Composibility via static discipline

- Be tolerant of inputs and strict on outputs

Moore's law

- "Cramming More Components Onto Integrated Circuits", Electronics, April 1965

Transistors/die doubles every ~18 months

- Cost per transistor
- Transistors per die

Lithography: the driver behind transistor count

- Components/area \( O(x^2) \) with feature size
- Total components \( O(a) \) with die area
- Switching rate \( O(x) \) with feature size
**CPU performance**

- Manhattan
- Microcomputer
- Microprocessor

**DRAM density**

**Disk: Price per GByte drops at ~30-35% per year**

**ENIAC**
- 1946
- Only one built
- 5000 adds/sec
- 20 10-digit registers
- 18,000 vacuum tubes
- 124,500 watts
- Not really stored program

**UNIVAC (Universal Automatic Computer)**
- 1951
- 46 sold
- 2000 ops/sec
- 1,000 12-digit words (mercury)
- 5000 tubes
- $1.5 million

**IBM System/360-40**
- 1964
- 1.6 MHz
- 16-256 KB core
- $225,000
- Family of six
- 32-bit
- Time-sharing
Cray 1: supercomputer
- 1976
- 80 sold
- 80 MHz
- 8 Mbyte SRAM
- 230,000 gates
- $5 million

DEC PDP-8 (1964)
- 60,000 sold
- 330,000 adds/sec
- 4096 12-bit words
- $18,000

Apple II
- 1977
- 1 MHz
- 6502 microprocessor
- 4 to 48 Kilobytes RAM
- $1300
- Basic, Visicalc

IBM’s wrist watch
- 2001
- Linux and X11
- 74 Mhz CPU
- 8 Megabyte flash
- 8 Megabyte DRAM
- Wireless

Software follows hardware

Cheap → Pervasive

Source: Internet Software Consortium (www.isc.org)
Pervasive → qualitative change

Number crunching
Word processing
Communication
Embedded
Sense/control

Heat is a problem

Recent Intel CPU Clock Rates

The Future: will it be painful?

What went right?
- Unbounded composibility
- General-purpose computers
- Only need to make one thing fast
- Separate architecture from implementation
- S/W can exploit new H/W
- Cumulative R&D investment over years