black hat®
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DIVIDE ET IMPERA: MEMORY RANGER RUNS DRIVERS IN ISOLATED KERNEL SPACES

Igor Korkin, Ph.D

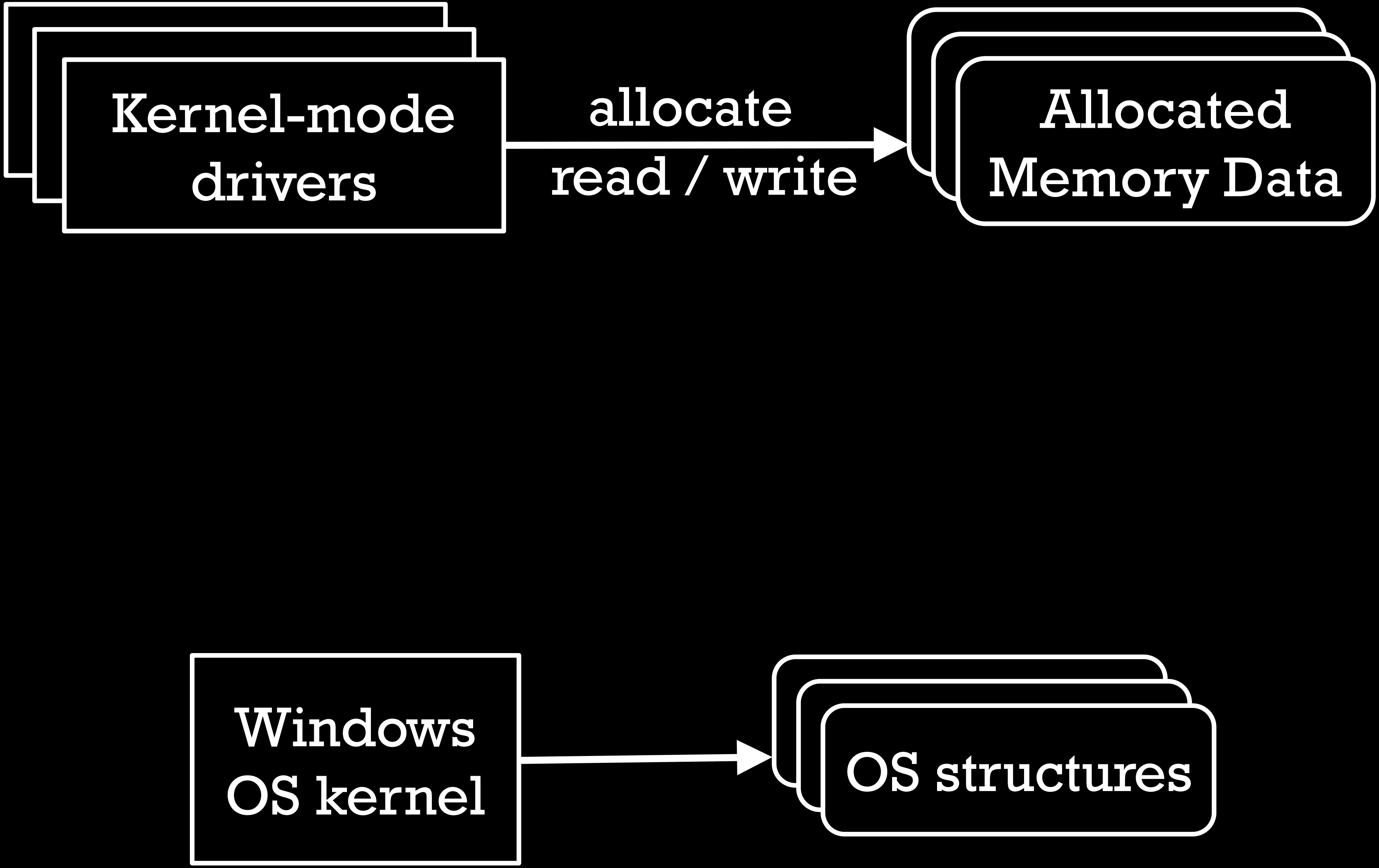
WHOAMI

- MEPhI Alumni, PhD in Cyber Security, published 23 papers
- Area of interest is Windows Kernel security:
  - Memory Forensics
  - Rootkits Detection
  - Bare-Metal Hypervisors
- Fan of academic cross-disciplinary research - igorkorkin.blogspot.com
- Love traveling and powerlifting - 📷 igor.korkin

AGENDA

- Attacking the kernel-mode memory
- Existing protection: Windows built-in security and research projects
- MemoryRanger hypervisor: idea, details, demos

ATTACKS ON KERNEL MODE MEMORY



Kernel-mode drivers

allocate

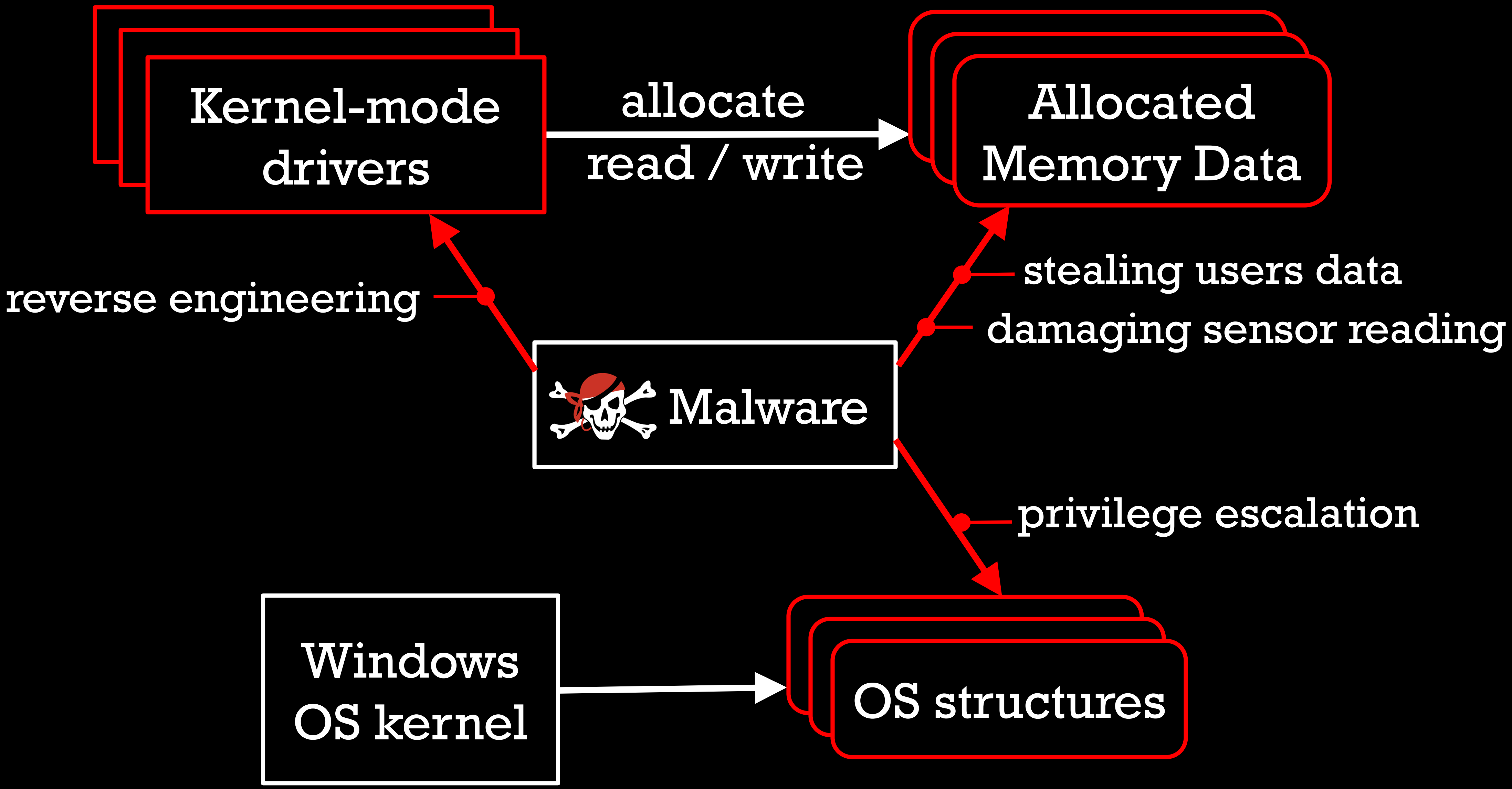
read / write

Allocated Memory Data

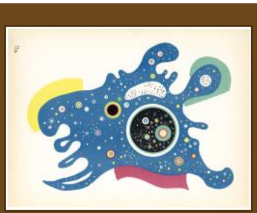
Windows OS kernel

OS structures

ATTACKS ON KERNEL MODE MEMORY



TWO HOUSES WITH PRIVATE ART COLLECTIONS

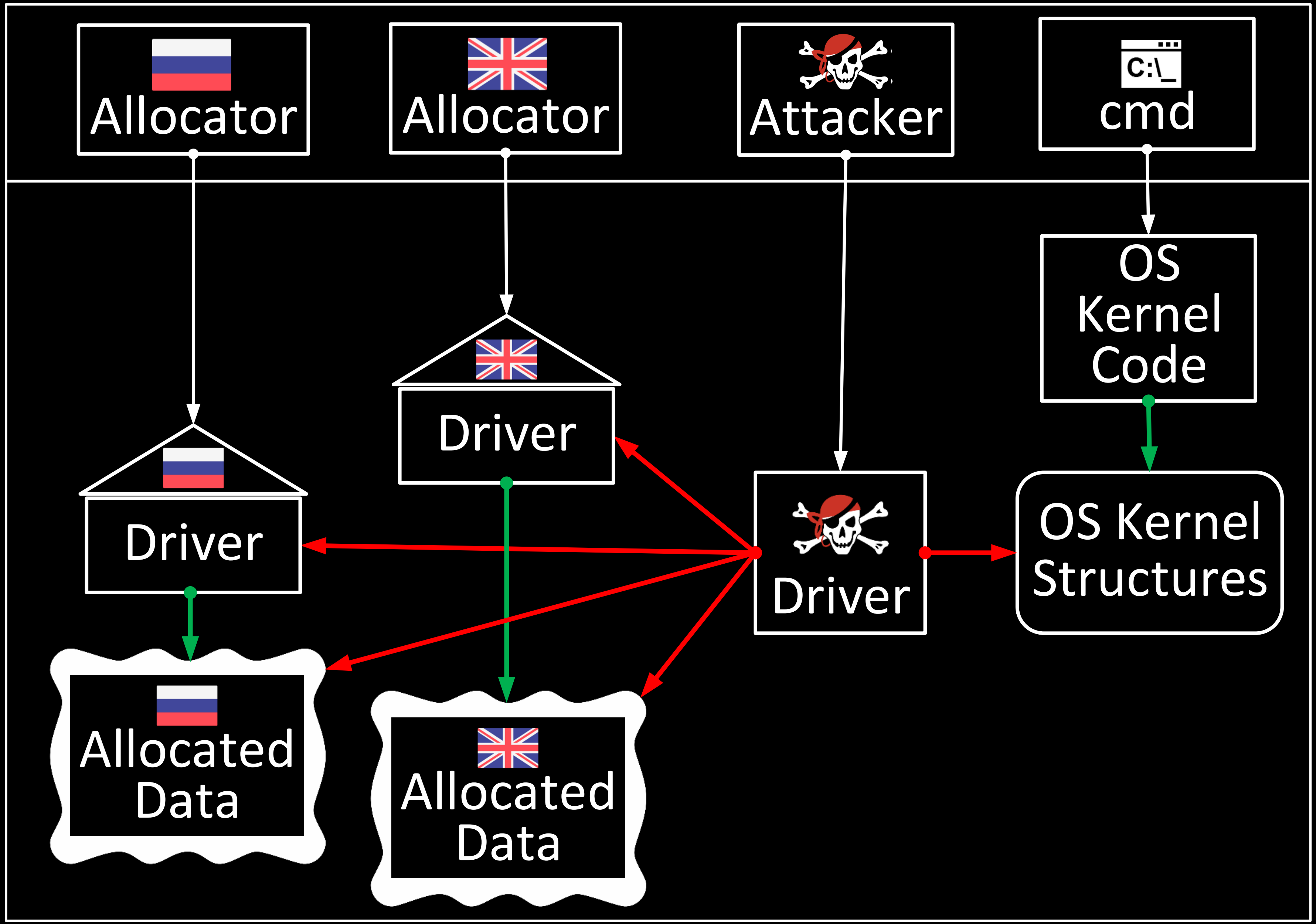


Stars by
Wassily Kandinsky

Girl with Balloon
by Banksy

Hi all! I am a hacker-attacker!
I will inspect these houses to
steal and damage painting!

DEMO: THE ATTACK



DEMO: THE ATTACK

The online version is here – https://www.youtube.com/embed/HNxc-tjy3QA?vq=hd1080

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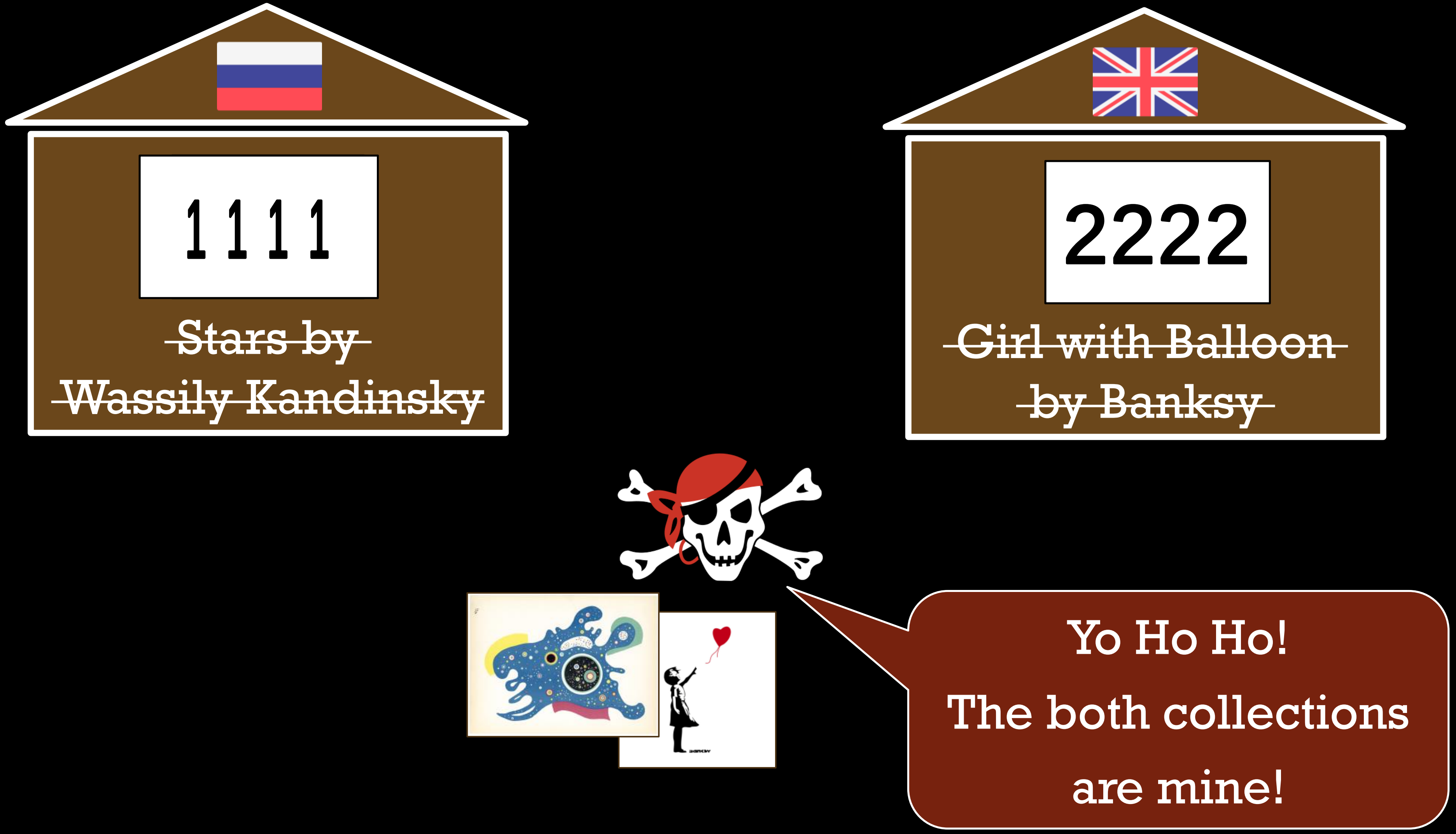


1111

~~Stars by Wassily Kandinsky~~

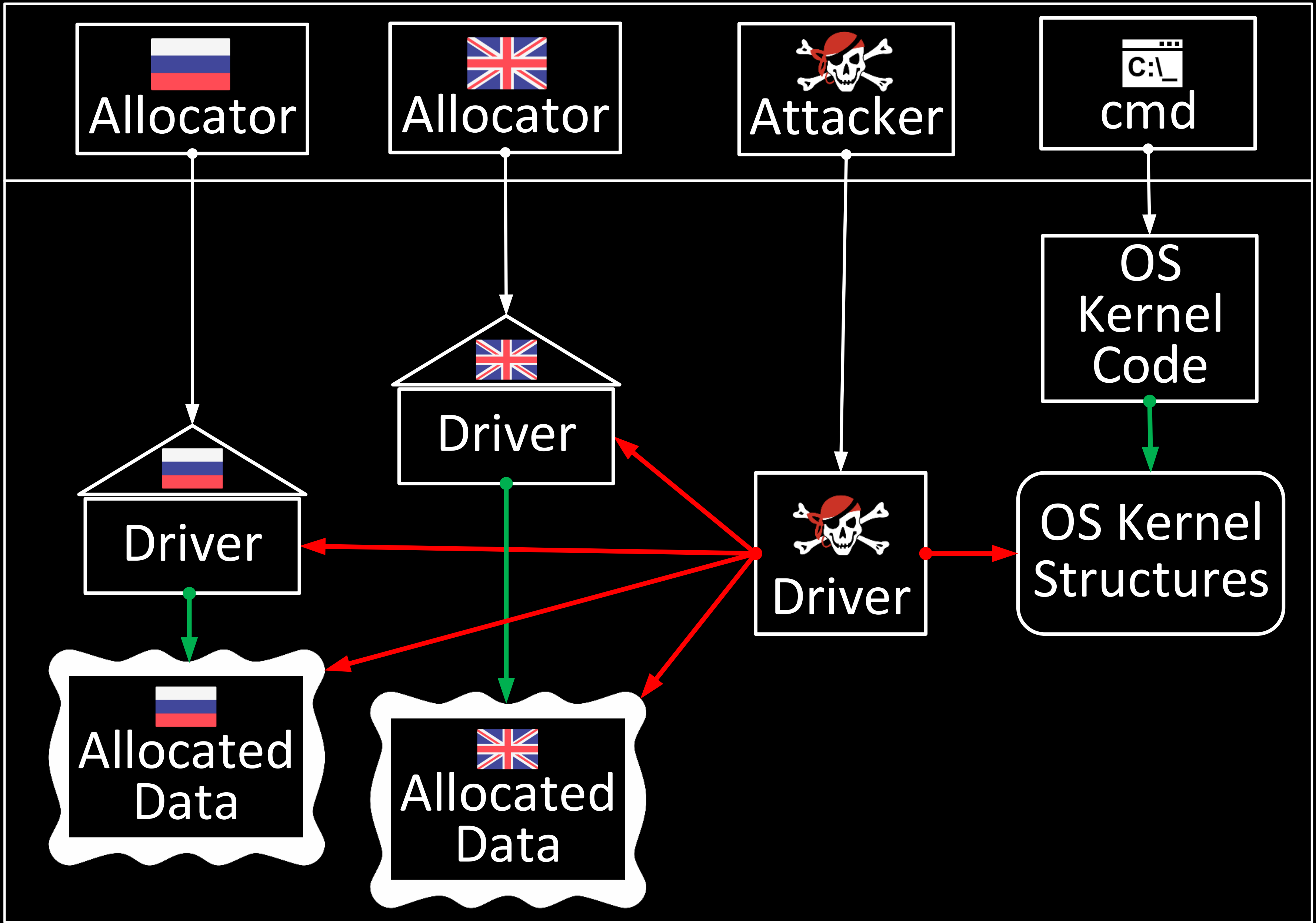
2222

~~Girl with Balloon by Banksy~~

Yo Ho Ho!

The both collections are mine!

THE ATTACK HAS NOT BEEN PREVENTED

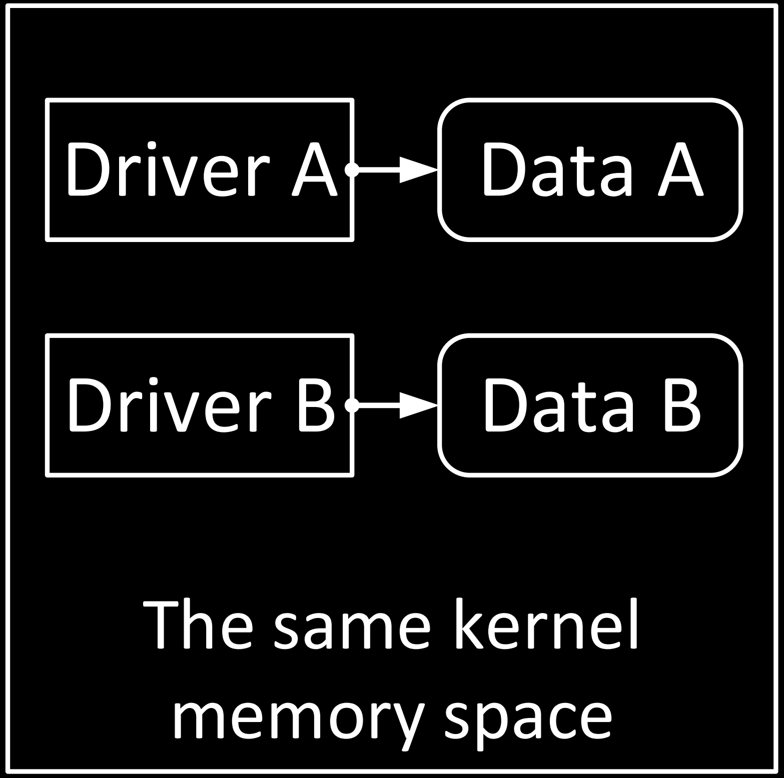


BACKGROUND ANALYSIS

Memory protection projects	Malware attacks on					
	Code of OS & third-party drivers		OS data: internal structures		Data of third-party drivers	
	Read	Write	Read	Write	Read	Write
Windows Security	-	BSOD 0xBE by Device Guard	-	BSOD 0x109 by PatchGuard	-	-
PrivGuard	-	-	-	+	-	-
LAKEED	+	+	+	+	-	-
LKMG	-	+	+	+	+	+
rR^X	+	+	-	-	-	-
AllMemPro	-	-	+	+	+	+
Memory Ranger	+	+	+	+	+	+

IDEA OF DRIVERS EXECUTION ISOLATION

Now all drivers share
the same memory space



Driver A

Data A

Driver B

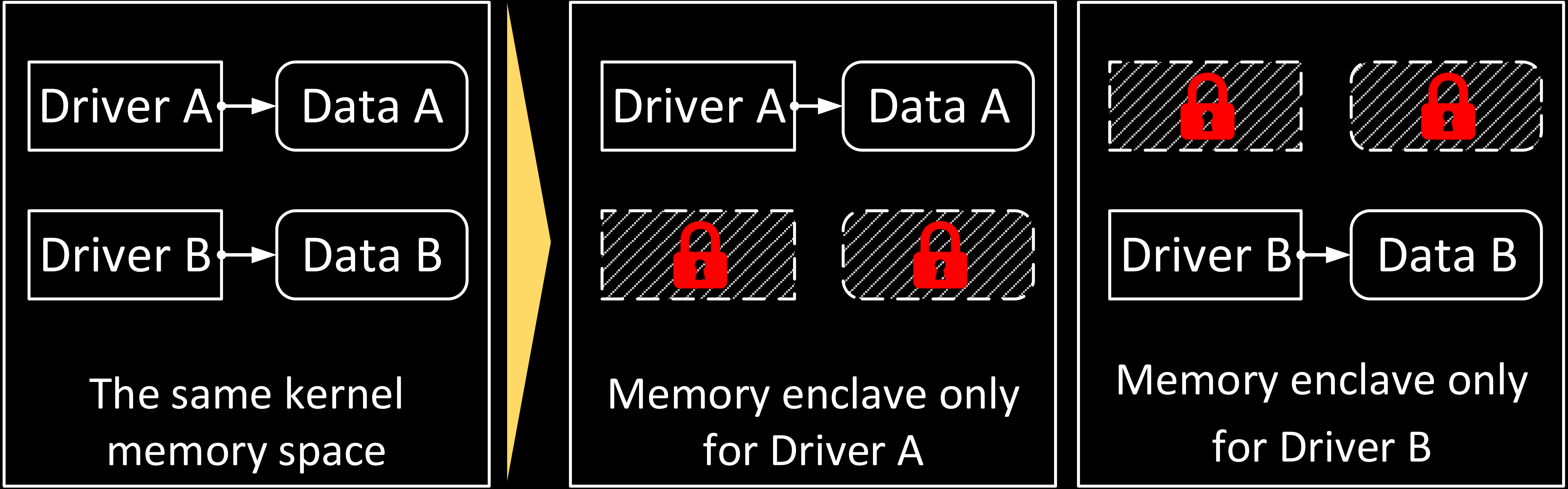
Data B

The same kernel
memory space

IDEA OF DRIVERS EXECUTION ISOLATION

Now all drivers share the same memory space

Let’s execute these two drivers into separate memory enclosures



Driver A

Data A

Driver B

Data B

The same kernel memory space

Driver A

Data A

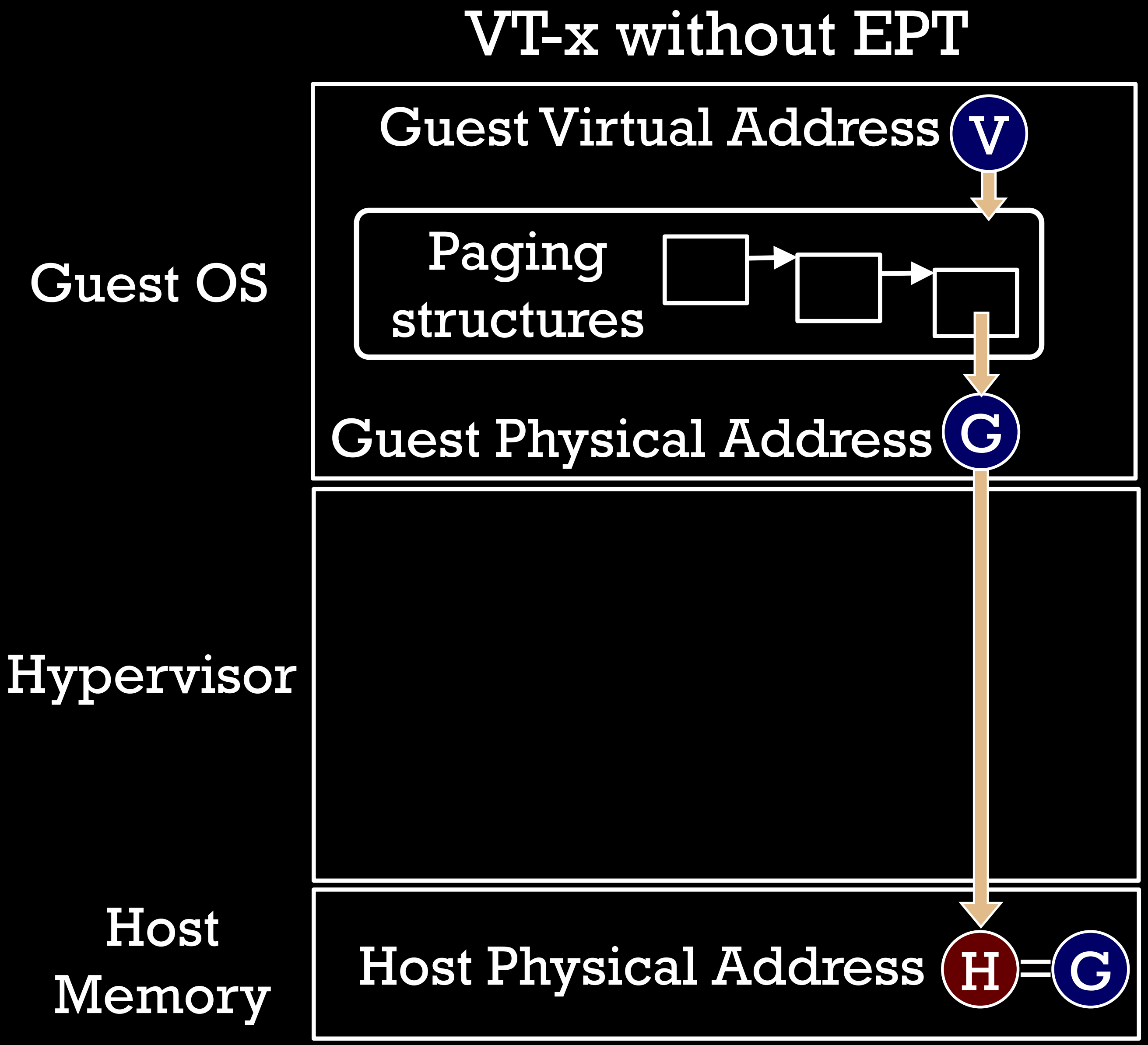
Memory enclave only for Driver A

Driver B

Data B

Memory enclave only for Driver B

PROCESSING MEMORY ACCESS: EPT FEATURE



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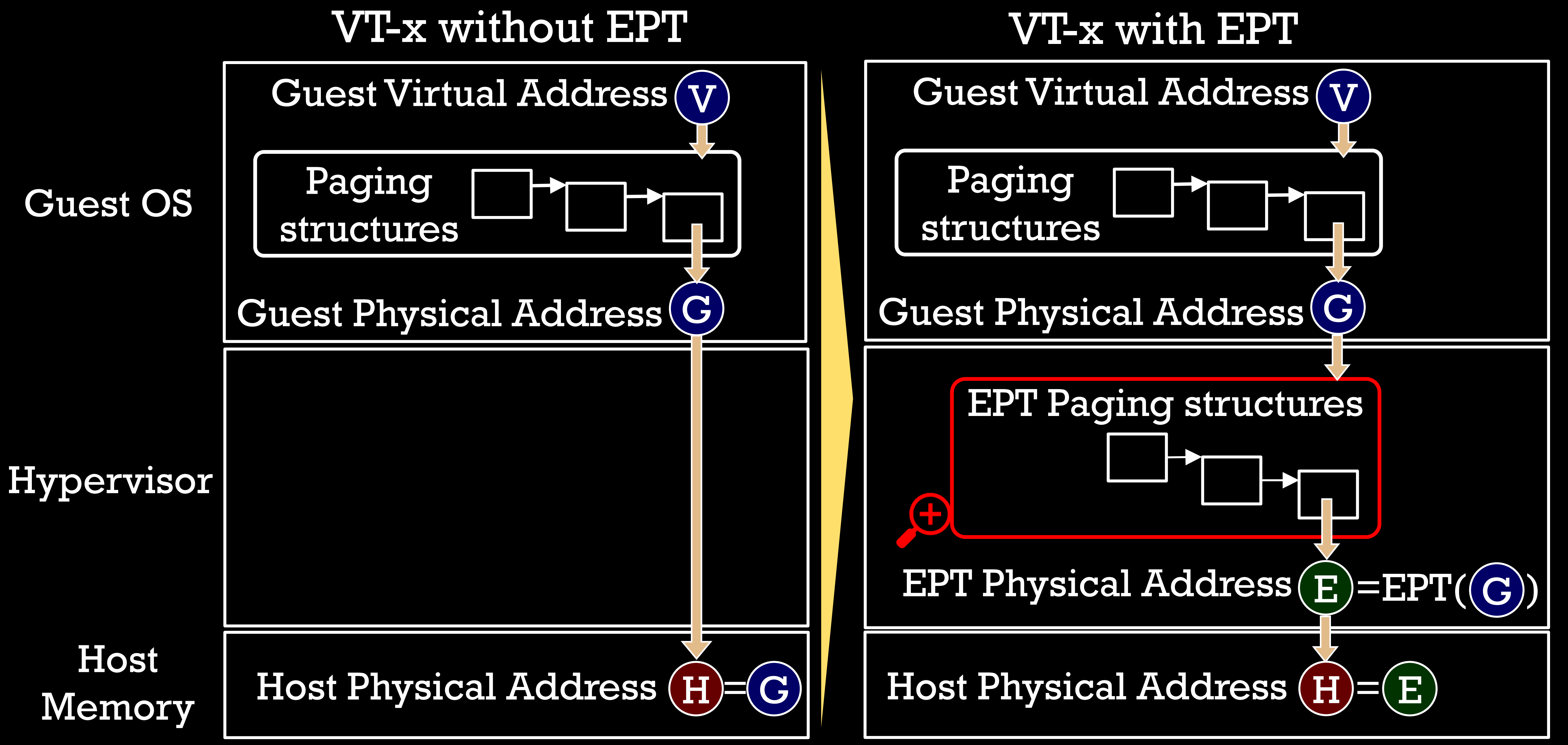
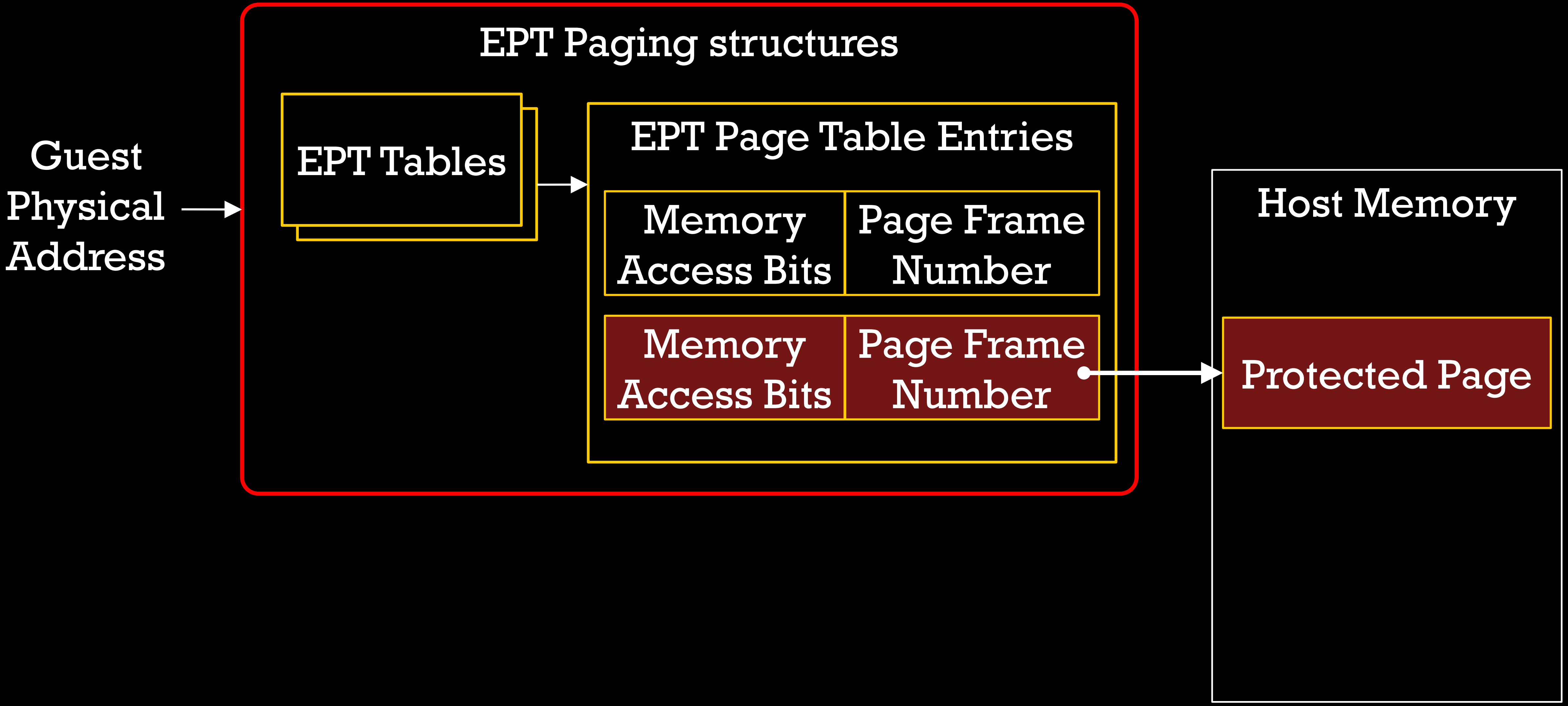


INSIDE EPT PAGING STRUCTURES. EPT PFN



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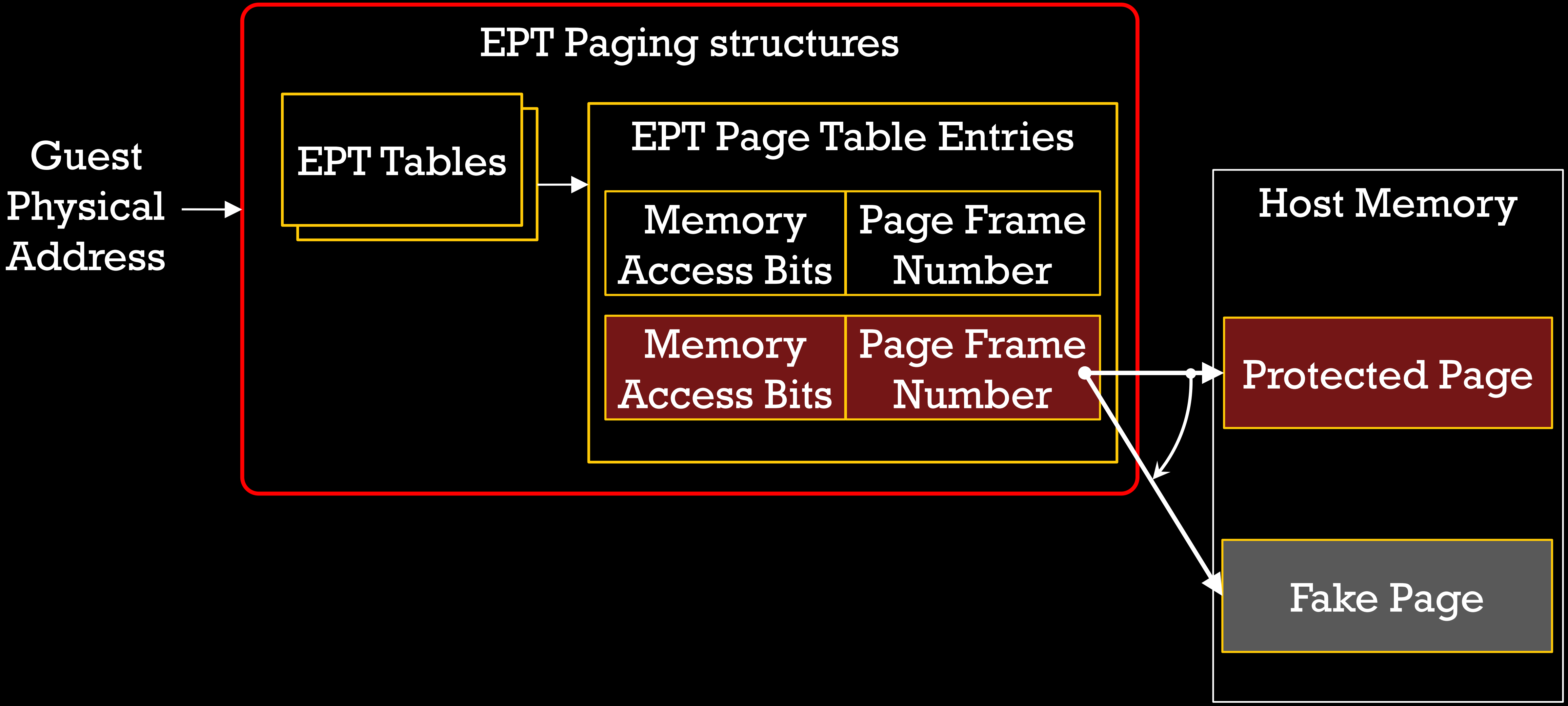
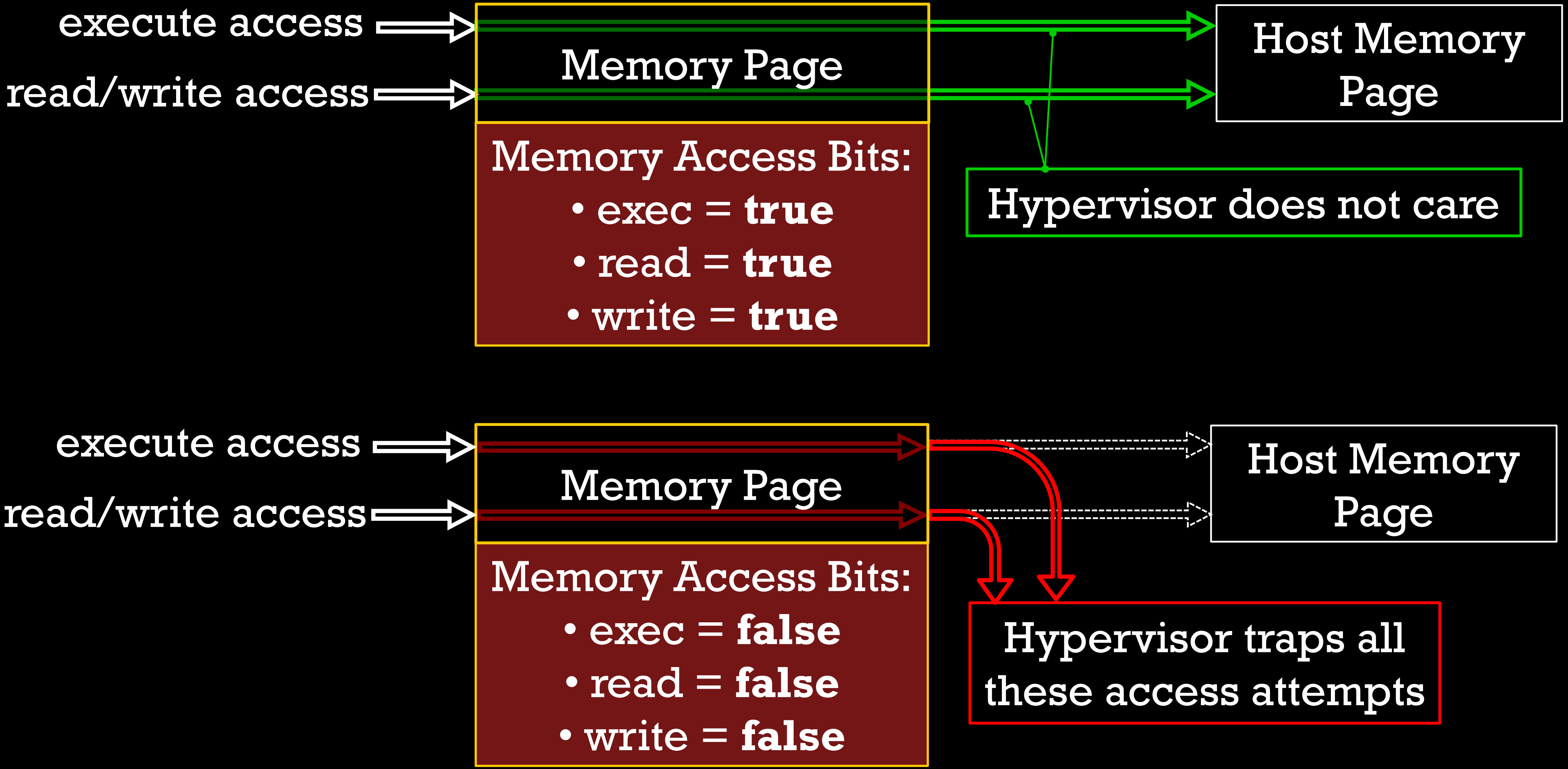
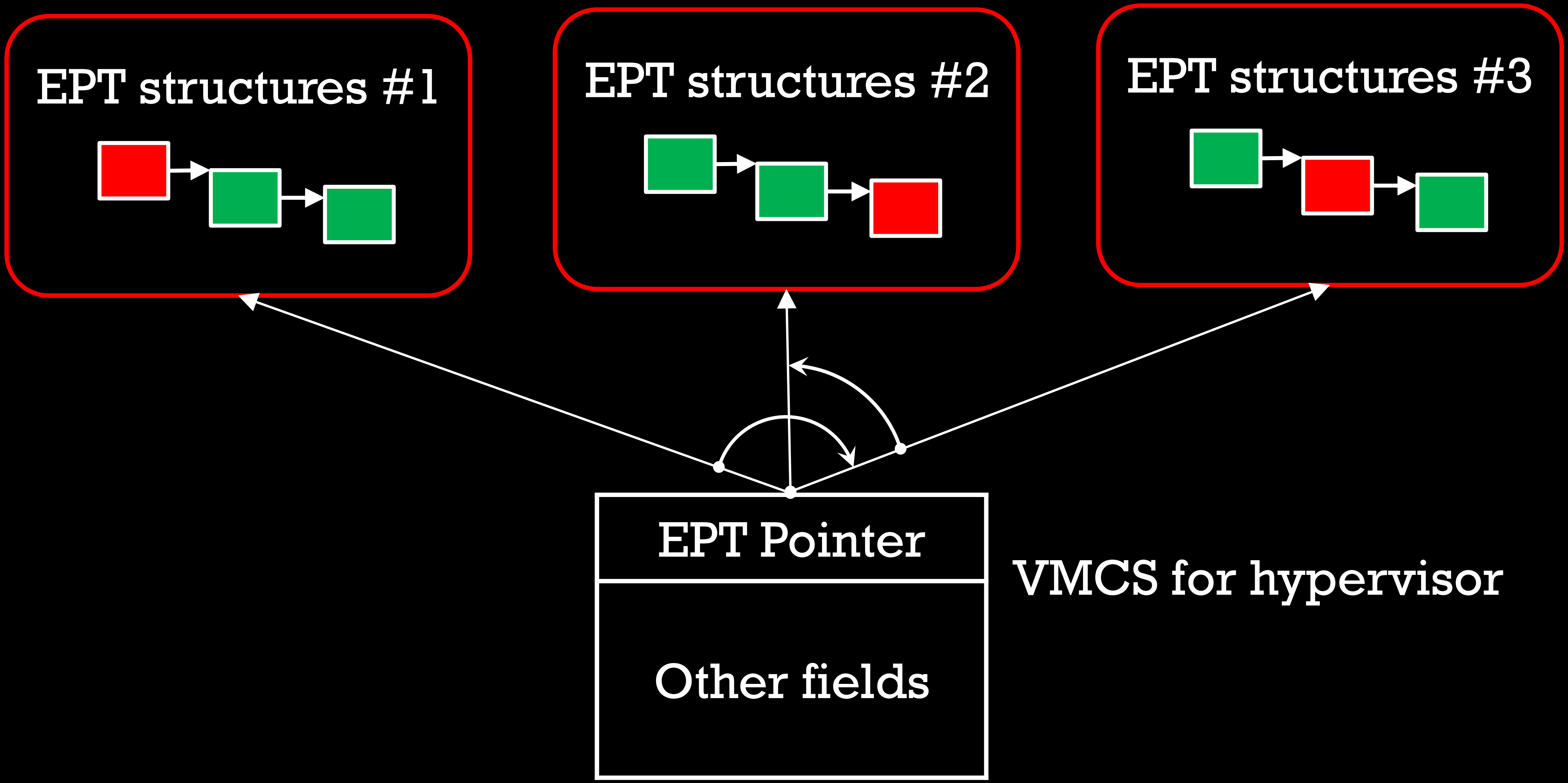


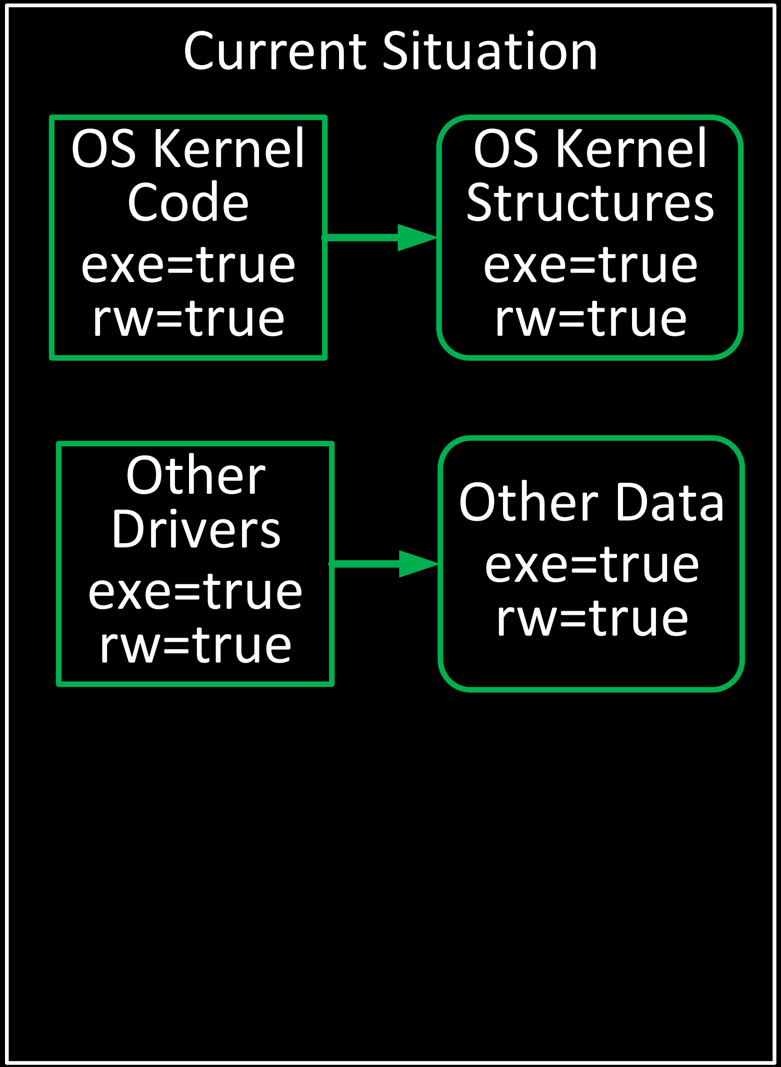
INSIDE EPT PAGING STRUCTURES. EPT BITS



INSIDE EPT PAGING STRUCTURES



APPLYING EPT FOR DRIVERS ISOLATION



Current Situation

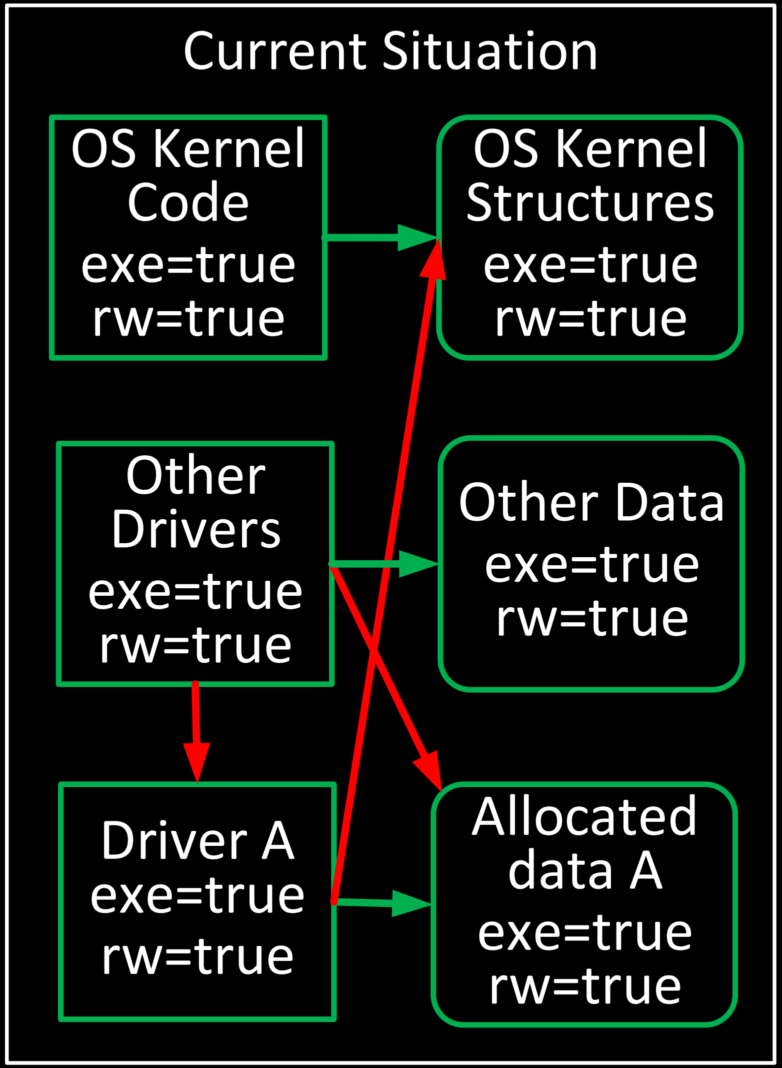
OS Kernel Code
exe=true
rw=true

OS Kernel Structures
exe=true
rw=true

Other Drivers
exe=true
rw=true

Other Data
exe=true
rw=true

APPLYING EPT FOR DRIVERS ISOLATION



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OS Kernel Code
exe=true
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OS Kernel Structures
exe=true
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Other Drivers
exe=true
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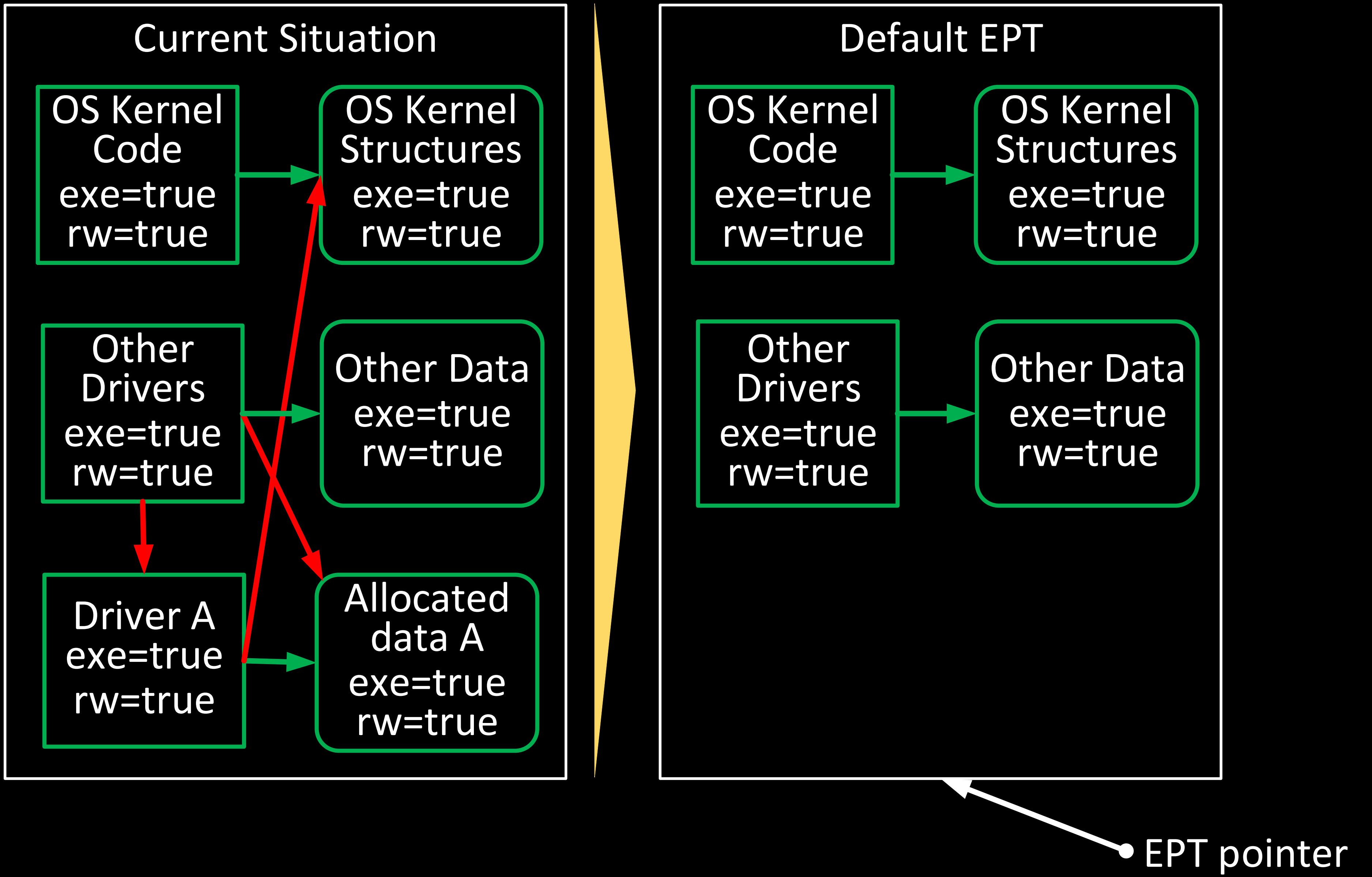
Other Data
exe=true
rw=true

Driver A
exe=true
rw=true

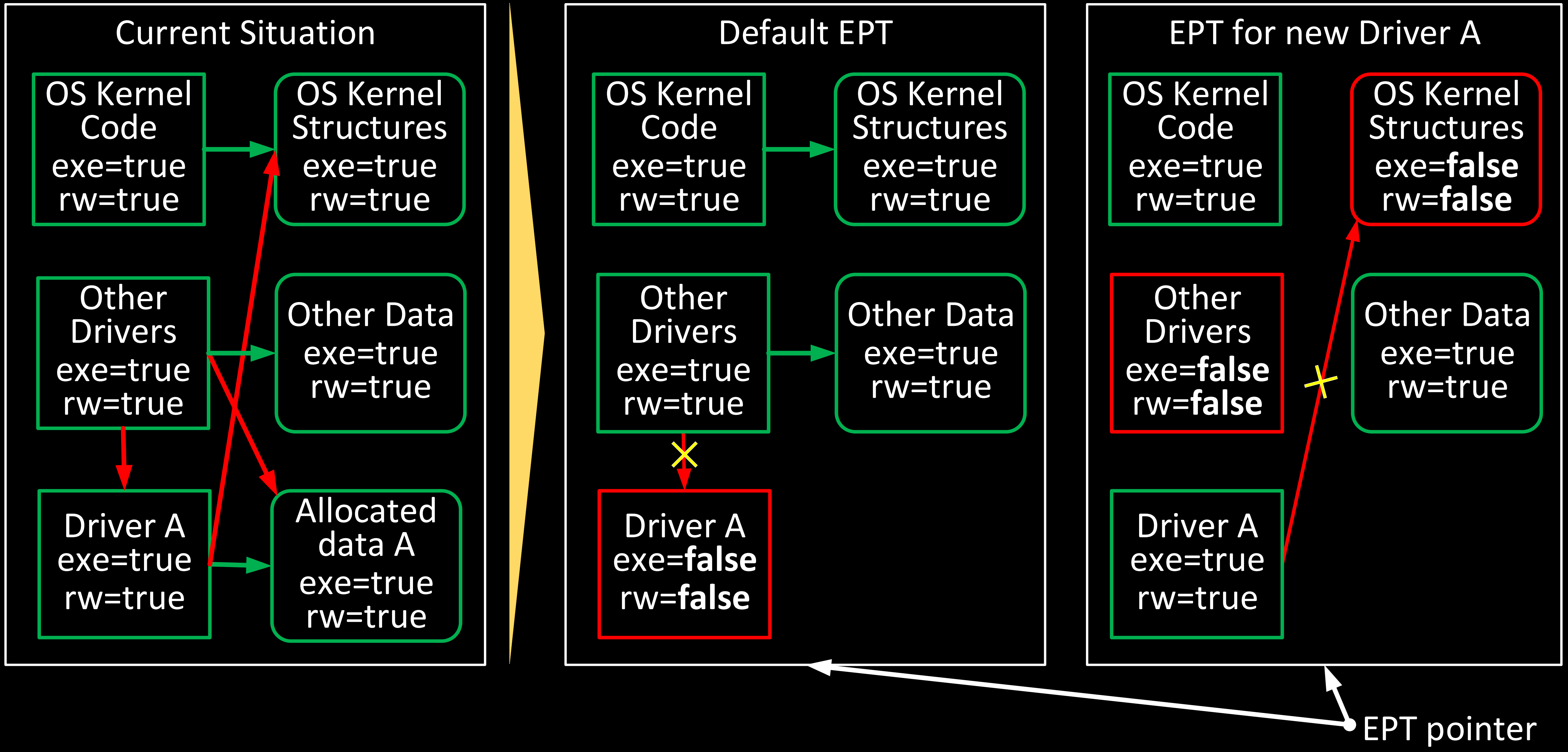
Allocated data A
exe=true
rw=true

APPLYING EPT FOR DRIVERS ISOLATION



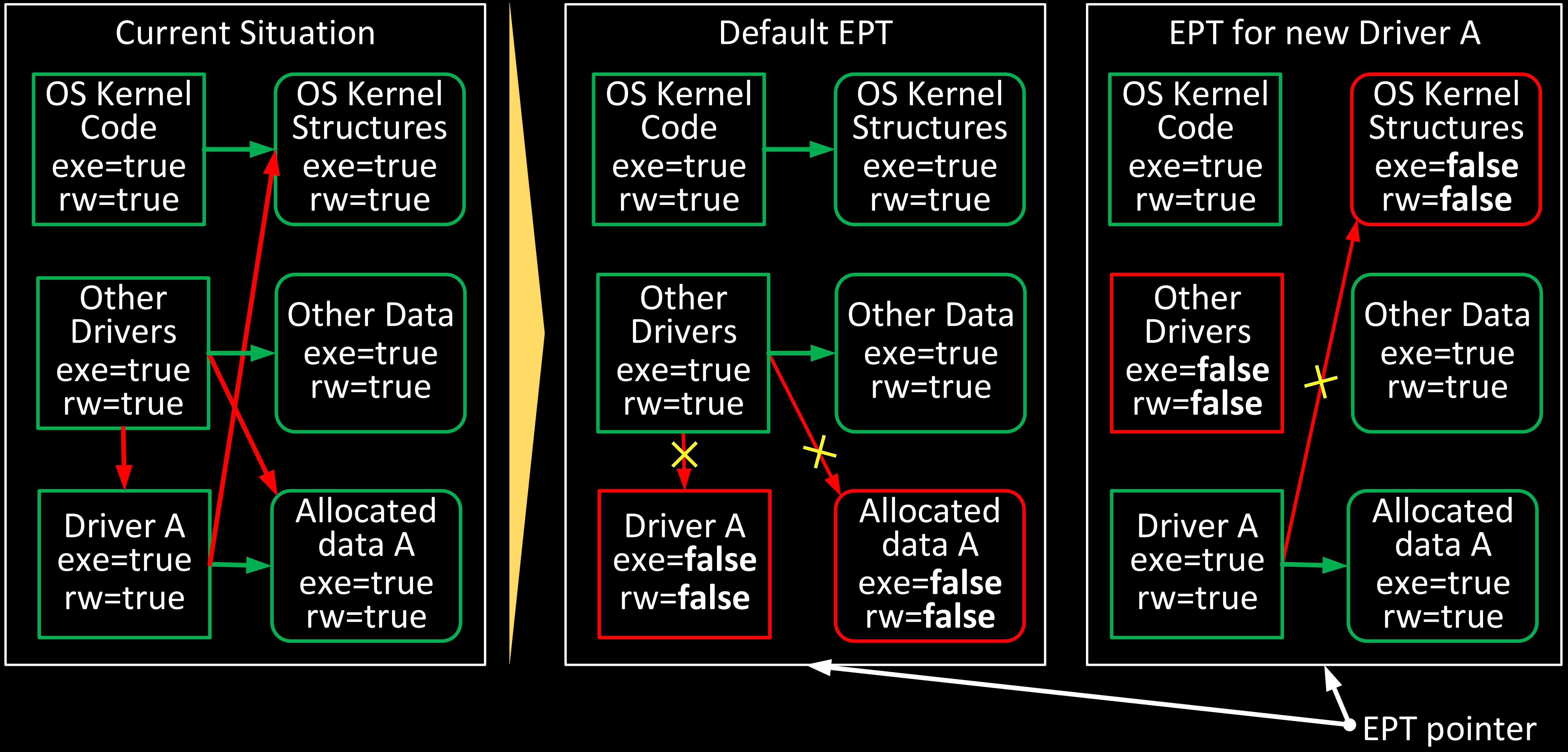
Current Situation
OS Kernel Code exe=true rw=true
OS Kernel Structures exe=true rw=true
Other Drivers exe=true rw=true
Other Data exe=true rw=true
Driver A exe=true rw=true
Allocated data A exe=true rw=true
Default EPT
OS Kernel Code exe=true rw=true
OS Kernel Structures exe=true rw=true
Other Drivers exe=true rw=true
Other Data exe=true rw=true
EPT pointer

APPLYING EPT FOR DRIVERS ISOLATION



Current Situation
OS Kernel Code exe=true rw=true
OS Kernel Structures exe=true rw=true
Other Drivers exe=true rw=true
Other Data exe=true rw=true
Driver A exe=true rw=true
Allocated data A exe=true rw=true
Default EPT
OS Kernel Code exe=true rw=true
OS Kernel Structures exe=true rw=true
Other Drivers exe=true rw=true
Other Data exe=true rw=true
Driver A exe=**false** rw=**false**
EPT for new Driver A
OS Kernel Code exe=true rw=true
OS Kernel Structures exe=**false** rw=**false**
Other Drivers exe=**false** rw=**false**
Other Data exe=true rw=true
Driver A exe=true rw=true
EPT pointer

APPLYING EPT FOR DRIVERS ISOLATION



Current Situation

OS Kernel Code exe=true rw=true

OS Kernel Structures exe=true rw=true

Other Drivers exe=true rw=true

Other Data exe=true rw=true

Driver A exe=true rw=true

Allocated data A exe=true rw=true

Default EPT

OS Kernel Code exe=true rw=true

OS Kernel Structures exe=true rw=true

Other Drivers exe=true rw=true

Other Data exe=true rw=true

Driver A exe=**false** rw=**false**

Allocated data A exe=**false** rw=**false**

EPT for new Driver A

OS Kernel Code exe=true rw=true

OS Kernel Structures exe=**false** rw=**false**

Other Drivers exe=**false** rw=**false**

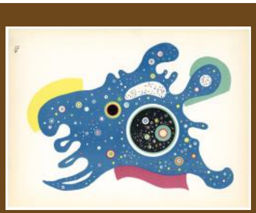
Other Data exe=true rw=true

Driver A exe=true rw=true

Allocated data A exe=true rw=true

EPT pointer

THREE HOUSES WITH PRIVATE ART COLLECTIONS



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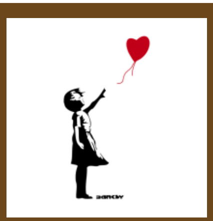

Girl with Balloon
by Banksy

No.5 by
Jackson Pollock

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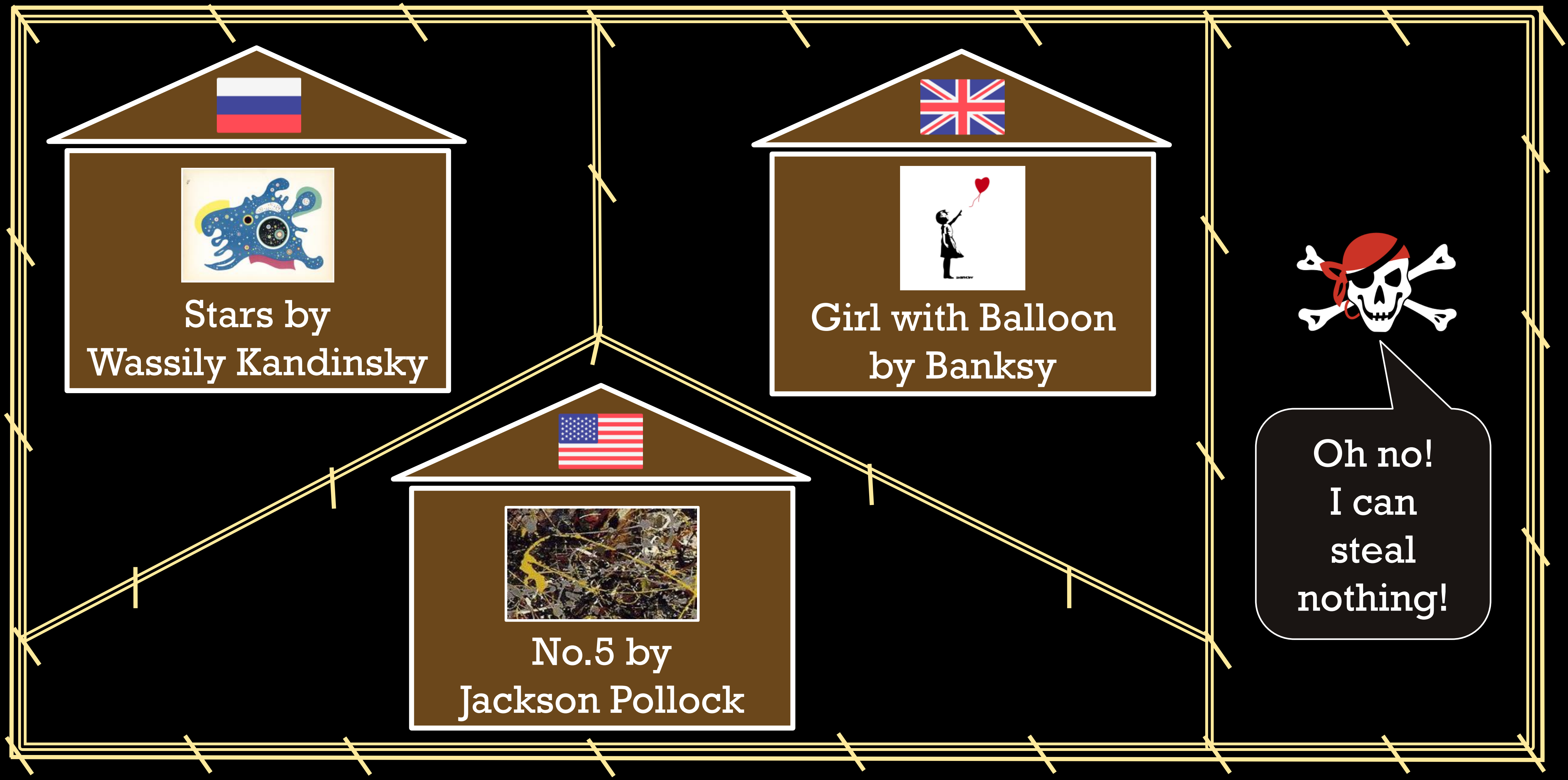

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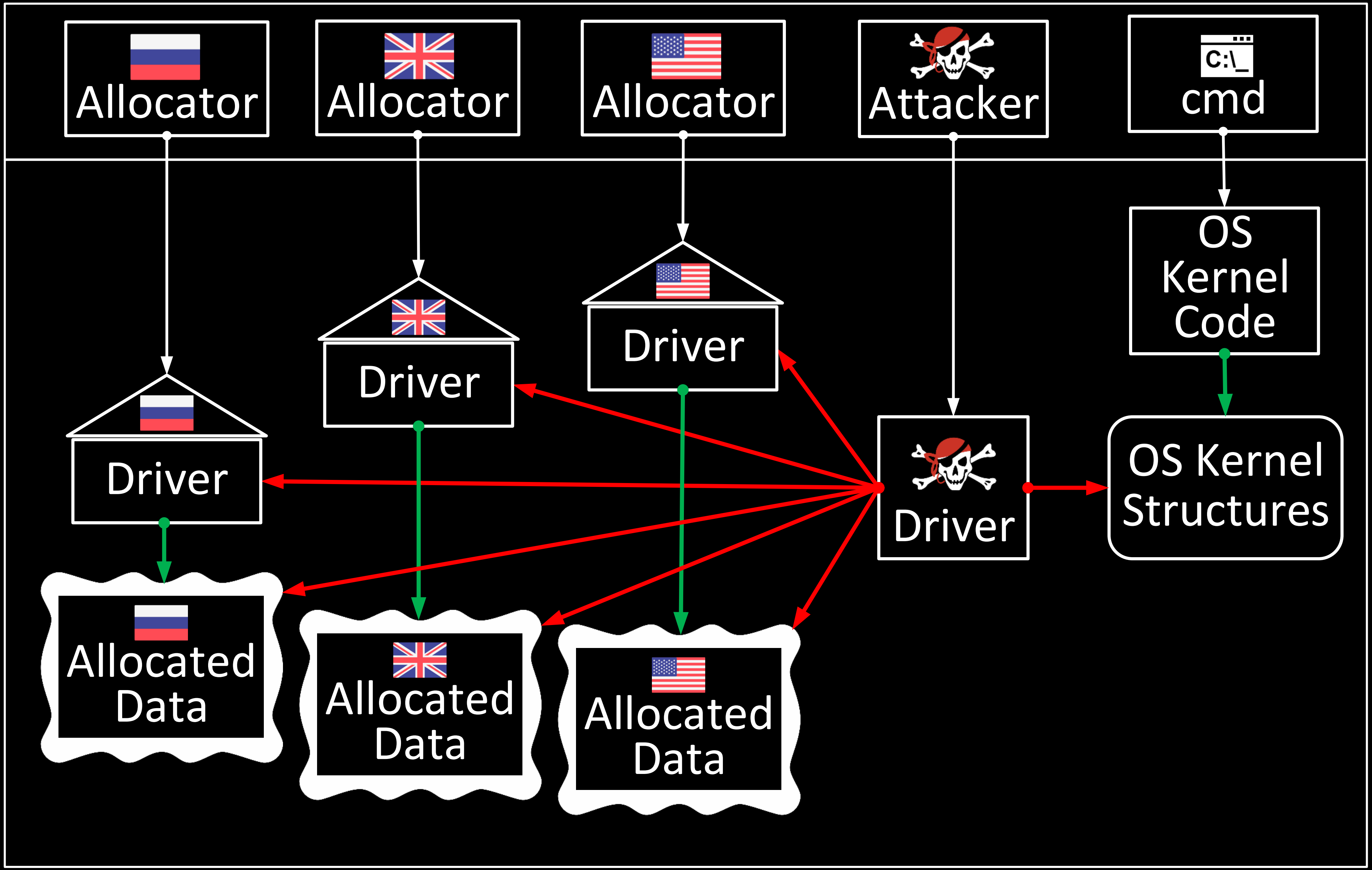
DEMO: THE ATTACK PREVENTION



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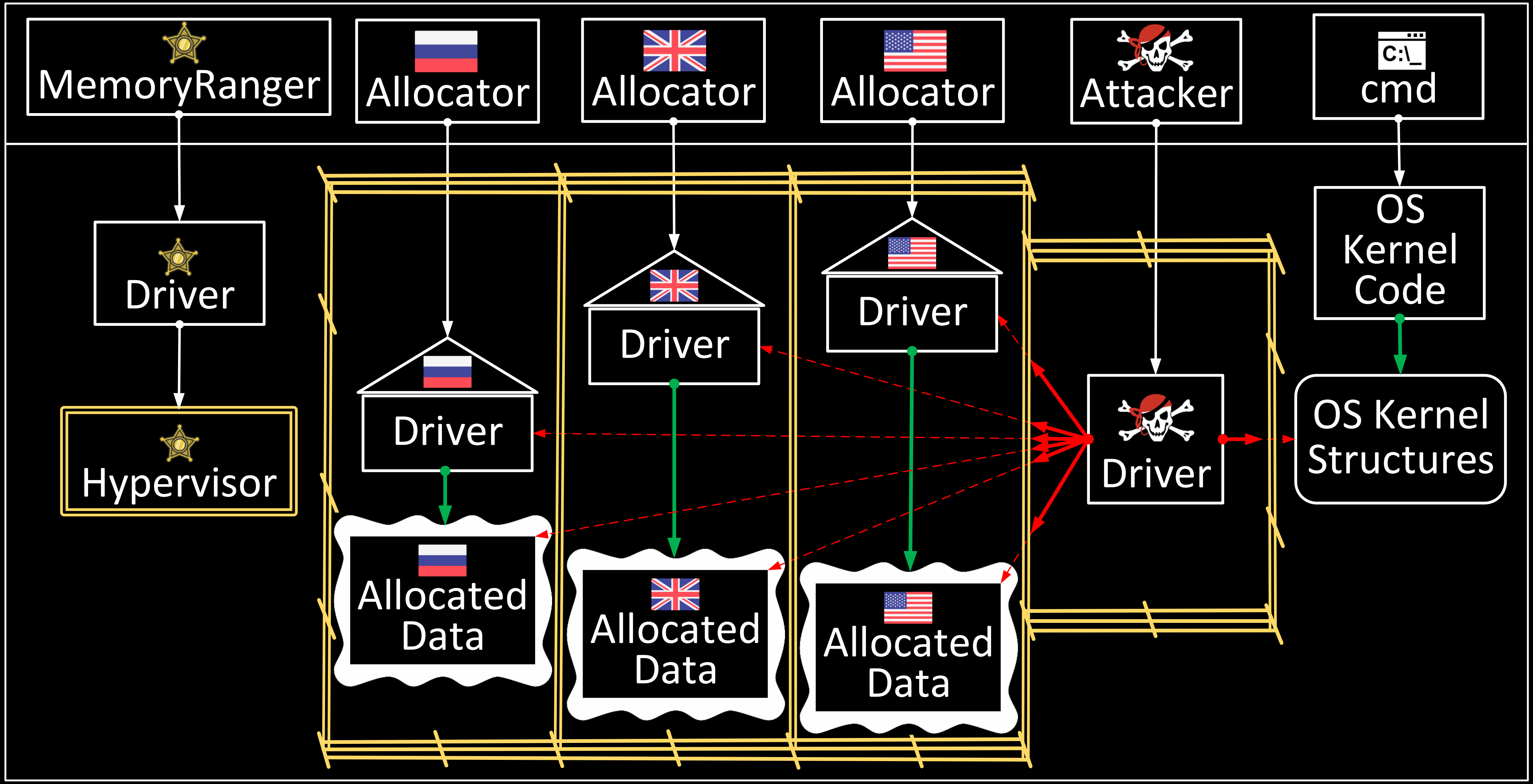


MEMORY RANGER: PRINCIPLE OF LEAST PRIVILEGE

Kernel-mode drivers	Drivers Code			
	🇷🇺	🇬🇧	🇺🇸	☠
🇷🇺	✓			
🇬🇧		✓		
🇺🇸			✓	
☠				✓
OS kernel	✓	✓	✓	✓

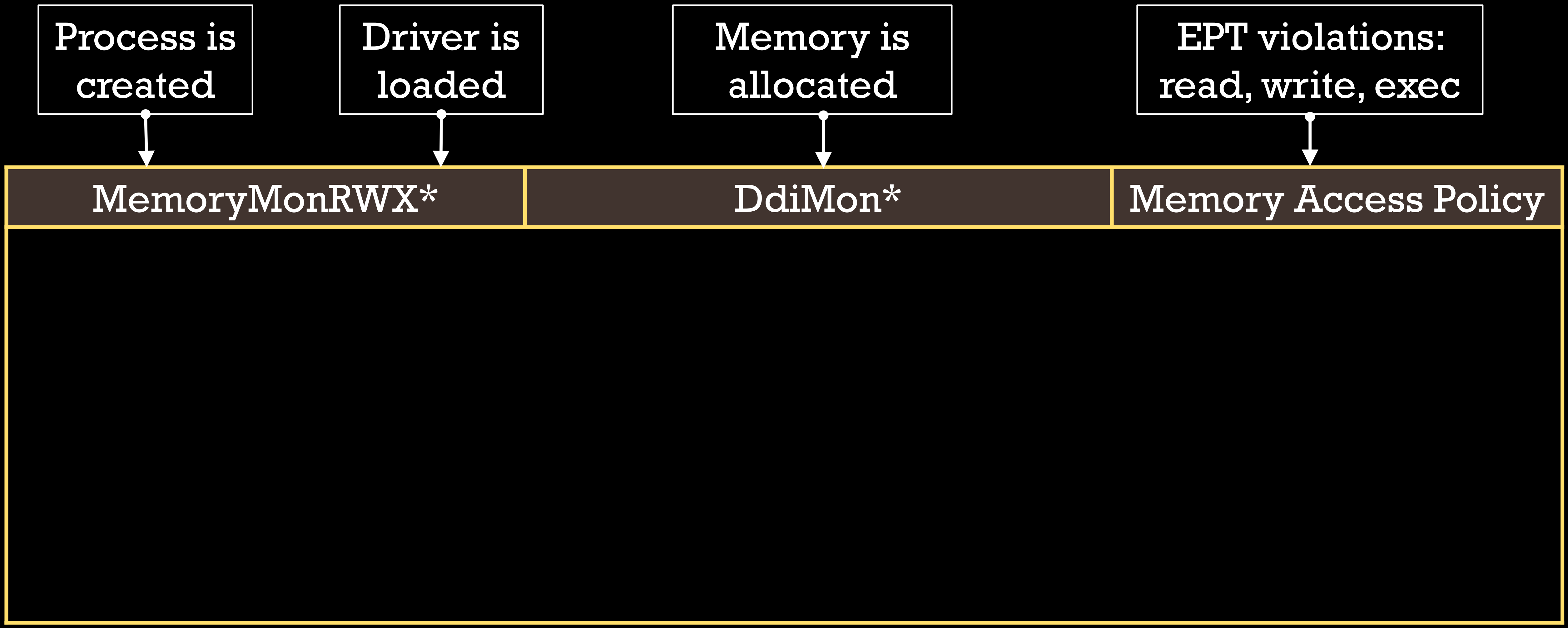
MEMORY RANGER: PRINCIPLE OF LEAST PRIVILEGE

Kernel-mode drivers	Drivers Code				Allocated Memory Data			
	🇷🇺	🇬🇧	🇺🇸	☠	🇷🇺	🇬🇧	🇺🇸	EPROCESS structures
🇷🇺	✓				✓			
🇬🇧		✓				✓		
🇺🇸			✓				✓	
☠				✓				
OS kernel	✓	✓	✓	✓	✓	✓	✓	✓

MEMORY RANGER: PRINCIPLE OF LEAST PRIVILEGE

Kernel-mode drivers	Drivers Code				Allocated Memory Data			
	🇷🇺	🇬🇧	🇺🇸	☠	🇷🇺	🇬🇧	🇺🇸	EPROCESS structures
🇷🇺	✓	✗	✗	✗	✓	✗	✗	✗
🇬🇧	✗	✓	✗	✗	✗	✓	✗	✗
🇺🇸	✗	✗	✓	✗	✗	✗	✓	✗
☠	✗	✗	✗	✓	✗	✗	✗	✗
OS kernel	✓	✓	✓	✓	✓	✓	✓	✓

MEMORY RANGER ARCHITECTURE: THREE PARTS



Process is created

Driver is loaded

Memory is allocated

EPT violations: read, write, exec

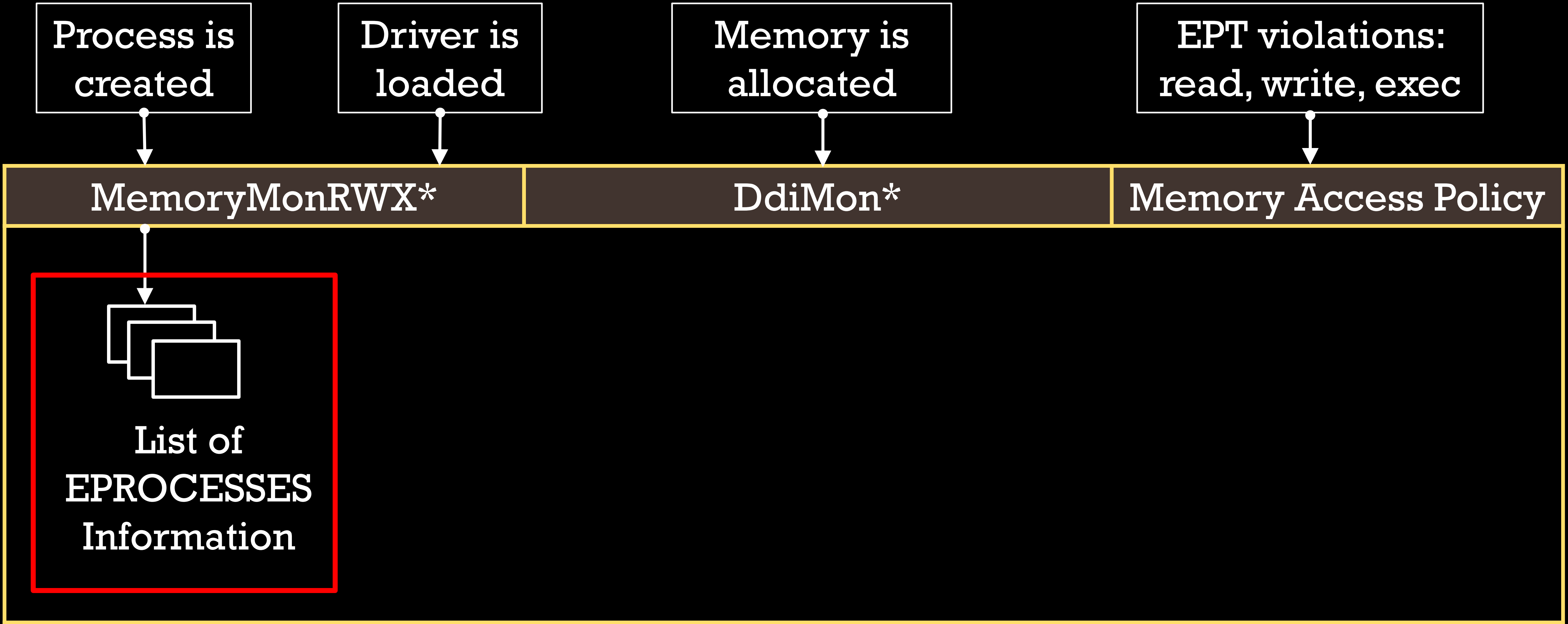
MemoryMonRWX*

DdiMon*

Memory Access Policy

* by Satoshi Tanda, @standa_t, https://github.com/tandasat

MEMORY RANGER ARCHITECTURE: THREE PARTS



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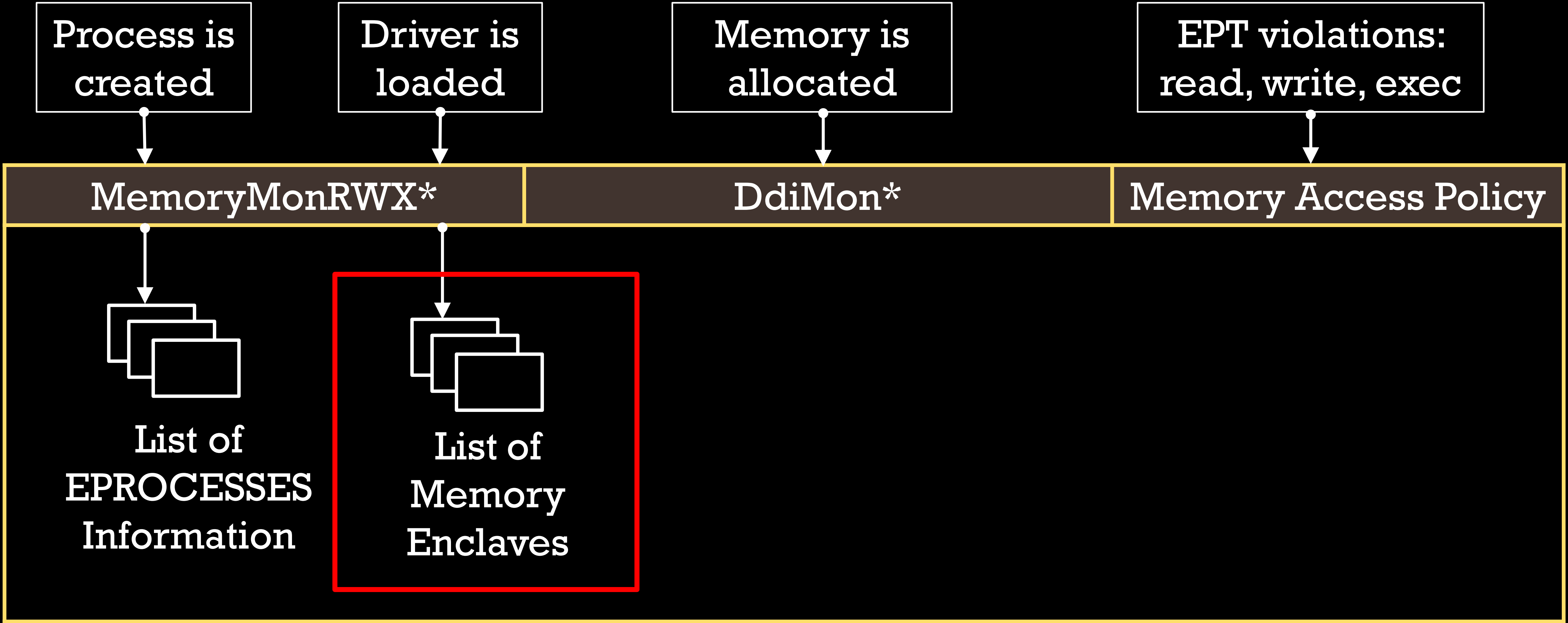

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List of EPROCESSES Information

List of Memory Enclaves

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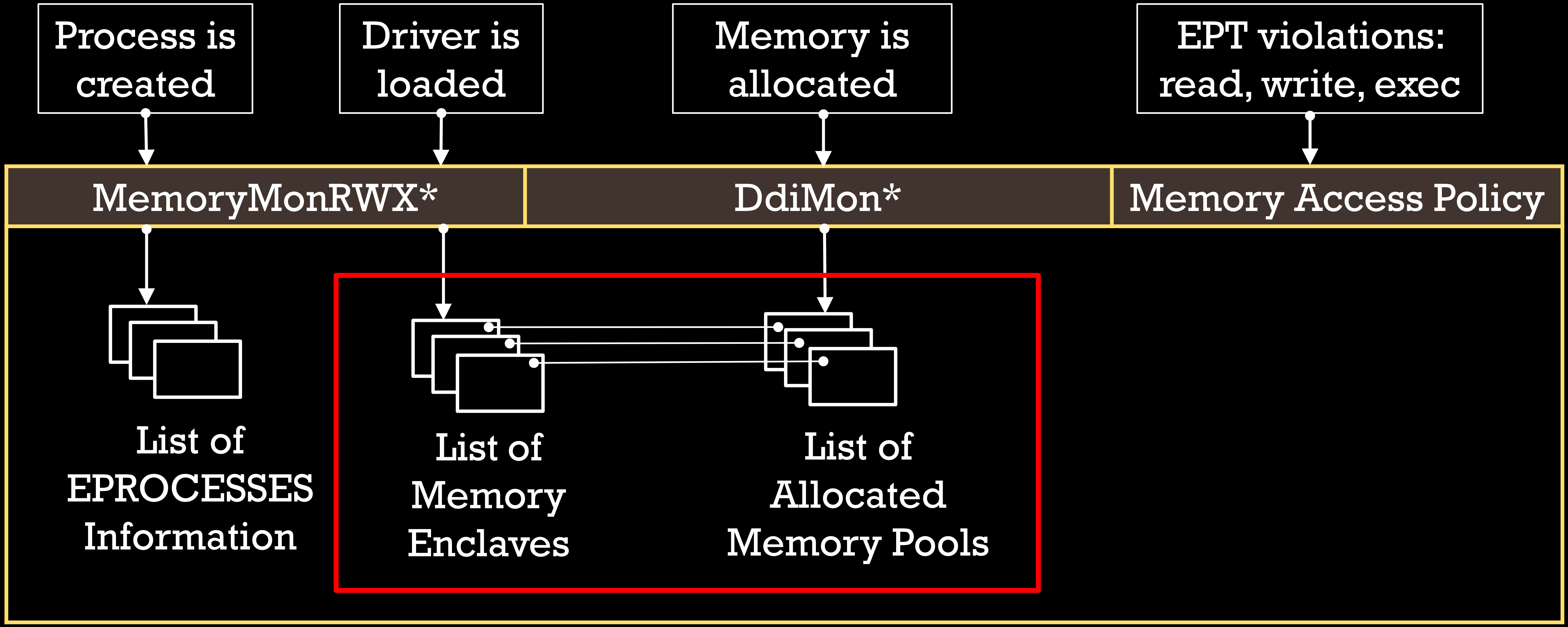
MEMORY RANGER ARCHITECTURE: THREE PARTS



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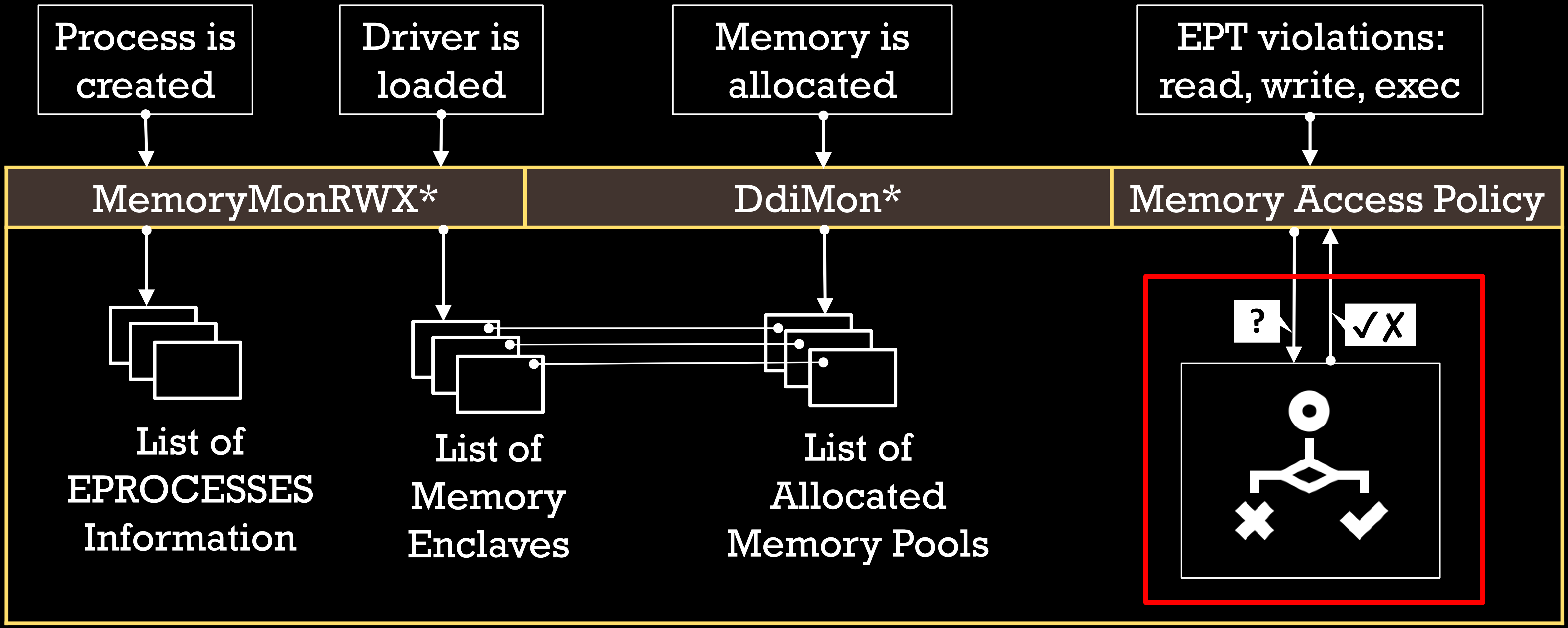

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MEMORY RANGER DISPATCHER (SIMPLIFIED)

```
switch (exit_reason){
        case (execute_violation):
                change_ept();
                break;
        case (read_violation|| write_violation):
                if (access_legal()==false){
                        set_pte(pfn, read|write, fake_page);
                        set_monitor_trap_flag();
                        break;
                }
        case (monitor_trap_flag):
                set_pte(pfn, no_access, original_page);
                clear_monitor_trap_flag();
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}
```

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HOW TO PROTECT YOUR DATA IN MEMORY?

1. Callback - creating a list of protected objects
   - Add objects' addresses & sizes to the list
   - Restrict memory access for objects memory via EPT

2. EPT dispatcher – processing EPT violations for this data
   - type_of_access – read or write
   - guest_ip is the 'source address'
   - fault_va is the 'destination address'
   - Temporary allow access to the data using MTF
   - Redirect access to the fake data using MTF and EPT.PFN

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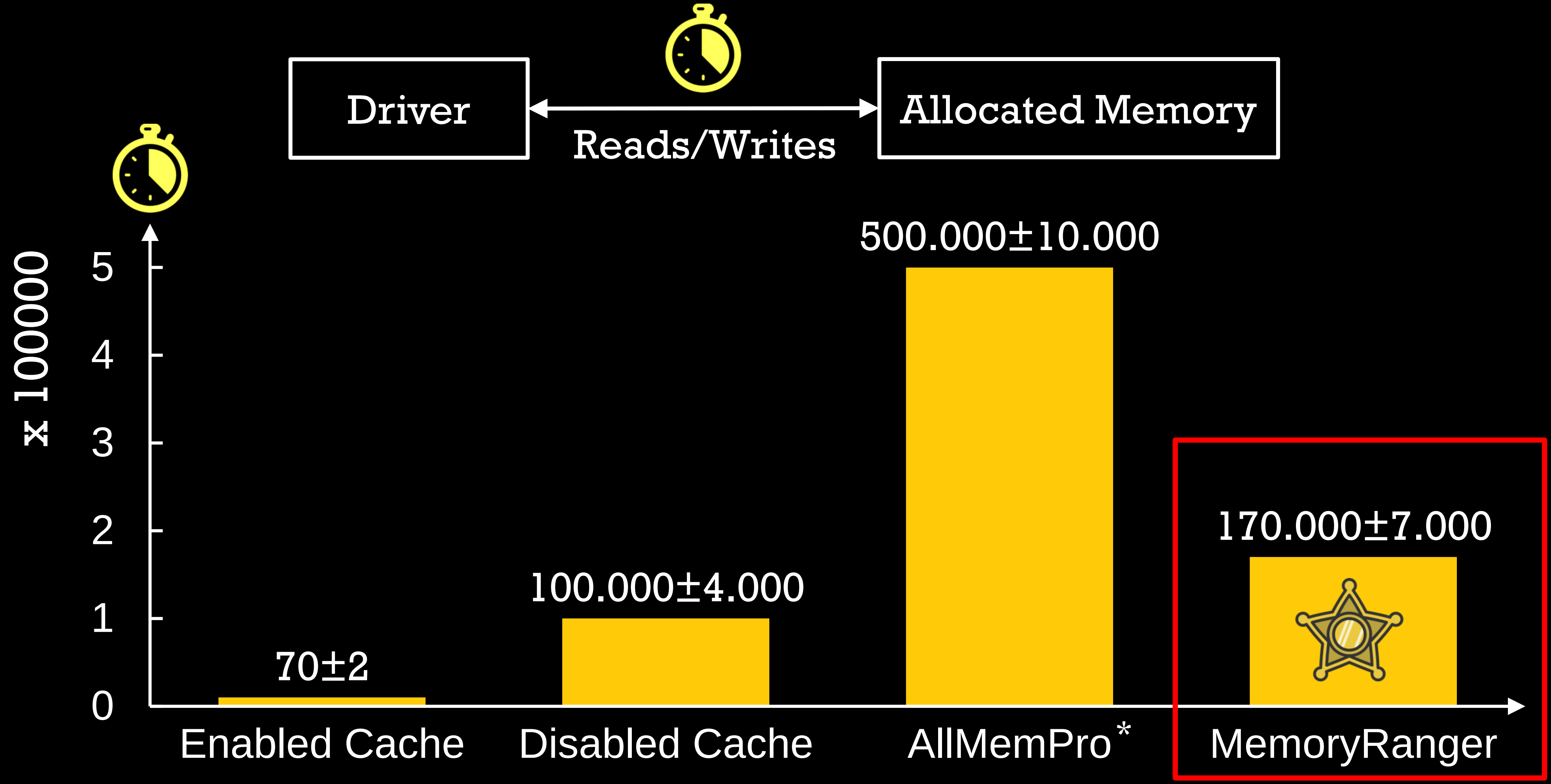
MEMORY RANGER BENCHMARKS: MEMORY ACCESS TIME



Driver

Reads/Writes

Allocated Memory

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

BLACK HAT SOUND BYTES OR CONCLUSION

- Kernel-mode memory is out of control
- MemoryRanger isolates drivers execution by using a specific EPT structure for each driver
- MemoryRanger seems to prevent Spectre and Meltdown CPU attacks: research is ongoing

Dīvide et Imperā*

from Latin divide and rule

* Cartledge, P. (2013). Sparta and Lakonia: A regional history 1300-362 BC. Routledge.

Thank you!

Igor Korkin igor.korkin@gmail.com

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