

# Hunting In Memory

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# Who are we

- Jared Atkinson
  - Defensive Service Technical Director - Specter Ops
  - Microsoft Cloud and Datacenter Management MVP (PowerShell)
  - Lead Developer PowerForensics
- Joe Desimone
  - Senior Malware Researcher - Endgame
  - Developer, Hunter, Reverse Engineer



# Overview

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- Why hunting in memory is important
- Memory based attacker techniques
- Existing tools and approaches
- New powershell tool for hunting at scale



# Importance of Memory Hunting

- Memory resident malware has been in use for over a decade, and is now ubiquitous
- Once a staple of 'APT'; now commonplace for crimeware
- Designed to evade PSPs and YOU
- Great signal to noise ratio; easy button hunting



# Attacker Techniques

- Classic memory/shellcode injection
- Reflective DLLs
- Memory Module
- Process and Module Hollowing
- PEB Unlinking
- Gargoyle (ROP/APCs)



# Classic Injection

- `OpenProcess` - Grab handle to target process
- `VirtualAllocEx` - Allocate a new chunk of memory in target
- `WriteProcessMemory` - Write the shellcode/payload into target
- `CreateRemoteThread` - Start a new thread to execute the payload



# Classic Injection - Poison Ivy

```
push 40
push 3000
push dword ptr ss:[ebp+10]
push 0
push dword ptr ss:[ebp+C]
call dword ptr ds:[esi+B1]
push eax
lea edi,dword ptr ss:[ebp-4]
push edi
push dword ptr ss:[ebp+10]
push dword ptr ss:[ebp+14]
push eax
push dword ptr ss:[ebp+C]
call dword ptr ds:[esi+B5]
pop eax
```

[esi+B1]:VirtualAllocEx

[esi+B5]:WriteProcessMemory



# Poison Ivy

push 0	
push dword ptr ss:[ebp-F80]	
call dword ptr ds:[esi+C9]	[esi+C9]:CreateRemoteThread
push eax	
push dword ptr ss:[ebp-F80]	
call dword ptr ds:[esi+A1]	[esi+A1]:CloseHandle
pop eax	





# Poison Ivy

+ 0x960000

+ 0x970000

+ 0x980000

+ 0x990000

+ 0x9a0000

+ 0x9b0000

+ 0x9c0000

+ 0x9d0000

+ 0x9f0000

Private

Private

Private

Private

Private

Private

Private

Private

Private

8 kB RWX

4 kB RWX

4 kB RWX

4 kB RWX

4 kB RWX

4 kB RWX

4 kB RWX

4 kB RWX

4 kB RWX



# Poison Ivy Thread

Stack - thread 2520	
Name	
0	ntkrnlpa.exe!KiDeliverApc+0xb3
1	ntkrnlpa.exe!ZwYieldExecution+0x19a4
2	ntkrnlpa.exe!NtWaitForSingleObject+0x9a
3	ntkrnlpa.exe!KeReleaseInStackQueuedSpinLockFromDpc...
4	ntdll.dll!KiFastSystemCallRet (No unwind info)
5	mswsock.dll+0x5f9f (No unwind info)
6	ws2_32.dll!select+0xa7 (No unwind info)
7	0x3b05f8 (No unwind info)
8	0x9603d8 (No unwind info)
9	0x3b0519 (No unwind info)
10	kernel32.dll!GetModuleFileNameA+0x1b4 (No unwind info)



# Reflective DLL Injection

- DLL that maps itself into memory - original design and code by Steven Fewer [1]
- Handy from attacker perspective - makes for a 'dumb' injector
- No longer have to code in assembly (like PI)
- Very common technique (ex: meterpreter, powershell empire)
- Allocate memory, map sections, resolve imports, fixup relocations, call entry



[1] <https://github.com/stephenfewer/ReflectiveDLLInjection>

# Meterpreter

- Classic DLL Reflection, such as meterpreter, is easy to find

0x2410000	Private: Commit	964 kB	RWX
0x1f20000	Private: Commit	396 kB	RWX
0x1d90000	Private: Commit	936 kB	RWX
0x220000	Private: Commit	128 kB	RWX

Exports		
Name	Address	Ordinal
Init	10001AE2	1
ReflectiveLoader()	1000237B	2



# Meterpreter

```
notepad.exe (2452) (0x2410000 - 0x2501000)

00000000  4d 5a e8 00 00 00 00 5b 52 45 55 89 e5 81 c3 74 MZ.....[REU....t
00000010  17 00 00 ff d3 81 c3 85 80 0e 00 89 3b 53 6a 04 .....;Sj.
00000020  50 ff d0 00 00 00 00 00 00 00 00 00 00 00 00 P.....
00000030  00 00 00 00 00 00 00 00 00 00 00 00 f8 00 00 00 .....
00000040  0e 1f ba 0e 00 b4 09 cd 21 b8 01 4c cd 21 54 68 .....!..L.!Th
00000050  69 73 20 70 72 6f 67 72 61 6d 20 63 61 6e 6e 6f is program canno
00000060  74 20 62 65 20 72 75 6e 20 69 6e 20 44 4f 53 20 t be run in DOS
00000070  6d 6f 64 65 2e 0d 0d 0a 24 00 00 00 00 00 00 00 mode....$.....
00000080  f4 1f 93 1a b0 7e fd 49 b0 7e fd 49 b0 7e fd 49 .....~.I.~.I.~.I
00000090  f6 2f 1c 49 9d 7e fd 49 f6 2f 22 49 af 7e fd 49 ./..I.~.I./"I.~.I
000000a0  f6 2f 1d 49 0b 7e fd 49 cd 07 1d 49 3f 7f fd 49 ./..I.~.I...I?...I
```



# Memory Module

- Similar to Reflective technique, except loader does all the work [1]
- Payload DLL doesn't need any special modifications
- Loader re-implements LoadLibrary(), but works on a buffer in memory
- Can map into local or remote process [2]
- Typical implementations avoid RWX



[1] Memory Module - <https://github.com/fancycode/MemoryModule>

[2] Manual Map - <https://github.com/DarthTon/Blackbone>

# NetTraveler - Memory Layout

- Uses legitimate looking permissions

▀ 0x3f0000	Private	108 kB	RW
0x3f0000	Private: Commit	4 kB	RW
0x3f1000	Private: Commit	40 kB	RX
0x3fb000	Private: Commit	8 kB	R
0x3fd000	Private: Commit	52 kB	RW
0x40a000	Private: Reserved	4 kB	



## NetTraveler - Active Thread

```
14 winhttp.dll!WinHttpSendRequest+0x2fe6 (No unwind info)
15 winhttp.dll!WinHttpSendRequest+0x3069 (No unwind info)
16 winhttp.dll!WinHttpSendRequest+0x212 (No unwind info)
17 0x3f6e82 (No unwind info)
18 0x3f679e (No unwind info)
19 0x3f5d65 (No unwind info)
```



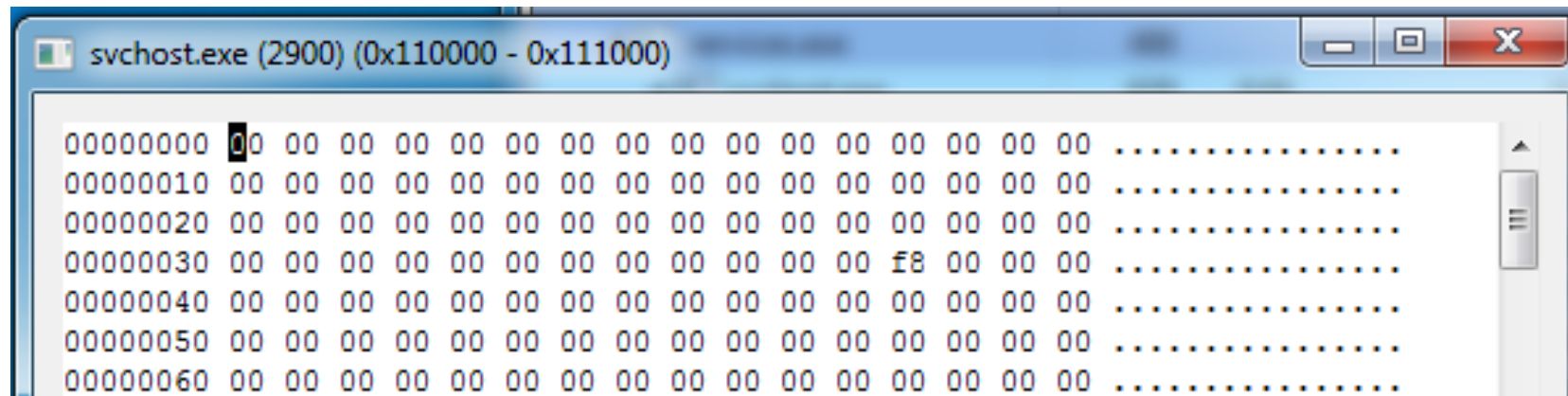


# Winnti - Memory Layout

▴ 0x110000	Private	28 kB	RWX
0x110000	Private: Commit	4 kB	RWX
0x111000	Private: Commit	12 kB	RX
0x114000	Private: Commit	4 kB	R
0x115000	Private: Commit	4 kB	RW
0x116000	Private: Rese...	4 kB	



# Winnti - Header Wipe




# Process Hollowing

- Create new, suspended process
- Allocate new memory, unmap (hollow) existing code
- Write payload
- Redirect execution - `SetThreadContext()` and `ResumeThread()`
- Stealthy variants
  - Create/Map sections to avoid `WriteProcessMemory`
  - Modify entry point instead of `SetThreadContext`



# DarkComet - Process Hollowing

0018F984	00401742	CALL to <b>CreateProcessA</b> from dark.0040173E
0018F988	0018FA38	ModuleFileName = "C:\Users\Joe\Desktop\dark.exe"
0018F98C	00000000	CommandLine = NULL
0018F990	00000000	pProcessSecurity = NULL
0018F994	00000000	pThreadSecurity = NULL
0018F998	00000000	InheritHandles = FALSE
0018F99C	00000004	CreationFlags = CREATE_SUSPENDED
0018F9A0	00000000	pEnvironment = NULL
0018F9A4	00000000	CurrentDir = NULL
0018F9A8	0018FE5C	pStartupInfo = 0018FE5C
0018F9AC	0018FE4C	pProcessInfo = 0018FE4C
0018F9B0	00000000	
0018F9B4	00000000	
0018F9B8	0000387A	
0018F9BC	75821072	kernel32.CreateProcessA



# DarkComet

Name	Base address	Size	Description
<b>dark.exe</b>	<b>0x400000</b>	<b>732 kB</b>	<b>WEBhu2 NXchu6</b>
advapi32.dll	0x76d60000	640 kB	Advanced Windows 32 F
0x3e0000	Mapped: Commit	96 kB	R C:\Users\Joe
0x400000	Private: Commit	732 kB	RWX
0x4c0000	Mapped: Commit	28 kB	R



# Module Overwriting

- Up until now, all examples have lead to non-image backed code executing
- Module Overwriting avoids this, making it more difficult to detect
- Flame and Careto are examples
- Map an unused module into target process
- Overwrite legitimate module with payload
- Odinaff had a similar trick but overwrote its own executable



# Odinaff

## In Memory

MajorLinkerVersion	0A
MinorLinkerVersion	00
SizeOfCode	00001200
SizeOfInitializedData	00001200
SizeOfUninitializedData	00000000
AddressOfEntryPoint	00002180
FileAlignment	00000200
MajorOperatingSystemVers...	0005
MinorOperatingSystemVer...	0001

## On Disk

MajorLinkerVersion	06
MinorLinkerVersion	00
SizeOfCode	00002000
SizeOfInitializedData	00006000
SizeOfUninitializedData	00000000
AddressOfEntryPoint	00001D04
FileAlignment	00001000
MajorOperatingSystemVers...	0004
MinorOperatingSystemVer...	0000



# PEB Unlinking

- Not an in memory technique, but rather an evasion
- Hide loaded DLL from security products, admins, hunters
- HackingTeam used this technique in their RAT
- Flame also unlinked shell32.dll
- To find peb unlinking, you could compare what the Win32 API reports as 'loaded' versus what you find is actually loaded with VirtualQuery/GetSectionName





# Gargoyle

- Technique developed by Josh Lospinoso to hide injected code from security products
- Payload lies dormant, with read only permissions
- Periodically 'wakes up.' Sets payload executable with an asynchronous procedure call and ROP. Permissions reverted, cycle repeats.
- <https://jlospinoso.github.io/security/assembly/c/cpp/developing/softwre/2017/03/04/gargoyle-memory-analysis-evasion.html>



# Available Tools

- Volatility / malfind
- GRR
- Rekall
- inVtero



# Detecting Injection

w/ PowerShell

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# PSReflect

- PowerShell module written by Matt Graeber (@mattifestation)
  - <https://github.com/mattifestation/PSReflect>
- Avoids the compilation artifacts associated with P/Invoke
  - IMO the cleanest way to deal with Win32 API from PowerShell
- Library to abstract the complexities of calling Win32 functions via Reflection
- Intuitive “domain specific language” for defining enums, structs, and P/Invoke function signatures
- Must include PSReflect code in your scripts/modules



# Get-InjectedThread

- Built on PSReflect
- PowerShell function to identify injected threads via detection methodology:
  - Use Windows Toolhelp API to get all threads
  - Iterate through each thread
  - Identify the thread's Base (Memory) Address
  - Query the memory page for which the Base Address belongs to
  - Check if the memory page's state is MEM\_COMMIT
  - Check if the memory page's type is not MEM\_IMAGE
- Returns details regarding offending process and thread
  - Check memory page permissions
  - Look for unnecessary privileges or integrity level
  - Identify abnormal user tokens



# Get-InjectedThread Output

- Injected Process Information
  - Process Id
  - Name
  - File Path (PEB and EPROCESS)
  - Command Line
- Thread Information
  - Thread Id
  - Unique Thread Token
  - Base Priority
  - Does thread have unique token?
- Memory Segment
  - Base Address
  - Size
  - Protection
  - State
  - Type
  - First 100 Bytes
- Token (Thread or Process)
  - Integrity Level
  - Enabled Privileges
  - SID / UserName
  - Logon Session Start Time
  - Logon Type
  - Authentication Package





Recycle Bin



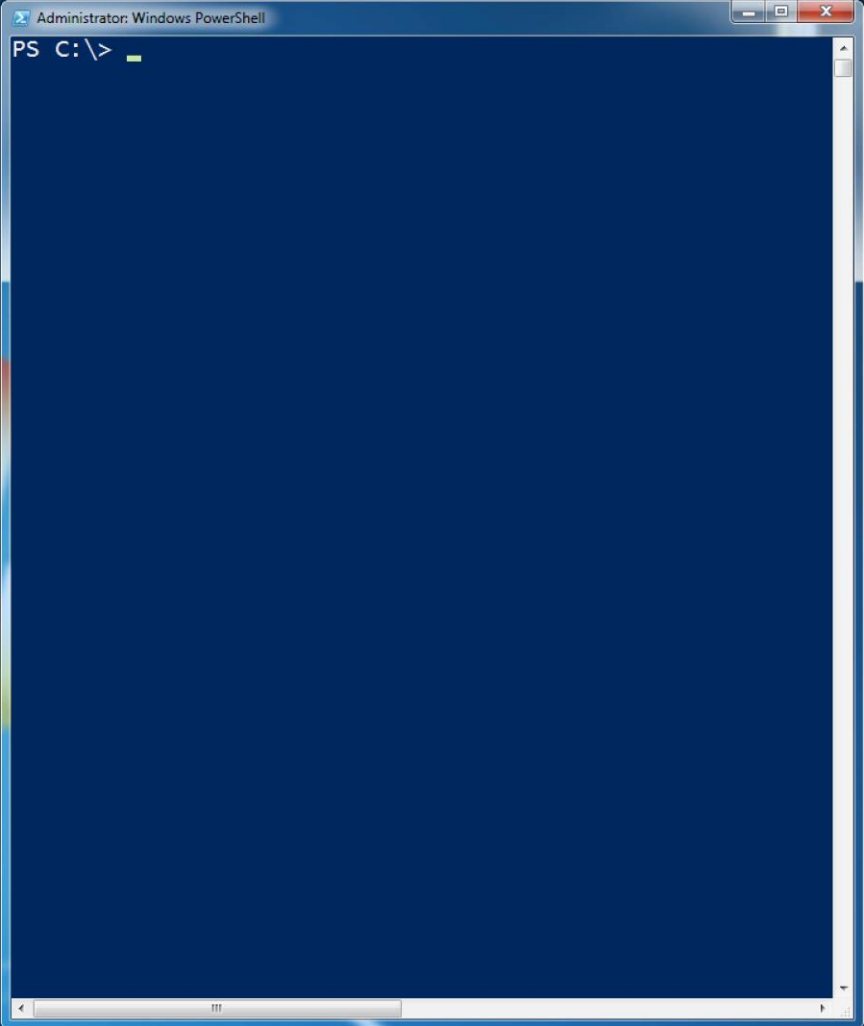
ThreadStart



2nd  
Myanmar L...



Get-Inject...



# Our Threat - 9002 Trojan

- Delivered as .zip file via Google Drive
- Zip archive contains one file
  - 2nd Myanmar Industrial Resource Development Symposium.exe
  - File has PowerPoint icon to trick users into opening
- Drops files upon execution
  - %USERPROFILE%\<random>\RealNetwork.exe (Legitimate Application)
  - %USERPROFILE%\<random>\main.dll (Loaded by MPAMedia.dll)
  - %USERPROFILE%\<random>\mpaplugins\MPAMedia.dll (DLL Side Loading)
  - Ppt
    - Opened in PowerPoint to keep up the ruse







Recycle Bin



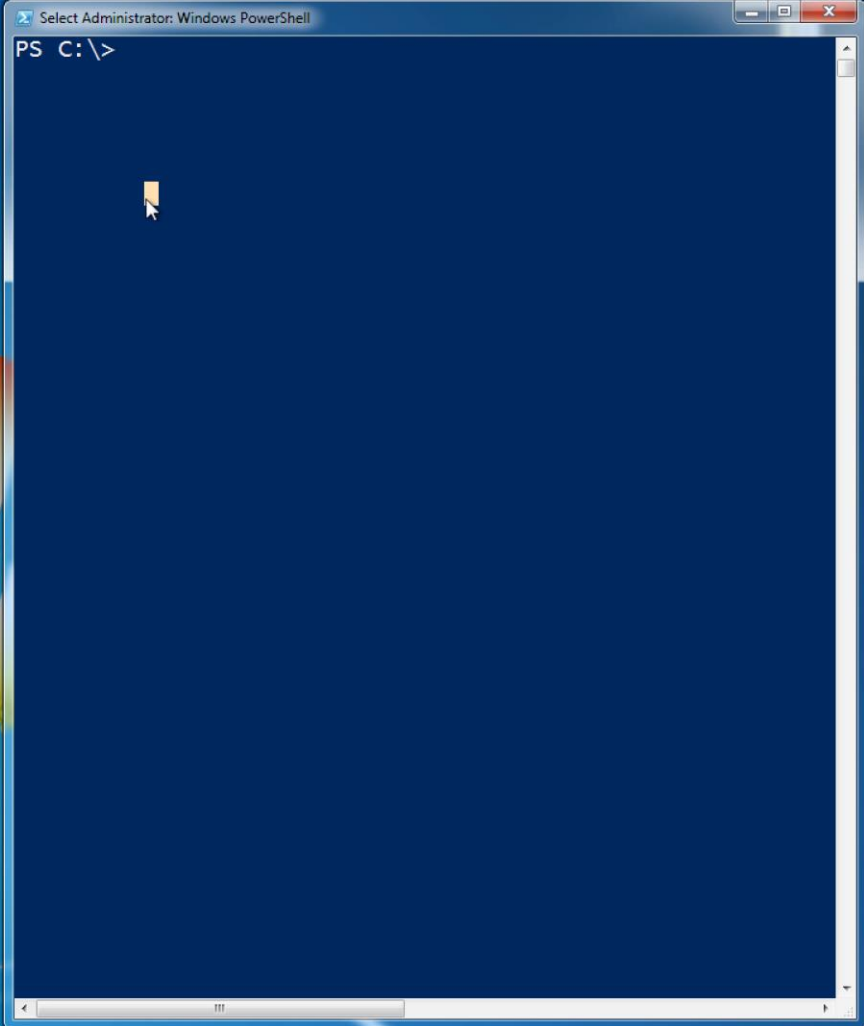
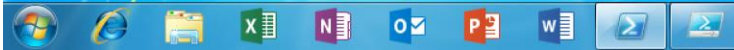
ThreadStart



2nd  
Myanmar I...



Get-Inject...



# Response

- Kill Thread
  - Stop-Thread
  - Built on Window's TerminateThread API
- Process Minidump
  - Out-Minidump (PowerSploit)
  - <https://github.com/PowerShellMafia/PowerSploit/blob/master/Exfiltration/Out-Minidump.ps1>
- Thread Dump
  - Dump-Thread



Process Hacker [Test-PC\Test]

Hacker View Tools Users Help

Refresh Options Find handles or DLLs System information Search Processes (Ctrl+K)

Processes Services Network Disk

Name	PID	CPU	I/O total ...	Private b...	User name	Desc
dwm.exe	876	0.70		61.41 MB	Test-PC\Test	Desk
svchost.exe	936			20.11 MB		Host
svchost.exe	1080			5.81 MB		Host
svchost.exe	1236	0.01		17.67 MB		Host
spoolsv.exe	1332			10.84 MB		Spoc
svchost.exe	1368			9.48 MB		Host
svchost.exe	1468			4.71 MB		Host
VGAuthService.exe	1576			3.67 MB		VMw
vmtoolsd.exe	1600	0.08		8.96 MB		VMw
svchost.exe	1800			1.01 MB		Host
TPAutoConnSvc.exe	1840	0.02		1.57 MB		Thin
TPAutoConnect.e...	1220	0.02		1.97 MB	Test-PC\Test	Thin
msdtc.exe	320			2.39 MB		Micr
sppsvc.exe	3288			4.82 MB		Micr
svchost.exe	3324			153.13 MB		Host
OfficeClickToRun.exe	2708			49.75 MB		Micr
AppVShNotify.exe	1512			1.05 MB	Test-PC\Test	AppV
PresentationFontCac...	3840			14.36 MB		Pres
taskhost.exe	3700			6.8 MB	Test-PC\Test	Host
SearchIndexer.exe	2644	0.13		17.26 MB		Micr
SearchProtocolH...	332			1.13 MB		Micr
SearchFilterHost.e...	2924			940 kB		Micr
OSPPSVC.EXE	3556			4.68 MB		Micr
lsass.exe	516			2.95 MB		Loca
lsim.exe	524	0.02		1.29 MB		Loca
csrss.exe	2152			9.7 MB		Clier
conhost.exe	2164			632 kB	Test-PC\Test	Con
conhost.exe	912			868 kB	Test-PC\Test	Con
conhost.exe	1116			1.63 MB	Test-PC\Test	Con
winlogon.exe	3004			2.21 MB		Wind
explorer.exe	3600	0.03		36.19 MB	Test-PC\Test	Wind
vmtoolsd.exe	3748	0.13	760 B/s	15.18 MB	Test-PC\Test	VMw
powershell_ise.exe	1292			87.46 MB	Test-PC\Test	Wind
powershell.exe	1344			30.87 MB	Test-PC\Test	Wind
ProcessHacker.exe	3588	1.29		6.64 MB	Test-PC\Test	Proc
RealNetwork.exe	2520	0.27	56 B/s	3.46 MB	Test-PC\Test	RN E

CPU Usage: 3.63% Physical memory: 620.25 MB (60.60%) Processes: 47

Administrator: Windows PowerShell

```
PS C:\> Get-InjectedThread | select ProcessName, ThreadId | fl
```

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**Questions?**