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#Be professional in embedded system

Embedded Linux (PART 1)

- INTRODUCTION TO EMBEDDED SYSTEM
- HISTORICAL BACKGROUND
- COURSE OUTLINE
- LOADING, LINKING AND ADDRESS BINDING
- MEMORY MANAGEMENT CONCEPTS
- FRAGMENTATION

ENG.KEROLES SHENOUDA

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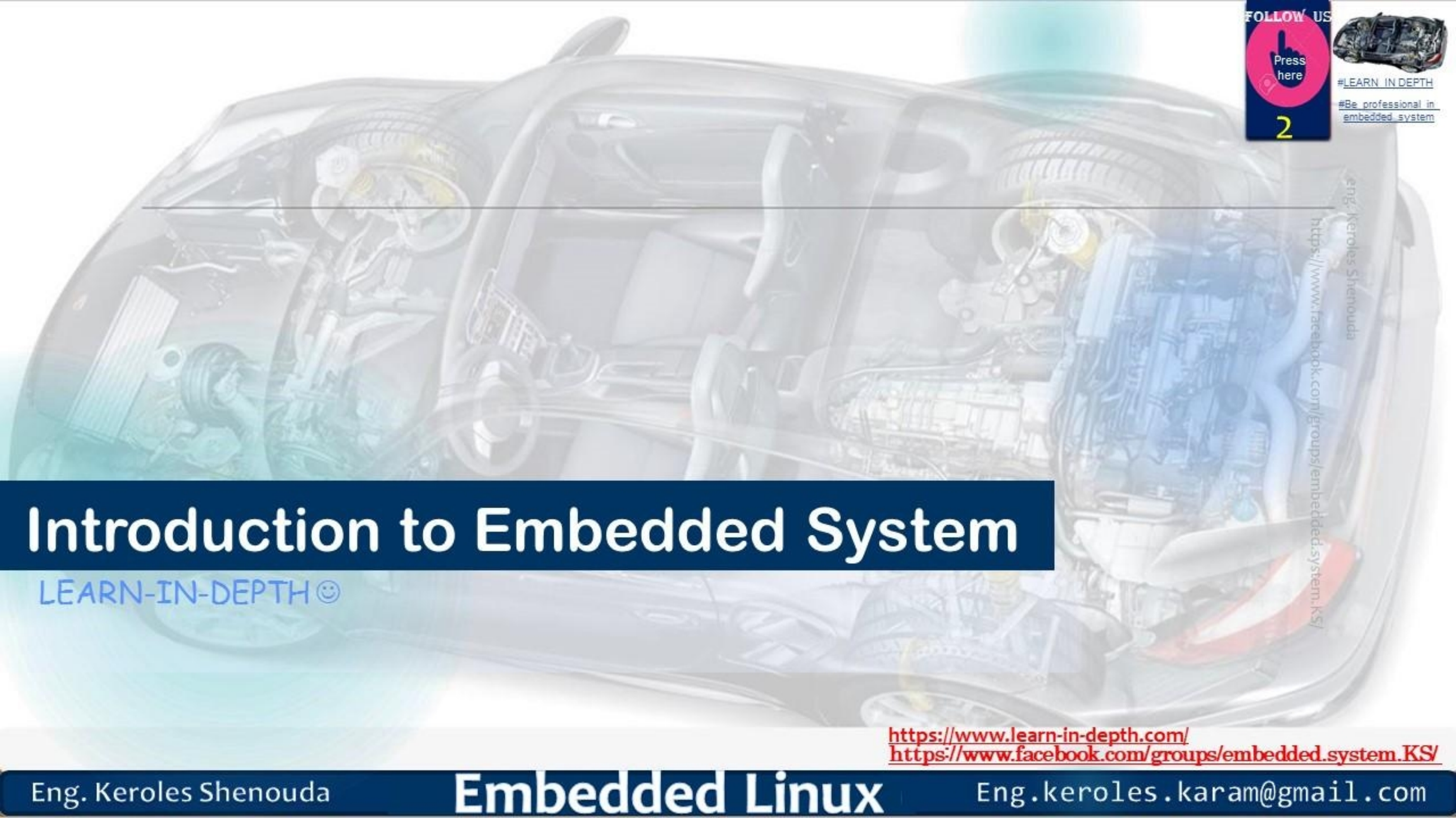

Introduction to Embedded System

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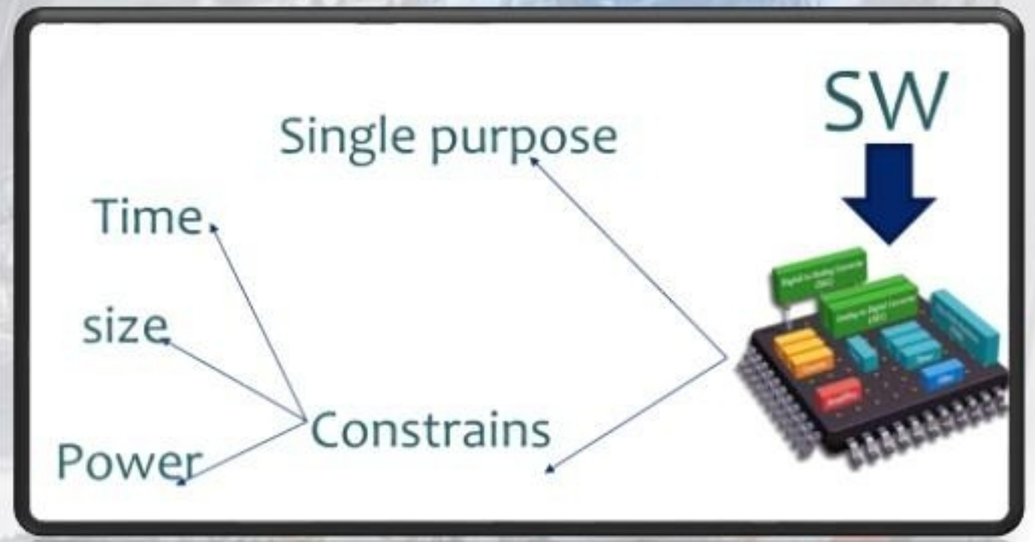
Embedded System What's that ?

An embedded system **is a special-purpose computer system** designed to perform **one or a few dedicated functions**, often with real-time computing constraints.
It is usually embedded as part of a complete device including hardware and mechanical parts.
In contrast, a general-purpose computer, such as a personal computer, can do many different tasks depending on programming.

Embedded systems control many of the common devices in use today.



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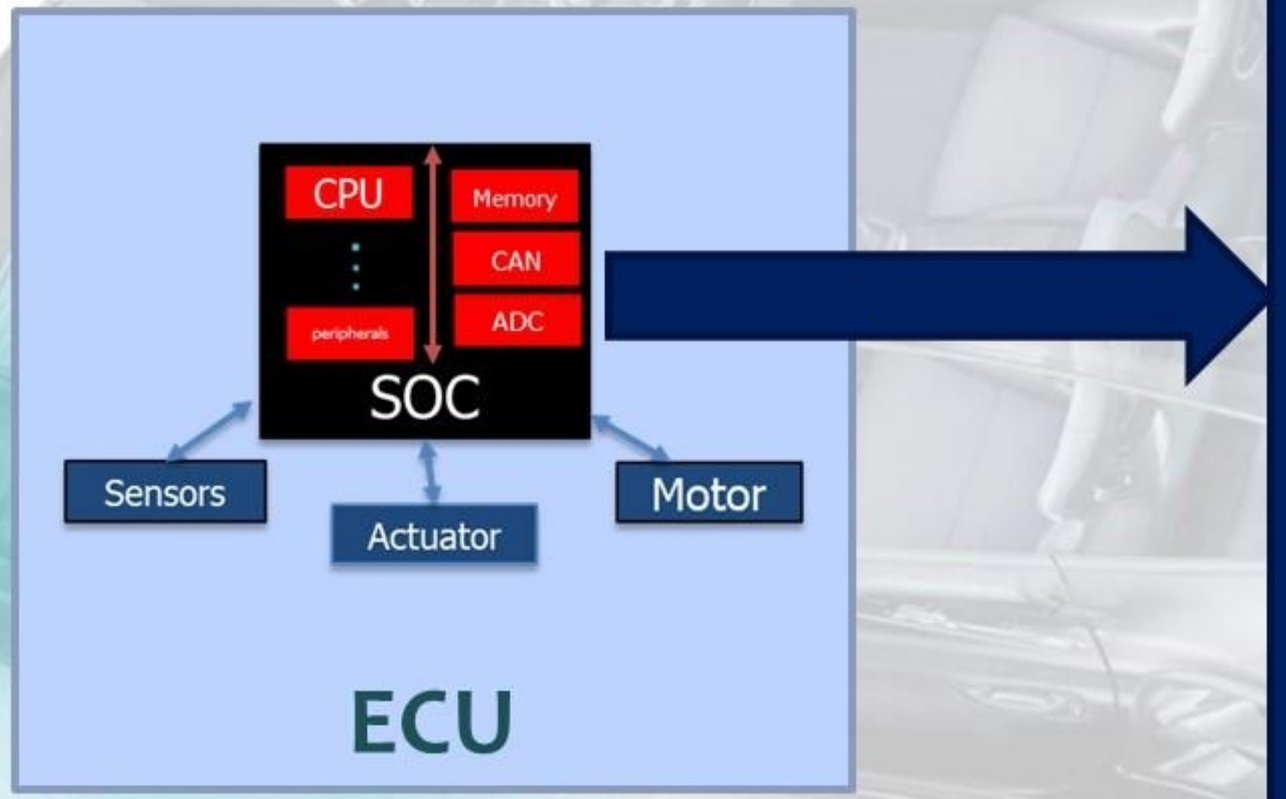
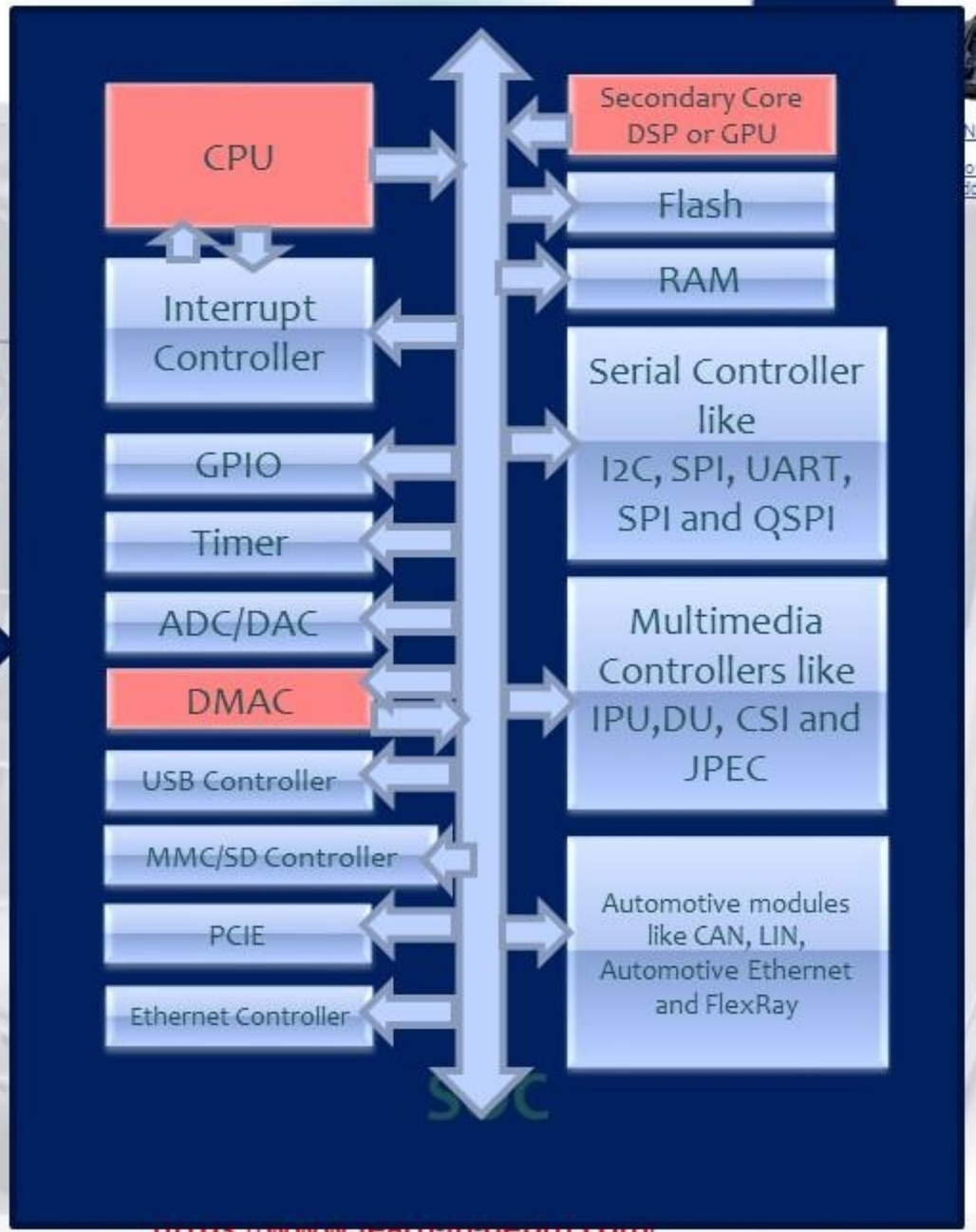
System on Chip (SOC)





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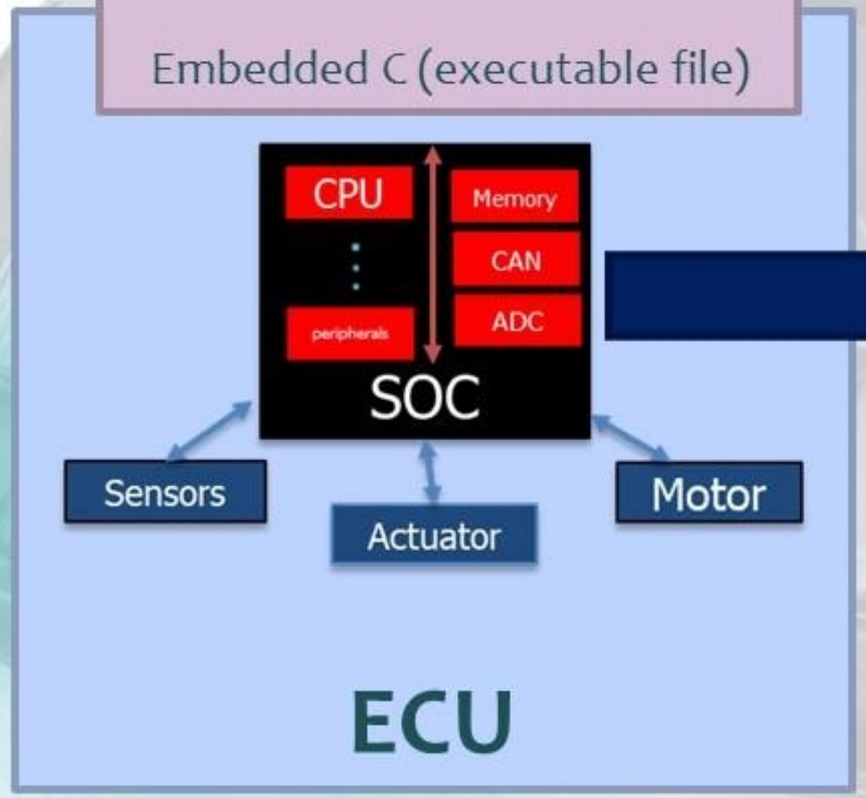
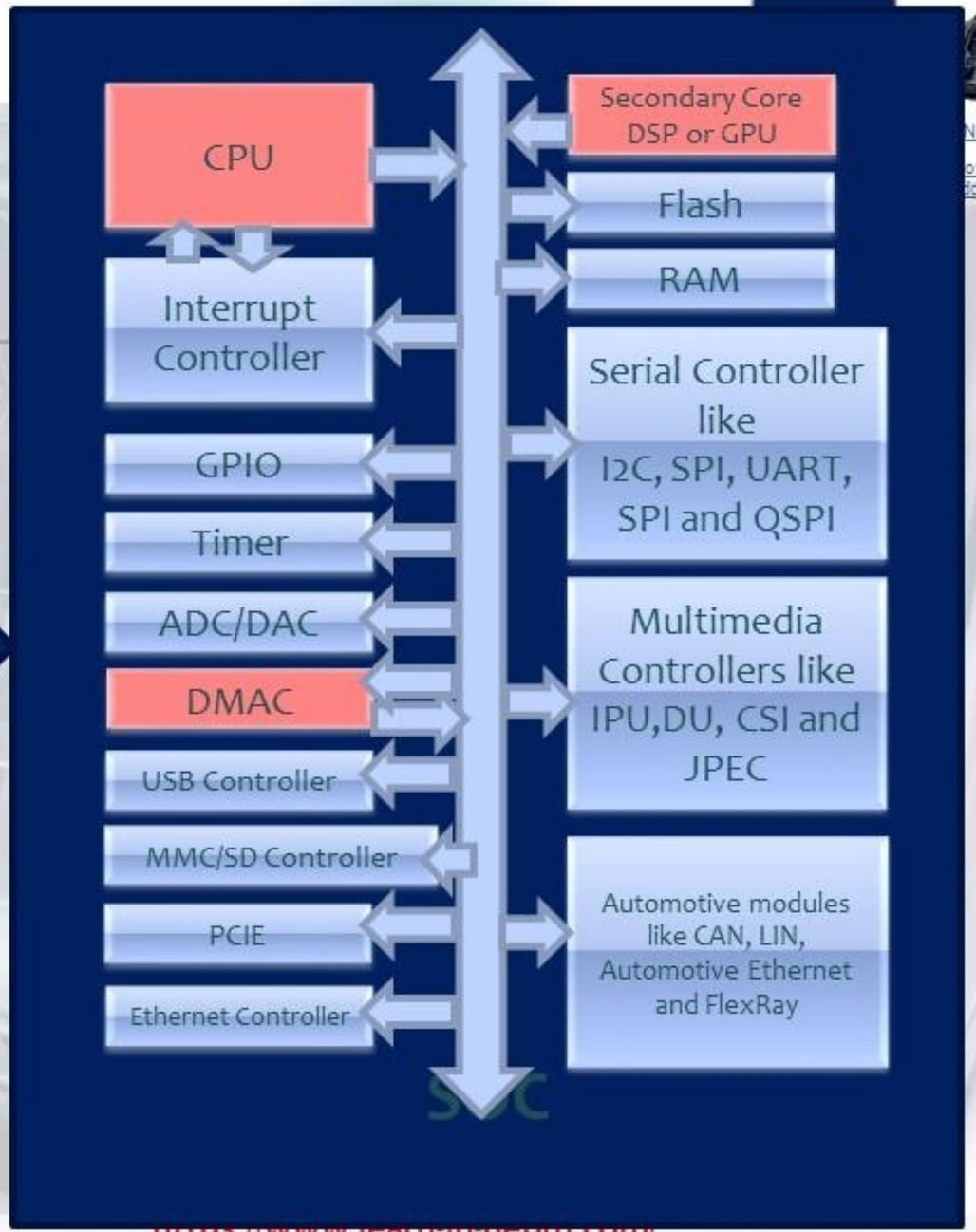
S ip (SOC)

```
(*(volatile unsigned char *)
0XFFFF0000) = 12 ;
```

Embedded C (executable file)





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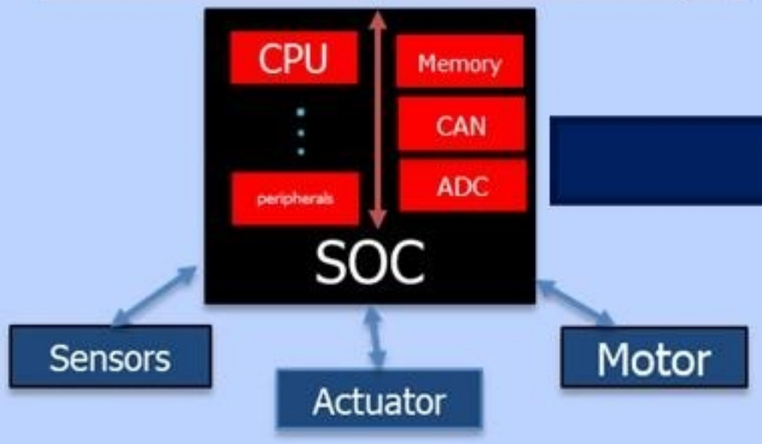
S ip (SOC)

```
(*(volatile unsigned long*)
0XFFFF0000) = 12 ;
(*(volatile unsigned long*)
0XFFFF0004) = 3 ;
```

Embedded C (executable file)



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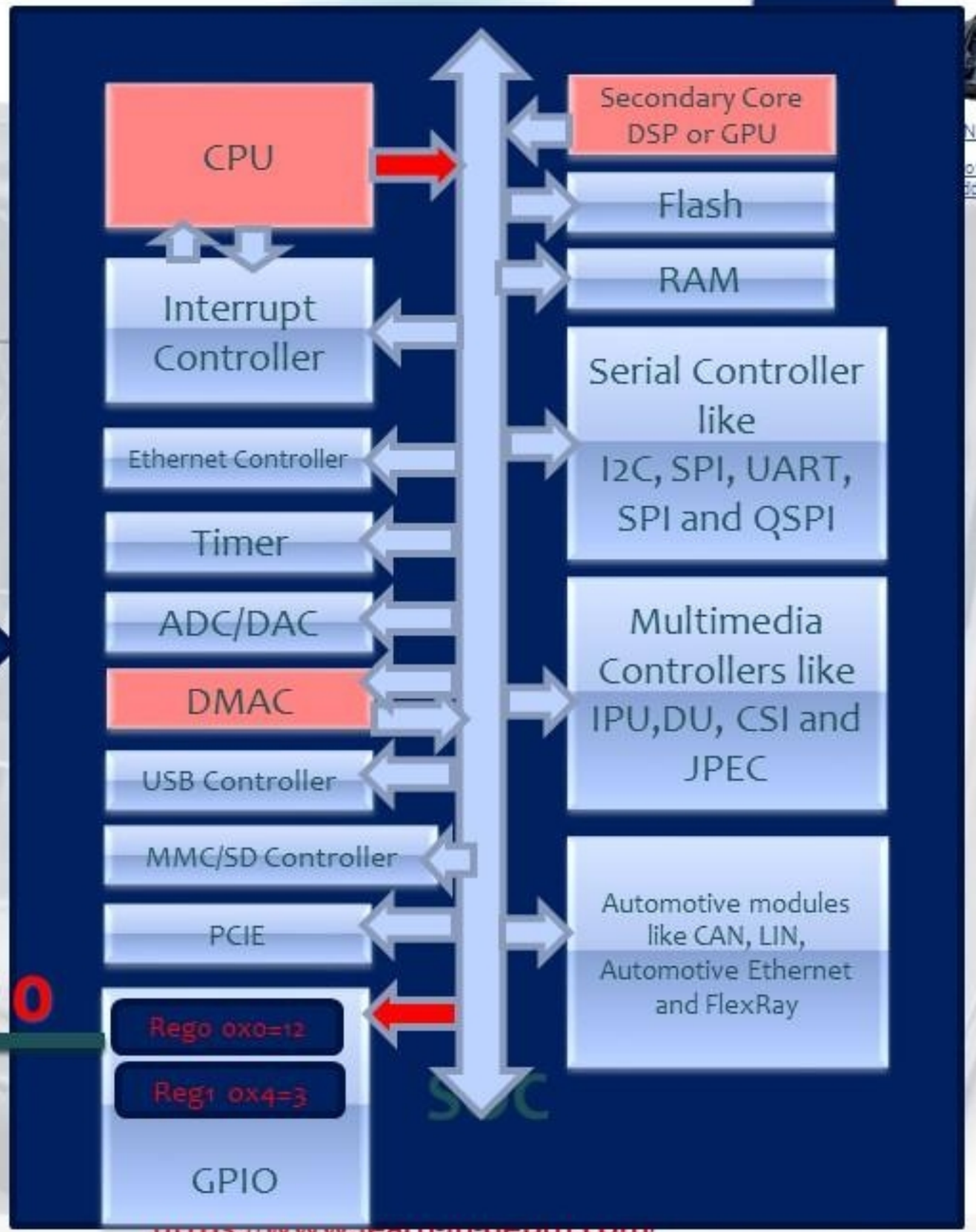

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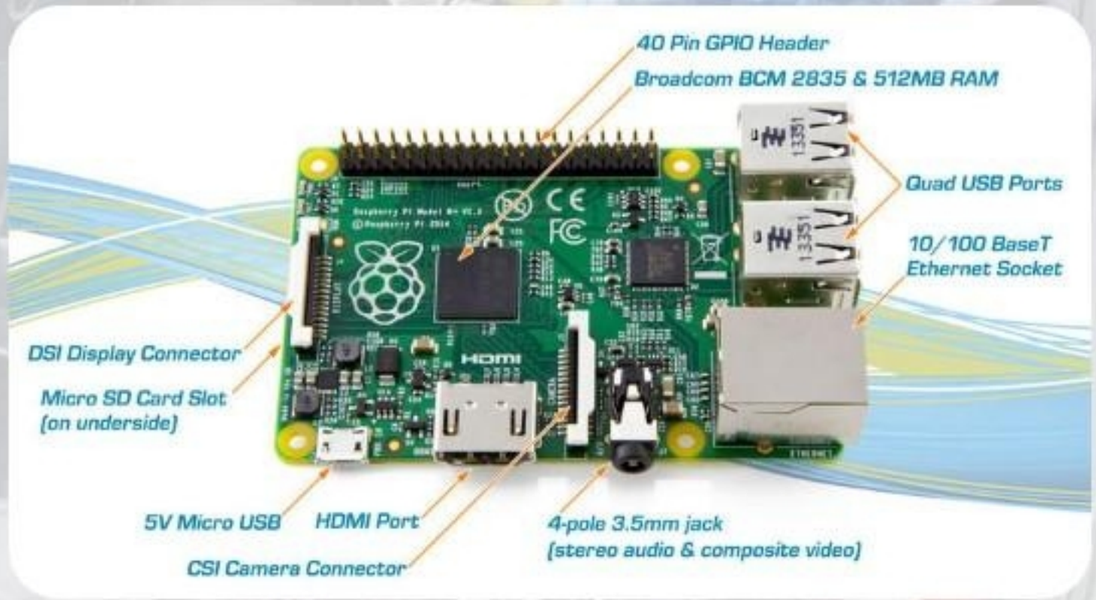
SOCs Examples: Raspberry Pi 2

The Raspberry Pi 2 Model B is the second generation Raspberry Pi. It replaced the original Raspberry Pi 1 Model B+ in February 2015. Compared to the Raspberry Pi 1 it has:

- A 900MHz quad-core ARM Cortex-A7 CPU
- 1GB RAM

Like the (Pi 1) Model B+, it also has:

- 4 USB ports
- 40 GPIO pins
- Full HDMI port
- Ethernet port
- Combined 3.5mm audio jack and composite video
- Camera interface (CSI)
- Display interface (DSI)
- Micro SD card slot
- VideoCore IV 3D graphics core



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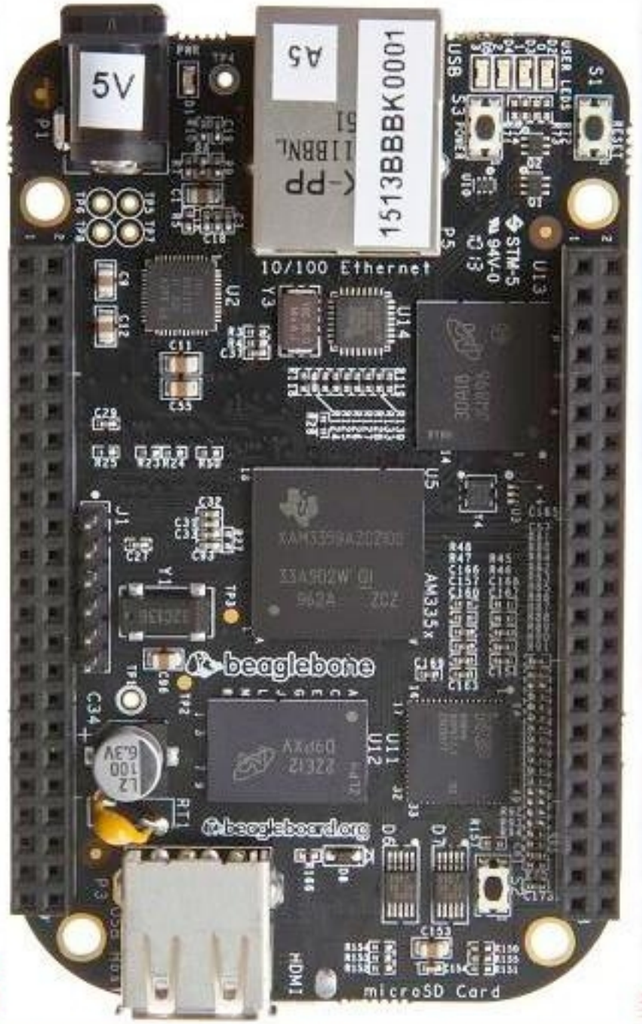
SOCs Examples: BeagleBone Black

- Processor: AM335x 1GHz ARM® Cortex-A8
  - 512MB DDR3 RAM
  - 4GB 8-bit eMMC on-board flash storage
  - 3D graphics accelerator
  - NEON floating-point accelerator
  - 2x PRU 32-bit microcontrollers
- Connectivity
  - USB client for power & communications
  - USB host
  - Ethernet
  - HDMI
  - 2x 46 pin headers



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Renesas RH850D1M

484-pin product

System
- PLL & SSCG
- Security / SHE
- System Health Mon.
  - WDT
  - Temp. Sensor
  - Clock Monitor
  - POC/LVI

Package: BGA484 / 1mm

32-bit CPU
- RH850 Core
  240 MHz
  3.0 – 5.5V, 1.2V (core)
  TJ: -40 to +150°C
- FPU, MPU
- On-Chip debug

Memory
- 3.75 MB / 5 MB Code Flash 512 KB iRAM
- 8 KB Flash$ | 32 KB Data$ | 64 KB Data Fl.

Automotive Interfaces
- 3 x CAN / CAN FD*
- 6 x CSI
- 4 x LIN UART
- 2 x I²C
- Ethernet AVB
- MLB50

Standard
- 16 x DMA
- 20 x A/D (12-bit)
- 48 x 16-bit Timer
- 7 x 32-bit Timer
- 24 x 12-bit PWM
- 1x RTC

Graphic Subsystem (240MHz)
- 2D Drw (D/AVE-HD) OpenVG1.1, BitBLT, RLE
- JPEG & Warping Hardware Engines
- Sprite Engine
- Vout Checker
- 2 x Vout(RGB, RSDS)
- Ser. Flash SDR/DDR
- 2 x Vin(RGB, CSI2)
- 3 MB VRAM
- DDR2-480 32-bit

(*) CAN FD is optional

Cluster
- 6 x SMC/ZPD
- 5 x Sound Generator
- PCM Sound
- 2 x I²S Sound

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SOC And FPGA

SoC FPGA devices integrate both processor and FPGA architectures into a single device. Consequently, they provide higher integration, lower power, smaller board size, and higher bandwidth communication between the processor and FPGA. They also include a rich set of peripherals, on-chip memory, an FPGA-style logic array, and high speed transceivers.

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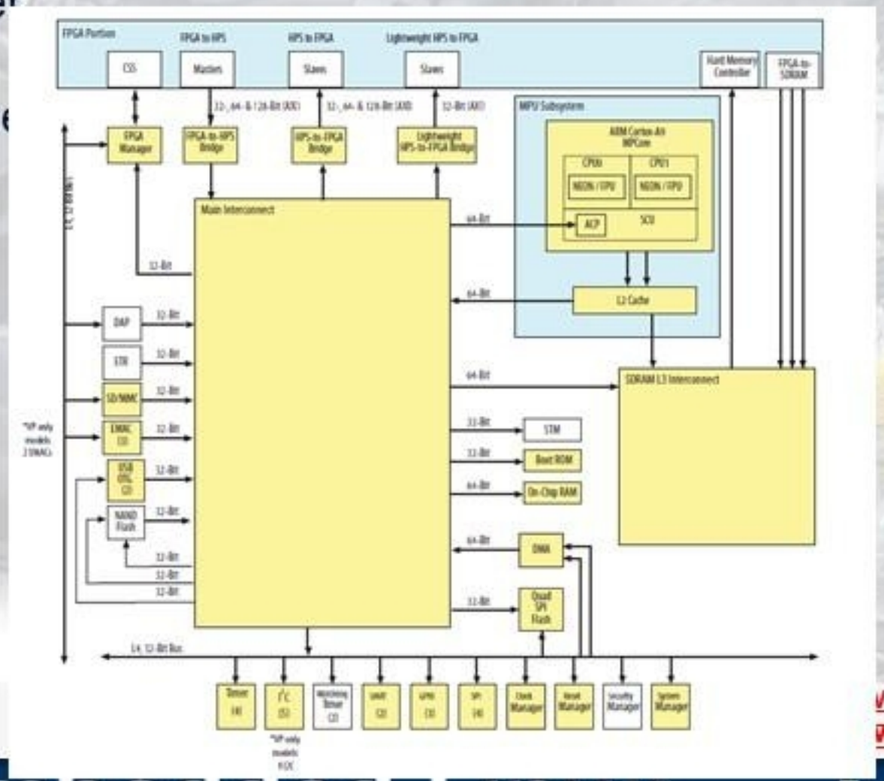

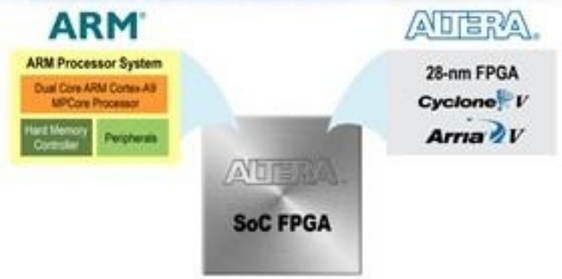

ARM + Altera = SoC FPGAs

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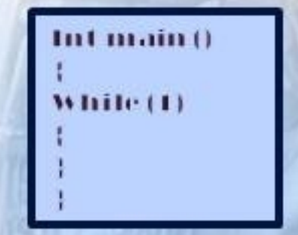
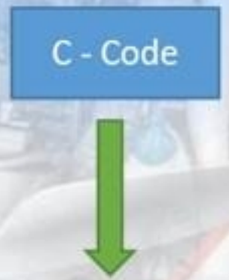
Bare metal SW

- "Bare metal" means **your application** is accessing the silicon chip **directly** without any intermediary like an OS.
- The application is the only software that executes on the microprocessor/microcontroller.
- So we can considered that the Drivers is a bare metal Code and the bios also.



Bare-Metal application



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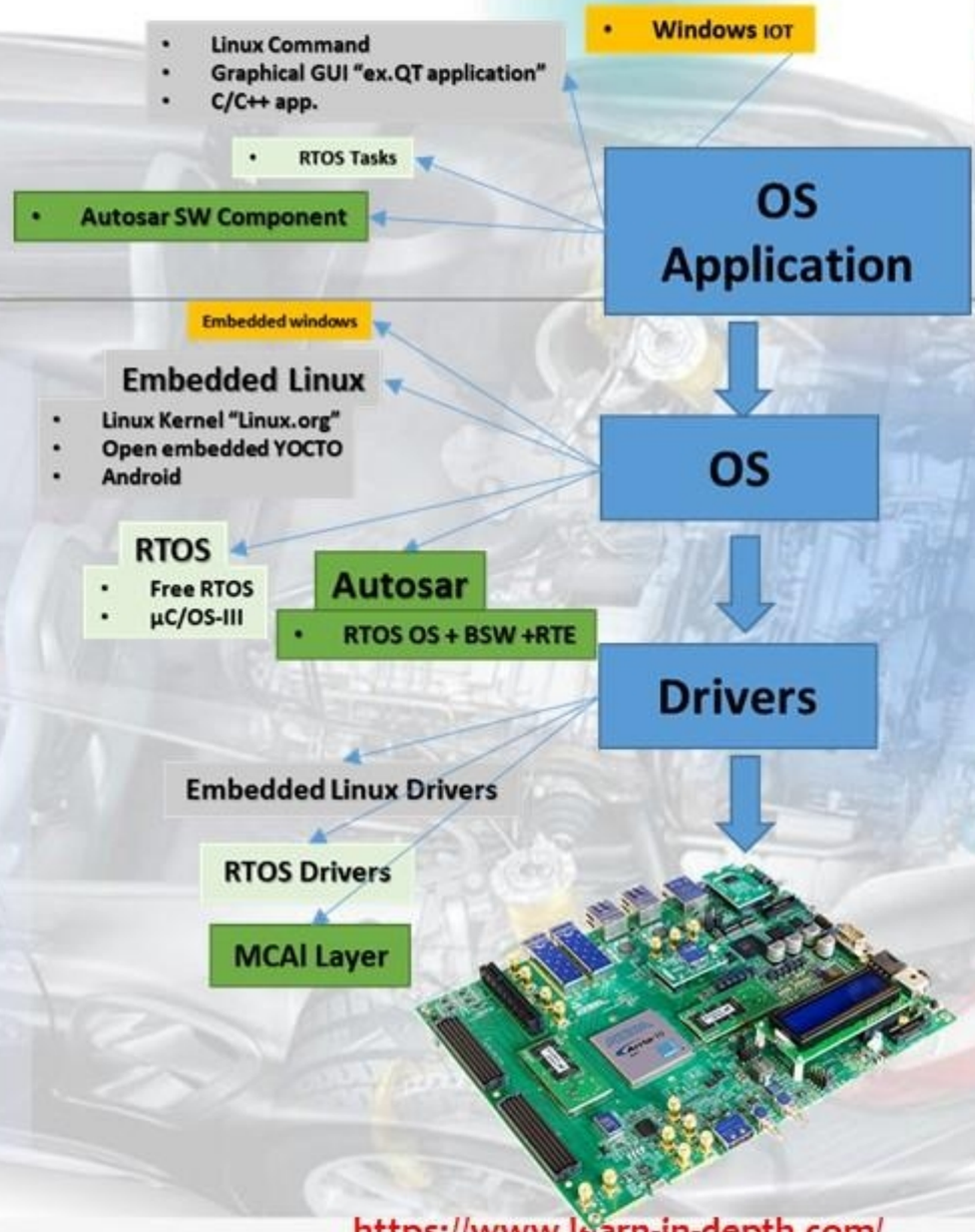
OS Application

- Write your application on the top of the Operating System.
- On desktop computers, the selection of an operating system (OS) is largely a matter of taste - Windows vs Apple vs Linux. There is relatively little choice.
- For an embedded system, the matter is much more complex. The large number of options available reflect the wide diversity of embedded applications.



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Embedded System Fields

- embedded System Basics
- Automotive Field
- Wireless Embedded System
- Embedded Linux field

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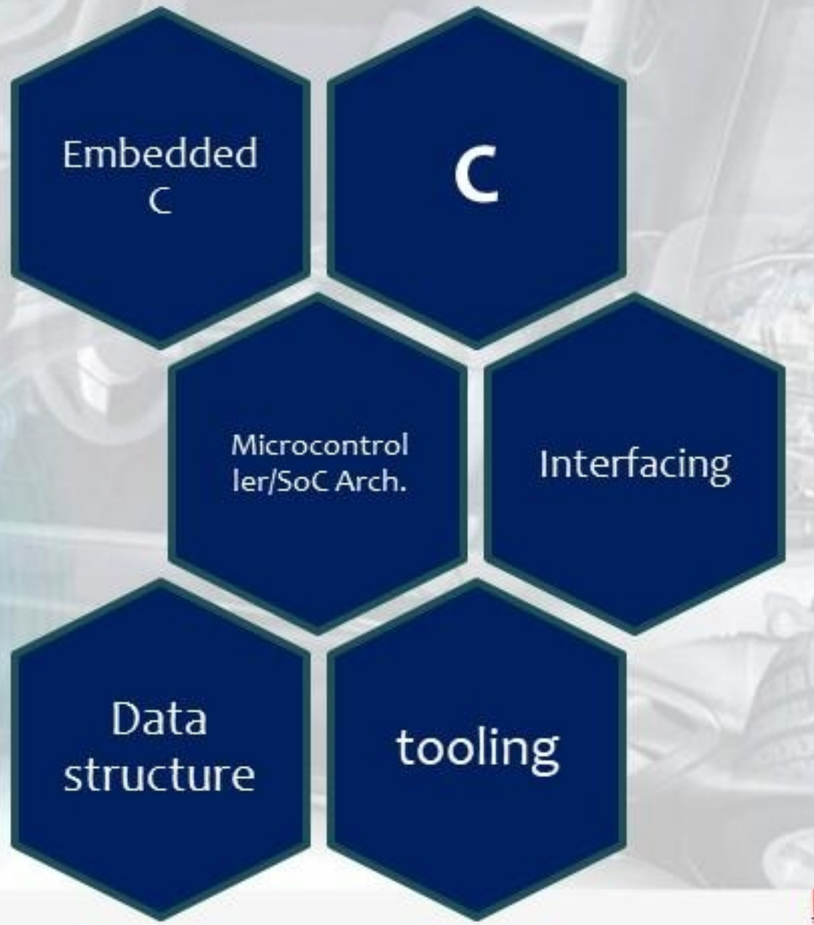
embedded System Basics



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To learn C/EmbeddedC

Step 1: Study the following Parts
==========
Part 1 : the Compiling process and charroduction to C Programming
Part2 : C Variables & Comments & Data Types & printf/scanf and Type casting
Part3: C fundamentals & C statements
Part4: Arrays & Strings
Part 5: C Functions
Part 6: Macros & #pragma
Part7: Structures & ENUM & UNION
Part8: pointers
Part9: Memory Allocation & Embedded C & Queue & Linked List
PART10: Embedded C (startup & Linker &)
Kindly you can find all the parts on:
https://www.learn-in-depth.com/embedded-c

Microcontroller/Interfacing

Step 1: Study the following Parts
==========
Part 1 : Memory, internal structure of a microcontroller, clocks, CPU registers, Von Neumann/Harvard Arch, pipeline And CISC/RISC
Part2 : GPIO Module
Part3: Keypad And LCD
Part4: Interrupt
Part 5: Timers
Part 6: ADC
Part7: UART
Part8: SPI
Part9: I2C
Part10: DDR4 SDRAM

Kindly you can find all the parts on:
https://www.learn-in-depth.com/soc

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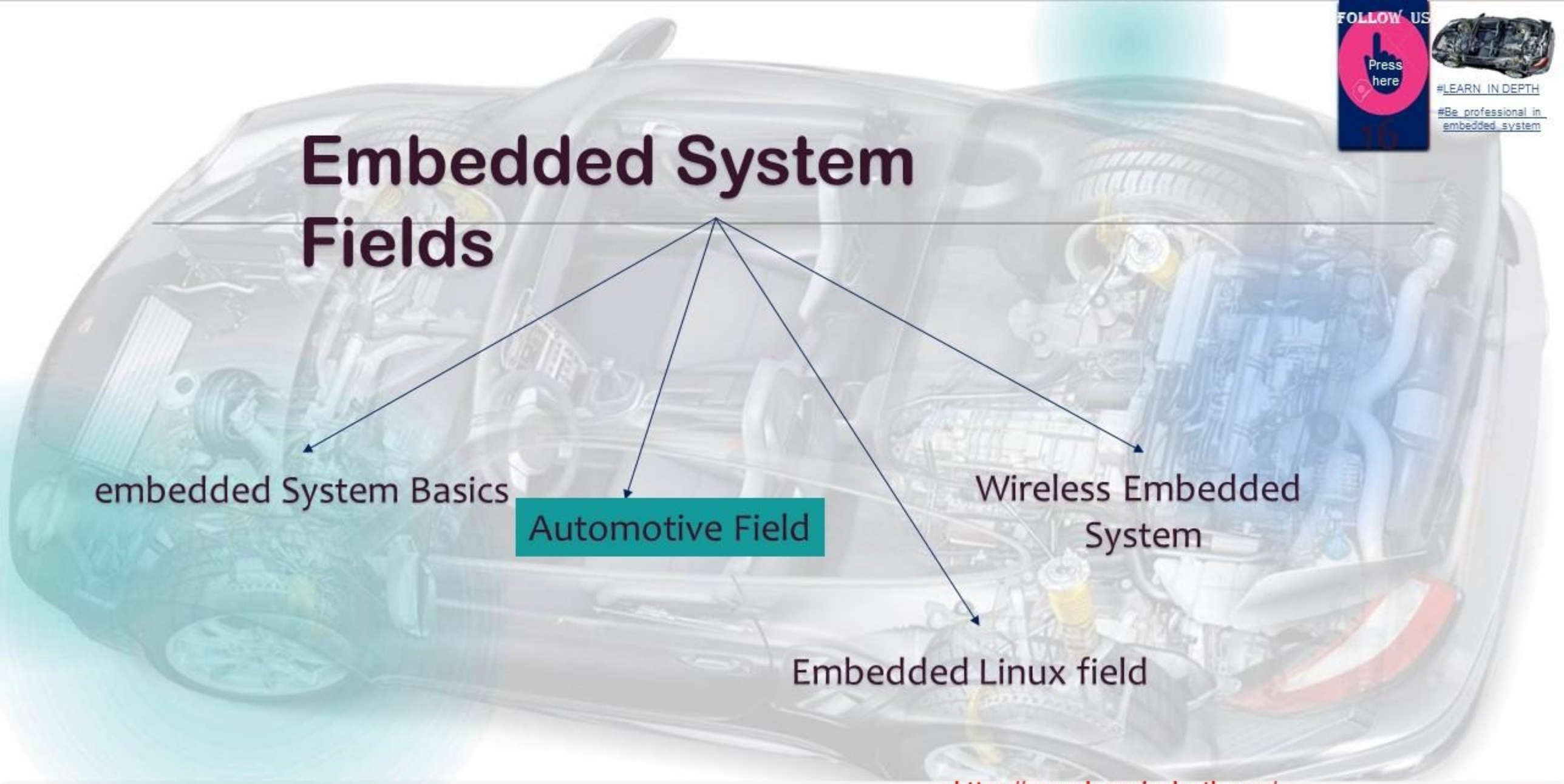
bedded.system.KS/



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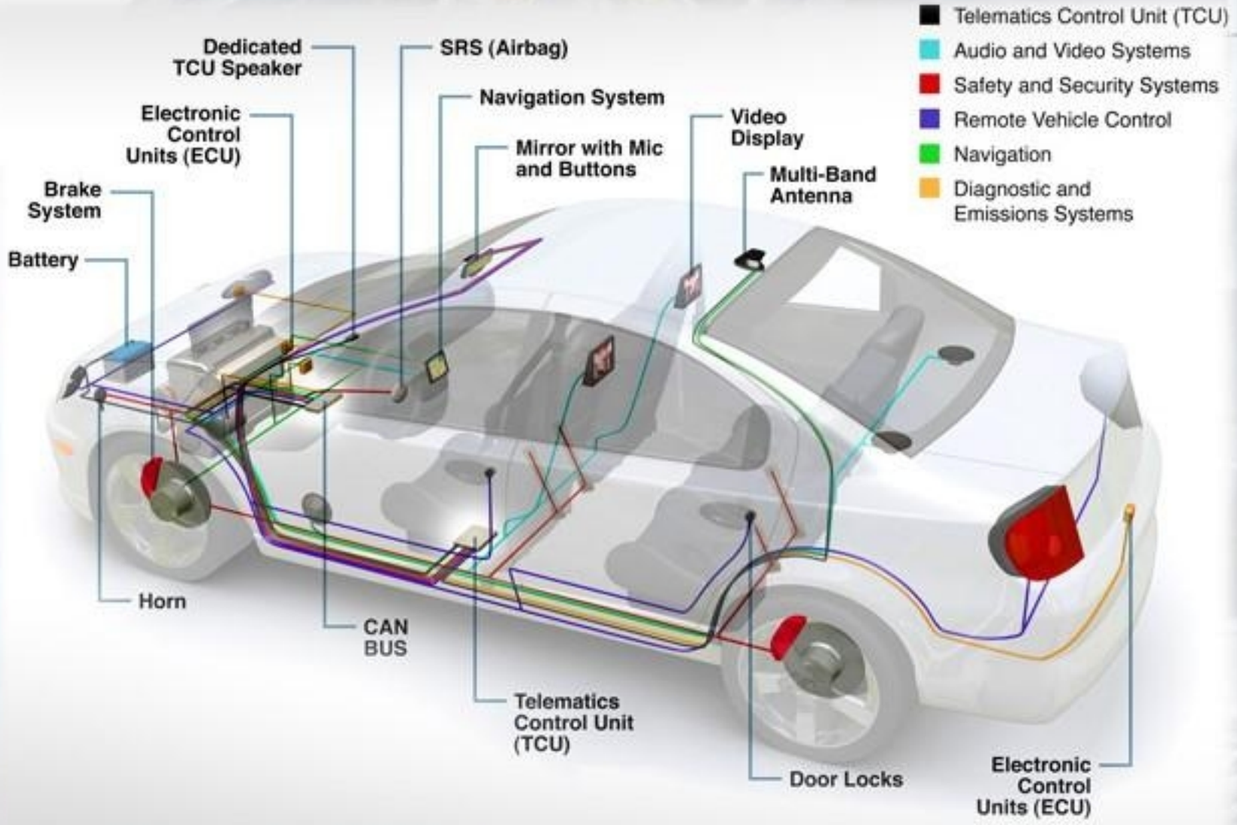
Embedded Automotive



Domain	Domain	HW Scope	View	SW Scope
OEM	Vehicle		OEM	Application Layer (f_1 f_2 ... f_n)
OEM Tier 1	Subsystem			Middleware ($task_1$ ... $task_m$ msg_1 ... msg_i)
Tier 1	ECU			Std. Services, ECU Abstraction, MCU Abstraction (MCAL), Complex Drivers
Tier 2	MCU		Suppliers	

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Automotive V Cycle

1 Vehicle requirement

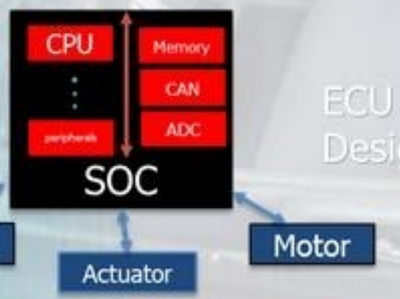
If Vehicle Validation failed

7 Vehicle Validation

2 System Design

If system Verification failed

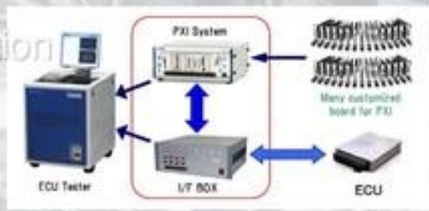
6 System Verification



3 ECU Design

If ECU Validation failed

5 ECU Verification



4 SOC Design

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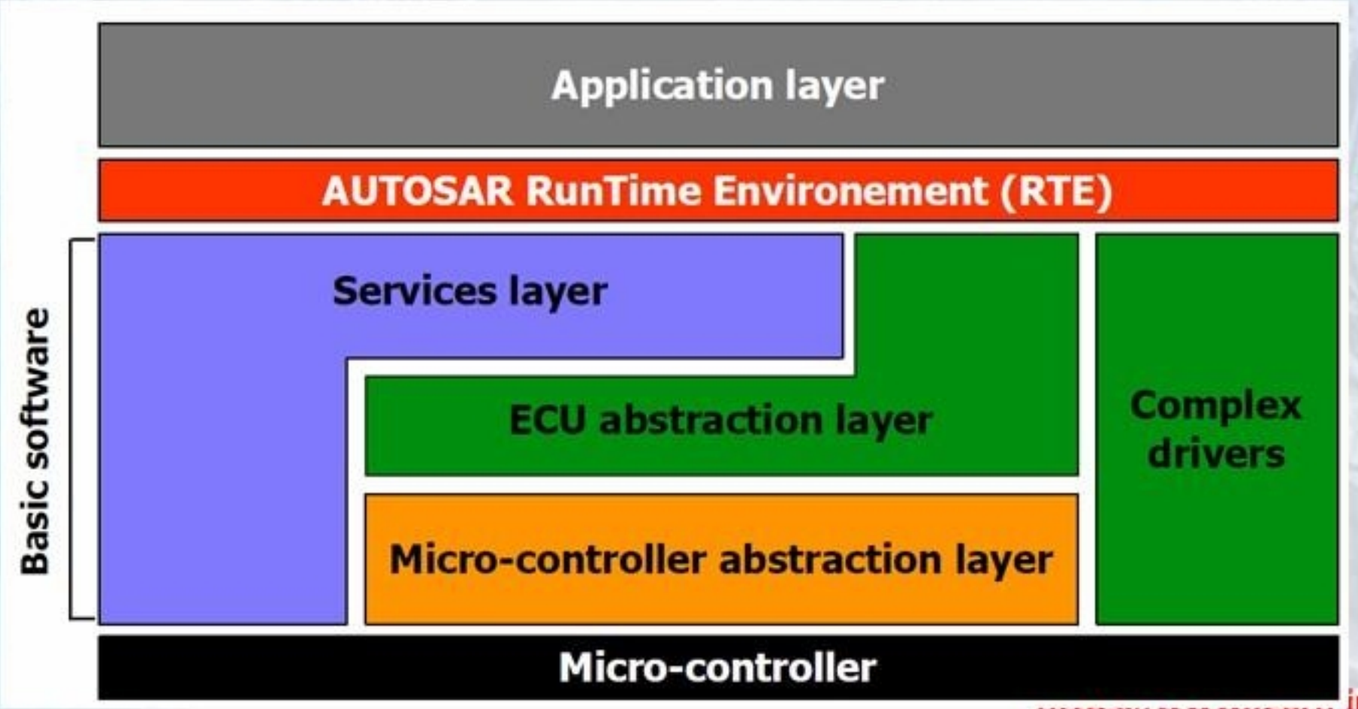
AUTOSAR

- AUTOSAR = AUTomotive Open System Architecture
- More informations on the site: http://www.autosar.org



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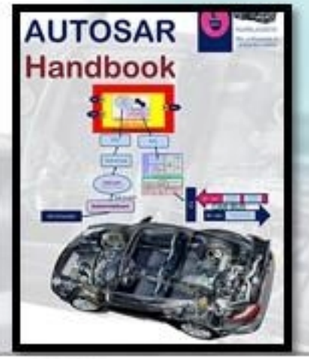
learn Embedded Automotive (AUTOSAR/RTOS) Basics



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Step 1: Study the following Parts

==========

Automotive Embedded System Part 1 (RTOS Basics)
Automotive Embedded System Part 2 (OSEK-vDX) PART1
Automotive Embedded System Part 3 (OSEK-vDX) PART2
Automotive Embedded System Part 4 (OSEK-vDX) PART3
Automotive Embedded System Part 5 (Introduction to AUTOSAR)
Automotive Embedded System Part 6 (AUTOSAR Application Layer)
Automotive Embedded System Part 7 (CAN)
Automotive Embedded System Part 8 (CANFD, TTCAN ,LIN and FlexRay)

Kindly you can find all the parts on

https://www.learn-in-depth.com/automotive

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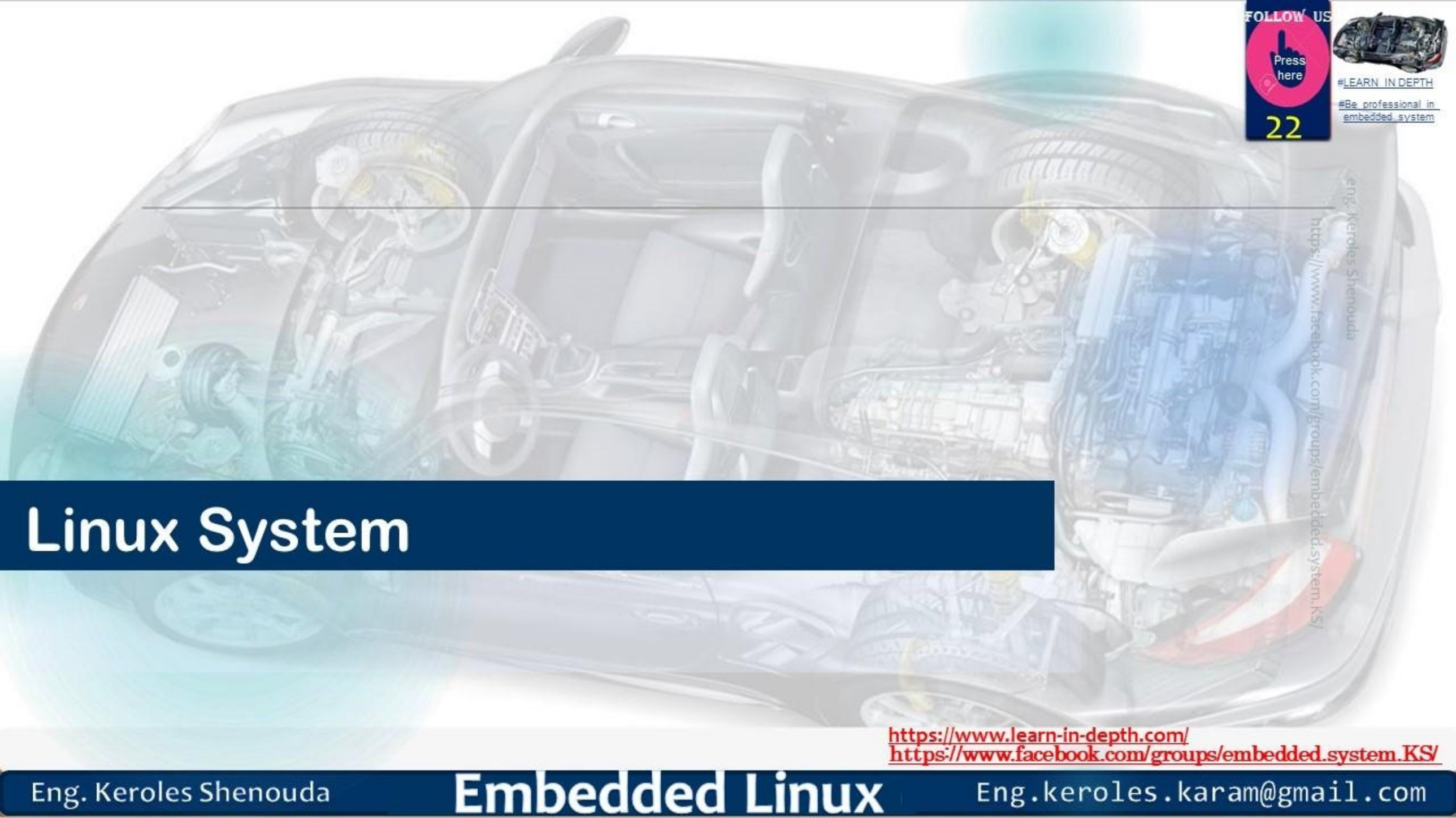

Linux System

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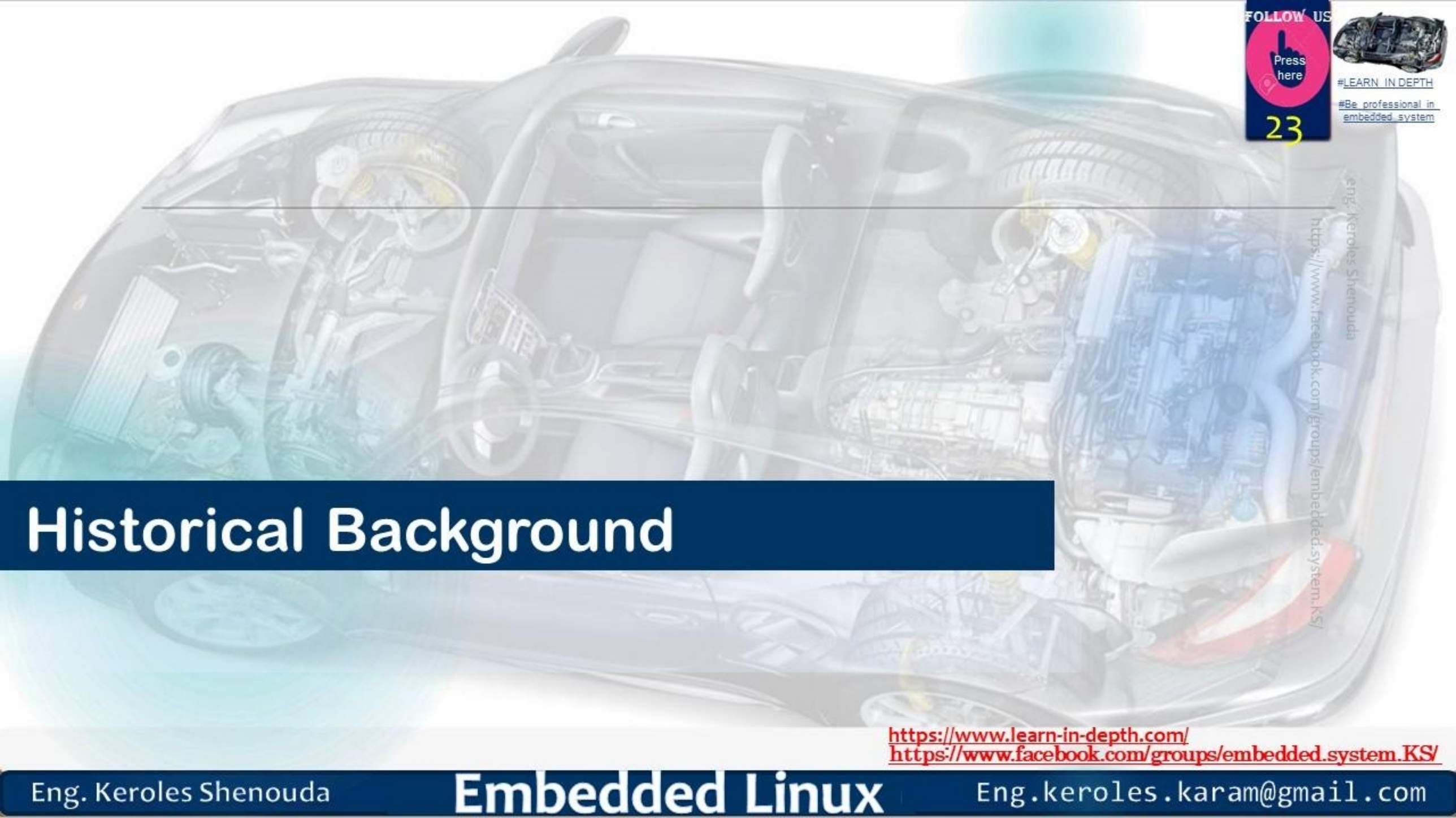

Historical Background

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Historical Background

- It started in bell Labs with terminated project for Multics Multi-user operating system
- Dennis Ritchie and Ken Thomson started to work on Unix 1969: first Implementation of Unix.
- 1972:Creation of "C" Programming Language to facilitate the porting.
- 1973: Complete rewrite of UNIX into "c"
- Richard Stallman is Believing in free Software, he formed the Free Software Foundation and Started the GNU [Gnu Not Unix] Project in 1983.

I'm doing a (free) operating system (just a hobby, won't be big and professional like gnu) for 386(486) AT clones.

(Linus Torvalds)

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What is Linux?
Linux + GNU Utilities = Free Unix

- Linux is an O/S core written by Linus Torvalds and others AND

- a set of small programs written by Richard Stallman and others. They are the GNU utilities.

http://www.gnu.org/

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What is Linux?

It's an Operating System

- Linux and Unix strive to be POSIX compliant.
- 64% of the world's servers run some variant of Unix or Linux.
- The Android phone and the Kindle run Linux.

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Linux Has Many Distributions

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Linux Has Many Distributions

- Some users uses CentOS in its Linux cluster which is a free version of RedHat Enterprise Linux with the trademarks removed

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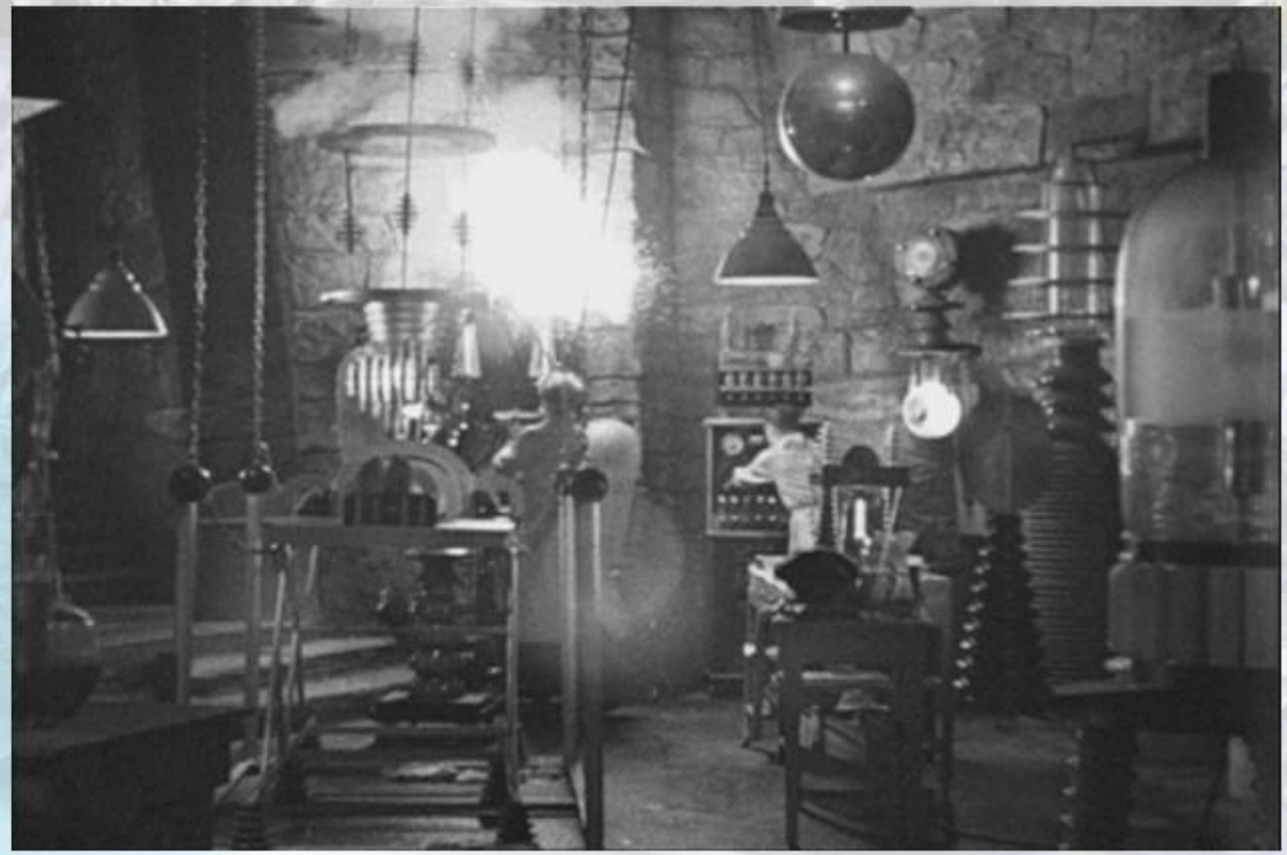
Let the Linux Lab Begin!



The Ideal Lab Facility

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How Linux is built

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https://www.youtube.com/watch?v=yVpbFMhOAwE

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Terminologies

- The term **Linux** refers to the **operating system kernel itself**
- However Linux is also used to refer to **a complete Linux system** that includes not only kernel but also libraries and application programs.
- The Linux distribution includes the basic linux system system installation and management utilities
  - Ubuntu, fedora and ….
- Linux kernel is distributed by a license called **GPL**.
- Linux kernel is a free software.
  - It means people can get Linux source code modify it use it and give away their own copies without any restrictions. However nobody can claim the ownership of outputs developed by using Linux and they cannot distribute binary.
  - only products when they distribute outputs developed by software **under GPL license.**
    - It means the **source code** should be available in addition **to the binary**.

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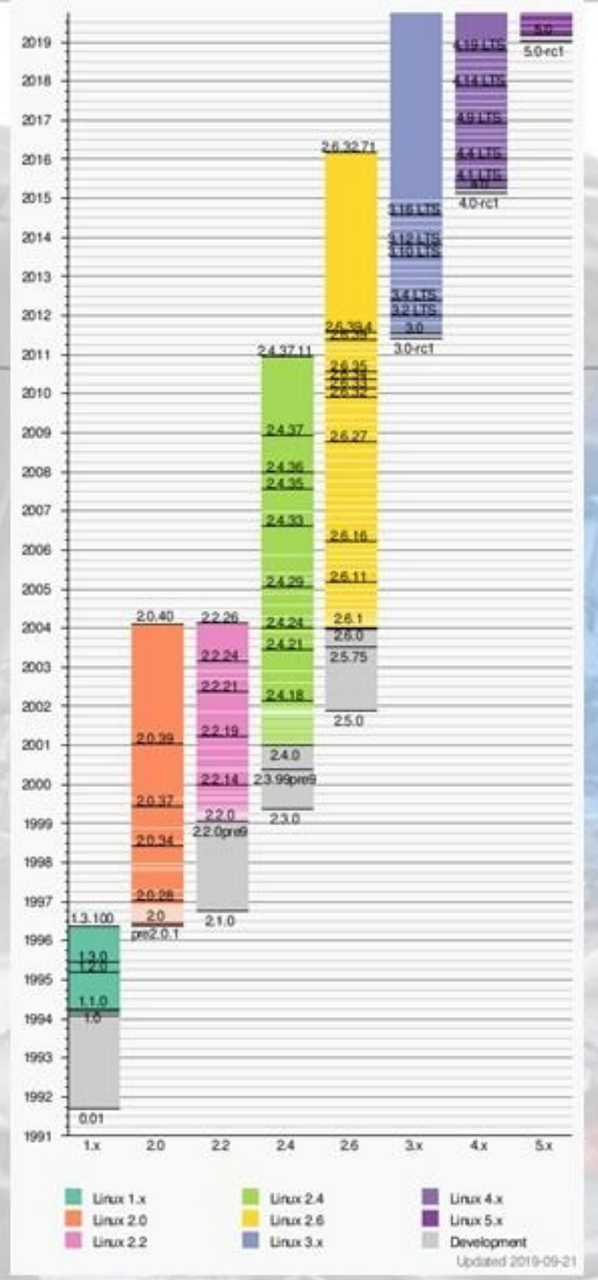
Linux version history



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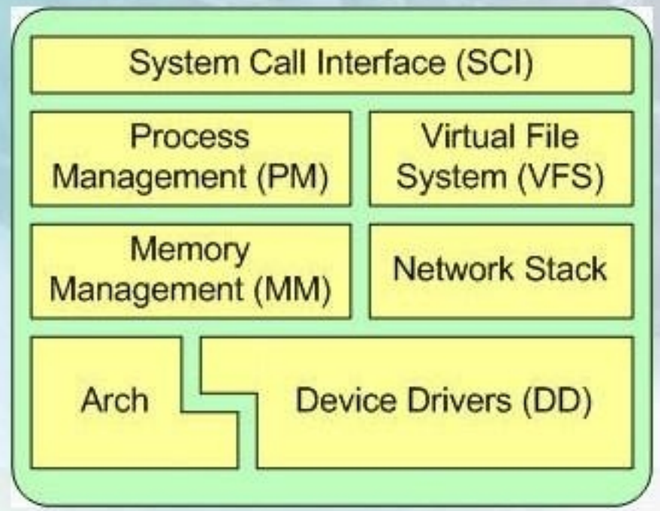
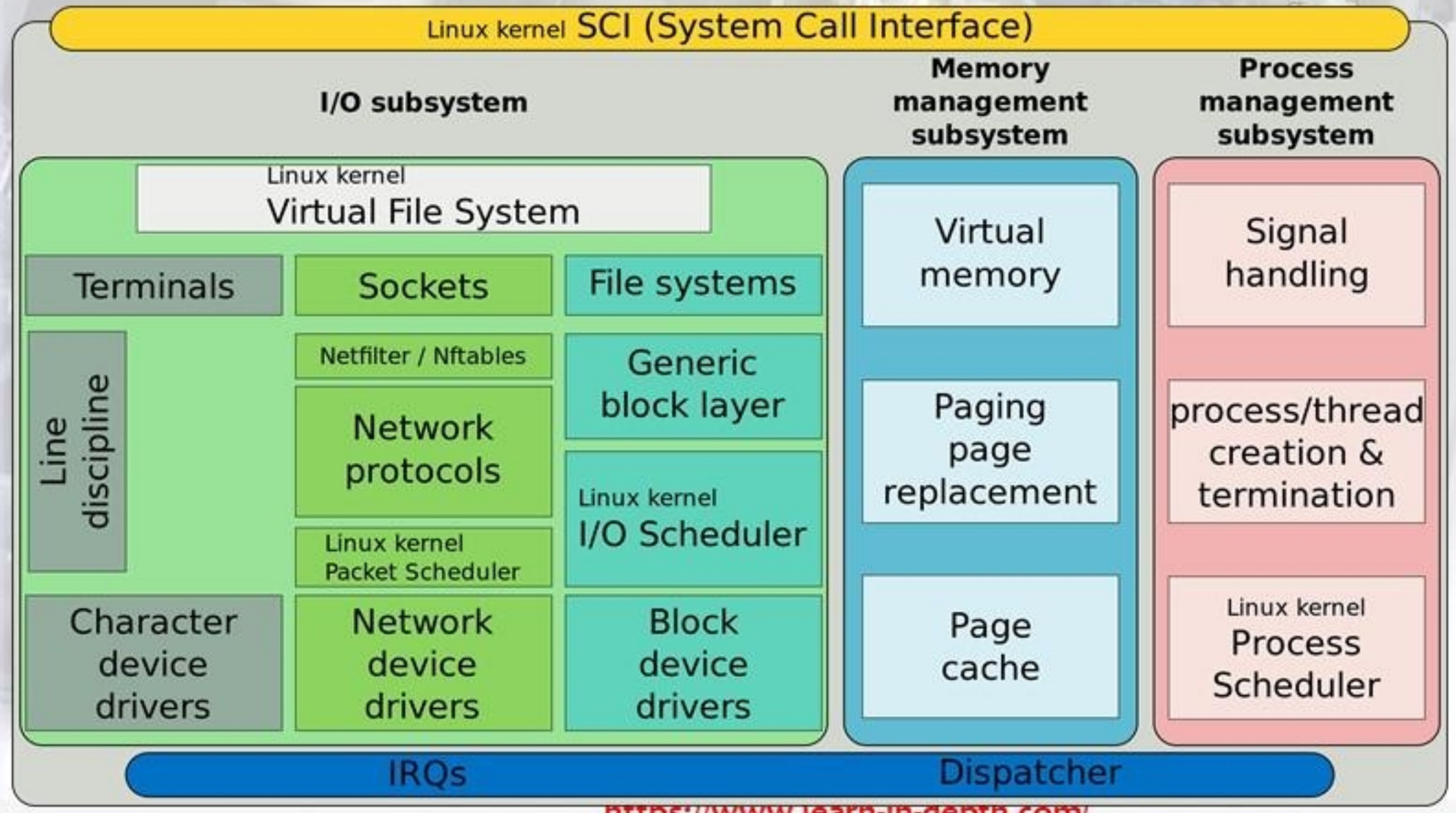
Linux kernel Components

- It is mainly composed of
  - process management
  - memory management
  - files systems
  - network protocols and
  - device drivers.





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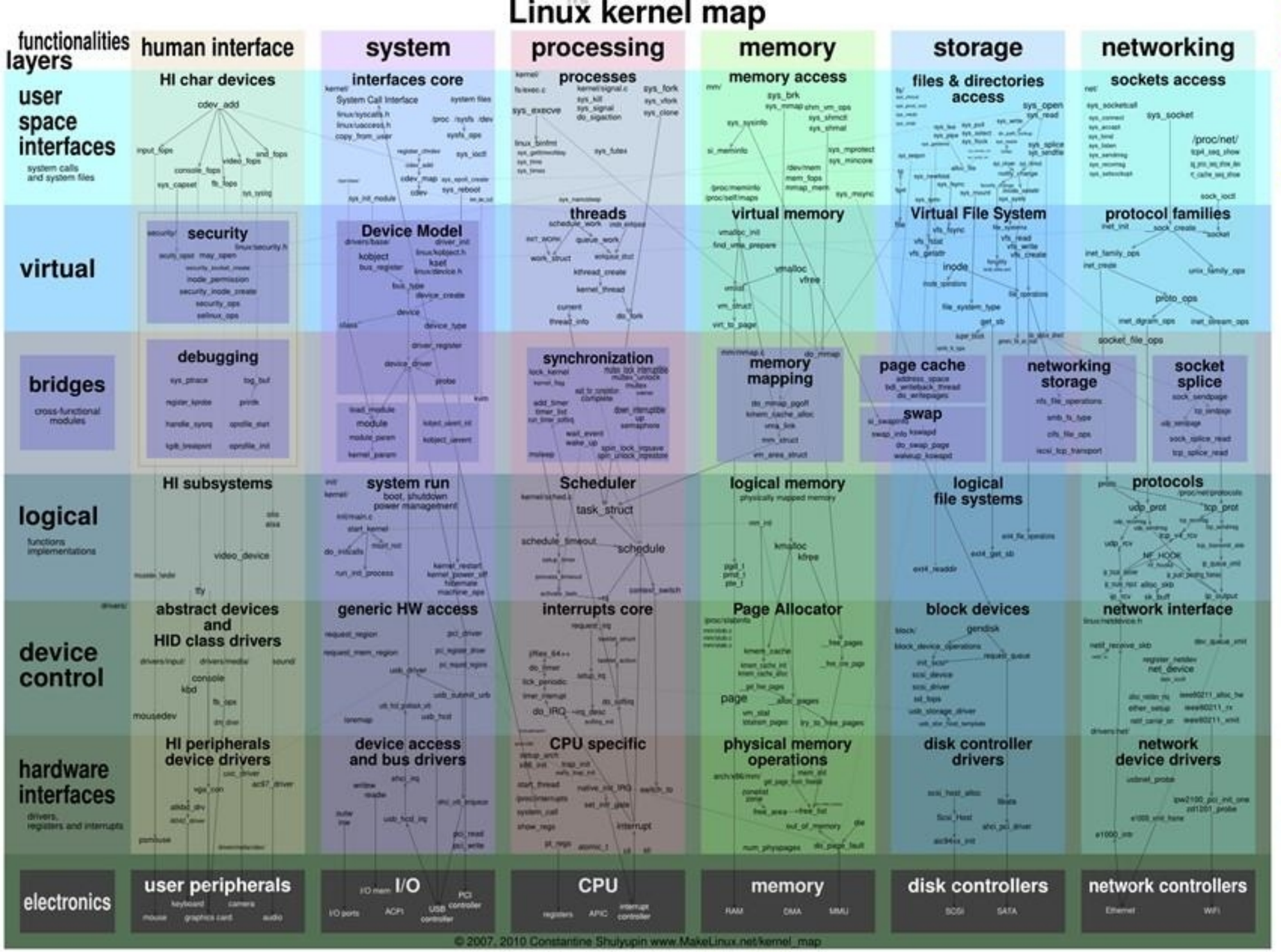
Linux kernel (Big Picture)



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http://www.makelinux.net/kernel_map/?fbclid=IwARorqSwJgnPPwu2wjxoDvGhMdKbtNPJbp6sisiXdf-ETqPvvwM-YS6goNym8

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Embedded Linux

Power ON

PreBootloader

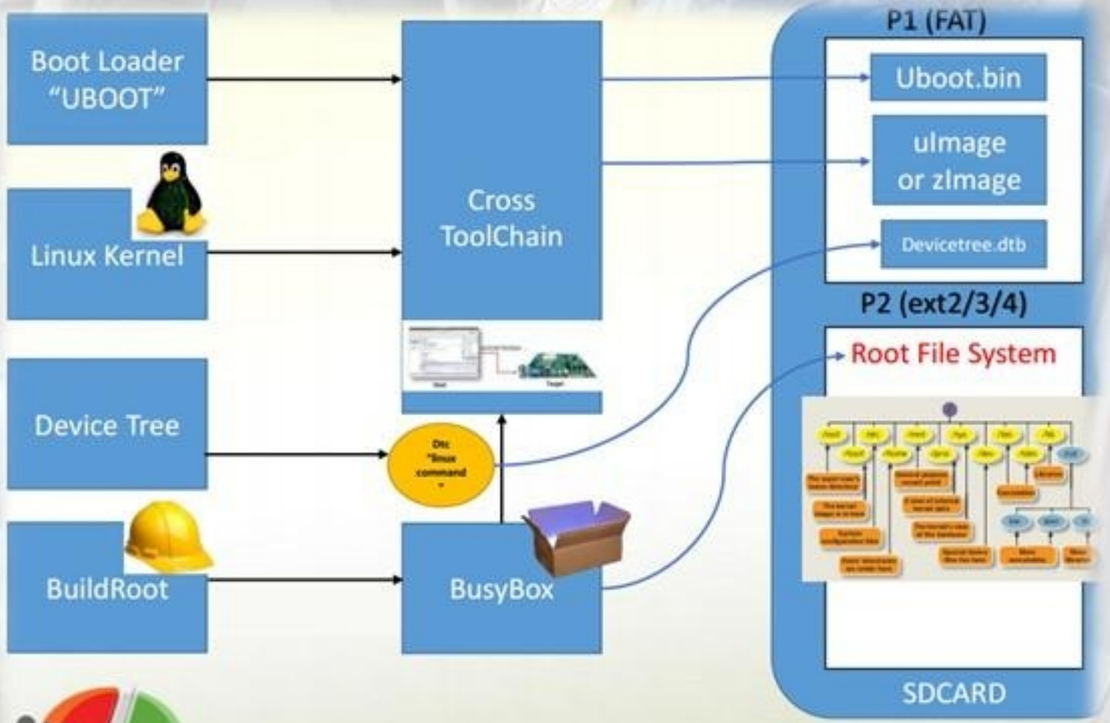
Main Bootloader "UBOOt"

Linux Kernel

Mount root FS

Invoke /sbin/init process

Linux Prompot



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Deep Learning

- **Computer Vision Applications**

1. Security systems using, for example, face recognition
2. Medical Examinations
3. Traffic Sign Recognition
4. Paper reading for the blind
5. Google's Image search

- And many others…

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Traffic Sign Recognition

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Deep Learning – Datasets

Dataset

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GTSRB

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Course Outline

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What you will learn ?

Phase 1
Understanding LINUX

Phase 2
Building and Booting LINUX

Phase 3
Linux Device Drivers and embedded Linux SW

- **Memory Management Basics**
- Loading, Linking and Address Binding
- Memory Management Concepts
- Address Binding
  - **Compile Time Binding**
  - **Load Time Binding**
  - **Execution Time Binding**
- Memory Allocation
- Fragmentation
- Contiguous and Noncontiguous Memory Allocation
- Paging
- T.L.B (Translation look-aside Buffer)
- **I/O Systems**
- **POSIX APIs**
- **Process and Threads**
- **Linux Commands**

- Buildroot
- Root FileSystem
- Linux Kernel
- Bootloader
- ToolChain

- Kernel Modules
- Linux Device Derivers
- Programming I2C, UART
- Programming GPIO
- ACCESS Display
- Advanced Topics

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Virtual Platforms

- VPs are software architectural-level models of complete real systems that can include:
- Processor(s)
- Peripheral components
- Memories
- Interconnect

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Virtual Platforms Benefits

- Hardware/software co-development at ESL (Electronic System Level)
- Efficient software development, debug, and performance analysis of application code, drivers, etc.
- Create early platform for architecture exploration and trade-off analysis
- Validate system functionality before implementation
- Easier, shorter, and less risk final integration stage where real silicon hardware is used
- Faster time to market and lower cost

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QEMU

- QEMU is a generic and open source machine emulator and virtualizer.
- When used as a machine emulator, QEMU can run OS and programs made for one machine (e.g. an ARM machine) on a different machine (e.g. your own PC).
- Machine ≡ Board ≡ Platform
- www.qemu.org

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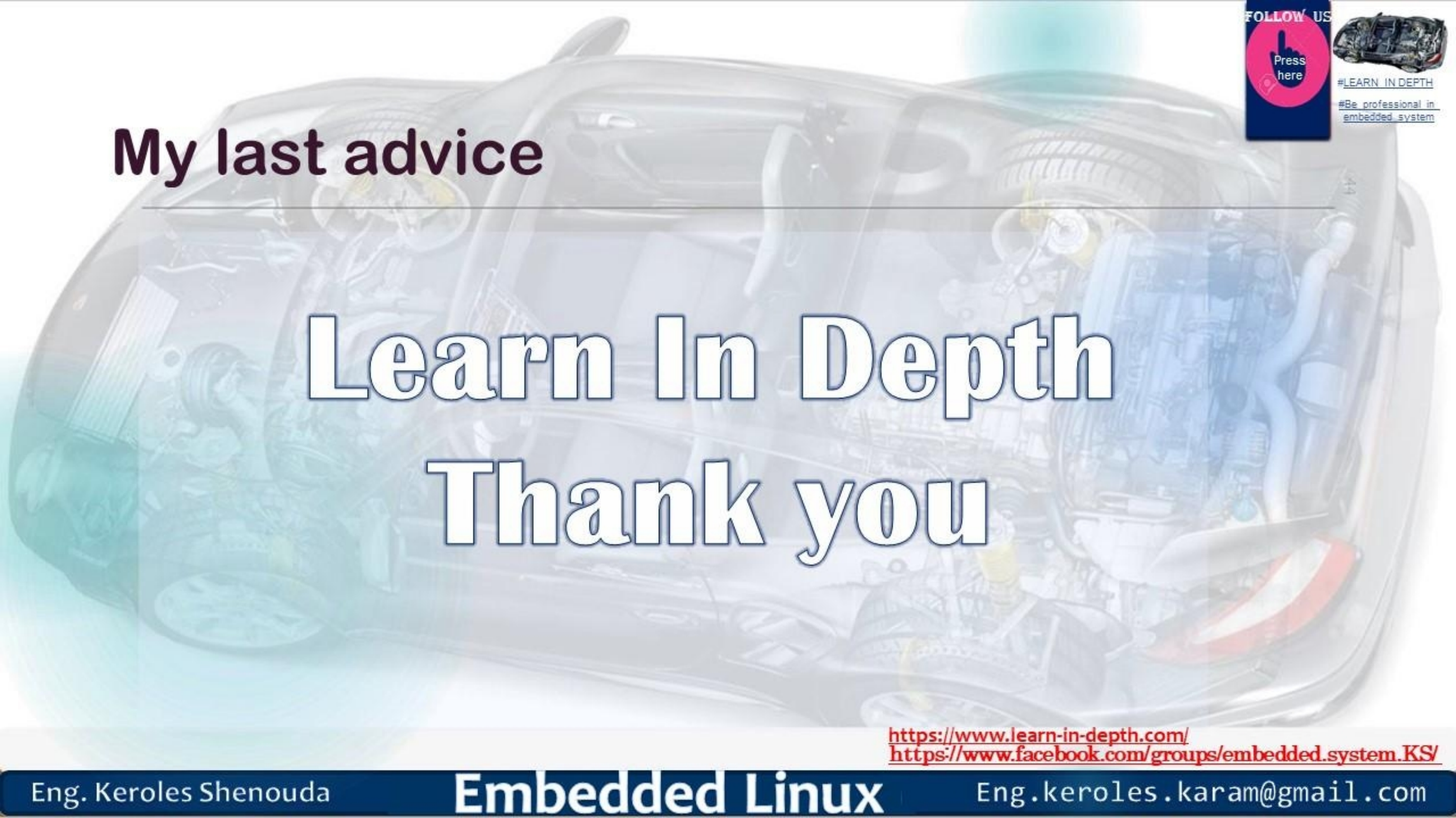

My last advice

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Thank you

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Define Loading, Linking and Address Binding

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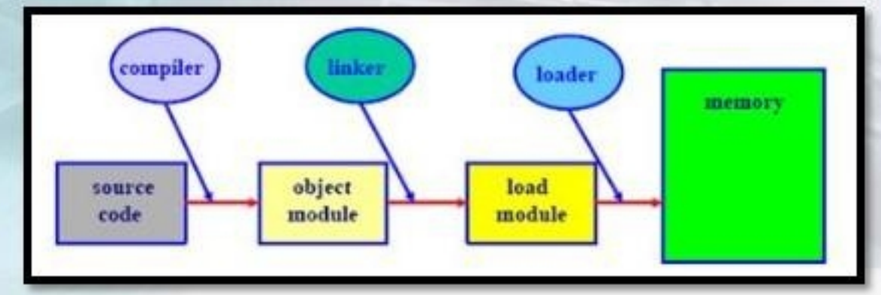
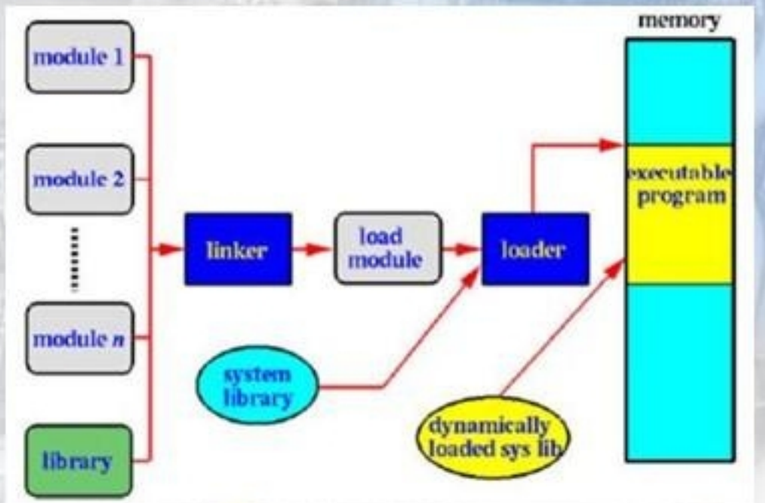
Define Loading, Linking and Address Binding

- Loading:
  - Bringing **Program** from **Secondary Memory** to main Memory
- Linking:
  - Establishing Linking between all modules of program (object files and libs) to one executable file according to Linker script.
  - Types of linking Static and dynamic Linking.





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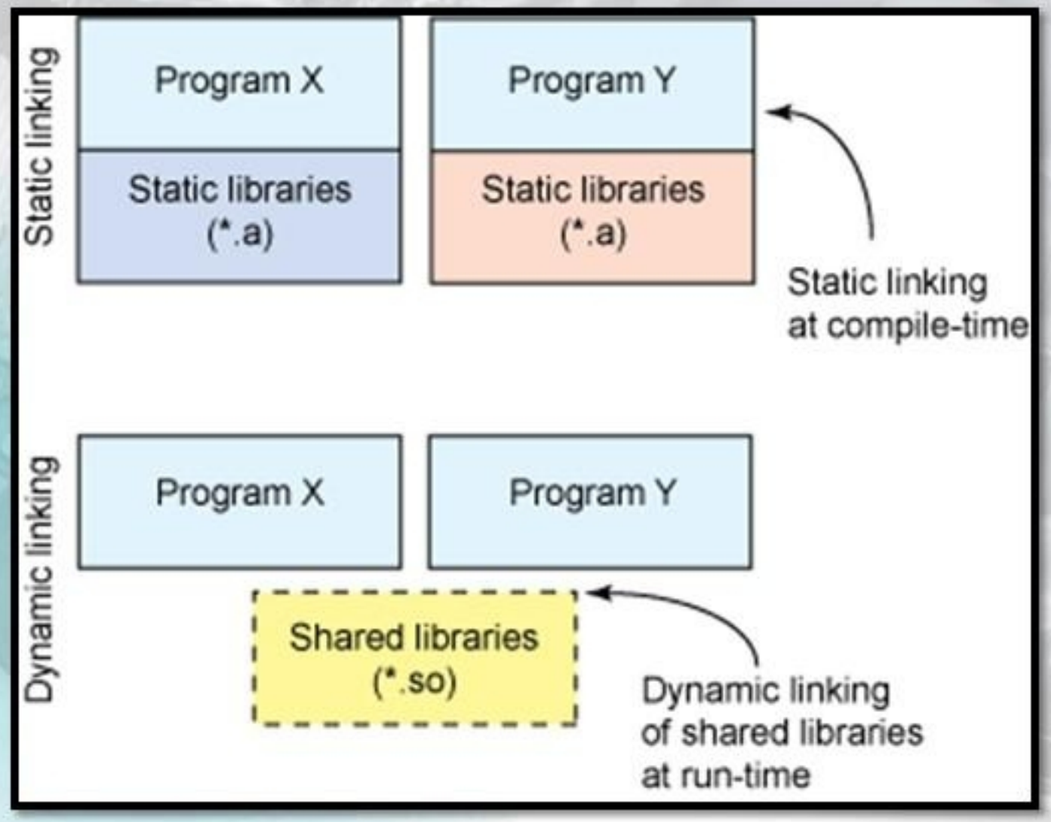
Static Vs dynamic linking



STATIC LINKING VERSUS DYNAMIC LINKING

STATIC LINKING	DYNAMIC LINKING
Process of copying all library modules used in the program into the final executable image	Process of loading the external shared libraries into the program and then bind those shared libraries dynamically to the program
Last step of compilation	Occurs at run time
Statistically linked files are larger in size	Dynamically linked files are smaller in size
Static linking takes constant load time	Dynamic linking takes less load time
There will be no compatibility issues with static linking	There will be compatibility issues with dynamic linking

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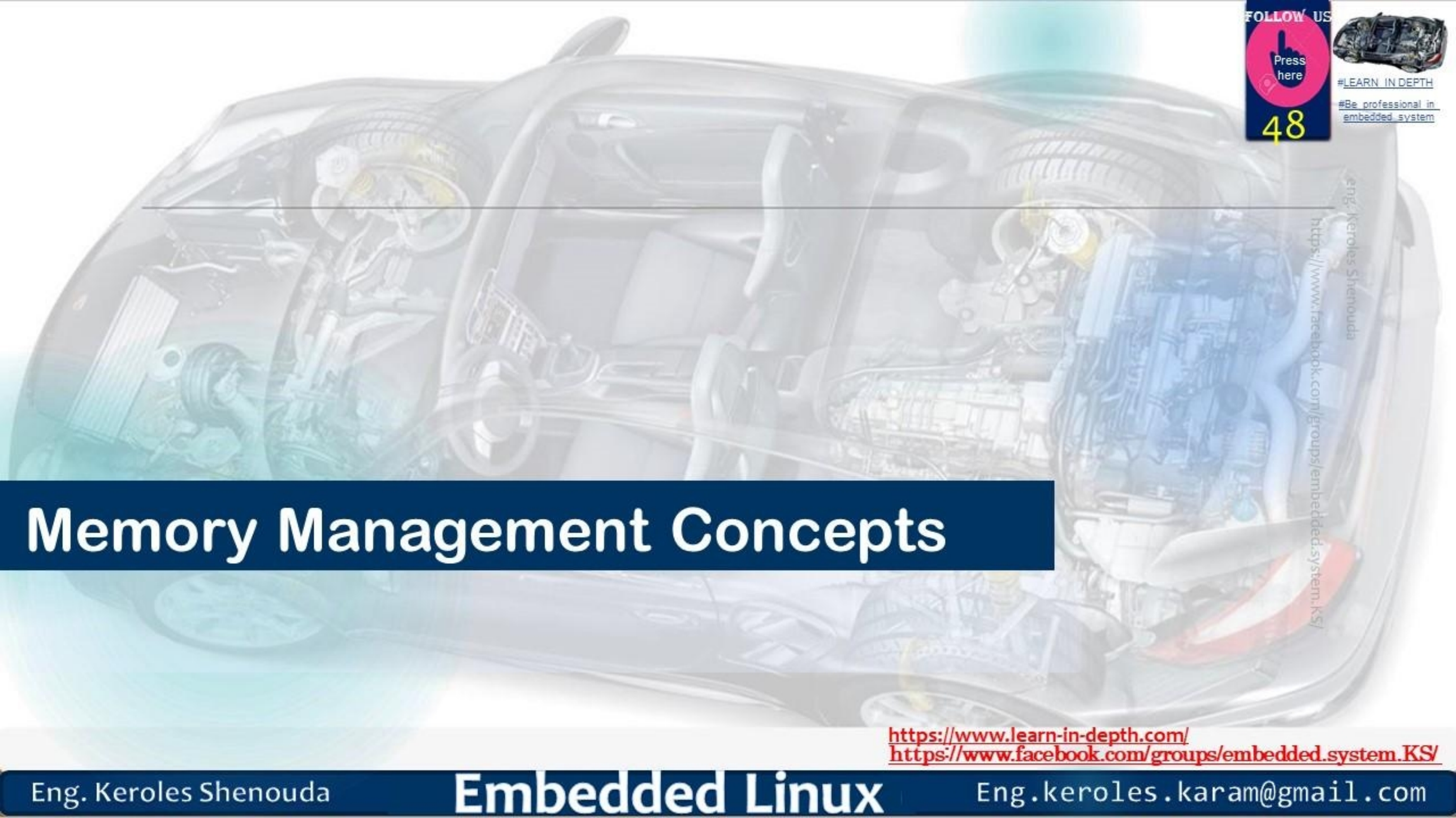

Memory Management Concepts

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Address Binding

- Address binding is **the process of mapping** the program's logical or virtual addresses to corresponding physical or main memory addresses.
- This Process moves between memory and the storage device like disk or sdcard partition during execution.

Resolve the **symbolic names**

Each *symbolic name* should be converted *to memory address*

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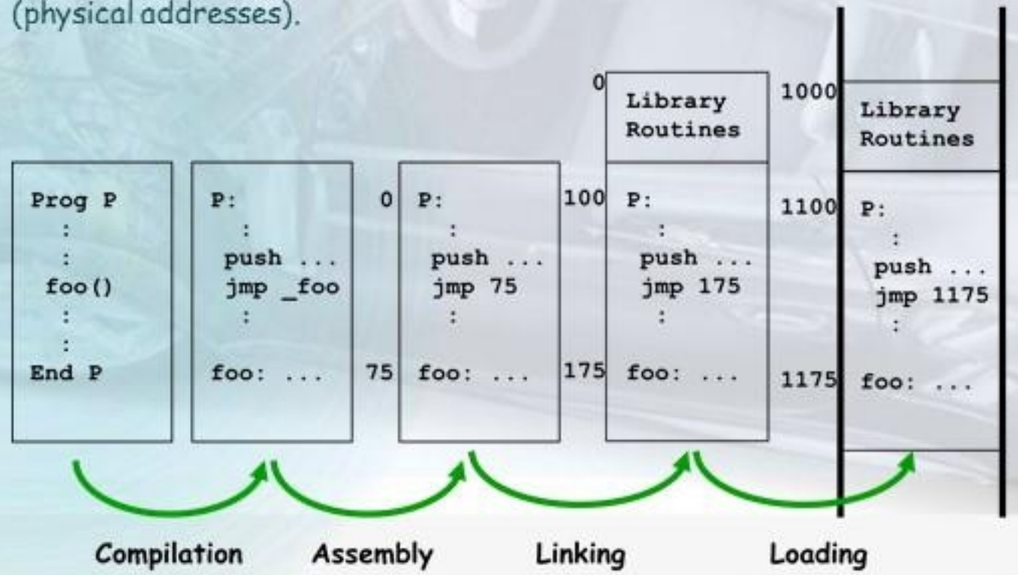
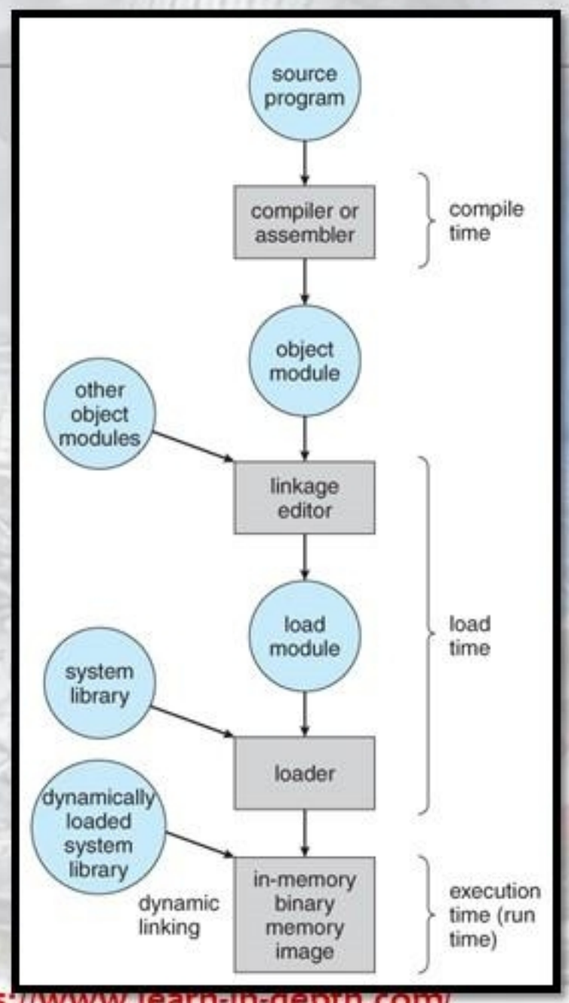
Types of Address

- Symbolic Addresses
  - Eg,variable names (such as variable i)
- Relocateable Addresses
  - A compiler typically binds symbolic addresses to relocatable addresses (interms of offsets).
- Absolute Addresses
  - The linkage editor or loader binds relocatable addresses to absolute addresses (physical addresses).





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Address Binding can happen at three different stages

Compile Time Binding

if program location is fixed and known ahead of time

Load Time Binding

if program location in memory is unknown until run-time AND location is fixed

Execution Time Binding

if processes can be moved in memory during execution
Requires hardware support!

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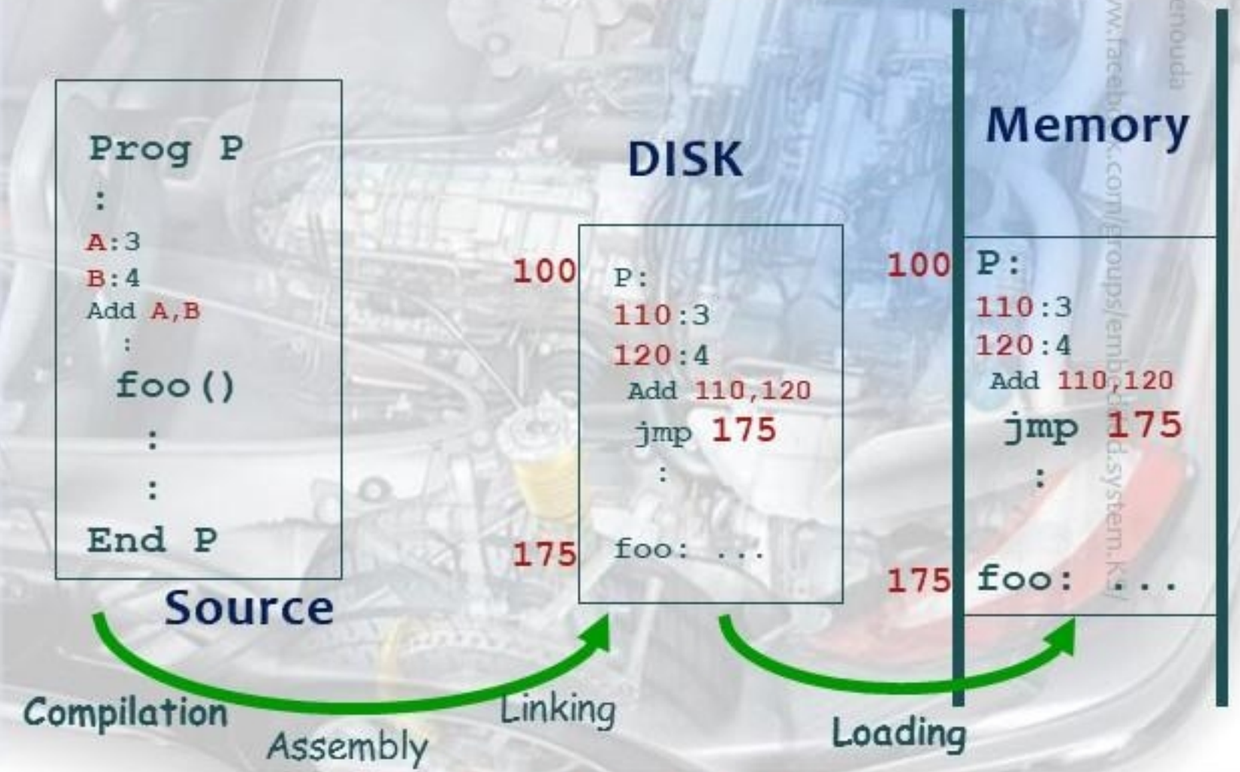
Compile Time Binding

- if memory **location** is **fixed** and **known** at compile time, absolute code with absolute address can be generated.
- Must Recompile Code if starting location changed.



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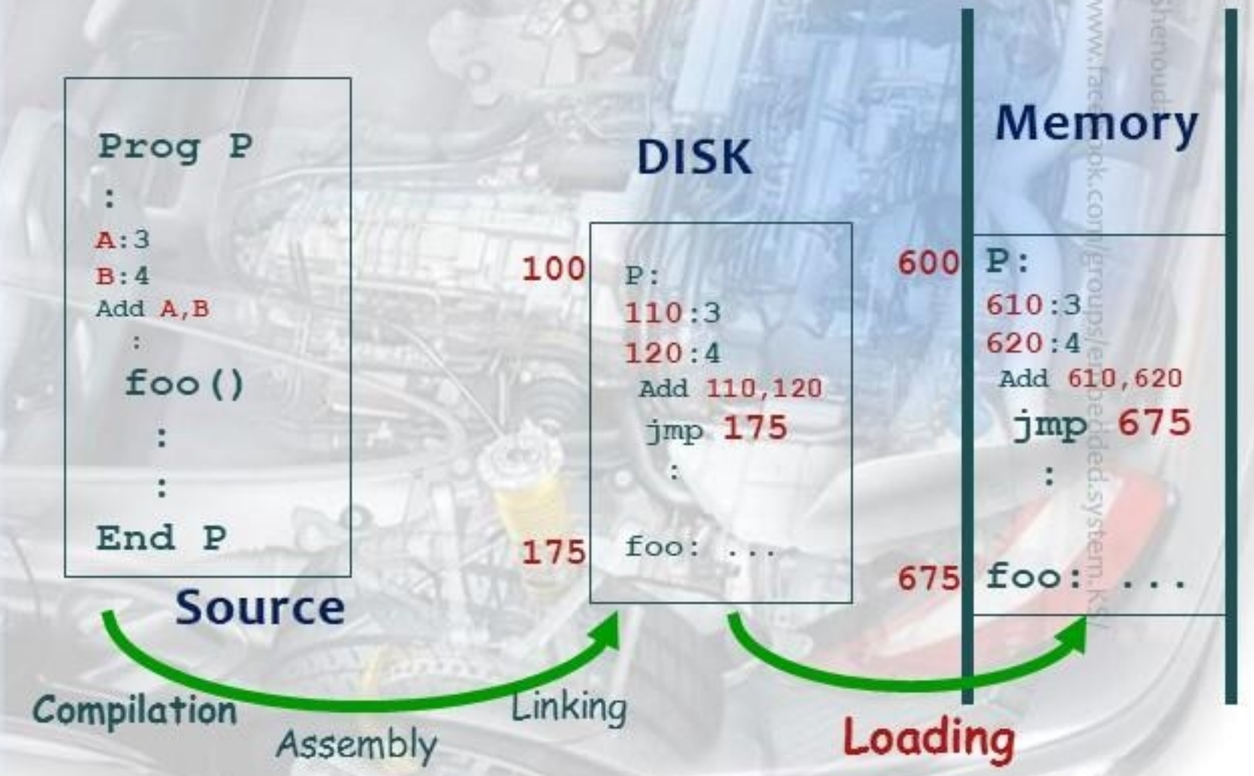
Load Time Binding

- if Memory location in memory is **unknown** at compile time AND location is fixed.
- The relocatable code with relative address can be generated.
- Binding is done when the program is **loaded** into the memory
- It is no need to recompile the program even **the starting location changes into the memory, as it needs only reload.**



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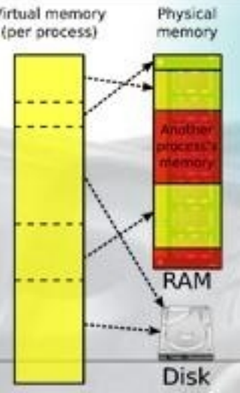
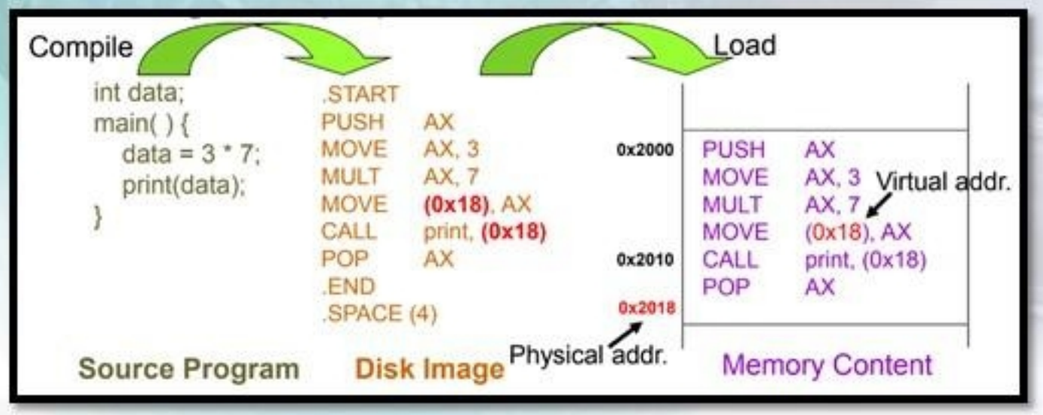
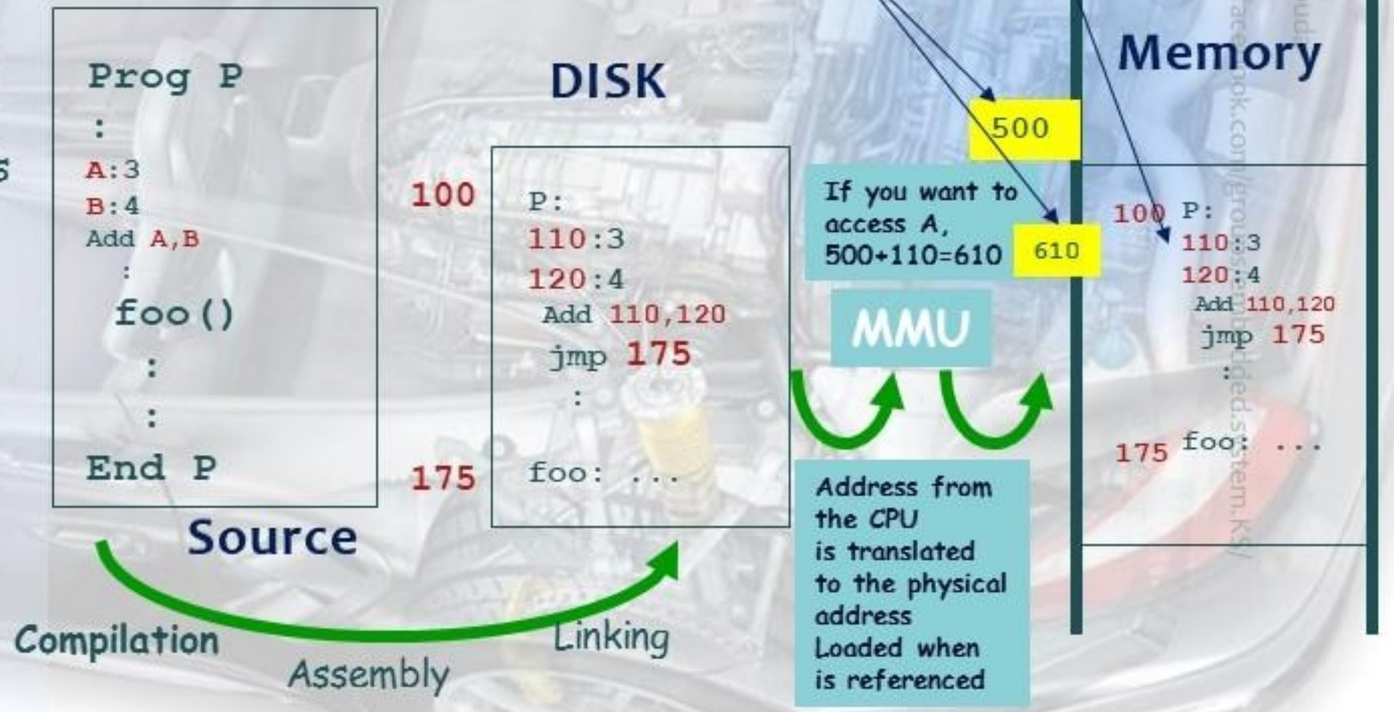
Execution Time Binding



- if processes can be moved in memory during execution
- Binding is delayed until **run time**
- Requires hardware support! (MMU) for address mapping
- Whenever CPU generates the address, binding is checked.
- Most general purpose OS use this method





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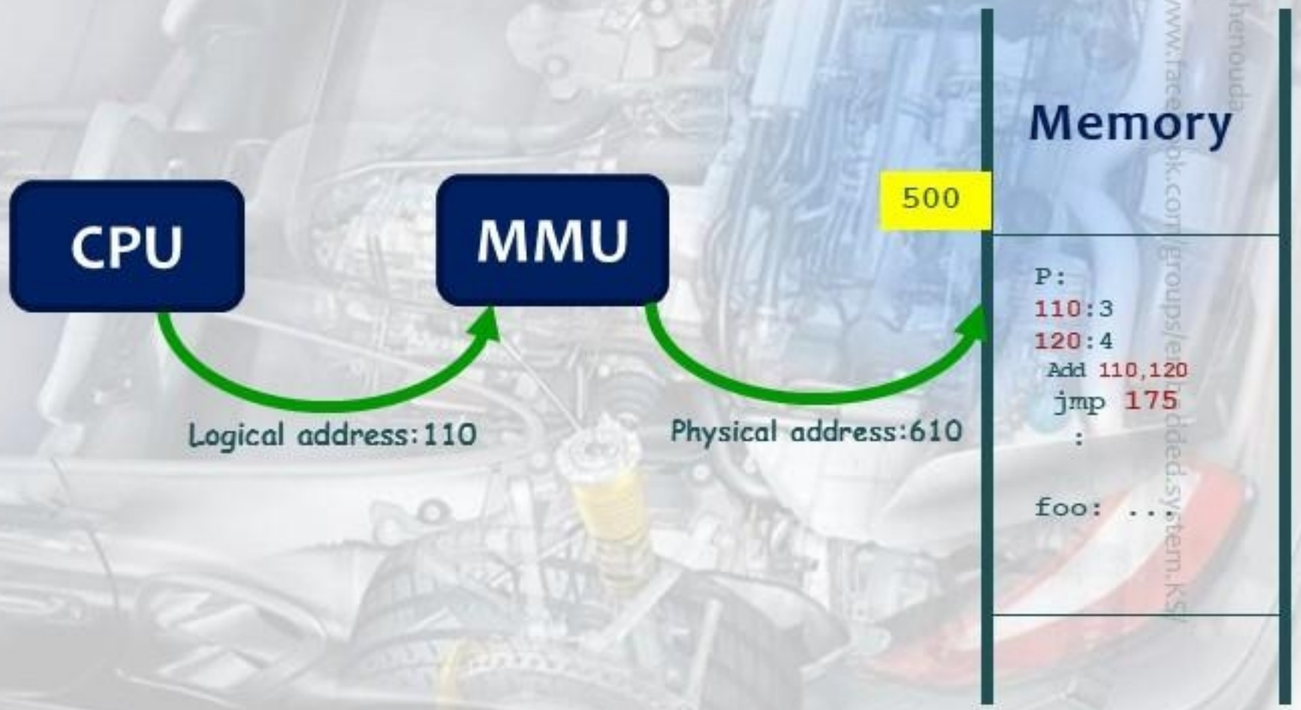
Memory Management Unit (MMU)

- Logical address-
  - Generated by the CPU
- Physical address-
  - Address seen by the memory unit
- CPU tries to access symbolic names via their logical addresses but uses physical address, thus logical addresses need to be changed to physical addresses by the MMU.



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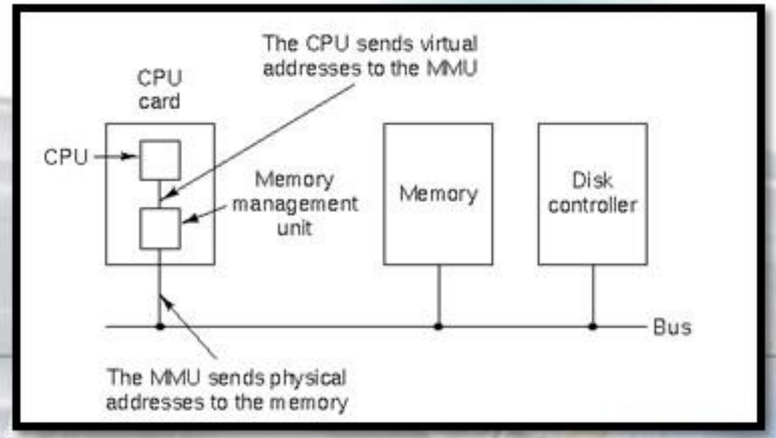
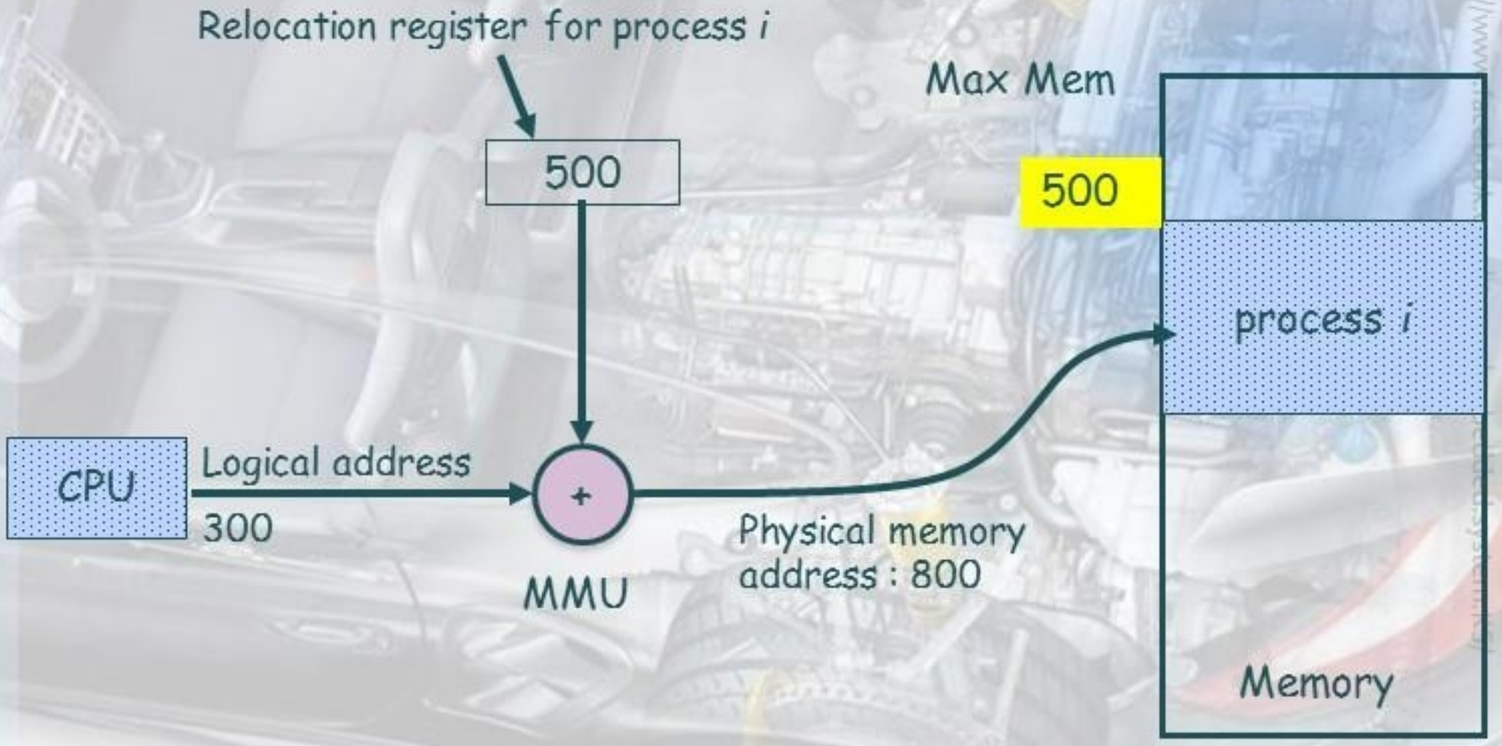
Memory Management Unit (MMU) Cont.



- MMU is the **Hardware device** that maps **virtual** to **physical** address.
- MMU contains ***base address register*** for running process
- Program & CPU
  - deal with logical address, but never sees physical address.



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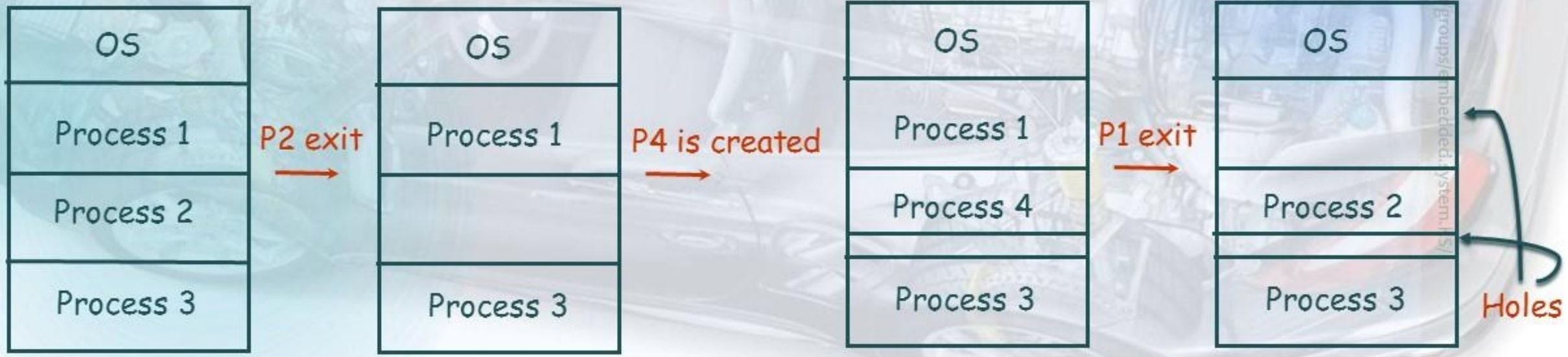
Memory Allocation

- Operating Systems occupies a certain part of memory till the system power is turned off.
- processes occupy or release memory space depending on creation and termination.
- Hole: is a large block of *available memory*.
- Holes of various size are **scattered** throughout memory.



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Memory Allocation Cont.

- When a process is created, it is allocated in a large enough hole.
- Operating system should continuously maintains information about
  - Allocated partitions
  - Free partitions (hole)

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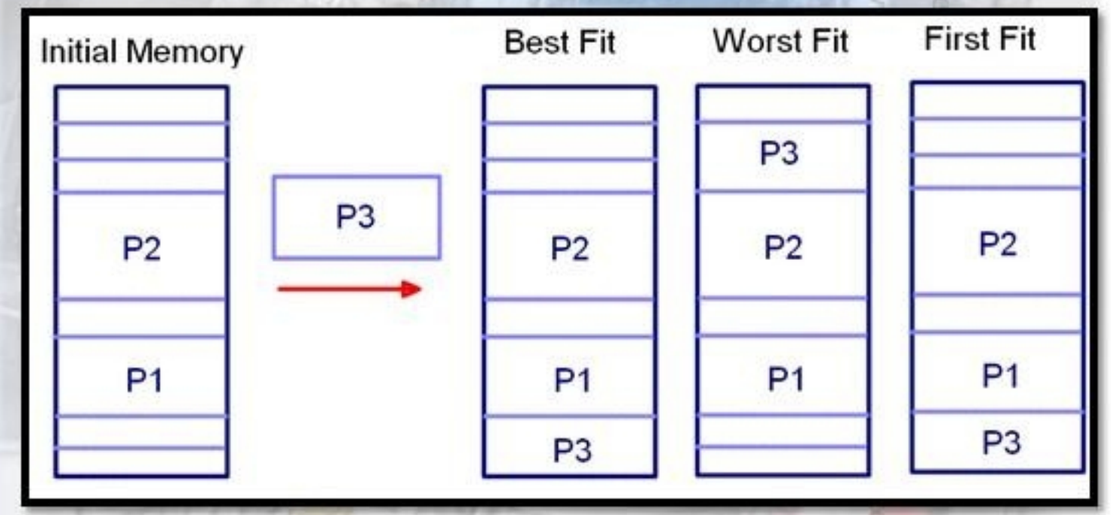
Dynamic Allocation problem

- How to satisfy a request of size *n* from a list of free holes.
- There are three algorithms:
  - **First-fit**: Allocate the *first* hole that is big enough.
  - **Best-fit**: Allocate the *smallest* hole that is big enough; must search entire list, unless ordered by size. Produces the smallest leftover hole.
  - **Worst-fit**: Allocate the *largest* hole; must also search entire list. Produces the largest leftover hole.
- First-fit and best-fit better than worst-fit in terms of speed and storage utilization.



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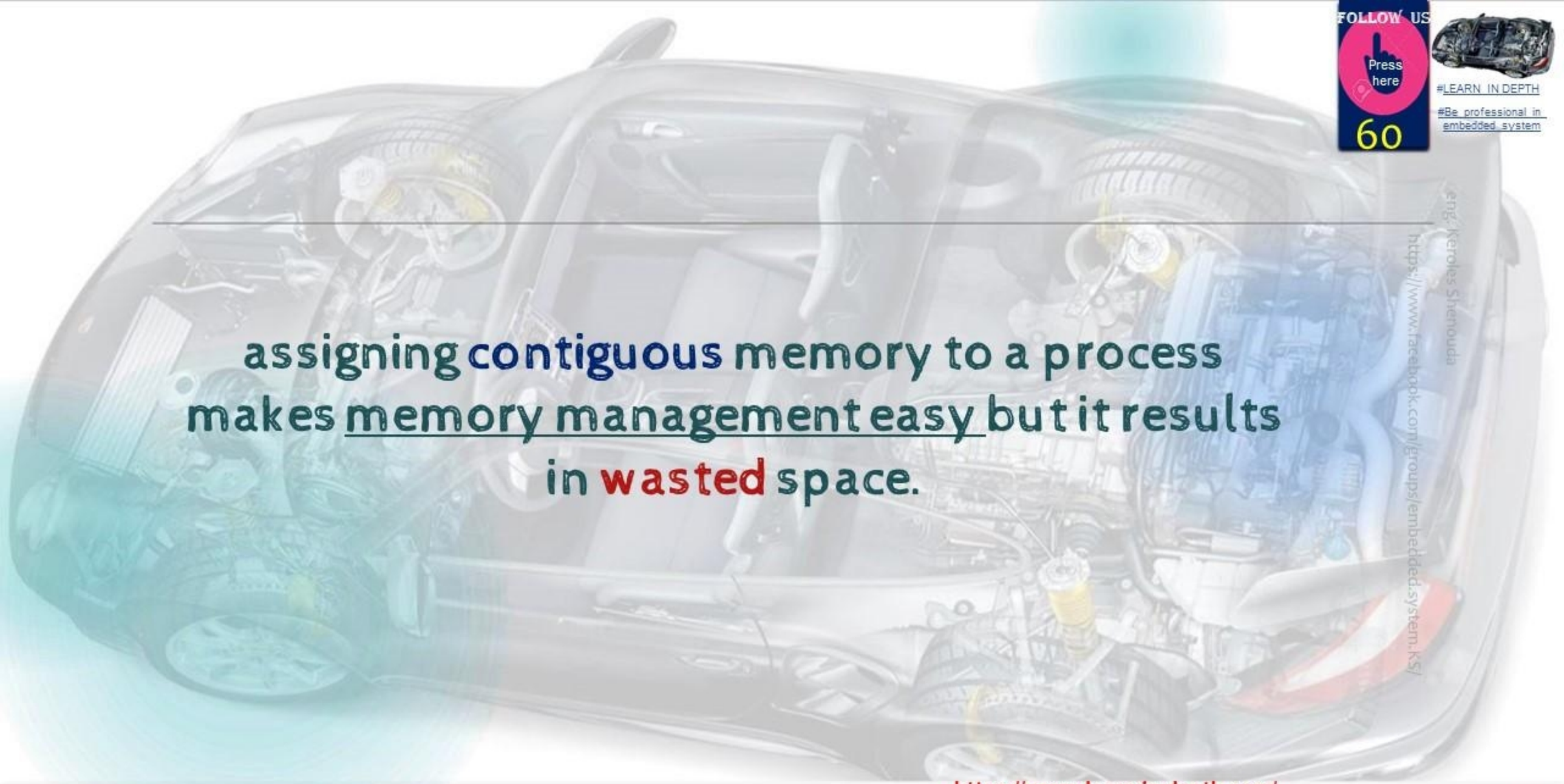

assigning contiguous memory to a process makes memory management easy but it results in wasted space.

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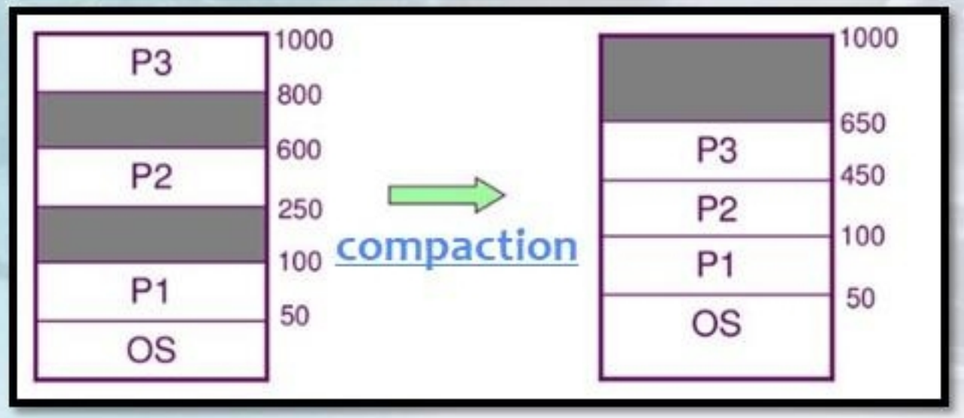
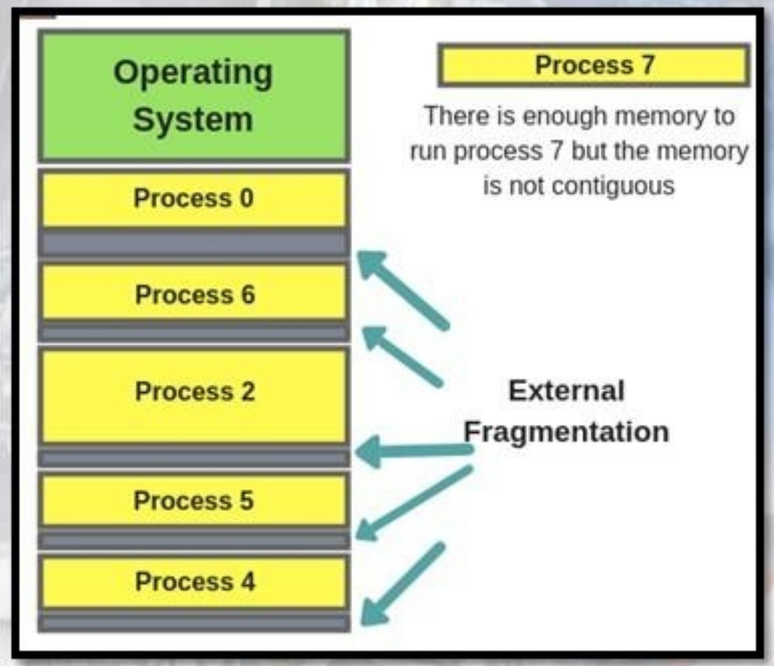
Fragmentation

- External Fragmentation
  - Total free memory space exists to satisfy a request, **but it is not contiguous**
  - Can be reduced by **compaction:**
    - Places all free memory together in one large block.





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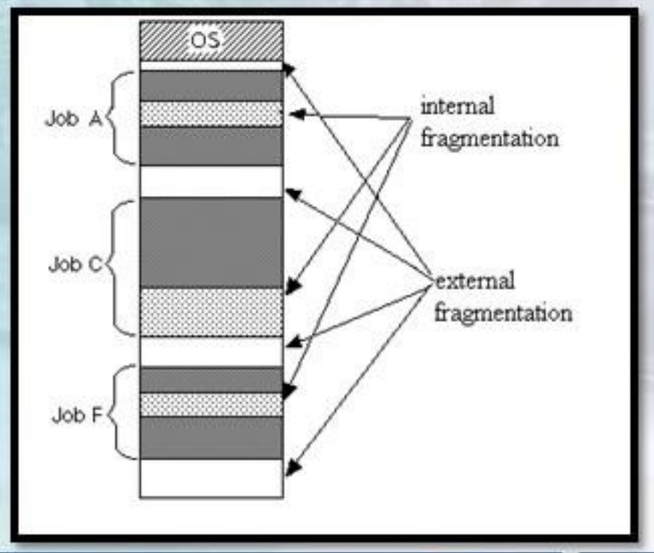
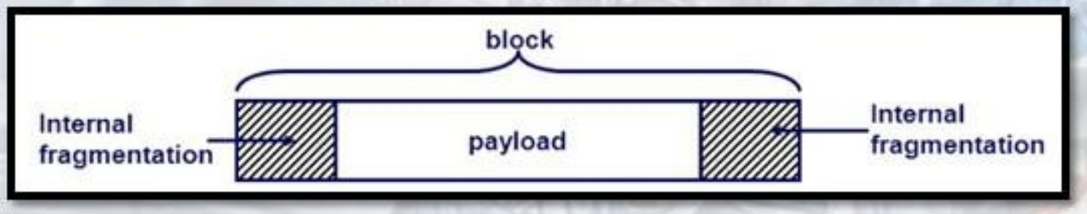
Fragmentation Cont.

- Internal Fragmentation
  - The allocated memory may be slightly larger than requested memory.
  - For some block, internal fragmentation is difference between the block size and the payload size.
  - Size partition is internal to a partition, but is not used.





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Internal Vs External Fragmentation

INTERNAL FRAGMENTATION VERSUS EXTERNAL FRAGMENTATION	
INTERNAL FRAGMENTATION	EXTERNAL FRAGMENTATION
A form of fragmentation that arises when there are sections of memory remaining because of allocating large blocks of memory for a process than required	A form of fragmentation that arises when there is enough memory available to allocate for the process but that available memory is not contiguous
Memory block assigned to a process is large - the remaining portion is left unused as it cannot be assigned to another process	Memory space is enough to reside a process, but it is not contiguous. Therefore, that space cannot be used for allocation
Solution is to assign partitions which are large enough for the processes	Compaction or shuffle memory content is the solution to overcome this

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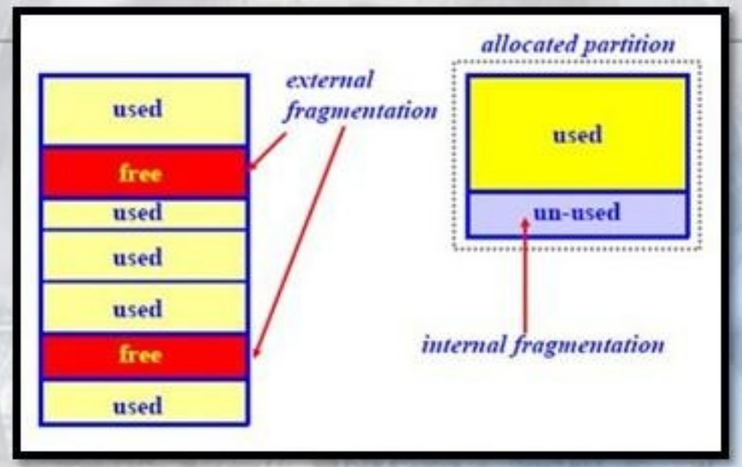

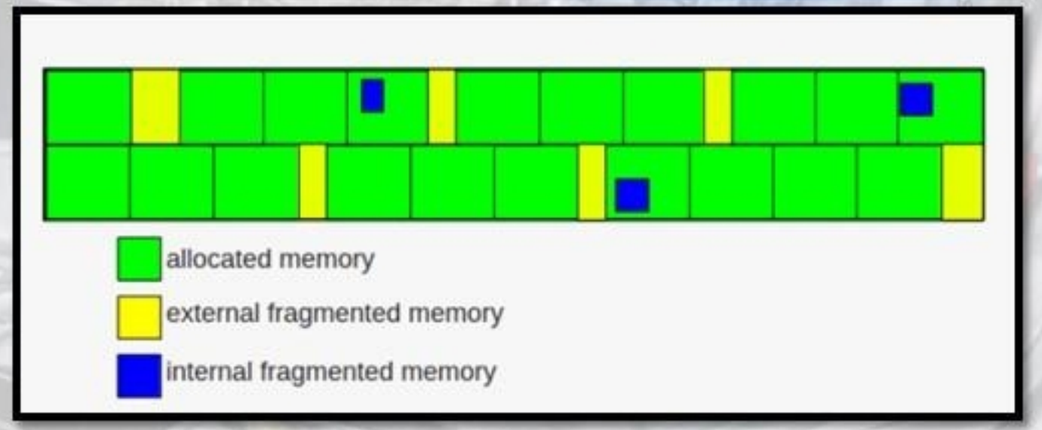

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Summary ☺

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Address Binding

Address binding is **the process of mapping** the program's logical or virtual addresses to corresponding physical or main memory addresses

Compile Time Binding

if memory **location** is **fixed** and **known** at compile time, absolute code with absolute address can be generated.

Load Time Binding

if Memory location in memory is **unknown** at compile time AND location is fixed.
The relocatable code with relative address can be generated.
Binding is done when the program is **loaded** into the memory

Execution Time Binding

if processes can be moved in memory during execution Binding is delayed until **run time**

Requires hardware support! (**MMU**) for address mapping

MMU is the **Hardware device** that maps **virtual** to **physical** address.

Dynamic Allocation

There are three algorithms:
First-fit, **Best-fit** and **Worst-fit**

Problem

Internal Vs External Fragmentation

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