# What does the Future Hold?

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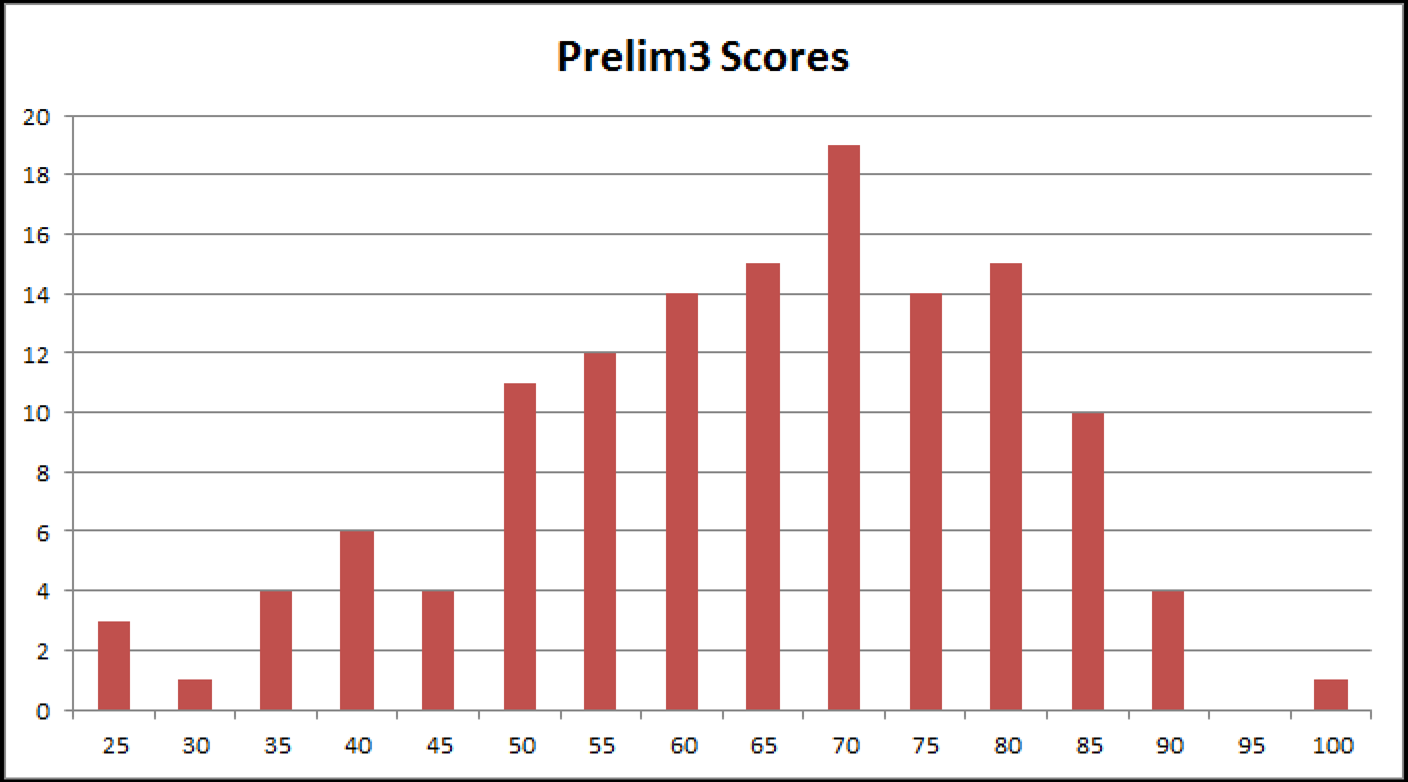
**CS 3410, Spring 2012**
Computer Science
Cornell University

# Announcements

## Prelim3 Results

- Mean 62.2 ± 15.5 (median 64.5), Max 97
- Pickup in Homework Passback Room



# Announcements

How to improve your grade?

***Submit a course evaluation and drop lowest homework score***

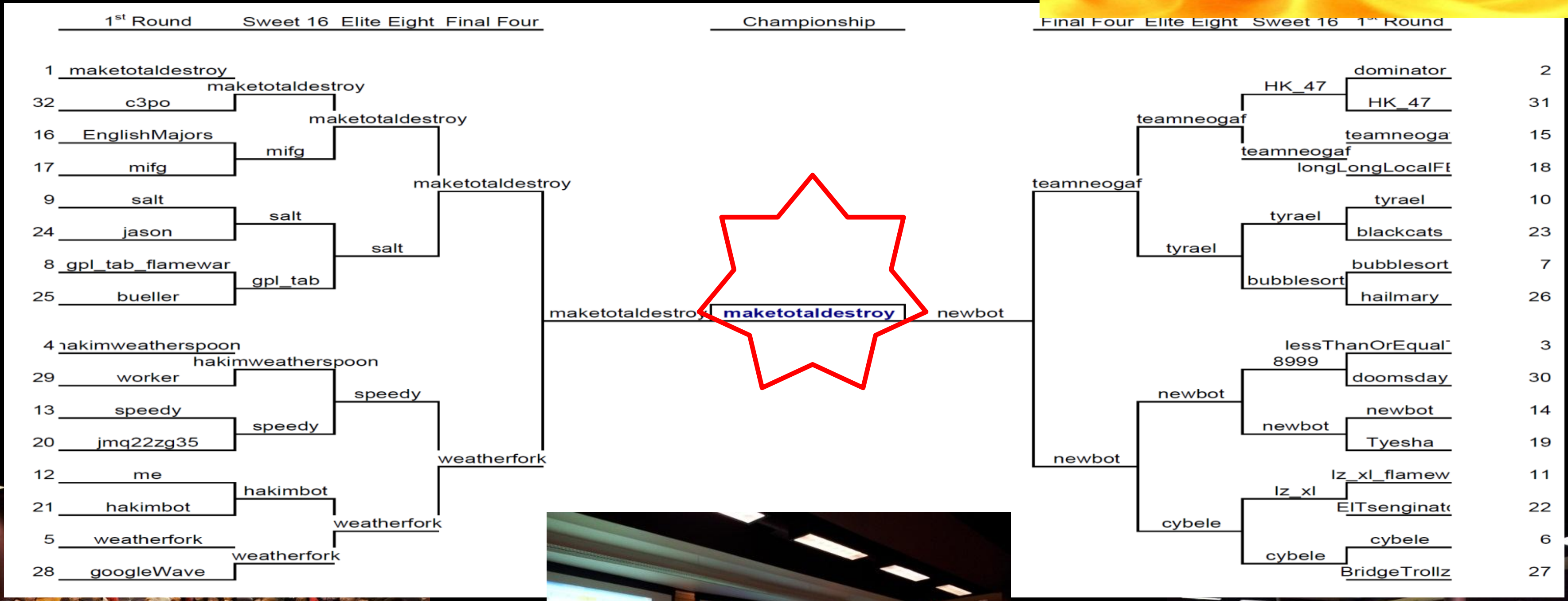
- To receive credit, Submit before Monday, May 7th

# Announceme

## FlameWar Pizza Party was great!

- Winner: Team ***MakeTotalDestroy***

Kenny Deakins and Luis Ruigomez


# Announcements

Final Project

Design Doc sign-up via CMS

sign up Sunday, Monday, or Tuesday

May 6th, 7th, or 8th

Demo Sign-Up via CMS.

sign up Tuesday, May 15th

or Wednesday, May 16th

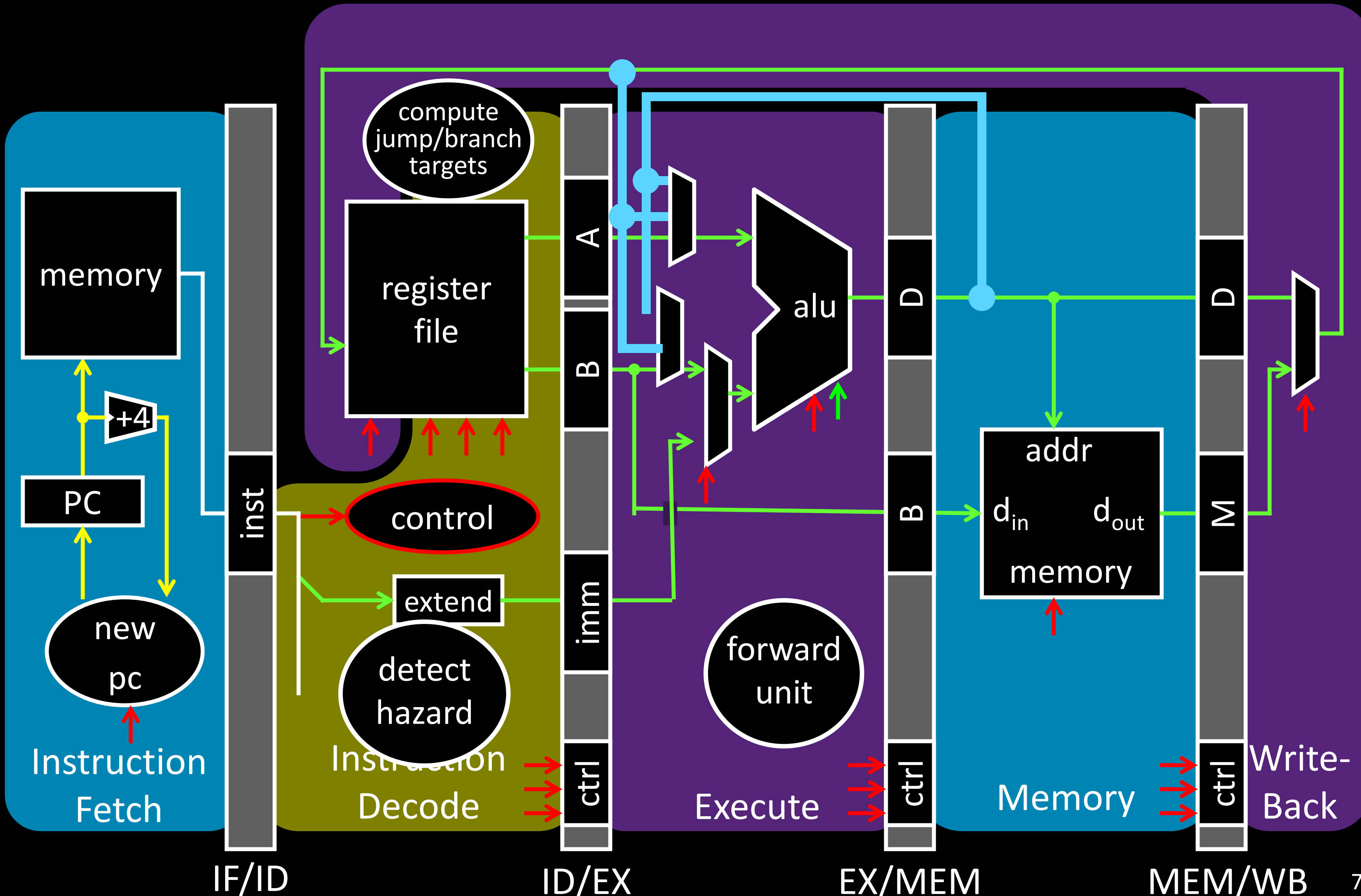
CMS submission due:

- Due 6:30pm Wednesday, May 16th

# Big Picture about the Future

# Big Picture

How a processor works? How a computer is organized?



# What’s next?

More of Moore

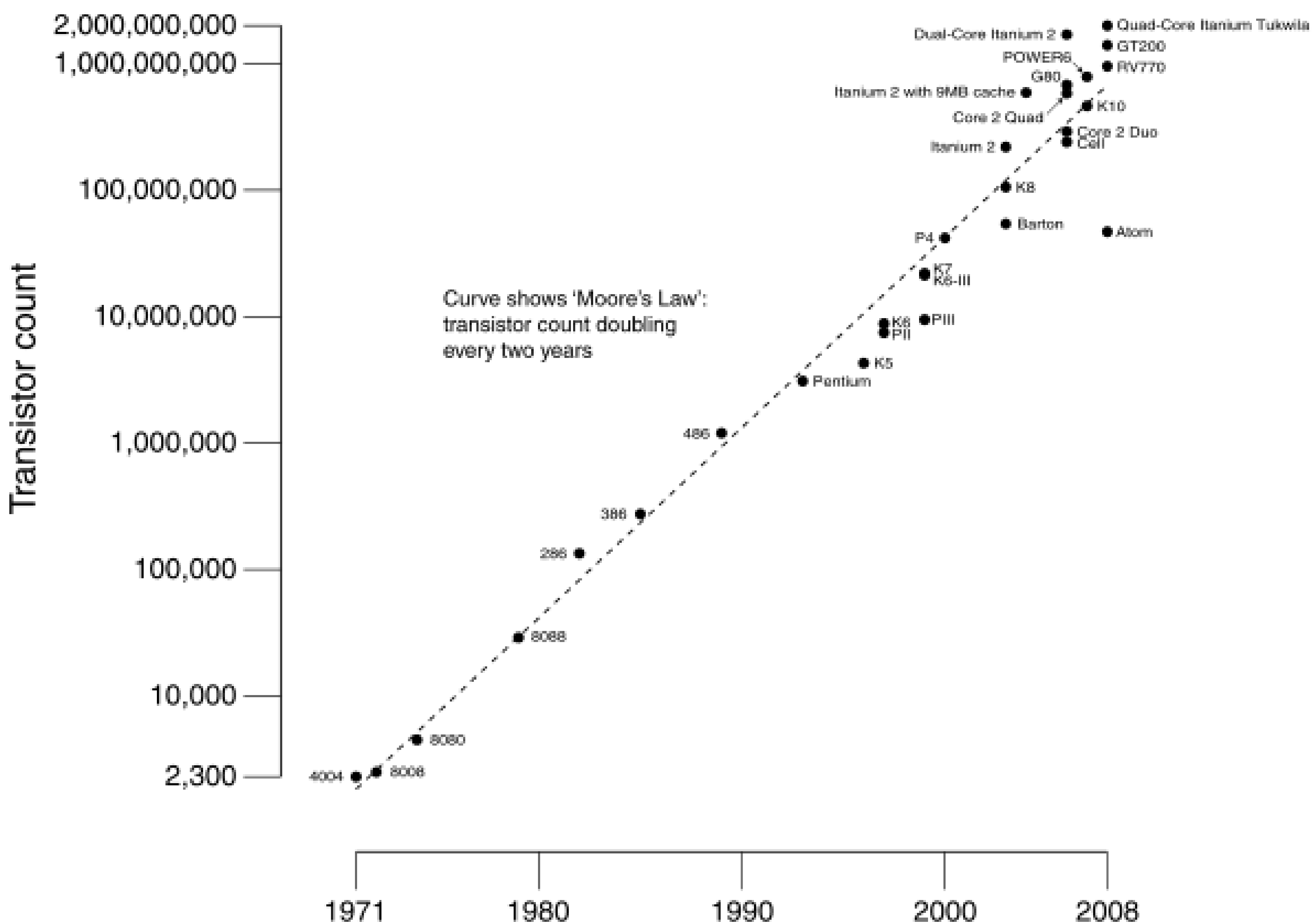
# Moore's Law

Moore's Law introduced in 1965

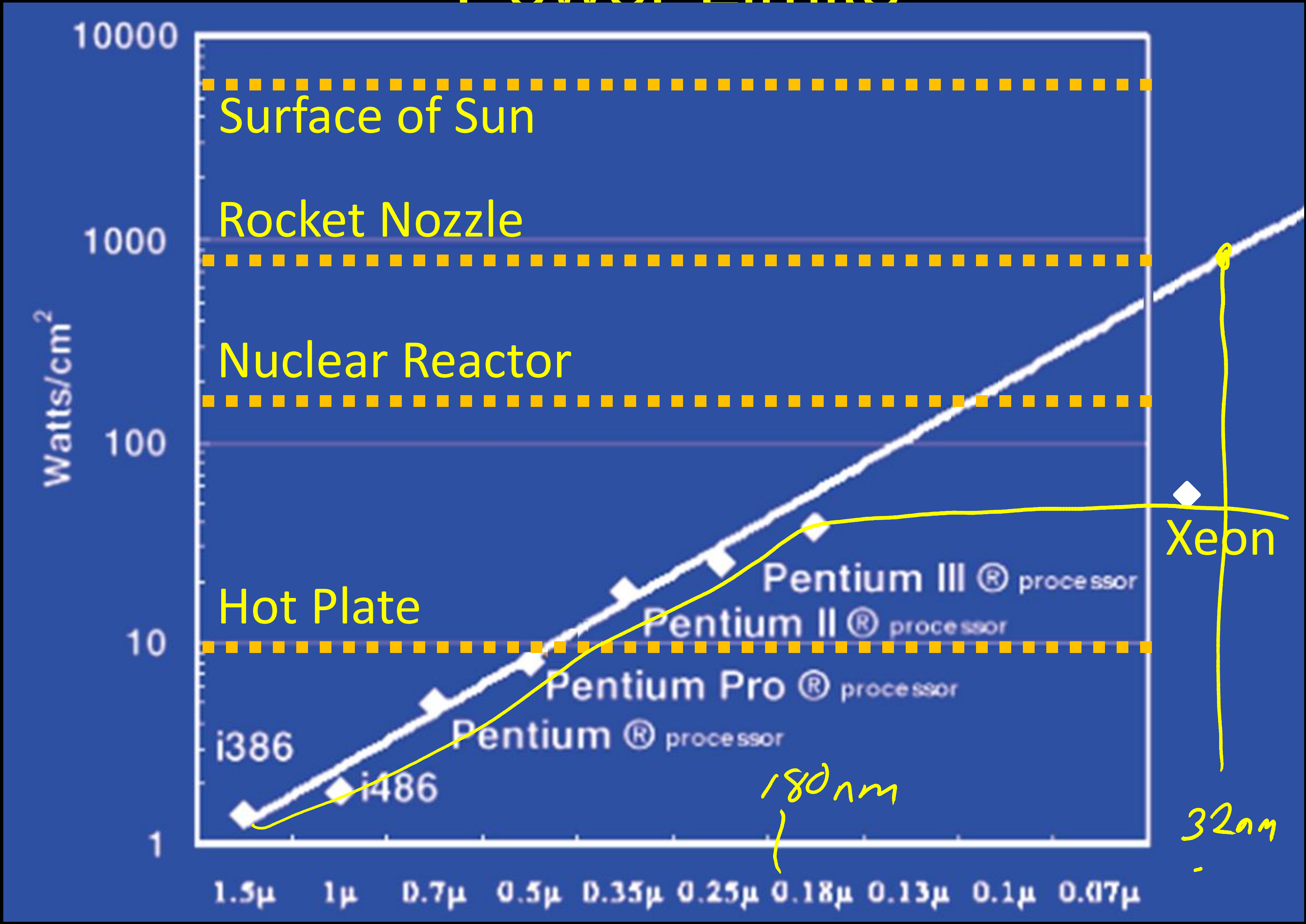
- Number of transistors that can be integrated on a single die would double every 18 to 24 months (i.e., grow exponentially with time).

Amazingly visionary

- 2300 transistors, 1 MHz clock (Intel 4004) - 1971
- 16 Million transistors (Ultra Sparc III)
- 42 Million transistors, 2 GHz clock (Intel Xeon) – 2001
- 55 Million transistors, 3 GHz, 130nm technology, 250mm2 die (Intel Pentium 4) – 2004
- 290+ Million transistors, 3 GHz (Intel Core 2 Duo) – 2007
- 731 Million transisters, 2-3Ghz (Intel Nehalem) – 2009
- 1.17 Billion transistors, 2-3Ghz (Intel Westmere) – 2011


Transistor count
2,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
2,300
1971
1980
1990
2000
2008
Curve shows 'Moore's Law':
transistor count doubling
every two years
4004
8008
8080
8088
286
386
486
Pentium
K5
K6
PII
PIII
K7
K6-III
P4
Barton
Atom
K8
Itanium 2
Cell
Core 2 Duo
Core 2 Quad
K10
Itanium 2 with 9MB cache
G80
POWER6
RV770
GT200
Dual-Core Itanium 2
Quad-Core Itanium Tukwila

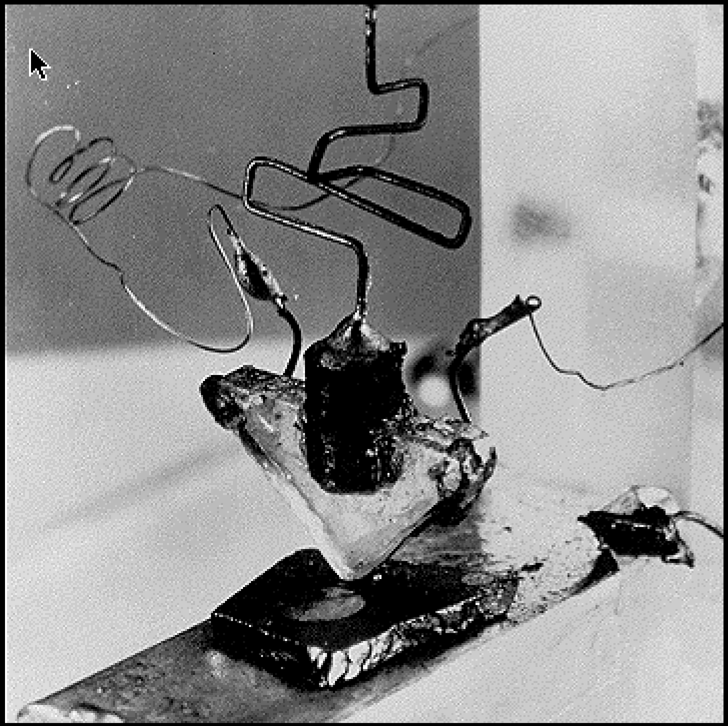
# Power Limits

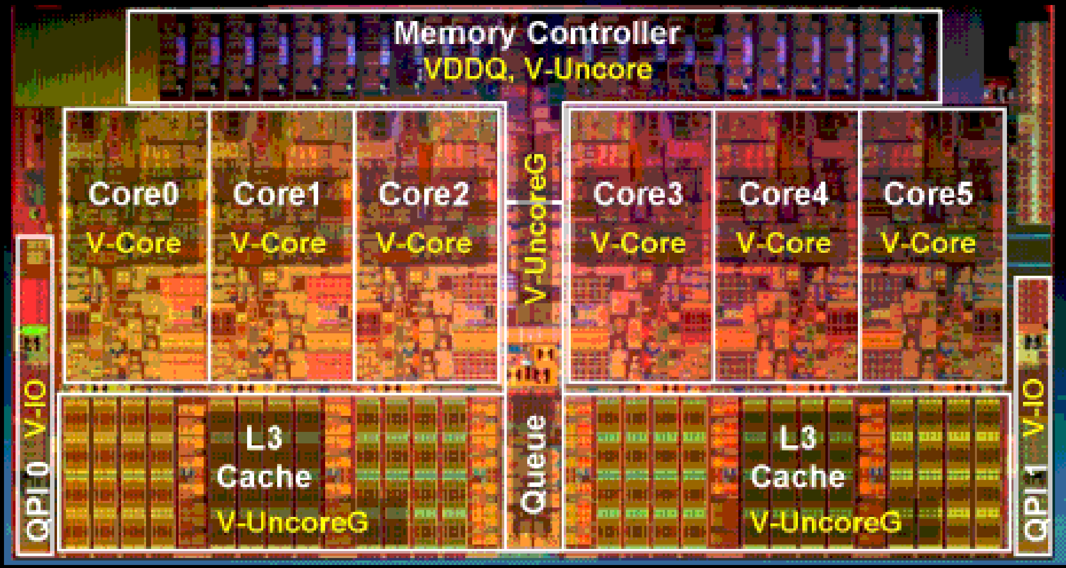


# What to do with all these transistors?

Multi-core

# Multi-core






The first transistor

- on a workbench at
  AT&T Bell Labs in 1947
- Bardeen, Brattain, and Shockley

An Intel Westmere

1.17 billion transistors

240 square millimeters

Six processing cores

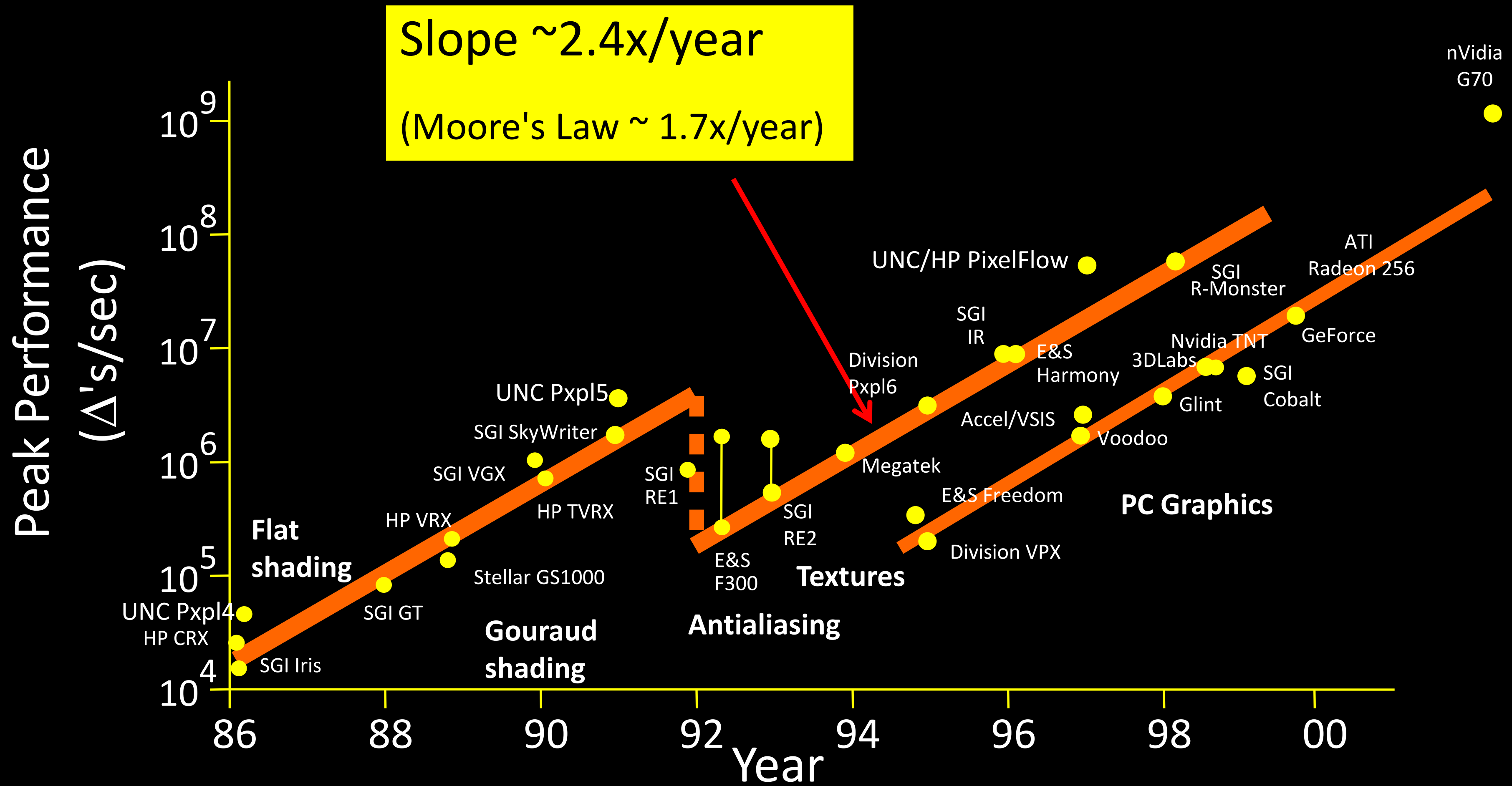
# What to do with all these transistors?

Many-core

and Graphical Processing units

# Faster than Moore's Law

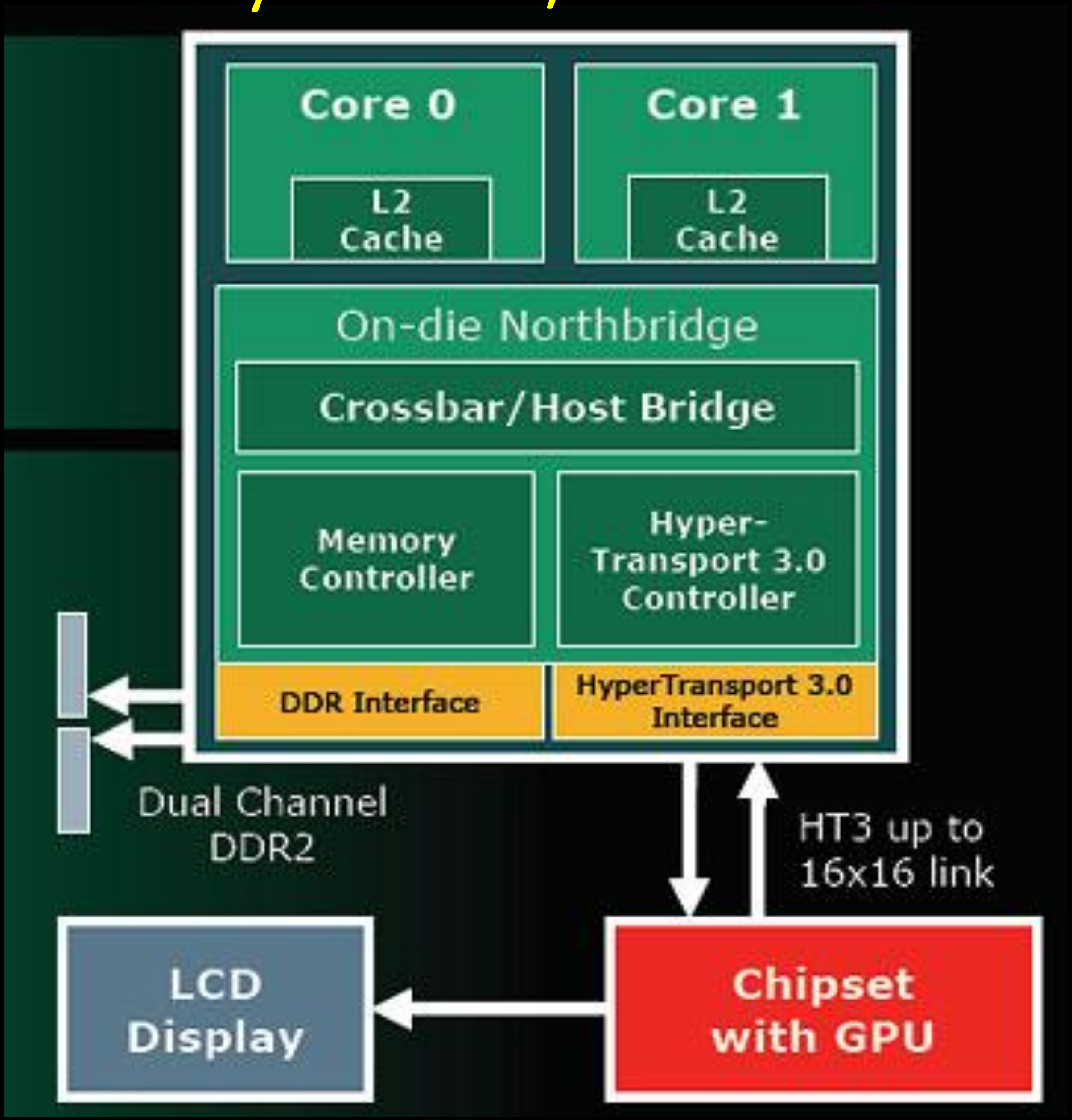
## One-pixel polygons (~10M polygons @ 30Hz)




Graph courtesy of Professor John Poulton (from Eric Haines)

# AMDs Hybrid CPU/GPU

## AMD’s Answer: Hybrid CPU/GPU

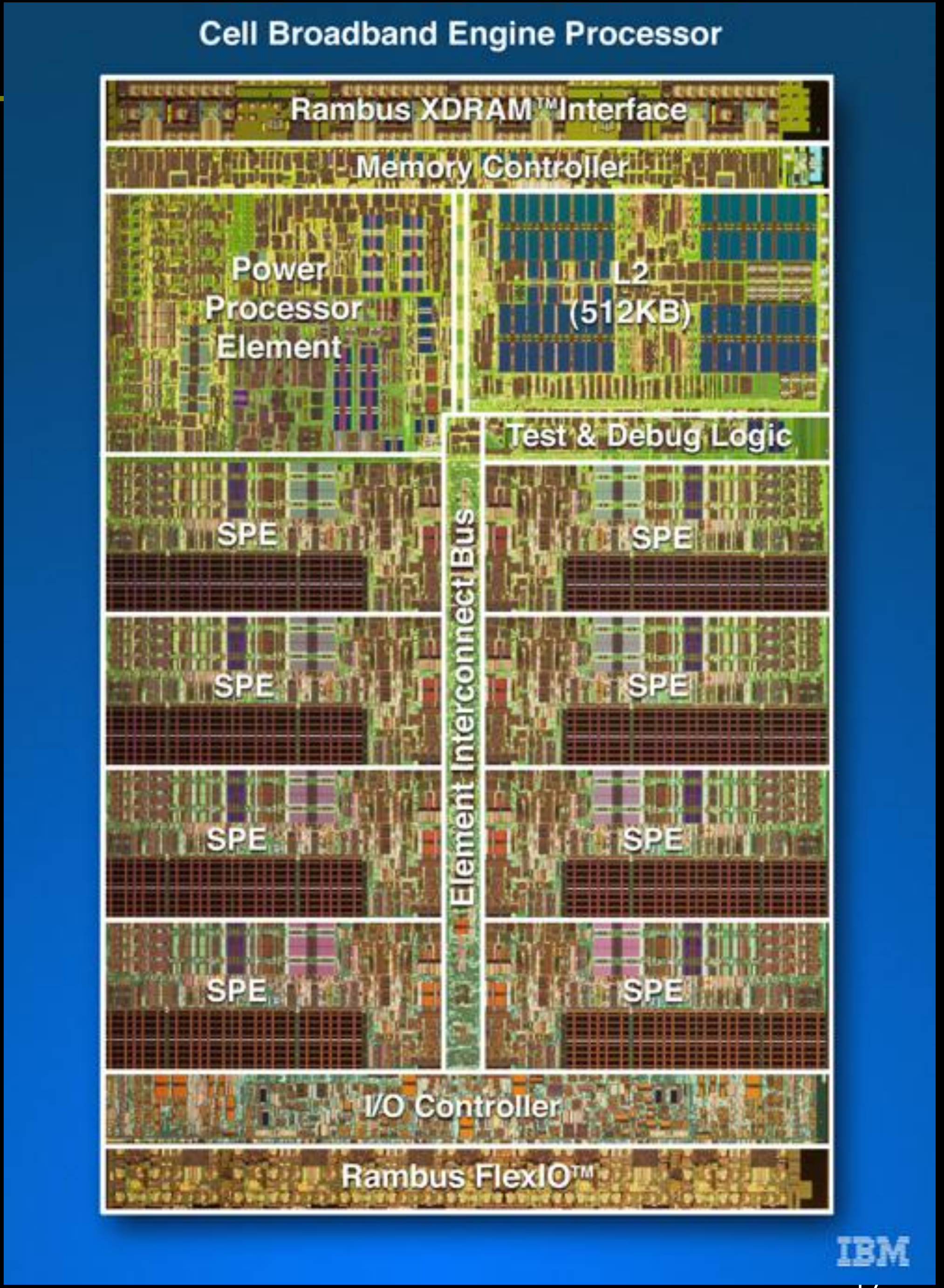


IBM/Sony/Toshiba

Sony Playstation 3

PPE

SPEs (synergestic)



# Parallelism

Must exploit parallelism for performance

- Lots of parallelism in graphics applications
- Lots of parallelism in scientific computing

SIMD: single instruction, multiple data

- Perform same operation in parallel on many data items
- Data parallelism

MIMD: multiple instruction, multiple data

- Run separate programs in parallel (on different data)
- Task parallelism

# NVidia Tesla Architecture

# Why are GPUs so fast?

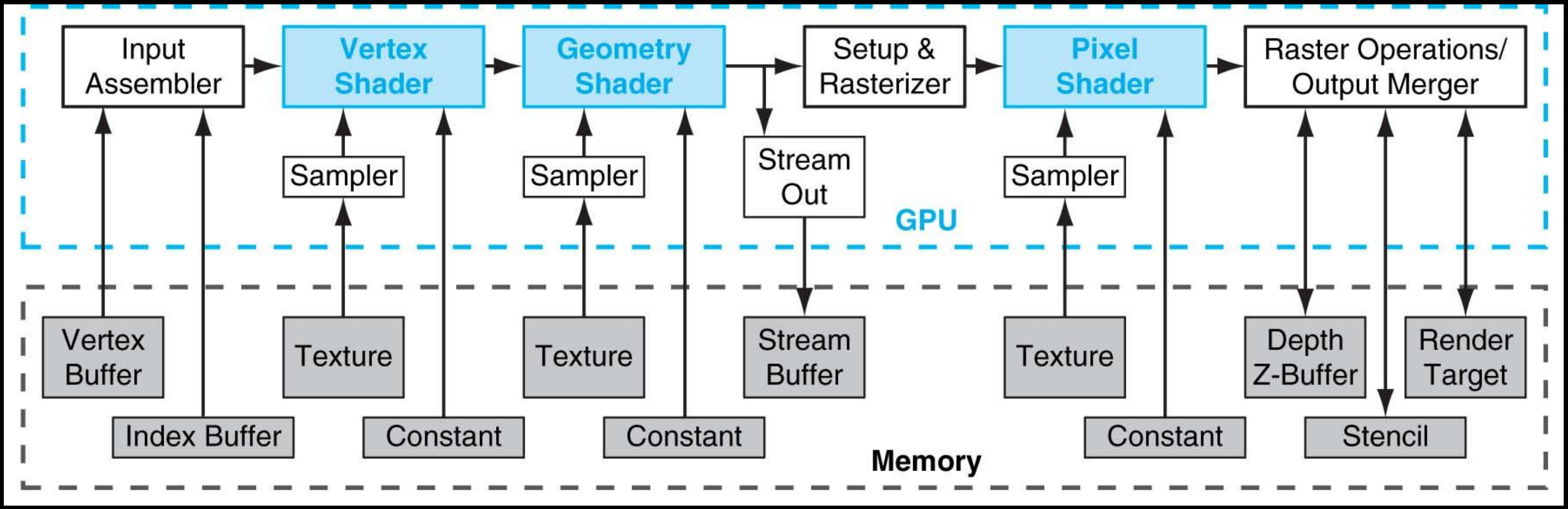



**FIGURE A.3.1 Direct3D 10 graphics pipeline.** Each logical pipeline stage maps to GPU hardware or to a GPU processor. Programmable shader stages are blue, fixed-function blocks are white, and memory objects are grey. Each stage processes a vertex, geometric primitive, or pixel in a streaming dataflow fashion. 

Pipelined and parallel

Very, very parallel: 128 to 1000 cores

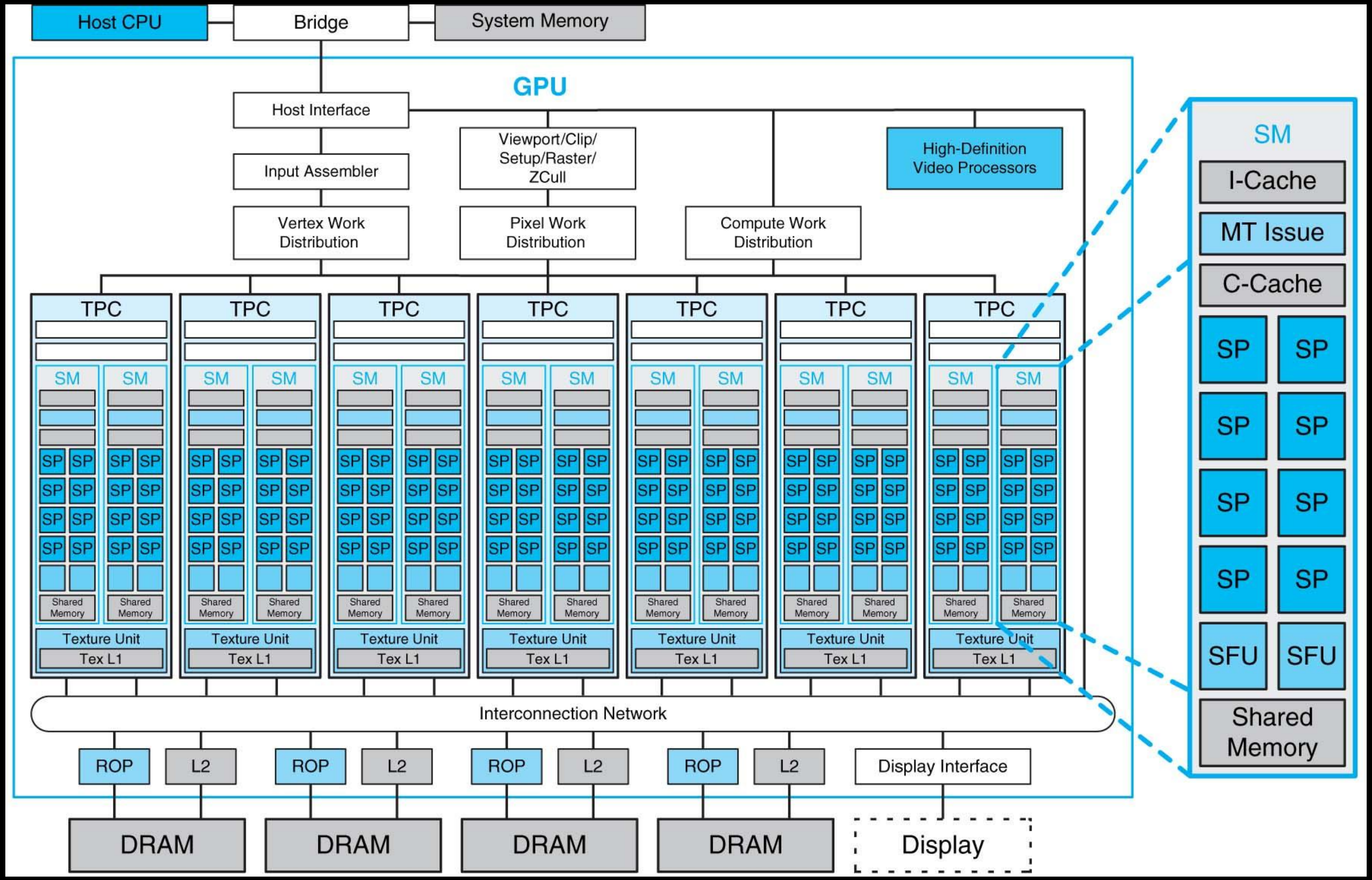



**FIGURE A.2.5 Basic unified GPU architecture.** Example GPU with 112 streaming processor (SP) cores organized in 14 streaming multiprocessors (SMs); the cores are highly multithreaded. It has the basic Tesla architecture of an NVIDIA GeForce 8800. The processors connect with four 64-bit-wide DRAM partitions via an interconnection network. Each SM has eight SP cores, two special function units (SFUs), instruction and constant caches, a multithreaded instruction unit, and a shared memory. 

# General computing with GPUs

Can we use these for general computation?

Scientific Computing

- MATLAB codes

Convex hulls

Molecular Dynamics

Etc.

NVIDIA's answer:

Compute Unified Device Architecture (CUDA)

- MATLAB/Fortran/etc. → "C for CUDA" → GPU Codes

# What to do with all these transistors?

Cloud Computing

# Cloud Computing

Datacenters are becoming a commodity

Order online and have it delivered

- Datacenter in a box: already set up with commodity hardware & software (Intel, Linux, petabyte of storage)
- Plug data, power & cooling and turn on
  - typically connected via optical fiber
  - uch datacenters


# Cloud Computing = Network of Datacenters

# Cloud Computing

Enable datacenters to coordinate over vast distances

- Optimize availability, disaster tolerance, energy
- Without sacrificing performance
- “cloud computing”

Drive underlying technological innovations.

# Cloud Computing

The promise of the Cloud

- A computer utility; a commodity
- Catalyst for technology economy
- Revolutionizing for health care, financial systems, scientific research, and society

However, cloud platforms today

- Entail significant risk: vendor lock-in vs control
- Entail inefficient processes: energy vs performance
- Entail poor communication: fiber optics vs COTS endpoints

# Example: Energy and Performance

Why don’t we save more energy in the cloud?

No one deletes data anymore!

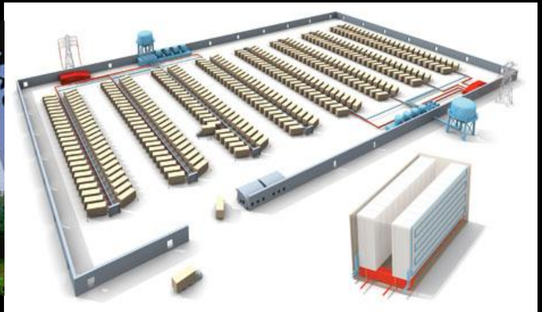
- Huge amounts of seldom-accessed data

Data deluge

- Google (YouTube, Picasa, Gmail, Docs), Facebook, Flickr
- 100 GB per second is faster than hard disk capacity growth!
- Max amount of data accessible at one time << Total data

New scalable approach needed to store this data

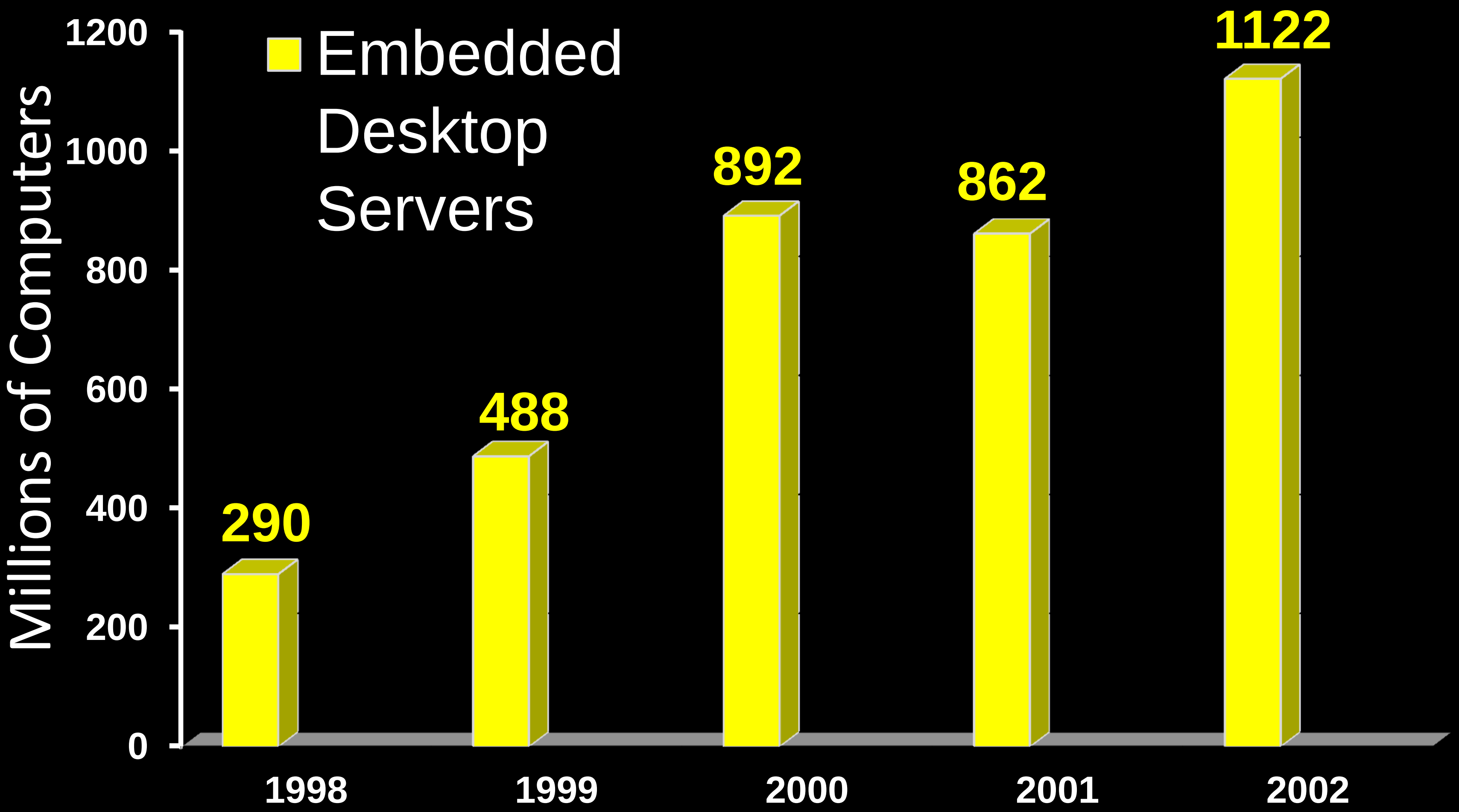
- Energy footprint proportional to number of HDDs is *not* sustainable

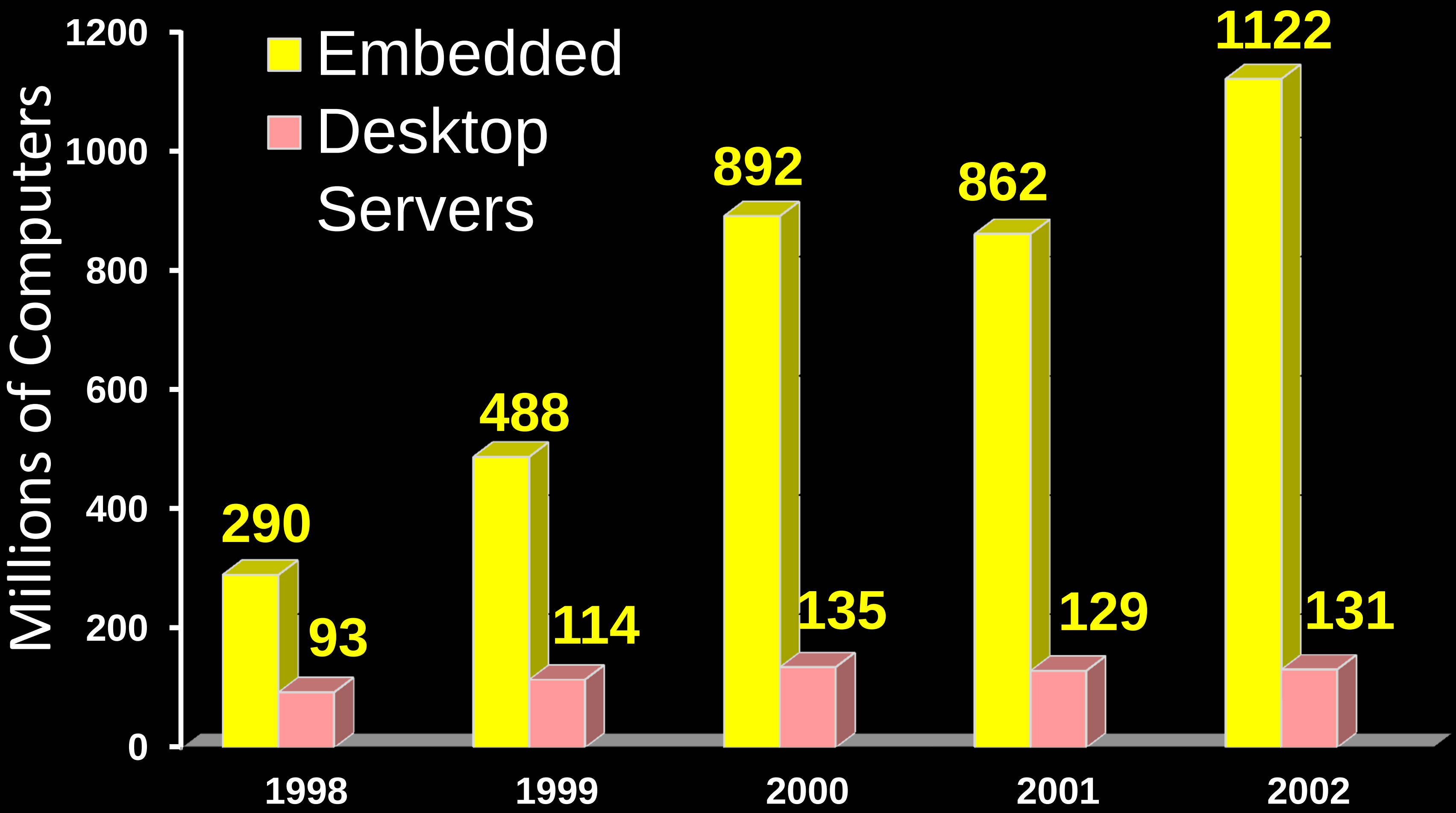
# What to do with all these transistors?

Embedded Processors

# Where is the Market?



# Where is the Market?



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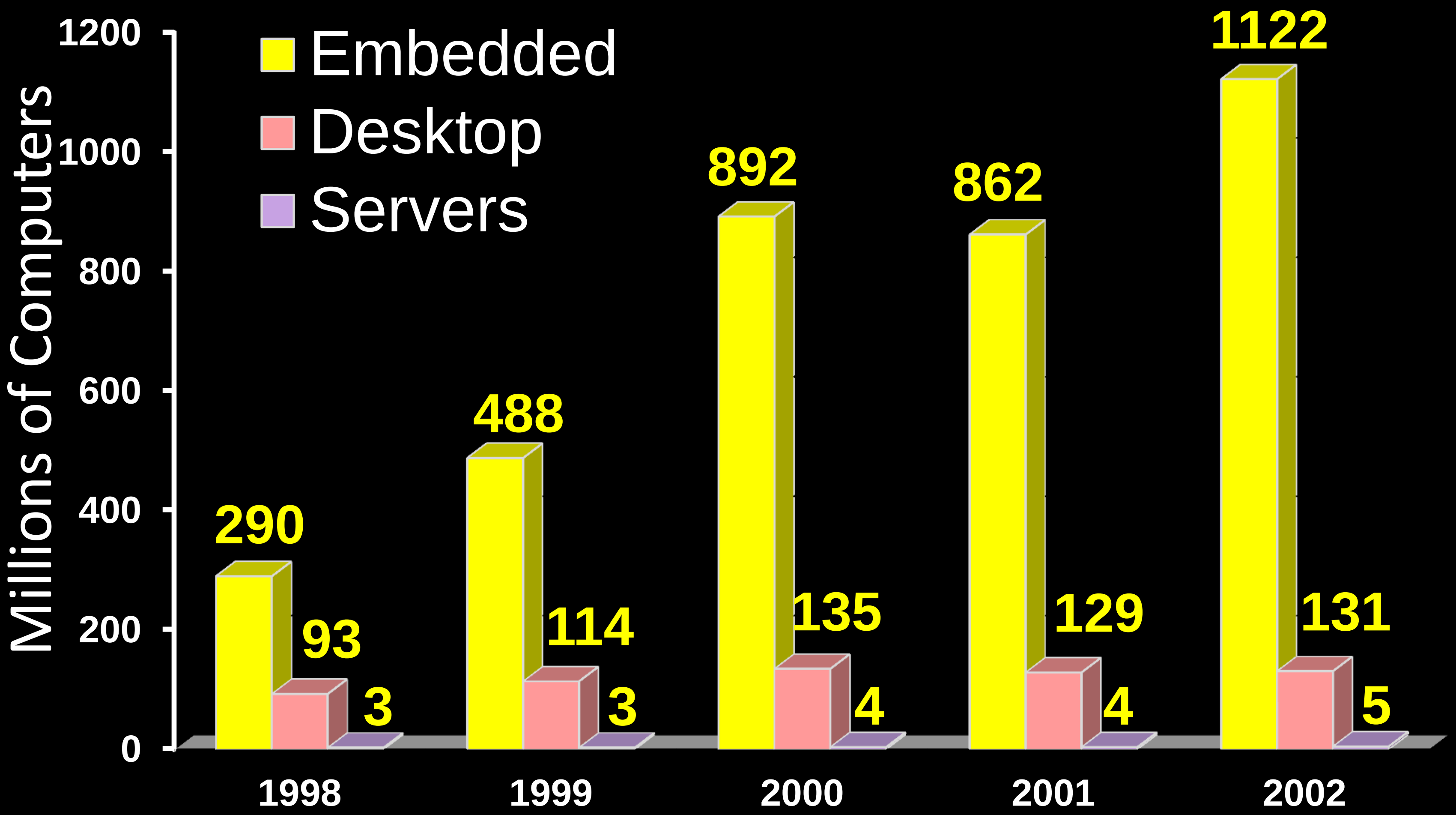
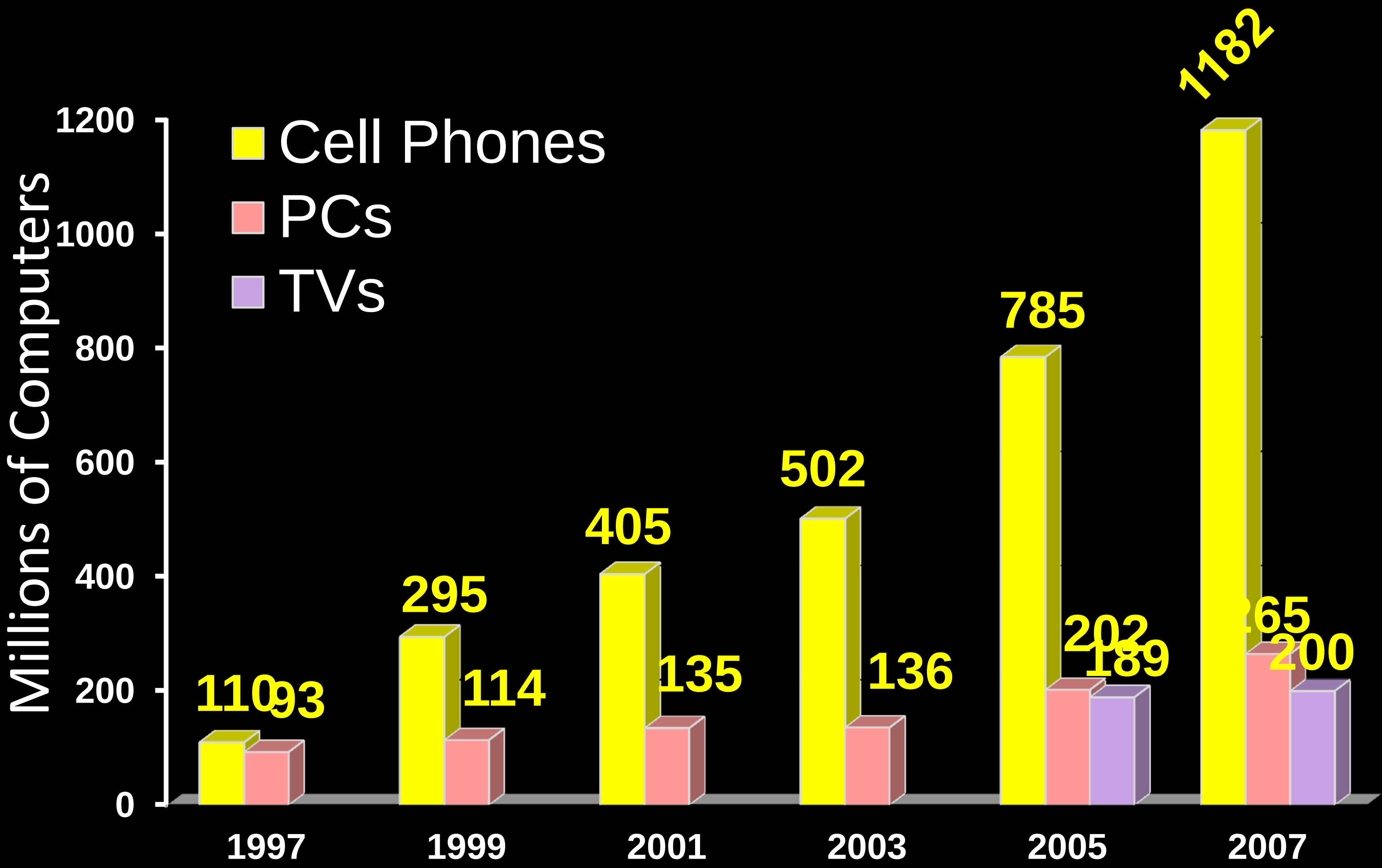
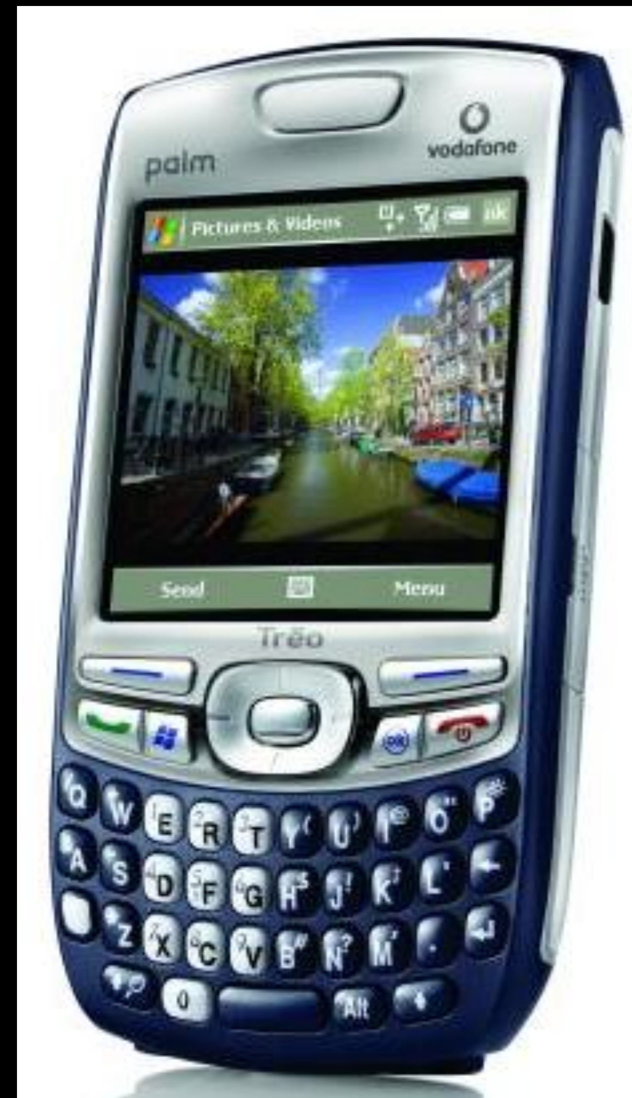


# Where is the Market?




151st St to US-69 S
KIOWA
ARROWHEAD
LINDENWOOD
Arrival
2:16
Menu
Turn In
6.0

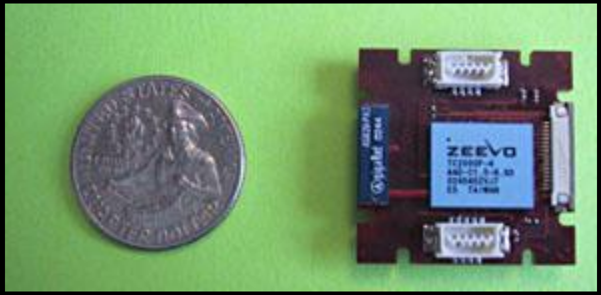

palm
vodafone
Pictures & Videos
Send
Menu
Treo

# Where to?

Sr

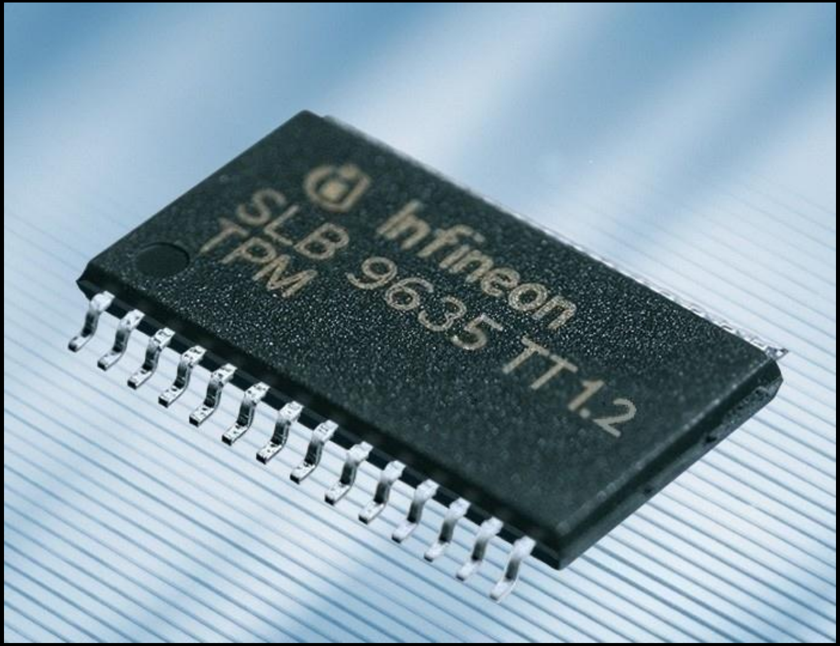

WASP MAV


Sensor
Network Node
Network Node
Network Node


ZEEVO

# Security?

Cryptography and security…

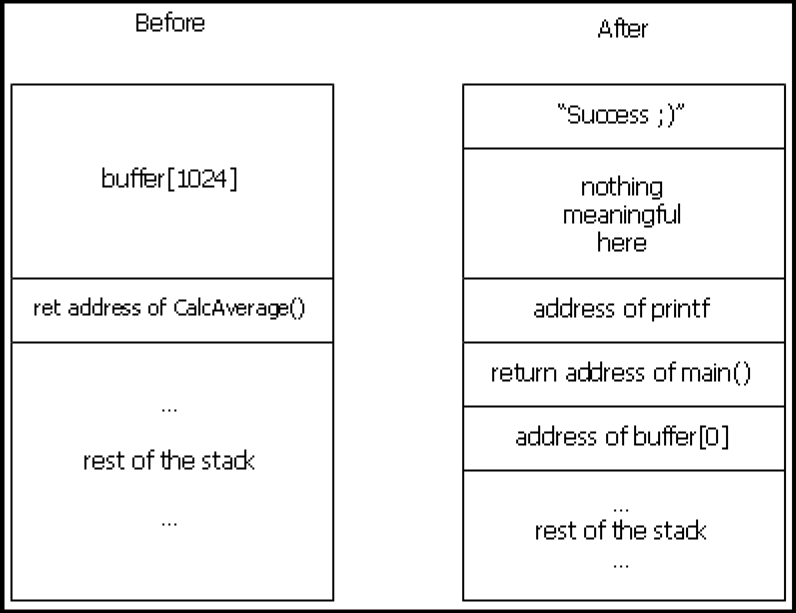



TPM 1.2


IBM 4758
Secure Cryptoprocessor

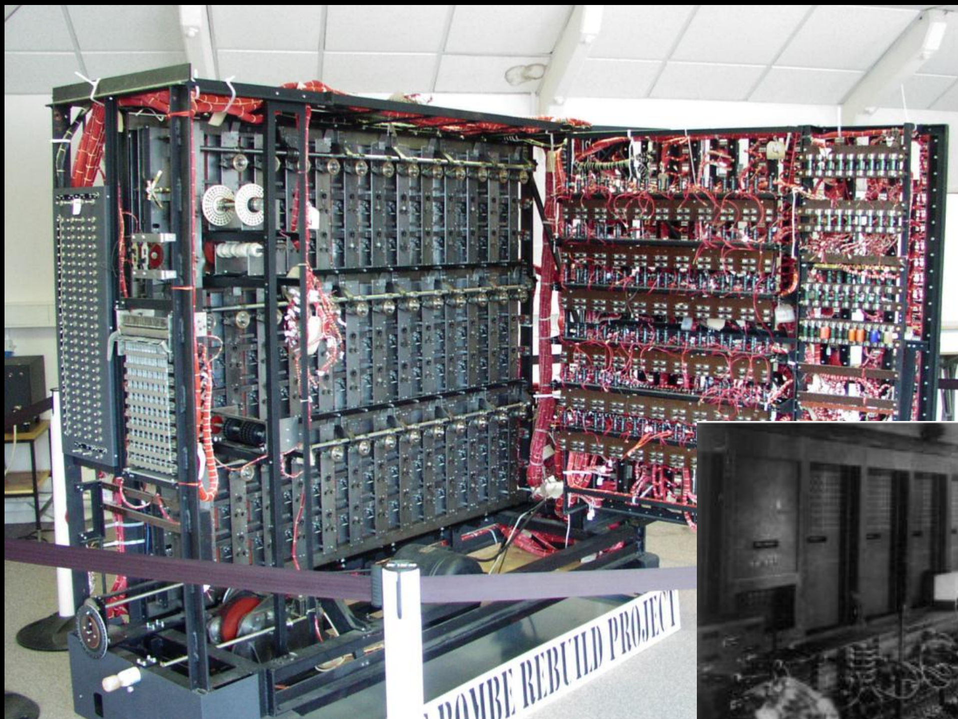
# Security?

## Stack Smashing…



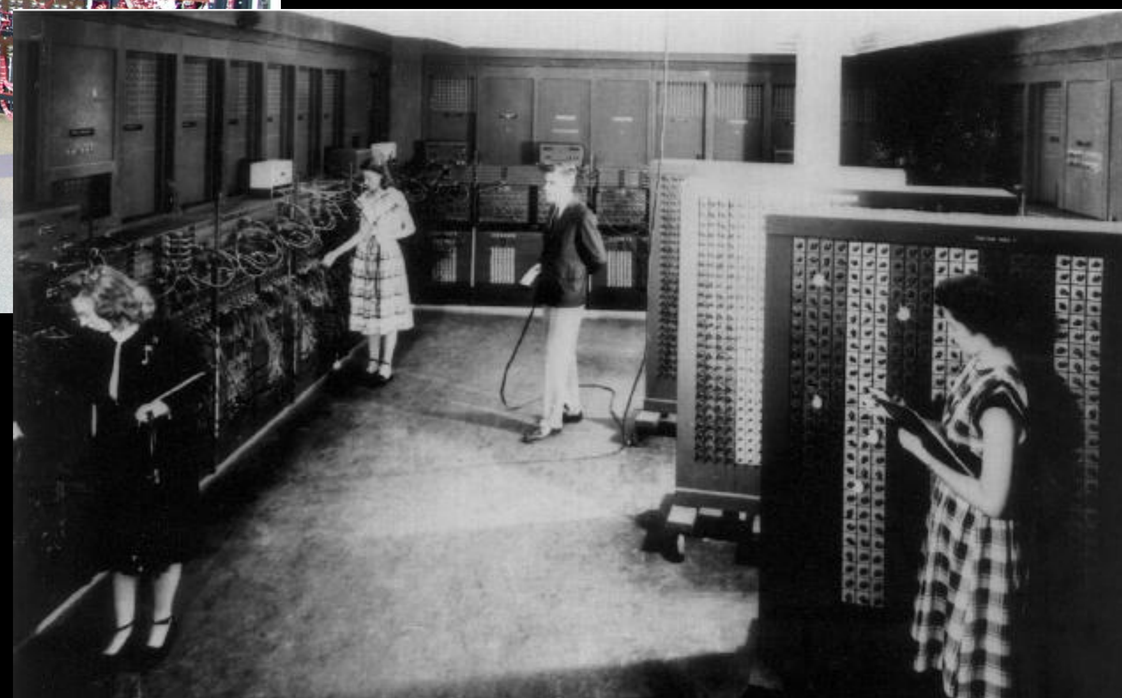
# What to do with all these transistors?

You could save the world one day?



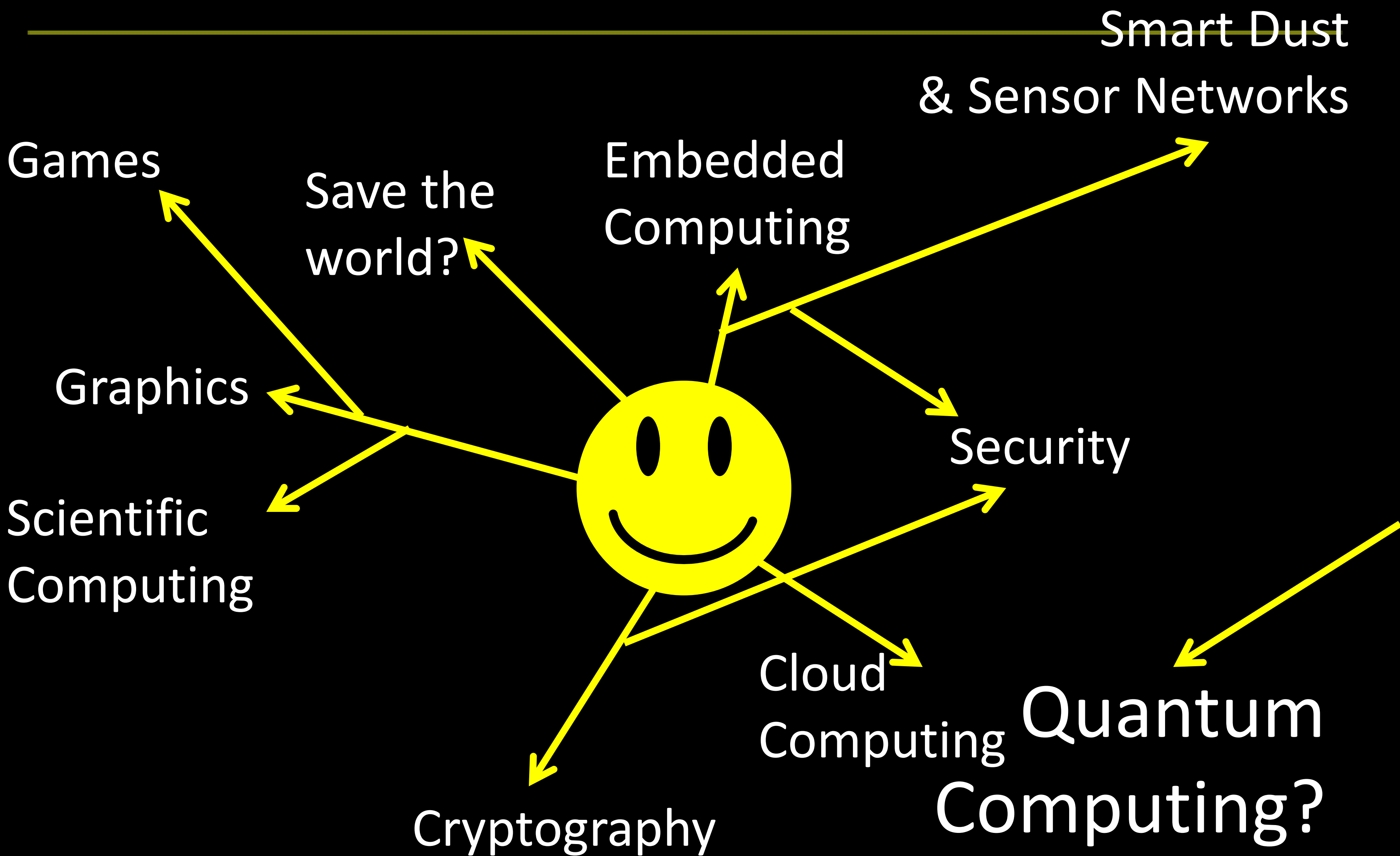

## ENIAC - 1946

First general purpose electronic computer. Designed to calculate ballistic trajectories



## Alan Turing's Bombe

Used to crack Germany's enigma machine


Smart Dust
& Sensor Networks
Games
Save the
world?
Embedded
Computing
Graphics
Security
Scientific
Computing
Cloud
Computing
Quantum
Computing?
Cryptography

# Survey Questions

Are you a better computer scientist and software engineering knowing “the low-level stuff”?

How much of computer architecture do software engineers actually have to deal with?

What are the most important aspects of computer architecture that a software engineer should keep in mind while programming?

# Why?

These days, programs run on hardware...

... more than ever before

Google Chrome

→ Operating Systems

→ Multi-Core & Hyper-Threading

→ Datapath Pipelines, Caches, MMUs, I/O & DMA

→ Busses, Logic, & State machines

→ Gates

→ Transistors

→ Silicon

→ Electrons

# Why?

Your job as a computer scientist will require knowledge the computer

Research/University

Industry

Government

# Where to?

CS 3110: Better concurrent programming

CS 4410/4411: The Operating System!

CS 4420/ECE 4750: Computer Architecture

CS 4450: Networking

CS 4620: Graphics

~~CS 4821: Quantum Computing~~

MEng

5412—Cloud Computing,  5414—Distr Computing,

5430—Systems Secuirty,

5300—Arch of Larg scale Info Systems

And many more…

# Thank you!

If you want to make an apple pie from scratch, you must first create the universe.

– Carl Sagan