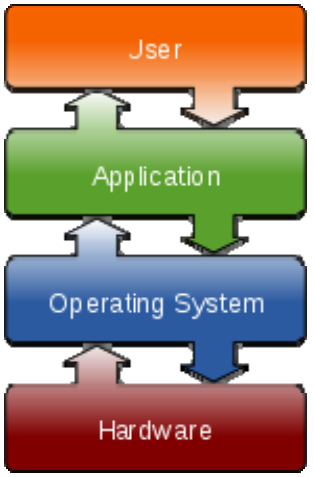
ENCE360
Operating Systems



Introduction to Operating Systems

Operating Systems

- Operating systems are *everywhere*, in all shapes and sizes
  - PC, Smartphone
  - Game console, Hand-held
  - TV, Thermostat
  - Car
- While you may never write an OS (but you may!), you *will* develop software for an OS
- Understanding operating systems will make you a better computer scientist/software engineer

  "I want to make computers dance for me."
- Last, but not least ...
  - Combines previous classes – hardware, algorithms, coding
  - Provides deep knowledge, insights

  "Operating systems are cool."

Let's Get Started!

- Virtualization
  - Time (CPU)
  - Space (memory)
- Concurrency
- Persistence (I/O)

Chapter 1
MODERN OPERATING SYSTEMS (MOS)
By Andrew Tanenbaum

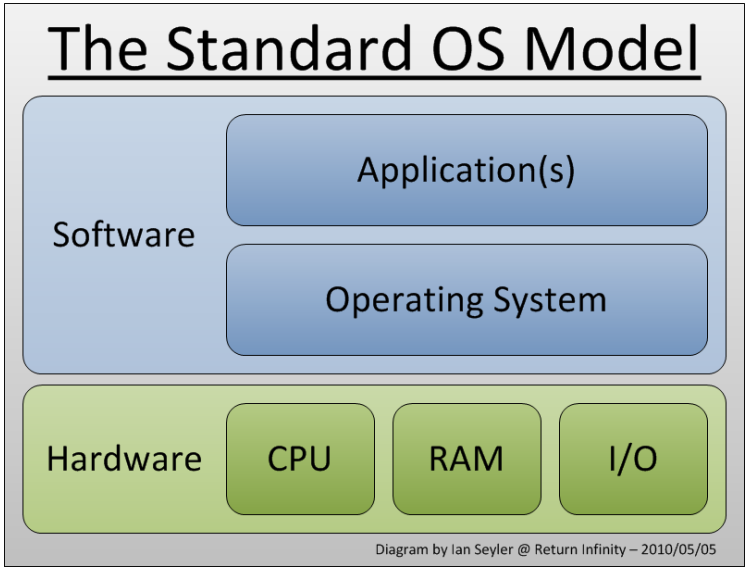
OPERATING SYSTEMS: THREE EASY PIECES
R. Arpaci-Dusseau and A. Arpaci-Dusseau,
March, 2015
http://www.ostep.org/

Operating Systems are Foundational

- "Nobody has time for all those crazy details."
  - Abstraction
- "Sharing all these devices… it's like herding cats!"
  - Resource Manager

Convience & Efficiency

- An OS is an extended machine
  - Hides messy details which must be performed
  - Presents user with virtual machine, easier to use
- An OS is a resource manager
  - Each program gets time with resource
  - Each program gets space on resource



Introduction

- What is an operating system
- History of operating systems
- The operating system zoo
- Computer hardware review
- Operating system concepts
- System calls
- Operating system structure

Refer to Chapter 1
MODERN OPERATING SYSTEMS (MOS)
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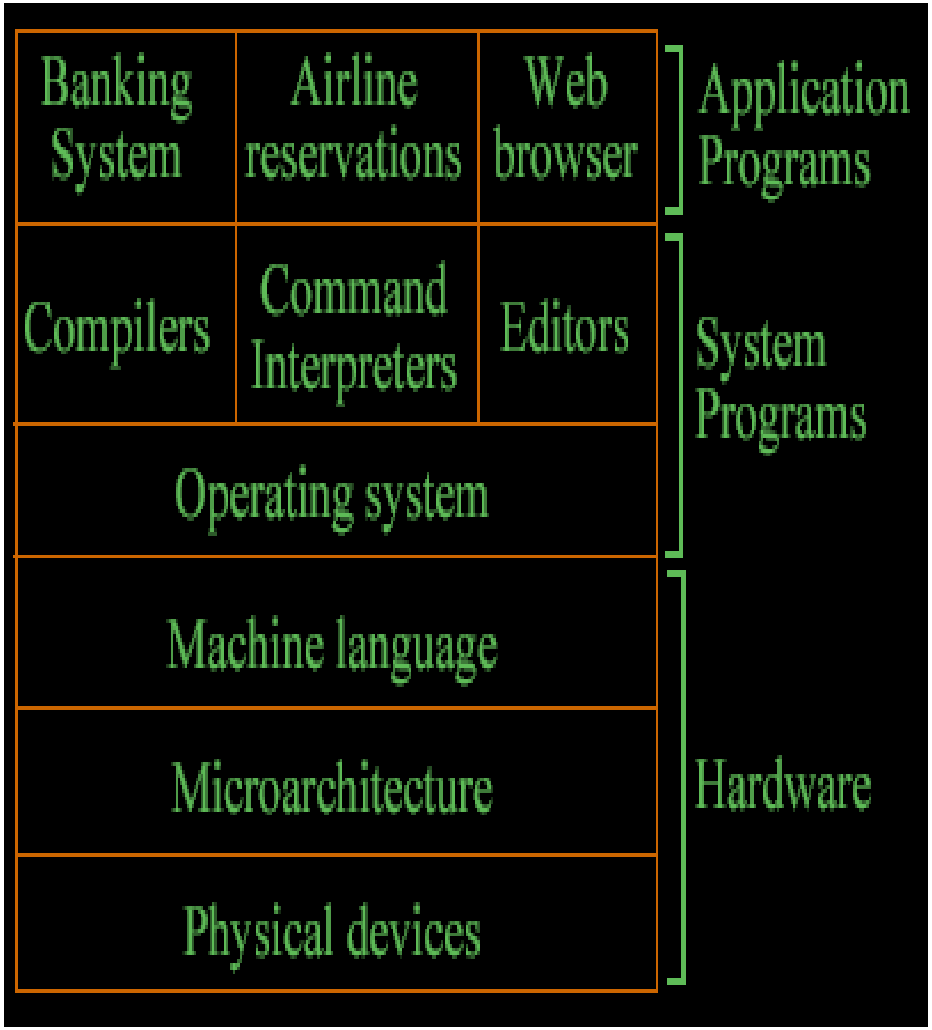
What is an Operating System

- It is an extended machine
  - Hides the messy details which must be performed
  - Presents user with a virtual machine, easier to use
- It is a resource manager
  - Each program gets time with the resource
  - Each program gets space on the resource

What is an Operating System

- **Operating system**
  1. **creates an "extended machine":**
     - **This means providing abstraction to make interactions between the hardware and the applications more convenient to programs and programmers**
  2. **Manages the available hardware resources in order to provide efficient use of this hardware.**



Layered architecture

History of Operating Systems

- First Generation:
  - (1945–55) Vacuum Tubes and Hard-wiring
- Second Generation:
  - (1955–65) Transistors and Batch Systems
- Third Generation:
  - (1965–1980) ICs and Multiprogramming
- Fourth Generation:
  - (1980–Present) Personal Computers
  - (Present–Future) Quantum Computing and AI


The newest Computer Model, 16 Colours, on Harddisk, including Mouse.....
You should wait, Your Majesty - In 6 months it costs only half.....

Before Operating Systems

The first digital computer was designed by Charles Babbage (1792-1871)

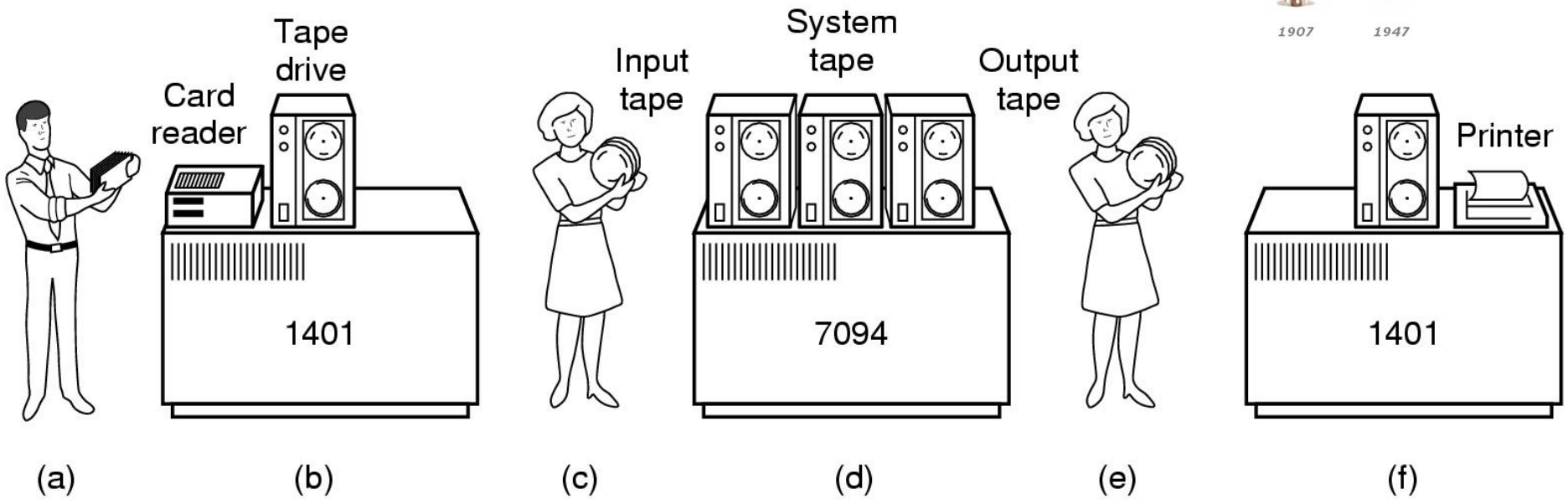
- **English mathematician who tried to build 'analytical engine'**
- **Ada Lovelace , daughter of Lord Byron was a programmer**
- **At the time the mechanical demands exceeded the available technology and this computer was not successfully constructed.**

First Generation

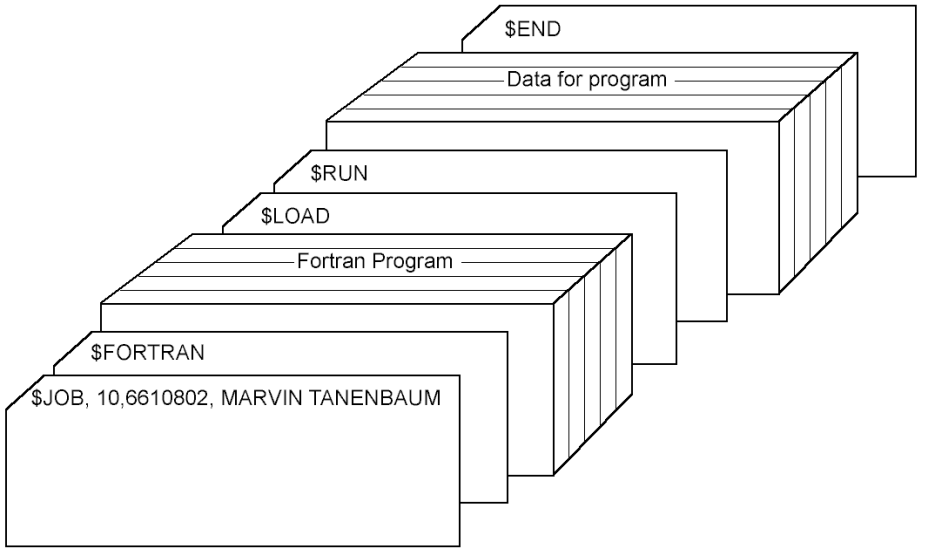
1907

- Each computer custom built, "programmed" with wires
  - No operating system

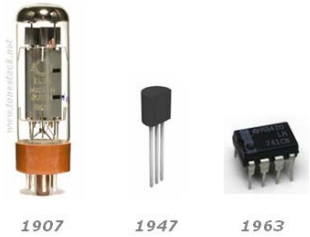
Second Generation

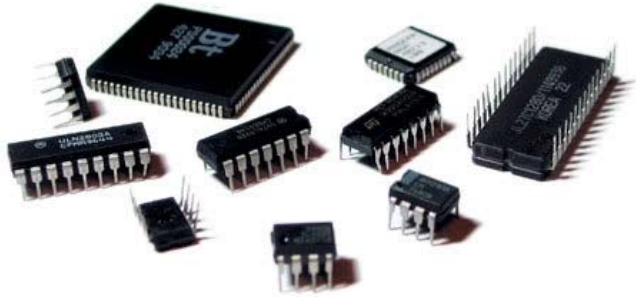


- Batch systems
- Programming
- "Operating system" only loaded, cleaned up jobs

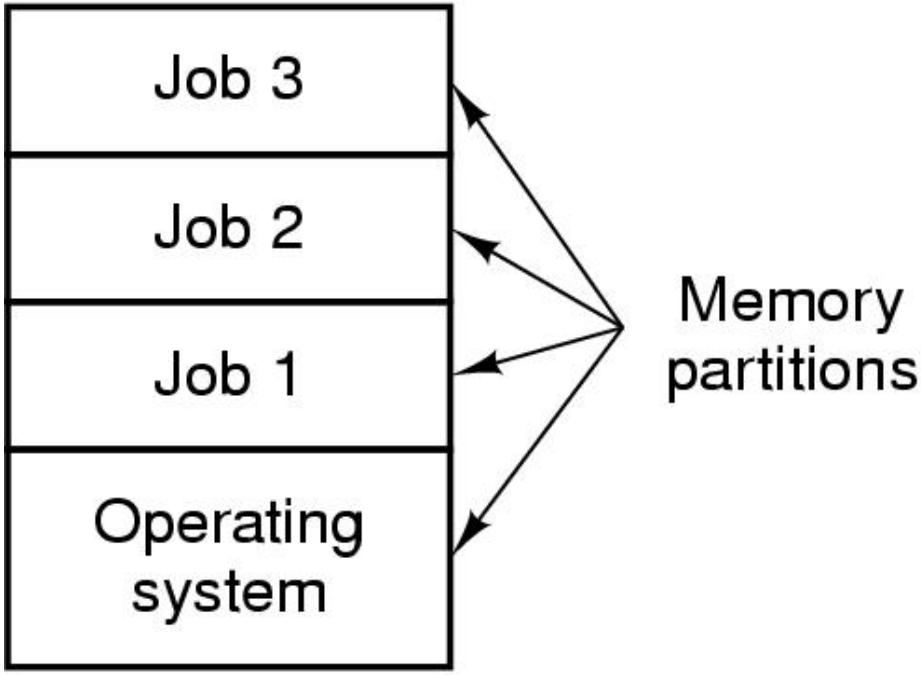


Third Generation





- Multiprogramming
  - Two+ jobs in memory
  - "Time sharing" and "multi-tasking"
- First real operating systems
  - MULTICS
    - Led to Unix led to **Linux**



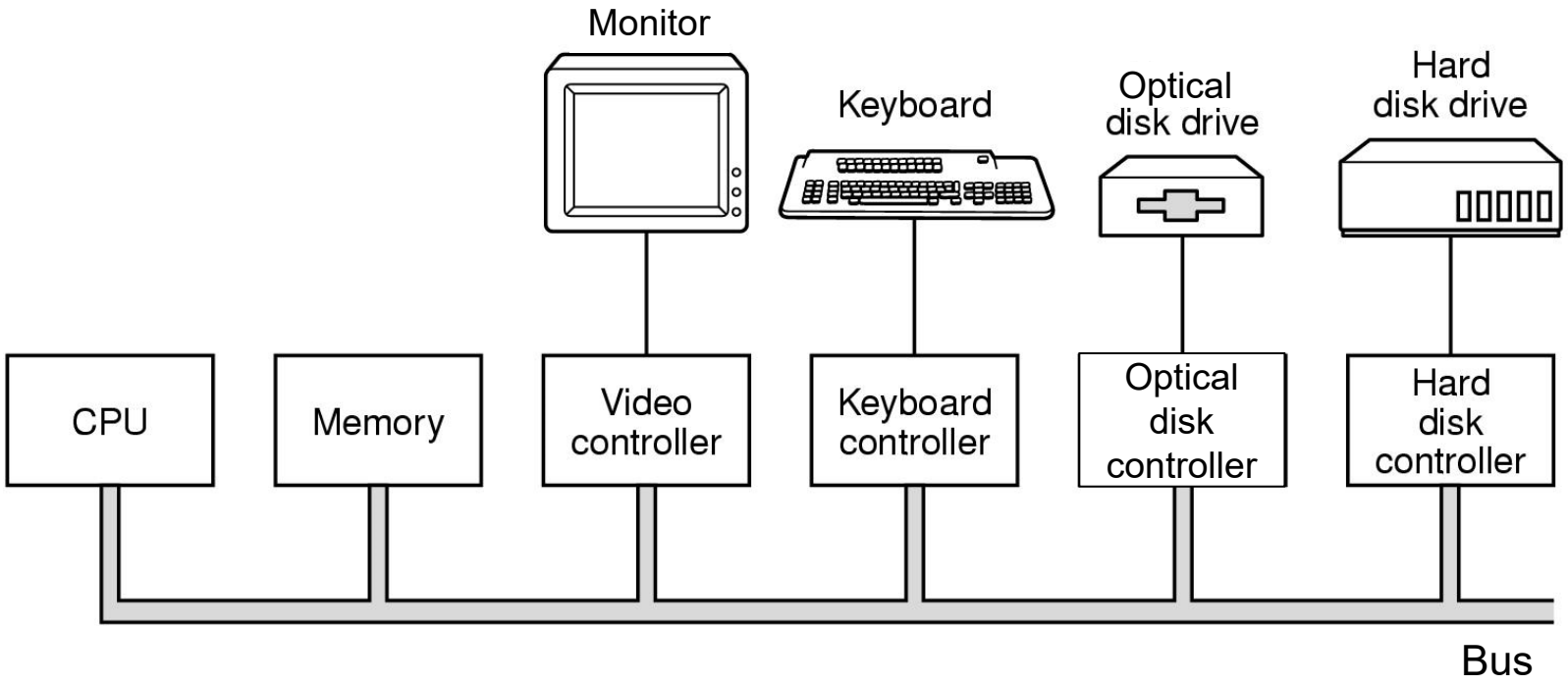
Fourth Generation

- Personal computers
- Modern operating systems
  - Linux, maxOS, Windows (DOS)
  - virtual memory
  - paging
  - TCP/IP
- Fifth generation?
  - Quantum computing and AI

The Operating System Zoo

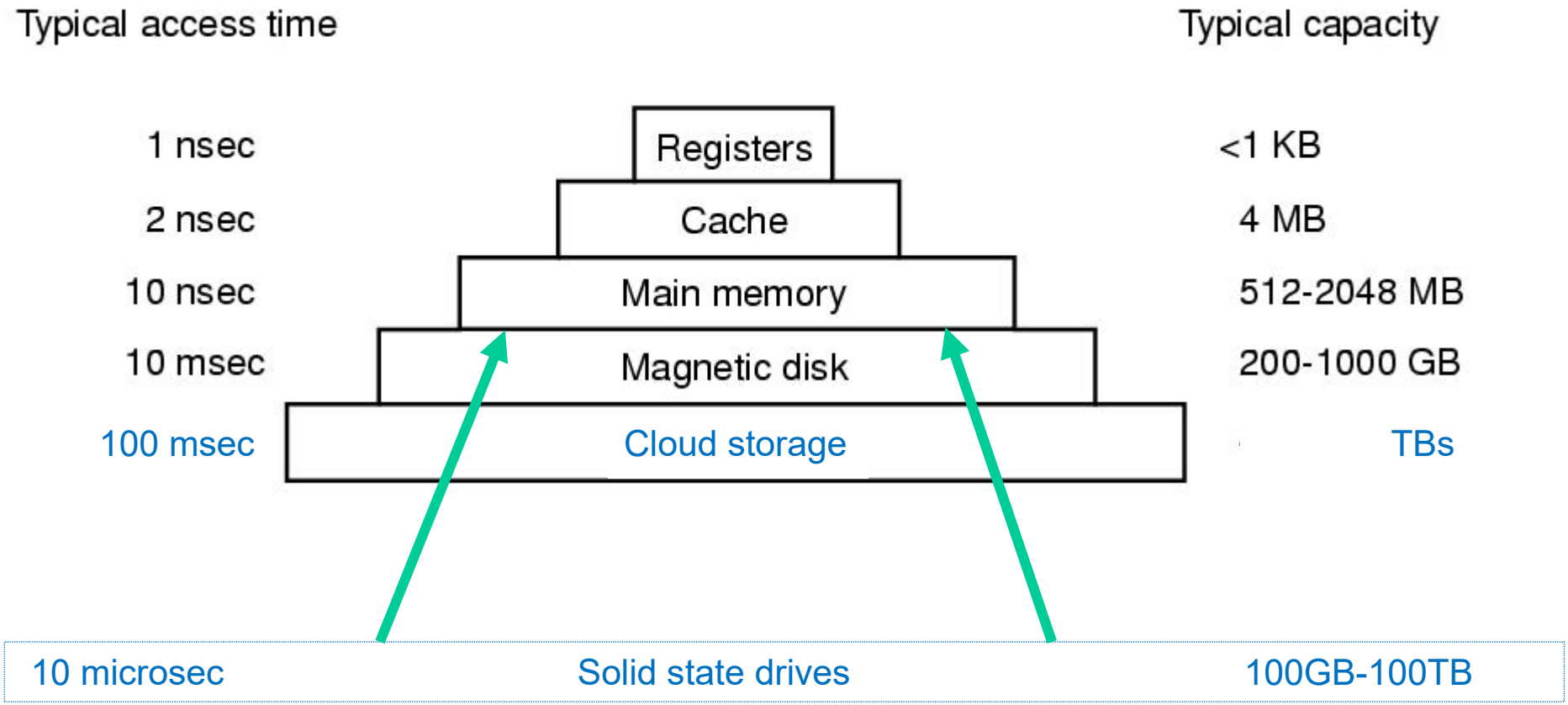
- Mainframe operating systems
- Server operating systems
- Multiprocessor operating systems
- Personal computer operating systems
- Real-time operating systems
- Embedded operating systems
- Mobile operating systems

Computer Hardware Review



- Components of a simple personal computer

Storage Hierarchy (Revised)



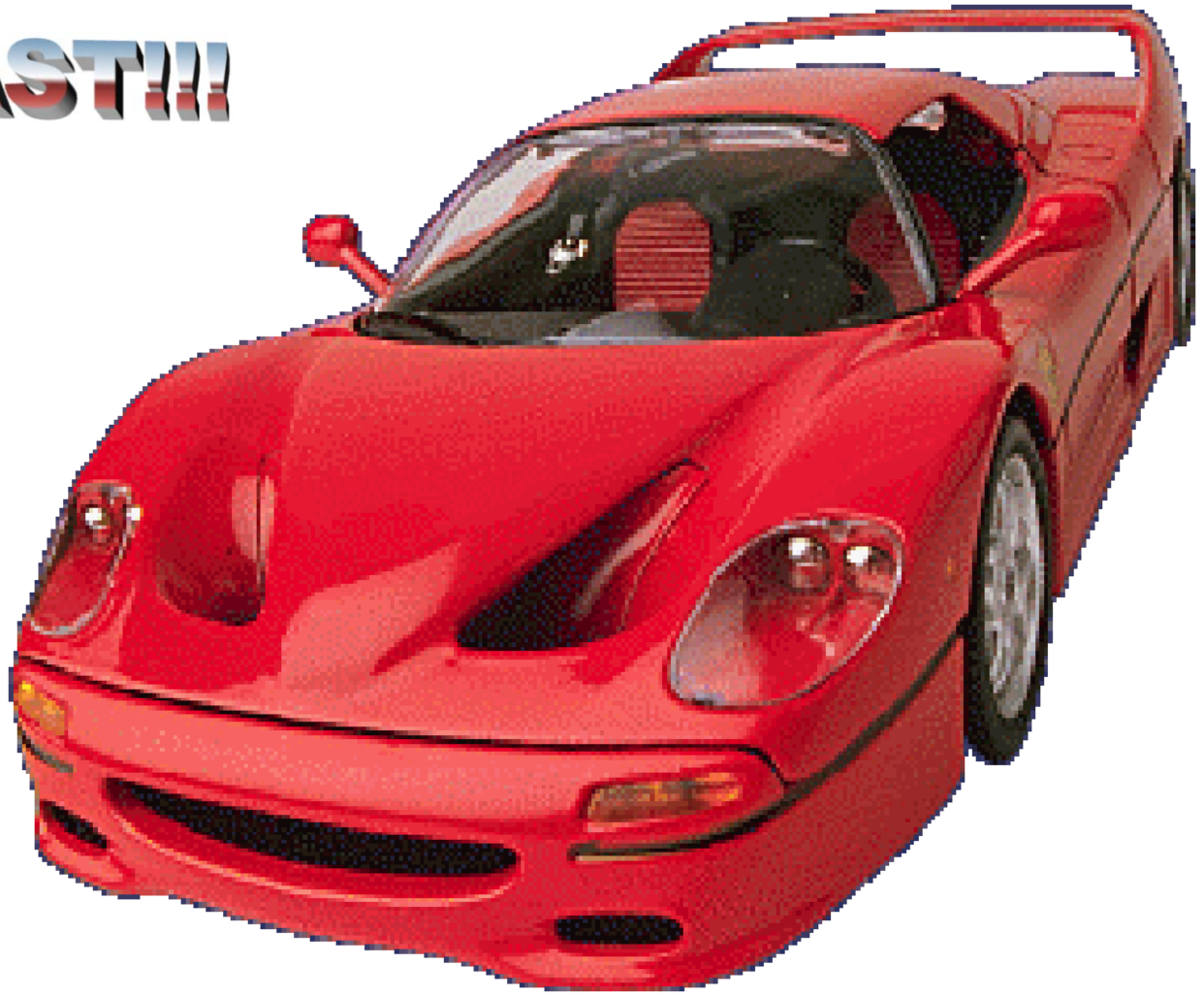
Computer Technology Objectives

FAST!!!

Cheap!!!

Reliable!!!

(pick two)



The need for speed

- 1980: 3MHz, real-time games (lo res)
- 1990: 16MHz, AI programs
- 2000: 1GHz, Computer Vision in real-time
- 2010: 3.9GHz 6-core (32nm)

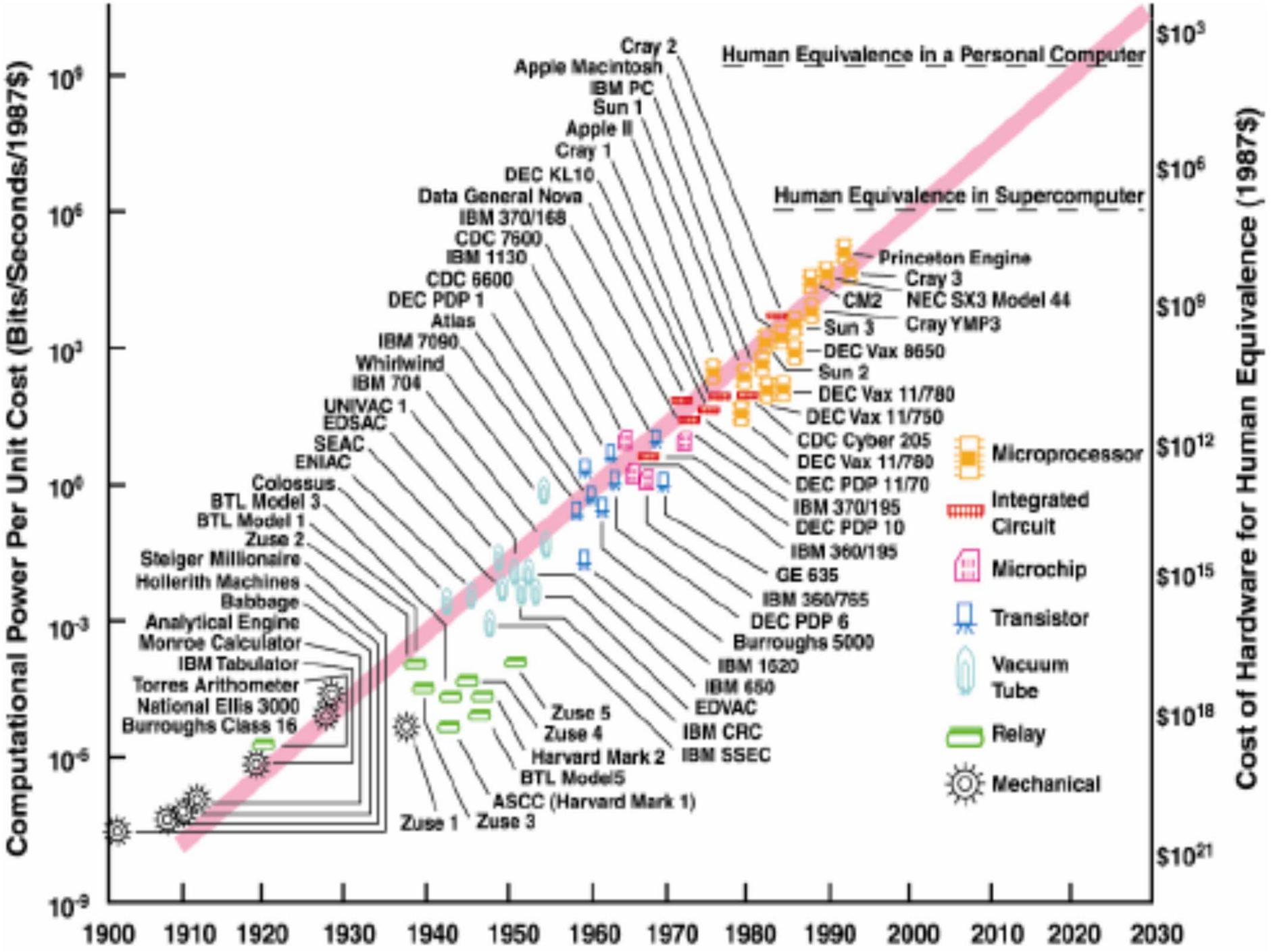
- **2018**: 4.4MHz 18-core (36 threads) 14nm (5nm in 2020)
  (Intel Core i9-7980XE)

- Future 5 years: Intel 80-core

Technology Trends

	Capacity	Speed
Logic	2x in 3 years	2x in 3 years
RAM	4x in 3 years	2x in 10 years
Disk	4x in 3 years	2x in 10 years

- Die size: 2x every 3 yrs
- Line width: halve / 7 yrs


Computational Power Per Unit Cost (Bits/Seconds/1987$)
Cost of Hardware for Human Equivalence (1987$)
Human Equivalence in a Personal Computer
Human Equivalence in Supercomputer
Cray 2
Apple Macintosh
IBM PC
Sun 1
Apple II
Cray 1
DEC KL10
Data General Nova
IBM 370/168
CDC 7600
IBM 1130
CDC 6600
DEC PDP 1
Atlas
IBM 7090
Whirlwind
IBM 704
UNIVAC 1
EDSAC
SEAC
ENIAC
Colossus
BTL Model 3
BTL Model 1
Zuse 2
Steiger Millionaire
Hollerith Machines
Babbage
Analytical Engine
Monroe Calculator
IBM Tabulator
Torres Arithometer
National Ellis 3000
Burroughs Class 16
Zuse 1
Zuse 3
ASCC (Harvard Mark 1)
BTL Model5
Harvard Mark 2
Zuse 4
Zuse 5
IBM SSEC
IBM CRC
EDVAC
IBM 650
IBM 1620
Burroughs 5000
DEC PDP 6
IBM 360/165
GE 635
IBM 360/195
DEC PDP 10
IBM 370/195
DEC PDP 11/70
DEC Vax 11/780
CDC Cyber 205
DEC Vax 11/750
DEC Vax 11/780
Sun 2
DEC Vax 8650
Cray YMP3
Sun 3
CM2
NEC SX3 Model 44
Cray 3
Princeton Engine
Microprocessor
Integrated Circuit
Microchip
Transistor
Vacuum Tube
Relay
Mechanical
$10^{9}
$10^{6}
$10^{3}
$10^{0}
$10^{-3}
$10^{-6}
$10^{-9}
$10^{3}
$10^{6}
$10^{9}
$10^{12}
$10^{15}
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1900
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1950
1960
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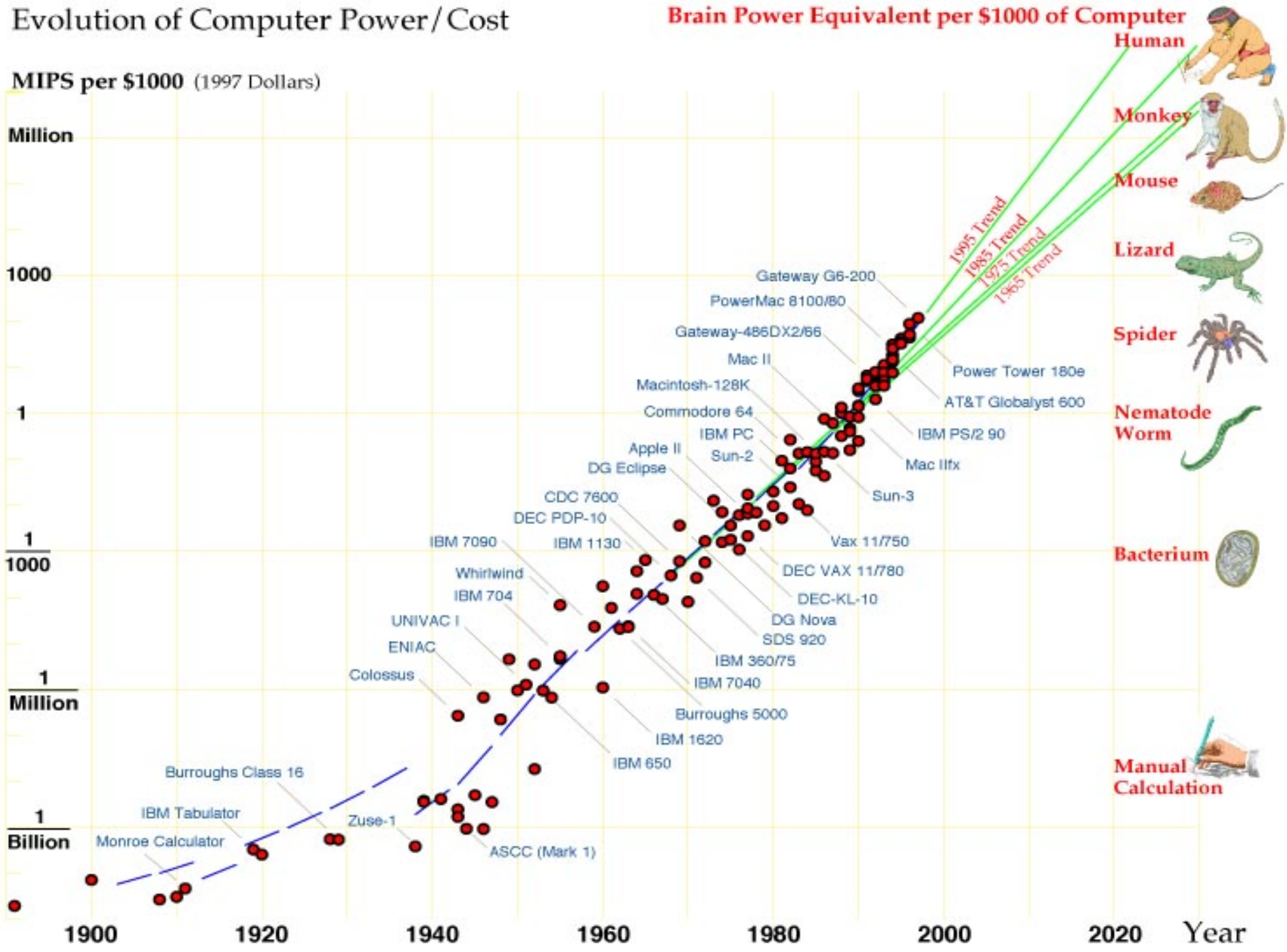
1990
2000
2010
2020
2030


Evolution of Computer Power/Cost
Brain Power Equivalent per $1000 of Computer
MIPS per $1000 (1997 Dollars)
Million
1000
1
1/1000
1/Million
1/Billion
1900
1920
1940
1960
1980
2000
2020
Year
Human
Monkey
Mouse
Lizard
Spider
Nematode Worm
Bacterium
Manual Calculation
1995 Trend
1985 Trend
1975 Trend
1965 Trend
Gateway G6-200
PowerMac 8100/80
Gateway-486DX2/66
Mac II
Macintosh-128K
Commodore 64
IBM PC
Apple II
Sun-2
DG Eclipse
CDC 7600
DEC PDP-10
IBM 7090
IBM 1130
Whirlwind
IBM 704
UNIVAC I
ENIAC
Colossus
Burroughs Class 16
IBM Tabulator
Monroe Calculator
Zuse-1
ASCC (Mark 1)
IBM 650
IBM 1620
Burroughs 5000
IBM 7040
IBM 360/75
SDS 920
DG Nova
DEC-KL-10
DEC VAX 11/780
Vax 11/750
Sun-3
Mac IIfx
IBM PS/2 90
AT&T Globalyst 600
Power Tower 180e

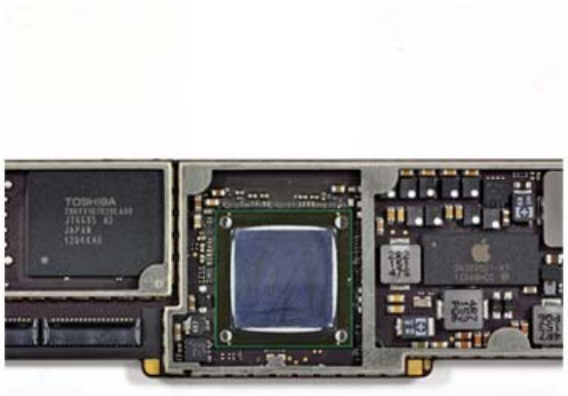
SoC vs CPU

the battle for the future of computing

- After more than 50 years at the top of the heap, the CPU finally has some competition from an upstart called the SoC.
- **CPU** cannot function without dozens of other chips. But it's possible to build a complete computer with just a single SoC.
- **SoC** usually contains a CPU, GPU (a graphics processor), memory, USB controller, power management circuits, and wireless radios (WiFi, 3G, 4G LTE, and so on).
- CPU=central processing unit, SoC=system-on-a-chip

SoC vs CPU

the battle for the future of computing

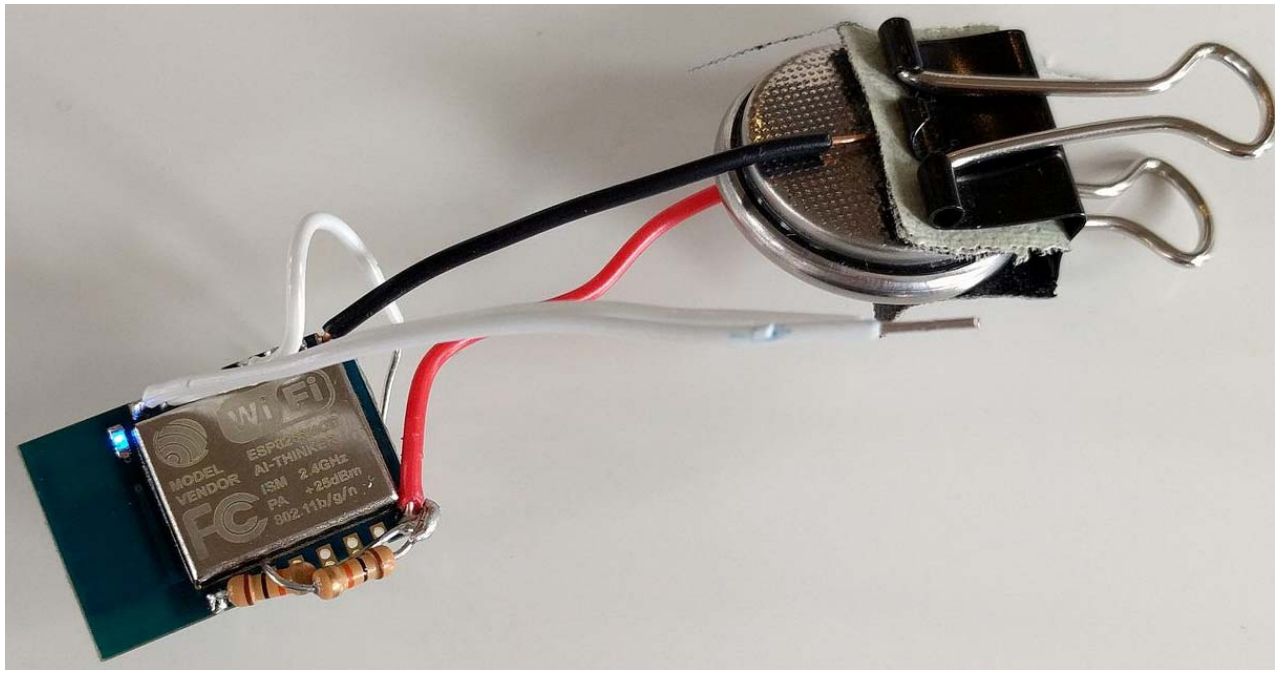


Typical CPU computer vs SoC computer (iPad)

- CPU=central processing unit, SoC=system-on-a-chip

SoC: $3 Wi-Fi chip with full TCP/IP stack and microcontroller

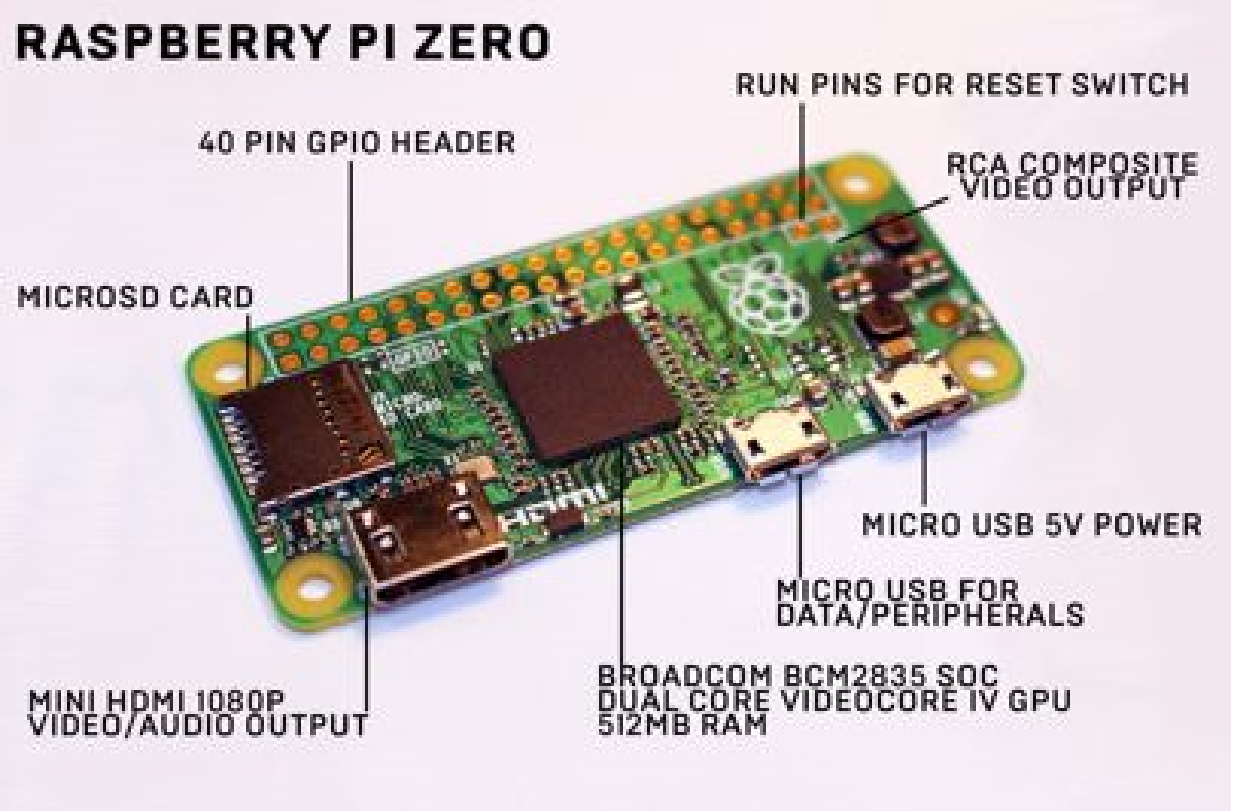
- **160MHz**
- WiFi(a,b,g)
- 16 GPIO
- UART
- ADC
- **Arduino**



ESP8266

SoC: $5 Rasperry Pi Zero

- **1GHz** ARM11 core, GPU
- 512MB RAM
- 64GB micro card
- HDMI out
- USB2
- $1.70 WiFi USB



Intel IPP = Integrated Performance Primitives

SIMD = **S**ingle **I**nstruction, **M**ultiple **D**ata (multiple 256bit registers)
(a supercomputer technique employed to achieve data level parallelism)
Using **SSE** = **S**treaming **S**IMD **E**xtensions (in silicon)

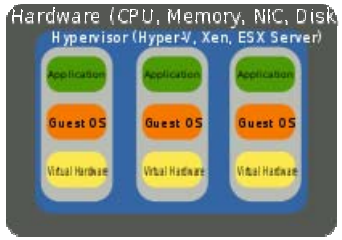
Is an Intel software library for processing:

- **Vector/Matrix Mathematics**
- **Computer Vision**
- **Cryptography**
- **Data Compression**
- **Image Colour Conversion**
- **Ray Tracing/Rendering**
- **Signal Processing**
- **Speech Coding**
- **Speech Recognition**
- **String Processing**

Nvidia GeForce GTX TITAN Z

- 5,760 CUDA cores
- 12 GB of GDDR5 memory

Virtualization



- Virtualization: feature of multi-core chips - designed to run multiple operating systems simultaneously.
- Teloportation: Virtual Machine is temporarily stopped and then resumed on a different computer
- Products: Parallels, **VirtualBox**, Virtual Iron, Virtual PC, Hyper-V, **VMware** KVM, QEMU, Adeos, Mac-on-Linux, Win4BSD, Win4Lin Pro, vBlade, . . .

Metric Units

Exp.	Explicit	Prefix	Exp.	Explicit	Prefix
10^{-3}	0.001	milli	10^{3}	1,000	Kilo
10^{-6}	0.000001	micro	10^{6}	1,000,000	Mega
10^{-9}	0.000000001	nano	10^{9}	1,000,000,000	Giga
10^{-12}	0.000000000001	pico	10^{12}	1,000,000,000,000	Tera
10^{-15}	0.000000000000001	femto	10^{15}	1,000,000,000,000,000	Peta
10^{-18}	0.000000000000000001	atto	10^{18}	1,000,000,000,000,000,000	Exa
10^{-21}	0.000000000000000000001	zepto	10^{21}	1,000,000,000,000,000,000,000	Zetta
10^{-24}	0.000000000000000000000001	yocto	10^{24}	1,000,000,000,000,000,000,000,000	Yotta

The metric prefixes

Max **64 bit** number = 18, 446,744, 073,709, 551,615
As a memory address, access 18,000 Petabytes of memory/disk
Or **access 18 million Terabyte hard disks**

The Hard Drive, 60 years on

- 1956: IBM shipped the first hard drive, the RAMAC 305, which held 5MB of data at $10,000 a megabyte. It is as big as two refrigerators and uses 50 24-inch platters.

- 2018: 16 terabyte HDD (Seagate)

- 2018: 100 terabyte SSD (Nimbus Data)

USB-C

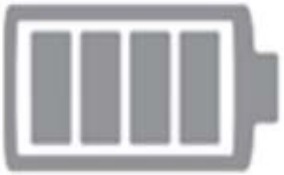
More Speed

40 Gbps

More Pixels

Two 4k

More Power



Up to 100w

More Protocols

THUNDERBOLT

SUPERSPEED USB

DisplayPort

PCI EXPRESS

Operating systems prepare for the next-generation hardware

Significant milestone releases:

Microsoft Windows 10

- Start menu back, virtual desktops
- Edge browser (no IE), same OS running on PCs, phones, etc

Apple macOS 10.14 Mojave (was Mac OS X)

- new Apple File System ... (**Mojave late 2018**)

Apple iOS 12

- Siri Shortcuts, Group FaceTime calls with up to 32 people, Memoji, and a more organized Lock Screen …

Google Android 8.1 Oreo

- notification grouping, video picture-in-picture, performance improvements, battery usage optimization, Bluetooth 5, system-level integration with VoIP apps, wide colour gamuts, Wi-Fi Aware, Android Go, hardware abstraction layer ... (**Android P late 2018**)

Best 2018 Linux distributions:

Overall: Ubuntu, Server: CentOS, Gaming: Fedora Games Spin, Lightweight: Lubuntu, for Programmers: Fedora, Beginner-Friendly: Manjaro (or Mint), Best-Looking: elementary OS, for Windows Users: Robolinux, for Kids: Sugar on a Stick (SoaS) …

Android

now over 88% of smart phone sales (Gartner)

Android is not an operating system. Android is a software stack for mobile devices that includes Linux, middleware and key applications.

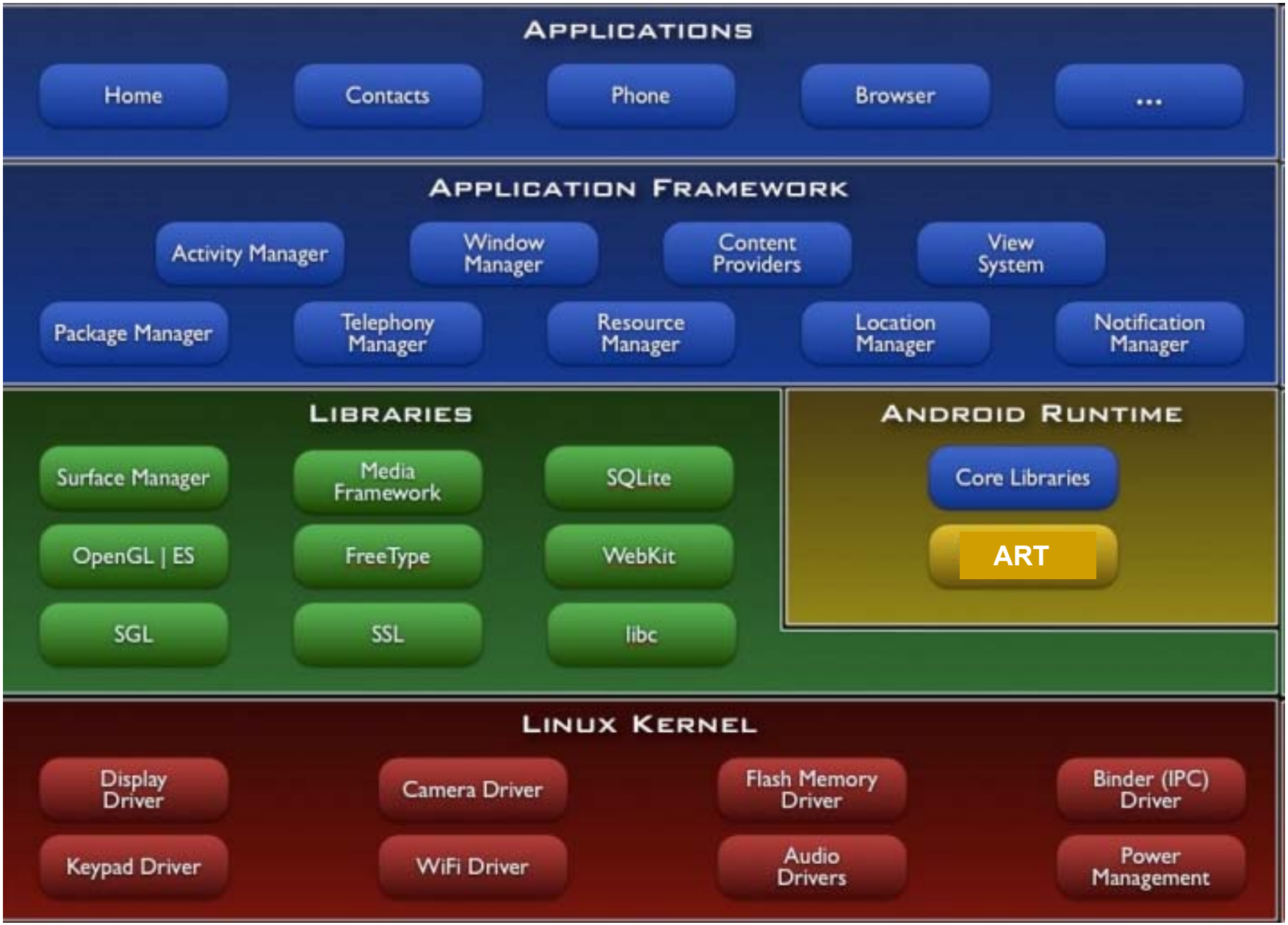
Android includes a set of core libraries that provides most of the functionality available in the core libraries of the Java programming language.

Every Android application runs in its own process, with its own instance of the **Android Runtime (ART)** (was *Dalvik Virtual Machine*) - **compiles** entire applications (Dalvik bytecode) into native machine code **during installation.**

The Android Runtime relies on the Linux kernel for underlying functionality such as threading and low-level memory management.

But the Linux kernal does not have a native X Window System or the full set of standard GNU libraries.

Architecture



Robot Operating System (ROS)

(is not an operating system)