Forensics for System Administrators

Memory Acquisition II

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WP8-T1

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Public

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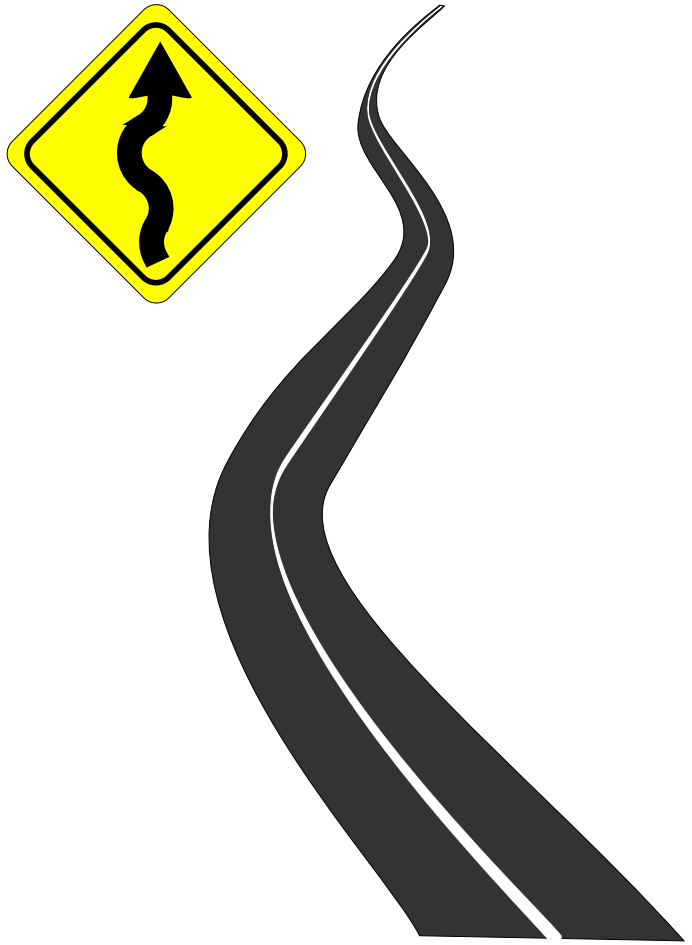
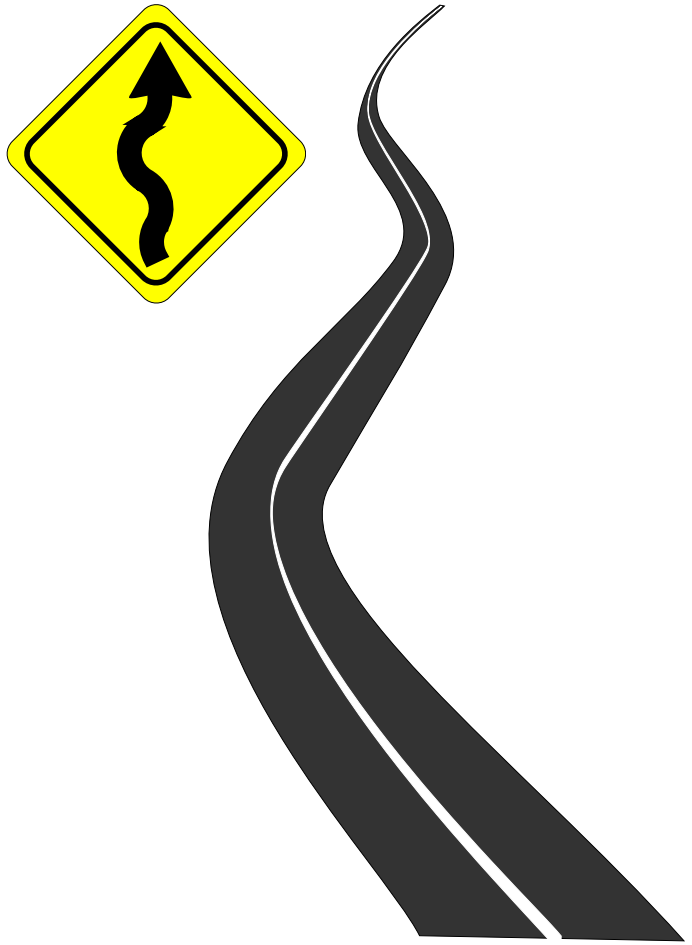
Agenda - Part I



- Technical Basics
  - Virtual vs. Physical Memory
- Main Memory Dumps
  - Simple
  - Kernel Module
- System Crash dumps
  - Linux Kdump
  - Windows crash dumps

Agenda - Part II



- Acquisition of Virtual Machine Memory
  - VMware
  - VirtualBox
  - Linux KVM/QEMU
- Swap & Hibernation
  - Linux Swap files/partitions
  - Windows pagefile, hibernation file
- Single Process Memory Dumps
  - Corefiles
  - Process Explorer

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Virtual Machine Memory

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Dump from Virtual Machine Host

- We will assume that one or more guests are compromised, but not the host
  - For memory dumps of compromised hosts - see Part I
  - Analysing compromised VM hosts is yet another story
- Pro
  - Suspend VM while dumping memory - state doesn't change during dump
  - No way for the rootkit on the guest to interfere or notice
- Still need profiles/symbol tables, etc. of the guest for later analysis

VMware

- **`vmss2core`** tool
  - Input: Suspend (`.vmss`), snapshot (`.vmsn`), and full memory (`.vmem`) files
  - Output: core dump files for typical OS debuggers
    - WinDbg, Gdb, Solaris MDB, Mac OS X
- Howto
  - Suspend the virtual machine
  - Copy the .vmss or .vmsn file from the machines directory (need to access the host)
    - WinDbg: `vmss2core -W` *`vmname`*`.vmsn`
    - Linux: `vmss2core -N` *`vmname`*`.vmsn`
    - Mac OS X: `vmss2core -X64` *`vmname`*`.vmsn`

VMware Workstation & ESXi

Live Demo

- Collection
  - Suspend the virtual machine
  - Copy the .vmss or .vmsn file from the machines directory
    - Access to the host OS required
- Processing: **`vmss2core`** tool
  - Input: Suspend (`.vmss`), snapshot (`.vmsn`), and full memory (`.vmem`) files
    - Windows: `vmss2core -W` *`vmname`*`.vmsn`
    - Linux: `vmss2core -N` *`vmname`*`.vmsn`
    - Mac OS X: `vmss2core -X64` *`vmname`*`.vmsn`
  - Output: core dump files for typical OS debuggers
    - WinDbg, Gdb, Solaris MDB, Mac OS X

VirtualBox

- Collection
  - Needs GNU binutils (for objdump)

```
$ vboxmanage debugvm "Name" dumpvmcore --filename forensic-img.elf
```

- Processing

```
$ objdump -h forensic-img.elf|egrep -w "(Idx|load1)"
Idx Name    Size      VMA                 LMA                 File off  Algn
  1 load1   40000000  0000000000000000  0000000000000000  00000720  2**0
```

```
$ size=0x40000000; off=0x720; head -c $(($size+$off)) forensic-img.elf |
tail -c +$(($off+1)) > forensic-img.raw

$ size=0x40000000; off=0x720; dd if=forensic-img.elf of=forensic-img.raw
bs=1 skip=$(($off)) count=$((0x$size))
```

- The raw image can be analysed with forensic tools

KVM/Qemu

- Collection

```
# virsh dump domain corefilepath
```

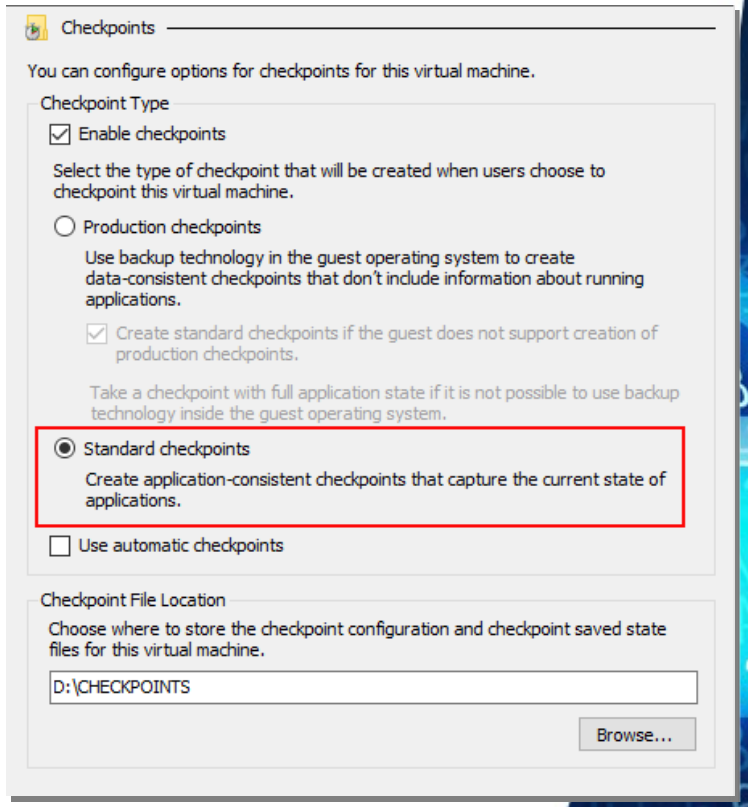
  - ***domain***: domain Name of the virtual guest
  - ***corefilepath***: path of the dump file on the host
- Processing
  - Can be used like a crash dump of the guest operating system
  - Qemu core dump format for Qemu backed VMs can be used directly in volatility

Hyper-V

- Ensure the VM has checkpoints enabled,
  - Configured as Standard checkpoints
- Taking a Checkpoint
  - Hyper-V Manager (GUI)
    - VM → Checkpoint
  - PowerShell (CLI)

```
PS > Checkpoint-VM -Name VMName
```

  - Hyper-V Memory checkpoints have `.vmrs` extension
- Processing steps needed?



Swap Space & Hibernation

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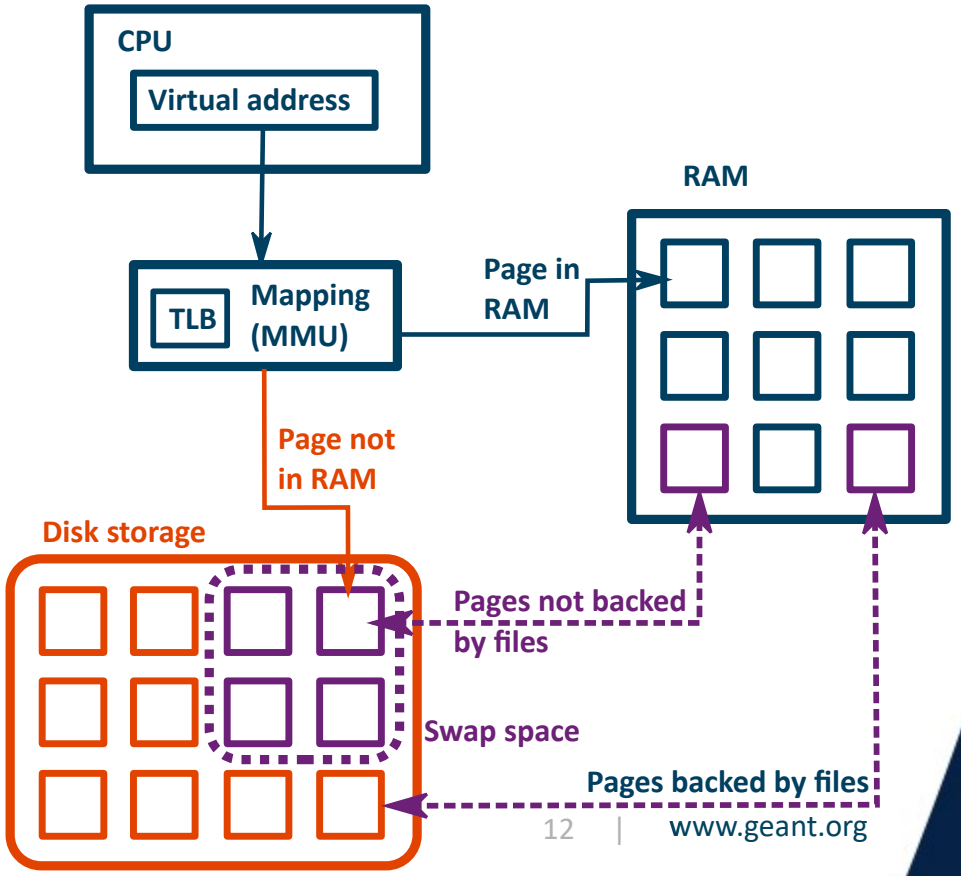
Swap Space

- When space in RAM gets filled up, pages are "*paged out*" to backing storage
- When needed (page fault), pages are "*paged in*" back to RAM
- Can be a (disk) partition
  - Linux/Solaris: Type 82
  - BSI: Type B8
- Or swap file
  - Windows:

    %SystemRoot%\pagefile.sys

    %SystemRoot%\swapfile.sys



Linux Swap

- Swap partition can be imaged with forensic imaging tools
  - I.e. **dd**, see next webinar
- Swap files can be copied like normal files
- Both best done post-mortem
- Search for forensic artefacts
  - Passwords, URLs, encryption keys, etc.
    - `strings`
    - `yara`
    - Hex editor (check performance with gigabyte-sized files)
    - `swap_digger`

Windows Swap Files

- Two files
  - **`%SystemRoot%\pagefile.sys`** and **`%SystemRoot%\swapfile.sys`**
  - Latter is used only for Universal Windows Platform (UWP) apps
    - Apps will be completely swapped out to this file,
    - `pagefile.sys` is not used for them
  - Hidden “protected operating system file”
  - Like Linux swap, they don’t have full memory copies
- Paging needs not to be disabled (enabled by default)
- Assert that pagefile is not zeroed out on shutdown

```
HKLM\SYSTEM\CurrentControlSet\Control\Session Manager\Memory
Management\ClearPageFileAtShutdown ≠ 1
```

Windows Swap File Collection

- Collection
  - Locked by Windows OS, cannot be accessed from user space
  - To copy
    - Boot into a live CD/stick, or
    - Mount the physical disk on another system, or
    - Extract the file(s) from a forensic disk image
- Processing
  - `strings`
  - `yara`
  - Hex editor (check performance with gigabyte-sized files)

Windows Hibernation File

- *Hibernation* = “suspend to disk” (*Sleep* = “suspend to RAM”)
  - Location: `%SystemRoot%\hiberfil.sys` (can be configured)
  - Hidden “protected operating system file”
  - Compressed with modified LZ77 algorithm, called “Xpress”
  - Contains kernel session, device drivers, application data
    - Since Windows 8, application data is stored in `swapfile.sys`
  - Will be encrypted by BitLocker (or other FDE), if used
- To hibernate
  - Activate hibernation: `powercfg.exe /hibernate on`
  - Hibernate: `shutdown /h`

Windows Hibernation File Collection

- Collection
  - Copy file through forensic disk imaging (see next webinar)
- Processing
  - volatility

```
vol.py imagecopy -f hiberfil.sys -O hiber.img –-profile=WinXXXX
```

    - WinXXXX: Need correct Windows profile
  - hibr2bin

```
hibr2bin /I c:\hiberfil.sys /o z:\hiber.img
```

Single Process Memory Dumps

Single Process Dumps

- Taking the image of a whole system sometimes may be too much
- Need only to investigate one (or a few) process(es)
- Lack of privileges to dump a whole system, i.e. just ordinary users
- Not allowed to take an image of the whole system, for confidentiality or privacy reasons

Linux Processes: /proc/*$pid*/mem

- Naive approach: `cat /proc/$pid/mem`

```
:~> echo $$
21349
:~> cat /proc/21349/mem > testmemdump
cat: /proc/21349/mem: Input/output error
:~> ls -l /proc/21349/mem
-rw------- 1 moeller users 0 Nov 25 11:06 /proc/21349/mem
:~> id
uid=1000(moeller) gid=100(users) …
```

- What happened?
  - `/proc/$pid/mem` contains only the process' mapped pages
  - Accessing an unmapped page yields EIO (I/O error)

Linux Processes: Copy with /proc/$pid/maps

- How to make sure that only mapped pages are dumped?
- Utilize `/proc/$pid/maps` to know the mapped regions

```
:~> cat /proc/self/maps
55d00e807000-55d00e809000 r--p 000f1000 00:2f 2038838      /bin/bash
55d00e809000-55d00e80d000 rw-p 000f3000 00:2f 2038838      /bin/bash
55d00e80d000-55d00e81b000 rw-p 00000000 00:00 0
55d00f325000-55d00f8d2000 rw-p 00000000 00:00 0            [heap]
7fb0163e2000-7fb016408000 r-xp 00000000 00:2f 3055433      /lib64/libtinfo.so.6.1
…
7fb017043000-7fb017044000 r--p 00025000 00:2f 3033470      /lib64/ld-2.26.so
7fb017044000-7fb017045000 rw-p 00026000 00:2f 3033470      /lib64/ld-2.26.so
7fb017045000-7fb017046000 rw-p 00000000 00:00 0
7fff9af16000-7fff9af37000 rw-p 00000000 00:00 0            [stack]
7fff9af8a000-7fff9af8e000 r--p 00000000 00:00 0            [vvar]
7fff9af8e000-7fff9af90000 r-xp 00000000 00:00 0            [vdso]
ffffffffff600000-ffffffffff601000 --xp 00000000 00:00 0    [vsyscall]
```

Linux Processes: Dump Tools

- Several Scripts and Programs for that
  - Python: memdump.py (https://gist.github.com/Dbof/b9244cfc607cf2d33438826bee6f5056)
  - Shell: See next page
- GDB/gcore
- Sysinternals Procdump-for-linux
  - `https://github.com/Sysinternals/ProcDump-for-Linux`
- Manually with `kill` (and some more stuff)

Linux Process Dump from Shell

- `dd if=/proc/$pid/mem of=/path/to/dump bs=1 skip=$((0x$col1)) count=$((0x$end - 0x$start))`
  - If getting seek errors, use method below
    - May be ignored though
- `xxd -s 0x$start -l $((0x$end - 0x$start)) /proc/$pid/mem`
  - Convert back to binary with `xxd -r` (or use dd in the first place)
- ***$start/$end***: Column 1/2 from process memory map file
- Practical tips
  - Avoid `$$` or `/proc/self` expansion - may evaluate to the id of the process doing the dump, not the process to be dumped
  - Use `kill -SIGSTOP` to freeze process while dumping, unfreeze with `kill -SIGCONT`

Linux Processes: Coredumps

- GDB/gcore
  - `gcore -a -o $prefix $pid`
  - File will be named *`$prefix`*`.$pid`, otherwise `gcore.`*`$pid`*
  - May not work if process blocks `ptrace`
  - From within a gdb: `generate-core-file`
- kill

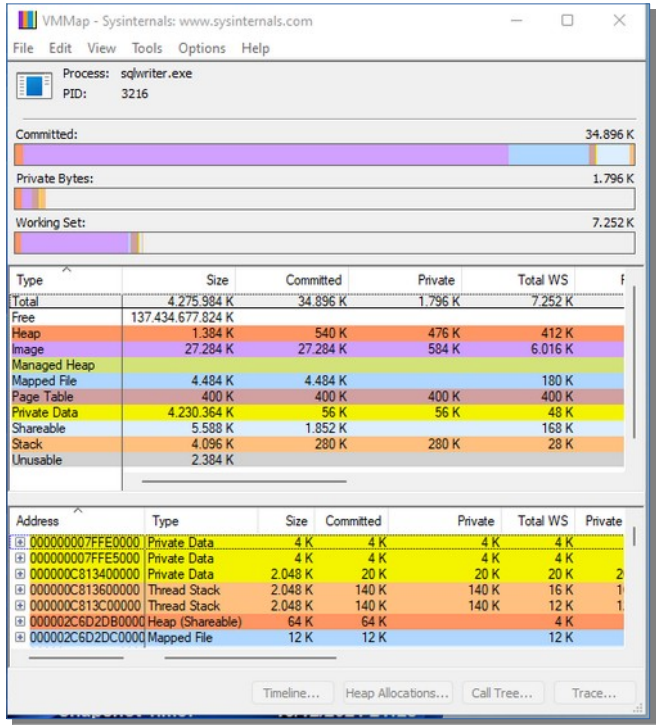
```
# ulimit -S -c unlimited                # unset soft limit on core dumps
# cat /proc/sys/kernel/core_pattern # where is dump is written to
# kill -SIGSEGV $pid                    # see signal(7)
```

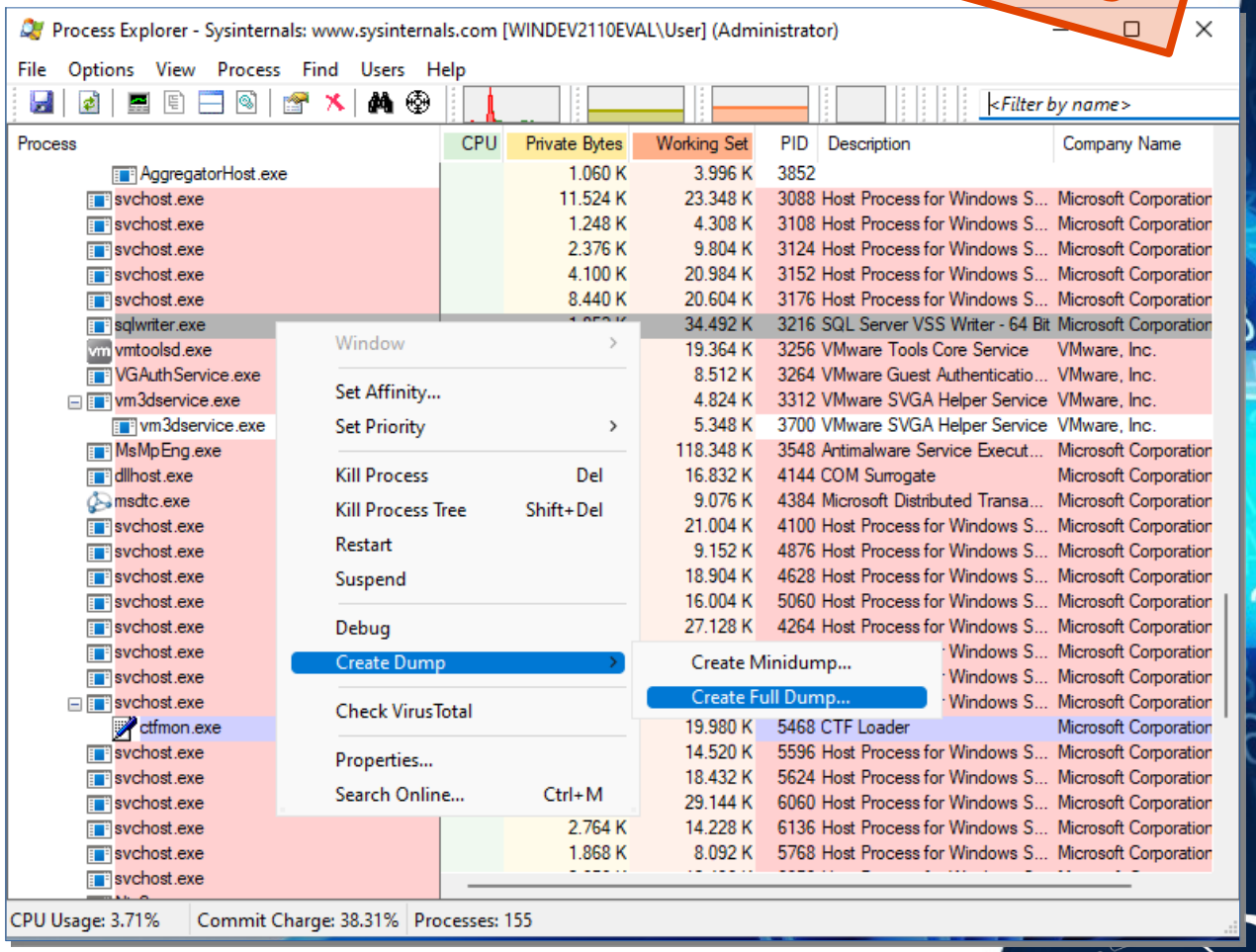
  - Does not work if process ignores or handles signals
  - Does not work with setuid/gid binaries
    - Unless `kernel_suid_dumpable = 2` (or 3) **(Beware ☠)**

Windows Processes: procexp

- Sysinternals ***Process Explorer*** (GUI)
  - Use ***full dump***
  - See also: ***VMMap***

Live Demo





Windows Processes: procdump

Live Demo

- Sysinternals ***Procdump*** (CLI)

```
PS> procdump.exe -ma $pid
PS> procdump.exe -ma $process_name
```

- Can specify conditions on when to dump
  - In case process is for unresponsive, crashing or consuming excessive resources
- Also possible to take multiple dumps several seconds apart
  - For monitoring resource usage or changes in processes internal state

Wrapping Up

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What have you learned?

- Memory dumps can be taken from VMs easily
  - However, some processing is necessary for forensic analysis
  - Big plus: No access to guest OS needed
- Hibernation file yields full memory contents
- Swap files/partitions do not
  - But some useful information can still be gained
- Single process memory dumps are easy too
  - Procdump can be used on both Linux and Windows

Thank you

Any questions?

Next Webinar: ***Persistent Storage Acquisition I***

December 18th, 2021

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  - https://gist.github.com/ssnkhan/60a2ab79480bd966876aac5d2c6c2e68
- Hibernation file
  - Hiber2bin: `https://github.com/comaeio/Hibr2Bin`
  - Volatility Hibernation file address space `https://github.com/volatilityfoundation/volatility/wiki/Hiber-Address-Space`
  - Windows hibernation file for fun 'n' profit, `https://www.blackhat.com/presentations/bh-usa-08/Suiche/BH_US_08_Suiche_Windows_hibernation.pdf`
- Linux swap_digger: `https://github.com/sevagas/swap_digger`

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References: Images und Testcases

- Computer Forensic Reference Data Sets (CFReDS)
  `http://www.cfreds.nist.gov/`
- Digital Forensics Tool Testing Images
  `http://dftt.sourceforge.net/`
- Digital Forensics Research Workshop (DFRWS)
  `http://www.dfrws.org/`
- Honeynet Project Challenges
  `https://www.honeynet.org/challenges`

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- Volatility LiME: https://github.com/504ensicsLabs/LiME
  - Schlafwandlers kcore_dump https://schlafwandler.github.io/posts/dumping-/proc/kcore/
- Hal Pomeranz automation script for AVML/LiME: https://github.com/halpomeranz/lmg
- Velocidex Pmem Suite (lin|win|osx)pmem: https://winpmem.velocidex.com/
- Moonsols mdd (v 1.3, 2013, for very old Windows versions): https://sourceforge.net/projects/mdd/

Sample Forensic Distributions

- SIFT (SAS Investigative Forensic Toolkit): https://www.sans.org/tools/sift-workstation/
- CAINE (Computer Aided Investigative Environment): https://www.caine-live.net/
- GRML Forensic: https://grml-forensic.org/
- ALT Linux Rescue: https://en.altlinux.org/Rescue
- BlackArch: https://blackarch.org/
- BackBox: https://www.backbox.org/
- KALI (formerly Backtrack): https://www.kali.org/downloads/
- Matriux: http://www.matriux.com/
- Safe Boot Disk (Windows based): https://www.forensicsoft.com/help/SAFE_Boot1-1/

References: Standards

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