Class 20

CSC 471 Modern Malware Analysis
Volatility

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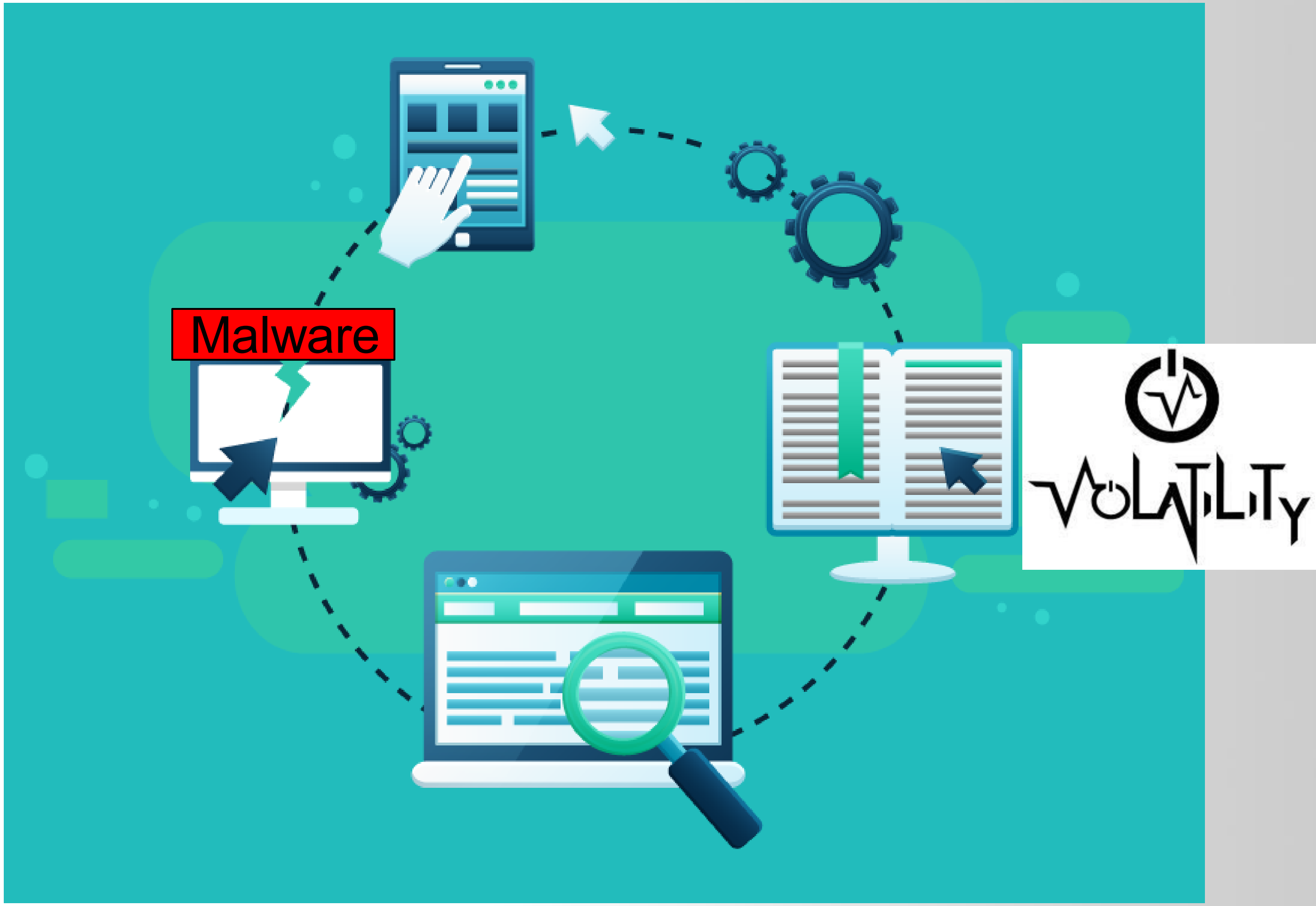
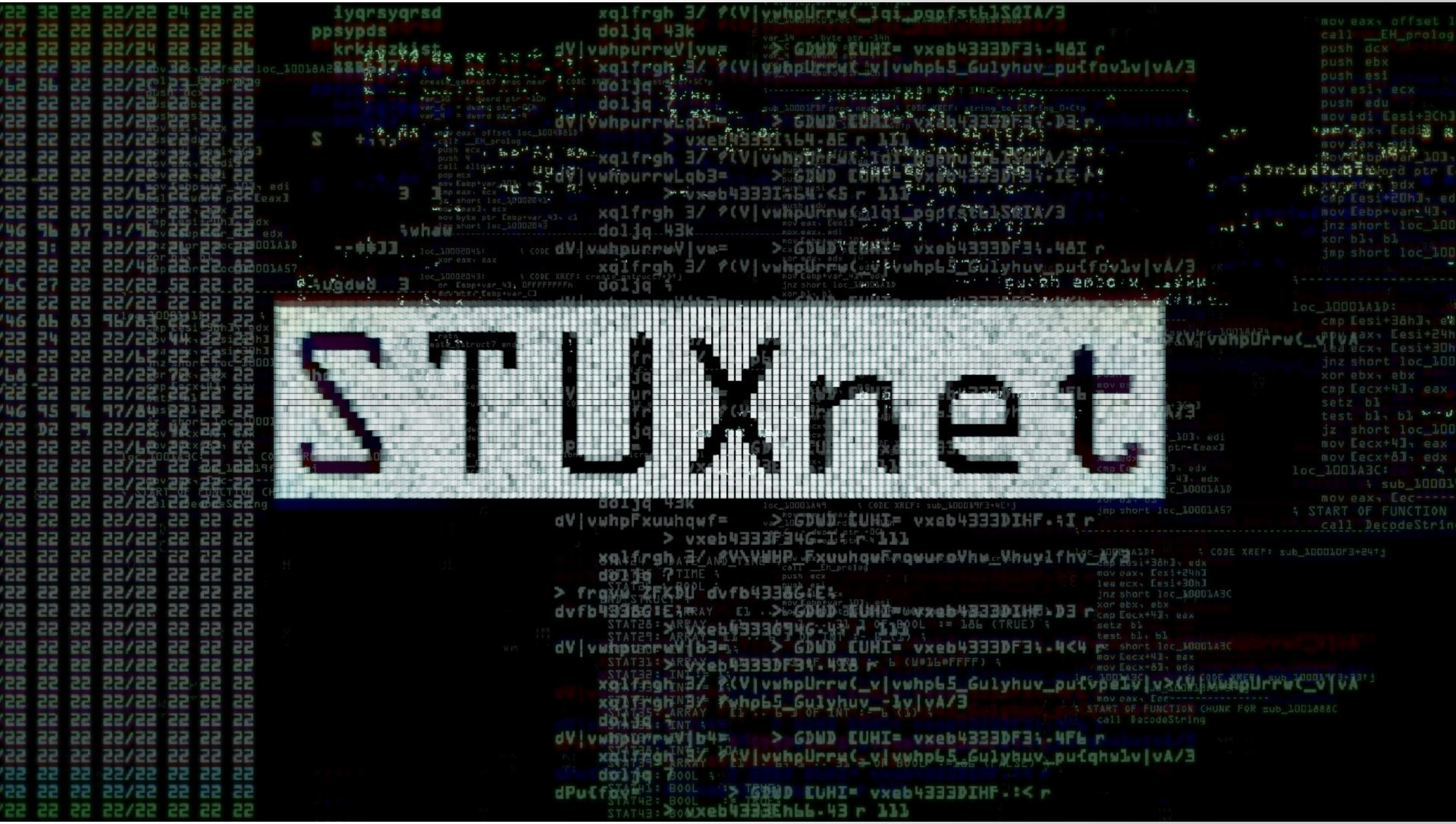
Analysis STUXnet Memory Dump Image

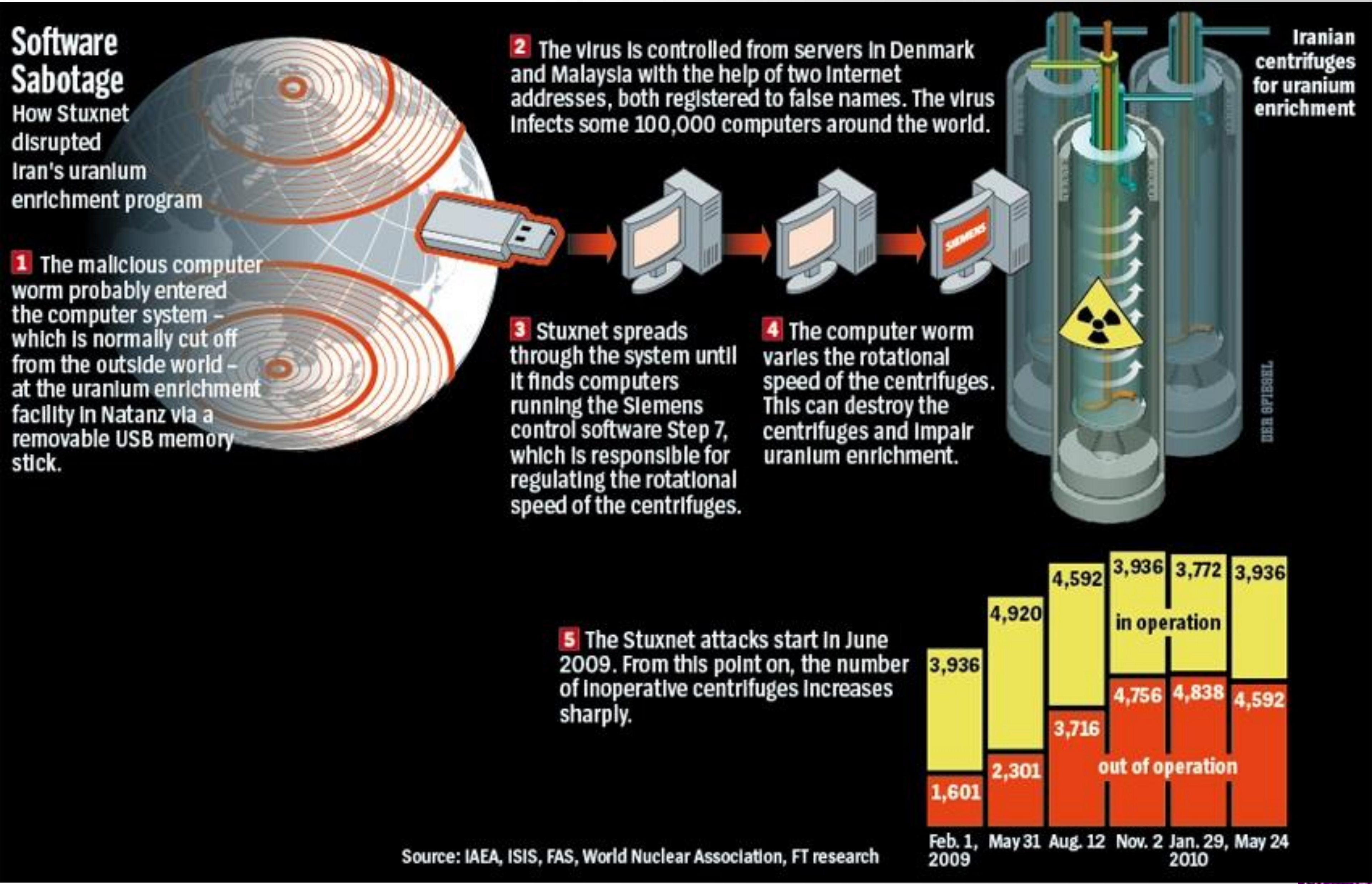


https://github.com/volatilityfoundation/volatility

STUXnet



STUXnet



Software Sabotage

How Stuxnet disrupted Iran's uranium enrichment program

1 The malicious computer worm probably entered the computer system – which is normally cut off from the outside world – at the uranium enrichment facility in Natanz via a removable USB memory stick.

2 The virus is controlled from servers in Denmark and Malaysia with the help of two Internet addresses, both registered to false names. The virus infects some 100,000 computers around the world.

3 Stuxnet spreads through the system until it finds computers running the Siemens control software Step 7, which is responsible for regulating the rotational speed of the centrifuges.

4 The computer worm varies the rotational speed of the centrifuges. This can destroy the centrifuges and impair uranium enrichment.

5 The Stuxnet attacks start in June 2009. From this point on, the number of inoperative centrifuges increases sharply.

Source: IAEA, ISIS, FAS, World Nuclear Association, FT research

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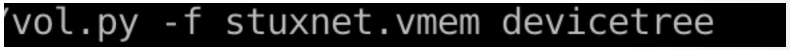
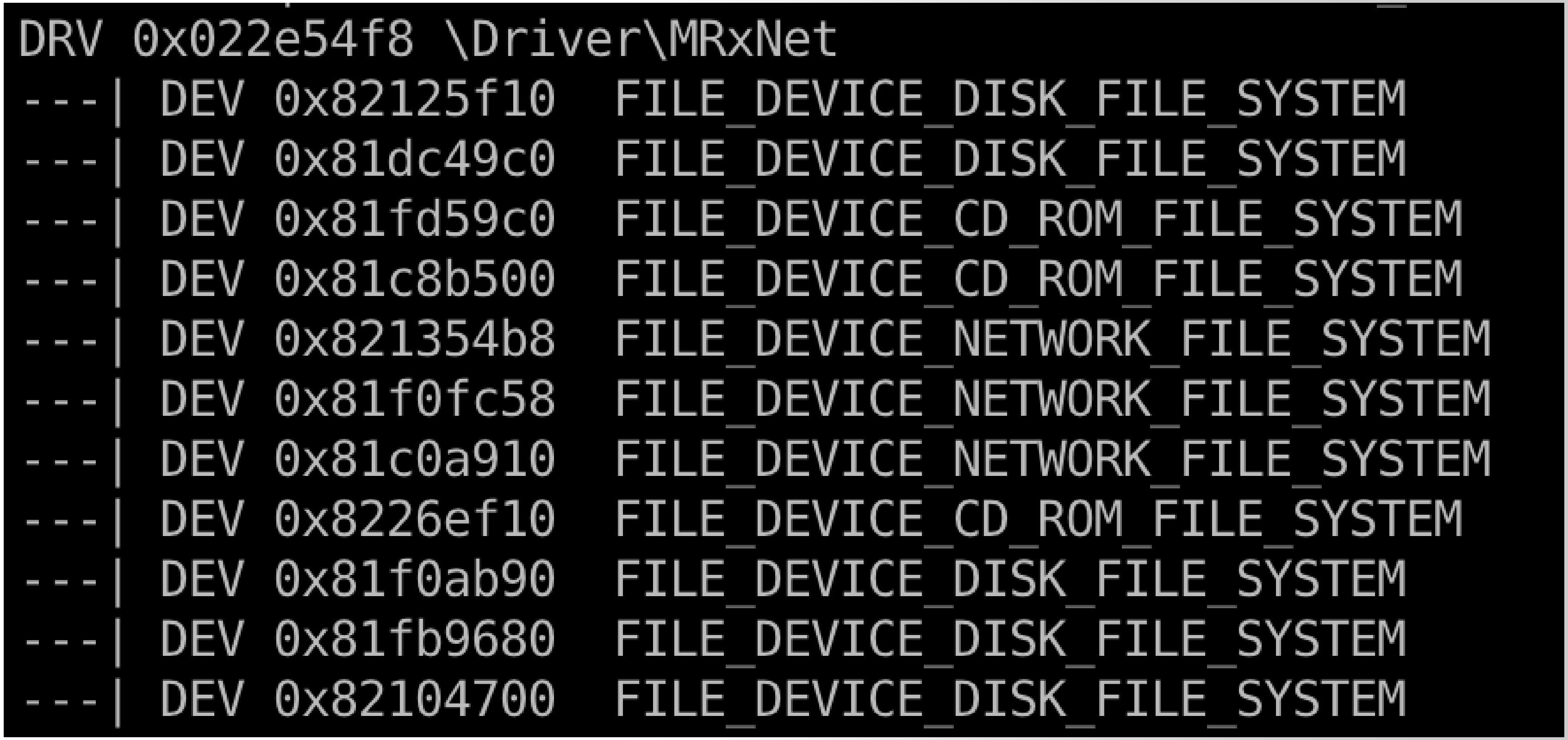


```
/vol.py -f stuxnet.vmem devicetree
```



```
DRV 0x022e54f8 \Driver\MRxNet
---| DEV 0x82125f10  FILE_DEVICE_DISK_FILE_SYSTEM
---| DEV 0x81dc49c0  FILE_DEVICE_DISK_FILE_SYSTEM
---| DEV 0x81fd59c0  FILE_DEVICE_CD_ROM_FILE_SYSTEM
---| DEV 0x81c8b500  FILE_DEVICE_CD_ROM_FILE_SYSTEM
---| DEV 0x821354b8  FILE_DEVICE_NETWORK_FILE_SYSTEM
---| DEV 0x81f0fc58  FILE_DEVICE_NETWORK_FILE_SYSTEM
---| DEV 0x81c0a910  FILE_DEVICE_NETWORK_FILE_SYSTEM
---| DEV 0x8226ef10  FILE_DEVICE_CD_ROM_FILE_SYSTEM
---| DEV 0x81f0ab90  FILE_DEVICE_DISK_FILE_SYSTEM
---| DEV 0x81fb9680  FILE_DEVICE_DISK_FILE_SYSTEM
---| DEV 0x82104700  FILE_DEVICE_DISK_FILE_SYSTEM
```

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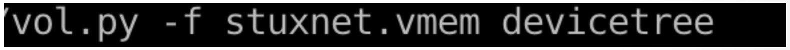

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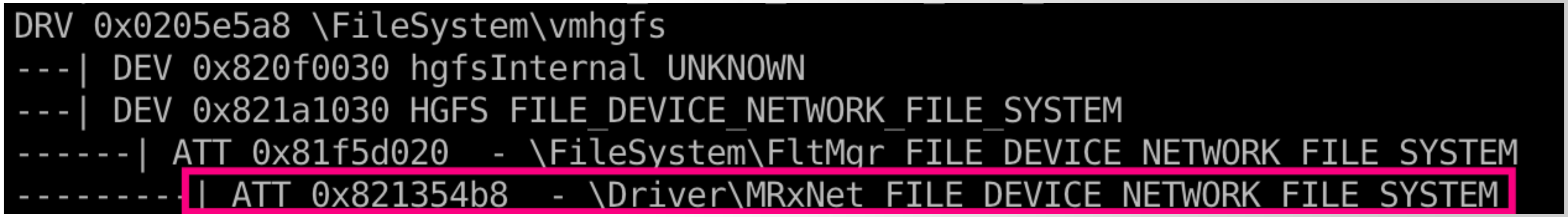
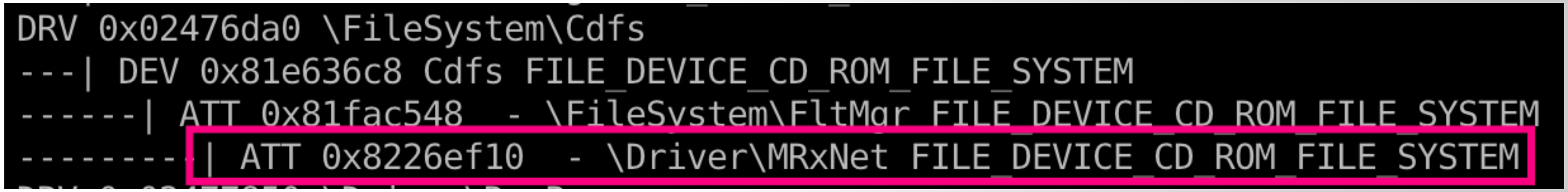
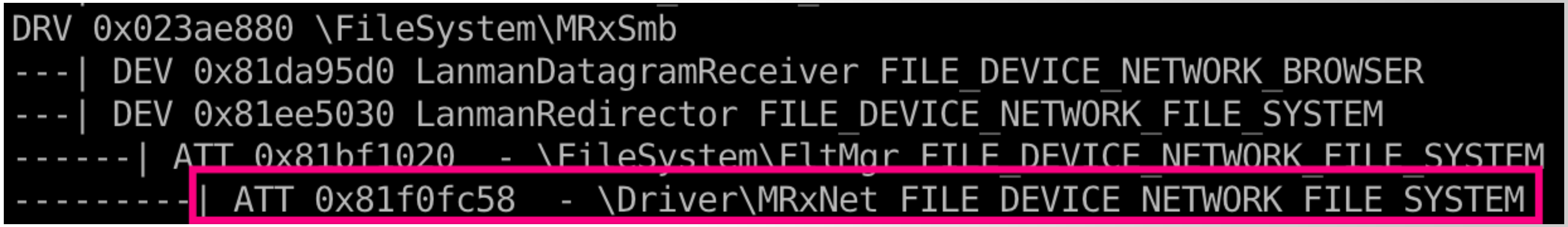


```
DRV 0x0205e5a8 \FileSystem\vmhgfs
---| DEV 0x820f0030 hgfsInternal UNKNOWN
---| DEV 0x821a1030 HGFS FILE_DEVICE_NETWORK_FILE_SYSTEM
------| ATT 0x81f5d020  - \FileSystem\FltMgr FILE_DEVICE_NETWORK_FILE_SYSTEM
---------| ATT 0x821354b8  - \Driver\MRxNet FILE_DEVICE_NETWORK_FILE_SYSTEM
```



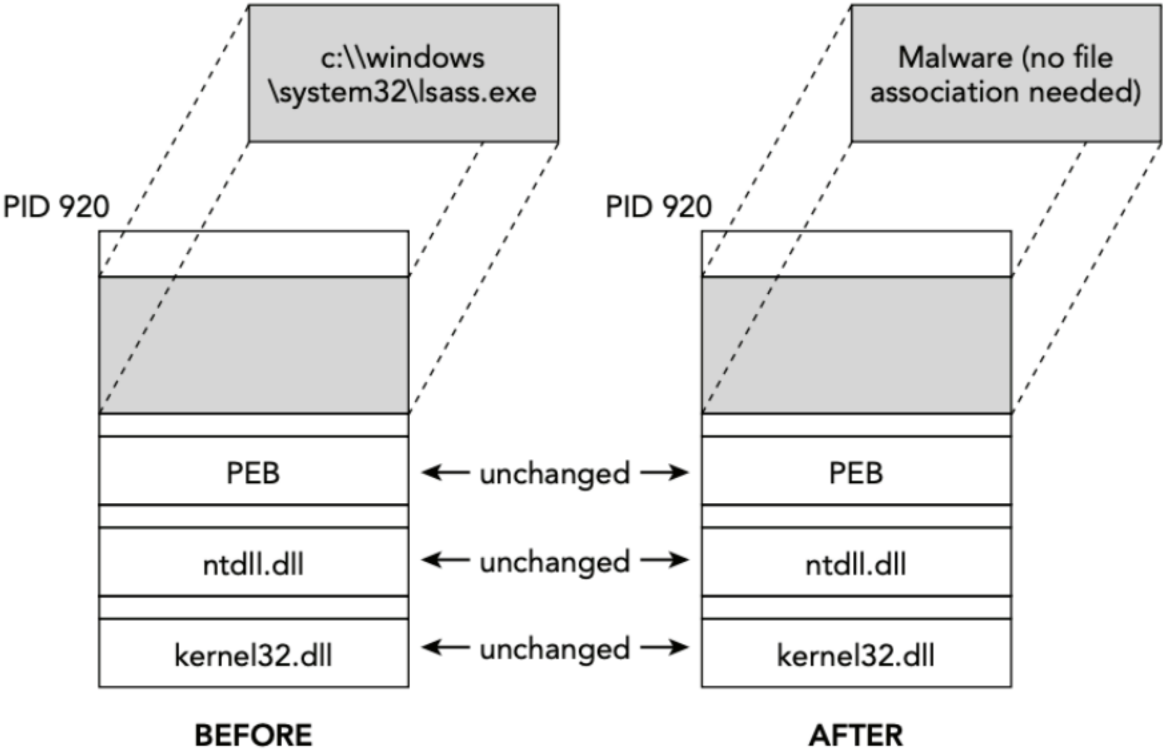
```
DRV 0x02476da0 \FileSystem\Cdfs
---| DEV 0x81e636c8 Cdfs FILE_DEVICE_CD_ROM_FILE_SYSTEM
------| ATT 0x81fac548  - \FileSystem\FltMgr FILE_DEVICE_CD_ROM_FILE_SYSTEM
---------| ATT 0x8226ef10  - \Driver\MRxNet FILE_DEVICE_CD_ROM_FILE_SYSTEM
```

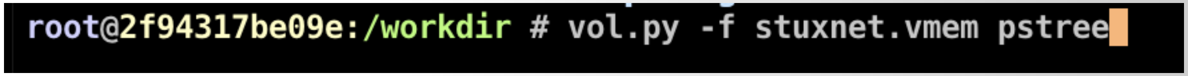


```
DRV 0x023ae880 \FileSystem\MRxSmb
---| DEV 0x81da95d0 LanmanDatagramReceiver FILE_DEVICE_NETWORK_BROWSER
---| DEV 0x81ee5030 LanmanRedirector FILE_DEVICE_NETWORK_FILE_SYSTEM
------| ATT 0x81bf1020  - \FileSystem\FltMgr FILE_DEVICE_NETWORK_FILE_SYSTEM
---------| ATT 0x81f0fc58  - \Driver\MRxNet FILE_DEVICE_NETWORK_FILE_SYSTEM
```

Now Stuxnet can filter or hide specifically named files and directories on those file systems!

Hollow Process Injection





```
root@2f94317be09e:/workdir # vol.py -f stuxnet.vmem pstree
```

Virtual address descriptor (VAD)

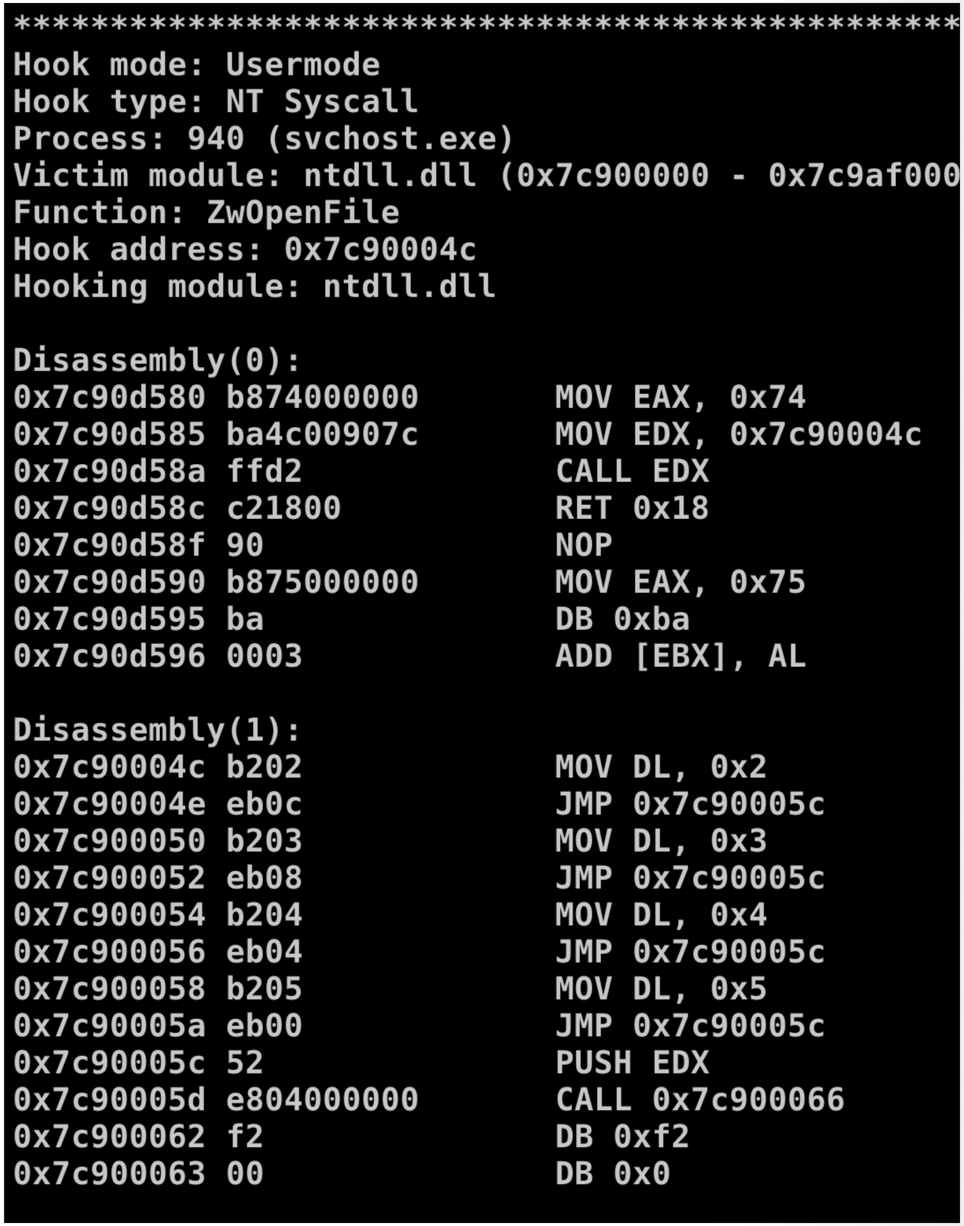
- The Virtual Address Descriptor tree is **used by the Windows memory manager to describe memory ranges used by a process as they are allocated**. When a process allocates memory with VirutalAlloc, the memory manager creates an entry in the VAD tree.

- As a result of being hollowed, the virtual address descriptor (VAD) characteristics for the region are drastically different. Only the legitimate one still has a copy of the lsass.exe file mapped into the region.

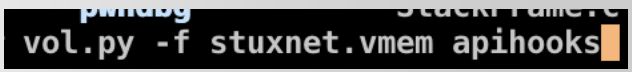
API Hooking

- Based on Symantec report, Stuxnet has hooked Ntdll.dll to monitor for requests to load specially crafted file names.
- These specially crafted filenames are mapped to another location instead — a location specified by Stuxnet.
- The functions hooked for this purpose in Ntdll.dll are:
  - ZwMapViewOfSection
  - ZwCreateSection
  - ZwOpenFile
  - ZwCloseFile
  - ZwQueryAttributesFile
  - ZwQuerySection

API Hooking



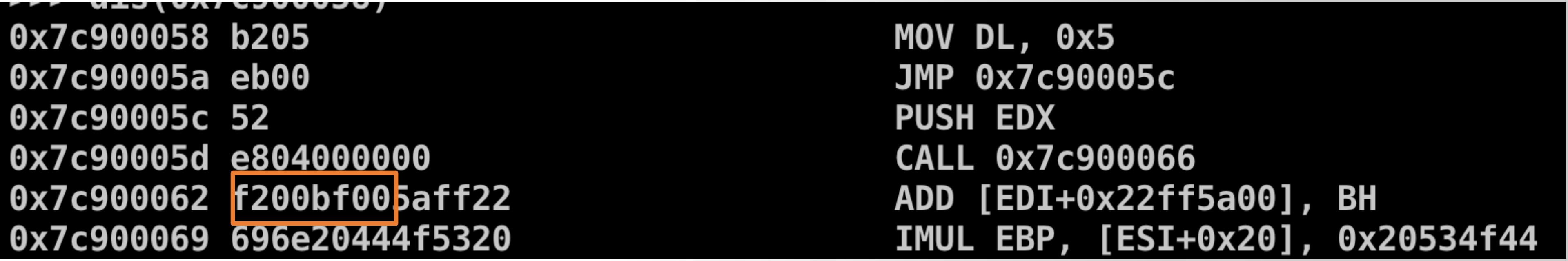
```
*************************************************
Hook mode: Usermode
Hook type: NT Syscall
Process: 940 (svchost.exe)
Victim module: ntdll.dll (0x7c900000 - 0x7c9af000
Function: ZwOpenFile
Hook address: 0x7c90004c
Hooking module: ntdll.dll

Disassembly(0):
0x7c90d580 b874000000       MOV EAX, 0x74
0x7c90d585 ba4c00907c       MOV EDX, 0x7c90004c
0x7c90d58a ffd2             CALL EDX
0x7c90d58c c21800           RET 0x18
0x7c90d58f 90               NOP
0x7c90d590 b875000000       MOV EAX, 0x75
0x7c90d595 ba               DB 0xba
0x7c90d596 0003             ADD [EBX], AL

Disassembly(1):
0x7c90004c b202             MOV DL, 0x2
0x7c90004e eb0c             JMP 0x7c90005c
0x7c900050 b203             MOV DL, 0x3
0x7c900052 eb08             JMP 0x7c90005c
0x7c900054 b204             MOV DL, 0x4
0x7c900056 eb04             JMP 0x7c90005c
0x7c900058 b205             MOV DL, 0x5
0x7c90005a eb00             JMP 0x7c90005c
0x7c90005c 52               PUSH EDX
0x7c90005d e804000000       CALL 0x7c900066
0x7c900062 f2               DB 0xf2
0x7c900063 00               DB 0x0
```



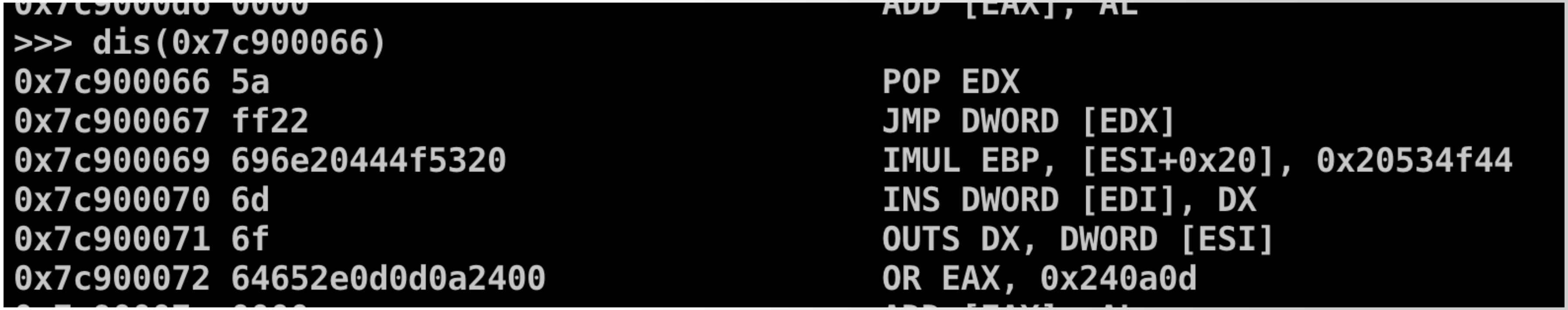
```
vol.py -f stuxnet.vmem apihooks
```

API Hooking

0x00bf00f2



```
>>> dis(0x7c900058)
0x7c900058 b205                         MOV DL, 0x5
0x7c90005a eb00                         JMP 0x7c90005c
0x7c90005c 52                           PUSH EDX
0x7c90005d e804000000                   CALL 0x7c900066
0x7c900062 f200bf005aff22               ADD [EDI+0x22ff5a00], BH
0x7c900069 696e20444f5320               IMUL EBP, [ESI+0x20], 0x20534f44
```



```
0x7c9000d8 0000                         ADD [EAX], AL
>>> dis(0x7c900066)
0x7c900066 5a                           POP EDX
0x7c900067 ff22                         JMP DWORD [EDX]
0x7c900069 696e20444f5320               IMUL EBP, [ESI+0x20], 0x20534f44
0x7c900070 6d                           INS DWORD [EDI], DX
0x7c900071 6f                           OUTS DX, DWORD [ESI]
0x7c900072 64652e0d0d0a2400             OR EAX, 0x240a0d
```

1. When the CALL at 0x7c90005d is executed, its return address (0x7c900062) is pushed onto the stack.
2. The POP EDX instruction at 0x7c900066 then removes that value from the stack and places it in EDX.
3. At 0x7c900067 , EDX is dereferenced and called. So the pointer being dereferenced is stored in 0x7c900062 .

Kernel Callback

- A **callback function** is one which is passed as an argument to another function and is invoked after the completion of the parent function.
  - In other words **callback** is a piece of executable code that is passed as an argument to other code, which is expected to *call back* (execute) the argument at some convenient time.
- Kernel Callback
  - Supported on 64 bit systems
  - Safe for multicore machines
  - Lists of events:
    - Process creation
    - Thread creation
    - System shutdown
    - File system registration
    - PnP(Plug and Play)
    - etc…

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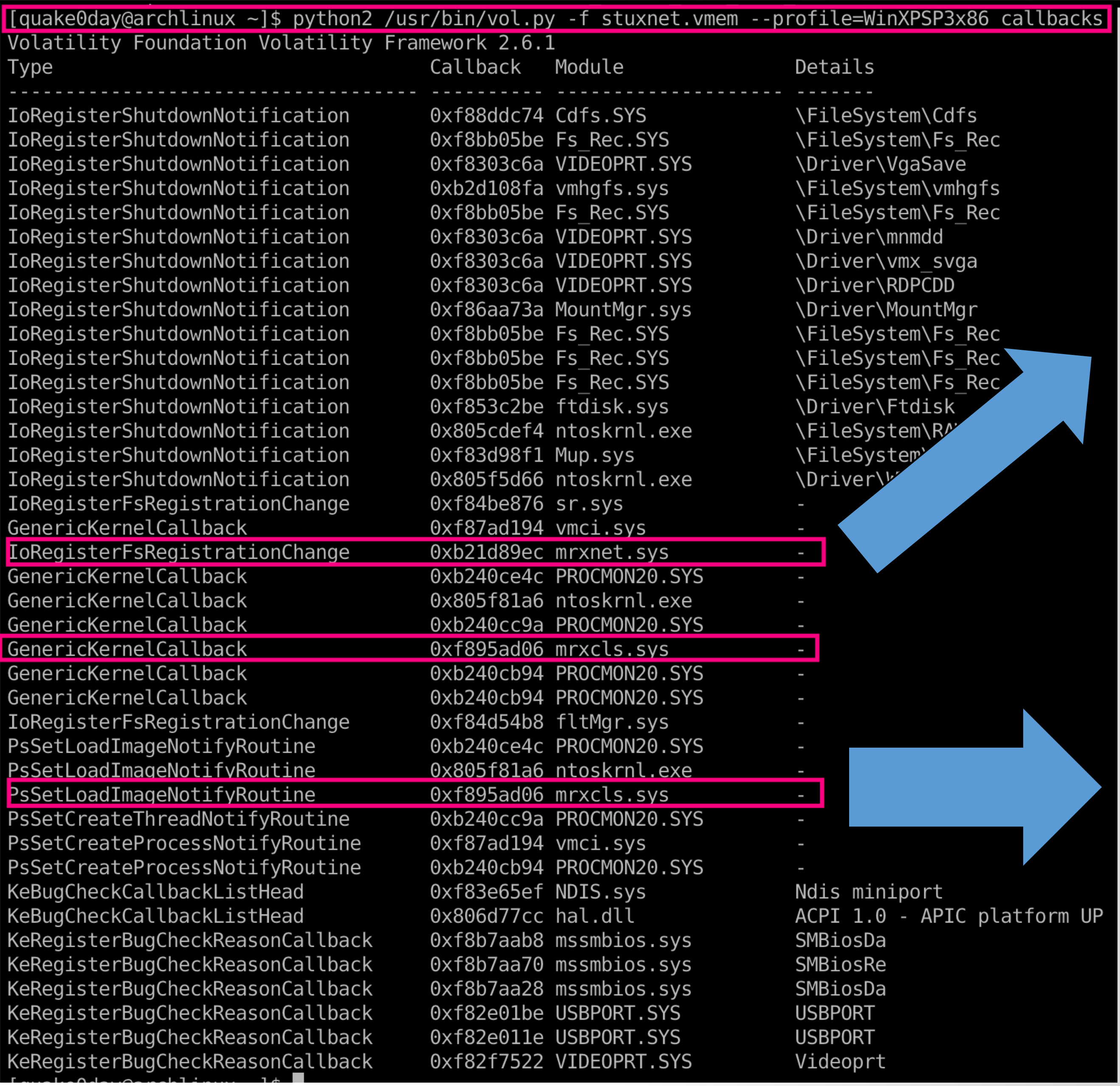

```
[quake0day@archlinux ~]$ python2 /usr/bin/vol.py -f stuxnet.vmem --profile=WinXPSP3x86 callbacks
Volatility Foundation Volatility Framework 2.6.1
Type                                 Callback   Module               Details
------------------------------------ ---------- -------------------- -------
IoRegisterShutdownNotification       0xf88ddc74 Cdfs.SYS             \FileSystem\Cdfs
IoRegisterShutdownNotification       0xf8bb05be Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification       0xf8303c6a VIDEOPRT.SYS         \Driver\VgaSave
IoRegisterShutdownNotification       0xb2d108fa vmhgfs.sys           \FileSystem\vmhgfs
IoRegisterShutdownNotification       0xf8bb05be Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification       0xf8303c6a VIDEOPRT.SYS         \Driver\mnmdd
IoRegisterShutdownNotification       0xf8303c6a VIDEOPRT.SYS         \Driver\vmx_svga
IoRegisterShutdownNotification       0xf8303c6a VIDEOPRT.SYS         \Driver\RDPCDD
IoRegisterShutdownNotification       0xf86aa73a MountMgr.sys         \Driver\MountMgr
IoRegisterShutdownNotification       0xf8bb05be Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification       0xf8bb05be Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification       0xf8bb05be Fs_Rec.SYS           \FileSystem\Fs_Rec
IoRegisterShutdownNotification       0xf853c2be ftdisk.sys           \Driver\Ftdisk
IoRegisterShutdownNotification       0x805cdef4 ntoskrnl.exe         \FileSystem\RA
IoRegisterShutdownNotification       0xf83d98f1 Mup.sys              \FileSystem
IoRegisterShutdownNotification       0x805f5d66 ntoskrnl.exe         \Driver\
IoRegisterFsRegistrationChange       0xf84be876 sr.sys               -
GenericKernelCallback                0xf87ad194 vmci.sys             -
IoRegisterFsRegistrationChange       0xb21d89ec mrxnet.sys           -
GenericKernelCallback                0xb240ce4c PROCMON20.SYS        -
GenericKernelCallback                0x805f81a6 ntoskrnl.exe         -
GenericKernelCallback                0xb240cc9a PROCMON20.SYS        -
GenericKernelCallback                0xf895ad06 mrxcls.sys           -
GenericKernelCallback                0xb240cb94 PROCMON20.SYS        -
GenericKernelCallback                0xb240cb94 PROCMON20.SYS        -
IoRegisterFsRegistrationChange       0xf84d54b8 fltMgr.sys           -
PsSetLoadImageNotifyRoutine          0xb240ce4c PROCMON20.SYS        -
PsSetLoadImageNotifyRoutine          0x805f81a6 ntoskrnl.exe         -
PsSetLoadImageNotifyRoutine          0xf895ad06 mrxcls.sys           -
PsSetCreateThreadNotifyRoutine       0xb240cc9a PROCMON20.SYS        -
PsSetCreateProcessNotifyRoutine      0xf87ad194 vmci.sys             -
PsSetCreateProcessNotifyRoutine      0xb240cb94 PROCMON20.SYS        -
KeBugCheckCallbackListHead           0xf83e65ef NDIS.sys             Ndis miniport
KeBugCheckCallbackListHead           0x806d77cc hal.dll              ACPI 1.0 - APIC platform UP
KeRegisterBugCheckReasonCallback     0xf8b7aab8 mssmbios.sys         SMBiosDa
KeRegisterBugCheckReasonCallback     0xf8b7aa70 mssmbios.sys         SMBiosRe
KeRegisterBugCheckReasonCallback     0xf8b7aa28 mssmbios.sys         SMBiosDa
KeRegisterBugCheckReasonCallback     0xf82e01be USBPORT.SYS          USBPORT
KeRegisterBugCheckReasonCallback     0xf82e011e USBPORT.SYS          USBPORT
KeRegisterBugCheckReasonCallback     0xf82f7522 VIDEOPRT.SYS         Videoprt
[quake0day@archlinux ~]$
```

Now Stuxnet can receive notification when new file system become available – So it can immediately spread or hide files

And is able to inject code into process when they try to load other DLLs.

Q & A

West Chester University