



  
**black hat**<sup>®</sup>  
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BRIEFINGS

# **You can Run, but you can't Hide**

## **Finding the Footprints of Hidden Shellcode**

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## whoami

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# Agenda

1. Why do security products scan memory?
2. Memory scanning & evasion recap
3. Detection opportunities for hidden shellcode
  - Detection via immutable code page principle violations
  - Detection via CFG bitmap anomalies
4. Hunting via process behaviour summaries

# Why do security products scan memory?

- On Windows x64, Microsoft has –
  - hardened the kernel,
  - claimed the hypervisor, and
  - made private executable memory an indefensible boundary for kernel-mode security products.
- This just leaves memory scanning.
  - It's not perfect, but it's still a valuable defensive layer.

# Overview of memory scanners

## Generic Scanners

- YARA - memory content signatures
- PE-sieve - image metadata anomalies and content heuristics
- Moneta - memory metadata anomalies



## Evasion recap

- Gargoyle - memory protection fluctuation via APC timer and ROP chain
- obfuscate-and-sleep - encrypted state fluctuation via post-sleep stub
- FOLIAGE - encrypted state fluctuation via APC timers and context manipulation
- Shellcode Fluctuation - memory protection fluctuation via post-sleep indirect stub
- DeepSleep - memory protection fluctuation via post-sleep ROP chain
- Ekko - encrypted state fluctuation via timer queues and context manipulation
  
- Scheduled Tasks ;-)

# Evasion recap

```
[+] host called home, sent: 56 bytes
[+] received output:

Y (<>) A >

Moneta v1.0 | Forrest Orr | 2020

... failed to grant SeDebug privilege to self. Certain processes will be
inaccessible.

... scan completed (0.531000 second duration)

[DESKTOP-C8F8KBR] User/2404 (x64) last: 53ms
beacon>
```

and you can see, I get no results from Moneta.

DEF CON DEFCON

28:51 / 43:33 • FOLIAGE - Sleep Chain Initialization >

Kyle Avery - Avoiding Memory Scanners: Customizing Malware to Evade YARA, PE-sieve, and More

<https://forum.defcon.org/node/241824>



# Evasion – key concept

“a common technique for reducing computational burden is to limit analysis on executable code pages only” - Josh Lospinoso

<https://lospi.net/security/assembly/c/cpp/developing/software/2017/03/04/gargoyle-memory-analysis-evasion.html>

**gargoyle**



a memory scanning  
evasion technique

```
VirtualProtect(pShellcode, sizeof(shellcode), PAGE_READWRITE, &OldProtect);
```



## Niche memory scanners

- Patriot - anomalous thread CONTEXT structures
- Hunt-Sleeping-Beacons - anomalous Wait call stacks
- TickTock - anomalous timer-queue timers

# Immutable code page principle violations

- Once code pages are written they should never change.
- The memory protection progression for code pages should only be RW to RX.
- Microsoft-Windows-Threat-Intelligence PROTECTVM\_LOCAL ETW events
- `IsExecutable(LastProtectionMask) && !IsExecutable(ProtectionMask)`
- (Optionally) Anomalous call stack detection

```
Microsoft Visual Studio Debug Console
[*] Enabling Microsoft-Windows-Threat-Intelligence (KEYWORD_PROTECTVM_LOCAL)
[*] Monitoring for VirtualProtect() for 30 seconds
[.] java.exe 0000014F66300000 RW- => RWX
[.] Ekko.exe 00007FF7962A0000 RW- => RWX
[.] Ekko.exe 00007FF7962A0000 RWX => RW-
[.] Ekko.exe 00007FF7962A0000 RW- => RWX
[!] Ekko.exe 00007FF7962A0000 is fluctuating
[.] Ekko.exe 00007FF7962A0000 RWX => RW-
[*] Done
```



# An interesting discovery



**Gabriel Landau**

I think I just made an interesting discovery. If you VirtualAlloc(RWX), it modifies the CFG bitmap accordingly. If you then VirtualAlloc(RW), the CFG bitmap stays as-is.



**Gabriel Landau**

We may be able to use this to find DLL hollowing and gargoyles-style?

# Control Flow Guard bitmap recap

- Time efficient lookup of valid indirect call targets
- One bitmap per process
- Each 2 bits corresponds to 16 virtual addresses
- x64 bitmap is 2TB – mostly shared or reserved
- PE files bring their own bitmap
- Copied to the correct offset in process bitmap during image load
- Permissive backwards compatibility for JIT
- Memory manager simply marks all executable private addresses as valid targets

# CFG bitmap anomalies

- The VAD tree only stores original protection and current protection.
- The CFG bitmap (inadvertently) records the location of all private memory addresses that are, **or have previously been**, executable during the lifetime of the process.
- This can be used to flag memory regions that have been changed from executable to non-executable.

Select Microsoft Visual Studio Debug Console

```
==== Hidden Executable Pages - scanning all processes ====  
ShellcodeFluctuation.exe(912) - 1 hidden allocations  
* 0000023F5F6C0000 MEM_PRIVATE  
- 0000023F5F6C0000 +0x001000 RW- --- 1/1 hidden pages
```

# Evasion opportunities

- Protection fluctuation approaches are actually quite noisy.
- Hide your code pages in plain sight.
- Obfuscate them against current signatures ahead of time.
- Encrypt your data pages when not in use.
- Or launch in a new process every time.
- Scheduled Tasks etc.

# Hunting via process behaviour summaries

```
ETW Syscall Monitor
ProtectVirtual
4 dumpy.exe::24e1dc53939b62d8e6d7a535351ebf2a71f9d617
  ProcessCreationTraits
  Syscalls
    dbgcore->kernelbase!OpenThread->ZwOpenThread(all, ALL_ACCESS)
    dbgcore->kernelbase!ReadProcessMemory[hooked]->ZwReadVirtualMemory(lsass)
    dbgcore->ntdll!NtOpenThread->ZwOpenThread(all, ALL_ACCESS)
    exe->kernelbase!LoadLibraryA[hooked]->ZwMapViewOfSection(dbgcore.dll)
    exe->kernelbase!LoadLibraryA->ZwMapViewOfSection(ktmw32.dll)
    exe->ntdll!NtOpenProcess->ZwOpenProcess(System, DUP_HANDLE)
    exe->ntdll!NtProtectVirtualMemory->ZwProtectVirtualMemory(self, ntdll!exe, EXECUTE_READ->EXECUTE_READWRITE)
    exe->ntdll!exe!NtProtectVirtualMemory[hooked]->ZwProtectVirtualMemory(self, ntdll!exe, EXECUTE_READWRITE->EXECUTE_READ)
    ucrtbase->kernelbase!LoadLibraryExW[hooked]->ZwMapViewOfSection(kernel.appcore.dll)
  TTPHash
    ecc0fdd31504dc1e4eae3d852370a87c3902fd68
4 ekko.exe::19385aad1e6e3bf97eae9833d900bed9568a59a
  ProcessCreationTraits
  Syscalls
    exe->kernelbase!LoadLibraryA->ZwMapViewOfSection(advapi32.dll)
    exe->kernelbase!LoadLibraryA->ZwMapViewOfSection(msvcrt.dll)
    exe->kernelbase!LoadLibraryA->ZwMapViewOfSection(rpctr4.dll)
    exe->kernelbase!LoadLibraryA->ZwMapViewOfSection(sechost.dll)
    ntdll!RtlpTimerCallback->kernelbase!VirtualProtect->ZwProtectVirtualMemory(self, exe!ntdll!RtlpTimerCallback, EXECUTE_READWRITE->READWRITE)
    ntdll!RtlpTimerCallback->kernelbase!VirtualProtect->ZwProtectVirtualMemory(self, exe!ntdll!RtlpTimerCallback, READWRITE->EXECUTE_READWRITE)
    ntdll!RtlpTimerCallback->kernelbase!VirtualProtect->ZwProtectVirtualMemory(self, UNKNOWN!ntdll!RtlpTimerCallback, EXECUTE_READWRITE->READWRITE)
    ntdll!RtlpTimerCallback->kernelbase!VirtualProtect->ZwProtectVirtualMemory(self, UNKNOWN!ntdll!RtlpTimerCallback, READWRITE->EXECUTE_READWRITE)
  TTPHash
    081cfc3f09e29f9daa1286337246eb1156fa7d13
4 shellcodefluctuation.exe::1b4ec792d9a72659f1b66e17fc14d6e90b7588a2
  ProcessCreationTraits
  Syscalls
    exe->kernelbase!VirtualProtect->ZwProtectVirtualMemory(self, kernel32!exe, EXECUTE_READ->EXECUTE_READWRITE)
    exe->kernelbase!VirtualProtect->ZwProtectVirtualMemory(self, kernel32!exe, EXECUTE_READWRITE->EXECUTE_READ)
  TTPHash
    ad4bd072f2391edbb4eedba904410ee2bff56edc
...
Installing vulnerable driver...
Enabling PPL via DKOM...
Starting UserTrace(SyscallSummariser-User-Trace)...
Disabling PPL via DKOM...
[*] Flushing state to file - size = 125174 bytes
```



# Black Hat Sound Bytes

- Threat-Intelligence ETW can be used to detect violations of the immutable code page principle.
- The CFG bitmap can be used to detect shellcode hidden at a point-in-time via changed memory protections such as Gargoyle.
- Kernel telemetry can be used to construct process behaviour summaries – which can be used to identify behavioural outliers for more detailed investigation.
- But, without intervention from Microsoft, private executable memory will likely remain an indefensible boundary for kernel-mode security products.

# Questions

## Tools

- <https://github.com/jdu2600/EtwTi-FluctuationMonitor>
- <https://github.com/jdu2600/CFG-FindHiddenShellcode>
- <https://github.com/jdu2600/Etw-SyscallMonitor>

# Detection References

- <https://github.com/VirusTotal/yara>
- <https://github.com/hasherezade/pe-sieve>
- <https://github.com/forrest-orr/moneta>
- <https://www.elastic.co/security-labs/hunting-memory>
- <https://www.elastic.co/blog/detecting-cobalt-strike-with-memory-signatures>
- <https://github.com/joe-desimone/patriot>
- <https://github.com/thefLink/Hunt-Sleeping-Beacons>
- <https://github.com/WithSecureLabs/TickTock>

# Evasion References

- <https://github.com/JLospinoso/gargoyle>
- <https://www.cobaltstrike.com/blog/cobalt-strike-3-12-blink-and-youll-miss-it/>
- <https://github.com/realoriginal/foilage>
- <https://github.com/mgeeky/ShellcodeFluctuation>
- <https://github.com/thefLink/DeepSleep>
- <https://github.com/Cracked5pider/Ekko>
- <https://www.blackhillsinfosec.com/avoiding-memory-scanners/>

# OS References

- <https://en.wikipedia.org/wiki/W%5EX>
- <https://learn.microsoft.com/en-us/windows/win32/api/memoryapi/nf-memoryapi-virtualprotect>
- <https://github.com/jdu2600/Windows10EtwEvents/blame/master/manifest/Microsoft-Windows-Threat-Intelligence.tsv>
- <https://www.elastic.co/security-labs/finding-truth-in-the-shadows>