

# Intro to OS

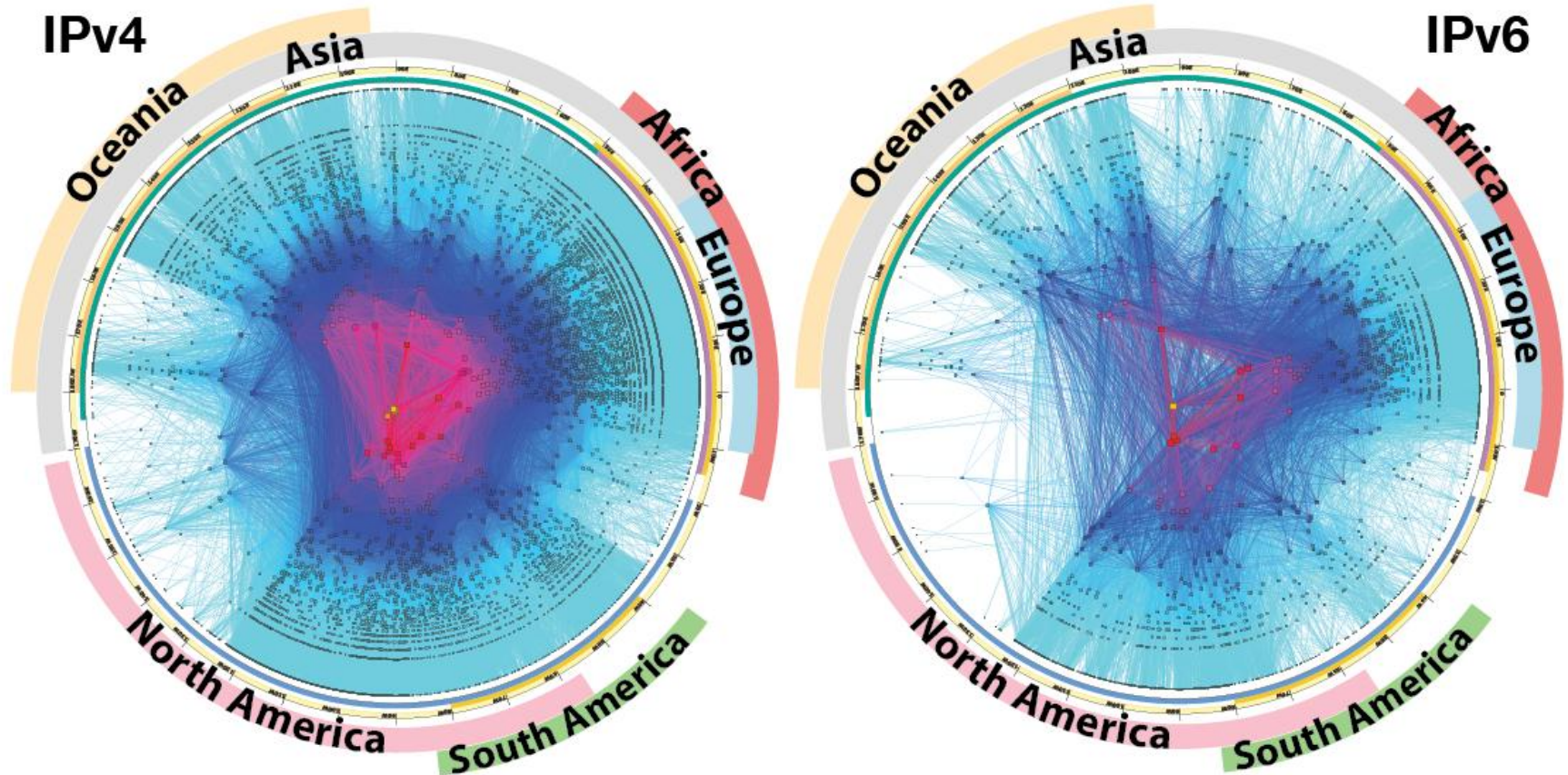
26 October 2025  
Lecture 1

Slides adapted from John Kubiatowicz (UC Berkeley)

# The Internet

## CAIDA's IPv4 vs IPv6 AS Core AS-level Internet Graph

Archipelago July 2015



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# OS at the heart of it all

- Make the incredible advance in the underlying hardware available to a rapidly evolving body of applications
  - Processing, Communications, Storage, Interaction
- The key building blocks

Scheduling



Concurrency



Address spaces



Protection, Isolation,  
Security



Networking,  
distributed systems  
(wait until 4<sup>th</sup> year)



Persistent storage,  
transactions,  
consistency,  
resilience

- Recall DB

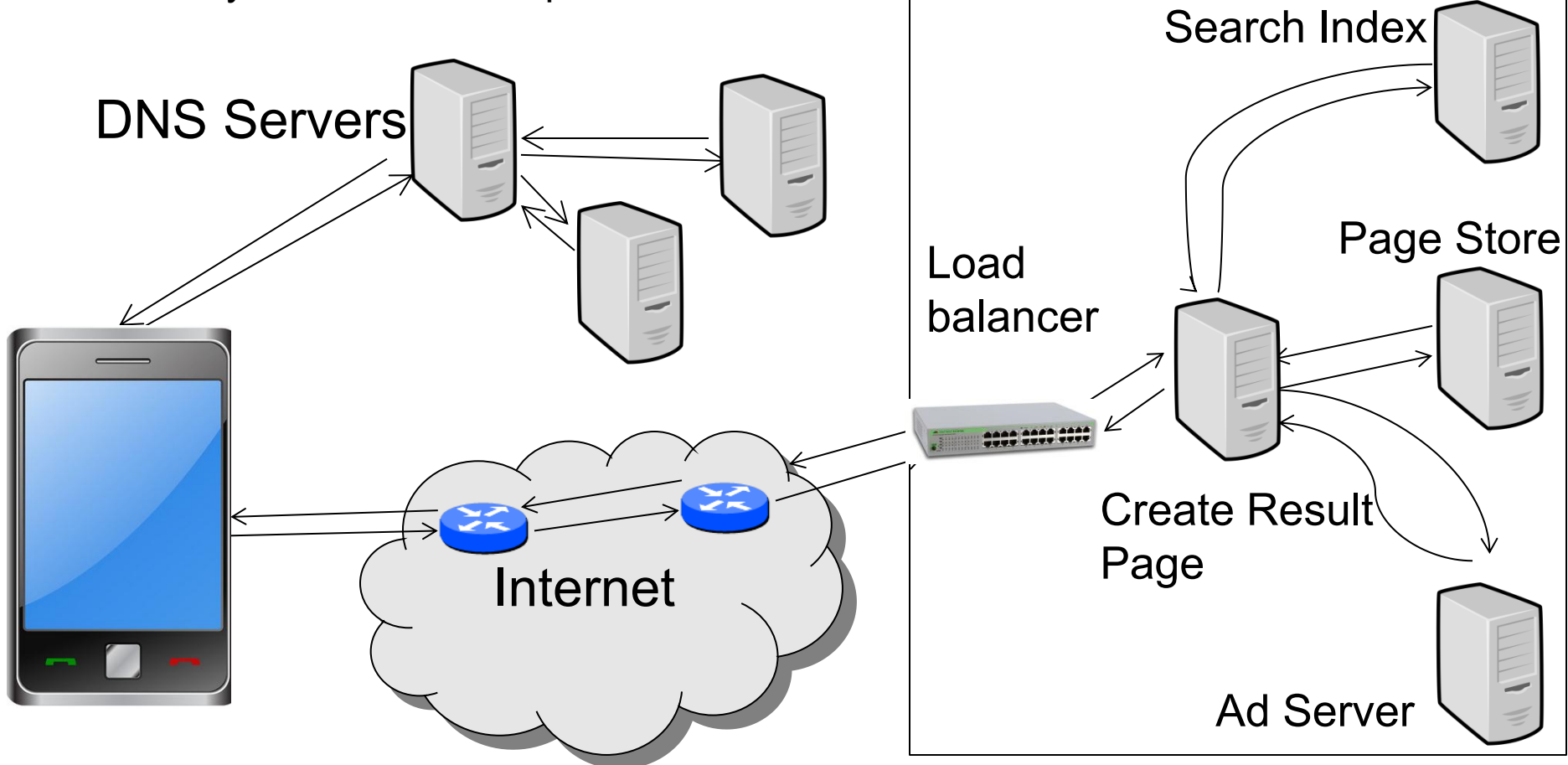


Interface to all  
devices



# Ex: What's in a Search Query?

- Complex interaction of multiple components in multiple administrative domains
  - Systems, services, protocols, etc.



# Why Study OS?

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- Some of you will **design and build operating systems** or components of them.
  - More now than ever (embedded, custom OS, Android variants)
- Many of you will create systems that **utilize the core concepts** in OS
  - Whether you build software or hardware
  - The concepts and design patterns appear at many levels
- All of you will **build applications** that utilize operating systems
  - The better you understand their design and implementation, the better use you'll make of them.
  - Windows, Android, Linux, Mac OS, iOS, etc.

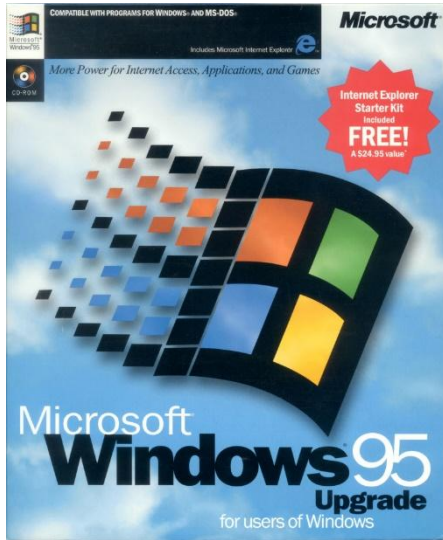
# Topics for Today

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- What is an Operating System?
  - And – what is it not?
- Examples of Operating Systems design
- What makes Operating Systems So Exciting?
- Course details and syllabus



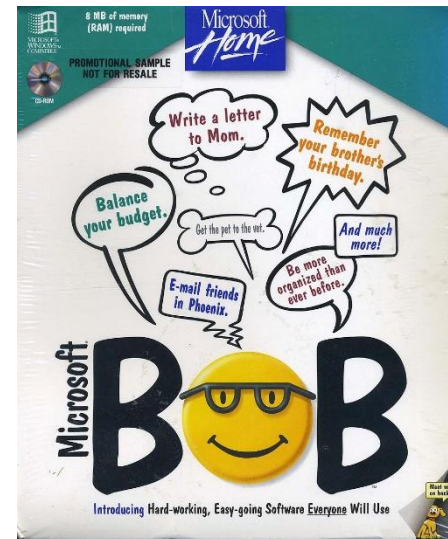
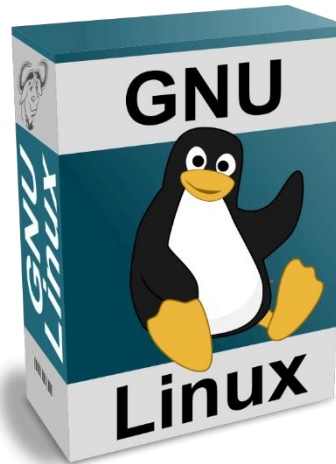
# What is an operating system?



<https://www.freebsd.org/gifs/bsdcomp-4.2.gif>



<https://www.ebluejay.com/ads/item/4330577>



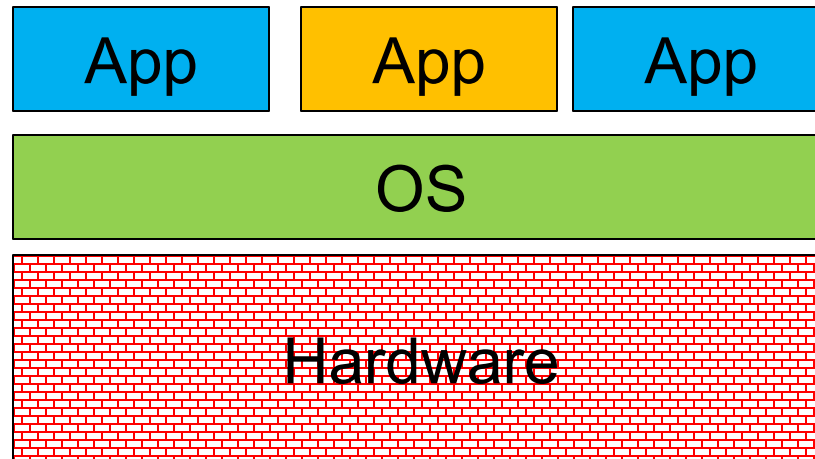
[https://all-free-download.com/free-vector/download/software-carton-box-with-gnu-linux-text-and-tux\\_55593.html](https://all-free-download.com/free-vector/download/software-carton-box-with-gnu-linux-text-and-tux_55593.html)

<https://msbob.org/images/originalphotos/314/4/2f84a9adeb8cf88452b3c41f.jpg>

# What is an Operating System?

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- Special layer of software that provides application software access to hardware resources
  - Convenient abstraction of complex hardware devices
  - Protected access to shared resources
  - Security and authentication
  - Communication among logical entities



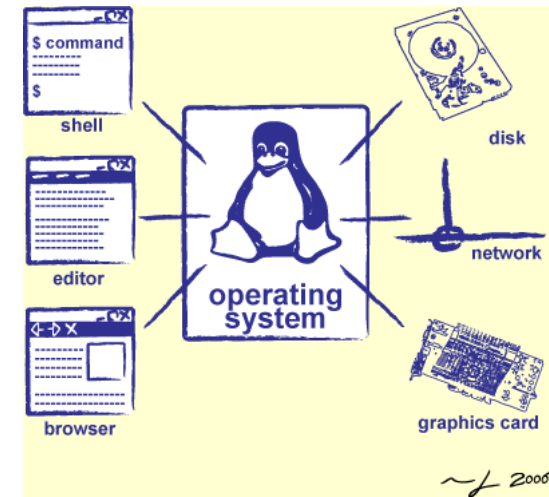
# Why “Operating”?



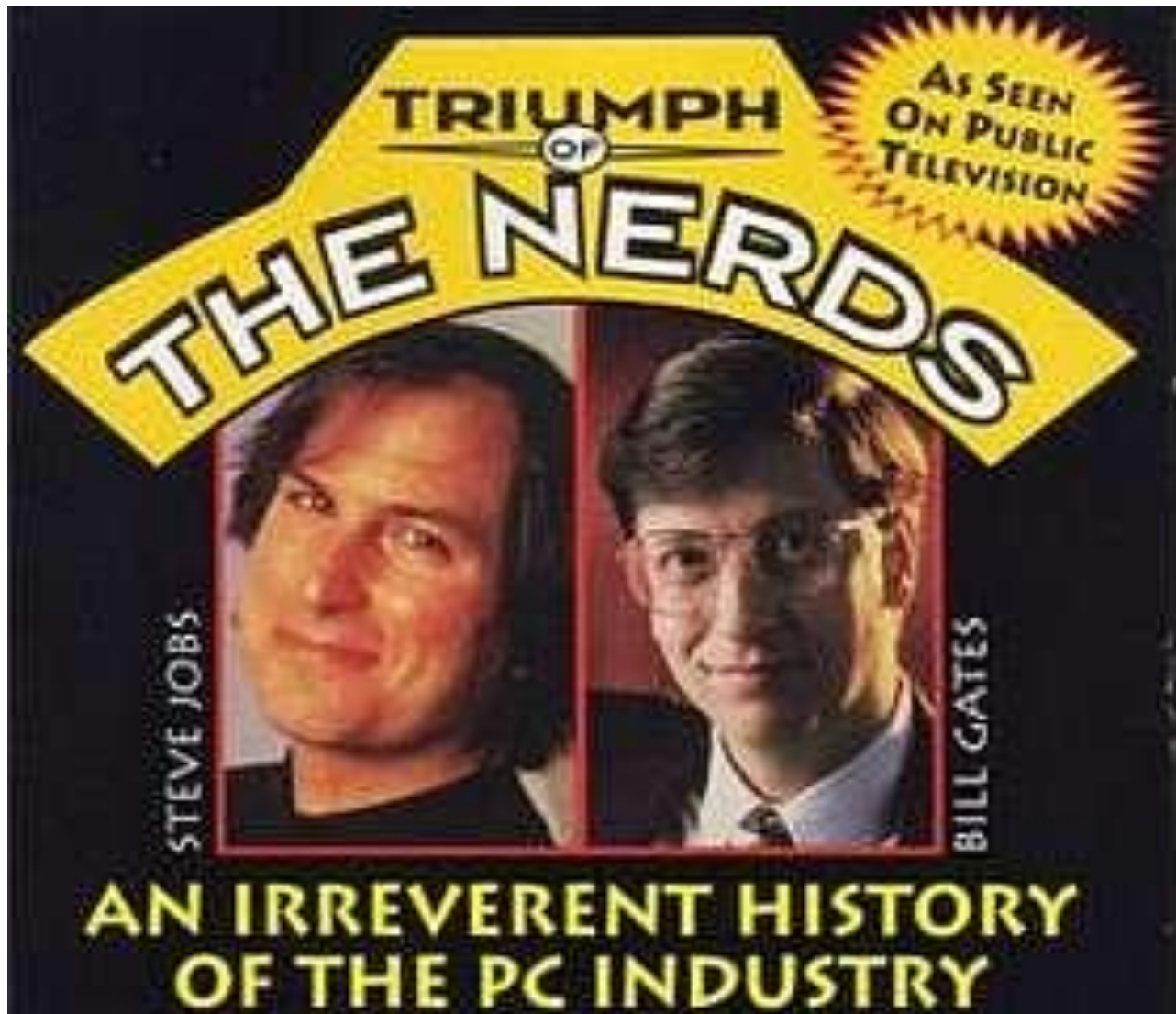
Switchboard operator



Computer Operator

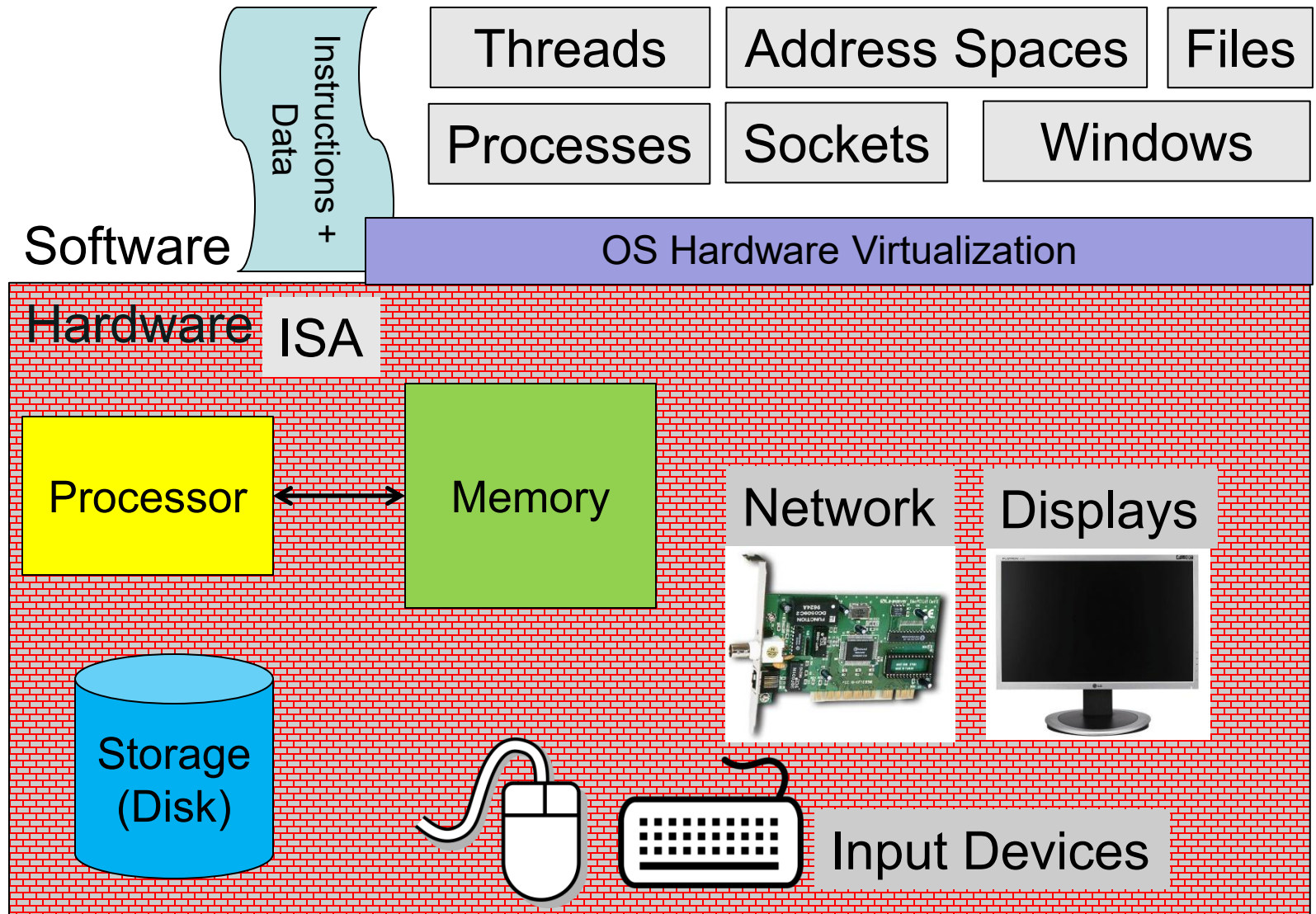


# Then came the 1990s

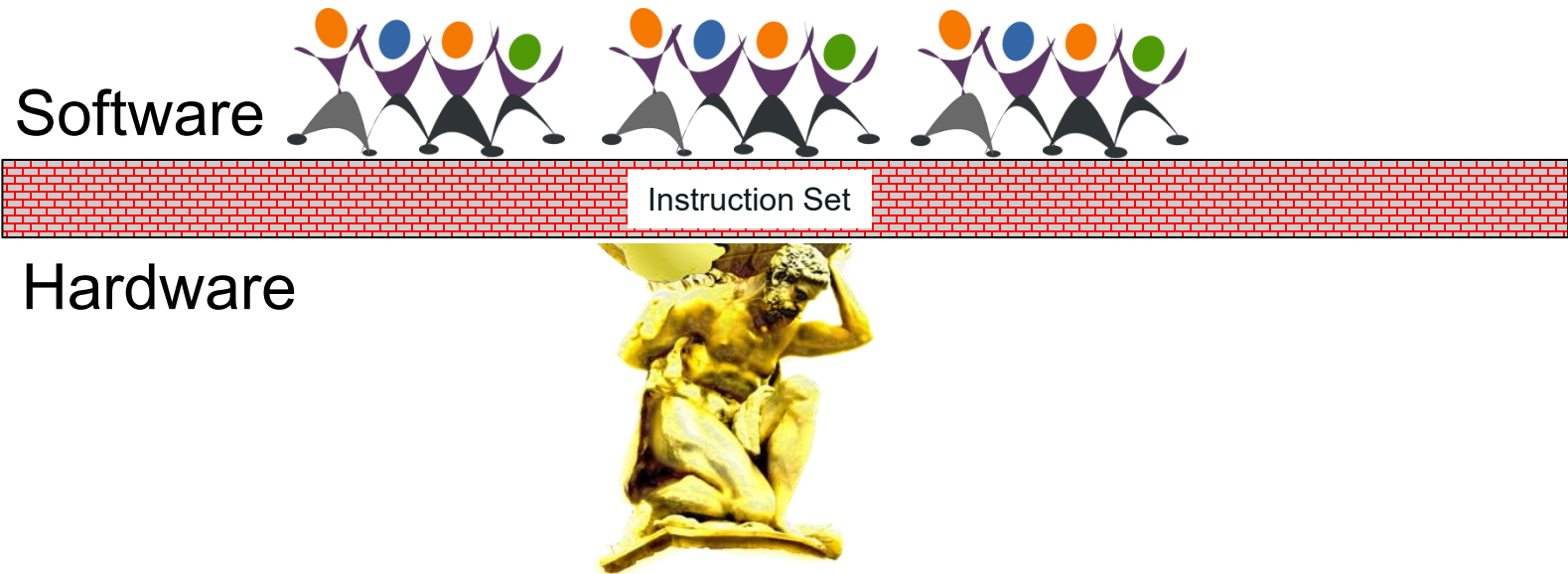


[http://www.tecnologiahechapalabra.com/img\\_noticias/2015/4/%7BCCF6763B-1361-4A0B-9BC2-251814610DE0%7D\\_tofn28.jpg](http://www.tecnologiahechapalabra.com/img_noticias/2015/4/%7BCCF6763B-1361-4A0B-9BC2-251814610DE0%7D_tofn28.jpg)

# OS Basics: “Virtual Machine” Boundary

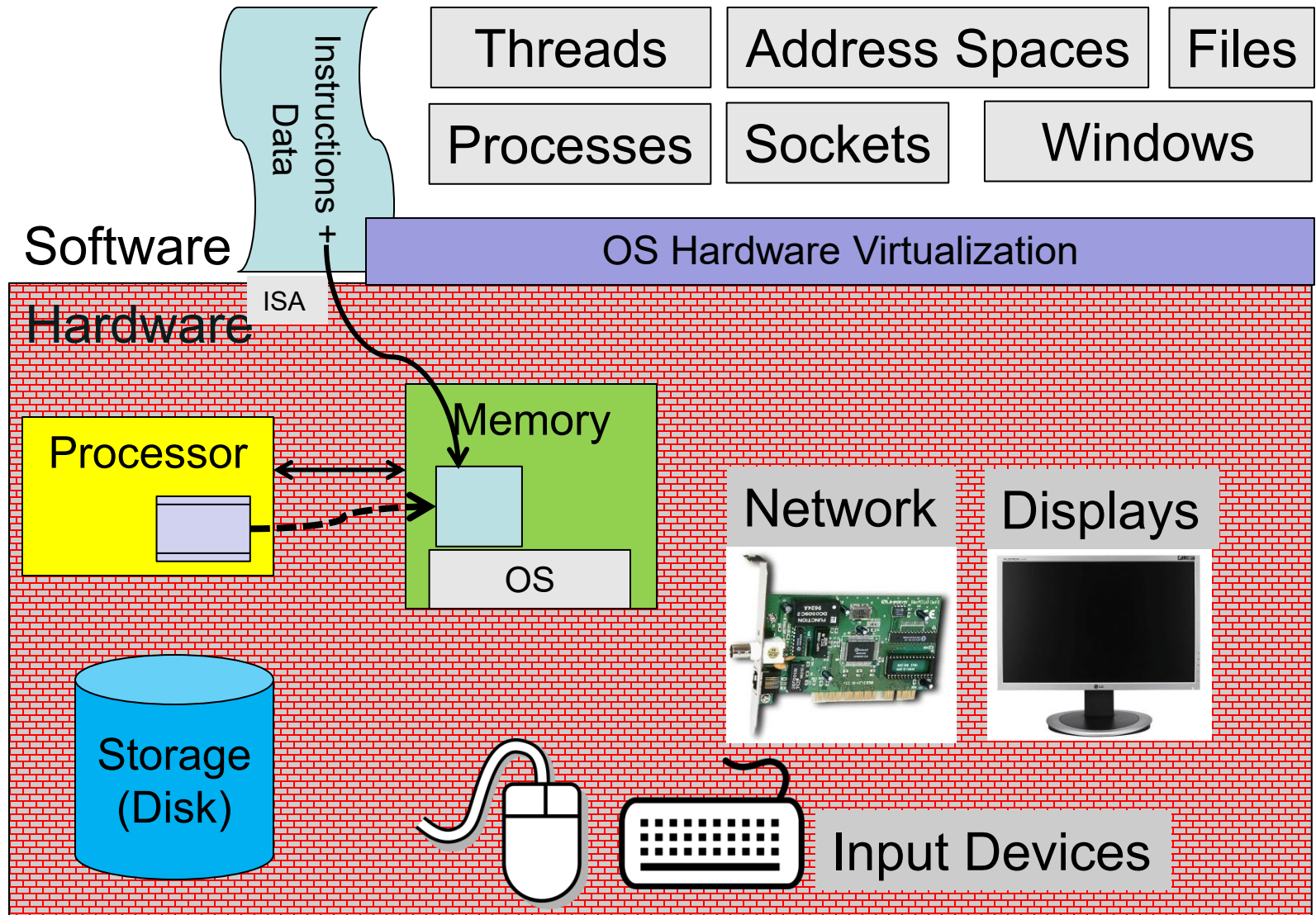


# Interfaces Provide Boundaries

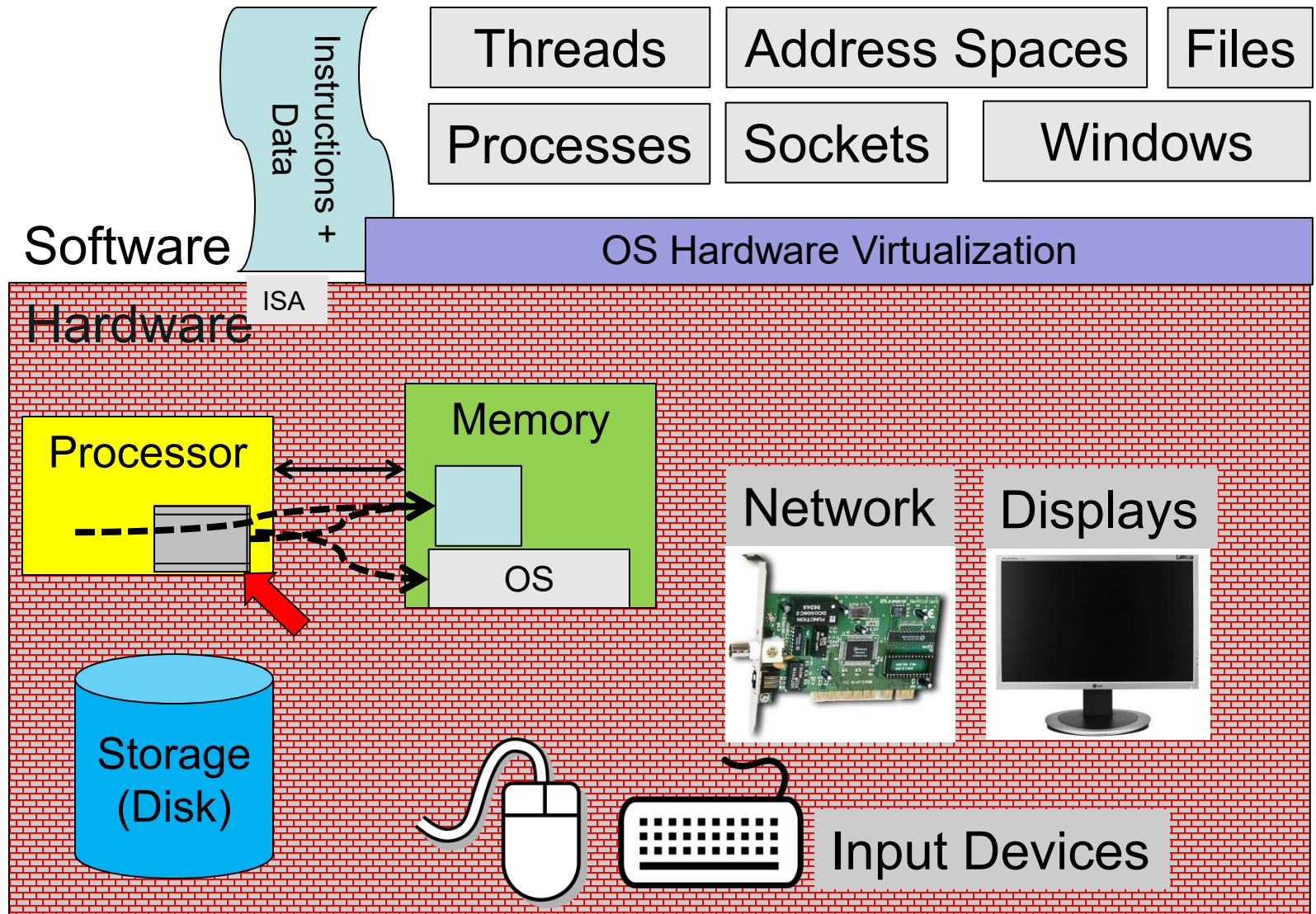


- Why do interfaces look the way they do?
  - History, functionality, stupidity, bugs management
  - Can take classes on Machine interfaces, Human Interfaces, Software engineering/management
- Should responsibilities be pushed across boundaries?
  - RISC architectures, Graphical Pipeline Architectures

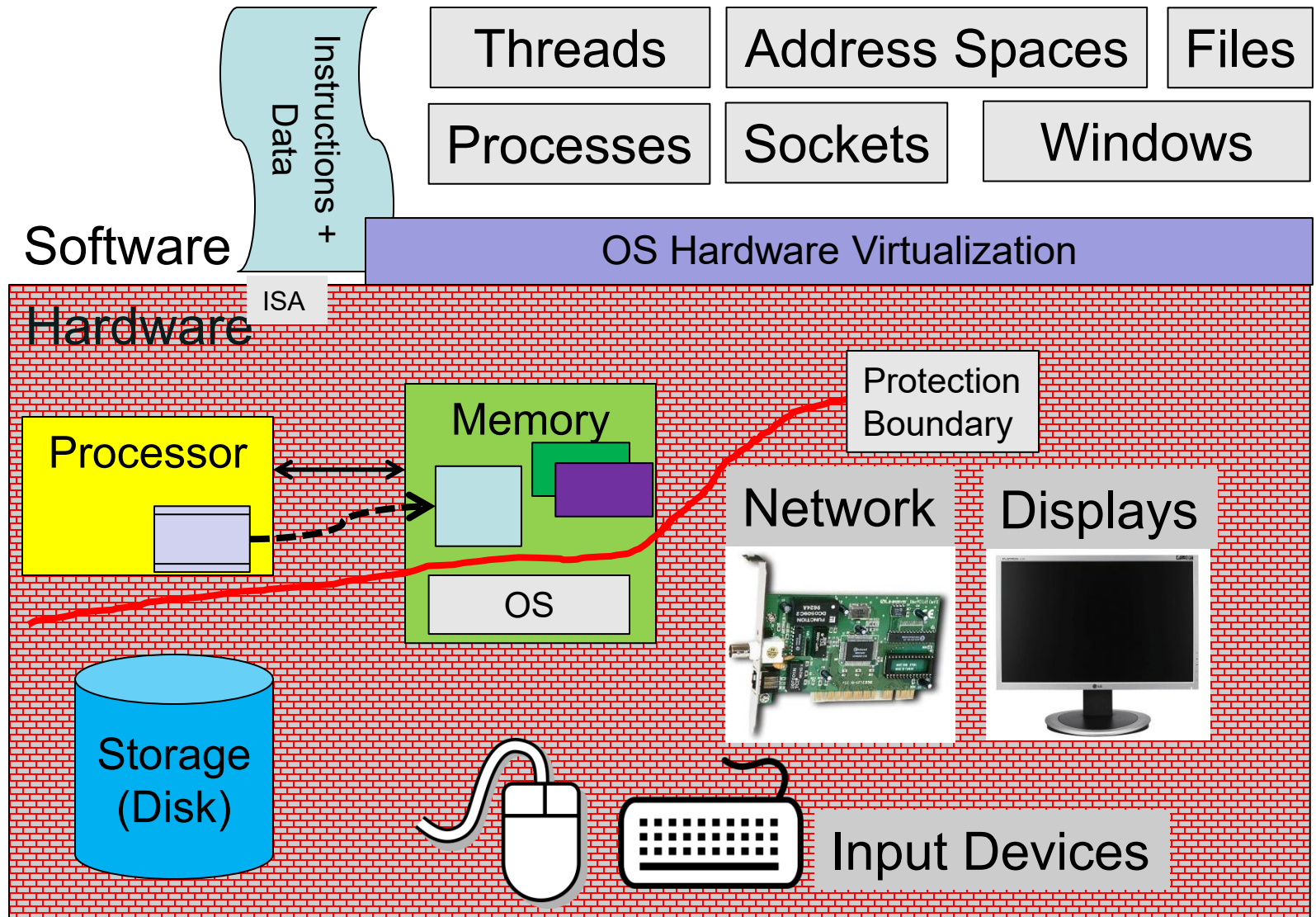
# OS Basics: Program → Process



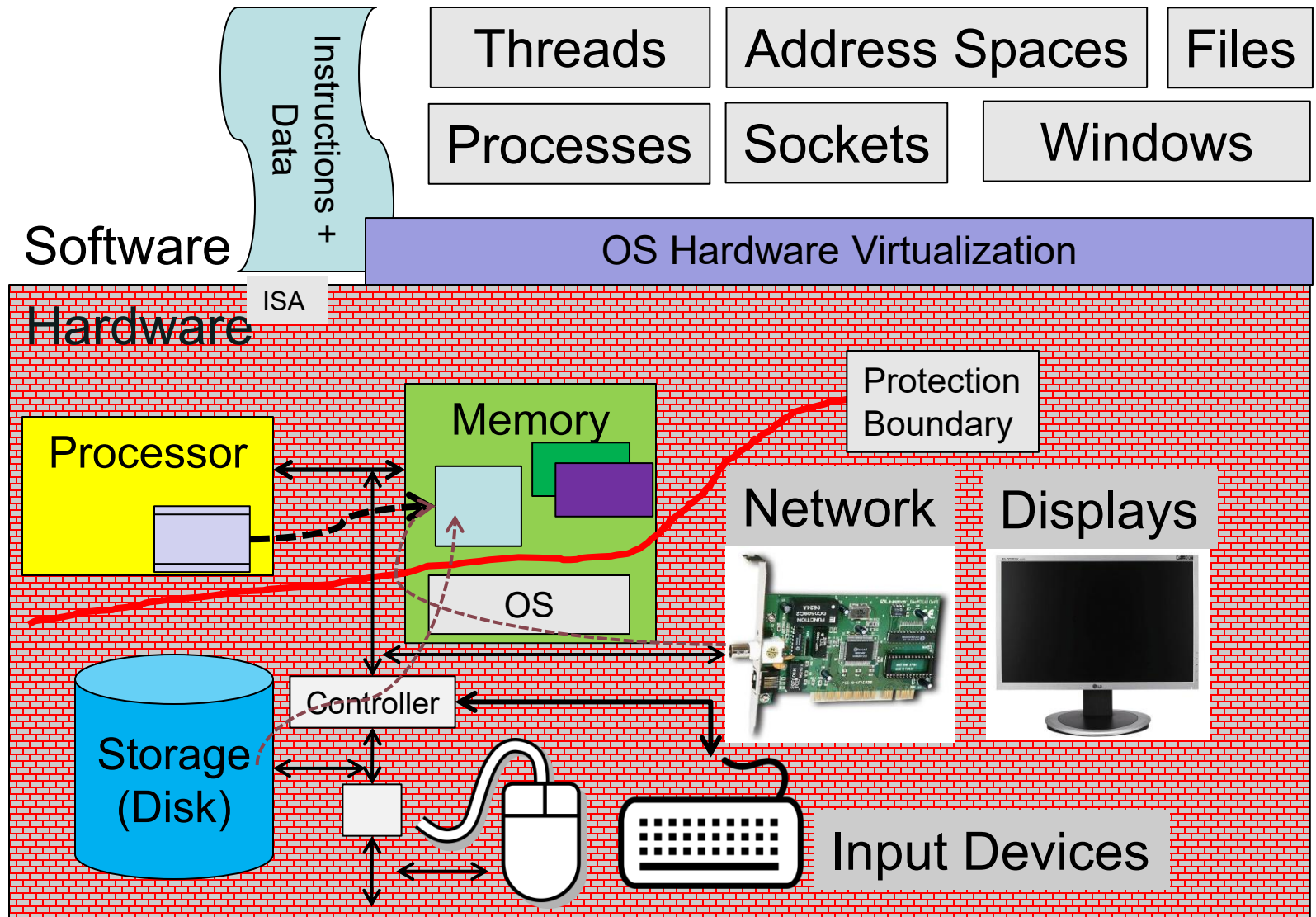
# OS Basics: Context Switch



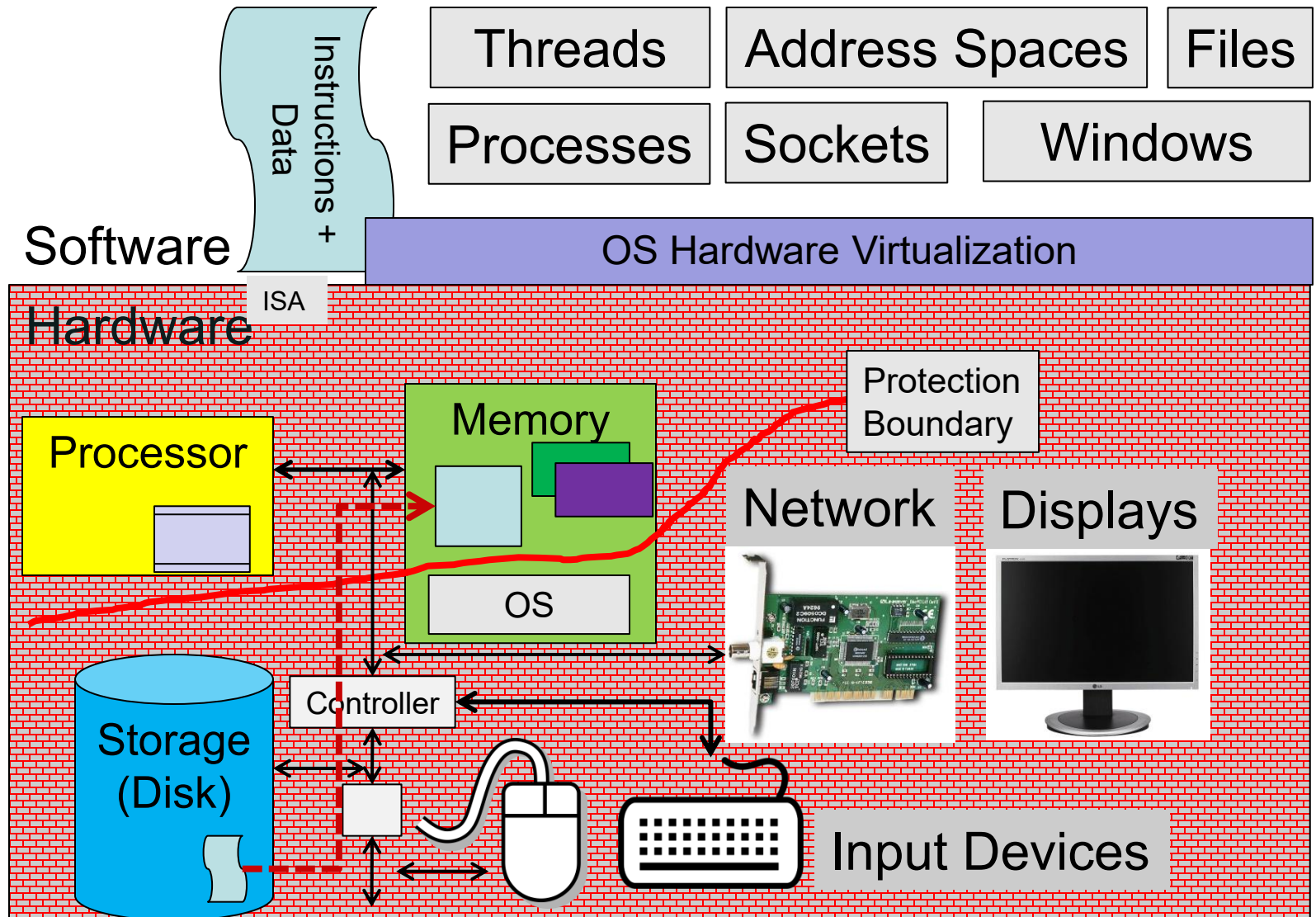
# OS Basics: Scheduling, Protection



# OS Basics: I/O



# OS Basics: Loading



# So Far

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- What is an Operating System?
  - And – what is it not?
- Examples of Operating Systems design
- What makes Operating Systems So Exciting?
- Course details and syllabus

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# What makes Operating Systems exciting and challenging?

# Moore's Law

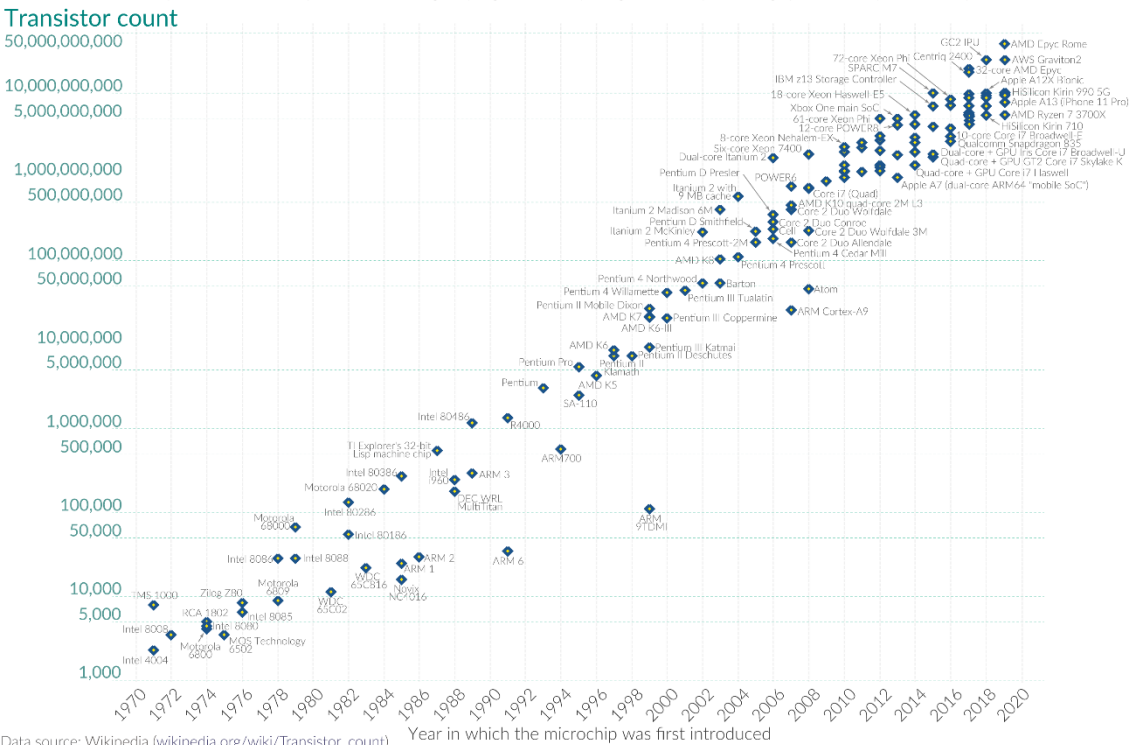
- Gordon Moore (co-founder of Intel) predicted in 1965 that the transistor density of semiconductor chips would double roughly every 18 months.



## Moore's Law: The number of transistors on microchips doubles every two years

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important for other aspects of technological progress in computing – such as processing speed or the price of computers.

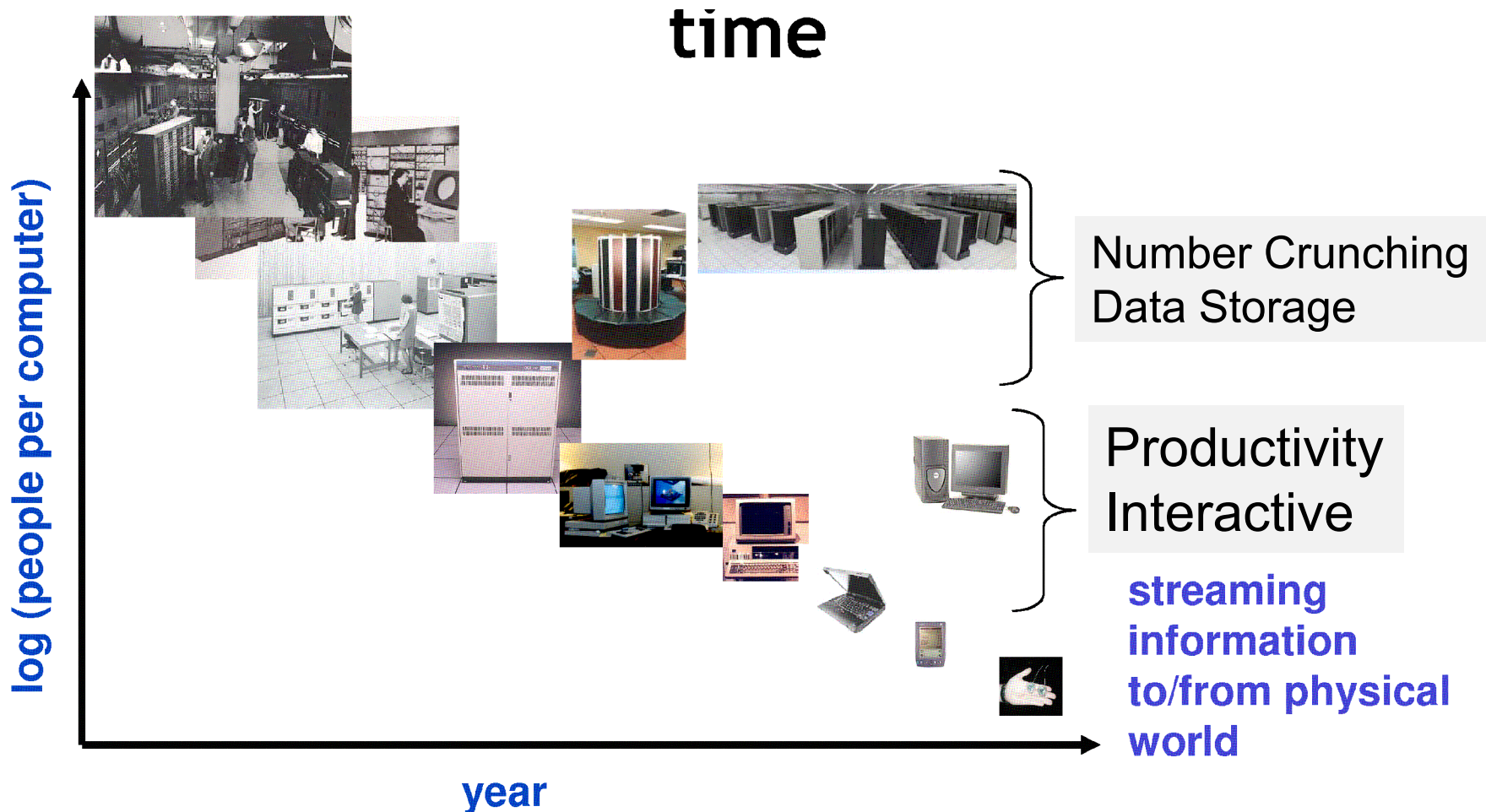
Our World  
in Data



Licensed under CC-BY by the authors Hannah Ritchie and Max Roser.

# People to Computer Ratio

Image credits: David Culler (UC Berkeley)



# Joy's Law of Performance

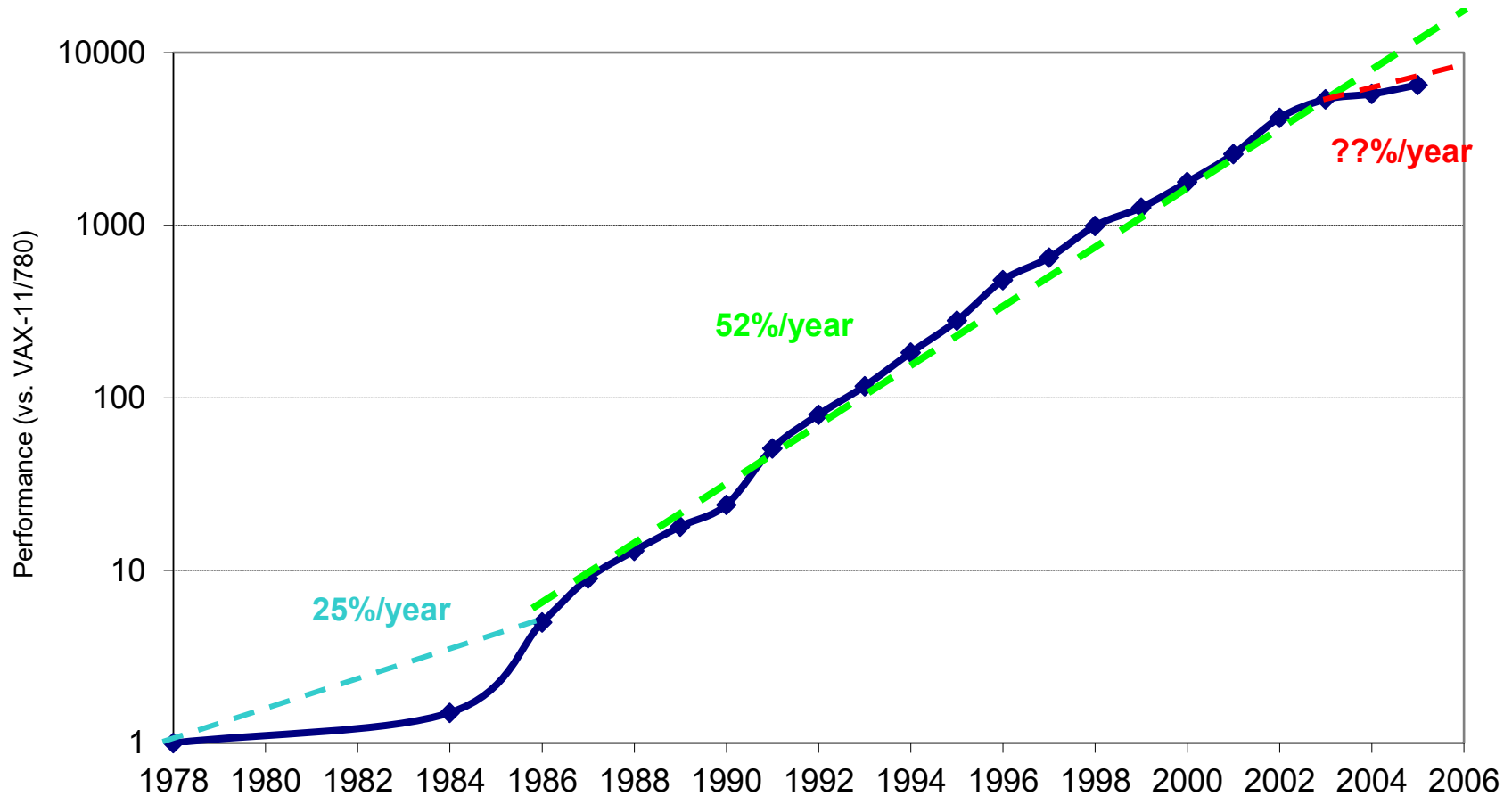
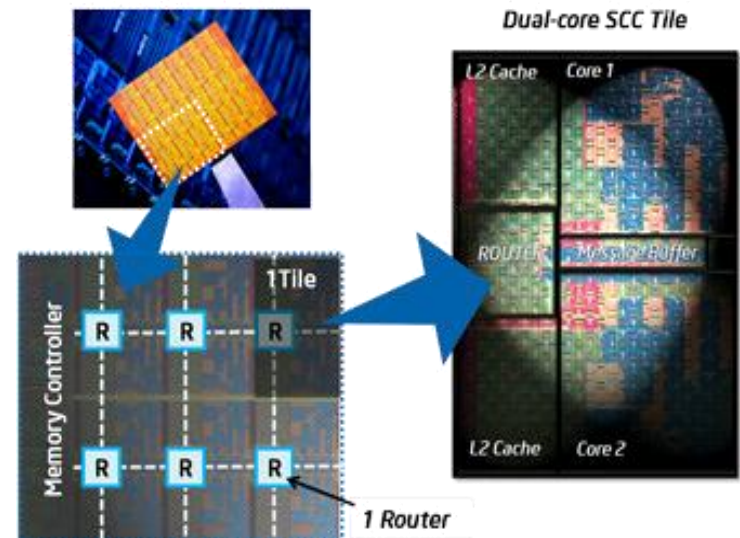
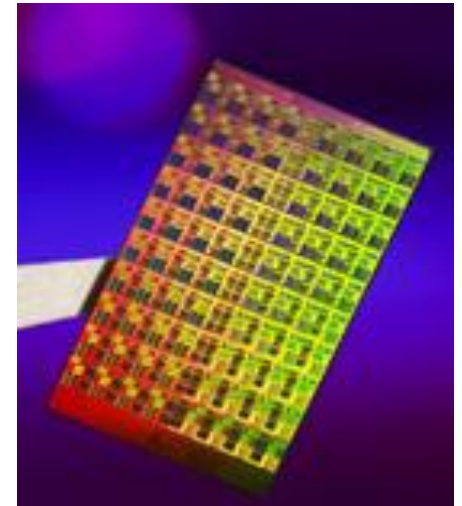


Image credit: From Hennessy and Patterson, *Computer Architecture: A Quantitative Approach*, 4th edition via Kubiawicz (UC Berkeley)

Slowdown led to multiple “cores” or processors per chip

# ManyCore Chips

- Intel 80-core multicore chip (Feb 2007)
  - 80 simple cores
  - Two FP-engines / core
  - Mesh-like network
  - 100 million transistors
  - 65nm feature size
- Intel Single-Chip Cloud Computer (August 2010)
  - 24 “tiles” with two cores/tile
  - 24-router mesh network
  - 4 DDR3 memory controllers
  - Hardware support for message-passing



# ManyCores

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**ManyCore** means many processors per chip

- 64? 128?
- Hard to say exact boundary

How to program them?

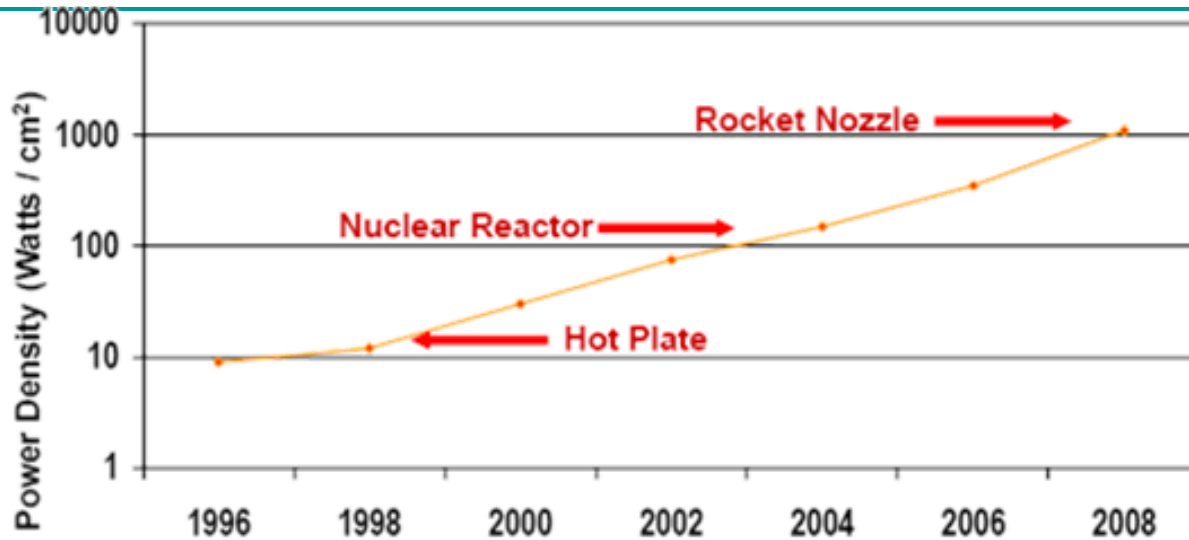
- Use 2 CPUs for video/audio
- 1 for word processor
- 1 for browser
- 76 for virus checking?

**Parallelism must be exploited at all levels**

- Software aware!

Software engineers must learn how to write parallelizable code

# Power Density



Power Density Becomes Too High to Cool Chips Inexpensively

- Moore's Law Extrapolation
  - Potential power density reaching amazing levels!
- Flip side: Battery life very important
  - Moore's law can yield more functionality at equivalent (or less) total energy consumption



# Batteries

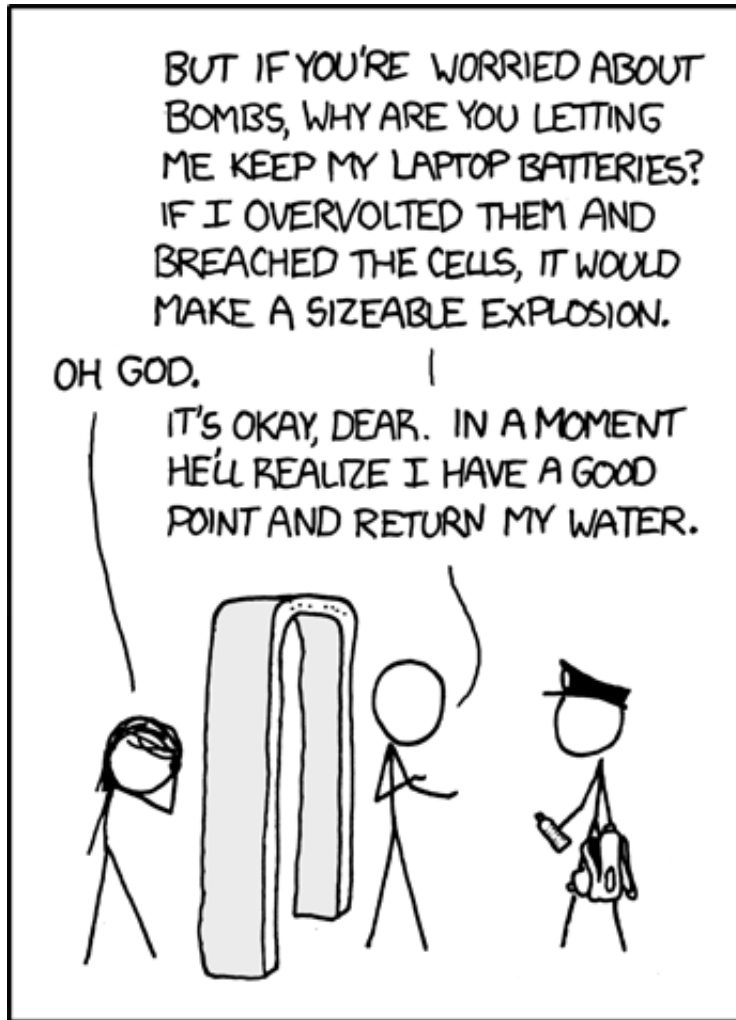
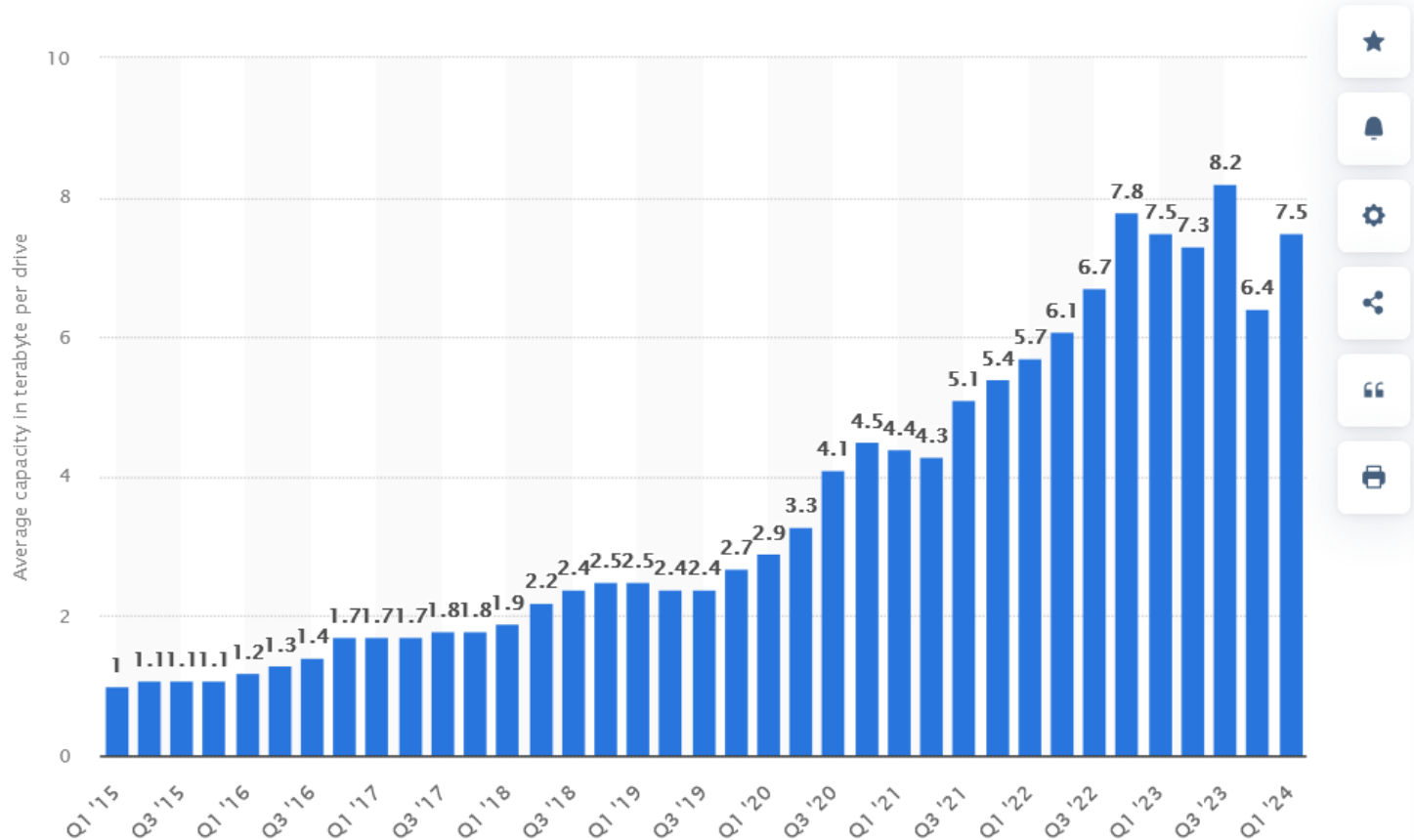


Image credit: XKCD



# Storage Capacity

Seagate's average capacity of hard disk drives (HDDs) worldwide from FY2015 to FY2024, by quarter (in terabyte per drive)

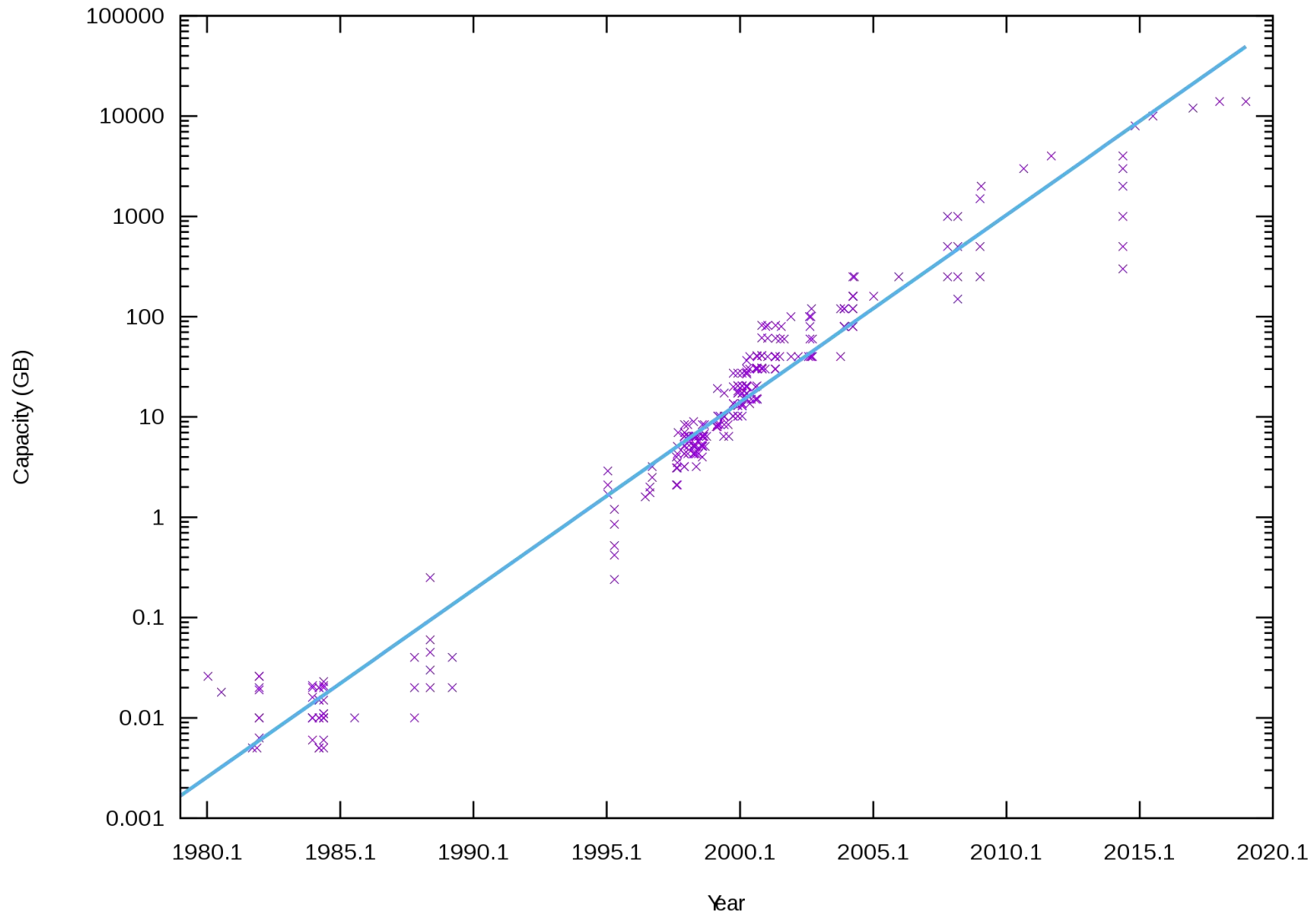


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[Additional Information](#)

[Show source](#)

# Storage Capacity



Credit: By IFile:Hard drive capacity over time.pngHankwangVector: derivative work Rentar - File:Hard drive capacity over time.png, Public Domain, <https://commons.wikimedia.org/w/index.php?curid=6040636>

# Network Capacity

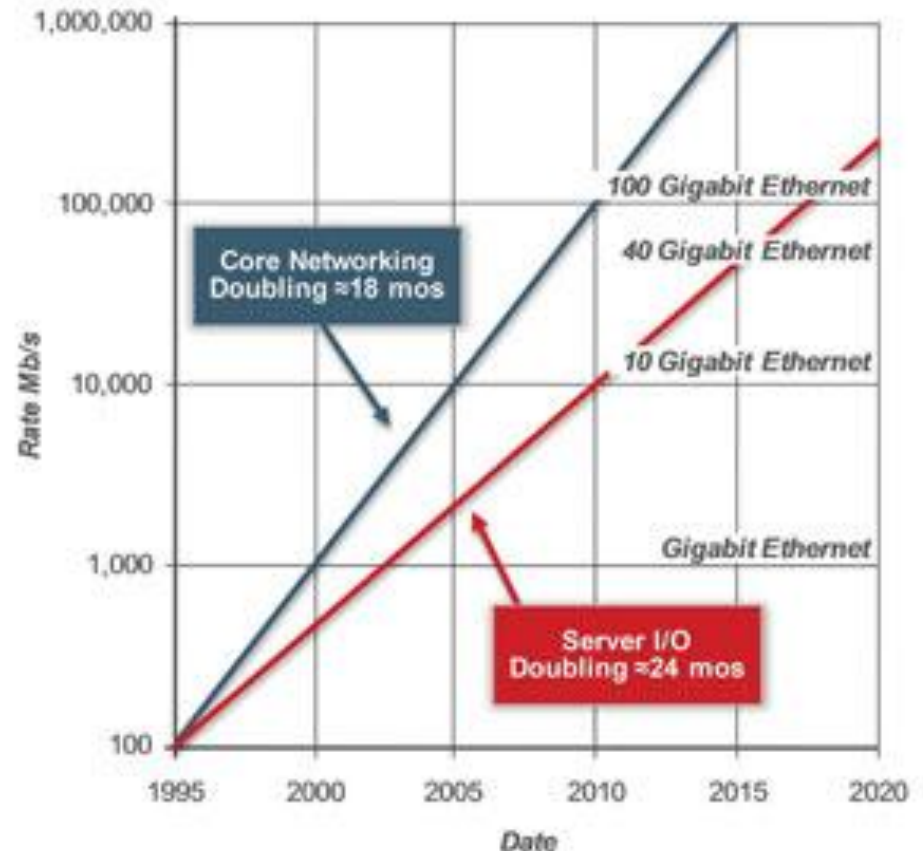
## Time Is Not Always On Our Side...

Not When It Comes to Developing the 100 Gigabit Ethernet Eco-System

by: John D'Ambrosia

OSP Magazine

... came to the realization that the bandwidth requirements of networking and computing applications were growing at different paces. The **bandwidth requirements of networking applications were doubling approximately every 18 months**, while the **bandwidth capabilities of computing applications were doubling approximately every 24 months**.



Source: <http://www.ospmag.com/issue/article/Time-Is-Not-Always-On-Our-Side>

# Internet Scale: 5.4 Billion Users

## WORLD INTERNET USAGE AND POPULATION STATISTICS 2023 Year Estimates

World Regions	Population ( 2022 Est.)	Population % of World	Internet Users 31 Dec 2021	Penetration Rate (% Pop.)	Growth 2000-2023	Internet World %
<a href="#">Africa</a>	1,394,588,547	17.6 %	601,940,784	43.2 %	13,233 %	11.2 %
<a href="#">Asia</a>	4,352,169,960	54.9 %	2,916,890,209	67.0 %	2,452 %	54.2 %
<a href="#">Europe</a>	837,472,045	10.6 %	747,214,734	89.2 %	611 %	13.9 %
<a href="#">Latin America / Carib.</a>	664,099,841	8.4 %	534,526,057	80.5 %	2,858 %	9.9 %
<a href="#">North America</a>	372,555,585	4.7 %	347,916,694	93.4 %	222 %	6.5 %
<a href="#">Middle East</a>	268,302,801	3.4 %	206,760,743	77.1 %	6,194 %	3.8 %
<a href="#">Oceania / Australia</a>	43,602,955	0.5 %	30,549,185	70.1 %	301 %	0.6 %
<a href="#">WORLD TOTAL</a>	7,932,791,734	100.0 %	5,385,798,406	67.9 %	1,392 %	100.0 %

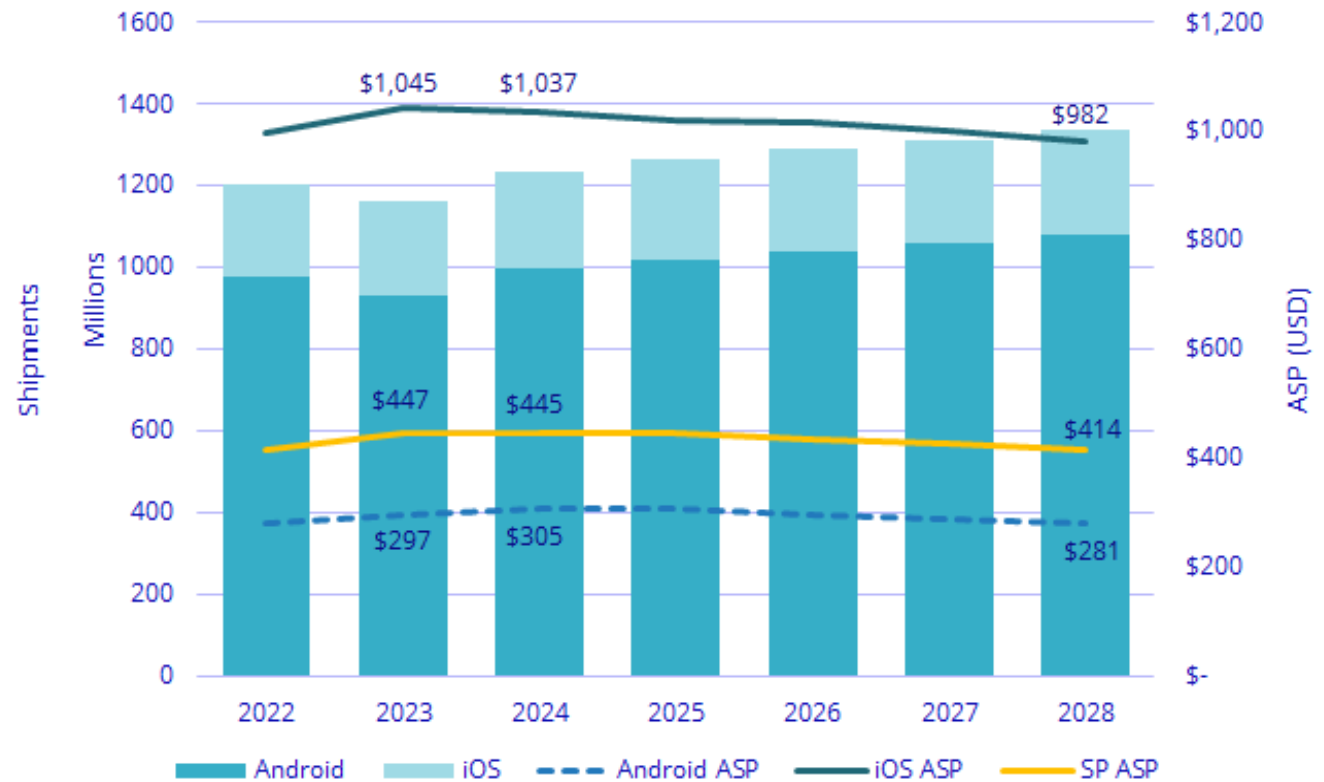
NOTES: (1) Internet Usage and World Population Statistics estimates are for June 30, 2022. (2) CLICK on each world region name for detailed regional usage information. (3) Demographic (Population) numbers are based on data from the [United Nations Population Division](#). (4) Internet usage information comes from data published by [Nielsen Online](#), by the [International Telecommunications Union](#), by [GfK](#), by local ICT Regulators and other reliable sources. (5) For definitions, navigation help and disclaimers, please refer to the [Website Surfing Guide](#). (6) The information from this website may be cited, giving the due credit to [www.internetworldstats.com](http://www.internetworldstats.com). Copyright © 2022, Miniwatts Marketing Group. All rights reserved worldwide.

# Not only PCs

And this ignores Smart TVs, DVRs, IoT



Worldwide Smartphone Forecast, 2024Q2



# What is an Operating System?

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## Referee

- Manage sharing of resources, Protection, Isolation
- Resource allocation, isolation, communication



## Illusionist

- Provide clean, easy to use abstractions of physical resources
  - Infinite memory, dedicated machine
  - Higher level objects: files, users, messages
  - Masking limitations, virtualization

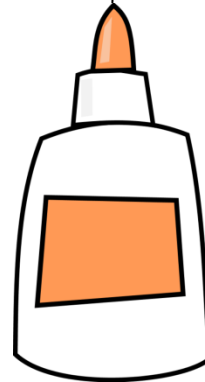
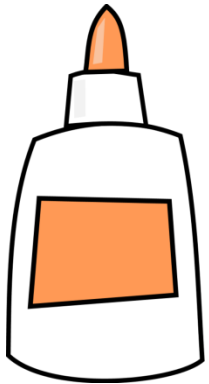


# What is an Operating System?

## Glue

- Common services
  - Storage, Window system, Networking
  - Sharing, Authorization
  - Look and feel

## Many hats



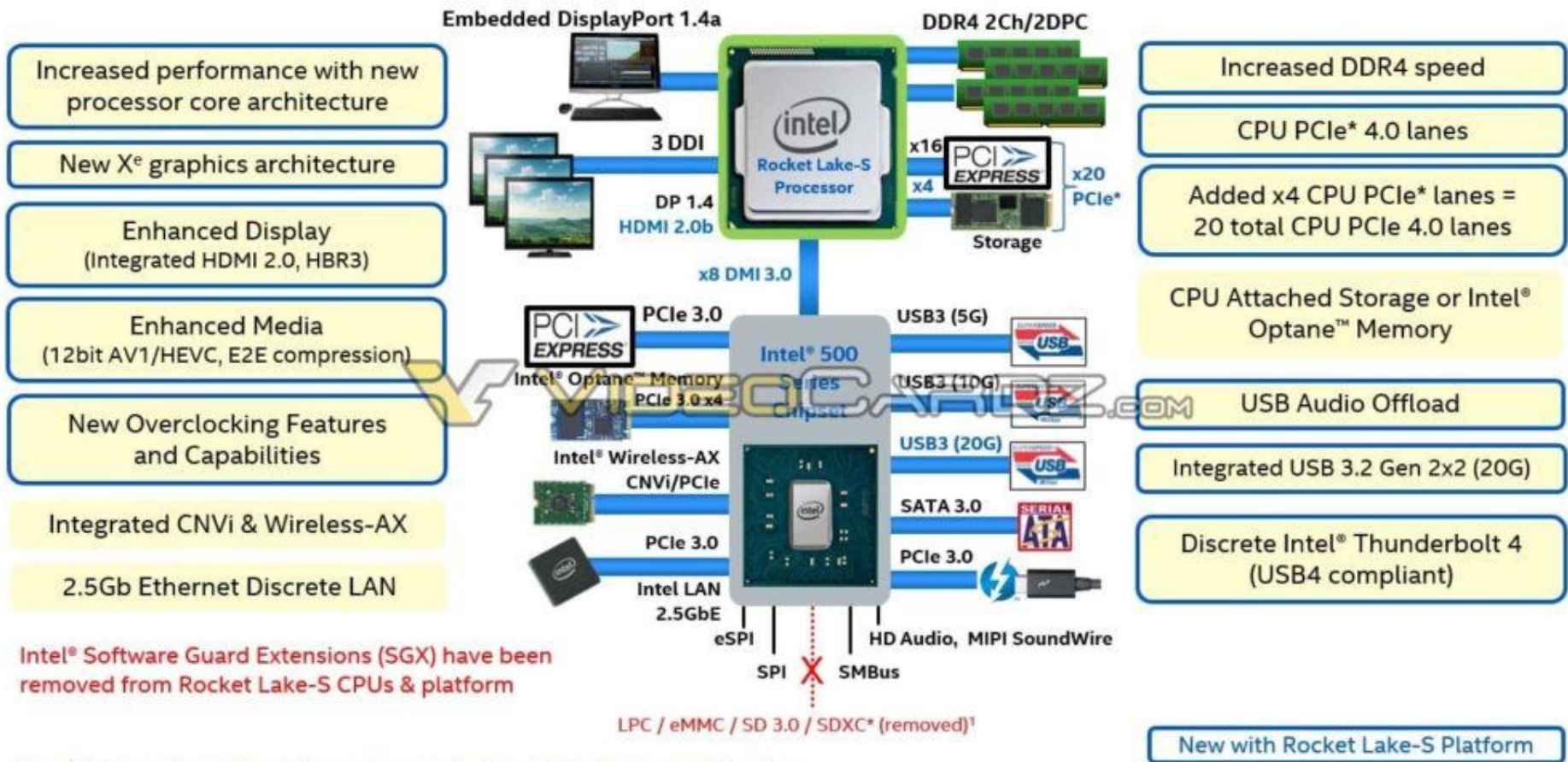
# Challenge: Complexity

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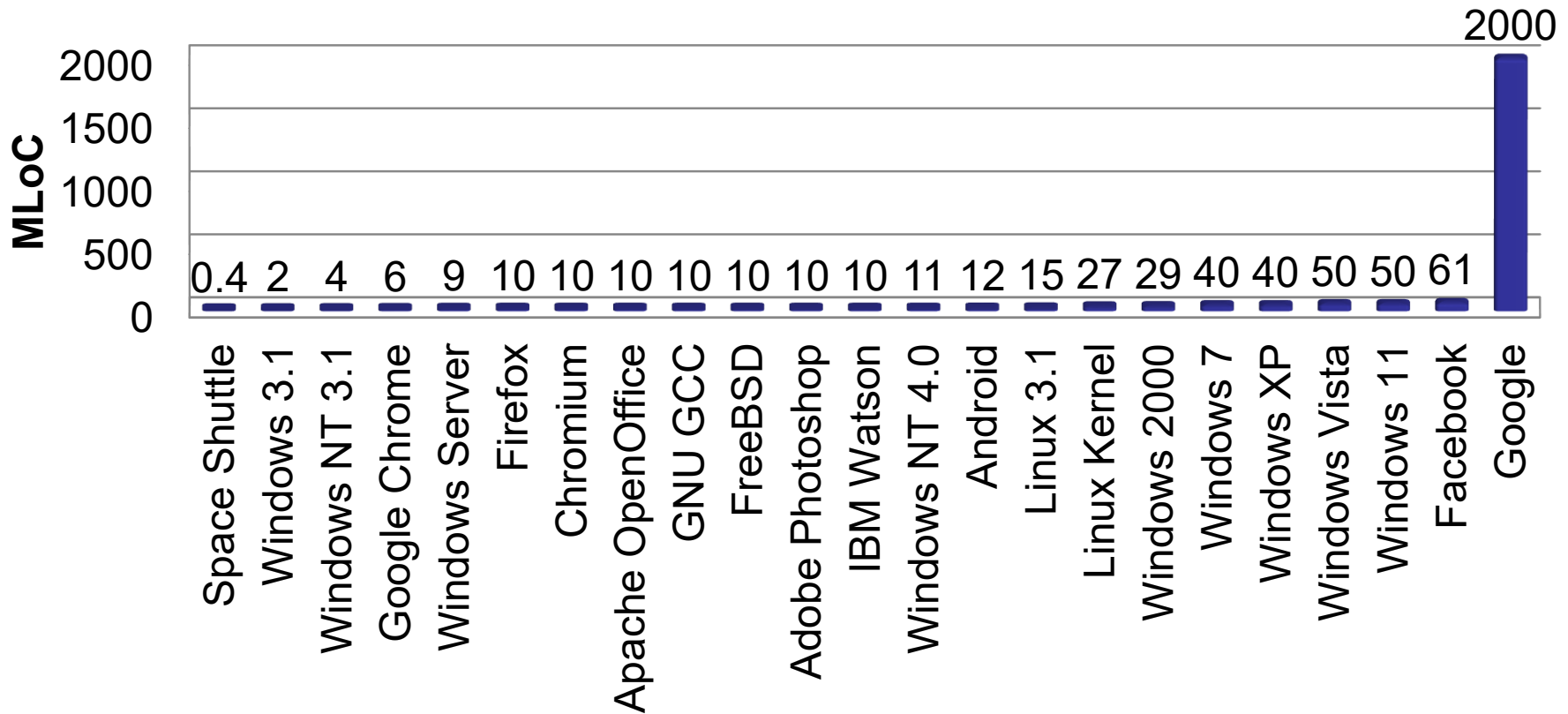
- Applications consisting of...
  - ... a **variety** of **software** modules that ...
  - ... run on a **variety** of **devices** (machines) that
    - ... implement different **hardware architectures**
    - ... run **competing** applications
    - ... **fail** in unexpected ways
    - ... can be under a variety of **attacks**
- **Not feasible to test software** for all possible environments and combinations of components and devices
  - The question is not whether there are bugs but **how serious the bugs are**

# A modern processor: Rocket Lake-S

Launched  
March 2021



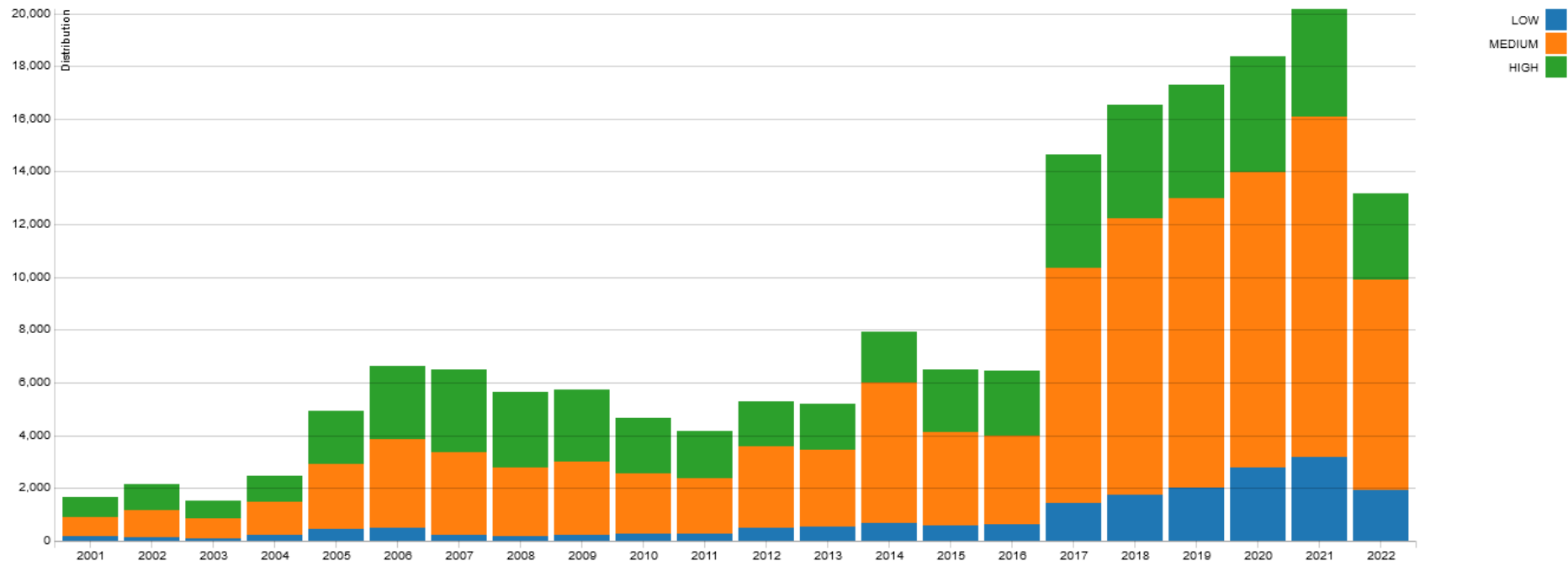
# Increasing Software Complexity



# Leads to Vulnerabilities

## CVSS Severity Distribution Over Time

This visualization is a simple graph which shows the distribution of vulnerabilities by severity over time. The choice of LOW, MEDIUM and HIGH is based upon the CVSS V2 Base score. For more information on how this data was constructed please see the [NVD CVSS page](#).



Source: <https://nvd.nist.gov/general/visualizations/vulnerability-visualizations/cvss-severity-distribution-over-time>

# Mars Rover (“Pathfinder”) Reqs

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- Pathfinder hardware limitations/complexity:
  - 20Mhz processor, 128MB of DRAM, VxWorks OS
  - Cameras, scientific instruments, batteries, solar panels, and locomotion equipment
  - Many independent processes work together
- Can’t hit reset button very easily!
  - Must reboot itself if necessary
  - Must always be able to receive commands from Earth

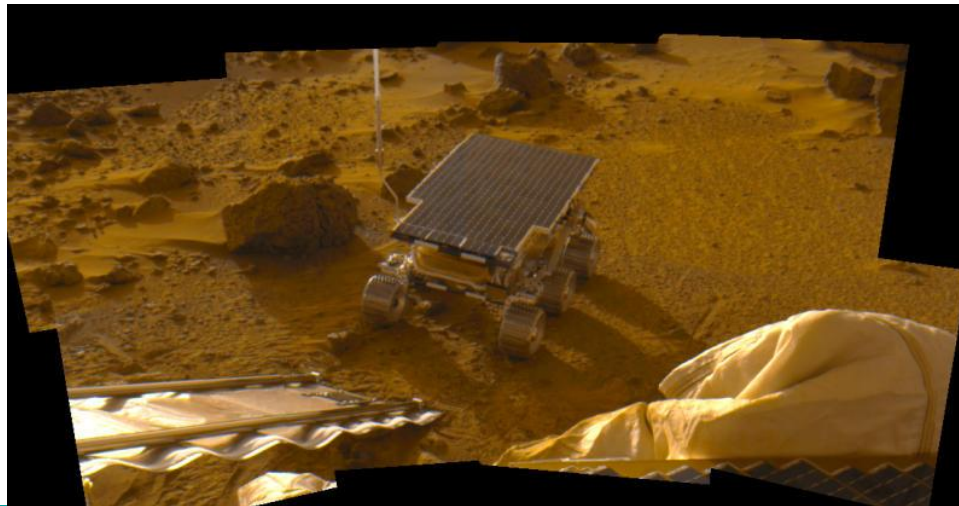


Image credit: Nasa/JPL

# Mars Rover (“Pathfinder”) Reqs

- Individual Programs must not interfere
  - Suppose MUT (Martian Universal Translator Module 😊) buggy
  - Better not crash antenna positioning software!
- Further, all software may crash occasionally
  - Automatic restart with diagnostics sent to Earth
  - Periodic checkpoint of results saved?
- Certain functions time critical:
  - Need to stop before hitting something
  - Must track orbit of Earth for communication
- A lot of similarity with the Internet of Things?
  - *Complexity, QoS, Inaccessibility, Power limitations ... ?*

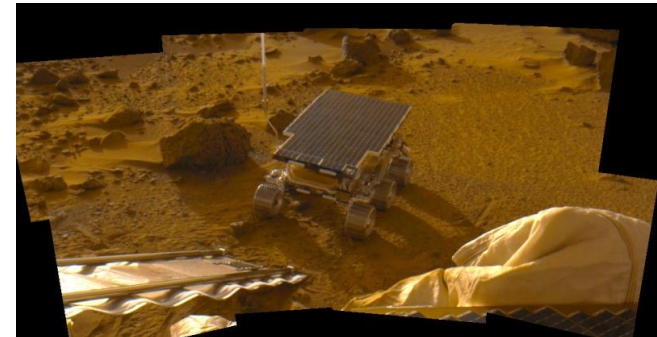


Image credit: Nasa/JPL

# More on errors and OS

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- [https://www.youtube.com/watch?v=AaZ\\_RSt0KP8](https://www.youtube.com/watch?v=AaZ_RSt0KP8)

# Taming Complexity

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- Every piece of computer hardware different
  - Different CPU
    - Pentium, PowerPC, ColdFire, ARM, MIPS
  - Different amounts of memory, disk, ...
  - Different types of devices
    - Mice, Keyboards, Sensors, Cameras, Fingerprint readers
  - Different networking environment
    - Cable, DSL, Wireless, Firewalls,...

## Questions:

1. Does the programmer need to write a **single program** that performs many independent activities?
2. Does **every program** have to be altered for **every piece** of hardware?
3. Does a **faulty program** crash everything?
4. Does every program **have access** to all hardware?

# Conclusion

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- What is an Operating System?
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