MANDIANT®

Reconstructing the Scene of the Crime

METASPLOIT AUTOPSY

MANDIANT®

Who are they?

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- Security Consultant / Researcher at MANDIANT

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- Engineer / Researcher at MANDIANT

Agenda

- ½ Demo
  - Pop it like its *hotttt*
- Problem / Solution
- Process Acquisition
- Metasploit
- Meterpreter Communication
- Metasploit Forensic Framework (MSFF)
- ½ Demo
  - Reconstructing it like its *hotttt*

Demo Part 1

- Box Windows XP Fresh SP3

Same box that our slides are running from…

Oh noes!

- MS08-067 meterpreter bind tcp

Back to our regularly scheduled slides...

Problem

- Meterpreter
  - Traditional disk forensics is helpless
    - Attack vector may never touch disk
  - No way to determine what happened
- Goal
  - Reconstruct attacker’s Meterpreter sessions with as much reliability as possible

Solution

- Acquire exploited processes’ address space
- Parse out meterpreter protocol from acquired memory sections
  - Reconstruct meterpreter sessions

MANDIANT Memoryze

ENUMERATION

- All running processes
  - Handle table
  - Memory sections
  - Ports
  - Strings
- Drivers
  - Including layered ones
- Certain kernel hooks

ACQUISITION

- Physical memory image
- Running process’s memory space
  - Binary
  - Loaded DLL’s
  - Stacks
  - Heaps
  - Data sections
- Drivers

MANDIANT Memoryze

- Can analyze memory live, or from image
  - Live analysis can use paging file for a more complete picture of memory
- Supported platforms
  - 32-bit Windows 2000, XP, 2003 Server
  - Beta support for Vista
- Download at
  - http://www.mandiant.com/

Process Acquisition

Why Process Acquisition?

- Acquisition was originally used mostly for malware analysis
  - Acquire packed binaries running in memory
    - Usually utilized debuggers
    - Can defeat most packers
- Acquisition has other uses:
  - Acquire unknown binaries for Virustotal
  - Acquire memory to look for protocol strings
    - Encrypted strings are unecrypted in memory

Classic Process Acquisition

- Current Methodology
  - Open handle to process, OR
  - Attach to process
    - `ReadProcessMemory(hProc, ImageBase, buffer, ImageSize, BytesRead)`
- Current drawbacks
  - Requires “touching” a process
  - Detecting debuggers is trivial
  - Gives an incomplete picture of memory

Process Acquisition: Memoryze

RELIES ON

- Physical memory access
- Virtual to physical address translation

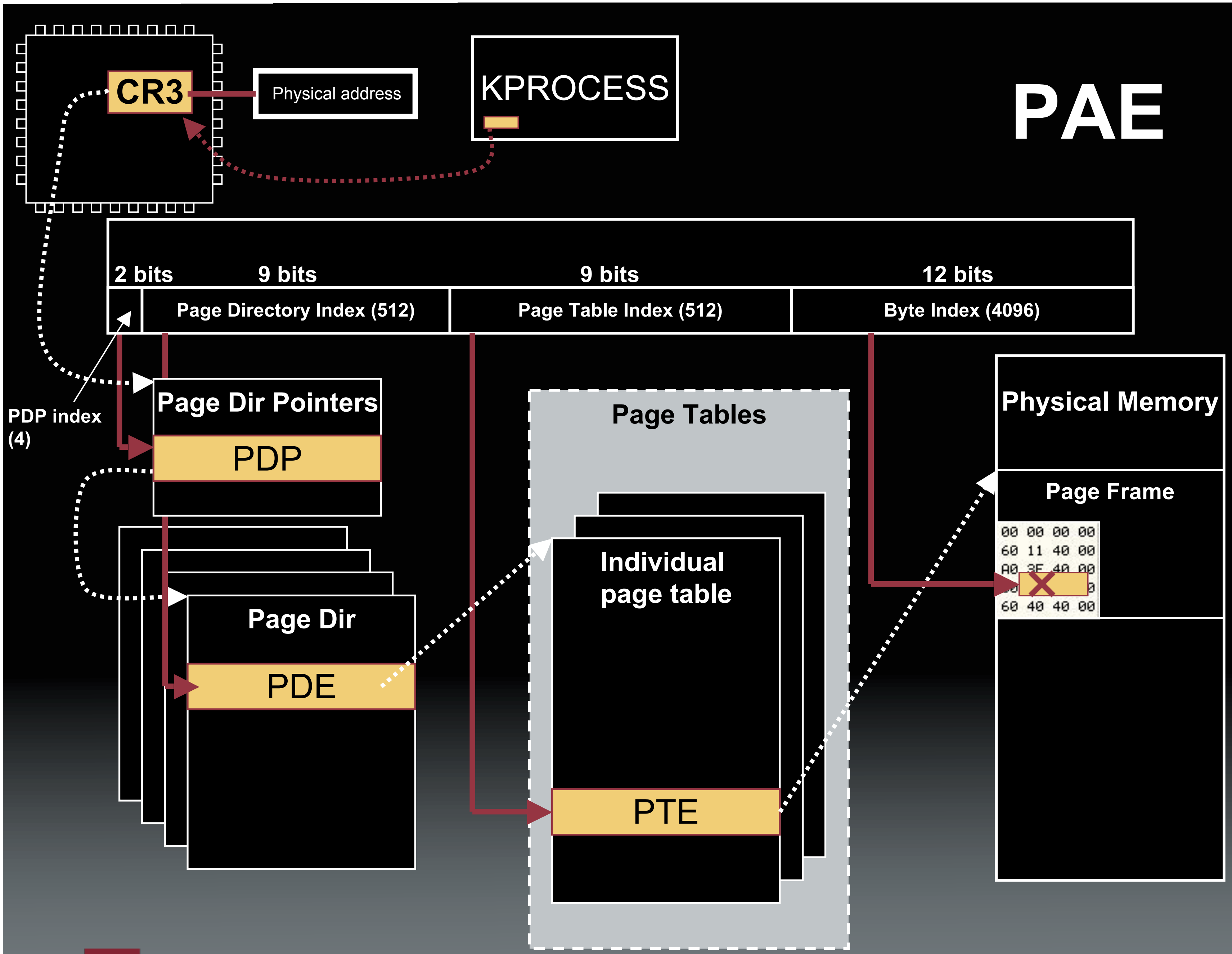
DOES NOT RELY ON

- Attaching to a process with a debugger
- Opening handles to processes or threads
- API calls
- The OS's Virtual Memory Manager

Memoryze: Process Acquisition

- Accessing Physical Memory
  - Live analysis
  - Acquisition
- `\Device\PhysicalMemory`
  - Section object exposed by Windows
  - Reading from handle allows application to read physical memory
  - Every virtual address must be translated to a physical offset within the section object

PAE



CR3

Physical address

KPROCESS

2 bits | 9 bits | 9 bits | 12 bits

Page Directory Index (512)

Page Table Index (512)

Byte Index (4096)

PDP index (4)

Page Dir Pointers

PDP

Page Dir

PDE

Page Tables

Individual page table

PTE

Physical Memory

Page Frame

```
00 00 00 00
60 11 40 00
A0 3F 40 00
60 40 40 00
```

Memoryze: Process Acquisition

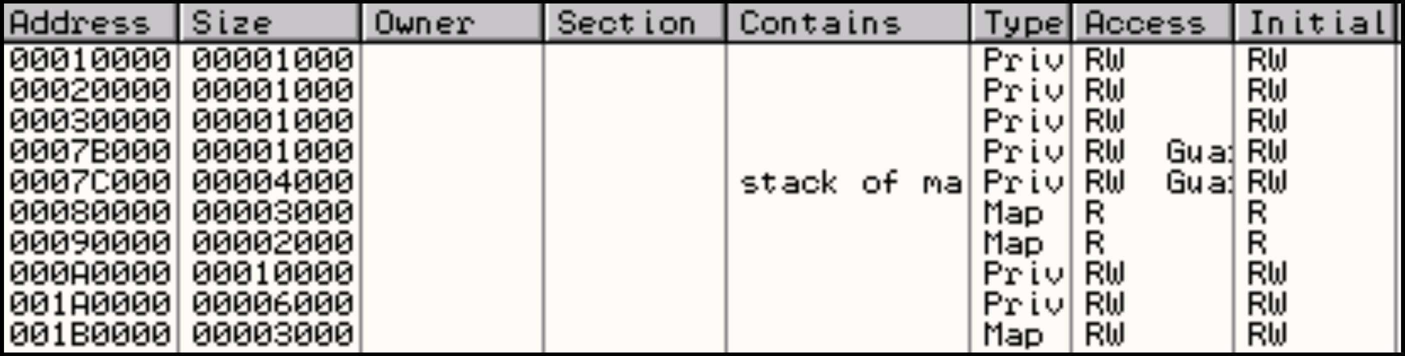
- Map physical memory into buffer
- Acquisition:
  - Write buffer to disk (`dd`)
- Analysis:
  - Scan buffer for known signatures of kernel structures, e.g. `EPROCESS`

New Process Acquisition

- Find all processes (EPROCESS) in physical memory
  - VadRoot within the EPROCESS structure
  - The VadRoot is the top node of a tree of Memory Manager Virtual Address Descriptor (MMVAD) entries
  - MMVAD entries contain the virtual start address and size of each memory section within a process
  - MMVAD entries containing mapped DLL’s or EXE’s will have a pointer to the path of the binary
    - Helps manage process’ virtual address space

Memoryze: Process Acquisition

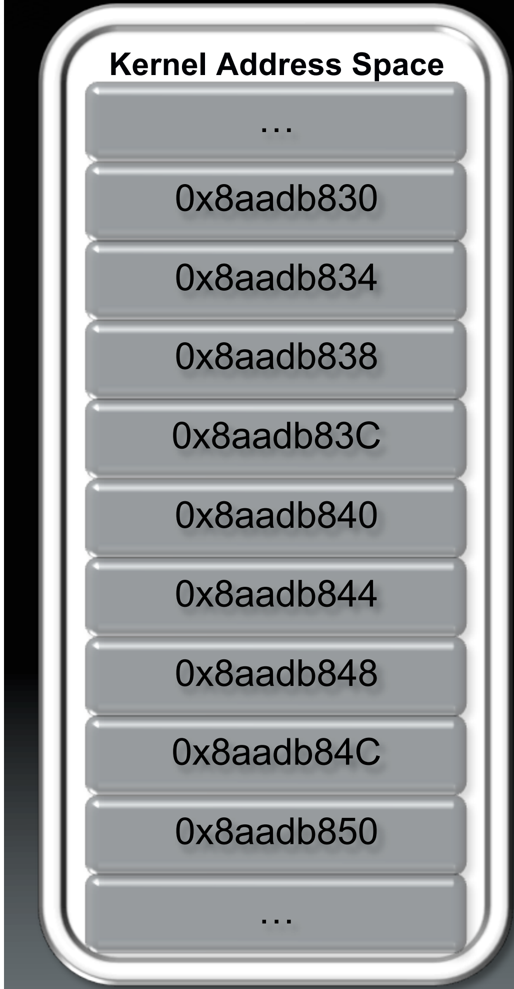
- OllyDbg’s memory map view shows the different sections



Address	Size	Owner	Section	Contains	Type	Access	Initial
00010000	00001000				Priv	RW	RW
00020000	00001000				Priv	RW	RW
00030000	00001000				Priv	RW	RW
0007B000	00001000				Priv	RW Gua:	RW
0007C000	00004000			stack of ma	Priv	RW Gua:	RW
00080000	00003000				Map	R	R
00090000	00002000				Map	R	R
000A0000	00010000				Priv	RW	RW
001A0000	00006000				Priv	RW	RW
001B0000	00003000				Map	RW	RW

- Each address range is an entry in `VadRoot`, represented by a MMVAD structure
- Enumeration of `VadRoot` allows access to heaps, stacks, and binary images

Finding Processes



Kernel Address Space

...

0x8aadb830

0x8aadb834

0x8aadb838

0x8aadb83C

0x8aadb840

0x8aadb844

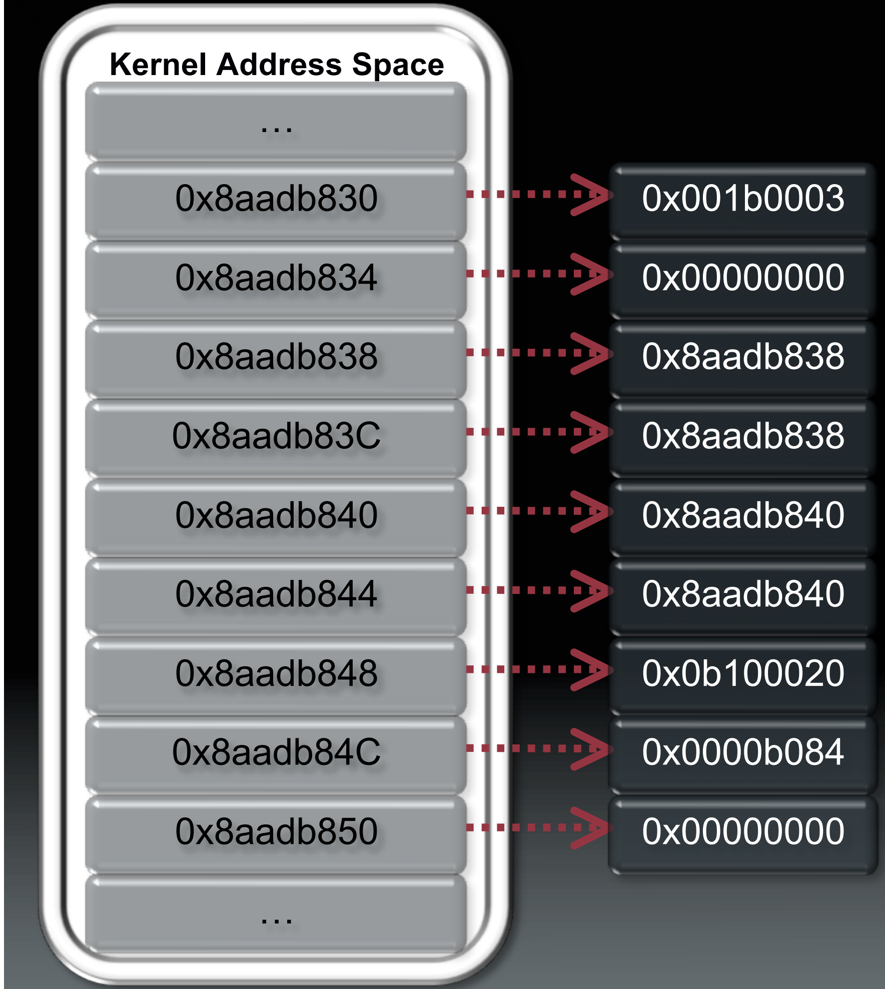
0x8aadb848

0x8aadb84C

0x8aadb850

...

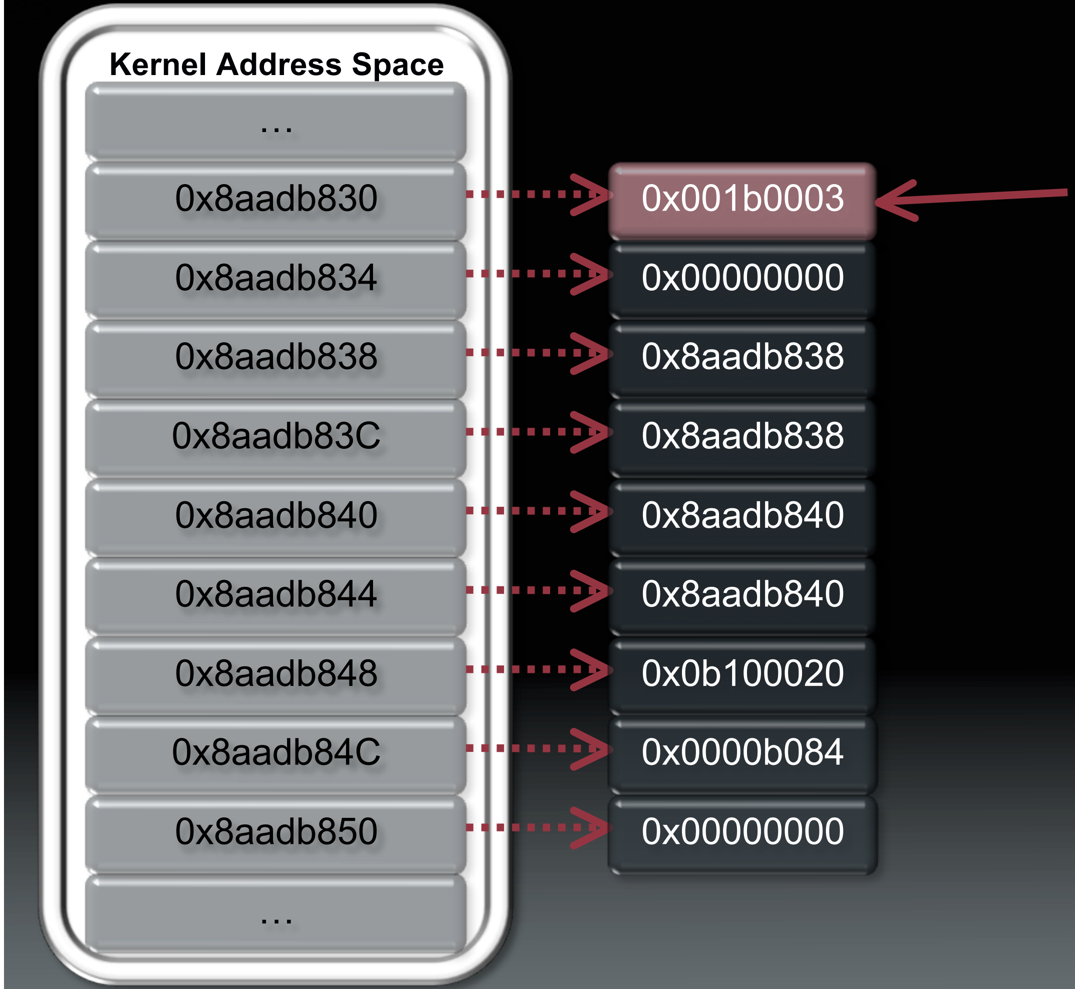
Finding Processes



Kernel Address Space

...	
0x8aadb830	0x001b0003
0x8aadb834	0x00000000
0x8aadb838	0x8aadb838
0x8aadb83C	0x8aadb838
0x8aadb840	0x8aadb840
0x8aadb844	0x8aadb840
0x8aadb848	0x0b100020
0x8aadb84C	0x0000b084
0x8aadb850	0x00000000
...	

Finding Processes

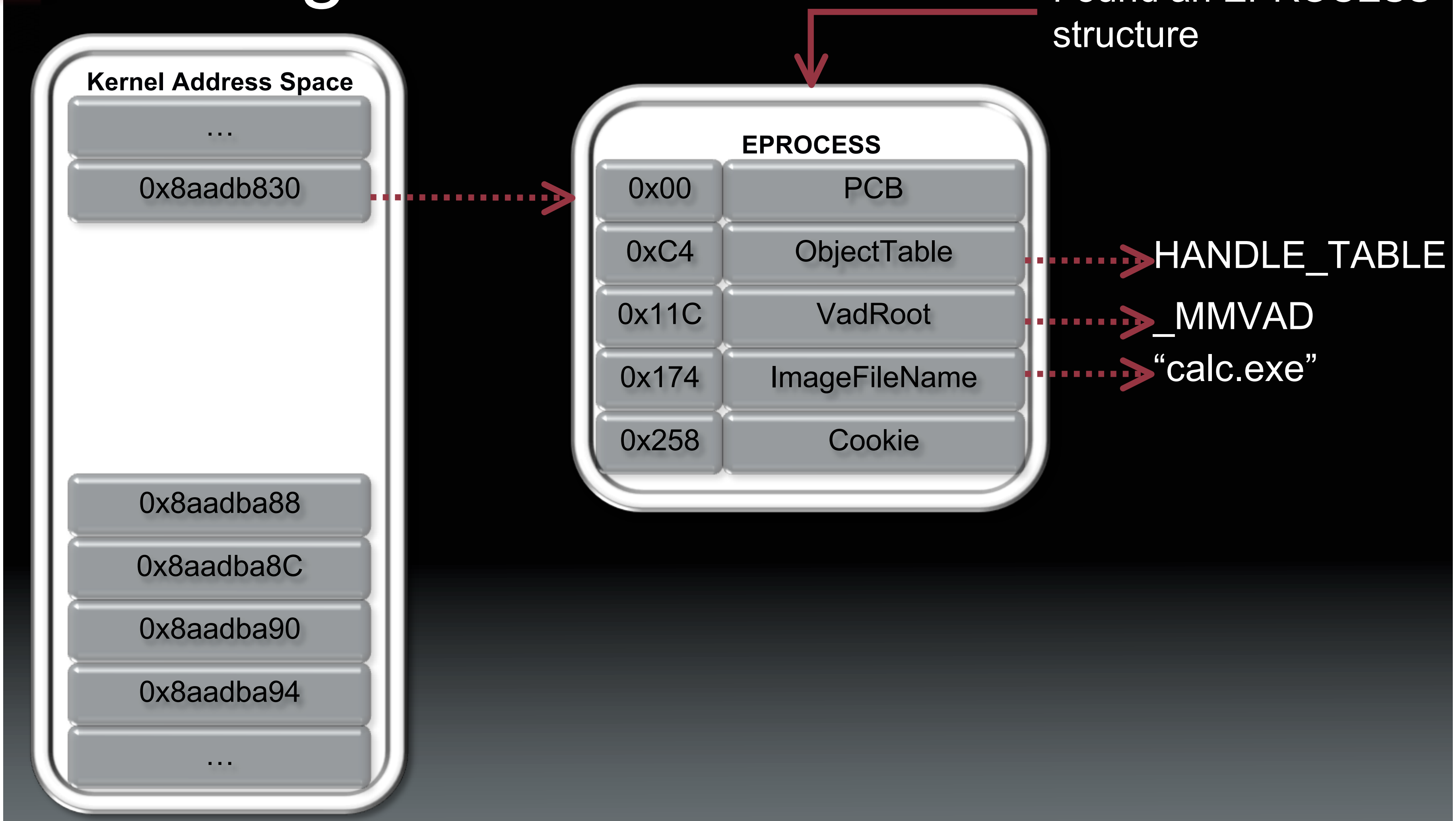


Kernel Address Space

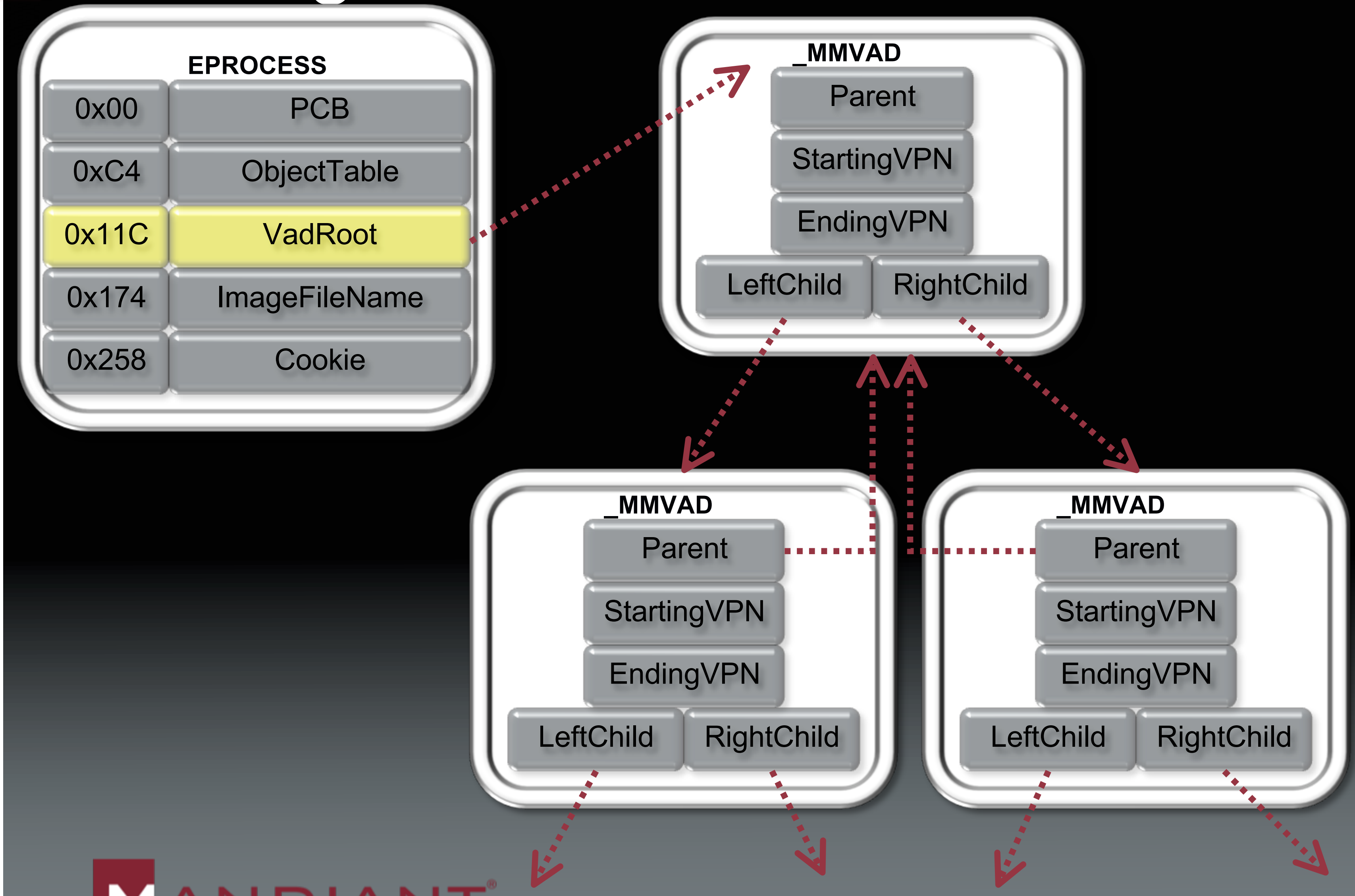
…	
0x8aadb830	0x001b0003
0x8aadb834	0x00000000
0x8aadb838	0x8aadb838
0x8aadb83C	0x8aadb838
0x8aadb840	0x8aadb840
0x8aadb844	0x8aadb840
0x8aadb848	0x0b100020
0x8aadb84C	0x0000b084
0x8aadb850	0x00000000
…	

Indicates EPROCESS, DISPATCH_HEADER, further checks are needed

Finding Processes



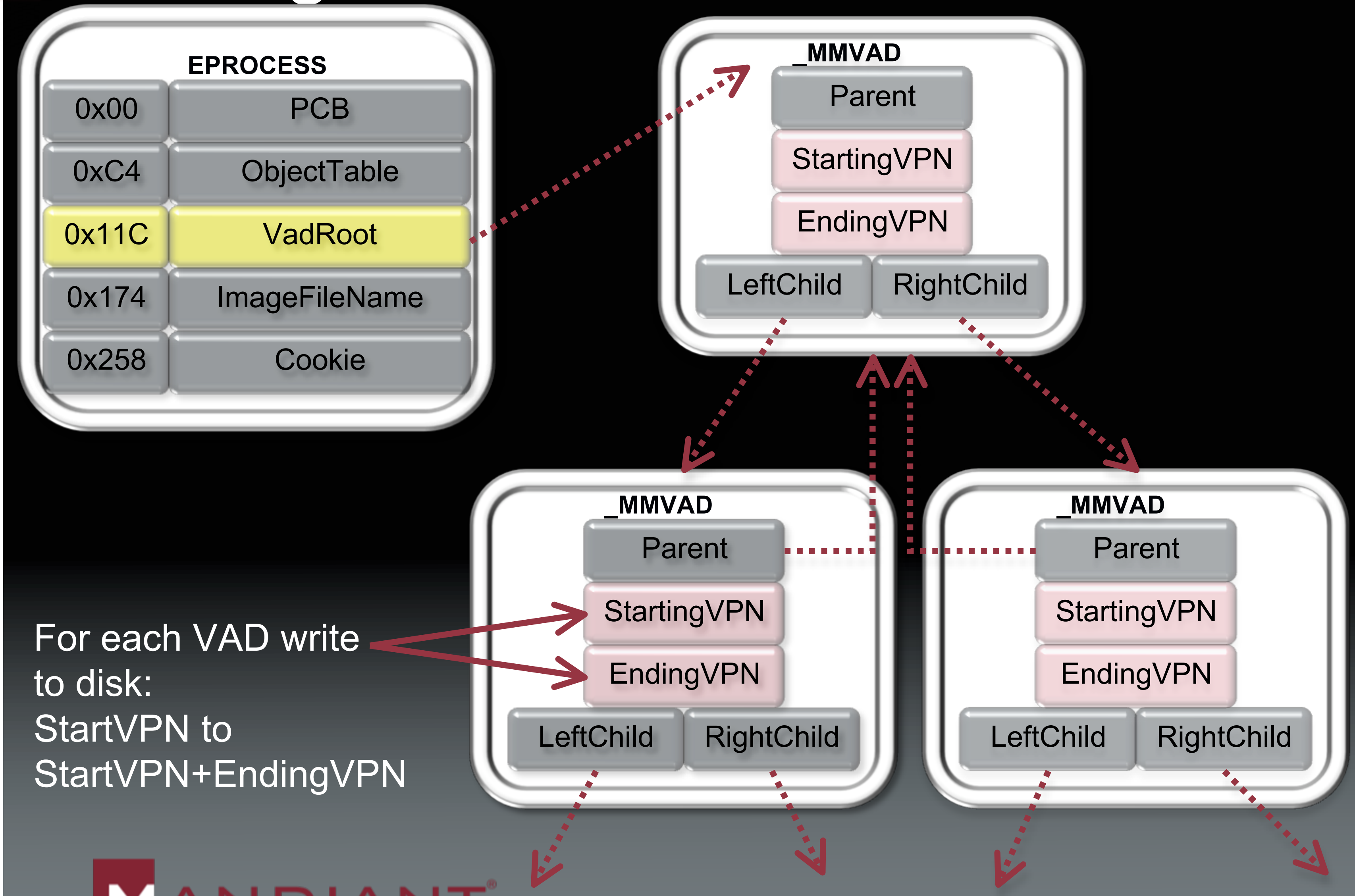
Parsing MMVAD



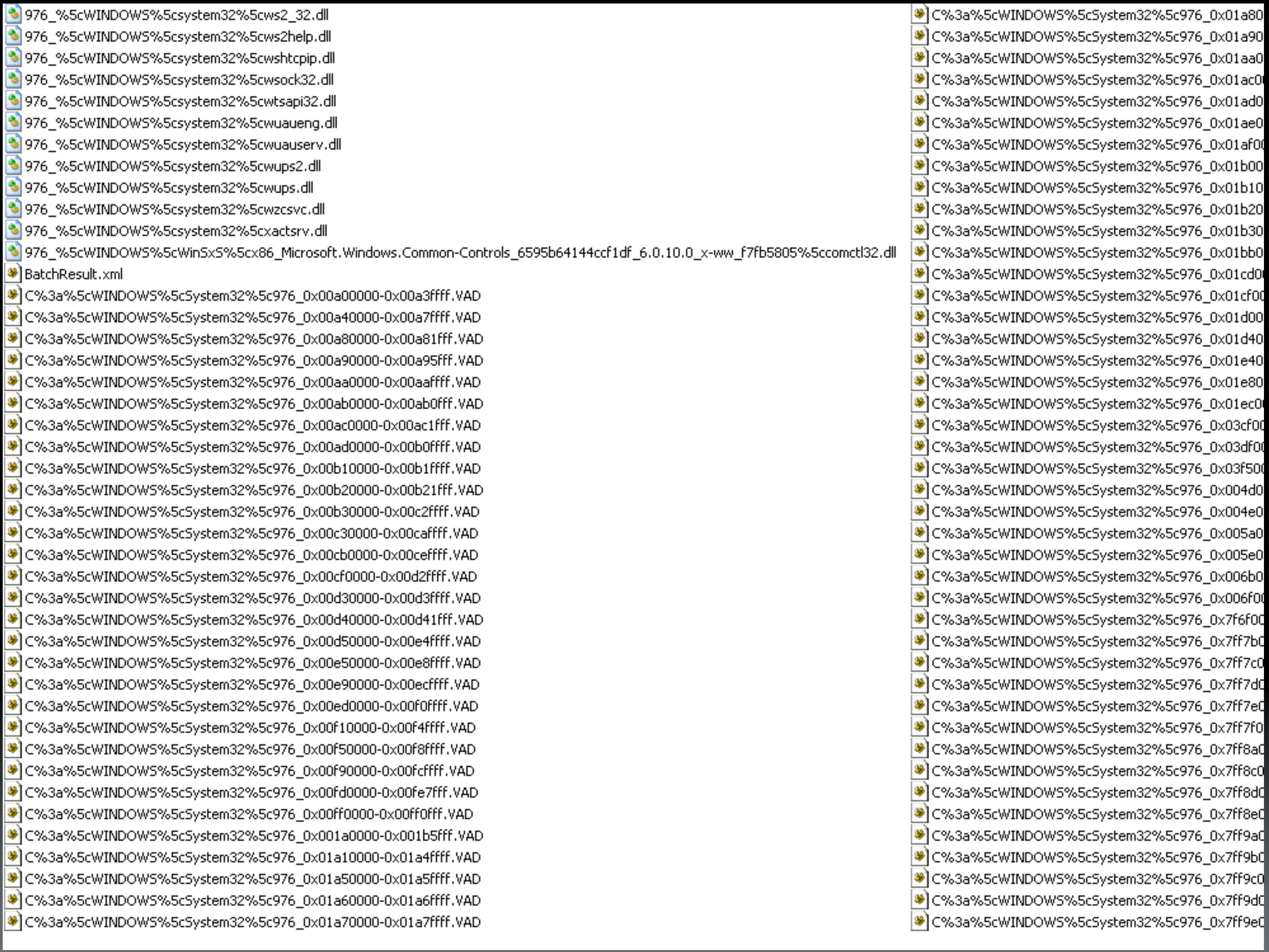
EPROCESS

0x00	PCB
0xC4	ObjectTable
0x11C	VadRoot
0x174	ImageFileName
0x258	Cookie

Writing VADs to disk



For each VAD write to disk:
StartVPN to StartVPN+EndingVPN



```
976_%5cWINDOWS%5csystem32%5cws2_32.dll
976_%5cWINDOWS%5csystem32%5cws2help.dll
976_%5cWINDOWS%5csystem32%5cwshtcpip.dll
976_%5cWINDOWS%5csystem32%5cwsock32.dll
976_%5cWINDOWS%5csystem32%5cwtsapi32.dll
976_%5cWINDOWS%5csystem32%5cwuaueng.dll
976_%5cWINDOWS%5csystem32%5cwuauserv.dll
976_%5cWINDOWS%5csystem32%5cwups2.dll
976_%5cWINDOWS%5csystem32%5cwups.dll
976_%5cWINDOWS%5csystem32%5cwzcsvc.dll
976_%5cWINDOWS%5csystem32%5cxactsrv.dll
976_%5cWINDOWS%5cWinSxS%5cx86_Microsoft.Windows.Common-Controls_6595b64144ccf1df_6.0.10.0_x-ww_f7fb5805%5ccomctl32.dll
BatchResult.xml
C%3a%5cWINDOWS%5cSystem32%5c976_0x00a00000-0x00a3ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00a40000-0x00a7ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00a80000-0x00a81fff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00a90000-0x00a95fff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00aa0000-0x00aaffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00ab0000-0x00ab0fff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00ac0000-0x00ac1fff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00ad0000-0x00b0ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00b10000-0x00b1ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00b20000-0x00b21fff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00b30000-0x00c2ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00c30000-0x00caffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00cb0000-0x00ceffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00cf0000-0x00d2ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00d30000-0x00d3ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00d40000-0x00d41fff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00d50000-0x00e4ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00e50000-0x00e8ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00e90000-0x00ecffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00ed0000-0x00f0ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00f10000-0x00f4ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00f50000-0x00f8ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00f90000-0x00fcffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00fd0000-0x00fe7fff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x00ff0000-0x00ff0fff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x001a0000-0x001b5fff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x01a10000-0x01a4ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x01a50000-0x01a5ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x01a60000-0x01a6ffff.VAD
C%3a%5cWINDOWS%5cSystem32%5c976_0x01a70000-0x01a7ffff.VAD
```

```
C%3a%5cWINDOWS%5cSystem32%5c976_0x01a80
C%3a%5cWINDOWS%5cSystem32%5c976_0x01a90
C%3a%5cWINDOWS%5cSystem32%5c976_0x01aa0
C%3a%5cWINDOWS%5cSystem32%5c976_0x01ac0
C%3a%5cWINDOWS%5cSystem32%5c976_0x01ad0
C%3a%5cWINDOWS%5cSystem32%5c976_0x01ae0
C%3a%5cWINDOWS%5cSystem32%5c976_0x01af0
C%3a%5cWINDOWS%5cSystem32%5c976_0x01b00
C%3a%5cWINDOWS%5cSystem32%5c976_0x01b10
C%3a%5cWINDOWS%5cSystem32%5c976_0x01b20
C%3a%5cWINDOWS%5cSystem32%5c976_0x01b30
C%3a%5cWINDOWS%5cSystem32%5c976_0x01bb0
C%3a%5cWINDOWS%5cSystem32%5c976_0x01cd0
C%3a%5cWINDOWS%5cSystem32%5c976_0x01cf0
C%3a%5cWINDOWS%5cSystem32%5c976_0x01d00
C%3a%5cWINDOWS%5cSystem32%5c976_0x01d40
C%3a%5cWINDOWS%5cSystem32%5c976_0x01e40
C%3a%5cWINDOWS%5cSystem32%5c976_0x01e80
C%3a%5cWINDOWS%5cSystem32%5c976_0x01ec0
C%3a%5cWINDOWS%5cSystem32%5c976_0x03cf0
C%3a%5cWINDOWS%5cSystem32%5c976_0x03df0
C%3a%5cWINDOWS%5cSystem32%5c976_0x03f50
C%3a%5cWINDOWS%5cSystem32%5c976_0x004d0
C%3a%5cWINDOWS%5cSystem32%5c976_0x004e0
C%3a%5cWINDOWS%5cSystem32%5c976_0x005a0
C%3a%5cWINDOWS%5cSystem32%5c976_0x005e0
C%3a%5cWINDOWS%5cSystem32%5c976_0x006b0
C%3a%5cWINDOWS%5cSystem32%5c976_0x006f0
C%3a%5cWINDOWS%5cSystem32%5c976_0x7f6f0
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff7b
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff7c
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff7d
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff7e
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff7f
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff8a
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff8c
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff8d
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff8e
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff9a
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff9b
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff9c
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff9d
C%3a%5cWINDOWS%5cSystem32%5c976_0x7ff9e
```

New Process Acquisition

- Allows dumping of full address space
- Overcomes most binary packing
- Captures communication protocol strings
- Bypasses any anti-debugging techniques
- Acquire(s):
  - DLL’s that are only in memory
  - Code corresponding to injected threads or shellcode

Metasploit

Have YOU read the developer docs?

Metasploit

- Open source exploit framework originally developed in Perl (1.x, 2.x) by HD Moore et al.
  - Currently Ruby (3.x)
- Platform independent
- Multiple payloads

Meterpreter

- The next generation of post-exploitation payloads
  - Forget `/bin/sh` and `cmd.exe`
    - Limited to `stdin,stderr,stdout`
    - Non-interactive
- Full functioning client → server interpreter
  - File upload / download
  - Key logging
  - Simple extension addition
- Can be completely memory resident

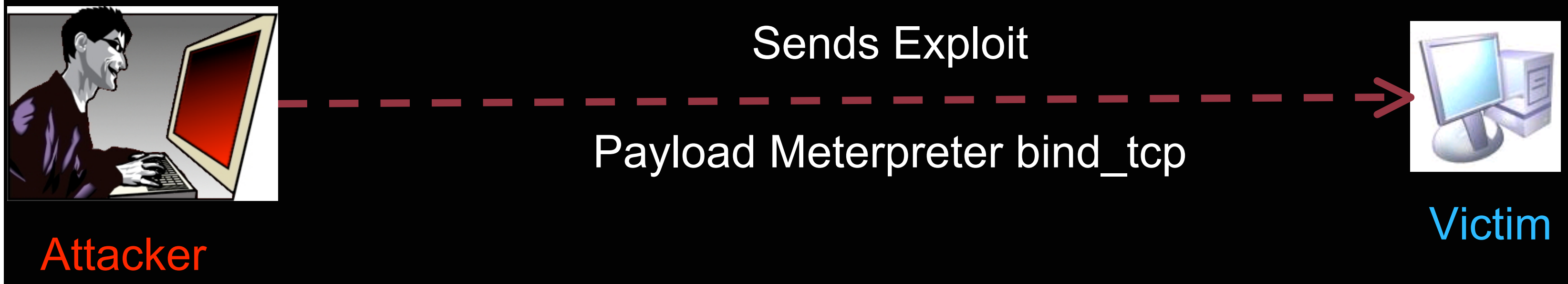
Under the Meterpreter Hood

- DLL gets injected into exploited process
- Hooks `LoadLibrary` (on Windows)
  - Applies hook to Win32 API `LoadLibrary`
  - Changes lower level API's behavior to allow `LoadLibrary` to load a DLL from memory
- Hooked API's to allow loading of `metsrv.dll` from memory
  - `NtOpenSection`, `NtCreateSection`
  - `NtQueryAttributesFile`
  - `NtOpenFile`, `NtMapViewOfSection`

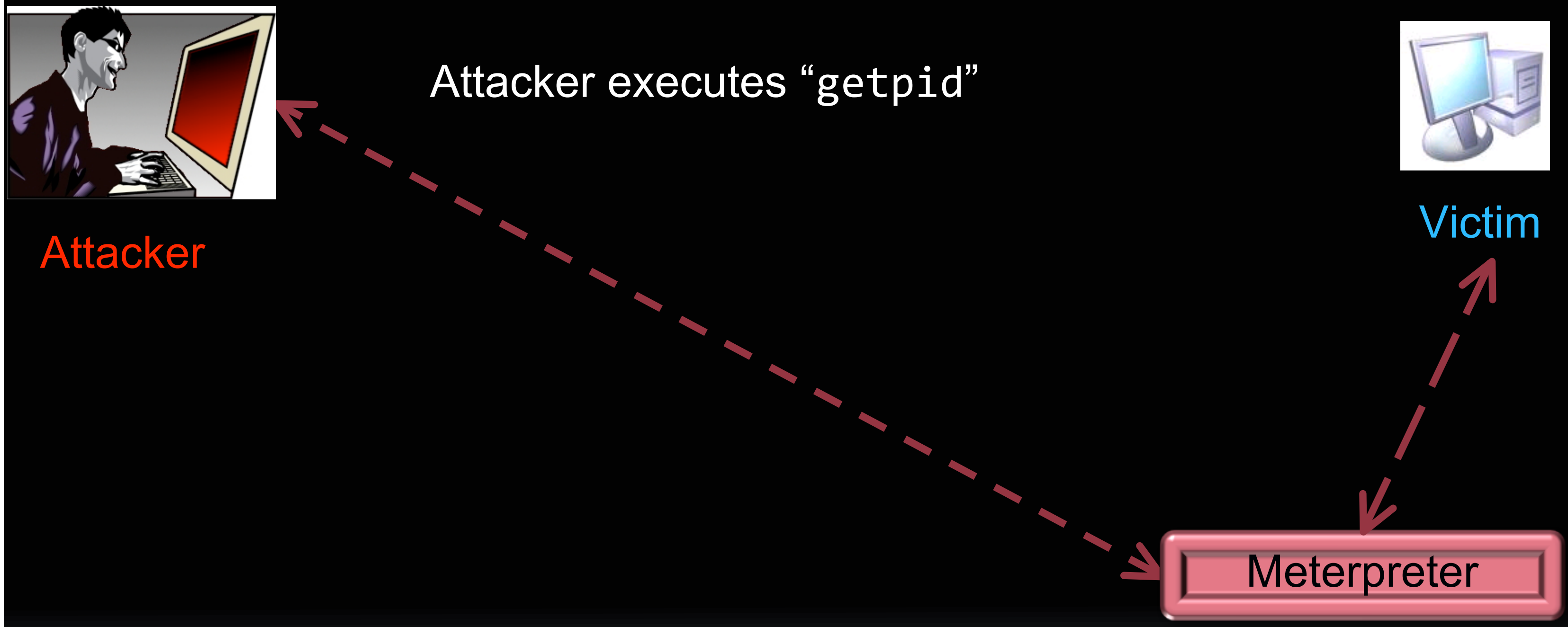
Meterpreter Communication

- TLV (really LTV) Structures
  - Provide communication protocol for meterpreter server and client
  - 32 bit Length and Type Fields
  - *n* bits Value Field

Meterpreter Communication

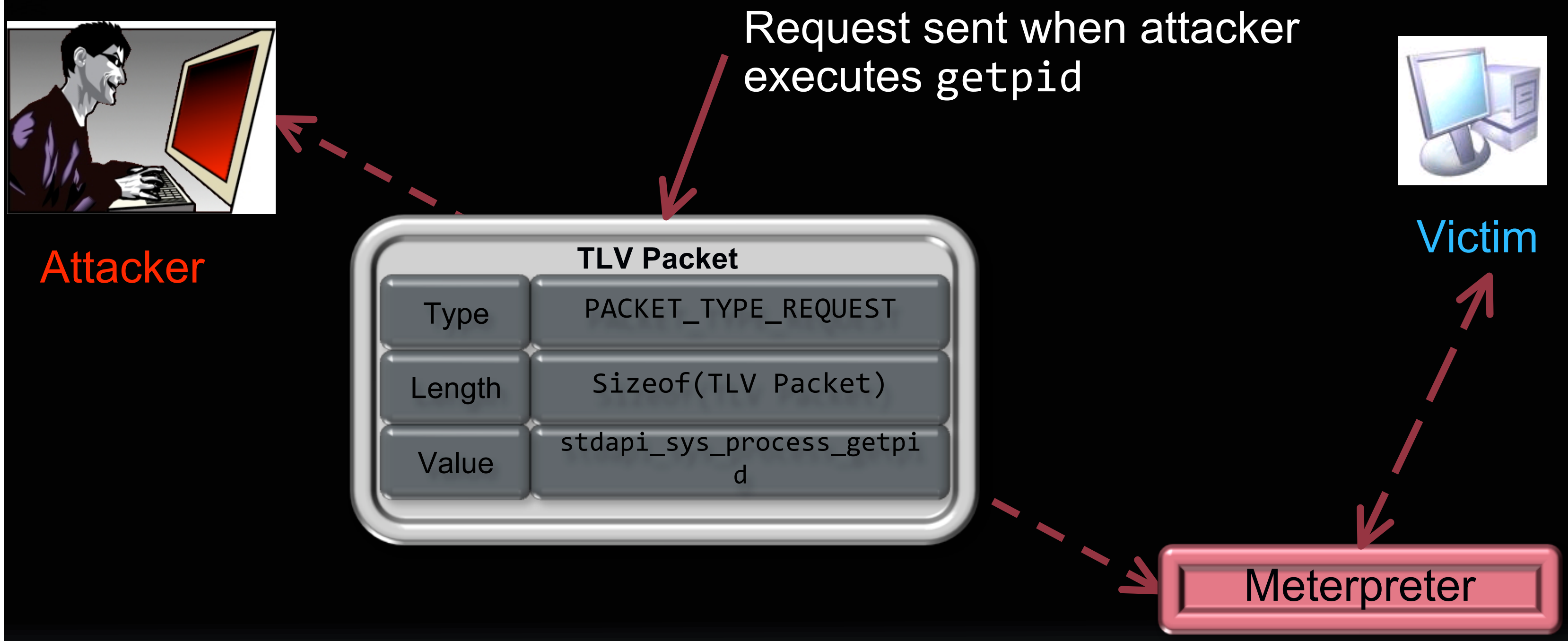


Meterpreter Communication



Attacker executes "`getpid`"

Meterpreter Communication

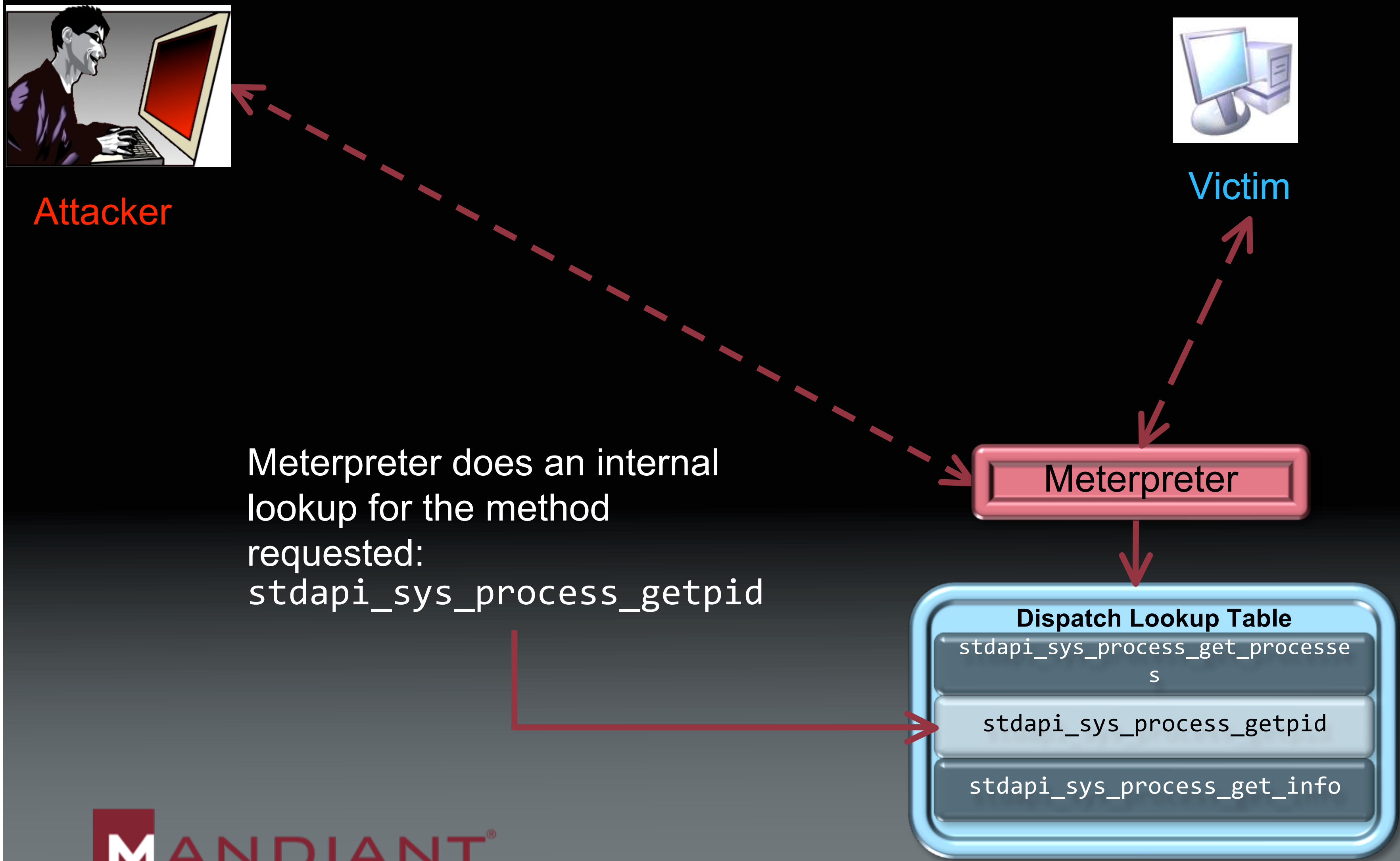


Request sent when attacker executes `getpid`

TLV Packet

Type	PACKET_TYPE_REQUEST
Length	Sizeof(TLV Packet)
Value	stdapi_sys_process_getpid

Meterpreter Communication



Attacker

Victim

Meterpreter

Meterpreter does an internal lookup for the method requested: `stdapi_sys_process_getpid`

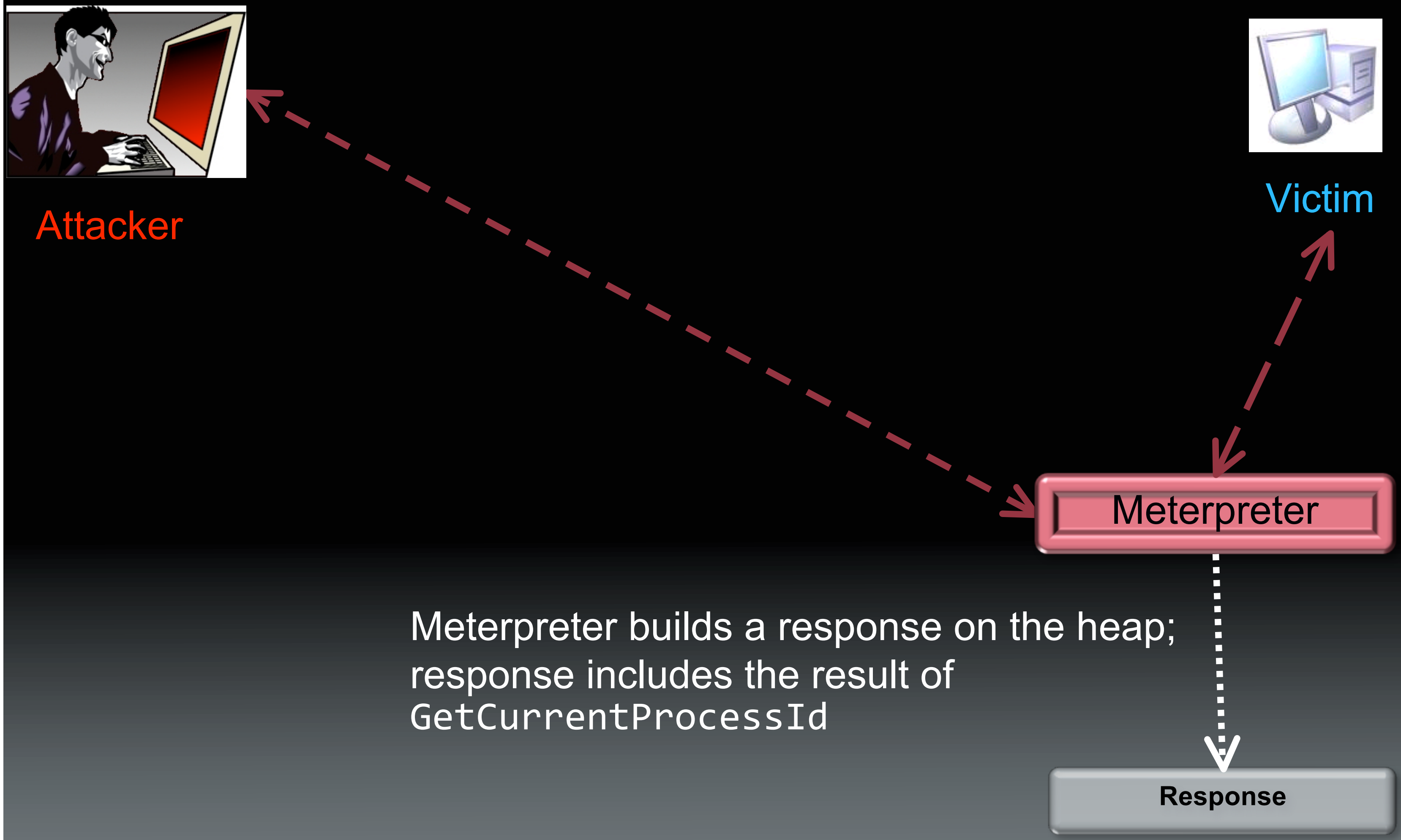
Dispatch Lookup Table

stdapi_sys_process_get_processe s

stdapi_sys_process_getpid

stdapi_sys_process_get_info

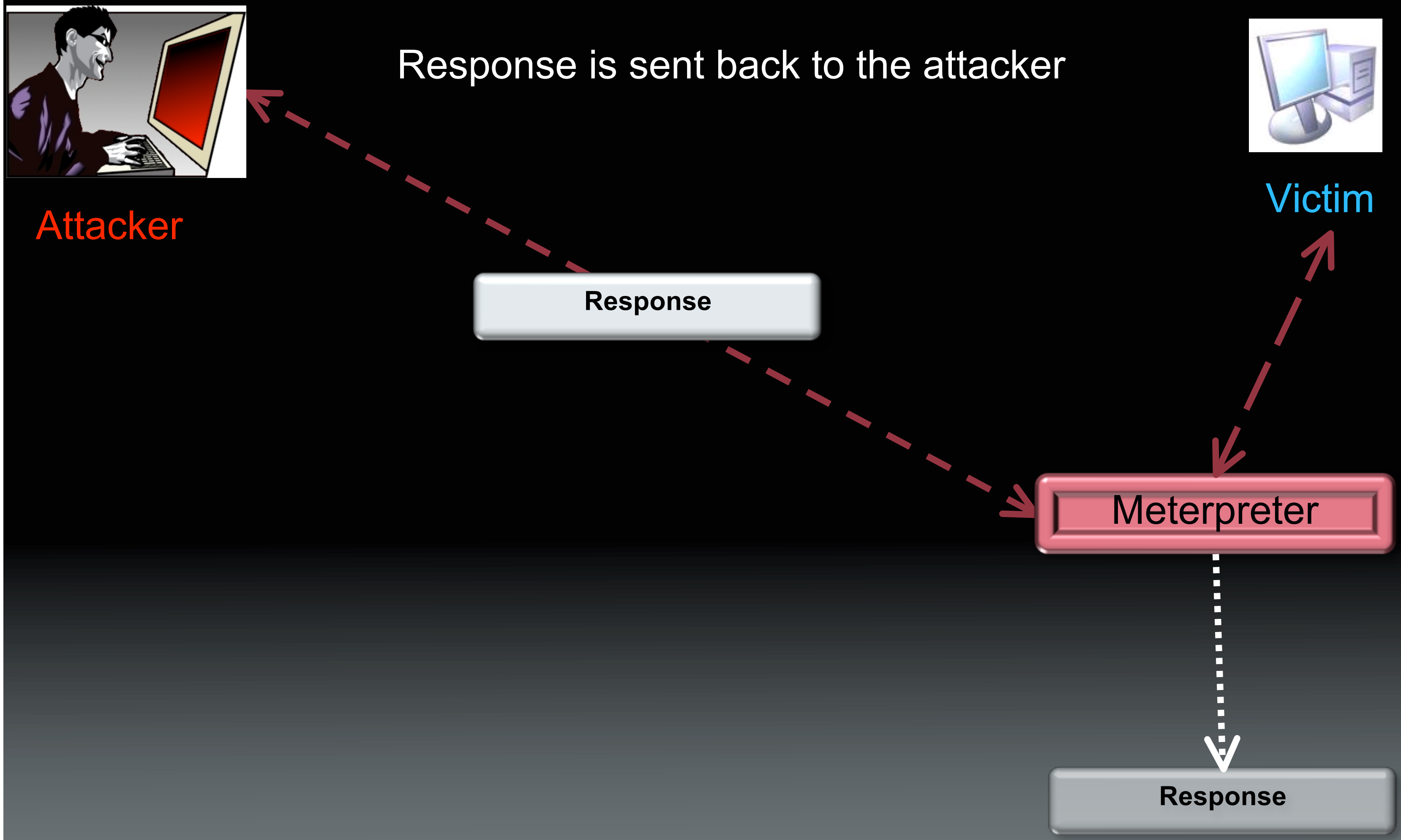
Meterpreter Communication



Meterpreter builds a response on the heap; response includes the result of `GetCurrentProcessId`

Meterpreter Communication

Response is sent back to the attacker



Attacker

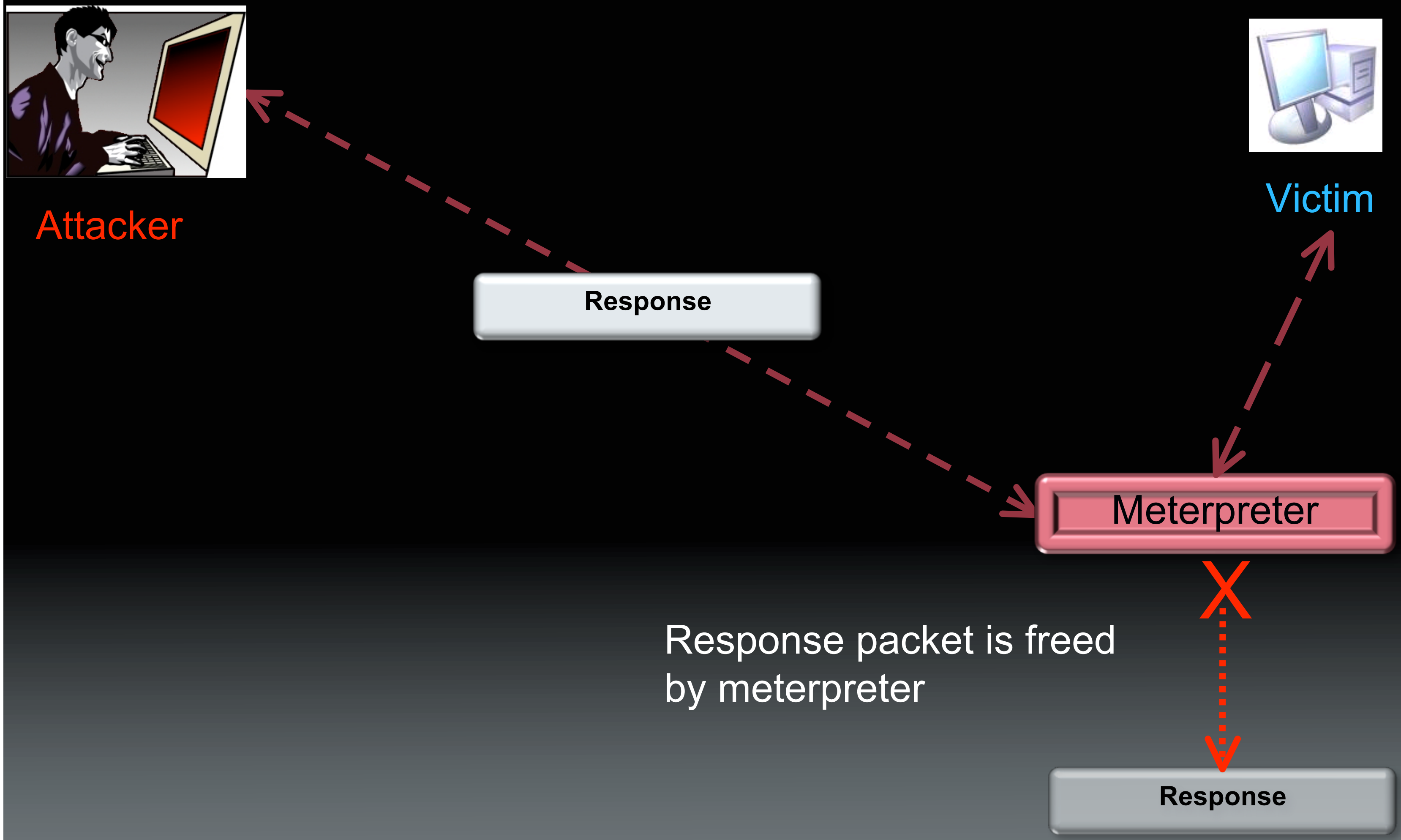
Victim

Response

Meterpreter

Response

Meterpreter Communication



Response packet is freed by meterpreter

Response Packet Structure (1 of 4)

<table>
<tr><th colspan="3">Response Packet</th></tr>
<tr><td>Length</td><td colspan="2"><code>sizeof(Response Packet)</code></td></tr>
<tr><td>Type</td><td colspan="2"><code>PACKET_TLV_TYPE_PLAIN_RESPONSE</code></td></tr>
<tr><td rowspan="3">Value</td><td>Length</td><td><code>sizeof(this tlv)</code></td></tr>
<tr><td>Type</td><td><code>TLV_TYPE_METHOD</code></td></tr>
<tr><td>Value</td><td><code>stdapi_sys_process_getpid</code></td></tr>
</table>

Response Packet Structure (2 of 4)

<table>
<tr><th colspan="2">Response Packet</th></tr>
<tr><td>Length</td><td><code>sizeof(Response Packet)</code></td></tr>
<tr><td>Type</td><td><code>PACKET_TLV_TYPE_PLAIN_RESPONSE</code></td></tr>
<tr><td>Value</td><td>
<table>
<tr><td>Length</td><td><code>sizeof(this tlv)</code></td></tr>
<tr><td>Type</td><td><code>TLV_TYPE_REQUEST_ID</code></td></tr>
<tr><td>Value</td><td><code>3164813846702899128916537536399</code></td></tr>
</table>
</td></tr>
</table>

Response Packet Structure (3 of 4)

<table>
<tr><th colspan="2">Response Packet</th></tr>
<tr><td>Length</td><td><code>sizeof(Response Packet)</code></td></tr>
<tr><td>Type</td><td><code>PACKET_TLV_TYPE_PLAIN_RESPONSE</code></td></tr>
<tr><td>Value</td><td>
<table>
<tr><td>Length</td><td><code>sizeof(this tlv)</code></td></tr>
<tr><td>Type</td><td><code>TLV_TYPE_PID</code></td></tr>
<tr><td>Value</td><td><code>0x000003EC</code></td></tr>
</table>
</td></tr>
</table>

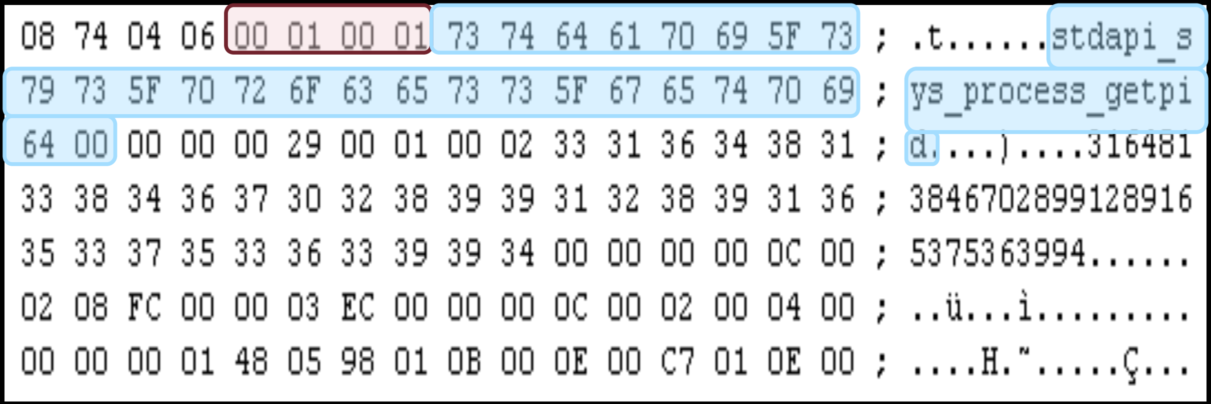
Response Packet Structure (4 of 4)

<table>
<tr><th colspan="2">Response Packet</th></tr>
<tr><td>Length</td><td>sizeof(Response Packet)</td></tr>
<tr><td>Type</td><td>PACKET_TLV_TYPE_PLAIN_RESPONSE</td></tr>
<tr><td>Value</td><td>
<table>
<tr><td>Length</td><td>sizeof(this tlv)</td></tr>
<tr><td>Type</td><td>TLV_TYPE_RESULT</td></tr>
<tr><td>Value</td><td>0x00000000</td></tr>
</table>
</td></tr>
</table>

Response Packet Structure

Response Packet		
Length	sizeof(Response Packet)	
Type	PACKET_TLV_TYPE_PLAIN_RESPONSE	
Value	Length	sizeof(this tlv)
	Type	TLV_TYPE_METHOD
	Value	stdapi_sys_process_getpid
	Length	sizeof(this tlv)
	Type	TLV_TYPE_REQUEST_ID
	Value	3164813846702899128916537536399
	Length	sizeof(this tlv)
	Type	TLV_TYPE_PID
	Value	0x000003EC
	Length	sizeof(this tlv)
	Type	TLV_TYPE_RESULT
	Value	0x00000000

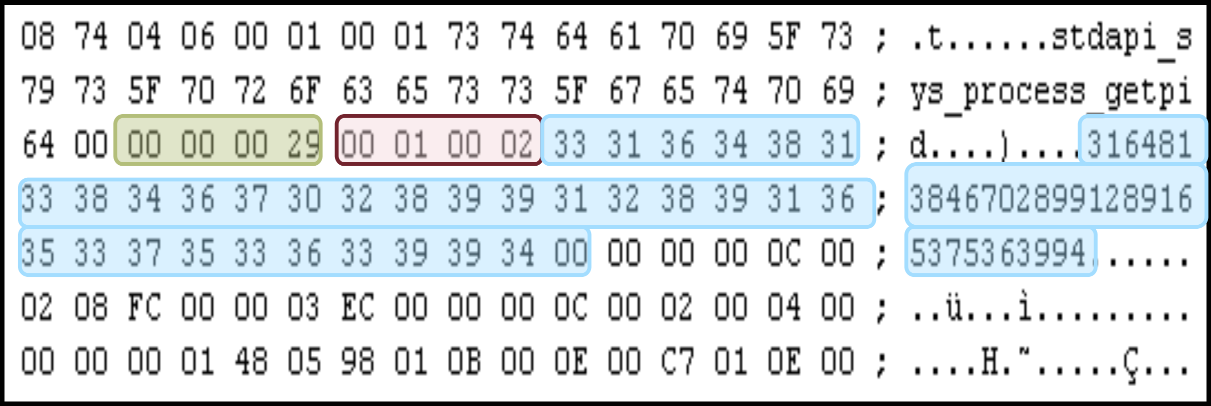
Response Packet from Memory



```
08 74 04 06 00 01 00 01 73 74 64 61 70 69 5F 73 ; .t......stdapi_s
79 73 5F 70 72 6F 63 65 73 73 5F 67 65 74 70 69 ; ys_process_getpi
64 00 00 00 00 29 00 01 00 02 33 31 36 34 38 31 ; d....)....316481
33 38 34 36 37 30 32 38 39 39 31 32 38 39 31 36 ; 3846702899128916
35 33 37 35 33 36 33 39 39 34 00 00 00 00 0C 00 ; 5375363994......
02 08 FC 00 00 03 EC 00 00 00 0C 00 02 00 04 00 ; ..ü...ì.........
00 00 00 01 48 05 98 01 0B 00 0E 00 C7 01 0E 00 ; ....H.˜.....Ç...
```

TLV Packet		
Length	*Doesn’t exist do to free()*	
Type:	TLV_TYPE_METHOD	0x00010001
Value:	stdapi_sys_process_getpid	

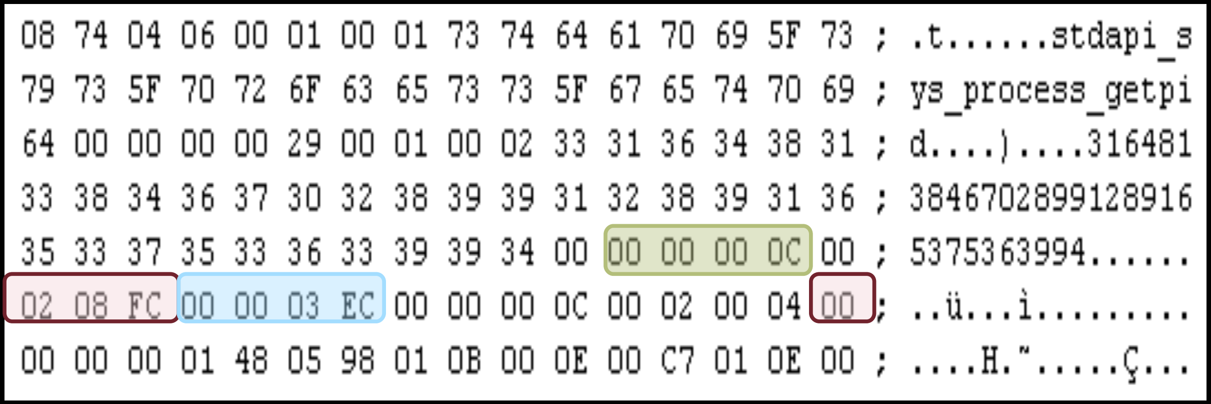
Response Packet from Memory



```
08 74 04 06 00 01 00 01 73 74 64 61 70 69 5F 73 ; .t......stdapi_s
79 73 5F 70 72 6F 63 65 73 73 5F 67 65 74 70 69 ; ys_process_getpi
64 00 00 00 00 29 00 01 00 02 33 31 36 34 38 31 ; d....)....316481
33 38 34 36 37 30 32 38 39 39 31 32 38 39 31 36 ; 3846702899128916
35 33 37 35 33 36 33 39 39 34 00 00 00 00 0C 00 ; 5375363994......
02 08 FC 00 00 03 EC 00 00 00 0C 00 02 00 04 00 ; ..ü...ì.........
00 00 00 01 48 05 98 01 0B 00 0E 00 C7 01 0E 00 ; ....H.˜.....Ç...
```

TLV Packet		
Length	0x29	
Type:	TLV_TYPE_REQUEST_ID	0x00010002
Value:	31648138467028991289165375363994	

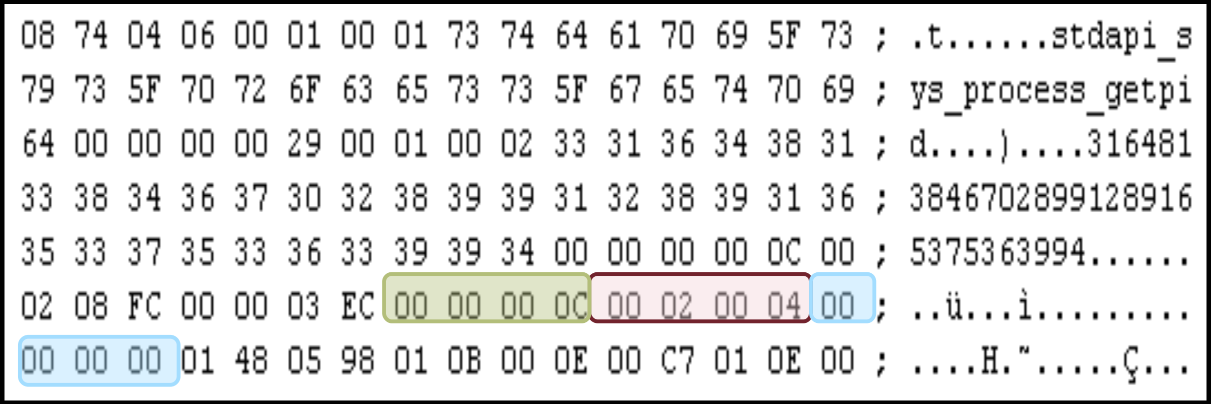
Response Packet from Memory



```
08 74 04 06 00 01 00 01 73 74 64 61 70 69 5F 73 ; .t......stdapi_s
79 73 5F 70 72 6F 63 65 73 73 5F 67 65 74 70 69 ; ys_process_getpi
64 00 00 00 00 29 00 01 00 02 33 31 36 34 38 31 ; d....)....316481
33 38 34 36 37 30 32 38 39 39 31 32 38 39 31 36 ; 3846702899128916
35 33 37 35 33 36 33 39 39 34 00 00 00 00 0C 00 ; 5375363994......
02 08 FC 00 00 03 EC 00 00 00 0C 00 02 00 04 00 ; ..ü...ì.........
00 00 00 01 48 05 98 01 0B 00 0E 00 C7 01 0E 00 ; ....H.˜.....Ç...
```

TLV Packet		
Length	0x0C	
Type:	TLV_TYPE_PID	0x000208FC
Value:	0x000003EC	

Response Packet from Memory



```
08 74 04 06 00 01 00 01 73 74 64 61 70 69 5F 73 ; .t......stdapi_s
79 73 5F 70 72 6F 63 65 73 73 5F 67 65 74 70 69 ; ys_process_getpi
64 00 00 00 00 29 00 01 00 02 33 31 36 34 38 31 ; d....)....316481
33 38 34 36 37 30 32 38 39 39 31 32 38 39 31 36 ; 3846702899128916
35 33 37 35 33 36 33 39 39 34 00 00 00 00 0C 00 ; 5375363994......
02 08 FC 00 00 03 EC 00 00 00 0C 00 02 00 04 00 ; ..ü...ì.........
00 00 00 01 48 05 98 01 0B 00 0E 00 C7 01 0E 00 ; ....H.˜.....Ç...
```

TLV Packet		
Length	0x0C	
Type:	TLV_TYPE_RESULT	0x00020004
Value:	0x00000000	

Meterpreter Communication

- The response packet is freed by meterpreter
- However…
- When Windows’ memory manager frees memory, it is not *immediately* reused.
  - It can take hours for memory to be reclaimed after it has been freed.

Metasploit Forensic Framework

Finding one pwned system at a time

Metasploit Forensic Framework

- Scan acquired VADs looking for:
  - Strings containing meterpreter methods
    - This indicates a TLV response to a specific method
    - Parsing out the response TLV gives analysts the data attackers received
      - Also indicates what commands were executed on the machine

Conclusion

- Windows memory manager gives analysts a chance to see artifact memory
- Large impact for forensics
  - Not so large on Metasploit project
- Combining memory analysis with further research will lead to better and more effective projects

DEMO

Demo Part 3

- Acquire `svchost.exe`
  - *Remember attacker terminated connection **roughly** 30 minutes ago*
  - Run Metasploit Forensic Framework (`msff`)

Questions???

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- peter.silberman@mandiant.com