EMBRY-RIDDLE
Aeronautical University
DAYTONA BEACH, FLORIDA

MemoryRanger Prevents Hijacking FILE_OBJECT structures in Windows Kernel

Igor Korkin

2019 ADFSL Conference

WHOAMI

- MEPhI Alumni, PhD in Cyber Security
- Area of interest is Windows Kernel security:
  - Memory Forensics
  - Rootkits Detection
  - Bare-Metal Hypervisors
- Fan of cross-disciplinary research - igorkorkin.blogspot.com
- Love traveling and powerlifting - igor.korkin

AGENDA

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- FILE_OBJECT hijacking: details and demo
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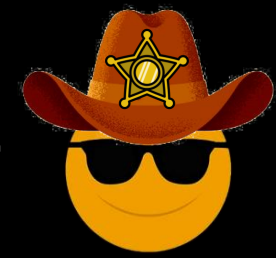

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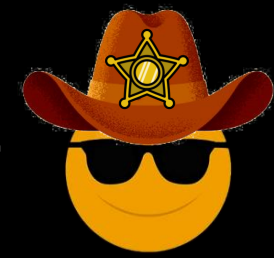

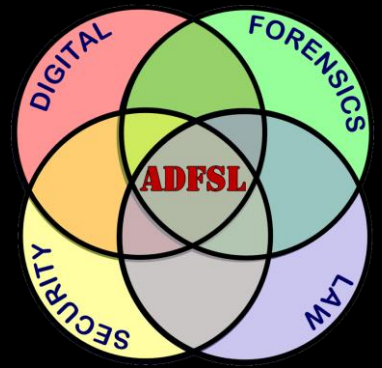

File Manager in Kernel Mode

COMPANY BUDGET 2019

	Budget
Team A	$3,000,000
Team B	$7,000,000


Document1 - Word
File
Share
COMPANY BUDGET 2019
Budget
Team A
$3,000,000
Team B
$7,000,000
Page 1 of 1
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ZwCreateFile routine

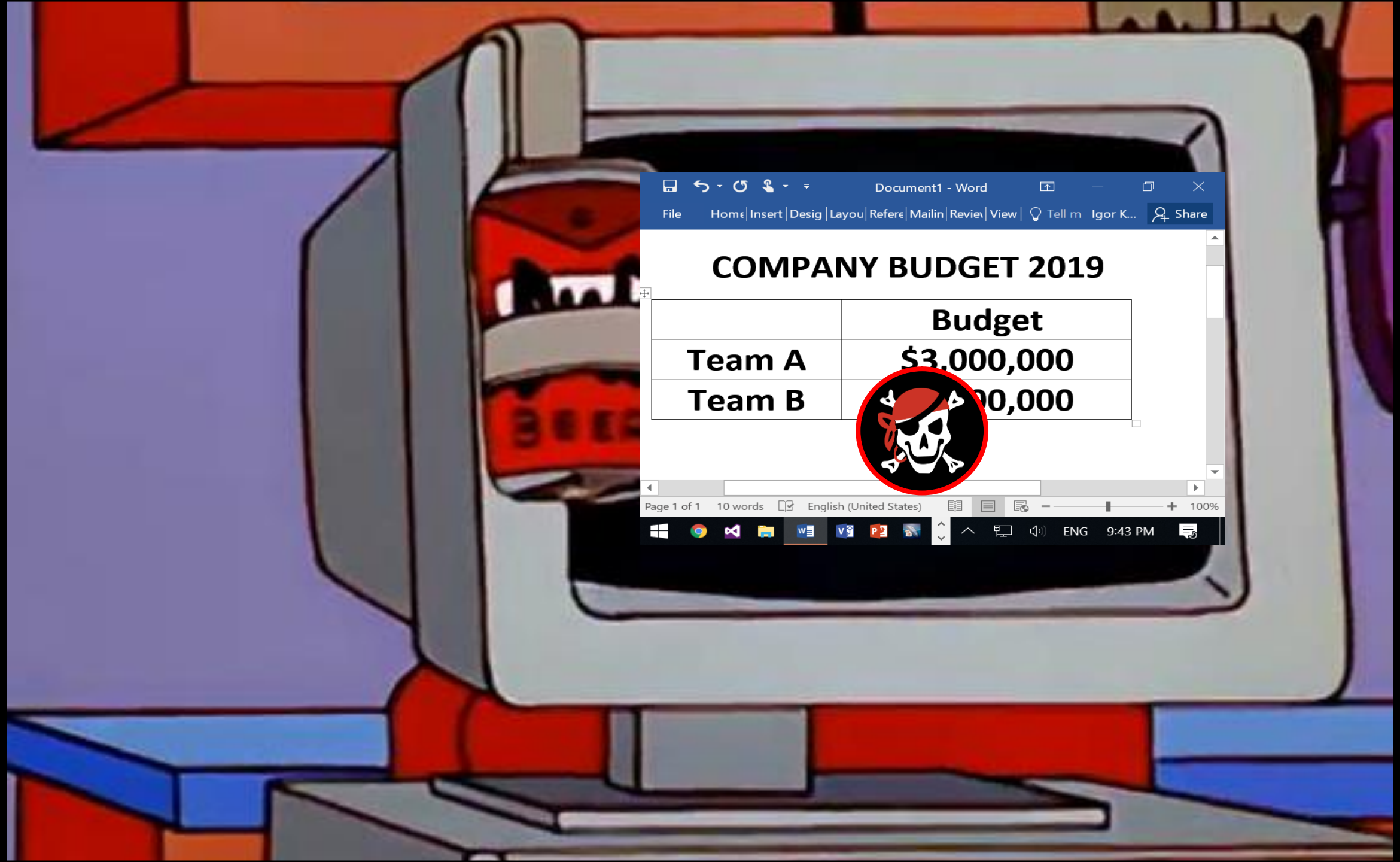
```
NTSTATUS ZwCreateFile(..., ShareAccess, ...);
```

ZWCREATEFILE ROUTINE

```
NTSTATUS ZwCreateFile(..., ShareAccess, ...);
```

ShareAccess

- ShareAccess flag determines whether other drivers can access the opened file.
- Calling ZwCreateFile with ShareAccess=0 gives the caller exclusive access to the file.


Document1 - Word
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Igor K...
Share
COMPANY BUDGET 2019
Budget
Team A
$3,000,000
Team B
Page 1 of 1
10 words
English (United States)
100%
ENG
9:43 PM

VS.

The Boss's Driver
ZwCreateFile("budget.txt", ShareAccess=0)

The Attacker's Driver

exclusive mode

budget.txt

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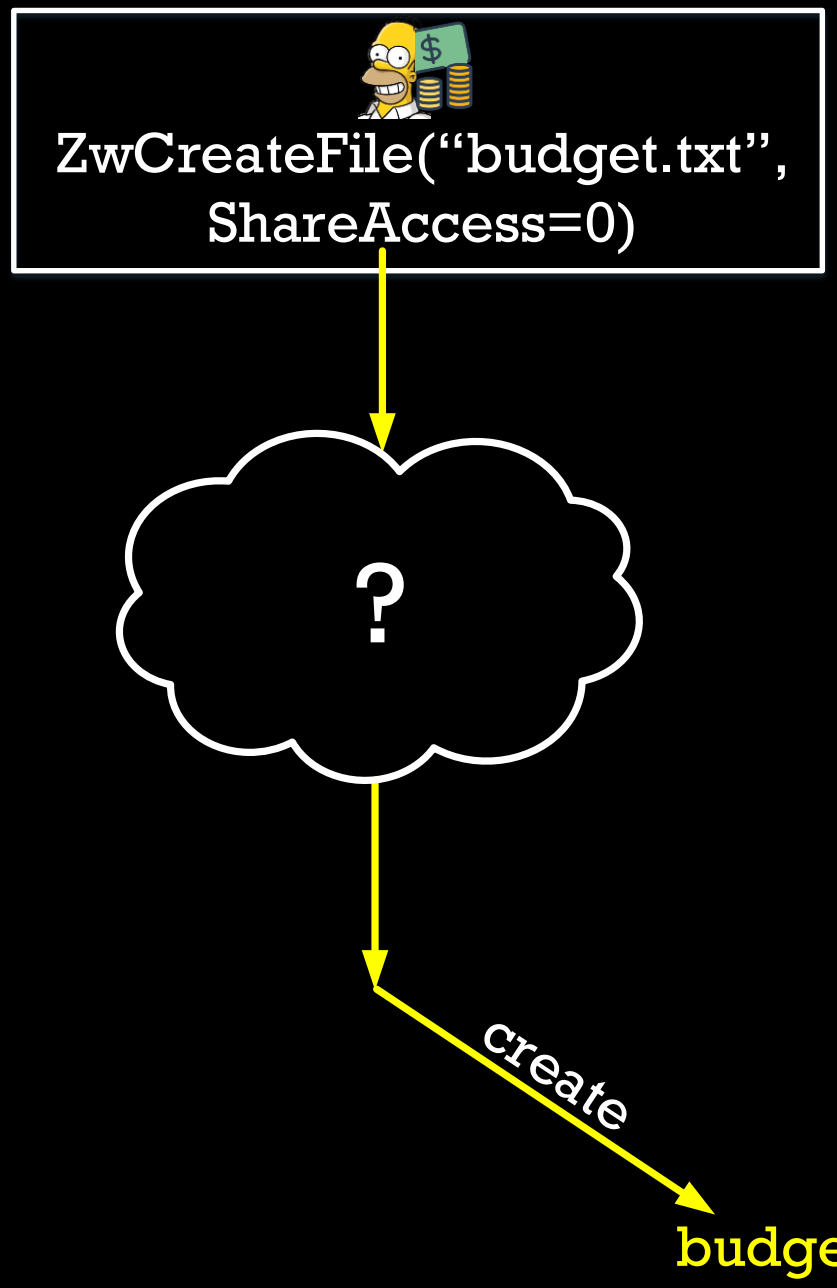
budget.txt

FILE SYSTEM ROUTINES IN WINDOWS KERNEL



FILE SYSTEM ROUTINES IN WINDOWS KERNEL

ZwCreateFile("budget.txt", ShareAccess=0)

I/O Manager

OS kernel components

create

budget.txt

FILE SYSTEM ROUTINES IN WINDOWS KERNEL

ZwCreateFile("budget.txt", ShareAccess=0)

I/O Manager

Object Manager

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FILE SYSTEM ROUTINES IN WINDOWS KERNEL

ZwCreateFile("budget.txt", ShareAccess=0)

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File System Drivers

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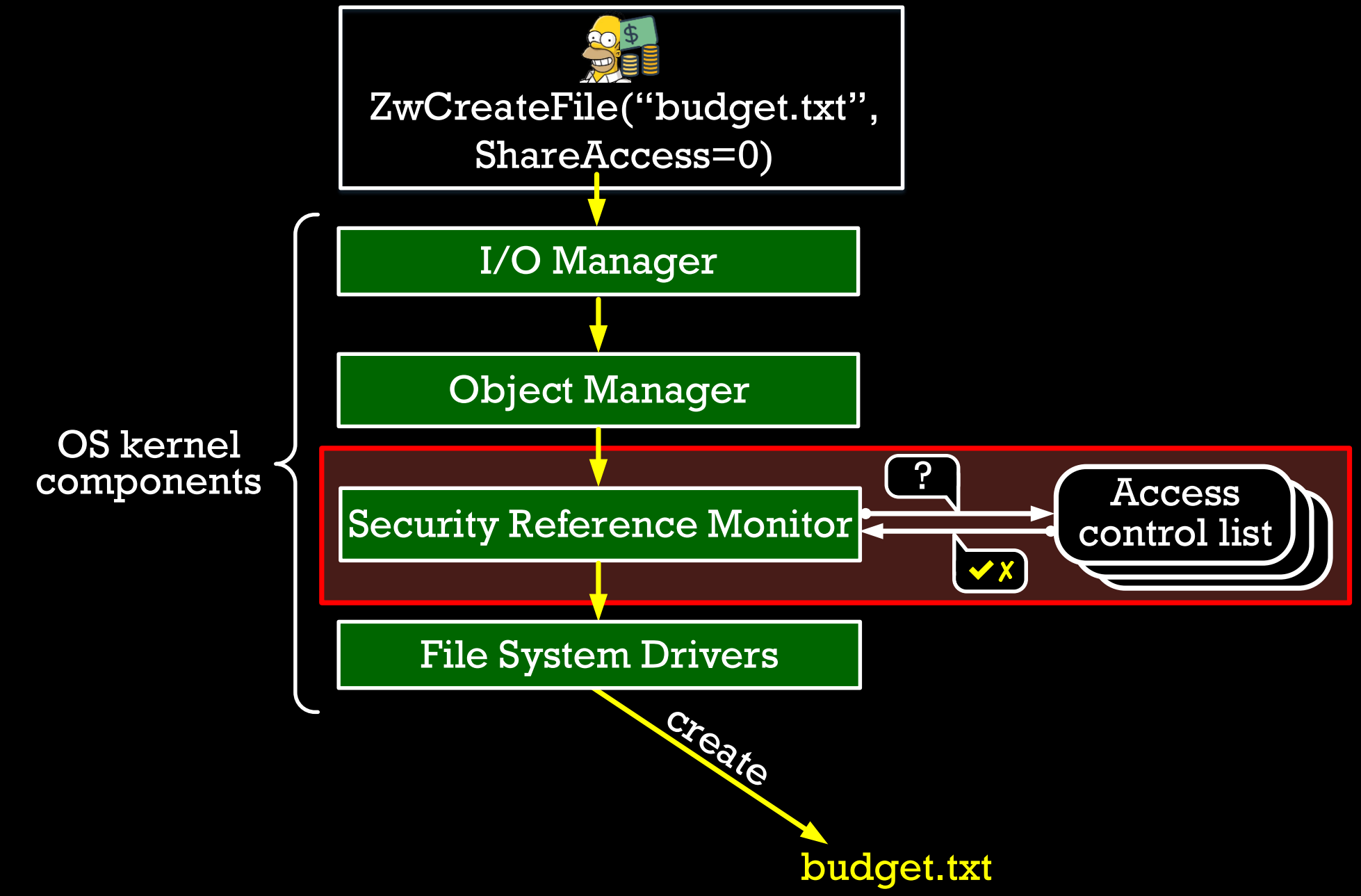

FILE SYSTEM ROUTINES IN WINDOWS KERNEL

ZwCreateFile("budget.txt", ShareAccess=0)

ZwCreateFile("hijacker.txt")

I/O Manager

Object Manager

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File System Drivers

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File System Drivers

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STATUS SHARING VIOLATION Code=0xC0000043

FILE SYSTEM ROUTINES IN WINDOWS KERNEL

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File Handle

FILE_OBJECT

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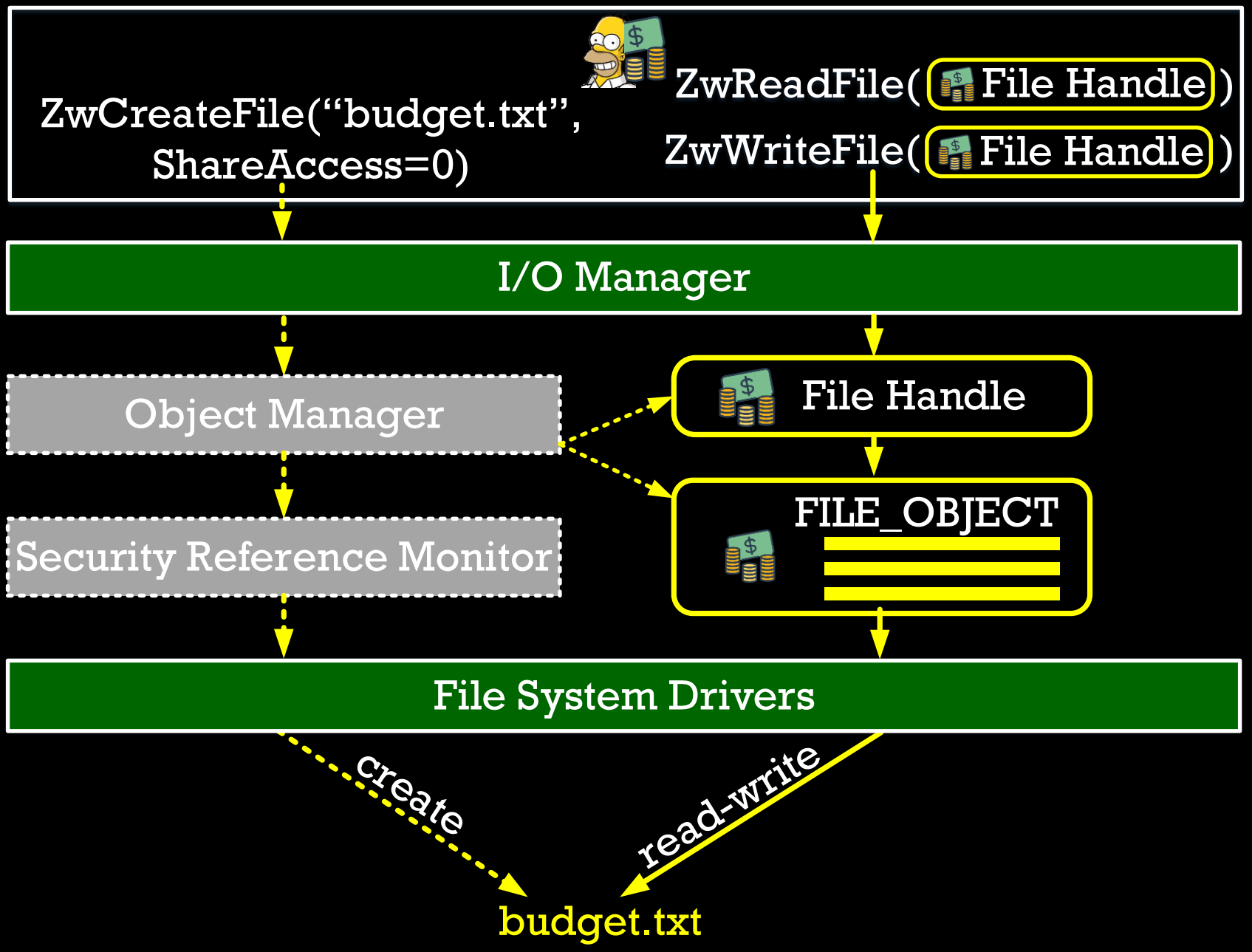

FILE SYSTEM ROUTINES IN WINDOWS KERNEL

ZwCreateFile("budget.txt", ShareAccess=0)

ZwReadFile(File Handle)

ZwWriteFile(File Handle)

Hey! I'm a hacker-attacker!

I/O Manager

Object Manager

Security Reference Monitor

File Handle

FILE_OBJECT

File System Drivers

create

read-write

budget.txt

FILE SYSTEM ROUTINES IN WINDOWS KERNEL

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I/O Manager

Object Manager

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File Handle

FILE_OBJECT

File Handle

FILE_OBJECT

File System Drivers

create

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budget.txt

1.Create a file

hijacker.txt

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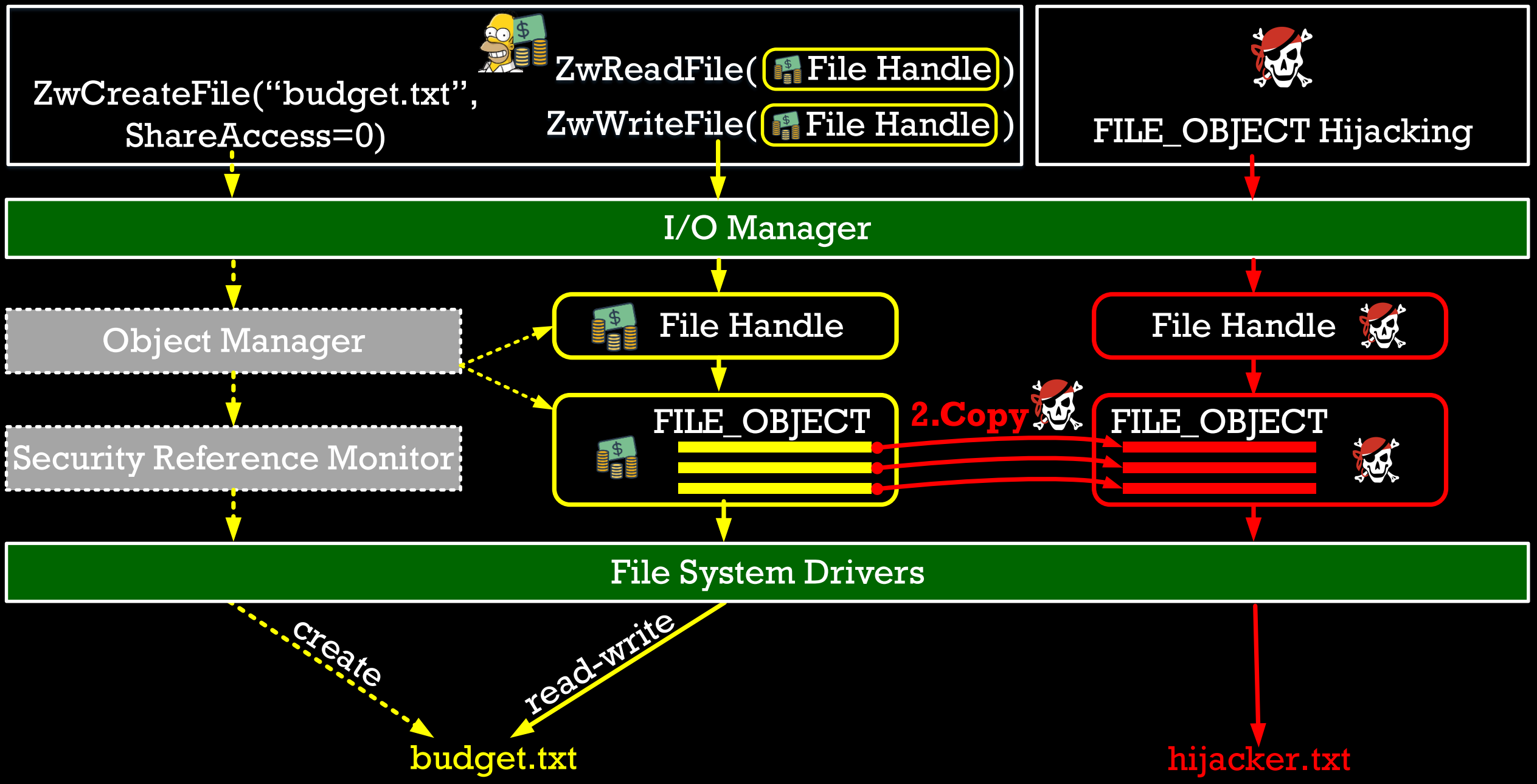

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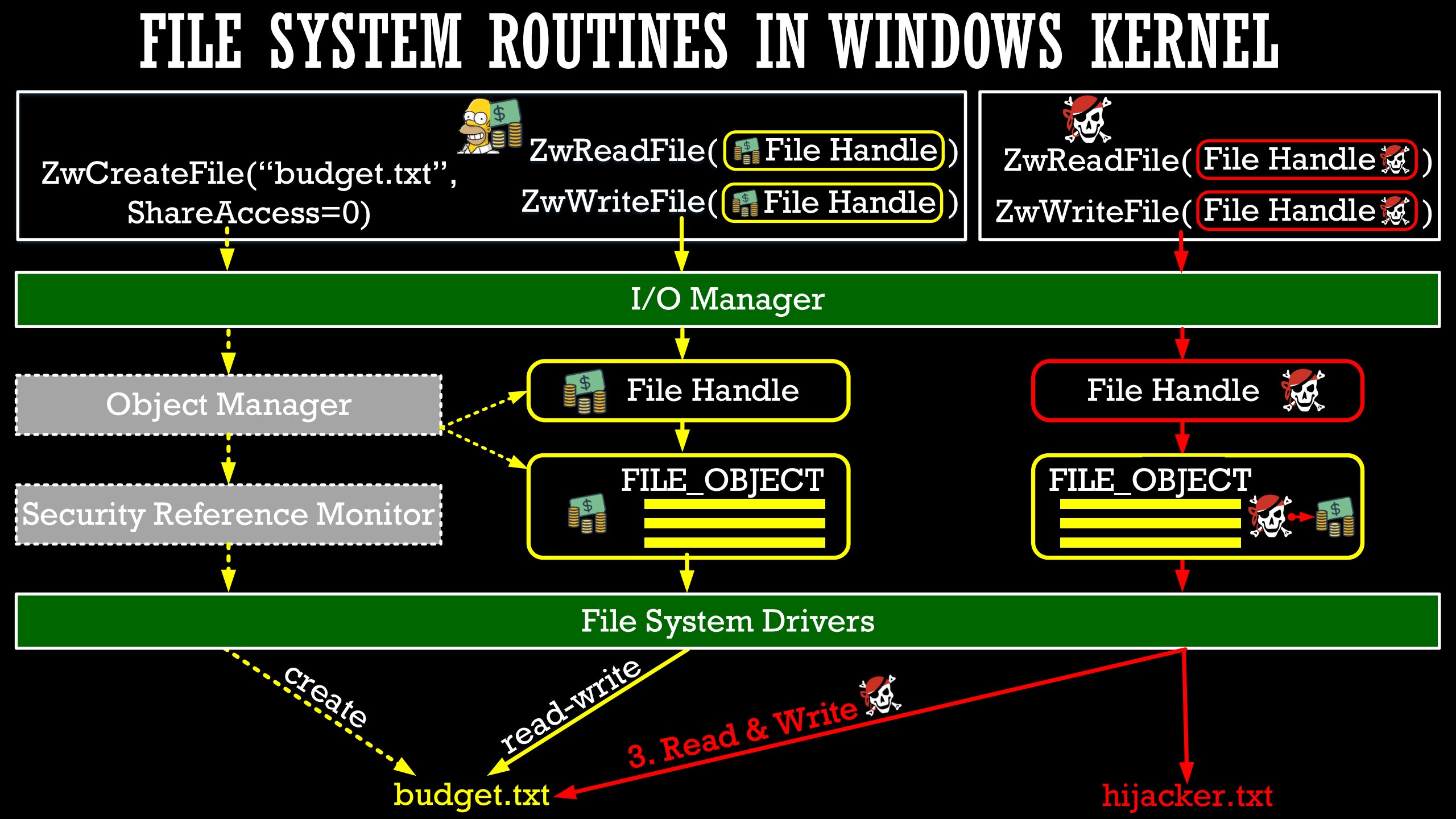


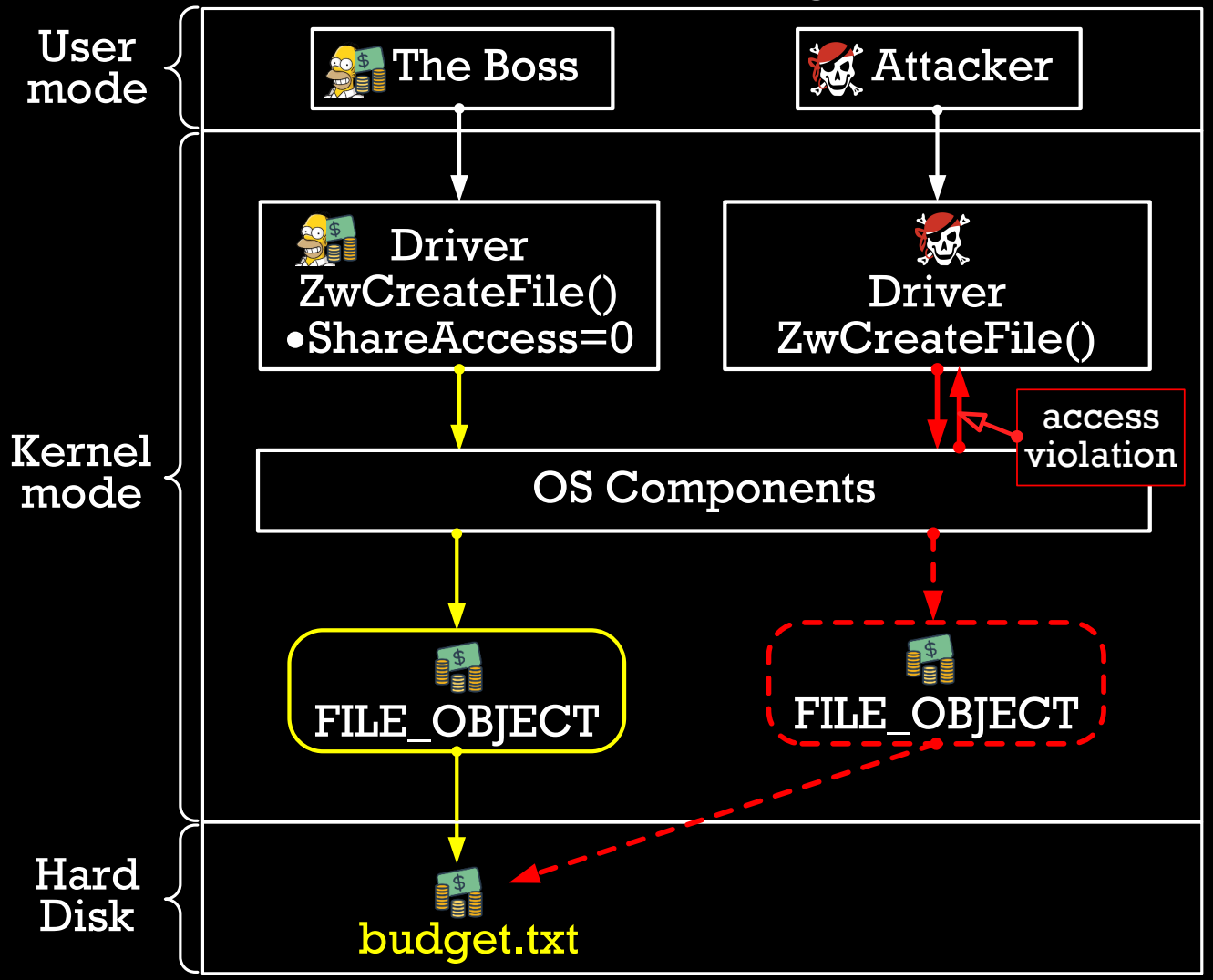
JUST 4 CRUCIAL FIELDS FOR FILES HIJACKING

```
typedef struct _FILE_OBJECT {
    …
PVPB Vpb;
PVOID FsContext;
PVOID FsContext2;
PSECTION_OBJECT_POINTERS SectionObjectPointer;
    …
} FILE_OBJECT;
```

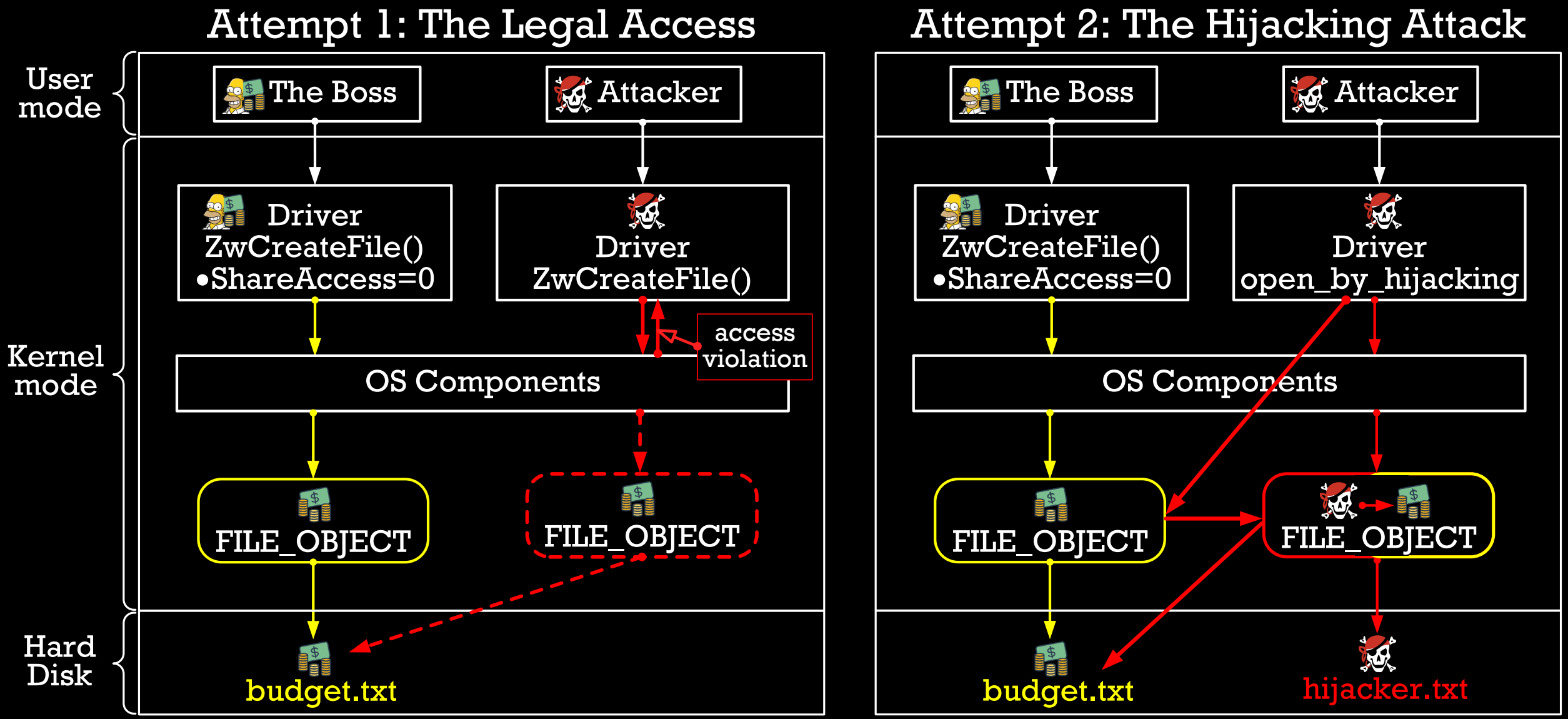
- The Vpb field points to a mounted Volume Parameter Block (VPB), associated with the target device object.
- FsContext points to the FSRTL_COMMON_FCB_HEADER structure, which has to be allocated by the file driver.
- FsContext2 field refers to the Context Control Block (CBB) associated with the file object
- SectionObjectPointer stores file-mapping and caching-related information for a file stream.

THE ATTACK

Attempt 1: The Legal Access



THE ATTACK

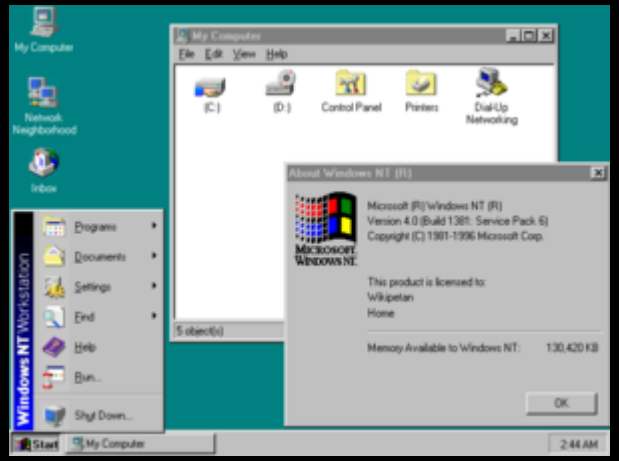

Attempt 1: The Legal Access
User mode
Kernel mode
Hard Disk
The Boss
Attacker
Driver
ZwCreateFile()
•ShareAccess=0
Driver
ZwCreateFile()
access violation
OS Components
FILE_OBJECT
FILE_OBJECT
budget.txt
Attempt 2: The Hijacking Attack
The Boss
Attacker
Driver
ZwCreateFile()
•ShareAccess=0
Driver
open_by_hijacking
OS Components
FILE_OBJECT
FILE_OBJECT
budget.txt
hijacker.txt

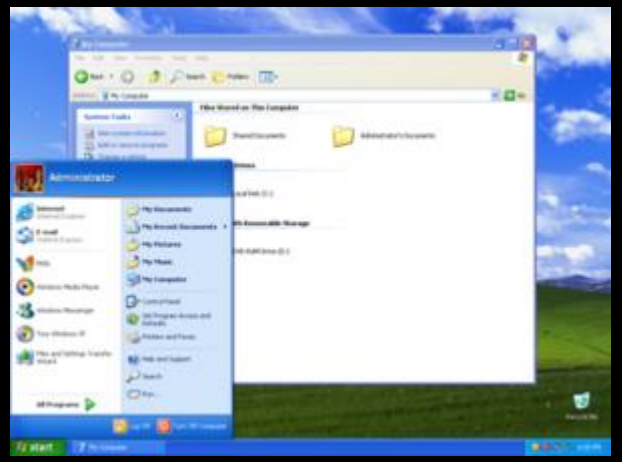
DEMO: THE ATTACK

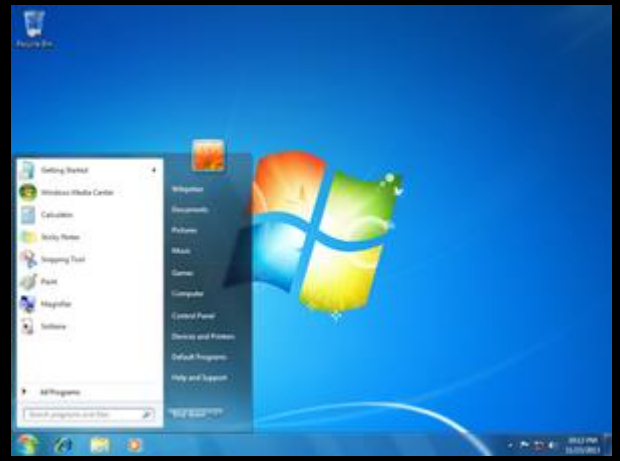
The online version is here –
https://www.youtube.com/watch?v=2mU85RluOSA?vq=hd1080

THE ANALYSIS OF THE ATTACK

- All Windows OSes since NT 4.0 are vulnerable for FILE_OBJECT hijacking:







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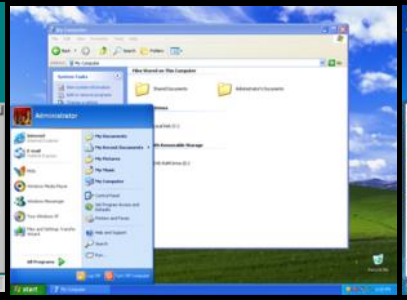
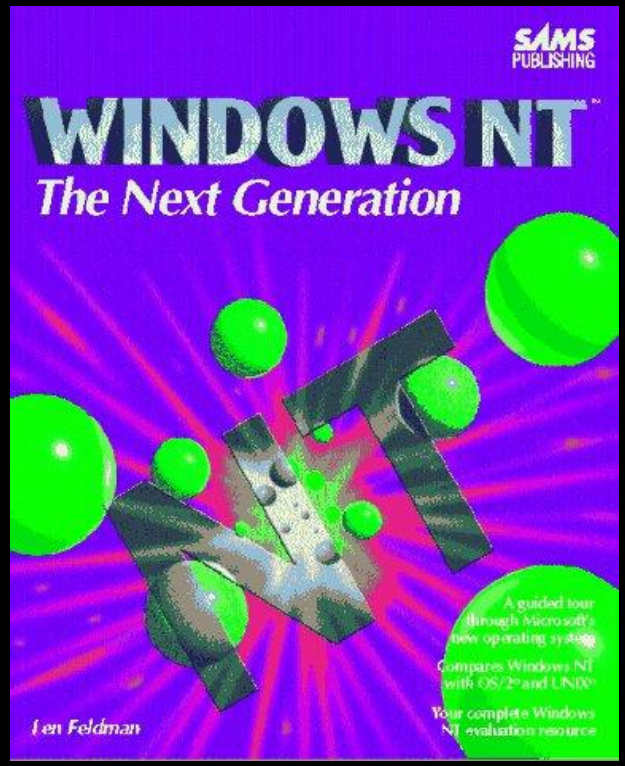


- **1993** - the first mention of Object Manager and Security Reference Monitor



Windows NT: The Next Generation
by Len Feldman, March 1, **1993**

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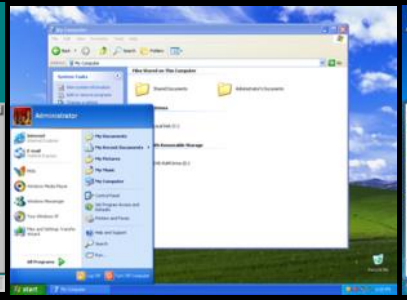

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- **1965** – the first memory isolation concept Multics* was developed for General Electric 645 mainframe. Multics joined to the ARPANet and gave rise to the Unix.

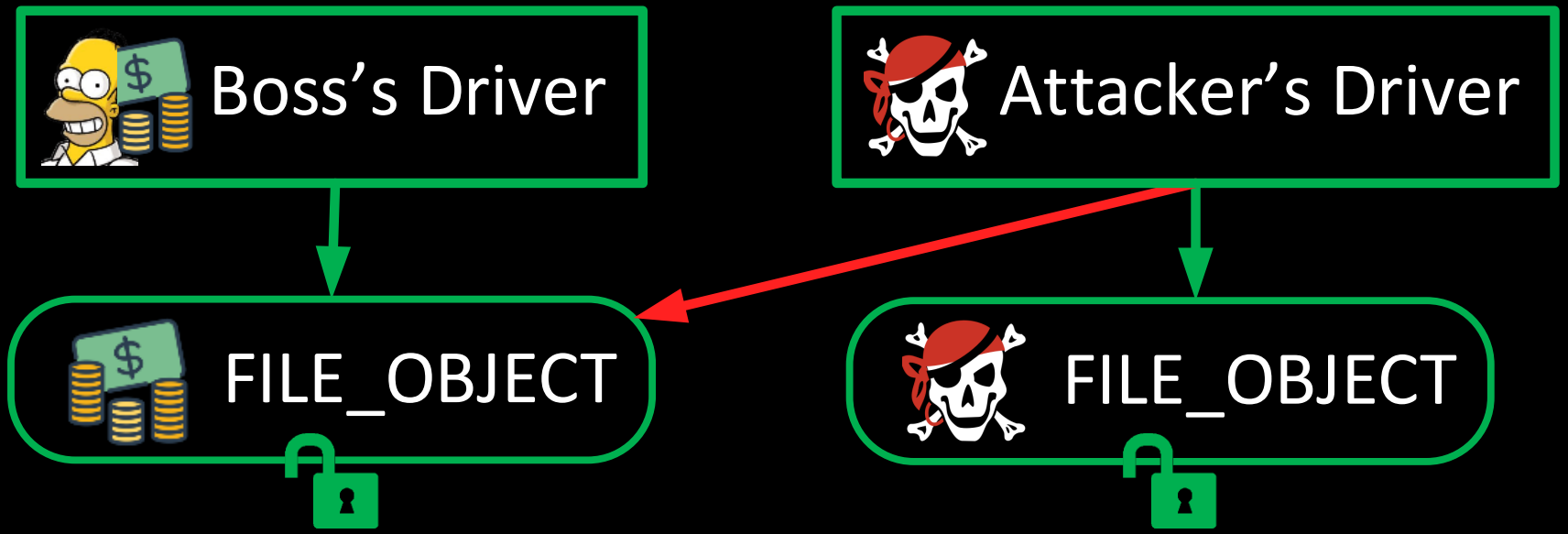
*DOI: http://dx.doi.org/10.1145/1463891.1463912

Two Fathers of Multics


Fernando Corbato

Victor Vyssotsky

THE FILE_OBJECT PROTECTION VIA ENCRYPTION



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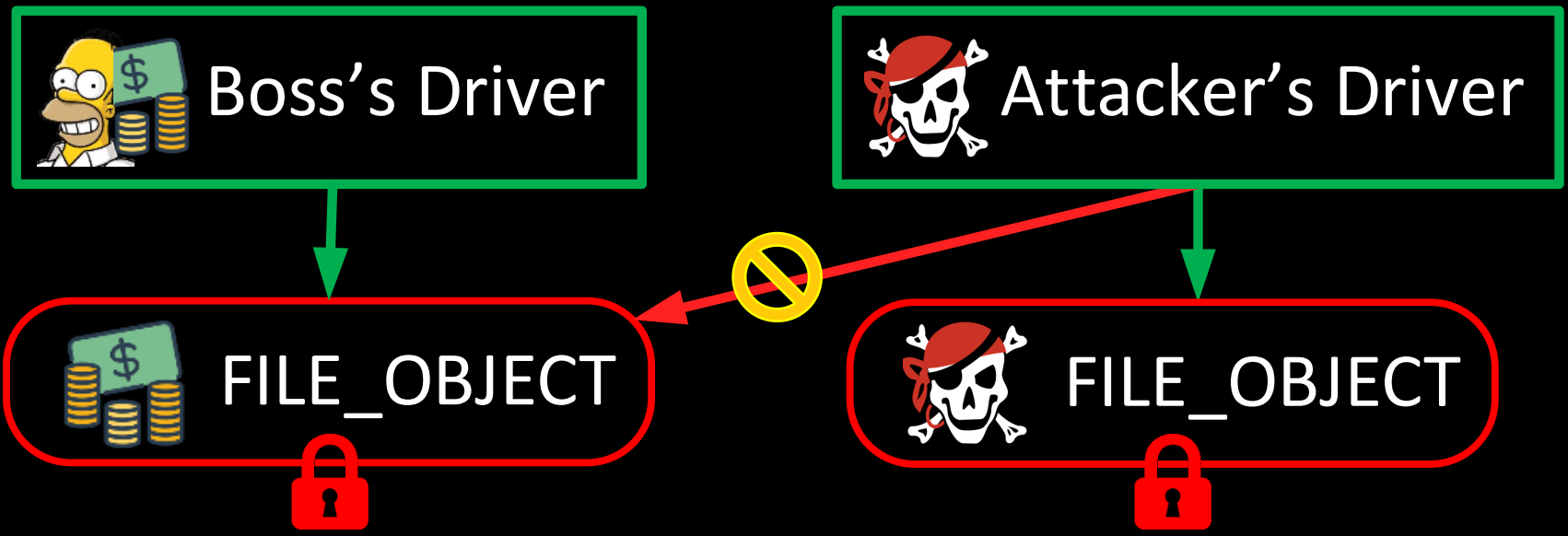

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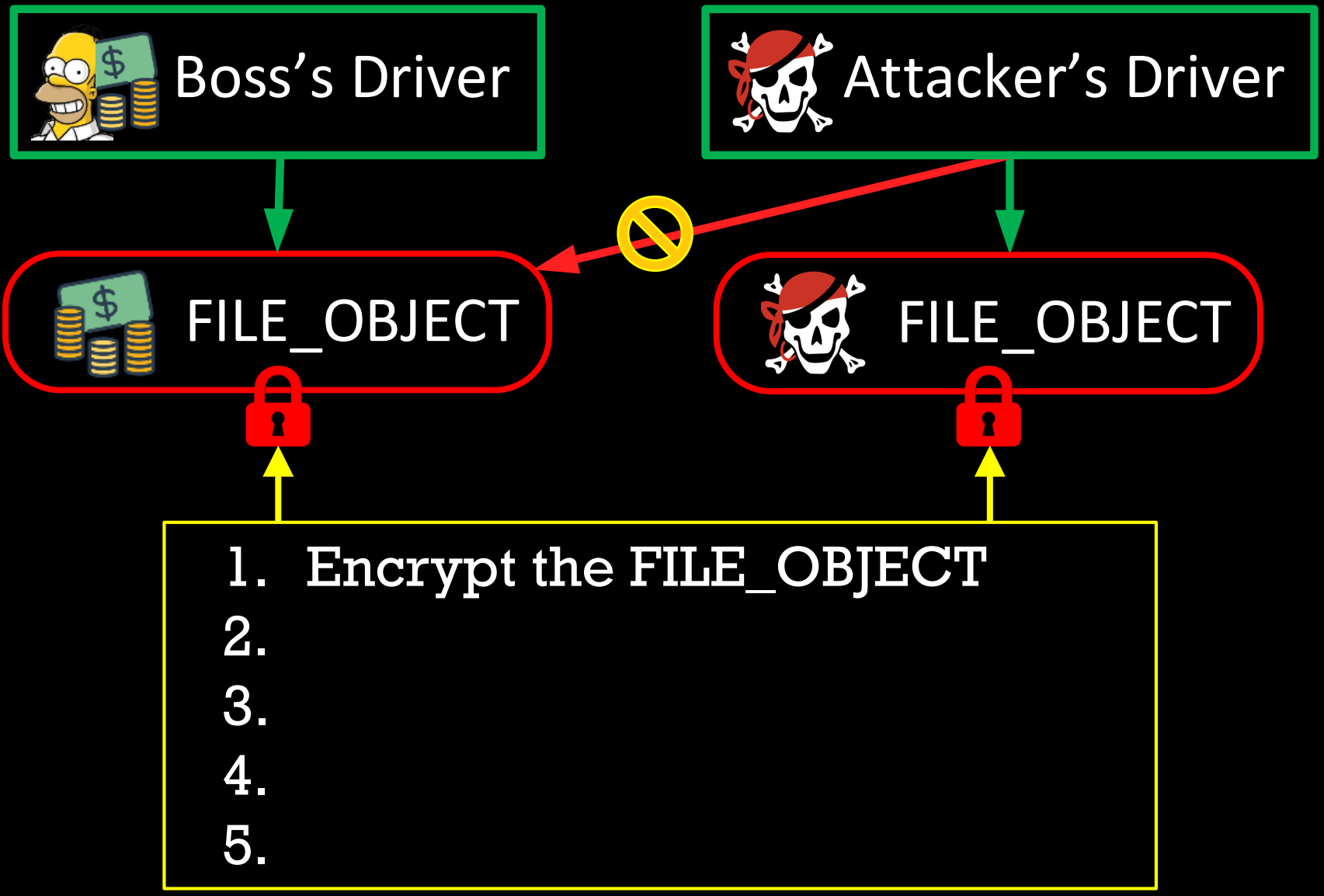

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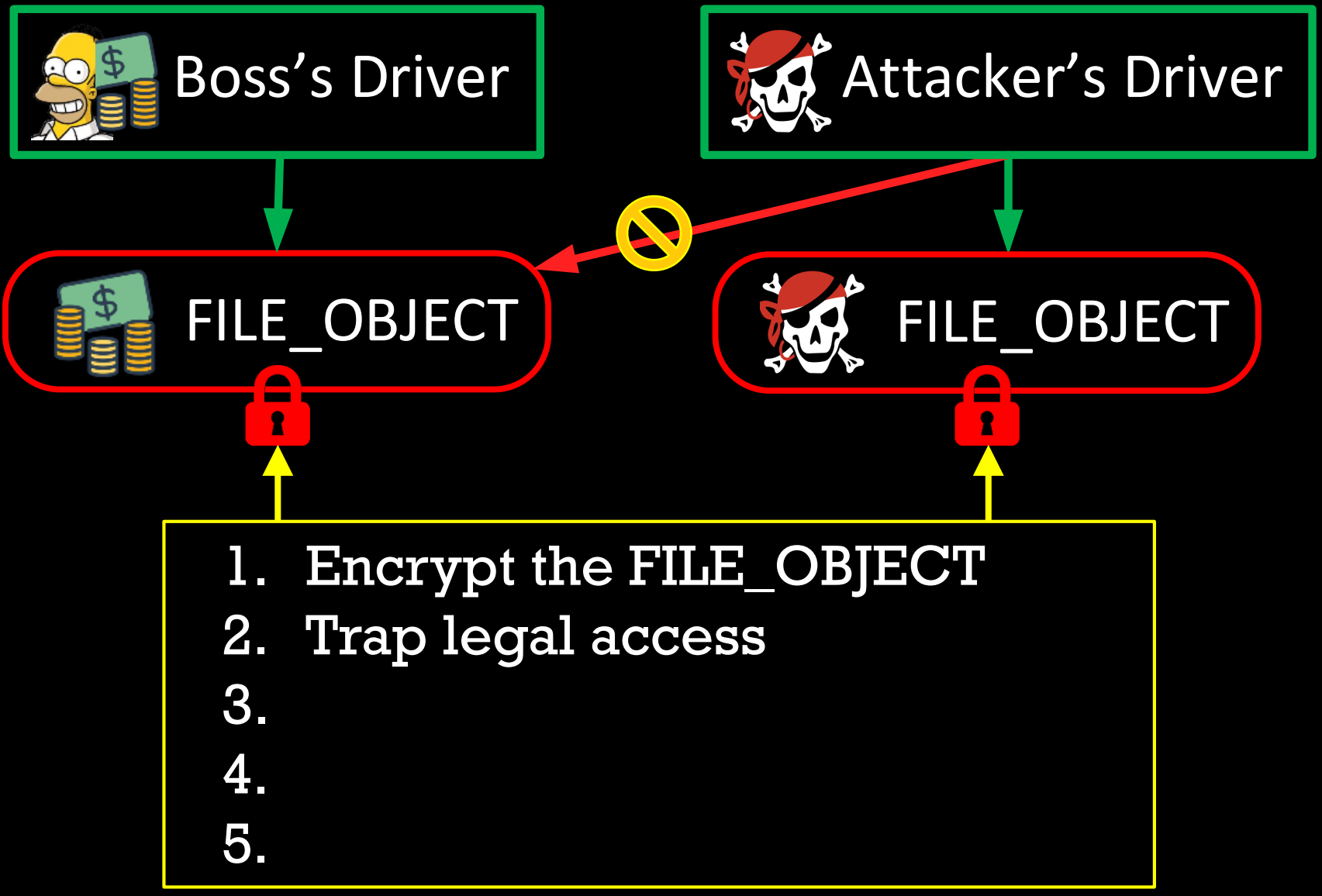

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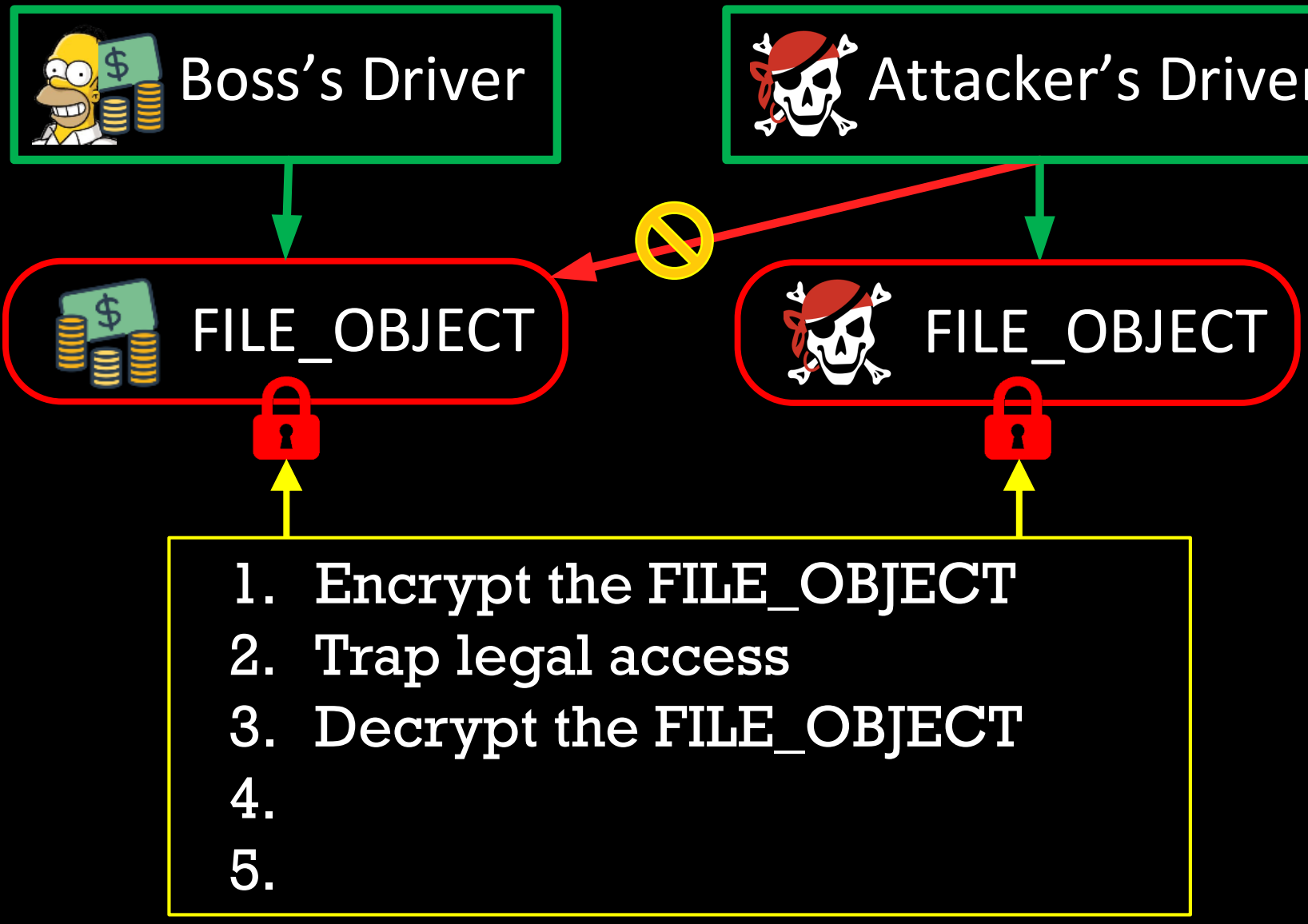

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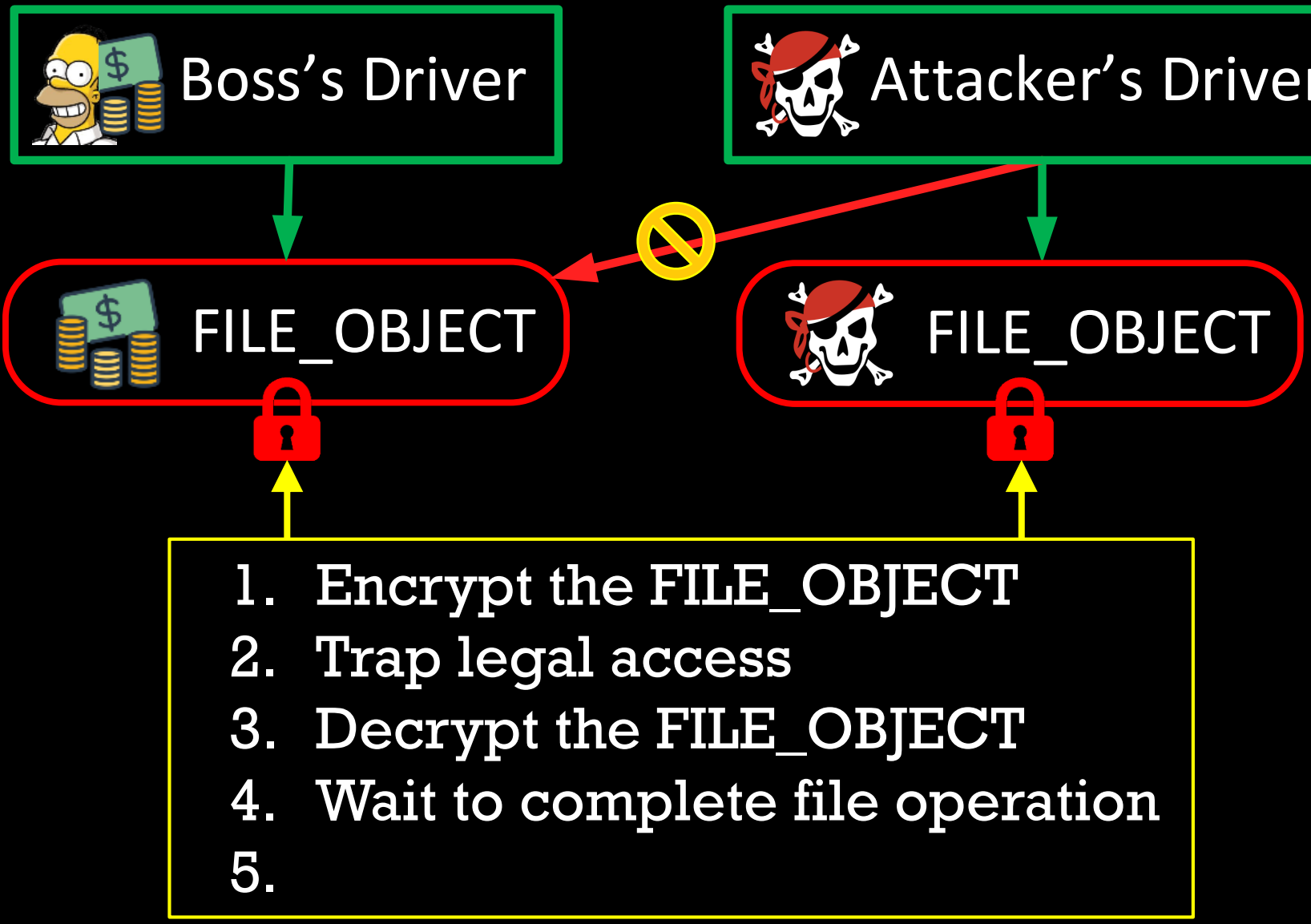

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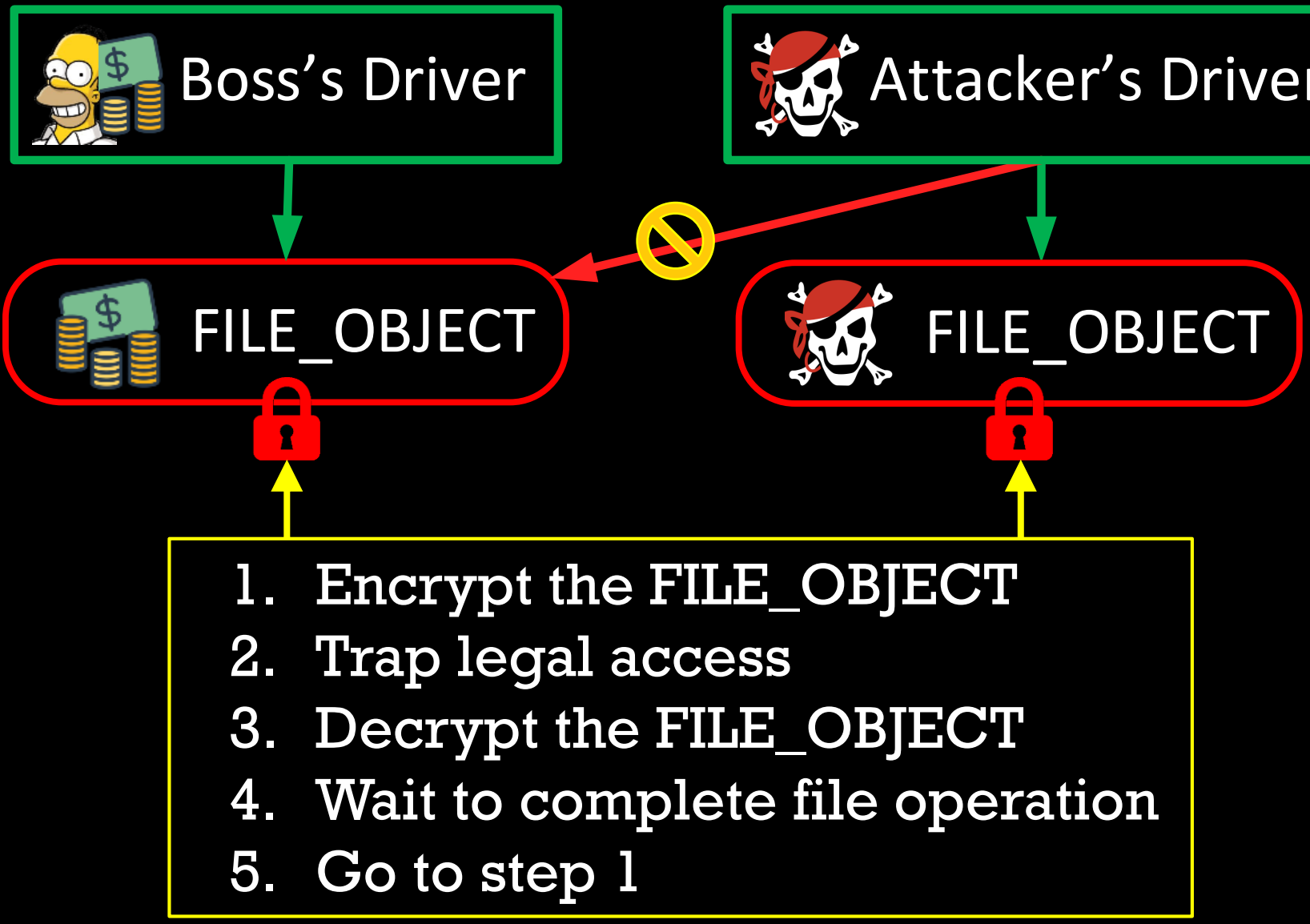

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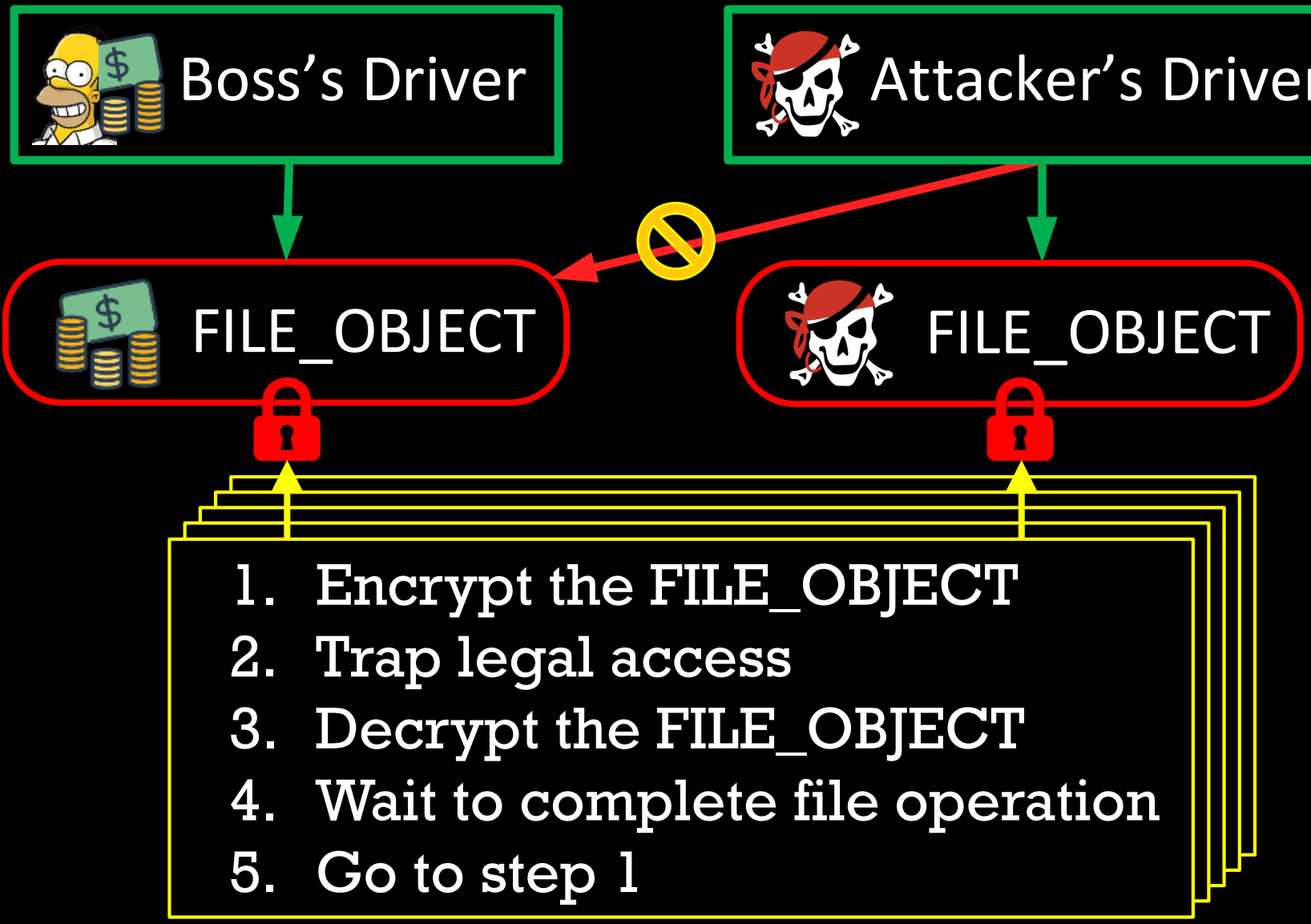


THE FILE_OBJECT PROTECTION VIA ENCRYPTION

Boss's Driver

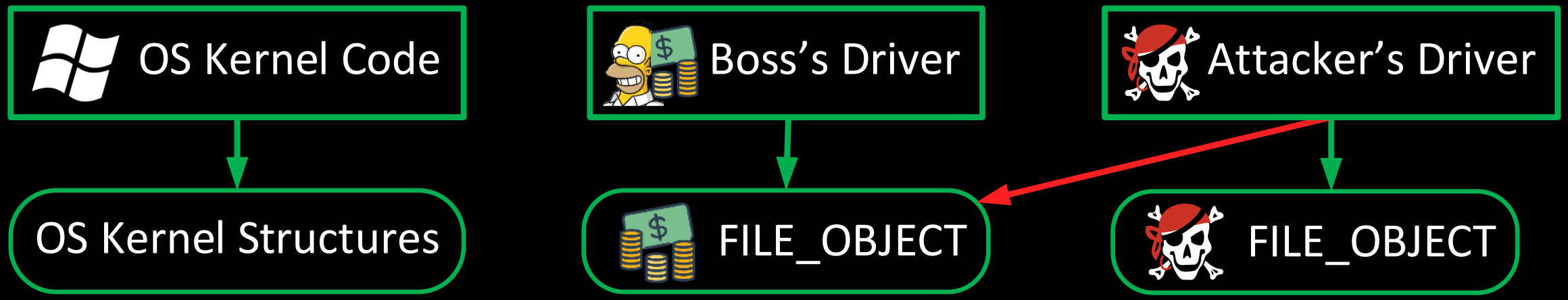
Attacker's Driver

FILE_OBJECT

FILE_OBJECT

1. Encrypt the FILE_OBJECT
2. Trap legal access
3. Decrypt the FILE_OBJECT
4. Wait to complete file operation
5. Go to step 1

WINDOWS KERNEL MEMORY



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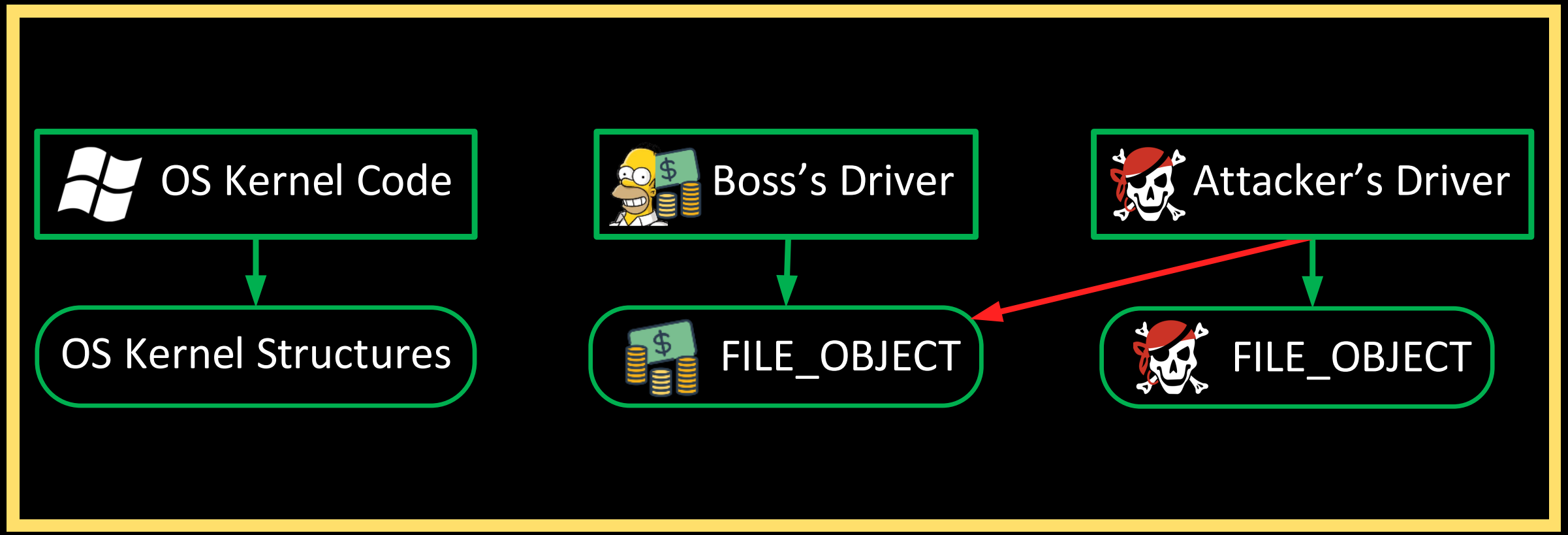

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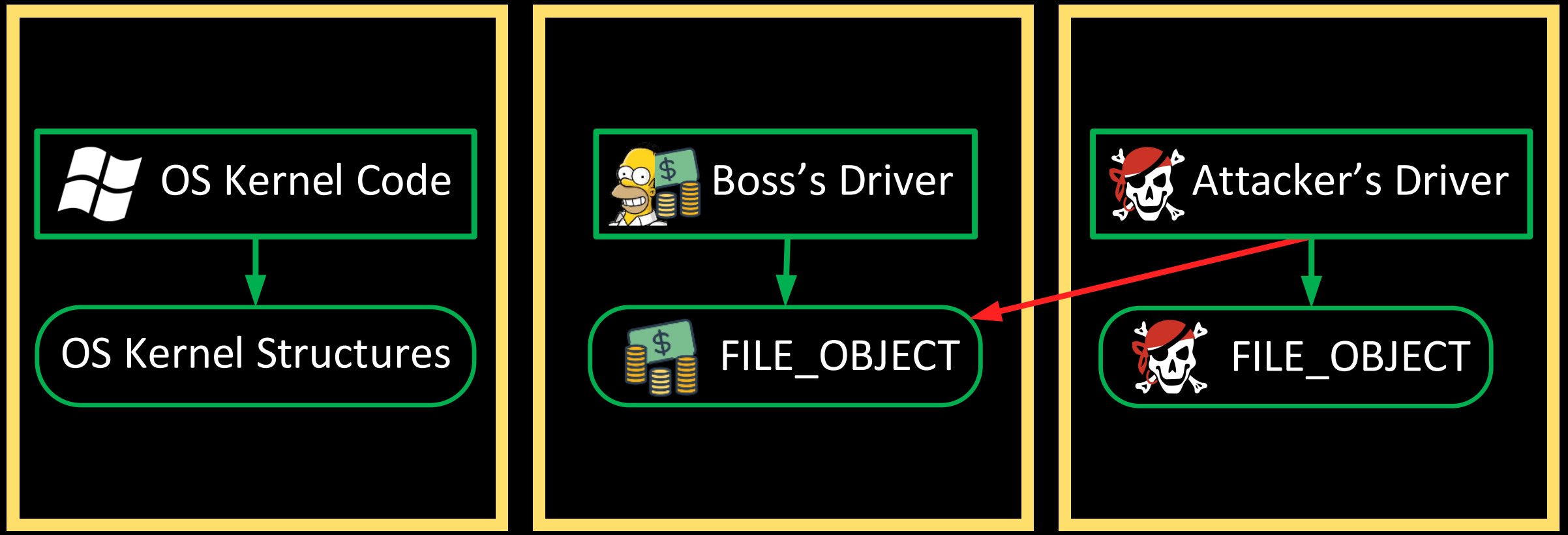

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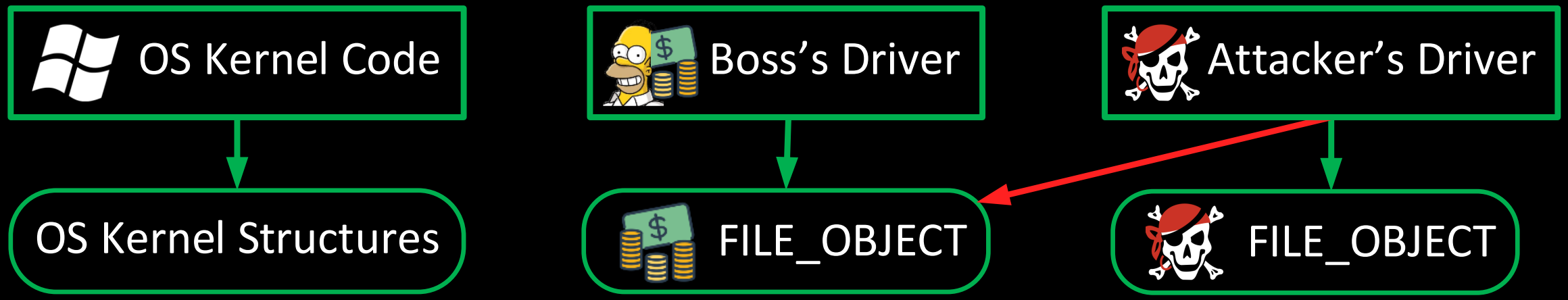
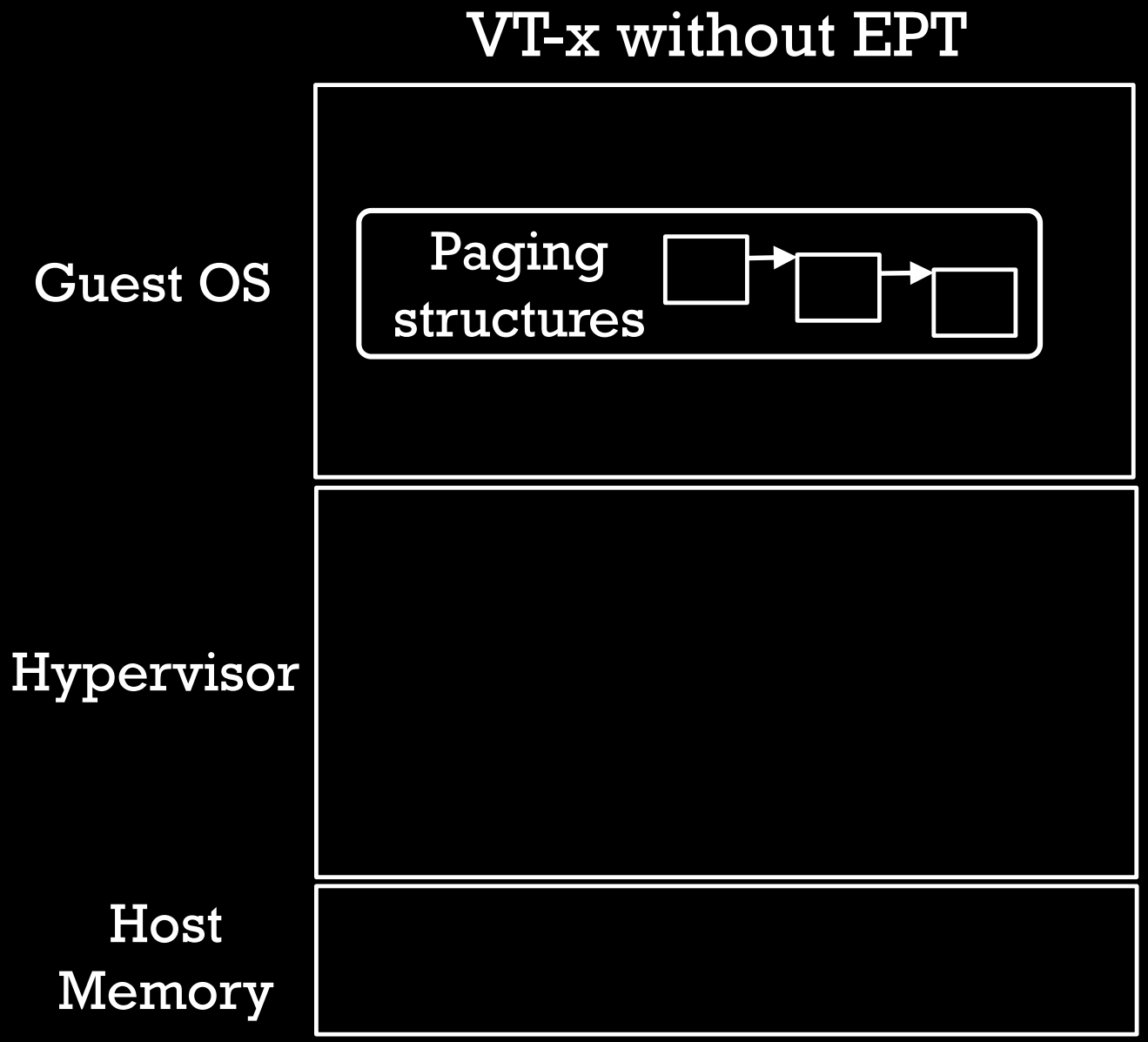


PROCESSING MEMORY ACCESS: EPT FEATURE



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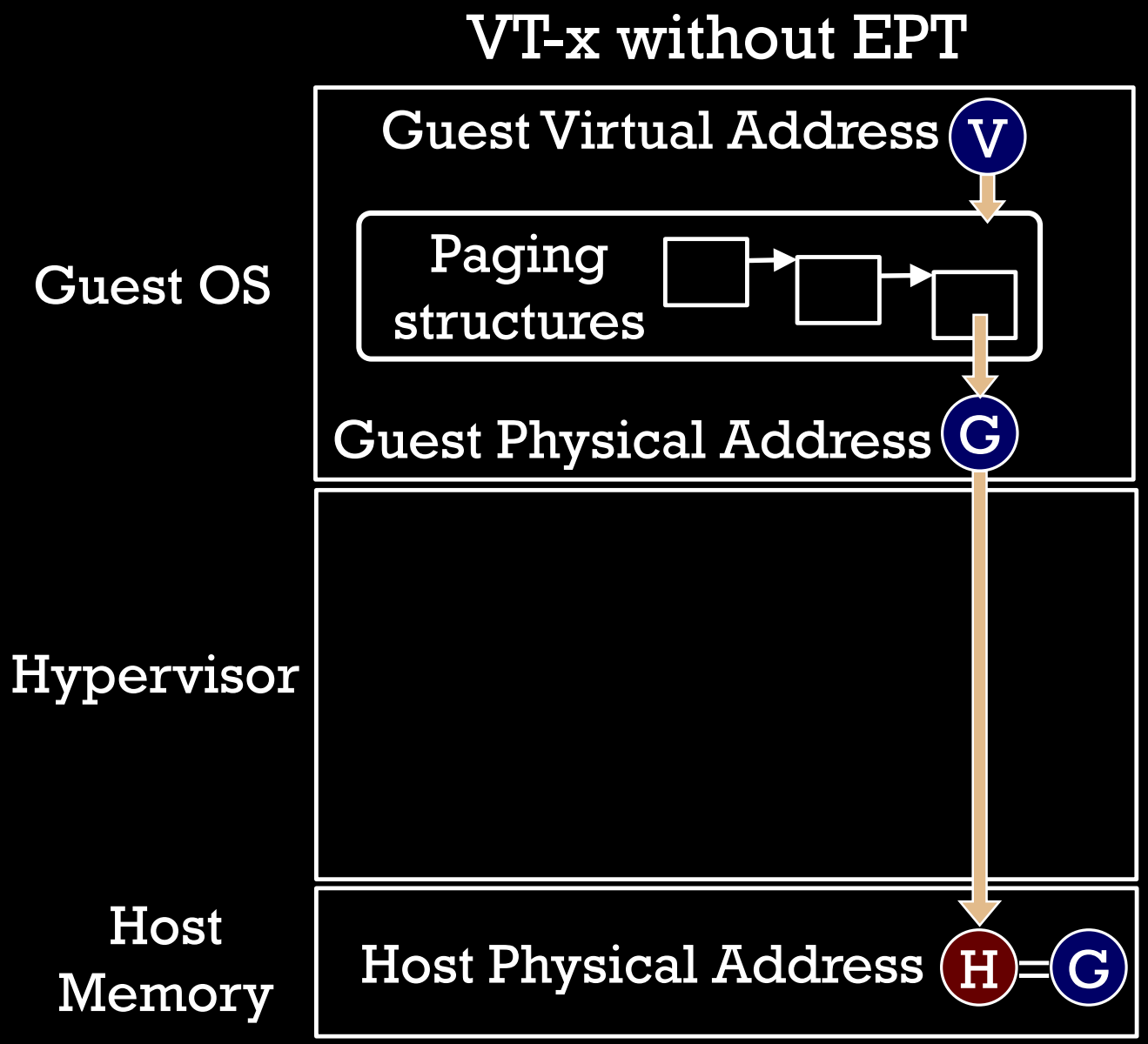

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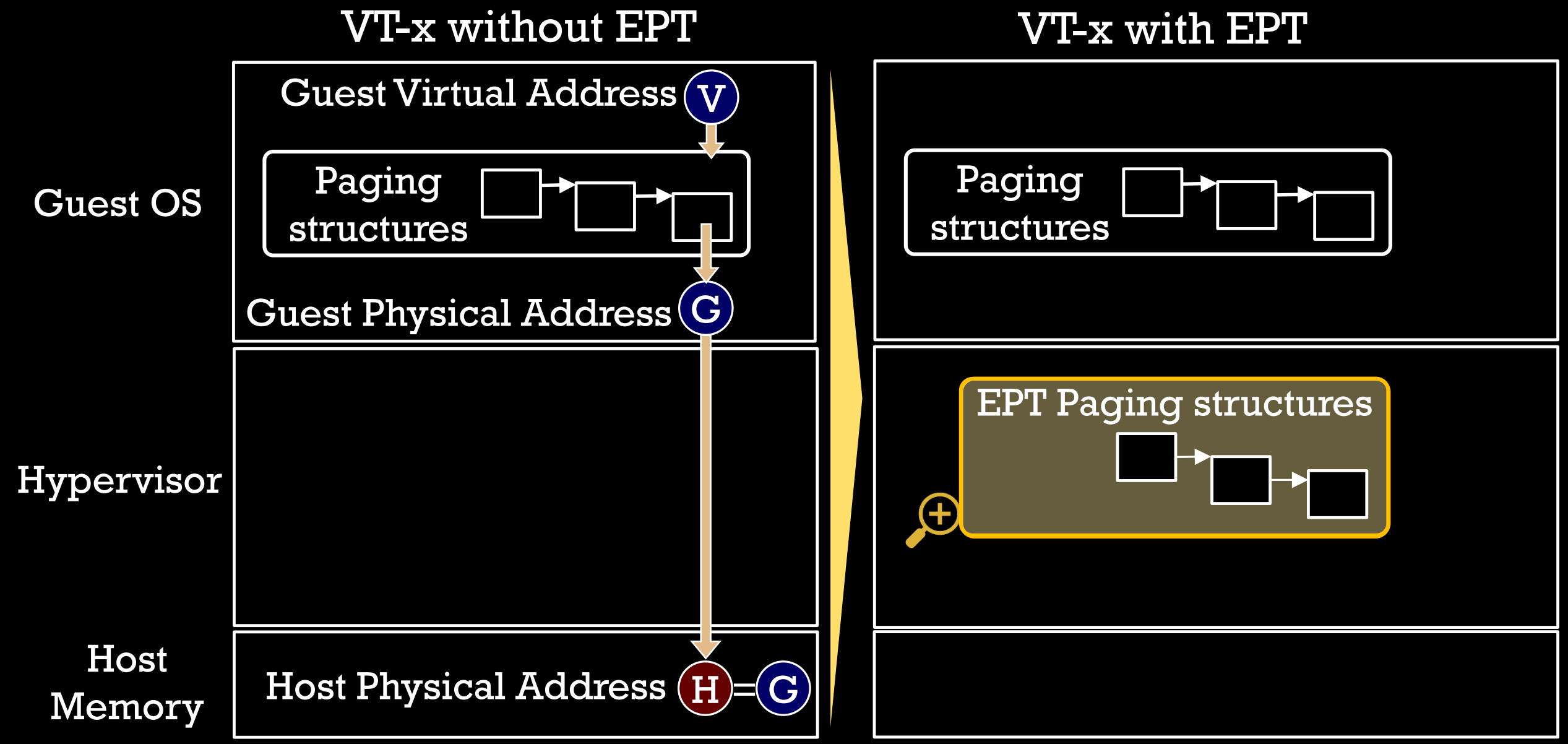

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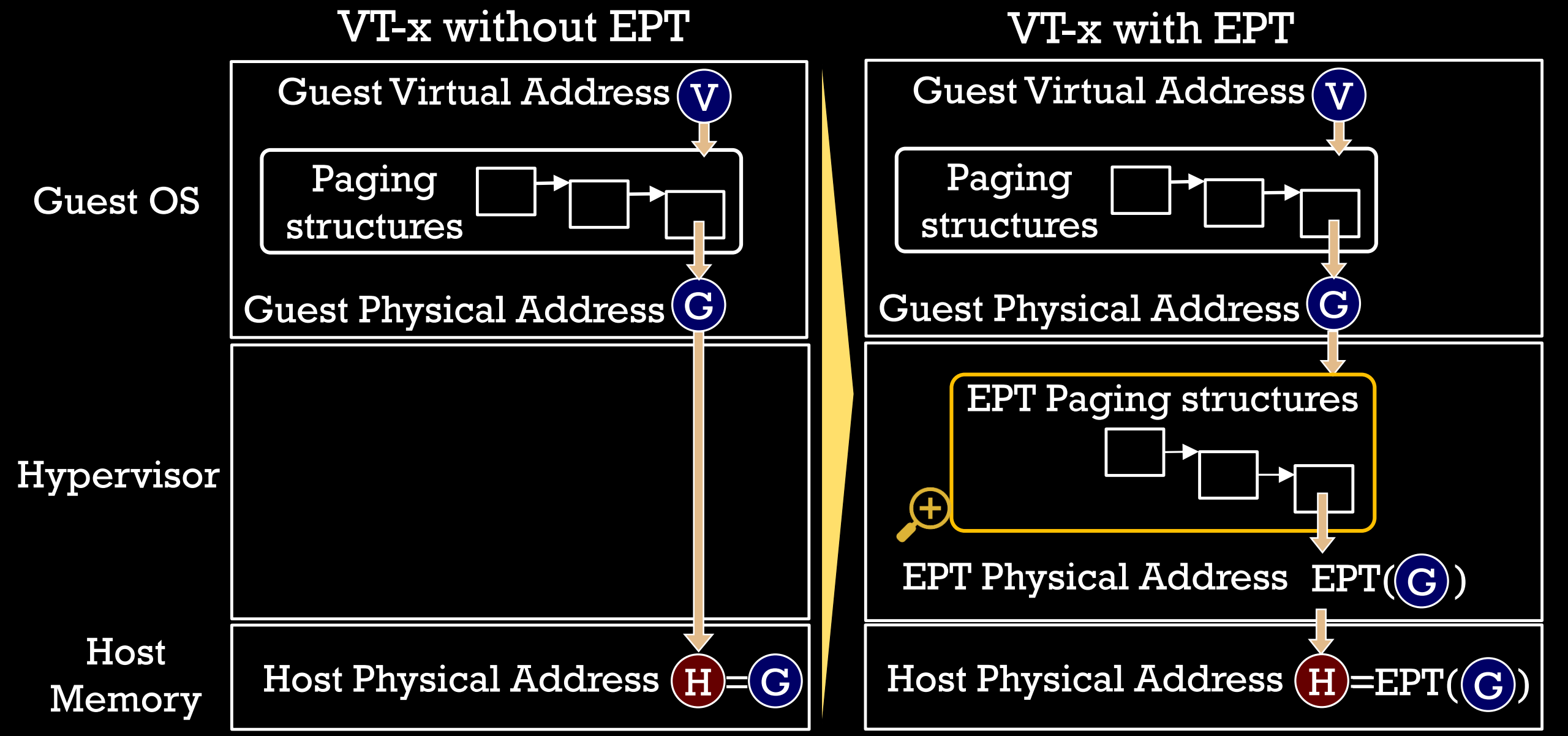
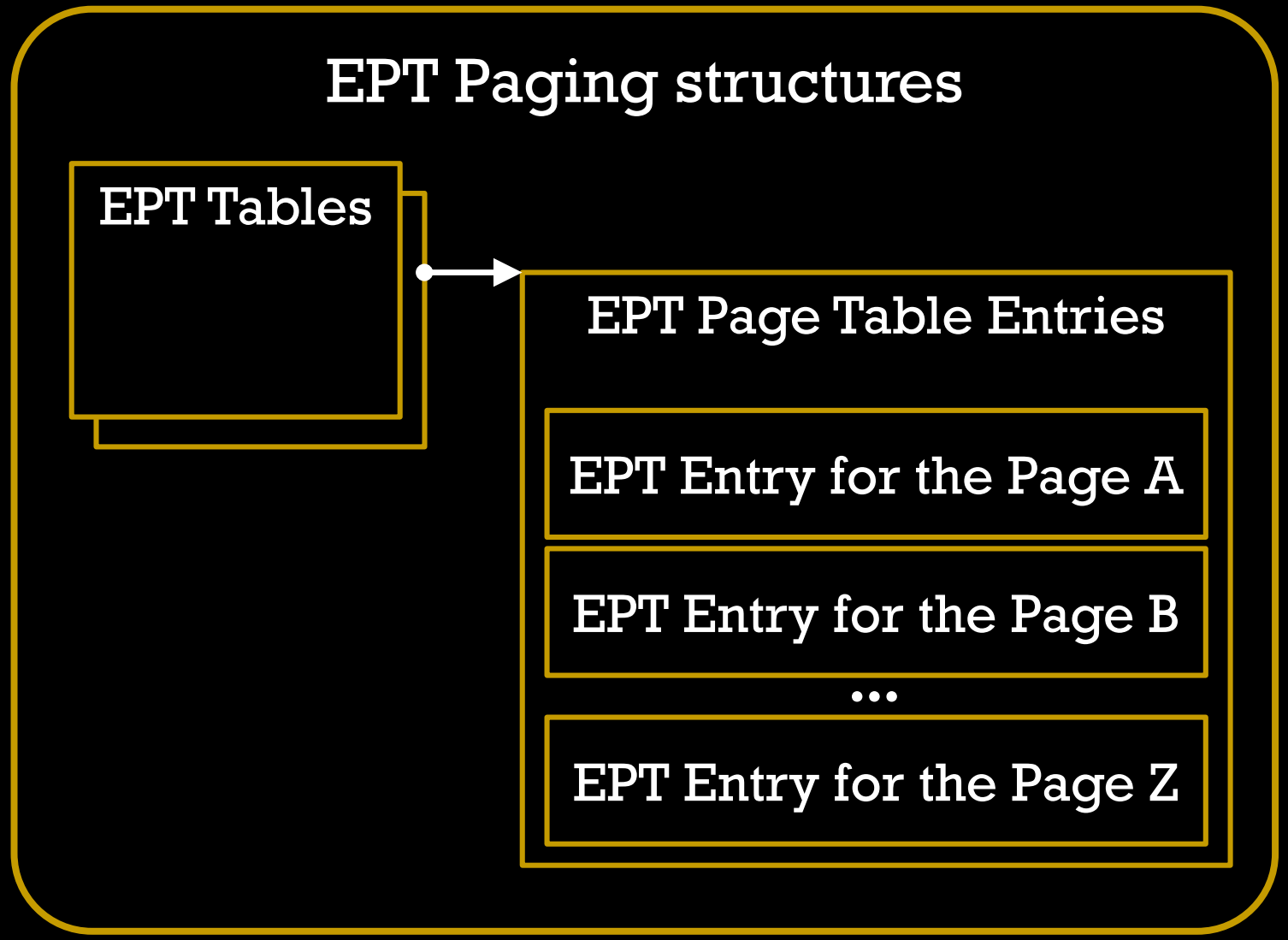


EPT PAGING STRUCTURES



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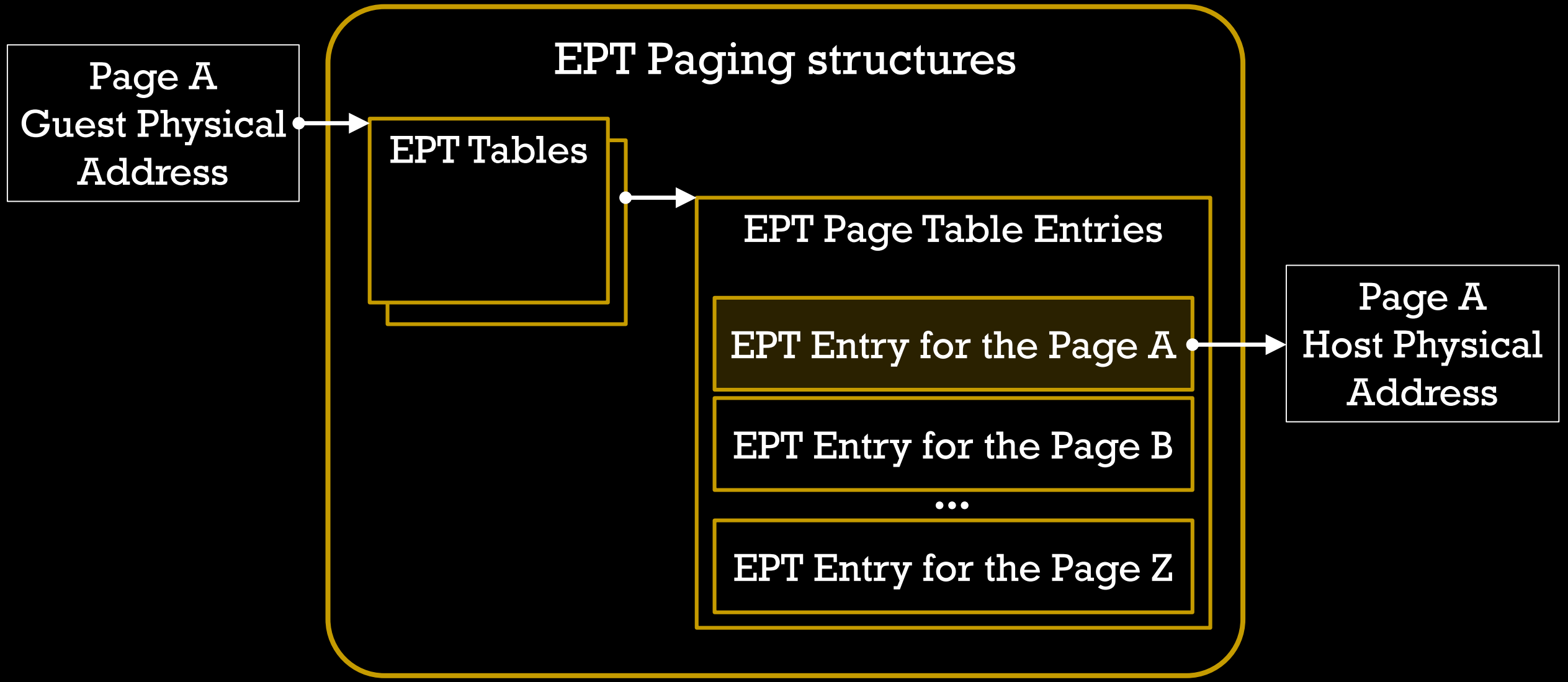

EPT MAIN FEATURES

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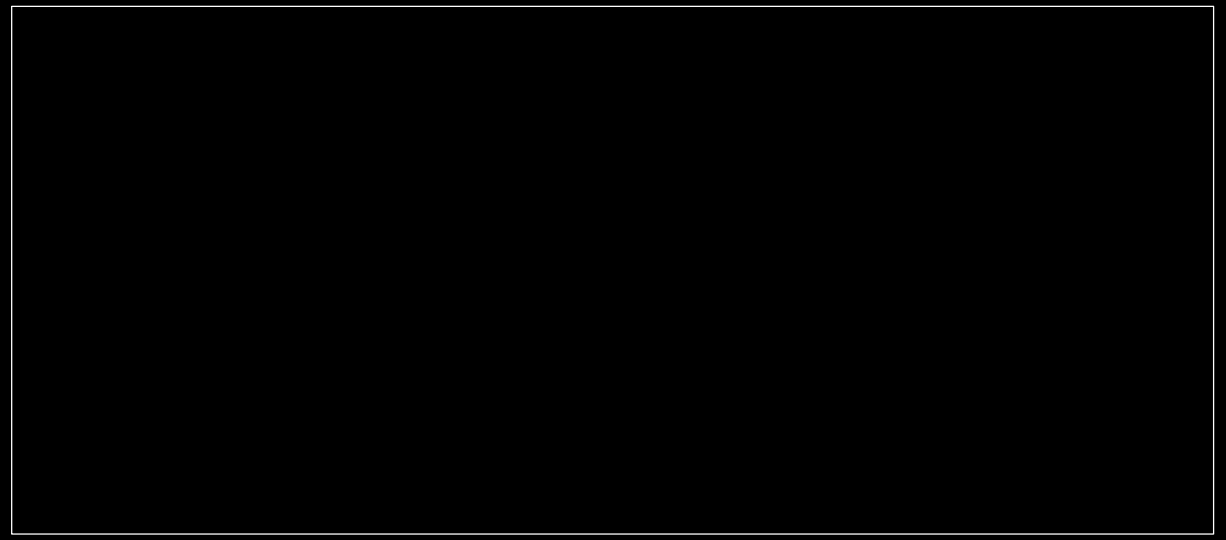

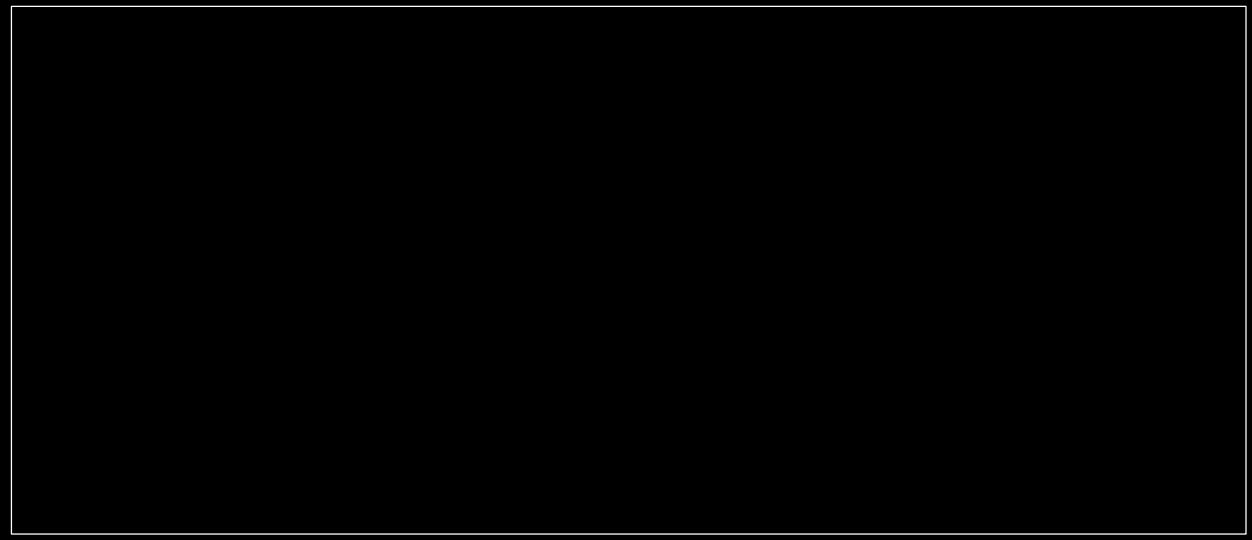

2.
3.

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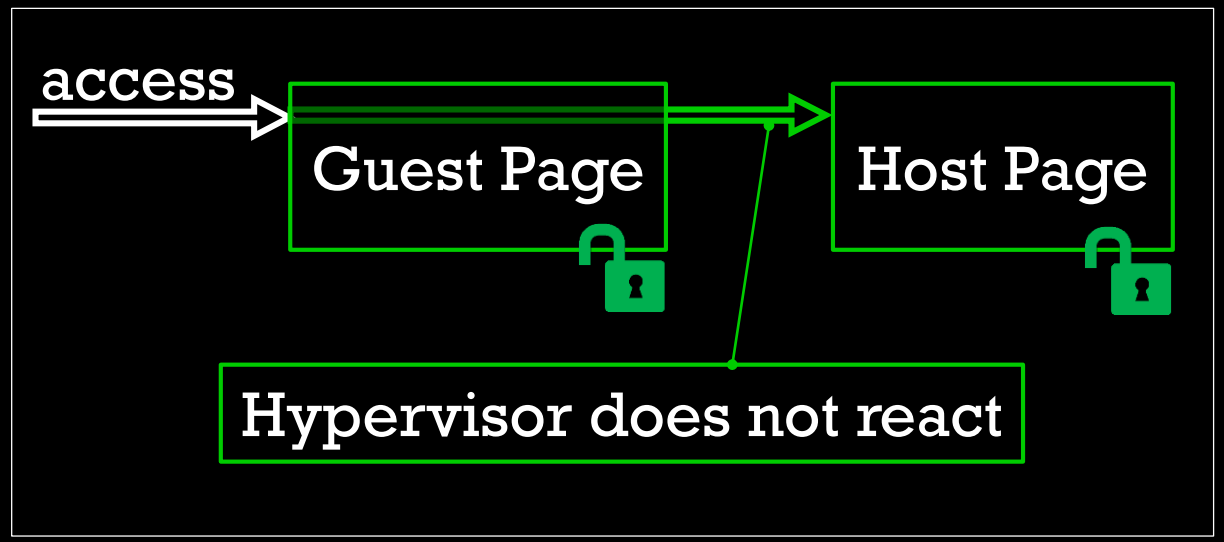

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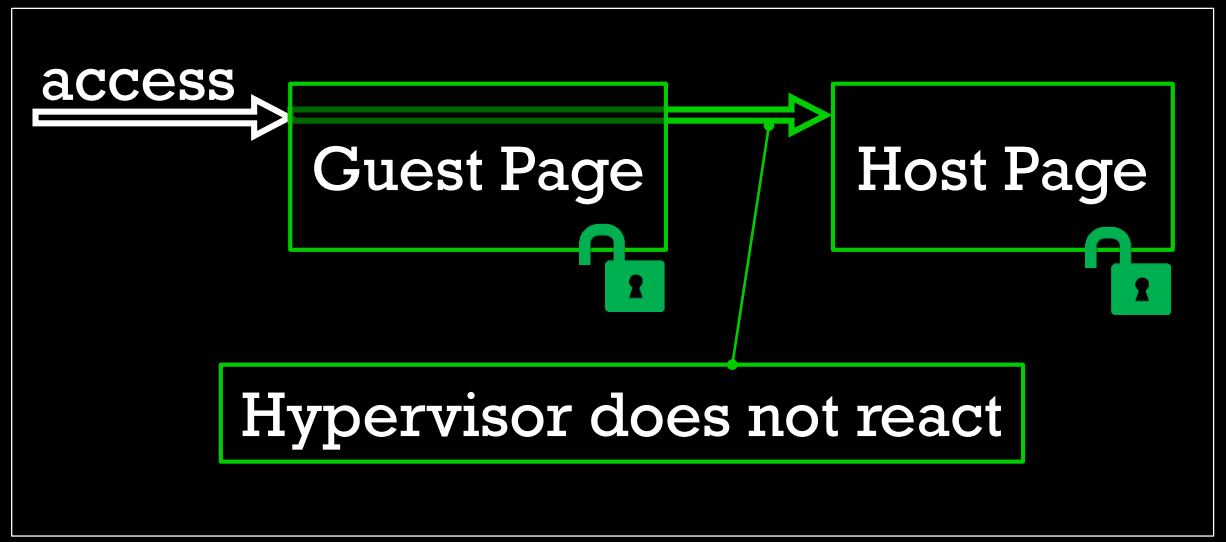

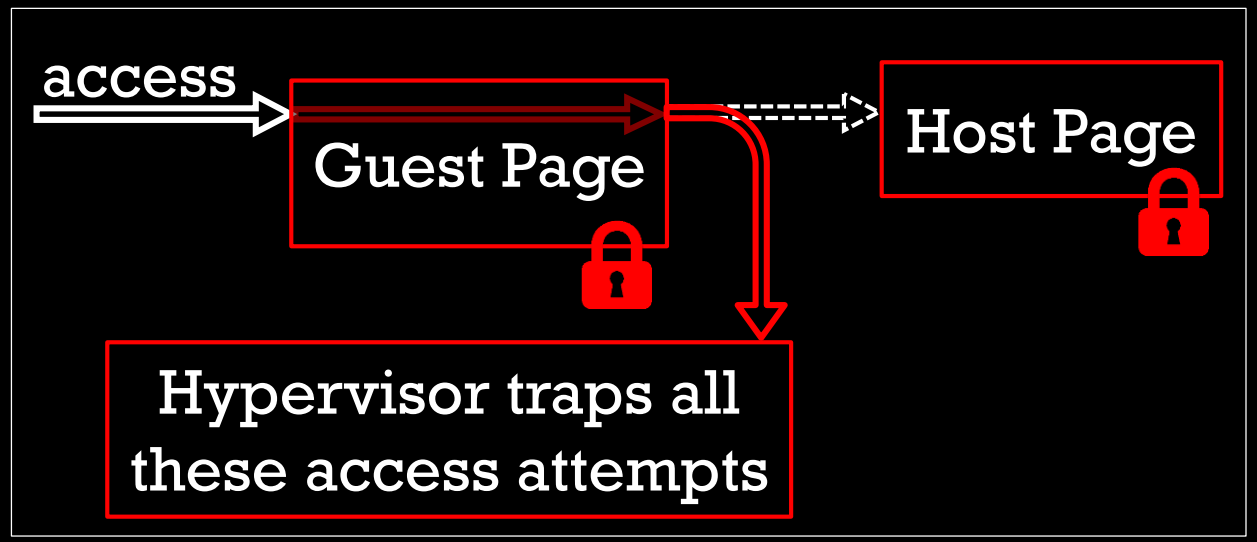

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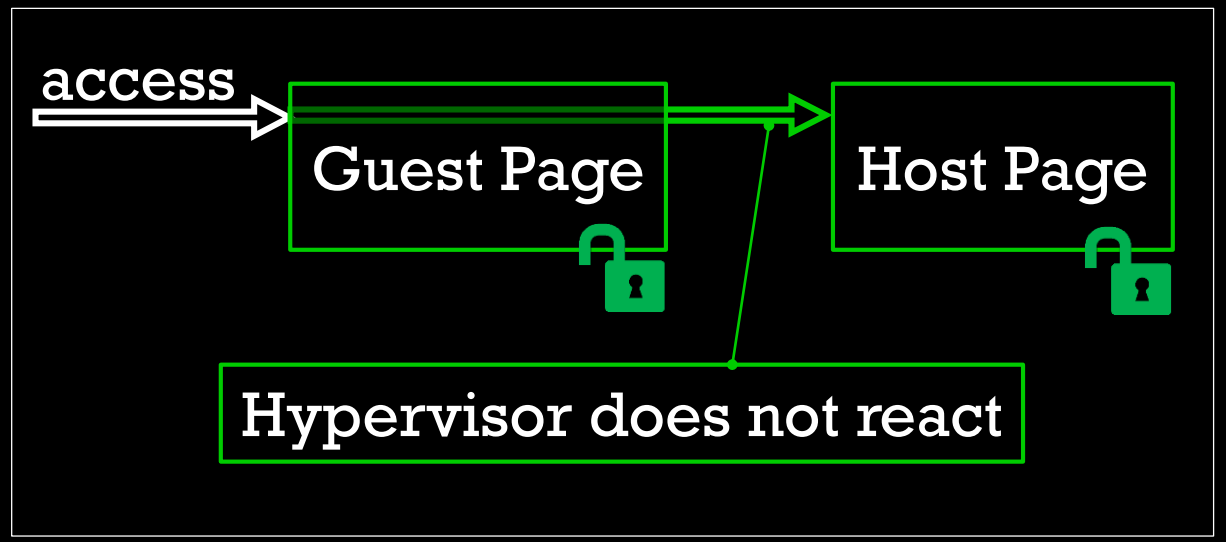

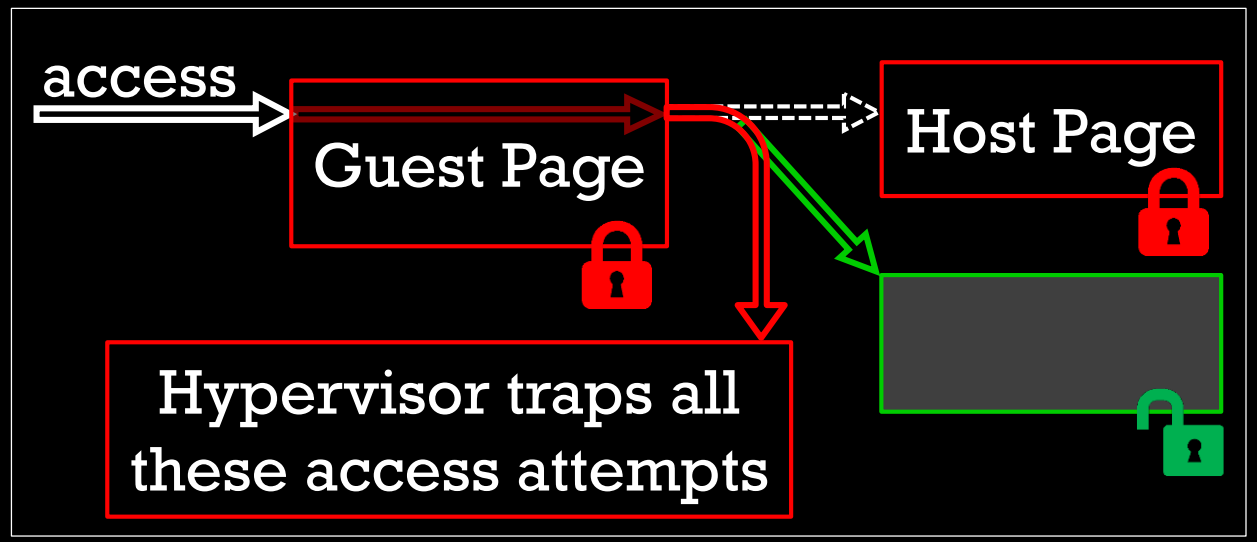

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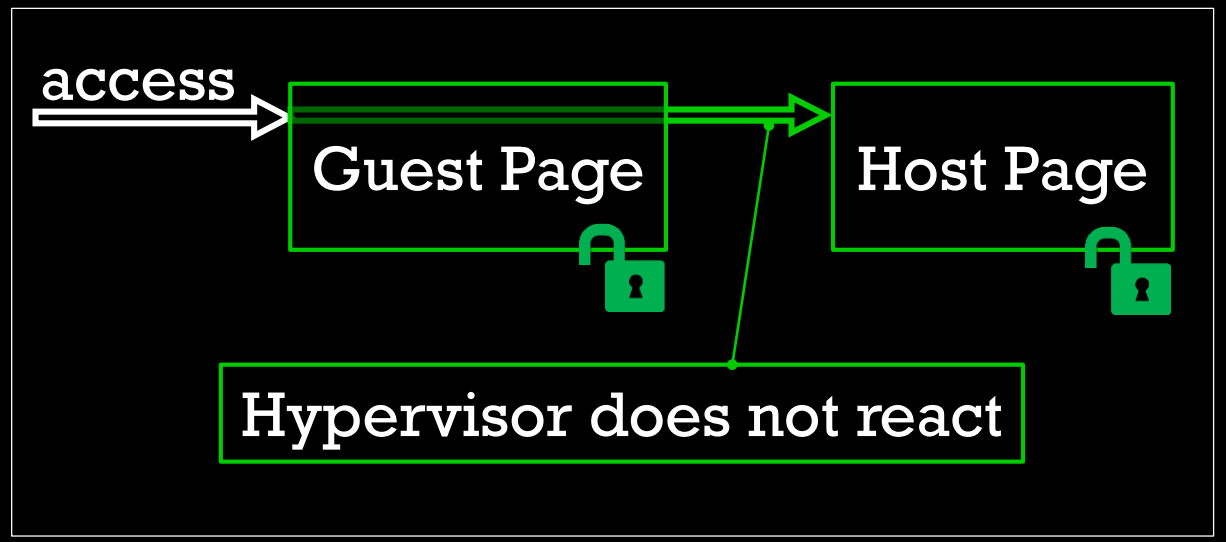

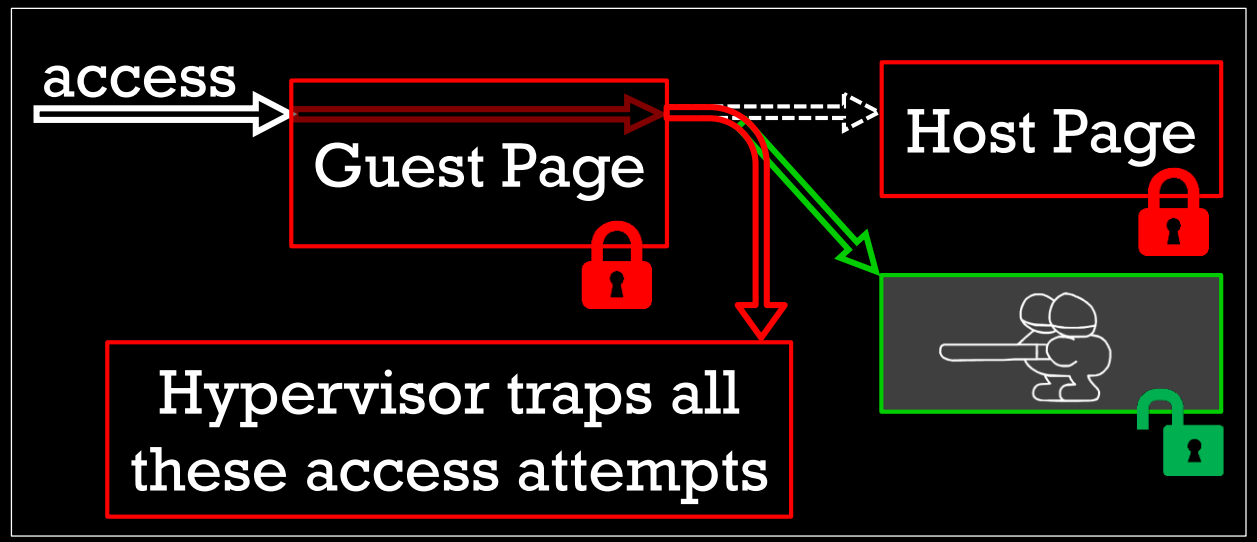

2.

3.

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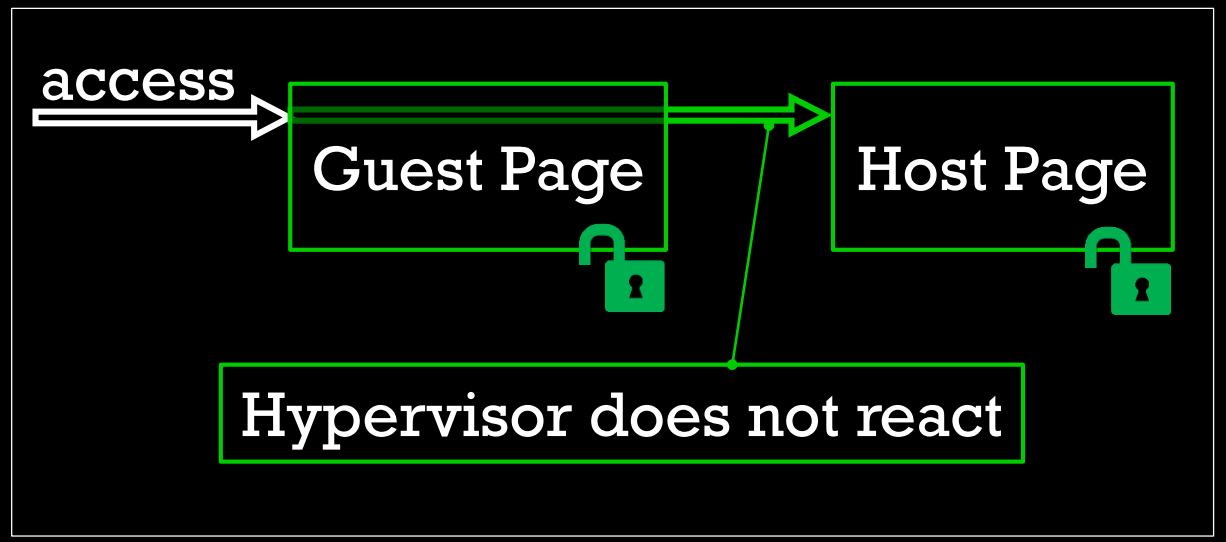

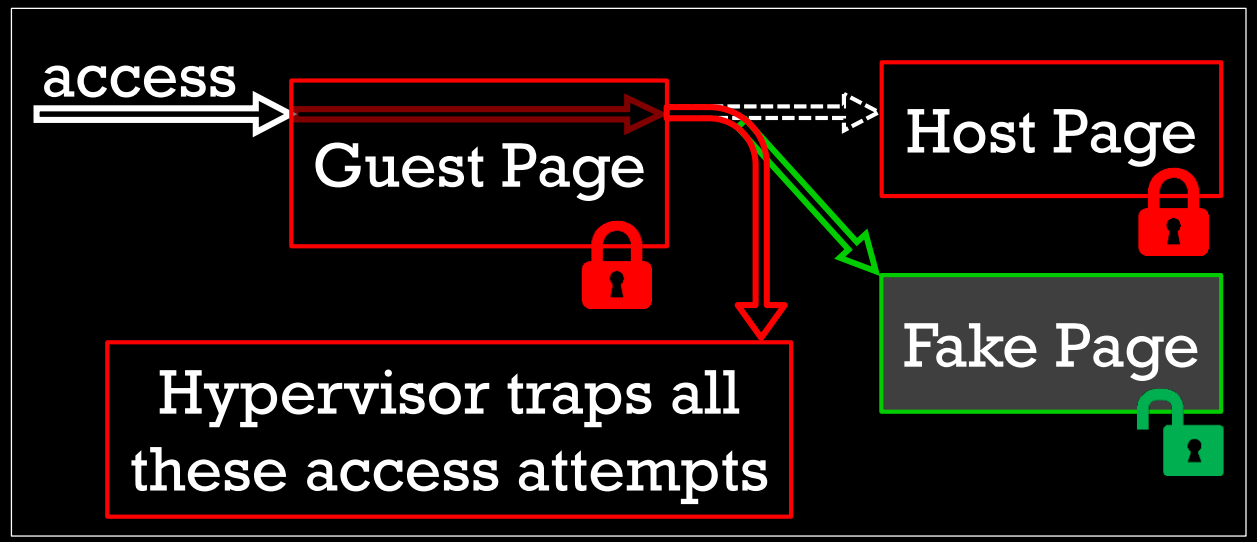

2. EPT memory settings can be updated in the real time
3.

EPT MAIN FEATURES

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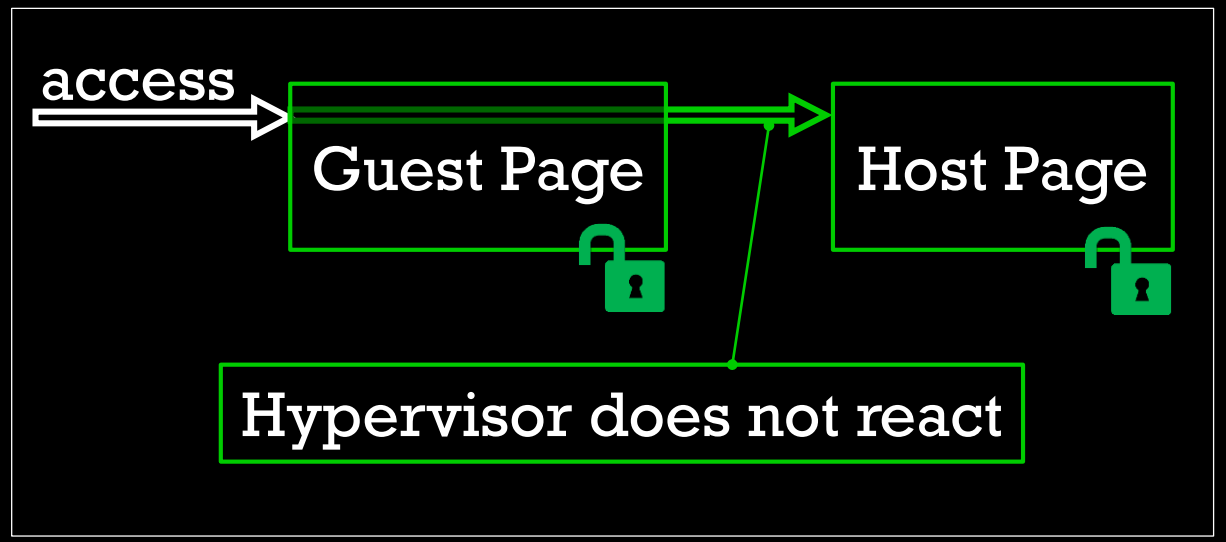
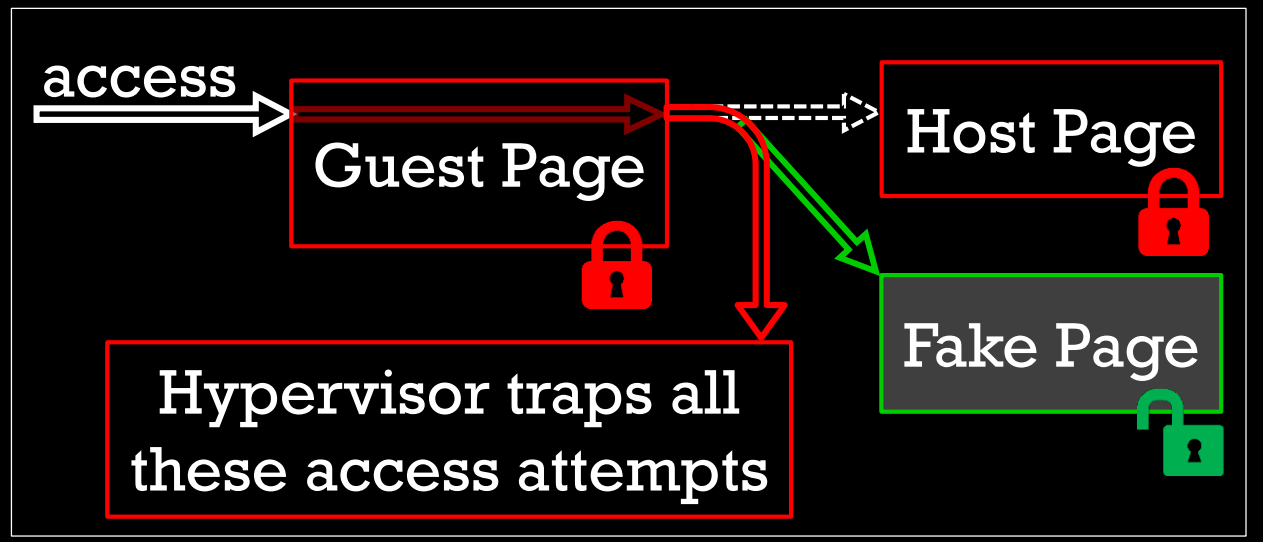
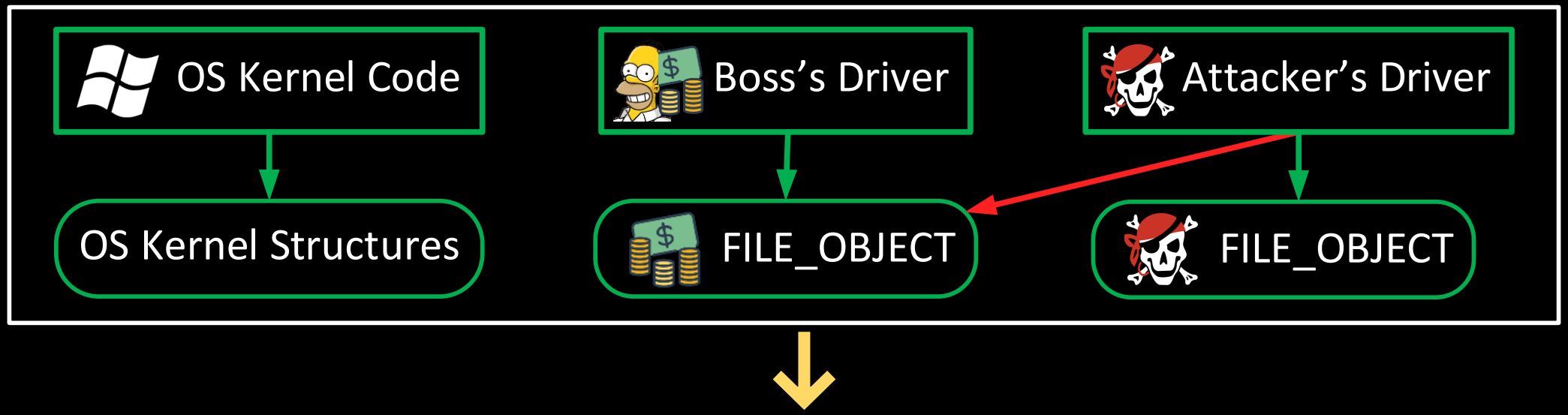


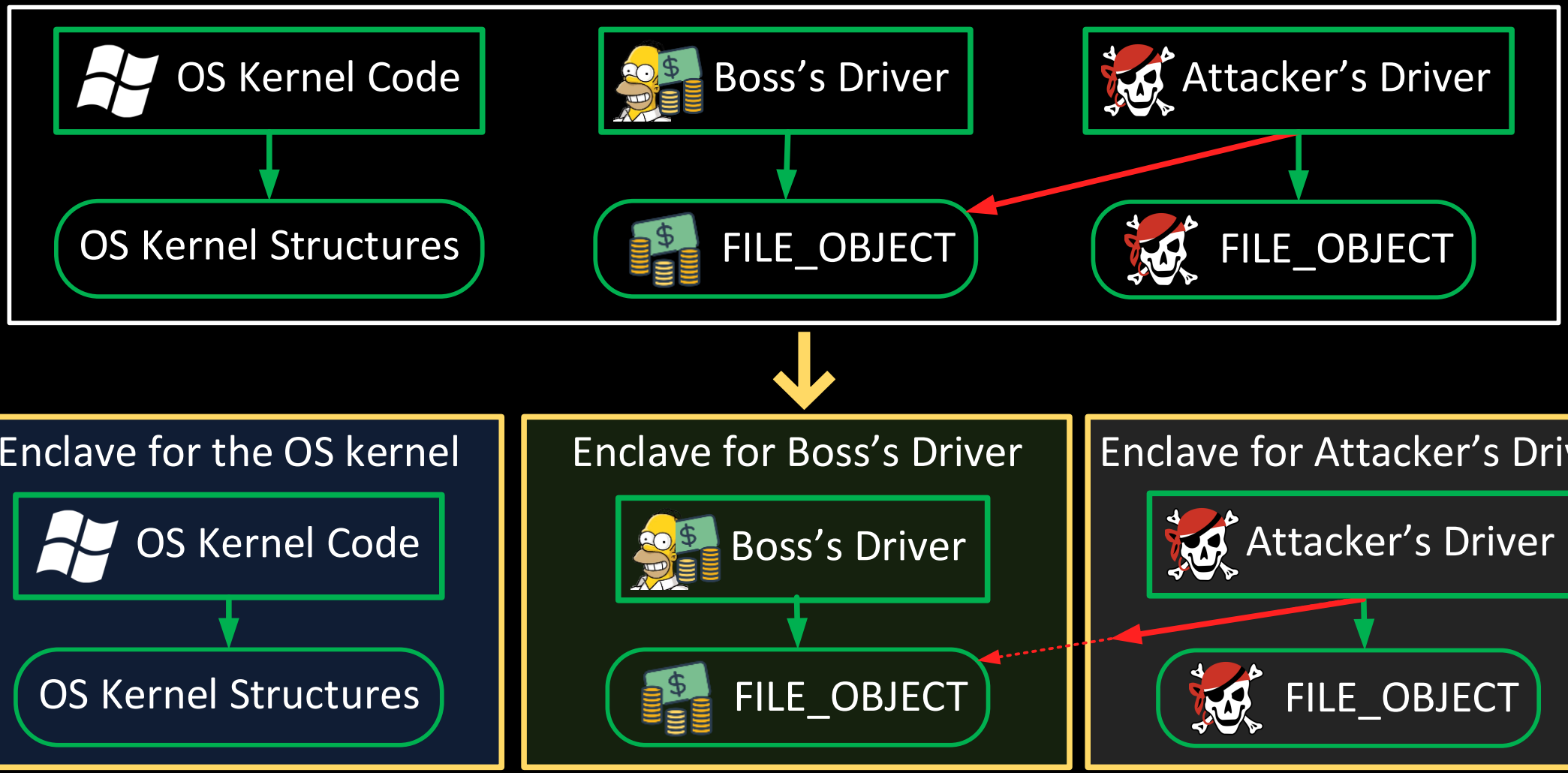


2. EPT memory settings can be updated in the real time
3. We can dynamically allocate several EPTs with different memory setting and switch between them in the real time

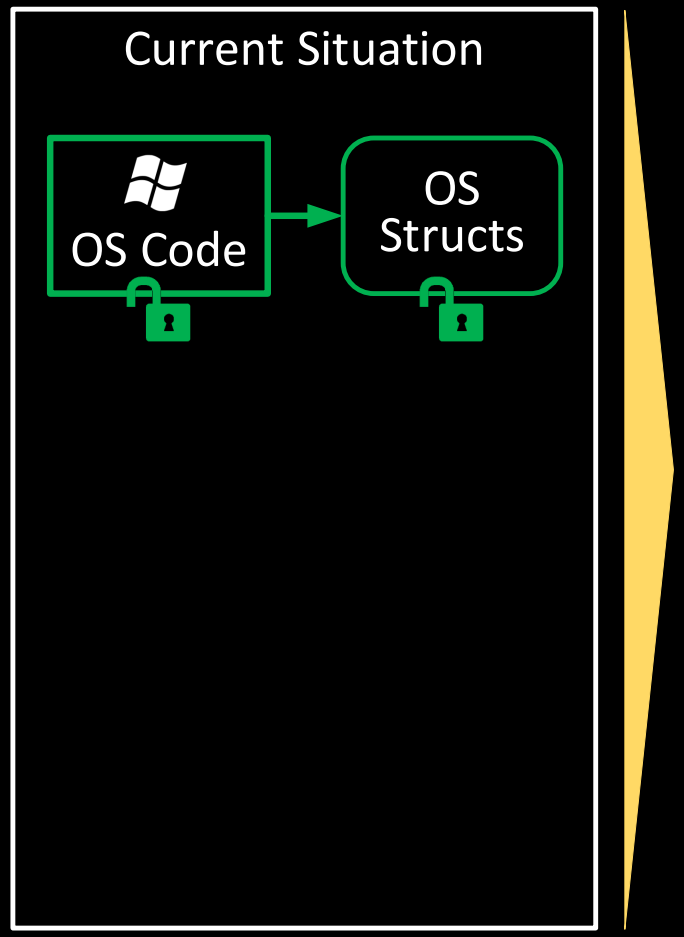
WINDOWS KERNEL MEMORY



WINDOWS KERNEL MEMORY



MEMORY RANGER PREVENTS FILE_OBJECT HIJACKING



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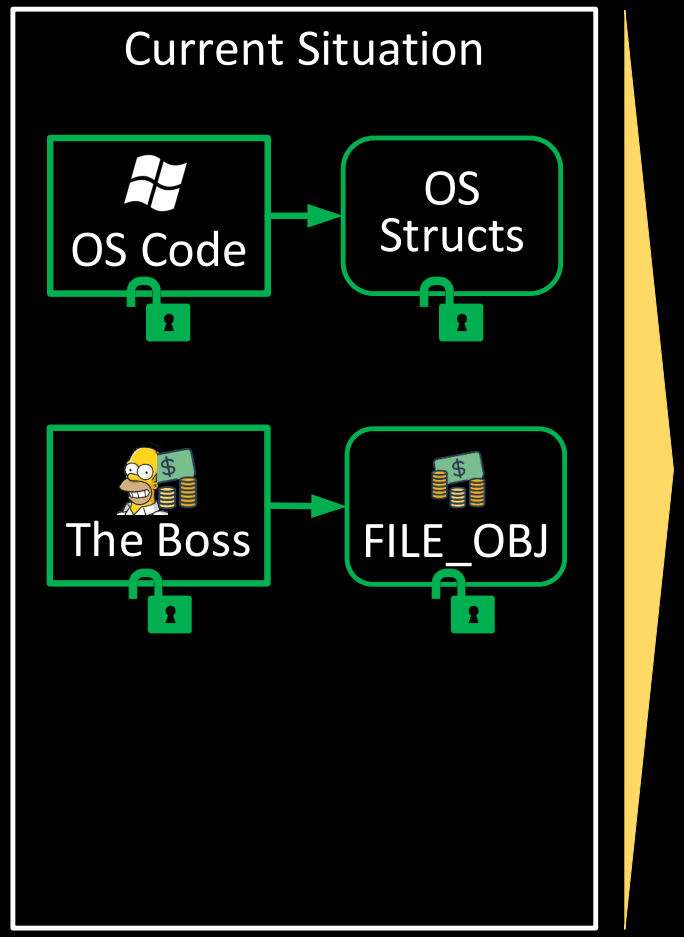

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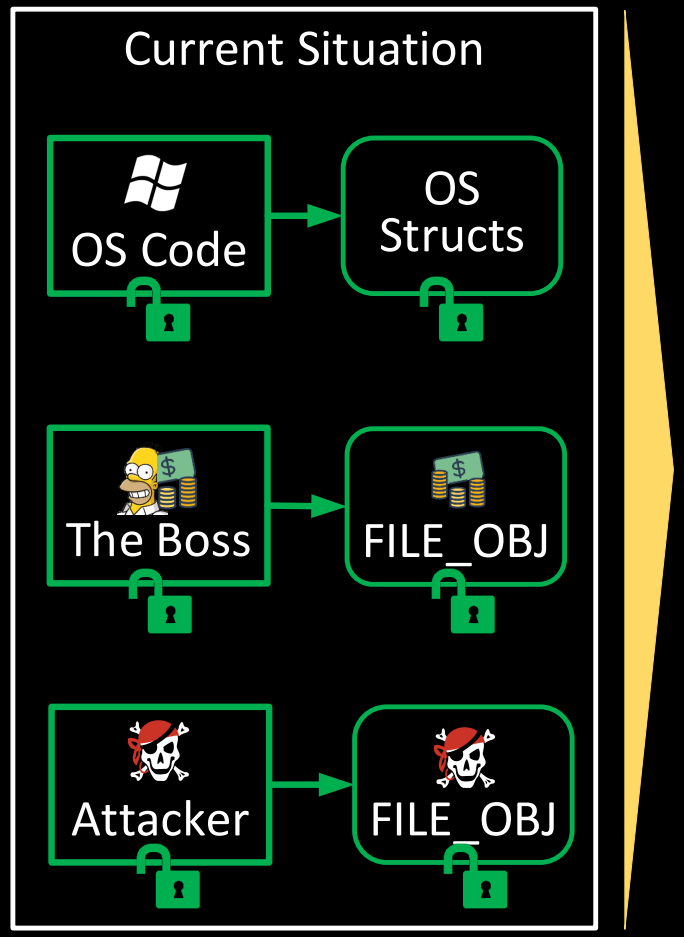

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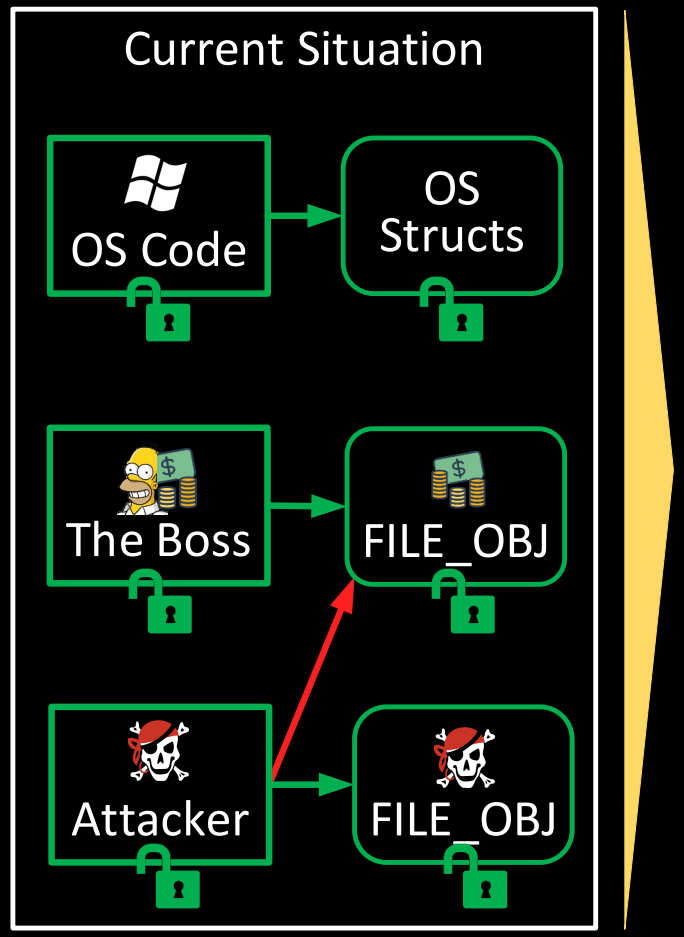

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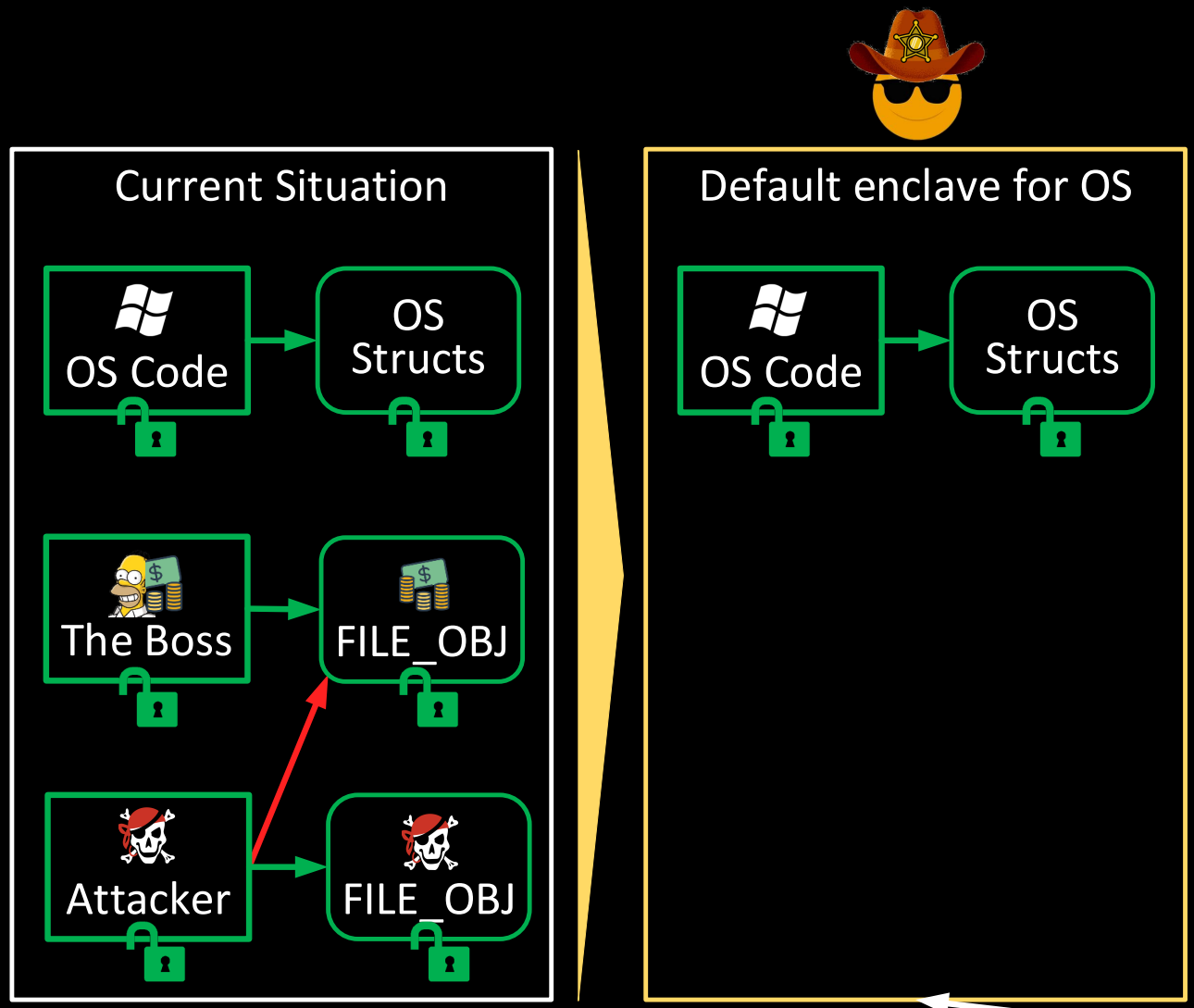

EPT pointer

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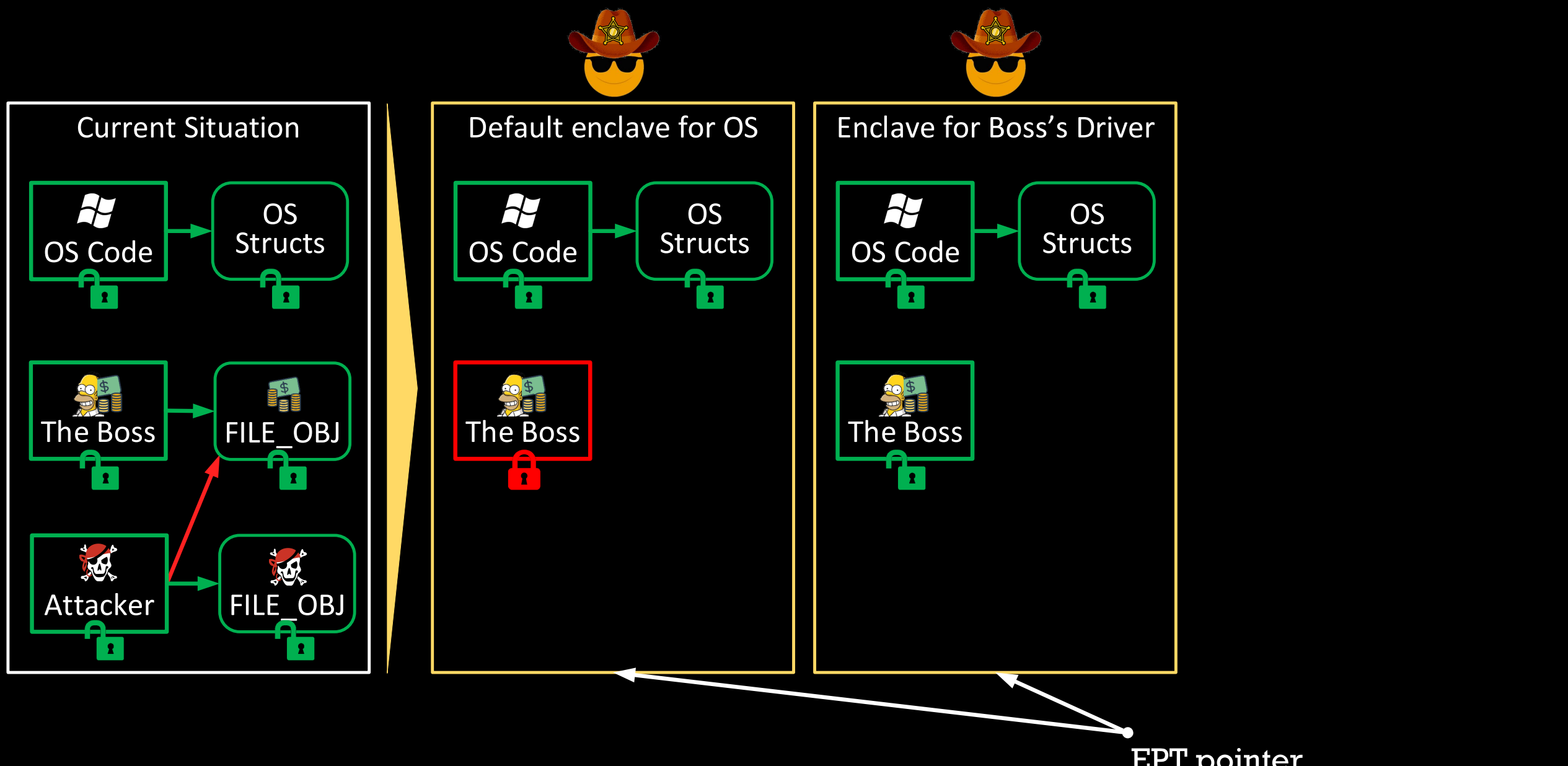

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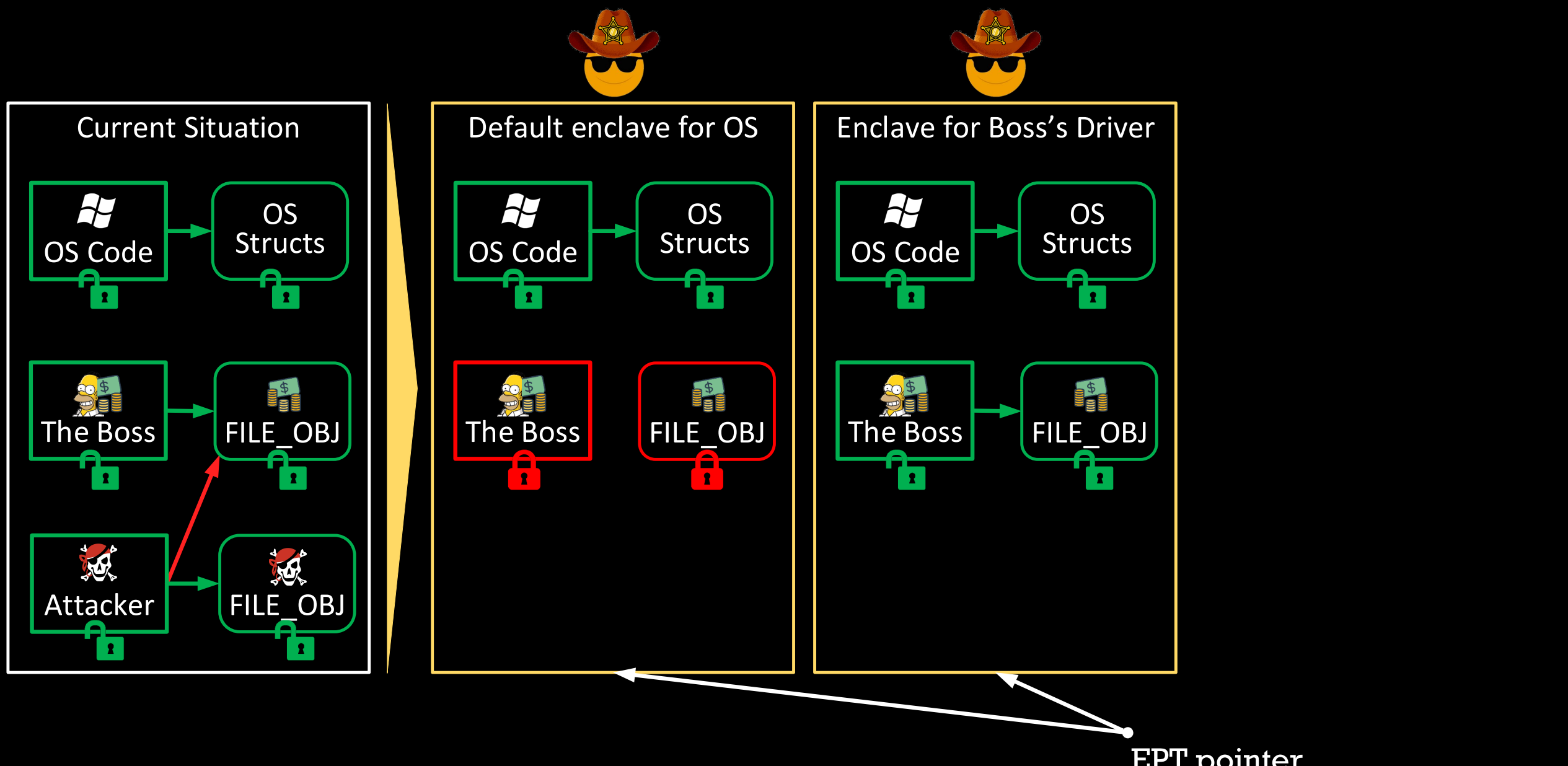

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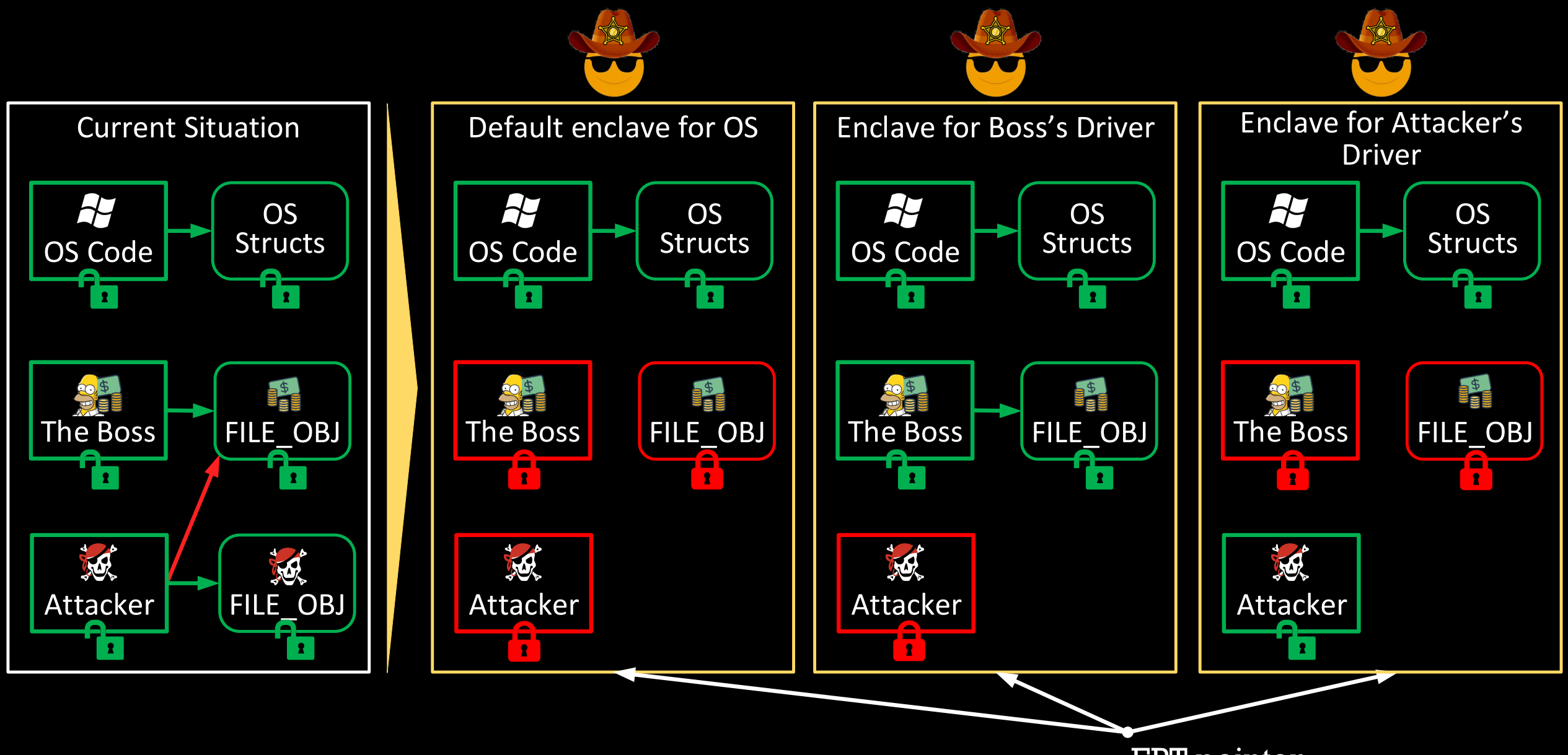

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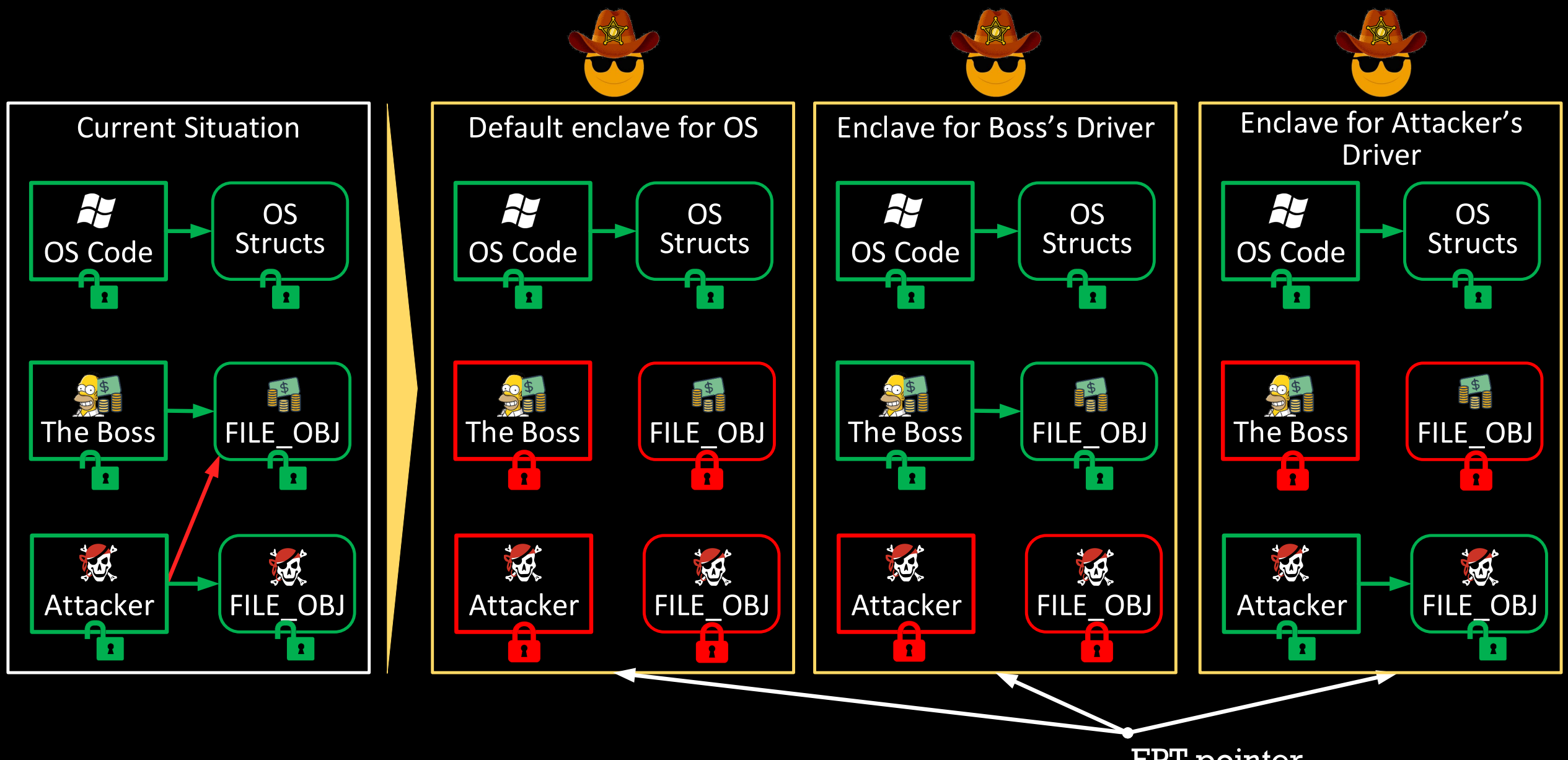

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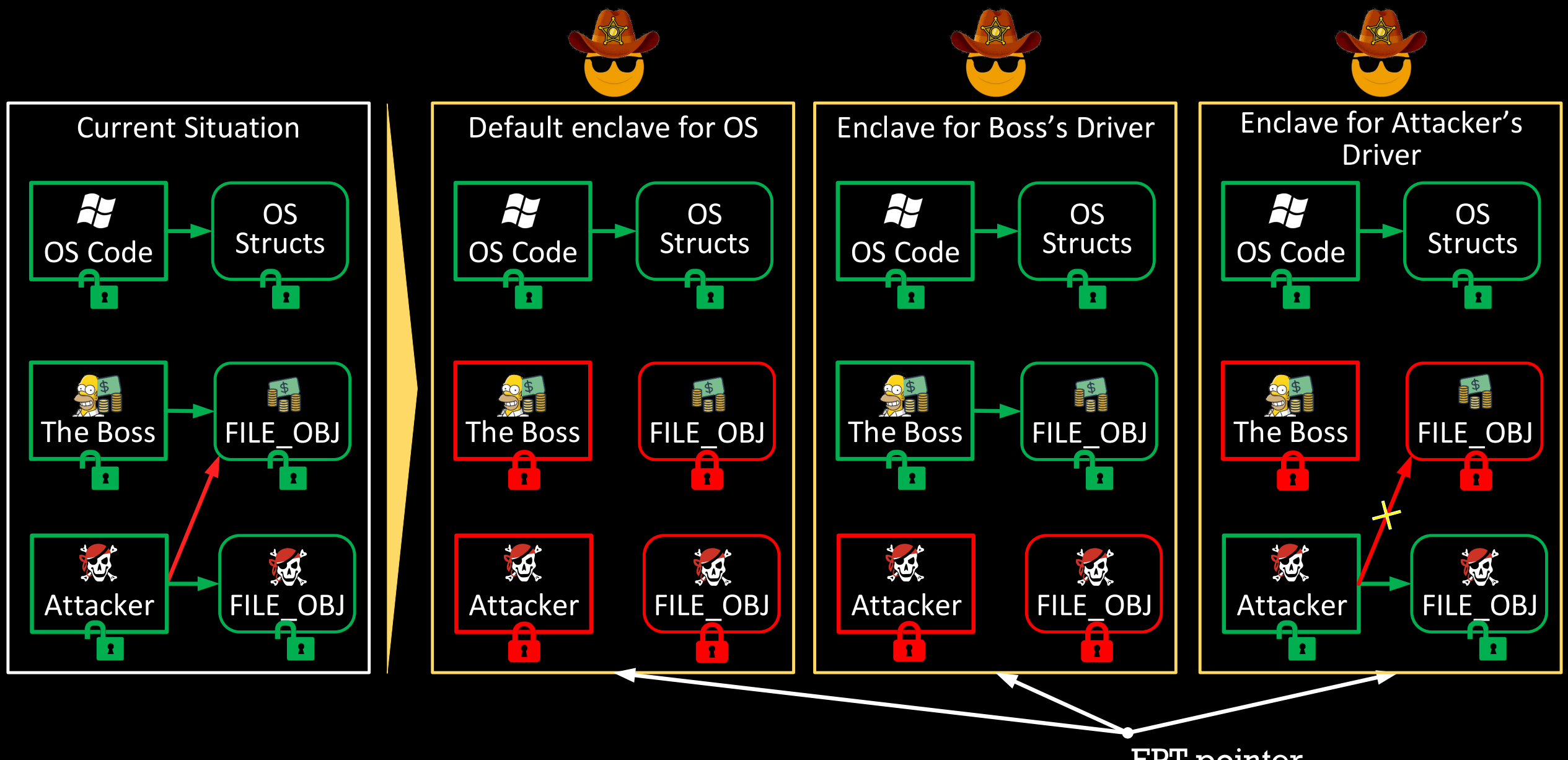

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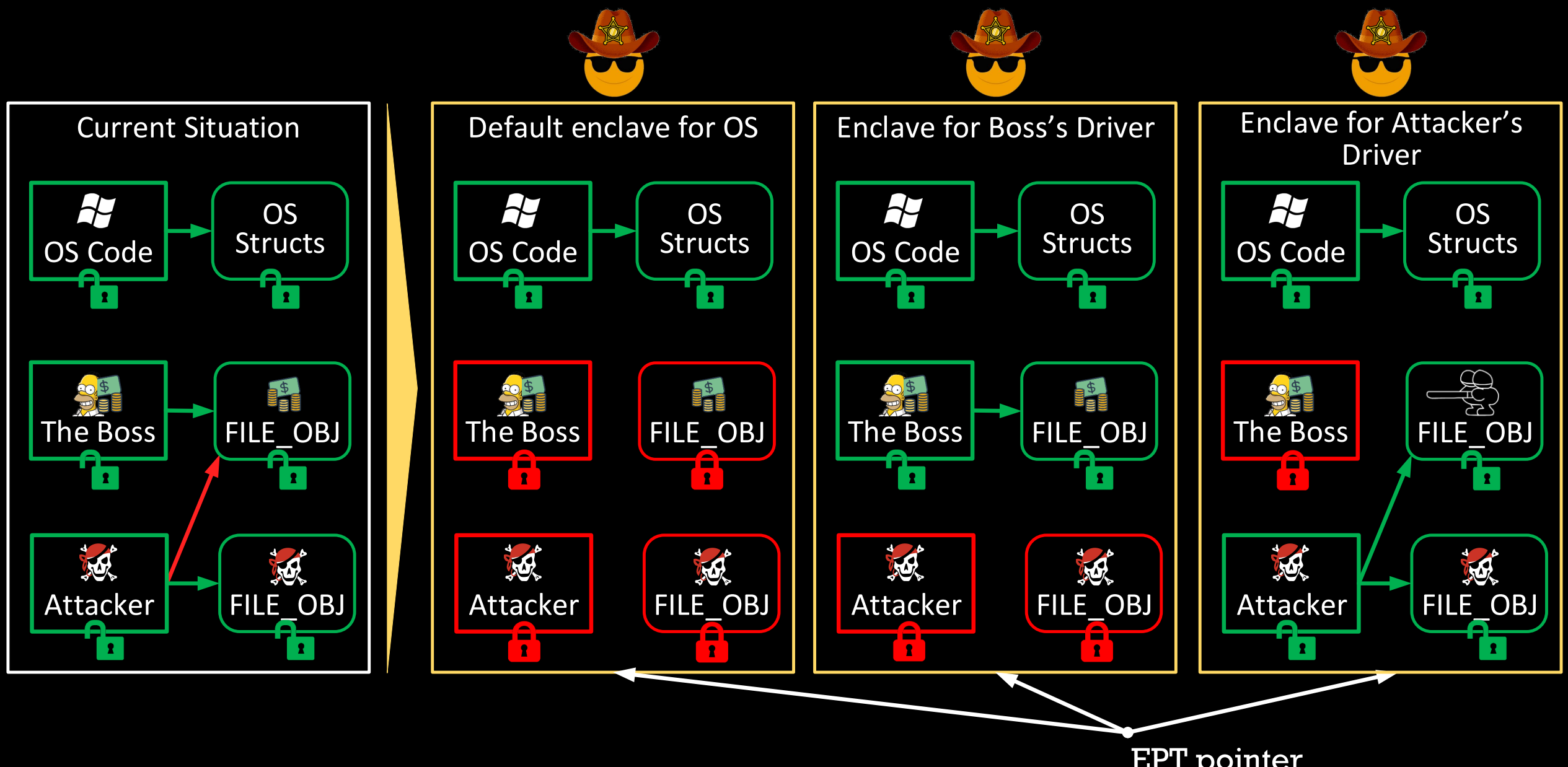
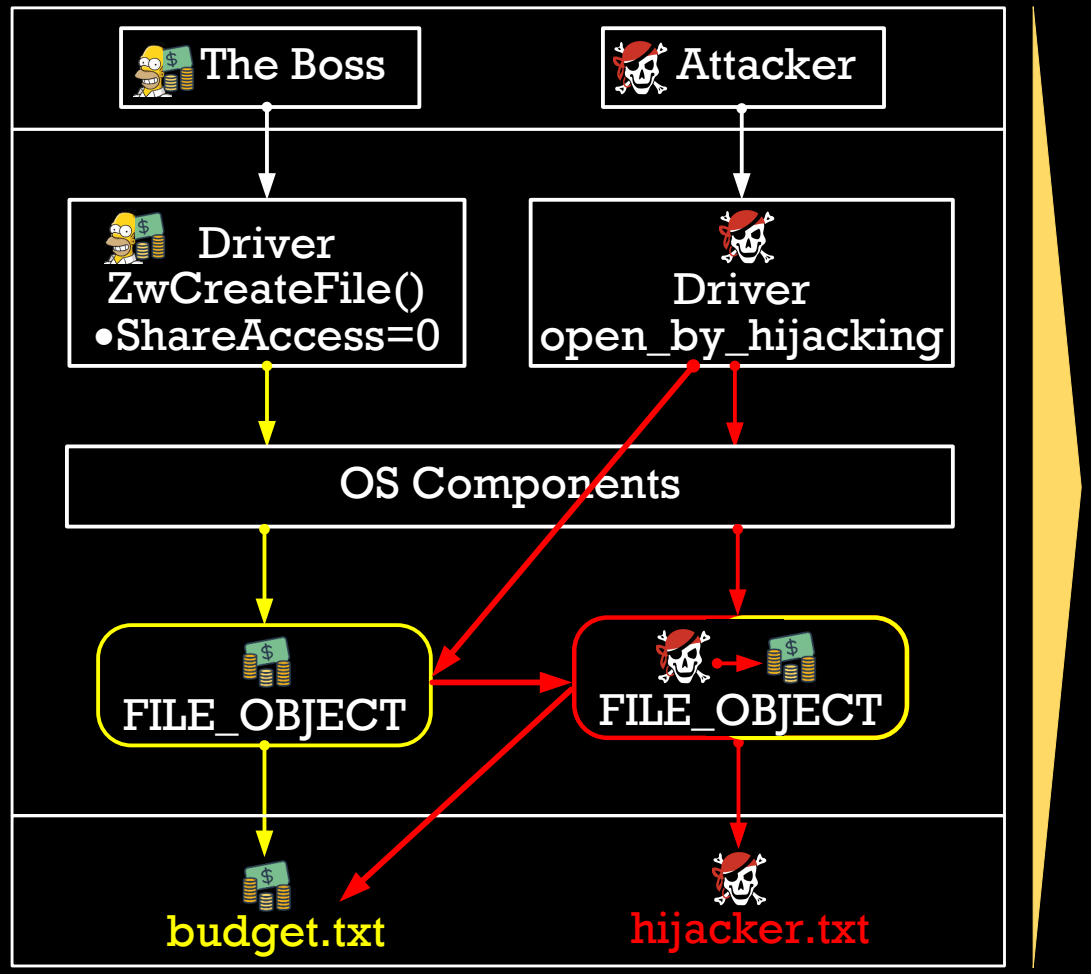


DEMO: PREVENTING THE HIJACKING

Attempt 2: The Hijacking Attack



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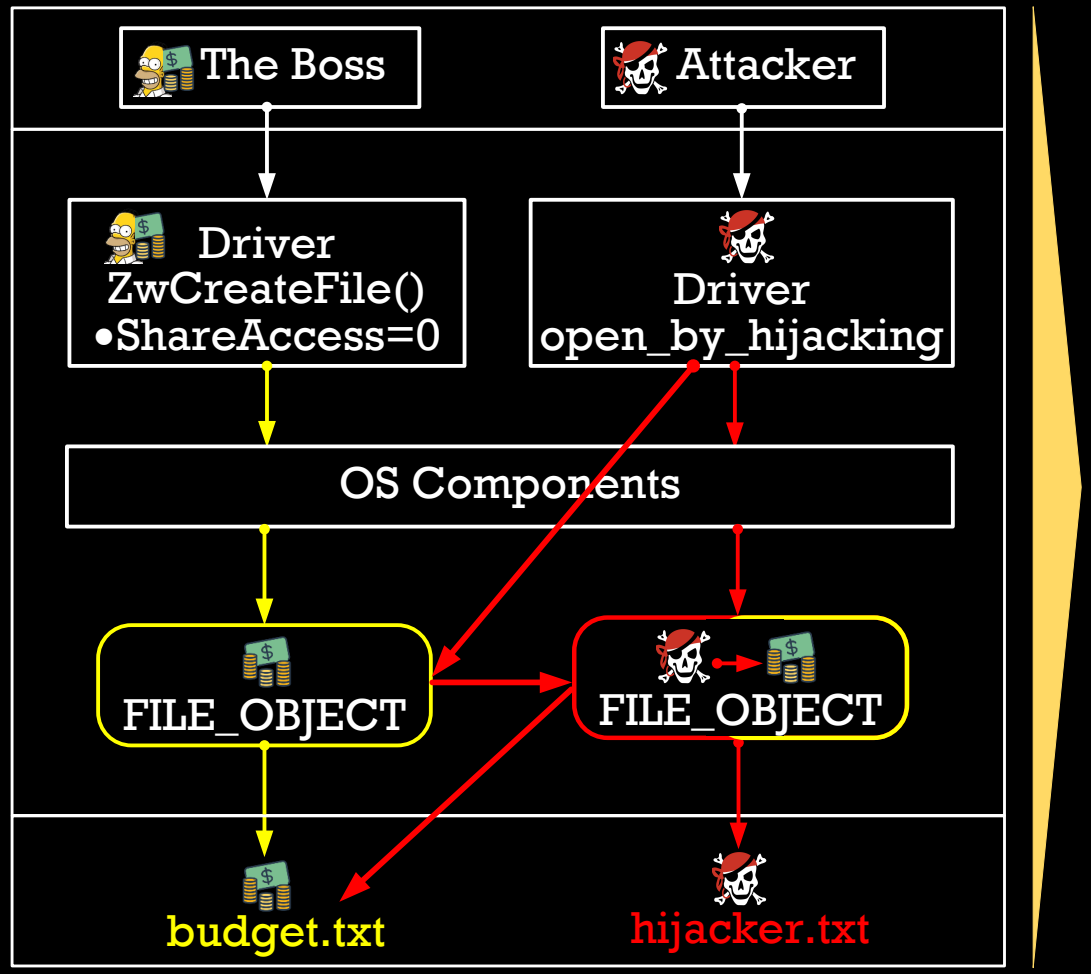
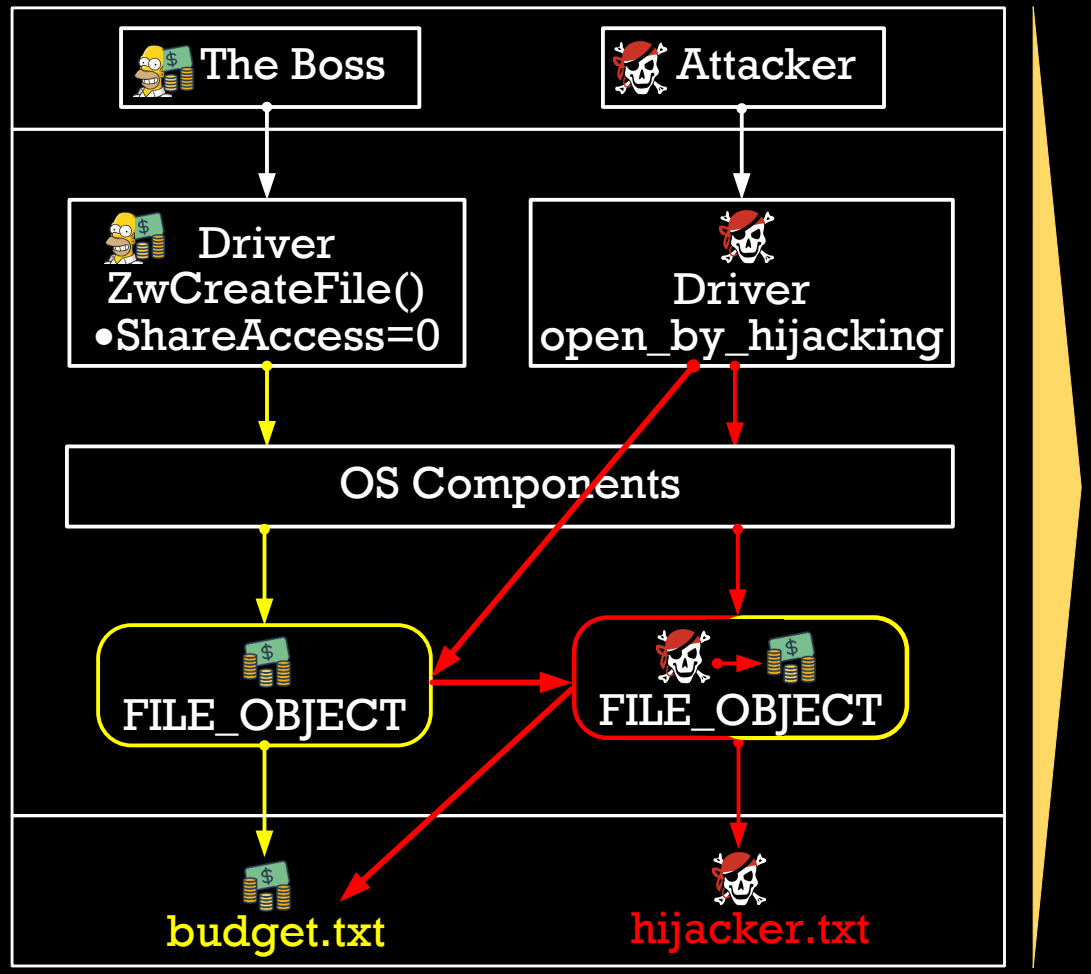


DEMO: THE ATTACK PREVENTION

The online version is here –
https://www.youtube.com/watch?v=8ONmC5Do4I4?vq=hd1080

DEMO: PREVENTING THE HIJACKING

Attempt 2: The Hijacking Attack



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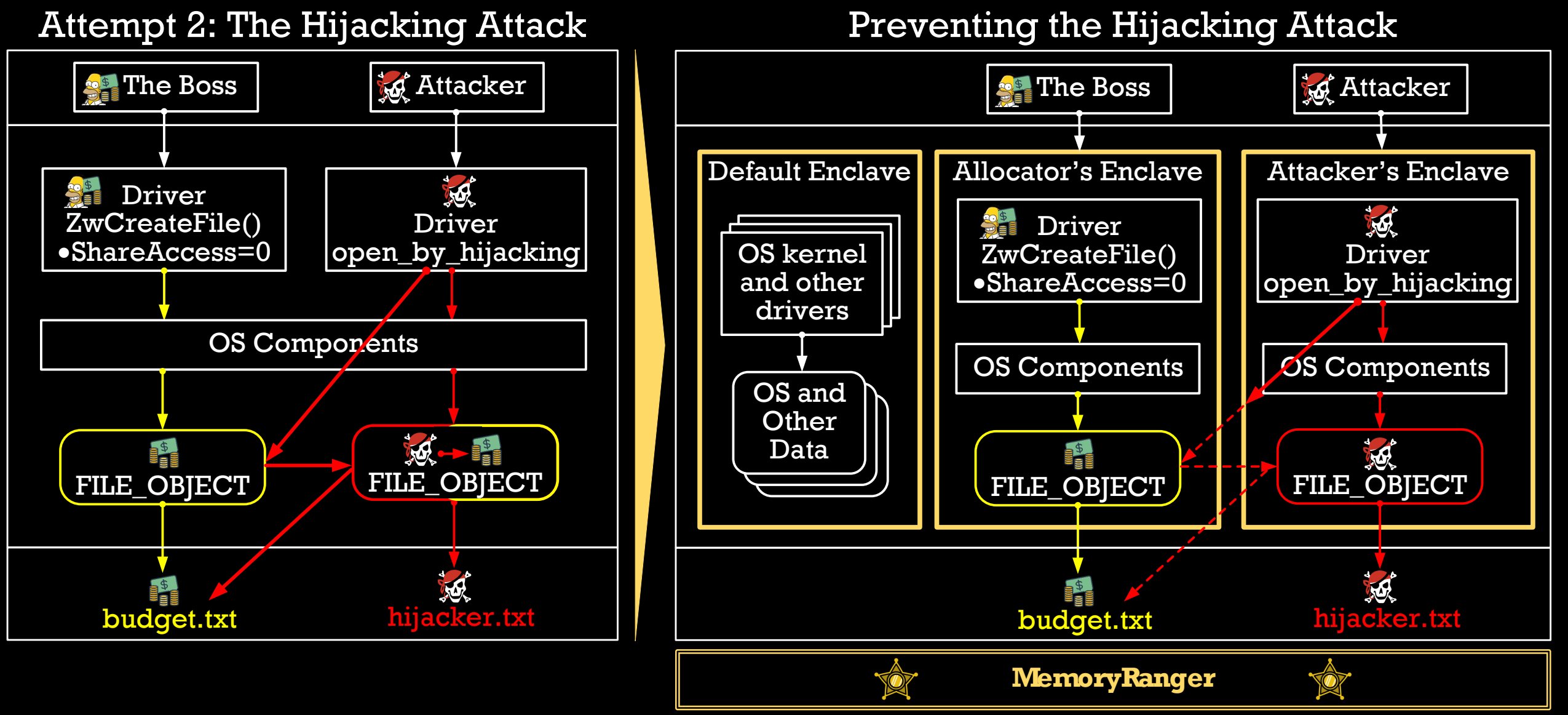
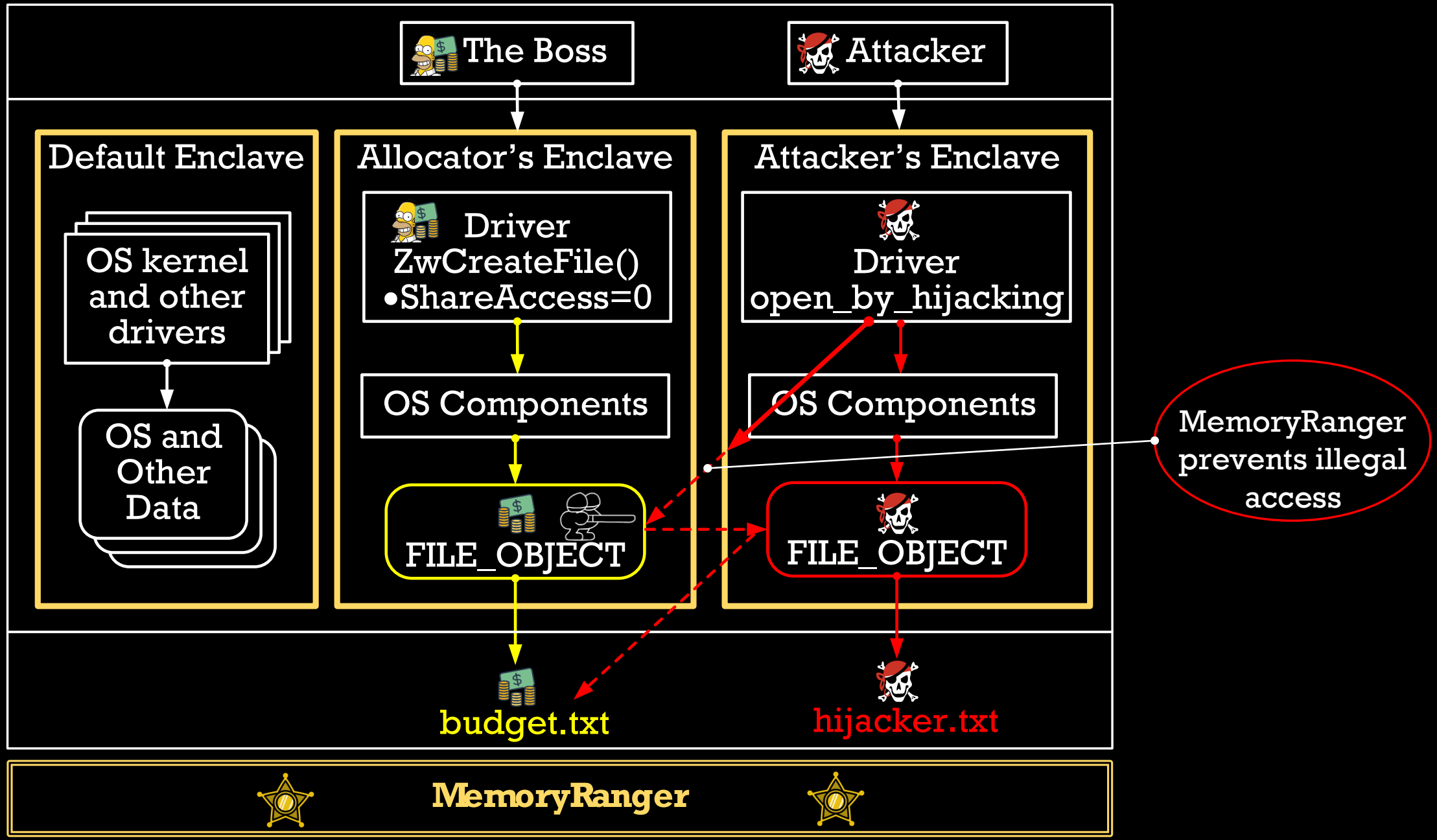
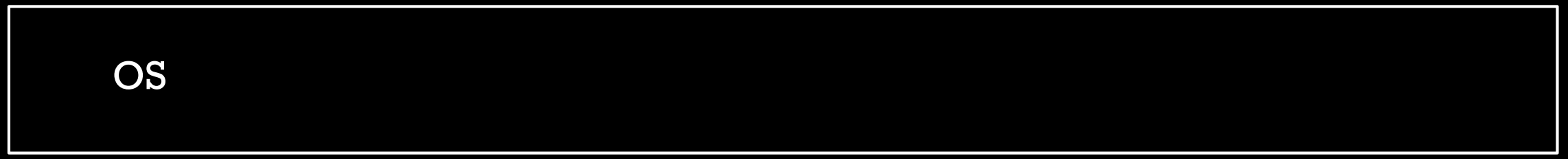


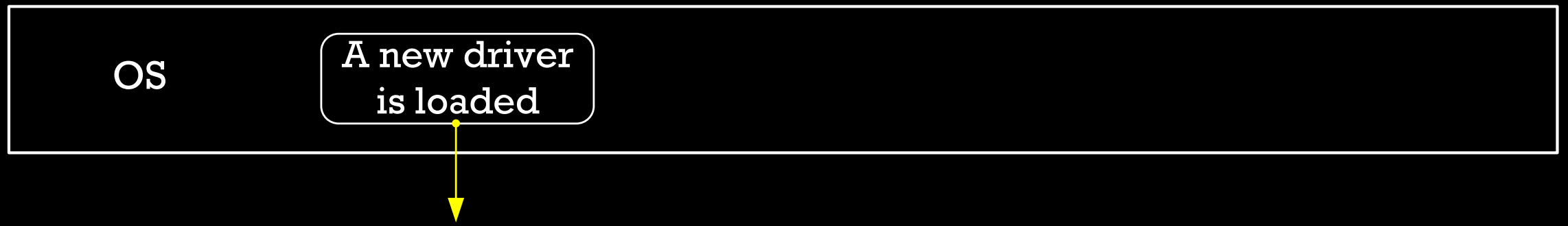
Preventing the Hijacking Attack



MEMORY RANGER ARCHITECTURE



MEMORY RANGER ARCHITECTURE



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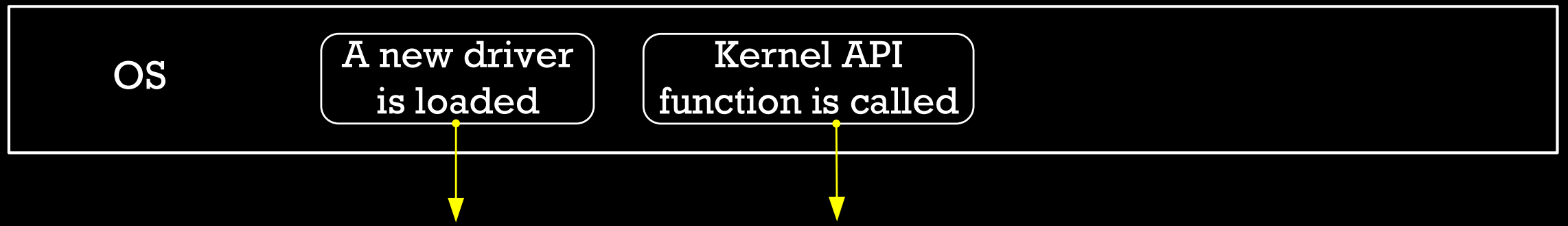
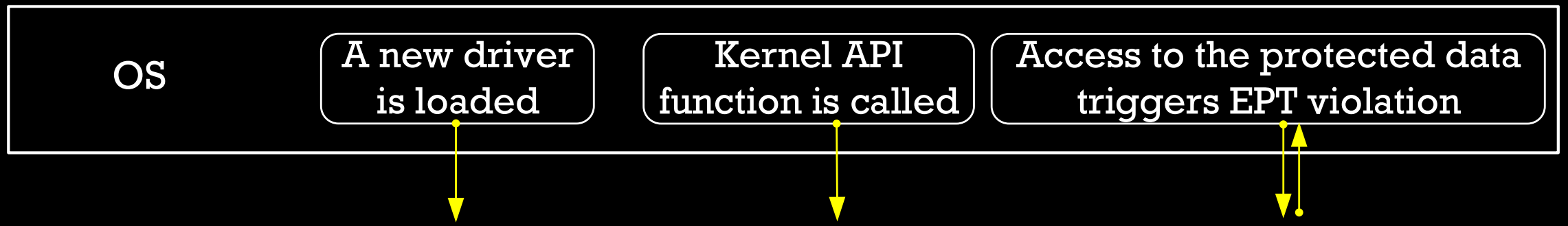
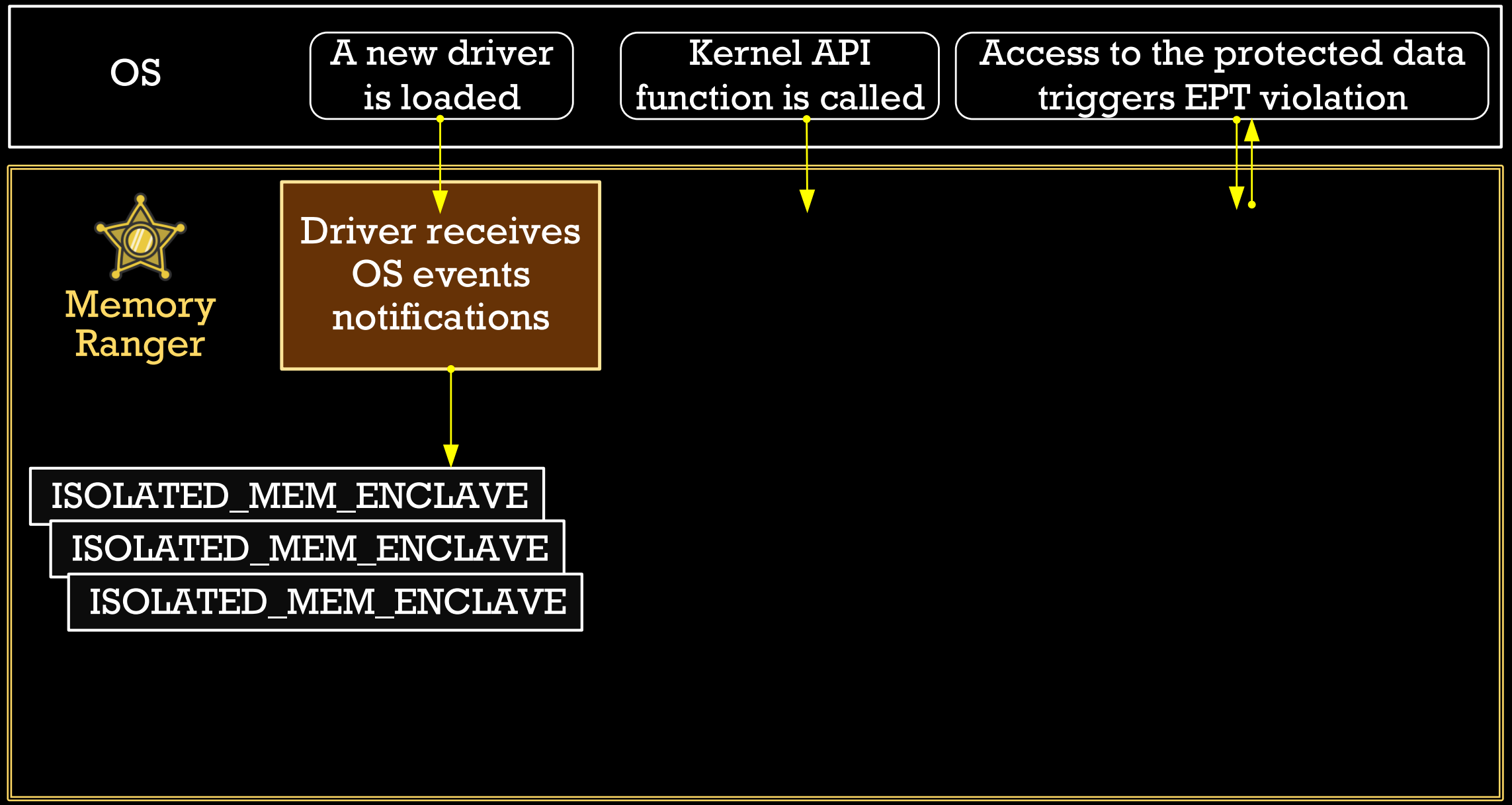


MEMORY RANGER ARCHITECTURE



MEMORY RANGER ARCHITECTURE



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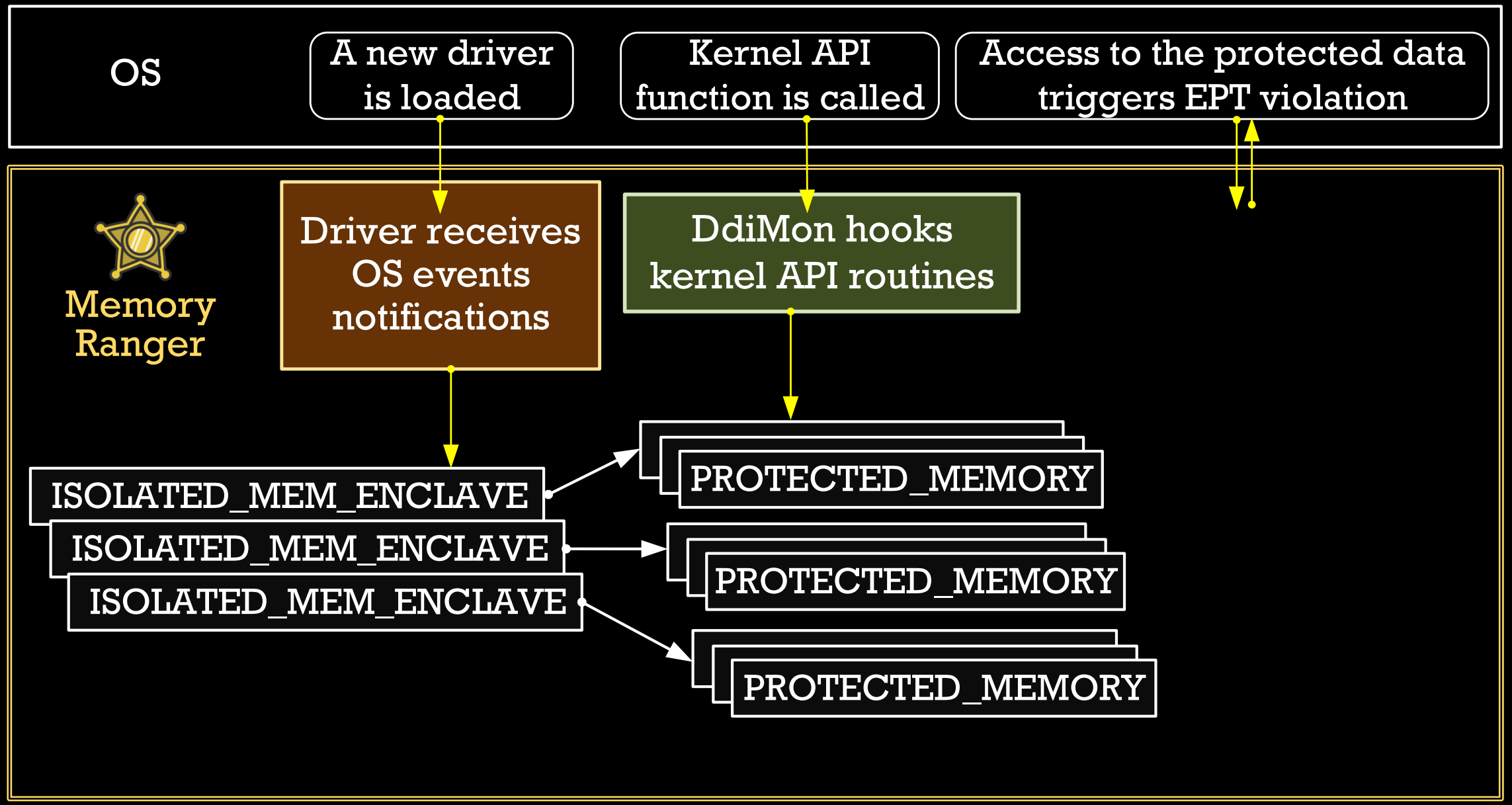

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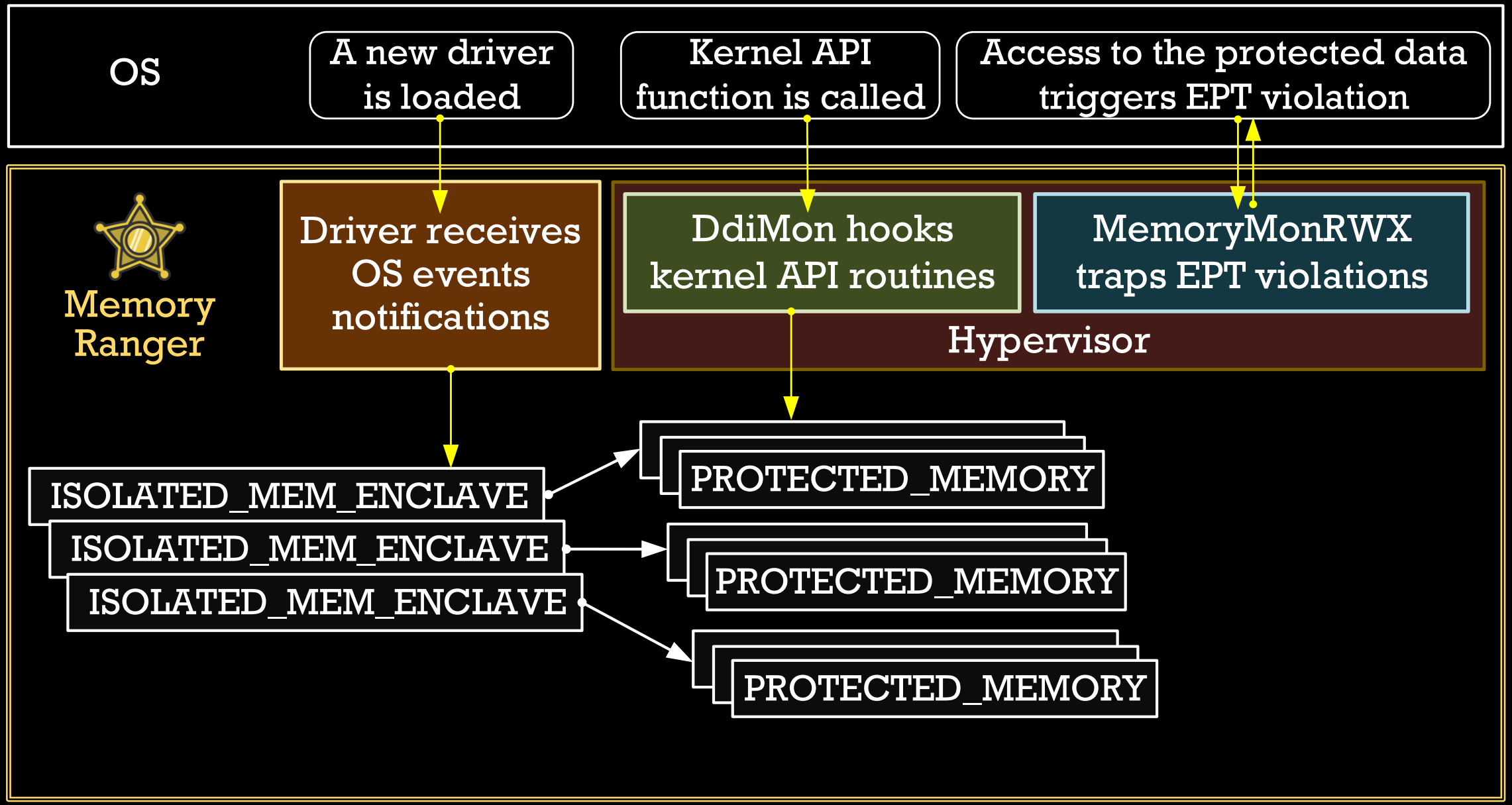

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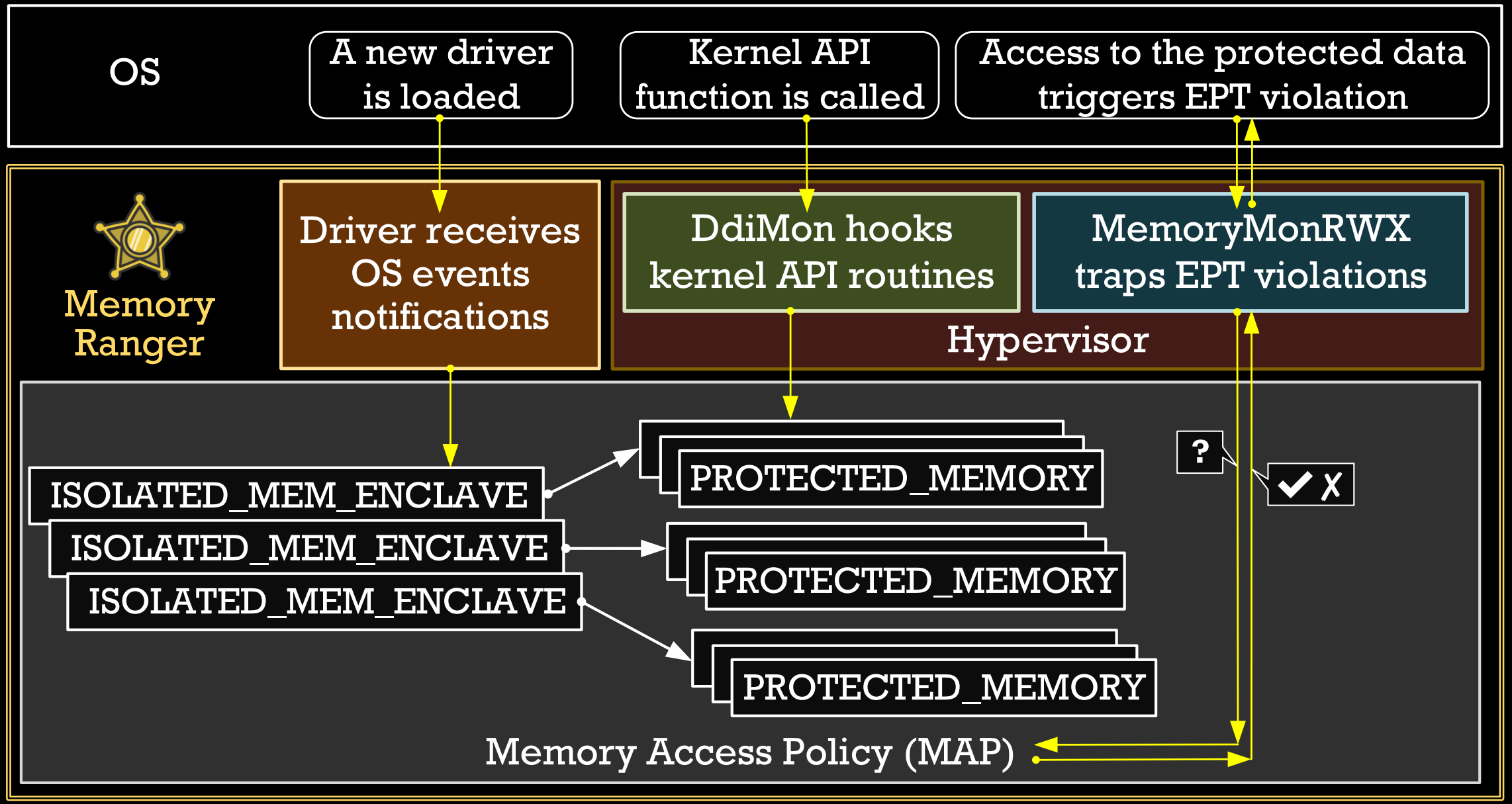
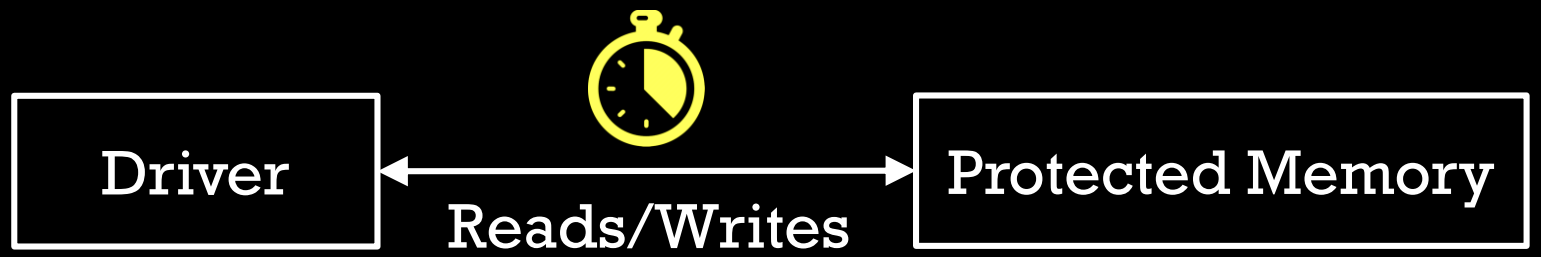


MEMORY RANGER BENCHMARKS: MEMORY ACCESS TIME



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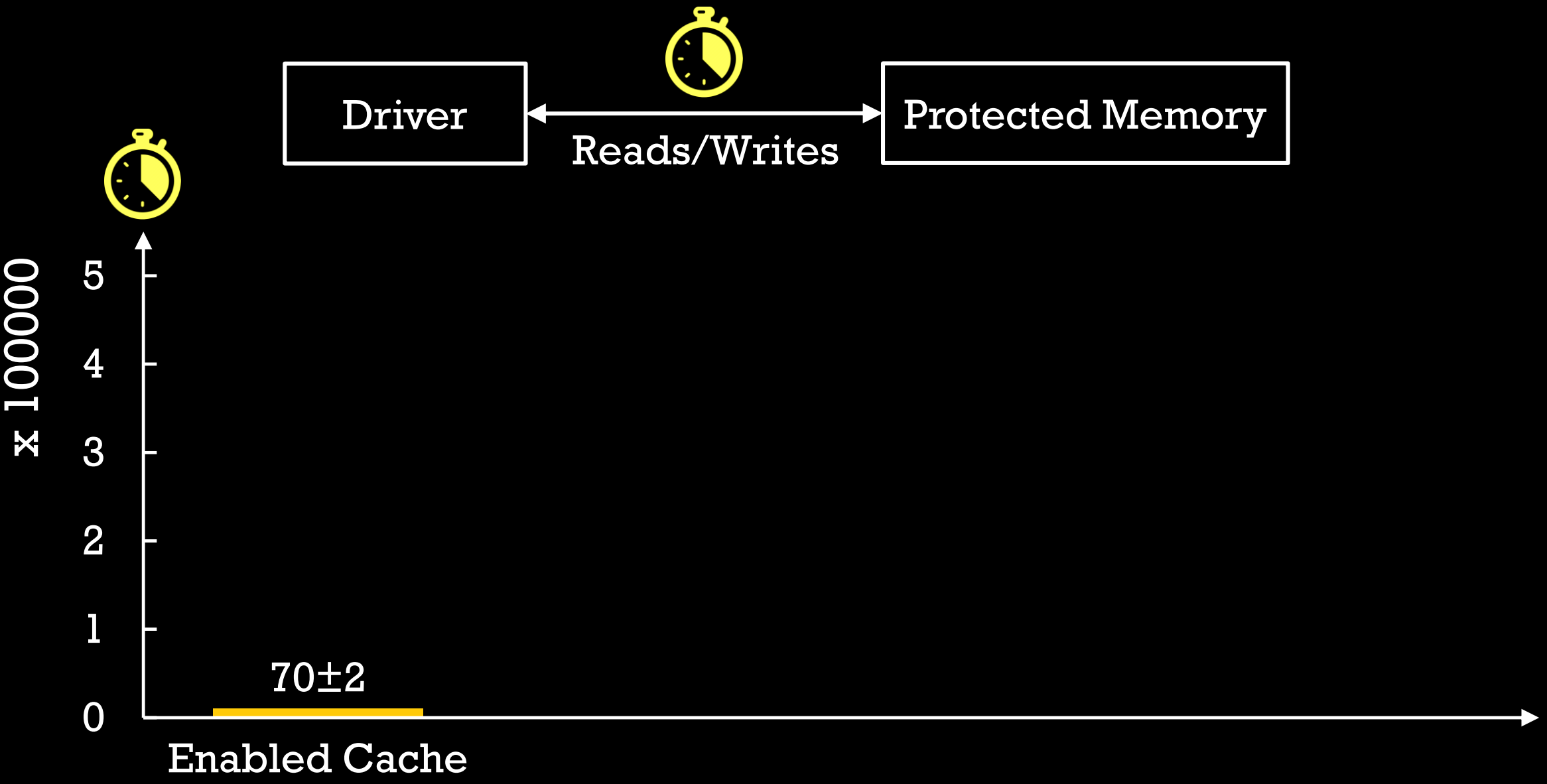
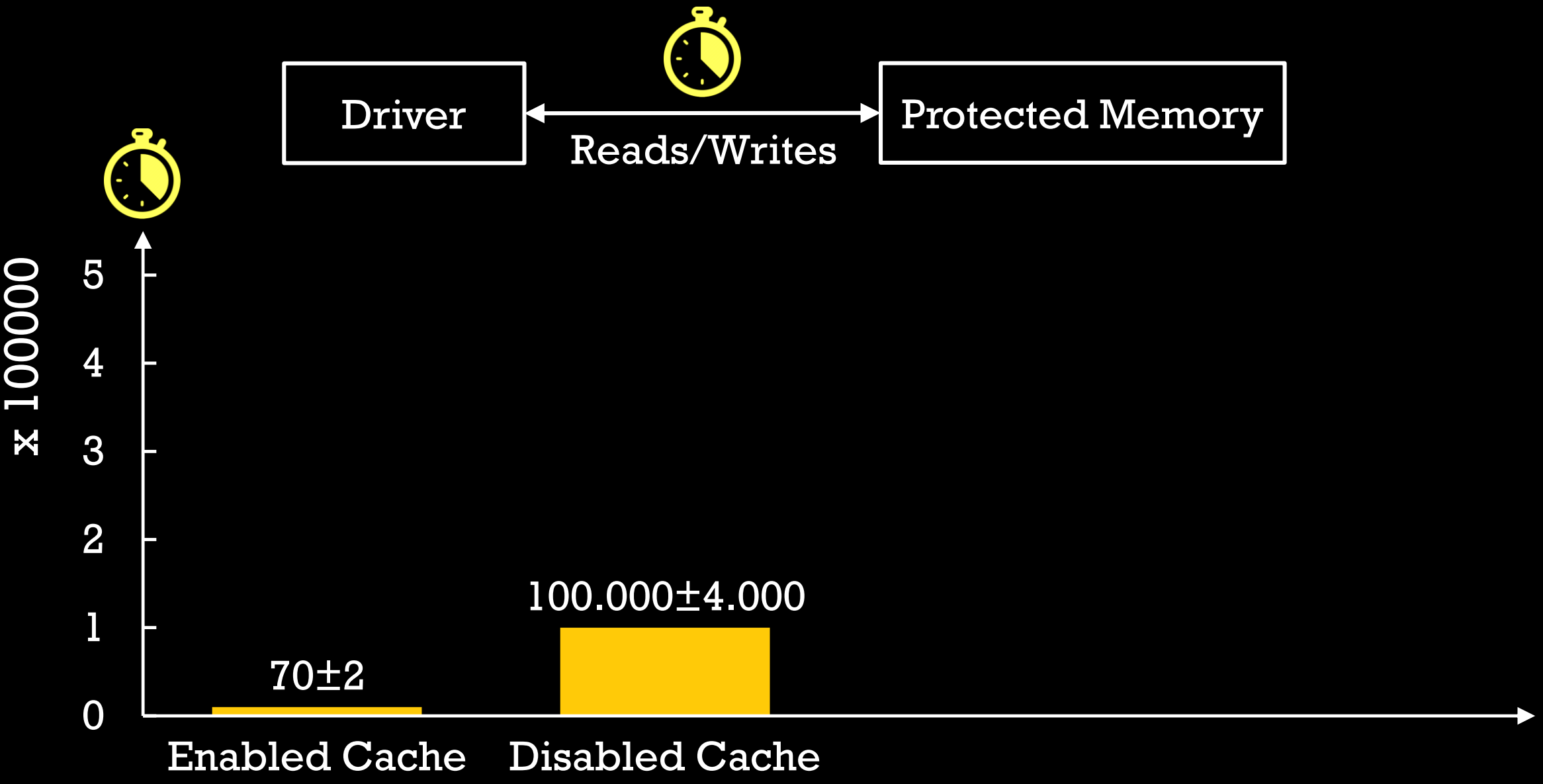


MEMORY RANGER BENCHMARKS: MEMORY ACCESS TIME



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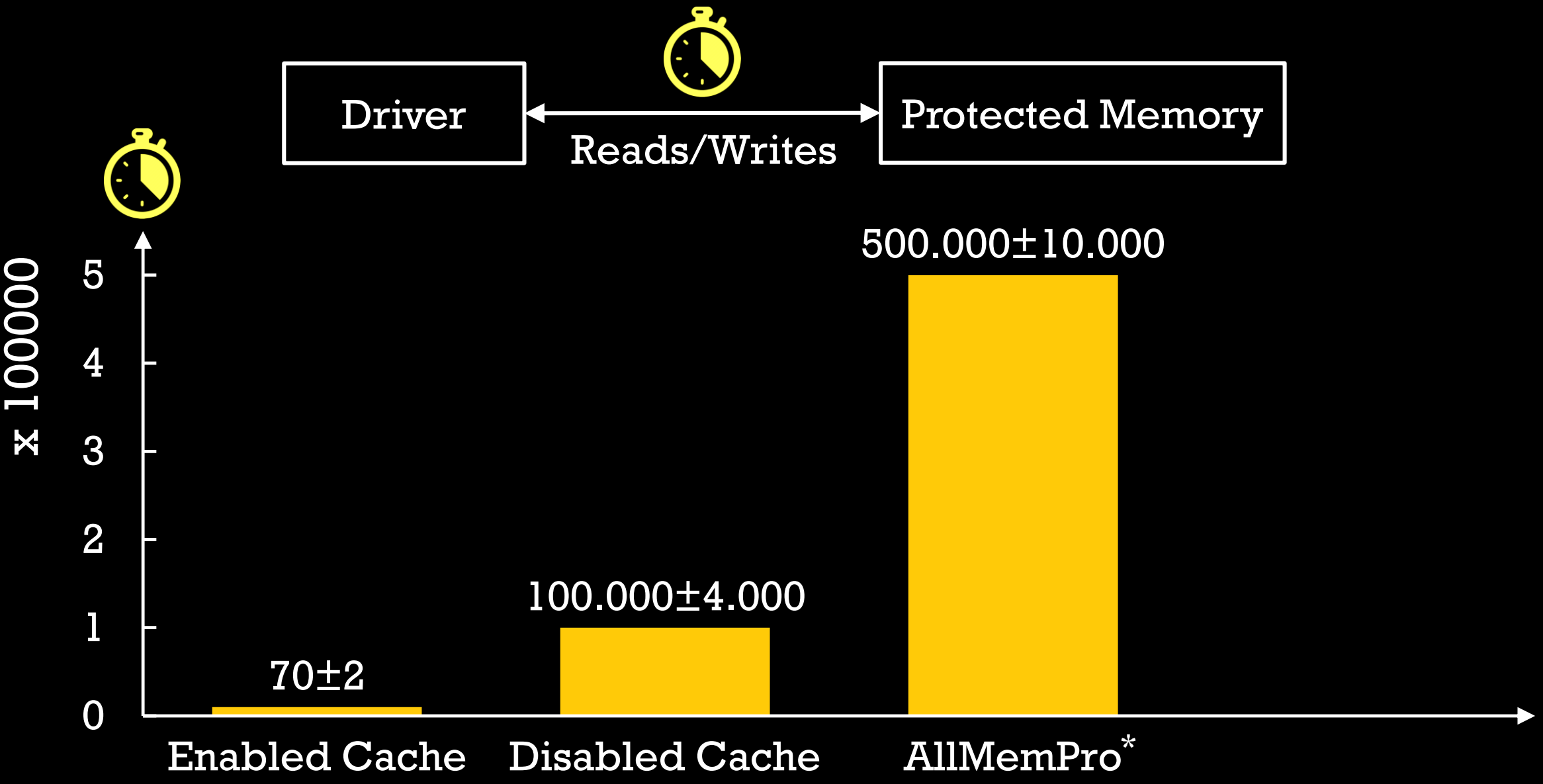

* AllMemPro details - http://bit.ly/AllMemPro

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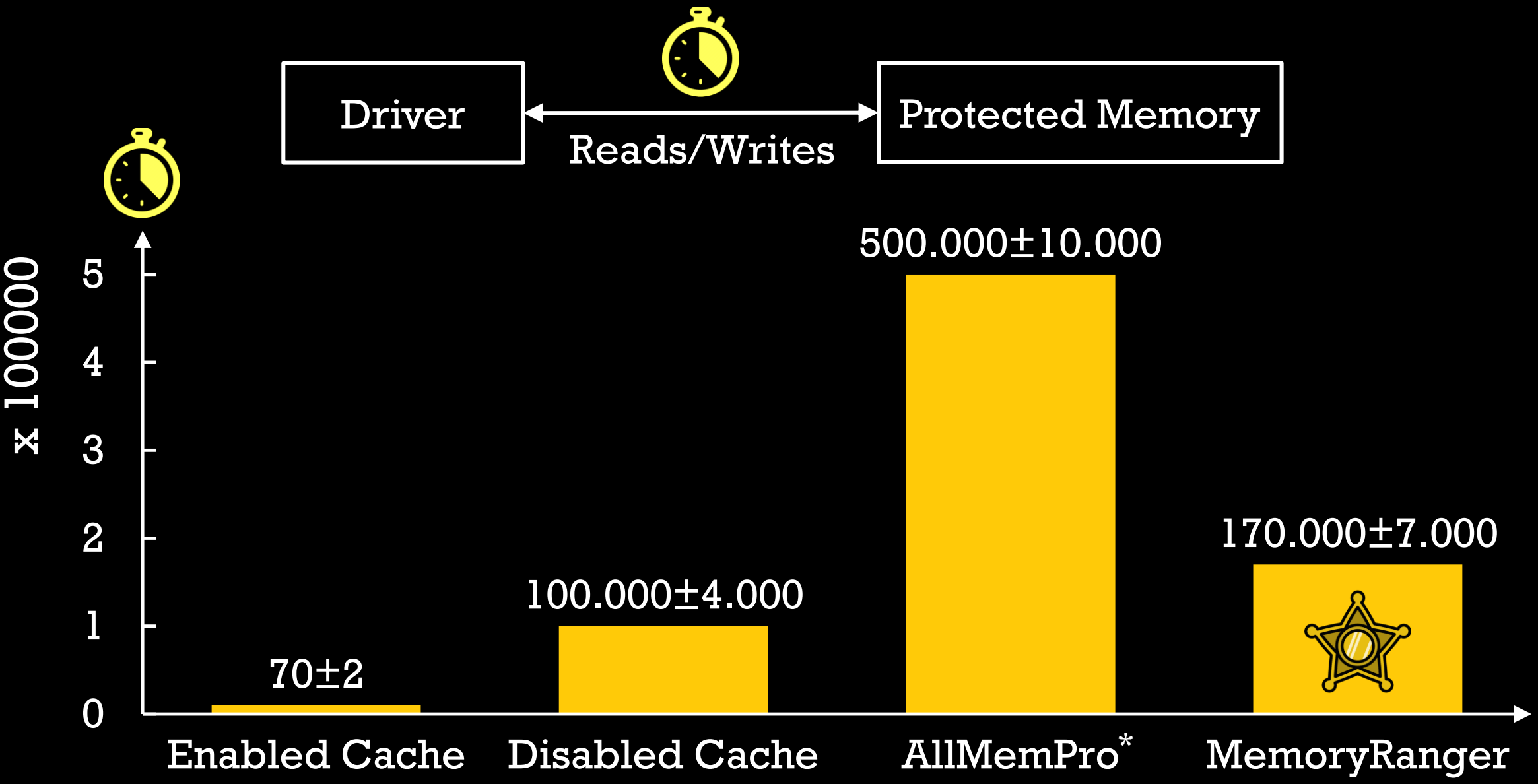

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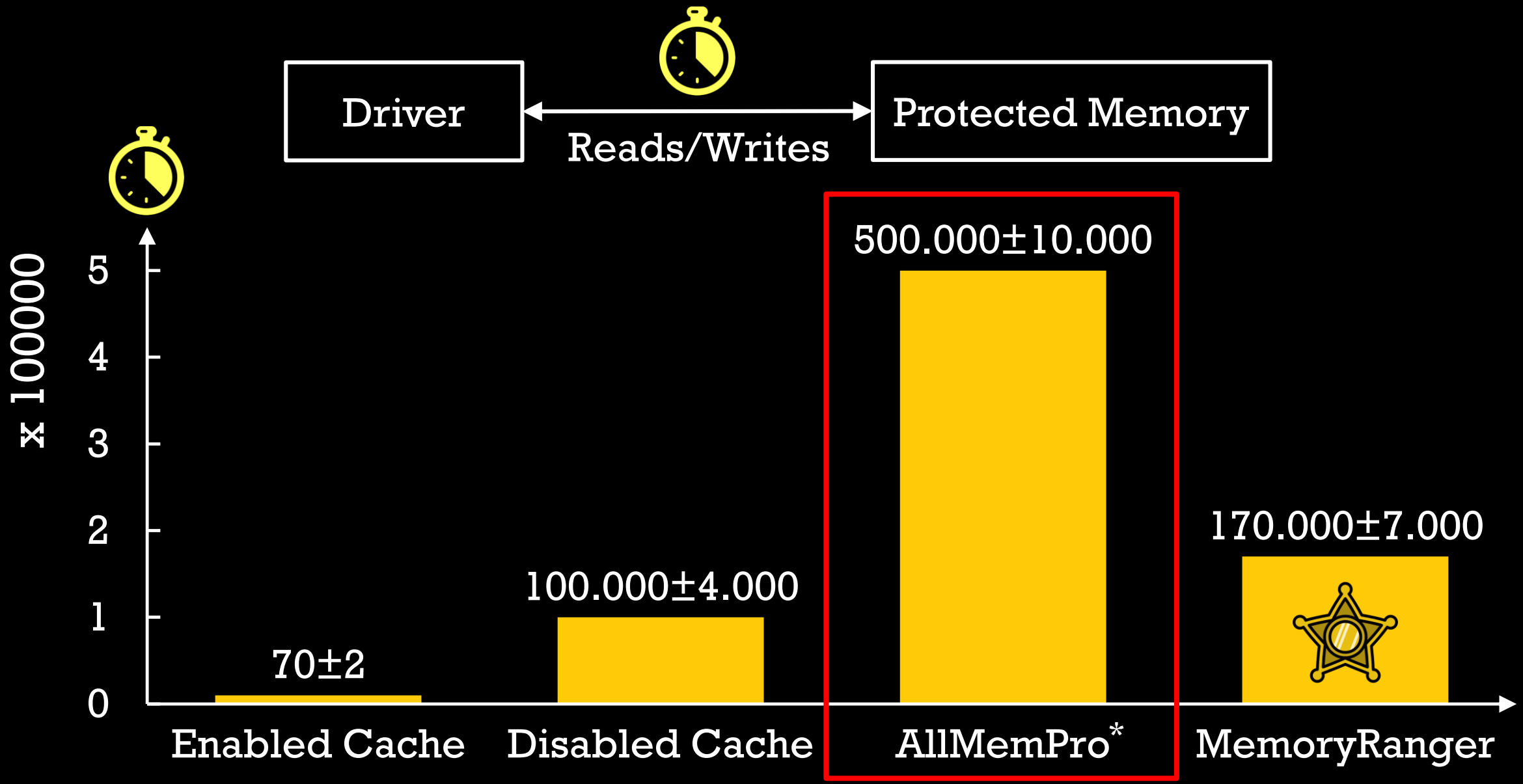

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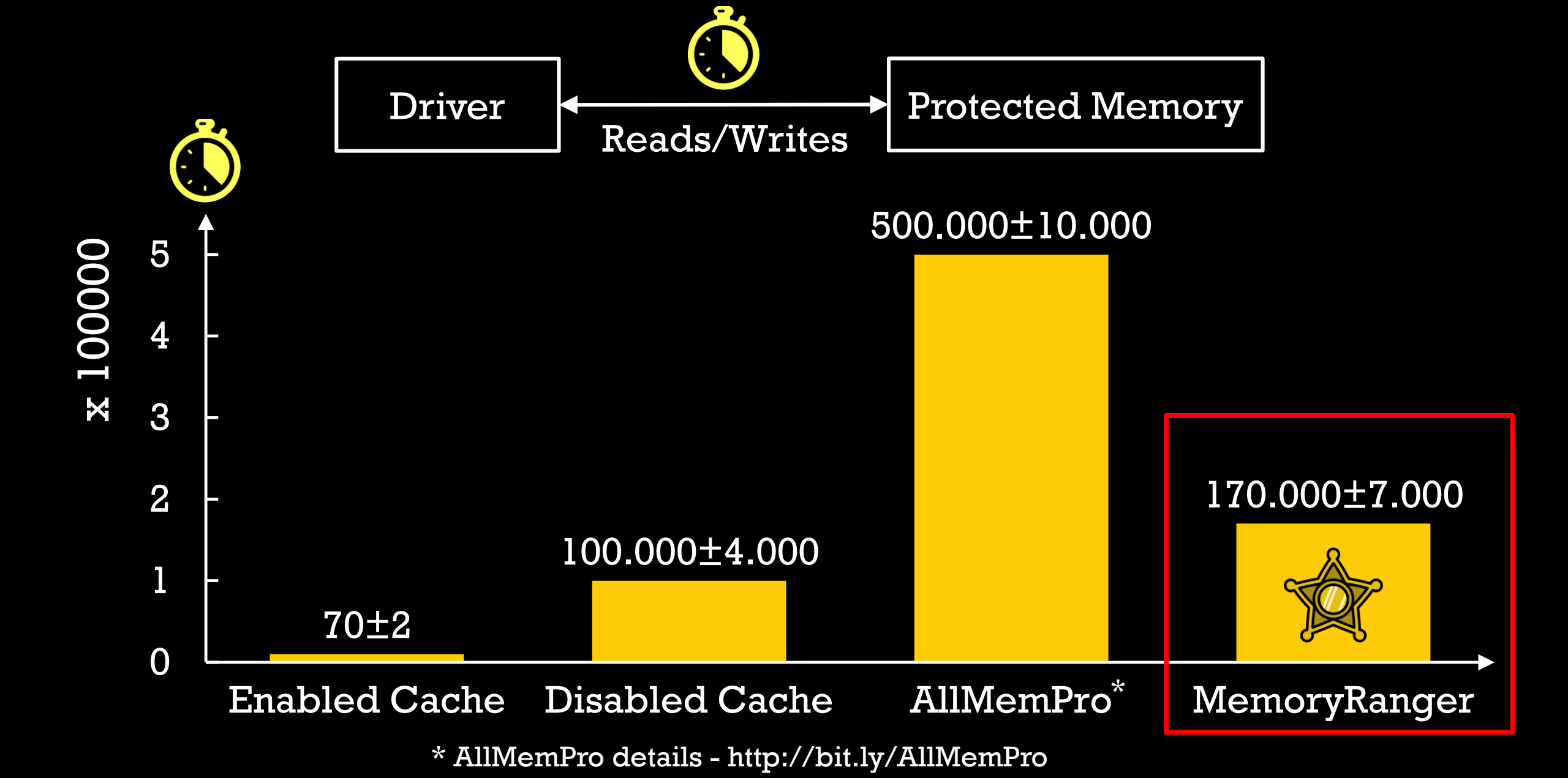

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THE CURRENT SITUATION WITH ATTACKS ON WINDOWS MEMORY

	Code	Drivers allocations	Dynamically Allocated Data by the OS		
Memory Regions					
Integrity					
Confidentiality					

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	Code	Drivers allocations	Dynamically Allocated Data by the OS		
Memory Regions	Drivers code				
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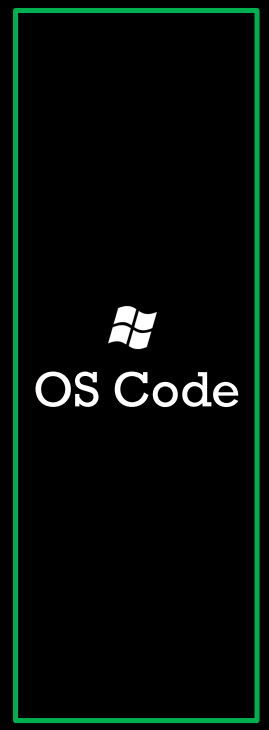
Memory Regions	Drivers code  OS Code				
Integrity					
Confidentiality					

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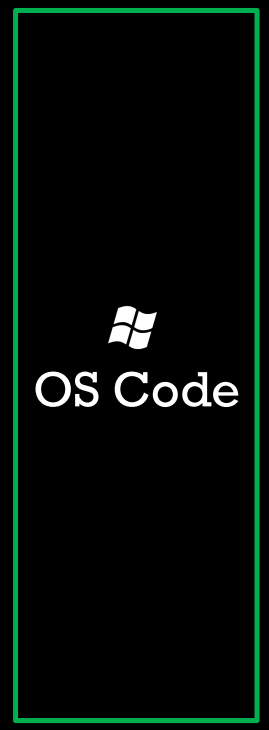
Memory Regions	Drivers code 				
Integrity	Device Guard				
Confidentiality					

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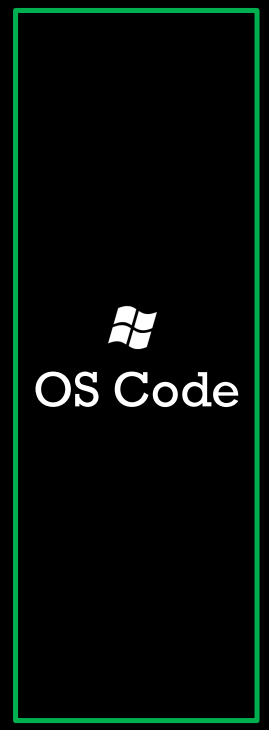
Memory Regions	Drivers code 				
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	Code	Drivers allocations	Dynamically Allocated Data by the OS		
Memory Regions	Drivers code → Allocated data OS Code				
Integrity	Device Guard				
Confidentiality					

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	Code	Drivers allocations	Dynamically Allocated Data by the OS		
Memory Regions	Drivers code → Allocated data OS Code				
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Confidentiality					

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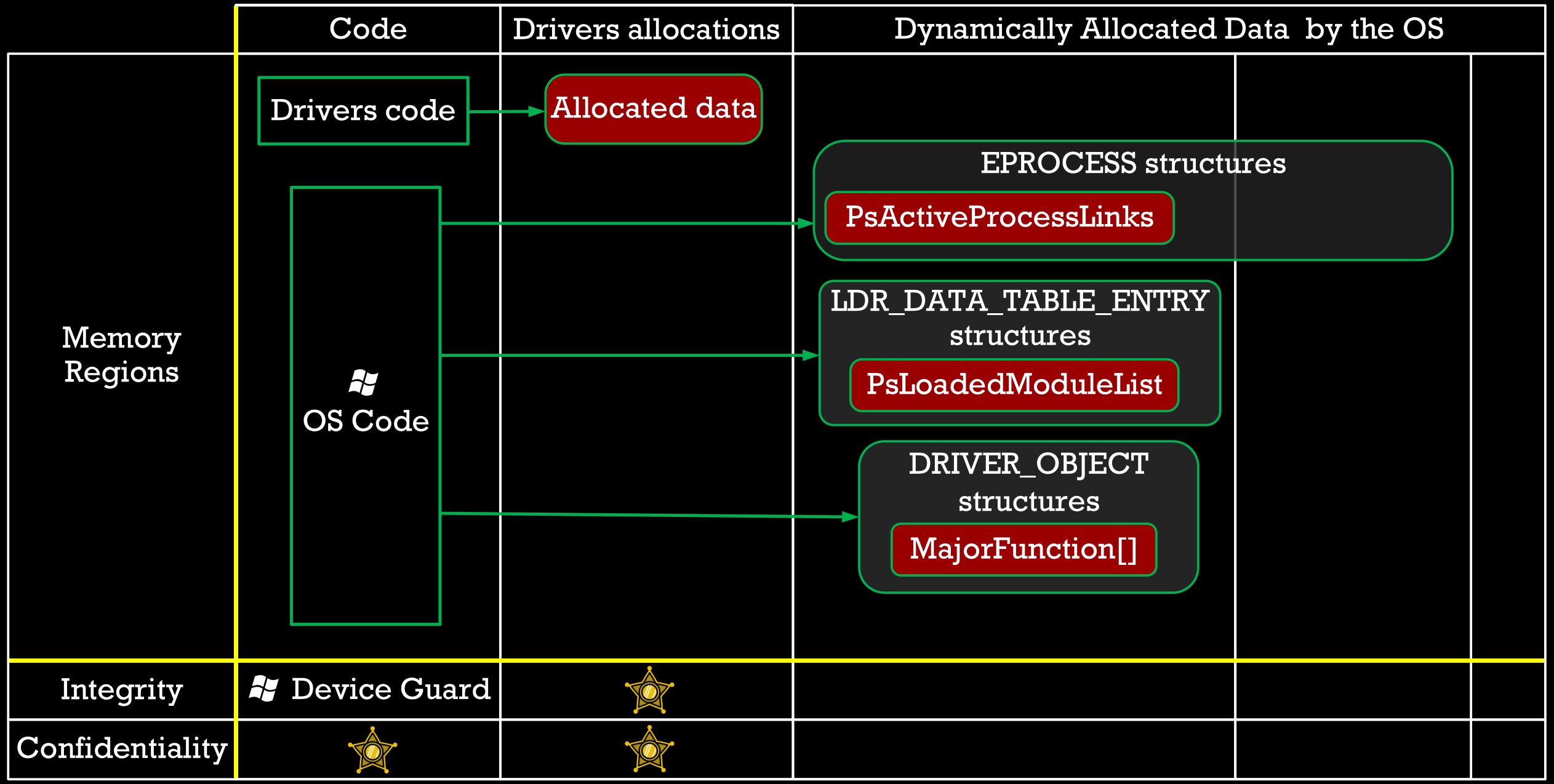

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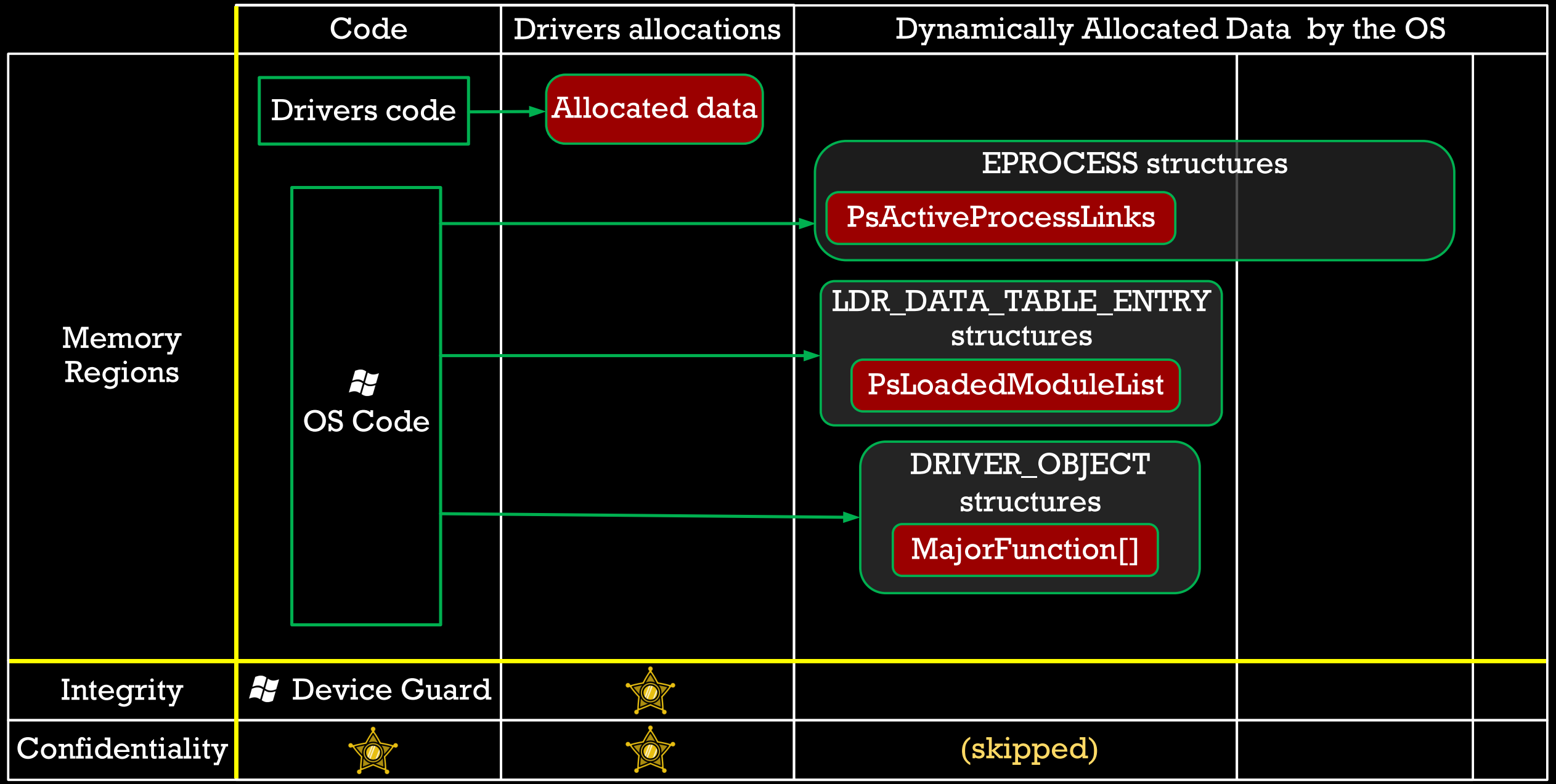

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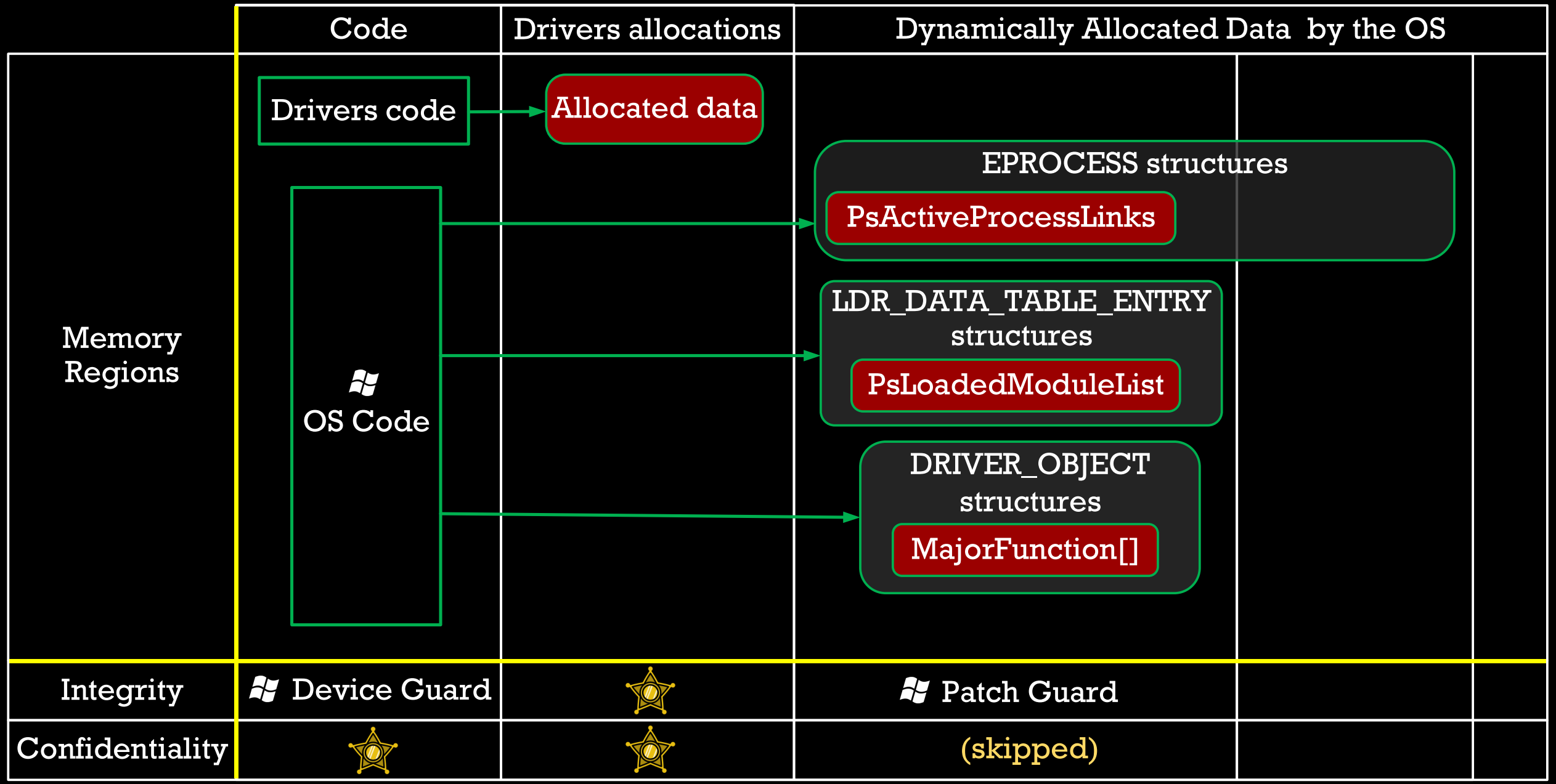

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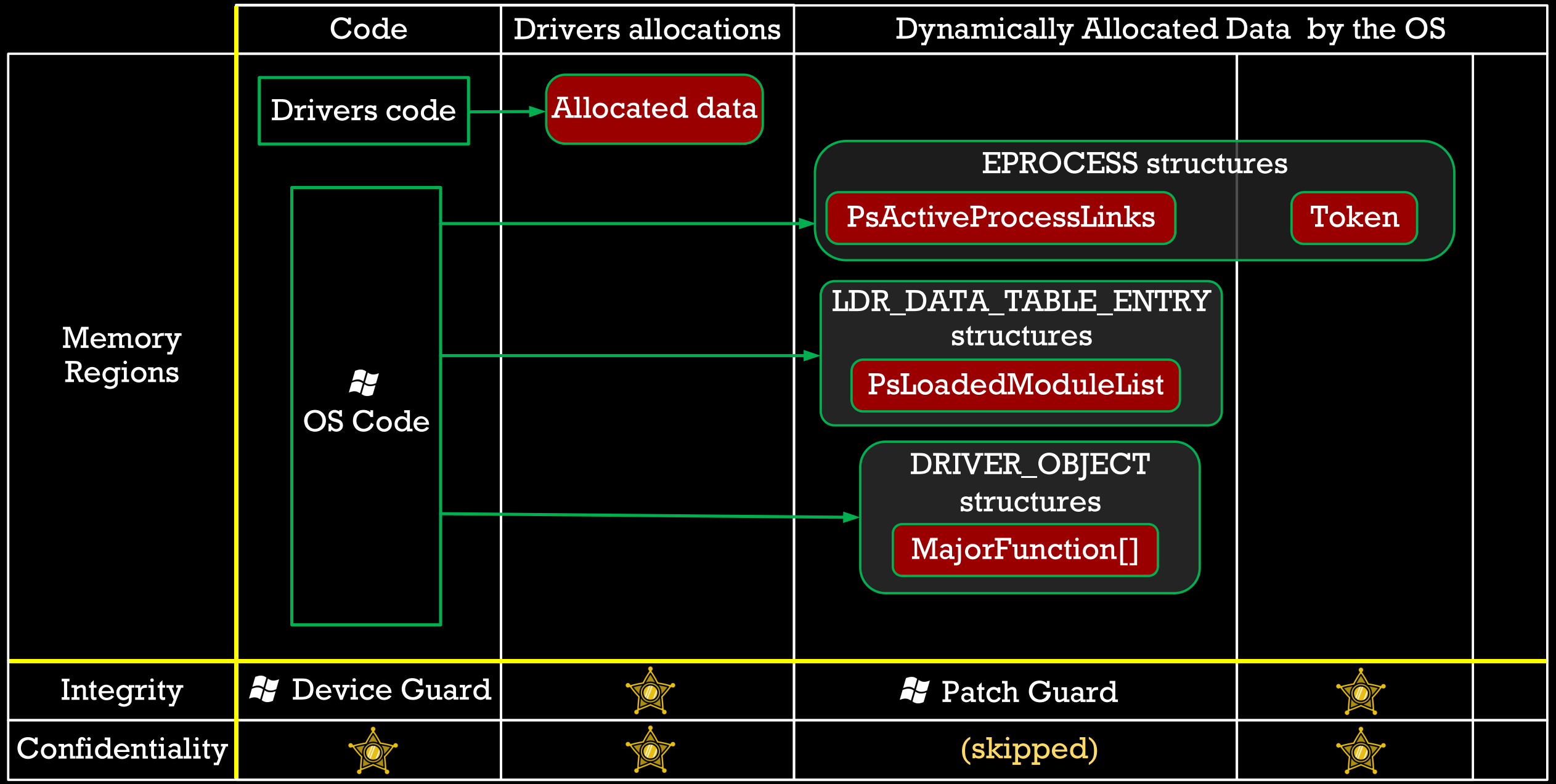

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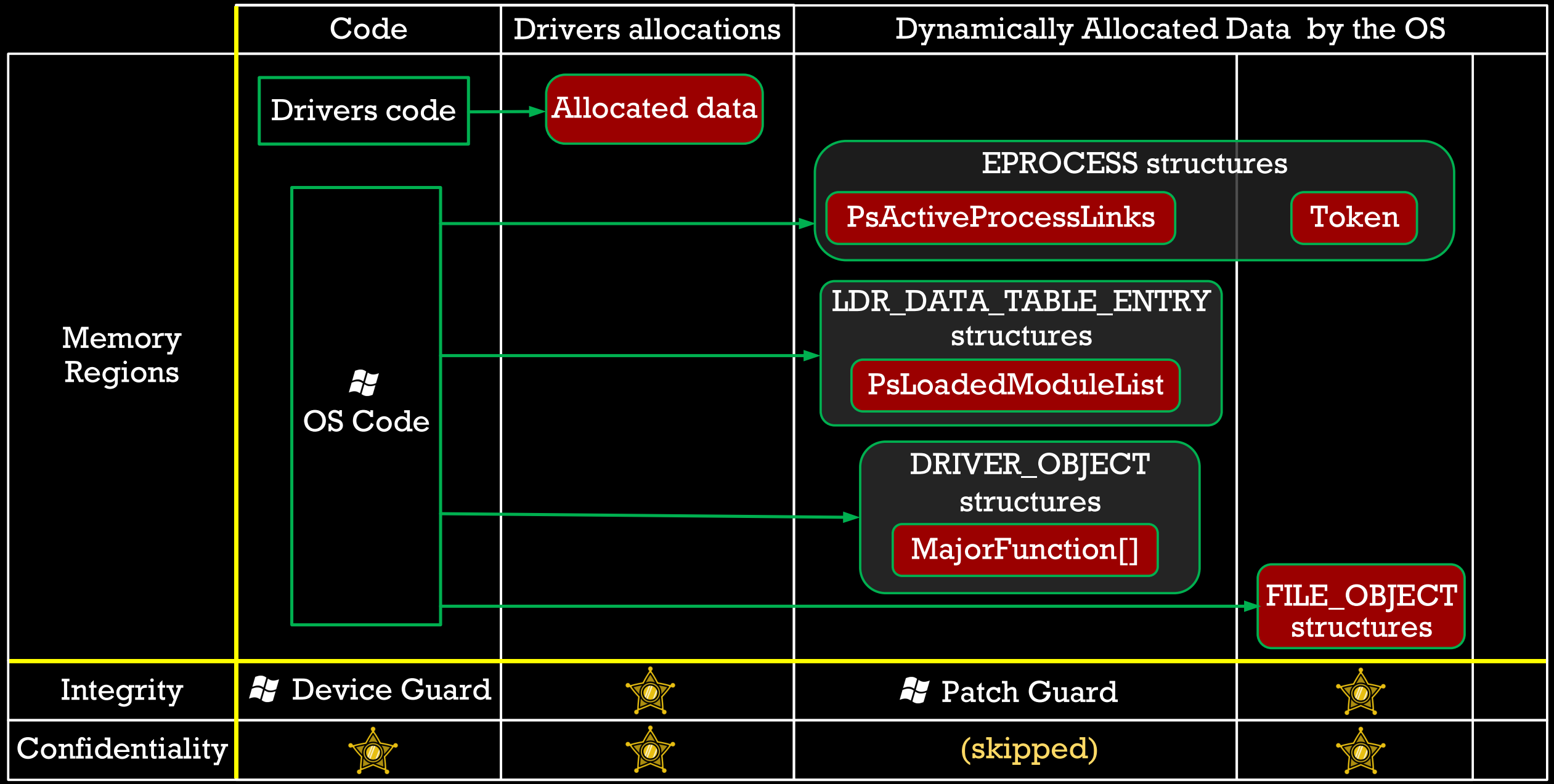

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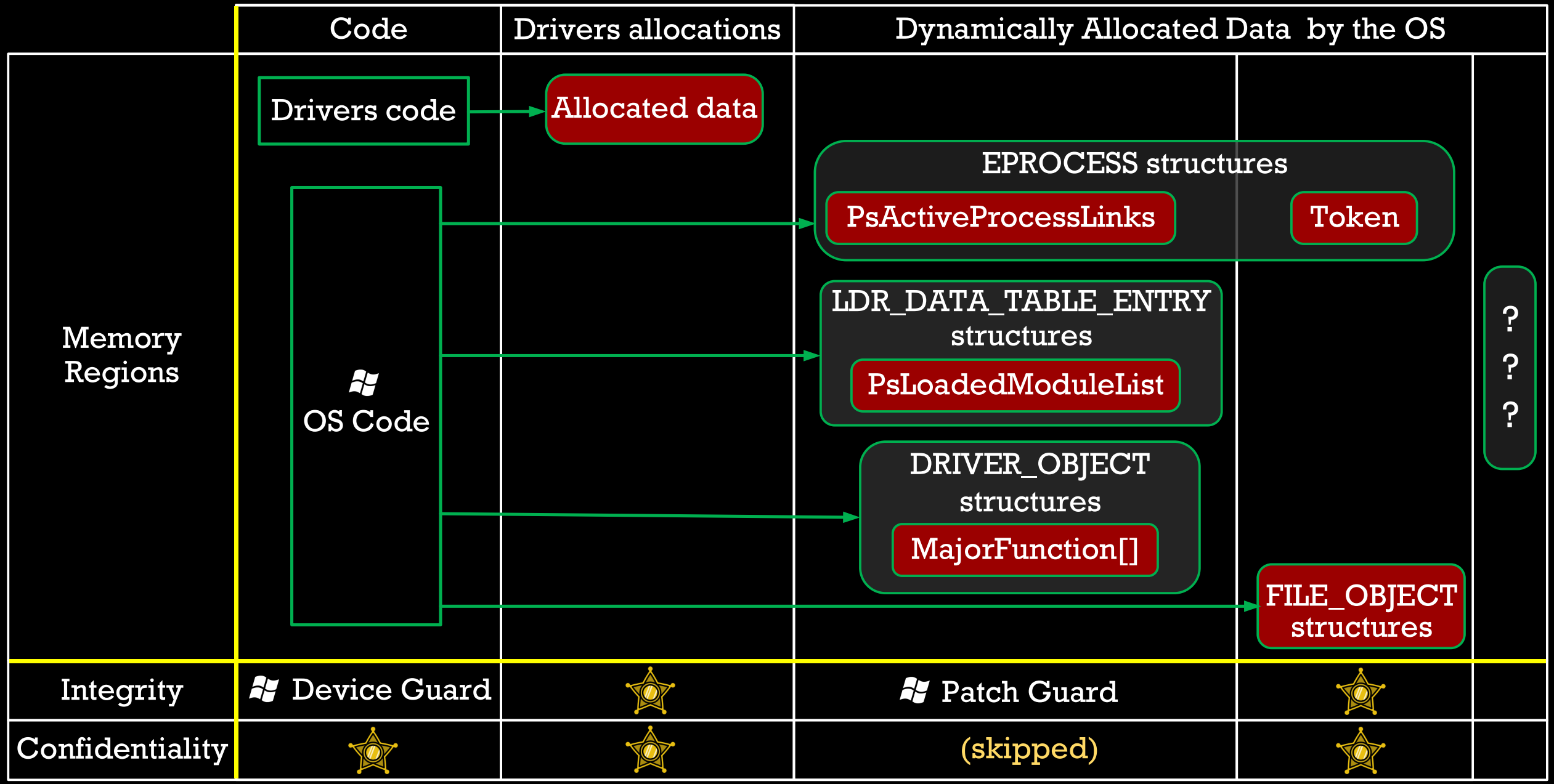
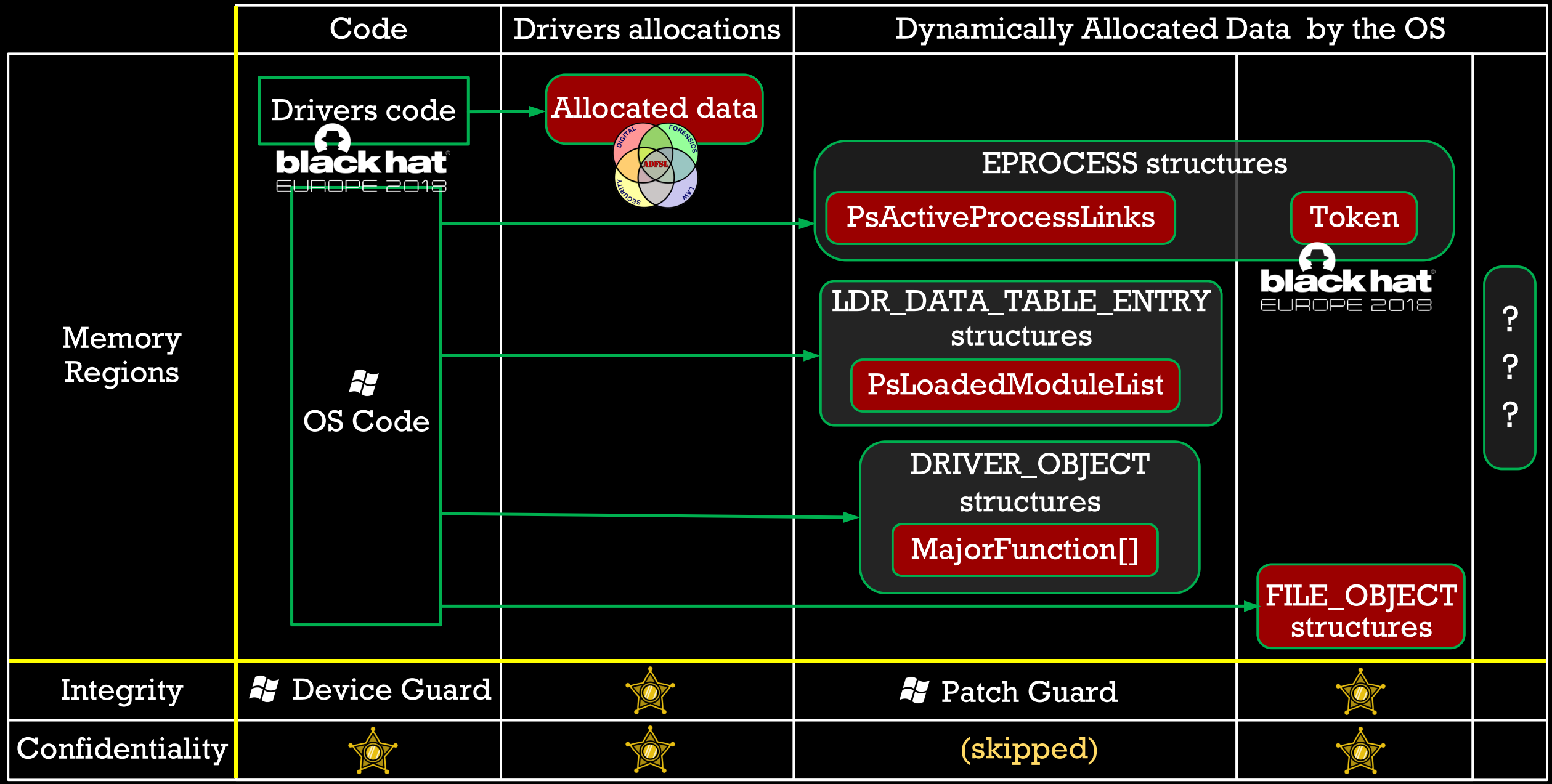


THE CURRENT SITUATION WITH ATTACKS ON WINDOWS MEMORY

	Code	Drivers allocations	Dynamically Allocated Data by the OS		
Memory Regions	Drivers code OS Code	Allocated data	EPROCESS structures PsActiveProcessLinks Token LDR_DATA_TABLE_ENTRY structures PsLoadedModuleList DRIVER_OBJECT structures MajorFunction[]	FILE_OBJECT structures	? ? ?
Integrity	Device Guard		Patch Guard		
Confidentiality			(skipped)		

THE CURRENT SITUATION WITH ATTACKS ON WINDOWS MEMORY



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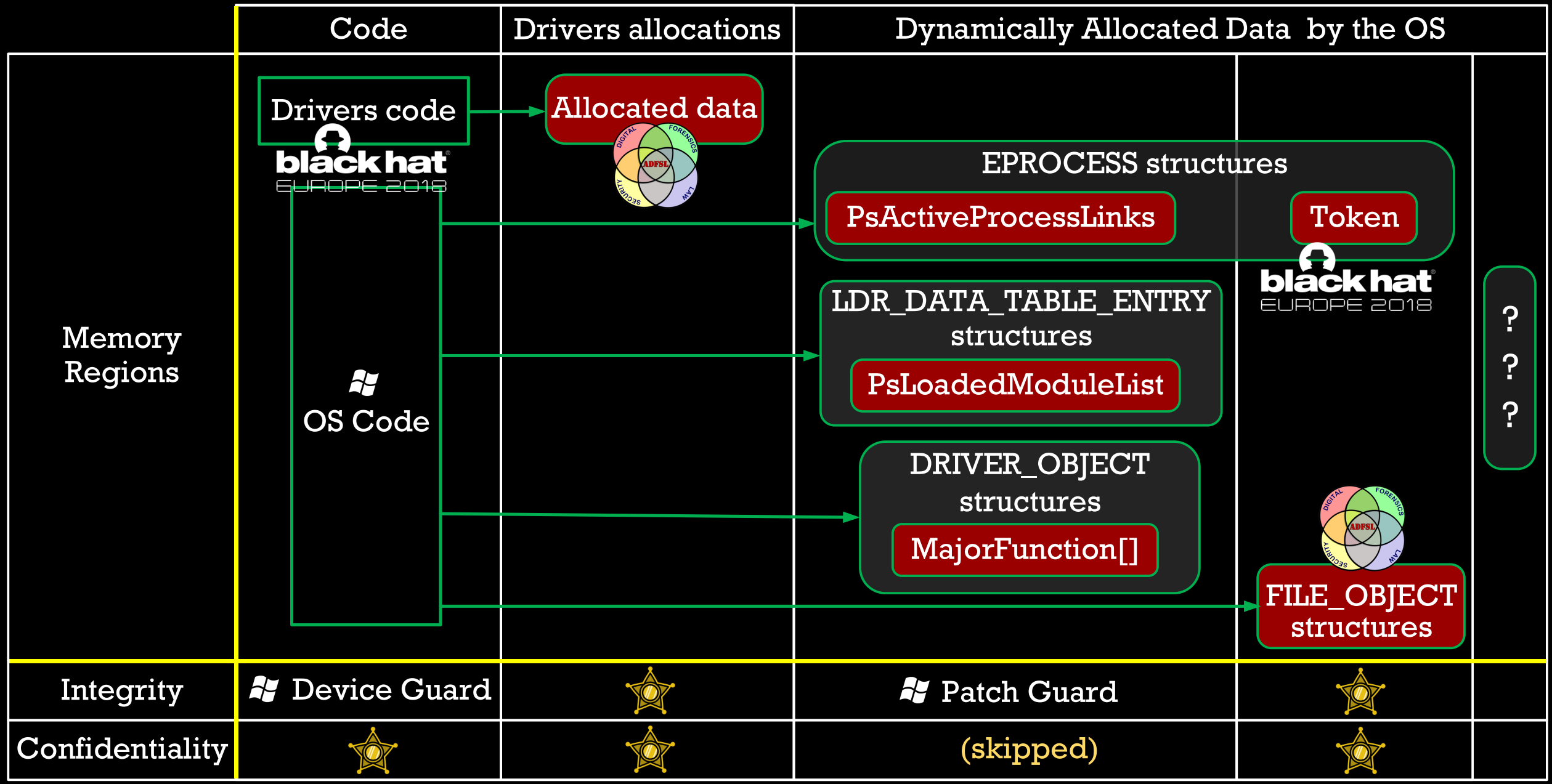


CONCLUSION

- All modern Windows OSes are vulnerable to FILE_OBJECT hijacking
- MemoryRanger prevents the hijacking attack by running drivers into isolated memory enclaves
- Research is ongoing

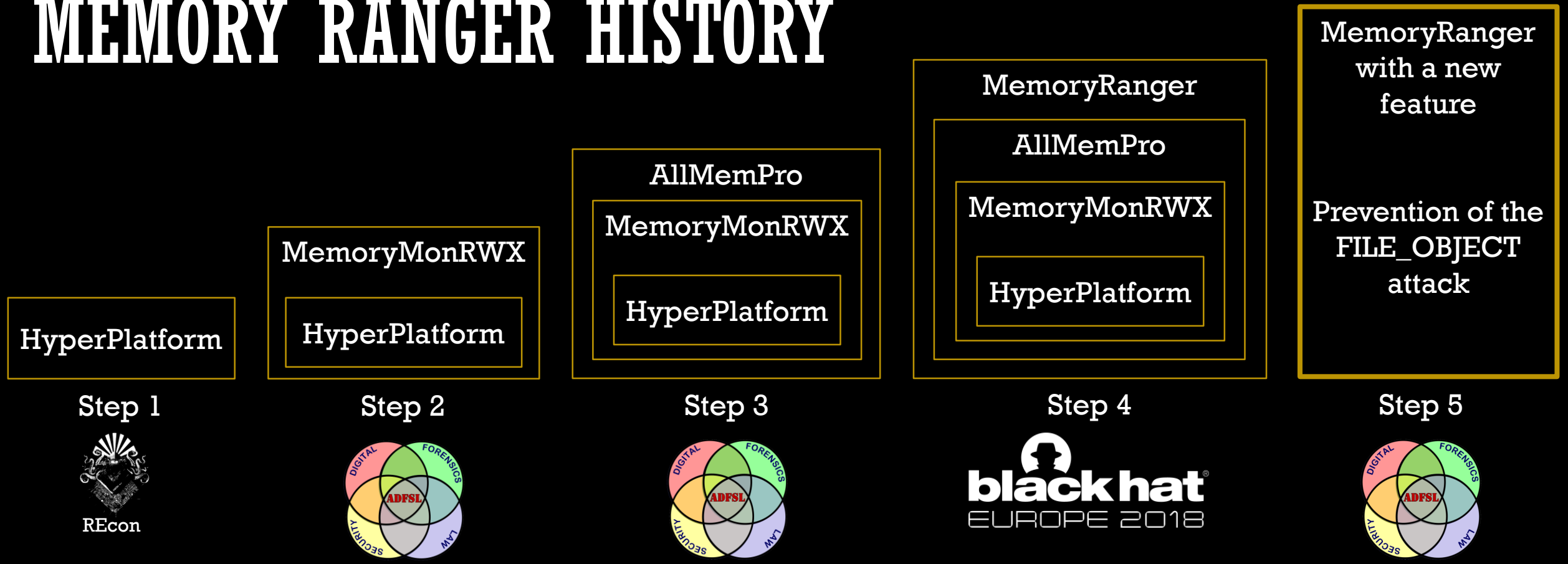
Thank you!

Igor Korkin igor.korkin@gmail.com

All the details & my CV are here igorkorkin.blogspot.com



MEMORY RANGER HISTORY



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3. Korkin, I. (2018). Hypervisor-Based Active Data Protection for Integrity and Confidentiality of Dynamically Allocated Memory in Windows Kernel. ADFSL, USA.
4. Korkin, I. (2018). Divide et Impera: MemoryRanger Runs Drivers in Isolated Kernel Spaces. BlackHat, UK
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