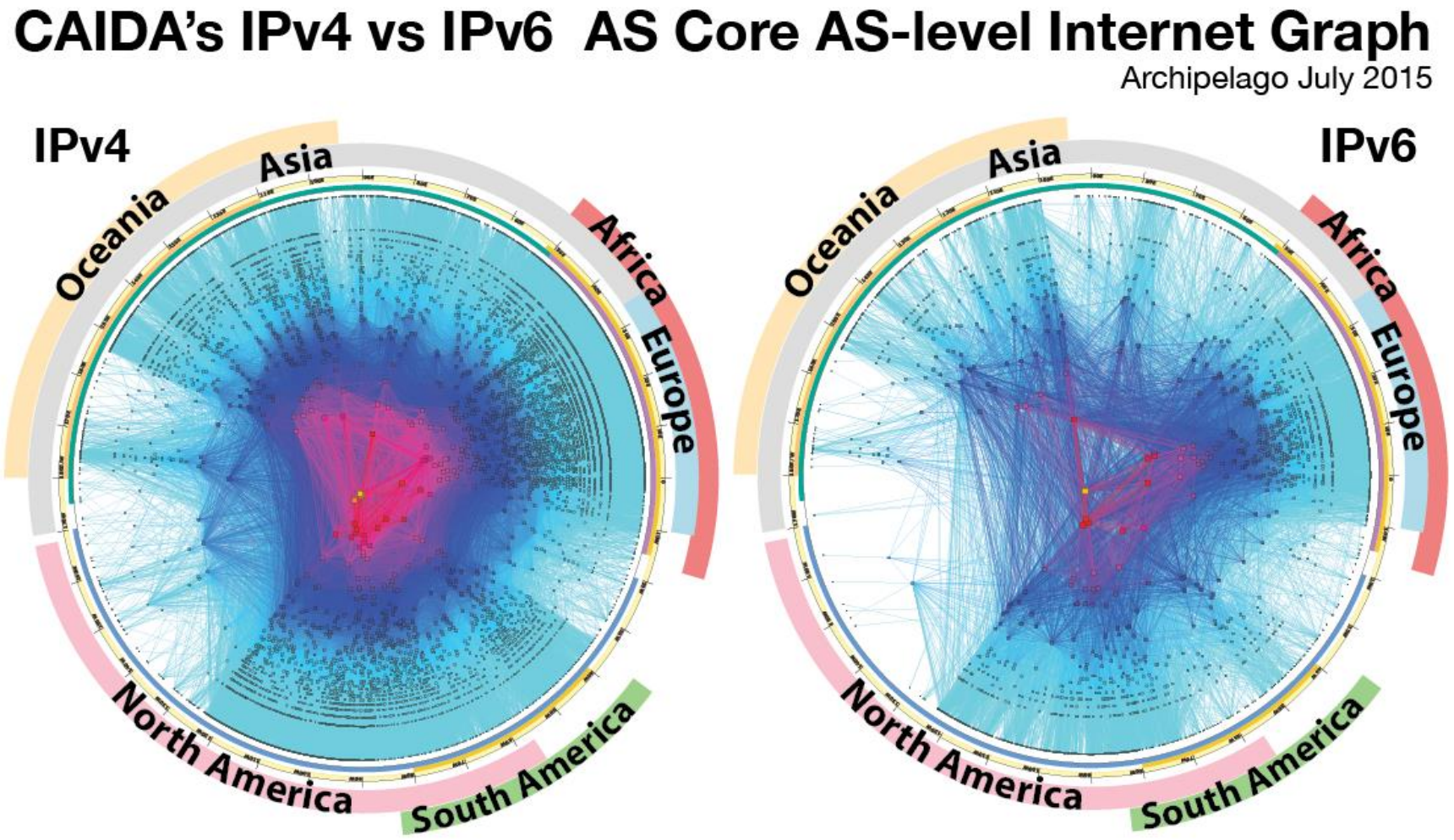
Lecturer: Dr. Michael J. May
Kinneret College

Intro to OS

7 November 2024
Lecture 1

Slides adapted from John Kubiatowicz (UC Berkeley)

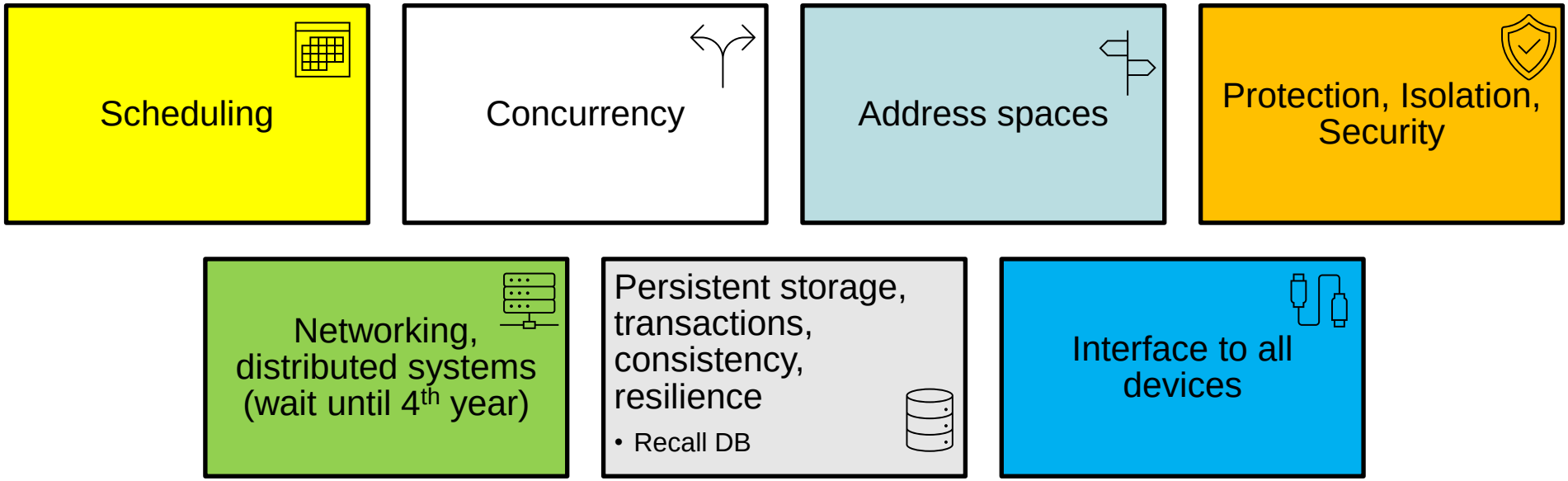
The Internet



OS at the heart of it all

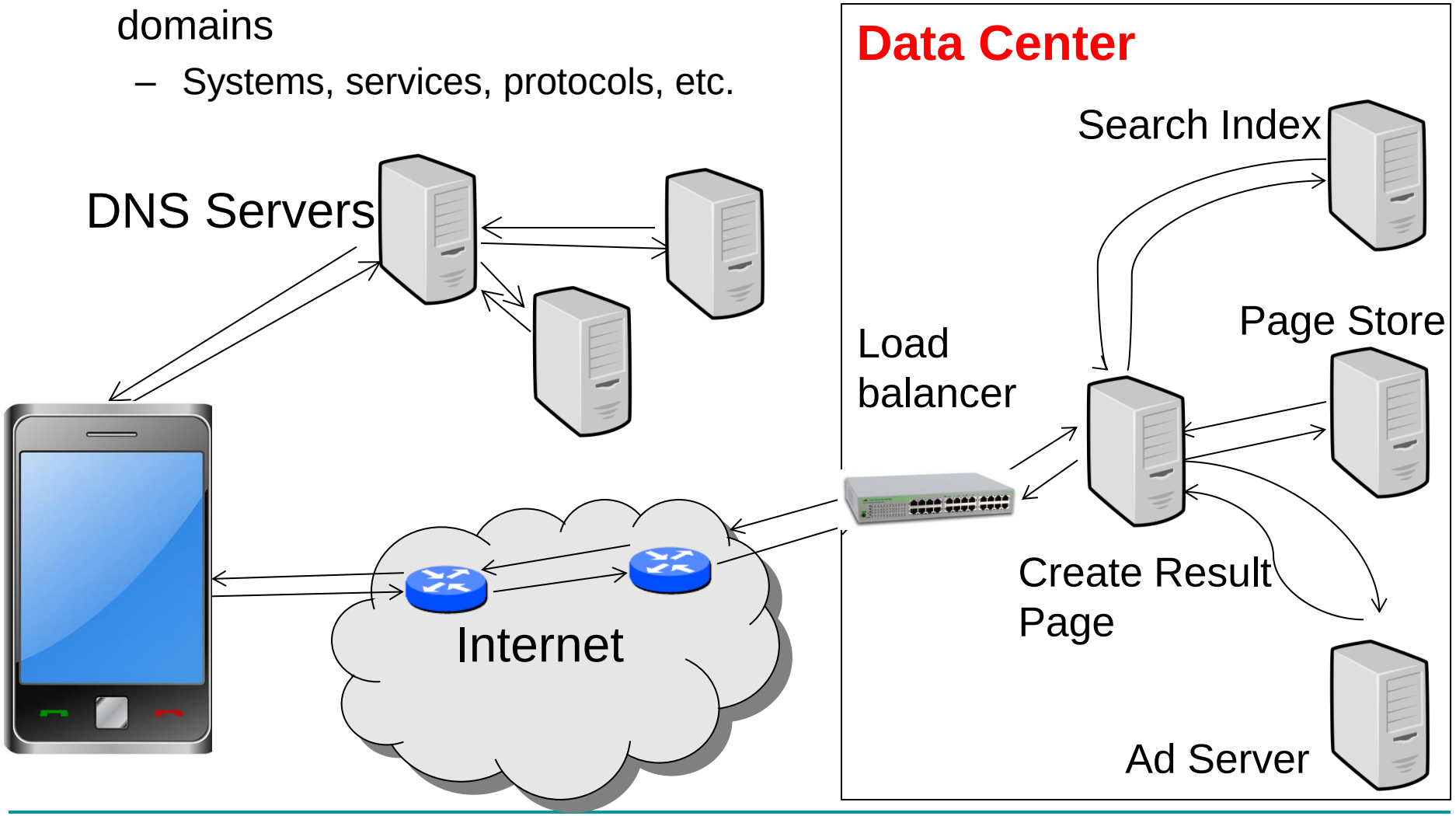
- Make the incredible advance in the underlying hardware available to a rapidly evolving body of applications
  - Processing, Communications, Storage, Interaction

- The key building blocks



Ex: What's in a Search Query?

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



Why Study OS?

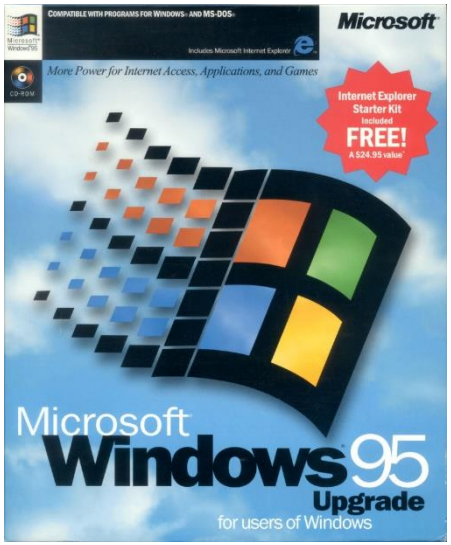
- Some of you will design and build operating systems or components of them.
  - More now than ever (embedded, custom OS, Android variants)
- Many of you will create systems that utilize the core concepts in OS
  - Whether you build software or hardware
  - The concepts and design patterns appear at 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.

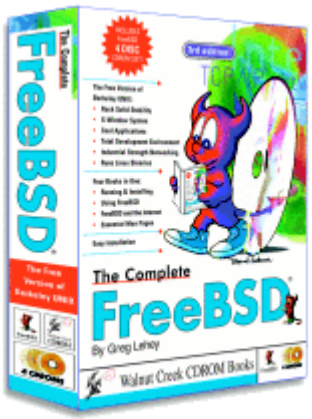
Topics for Today

- 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

Today's word cloud

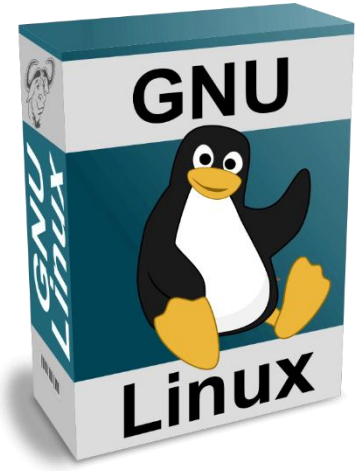
What is an operating system?

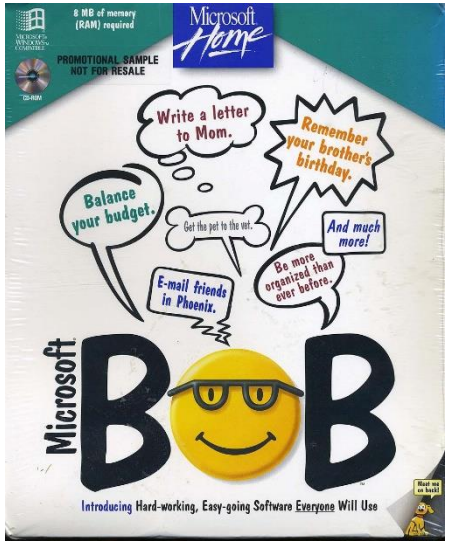




https://www.freebsd.org/gifs/bsdcomp-4.2.gif

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



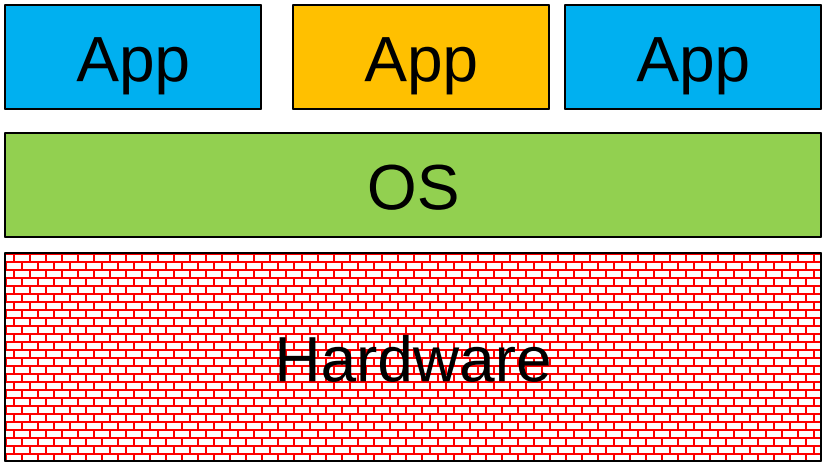


https://all-free-download.com/free-vector/download/software-carton-box-with-gnu-linux-text-and-tux_55593.html

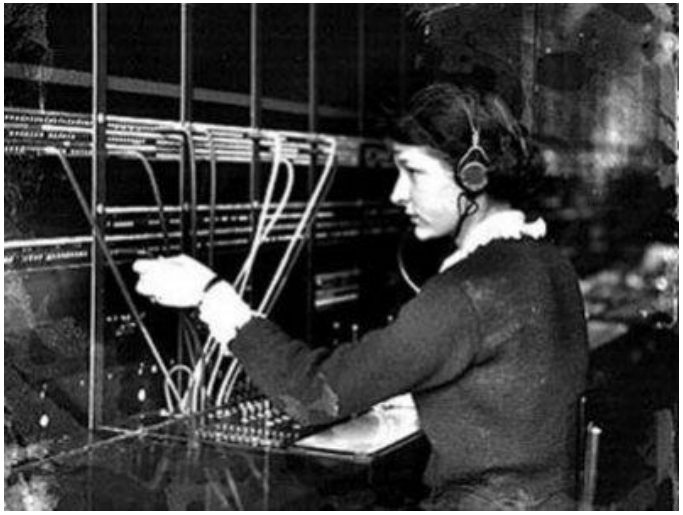
https://msbob.org/images/originalphotos/314/4/2f84a9adeb8cf88452b3c41f.jpg

What is an Operating System?

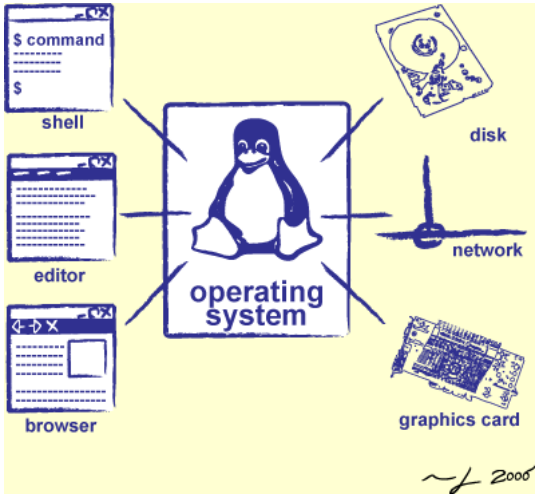
- Special layer of software that provides application software access to hardware resources
  - Convenient abstraction of complex hardware devices
  - Protected access to shared resources
  - Security and authentication
  - Communication among logical entities



Why “Operating”?



Switchboard operator

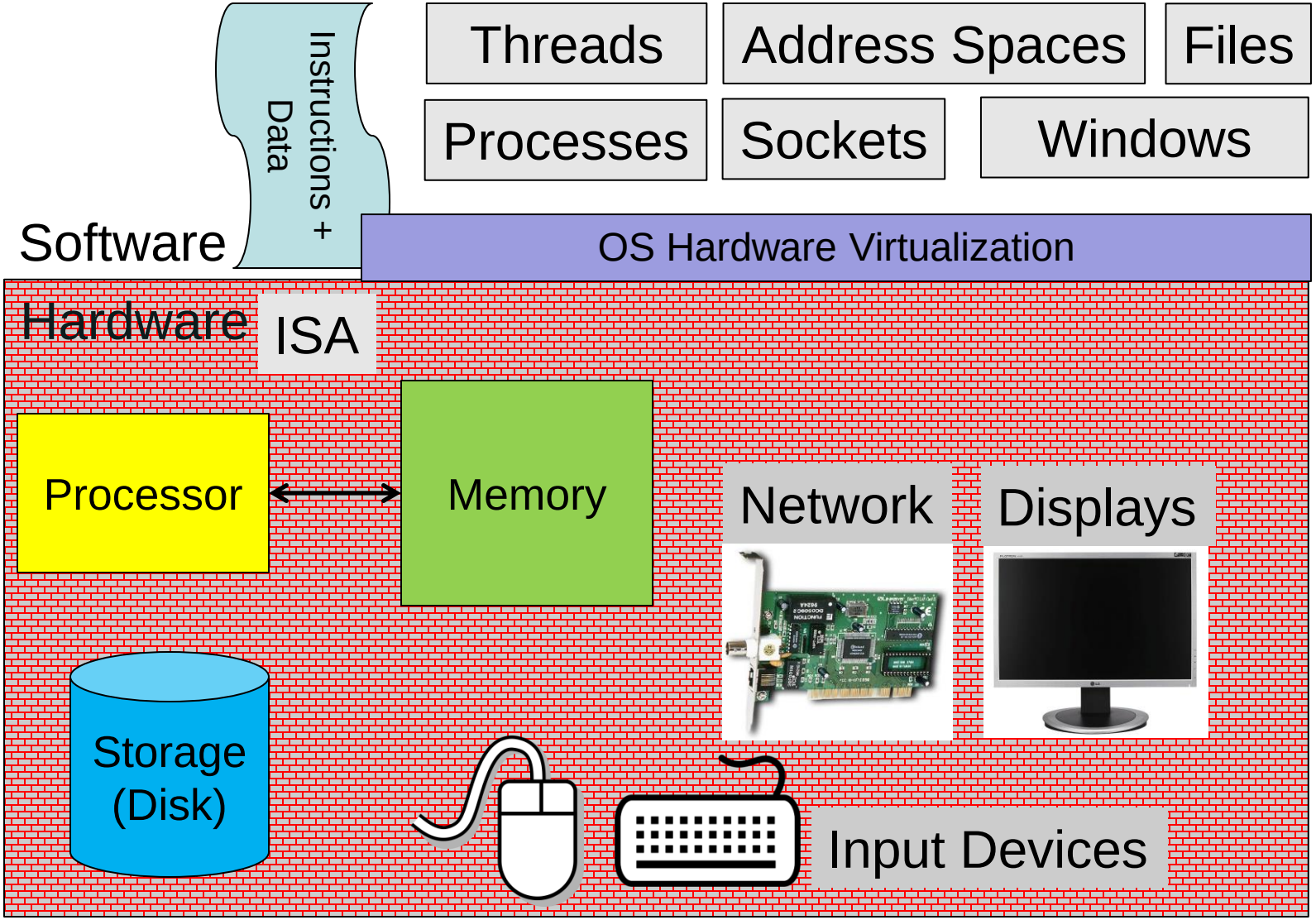


Computer Operator

Then came the 1990s

http://www.tecnologiahechapalabra.com/img_noticias/2015/4/%7BCCF6763B-1361-4A0B-9BC2-251814610DE0%7D_tofn28.jpg

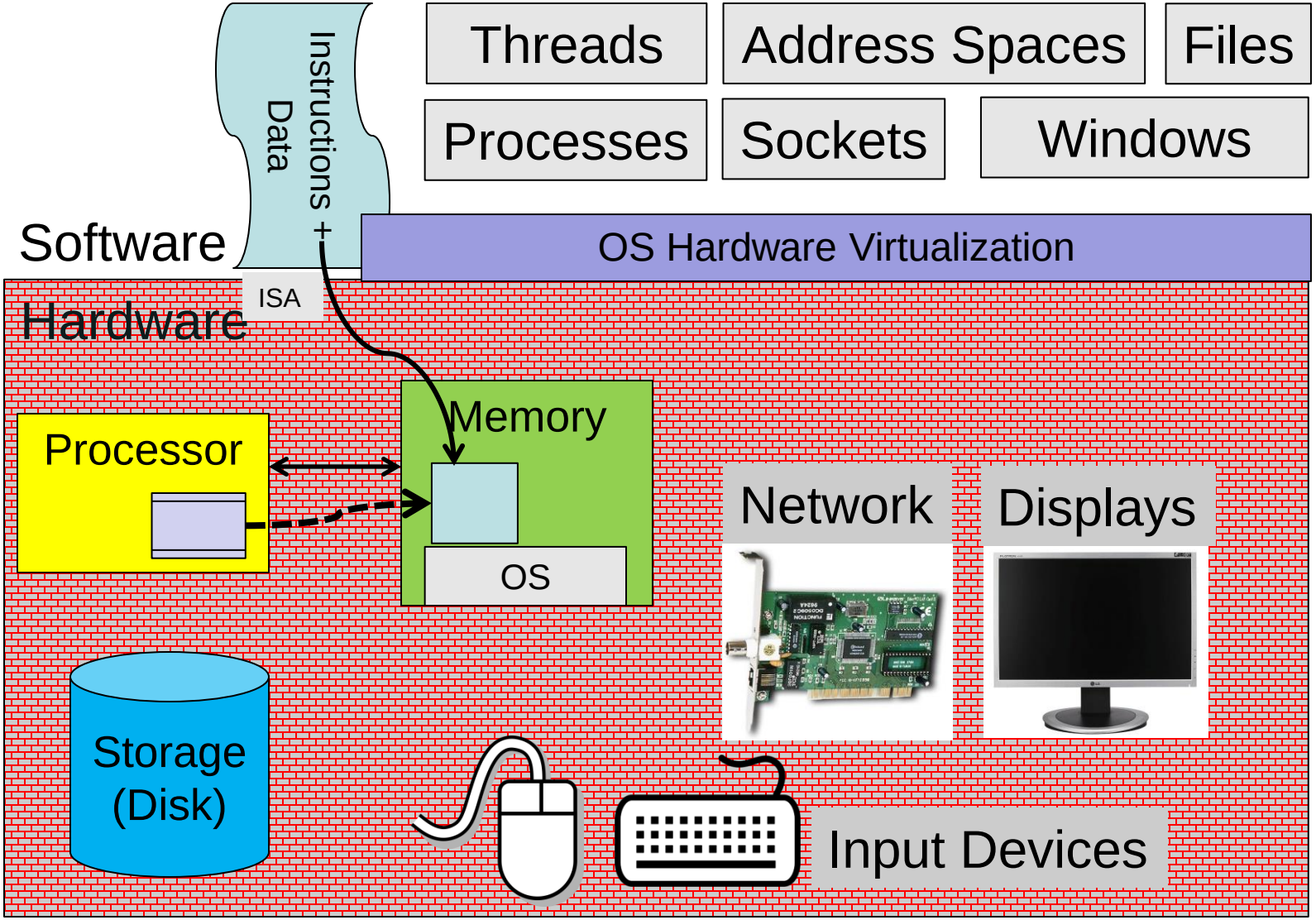
OS Basics: “Virtual Machine” Boundary



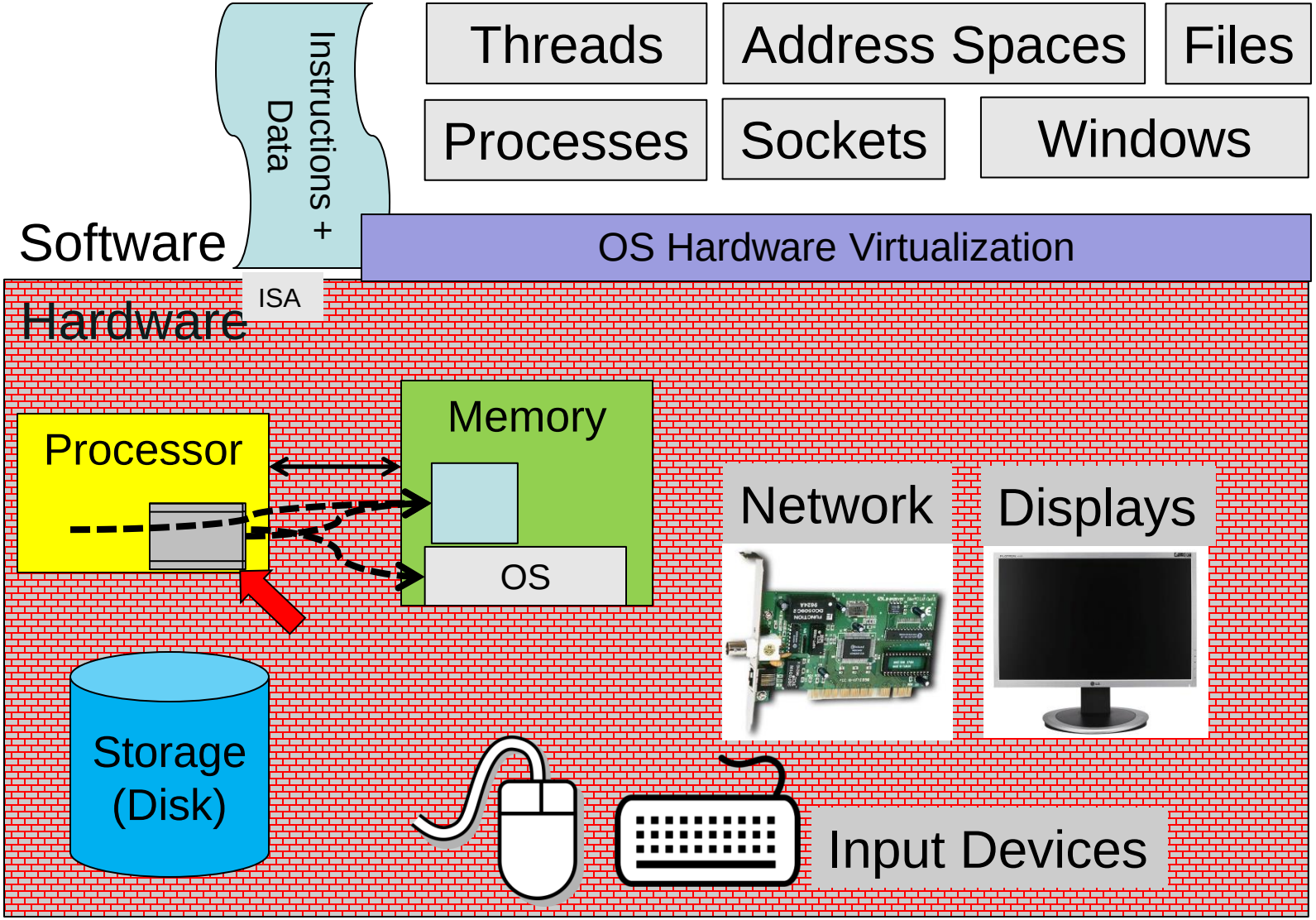
Interfaces Provide Boundaries

- 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

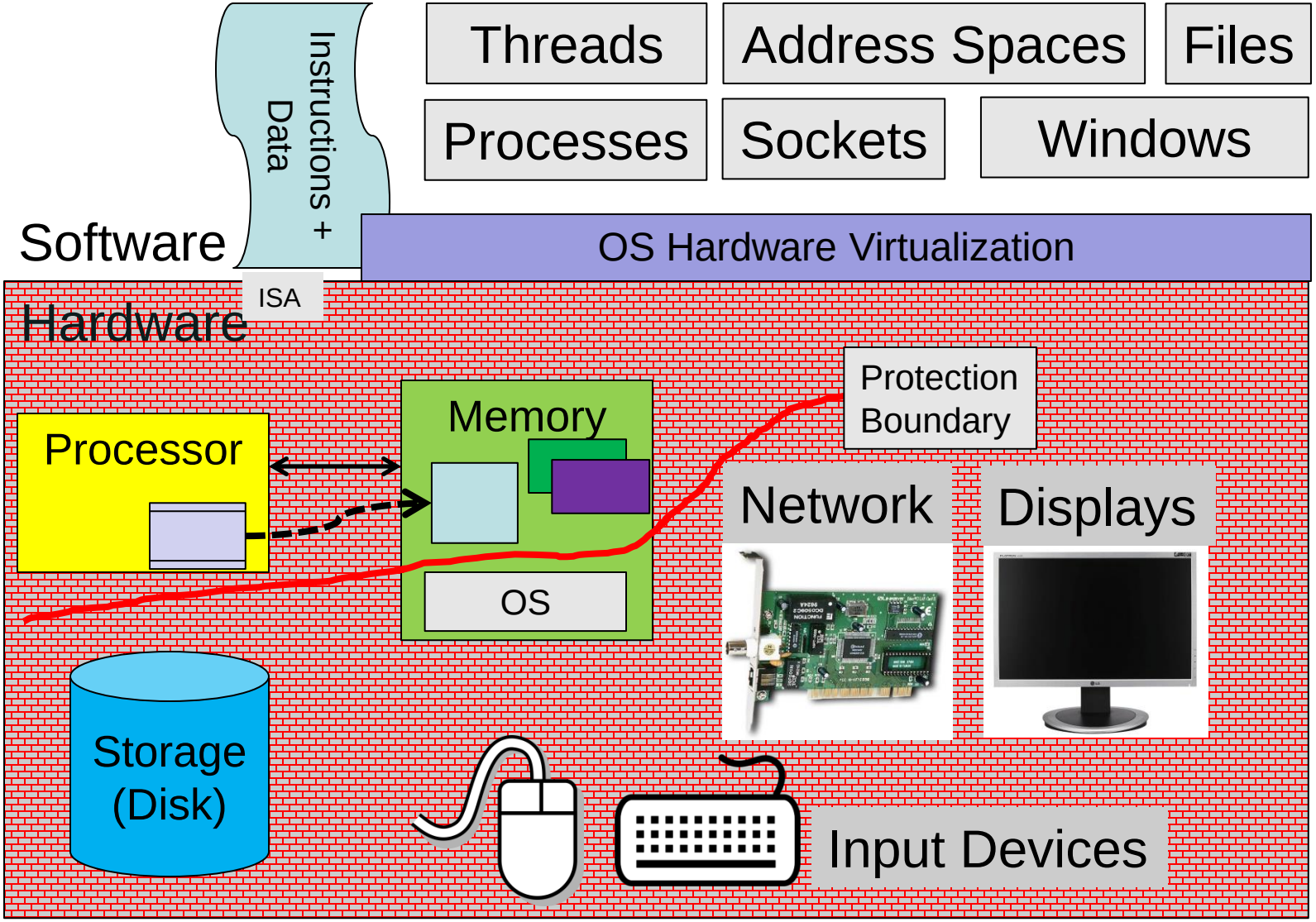
OS Basics: Program → Process



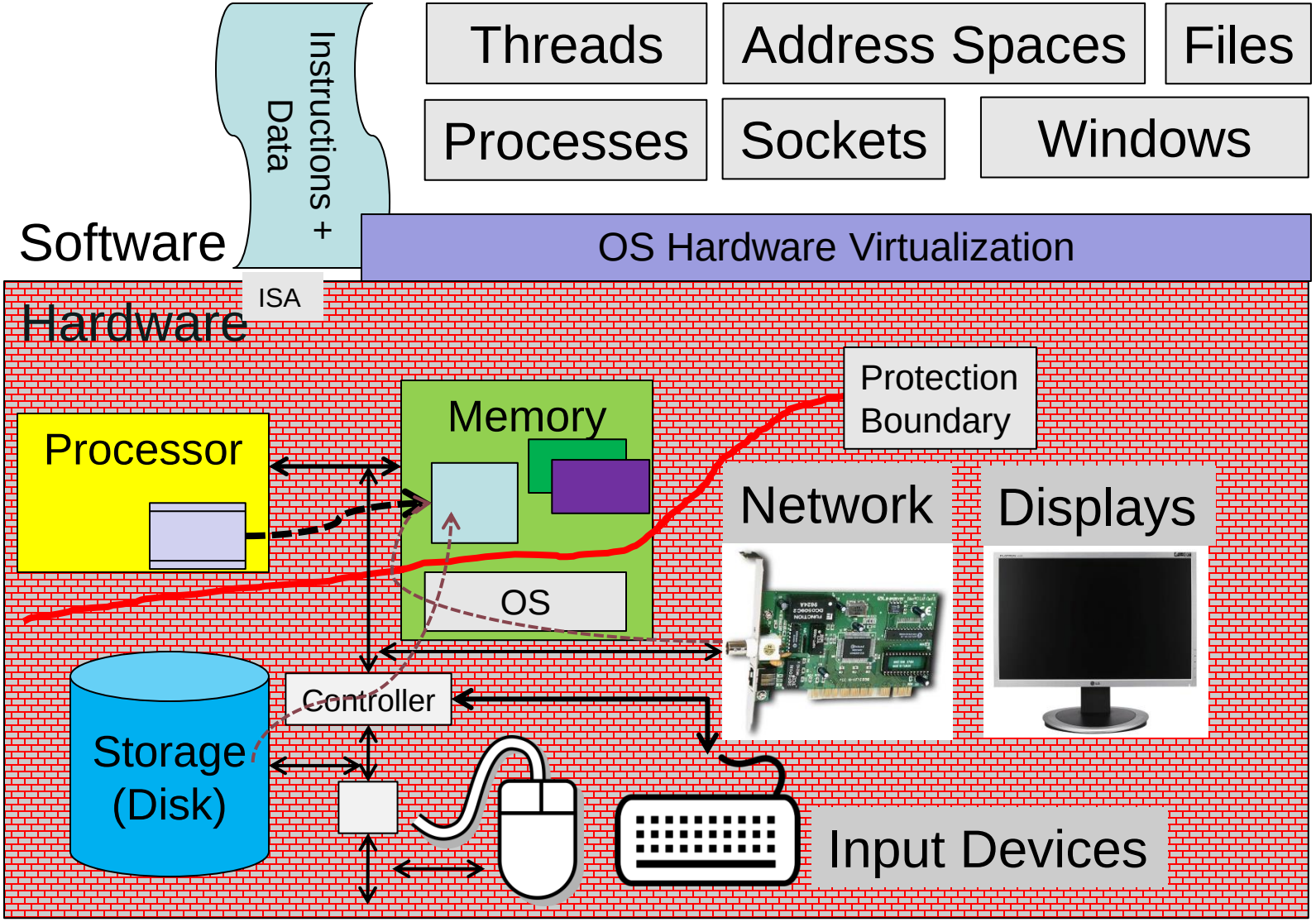
OS Basics: Context Switch



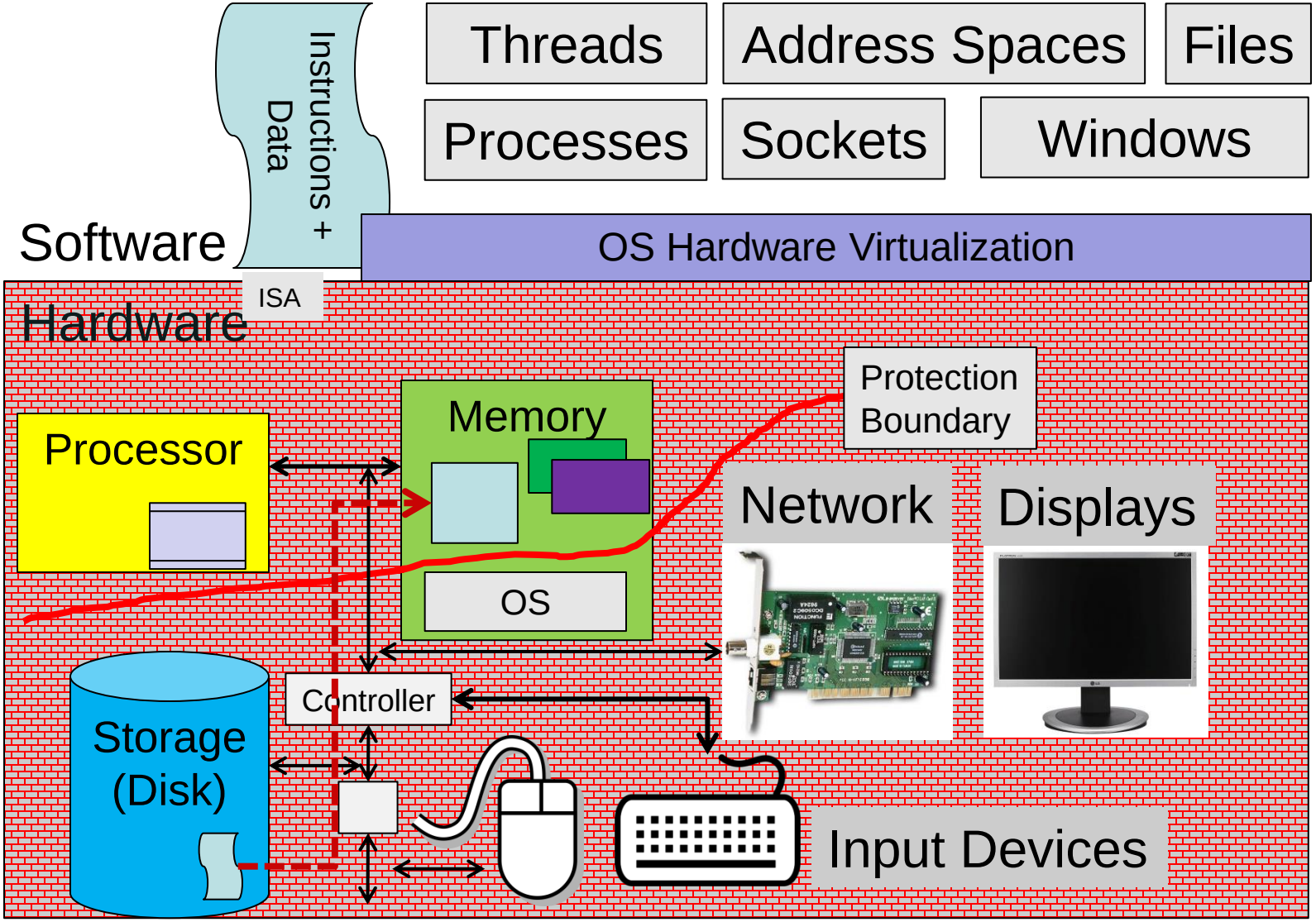
OS Basics: Scheduling, Protection



OS Basics: I/O


Threads
Address Spaces
Files
Processes
Sockets
Windows
Instructions + Data
Software
OS Hardware Virtualization
ISA
Hardware
Protection Boundary
Memory
Processor
OS
Network
Displays
Controller
Storage (Disk)
Input Devices

OS Basics: Loading



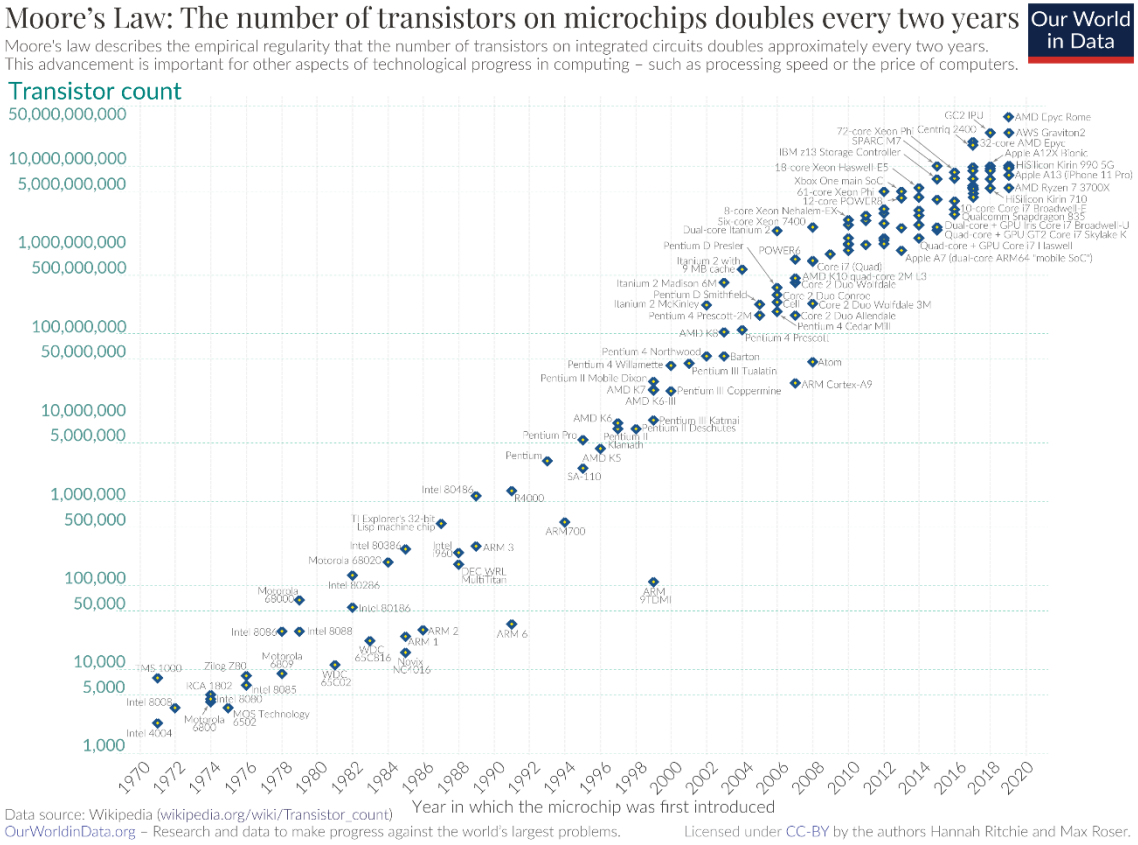
So Far

- 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 makes Operating Systems exciting and challenging?

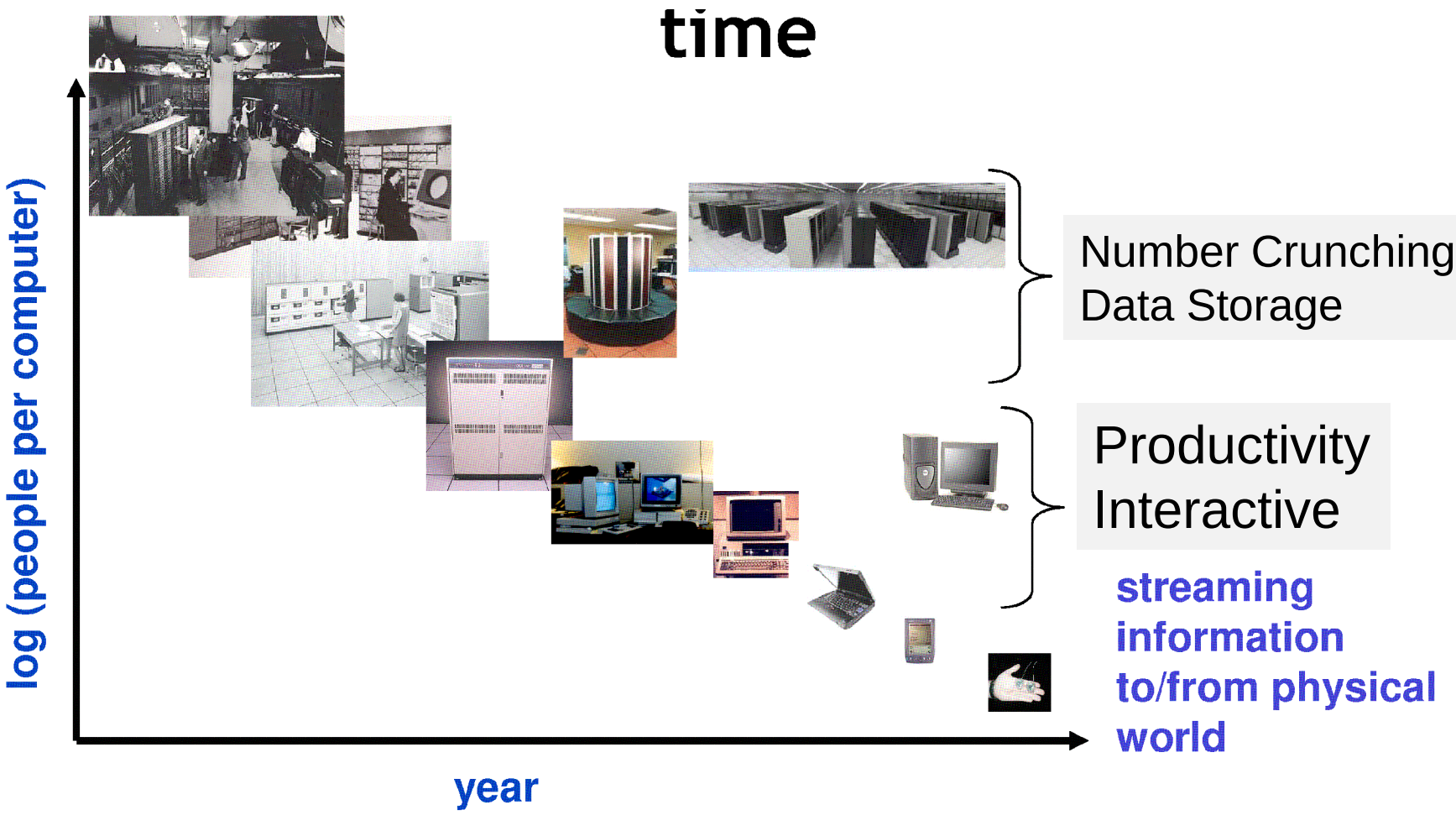
Moore's Law

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



People to Computer Ratio

Image credits: David Culler (UC Berkeley)



Joy's Law of Performance

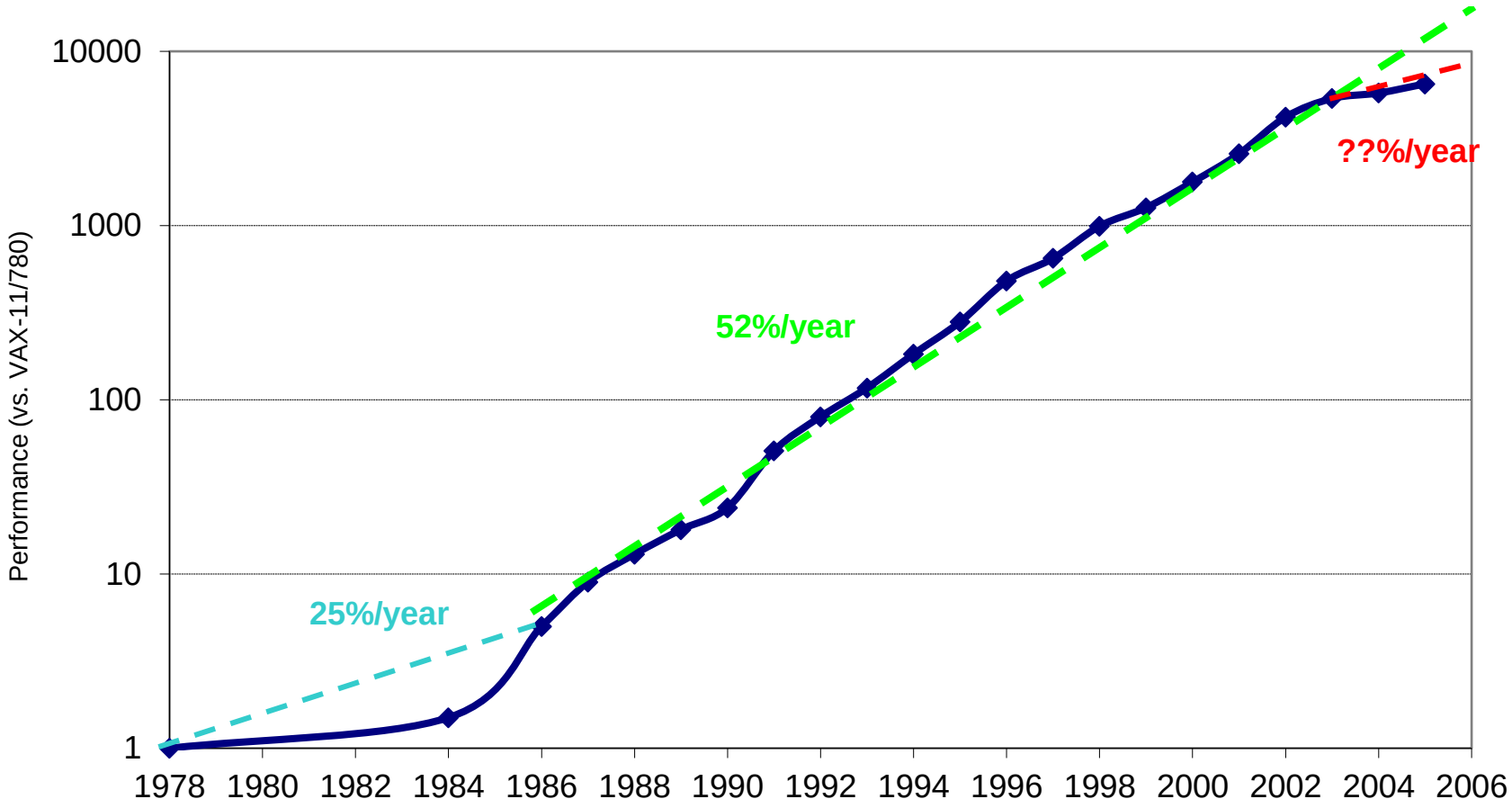
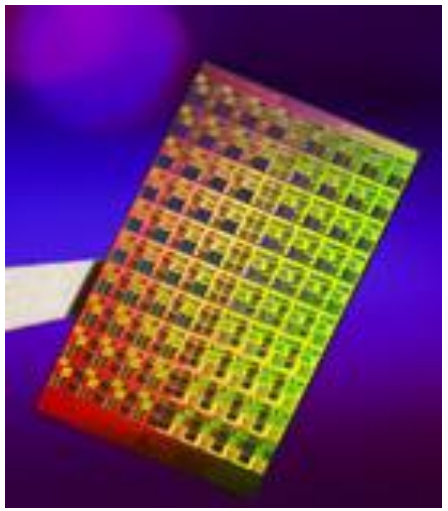


Image credit: From Hennessy and Patterson, *Computer Architecture: A Quantitative Approach*, 4th edition via Kubiatowicz (UC Berkeley)

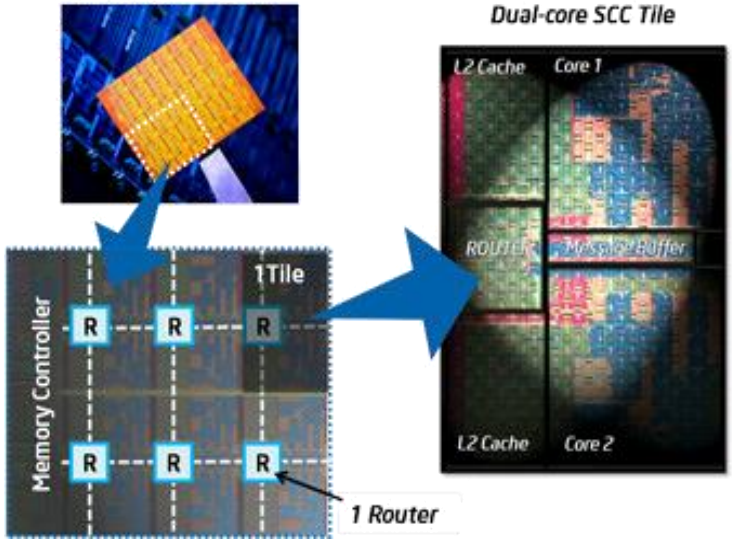
Slowdown led to multiple "cores" or processors per chip

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

ManyCore means many processors per chip

- 64? 128?
- Hard to say exact boundary

How to program them?

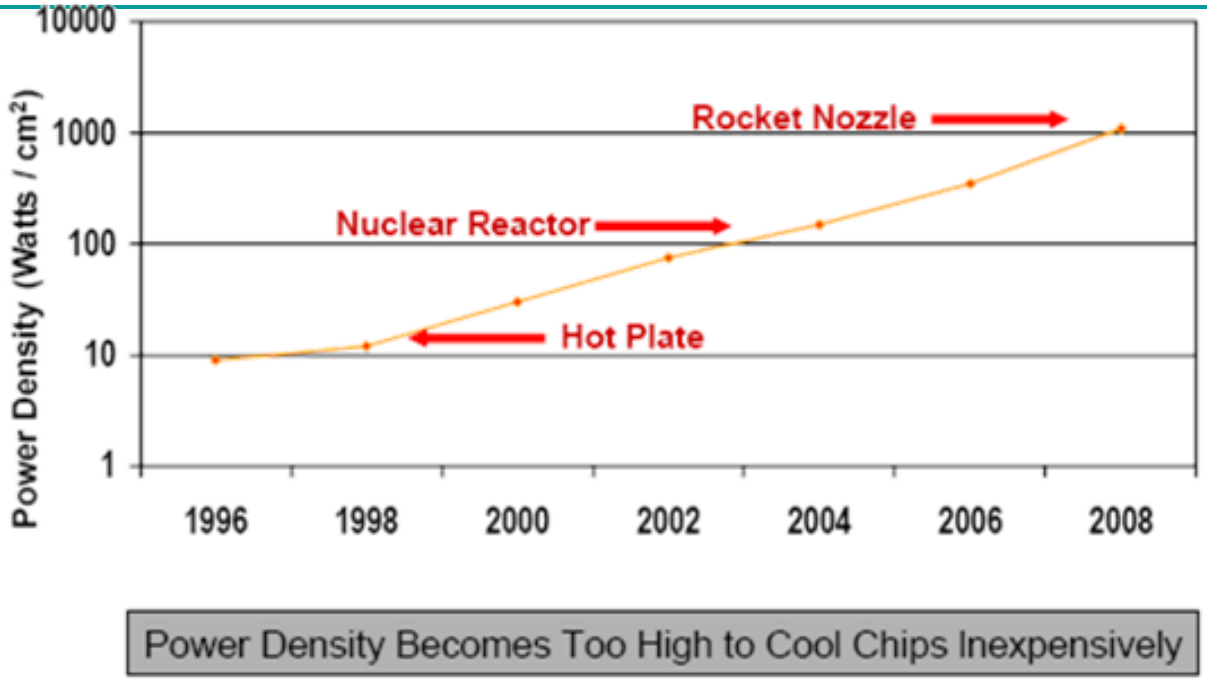
- Use 2 CPUs for video/audio
- 1 for word processor
- 1 for browser
- 76 for virus checking?

Parallelism must be exploited at all levels

- Software aware!

Software engineers must learn how to write parallelizable code

Power Density



- 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

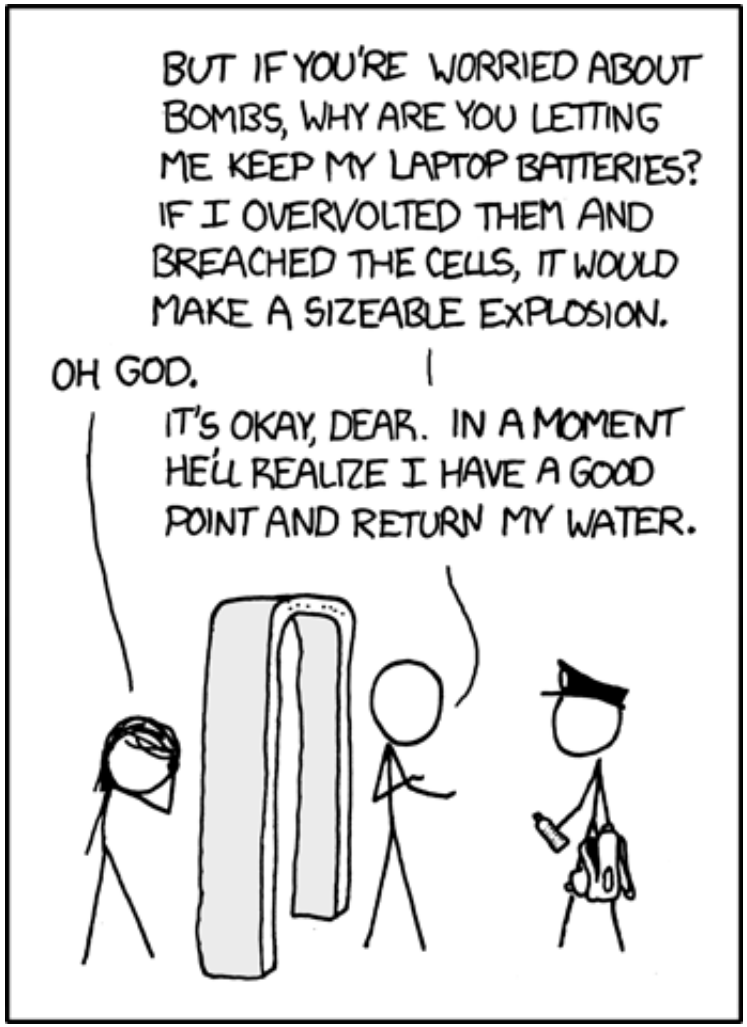
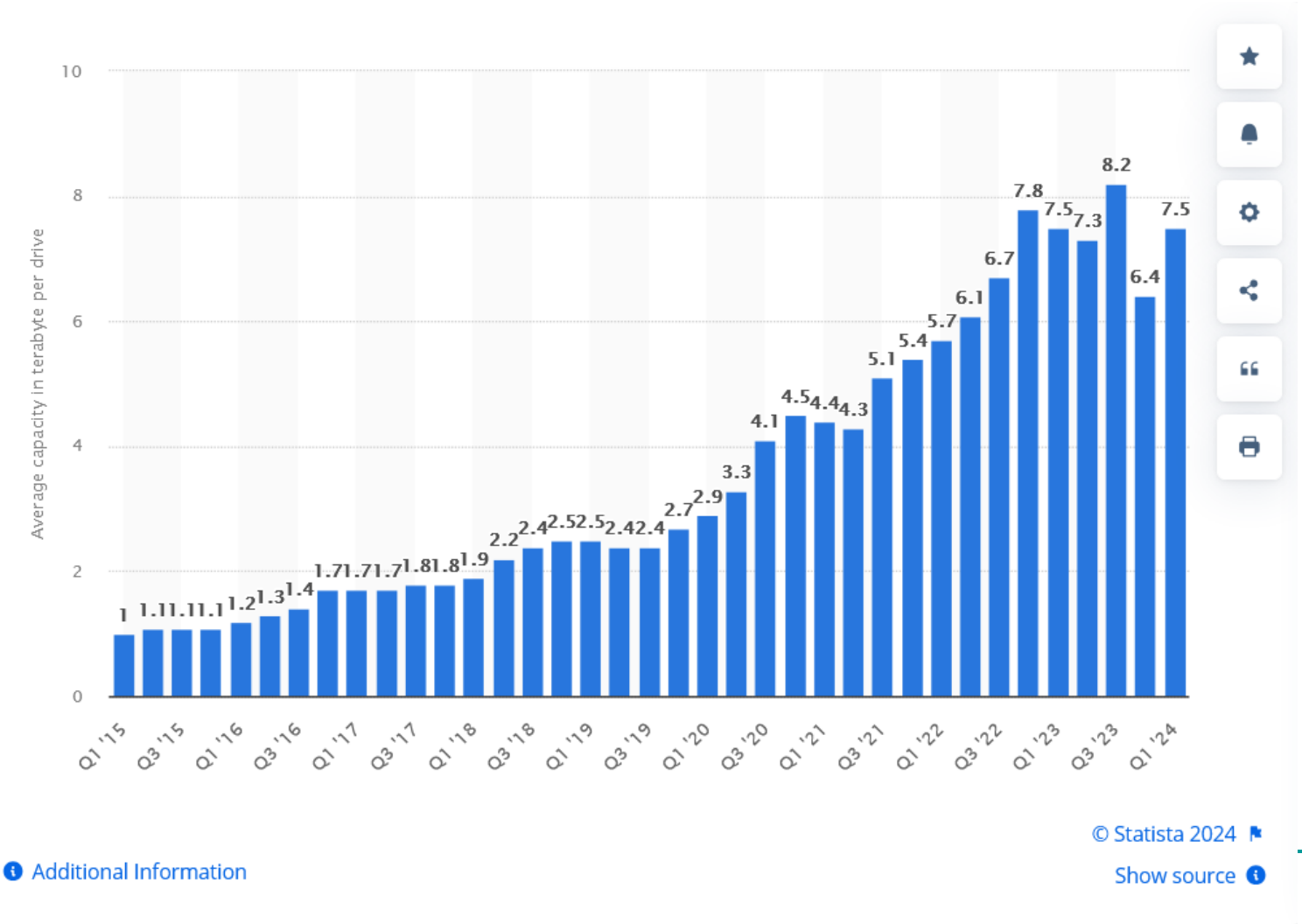


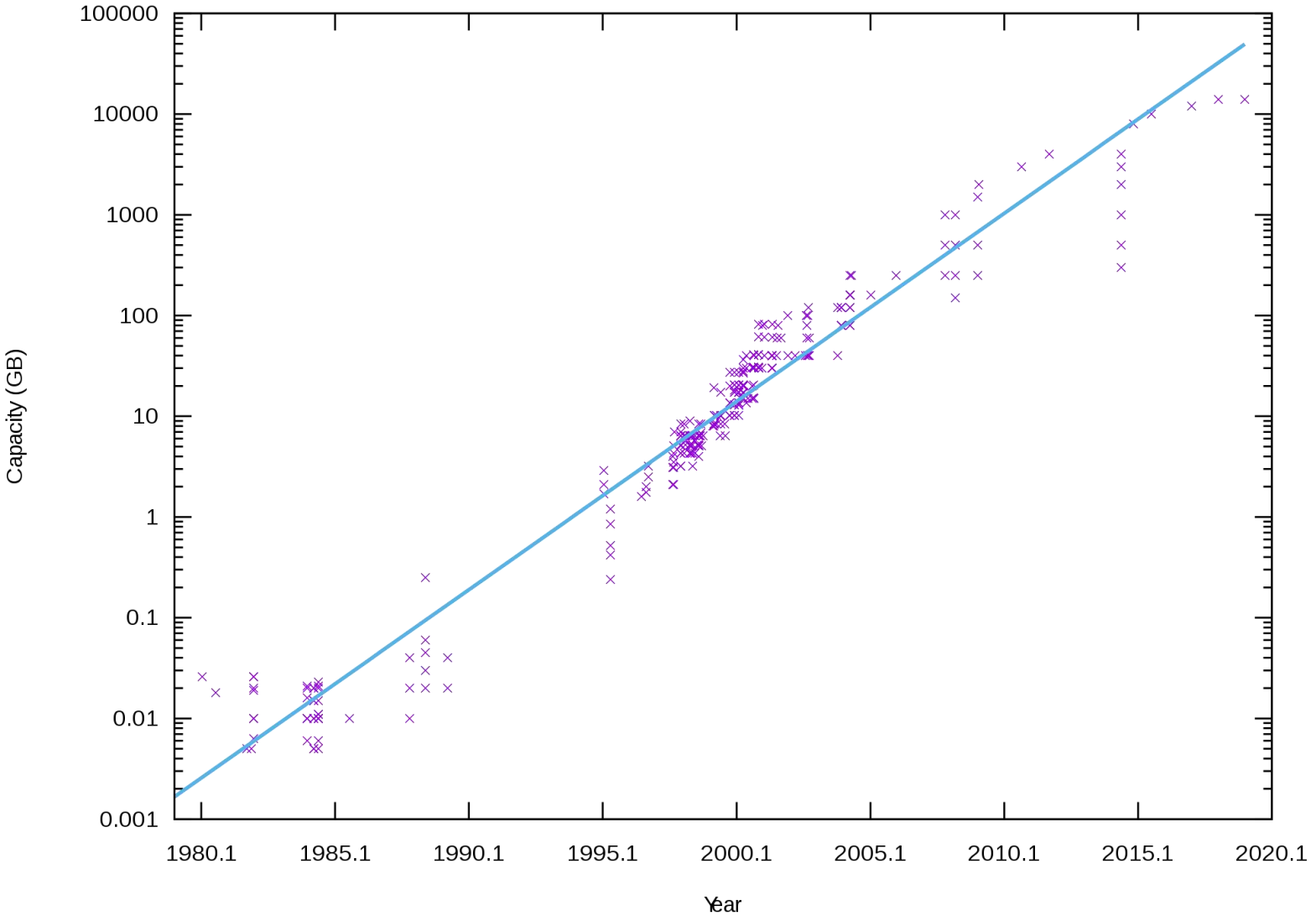
Image credit: XKCD

Storage Capacity

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



Storage Capacity



Credit: By !File: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

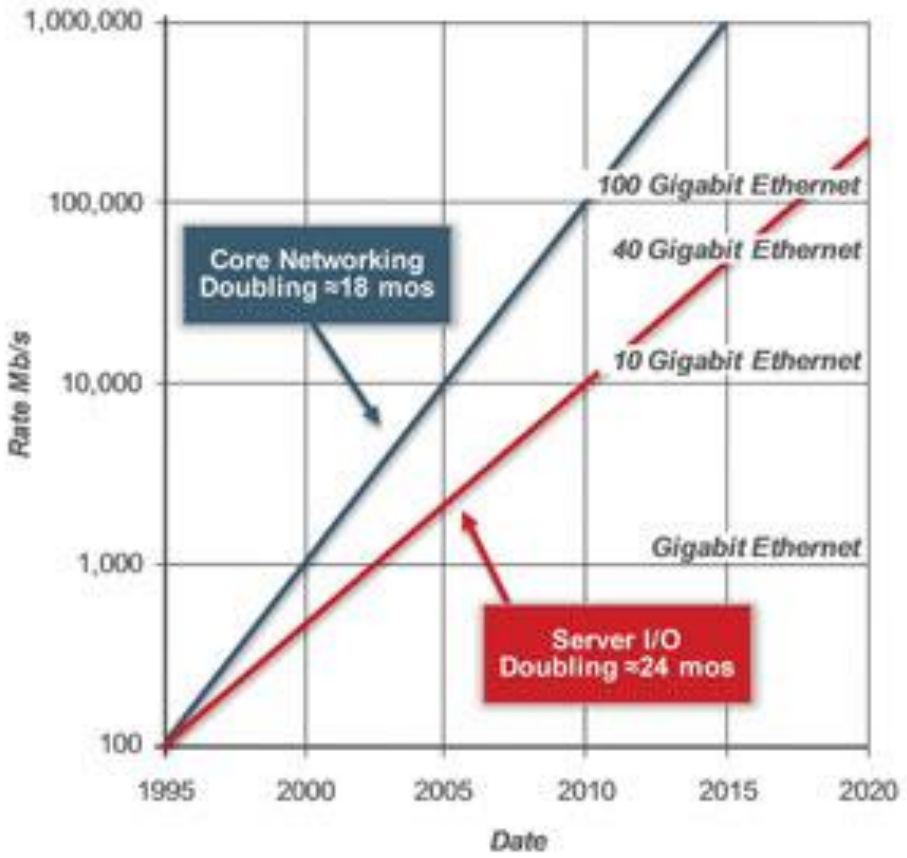
Time Is Not Always On Our Side...

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

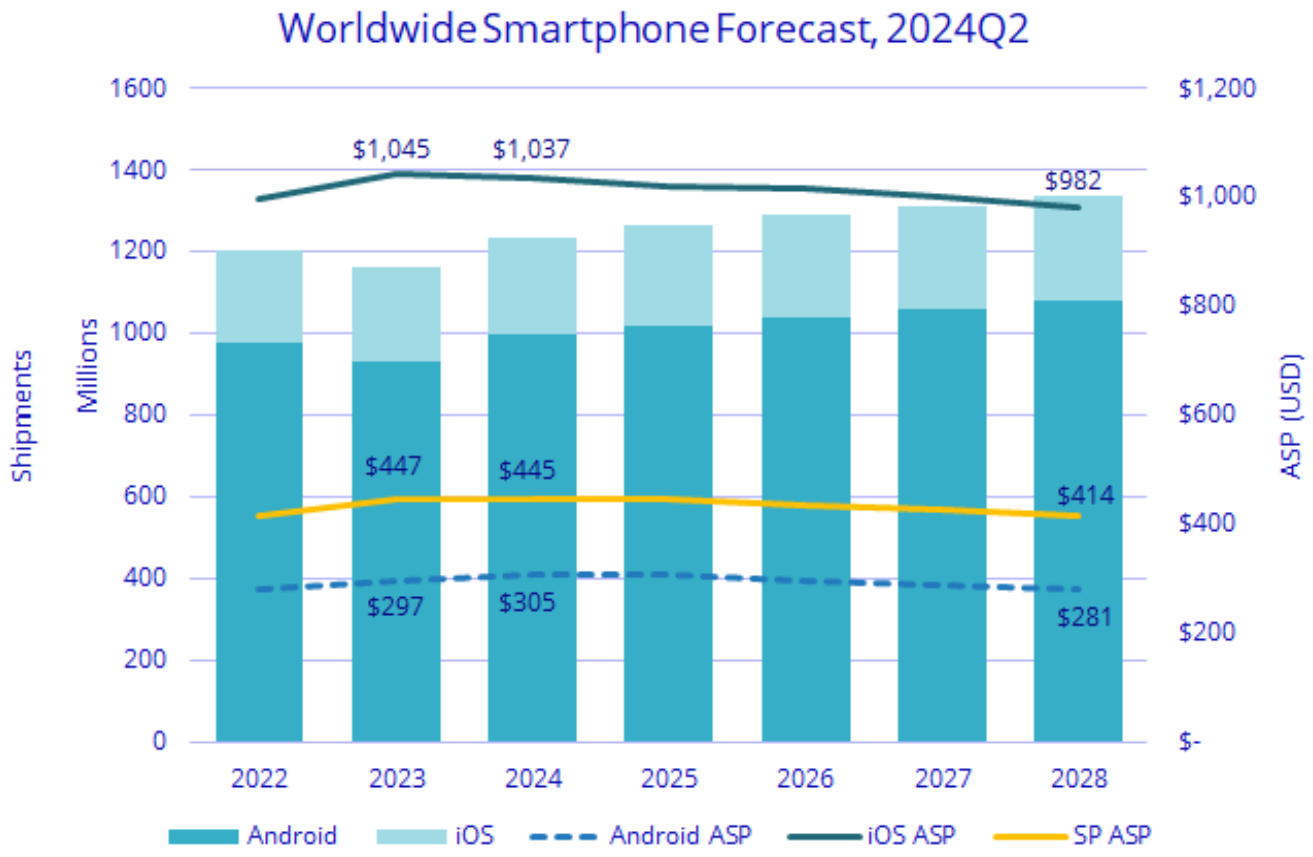
WORLD INTERNET USAGE AND POPULATION STATISTICS
2023 Year Estimates

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

Not only PCs

And this ignores Smart TVs, DVRs, IoT



What is an Operating System?

Referee

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

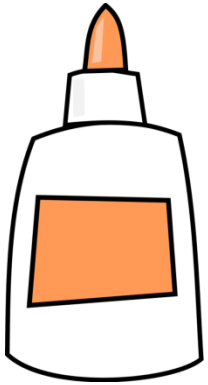
Illusionist

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

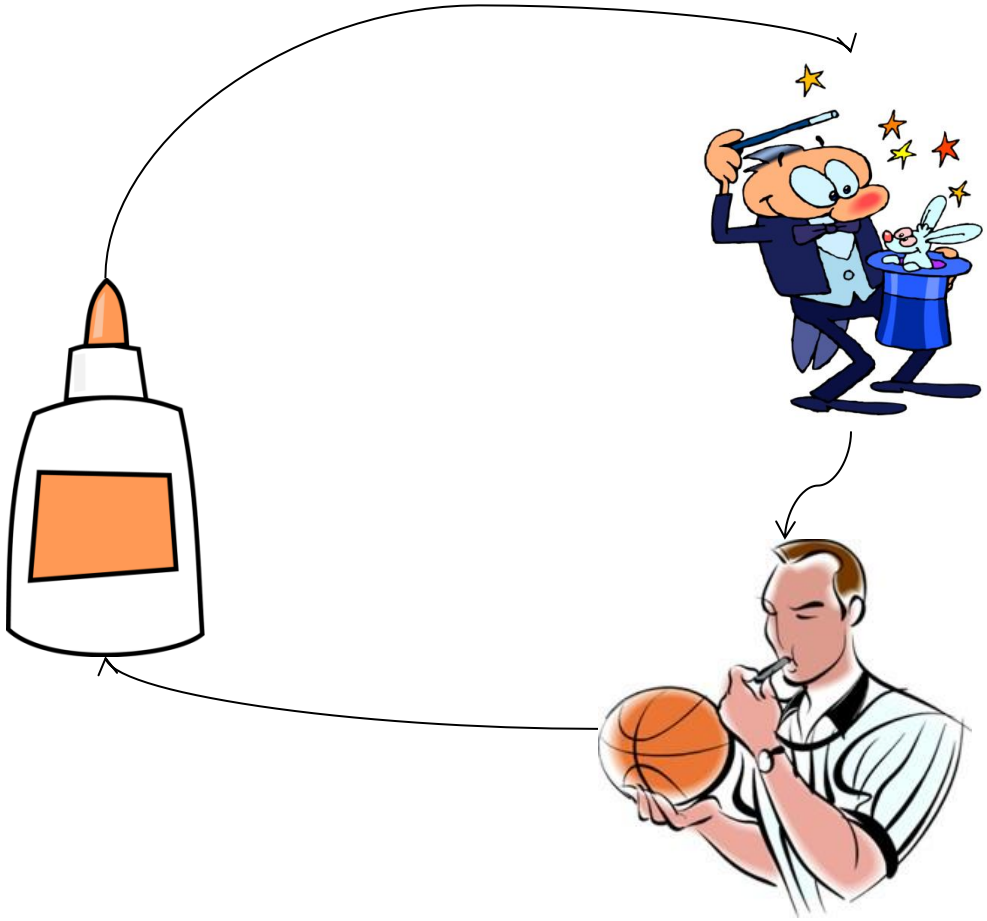
What is an Operating System?

Glue

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



Many hats

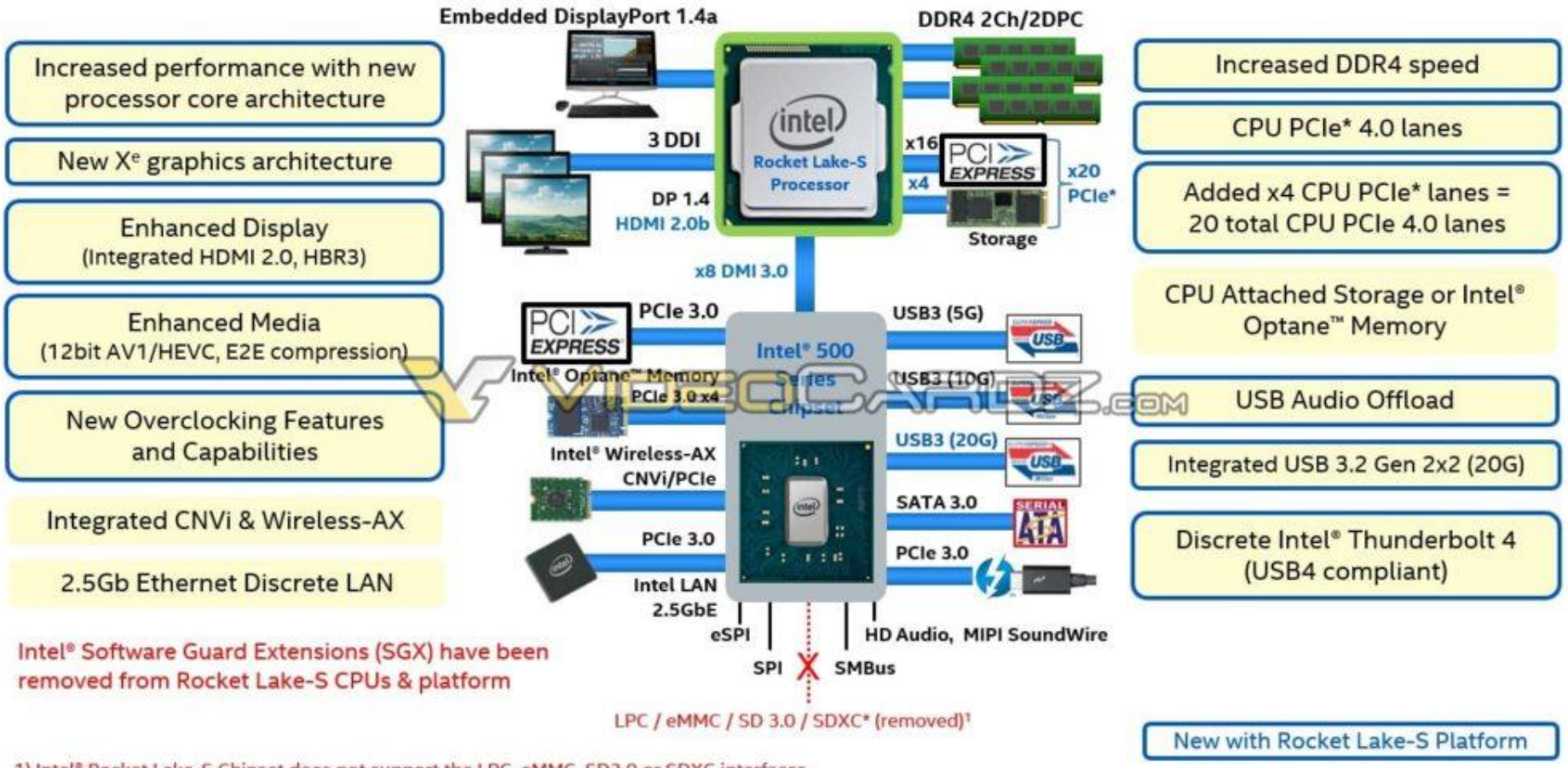


Challenge: Complexity

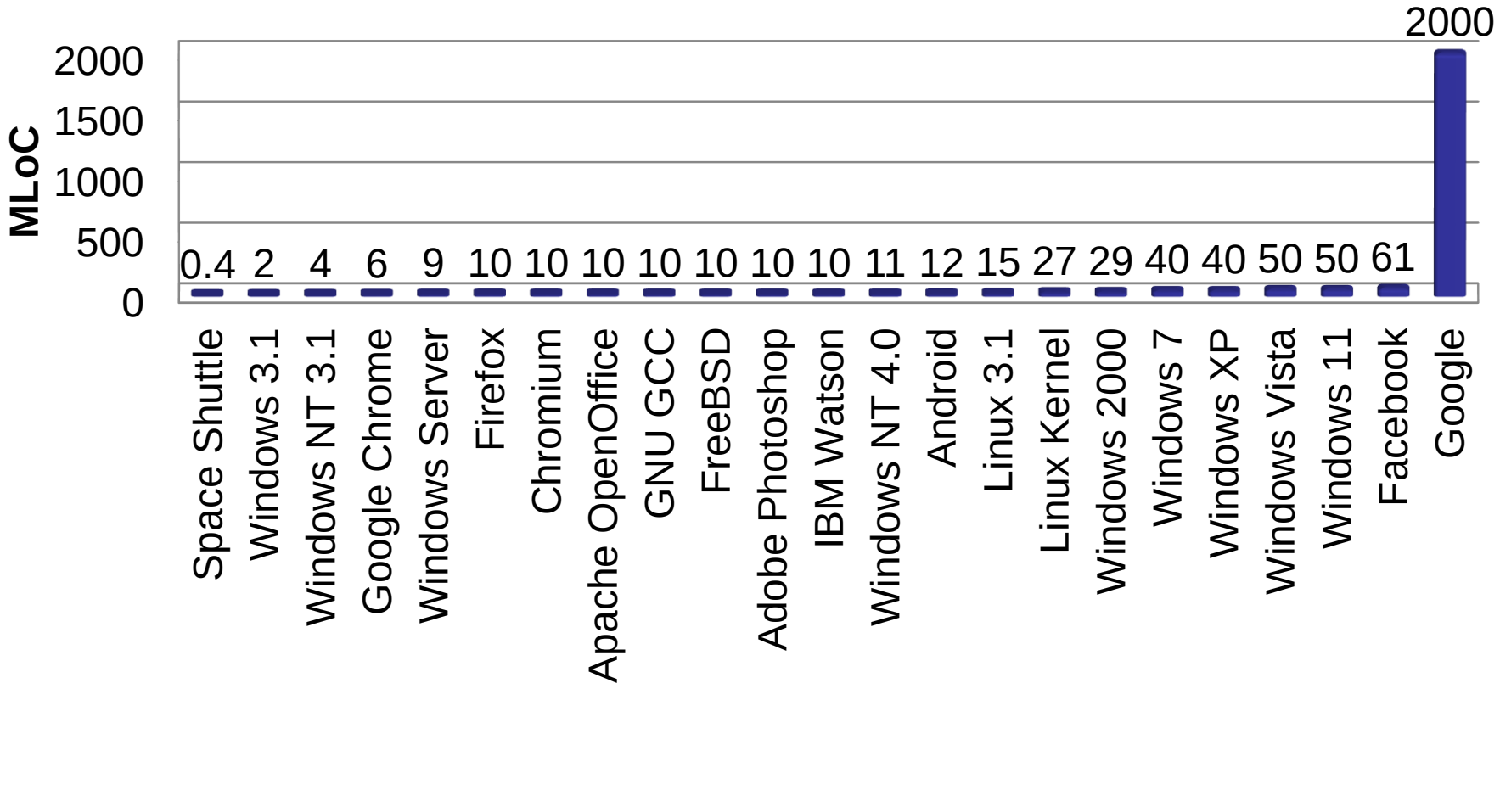
- Applications consisting of…
  - … a variety of software modules that …
  - … run on a variety of devices (machines) that
    - … implement different hardware architectures
    - … run competing applications
    - … fail in unexpected ways
    - … can be under a variety of attacks
- Not feasible to 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

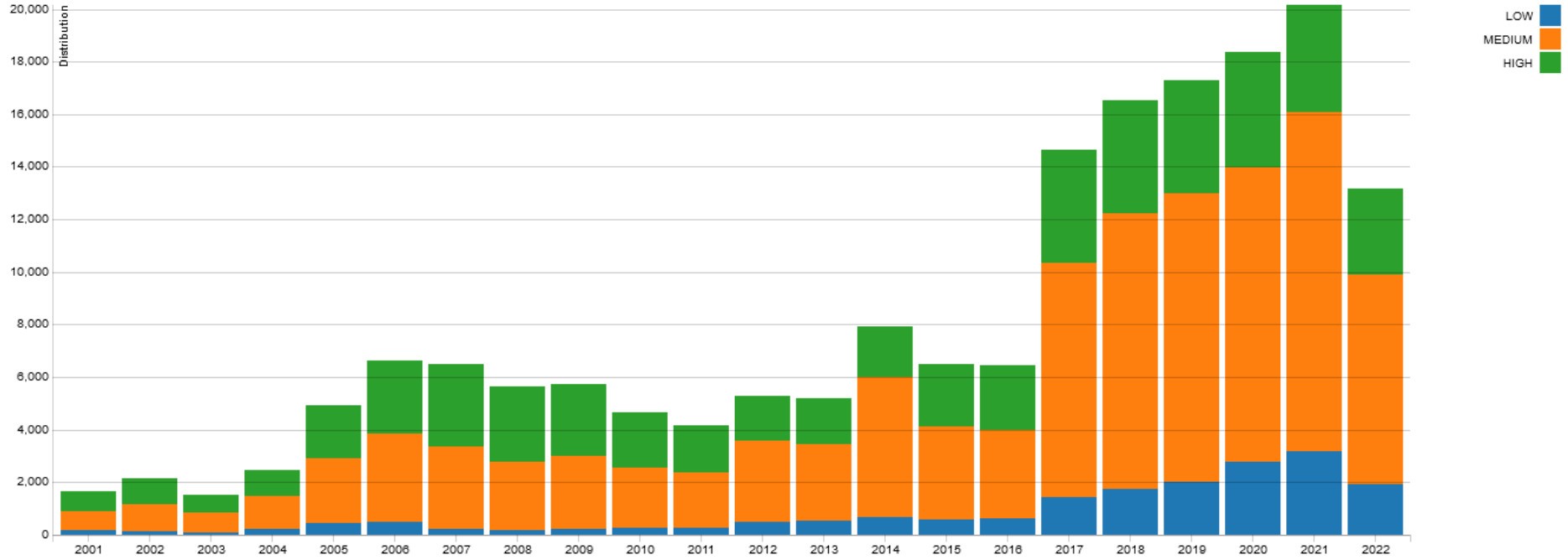


Source: http://www.informationisbeautiful.net/visualizations/million-lines-of-code/

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

- 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

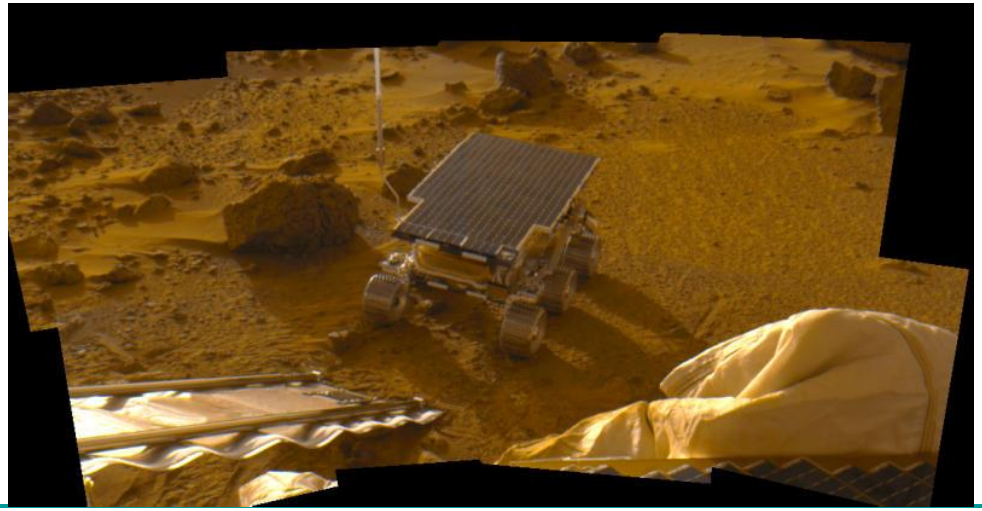


Image credit: Nasa/JPL

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, Inaccessbility, Power limitations … ?

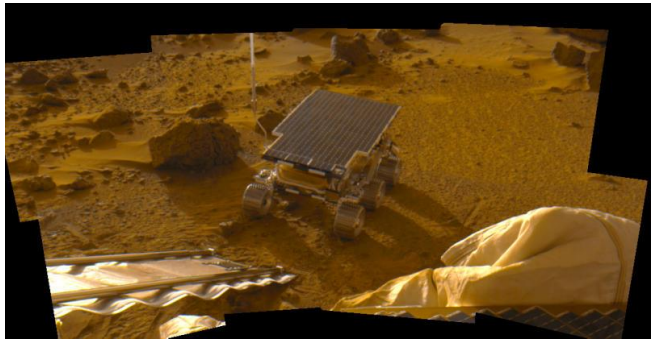


Image credit: Nasa/JPL

More on errors and OS

The Universe is Hostile to Computers

9.3M views • 2 weeks ago

- https://www.youtube.com/watch?v=AaZ_RSt0KP8

Taming Complexity

- 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

- 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