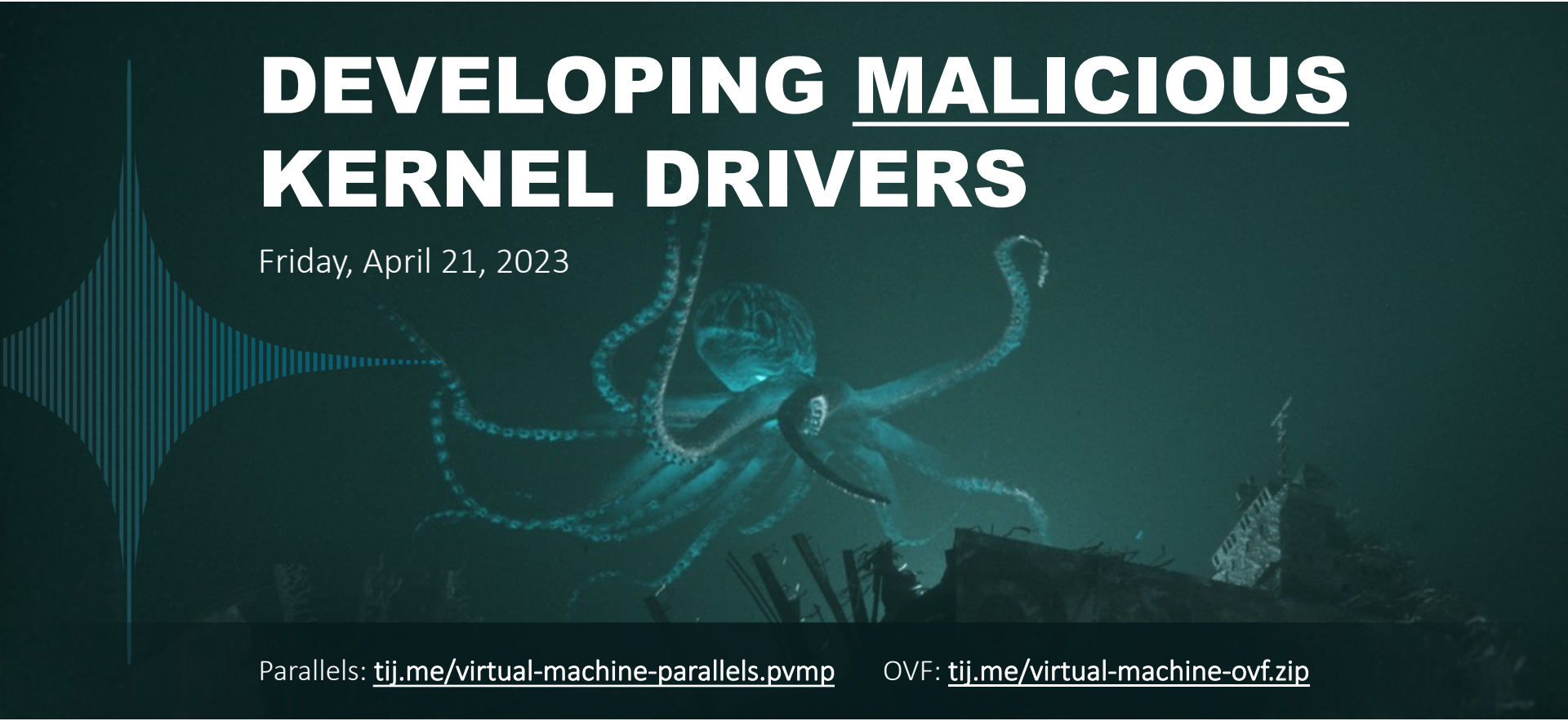


DEVELOPING MALICIOUS KERNEL DRIVERS

Friday, April 21, 2023

Parallels: tij.me/virtual-machine-parallels.pvmp OVF: tij.me/virtual-machine-ovf.zip

ABOUT

Tijme Gommers

- Product Lead / Red Teamer
- Works at Northwave Cyber Security
- Forensics at Hunted (NPO3)
- Lives in the Netherlands
- Author of open-source software
  Kernel Mii, Raivo OTP, WikiRaider
- Socials username is @tijme
  Twitter, GitHub, LinkedIn

ABOUT

Jan-Jaap Korpershoek

- Red Teamer / Reverse Engineer
- Works at Northwave Cyber Security
- Background in technical computer science
- Lives in the Netherlands
- Social media
  GitHub: @JJK96

INDEX

Computer Architecture
- CPU, memory, kernel mode & user mode

Drivers
- Hardware & software kernel drivers

Kernel Malware
- A true attack, which we will also carry out

Development / Exploitation
90 min
- Becoming the APT

Icon(s) from Icons8

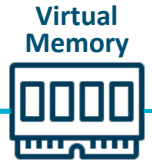
COMPUTER ARCHITECTURE 101

Virtual memory

- `lsass.exe`

`mov rax, [rax]`

`rax contains address of some LSASS credential`



`int`

`4 bytes`

Offset	Value
0x82AD1000	**0x70**
0x82AD1001	**0x61**
0x82AD1002	**0x73**
0x82AD1003	**0x73**
0x82AD1004	0x00
0x82AD1005	0x00
0x82AD1006	0x00
0x82AD1007	0x00
0x82AD1008	0x00
0x82AD1009	0x00
0x82AD100A	0x00
0x82AD100B	0x00
0x82AD100C	0x00
0x82AD100D	0x00

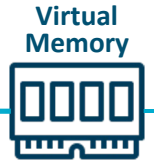
COMPUTER ARCHITECTURE 101

Virtual memory

- `my_malware.exe`

`mov rax, [rax]`

`rax contains address of some LSASS credential`



`int`

`4 bytes`

Offset	Value
0x82AD1000	**0x00**
0x82AD1001	**0x00**
0x82AD1002	**0x00**
0x82AD1003	**0x00**
0x82AD1004	0x00
0x82AD1005	0x00
0x82AD1006	0x00
0x82AD1007	0x00
0x82AD1008	0x00
0x82AD1009	0x00
0x82AD100A	0x00
0x82AD100B	0x00
0x82AD100C	0x00
0x82AD100D	0x00

COMPUTER ARCHITECTURE 101

Physical memory

- `lsass.exe`

`int`

`4 bytes`

Virtual Memory

`ASS credential`

Offset	Value
0x82AD1000	**0x70**
0x82AD1001	**0x61**
0x82AD1002	**0x73**
0x82AD1003	**0x73**
0x82AD1004	0x00
0x82AD1005	0x00
0x82AD1006	0x00
0x82AD1007	0x00
0x82AD1008	0x00
0x82AD1009	0x00
0x82AD100A	0x00
0x82AD100B	0x00
0x82AD100C	0x00
0x82AD100D	0x00

Physical offset	Value
0x11AF0000	0x00
0x11AF0001	0x00
0x11AF0002	**0x70**
0x11AF0003	**0x61**
0x11AF0004	**0x73**
0x11AF0005	**0x73**
0x11AF0006	0x00
0x11AF0007	0x00
0x11AF0008	0x00
0x11AF0009	0x00
0x11AF000A	0x00
0x11AF000B	0x00
0x82AD100C	0x00
0x82AD100D	0x00

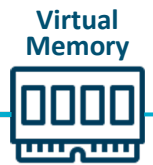
COMPUTER ARCHITECTURE 101

Physical memory

- `my_malware.exe`

`int`

`4 bytes`



`ASS credential`

Offset	Value
0x82AD1000	**0x00**
0x82AD1001	**0x00**
0x82AD1002	**0x00**
0x82AD1003	**0x00**
0x82AD1004	0x00
0x82AD1005	0x00
0x82AD1006	0x00
0x82AD1007	0x00
0x82AD1008	0x00
0x82AD1009	0x00
0x82AD100A	0x00
0x82AD100B	0x00
0x82AD100C	0x00
0x82AD100D	0x00

Physical offset	Value
0x11AF0000	0x00
0x11AF0001	0x00
0x11AF0002	0x70
0x11AF0003	0x61
0x11AF0004	0x73
0x11AF0005	0x73
0x11AF0006	0x00
0x11AF0007	0x00
0x11AF0008	**0x00**
0x11AF0009	**0x00**
0x11AF000A	**0x00**
0x11AF000B	**0x00**
0x82AD100C	0x00
0x82AD100D	0x00

COMPUTER ARCHITECTURE 1

Physical memory

- lsass.exe
- my_malware.exe

int

4 bytes

Virtual Memory

ASS credential

Windows Memory Mapping

Runs in kernel mode

Offset	Value
0x82AD1000	**0x00**
0x82AD1001	**0x00**
0x82AD1002	**0x00**
0x82AD1003	**0x00**
0x82AD1004	0x00
0x82AD1005	0x00
0x82AD1006	0x00
0x82AD1007	0x00
0x82AD1008	0x00
0x82AD1009	0x00
0x82AD100A	0x00
0x82AD100B	0x00
0x82AD100C	0x00
0x82AD100D	0x00

Physical offset	Value
0x11AF0000	0x00
0x11AF0001	0x00
0x11AF0002	0x70
0x11AF0003	0x61
0x11AF0004	0x73
0x11AF0005	0x73
0x11AF0006	0x00
0x11AF0007	0x00
0x11AF0008	**0x00**
0x11AF0009	**0x00**
0x11AF000A	**0x00**
0x11AF000B	**0x00**
0x82AD100C	0x00
0x82AD100D	0x00

COMPUTER ARCHITECTURE 101

Computer memory

User mode to kernel mode

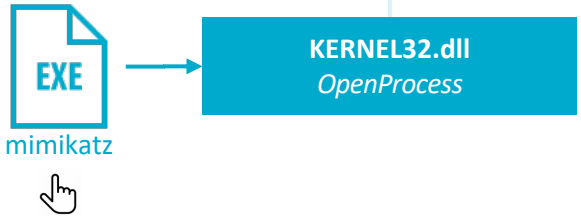
mimikatz

Icon(s) from Icons8

COMPUTER ARCHITECTURE 101

Computer memory

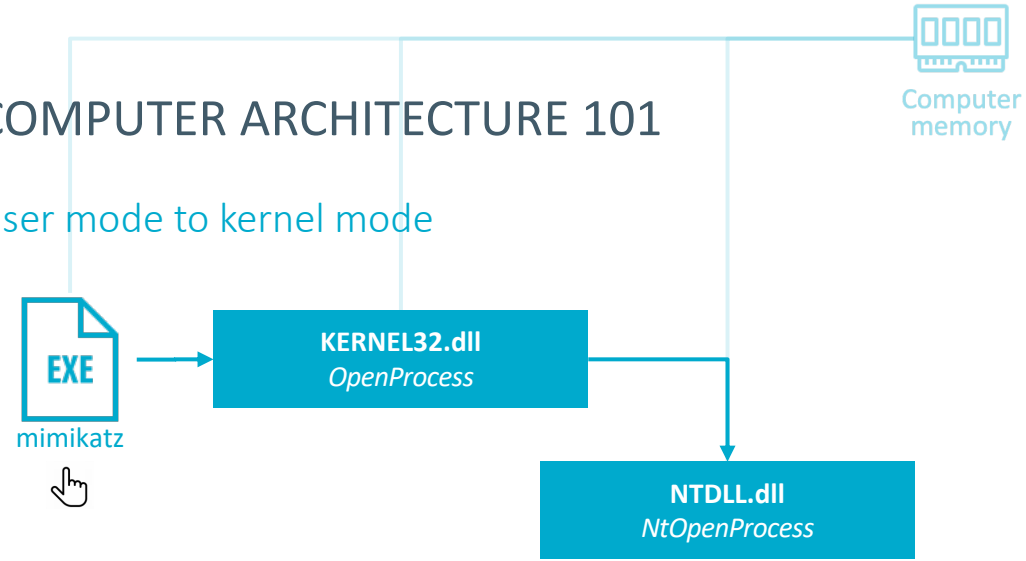
User mode to kernel mode



Icon(s) from Icons8

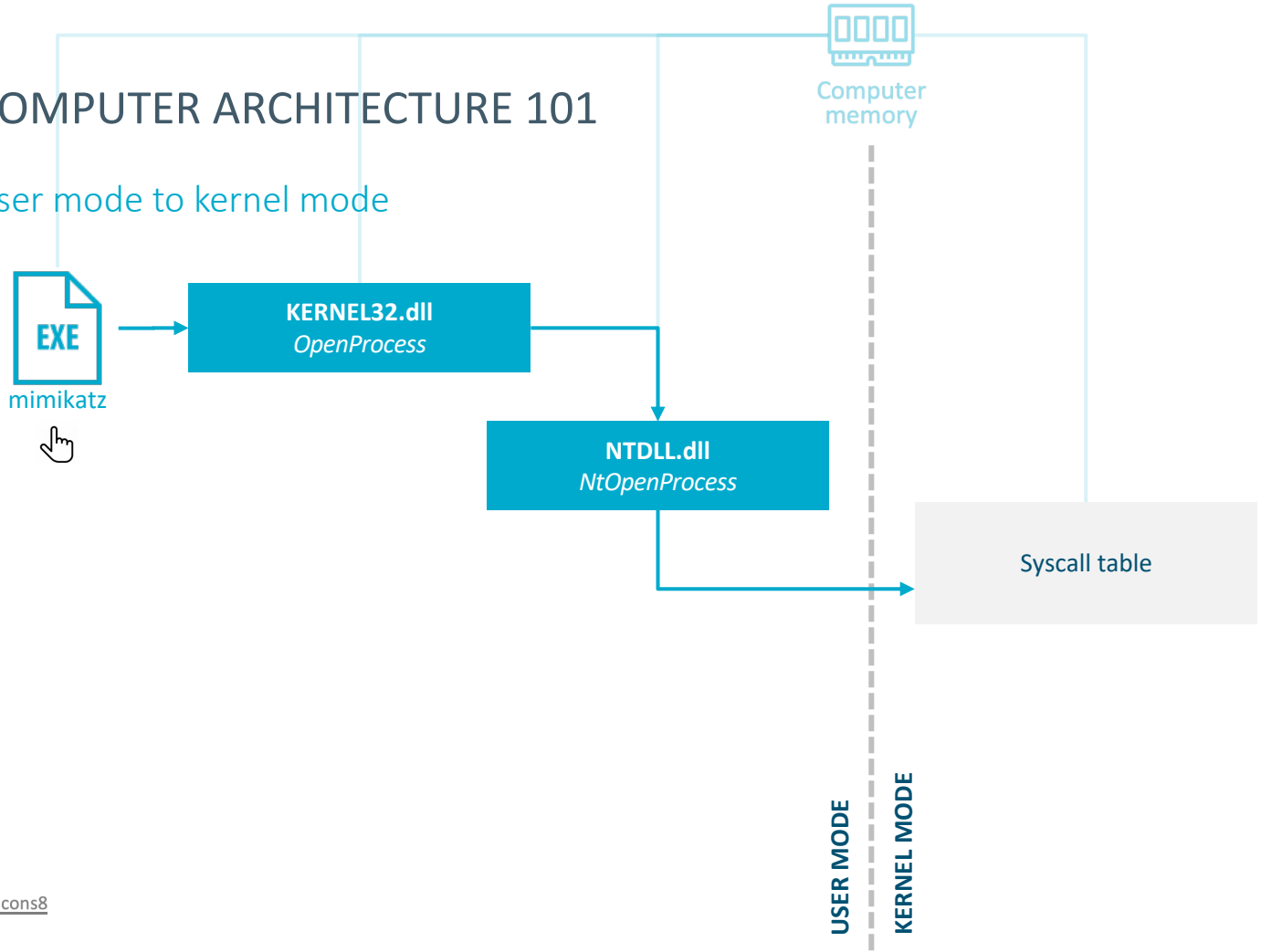
COMPUTER ARCHITECTURE 101

User mode to kernel mode



COMPUTER ARCHITECTURE 101

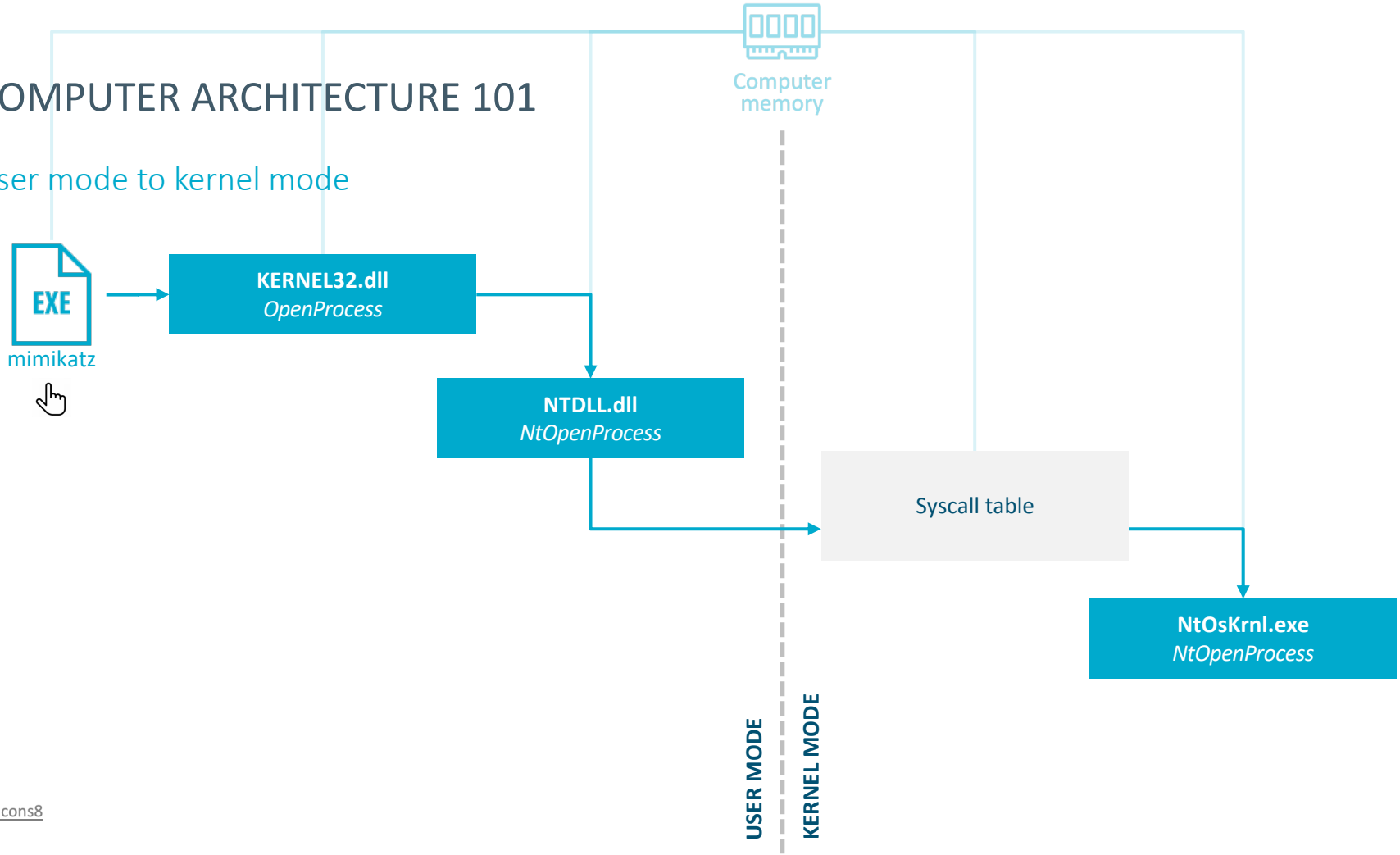
User mode to kernel mode



Icon(s) from Icons8

COMPUTER ARCHITECTURE 101

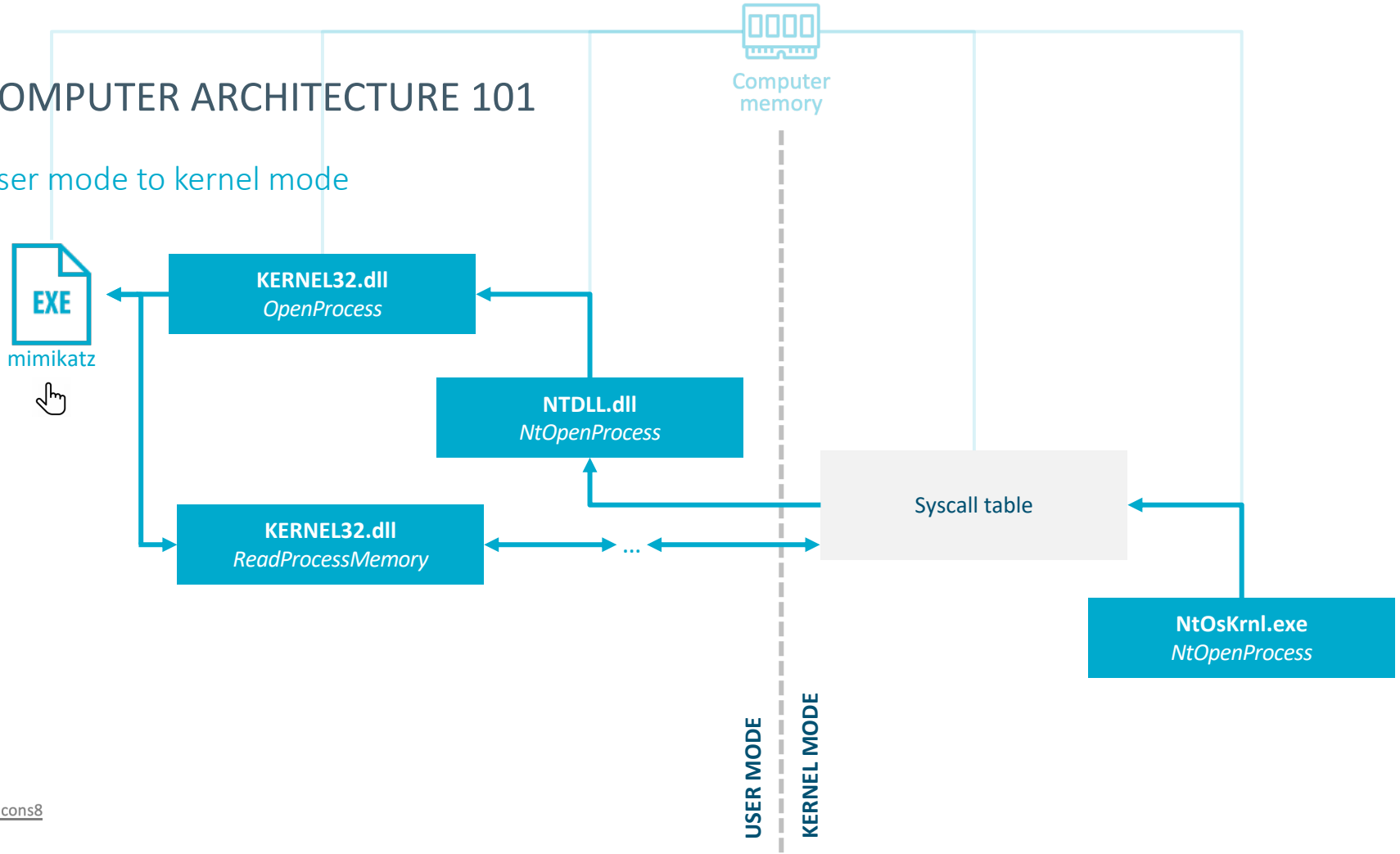
User mode to kernel mode



Icon(s) from Icons8

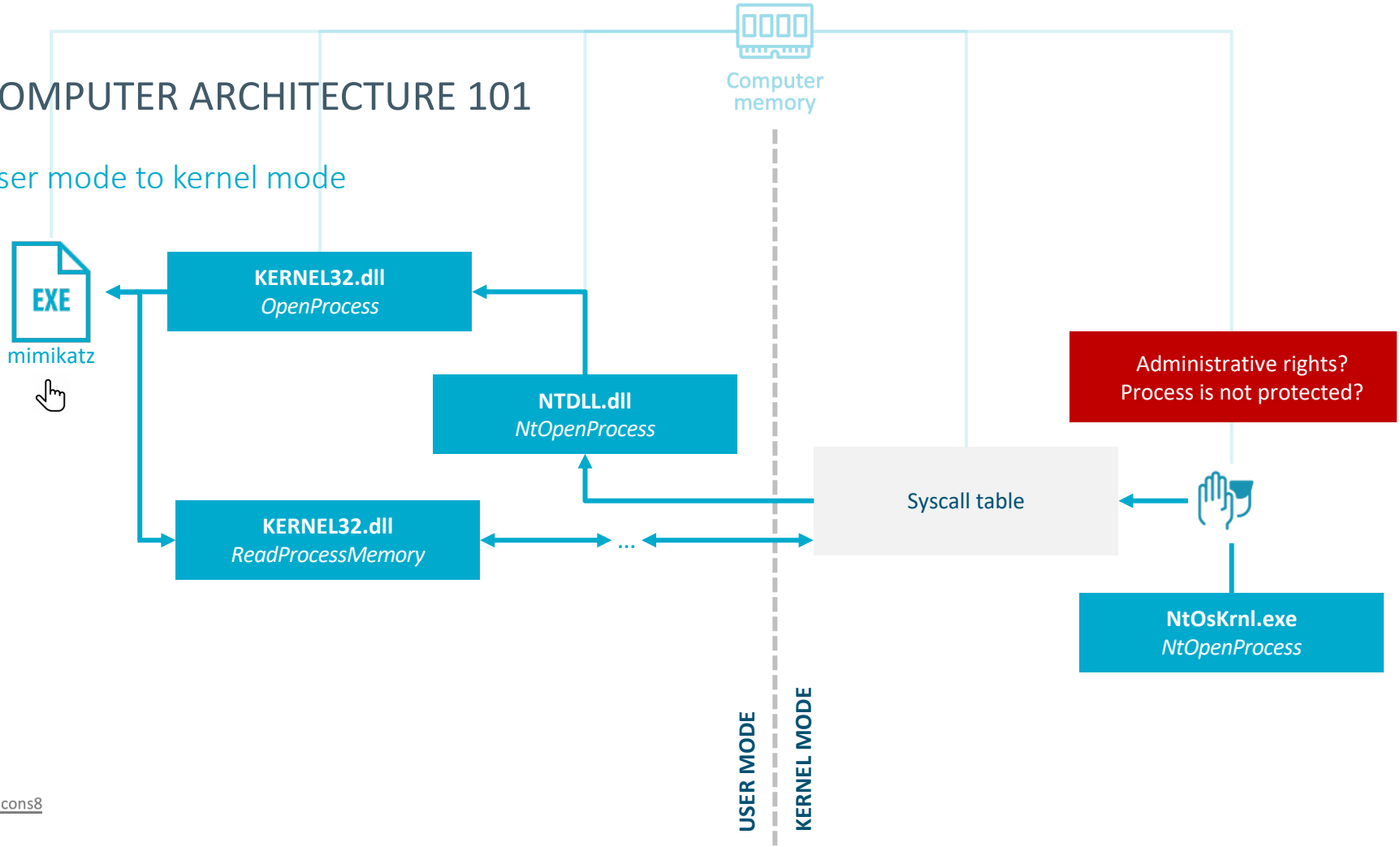
COMPUTER ARCHITECTURE 101

User mode to kernel mode

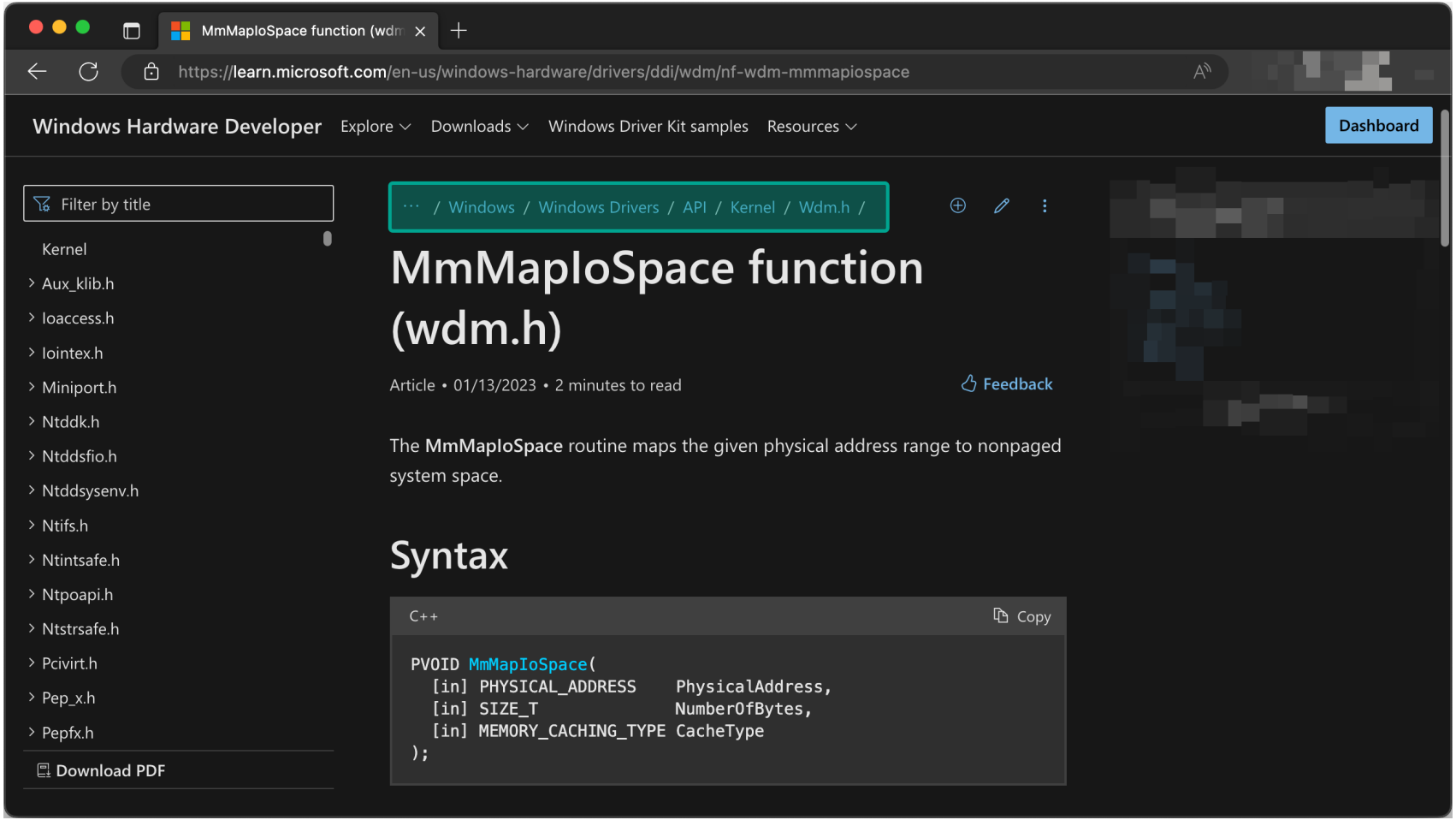


COMPUTER ARCHITECTURE 101

User mode to kernel mode



Icon(s) from Icons8


MmMapIoSpace function (wdm
https://learn.microsoft.com/en-us/windows-hardware/drivers/ddi/wdm/nf-wdm-mmmapiospace
Windows Hardware Developer
Explore
Downloads
Windows Driver Kit samples
Resources
Dashboard
Filter by title
Kernel
Aux_klib.h
Ioaccess.h
Iointex.h
Miniport.h
Ntddk.h
Ntddsfio.h
Ntddsysenv.h
Ntifs.h
Ntintsafe.h
Ntpoapi.h
Ntstrsafe.h
Pcivirt.h
Pep_x.h
Pepfx.h
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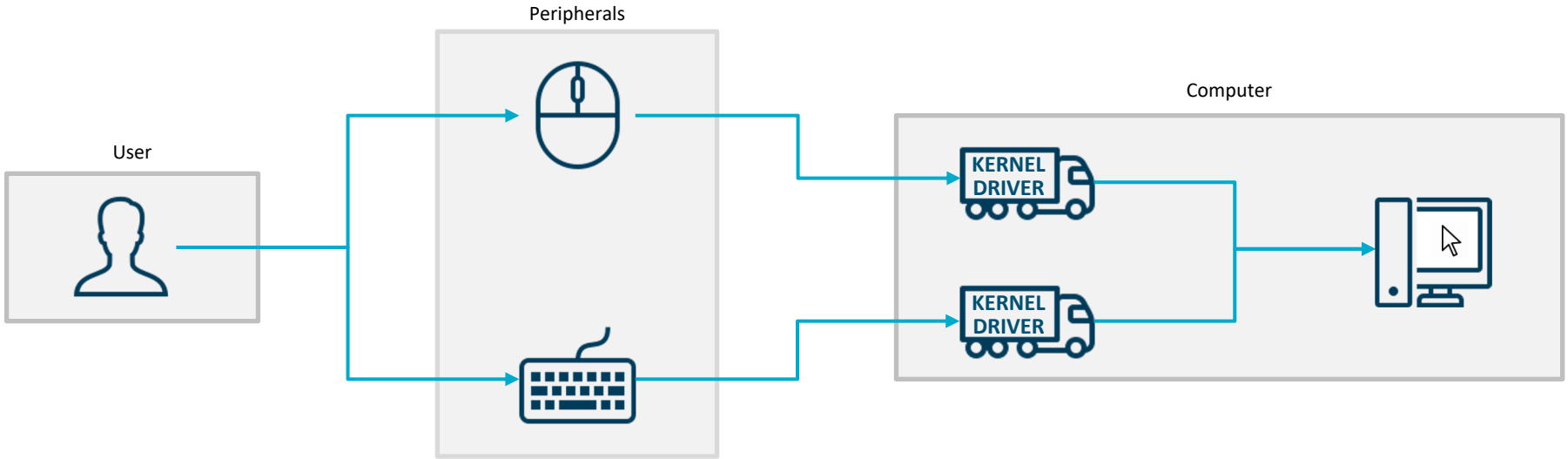
... / Windows / Windows Drivers / API / Kernel / Wdm.h /
MmMapIoSpace function (wdm.h)
Article • 01/13/2023 • 2 minutes to read
Feedback
The MmMapIoSpace routine maps the given physical address range to nonpaged system space.
Syntax
C++
Copy
PVOID MmMapIoSpace(
[in] PHYSICAL_ADDRESS PhysicalAddress,
[in] SIZE_T NumberOfBytes,
[in] MEMORY_CACHING_TYPE CacheType
);

DRIVERS 101

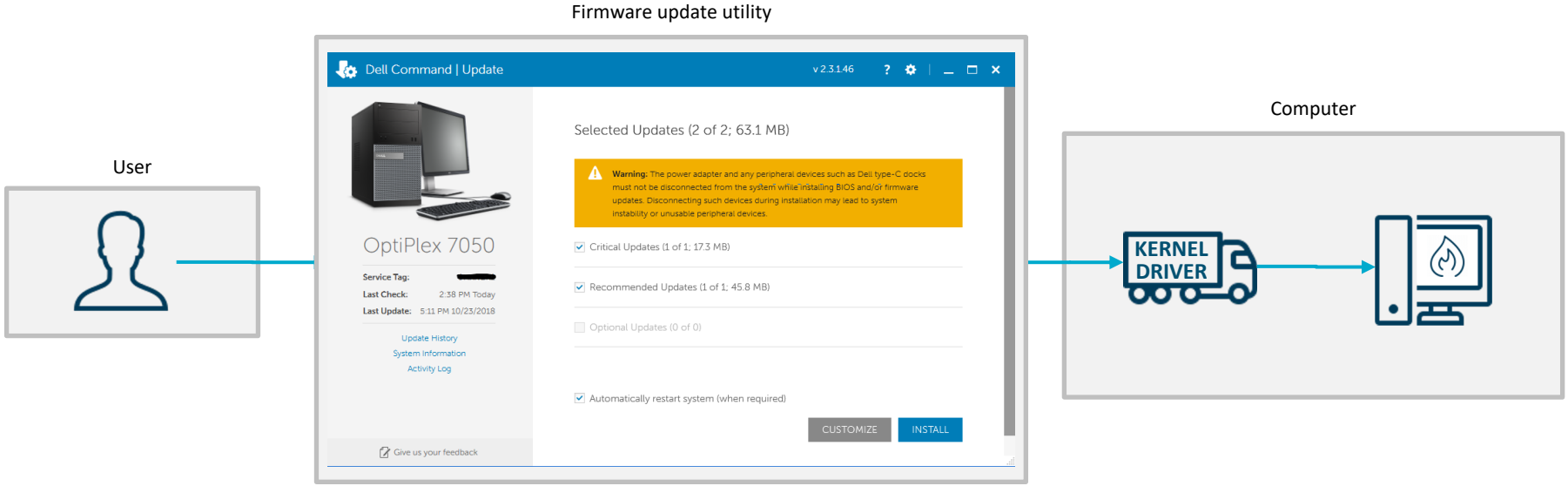
Hardware drivers



Icon(s) from Icons8

DRIVERS 101

Software drivers

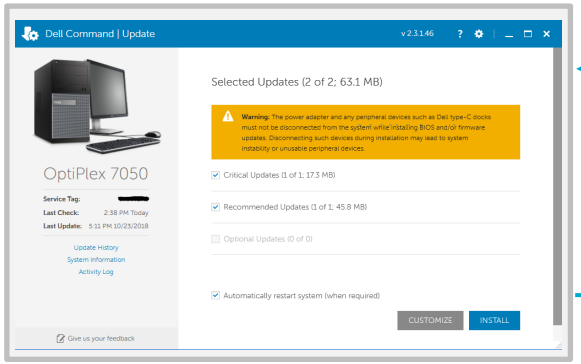


Icon(s) from Icons8

DRIVERS 101

Input/output control codes (IOCTL's)

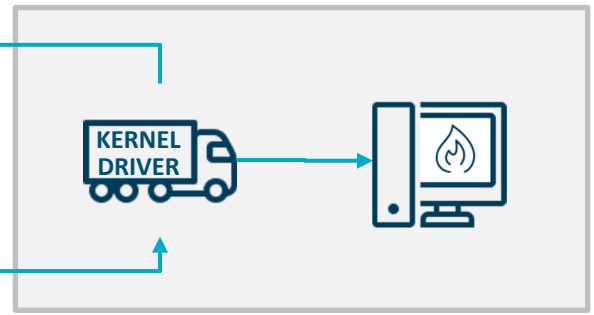
Firmware update utility



Input/output control code (IOCTL)
0x8000400C: Read firmware status

Input/output control code (IOCTL)
0x8000500D: Update firmware to given binary

Computer



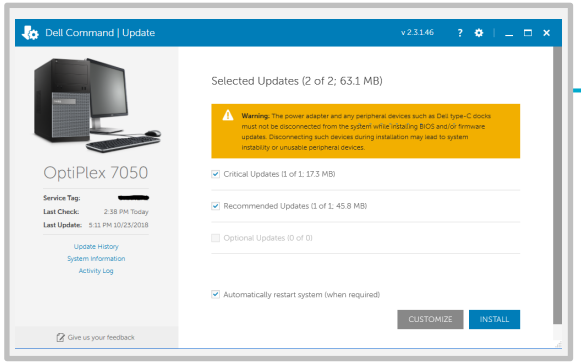
Note: These IOCTLs are fictional

Icon(s) from Icons8

DRIVERS 101

Input/output control codes (IOCTL's)

Firmware update utility



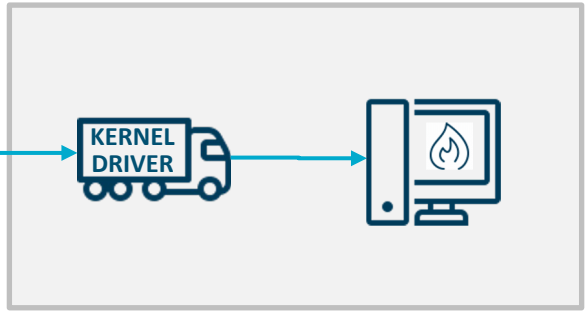
Input/output control code (IOCTL)
0x8000500D: Update firmware to given binary

```
char * data = ...;
size_t size = 0x1000;

HANDLE handle = CreateFile("\\\\.\\dbutil_2_3", ...)

DeviceIoControl(handle, 0x8000500D, data, size, ...)
```

Computer



Note: This example is fictional

Icon(s) from Icons8

DRIVERS 101

Switch statement of supported IOCTL's in driver source code

When someone calls DeviceIoControl(…)


```
void IRP_MJ_DEVICE_CONTROL (DEVICE_OBJECT* device, IRP* irp) {
    DeviceIoControl* IoControl = irp->Tail->CurrentStackLocation->DeviceIoControl;
    VOID* UserBuffer = irp->Associated Irp->SystemBuffer;

    switch (IoControl->IoControlCode) {
        case 0x8000400C:
            UserBuffer readFirmwareStatus();
            break;
        case 0x8000500D:
            writeFirmware(UserBuffer);
            break;
        case 0x8000600E:
            break;
        default:
            puts("Unknown IOCTL");
    }
}
```

Note: These IOCTLs are fictional

Updating your system's firmware. Do not power down your system.

Waiting for Intel(R) ME FW Update to complete

Flash Progress

84%

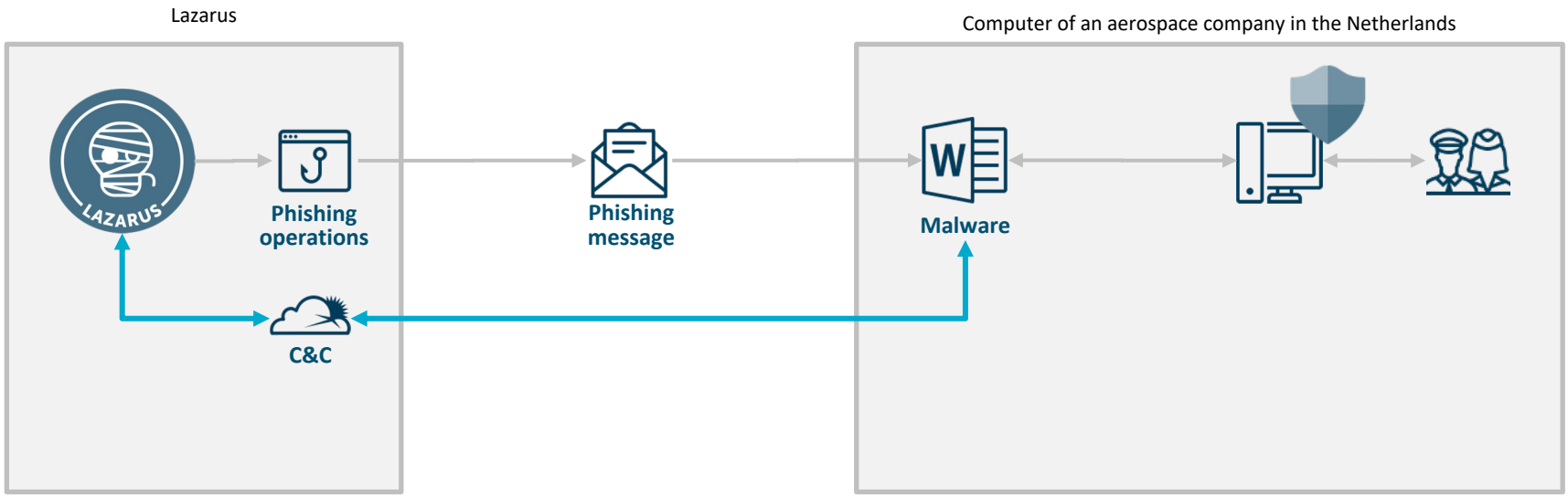
DRIVERS 101

Installation

- Driver signing useful for threat actors, but probably not for red teams.
- In this lab we'll exploit an existing driver instead! **dbutil_2_3.sys**

A TRUE ATTACK (2021)

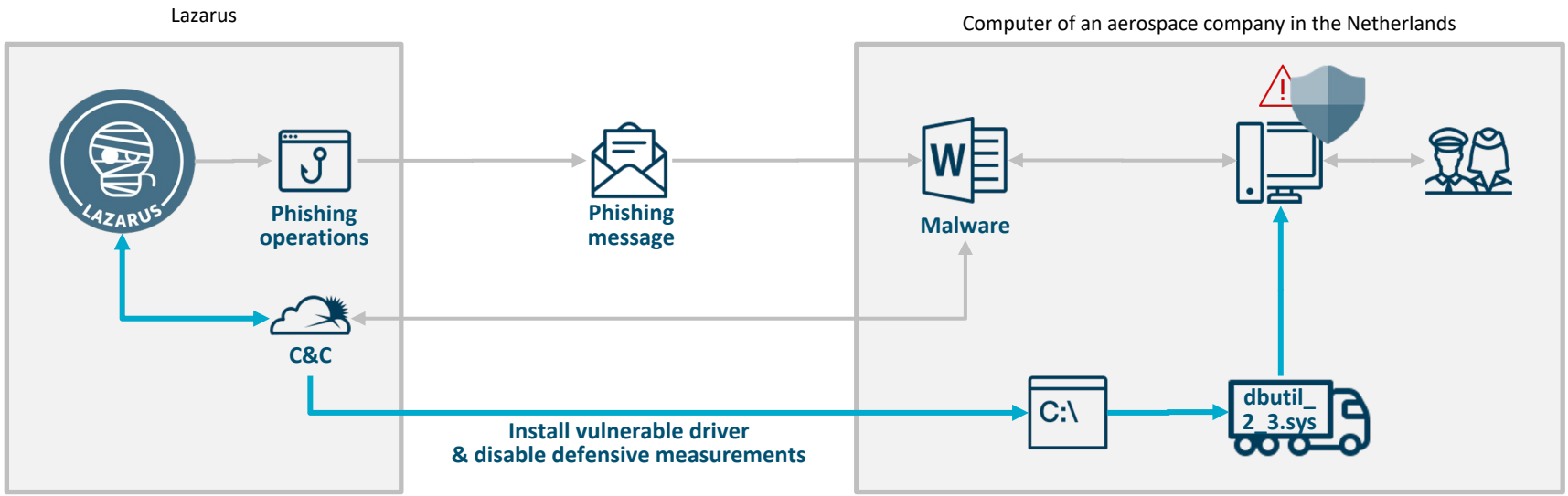
Research by ESET



Icon(s) from Icons8

A TRUE ATTACK (2021)

Research by ESET



Icon(s) from Icons8

EXERCISES

Icon(s) from Icons8

Download the exercise files at **https://tij.me/exercise1-good-luck.zip**

PROGRAMMING

Compiling C files

1. Start “**x64 Native Tools Command Prompt For VS**”

2. Compile your code

```
cl.exe <filename.c>
```

BECOMING THE APT

Exercise 1 25 min

1. Boot your virtual machine (64-bit Windows 10).
2. Download the exercise files at tij.me/exercise1-good-luck.zip.
3. Enable LSASS PPL by running enable-lsass-ppl.reg.
4. Install the vulnerable driver.

```
sc.exe create dbutil_2_3 binPath= "c:\dbutil_2_3.sys" type= kernel start= auto
sc.exe start dbutil_2_3
```

5. Reboot your virtual machine.
   #protip: create a snapshot you can revert to.
6. Find the driver device name using WinObj (sysinternals).
7. Compile exercise1.c and use it to open a handle to the driver.

DEBUGGING

Debugging the kernel using WinDBG

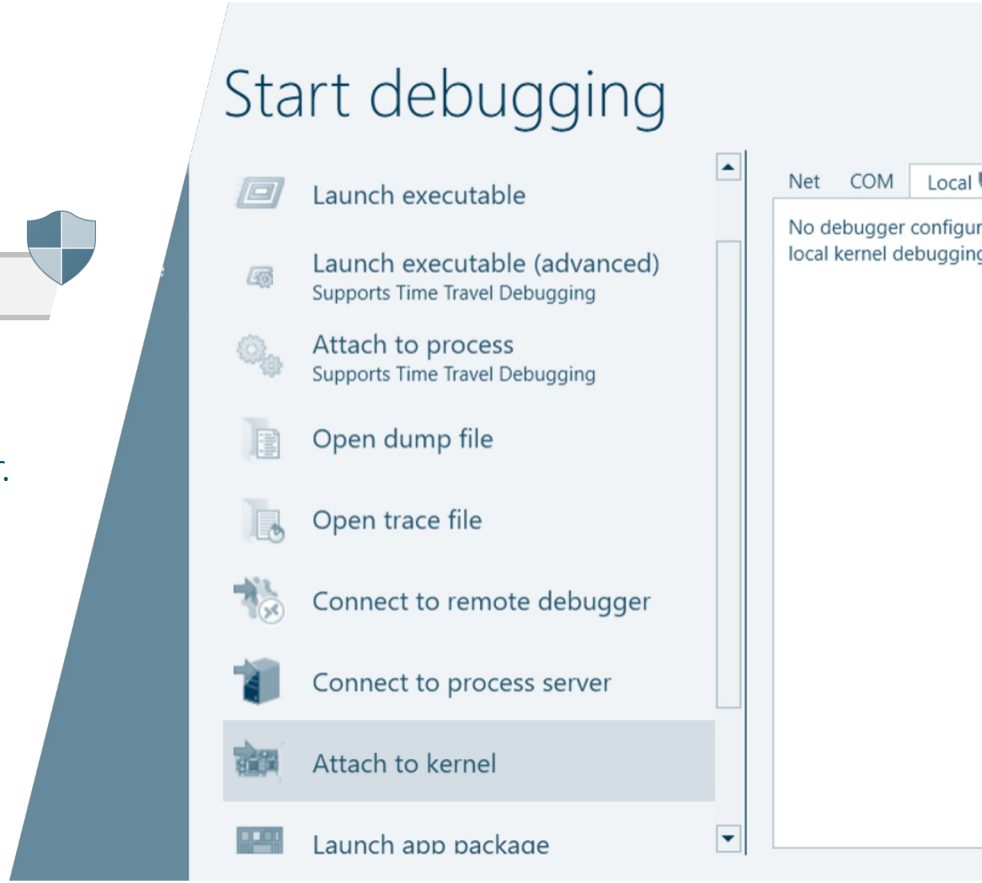
1. Enable debugging mode.

```
bcdedit.exe –debug on
```

2. Reboot your virtual machine.

   #protip: create a snapshot you can revert to.

3. Start WinDBG (sysinternals) as administrator.



DEBUGGING

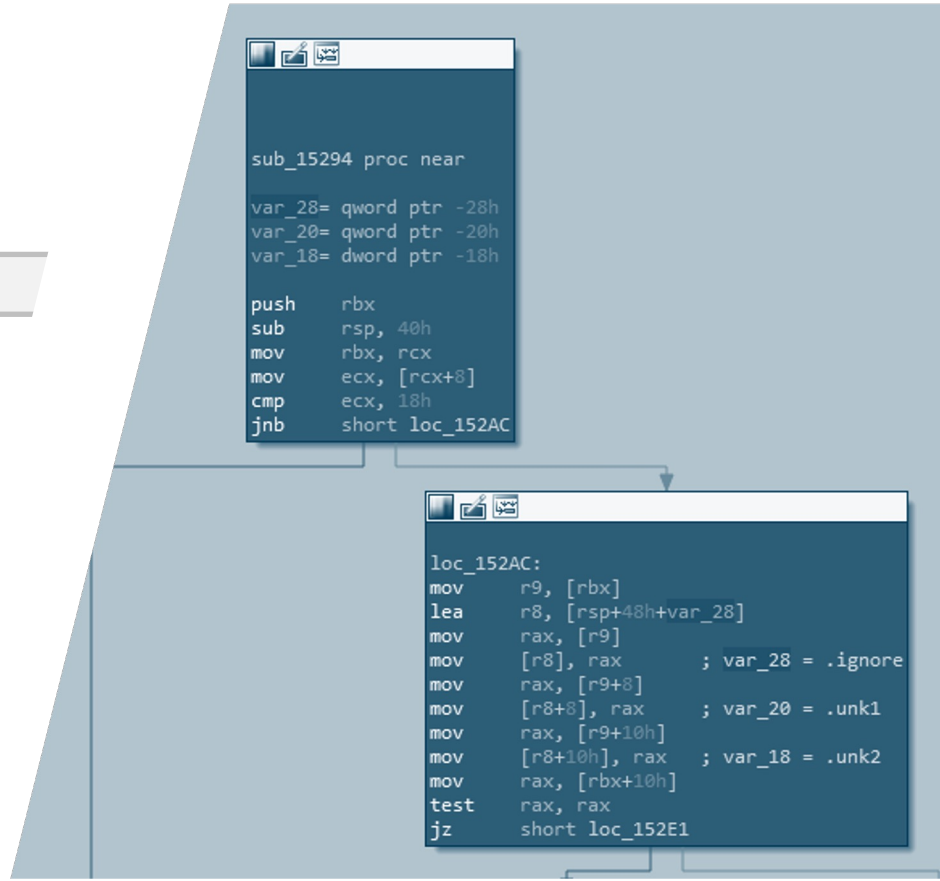
Calling convention

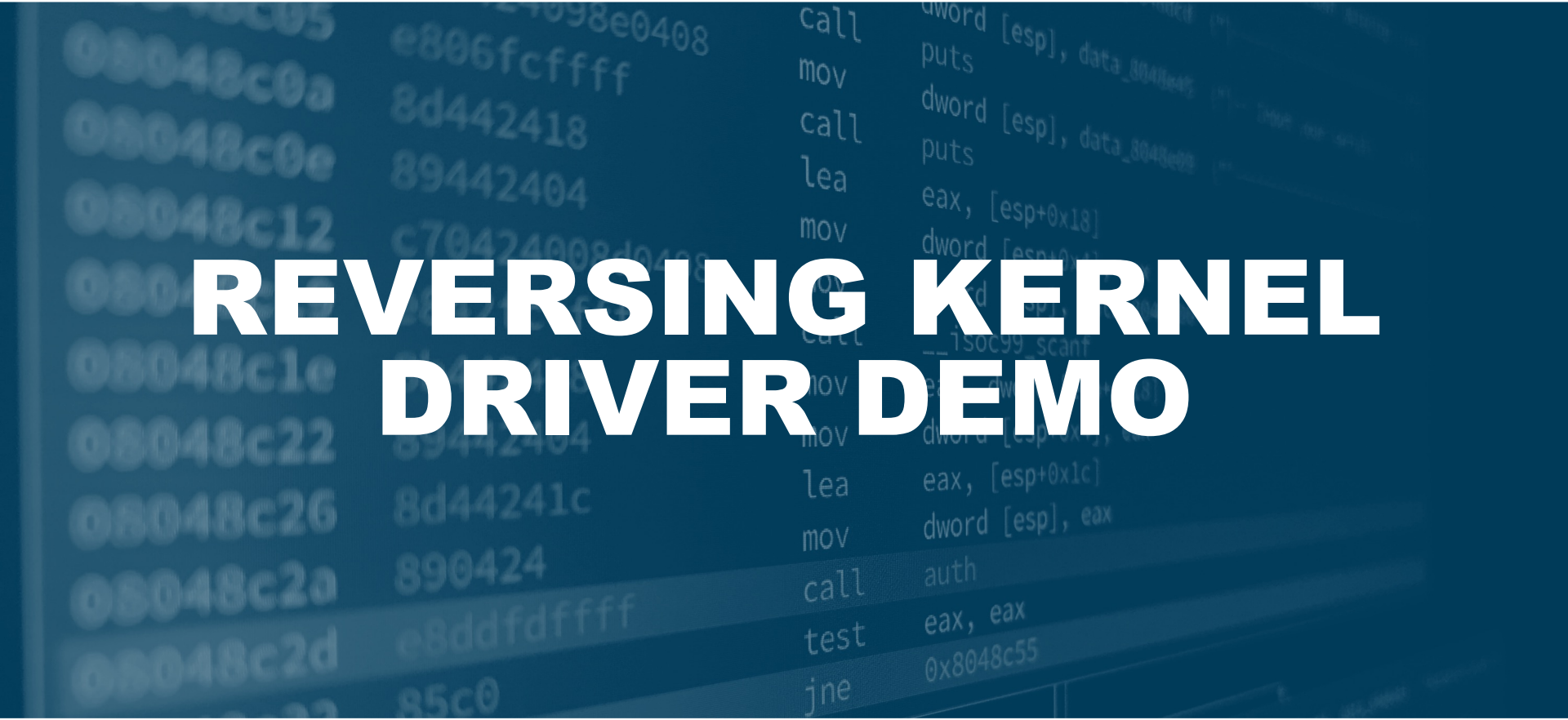
1. Suppose we perform a memmove.

```
memmove(void* dst, void* src, size_t len);
```

2. Then:

```
rcx = <dst>
rdx = <src>
r8 = <length>
call memmove
```

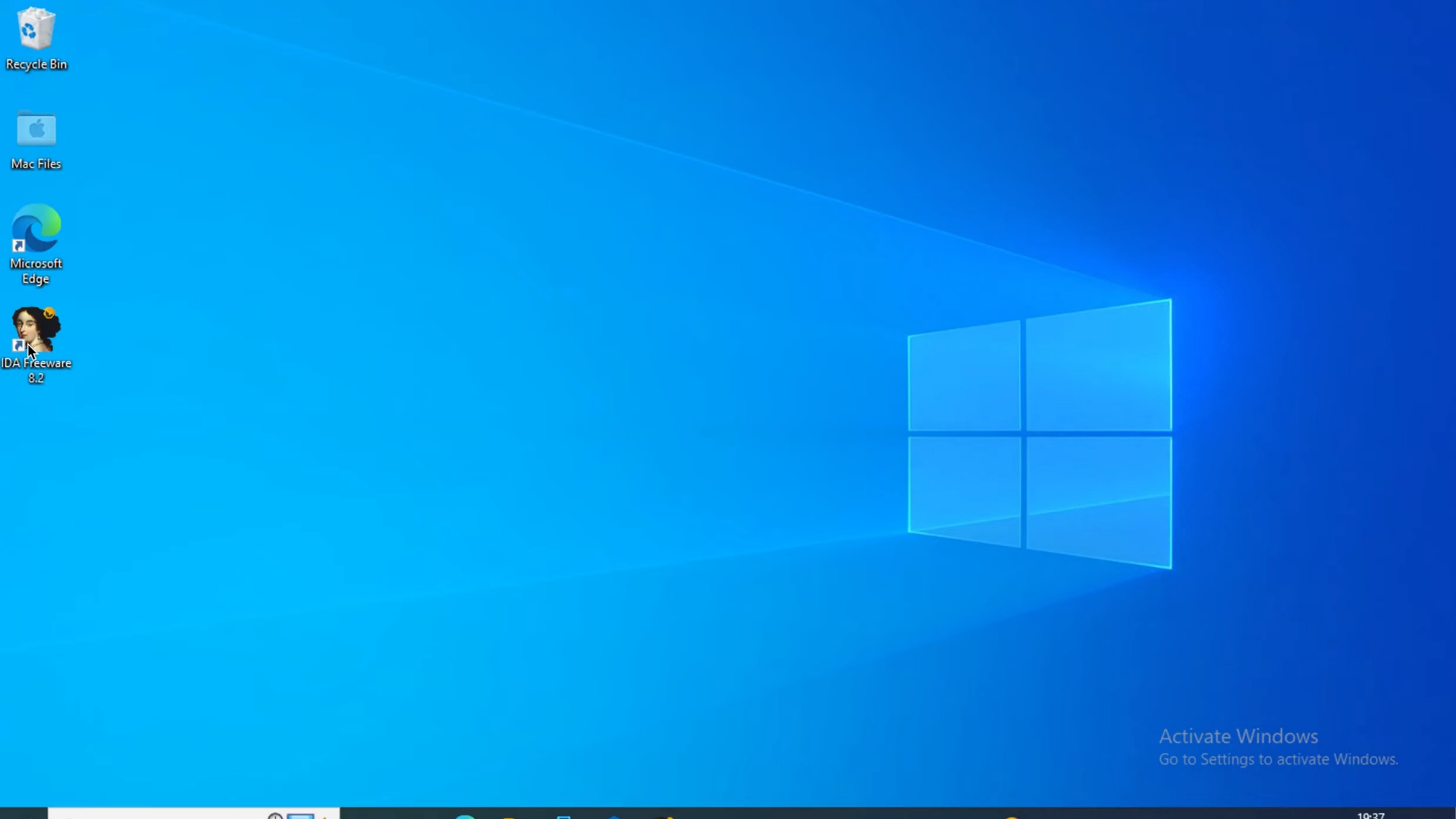




REVERSING KERNEL DRIVER DEMO

Icon(s) from Icons8

Download the exercise files at **https://tij.me/exercise1-good-luck.zip**, **easy mode cheatsheet at https://tij.me/exercise-cheatsheet.pdf**


Recycle Bin
Mac Files
Microsoft Edge
IDA Freeware 8.2
Activate Windows
Go to Settings to activate Windows.

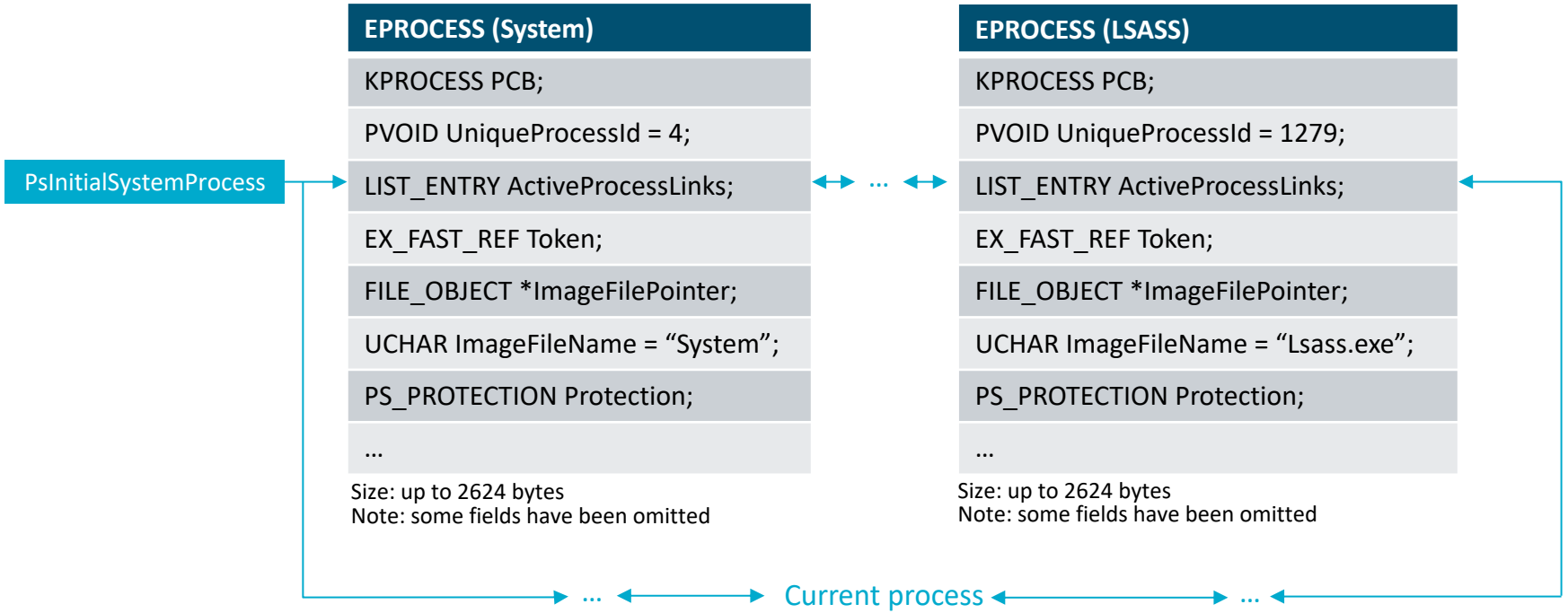
BECOMING THE APT

Exercise 2 45 min

1. Download the exercise file at tij.me/exercise2-you-can-do-it.c.
2. Use IDA Free to reverse the vulnerable driver.
   2.1. Find the I/O control code (IOCTL) callback function.
   2.2. Find the given vulnerable IOCTL numbers.
3. Adjust exercise2.c to interact with the IOCTL (legitimately).

WINDOWS KERNEL 101

You can find most structs on vergiliusproject.com



Icon(s) from Icons8

Download the exercise files at **https://tij.me/exercise2-you-can-do-it.c**, easy mode cheatsheet at **https://tij.me/exercise-cheatsheet.pdf**

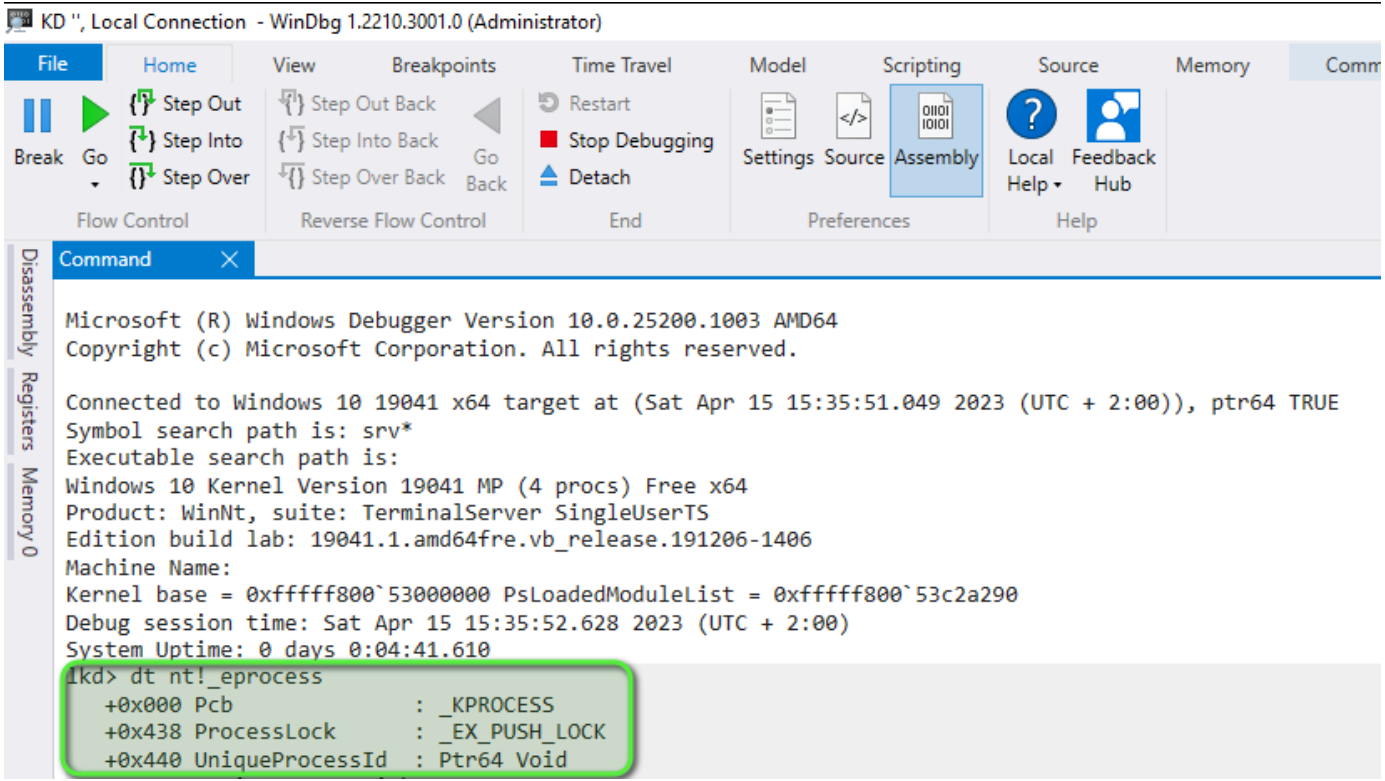
WINDOWS KERNEL 101

You can find most structs on vergiliusproject.com

```
typedef struct _LIST_ENTRY {
    struct _LIST_ENTRY *Flink;
    struct _LIST_ENTRY *Blink;
} LIST_ENTRY, *PLIST_ENTRY, PRLIST_ENTRY;
```


Download the exercise files at **https://tij.me/exercise2-you-can-do-it.c**, easy mode cheatsheet at **https://tij.me/exercise-cheatsheet.pdf**

WINDBG 101


KD '', Local Connection - WinDbg 1.2210.3001.0 (Administrator)
File
Home
View
Breakpoints
Time Travel
Model
Scripting
Source
Memory
Break
Go
Step Out
Step Into
Step Over
Step Out Back
Step Into Back
Step Over Back
Go Back
Restart
Stop Debugging
Detach
Settings
Source
Assembly
Local Help
Feedback Hub
Flow Control
Reverse Flow Control
End
Preferences
Help
Disassembly
Registers
Memory 0
Command
Microsoft (R) Windows Debugger Version 10.0.25200.1003 AMD64
Copyright (c) Microsoft Corporation. All rights reserved.
Connected to Windows 10 19041 x64 target at (Sat Apr 15 15:35:51.049 2023 (UTC + 2:00)), ptr64 TRUE
Symbol search path is: srv*
Executable search path is:
Windows 10 Kernel Version 19041 MP (4 procs) Free x64
Product: WinNt, suite: TerminalServer SingleUserTS
Edition build lab: 19041.1.amd64fre.vb_release.191206-1406
Machine Name:
Kernel base = 0xfffff800`53000000 PsLoadedModuleList = 0xfffff800`53c2a290
Debug session time: Sat Apr 15 15:35:52.628 2023 (UTC + 2:00)
System Uptime: 0 days 0:04:41.610
lkd> dt nt!_eprocess
+0x000 Pcb : _KPROCESS
+0x438 ProcessLock : _EX_PUSH_LOCK
+0x440 UniqueProcessId : Ptr64 Void

BECOMING THE APT

Exercise 3 20 min + your own time

1. Download the exercise file at tij.me/exercise3-final-boss.c.
2. Understand the vulnerability.
3. Adjust exploit.c to exploit the vulnerability.
   - 2.1. Find PsInitialSystemProcess.
   - 2.2. Iterate over all other EPROCESS's.
   - 2.3. Identify which EPROCESS is LSASS.
   - 2.4. Disable Protected Process Light on LSASS.
4. Use ProcDump to dump LSASS!

```
procdump -ma lsass.exe lsass.dmp
```

RECOMMENDED LITERATURE

1. Low-Level Programming
   Igor Zhirkov
2. Windows Kernel Programming
   Pavel Yosifovich
3. Practical Reverse Engineering
   Bruce Dang
4. Windows Internals
   Pavel Yosifovich