Embedded System Design

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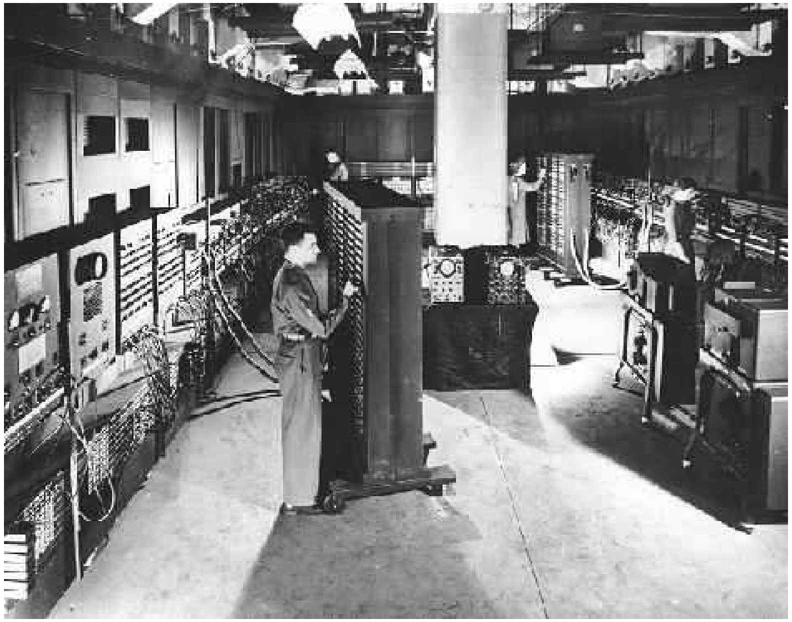
NCTU, Summer 2005

Spot the Computer



Hidden Computers

Casio
Camera
Watch

Nokia 7110
Browser
Phone

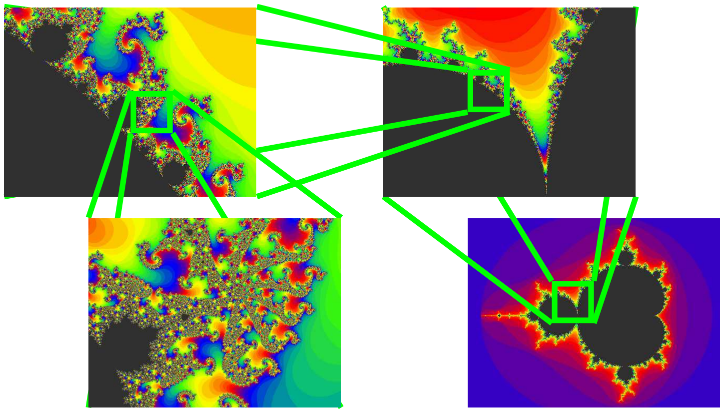
Sony
Playstation 2

Philips
DVD Player

Philips
TiVo Recorder

Technical Challenges

Real-time



Complexity

Photo by Thomas Danoghue

Concurrency

Legacy Languages

Software complexity growing

Size of Typical Embedded System

1985	13 kLOC	
1989	21 kLOC	↓ 44 % per year
1998	1 MLOC	
2000	2 MLOC	
2008	16 MLOC	≈ Windows NT 4.0
2010	32 MLOC	≈ Windows 2000

Source: “ESP: A 10-Year Retrospective,” Embedded Systems Programming, November 1998

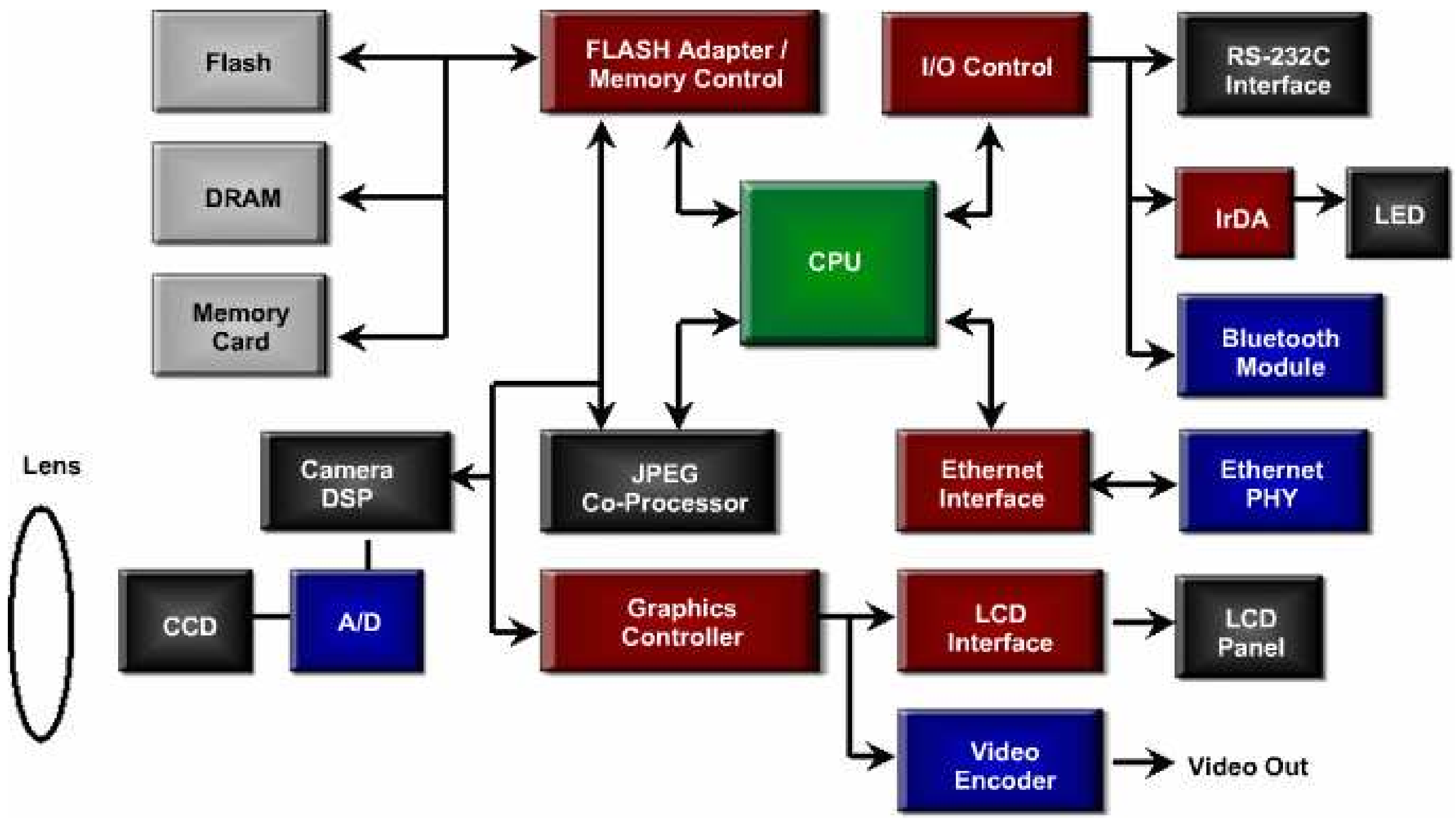
Written in stone-age languages

"Which of the following programming languages have you used for embedded systems in the last 12 months?"

C	81%
Assembly	70%
C++	39%
Visual Basic	16%
Java	7%

Source: "ESP: A 10-Year Retrospective," Embedded Systems Programming, November 1998

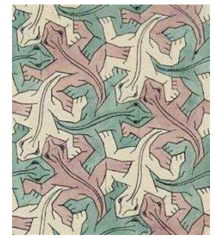
Digital Camera Block Diagram



The Design Challenge

Design optimal device that meets constraints on

Price



Functionality

Performance

Size

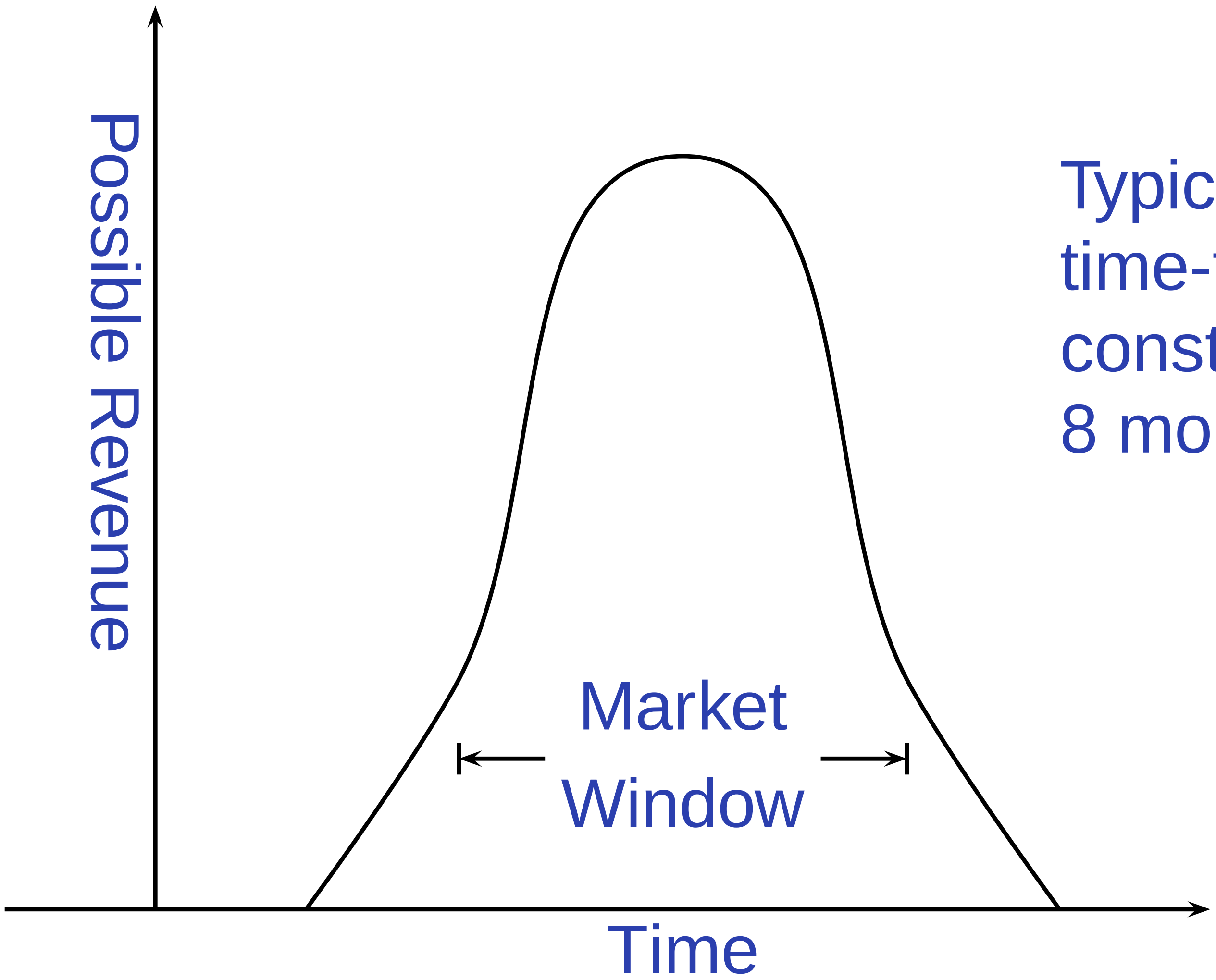
Power

Time-to-market

Maintainability

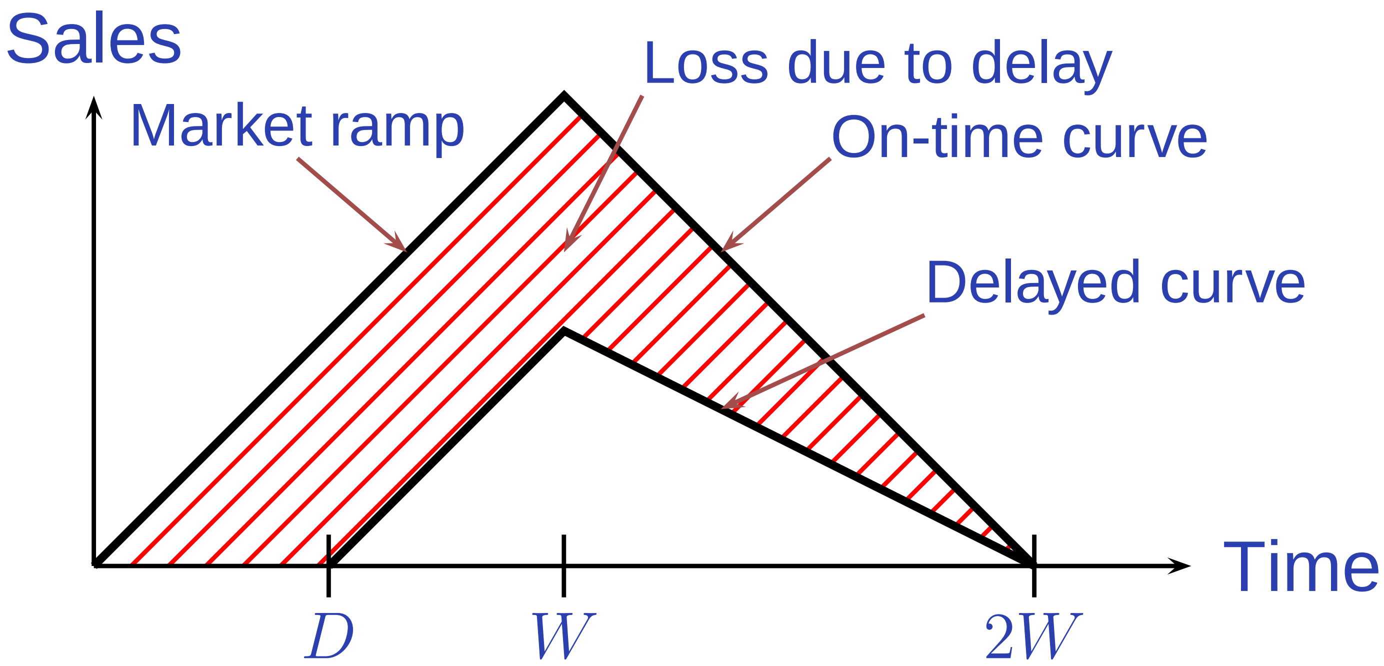
Safety

The Time-to-Market Challenge



Typical
time-to-market
constraint:
8 months

Simplified Revenue Model



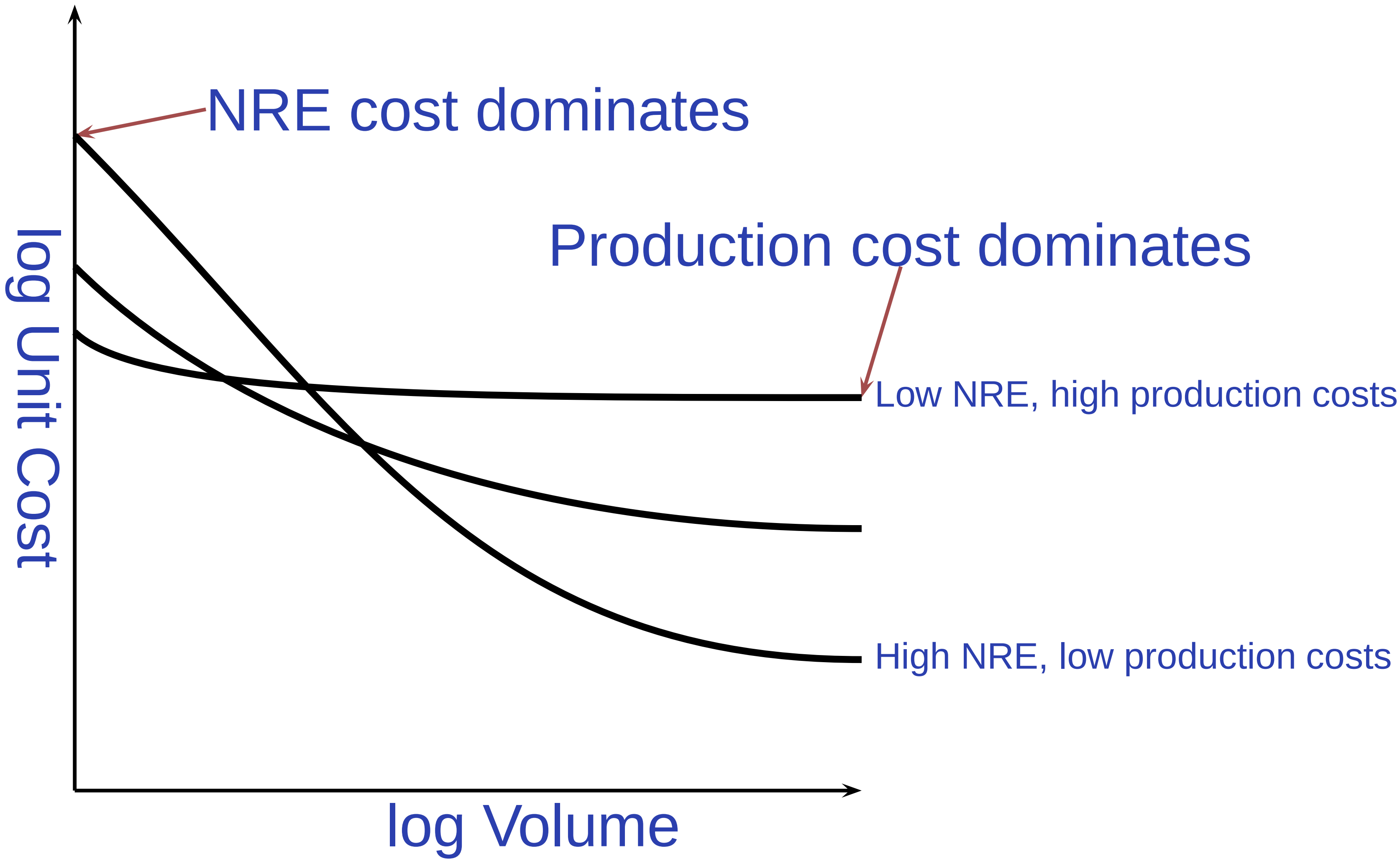
Assuming a constant market ramp, on-time revenue is $\frac{1}{2}bh = \frac{1}{2} \cdot 2W \cdot W = W^2$ and delayed revenue is $\frac{1}{2}(2W - D)(W - D)$ so fractional revenue loss is

$$\frac{D(3W - D)}{2W^2} = O(D^2)$$

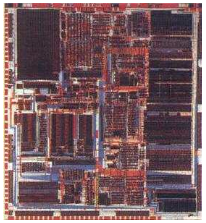
Example: when $W = 26$ and $D = 10$, fraction lost is about 50%.

NRE

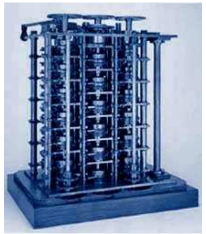
Nonrecurring engineering cost:
The cost of producing the first one.



Embedded System Technologies



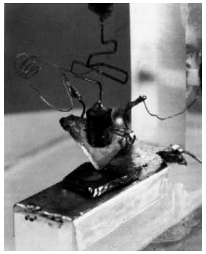
Integrated Circuits



Processing elements

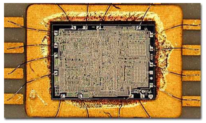
Design tools

IC Technology

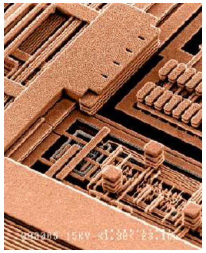


1947: First transistor (Shockley, Bell Labs)

1958: First integrated circuit (Kilby, TI)

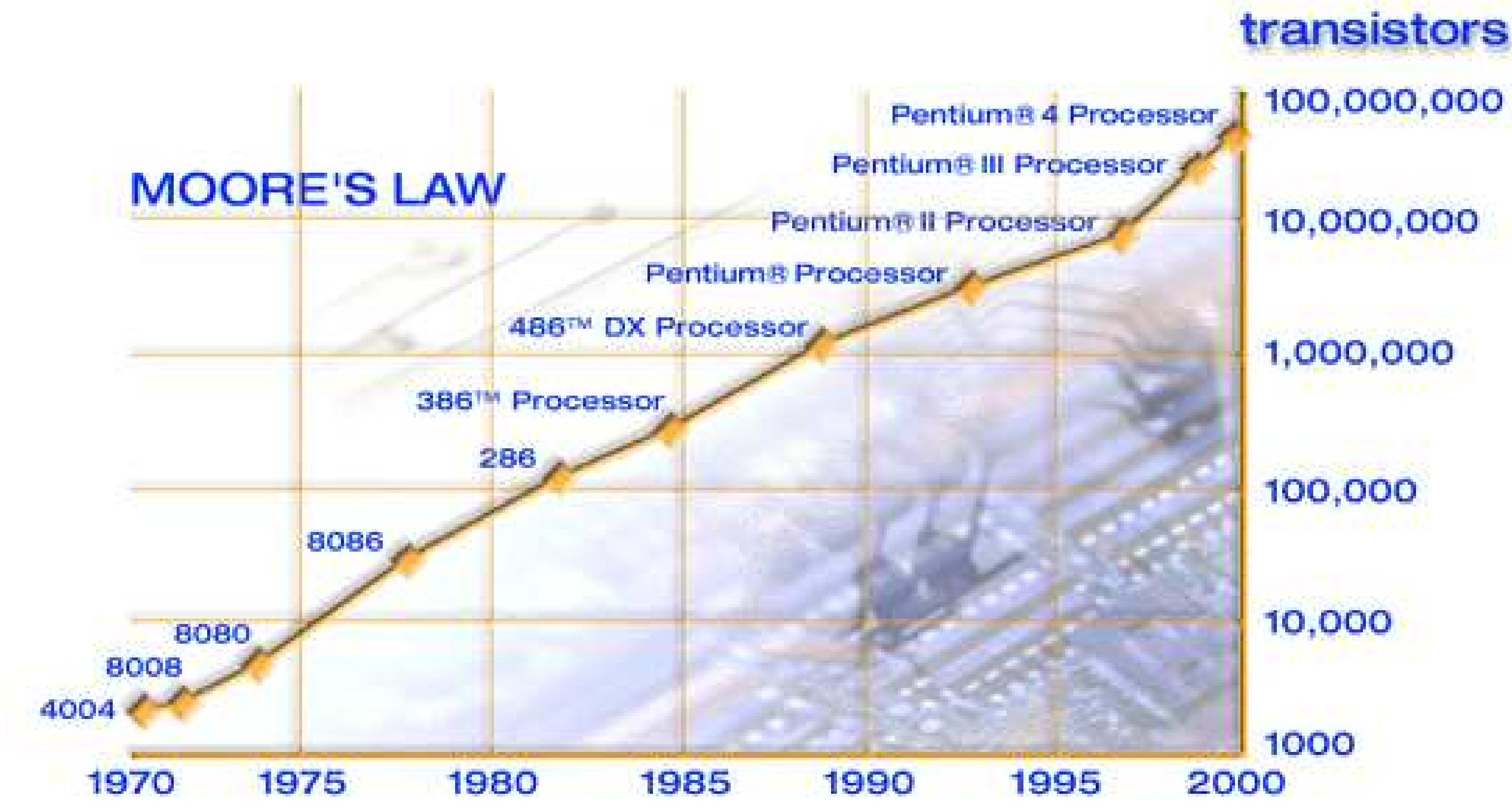


1971: First microprocessor (4004: Intel)



Today: six wire layers, 100 nm features

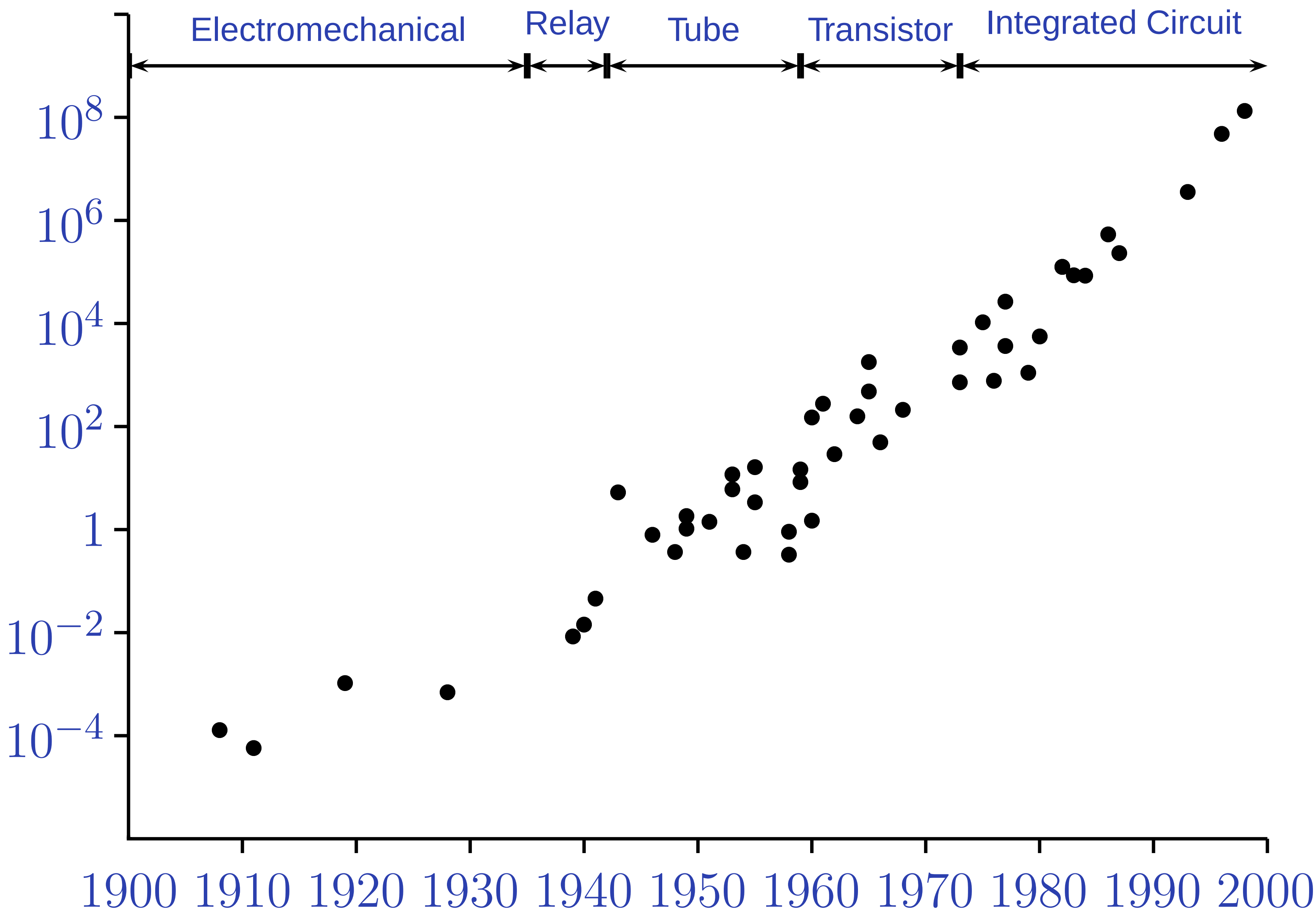
Moore's Law



Gordon Moore, 1965: Exponential growth in the number of transistors per IC

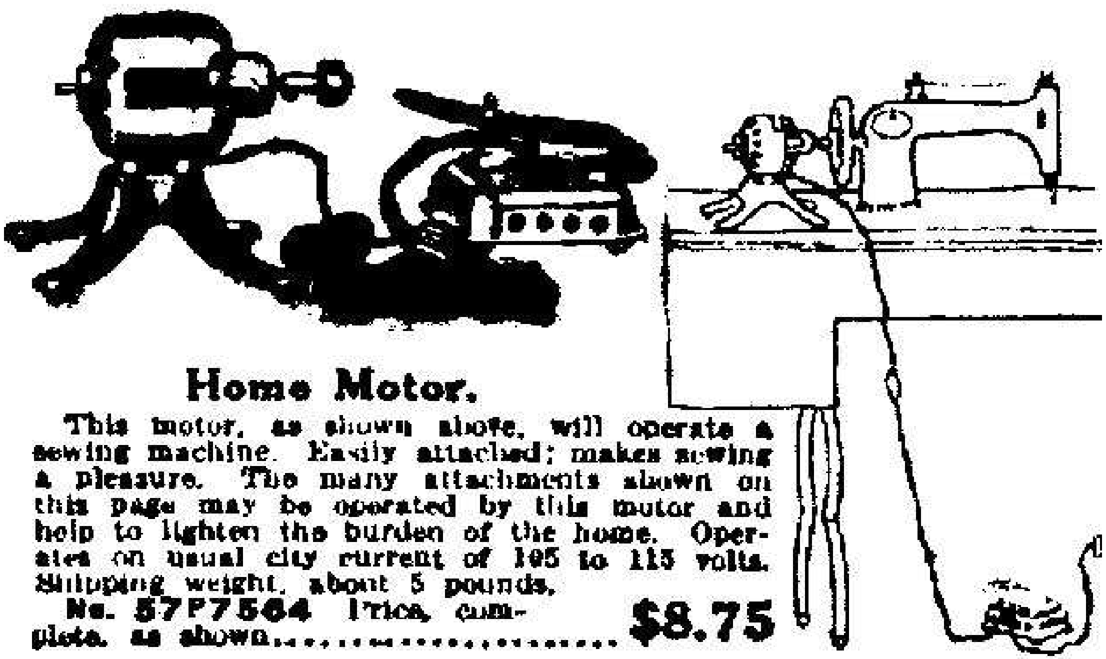
Source: Intel

$1000 buys you this many CPS



Source: Ray Kurzweil, *The Age of Spiritual Machines*

1918 Sears Roebuck Catalog



About $100 in today’s dollars.

From Donald Norman, *The Invisible Computer*, 1998.

Spectrum of IC choices

Flexibility ↑

	You choose
Full Custom	polygons (Intel)
ASIC	circuit (Sony)
Gate Array	wires
FPGA	logic network
PLD	logic function
GP Processor	program (e.g., Pentium)
SP Processor	program (e.g., DSP)
Multifunction	settings (e.g., Ethernet)
Fixed-function	part number (e.g., 74LS00)

Hardware and Software

Hardware	Software
Parallel	Sequential
Synchronous	Asynchronous
Logic Gates	Stored programs
Wire-based communication	Memory-based communication
Fixed topology	Highly programmable
Low power	High power
More detailed	Less detailed
High NRE	No NRE
Faster	Slower

Design Tools

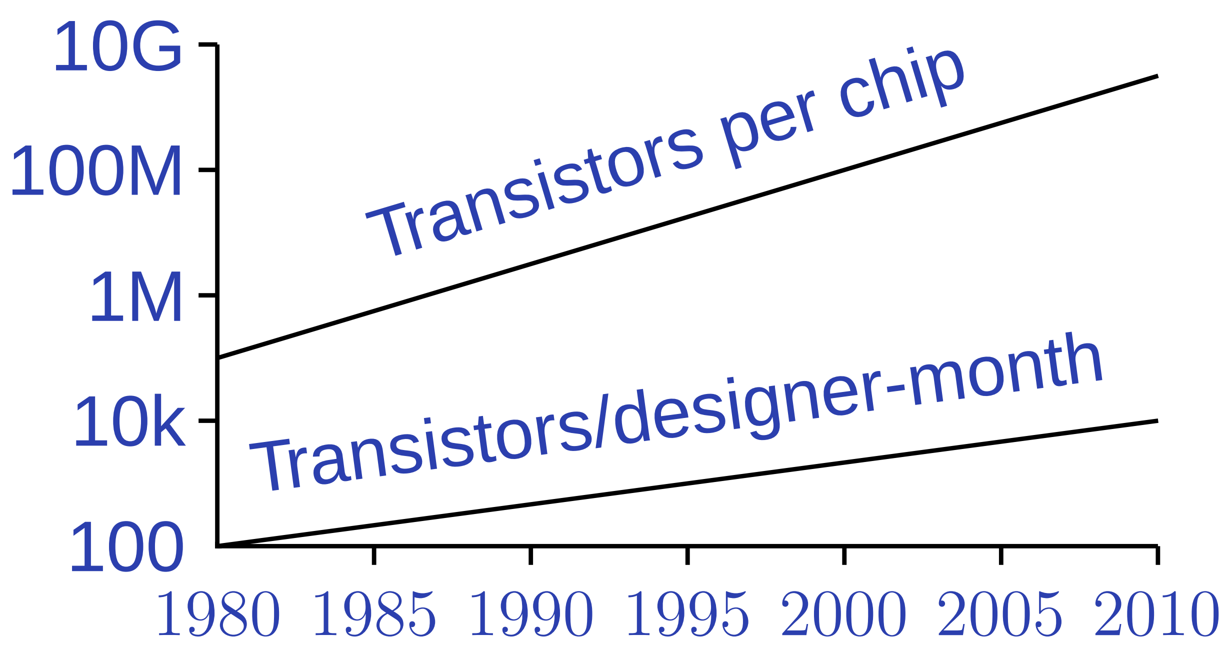
Hardware	**Software**
Logic Synthesis	Compilers
Place-and-route	Assemblers
DRC/ERC/LVS	Linkers
Simulators	Debuggers

Cost of Designs is Rising

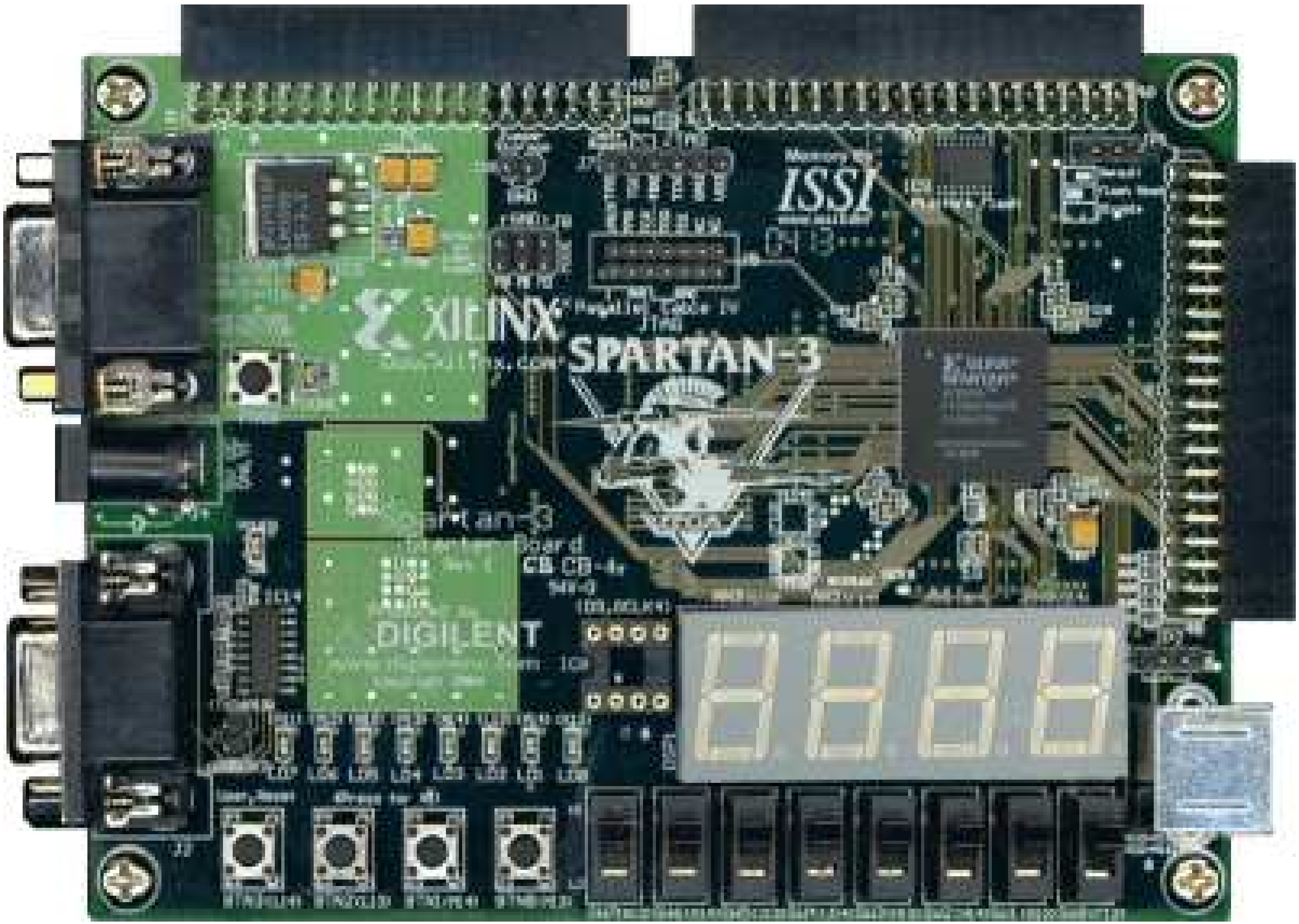
1981: 100 designer-months for leading-edge chip
    10k transistors, 100 transistors/month

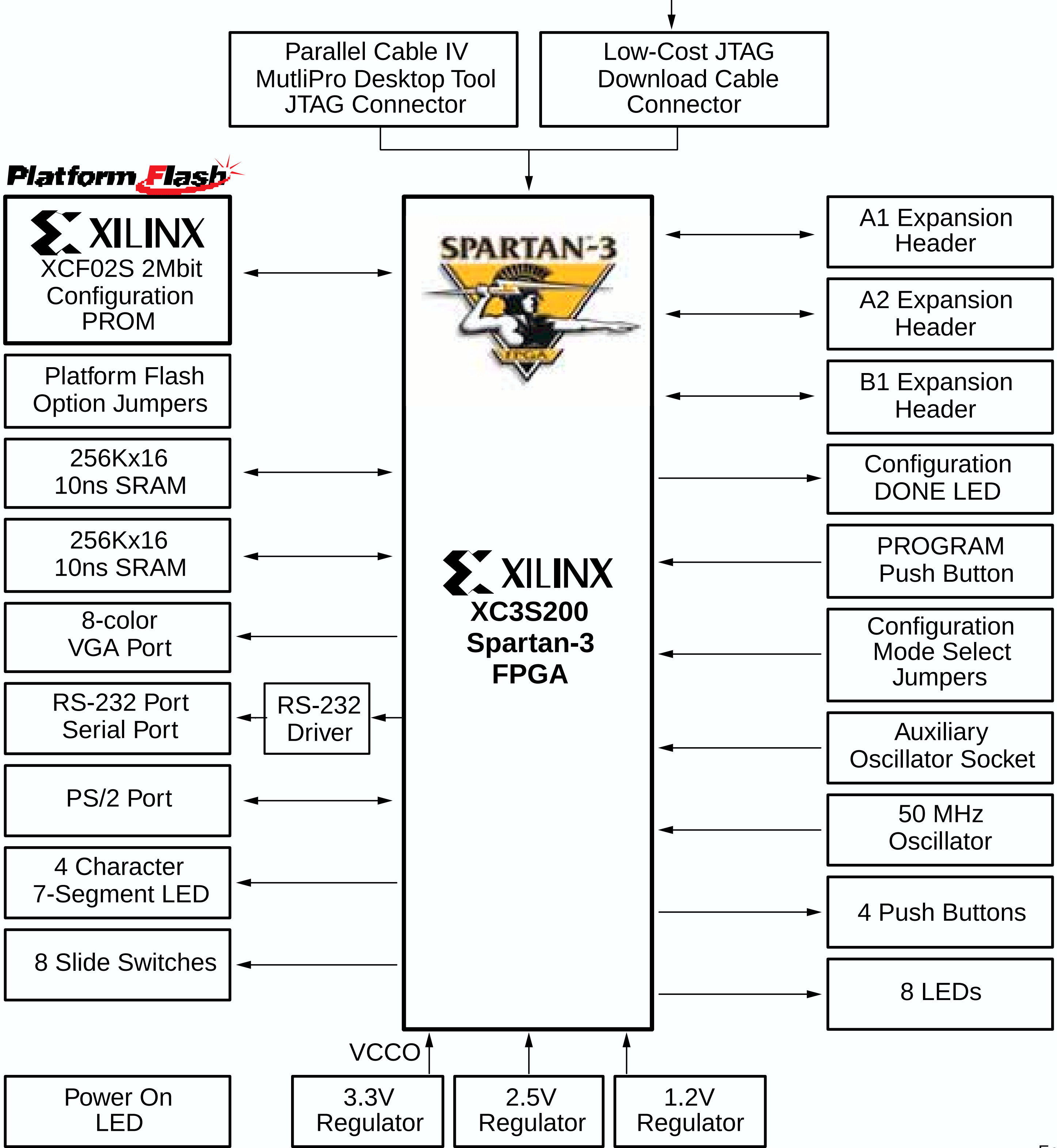
2002: 30 000 designer-months
    150M transistors, 5000 transistors/month

Design cost increased from $1M to $300M



The Digilent Spartan-3 Starter Board




Parallel Cable IV
MutliPro Desktop Tool
JTAG Connector
Low-Cost JTAG
Download Cable
Connector
Platform Flash
XILINX
XCF02S 2Mbit
Configuration
PROM
Platform Flash
Option Jumpers
256Kx16
10ns SRAM
256Kx16
10ns SRAM
8-color
VGA Port
RS-232 Port
Serial Port
RS-232
Driver
PS/2 Port
4 Character
7-Segment LED
8 Slide Switches
SPARTAN-3
XILINX
XC3S200
Spartan-3
FPGA
A1 Expansion
Header
A2 Expansion
Header
B1 Expansion
Header
Configuration
DONE LED
PROGRAM
Push Button
Configuration
Mode Select
Jumpers
Auxiliary
Oscillator Socket
50 MHz
Oscillator
4 Push Buttons
8 LEDs
VCCO
Power On
LED
3.3V
Regulator
2.5V
Regulator
1.2V
Regulator

Class Structure

First half of course: Five Introductory Labs:

1. Count in C on the 7-segment display
2. Serial Terminal in C
3. VHDL system reverse-engineering
4. Sum the contents of a small memory in VHDL
5. Create a simple peripheral

Second half project: **Design-your-own**

Custom Project Ideas

Broadly: C + VHDL + peripheral(s)

Video game (e.g., Pac-Man)

Simple video effects processor

Digital picture frame

Serial terminal

Serial port monitor

Very fancy digital clock (w/ video)

I/O Resources

The Digilent board is simple:

- 8-color VGA display
- RS-232 serial port
- PS/2 port
- 1MB SRAM
- Switches and LEDs

Interesting projects will include video and the keyboard and/or serial port.