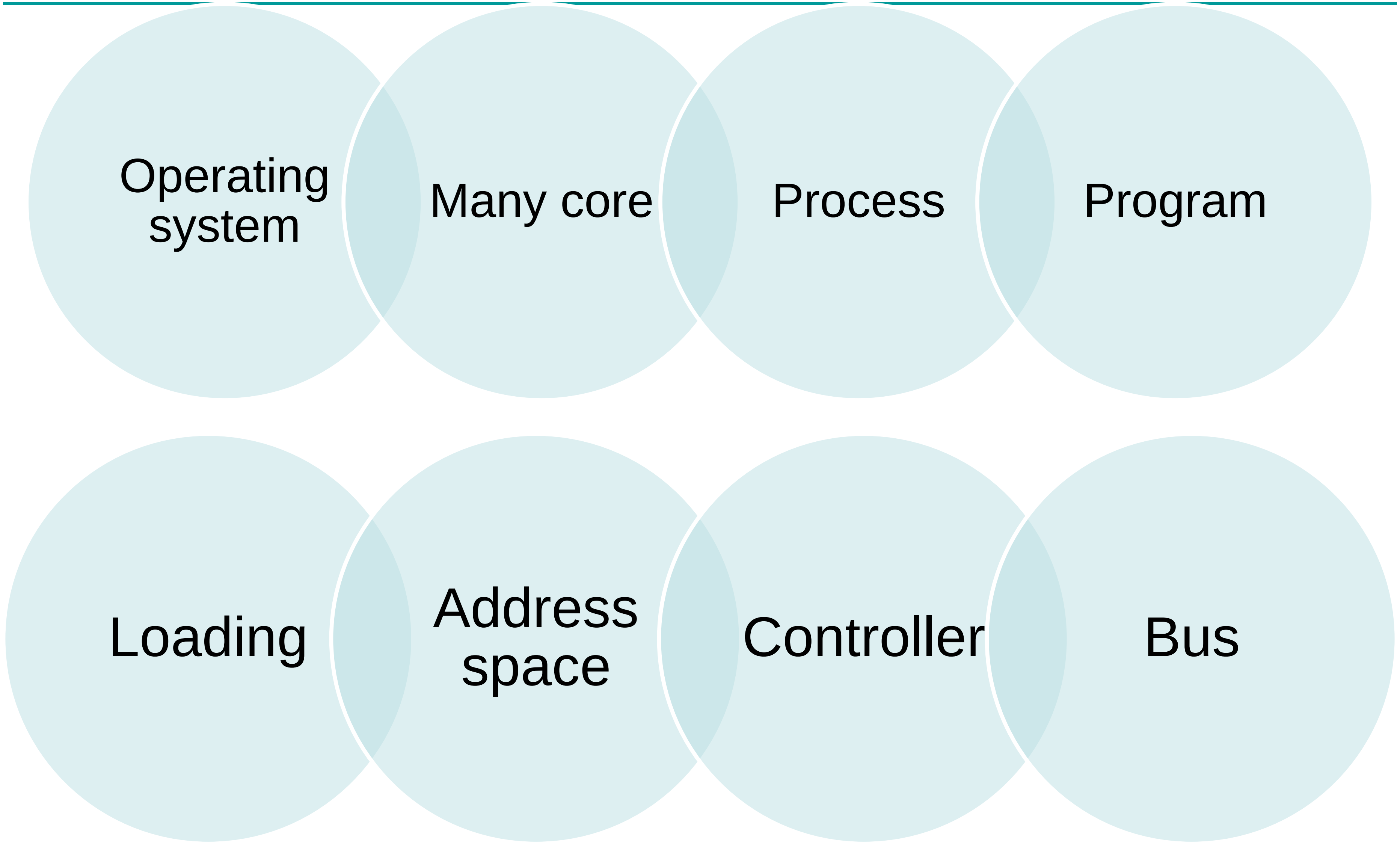
Lecturer: Dr. Michael J. May
Kinneret College

History, VMs, 4 Main Concepts

14 November 2024
Lecture 2

Slides adapted from John Kubiatowicz (UC Berkeley)

Main concepts from last time



Operating system

Many core

Process

Program

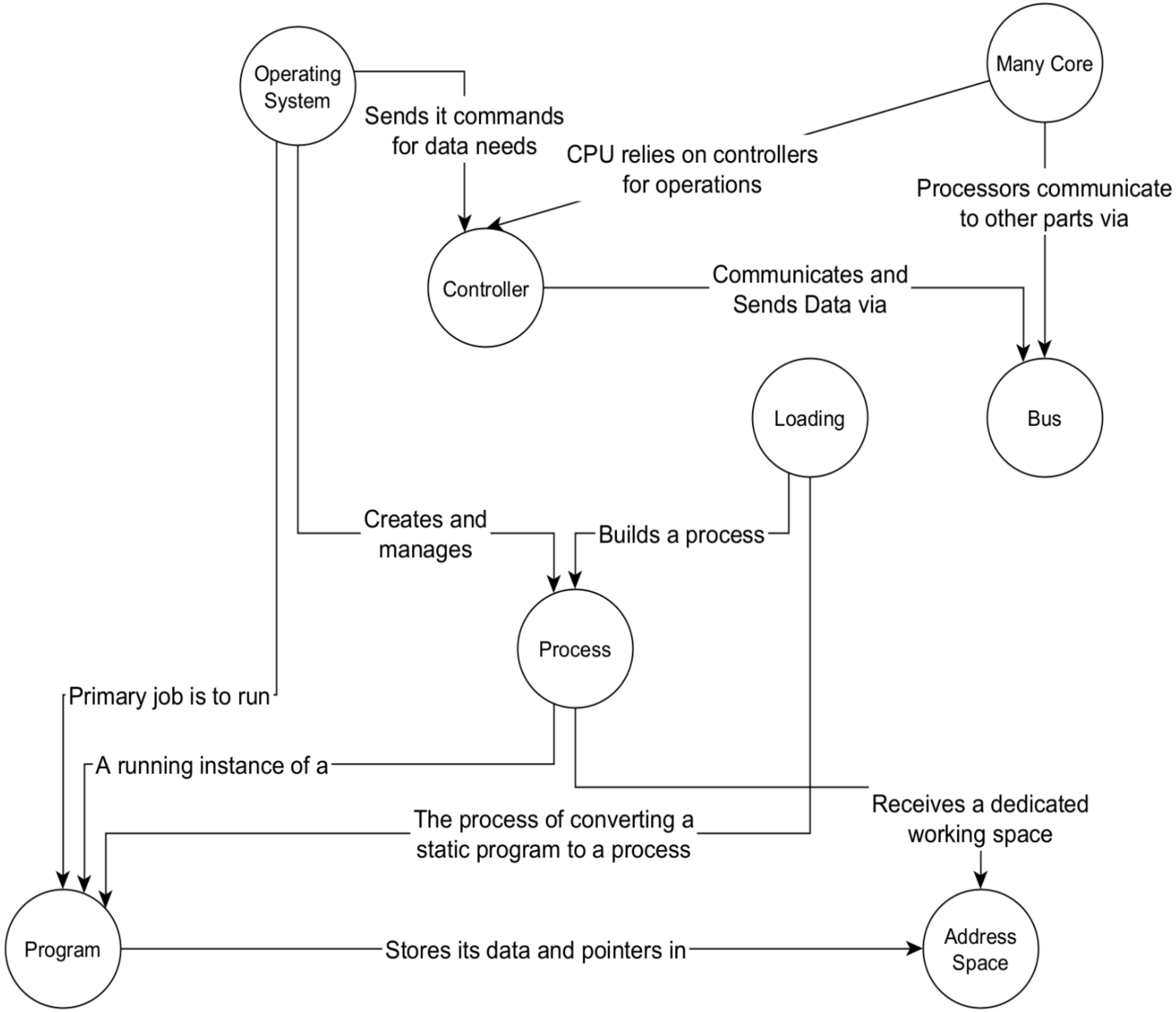
Loading

Address space

Controller

Bus

Main concepts from last time


Operating System
Sends it commands for data needs
Many Core
CPU relies on controllers for operations
Processors communicate to other parts via
Controller
Communicates and Sends Data via
Loading
Bus
Creates and manages
Builds a process
Process
Primary job is to run
A running instance of a
Receives a dedicated working space
The process of converting a static program to a process
Program
Stores its data and pointers in
Address Space

Topics for Today

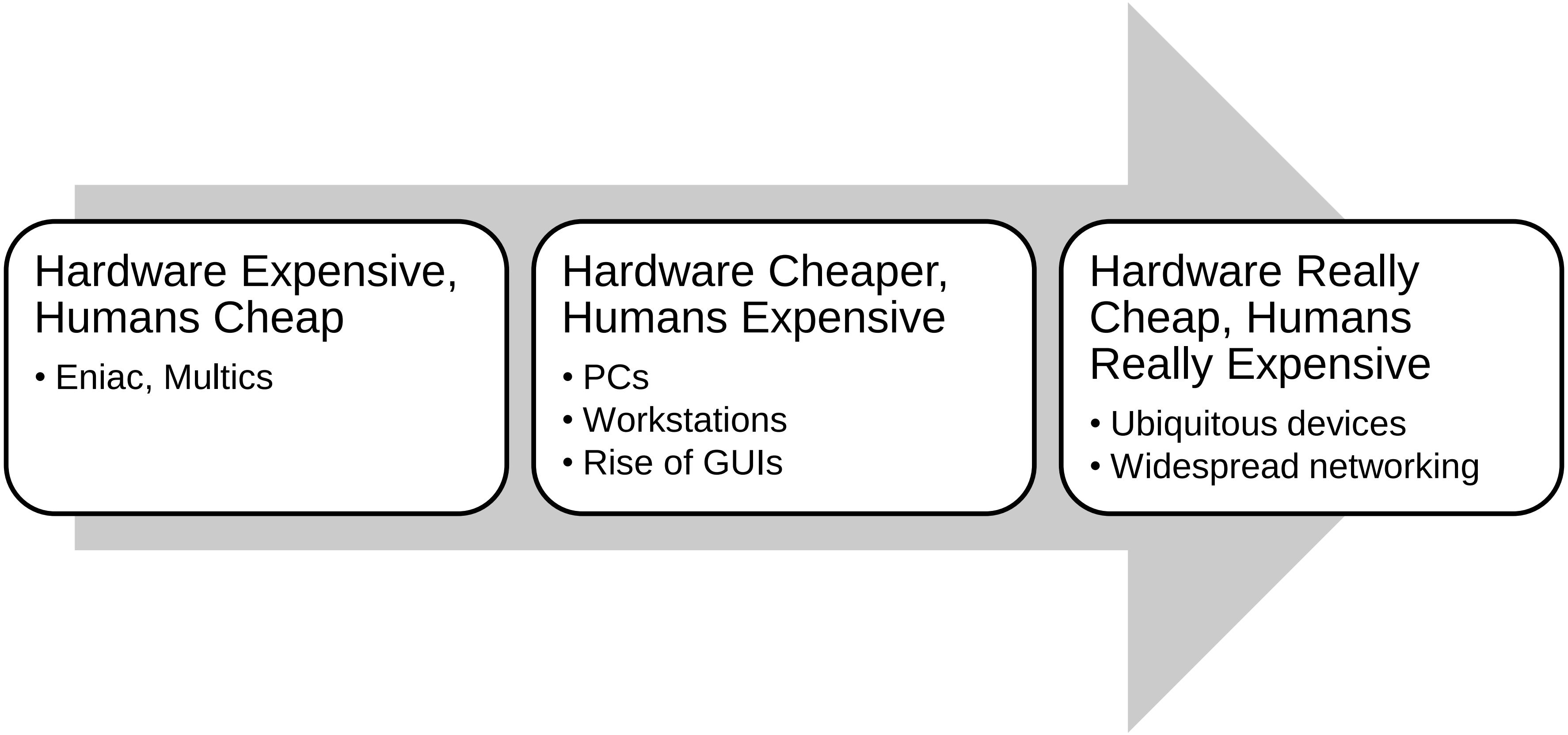
- (Brief) OS History
- Virtual Machines
- 4 Main OS Concepts
  - Thread
  - Address
  - Process
  - Dual mode

Today’s concepts

Stack
Concepts
Interface
Expensive
Humans
Address
one
time
user
System
program
4
mode
OS
Virtual
Thread
Eniac
VMs
Brief
Process
Hardware
memory
Ubiquitous
Dual
History
Phases
CPU
Main
programs
threads
registers
file
VM
kernel

Very Brief History of OS

- Several Distinct Phases:



Hardware Expensive, Humans Cheap

- Eniac, Multics

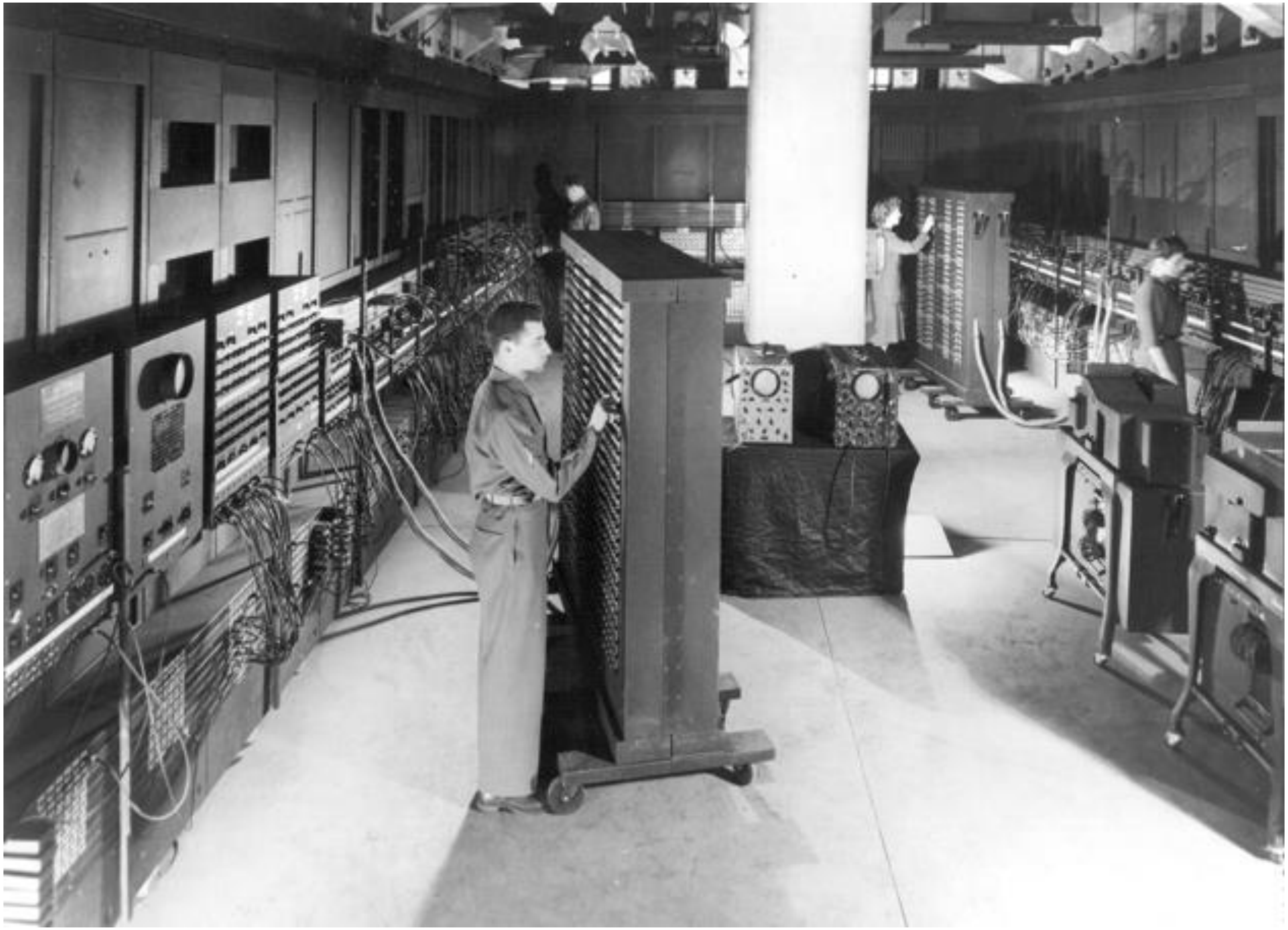
Hardware Cheaper, Humans Expensive

- PCs
- Workstations
- Rise of GUIs

Hardware Really Cheap, Humans Really Expensive

- Ubiquitous devices
- Widespread networking

ENIAC (source: US Army)

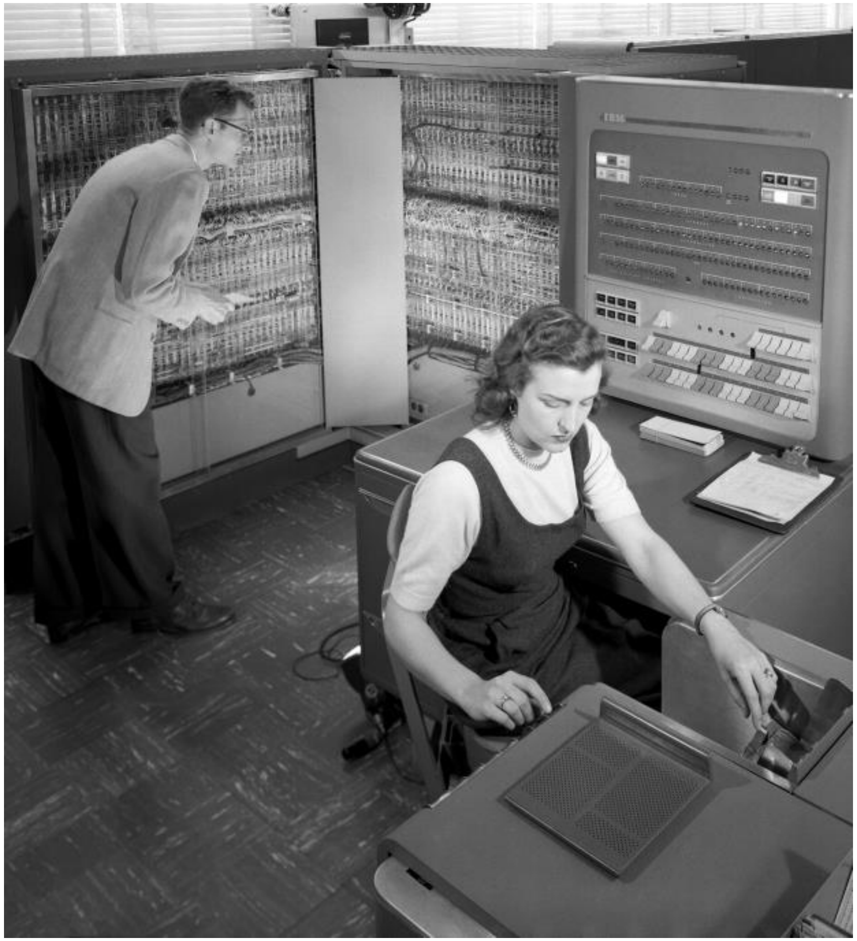


IBM Beginnings

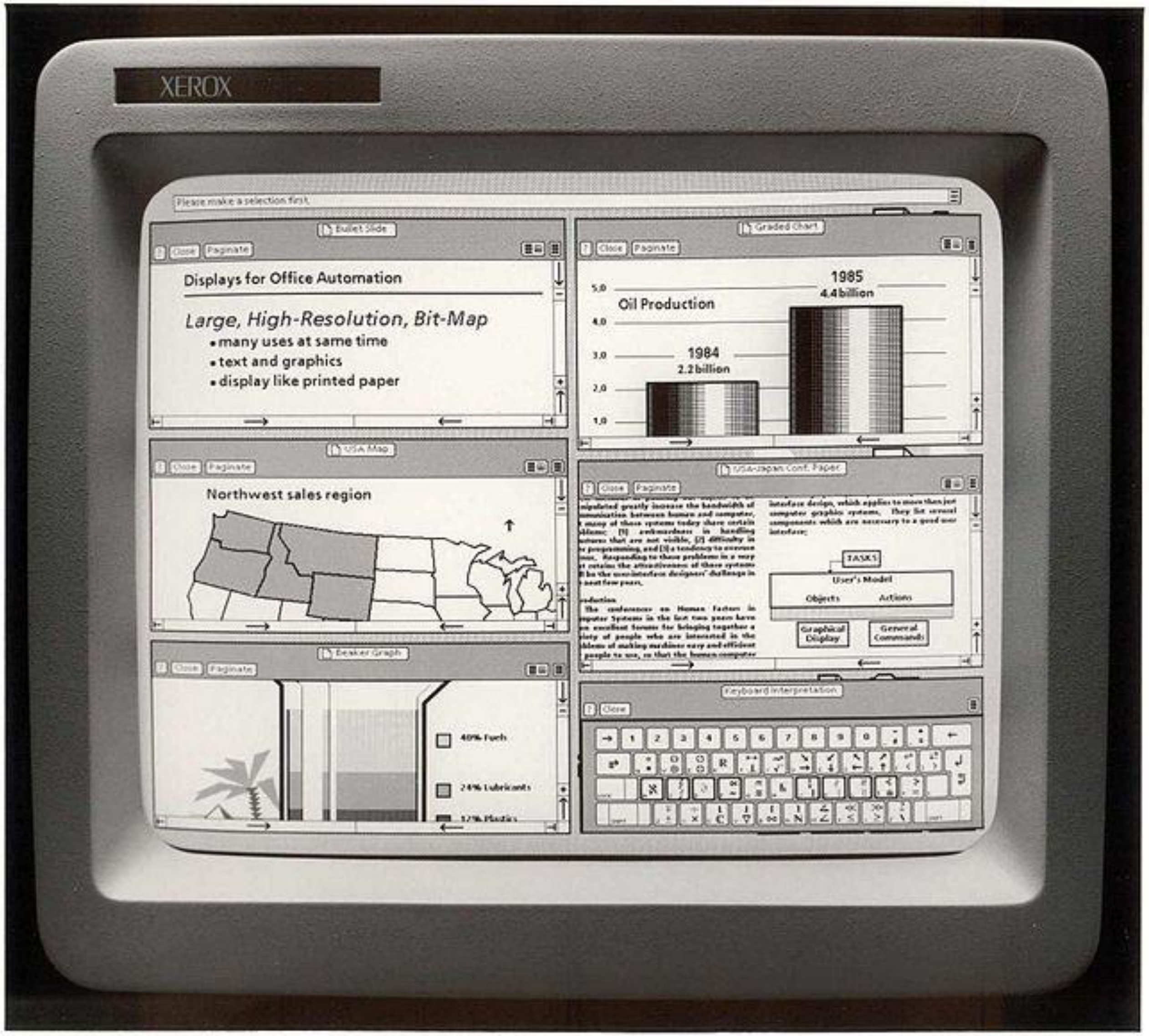
"I think there is a world market for maybe five computers"

- Attributed to Thomas J. Watson in 1943
- Probably never said, but in 1953, IBM assumed only 20 prospective companies could buy the IBM 701

IBM type 704 (source: Langley NACA)



The First GUIs: XEROX



Displays for Office Automation

Large, High-Resolution, Bit-Map

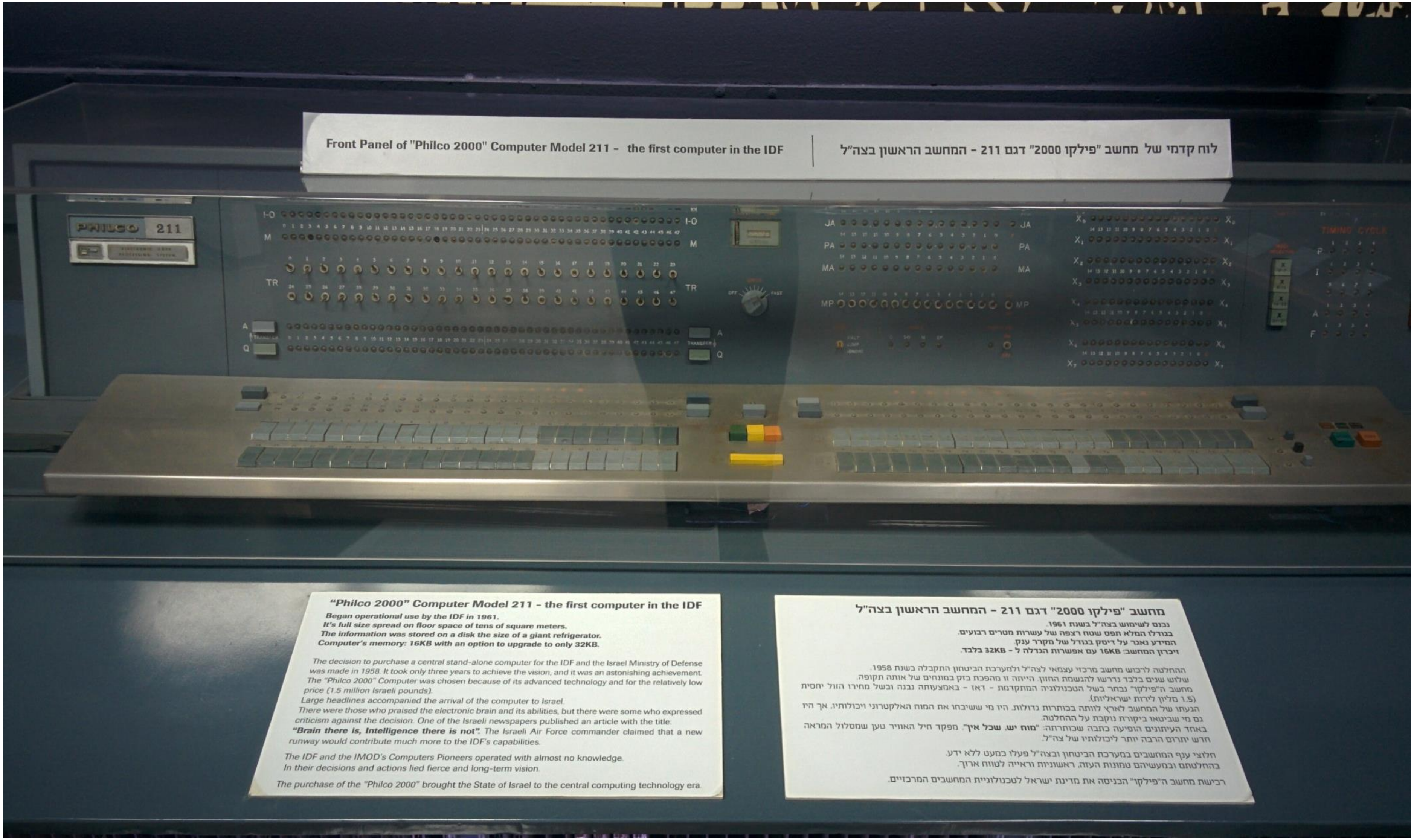
- many uses at same time
- text and graphics
- display like printed paper

By Source (WP:NFCC#4), Fair use

Today: Hand held

Image source: Blue Ion
http://www.blueion.com/blog/2014/01/07/too-big-to-ignore/

First computer in IDF



Front Panel of "Philco 2000" Computer Model 211 - the first computer in the IDF

לוח קדמי של מחשב "פילקו 2000" דגם 211 - המחשב הראשון בצה"ל

"Philco 2000" Computer Model 211 - the first computer in the IDF

Began operational use by the IDF in 1961.
It's full size spread on floor space of tens of square meters.
The information was stored on a disk the size of a giant refrigerator.
Computer's memory: 16KB with an option to upgrade to only 32KB.

The decision to purchase a central stand-alone computer for the IDF and the Israel Ministry of Defense was made in 1958. It took only three years to achieve the vision, and it was an astonishing achievement.
The "Philco 2000" Computer was chosen because of its advanced technology and for the relatively low price (1.5 million Israeli pounds).
Large headlines accompanied the arrival of the computer to Israel.
There were those who praised the electronic brain and its abilities, but there were some who expressed criticism against the decision. One of the Israeli newspapers published an article with the title: ***"Brain there is, Intelligence there is not".*** *The Israeli Air Force commander claimed that a new runway would contribute much more to the IDF's capabilities.*

The IDF and the IMOD's Computers Pioneers operated with almost no knowledge.
In their decisions and actions lied fierce and long-term vision.

The purchase of the "Philco 2000" brought the State of Israel to the central computing technology era.

מחשב "פילקו 2000" דגם 211 - המחשב הראשון בצה"ל

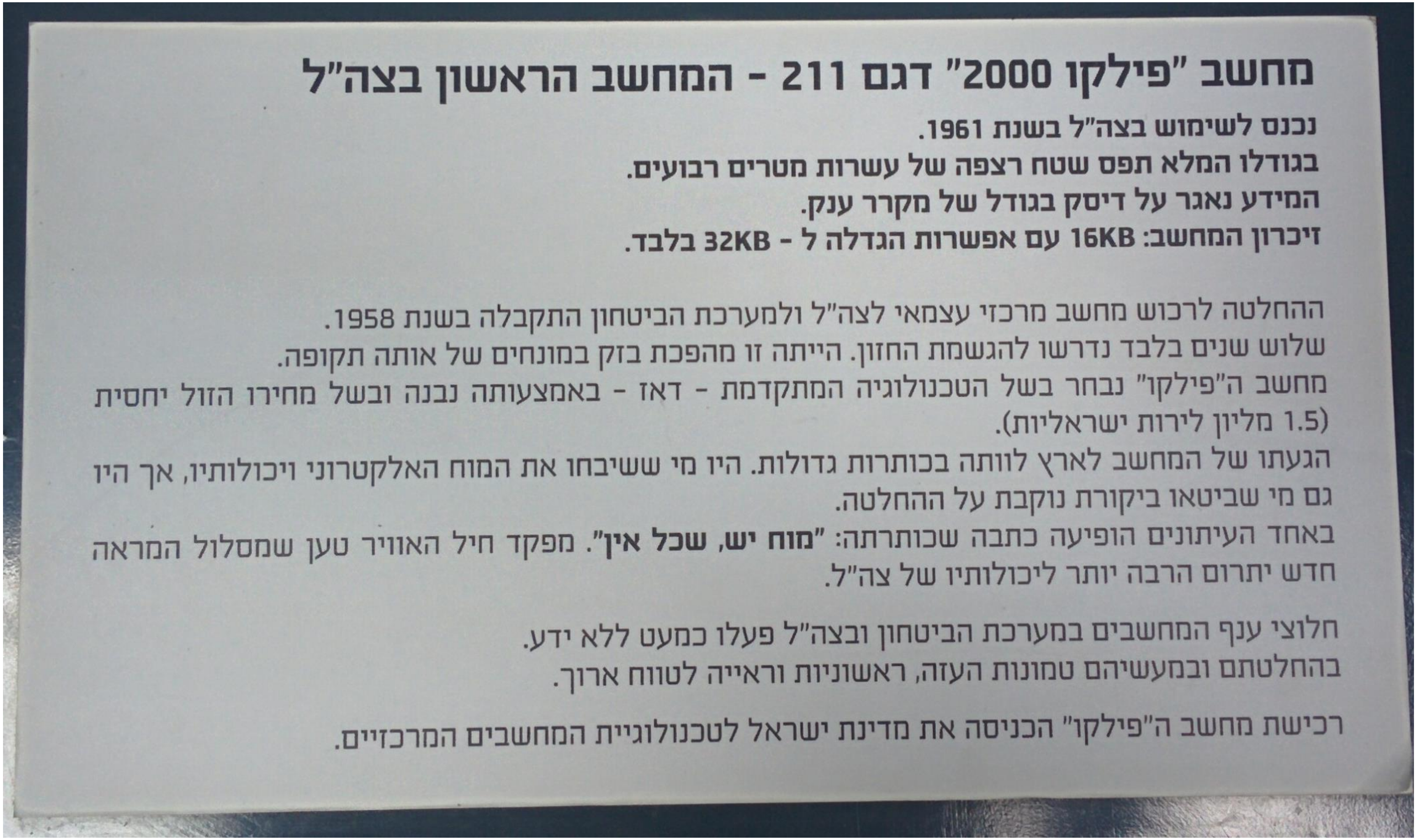
נכנס לשימוש בצה"ל בשנת 1961.
בגודלו המלא תפס שטח רצפה של עשרות מטרים רבועים.
המידע נאגר על דיסק בגודל של מקרר ענק.
זיכרון המחשב: 16KB עם אפשרות הגדלה ל - 32KB בלבד.

ההחלטה לרכוש מחשב מרכזי עצמאי לצה"ל ולמערכת הביטחון התקבלה בשנת 1958.
שלוש שנים בלבד נדרשו להגשמת החזון. הייתה זו מהפכת בזק במונחים של אותה תקופה.
מחשב ה"פילקו" נבחר בשל הטכנולוגיה המתקדמת - דאז - באמצעותה נבנה ובשל מחירו הזול יחסית (1.5 מליון לירות ישראליות).
הגעתו של המחשב לארץ לוותה בכותרות גדולות. היו מי ששיבחו את המוח האלקטרוני ויכולותיו, אך היו גם מי שביטאו ביקורת נוקבת על ההחלטה.
באחד העיתונים הופיעה כתבה שכותרתה: **"מוח יש, שכל אין"**. מפקד חיל האוויר טען שמסלול המראה חדש יתרום הרבה יותר ליכולותיו של צה"ל.

חלוצי ענף המחשבים במערכת הביטחון ובצה"ל פעלו כמעט ללא ידע.
בהחלטתם ובמעשיהם טמונות העזה, ראשוניות וראייה לטווח ארוך.

רכישת מחשב ה"פילקו" הכניסה את מדינת ישראל לטכנולוגיית המחשבים המרכזיים.

First computer in IDF



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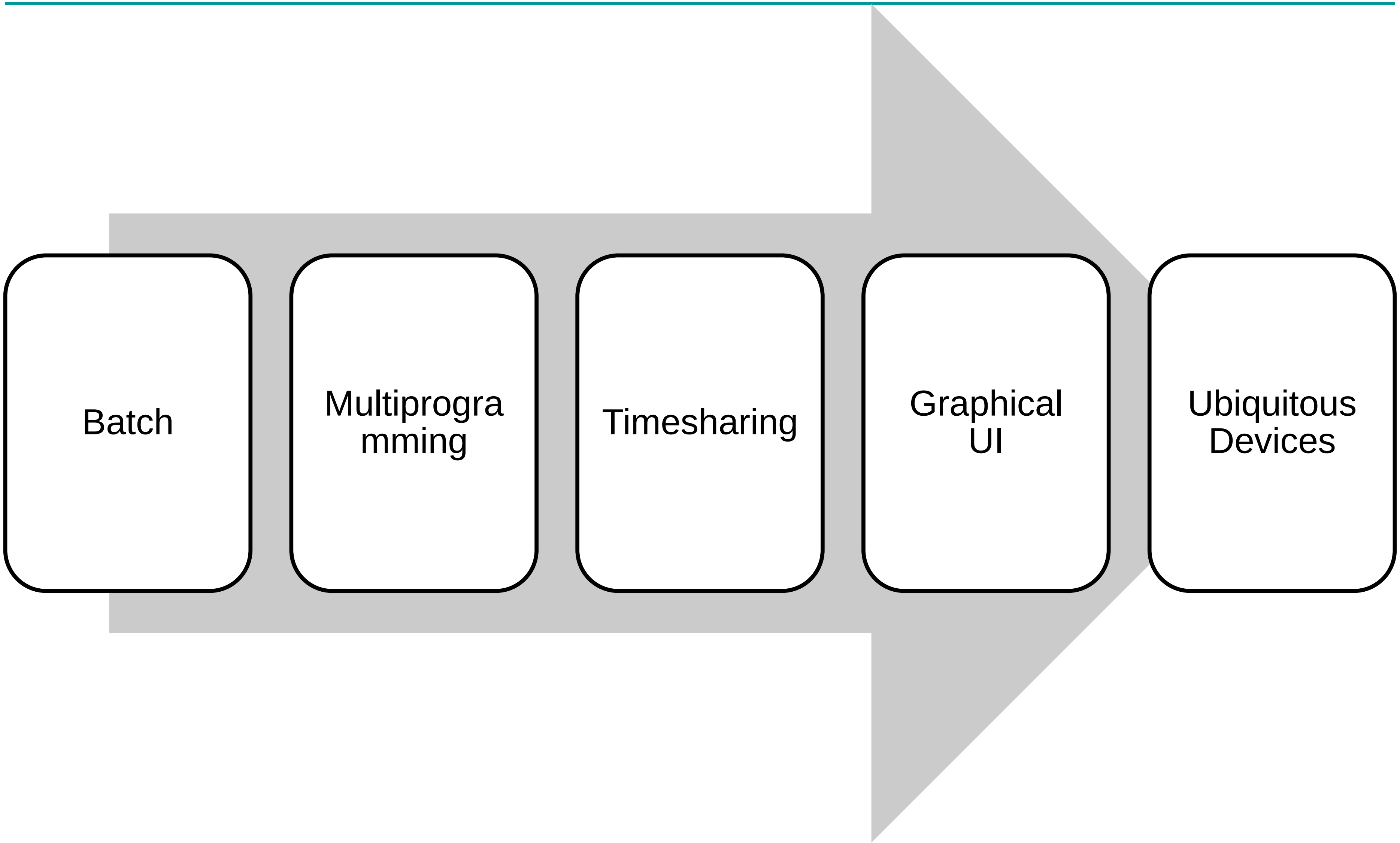
Evolving Hardware & OS



Batch

Multiprogramming

Timesharing

Graphical UI

Ubiquitous Devices

Making new OS is expensive

Small OS

- 100K lines

Large OS

- 10M lines
- 5M in a browser!

100-1000 person-years of effort

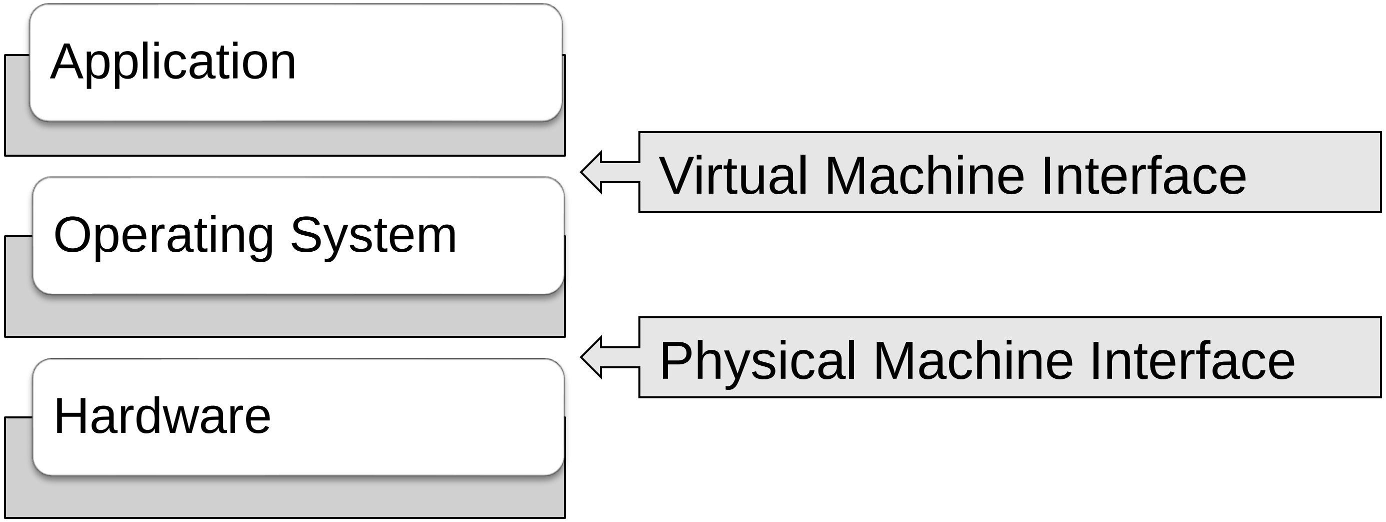
OS Archaeology

- Because of the cost of developing an OS from scratch, most modern OSes have a long lineage:
- Multics → AT&T Unix → BSD Unix → Ultrix, SunOS, NetBSD,…
- Mach (micro-kernel) + BSD → NextStep → XNU → Apple OSX, iPhone iOS
- Linux → Android OS
- CP/M → QDOS → MS-DOS → Windows 3.1 → NT → 95 → 98 → 2000 → XP → Vista → 7 → 8 → phone → 10 → 11…
- Linux → RedHat, Ubuntu, Fedora, Debian, Suse,…

So Far

- (Brief) OS History
- Virtual Machines
- 4 Main OS Concepts
  - Thread
  - Address
  - Process
  - Dual mode

Virtual Machine Abstraction



- Software Engineering Problem:
  - Turn hardware/software quirks ⇒ what programmers want/need
  - Optimize for convenience, utilization, security, reliability, etc…
- For Any OS area (e.g. file systems, virtual memory, networking, scheduling):
  - What's the hardware interface? (physical reality) Hardware Abstraction Layer (HAL) hides
  - What's the application interface? (nicer abstraction)

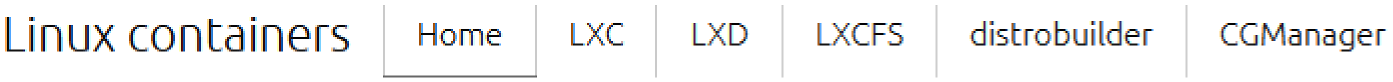
Virtual Machines

- Software emulation of an abstract machine
  - Give programs illusion they own the machine
  - Make it look like hardware has features you want
- Three types of “Virtual Machines”
  - Container: Isolate processes from one another at the file system and environment variables
  - Process VM: supports the execution of a single program; this functionality typically provided by OS
  - System VM: supports the execution of an entire OS and its applications (e.g., VMWare Fusion, Virtual box, Parallels Desktop, Xen)

Containers

- Virtual Machine light (VM--)
  - Less isolation than full VM
  - Shared physical resources (scheduler, main memory)
  - Separate parts of file system, OS libraries
- Popular for isolating applications and reducing potential conflicts

Linux VServer


Linux containers | Home | LXC | LXD | LXCFS | distrobuilder | CGManager

Sylabs.io SINGULARITY

docker

kubernetes

Process VMs

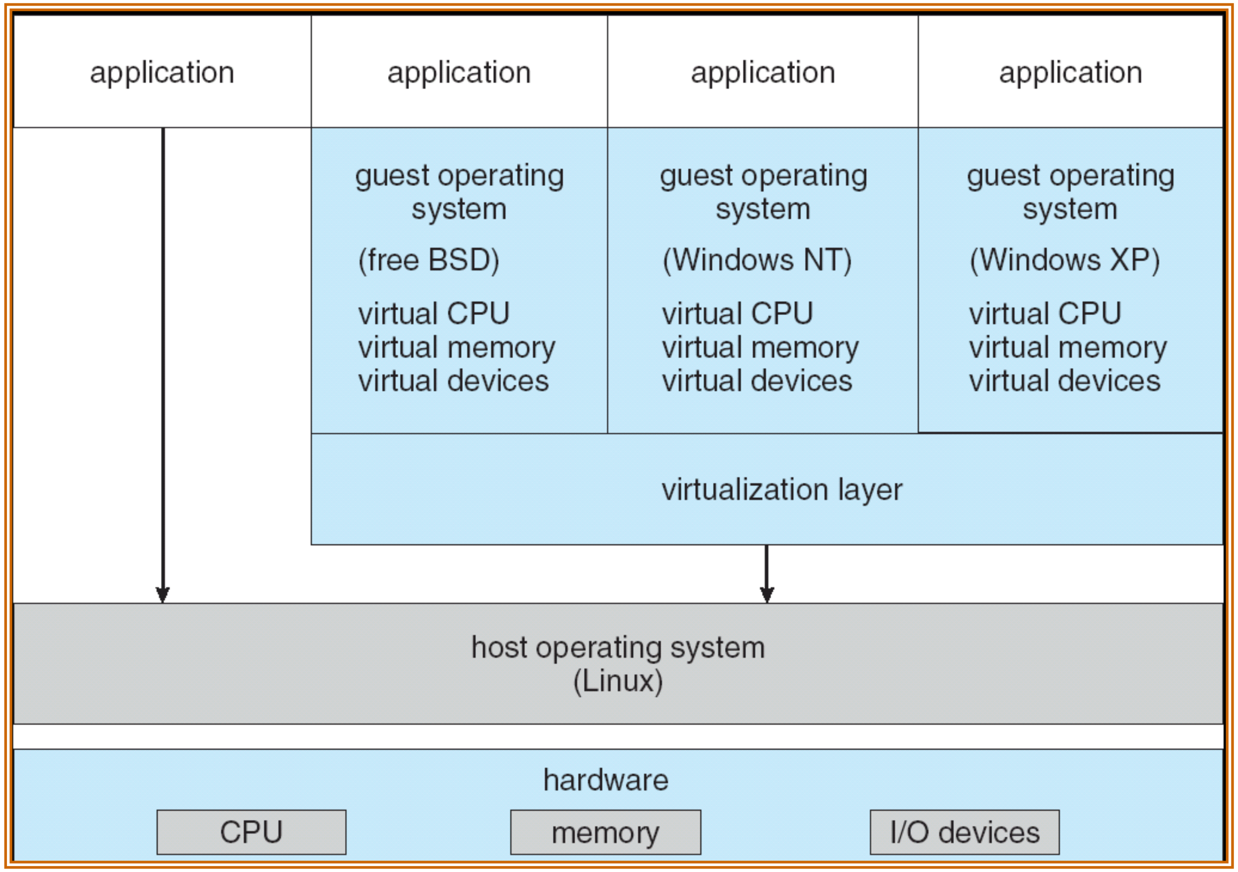
- Programming simplicity
  - Each process thinks it has all memory/CPU time
  - Each process thinks it owns all devices
  - Different devices appear to have same high level interface
  - Device interfaces more powerful than raw hardware
    - Bitmapped display ⇒ windowing system
    - Ethernet card ⇒ reliable, ordered, networking (TCP/IP)

- Fault Isolation
  - Processes unable to directly impact other processes
  - Bugs cannot crash whole machine

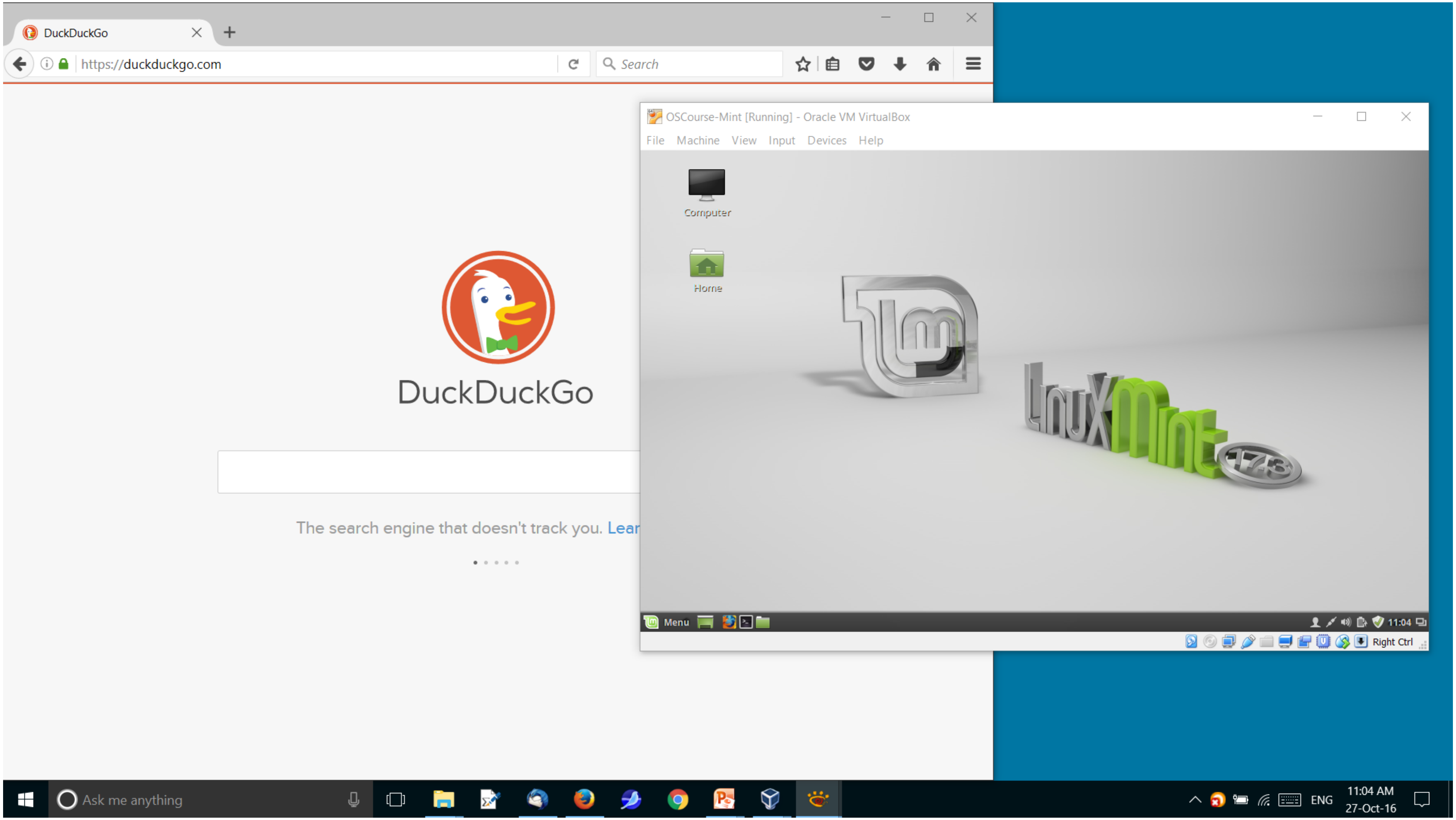
- Protection and Portability
  - Java interface safe and stable across many platforms

System VMs: Layers of OSes

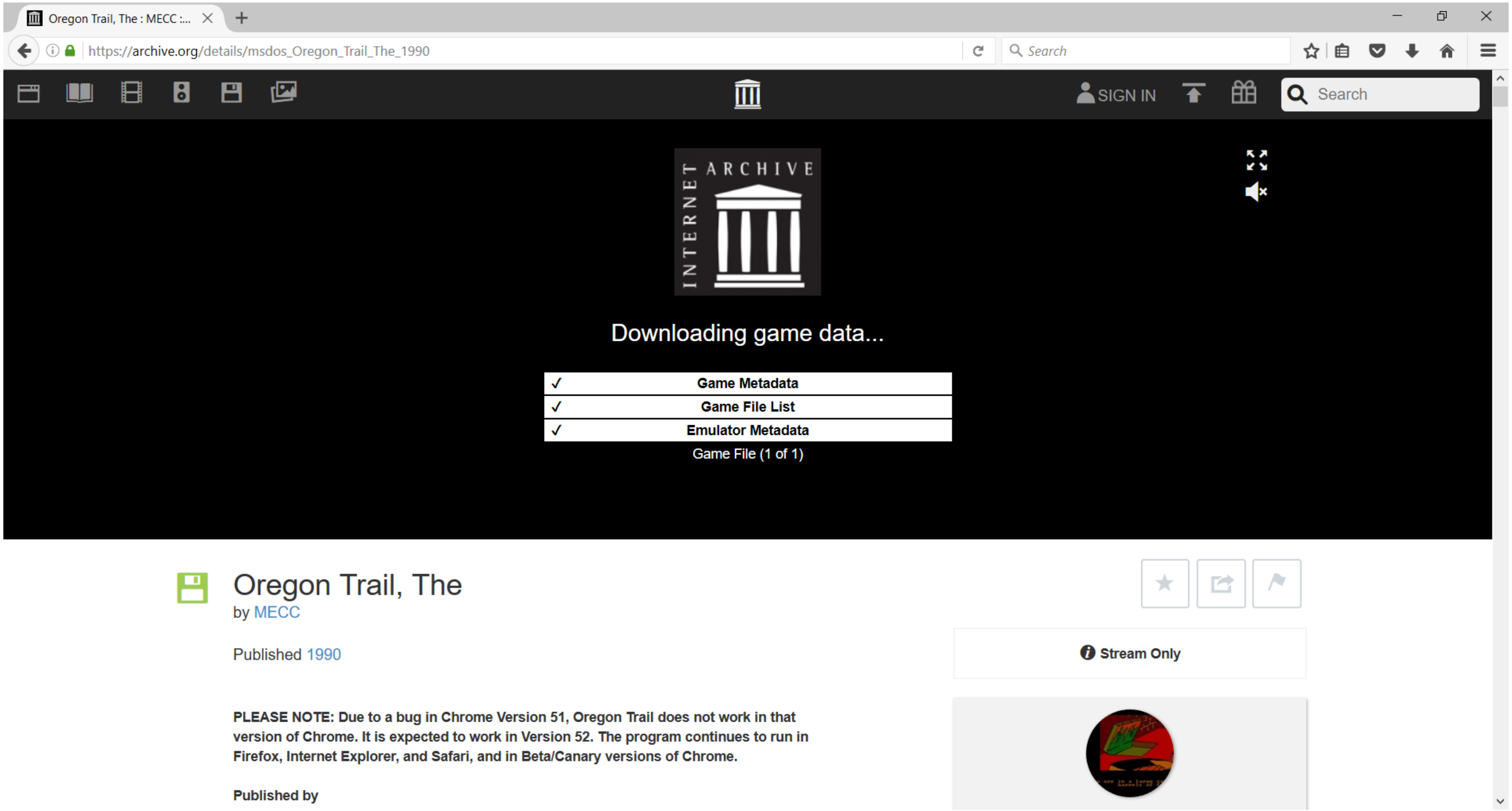
- Useful for OS development
  - When OS crashes, restricted to one VM
  - Can aid testing programs on other OSs



How it looks


DuckDuckGo
https://duckduckgo.com
Search
DuckDuckGo
The search engine that doesn't track you. Lear
OSCourse-Mint [Running] - Oracle VM VirtualBox
File
Machine
View
Input
Devices
Help
Computer
Home
Menu
11:04
Right Ctrl
Ask me anything
ENG
11:04 AM
27-Oct-16

Why not in a browser?



Oregon Trail, The : MECC :...
https://archive.org/details/msdos_Oregon_Trail_The_1990
Search
SIGN IN
Search
INTERNET ARCHIVE

Downloading game data...

✓ Game Metadata
✓ Game File List
✓ Emulator Metadata
Game File (1 of 1)

Oregon Trail, The

by MECC

Published 1990

Stream Only

PLEASE NOTE: Due to a bug in Chrome Version 51, Oregon Trail does not work in that version of Chrome. It is expected to work in Version 52. The program continues to run in Firefox, Internet Explorer, and Safari, and in Beta/Canary versions of Chrome.

Published by

Of course, this is sandboxed…

VM inside a VM

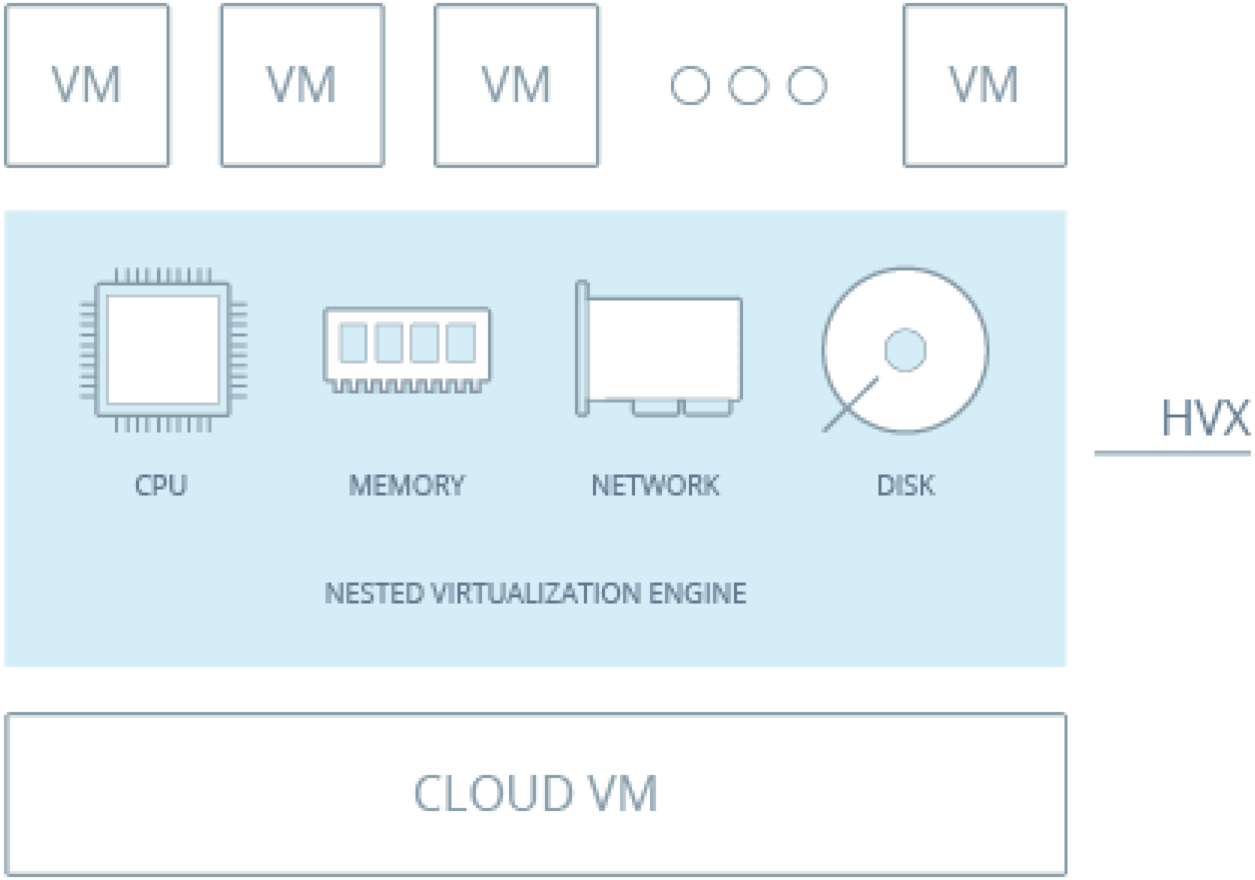


Image credit: Ravello Systems

Why not run a VM inside a VM?
Turtles all the way down…

VMs in Action

Every cloud service provider

Shared hardware for servers

Data Centers

Rapid provisioning, scale up, and load balancing

So Far

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  - Process
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What is an OS, Really?

Most Likely:

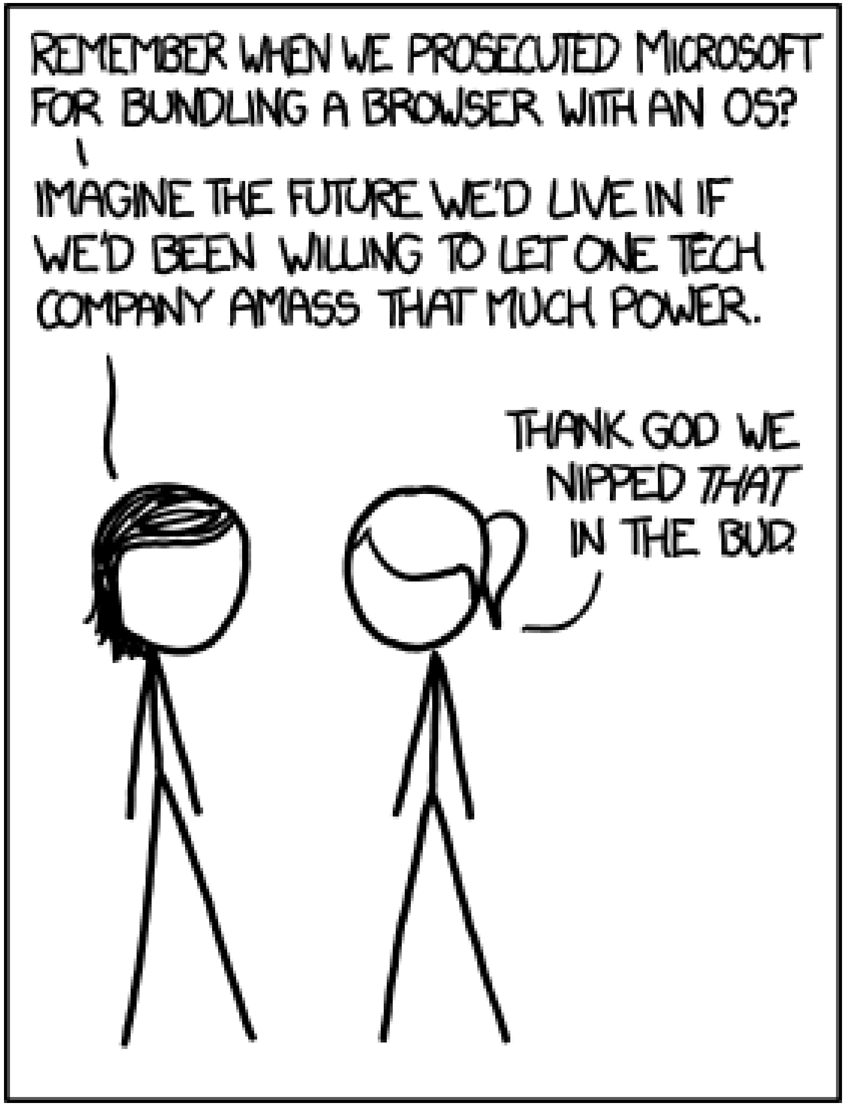
- Memory Management
- I/O Management
- CPU Scheduling
- Communications? (Does Email belong in OS?)
- Multitasking/multiprogramming?

What about?

- File System?
- Multimedia Support?
- User Interface?
- Internet Browser? ☺

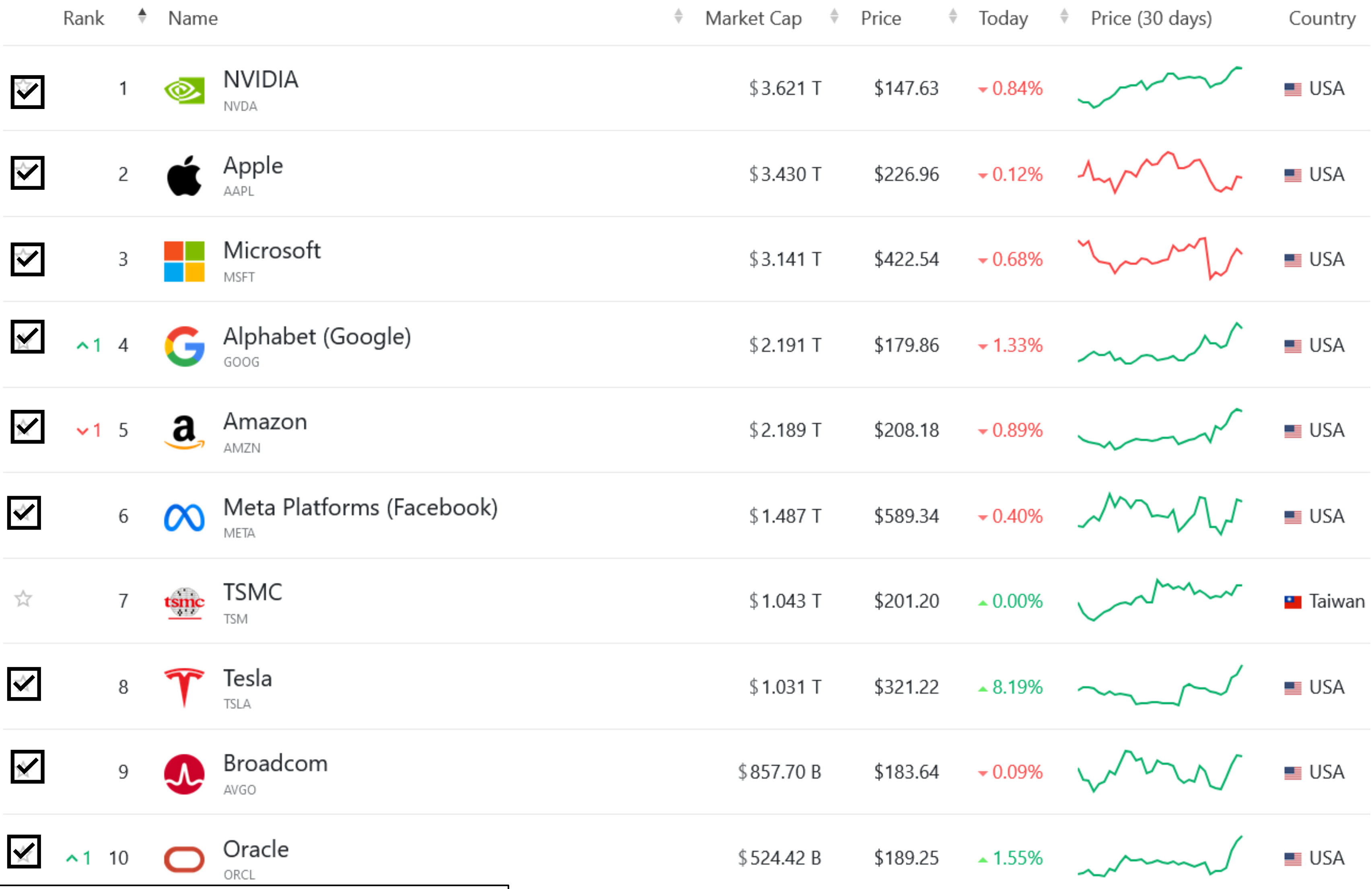
Is this only interesting to academics?

https://xkcd.com/1118/


REMEMBER WHEN WE PROSECUTED MICROSOFT FOR BUNDLING A BROWSER WITH AN OS?
IMAGINE THE FUTURE WE'D LIVE IN IF WE'D BEEN WILLING TO LET ONE TECH COMPANY AMASS THAT MUCH POWER.
THANK GOD WE NIPPED *THAT* IN THE BUD.

Top 10 Tech Companies 2024

Develops their own OS?



	Rank	Name	Market Cap	Price	Today	Price (30 days)	Country
☑	1	NVIDIA NVDA	$3.621 T	$147.63	▾ 0.84%		USA
☑	2	Apple AAPL	$3.430 T	$226.96	▾ 0.12%		USA
☑	3	Microsoft MSFT	$3.141 T	$422.54	▾ 0.68%		USA
☑	^1 4	Alphabet (Google) GOOG	$2.191 T	$179.86	▾ 1.33%		USA
☑	v1 5	Amazon AMZN	$2.189 T	$208.18	▾ 0.89%		USA
☑	6	Meta Platforms (Facebook) META	$1.487 T	$589.34	▾ 0.40%		USA
☆	7	TSMC TSM	$1.043 T	$201.20	▴ 0.00%		Taiwan
☑	8	Tesla TSLA	$1.031 T	$321.22	▴ 8.19%		USA
☑	9	Broadcom AVGO	$857.70 B	$183.64	▾ 0.09%		USA
☑	^1 10	Oracle ORCL	$524.42 B	$189.25	▴ 1.55%		USA

https://companiesmarketcap.com/tech/largest-tech-companies-by-market-cap/

Operating System “Definition”

No universally accepted definition

“Everything a vendor ships when you order an operating system” is good approximation

- But varies wildly

“The one program running at all times on the computer” is the kernel.

- Everything else is either a system program (ships with the operating system) or an application program

4 Fundamental OS Concepts

Thread

- Single unique execution context
- Program Counter, Registers, Execution Flags, Stack

Address Space with Translation

- Programs execute in an *address space* that is distinct from the memory space of the physical machine

Process

- An instance of an executing program is *a process consisting of an address space and one or more threads of control*

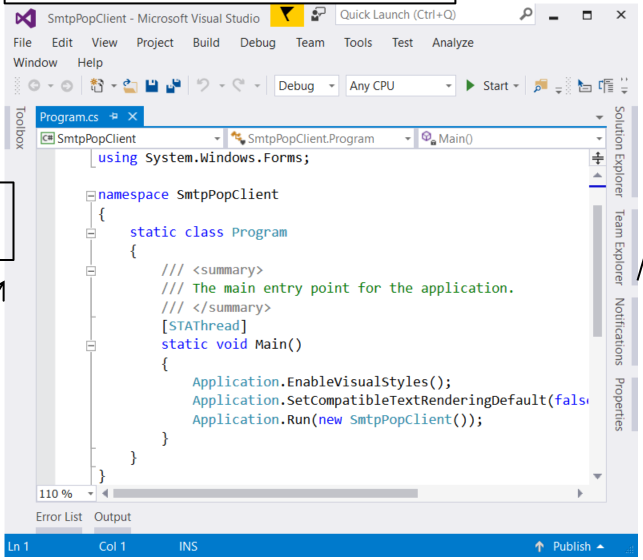
Dual Mode operation/Protection

- Only the “system” can access certain resources
- The OS and the hardware are protected from user programs and user programs are isolated from one another by *controlling the translation* from program virtual addresses to machine physical addresses

OS’ Bottom Line: Run Stuff

1. Load instruction and data segments of executable file into memory
2. Create stack and heap
3. “Transfer control to it”
4. Provide services to it
5. While protecting OS and it

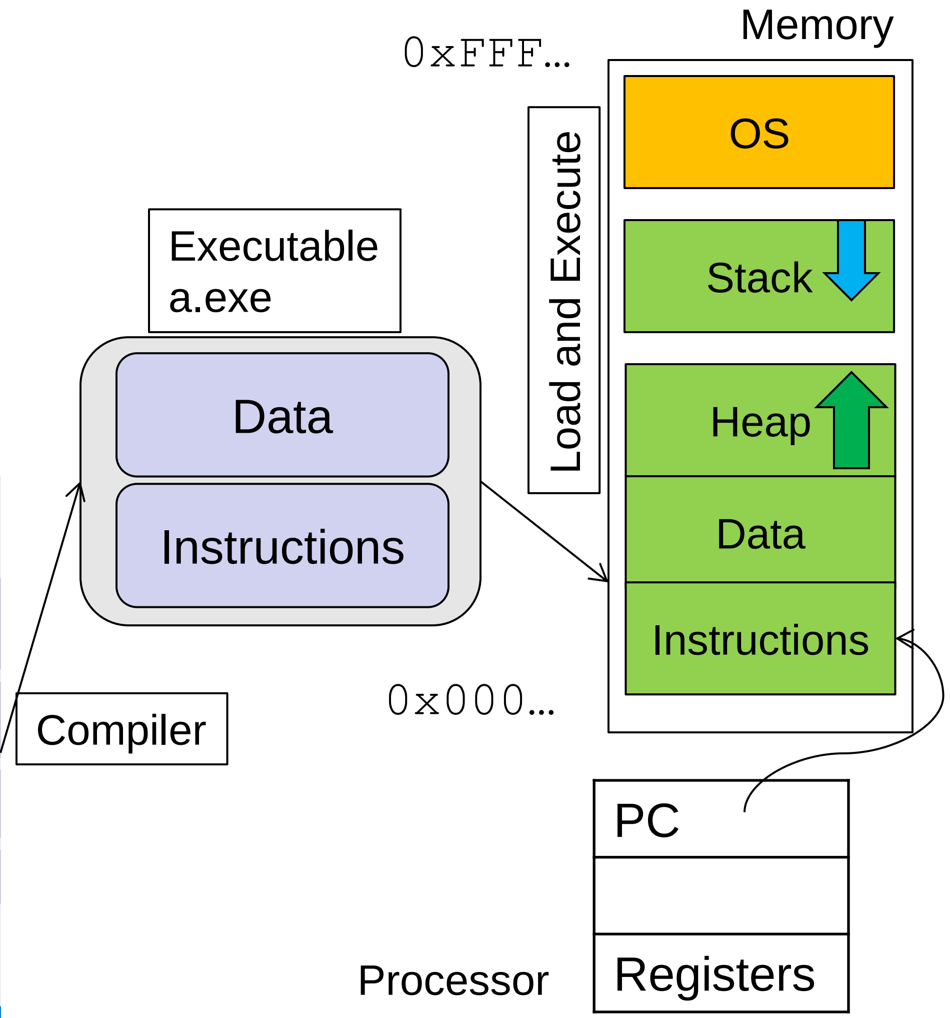
Program source code



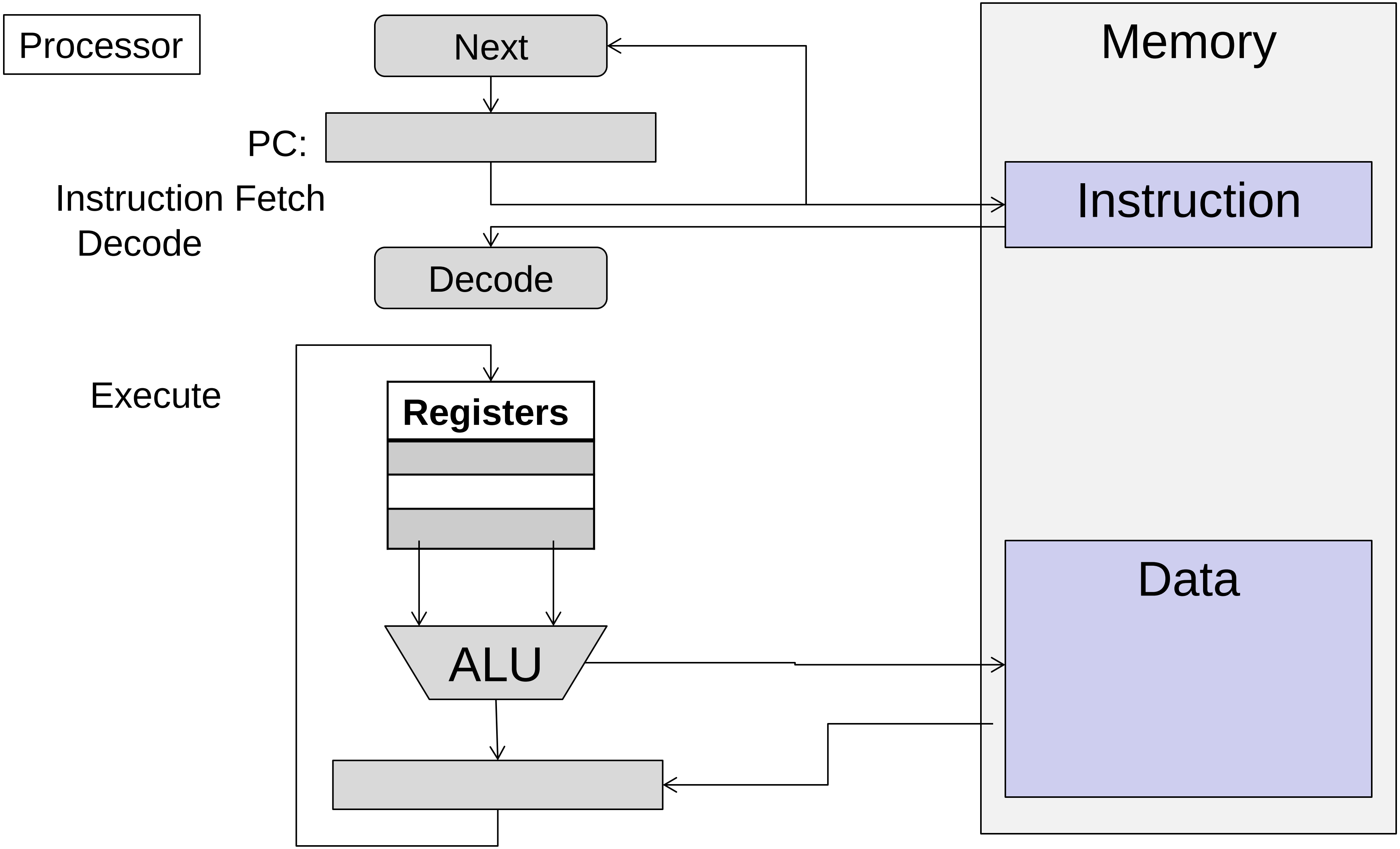
```
using System.Windows.Forms;

namespace SmtpPopClient
{
    static class Program
    {
        /// <summary>
        /// The main entry point for the application.
        /// </summary>
        [STAThread]
        static void Main()
        {
            Application.EnableVisualStyles();
            Application.SetCompatibleTextRenderingDefault(fals
            Application.Run(new SmtpPopClient());
        }
    }
}
```

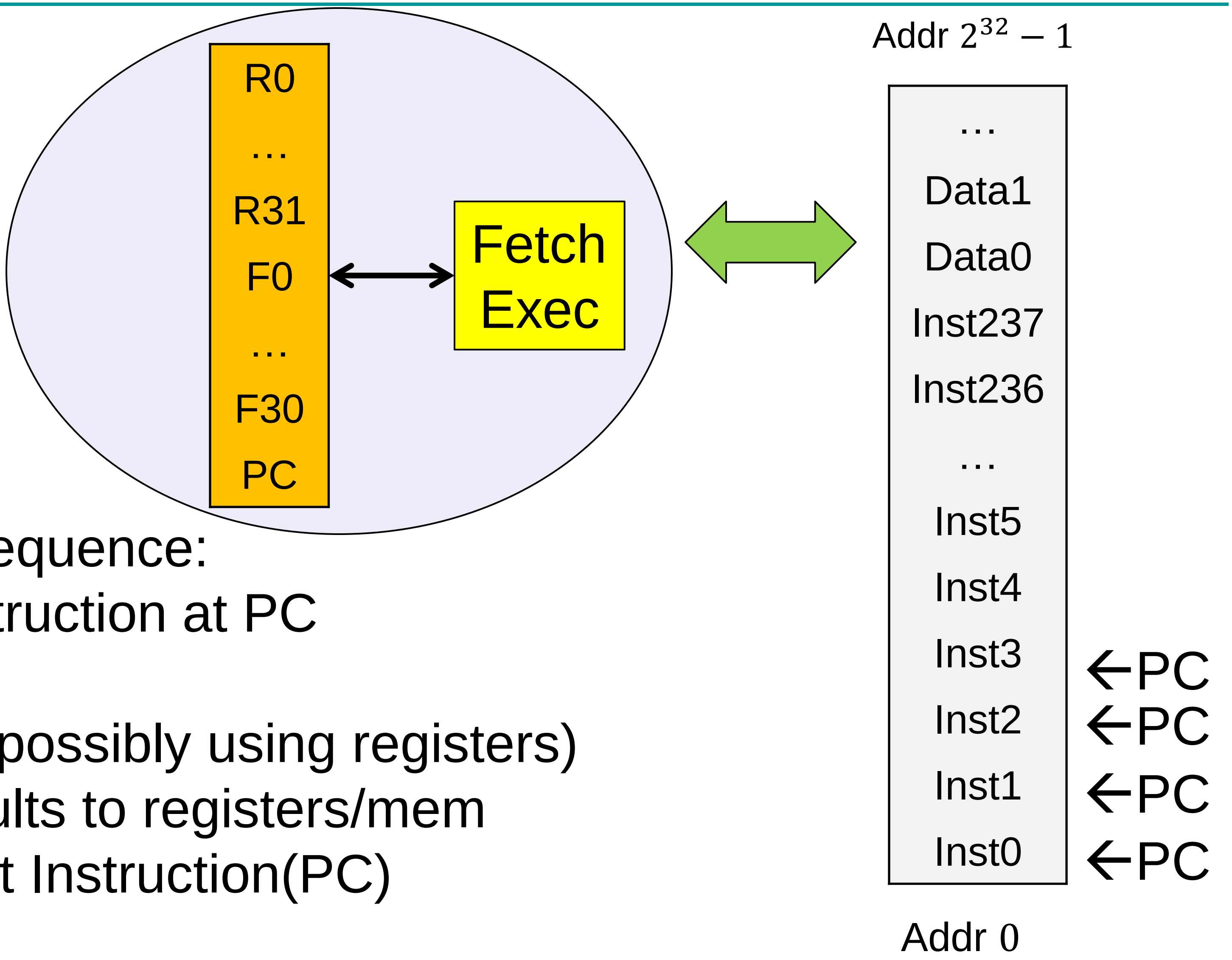
Editor



The Instruction Cycle



What happens during program execution?



Execution sequence:

Fetch Instruction at PC
- Decode
- Execute (possibly using registers)
- Write results to registers/mem
- PC = Next Instruction(PC)

Repeat

First OS Concept: Thread of Control

- Thread: Single unique execution context
  - Program Counter, Registers, Execution Flags, Stack
- A thread is executing on a processor when it is resident in the processor registers.
- PC register holds the address of executing instruction in the thread.
- Certain registers hold the *context* of thread
  - Stack pointer holds the address of the top of stack
    - Other conventions: Frame Pointer, Heap Pointer, Data
  - May be defined by the instruction set architecture or by compiler conventions
- Registers hold the root state of the thread.
  - The rest is “in memory”

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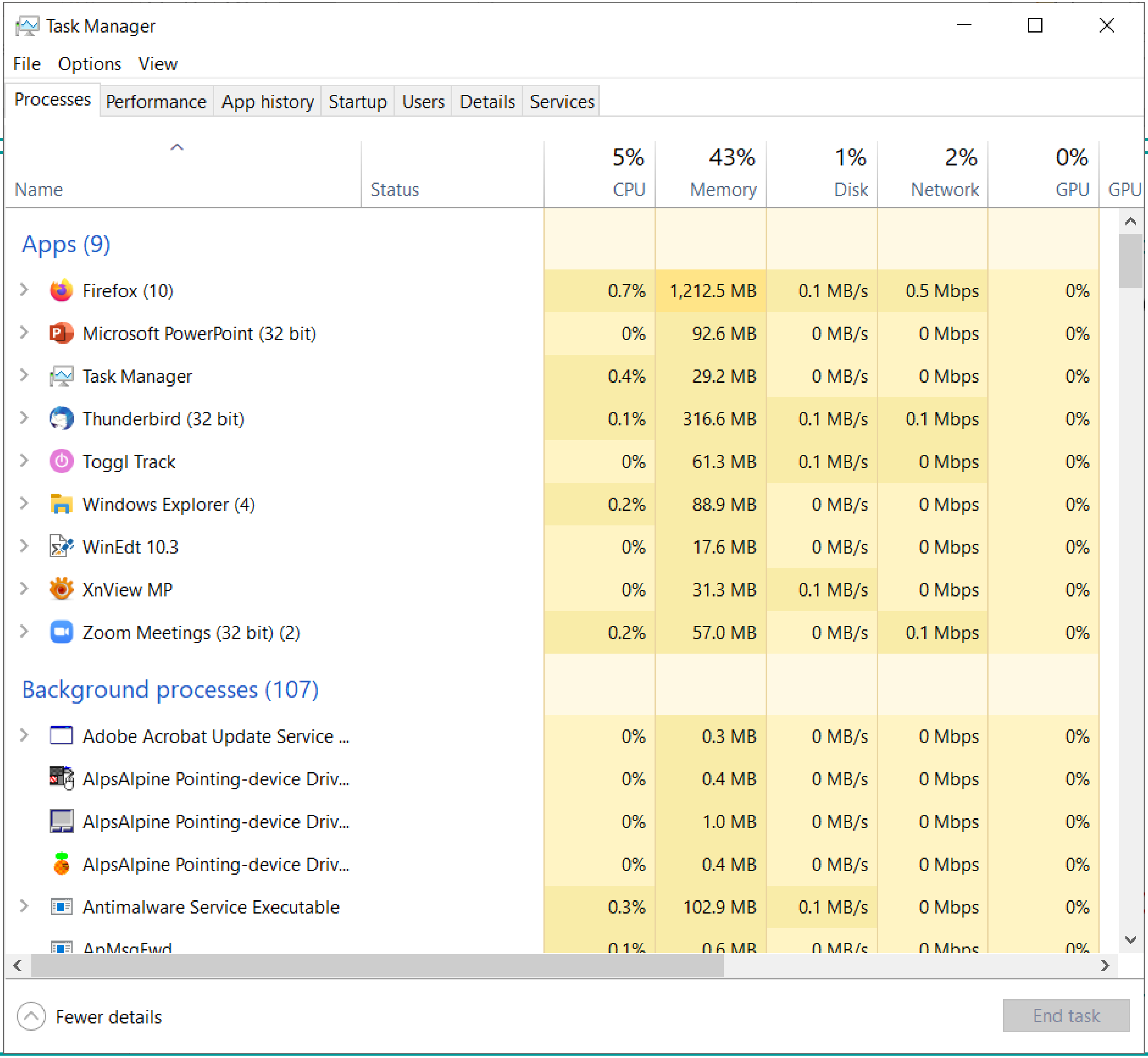
Protecting Programs

- Problem: Run multiple applications in such a way that they are protected from one another
- Goal:
  - Keep User Programs from crashing the OS
  - Keep User Programs from crashing each other
  - [Keep Parts of OS from crashing other parts?]
- (Some of the required) Mechanisms:
  - Address Translation
  - Dual Mode Operation

Later

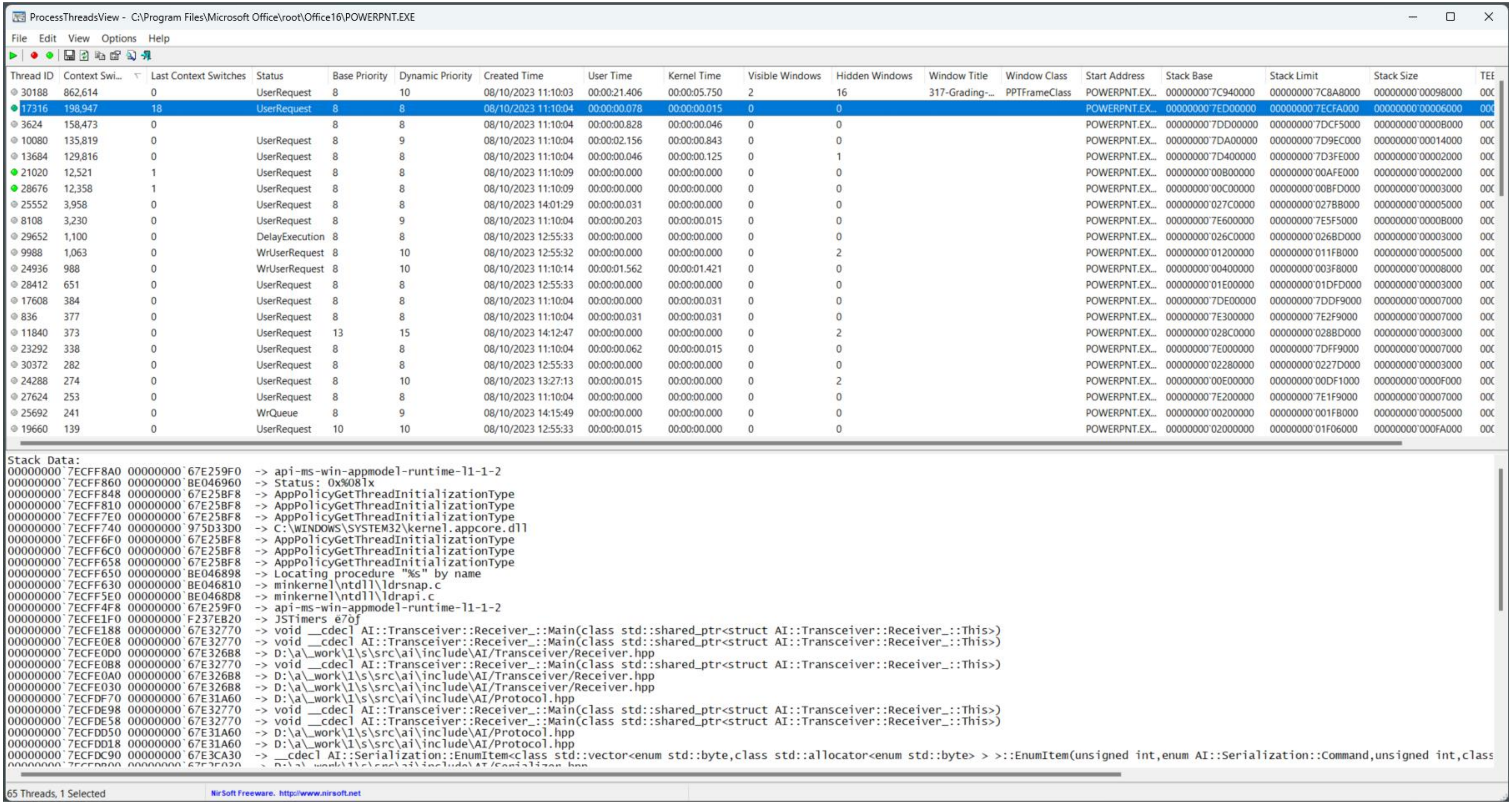
Simple Policy:

- Programs are not allowed to read/write memory of other Programs or of the Operating System



Name	Status	5% CPU	43% Memory	1% Disk	2% Network	0% GPU	GPU
Apps (9)							
Firefox (10)		0.7%	1,212.5 MB	0.1 MB/s	0.5 Mbps	0%	
Microsoft PowerPoint (32 bit)		0%	92.6 MB	0 MB/s	0 Mbps	0%	
Task Manager		0.4%	29.2 MB	0 MB/s	0 Mbps	0%	
Thunderbird (32 bit)		0.1%	316.6 MB	0.1 MB/s	0.1 Mbps	0%	
Toggl Track		0%	61.3 MB	0.1 MB/s	0 Mbps	0%	
Windows Explorer (4)		0.2%	88.9 MB	0 MB/s	0 Mbps	0%	
WinEdt 10.3		0%	17.6 MB	0 MB/s	0 Mbps	0%	
XnView MP		0%	31.3 MB	0.1 MB/s	0 Mbps	0%	
Zoom Meetings (32 bit) (2)		0.2%	57.0 MB	0 MB/s	0.1 Mbps	0%	
Background processes (107)							
Adobe Acrobat Update Service ...		0%	0.3 MB	0 MB/s	0 Mbps	0%	
AlpsAlpine Pointing-device Driv...		0%	0.4 MB	0 MB/s	0 Mbps	0%	
AlpsAlpine Pointing-device Driv...		0%	1.0 MB	0 MB/s	0 Mbps	0%	
AlpsAlpine Pointing-device Driv...		0%	0.4 MB	0 MB/s	0 Mbps	0%	
Antimalware Service Executable		0.3%	102.9 MB	0.1 MB/s	0 Mbps	0%	
ApMsgFwd		0.1%	0.6 MB	0 MB/s	0 Mbps	0%	

Threads View



ProcessThreadsView - C:\Program Files\Microsoft Office\root\Office16\POWERPNT.EXE

Thread ID	Context Swi...	Last Context Switches	Status	Base Priority	Dynamic Priority	Created Time	User Time	Kernel Time	Visible Windows	Hidden Windows	Window Title	Window Class	Start Address	Stack Base	Stack Limit	Stack Size	TEE
30188	862,614	0	UserRequest	8	10	08/10/2023 11:10:03	00:00:21.406	00:00:05.750	2	16	317-Grading-...	PPTFrameClass	POWERPNT.EX...	00000000`7C940000	00000000`7C8A8000	00000000`00098000	00C
17316	198,947	18	UserRequest	8	8	08/10/2023 11:10:04	00:00:00.078	00:00:00.015	0	0			POWERPNT.EX...	00000000`7ED00000	00000000`7ECFA000	00000000`00006000	00C
3624	158,473	0		8	8	08/10/2023 11:10:04	00:00:00.828	00:00:00.046	0	0			POWERPNT.EX...	00000000`7DD00000	00000000`7DCF5000	00000000`0000B000	00C
10080	135,819	0	UserRequest	8	9	08/10/2023 11:10:04	00:00:02.156	00:00:00.843	0	0			POWERPNT.EX...	00000000`7DA00000	00000000`7D9EC000	00000000`00014000	00C
13684	129,816	0	UserRequest	8	8	08/10/2023 11:10:04	00:00:00.046	00:00:00.125	0	1			POWERPNT.EX...	00000000`7D400000	00000000`7D3FE000	00000000`00002000	00C
21020	12,521	1	UserRequest	8	8	08/10/2023 11:10:09	00:00:00.000	00:00:00.000	0	0			POWERPNT.EX...	00000000`00B00000	00000000`00AFE000	00000000`00002000	00C
28676	12,358	1	UserRequest	8	8	08/10/2023 11:10:09	00:00:00.000	00:00:00.000	0	0			POWERPNT.EX...	00000000`00C00000	00000000`00BFD000	00000000`00003000	00C
25552	3,958	0	UserRequest	8	8	08/10/2023 14:01:29	00:00:00.031	00:00:00.000	0	0			POWERPNT.EX...	00000000`027C0000	00000000`027BB000	00000000`00005000	00C
8108	3,230	0	UserRequest	8	9	08/10/2023 11:10:04	00:00:00.203	00:00:00.015	0	0			POWERPNT.EX...	00000000`7E600000	00000000`7E5F5000	00000000`0000B000	00C
29652	1,100	0	DelayExecution	8	8	08/10/2023 12:55:33	00:00:00.000	00:00:00.000	0	0			POWERPNT.EX...	00000000`026C0000	00000000`026BD000	00000000`00003000	00C
9988	1,063	0	WrUserRequest	8	10	08/10/2023 12:55:32	00:00:00.000	00:00:00.000	0	2			POWERPNT.EX...	00000000`01200000	00000000`011FB000	00000000`00005000	00C
24936	988	0	WrUserRequest	8	10	08/10/2023 11:10:14	00:00:01.562	00:00:01.421	0	0			POWERPNT.EX...	00000000`00400000	00000000`003F8000	00000000`00008000	00C
28412	651	0	UserRequest	8	8	08/10/2023 12:55:33	00:00:00.000	00:00:00.000	0	0			POWERPNT.EX...	00000000`01E00000	00000000`01DFD000	00000000`00003000	00C
17608	384	0	UserRequest	8	8	08/10/2023 11:10:04	00:00:00.000	00:00:00.031	0	0			POWERPNT.EX...	00000000`7DE00000	00000000`7DDF9000	00000000`00007000	00C
836	377	0	UserRequest	8	8	08/10/2023 11:10:04	00:00:00.031	00:00:00.031	0	0			POWERPNT.EX...	00000000`7E300000	00000000`7E2F9000	00000000`00007000	00C
11840	373	0	UserRequest	13	15	08/10/2023 14:12:47	00:00:00.000	00:00:00.000	0	2			POWERPNT.EX...	00000000`028C0000	00000000`028BD000	00000000`00003000	00C
23292	338	0	UserRequest	8	8	08/10/2023 11:10:04	00:00:00.062	00:00:00.015	0	0			POWERPNT.EX...	00000000`7E000000	00000000`7DFF9000	00000000`00007000	00C
30372	282	0	UserRequest	8	8	08/10/2023 12:55:33	00:00:00.000	00:00:00.000	0	0			POWERPNT.EX...	00000000`02280000	00000000`0227D000	00000000`00003000	00C
24288	274	0	UserRequest	8	10	08/10/2023 13:27:13	00:00:00.015	00:00:00.000	0	2			POWERPNT.EX...	00000000`00E00000	00000000`00DF1000	00000000`0000F000	00C
27624	253	0	UserRequest	8	8	08/10/2023 11:10:04	00:00:00.000	00:00:00.000	0	0			POWERPNT.EX...	00000000`7E200000	00000000`7E1F9000	00000000`00007000	00C
25692	241	0	WrQueue	8	9	08/10/2023 14:15:49	00:00:00.000	00:00:00.000	0	0			POWERPNT.EX...	00000000`00200000	00000000`001FB000	00000000`00005000	00C
19660	139	0	UserRequest	10	10	08/10/2023 12:55:33	00:00:00.015	00:00:00.000	0	0			POWERPNT.EX...	00000000`02000000	00000000`01F06000	00000000`000FA000	00C

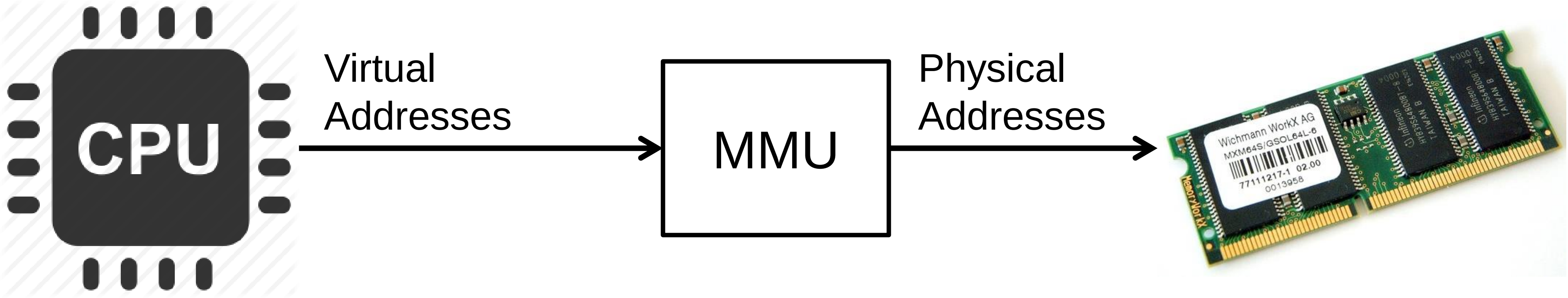
```
Stack Data:
00000000`7ECFF8A0 00000000`67E259F0  -> api-ms-win-appmodel-runtime-l1-1-2
00000000`7ECFF860 00000000`BE046960  -> Status: 0x%08lx
00000000`7ECFF848 00000000`67E25BF8  -> AppPolicyGetThreadInitializationType
00000000`7ECFF810 00000000`67E25BF8  -> AppPolicyGetThreadInitializationType
00000000`7ECFF7E0 00000000`67E25BF8  -> AppPolicyGetThreadInitializationType
00000000`7ECFF740 00000000`975D33D0  -> C:\WINDOWS\SYSTEM32\kernel.appcore.dll
00000000`7ECFF6F0 00000000`67E25BF8  -> AppPolicyGetThreadInitializationType
00000000`7ECFF6C0 00000000`67E25BF8  -> AppPolicyGetThreadInitializationType
00000000`7ECFF658 00000000`67E25BF8  -> AppPolicyGetThreadInitializationType
00000000`7ECFF650 00000000`BE046898  -> Locating procedure "%s" by name
00000000`7ECFF630 00000000`BE046810  -> minkernel\ntdll\ldrsnap.c
00000000`7ECFF5E0 00000000`BE0468D8  -> minkernel\ntdll\ldrapi.c
00000000`7ECFF4F8 00000000`67E259F0  -> api-ms-win-appmodel-runtime-l1-1-2
00000000`7ECFE1F0 00000000`F237EB20  -> JSTimers ë7òf
00000000`7ECFE188 00000000`67E32770  -> void __cdecl AI::Transceiver::Receiver_::Main(class std::shared_ptr<struct AI::Transceiver::Receiver_::This>)
00000000`7ECFE0E8 00000000`67E32770  -> void __cdecl AI::Transceiver::Receiver_::Main(class std::shared_ptr<struct AI::Transceiver::Receiver_::This>)
00000000`7ECFE0D0 00000000`67E326B8  -> D:\a\_work\1\s\src\ai\include\AI/Transceiver/Receiver.hpp
00000000`7ECFE0B8 00000000`67E32770  -> void __cdecl AI::Transceiver::Receiver_::Main(class std::shared_ptr<struct AI::Transceiver::Receiver_::This>)
00000000`7ECFE0A0 00000000`67E326B8  -> D:\a\_work\1\s\src\ai\include\AI/Transceiver/Receiver.hpp
00000000`7ECFE030 00000000`67E326B8  -> D:\a\_work\1\s\src\ai\include\AI/Transceiver/Receiver.hpp
00000000`7ECFDF70 00000000`67E31A60  -> D:\a\_work\1\s\src\ai\include\AI/Protocol.hpp
00000000`7ECFDE98 00000000`67E32770  -> void __cdecl AI::Transceiver::Receiver_::Main(class std::shared_ptr<struct AI::Transceiver::Receiver_::This>)
00000000`7ECFDE58 00000000`67E32770  -> void __cdecl AI::Transceiver::Receiver_::Main(class std::shared_ptr<struct AI::Transceiver::Receiver_::This>)
00000000`7ECFDD50 00000000`67E31A60  -> D:\a\_work\1\s\src\ai\include\AI/Protocol.hpp
00000000`7ECFDD18 00000000`67E31A60  -> D:\a\_work\1\s\src\ai\include\AI/Protocol.hpp
00000000`7ECFDC90 00000000`67E3CA30  -> __cdecl AI::Serialization::EnumItem<class std::vector<enum std::byte,class std::allocator<enum std::byte> > >::EnumItem(unsigned int,enum AI::Serialization::Command,unsigned int,class
00000000`7ECFDB00 00000000`67E2F030  -> D:\a\_work\1\s\src\ai\include\AI/Serializer.hpp
```

65 Threads, 1 Selected

NirSoft Freeware. http://www.nirsoft.net

Address Translation

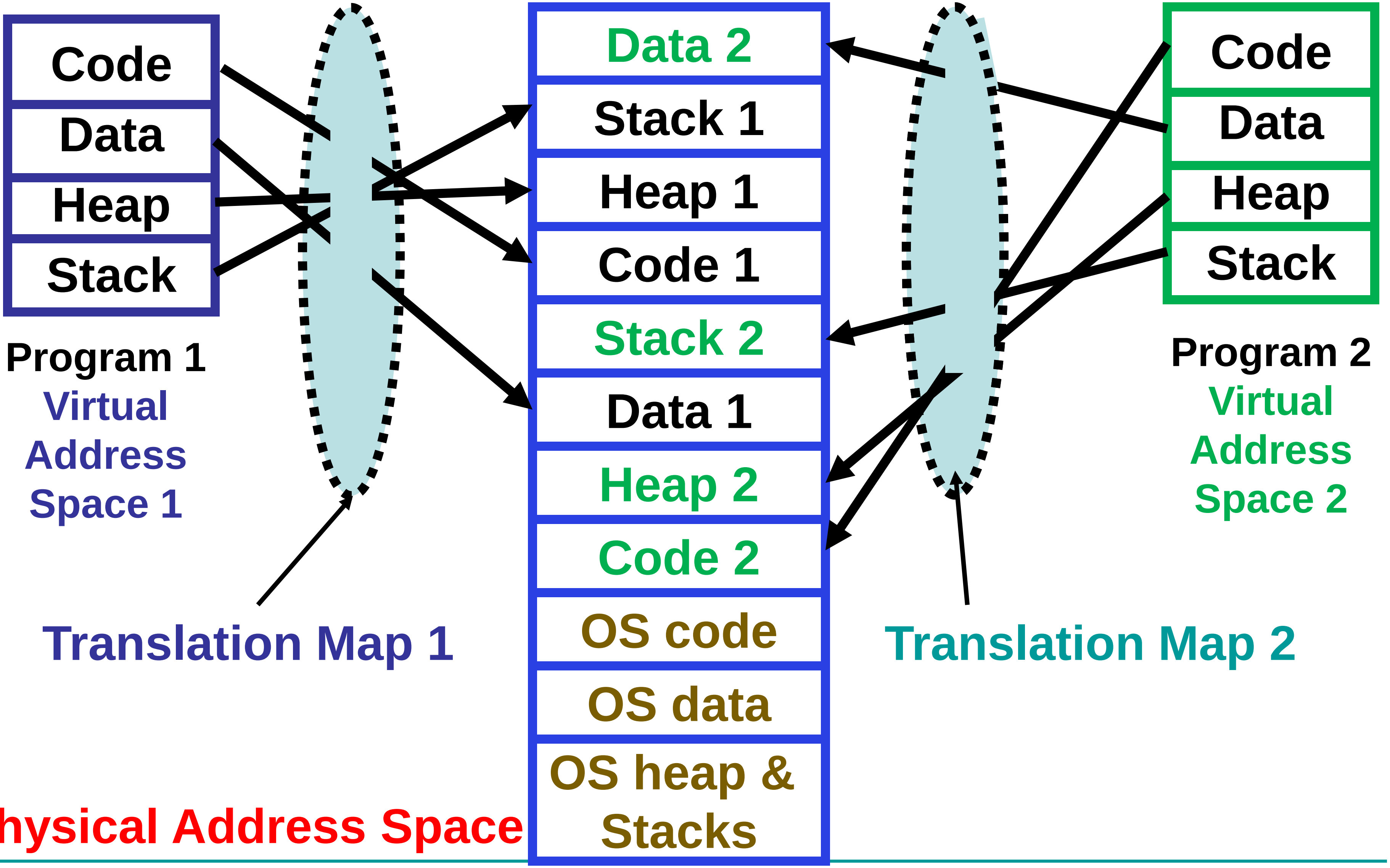
- Address Space
  - A group of memory addresses usable by something
  - Each program (process) and kernel has potentially different address spaces.
- Address Translation:
  - Translate from Virtual Addresses (emitted by CPU) into Physical Addresses (of memory)
  - Mapping *often* performed in Hardware by Memory Management Unit (MMU)



You can’t read or corrupt what you can’t ask for

https://cdn3.whatculture.com/images/2015/03/The-Matrix-Neo-Mouth.jpg

Example of Address Translation



Code
Data
Heap
Stack

Program 1
Virtual
Address
Space 1

Data 2
Stack 1
Heap 1
Code 1
Stack 2
Data 1
Heap 2
Code 2
OS code
OS data
OS heap &
Stacks

Code
Data
Heap
Stack

Program 2
Virtual
Address
Space 2

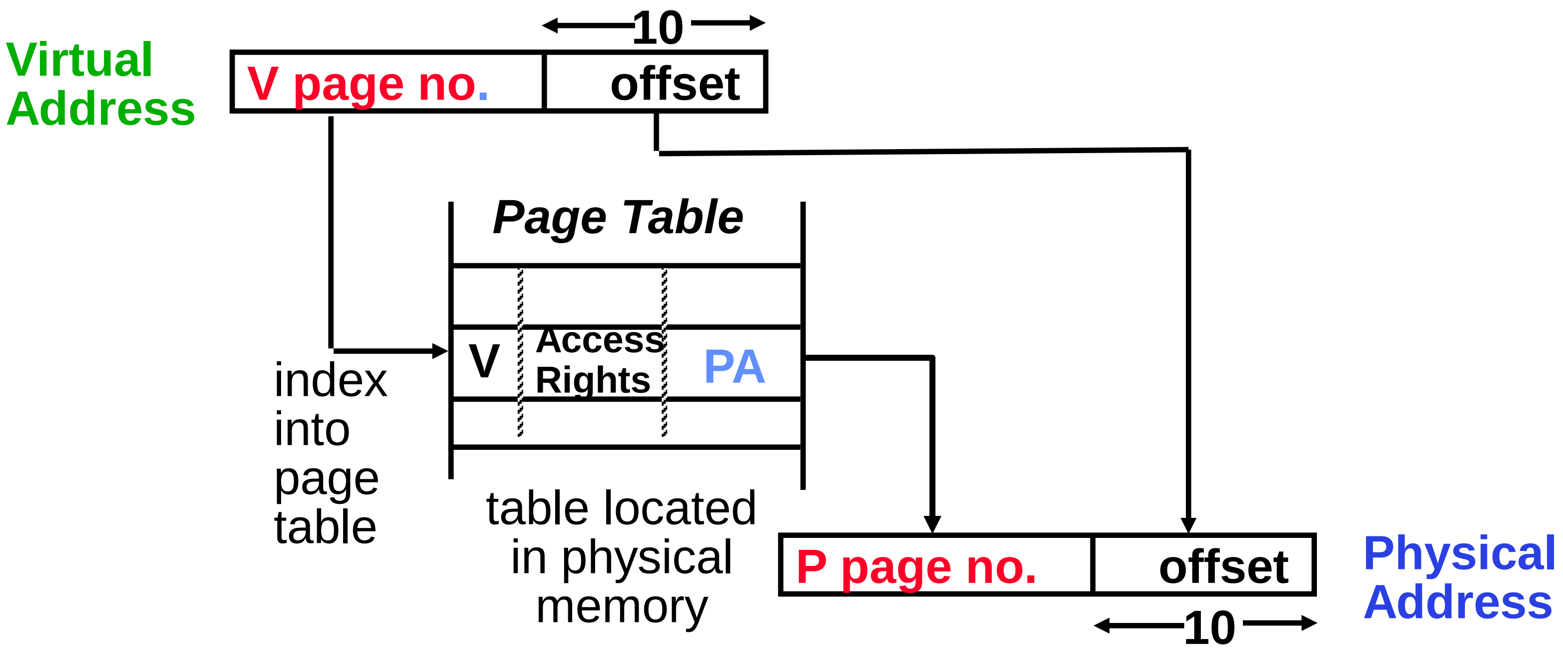
Translation Map 1

Translation Map 2

Physical Address Space

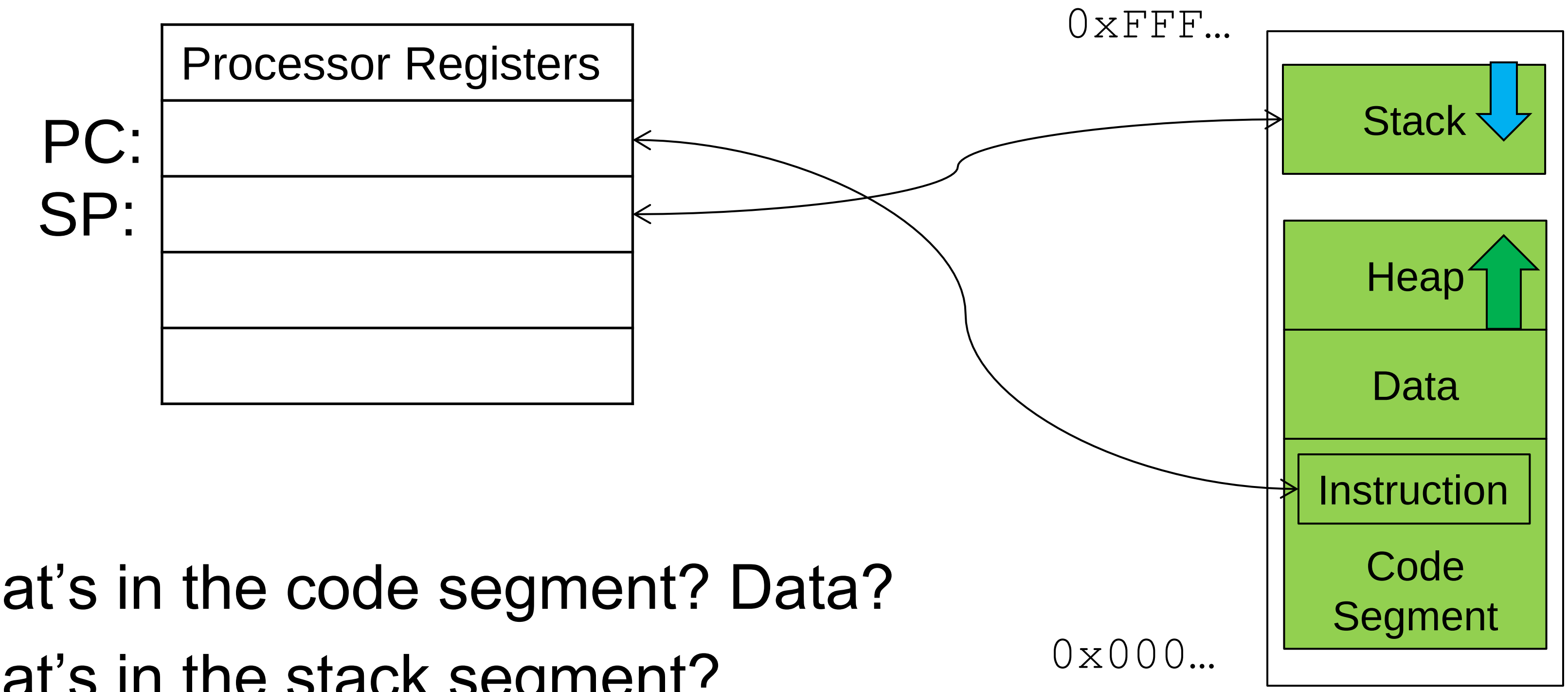
Address Translation Details

- For now, assume translation happens with table (called a Page Table):



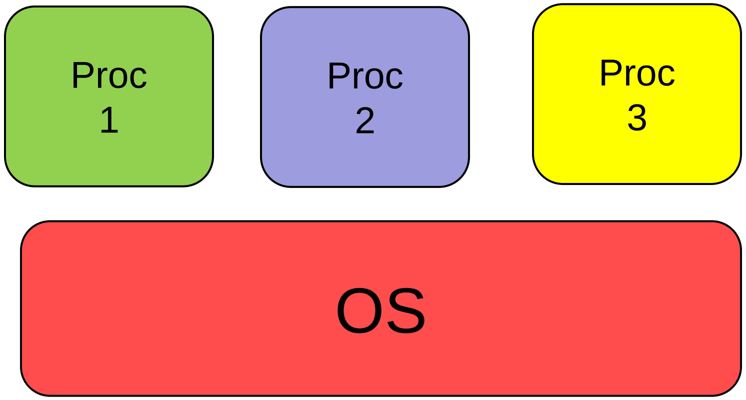
- Translation helps protection:
  - Control translations, control access
  - Should Users be able to change Page Table???

Address Space: In a Picture



- What's in the code segment? Data?
- What's in the stack segment?
  - How is it allocated? How big is it?
- What's in the heap segment?
  - How is it allocated? How big?

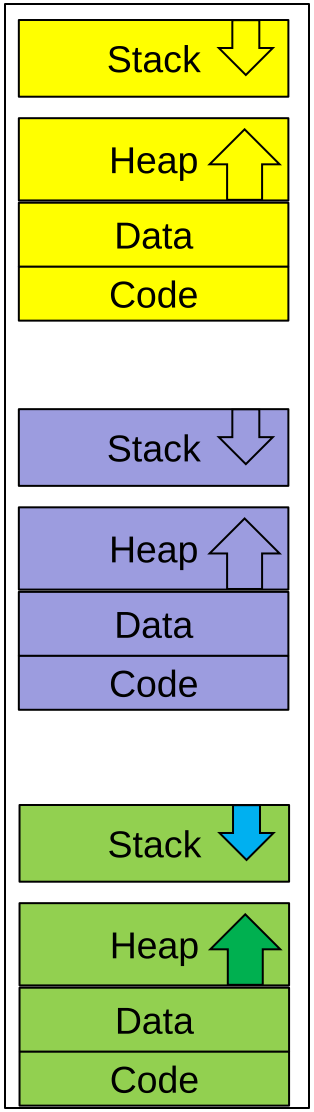
Multiprogramming – Multiple Threads of Control


Proc 1

Proc 2

Proc 3

OS


Stack

Heap

Data

Code

Stack

Heap

Data

Code

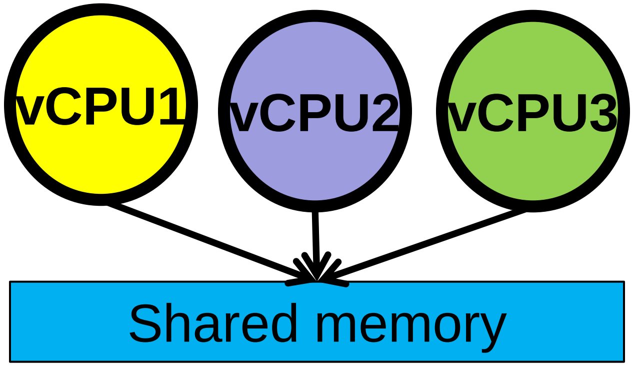
Stack

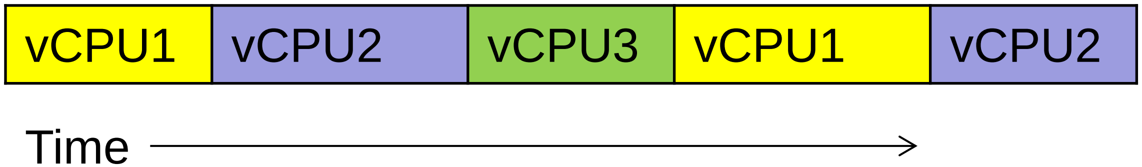
Heap

Data

Code

How can we give the illusion of multiple processors?





- Assume a single processor. How do we provide the illusion of multiple processors?
  - Multiplex in time!
- Each virtual “CPU” needs a structure to hold:
  - Program Counter (PC), Stack Pointer (SP)
  - Registers (Integer, Floating point, others…?)

- How switch from one virtual CPU to the next?
  - Save PC, SP, and registers in current state block
  - Load PC, SP, and registers from new state block
- What triggers switch?
  - Timer, voluntary yield, I/O, other things

Conclusion

- (Brief) OS History
- Virtual Machines
- 4 Main OS Concepts
  - Thread
  - Address
  - Process
  - Dual mode