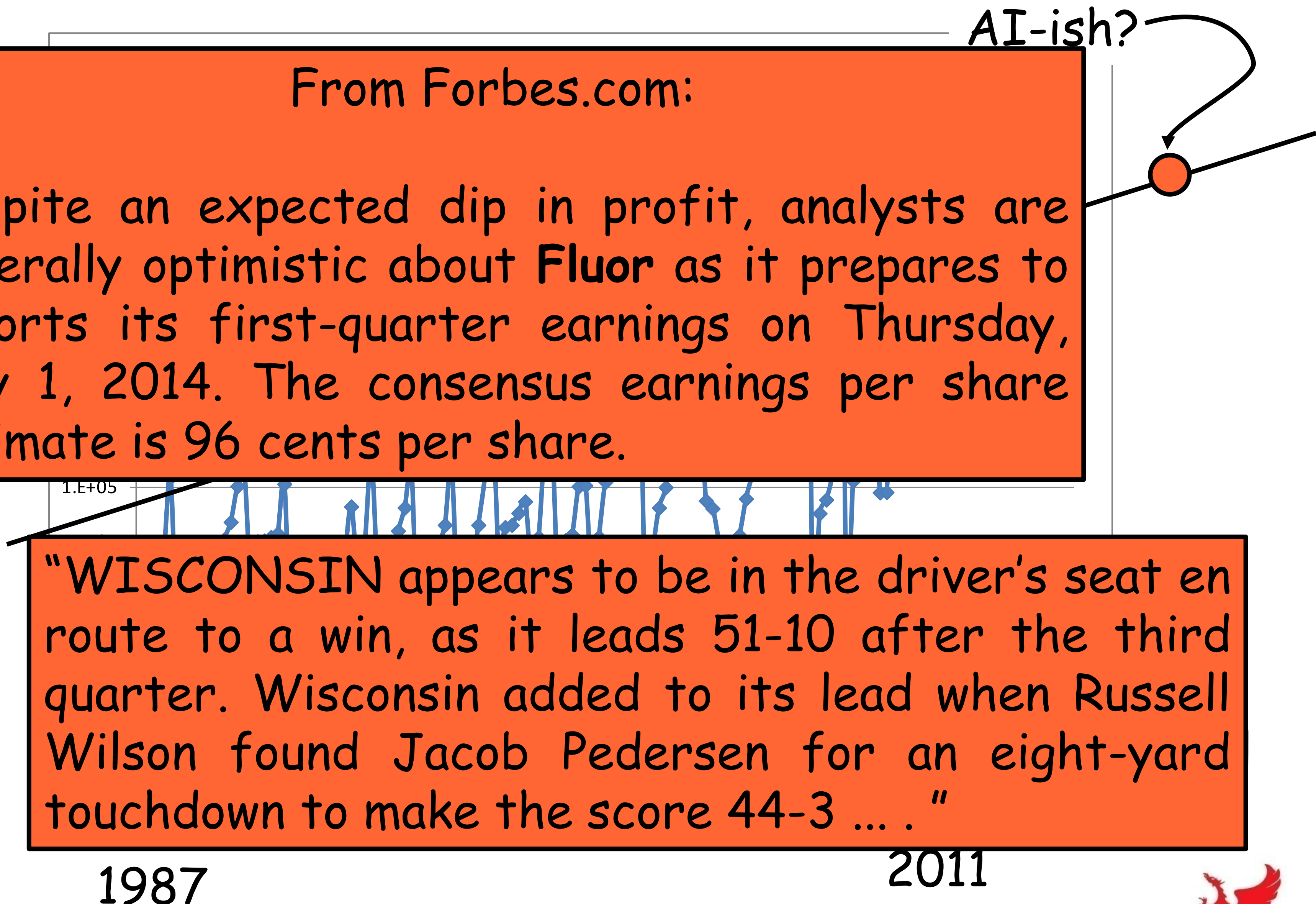
Big Data can look like AI



Patterns that look like
Creativity/Intelligence

What is you prediction?



From Forbes.com:

Despite an expected dip in profit, analysts are generally optimistic about **Fluor** as it prepares to reports its first-quarter earnings on Thursday, May 1, 2014. The consensus earnings per share estimate is 96 cents per share.

"WISCONSIN appears to be in the driver's seat en route to a win, as it leads 51-10 after the third quarter. Wisconsin added to its lead when Russell Wilson found Jacob Pedersen for an eight-yard touchdown to make the score 44-3 ... . "

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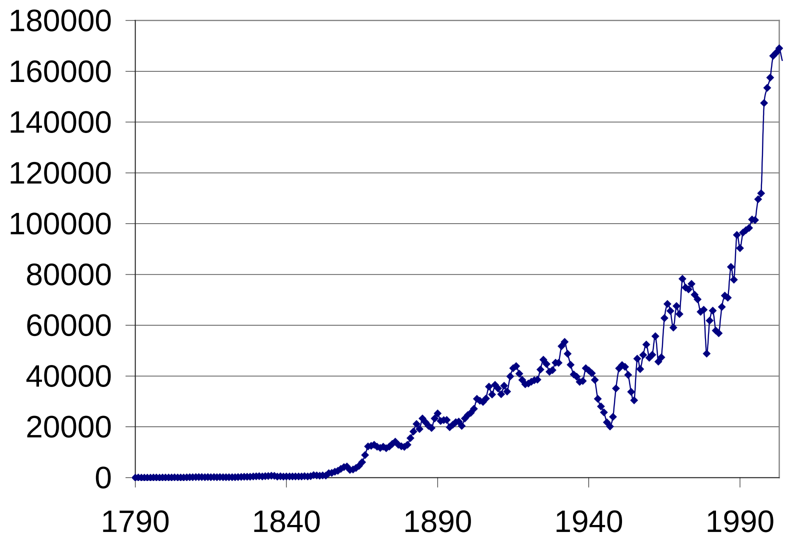
Rate of change is also e^x!

- After thought this should be obvious
  - Tools enable faster turnaround
  - Expectations grow
  - Standing on the shoulders of the past
- Examples:
  - Extended Moore's
  - Email: "Email is for
  - Rate of patents



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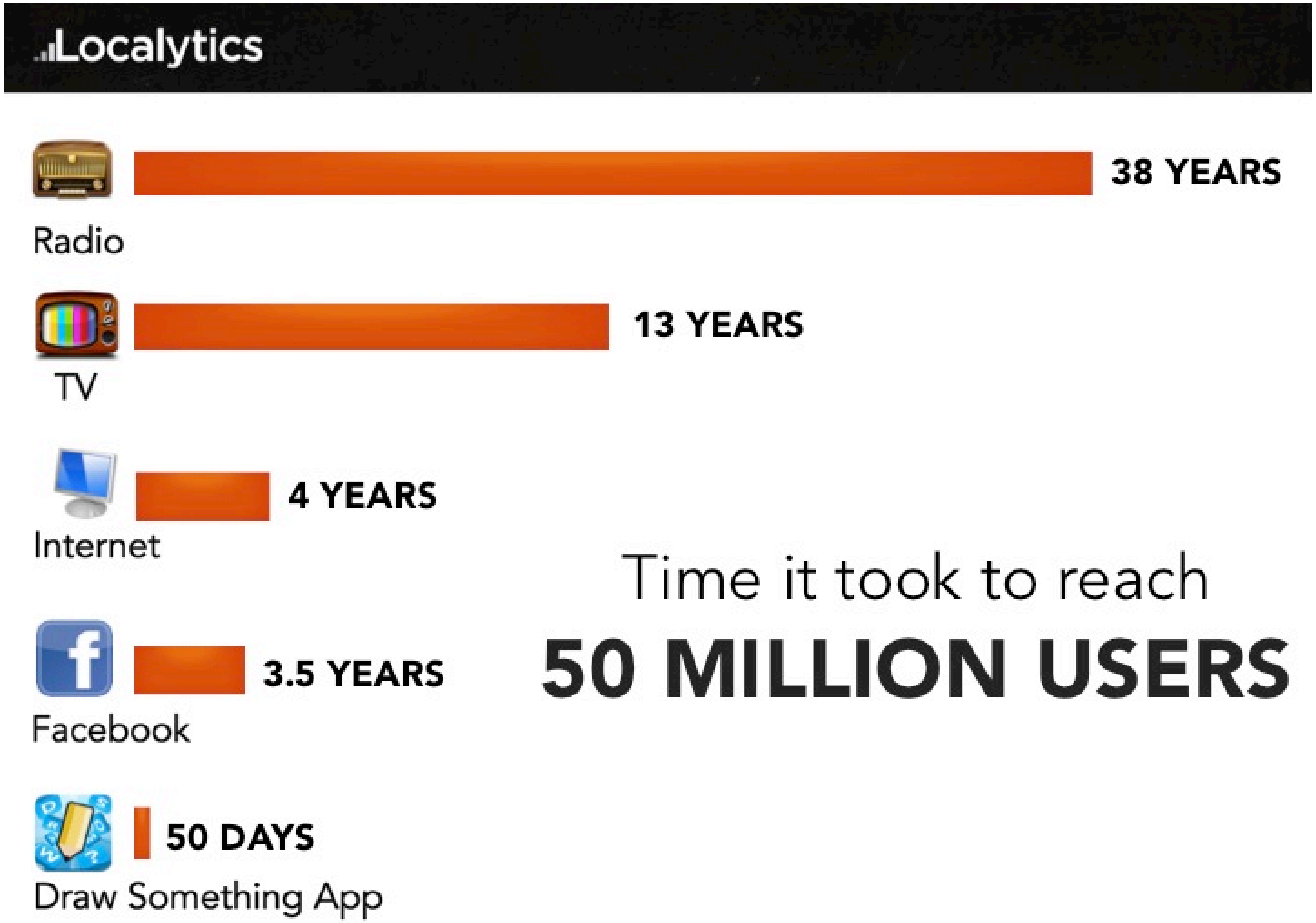
Rate of Adoption



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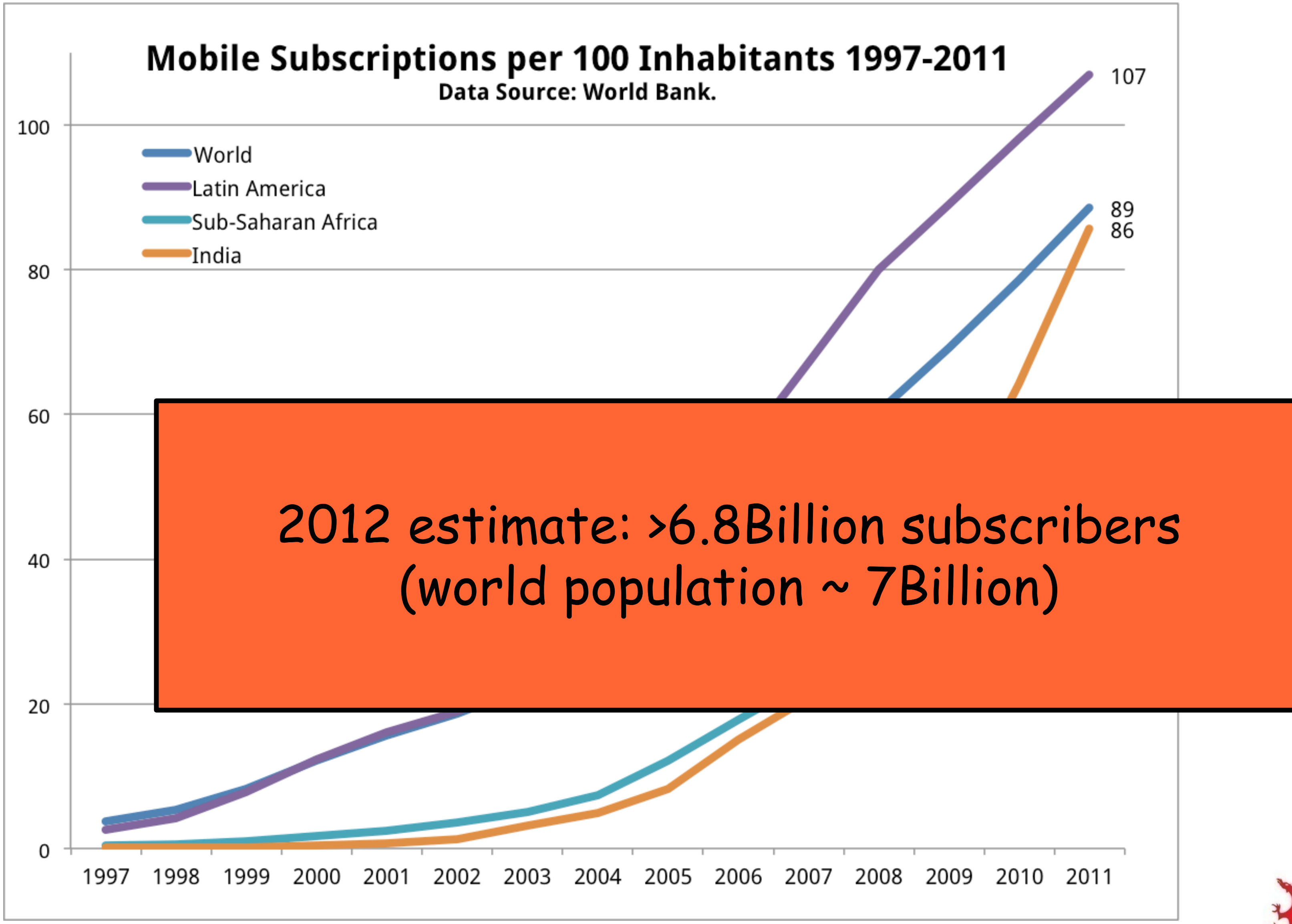
Cell Phones



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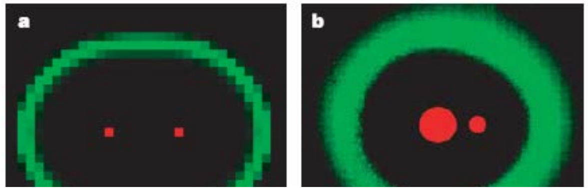
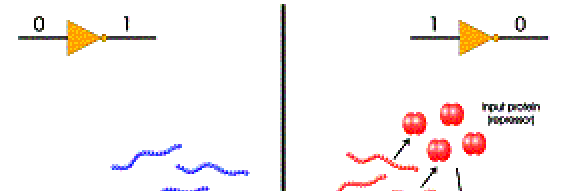
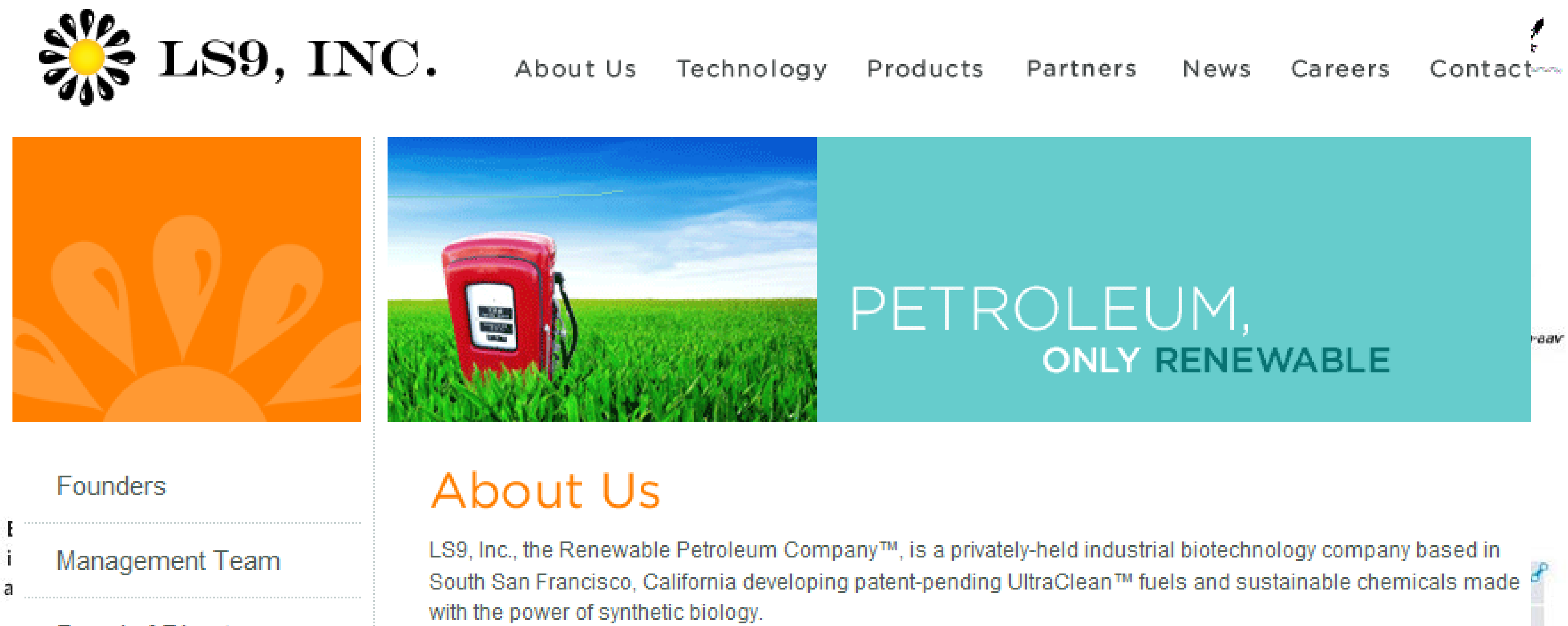
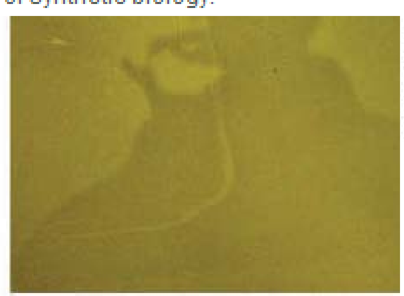
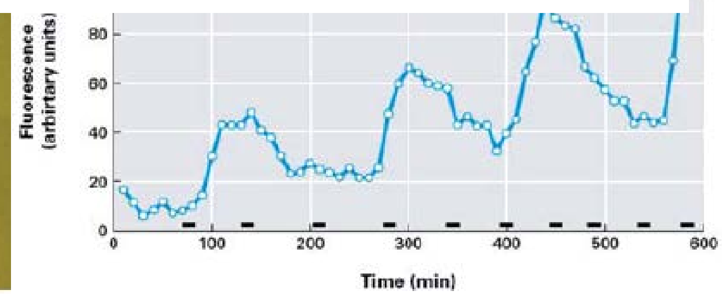
Synthetic Biology





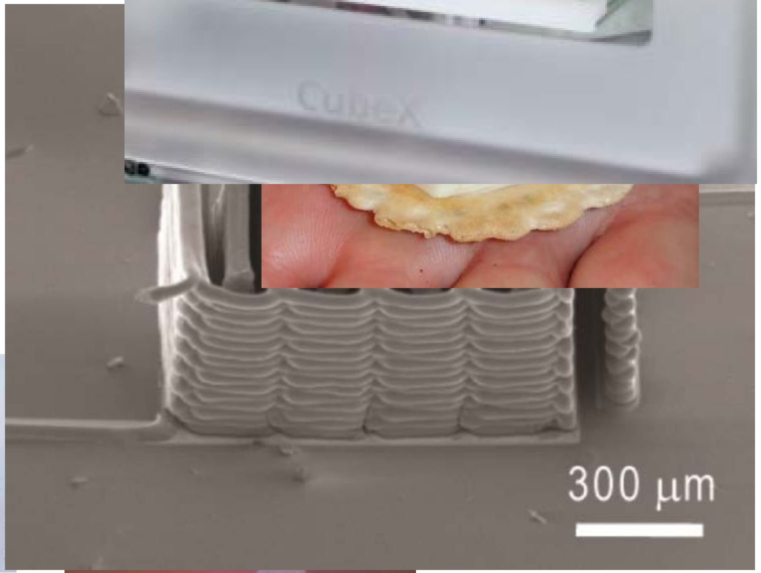


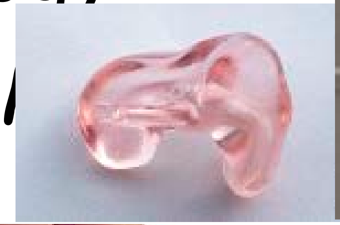


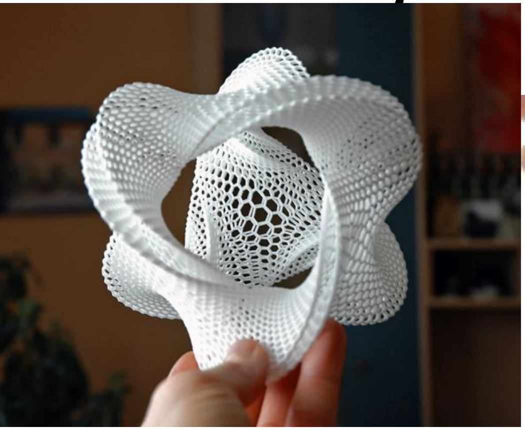


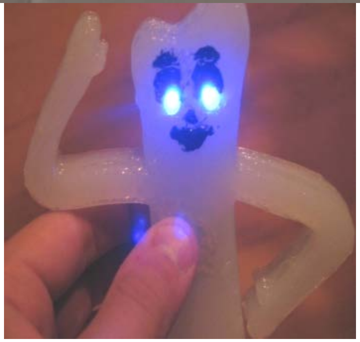
Manufacturing Through

- Inkjet printers
- 3D printers
- FPGAs
- Modular Robots
- Synthetic Biology
- Programmable









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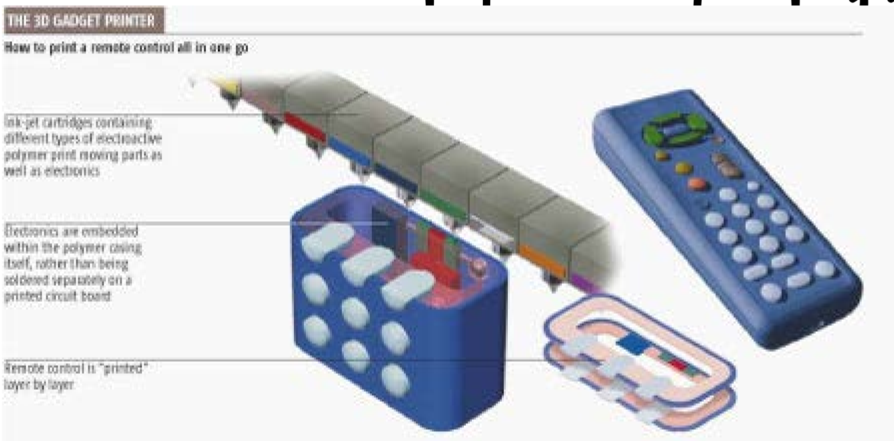
Inkjet printers

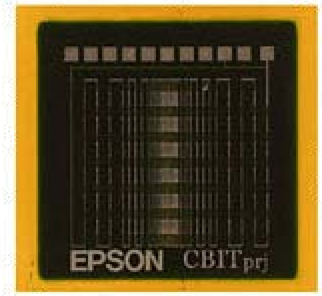
- They print more than ink.
- E.g.,: Epson prints 20 layer

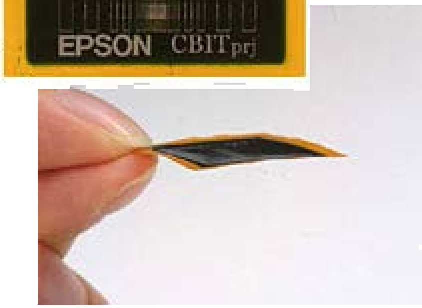


10μm pitch

50 μm

printer





- *jet printers
  - Electroactive polymers
  - Embed electronics directly
  - Polymer electronics

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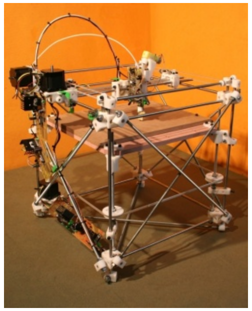
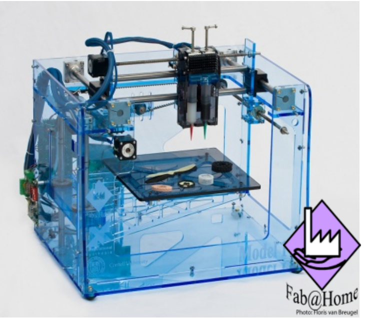
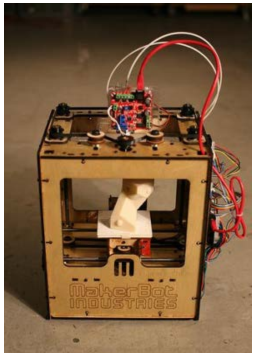
Additive Manufacturing

- From CAD → Product with little or no human intervention
- Supports
  - Tremendous geometric flexibility
  - Internal spaces & embedded components
  - Multi-material & gradient material structures

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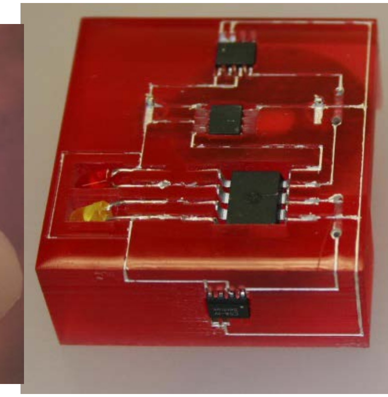
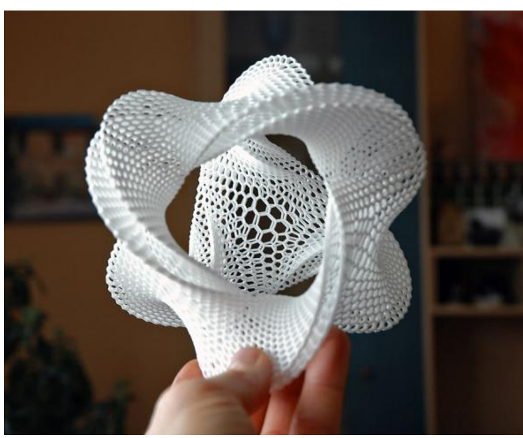
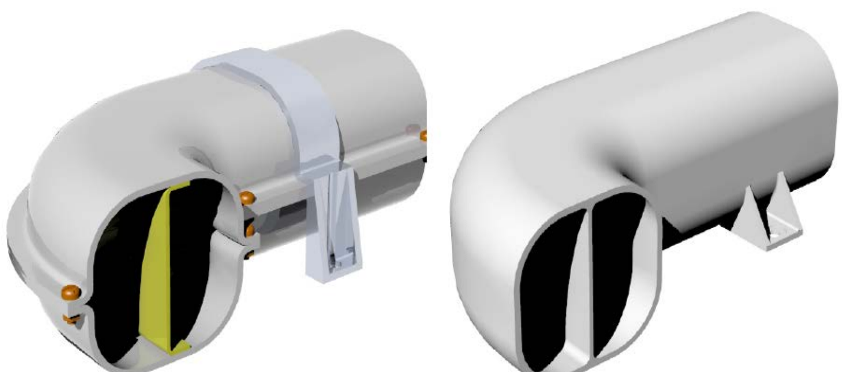




Additive Manufacturing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Manufacturing Through Computation

- Inkjet printers

er

STAPLES

Office Centre

Robotics

ATM
GM
NACHI
APPLANIX
Google
NetApp
intel
ibeo
vector
MR 20
008

The World is Changing

- Technology Trends
  - Nanotechnology
  - Synthe
  - Computers
  - Robotics
- Some Implications
- What Should We Do?

Clean ubiquitous Cheap Energy

More Knowledge available to more people

Safer & Faster travel

A level playing field

Customized anything

Better Health

Dematerialization of Value

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Utopia?

- Technology Trends
  - Nanotechnology
  - Synthe
  - Computers
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Clean ubiquitous Cheap Energy

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Better Health

Dematerialization of Value

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Fast Food?

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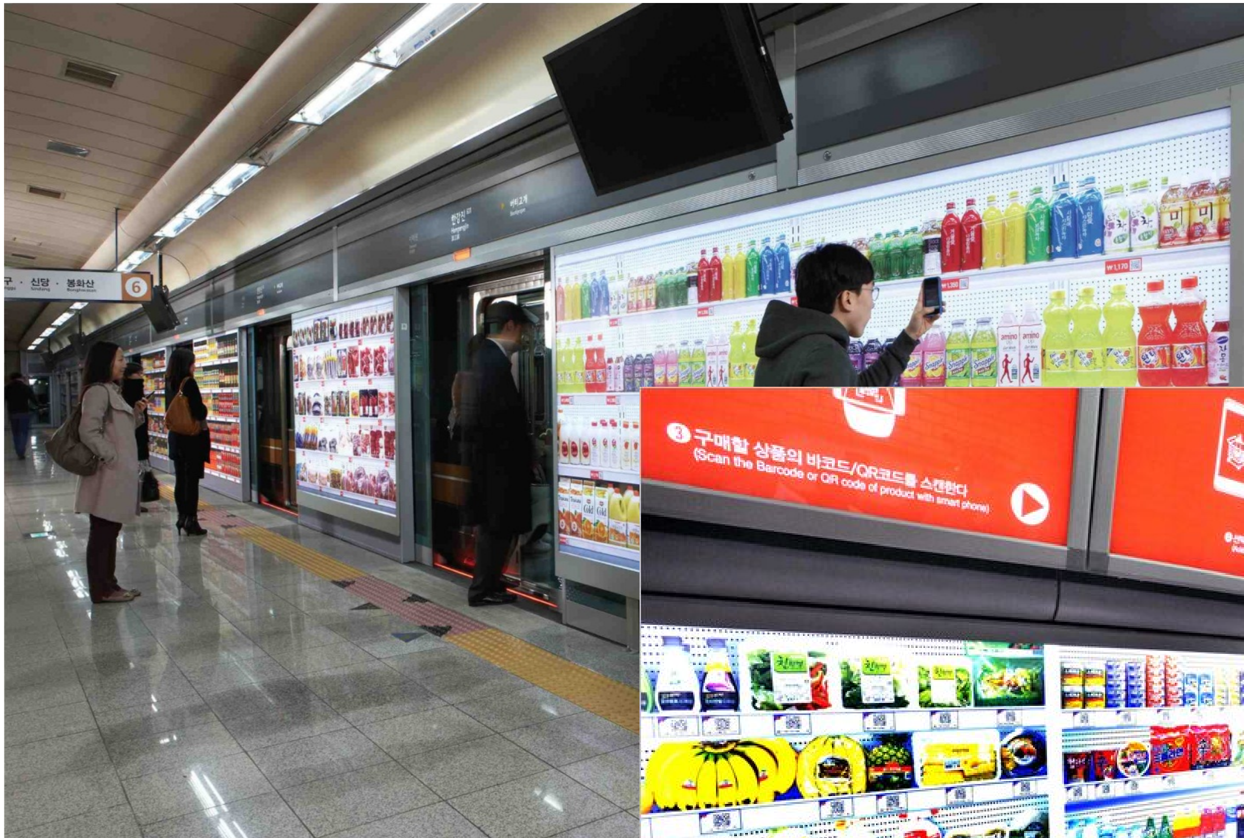
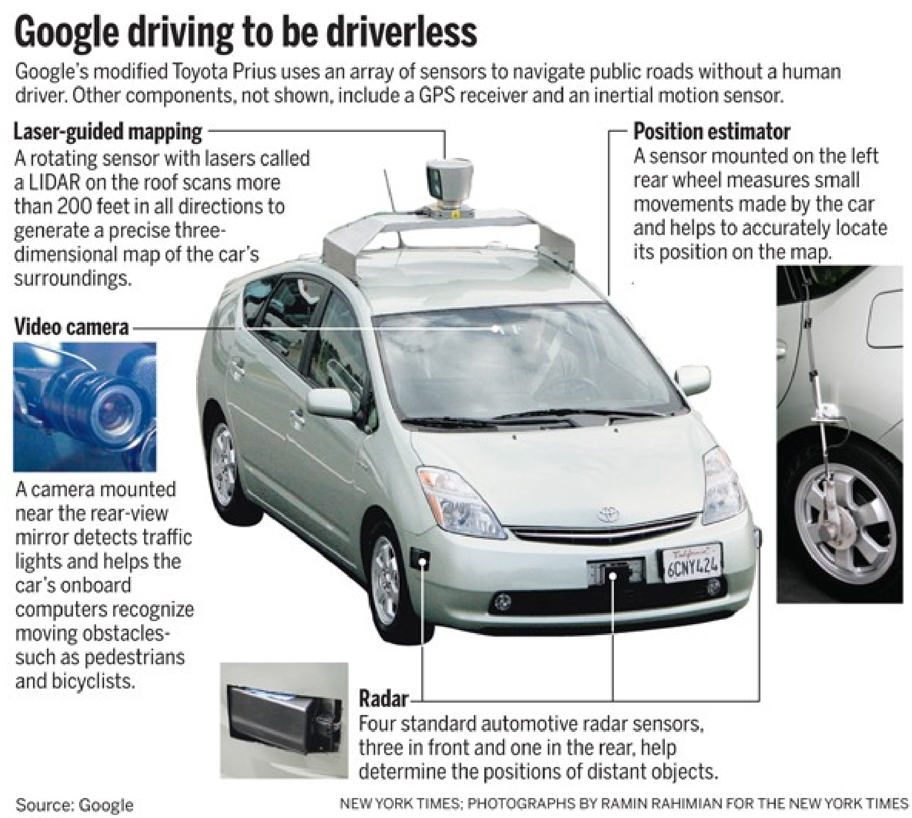
Faster supermarket?



Transportation

- Today over 3.8M Professional drivers
- Driverless car?



Shopping in the future

- Combine:
  - Robotics
  - Machine learning
  - Big data
  - Internet of things
  - 3D printers
- Anyone left in the store?
- Is there a store?

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Professionals?

- Only 55% of law school 2011 graduating class found a job.

SMARTER THAN YOU THINK

Armies of Expensive Lawyers, Replaced by Cheaper Software

Ramin Rahimian for The New York Times

"People get bored, people get headaches. Computers don't," said Bill Herr, a lawyer who used to work for a chemical

- Only 55% graduatin
- Doctors?

Home > Healthcare IT

News

AI found better than do treating patients

AI can think like a doctor, but faster and researchers find

By Lucas Mearian

February 12, 2013 05:32 PM ET 23 Comments

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Robo doc detects cancer 40% better than humans

Prototype cyber-surgeon faster, more accurate at finding tumours

By Mark Harris in Seattle August 21st 2009 0 COMMENTS

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Robots could soon become commonplace in operating theatres

Would you trust a robot to delve into your innards? If Canadian researchers are right, you should.

A prototype touchy-feely robot has been shown to detect tumour tissue in half the time, and with 40 per cent more accuracy than a human surgeon.

Related stories

View your 3D likeness prior to plastic surgery

A tweet a day keeps the doctor away

- Only 55%
  graduati
- Doctors?
- Pharamci
  promoted

Professionals?

- Only 55% of law school 2011 graduating class found a job.
- Doctors?
- Pharamcists: Just a few years ago promoted as a great degree to get.
- Writer? I'm not so sure.

"WISCONSIN appears to be in the driver's seat en route to a win, as it leads 51-10 after the third quarter. Wisconsin added to its lead when Russell Wilson found Jacob Pedersen for an eight-yard touchdown to make the score 44-3 ... . "

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What Should You Do Today?

- Study for 213 final.

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What Should You Do Today?

- More seriously:
  - Learn to learn
  - Be flexible
  - Expect to continue to learn

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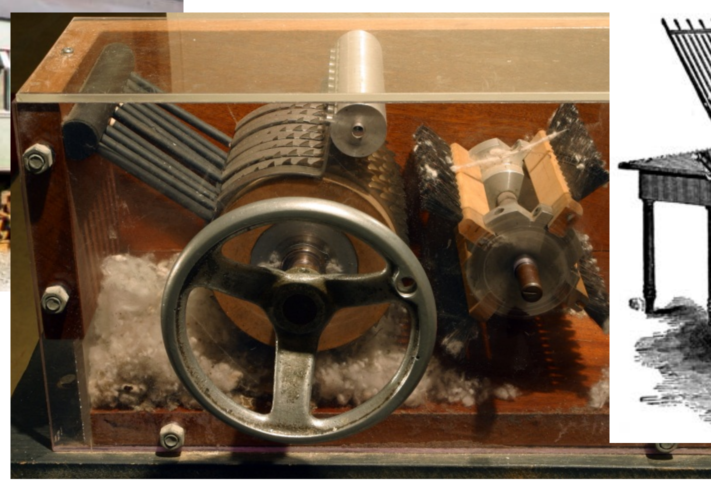
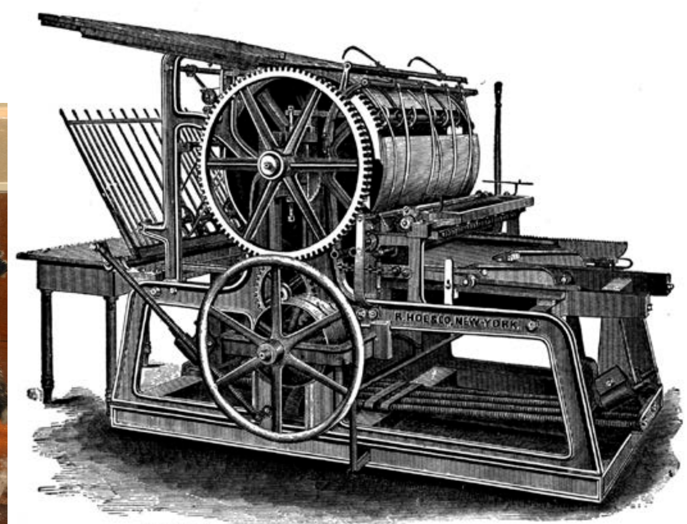
Technology Revolutions

- TR1: (aka First Industrial Revolution) 1760-1830
  - Coal powered steam engine
  - Cotton Gin
  - Steam-powered printing presses

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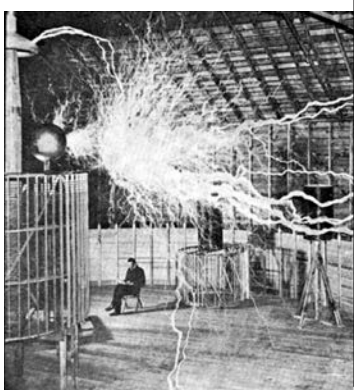
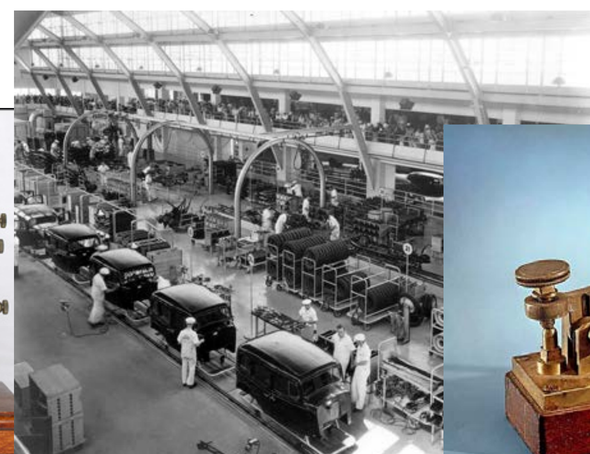
Technology Revolutions

- TR1: (aka First Industrial Revolution) 1760-1830
  - Coal powered steam engine
  - Cotton Gin
  - Steam-powered printing presses
- TR2: (aka Second IR) 1860-1910
  - Electricity/Internal Combustion Engine
  - Assembly Lines
  - Telegraph/Telephone





Technology Revolutions

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  - Coal powered steam engine
  - Cotton Gin
  - Steam-powered printing presses
- TR2: (aka Second IR) 1860-1910
  - Electricity/Internal Combustion Engine
  - Assembly Lines
  - Telegraph/Telephone
- Third Technology Revolution 1965-?
  - Renewables
  - Manufacturing without assembly
  - Computation

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Just Like TR1 and TR2

TR3 will:

- Improve productivity
- Increase wealth (on average)
- Cause massive disruption

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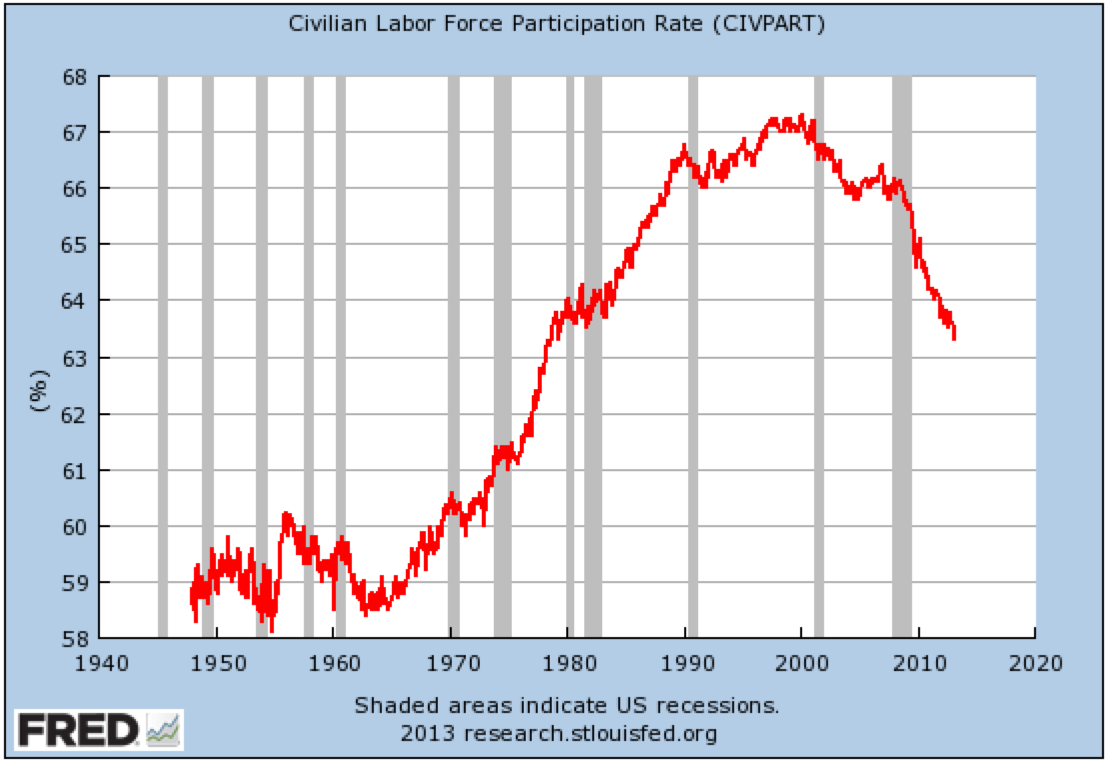
Wait one second …

- Didn't the industrial revolution add more jobs than it took away?



But, TR3 is different

- Continued exponential improvement
(E.g., Computation, Networking, Renewable energy, Synthetic biology, ML&BD, Robotics, …)
- Technology is able to do "uniquely human" cognitive and physical tasks.
- Lowering the labor component of the marginal cost of production

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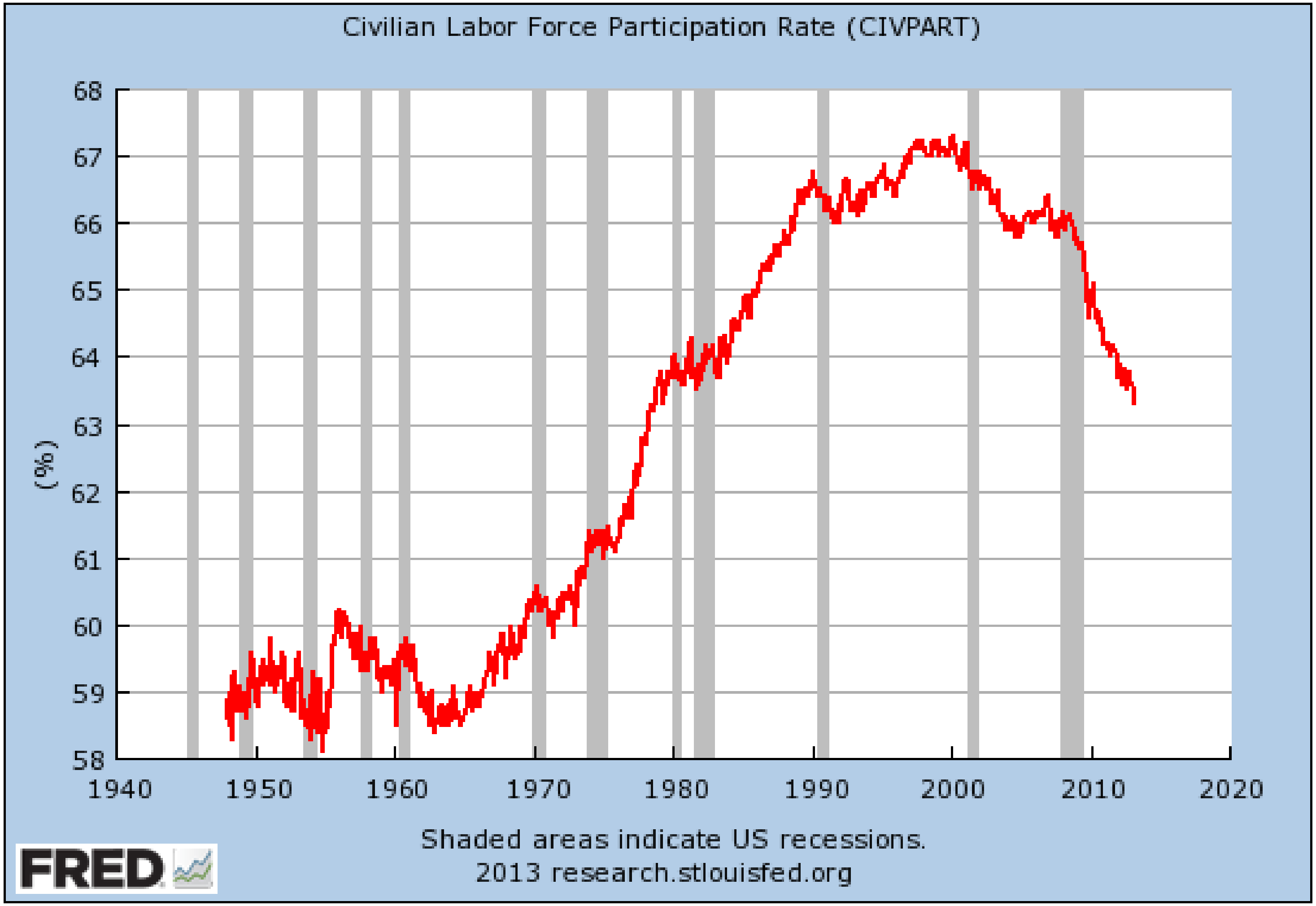
Wait a Second!

- Where are the exponential job losses?



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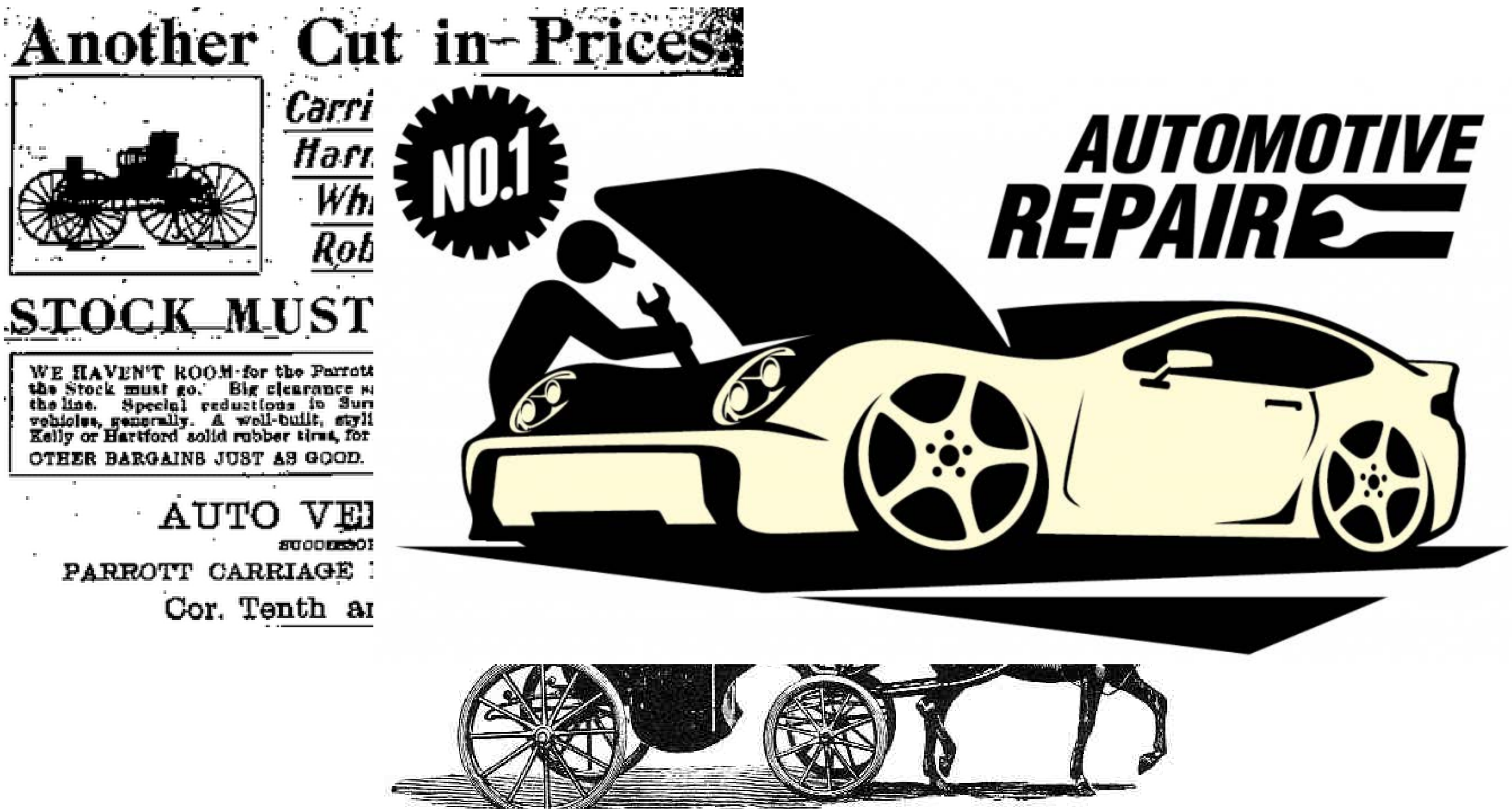
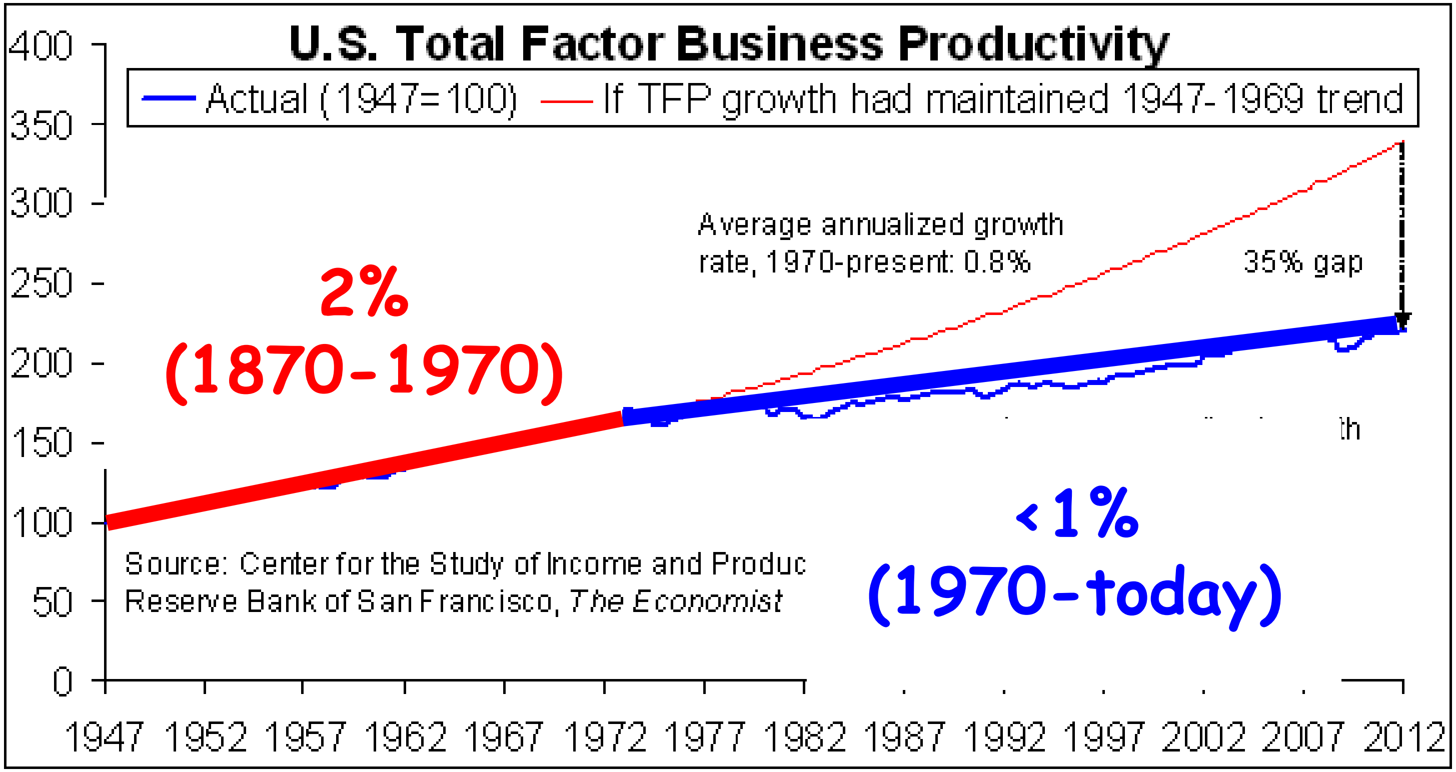
Wait a Second!

- Where are the exponential job losses?
- What about new jobs?



Wait a Second!

- Where are the exponential job losses?
- What about new jobs?
- Rate of productivity increase has slowed



Component Model of Jobs

- Jobs are not distinct monolithic entities.
- Jobs require skills, abilities, knowledge, …
  - Surgeon requires:
    - Finger dexterity
    - Reading
    - Image recognition
    - Planning
    - Active listening
    - Critical thinking
    - Assisting/caring for others

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Component Model of Jobs

- Jobs are not distinct monolithic entities.
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  - Surgeon requires:
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    - Active listening
    - Critical thinking
    - Assisting/caring for others

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Component Model of Jobs

- Jobs are not distinct monolithic entities.
- Jobs require skills, abilities, knowledge, …
  - Plumber requires:
    - Finger dexterity
    - Reading
    - Image recognition
    - Planning
    - Active listening
    - Critical thinking
    - ~~Assisting/caring for others~~
    - Housing codes

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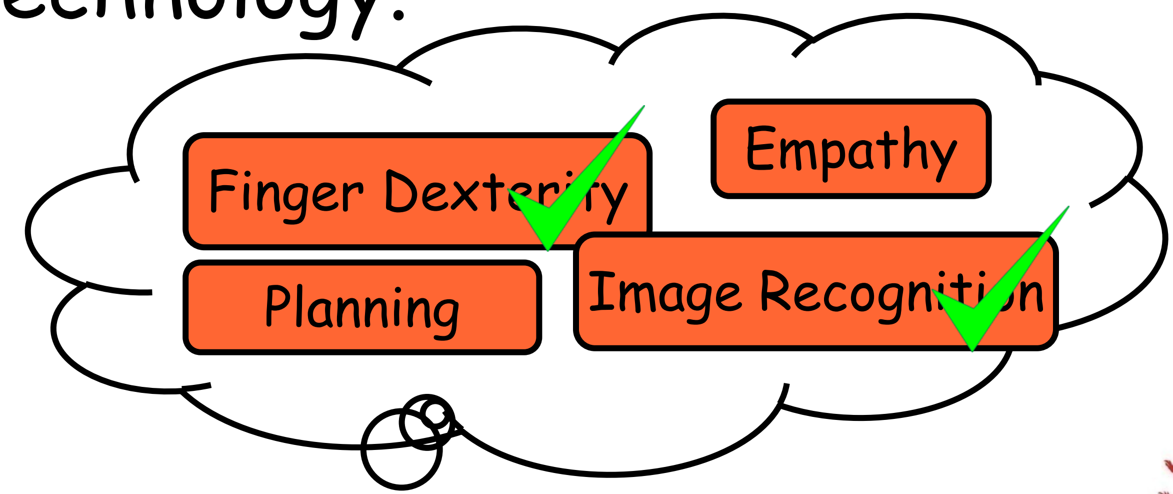
Component Model of Jobs

- Jobs are not distinct.
- Jobs require skills, abilities, knowledge, …
- Jobs replaced by technology only when all/most components can be done by technology.

Not Replaced



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Component Model of Jobs

- Jobs are not distinct monolithic entities.
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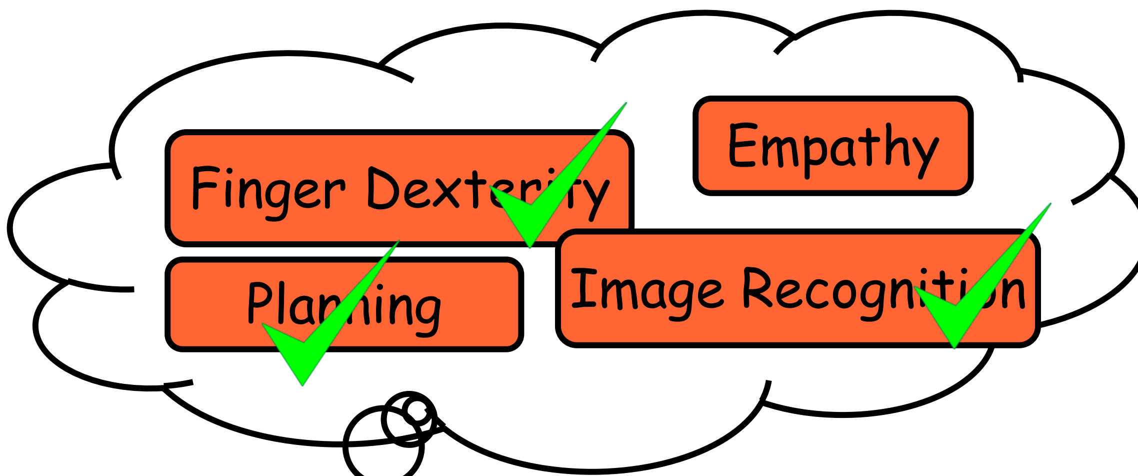
- Jobs replaced by technology only when all/most components can be done by technology.

Maybe Replaced?



Component Model of Jobs

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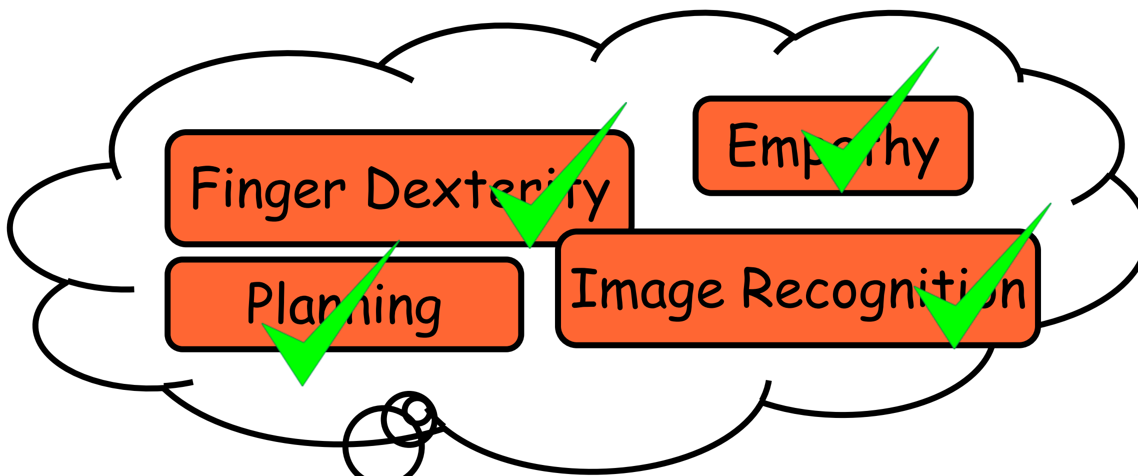
Replaced!



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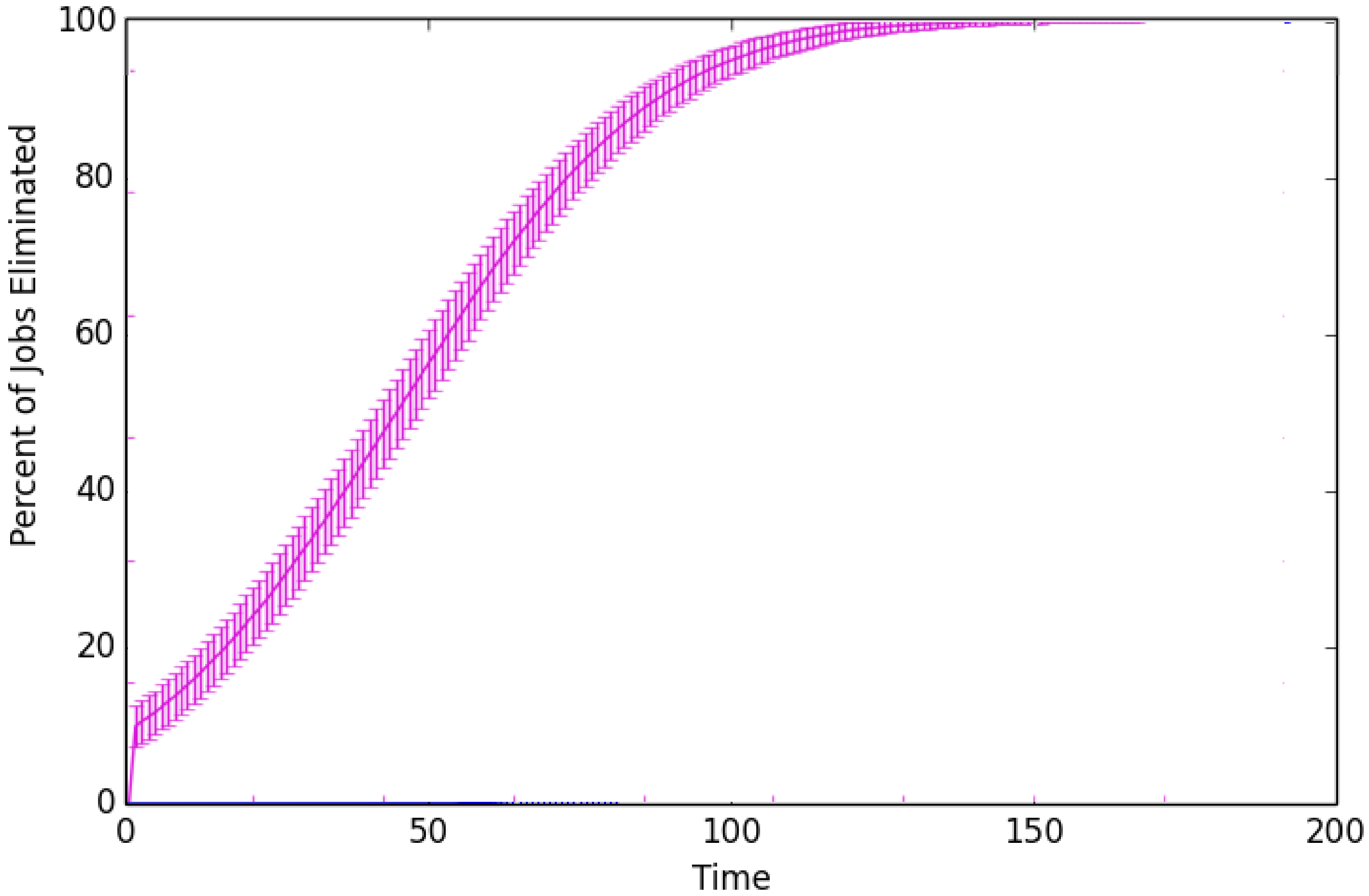
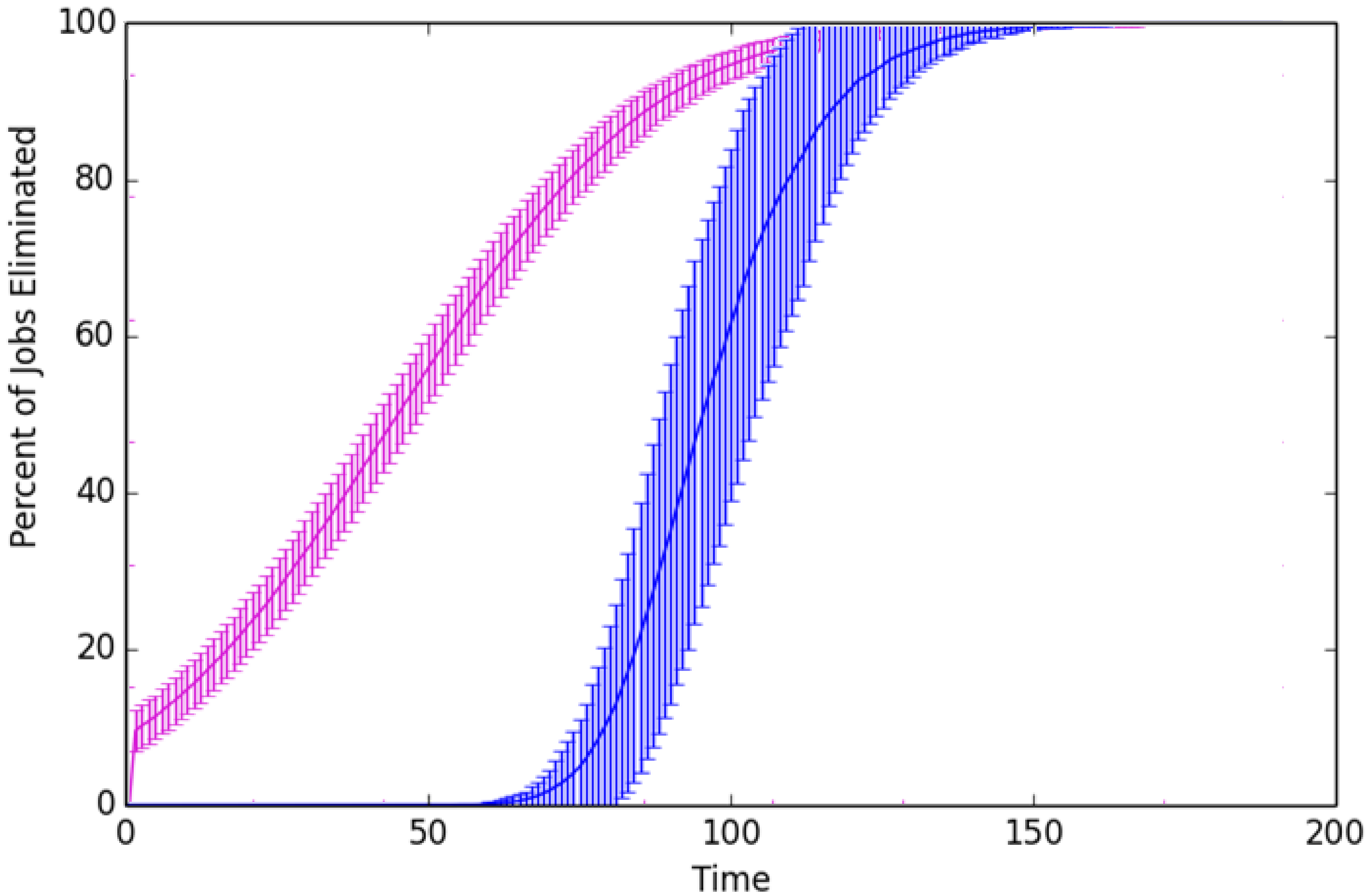
Monolithic Jobs Model Prediction



Component Jobs Model Prediction



Once it starts, change will be rapid

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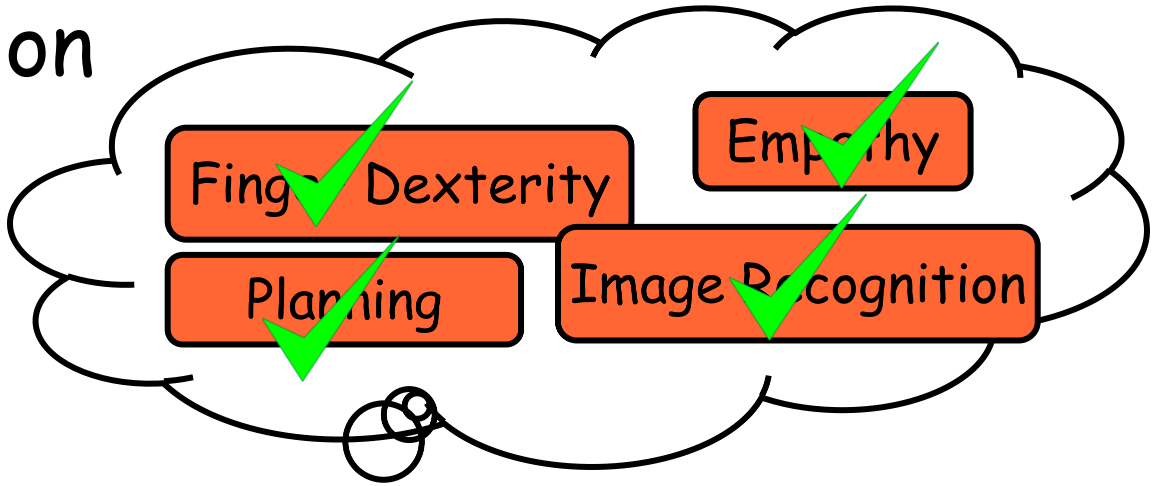
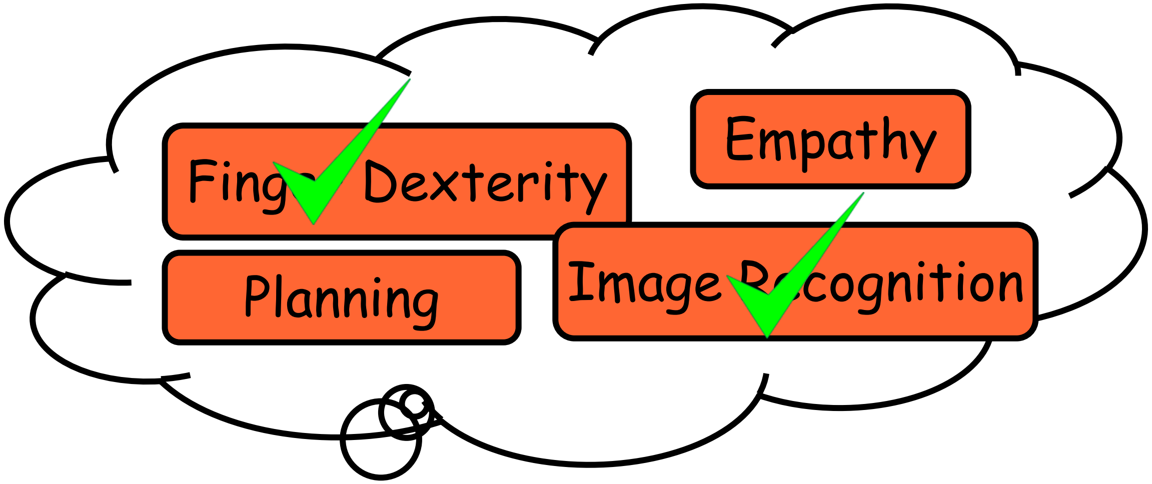
Technology's Impact on Jobs

- Substitution



Technology's Impact on Jobs

- Substitution
- Complementation



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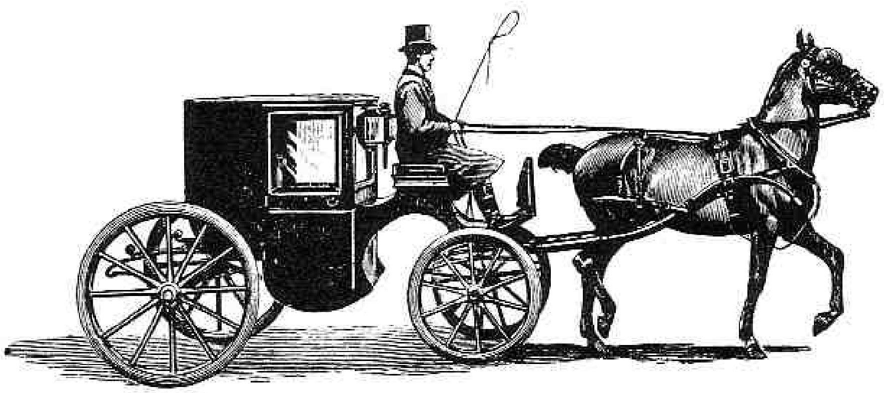
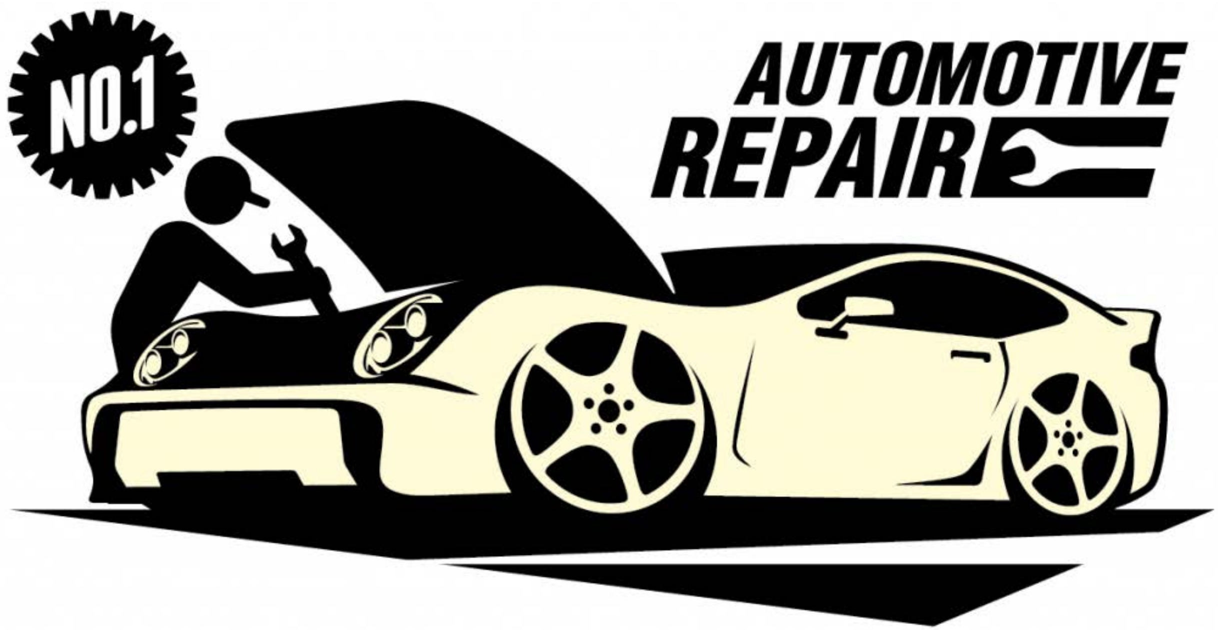
Technology's Impact on Jobs

- Substitution
- Complementation
- Elimination



Technology's Impact on Jobs

- Substitution
- Complementation
- Elimination
- Creation



Technology's Impact on Jobs

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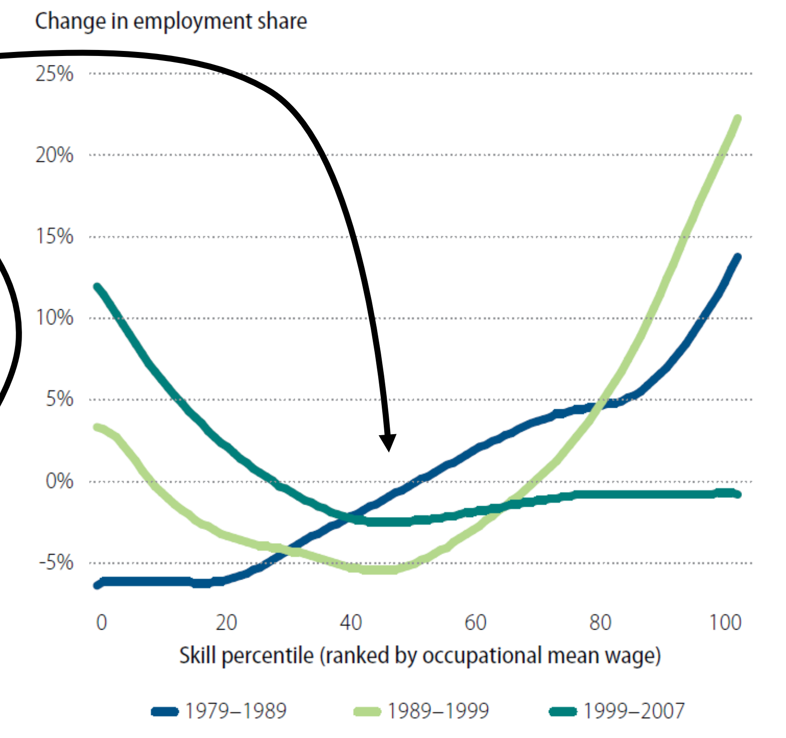

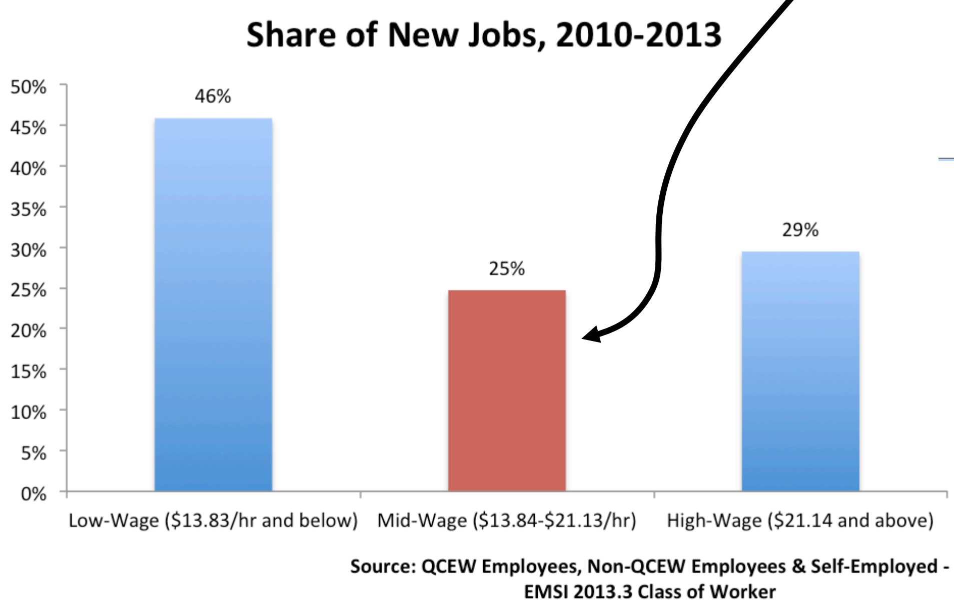

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Technology's Impact on Jobs

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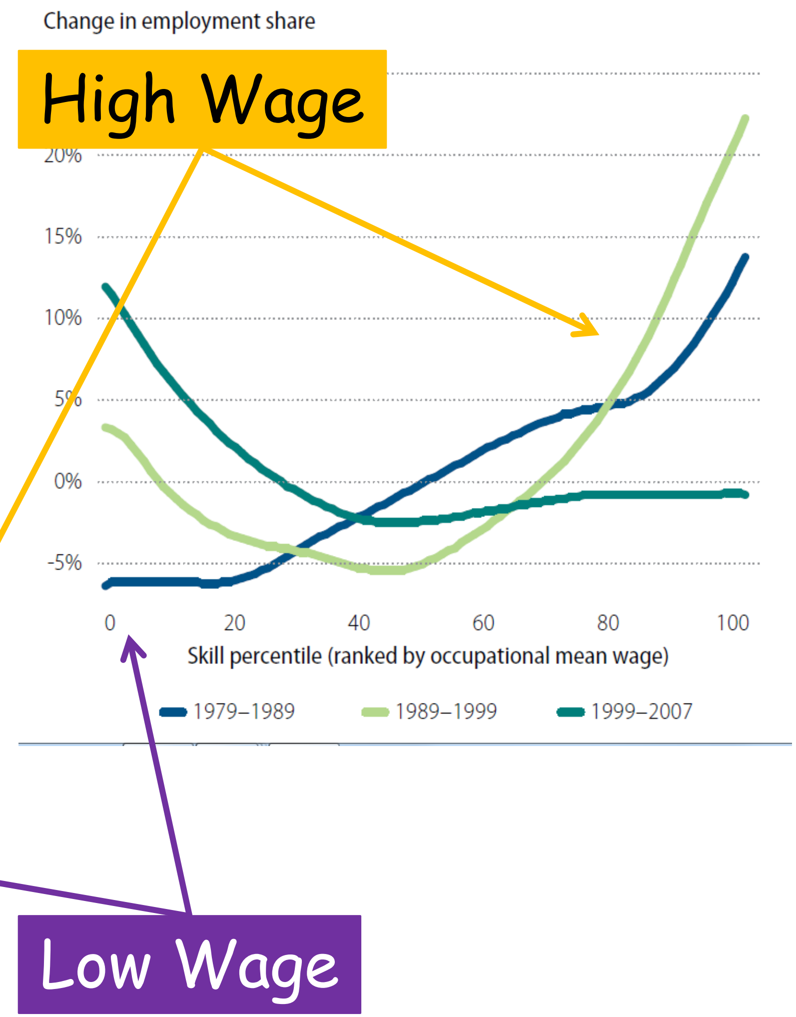
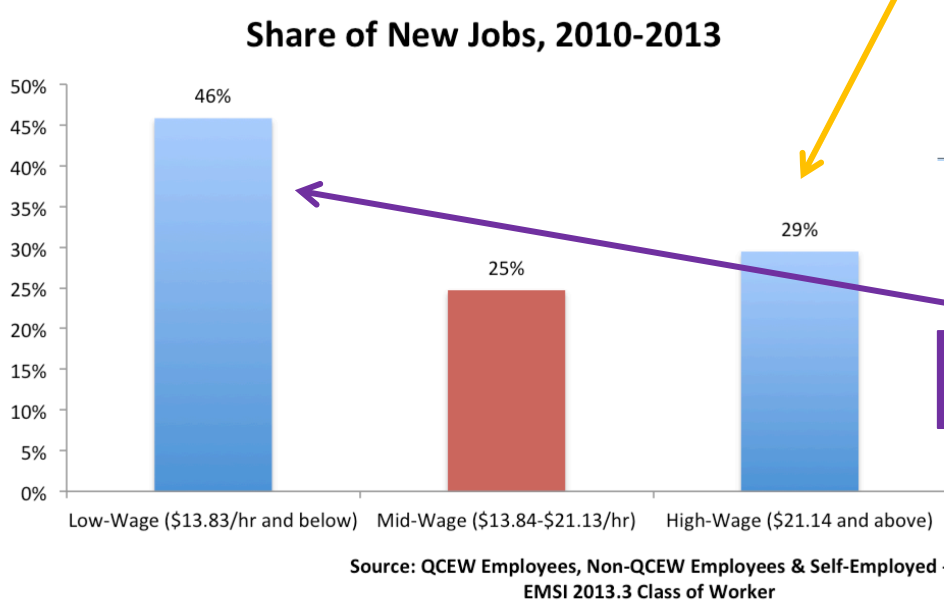
- Creation





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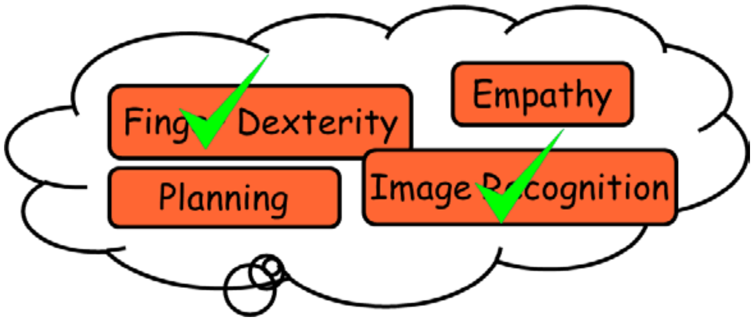
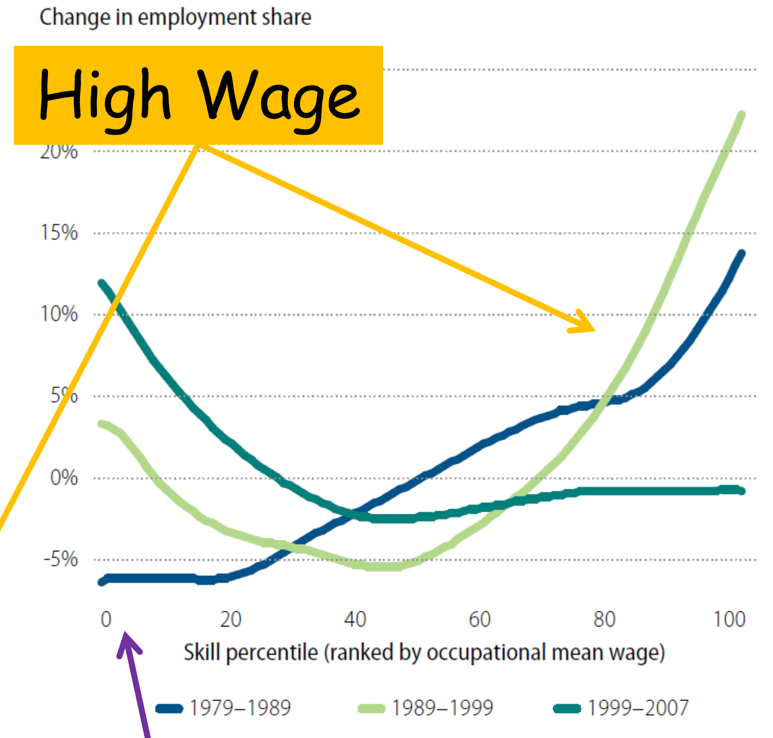
Technology's Impact

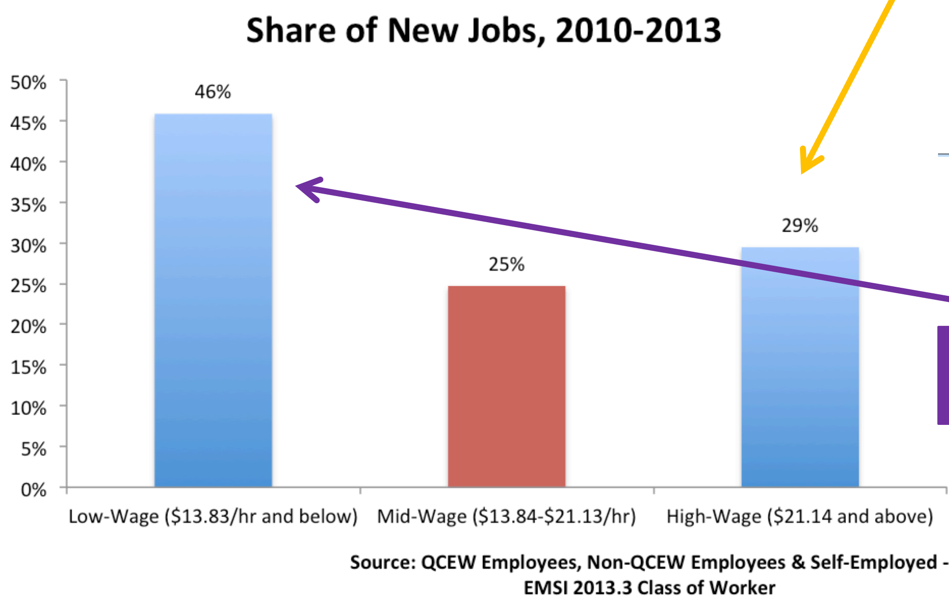
Hard for Tech/
Hard for Humans



Complementation



High Wage



Low Wage

Hard for Tech/
Easy for Humans

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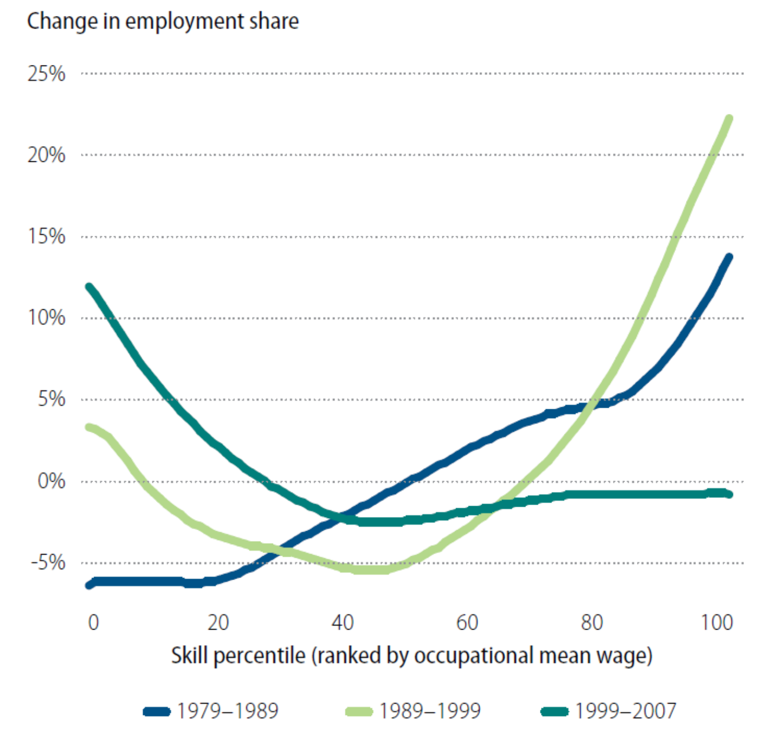
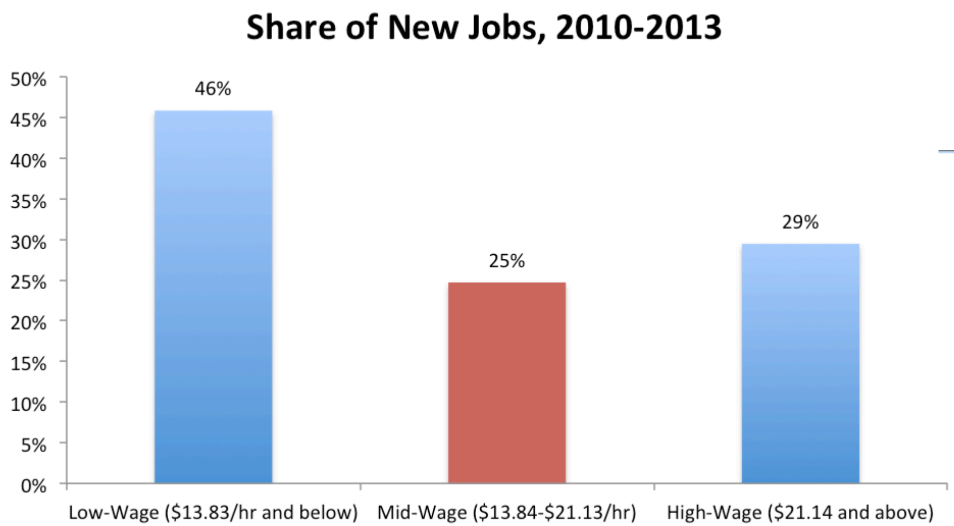
Technology's Impact on Jobs

- Substitution
- Complementation
- Elimination
- Creation



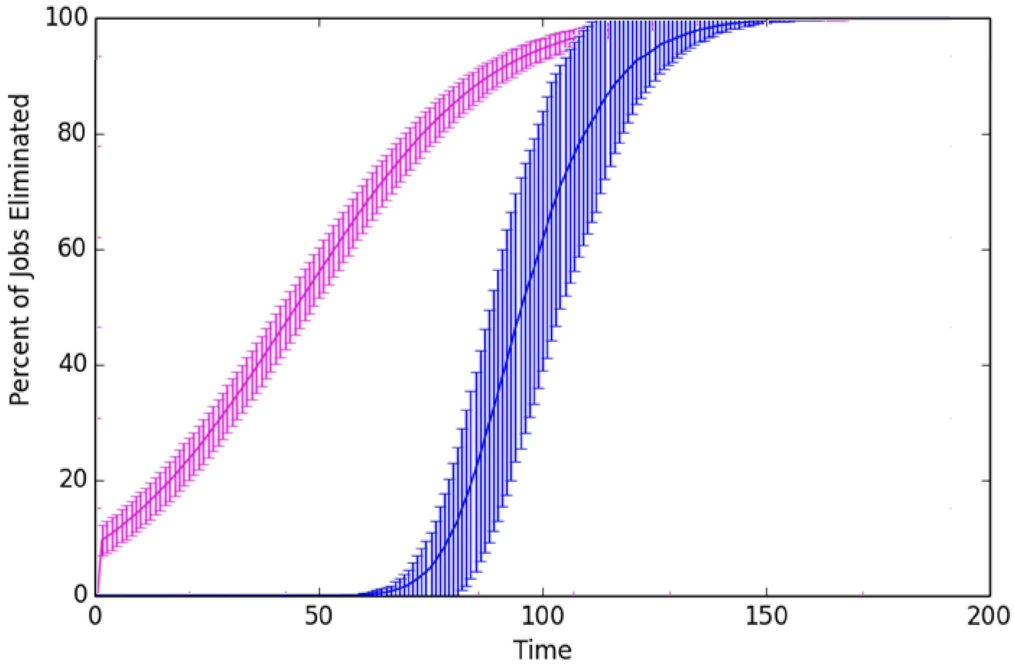


Source: QCEW Employees, Non-QCEW Employees & Self-Employed - EMSI 2013.3 Class of Worker

Productivity Inequality → Income Inequality

Wait a Second. Hmmm.

- Where are the exponential job losses? **Around the corner.**



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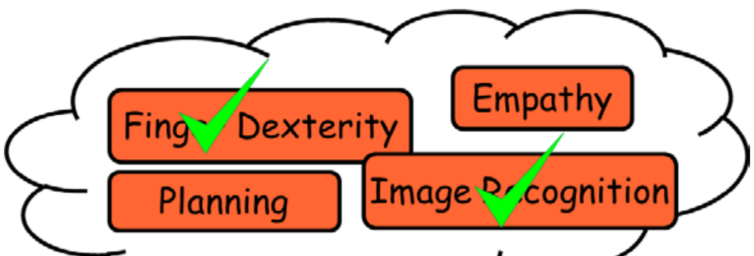
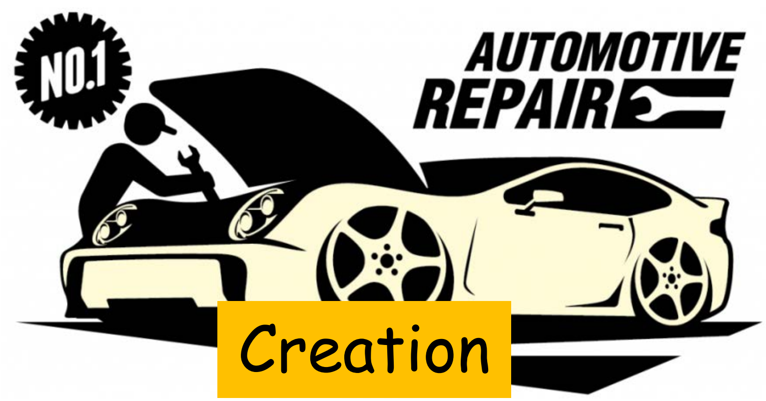
Wait a Second. Hmmm.

- Where are the exponential job losses?
  Around the corner.
- What about new jobs?
  How long do they remain in human domain?



Complementation



Creation

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What Are The New Jobs?

- Yes, there will be traditional jobs which require, e.g.,
  - Creativity
  - Empathy
  - Entrepreneurship
  - Social Skills

Aside:
Requires changing our educational goals and methods!

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What About New Jobs?

- Yes, there will be traditional jobs which require, e.g.,
  - Creativity
  - Empathy
  - Entrepreneurship
  - Social Skills
- But, as technology improves it will continue to take away jobs

Department of Artificial Empathy?

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What About New Jobs?

- Yes, there will be traditional jobs which require, e.g.,
  - Creativity
  - Empathy
  - Entrepreneurship
  - Social Skills
- But, as technology improves it will continue to take away jobs
- And, those that remain are low paying.

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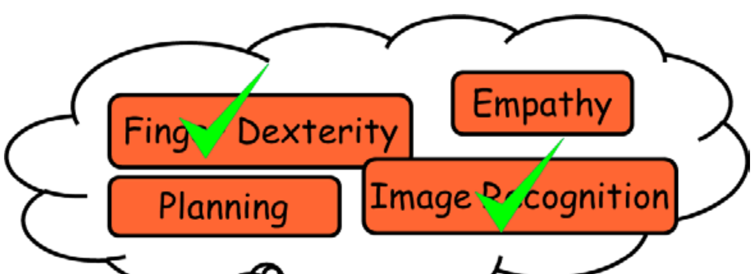
Wait a Second. Hmmm.

- Where are the exponential job losses?
  Around the corner.
- What about new jobs?
  How long do they remain in human domain?
- Rate of productivity increase has slowed
  Not, really.
  Average doesn't tell the whole story.



Complementation

Hard for Tech/
Easy for Humans

Hard for Tech/
Hard for Humans

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Not Much Work Now for Horses

TR2: Forever ended the horse as a factor of production.

Not Much Work Now for Horses

With respect to human labor:
TR3 is the last Technology Revolution

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~~Horror~~ or Opportunity?

- TR3 poses 2 existential questions for most everyone:
  - How to get the resources needed for life?
  - How to find meaning and dignity?

We Need a Change in Perspective

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Plenty of Resources

- TR3 economy produces an abundance of goods and services
  - Marginal Cost of Production approaches 0$
  - ∴Price approaches 0$

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Plenty of Resources

- TR3 economy produces an abundance of goods and services
- Most people are unemployable
  - Most jobs are substituted or destroyed
  - (some are created for a limited time.)
  - (Most jobs left pay poorly)

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Plenty of Resources

- TR3 economy produces an abundance of goods and services
- Most people are unemployable (Technology is just cheaper, better, …)
- What do they do?

stackoverflow

© 2016 Goldstein

StackOverflow

stackoverflow.com/questions/33279374/why-am-i-getting-tiff-page-1-not-found-lebtonica-warning-in-te

StackExchange sign up log in tou

stackoverflow Questions Jobs

Why am I getting “tiff page 1 not found” Lebtonica warning in Tesseract

ABBYY FineReader Engine
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Request a free trial

9

1

I just started using Tesseract.

I am following the instructions described here.

I have created a test image like this:

```
training/text2image --text=test.txt --outputbase=eng.Arial.exp0 --font='Arial' --fonts_dir=/
```

Now I want to train the Tesseract like follows:

```
tesseract eng.Arial.exp0.tif eng.Arial.exp0 box.train
```

Here is the output that I have:

```
 leptonica-1.72
  libjpeg 8d (libjpeg-turbo 1.3.0) : libpng 1.2.50 : libtiff 4.0.3 : zlib 1.2.8
```

Any idea why this happens?

Thanks!

ocr tesseract

share improve this question edited Oct 22 '15 at 11:05 asked Oct 22 '15 at 10:56 Mikayel Egibyan 53 ● 5

This question has an open bounty worth +50 reputation from Nick Weaver ending **in 1 hour**.

This question has not received enough attention.

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Mini Reputation Economies

stackoverflow

- Members of this community:
  - Ask and answer programming questions
  - Very high quality.
  - No one is paid (in dollars)
- The Economics:
  - Users gain reputation by participating
  - Reputation gives them privileges
  - Reputation can be traded

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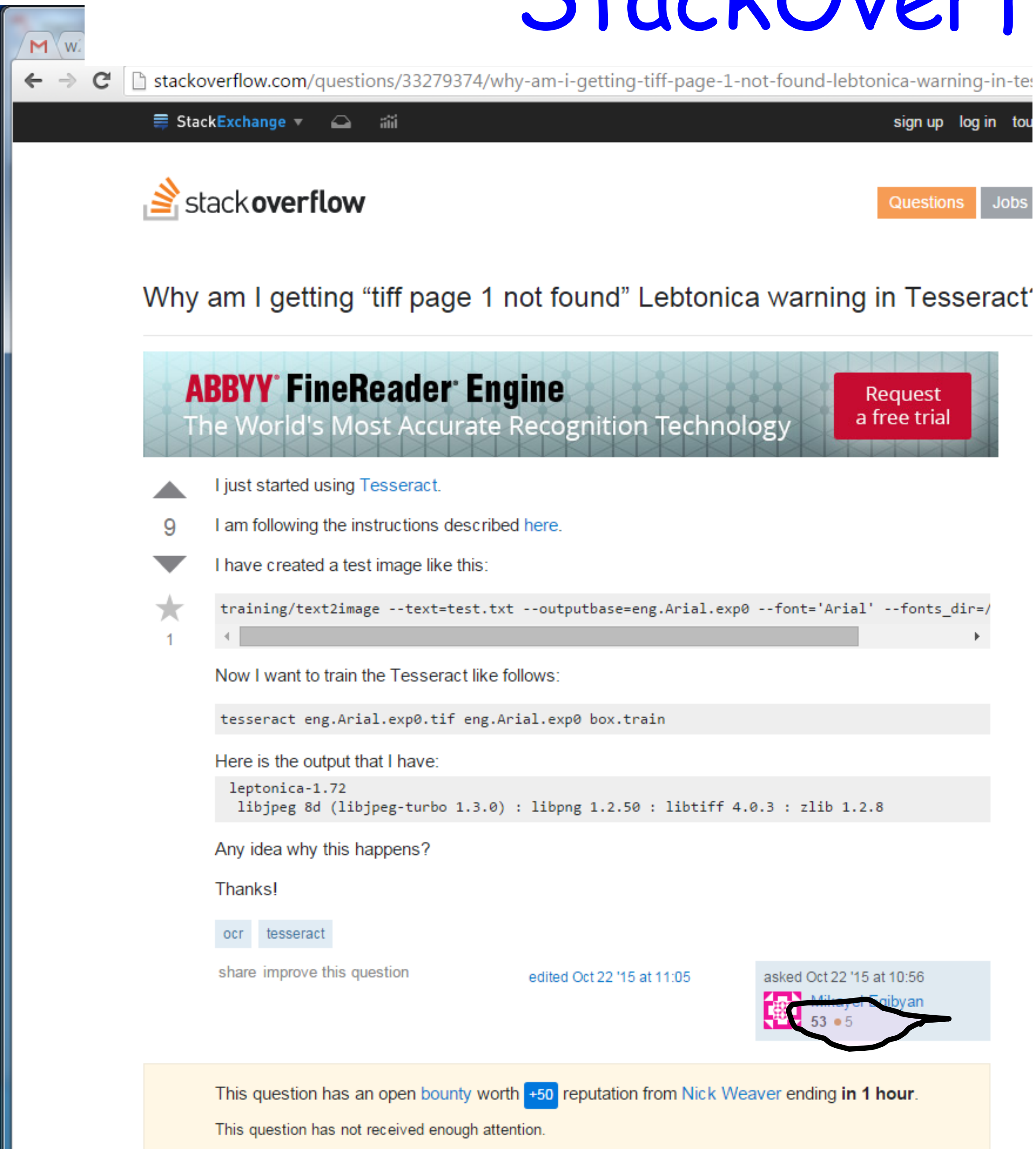
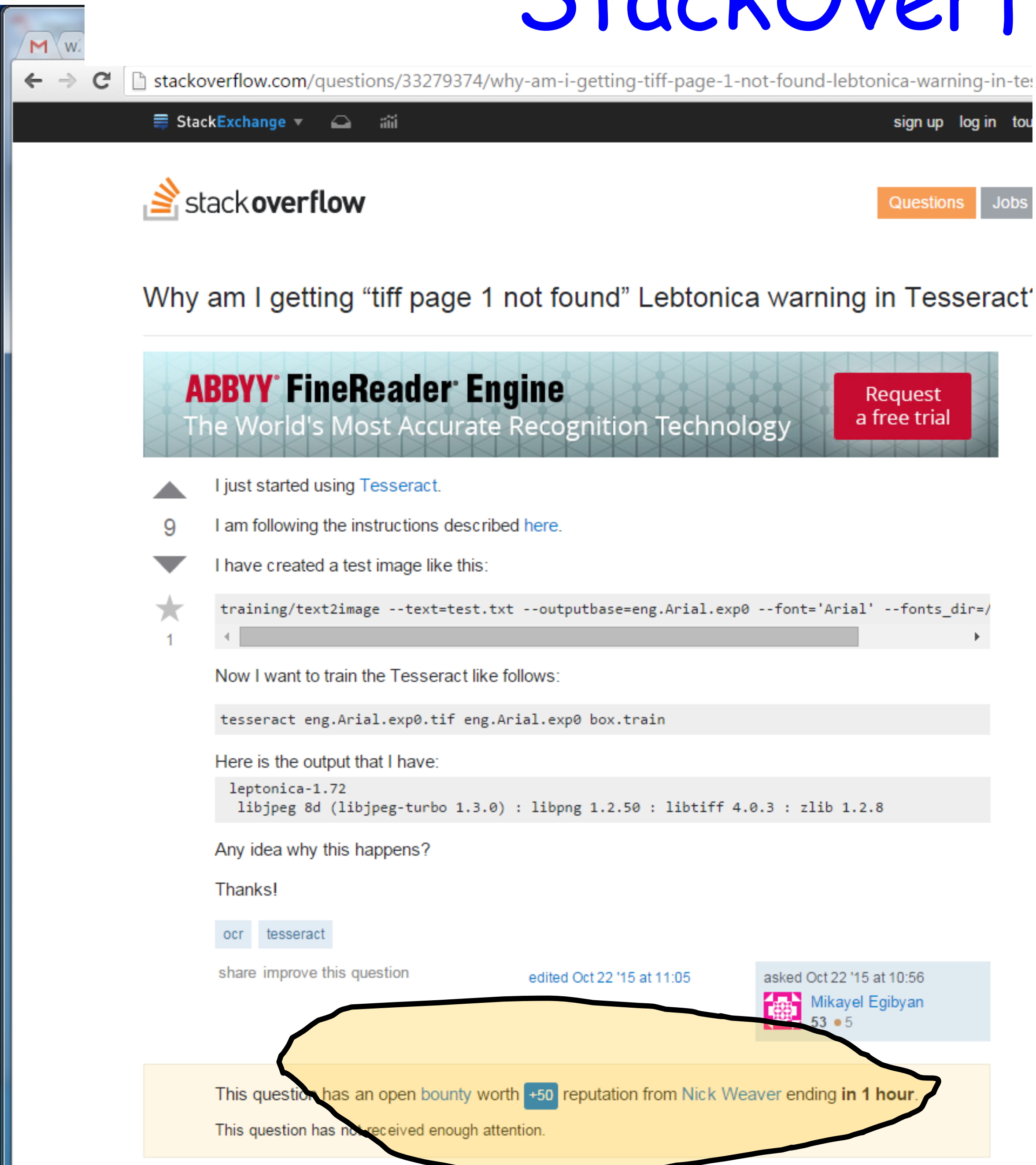
StackOverflow



Reputation as an “Asset”

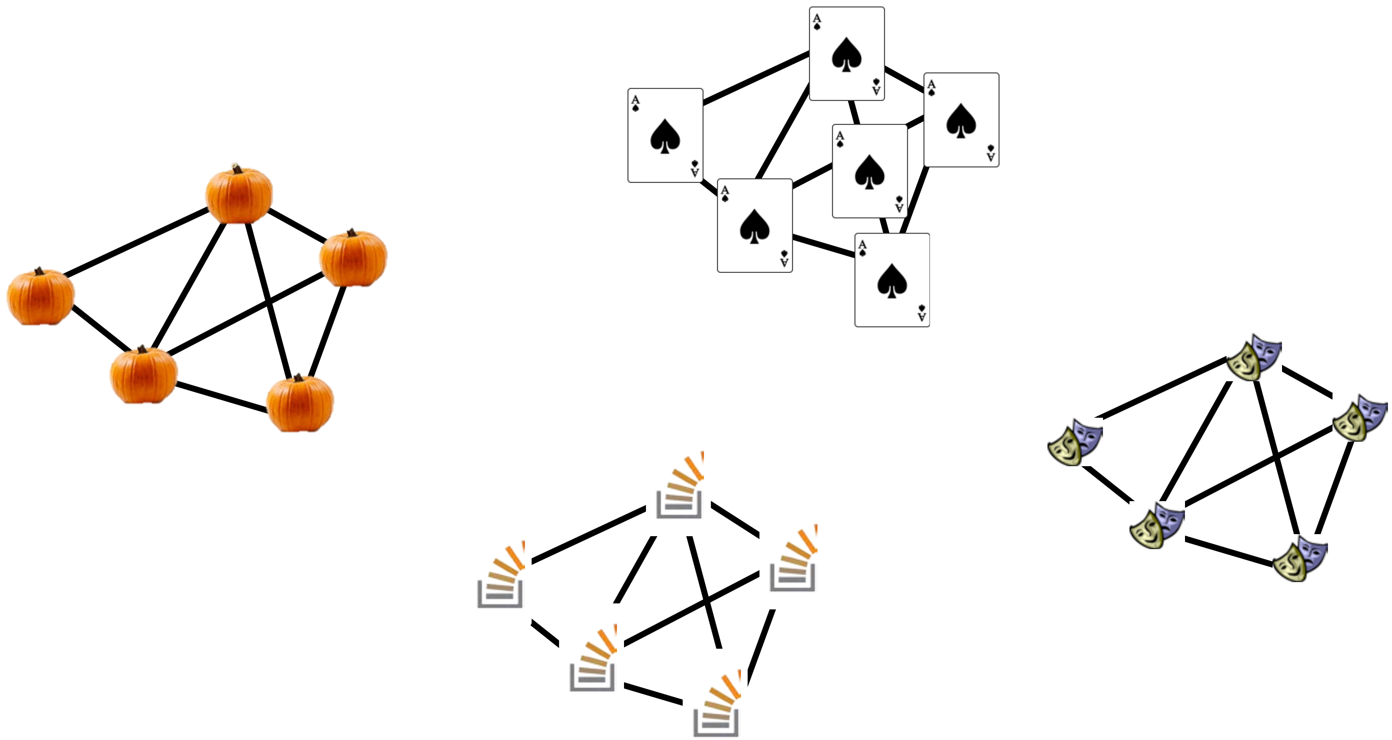
StackOverflow



Reputation as a “Currency.”

Not Just Programming

Many Communities



In each of these communities people can pursue their passion, finding meaning, pleasure & dignity.

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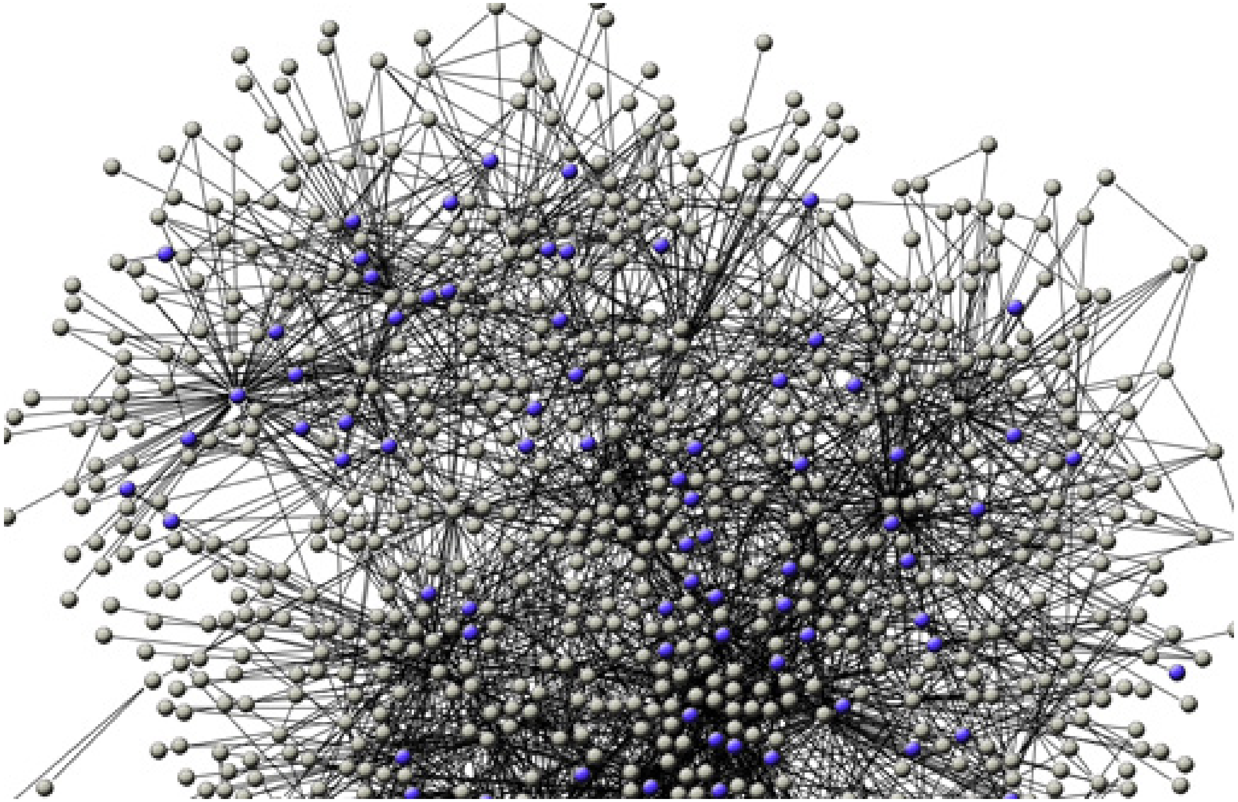
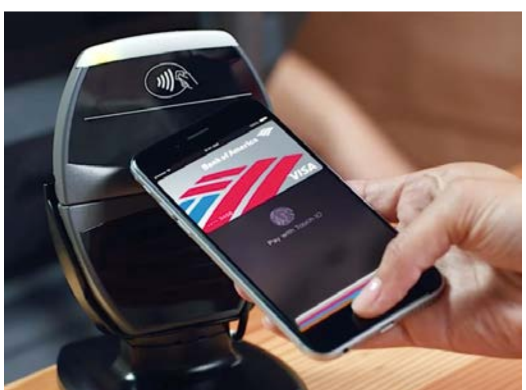
TR3 Enables Reputation Economies

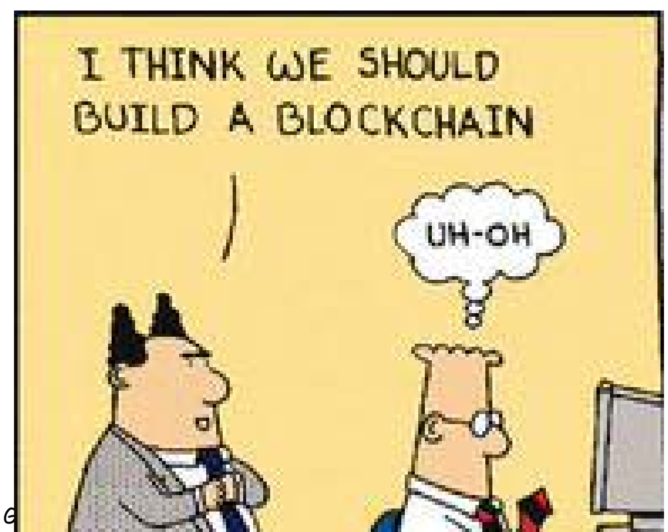
- Expanding networks enable people to find and connect to other people in their niche (no matter how weird)



TR3 Enables Reputation Economies

- Expanding networks enable people to find and connect to other people in their niche (no matter how weird)
- Computational resources provide the accounting systems, transactional mechanisms, etc. needed to track and trade reputation





© 2016 G

TR3 Enables Reputation Economies

- Expanding networks enable people to find and connect to other people in their niche (no matter how weird)
- Computational resources provide the accounting systems, transactional mechanisms, etc. needed to track and trade reputation
- Turning reputation into a currency addresses both existential questions.

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Reputation as Money

- What makes money work:
  - A metric of value
  - A method of accounting
  - Trust that it is transferable

Today's Money

- What makes money work:
  - A metric of value
  - A method of accounting
  - Trust that it is transferable

- So today's currency is:
  - A static token
  - Backed by the state

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Today's Money

- What makes money work:
  - A metric of value
  - A method of accounting
  - Trust that it is transferable

- So today's currency is:
  - A static token
  - Backed by the state

But remember, it has no intrinsic value!

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TR3 & Money

- Currency doesn't need to be static token.
- Nor backed only by the state.

Pure reputation economy?

Let's examine a transitional Economy

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TR3 & Money

- Currency doesn't need to be static token.
- Nor backed only by the state.

- Imagine that everyone can issue their own money backed by their reputation.

Who accepts Seth-Dollars?

- Certainly, I must.
- Anyone who expects to trade with me.
- People in my communities
- Most anyone who expects to trade with someone I trade with, etc.
- The further the separation the less likely.
- Everyone will decide their risk t

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Who accepts Seth-Dollars?

- Certainly, I must.
- Anyone who expects to trade with me.
- People in my communities
- Most anyone who expects to trade with someone I trade with, etc.
- The further the separation the less likely.
- Everyone will decide their risk tolerance.

Currency is "executable" and can have means to reduce risk.

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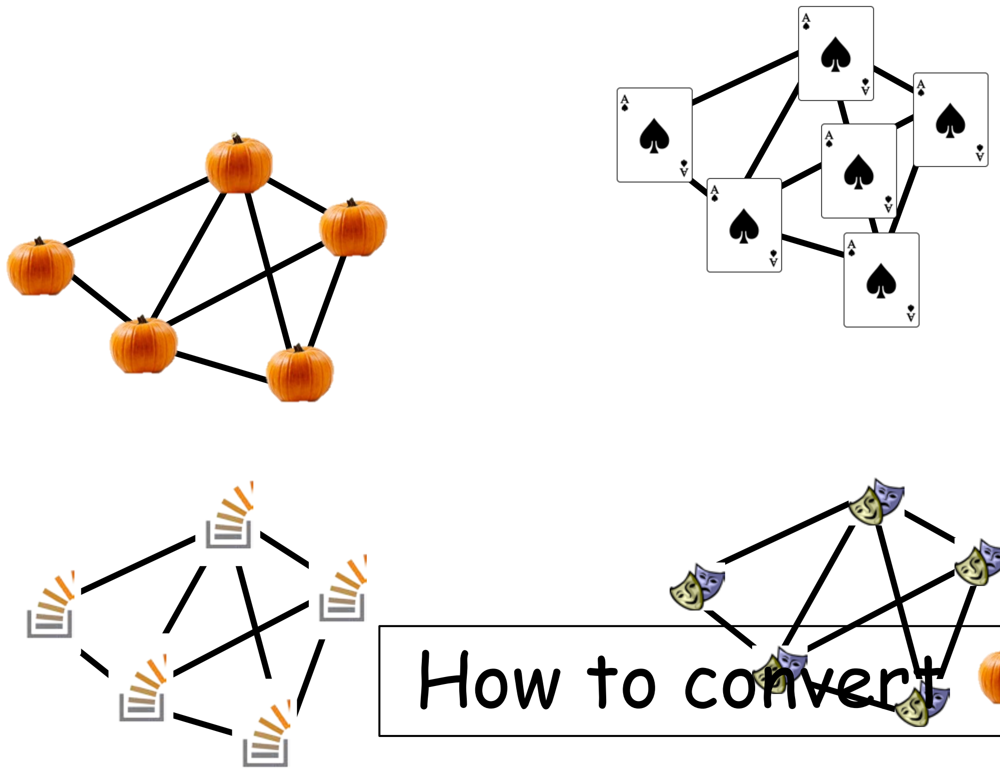
We Are All
Members of Multiple Communities



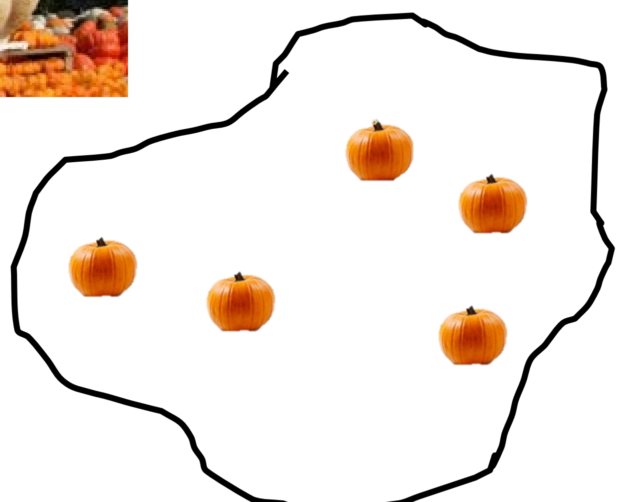
How to convert $ into $?

Reputation$ Addresses Both Existential Questions

Beni Loves to grow pumpkins

Reputation$ Addresses Both Existential Questions

He is part of the "Pumpkin Network"



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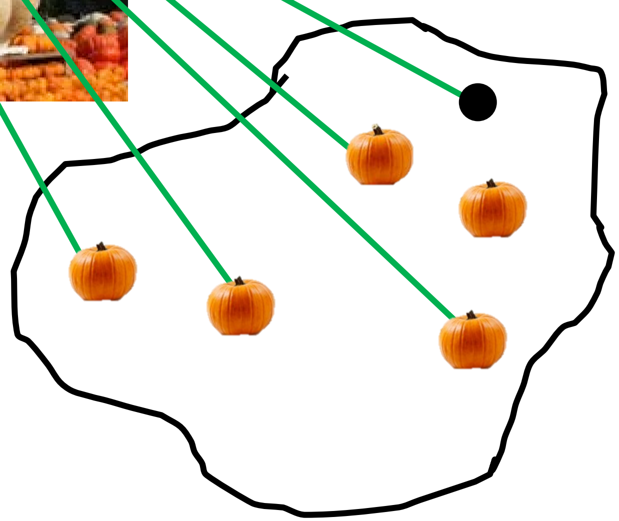
Reputation$ Addresses Both Existential Questions



People "give" reputation to Beni

Reputation$ Addresses Both Existential Questions

Beni Spends reputation on pumkin seeds
or
Food
or
...

Reputation$ Addresses Both Existential Questions

As Beni pursues his passion he gets the resources he needs.

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Bootstrapping

- Government will back first X$ of every citizen.
  - Doesn't really cost anything.
  - Think FDIC.

- Everyone's reputation(s) will act as a multiplier on their currency.

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Opportunity!

- TR3 provides answers to:
  - How to get the resources needed for life?
  - How to find meaning and dignity?

We Need a Change in Perspective

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Impacts of TR3

- Without Plan
  - Massive disr
  - Increased w
  - Bad stuff

- With Planning
  - An amazing future
- Best chance for success is a bottom-up, distributed system that uses the market
  ➔ Reinvent Money based on Reputation

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Impacts of TR3

- Without Planning:
  - Massive disruption
  - Increased wealth inequality
  - Bad stuff
- With Planning
  - An amazing future
- Best chance for success is a bottom-up, distributed system that uses the market
  ➔ Reinvent Money based on Reputation

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TAs for Fall 2016

- The instructors for 15/18-213/513 need you

  please apply if you did well in 213 and want to be a TA

You?

https://www.ugrad.cs.cmu.edu/ta/F16/

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Office Hours

- I am there every week…
- It ~~is~~ was usually not very crowded
- Just come by to check in even if you do not have a question

Thank you for coming to check in and hang out!

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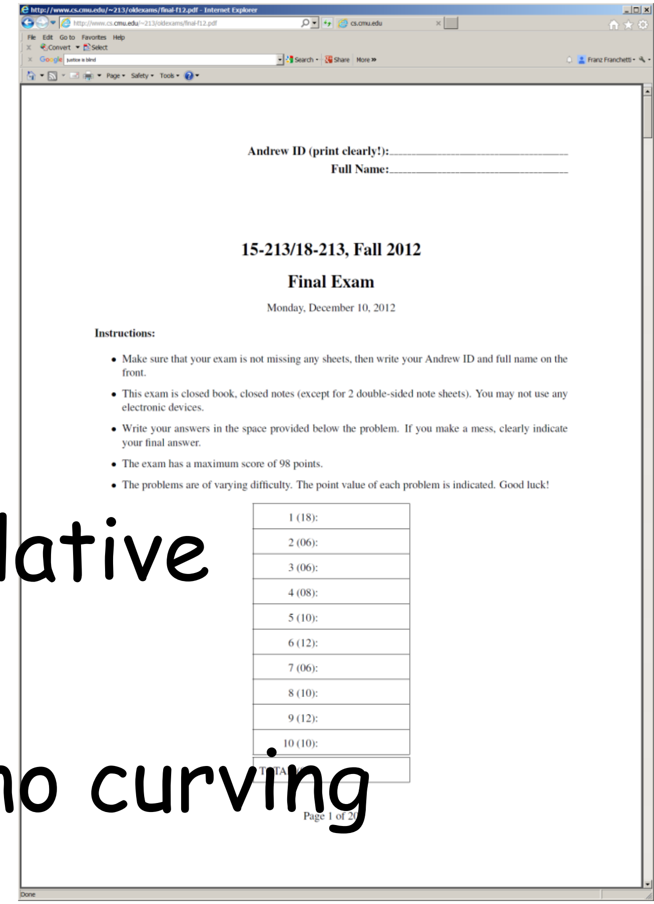
Final Exams and Grade

- Please study well
  imitate machine learning

- Attend the *Final Review*
  May 1, Rashid Auditorium, 6pm

- Remember the exam is cumulative
  http://www.cs.cmu.edu/~213/exams.html



Andrew ID (print clearly!):

Full Name:

15-213/18-213, Fall 2012

Final Exam

Monday, December 10, 2012

Instructions:

- Make sure that your exam is not missing any sheets, then write your Andrew ID and full name on the front.
- This exam is closed book, closed notes (except for 2 double-sided note sheets). You may not use any electronic devices.
- Write your answers in the space provided below the problem. If you make a mess, clearly indicate your final answer.
- The exam has a maximum score of 98 points.
- The problems are of varying difficulty. The point value of each problem is indicated. Good luck!

1 (18):	
2 (06):	
3 (06):	
4 (08):	
5 (10):	
6 (12):	
7 (06):	
8 (10):	
9 (12):	
10 (10):	
TOTA	

Page 1 of 2

- Grading algorithm: (almost) no curving
  exam/lab distribution:
  http://www.cs.cmu.edu/~213/syllabus/syllabus.pdf
  weight of labs: http://www.cs.cmu.edu/~213/assignments.html

- Double-check your scores
  get in touch with us if anything looks wrong in autolab

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Course Evaluation

- Please fill out the course evaluation
  you should have and will receive email about it
- Please provide constructive comments
  this is your chance to make 213 better
- Please be fair with your scores
  the university administration analyzes these numbers
- TA evaluation
  https://www.ugrad.cs.cmu.edu/ta/S16/feedback

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Thank You!

Home
Schedule
Assignments
Exams
Lab Machines
Resources
Style Guideline
FAQ

Textbook
Autolab

15-213: Intro to Computer Systems, Spring 2016

Date		Lecture/Recitation	Lec	Reading	Labs
Jan	11	***No recitations***			
Jan	12	Overview (pdf , video)	ff/scg	1	
Jan	14	Bits and Bytes (pdf , video)	ff	2.1	L1 (datalab) out
Jan	18	***MLK Day, No recitation*** / *Linux Boot Camp* (pdf , pptx , old pdf)			
Jan	19	Integers (pdf , video)	ff	2.2-2.3	
J[illegible]	[illegible]	[illegible]ting Point (pdf , vide[illegible]	ff	[illegible]4	
Jan	[illegible]5	*Re[illegible]tat[illegible]* (p[illegible]f [illegible]pt[illegible])			
Jan	[illegible]6	Ma[illegible]hin[illegible] Pr[illegible] [illegible]ics ([illegible], vi[illegible]eo)	[illegible]	[illegible]1-3.5	
Jan	28	Machine Prog: Control (pdf , video)	scg	3.6	L1 due, L2 (bombla
Feb	1	*Recitation 4* (pdf , odp)			
Feb	2	Machine Prog: Procedures (pdf , video)	scg	3.7	
Feb	4	Machine Prog: Data (pdf , video)	ff	3.8-3.9	
Feb	8	*Recitation 5* (pdf , odp)			
Feb	9	Machine Prog: Advanced (pdf , video)	ff	3.10	L2 due, L3 (attackla
Feb	11	Code Optimization (pdf , video)	ff	5	
Feb	15	*Recitation 6* (pdf , odp)			
Feb	16	The Memory Hierarchy (pdf , video)	ff	6.1-6.3	L3 due, L4 (cachela
Feb	18	Cache Memories (pdf , video)	ff	6.4-6.7	
Feb	22	*Recitation 7* (pdf , odp , C Bootcamp pdf)			

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