

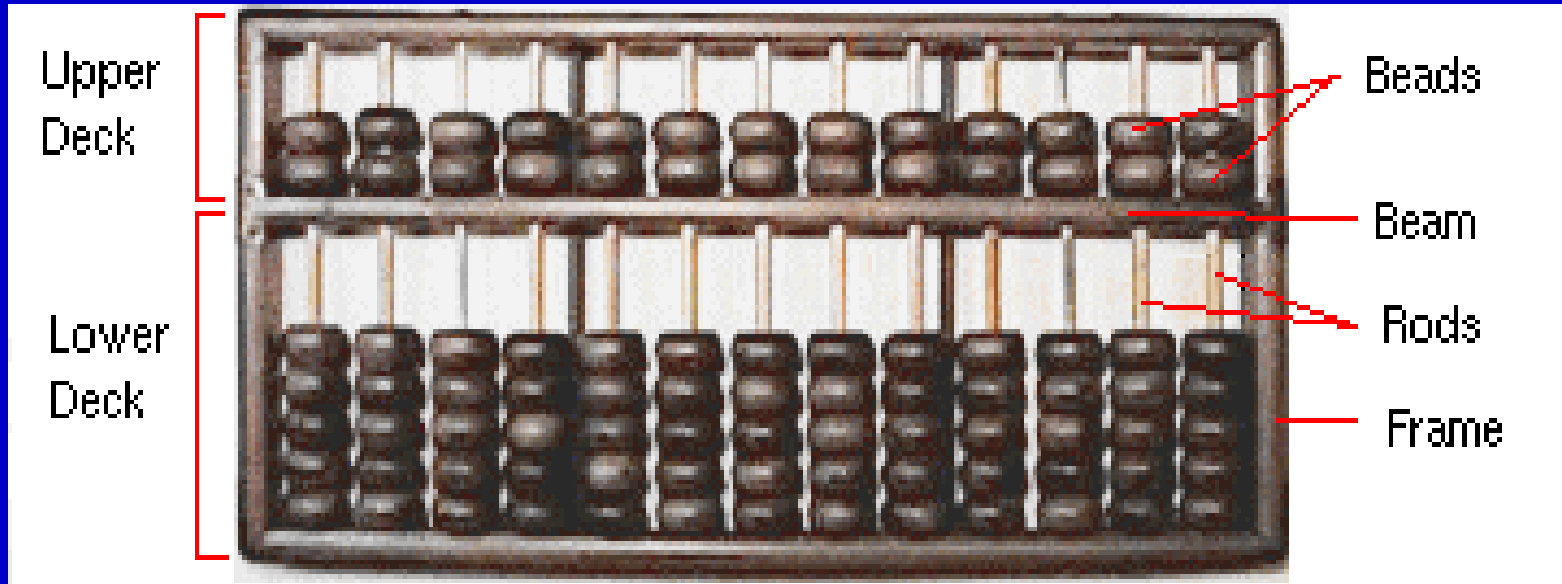
# Introduction

# Outline

- Computer: A historical perspective
- Forces behind computer evolution and design
  - Supply: technology, architecture
  - Demand: applications
- Implementation technology and its trends
- Applications of processors

電腦是什麼時候發展出來的？

大約一千三百多年前...



為什麼我們不稱它為「電腦」？

電動算盤

# 「電腦」倒底是什麼？

- A device that computes, especially a programmable electronic machine that performs high-speed mathematical or logical operations or that assembles, stores, correlates, or otherwise processes information  
-- *The American Heritage Dictionary of the English Language*, 4th Edition, 2000

# 其實歷史上已有許多計算裝置發展出來

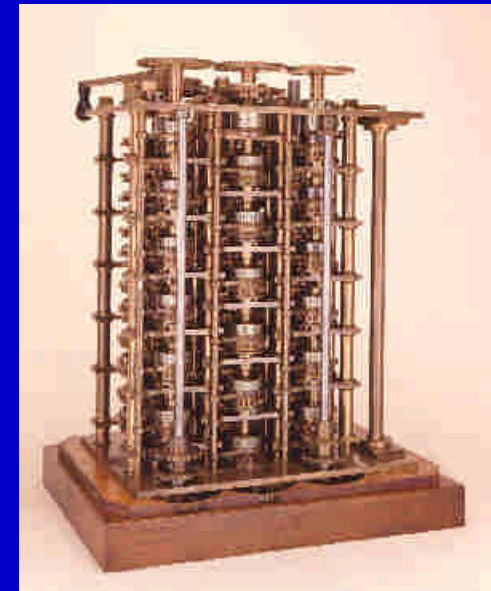
- Special-purpose versus general-purpose
- Non-programmable versus programmable
- Scientific versus office data processing
- Mechanical, electromechanical, electronic, ...



Tabulating machine  
(H. Hollerith, 1889)



Harvard Mark I  
(IBM, H. Aiken, 1944)



Difference Engine  
(C. Babbage, 1822)

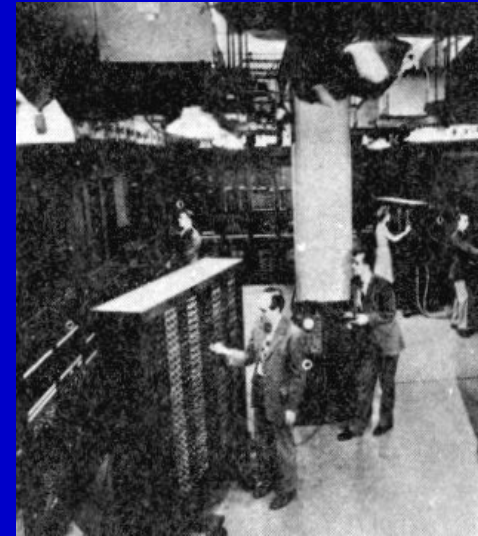
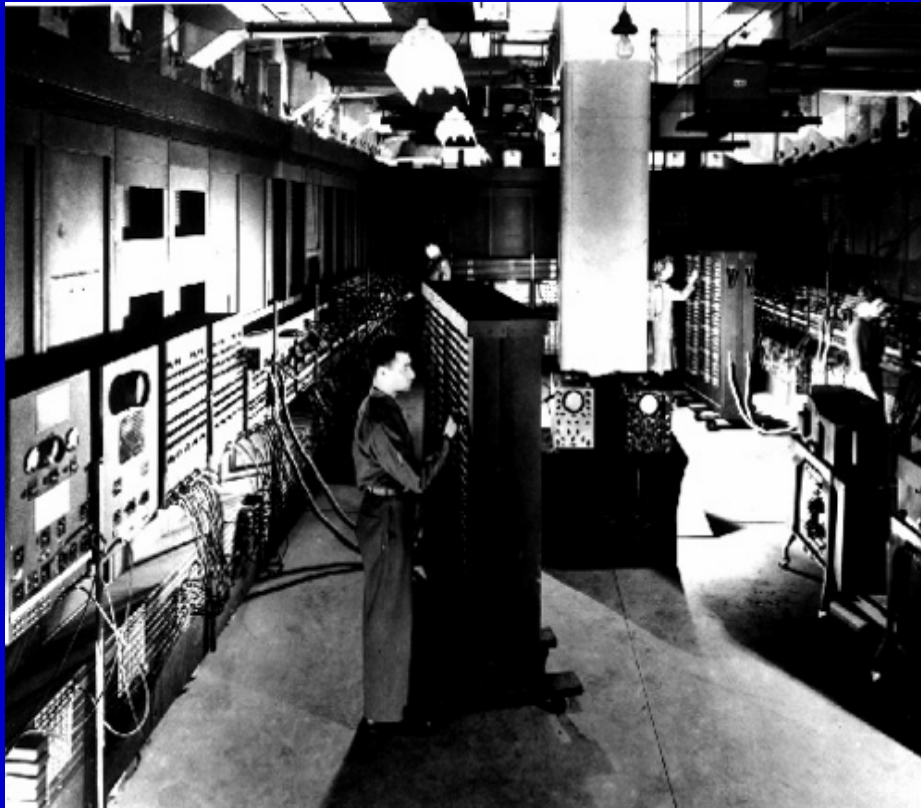
第一部  
全電子式  
可程式  
一般用途  
的電腦  
是什麼時候發展出來的？

# 第一部「電」腦

- 一般認為：ENIAC (*Electronic Numerical Integrator and Calculator*)
- Work started in 1943 in Moore School of Electrical Engineering at the University of Pennsylvania, by John Mauchly and J. Presper Eckert
- Completed in 1946
- 約25公尺長、2.5公尺高
- 20 10-digit registers, each 2 feet
- 使用18,000個真空管  
(electronic switches, 1906年發明)
- 每秒執行1900個加法
- Programming manually by plugging cables and setting switches



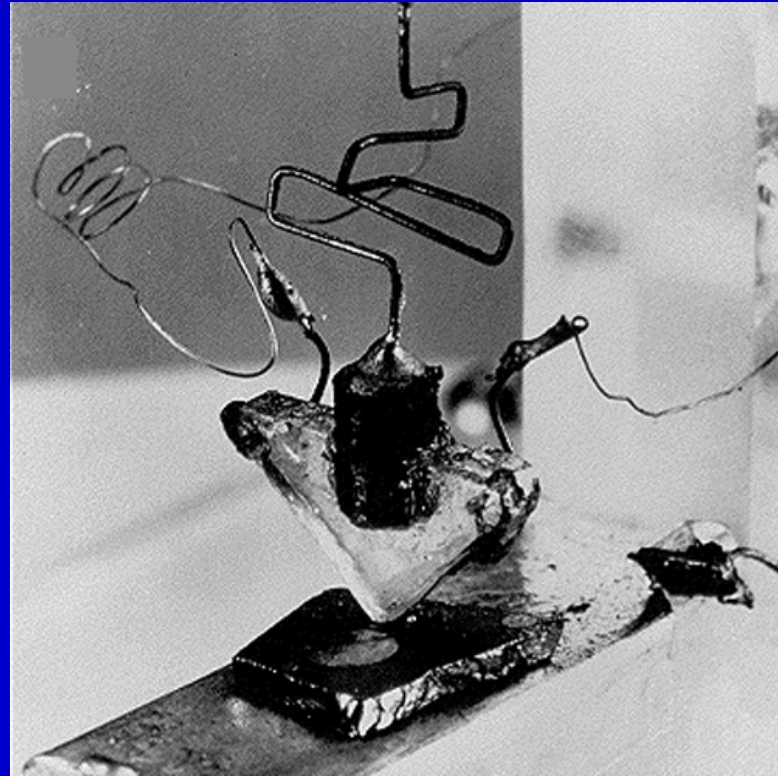
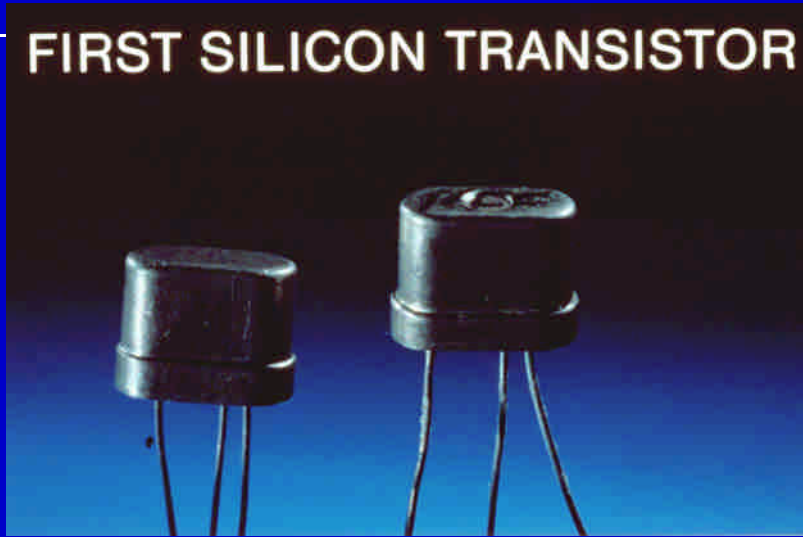
# ENIAC



# 大約同一時期，人們發明了電晶體

- By W. Shockley, J. Bardeen, W. Brattain of Bell Lab. in 1947
  - Much more reliable than vacuum tubes

FIRST SILICON TRANSISTOR



# 不久後電腦開始商品化



UNIVAC (Remington-Rand, 1951)

主要用途為商務、辦公室自動化  
其次為科學計算



IBM 701 (IBM, 1952)

# 使用電晶體的電腦也跟著出現

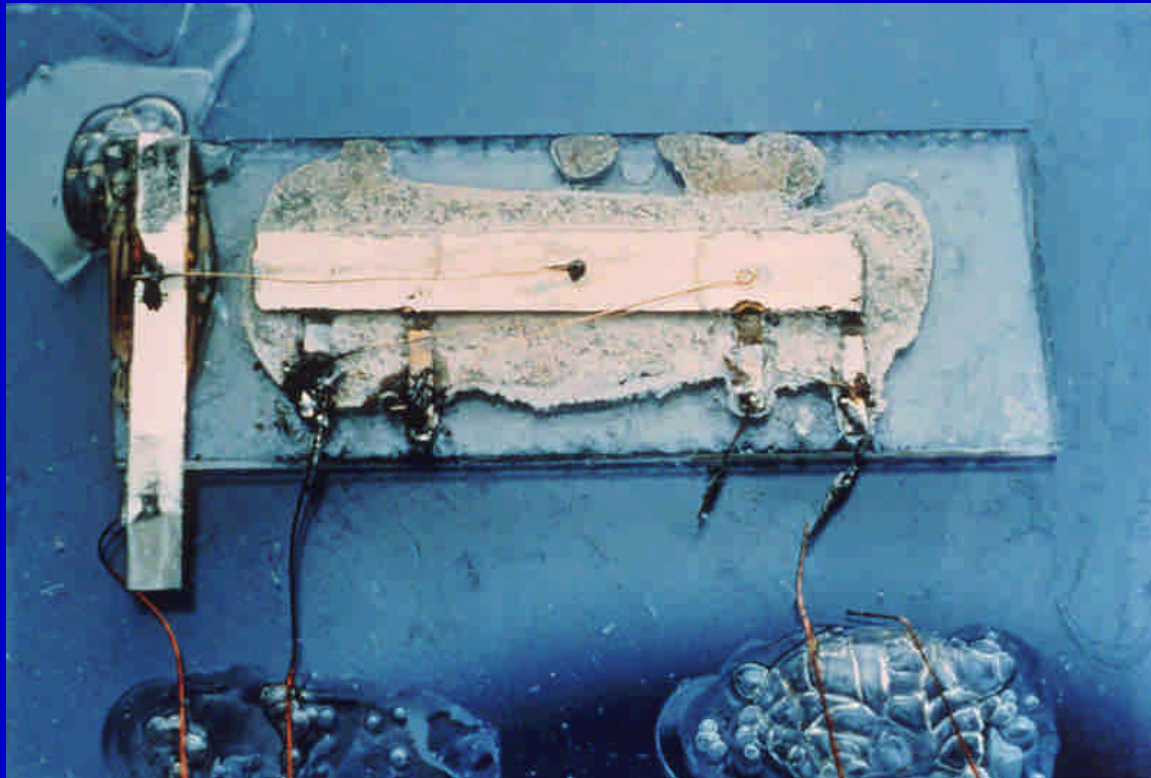
- Ex.: IBM 1401 (IBM, 1959)



This is how  
IBM is called  
"Big Blue"!

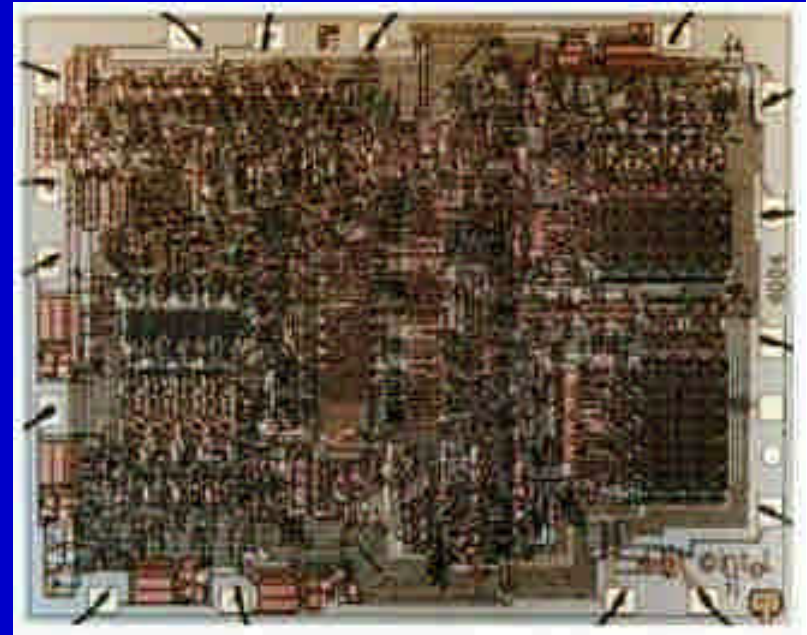
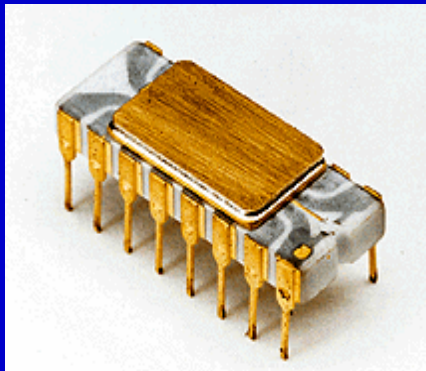
## 電腦元件的另一大突破是IC

- 1958年德州儀器公司的Jack Kilby: integrated a transistor with resistors and capacitors on a single semiconductor chip, which is a monolithic IC



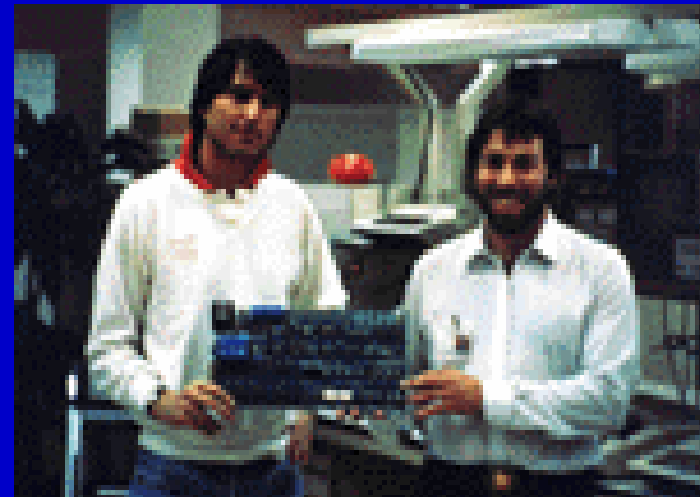
## 當更多的電晶體能放入IC後...

- 1971年第一個微處理器：Intel 4004
  - 108 KHz, 0.06 MIPS
  - 2300 transistors (10 microns)
  - Bus width: 4 bits
  - Memory addr.: 640 bytes
  - For Busicom calculator (original commission was 12 chips)



## 微處理器造就了...

- 1977年Apple II: Steve Jobs, Steve Wozniak  
Motorola 6502 CPU, 48Kb RAM



## 以及PC

- 1981年IBM PC: Intel 8088, 4.77MHz, 16Kb RAM, two 160Kb floppy disks



Microsoft Corporation, 1978

也造就了微軟

## 一些週邊設備也早已發展出來

- 1973: Researchers at Xerox PARC developed an experimental PC: Alto
  - Mouse, Ethernet, bit-mapped graphics, icons, menus, WYSIWYG editing
- Hosted the invention of:
  - Local-area networking
  - Laser printing
  - All of modern client / server distributed computing



# 讓PC成爲真正有用的東西--應用程式

- 1979: 1st electronic spreadsheet (VisiCalc for Apple II) by Don Bricklin and Bob Franston
  - “The killer app for early PCs”
  - Followed by dBASE II, ...



9 10

### A VISICALC™ Screen:

Current Entry's coordinates

Entry Type: V for value, L for label, /- for repeating label.

Recalculation Order Indicator: If R, across rows; if C, down columns.

Memory Indicator: How many K memory available; if flashing M, out of room.

Direction Indicator: If ., arrows keys will move cursor up and down; if -, arrow keys will move cursor left and right.

Explicit Format indication

Entry Contents

Entry Contents Line

Prompt Line

Edit Line: flashing block means awaiting input.

Row and Column labels

Dollars and Cents Format (/FS)

Label Entry

Cursor

Two windows when the screen is split.

Right Justified Format (/FR)

Integer Format (/FI)

Graph Format (/F\*)

Value Entry

Left Justified Format (/FL)

General Format (/FG)

Repeating Label (/--)

YEAR	1979	TOTAL	%/SALES
# SOLD	100	3066	100
PRICE	1.20	3680	67
SALES	120	2453	67
COST	80	1900	62
UHD	15	495	13
PROFIT	5	118	3

# 人們也先後發展出許多其他東西...



# 80年代，IC的集成進入VLSI

- New processor architecture was introduced:  
*RISC (Reduced Instruction Set Computer)*
  - IBM: John Cocke
  - UC Berkeley: David Patterson
  - Stanford: John Hennessy
- Commercial RISC processors around 1985
  - MIPS: MIPS
  - Sun: Sparc
  - IBM: Power RISC
  - HP: PA-RISC
  - DEC: Alpha
- They compete with CISC (complex instruction set computer) processors, mainly Intel x86 processors, for the next 15 years



## 後來的故事 ...

在計算機結構方面比較不精彩  
不過似乎後PC的時代已經來臨  
(Embedded Computer)

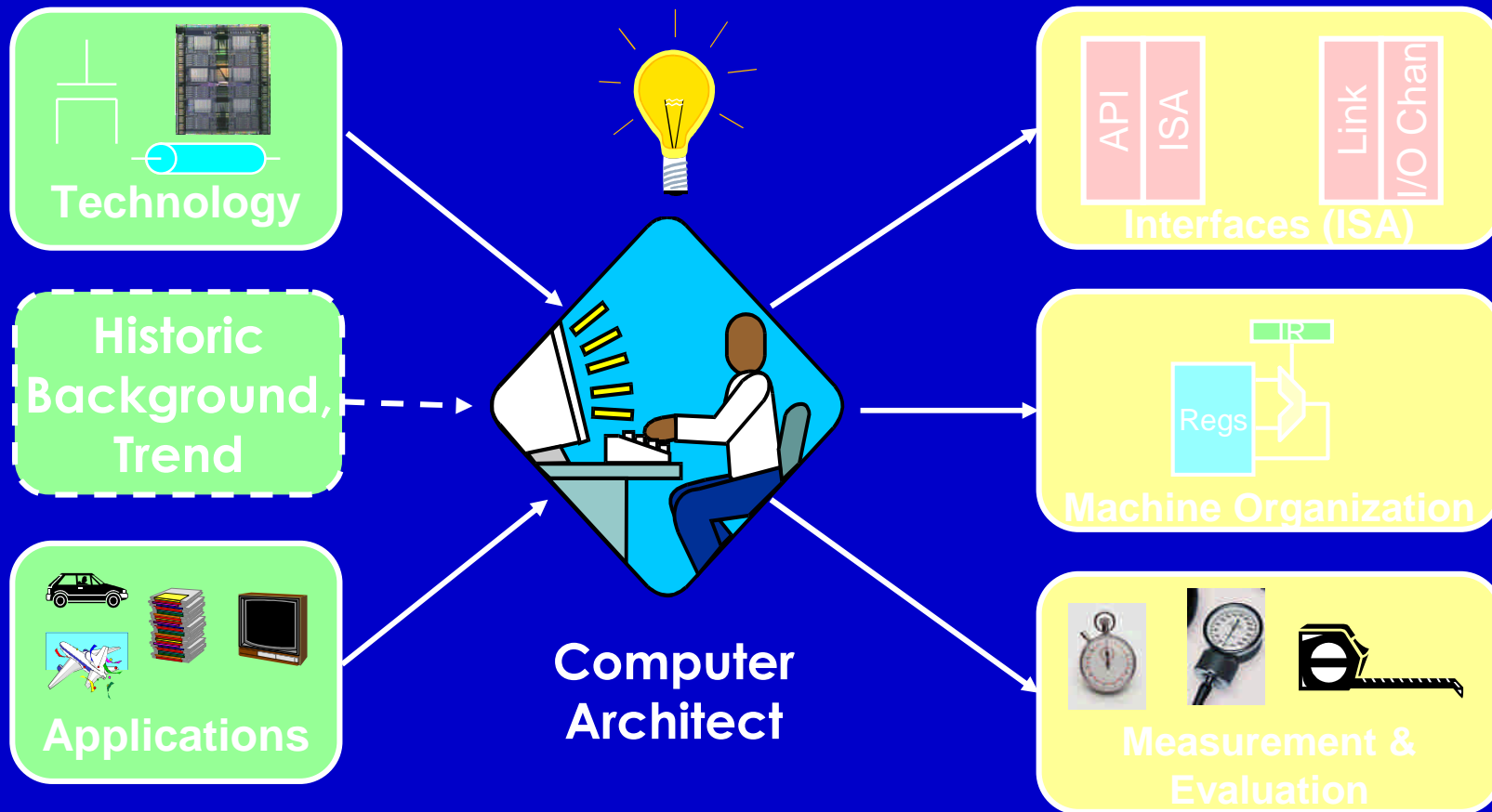


# Summary: Technology and Computers

- Computer generation according to technology:

<b>Generation</b>	<b>Date</b>	<b>Technology</b>	<b>Relative Performance per unit cost</b>
<b>1</b>	<b>1950-1959</b>	<b>Vacuum tubes</b>	<b>1</b>
<b>2</b>	<b>1960-1968</b>	<b>Transistor</b>	<b>35</b>
<b>3</b>	<b>1968-1977</b>	<b>IC</b>	<b>900</b>
<b>4</b>	<b>1978-?</b>	<b>LSI/VLSI</b>	<b>2,400,000</b>

# Why Do I Want to Know History?



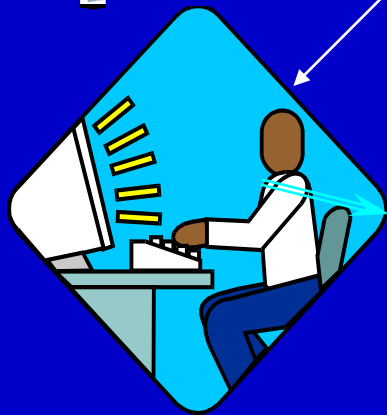
# In Fact, Architecture Design Is an Iterative Process

-- searching the space of possible designs

-- at all levels of computer systems



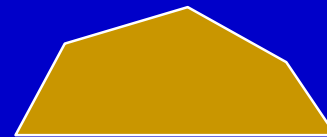
New concepts created



Estimate  
Cost &  
Performance

Sort

Historical background and understanding of trends help the selection process



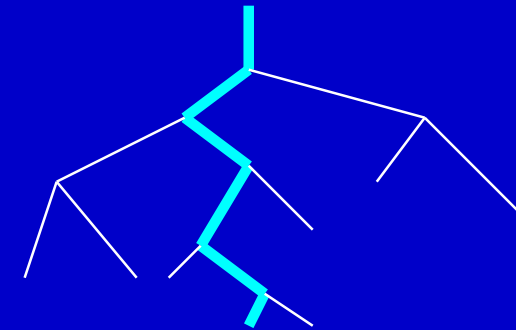
Bad ideas



Mediocre ideas



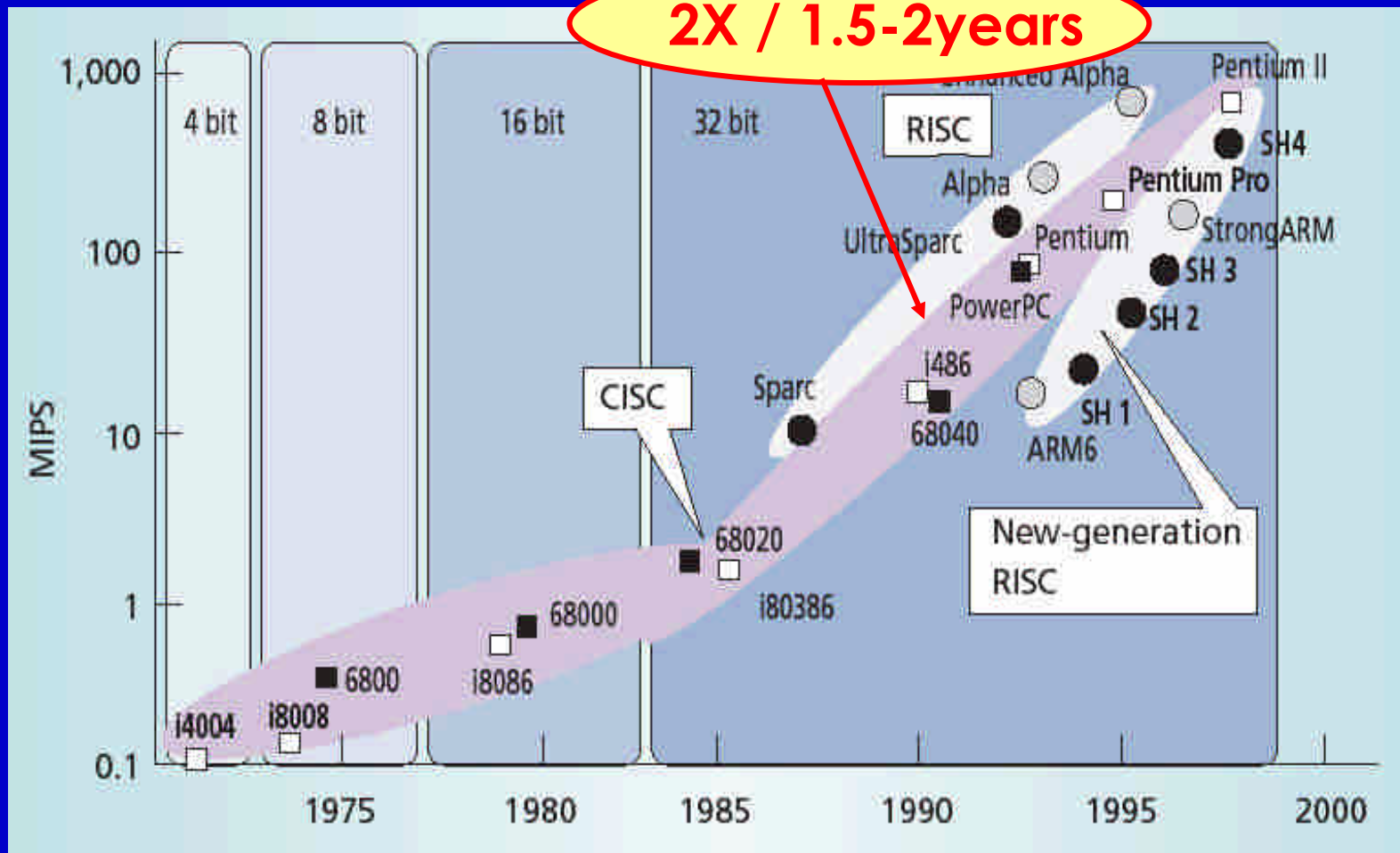
Good ideas



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# Let's Start with Processor Performance



(“The Cooler the Better: New Directions in the Nomadic Ages,” *Computer*, April 2001.)

# Why Such Changes?

Several factors:

- IC technology:

clock rate, power, transistors per chip

↓ enable

- Computer architecture:

pipeline, cache, MMX, instructions per cycle

↓ supported by

- Mass market:

market share, revenue, applications

# Outline

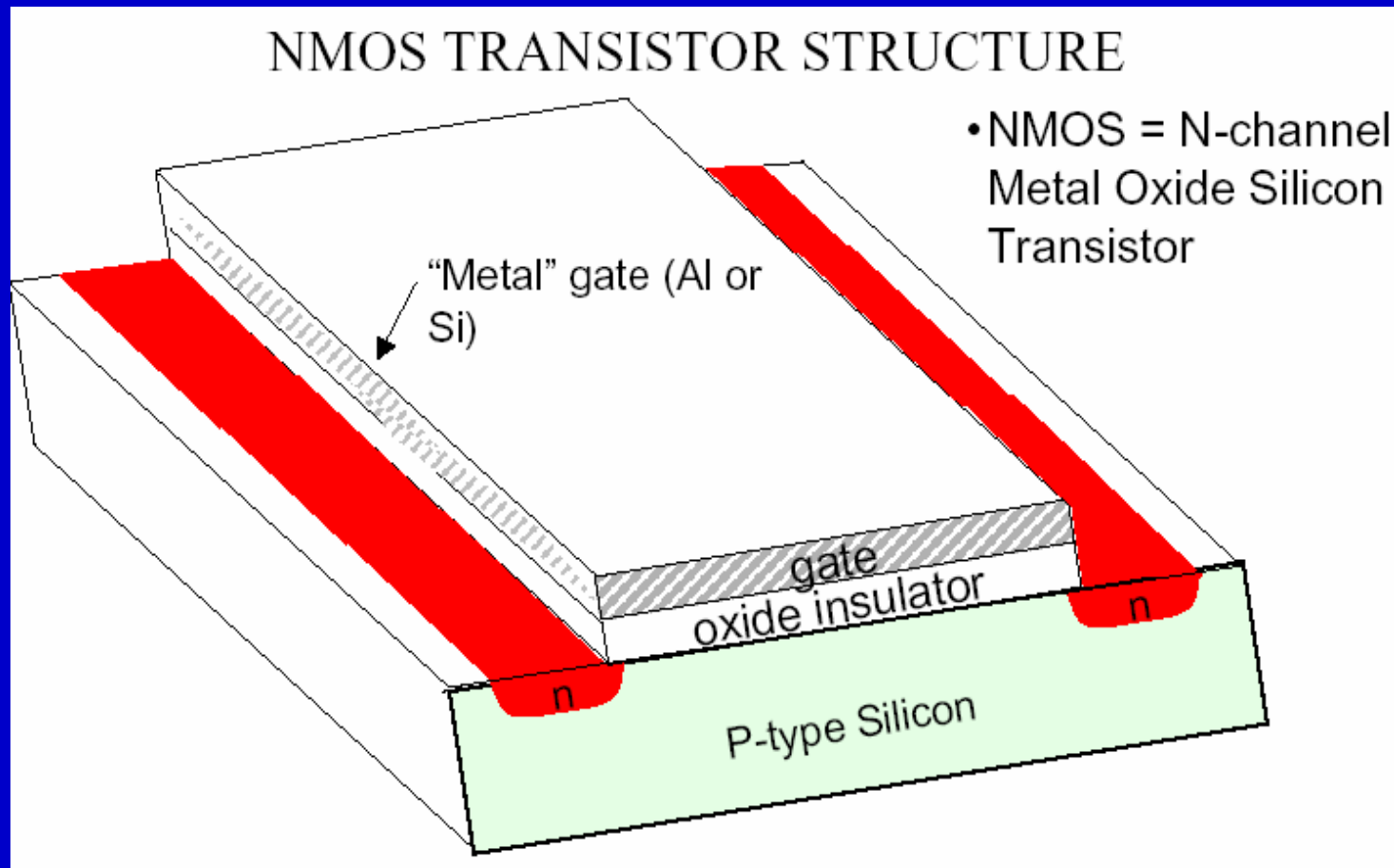
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# VLSI IC Technology

	2001	2005	2010	2016
Line width (nm)	130	80	45	22
Clock (GHz)	1.7	5.2	11.5	28.8
DRAM cost (microcents/bit)	7.7	1.9	0.34	0.042
MPU cost (microcent/trans)	97	24	4.31	0.54
Supply voltage(V)	1.2	1.0	0.8	0.6
Wiring levels	7	9	10	10

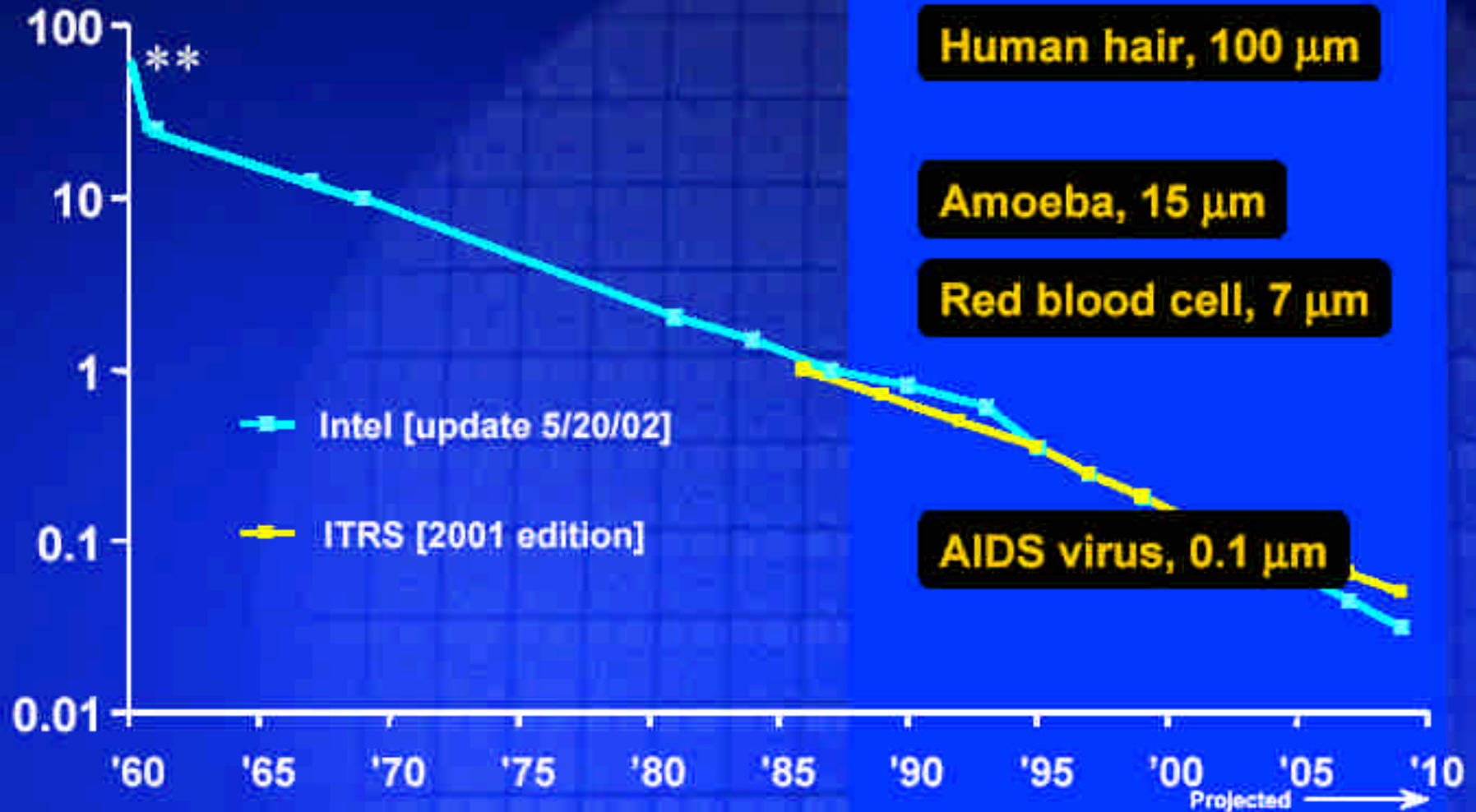
cost per transistor ↓ chip density ↑

# Line Width/Feature Size



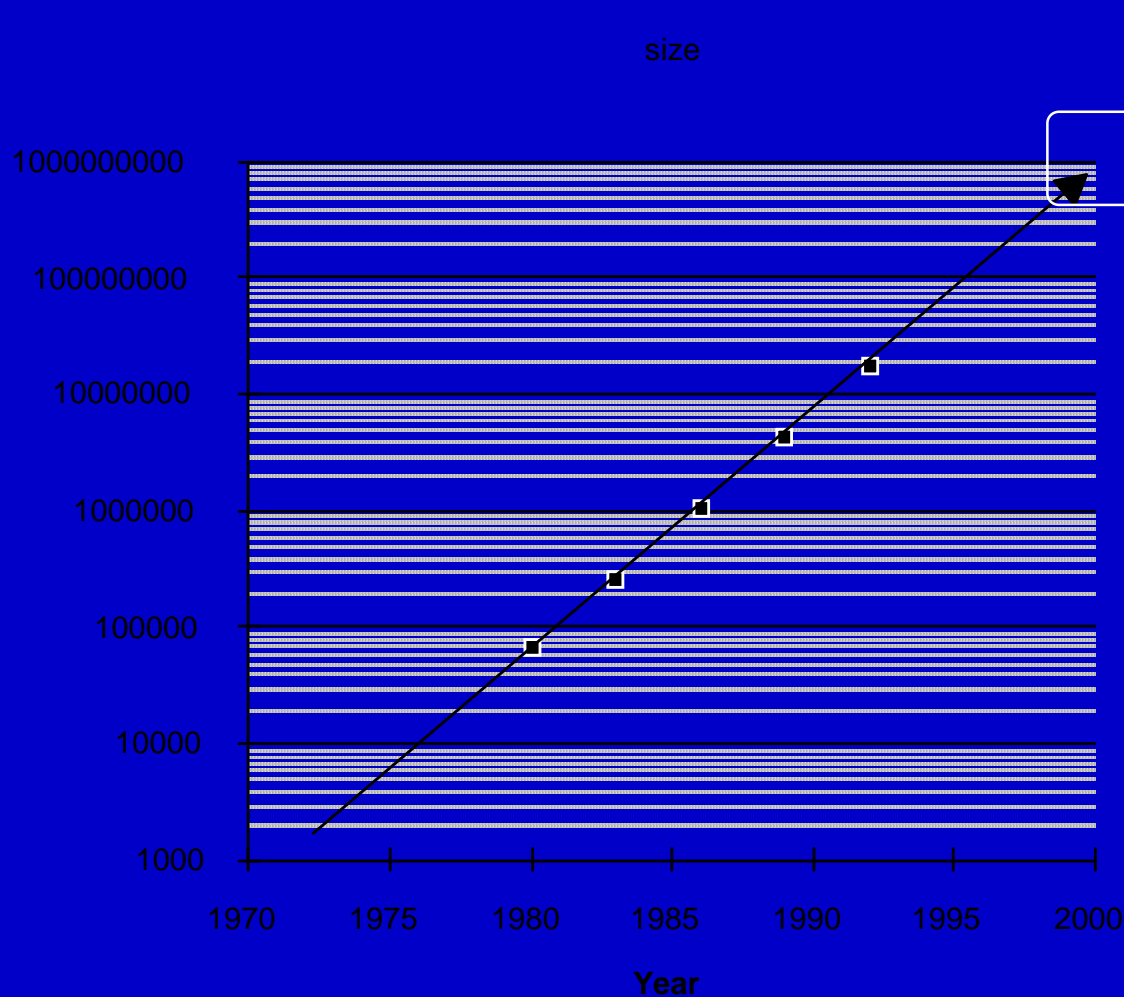
# Minimum Feature Size

Feature Size  
(microns)



\*\* Planar Transistor; remaining data points are ICs.  
Source: Intel, post '86 trend data provided by SIA  
International Technology Roadmap for Semiconductors (ITRS)  
\* [ITRS DRAM Half-Pitch vs. Intel "Lithography"]

# Technology Trends: Memory Capacity (1 Chip DRAM)



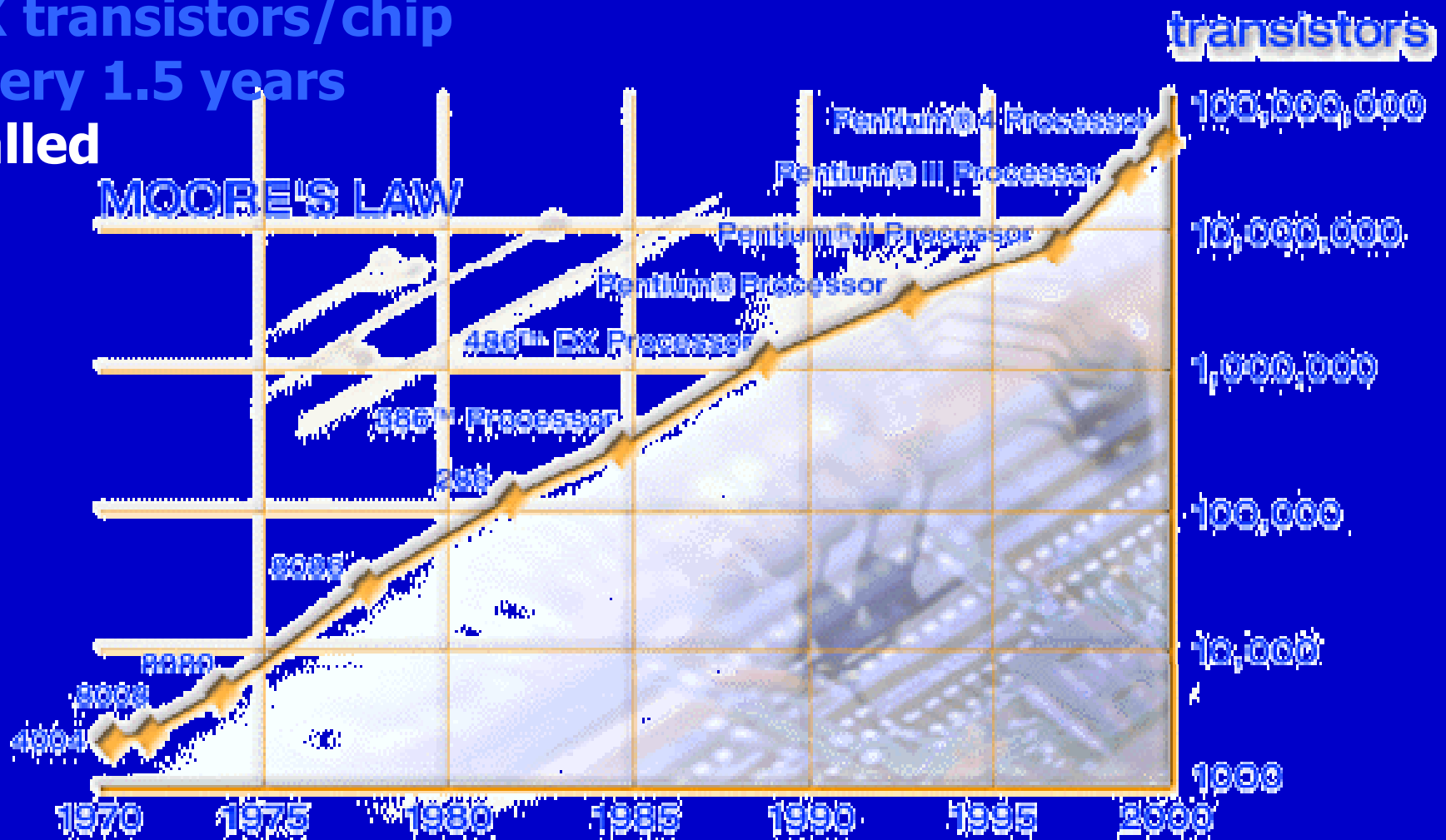
year	size(Mbit)
1980	0.0625
1983	0.25
1986	1
1989	4
1992	16
1996	64
2000	256

1.4X/yr, or doubling  
every 2 years

4000X since  
1980

# Technology Trends: Microprocessor Capacity

2X transistors/chip  
every 1.5 years  
Called



# Technology => Dramatic Change

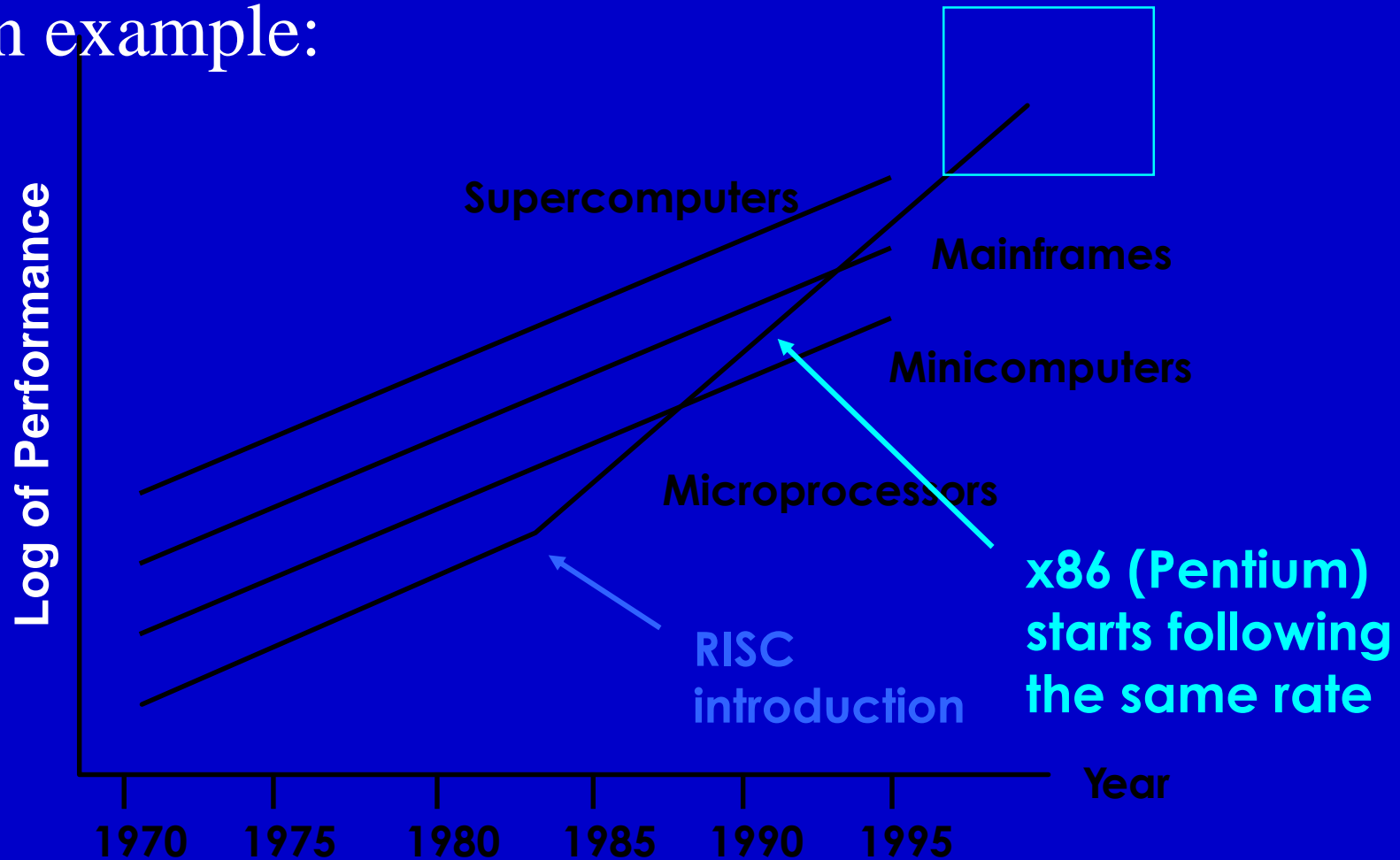
- Processor
  - 2X in speed every 1.5 years; 100X in last decade
- Memory
  - DRAM capacity: 2x / 2 years; 64X size in last decade
  - Cost per bit: improves about 25% per year
- Disk
  - Capacity: > 2X every year; 120X in last decade
  - Cost per bit: improves about 100% per year

# Technology Progress: Implication

- Minimum feature size: halve every 7 years
  - $O(n^2)$  with respect to transistor count and  $O(n)$  with respect to switching time
    - $O(n^3)$  improve in computing with lithography
  - Power dissipation
- Wafer size: X2 every 3 years
  - $O(n^2)$  with respect to transistor count
- Others: provide one-time improvement
- Price: lower costs due to
  - Simpler development and higher volumes with CMOS
- *Highly integrated chips with improved speed, reliability, cost, functionality*

# Technology Enables Architectural Innovation

- An example:



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# Computer Progress Supported/Driven by Market and Usage

- Applications drive machine “balance”
  - Numerical simulations: floating-point, memory BW
  - Transaction processing: I/O, INT performance
  - Media processing: low-precision ‘pixel’ arithmetic
- Applications drive machine performance
  - What if my computer runs all my software very fast?
  - Programs use increasing amount of memory:
    - 1.5-2 per year, or 0.5-1 addressing bit per year
  - High-level programming languages replace assembly languages => compilers important
    - Compiler and architecture work together
- Effects of compatibility and ease of use
- Effects of market demands and market share
  - Can investment in R&D, production be paid off?

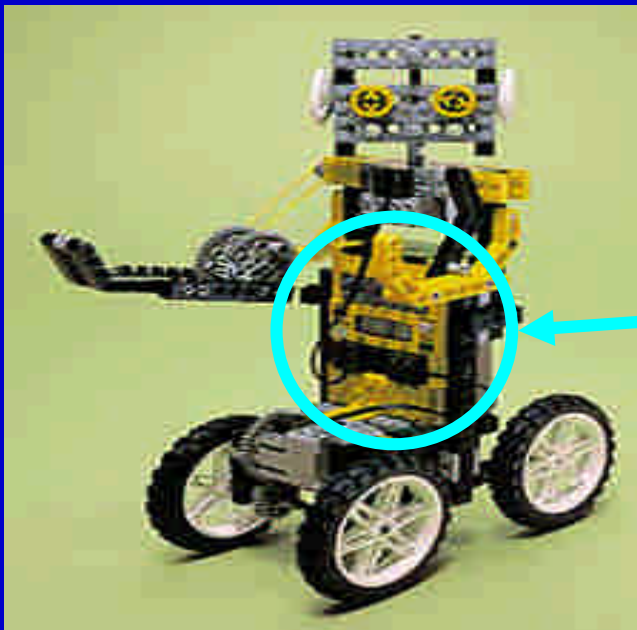
# Computer Usage: General Purpose

- Uses: commercial (int.), scientific (FP, graphics), home (int., audio, video, graphics)
  - Software compatibility is the most important factor
  - Short product life; higher price and profit margin
  - OS issue: OS serves another interface above arch.
    - Effects of OS developments on architecture
    - RISC-based Unix workstation vs x86-based PC: (1) units sold is only 1% of PC's, (2) emphasize more on performance than on price
      - survive only if performance is high enough?
      - effects of Linux-based PCs?
- Future:
  - Use increased transistors for performance, human interface (multimedia), bandwidth, monitoring

# Computer Usage: Embedded

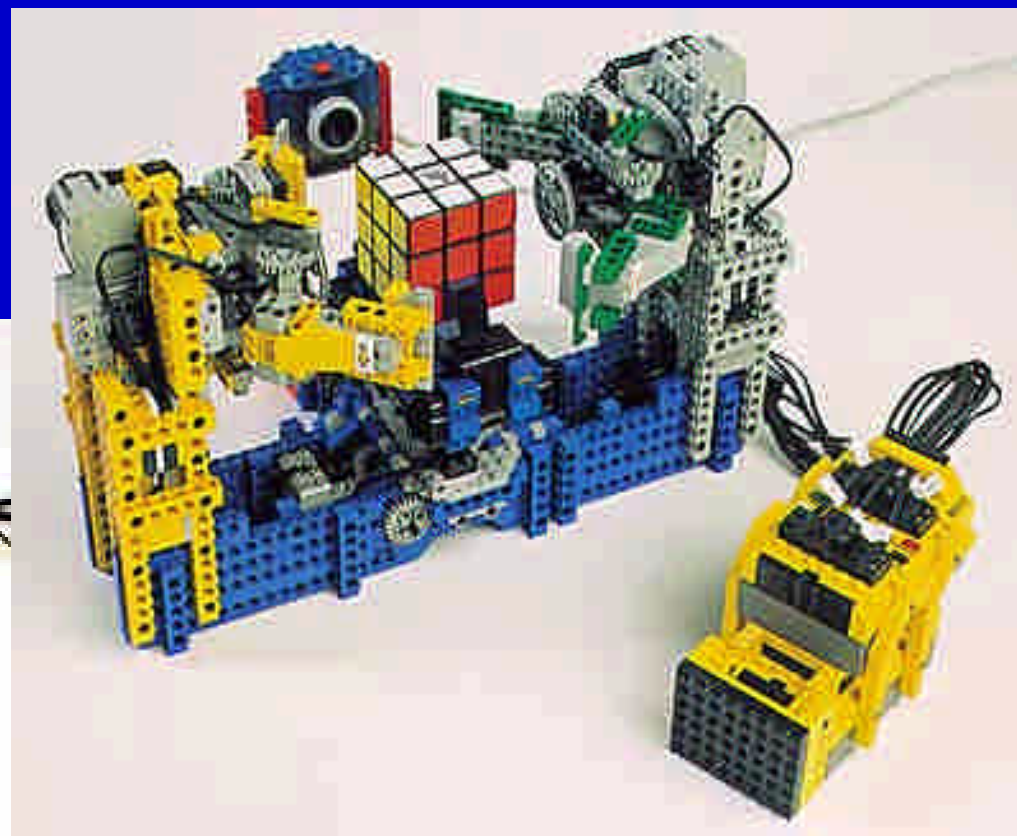
- A computer inside another device used for running one predetermined application
- Uses: control (traffic, printer, disk); consumer electronics (video game, CD player, PDA)

## Lego Mindstorms

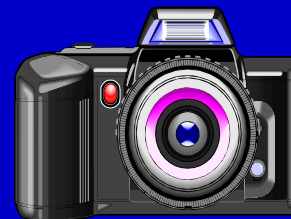
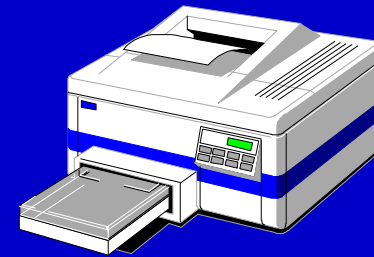
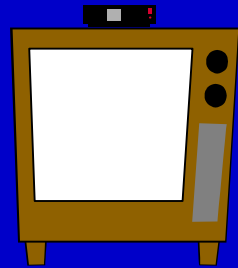


Robotic command explorer:  
A “Programmable Brick”,  
Hitachi H8 CPU (8-bit), 32KB RAM,  
LCD, batteries,  
infrared transmitter/receiver,  
4 control buttons, 6 connectors

# 它可以做什麼？



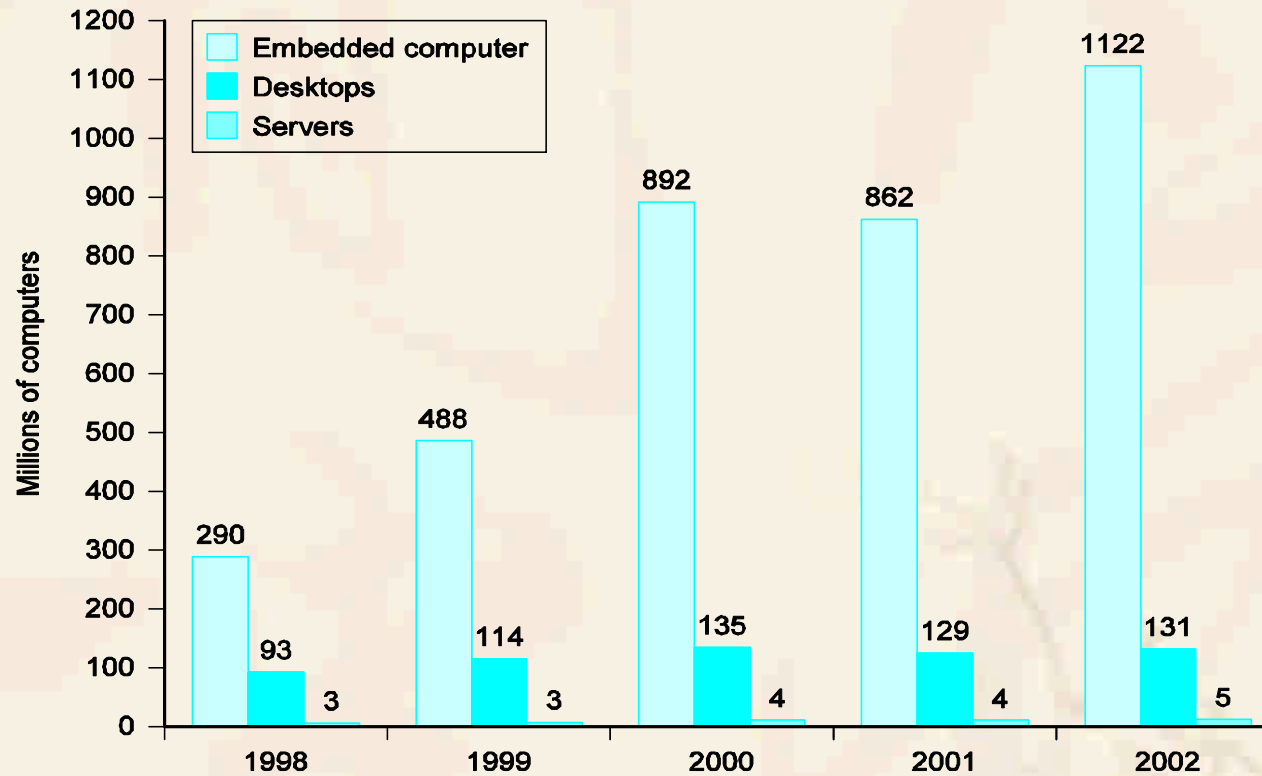
# 生活裡的應用比比皆是



# Embedded Computers

- Typically w/o FP or MMU, but integrating various peripheral functions, e.g., DSP
  - Large variety in ISA, performance, on-chip peripherals
  - Compatibility is non-issue, new ISA easy to enter, low power become important
- More architecture and survive longer:  
4- or 8-bit microprocessor still in use  
(8-bit for cost-sensitive, 32-bit for performance)
- Large volume sale (billions) at low price (\$40-\$5)
- Use of microprocessor:
  - 1995 #1: x86; #2: 6800; #3: Hitachi SuperH (Sega)
  - 2002 #1: ARM #2: x86; #3: Motorola 6800
- Trend: lower cost, more functionality
  - system-on-chip,  $\mu$ P core on ASIC

# The Number of Distinct Processors Sold



# Summary

- Computer architecture studies instruction set architecture and computer organization
- Instruction set architecture is about interface
- All computers consist of five components:
  - Processor: (1) datapath and (2) control
  - (3) Memory
  - (4) Input devices and (5) output devices
- Architecture design is an iterative process; must consider:
  - Device technology
  - Application and market
  - Performance evaluation