

SANS DFIR

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General Approach to Document Analysis

1. Examine the document for anomalies, such as risky tags, scripts, and embedded artifacts.
2. Locate embedded code, such as shellcode, macros, JavaScript, or other suspicious objects.
3. Extract suspicious code or objects from the file.
4. If relevant, deobfuscate and examine macros, JavaScript, or other embedded code.
5. If relevant, emulate, disassemble and/or debug shellcode that you extracted from the document.
6. Understand the next steps in the infection chain.

Microsoft Office Format Notes

Binary Microsoft Office document files (.doc, .xls, etc.) use the OLE2 (a.k.a. Structured Storage) format.

SRP streams in OLE2 documents sometimes store a cached version of earlier VBA macro code.

OOXML document files (.docx, .xslm, etc.) supported by Microsoft Office are compressed zip archives.

VBA macros in OOXML documents are stored inside an OLE2 binary file, which is within the zip archive.

Excel supports XLM macros that are embedded as formulas in sheets without the OLE2 binary file.

RTF documents don't support macros but can contain malicious embedded files and objects.

Useful MS Office File Analysis Commands

zipdump.py file.pptx Examine contents of OOXML file *file.pptx*.

zipdump.py file.pptx -s 3 -d Extract file with index 3 from *file.pptx* to STDOUT.

olevba.py file.xlsm Locate and extract macros from *file.xlsm*.

oledump.py file.xls -s 3 -v Extract VBA source code from stream 3 in *file.xls*.

xmldump.py pretty Format XML file supplied via STDIN for easier analysis.

oledump.py file.xls -p plugin_http_heuristics Find obfuscated URLs in *file.xls* macros.

vmonkey file.doc Emulate the execution of macros in *file.doc* to analyze them.

evilclippy -uu file.ppt Remove the password prompt from macros in *file.ppt*.

msoffcrypted-tool infile.docm outfile.docm -p Decrypt *outfile.docm* using specified password to create *outfile.docm*.

pcodecmp file.doc Disassemble VBA-stomped p-code macro from *file.doc*.

pcode2code file.doc Decompile VBA-stomped p-code macro from *file.doc*.

rtfobj.py file.rtf Extract objects embedded into RTF *file.rtf*.

rtfdump.py file.rtf List groups and structure of RTF file *file.rtf*.

rtfdump.py file.rtf -o Examine objects in RTF file *file.rtf*.

rtfdump.py file.rtf file.doc Extract hex contents from group in RTF file *file.rtf*.

xlmdeobfuscator --file file.xlsm Deobfuscate XLM (Excel 4) macros in *file.xlsm*.

Risky PDF Keywords

/OpenAction and /AA specify the script or action to run automatically.

/JavaScript, /JS, /AcroForm, and /XFA can specify JavaScript to run.

/URI accesses a URL, perhaps for phishing.

/SubmitForm and /GoToR can send data to URL.

/ObjStm can hide objects inside an object stream.

/XObject can embed an image for phishing.

Be mindful of obfuscation with hex codes, such as /JavaScript vs. /J#61vaScript. (See examples)

Useful PDF File Analysis Commands

pdfid.py file.pdf -n Display risky keywords present in file *file.pdf*.

pdf-parser.py file.pdf -a Show stats about keywords. Add "-o" to include object streams.

pdf-parser.py file.pdf -o id Display contents of object id. Add "-d" to dump object's stream.

pdf-parser.py file.pdf -r id Display objects that reference object id.

qpdf --password=pass --decrypt infile.pdf outfile.pdf Decrypt *infile.pdf* using password *pass* to create *outfile.pdf*.

Shellcode and Other Analysis Commands

xorsearch -W -d 3 file.bin Locate shellcode patterns inside the binary file *file.bin*.

sctdbg /f file.bin Emulate execution of shellcode in *file.bin*. Use "/off" to specify offset.

runsc32 -f file.bin -n Execute shellcode in file *file.bin* to observe behavior in an isolated lab.

base64dump.py file.txt List Base64-encoded strings present in file *file.txt*.

numbers-to-string.py file Convert numbers that represent characters in *file* to a string.

Additional Document Analysis Tools

SpiderMonkey, cscript, and [box-js](#) help deobfuscate JavaScript that you extract from document files.

Use the debugger built into Microsoft Office to deobfuscate macros in an isolated lab.

Use [AMSIScriptContentRetrieval.ps1](#) to observe Microsoft Office execute macros in an isolated lab.

Some [automated analysis sandboxes](#) can analyze aspects of malicious document files.

REMnux distro includes many of the free document analysis tools mentioned above.

Authored by Lenny Zeltser ([zeltser.com](#)) with feedback from [Pedro Bueno](#) and [Didier Stevens](#). Malicious document analysis and related topics are covered in the SANS Institute course [FOR610: Reverse-Engineering Malware](#), which they've co-authored. [Creative Commons v3 "Attribution" License](#) for this cheat sheet version 4.1. More at [zeltser.com/cheat-sheets](#).

Getting Started with REMnux

1. Get REMnux as a virtual appliance, install the distro on a dedicated system, or add it to an existing one.
2. Review REMnux documentation at docs.remnux.org.
3. Keep your system up to date by periodically running “remnux upgrade” and “remnux update”.
4. Become familiar with REMnux malware analysis tools available as Docker images.
5. Know default logon credentials: remnux/malware

General Commands on REMnux

Shut down the system **shutdown**
 Reboot the system **reboot**
 Switch to a root shell **sudo -s**
 Renew DHCP lease **renew-dhcp**
 See current IP address..... **myip**
 Edit a text file..... **code file**
 View an image file..... **feh file**
 Start web server **httpd start**
 Start SSH server..... **sshd start**

Analyze Windows Executables

Static Properties: manalyze, peframe, pefile, exiftool, clamscan, pescan, portex, bearcommander, pecheck
Strings and Deobfuscation: pestr, bbrack, brxor.py, base64dump, xorsearch, flastreings, floss, cyberchef
Code Emulation: binee, capa, vivbin
Disassemble/Decompile: ghidra, [cutter](#), objdump, r2
Unpacking: bytelist, [de4dot](#), upx

Reverse-Engineer Linux Binaries

Static Properties: trid, exiftool, pyew, [readelf.py](#)
Disassemble/Decompile: ghidra, [cutter](#), objdump, r2
Debugging: edb, gdb
Behavior Analysis: ltrace, strace, frida, sysdig, [unhide](#)

Investigate Other Forms of Malicious Code

Android: apktool, droidlysis, [androgui.py](#), baksmali, [dex2jar](#)
Java: cfr, procyon, jad, jd-gui, [idx_parser.py](#)
Python: [pyinstxtractor.py](#), pycdc
JavaScript: js, js-file, [objects.js](#), [box-js](#)
Shellcode: [shellcode2exe.bat](#), scdbg, xorsearch
PowerShell: pwsh, [base64dump](#)
Flash: swfdump, [flare](#), flasm, [swf_mastah.py](#), xxxswf

Examine Suspicious Documents

Microsoft Office Files: vmonkey, pcodedmp, olevba, xlmdeobfuscator, [oledump.py](#), msoffice-crypt, ssview
RTF Files: rtfobj, rtfdump
Email Messages: emldump, msgconvert
PDF Files: pdfid, pdfparser, pdfextract, pdfdecrypt, peepdf, pdftk, pdfresurrect, qpdf, pdfobjflow
General: [base64dump](#), [tesseract](#), exiftool

Explore Network Interactions

Monitoring: burpsuite, networkminer, polarproxy, mitmproxy, wireshark, tshark, ngrep, tcpextract
Connecting: [thug](#), nc, [tor](#), wget, [curl](#), irc, ssh, [unfurl](#)
Services: fakedns, fakemail, [accept-all-ips](#), nc, [httpd](#), inetsim, fakenet, sshd, myip

Gather and Analyze Data

Network: [Automater.py](#), shodan, [ipwhois_cli.py](#), pdnstool
Hashes: [malwoverview.py](#), nsrlookup, [Automater.py](#), vt, [virustotal-search.py](#)
Files: yara, [scalpel](#), bulk_extractor, ioc_writer
Other: dextray, [viper](#), [time-decode.py](#)

Other Analysis Tasks

Memory Forensics: vol.py, vol3, [linux_mem_diff.py](#), aeskeyfind, rsakeyfind, bulk_extractor
File Editing: wxHexEditor, scite, [code](#), xpdf, [convert](#)
File Extraction: 7z, [unzip](#), unrar, cabextract

Use Docker Containers for Analysis

Thug Honeyclient: remnux/thug
JSDetox JavaScript Analysis: remnux/jsdetox
Rekall Memory Forensics: remnux/recall
RetDec Decompiler: remnux/retdec
Radare2 Reversing Framework: remnux/radare2
Ciphey Automatic Decrypter: remnux/ciphey
Viper Binary Analysis Framework: remnux/viper
REMnux in a Container: remnux/remnux-distro

Interact with Docker Images

List local images **docker images**
 Update local image..... **docker pull image**
 Delete local image..... **docker rmi imageid**
 Delete unused resources.... **docker system prune**
 Open a shell inside a **docker run --rm -it image bash**
 transient container
 Map a local TCP port 80 to ... **docker run --rm -it -p 80:80**
 container's port 80 **image bash**
 Map your current directory... **docker run --rm -it -v .:dir**
 into container **image bash**

Overview of the Code Analysis Process

1. Examine static properties of the Windows executable for initial assessment and triage.
2. Identify strings and API calls that highlight the program's suspicious or malicious capabilities.
3. Perform automated and manual behavioral analysis to gather additional details.
4. Emulate code execution to identify characteristics and areas for further analysis.
5. Use a disassembler and decompiler to statically examine code related to risky strings and APIs.
6. Use a debugger for dynamic analysis to examine how risky strings and API calls are used.
7. If appropriate, unpack the code and its artifacts.
8. As your understanding of the code increases, add comments, labels; rename functions, variables.
9. Progress to examine the code that references or depends upon the code you've already analyzed.
10. Repeat steps 5–9 above as necessary (the order may vary) until analysis objectives are met.

Common 32-Bit Registers and Uses

EAX	Addition, multiplication, function results
ECX	Counter; used by LOOP and others
EBP	Baseline/frame pointer for referencing function arguments (EBP+value) and local variables (EBP-value)
ESP	Points to the current "top" of the stack; changes via PUSH, POP, and others
EIP	Instruction pointer; points to the next instruction; shellcode gets it via call/pop
EFLAGS	Contains flags that store outcomes of computations (e.g., Zero and Carry flags)
FS	F segment register; FS[0] points to SEH chain, FS[0x30] points to the PEB.

Common x86 Assembly Instructions

mov EAX, 0xB8	Put the value 0xB8 in EAX.
push EAX	Put EAX contents on the stack.
pop EAX	Remove contents from top of the stack and put them in EAX.
lea EAX, [EBP-4]	Put the address of variable EBP-4 in EAX.
call EAX	Call the function whose address resides in the EAX register.
add esp, 8	Increase ESP by 8 to shrink the stack by two 4-byte arguments.
sub esp, 0x54	Shift ESP by 0x54 to make room on the stack for local variable(s).
xor EAX, EAX	Set EAX contents to zero.
test EAX, EAX	Check whether EAX contains zero, set the appropriate EFLAGS bits.
cmp EAX, 0xB8	Compare EAX to 0xB8, set the appropriate EFLAGS bits.

Understanding 64-Bit Registers

EAX→RAX, ECX→RCX, EBX→RBX, ESP→RSP, EIP→RIP

Additional 64-bit registers are R8–R15.

RSP is often used to access stack arguments and local variables, instead of EBP.

||||| R8 (64 bits)
 _____ ||||| R8D (32 bits)
 _____ ||||| R8W (16 bits)
 _____ ||||| R8B (8 bits)

Passing Parameters to Functions

arg0	[EBP+8] on 32-bit, RCX on 64-bit
arg1	[EBP+0xC] on 32-bit, RDX on 64-bit
arg2	[EBP+0x10] on 32-bit, R8 on 64-bit
arg3	[EBP+0x14] on 32-bit, R9 on 64-bit

Decoding Conditional Jumps

JA / JG	Jump if above/jump if greater.
JB / JL	Jump if below/jump if less.
JE / JZ	Jump if equal; same as jump if zero.
JNE / JNZ	Jump if not equal; same as jump if not zero.
JGE / JNL	Jump if greater or equal; same as jump if not less.

Some Risky Windows API Calls

Code injection: CreateRemoteThread, OpenProcess, VirtualAllocEx, WriteProcessMemory, EnumProcesses

Dynamic DLL loading: LoadLibrary, GetProcAddress

Memory scraping: CreateToolhelp32Snapshot, OpenProcess, ReadProcessMemory, EnumProcesses

Data stealing: GetClipboardData, GetWindowText

Keylogging: GetAsyncKeyState, SetWindowsHookEx

Embedded resources: FindResource, LockResource

Unpacking/self-injection: VirtualAlloc, VirtualProtect

Query artifacts: CreateMutex, CreateFile, FindWindow, GetModuleHandle, RegOpenKeyEx

Execute a program: WinExec, ShellExecute, CreateProcess

Web interactions: InternetOpen, HttpOpenRequest, HttpSendRequest, InternetReadFile

Additional Code Analysis Tips

Be patient but persistent; focus on small, manageable code areas and expand from there.

Use dynamic code analysis (debugging) for code that's too difficult to understand statically.

Look at jumps and calls to assess how the specimen flows from "interesting" code block to the other.

If code analysis is taking too long, consider whether behavioral or memory analysis will achieve the goals.

When looking for API calls, know the official API names and the associated native APIs (Nt, Zw, Rtl).

Overview of the Malware Analysis Process

1. Use [automated analysis sandbox](#) tools for an initial assessment of the suspicious file.
2. Set up a [controlled, isolated laboratory](#) in which to examine the malware specimen.
3. Examine static properties and meta-data of the specimen for triage and early theories.
4. Emulate code execution to identify malicious capabilities and contemplate next steps.
5. Perform behavioral analysis to examine the specimen's interactions with its environment.
6. Analyze relevant aspects of the code statically with a disassembler and decompiler.
7. Perform dynamic code analysis to understand the more difficult aspects of the code.
8. If necessary, unpack the specimen.
9. Repeat steps 4-8 above as necessary (the order may vary) until analysis objectives are met.
10. Augment your analysis using other methods, such as memory forensics and threat intel.
11. [Document findings](#), save analysis artifacts and clean up the laboratory for future analysis.

Behavioral Analysis

Be ready to revert to good state via virtualization snapshots, [Clonezilla](#), [dd](#), [FOG](#), [PXE booting](#), etc.

Monitor local interactions ([Process Explorer](#), [Process Monitor](#), [ProcDOT](#), [Noriben](#)).

Detect major local changes ([RegShot](#), [Autoruns](#)).

Monitor network interactions ([Wireshark](#), [Fiddler](#)).

Redirect network traffic ([fakedns](#), [accept-all-ips](#)).

Activate services ([INetSim](#) or actual services) requested by malware and reinfect the system.

Adjust the runtime environment for the specimen as it requests additional local or network resources.

Ghidra for Static Code Analysis

- Go to specific destination **g**
- Show references to instruction **Ctrl+Shift+f**
- Insert a comment **;**
- Follow jump or call **Enter**
- Return to previous location **Alt+Left**
- Go to next location **Alt+Right**
- Undo. **Ctrl+z**
- Define data type **t**
- Add a bookmark **Ctrl+d**
- Text search **Ctrl+Shift+e**
- Add or edit a label **l**
- Disassemble values **d**

x64dbg/x32dbg for Dynamic Code Analysis

- Run the code **F9**
- Step into/over instruction **F7/F8**
- Execute until selected instruction **F4**
- Execute until the next return **Ctrl+F9**
- Show previous/next executed instruction. **-/+**
- Return to previous view *****
- Go to specific expression **Ctrl+g**
- Insert comment/label **;/:**
- Show current function as a graph **g**
- Find specific pattern **Ctrl+b**
- Set software breakpoint on specific instruction .. **Select instruction » F2**
- Set software breakpoint on API **Go to Command prompt » SetBPX API Name**
- Highlight all occurrences of the keyword **h » Click on keyword in disassembler**
- Assemble instruction in place of selected one .. **Select instruction » Spacebar**
- Edit data in memory or instruction opcode ... **Select data or instruction » Ctrl+e**
- Extract API call references. **Right-click in disassembler » Search for » Current module » Intermodular calls**

Unpacking Malicious Code

Determine whether the specimen is packed by using [Detect It Easy](#), [Exeinfo PE](#), [Bytehist](#), [peframe](#), etc.

To try unpacking the specimen quickly, infect the lab system and dump from memory using [Scylla](#).

For more precision, find the Original Entry Point (OEP) in a debugger and dump with [OllyDumpEx](#).

To find the OEP, anticipate the condition close to the end of the unpacker and set the breakpoint.

Try setting a memory breakpoint on the stack in the unpacker's beginning to catch it during cleanup.

To get closer to the OEP, set breakpoints on APIs such as [LoadLibrary](#), [VirtualAlloc](#), etc.

To intercept process injection set breakpoints on [VirtualAllocEx](#), [WriteProcessMemory](#), etc.

If cannot dump cleanly, examine the packed specimen via dynamic code analysis while it runs.

Rebuild imports and other aspects of the dumped file using [Scylla](#), [Imports Fixer](#), and [pe_unmapper](#).

Bypassing Other Analysis Defenses

Decode obfuscated strings statically using [FLOSS](#), [xorsearch](#), [Balbuzard](#), etc.

Decode data in a debugger by setting a breakpoint after the decoding function and examining results.

Conceal [x64dbg/x32dbg](#) via the [ScyllaHide](#) plugin.

To disable anti-analysis functionality, locate and patch the defensive code using a debugger.

Look out for tricky jumps via [TLS](#), [SEH](#), [RET](#), [CALL](#), etc. when stepping through the code in a debugger.

If analyzing shellcode, use [scdbg](#) and [runsc](#).

Disable ASLR via [setdllcharacteristics](#), [CFF Explorer](#).

Object Header (obj_phys_t)

Offset	Size (in bytes)	Field	Notes
0	8	o_cksum	Fletcher 64 Checksum
8	8	o_oid	Object ID
16	8	o_xid	Transaction ID
24	2	o_type.type	Object Type
26	2	o_type.flags	Object Flags
28	4	o_subtype	Object Subtype

Object Type (Hex)	Object Type (Dec)	Object Type/Subtype
0x0000	0	None
0x0100	1	Container Super Block
0x0200	2	B-Tree
0x0300	3	B-Tree Node
0x0500	5	Spaceman
0x0B00	11	Object Map (OMAP)
0x0D00	13	File System (Volume Super Block)
0x0E00	14	File System Tree

Container Super Block (nx_superblock_t)

Offset	Size (in bytes)	Field	Notes
32	4	magic "NXSB"	Container Magic Number: 0x4E585342 = "NXSB"
36	4	nx_block_size	Block Size (ie: 4096)
40	8	nx_block_count	Block Count (Block Count*Block Size = Container Size in Bytes)
48	8	nx_features	Features
56	8	nx_read_only_compatible_features	Read-only Compatible Features
64	8	nx_incomptable_features	Incompatible Features
72	16	nx_uuid	Container UUID (diskutil info /dev/disk#)
88	8	nx_next_oid	Next Object ID (OID)
96	8	nx_next_xid	Next Transaction ID (XID)
104	4	nx_xp_desc_blocks	Blocks used by Checkpoint Descriptor Area
108	4	nx_xp_data_blocks	Blocks used by Checkpoint Data Area
112	8	nx_xp_desc_base	Base address of Checkpoint Descriptor Area or Physical Object ID
120	8	nx_xp_data_base	Base address of Checkpoint Data Area or Physical Object ID
128	4	nx_xp_desc_next	Next Index for Checkpoint Descriptor Area
132	4	nx_xp_data_next	Next Index for Checkpoint Data Area
136	4	nx_xp_desc_index	Index for first item in Checkpoint Descriptor Area
140	4	nx_xp_desc_len	Number of blocks in Checkpoint Descriptor Area Used
144	4	nx_xp_data_index	Index for first item in Checkpoint Data Area
148	4	nx_xp_data_len	Number of blocks in Checkpoint Data Area Used
152	8	nx_spaceman_oid	Space Manager Object ID (OID)
160	8	nx_omap_oid	Container Object Map Object ID (OID)
168	8	nx_reaper_oid	Reaper Object ID (OID)
176	4	nx_test_type	Reserved for Testing
180	4	nx_max_file_systems	Maximum Number of Volumes in this Container
184	8	nx_fs_oid[0]	Array of OIDs for Volumes in this Container

APFS Format References:

- Apple File System Reference (Apple Developer Documentation)
- 2019-02-07

APFS is Little Endian & 64-bit

Updated: 01/2020

Volume Super Block (apfs_superblock_t)

Offset	Size (in bytes)	Field	Notes
32	4	apfs_magic "APSB"	Volume Magic Number 0x41505342 = "APSB"
36	4	apfs_fs_index	Index in Volume Array
40	8	apfs_features	Features
48	8	apfs_readonly_compatible_features	Read-only Incompatible Features
56	8	apfs_incompatible_features	Incompatible Features
64	8	apfs_unmount_time	Timestamp when volume was last unmounted
72	8	apfs_fs_reserve_block_count	Block Pre-allocated for Volume (Default is none)
80	8	apfs_fs_quota_block_count	Maximum Block Allocated (Default is none)
88	8	apfs_fs_alloc_count	Number of blocks currently allocated
96	2	wrapped_crypto_state_t. wrapped_crypto_state.major_version	Key Encryption Metadata – Major Version
98	2	wrapped_crypto_state_t. wrapped_crypto_state.minor_version	Key Encryption Metadata – Minor Version
100	4	wrapped_crypto_state_t. wrapped_crypto_state.cpflags	Key Encryption Metadata – Encryption State Flags
104	4	wrapped_crypto_state_t. wrapped_crypto_state.persistent_class	Key Encryption Metadata – Protection Class
108	4	wrapped_crypto_state_t. wrapped_crypto_state.key_os_version	Key Encryption Metadata – Creator OS Version 0x39004313 = 19 C 57 – 19C57 – Catalina 10.15.2
112	2	wrapped_crypto_state_t. wrapped_crypto_state.key_revision	Key Encryption Metadata – Key Version
114	2	wrapped_crypto_state_t. wrapped_crypto_state.key_len	Key Encryption Metadata – Key Size (0 for no Encryption)
N/A	0	wrapped_crypto_state_t. wrapped_crypto_state.persistent_key	Key Encryption Metadata – Wrapped Key No Key field is null, see key_len above
116	4	apfs_root_tree_oid_type	Type of Root File System Tree = B-Tree
120	4	apfs_extentref_tree_oid_type	Type of Extent Reference Tree = B-Tree, Physical
124	4	apfs_snap_meta_tree_oid_type	Type of Snapshot Metadata Tree = B-Tree, Physical
128	8	apfs_omap_oid	Physical Object ID (OID) of Object Map
136	8	apfs_root_tree_oid	Virtual Object ID (OID) of Root File System Tree
144	8	apfs_extentref_tree_oid	Physical Object ID (OID) of Extent Reference Tree
152	8	apfs_snap_meta_tree_oid	Virtual Object ID (OID) of Snapshot Metadata Tree
160	8	apfs_revert_to_xid	Transaction ID (XID) that volume will revert to
168	8	apfs_revert_to_sbblock_oid	Virtual Object ID (OID) of Volume Superblock to revert to
176	8	apfs_next_obj_id	Next Object ID (OID)
184	8	apfs_num_files	Number of Regular Files
192	8	apfs_num_directories	Number of Directories
200	8	apfs_num_symlinks	Number of Symbolic Links
208	8	apfs_num_other_fsojects	Number of Other Files
216	8	apfs_num_snapshots	Number of Snapshots
224	8	apfs_total_blocks_allocated	Blocks Allocated by Volume
232	8	apfs_total_blocks_freed	Blocked Freed by Volume
240	16	apfs_vol_uuid	Volume UUID (diskutil info /dev/disk#s# [Volume])
256	8	apfs_last_mod_time	Last Modified Timestamp
264	8	apfs_fs_flags	Flags
272	32	apfs_modified_by_t.formatted_by.id[]	Format Program and Version
304	8	apfs_modified_by_t.formatted_by.timestamp	Format Timestamp
312	8	apfs_modified_by_t.formatted_by.last_xid	Format Transaction ID (XID)
320	32	apfs_modified_by_t.modified_by.id[]	Last Modified Program and Version
352	8	apfs_modified_by_t.modified_by.timestamp	Last Modified Timestamp
360	8	apfs_modified_by_t.modified_by.last_xid	Last Modified Transaction ID (XID)
368	336	apfs_modified_by_t.modified_by[1-7]	Array of apfs_modified_by_t[8]
704	256	apfs_volname	APFS Volume Name
960	4	apfs_next_doc_id	Next Document ID
964	2	apfs_role	APFS Role (None, System, Data, Preboot, VM, Recovery)
966	2	apfs_reserved	Reserved
976	8	apfs_root_to_xid	Transaction ID (XID) of Snapshot to Root
984	8	apfs_er_state_oid	Current State of Encryption/Decryption

B-Tree Node (btree_node_phys_t)

Offset	Size (in bytes)	Field	Notes
32	2	btn_flags	Flags (Leaf Node)
34	2	btn_level	Number of Child Levels below this Node
36	4	btn_nkeys	Number of Keys
40	2	btn_table_space.off	Offset to Table of Contents (after btree_node_phys_t)
42	2	btn_table_space.len	Length of Table of Contents
44	2	btn_freespace.off	Offset Key/Value Free Space
46	2	btn_freespace.len	Length of Key/Value Free Space
48	2	btn_key_free_list.off	Offset to Free Key Space
50	2	btn_key_free_list.len	Length of Free Key Space
52	2	btn_val_free_list.off	Offset to Free Value Space
54	2	btn_val_free_list.len	Length of Free Value Space

B-Tree Node – Table of Contents

Offset	Size (in bytes)	Field	Notes
TOC Entry + 2	2	key_offset	Key Offset
TOC Entry + 4	2	key_length	Key Length
TOC Entry + 6	2	value_offset	Value Offset
TOC Entry + 8	2	value_length	Value Length

B-Tree Node – File System Key

Offset	Size (in bytes)	Object ID – Inode Number
7	1	Entry Kind
		0x30 – Inode
		0x60 – Data Stream
		0x40 – Xattr (2 byte Name Length + Variable Xattr Name)
		0x60 – File Extent (8 byte Logical Address)

Value – Inode File Metadata

Offset	Size (in bytes)	Field	Notes
0	8	parent_id	Parent Inode Number
8	8	private_id	Inode Number
16	8	create_time	Create Timestamp
24	8	mod_time	Modification Timestamp
32	8	change_time	Change Timestamp
40	8	access_time	Access Timestamp
48	8	internal_flags	Internal Flags
56	4	nchildren or nlink	Children or Links
60	4	default_protection_class	Default Protection Class
64	4	write_generation_counter	Write Generation Counter
68	4	bsd_flags	BSD Flags
72	4	owner	Owner
76	4	group	Group
80	2	mode	File Mode
82	2	pad1	Pad1
84	8	pad2	Pad2
92	2	xf_num_exts	Number of Extended Fields
94	2	xf_used_data	Extended Fields Data Used
96	x_field_t[] = 4 bytes Each	Extended Field: x_type (1 byte), x_flags (1 byte), x_size (2 bytes)	
96	4	EXAMPLE EXTENDED FIELD: 0x04 = 4, 0x02 (Do Not Copy), 0x1100 = 17 (File Name)	
100	4	EXAMPLE EXTENDED FIELD: 0x08 = 8, 0x20 (System Field), 0x2800 = 40 (Data Stream)	
104	{17}	File Name	smudge_yoda.jpeg (w/1 padding bytes 0x00), 17 total bytes
120	{40}	Data Stream (Size: First 8 bytes, Allocated: Next 8 bytes)	0x0000000000000000 – 7 unused bytes Size: 0x261C020000000000 = 138278 bytes Allocated: 0x0020020000000000 = 139264

Value – Inode File Extent

Offset	Size (in bytes)	Field
0	8	File Size
8	8	Physical Block Location
16	8	Crypto ID

Directory Commands

cd ..	Change Directory...up one directory (../.. - two directories up)	ls -lh	List Directory items...with human readable sizes
cd /var/log	Change Directory...to /var/log	ls -R	List Directory items...recursively
cd ~	Change Directory...to your home directory	open .	Open Current Directory
cd /	Change Directory...to the root directory	pwd	Print Working Directory
ls	List Directory (Short Listing)	mkdir	Create a Directory
ls -l	List Directory (Long Listing)	rmdir	Remove a Directory
ls -a	List Directory items...including hidden items (files beginning with ".")	rm -r	Remove a Directory (and its contents)
		.	Current Directory
		..	Parent Directory

File Commands

pico <filename>	Open a file in a simple text editor (q to quit editor)
xxd <filename>	Open a file in a hex editor
open <filename>	Opens a file in the default program
open -a <programname> <filename>	Opens a file in a specified program
cat <filename>	Concatenate a file to the terminal screen
<command> more	Pipe command output to more to show contents screen by screen
<command> less	Pipe command output to less to show contents screen by screen (and be able to go back and forth)
rm <filename>	Remove File
cp <filename> <newfilename>	Copy File
mv <filename> <newfilename>	Move File
<command> > <filename>	Redirect command output to a file
<command> >> <filename>	Append command output to a file
touch <filename>	Create an empty file
head <filename>	Show first 10 lines of a file
tail <filename>	Show last 10 lines of a file (-f to watch appended input)
strings <filename>	Show the strings of a file
exiftool <filename>	Show the exif/metadata of the file
plutil -p <propertylist>	Print the contents of a property list
file <filename>	Show a file signature type
grep -i <searchterm> <filename>	Search for term within a file (case-insensitive)
python <file>.py	Execute a Python program

Miscellaneous Commands

sudo <command>	Execute program as another user (default is root user)
sudo -s	Open a privileged shell
su -	Substitute User to root
whoami / id	Display Effective User ID / Show UID/GID Info
history	Command History
man <command>	Command Manual (q to exit manual)

Terminal Shortcuts

Control + A	Jump to beginning of line	Command + T	New Terminal Tab
Control + E	Jump to end of of line	Command + W	Close Terminal Tab
Tab	Tab Completion	Command + +/-	Increase or Decrease Terminal Font Size
Control + C	Kill Current Command	Option + Left/Right Arrow	Move back/forth by word
Command + K or Control + L	Clear Screen (or clear command)	Option + Click in Command Line	Put command line cursor where mouse cursor is

Generic Tool Compilation and Installation

```
tar -xvf <archive>.tar.gz
./configure
make
sudo make install
```

Live Response

<code>date</code>	Local System Time (<code>-u</code> for UTC)
<code>hostname</code>	System Hostname
<code>uname -a</code>	OS & Architecture Information
<code>sw_vers</code>	macOS Version & Build
<code>netstat -anf inet</code> or <code>netstat -an</code>	Active Network Connections
<code>lsof -i</code>	Active Network Connections (by process)
<code>netstat -rn</code>	Routing Table
<code>arp -an</code> <code>ndp -an</code>	ARP Table (IPv4 IPv6)
<code>ifconfig</code>	Network Interface Configuration
<code>lsof</code>	List Open Files
<code>who -a, w</code>	List Logged On Users
<code>last</code>	List user logins
<code>ps aux</code>	List Processes
<code>system_profiler -xml</code> <code>-detaillevel full > file.spx</code>	System Profiler (XML, Full Detail Level), open with System Information.app

Disk & Partitions

<code>/dev/</code>	Device Directory
<code>diskutil list</code>	List Connected Disks
<code>diskutil info <disk></code>	Disk Information (use Disks <code>/dev/disk#</code> , <code>disk#</code> , or partitions <code>/dev/disk#s#</code>)
<code>diskutil cs ap list</code>	List partitions using CoreStorage (cs) or APFS Containers (ap)
<code>gpt -r show [-l]</code>	List partitions using GUID Partition Table Format (<code>-l</code> to show label rather than GUID) – 10.13+ SIP must be disabled.
<code>csrutil disable enable</code>	Disable/Enable SIP, must reboot into Recovery Mode (Reboot, Cmd+Option+R)
<code>mmfs <diskimage></code>	Display partitions using The Sleuth Kit
<code>hdiutil imageinfo *.dmg</code>	Disk Image Information including Partition Data

Keychains

<code>security list-keychains</code>	List Keychains on a system for a logged in user
<code>security dump-keychains -d <keychain></code>	Dump contents of a Keychain

Extended Attributes

<code>xattr -xl <file></code>	Show Extended Attributes of a file
<code>xattr -p <attribute name> <file> xxd -r -p</code> <code>>output_file.plist</code>	Extract embedded binary property list from extended attribute
<code>istat /dev/disk# <CNID></code>	Use The Sleuth Kit to view file information including extended attributes
<code>icat /dev/disk# <CNID>-<TSK Attribute Number></code>	View a specific extended attribute using The Sleuth Kit

Log Analysis

<code>bzcat system.log.1.bz2</code> <code>system.log.0.bz2 >> system_all.log</code> <code>cat system.log >> system_all.log</code>	Create a “all-in-one” system.log file. Can also be used with <code>gzcat</code> for Gzip compressed log files
<code>syslog -f <file> -d <directory></code>	View ASL File or Directory of ASL files
<code>syslog -T utc -F raw -d /var/log/asl</code>	Output ASL files the <code>/var/log/asl</code> directory and output in raw format with UTC timestamps.
<code>praudit -xn /var/audit/*</code>	View audit logs in XML format without user/group resolution
<code>sudo log collect</code>	Create a logarchive bundle on live system, root required
<code>log show</code>	View logs in logarchive bundle (use with <code>--predicate</code> to filter)
<code>log stream</code>	View live logs (use with <code>--predicate</code> to filter)

Time Machine

<code>tmutil uniquesize <machinedirectory_path>/*</code>	Show the unique sizes of each snapshot
<code>tmutil calculatedrift <machinedirectory_path></code>	Show the size changes (added/removed/changed) between each snapshot
<code>tmutil compare <snapshotdirectory1></code> <code><snapshotdirectory2></code>	Compare the file changes (added/removed/changed) between two snapshots

Spotlight

<code>mdls <file></code>	List the Spotlight metadata for a file
<code>mdfind "<attribute_name> == *"</code>	Find files based on a specific metadata query
<code>mdfind -onlyin /Volumes/mounted_disk</code>	Find files only in a certain directory or mounted image.
<code>mdimport -X -A</code>	Print a list of attributes that can be queried.

Memory Analysis & Encrypted Containers

<code>vol.py --profile=<profile> -f <memory image> <plugin></code>	Volatility Usage
<code>hdiutil attach -readonly -nomount -stdinpass filevault2image.dmg</code>	Mount a FileVault volume using a password
<code>security unlock-keychain FileVaultMaster.keychain diskutil corestorage unlockvolume <UUID> -recoverykeychain FileVaultMaster.keychain</code>	Access and mount a FileVault volume using a master password
<code>diskutil corestorage unlockvolume <UUID> -passphrase <recovery key></code>	Mount a FileVault volume using the Recovery Key
<code>hdiutil attach -readonly -nomount -stdinpass sekretstuff_USB.dmg</code>	Mount an Encrypted DMG File
<code>strings <MemoryImage> sort -u > dictionary.txt</code>	Create a dictionary file

Disk Arbitration

```
sudo launchctl load /System/Library/LaunchDaemons/com.apple.diskarbitrationd.plist
sudo launchctl unload /System/Library/LaunchDaemons/com.apple.diskarbitrationd.plist
ps auxw | grep diskarbitrationd
```

Image Mount & Eject

APFS with xmount (xmount v.0.7.*)	<pre>\$ sudo mkdir /Volumes/galaga_image/ \$ sudo mkdir /Volumes/galaga_mounted/ \$ sudo xmount --in ewf ~/FOR518/galaga.E01 --out dmg /Volumes/galaga_image/ \$ hdiutil attach -nomount /Volumes/galaga_image/galaga.dmg \$ sudo mount_apfs -o rdonly,noexec,noowners /dev/disk# /Volumes/galaga_mounted/</pre>
HFS+ Method 1 – xmount (xmount v.0.7.*)	<pre>\$ mkdir /Volumes/dademurphy_image/ \$ mkdir /Volumes/dademurphy_mounted/ \$ sudo xmount --in ewf ~/FOR518/dademurphy.E01 --out dmg /Volumes/dademurphy_image/ \$ hdiutil attach -nomount /Volumes/dademurphy_image/dademurphy.dmg \$ mount_hfs -j -o rdonly,noexec,noowners /dev/disk# /Volumes/dademurphy_mounted/</pre>
Eject Disk	<pre>\$ diskutil list \$ diskutil eject /dev/disk# \$ mount \$ sudo umount /Volumes/galaga_image/</pre>

Timestamp Formats

APFS	64-bit – Number of Seconds from 1/1/1970 00:00:00 UTC
HFS+/MacOS	32-bit – Number of seconds from 1/1/1904 00:00:00 UTC
UNIX Epoch	32-bit – Number of seconds from 1/1/1970 00:00:00 UTC
Mac Epoch/Mac Absolute/Cocoa/WebKit	32-bit – Number of seconds from 1/1/2001 00:00:00 UTC
Property List Dates in Xcode	Local Host System Time

Number of 512-byte Blocks Used	Hostname	Directory	Username	Command
	nibble:/	sledwards\$	ls -la	
	total 1014190			
	drwxr-xr-x@	41	root	wheel 1462 Feb 16 21:14 .
	drwxr-xr-x@	41	root	wheel 1462 Feb 16 21:14 ..
	d--x--x--x+	8	root	wheel 272 Nov 5 01:11 .DocumentRevisions-V100
	d-wx-wx-wt	2	root	wheel 68 Nov 4 21:05 .Trashes
	-rw-r--r--+	1	sledwards	admin 312 Mar 9 2013 .apdisk
	srwxrwxrwx	1	root	wheel 0 Feb 15 21:29 .dbfsevents
	lrwxr-xr-x@	1	root	wheel 11 Sep 23 08:47 etc -> private/etc
	-rwxr-xr-x@	1	root	wheel 8393032 Sep 29 22:39 mach_kernel

GPT Header		
Offset	Size (in bytes)	Field
0	8	Signature (EFI PART)
8	4	Revision (1.0)
12	4	Size of Header (bytes)
16	4	Header CRC32
20	4	Reserved
24	8	LBA of GPT Header
32	8	LBA of Backup GPT Header
40	8	First Usable LBA
48	8	Last Usable LBA
56	16	Disk GUID
72	8	Starting LBA of GUID Partition Table (Little Endian)
80	4	Number of Partition Entries Available (Little Endian)
84	4	Size of Partition Entry
88	4	Partition Entry Array CRC32
92	Rest	Reserved

GPT Table Entry		
Offset	Size (in bytes)	Field
0	16	Partition Type GUID
16	16	Unique Partition GUID
32	8	Starting LBA (Little Endian)
40	8	Ending LBA (Little Endian)
48	8	Attributes
56	72	Partition Name
128	Rest	Reserved

GPT Partitions GUIDs	
Type	Common GPT Partition GUIDs
EFI System Partition	C12A7328-F81F-11D2-BA4B-00A0C93EC93B
HFS+ Partition	48465300-0000-11AA-AA11-00306543ECAC
Apple Boot Partition	426F6F74-0000-11AA-AA11-00306543ECAC
Apple CoreStorage (possible FileVault or Fusion Drive)	53746F72-6167-11AA-AA11-00306543ECAC
APFS Partition	7C3457EF-0000-11AA-AA11-00306543ECAC
Basic Data Partition (Boot Camp)	EBD0A0A2-B9E5-4433-87C0-68B6B72699C7

The aim of this guide is to provide a list of the most interesting files and folders in the “Data” and “Shared” folders for the most commonly used third-party apps.

iOS third-party apps can be installed from the Apple App Store, where they are organized based on categories (e.g., Social Networking, Business/Productivity, Navigation & Travel, and so on).

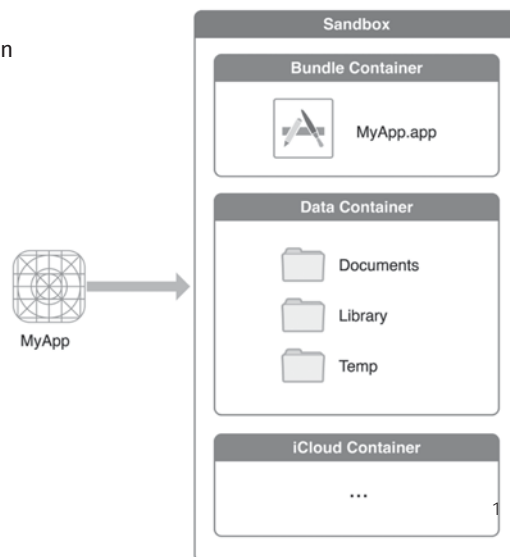
Once an app is installed on an iOS device:

- App Bundle is installed in a subfolder in the **/private/var/containers/Bundle** folder
- App Data is stored in a subfolder in the **/private/var/mobile/Containers/Data/Application/** folder (App Sandbox)

The easiest way to track down an iOS application’s Data folder is to analyze the **/private/var/mobile/Library/FrontBoard/applicationstate.db** database, as described in a blog post by Alexis Brignoni².

Some Apps can also store data in other subfolders like the **/private/var/mobile/Containers/Share/AppGroup/** folder. Two good ways to locate the Sandbox folder for the AppGroup are mentioned in blog posts by Scott Vance³ and Yogesh Khatri⁴.

The internal structure of an App folder can be determined by the developer, but Apple provides some guidelines in its *File System Programming Guide*⁵.



¹ Image is extracted from:

<https://developer.apple.com/library/archive/documentation/FileManagement/Conceptual/FileSystemProgrammingGuide/FileSystemOverview/FileSystemOverview.html>

² <https://abrignoni.blogspot.com/2018/12/identifying-installed-and-uninstalled.html>

³ <https://blog.d204n6.com/2020/09/ios-tracking-bundle-ids-for-containers.html>

⁴ <https://www.swiftforensics.com/2021/01/ios-application-groups-shared-data.html>

⁵ <https://developer.apple.com/library/archive/documentation/FileManagement/Conceptual/FileSystemProgrammingGuide/FileSystemOverview/FileSystemOverview.html>

Entertainment/Photo & Video

Amazon Prime Video

APPSTORE URL: <https://apps.apple.com/us/app/amazon-prime-video/id545519333>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/<ID>/	store	JSON
/Library/Application Support/com.amazon.AIVWebImageCache/	*	Various
/Library/Caches/com.amazon.AIVAdvertCache/	*	Various
/Library/Preferences/	com.amazon.aiv.AIVApp.plist	Plist

Google Photos

APPSTORE URL: <https://apps.apple.com/us/app/google-photos/id962194608>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Caches/com.google.common.SSO/<User_ID>/	Profile.plist	Plist
/Library/Application Support/store/	collections-<User_ID>	SQLite
/Library/Application Support/store/	photos-<User_ID>	SQLite
/Library/Preferences/	com.google.photos.plist	Plist

Instagram

APPSTORE URL: <https://apps.apple.com/us/app/instagram/id389801252>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	time_in_app-<User_ID>.db	SQLite
/Library/Caches/<User_ID>/	*	Various
/Library/Caches/com.burbn.instagram.IGImageCache/	*	Images
/Library/Caches/com.burbn.instagram.IGSparseVideoCache/	*	Videos
/Library/Caches/Items/	lastentries.<User_ID>1.coded	Plist
/Library/Application Support/<User_ID>/	pending-requests.plist	Plist
/Library/Application Support/DirectSQLiteDatabase/	<User_ID>.db	SQLite
/Library/Preferences/	com.burbn.instagram.plist	Plist

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/<User_ID>/user_bootstrap/	shared_bootstraps.plist	SQLite
/Library/Preferences/	group.com.burbn.instagram.plist	Plist

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<https://salt4n6.com/2018/05/15/a-few-interesting-ios-forensic-artefacts>

<http://xml.jips-k.org/full-text/view?doi=10.3745/JIPS.03.0097>

<https://www.forensicrofocus.com/articles/forensic-analysis-of-third-party-application-instagram>

Entertainment/Photo & Video (CONTINUED)

Imgur

APPSTORE URL: <https://apps.apple.com/us/app/imgur-funny-meme-gif-maker/id639881495>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	default.realm	Realm
/Library/Caches/com.hackemist.SDImageCache/default/	*	Various
/Library/Caches/Logs/	*.log	TXT
/Library/Preferences/	imgurmobile.plist	Plist

REFERENCES:

<https://abrignoni.blogspot.com/2019/12/ios-imgur-app-realm-database-example.html>

Netflix

APPSTORE URL: <https://apps.apple.com/us/app/netflix/id363590051>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	store.sqlite	SQLite
/Library/assetCache/	*	JPG
/Library/Caches/br/ch/	*	Various
/Library/Caches/com.netflix.Netflix/	Cache.db	SQLite
/Library/Caches/com.netflix.Netflix/fsCachedData/	*	Various
/Library/Preferences/	com.netflix.Netflix.plist	Plist

Pinterest

APPSTORE URL: <https://apps.apple.com/us/app/pinterest/id429047995>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	activeUser	Plist
/Documents/	activeUser<User_ID>	Plist
/Library/Caches/com.pinterest.PINDiskCache.PINRemoteImageManagerCache/	*	Various
/Library/Caches/com.pinterest.PINDiskCache.PINRemoteModelCache/	*	Various
/Library/Preferences/	pinterest.plist	Plist

Snapchat

APPSTORE URL: <https://apps.apple.com/us/app/snapchat/id447188370>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	user.plist	Plist
/Documents/	chatConversationStore.plist	Plist
/Documents/	friendsForAsyncDecode.plist	Plist
/Documents/	stories.plist	Plist
/Documents/gallery_data_object/1/<User_ID>/	scdb-27.sqlite3	SQLite
/Documents/global_scoped/Gallery/	*	Various
/Library/Caches/com.snap.file_manager_1_SCContent_<GUID>/	*	Various
/Library/Caches/SCCache/	*	Various
/Library/Preferences/	com.toyopagroup.picaboo.plist	Plist

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https://www.researchgate.net/profile/Imam_Riadi/publication/320467249_The_digital_forensic_analysis_of_snapchat_application_using_XML_records/links/59e73e87a6fdcc0e882d82e7/The-digital-forensic-analysis-of-snapchat-application-using-XML-records.pdf

<https://www.marshall.edu/forensics/files/Cindy-Q-Wu-Forensic-Analysis-of-Data-Transience-PPT.pdf>

<https://resources.infosecinstitute.com/ios-application-security-part-10-ios-file-system-and-forensics/#gref>

<https://doubleblak.com/blogPosts.php?id=5>

http://www.carpeindicium.com/blog/gone_10-seconds

Private Photo Vault

APPSTORE URL: <https://apps.apple.com/us/app/private-photo-vault-pic-safe/id41751834>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/	PPVCoreData.sqlite	SQLite
/Library/PPV_Pics/	*	Various
/Library/Preferences/	com.enchantedcloud.photovault.plist	Plist

REFERENCES:

<https://cdn.ymaws.com/www.oshean.org/resource/resmgr/Email/ruledtheword.pdf>

Spotify

APPSTORE URL: <https://apps.apple.com/us/app/spotify-music-and-podcasts/id324684580>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/	mercury.db	SQLite
/Library/Application Support/PersistentCache/	*	JPG
/Library/Application Support/Users/<User_ID>-user/	*	Various
/Library/Caches/com.spotify.client/nsurlcache/fsCachedData/	*	JPG
/Library/Preferences/	com.spotify.client.plist	Plist

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<https://arstechnica.com/information-technology/2016/11/for-five-months-spotify-has-badlyabused-users-storage-drives>

YouTube

APPSTORE URL: <https://apps.apple.com/us/app/tiktok/id835599320>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Caches/com.google.common.SSO/<User_ID>/	Profile.plist	Plist
/Library/Caches/com.pinterest.PINDiskCache.com.youtube.innertube.imageservice.cache/	*	Various
/Library/Preferences/	com.google.ios.youtube.plist	Plist

TikTok

APPSTORE URL: <https://apps.apple.com/us/app/tiktok/id835599320>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	AwemelM.db	SQLite
/Documents/drafts/	*	Various
/Library/Application Support/ChatFiles/<User-ID>/	db.sqlite	SQLite
/Library/AWEVideoCache/FileCache/	*	M4V
/Library/Caches/com.ibireme.yykit/images/data/	*	Various
/Library/Caches/TTPlayerCache/	*	M4V
/Library/Heimdallr/	heimdallr.db	SQLite
/Library/Preferences/	com.zhiliaoapp.musically.plist	Plist

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<https://abrignoni.blogspot.com/2018/11/finding-tiktok-messages-in-ios.html>

<https://www.systoolsgroup.com/updates/retrieve-messages-from-tiktok>

<https://blog.oxygen-forensic.com/whos-knocking-tiktok>

Doodle

APPSTORE URL: <https://apps.apple.com/us/app/doodle-easy-scheduling/id938182547>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	doodle.yapdb	SQLite
/Library/Caches/com.doodle.Doodle-App/fsCachedData/	*	Various
/Library/Preferences/	com.doodle.Doodle-App.plist	Plist

Dropbox

APPSTORE URL: <https://apps.apple.com/us/app/dropbox-backup-sync-share/id327630330>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	spotlight.db	SQLite
/Documents/Users/<User_ID>/	Dropbox.sqlite	SQLite
/Documents/Users/<User_ID>/	metadata.db	SQLite
/Documents/Users/<User_ID>/	offline.db	SQLite
/Documents/Users/<User_ID>/	recent_actions_local.db	SQLite
/Documents/Users/<User_ID>/	recent_actions_server.db	SQLite
/Documents/Users/<User_ID>/	starred_infos_local.db	SQLite
/Library/Cache/Users/<User_ID>/FileCache/Loaded/	*	Various
/Library/Preferences/	com.getdropbox.Dropbox.plist	Plist

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/File Provider Storage/<User-ID>/local-storage/	*	Various
/Library/Preferences/	group.com.getdropbox.Dropbox.plist	Plist
/Users/<User_ID>/	Dropbox.sqlite	SQLite
/Users/<User_ID>/	file_provider_metadata_with_assistant.db	SQLite
/Users/<User_ID>/	upload_queue_v2.db	SQLite
/Users/<User_ID>/FileCache/	*	Various

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<https://www.tandfonline.com/doi/abs/10.1080/00450618.2015.1110620?scroll=top&needAccess=true&journalCode=tajf20>

Dust

APPSTORE URL: <https://apps.apple.com/us/developer/radical-app-llc/id1004670836>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	<User_ID>	Realm
/Documents/	contacts.json	JSON
/Documents/	default.realm	Realm
/Library/Preferences/	com.mentionmobile.cyberdust.plist	Plist
/SplashBoard/Snapshots/	*	KTX

REFERENCES:

<https://www.nw3c.org/docs/research/dust.pdf>

Eventbrite

APPSTORE URL: <https://apps.apple.com/us/app/eventbrite/id487922291>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	default.realm	Realm
/Library/Caches/com.eventbrite.attendee/com.alamofire.imagedownloader/fsCachedData/	*	JPG
/Library/Preferences/	com.eventbrite.attendee.plist	Plist

Gmail

APPSTORE URL: <https://apps.apple.com/us/app/gmail-email-by-google/id422689480>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Preferences/	com.google.Gmail.plist	
/Library/Caches/com.google.commmmon.SSO/<User_ID>/	Profile.plist	Plist
/Documents/drivekit/users/<User_ID>/gdx-cello/	cello.db	SQLite
/Library/Application Support/data/<Email_Address>/	sqllitedb	SQLite

Google Drive

APPSTORE URL: <https://apps.apple.com/us/app/google-drive/id507874739>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/<User_ID>/	comments_snapshot_<User_ID>.db	SQLite
/Documents/drivekit/users/<User_ID>/cello/	cello.db	SQLite
/Documents/drivekit/users/<User_ID>/files/	*	Various
/Documents/drivekit/users/<User_ID>/logs/	*	TXT
/Documents/drivekit/users/<User_ID>/thumbnails/	*	Various
/Library/Caches/drivekit/users/<User_ID>/image-fetcher-cache/main-cache/	cacheV0.db	SQLite
/Library/Preferences/	com.google.Drive.plist	Plist

LinkedIn

APPSTORE URL: <https://apps.apple.com/us/app/linkedin-network-job-finder/id288429040>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	Messenger.sqlite	SQLite
/Documents/LImageCache	*	Various
/Library/Caches/WebKit/NetworkCache/	*	Various
/Library/Preferences/	com.linkedin.Linkedin.plist	Plist

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<https://www.tandfonline.com/doi/abs/10.1080/00450618.2015.1066854?src=recsys&journalCode=tajf20>

<https://digitalcommons.newhaven.edu/cgi/viewcontent.cgi?article=1017&context=electricalcomputerengineering-facpubs>

<https://it.scribd.com/document/57611870/Shmoocon-2011-Inside-the-App-All-Your-Data-are-Belong-to-Me>

LogMeIn

APPSTORE URL: <https://apps.apple.com/us/app/logmein/id479229407>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/LogMeInConfig/	com.logmein.ignition.xml	XML
/Library/LogMeInConfig/	sessiondata.xml	XML
/Library/Preferences/	com.logmein.logmein.plist	Plist

Microsoft OneDrive

APPSTORE URL: <https://apps.apple.com/us/app/microsoft-onedrive/id477537958>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Database/	moddatabase.db	SQLite
/Library/Preferences/	com.microsoft.skydrive.plist	Plist
/SplashBoard/Snapshots/	*	KTX

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Preferences/	group.com.microsoft.onedrive.plist	Plist
/OneDrive/DatabaseQT/	QTMetadatabase.db	SQLite
/OneDrive/StramCacheQT/	*	Various

Microsoft Teams

APPSTORE URL: <https://apps.apple.com/us/app/microsoft-teams/id1113153706>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/.IntuneMAM/	Config.plist	Plist
/Library/Shift/	Shift.sqlite	SQLite
/Library/Preferences/	com.microsoft.skype.teams.plist	Plist
/SplashBoard/Snapshots/	*	KTX

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Preferences/	group.com.microsoft.skype.teams.plist	Plist
/SkypeSpacesDogfood/<Team_ID>/	SkypeSpacesDogfood-<GUID>.sqlite	SQLite
/SkypeSpacesDogfood/Downloads/<Team_ID>/	*	Various

ProtonMail

APPSTORE URL: <https://apps.apple.com/us/app/protonmail-encrypted-email/id979659905>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Caches/SentryCras/ProtonMail/Data/	CrashState.json	JSON
/Library/Preferences/	ch.protonmail.protonmail.plist	Plist

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/	ProtonMail.sqlite	SQLite
/Library/Preferences/	group.ch.protonmail.protonmail.plist	Plist

Silent Phone

APPSTORE URL: <https://apps.apple.com/us/app/silent-phone/id554269204>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/com.silentcircle.SilentPhone/Chat/	ChatMessages_cipher.db	SQLite
/Library/Application Support/com.silentcircle.SilentPhone/tivi/	axo_<User-ID>_secure_sql.db	SQLite
/Library/Application Support/com.silentcircle.SilentPhone/tivi/	zids_sqlite.db	SQLite
/Library/Preferences/	com.silentcircle.SilentPhone.plist	Plist

Slack

APPSTORE URL: <https://apps.apple.com/us/app/slack/id618783545>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/Slack/<Workspace_id>/Database/	main_db	SQLite
/Library/Caches/com.tinspeck.chatlyio/fsCachedData/	*	JPG
/Library/Caches/default/com.hackemist.SDWebImageCache.default/	*	JPG
/Library/Preferences/	com.tinspeck.chatlyio.plist	Plist

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<https://abrignoni.blogspot.com/2018/10/finding-slack-app-messages-in-ios.html>

Tutanota

APPSTORE URL: <https://apps.apple.com/us/app/tutanota/id922429609>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Preferences/	de.tutao.tutanota.plist	Plist
/Library/WebKit/WebsiteData/IndexedDB/v1/file_0/	IndexedDB.sqlite3	SQLite
/Library/WebKit/WebsiteData/LocalStorage/	file_0.localstorage	SQLite
/SplashBoard/Snapshots/	*	KTX

Business/Production (CONTINUED)

Wire

APPSTORE URL: <https://apps.apple.com/us/app/wire-secure-messenger/id930944768>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Preferences/	com.wearezeta.zclient.ios.plist	Plist
/SplashBoard/Snapshots/	*	KTX

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/AccountData/<GUID>/store/	store.wiredatabase	SQLite
/Accounts/	*	JSON
/Library/Caches/	*	Various
/Library/Preferences/	group.com.wearezeta.zclient.ios.plist	Plist

REFERENCES:

<https://www.x41-dsec.de/reports/X41-Kudelski-Wire-Security-Review-iOS.pdf>

<https://blog.oxygen-forensic.com/wire-app-extraction>

<https://wire-docs.wire.com/download/Wire+Security+Whitepaper.pdf>

Navigation & Travel

Air France

APPSTORE URL: <https://apps.apple.com/us/app/air-france/id391968627>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/	bagtracking.realm	Realm
/	checkinKit.realm	Realm
/	entertainmentKit.realm	Realm
/	flightStatusKit.realm	Realm
/	reservation.realm	Realm
/	trackandtrace.realm	Realm

Airbnb

APPSTORE URL: <https://apps.apple.com/app/airbnb/id401626263>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	guest_inbox_<User_ID>.db	SQLite
/Documents/	host_experience_inbox_<User_ID>.db	SQLite
/Documents/	host_inbox_<User_ID>.db	SQLite
/Library/Application Support/	guest_inbox_<User_ID>.db	SQLite
/Library/Application Support/	messaging_core.sqlite3	SQLite
/Library/Caches/	<User_ID>_itinerary.db	SQLite
/Library/Caches/	AIRAccount_active_account_login	Plist
/Library/Caches/	AIRUser_<User_ID>	Plist
/Library/Caches/	AIRWishlist_<User_ID>	Plist
/Library/Caches/default/ com.hackemist.SDWebImageCache.default/	*	PNG
/Library/Preferences/	com.airbnb.app.plist	Plist

REFERENCES:

<https://blog.oxygen-forensic.com/untangling-airbnb/>

Foursquare Swarn

APPSTORE URL: <https://apps.apple.com/us/app/foursquare-swarm-check-in-app/id870161082>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Caches/	foursquare.sqlite	SQLite
/Library/Preferences/	com.foursquare.robin.plist	Plist

ZOOM

APPSTORE URL: <https://apps.apple.com/us/app/zoom-cloud-meetings/id546505307>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/data/	*	JPG
/Documents/data/	zoommeeting.db	SQLite
/Documents/data/	zoomus.db	SQLite
/Documents/data/	zoomus.tmp.db	SQLite
/Documents/data/<User_ID>/	<User_ID>@xmpp.zoom.us.asyn.db	SQLite
/Documents/data/<User_ID>/	<User_ID>@xmpp.zoom.us.db	SQLite
/Documents/data/<User_ID>/	<User_ID>@xmpp.zoom.us.idx.db	SQLite
/Documents/data/<User_ID>/	<User_ID>@xmpp.zoom.us.sync.db	SQLite
/Library/Preferences/	us.zoom.videomeetings.plist	Plist

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<https://www.hecfblog.com/2020/04/daily-blog-684-solution-saturday-42520.html>

Booking

APPSTORE URL: <https://apps.apple.com/us/app/booking-com-hotels-travel/id367003839>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/	BookingClouds	Plist
/Library/Application Support/	KeyValueStorageAccountDomain	Plist
/Library/Application Support/	KeyValueStorageRecentsDomain	Plist
/Library/Application Support/	KeyValueStorageSharedDomain	Plist
/Library/Caches/	location_cache_V2.db	SQLite
/Library/Caches/com.booking.BookingApp/ com.alamofire.imagedownloader/fsCachedData/	*	JPG
/Library/Caches/com.booking.BookingApp/ fsCachedData/	*	JSON
/Library/Preferences/	com.booking.BookingApp.plist	Plist

Google Maps

APPSTORE URL: <https://apps.apple.com/us/app/google-maps-transit-food/id585027354>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/GMSCacheStorage-AZSpotlight StorageModel/GMSCacheStorage-AZSpotlightStorageModel/	AZSpotlightStorageModel.sqlite	SQLite
/Library/Application Support/CachedRoutes/	*	Plist
/Library/Application Support/ GMSCacheStorage-MyMaps/	MyMaps.sqlite	SQLite
/Library/Application Support/ GMSCacheStorage-SavedUserEvent3/	SavedUserEvent3.sqlite	SQLite
/Library/Application Support/ GMSCacheStorage-Tiles/	Tiles.sqlite	SQLite
/Library/Caches/ImageCache	*	JPG
/Library/Caches/com.google.common.SSO/<User_ID>/	Profile.plist	Plist
/Library/Preferences/	com.google.Maps.plist	Plist

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Preferences/	CurrentDirections	Plist
/Library/Preferences/	group.com.google.Maps.plist	Plist

REFERENCES:

<https://commons.erau.edu/cgi/viewcontent.cgi?article=1414&context=jdfsl>

<https://www.iirte.org/wp-content/uploads/papers/v8i4/D4374118419.pdf>

Navigation & Travel (CONTINUED)

KLM

APPSTORE URL: <https://apps.apple.com/us/app/klm/id391732065>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	CoreAppRedesign_iPhone.sqlite	SQLite
/Library/Caches/com.klm.mobile.iphone.klmmobile/fsCachedData/	*	Various
/Library/Preferences/	com.klm.mobile.iphone.klmmobile.plist	Plist

Lufthansa

APPSTORE URL: <https://apps.apple.com/us/app/lufthansa/id299219152>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	*	HTML
/Library/Application Support/	Database.sqlite	SQLite
/Library/Caches/com.lufthansa.launcher/fsCachedData/	*	XML
/Library/Preferences/	com.lufthansa.launcher.plist	Plist

Skyscanner

APPSTORE URL: <https://apps.apple.com/us/app/skyscanner-travel-deals/id415458524>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	MiniEvents.sqlite	SQLite
/Documents/WatchedFlights/	WatchedFlights.json	JSON
/Library/Caches/com.hackemist.SDImageCache/default/	*	JPG
/Library/Caches/net.skyscanner.iphone/netcache/	Cache.db	SQLite
/Library/Caches/net.skyscanner.iphone/netcache/fsCachedData/	*	JSON
/Library/Preferences/	net.skyscanner.iphone.plist	Plist

Tripadvisor

APPSTORE URL: <https://apps.apple.com/us/app/uber/id368677368>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	database.db	SQLite
/Library/Application Support/com.ubercab.UberClient/	*	Various
/Library/Application Support/Persistent Storage/BootstrapStore/RealtimeRider.StreamModelKey/	client	JSON
/Library/Caches/com.ubercab.UberClient/com.uber.images/fsCachedData/	*	Various
/Library/Preferences/	com.ubercab.UberClient.plist	Plist

REFERENCES:

https://www.researchgate.net/publication/323759986_A_Dynamic_and_Static_Analysis_of_the_Uber_Mobile_Application_from_a_Privacy_Perspective

Uber

APPSTORE URL: <https://apps.apple.com/us/app/uber/id368677368>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	database.db	SQLite
/Library/Application Support/com.ubercab.UberClient/	*	Various
/Library/Application Support/Persistent Storage/BootstrapStore/RealtimeRider.StreamModelKey/	client	JSON
/Library/Caches/com.ubercab.UberClient/com.uber.images/fsCachedData/	*	Various
/Library/Preferences/	com.ubercab.UberClient.plist	Plist

REFERENCES:

https://www.researchgate.net/publication/323759986_A_Dynamic_and_Static_Analysis_of_the_Uber_Mobile_Application_from_a_Privacy_Perspective

Waze

APPSTORE URL: <https://apps.apple.com/us/app/waze-navigation-live-traffic/id323229106>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Document/	user	TXT
/Document/	session	TXT
/Document/	preferences	TXT
/Document/	user.db	SQLite
/Library/Preferences/	com.waze.iphone.plist	Plist

Utilities

Brave Browser

APPSTORE URL: <https://apps.apple.com/us/app/brave-private-browser-vpn/id1052879175>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/Downloads/	*	Various
/Library/Application Support/	Brave.sqlite	SQLite
/Library/Preferences/	com.brave.ios.browser.plist	Plist

Burner

APPSTORE URL: <https://apps.apple.com/us/app/burner-private-phone-line/id505800761>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Caches/com.adhoclabs.burner/	Cache.db	SQLite
/Library/Caches/com.adhoclabs.burner/fsCachedData/	*	Various
/Library/Preferences/	com.adhoclabs.burner.plist	Plist
/SplashBoard/Snapshots/	*	KTX

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/	Phoenix.sqlite	SQLite

REFERENCES:

<https://digitalforensictips.com/2013/07/forensic-artifact-analysis-of-the-burner-app-for-the-iphone>

DuckDuckGo Browser

APPSTORE URL: <https://apps.apple.com/us/app/duckduckgo-privacy-browser/id663592361>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Preferences/	com.duckduckgo.mobile.ios.plist	Plist

Firefox

APPSTORE URL: <https://apps.apple.com/us/app/firefox-private-safe-browser/id989804926>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Caches/WebKit/NetworkCache/	*	Various
/Library/Preferences/	org.mozilla.ios.Firefox.plist	Plist

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/profile.profile/	browser.db	SQLite
/profile.profile/	logins.db	SQLite
/profile.profile/	places.db	SQLite
/profile.profile/	tabState.archive	Plist
/Library/Preferences/	group.org.mozilla.ios.Firefox.plist	Plist

Firefox Focus

APPSTORE URL: <https://apps.apple.com/us/app/firefox-focus-privacy-browser/id1055677337>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Preferences/	org.mozilla.ios.Focus.plist	Plist
/Library/Caches/KSCrash/Firefox Focus/Data/	CrashState.json	JSON

Google Chrome

APPSTORE URL: <https://apps.apple.com/us/app/google-chrome/id535886823>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/Google/Chrome/Default/	*	Various
/Library/Caches/com.google.common.SSO/<User_ID>/	Profile.plist	Plist
/Library/Preferences/	com.google.chrome.ios.plist	Plist

Microsoft Edge

APPSTORE URL: <https://apps.apple.com/us/app/microsoft-edge-web-browser/id1288723196>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	OfflineCache.sqlite	SQLite
/Documents/CitrixLogs/Diagnostics/	*	CSV
/Documents/TabScreenshot/	*	JPG
/Library/Application Support/ChromeSync/	*	Various
/Library/Caches/com.microsoft.msedge/fsCachedData/	*	Various
/Library/Preferences/	com.microsoft.msedge.plist	Plist

Onion Browser

APPSTORE URL: <https://apps.apple.com/us/app/onion-browser/id519296448>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	bookmarks.plist	Plist
/Library/Caches/com.miketigas.OnionBrowser/	Cache.db	SQLite
/Library/Caches/tor/	state	TXT
/Library/Preferences/	com.miketigas.OnionBrowser.plist	Plist

REFERENCES:

https://roselabs.nl/files/audit_reports/Cure53_-_Onion_Browser.pdf

Social Networking

CoverMe

APPSTORE URL: <https://apps.apple.com/us/app/coverme-private-text-call/id593652484>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	ContactCache	Plist
/Documents/	miliao.db	SQLite
/Documents/	notification.plist	Plist
/Documents/	Profile.plist	Plist
/Library/logs/	*.log	TXT
/Library/Preferences/	com.coverme.covermeAdhoc.plist	Plist

Discord

APPSTORE URL: <https://apps.apple.com/us/app/discord-talk-chat-hang-out/id985746746>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/mmkv/	mmkv.default	JSON
/Documents/RCTAsyncLocalStorage_V1/	<GUID>	JSON
/Documents/RCTAsyncLocalStorage_V1/	manifest.json	JSON
/Library/Caches/com.hackemist.SDImageCache/	*	PNG
/Library/Caches/com.hammerandchisel.discord/	Cache.db	SQLite
/Library/Caches/com.hammerandchisel.discord/fsCachedData/	*	JSON
/Library/Preferences/	com.hammerandchisel.discord.plist	Plist

REFERENCES:

<https://abrignoni.blogspot.com/2018/08/finding-discord-chats-in-ios.html>

<https://abrignoni.blogspot.com/2020/08/update-on-discord-forensic-artifacts.html>

<https://www.nw3c.org/docs/research/discord.pdf>

Facebook

APPSTORE URL: <https://apps.apple.com/us/app/facebook/id284882215>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	time_in_app_<User_ID>.db	SQLite
/Library/Caches/com.facebook.Facebook.MosaicGImageDiskCache/	*	Various
/Library/Caches/graphStoreDB/	GraphStore_<User_ID>.sqlite3	SQLite
/Library/Caches/messenger_contacts.<GUID>/	fbsyncstore.db	SQLite
/Library/Caches/search_bootstrap.<GUID>/search/	graph_search_entity_bootstrap.data	File
/Library/Caches/video_cache.<GUID>/storage/	*	Plist
/Library/Preferences/	com.facebook.Facebook.plist	Plist

REFERENCES:

https://www.academia.edu/10726810/Social_Media_Forensics_on_Mobile_Devices

<https://www.tandfonline.com/doi/abs/10.1080/00450618.2015.1066854?src=recsys&journalCode=tajf20>

https://www.fbiic.gov/public/2011/jul/Facebook_Forensics-Finalized.pdf

https://www.researchgate.net/publication/224221519_Third_Party_Application_Forensics_on_Apple_Mobile_Devices

<https://www.diva-portal.org/smash/get/diva2:651693/fulltext01.pdf>

Facebook Messenger

APPSTORE URL: <https://apps.apple.com/us/app/messenger/id454638411>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/com.facebook.Messenger.preferences/	<User_ID>.session	Plist
/Documents/messenger_secure_messages.sessionless1/	<User_ID>_threadStateStore.db	SQLite
/Documents/messenger_secure_messages.sessionless1/	<User_ID>_v1464784789_tincan.db	SQLite
/Library/Caches/graphStoreDB/	GraphStore_<User_ID>.sqlite3	SQLite
/Library/Preferences/	com.facebook.Messenger.plist	Plist

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/	lightspeed-<User_ID>.db	SQLite
/_store_<GUID>/messenger_contacts.v1/	fbomnystore.db	SQLite
/shared_messenger_contacts.<GUID>/	fbomnystore.db	SQLite
/shared_messenger_messages.<GUID>/	orca2.db	SQLite
/lightspeed-imageCache/	*	Various

REFERENCES:

https://www.academia.edu/10726810/Social_Media_Forensics_on_Mobile_Devices

<https://boncaldoforensics.wordpress.com/2018/07/28/facebook-messenger-windows-app-store-forensics>

<https://www.champlain.edu/Documents/LCDI/iPhone%20Artifacts.pdf>

<https://sqliteforensictoolkit.com/forensic-browser-for-sqlite-structured-storage-manager>

Google Duo

APPSTORE URL: <https://apps.apple.com/us/app/google-duo/id1096918571>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/logs/	*	TXT
/Library/Application Support/	DataStore	SQLite
/Library/Caches/com.google.common.SSO/<User_ID>/	Profile.plist	Plist
/Library/Preferences/	com.google.Tachyon.plist	Plist

Houseparty

APPSTORE URL: <https://apps.apple.com/us/app/houseparty/id1065781769>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	houseparty.rocky.phonenumbers	Realm
/Documents/	houseparty.rocky.realm	Realm
/Library/Caches/com.herzick.houseparty/fsCachedData/	*	JSON
/Library/IBGLog/	INGUserAttribute.txt	TXT
/Library/Preferences/	com.herzick.houseparty.plist	Plist
/Library/Preferences/	Houseparty.plist	Plist
/SplashBoard/Snapshots/	*	KTX

REFERENCES: <https://abrignoni.blogspot.com/2020/04/ios-houseparty-app-more-realm.html>

Social Networking (CONTINUED)

imo

APPSTORE URL: <https://apps.apple.com/us/app/imo-video-calls-and-chat-hd/id1400579543>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	imo_acc	Plist
/Documents/	imo_last_ts_log_appAlive	Plist
/Documents/	imo_save_media_local_setting_1	Plist
/Documents/	imo_stories	Plist
/Library/Caches/default/com.hackemist.SDWebImageCache.default/	*	Various
/Library/Caches/videos/	*	Various
/Library/Preferences/	co.babypenguin.imo.plist	Plist
/SplashBoard/Snapshots/	*	KTX

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/	IMODb2.sqlite	SQLite
/	IMOShareDb.sqlite	SQLite
/Library/Preferences/	group.co.babypenguin.plist	Plist

REFERENCES:

<https://www.sciencedirect.com/science/article/abs/pii/S1742287618300094>

<http://pr.hec.gov.pk/jspui/bitstream/123456789/13429/1/Muhammad%20Asad%20Khan%20Sudoza%20electrical%20engg%202019%20NUST%20isb%20pr.pdf>

<https://www.champlain.edu/Documents/LCDI/iPhone%20Artifacts.pdf>

<https://sqliteforensictoolkit.com/forensic-browser-for-sqlite-structured-storage-manager>

Kik Messenger

APPSTORE URL: <https://apps.apple.com/us/app/kik/id357218860>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Caches/com.kik.chat/fsCachedData/	*	Various
/Library/Preferences/	com.kik.chat.plist	Plist
/SplashBoard/Snapshots/	*	KTX

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/cores/private/<User-ID>/	kik.sqlite	SQLite
/cores/private/<User-ID>/app-lock/	app-lock-settings	JSON
/cores/private/<User-ID>/attachments/	*	Various
/cores/private/<User-ID>/defaults/	kik.defaults	Plist
/cores/private/<User-ID>/globalDefaults/	kik.defaults	Plist
/cores/private/<User-ID>/suggested-chats/	suggested	JSON
/cores/private/<User-ID>/urlData/	*	PNG
/globalDefaults/	kik.defaults	Plist
/Library/Preferences/	group.com.kik.chat.plist	Plist

REFERENCES:

<https://www.sciencedirect.com/science/article/pii/B9781597496599000067>

https://researchonline.gcu.ac.uk/files/24282895/K.Ovens_revisedKMOvensManuscript3_2.pdf

<https://www.scribd.com/doc/145278610/Artefacts-of-Kik-Messenger-on-iOS>

<https://blog.oxygen-forensic.com/kickin-kik>

LINE

APPSTORE URL: <https://apps.apple.com/us/app/line/id443904275>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/PrivateStore/	*	Various
/Library/Caches/jp.naver.line/fsCachedData/	*	Various
/Library/Preferences/	jp.naver.line.plist	Plist

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/KeepFileProvider/	Keep.sqlite	SQLite
/Library/Application Support/PrivateStore/<User-ID>/Messages/	ChatExt.sqlite	SQLite
/Library/Application Support/PrivateStore/<User-ID>/Messages/	E2EEData.sqlite	SQLite
/Library/Application Support/PrivateStore/<User-ID>/Messages/	Line.sqlite	SQLite
/Library/Preferences/	group.com.linecorp.line.plist	Plist

REFERENCES:

<https://prezi.com/mloxlacowypf/iphone-forensic-line/>

<https://reincubate.com/support/how-to/recover-iphone-hike-line-wechat-messages/>

<https://pdfs.semanticscholar.org/fe66/52f6fe64ce1af44dd7d433ecf5a00b57ca0a.pdf>

MeWe

APPSTORE URL: <https://apps.apple.com/us/app/mewe-network/id918464474>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	Sgrouplesdb.sqlite	SQLite
/Library/Caches/com.mewe/fsCachedData/	*	Various
/Library/Caches/com.hackemist.SDImageCache/	*	Various
/Library/Preferences/	com.mewe.plist	Plist

Signal

APPSTORE URL: <https://apps.apple.com/us/app/signal-private-messenger/id874139669>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Caches/	*	JPG
/Library/Logs/	*.log	TXT
/Library/Preferences/	org.whispersystems.signal.plist	Plist

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/Attachments/	*	Various
/grdb/	signal.sqlite	SQLite
/Library/Preferences/	group.org.whispersystems.signal.group.plist	Plist
/ProfileAvatars/	*	JPG

REFERENCES:

<https://github.com/Magpol/HowTo-decrypt-Signal.sqlite-for-iOS>

<https://support.magnetforensics.com/s/article/Decrypt-app-data-using-the-iOS-Keychain-and-GrayKey>

<https://pdfs.semanticscholar.org/fe66/52f6fe64ce1af44dd7d433ecf5a00b57ca0a.pdf>

<https://isc.sans.edu/forums/diary/Looking+for+the+insider+Forensic+Artifacts+on+iOS+Messaging+App/21363>

<http://www.ijits-bg.com/contents/IJITS-No4-2019/2019-N4-07.pdf>

Social Networking (CONTINUED)

Skout

APPSTORE URL: <https://apps.apple.com/us/app/skout-meet-new-people/id302324249>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/SKOUT/	SKCache.sqlite	SQLite
/Library/Caches/default/com.hackemist.SDWebImageCache.default/	*	Various
/Library/Preferences/	com.skout.SKOUT.plist	Plist
/SplashBoard/Snapshots/	*	KTX

Skype

APPSTORE URL: <https://apps.apple.com/us/app/skype-for-iphone/id304878510>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/RCTAsyncLocalStorage_V1/	manifest.json	JSON
/Library/Application Support/Skype4LifeSlimCore/<Skype_Username>/	main.db	SQLite
/Library/Caches/Logs/	com.skype*.log	TXT
/Library/LocalDatabase/	s4l-<Skype_Username>.db	SQLite
/Library/Preferences/	com.skype.skype.plist	Plist

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/	s4l-<Skype_Username>.db	SQLite

REFERENCES:

<https://bebinary4n6.blogspot.com/2019/07>

<https://pdfs.semanticscholar.org/fe66/52f6fe64ce1af44dd7d433ecf5a00b57ca0a.pdf>

Telegram

APPSTORE URL: <https://apps.apple.com/us/app/telegram-messenger/id686449807>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Preferences/	ph.telega.Telegraph.plist	Plist
/Library/Caches/ph.telega.Telegraph/fsCachedData/	*	Various

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/telegram-data/account-<Account_ID>/postbox/db/	db_sqlite	SQLite
/telegram-data/account-<Account_ID>/postbox/media/	*	Various
/telegram-data/logs/	*	TXT
/telegram-data/share-logs/	*	TXT

REFERENCES:

<https://www.forensicrobotics.com/news/telegram-messenger-data-extraction-in-oxygen-forensic-detective>

TextNow

APPSTORE URL: <https://apps.apple.com/us/app/textnow-call-text-unlimited/id314716233>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	<User-ID>	SQLite
/Documents/com.hackemist.SDWebImageCache.default/	*	JPG
/Library/Application Support/	eventHistory.db	SQLite
/Library/Caches/Logs/sip/	*.log	TXT
/Library/Caches/media/	*	JPG
/Library/Preferences/	com.tinginteractive.usms.plist	Plist

Tinder

APPSTORE URL: <https://apps.apple.com/us/app/tinder-dating-new-people/id547702041>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/	Tinder2.sqlite	SQLite
/Library/Preferences/	com.cardify.tinder.plist	Plist

Viber Messenger

APPSTORE URL: <https://apps.apple.com/us/app/viber-messenger-chats-calls/id382617920>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/Attachments/	*	Various
/Documents/ChatExIcons/	*	Various
/Documents/UserEngagement/	*	Various
/Library/Caches/com.viber/fsCachedData/	*	Various
/Library/Preferences/	com.viber.plist	Plist
/SplashBoard/Snapshots/	*	KTX

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/com.viber/AttachmentsPreview/	*	Various
/com.viber/ContactIcons/	*	JPG
/com.viber/database/	Contacts.data	SQLite
/com.viber/settings/	Settings.data	SQLite

REFERENCES:

<https://pdfs.semanticscholar.org/fe66/52f6fe64ce1af44dd7d433ecf5a00b57ca0a.pdf>

<https://blog.oxygen-forensic.com/viber-messenger-forensics>

<https://blog.digital-forensics.it/2019/12/checkra1n-era-ep-4-analyzing.html>

WeChat

APPSTORE URL: <https://apps.apple.com/us/app/wechat/id414478124>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/<User_ID>/	mmsetting.archive	Plist
/Documents/<User_ID>/	wc005_008.db	SQLite
/Documents/<User_ID>/DB/	MM.sqlite	SQLite
/Documents/<User_ID>/DB/	WCDB_Contact.sqlite	SQLite
/Library/Preferences/	com.tencent.xin.plist	Plist

REFERENCES:

https://www.researchgate.net/publication/261016959_Forensic_Analysis_of_Social_Networking_Application_on_iOS_devices

<https://www.ictsecuritymagazine.com/articoli/wechat-forensics-parte-i>

Social Networking (CONTINUED)

WhatsApp Messenger

APPSTORE URL: <https://apps.apple.com/us/app/whatsapp-messenger/id310633997>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	Blockedcontacts.dat	Plist
/Documents/	calls.backup.log	Plist
/Documents/	StatusMessages.plist	Plist
/Library/Caches/ChatMedia/	*	Various
/Library/Caches/GalleryMedia/	*	Various
/Library/Caches/net.whatsapp.WhatsApp/ fsCachedData/	*	Various
/Library/Caches/spotlight-profile-v2/	*	PNG
/Library/Logs/	whatsapp-*.log	TXT
/Library/Preferences/	net.whatsapp.WhatsApp.plist	Plist
/SplashBoard/Snapshots/	*	KTX

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/	calls.log	Plist
/	CallHistory.sqlite	SQLite
/	ChatStorage.sqlite	SQLite
/	ContactsV2.sqlite	SQLite
/	current_wallpaper.jpg	JPG
/	Location.sqlite	SQLite
/Biz/	Biz.sqlite	SQLite
/fts/	ChatSearch*.sqlite	SQLite
/Library/Preferences/	group.net.whatsapp.WhatsApp. shared.plist	Plist
/Media/Profile/	*	Various
/Message/Media/	*	Various
/stickers/	*	Various

REFERENCES:

https://www.group-ib.com/blog/whatsapp_forensic_artifacts

<https://pdfs.semanticscholar.org/fe66/52f6fe64ce1af44dd7d433ecf5a00b57ca0a.pdf>

<https://sudonull.com/post/30099-WhatsApp-in-the-palm-of-your-hand-where-and-how-can-you-detect-forensic-artifacts-Group-IB-Blog>

https://www.ijesm.co.in/uploads/68/5543_pdf.pdf

<http://www.securitybydefault.com/2011/06/what-whatsapp-doesnt-tell-you.html>

Wickr Me

APPSTORE URL: <https://apps.apple.com/us/app/wickr-me-private-messenger/id528962154>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Caches/KSCrashReports/Wickr Me/	*	JSON
/Library/Caches/Sessions/Wickr Me/	*	JSON
/Library/Preferences/	com.mywickr.wickr.plist	Plist

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/	wickrLocal.sqlite	SQLite

REFERENCES:

<https://thebinaryhick.blog/2019/08/23/wickr-alright-well-call-it-a-draw>

<https://blog.oxygen-forensic.com/wickr-some-forensics-up>

<https://support.magnetforensics.com/s/article/Decrypt-app-data-using-the-iOS-Keychain-and-GrayKey>

News

Reddit

APPSTORE URL: <https://apps.apple.com/us/app/reddit/id1064216828>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/release02/accounts/	*	Plist
/Documents/release02/accountData/	*	Plist
/Library/Caches/com.reddit.Reddit/ fsCachedData/	*	Various
/Library/Caches/com.reddit.Reddit/ imagedownload/fsCachedData/	*	Various
/Library/Preferences/	com.reddit.Reddit.plist	Plist

Twitter

APPSTORE URL: <https://apps.apple.com/us/app/twitter/id333903271>

DEVELOPER WEBSITE: <http://twitter.com/download/iphone>

APP SUPPORT: <https://support.twitter.com/articles/20169906>

PRIVACY POLICY: <https://twitter.com/privacy>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/com.atebits.tweetie. application-important-state/	*	Various
/Documents/com.atebits.tweetie. application-state/	app.acct.<Twitter_Username>	Plist
/Documents/com.atebits.tweetie. compose.attachments/	*	JPG
/Documents/com.atebits.tweetie. direct-message.attachments/	*	Various
/Library/Caches/com.atebits.Tweetie2/ fsCachedData/	*	Various
/Library/Caches/com.atebits.tweetie. direct-message.cache/	<User_ID>-<User_Number>	Plist
/Library/Caches/com.twitter.simple. disk.caches/	*	MP4
/Library/Caches/TIPIImagePipeline/	*	PNG
/Library/Preferences/	com.atebits.Tweetie2.plist	Plist

/private/var/mobile/Containers/Shared/AppGroup/<APP_GUID>		
Internal App Path	File Name	File Type
/com.atebits.tweetie.scribe/	Scribe.2.sqlite-sqlite	SQLite
/Library/Preferences/	group.com.atebits.Tweetie2.plist	Plist
/TFModelCache1/<User_ID>/database/	modelCache.sqlite3	SQLite

REFERENCES:

<http://cs.lewisu.edu/mathcs/msisprojects/papers/kevinswartz.pdf>

https://www.academia.edu/10726810/Social_Media_Forensics_on_Mobile_Devices

https://www.tandfonline.com/doi/abs/10.1080/00450618.2015.1066854?src=recsys&_journalCode=tajf20

Shopping

Amazon Shopping

APPSTORE URL: <https://apps.apple.com/us/app/amazon-shopping/id297606951>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Caches/com.amazon.Amazon/	Cache.db	SQLite
/Library/Caches/com.amazon.Amazon/ fsCachedData/	*	Various
/Library/Caches/WebKit/NetworkCache/ Version 14/	*	Various
/Library/Preferences/	com.amazon.Amazon.plist	Plist
/Library/WebKit/WebsiteData/LocalStorage/	https_www.amazon.com_0.localstorage	SQLite

Health & Fitness

Fitbit

APPSTORE URL: <https://apps.apple.com/us/app/google-translate/id414706506>

APPSTORE URL: <https://apps.apple.com/us/app/fitbit-health-fitness/id462638897>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	fitbit.sqlite	SQLite
/Library/Application Support/Fitbit/Defaults/	UserInfo.plist	Plist
/Library/Caches/com.fitbit.FitbitMobile/	*	JSON
/Library/Preferences/	com.fitbit.FitbitMobile.plist	Plist

Runtastic

APPSTORE URL: <https://apps.apple.com/us/app/adidas-running-app-runtastic/id336599882>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/raw_traces/<User_ID>/	*	CSV
/Library/Application Support/runtastic/	RTCoreDataAdditionalSessionInfo.sqlite	SQLite
/Library/Application Support/runtastic/	RTCoreDataGeolmageInfo.sqlite	SQLite
/Library/Application Support/runtastic/	RTCoreDataHeartRateInfo.sqlite	SQLite
/Library/Application Support/runtastic/	RTCoreDataLiveTrackingInfo.sqlite	SQLite
/Library/Application Support/runtastic/	RTCoreDataLocationInfo.sqlite	SQLite
/Library/Application Support/runtastic/	RTCoreDataRoute.sqlite	SQLite
/Library/Application Support/runtastic/	RTCoreDataSession.sqlite	SQLite
/Library/Application Support/runtastic/	RTCoreDataSpeedInfo.sqlite	SQLite
/Library/Application Support/runtastic/	RTCoreDataUser.sqlite	SQLite
/Library/Application Support/runtastic/	RTDatabaseEventTrace.sqlite	SQLite
/Library/Application Support/runtastic/	RTDatabaseGoalInfo.sqlite	SQLite
/Library/Application Support/runtastic/	RTDatabaseStepInfo.sqlite	SQLite
/Library/Application Support/runtastic/	RTDatabaseWorkout.sqlite	SQLite
/Library/Preferences/	at.runtastic.gpsportapp.plist	Plist

Strava

APPSTORE URL: <https://apps.apple.com/us/app/strava-run-ride-swim/id426826309>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Application Support/	Strava.sqlite	SQLite
/Library/Application Support/	Strava.sqlite.error	SQLite
/Library/Preferences/	com.strava.stravaride.plist	Plist

REFERENCES:

https://deepsec.net/docs/Slides/2019/Still_Secure_We_Empower_What_We_Harden_Because_We_Can_Conceal_-_Yury_Chemerkin.pdf

Finance

Paypal

APPSTORE URL: <https://apps.apple.com/us/app/paypal/id283646709>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Library/Preferences/	com.yourcompany.PPClient.plist	Plist

Venmo

APPSTORE URL: <https://apps.apple.com/us/app/venmo/id351727428>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	Model.sqlite	SQLite
/Documents/	mParticle28.db	SQLite
/Library/Caches/com.hackemist.SDImageCache/default/	*	Various
/Library/Preferences/	net.kortina.labs.Venmo.plist	Plist
/SplashBoard/Snapshots/	*	KTX

REFERENCES: <https://thebinaryhick.blog/2019/11/07/venmo-the-app-for-virtual-ballers>

Reference

Google Translate

APPSTORE URL: <https://apps.apple.com/us/app/google-translate/id414706506>

/private/var/mobile/Containers/Data/Application/<APP_GUID>		
Internal App Path	File Name	File Type
/Documents/	translate.db	SQLite
/Library/Preferences/	com.google.Translate.plist	Plist

Automated Malware Analysis

Virustotal: <http://www.virustotal.com>

Jotti's Malware Scan: <http://virusscan.jotti.org>

Threat Information and Internet Status

Shadowserver: <http://www.shadowserver.org>

National Vulnerability Database: <http://nvd.nist.gov>

Mitre CVE: <http://cve.mitre.org>

Useful Tools

Sysinfo CLSIDs/Startup Info: www.processlibrary.com

Services to Block Malicious Web Sites

Siteadvisor <http://www.siteadvisor.com>

Linkscanner <http://linkscanner.explabs.com>

OpenDNS <http://www.opendns.org>

Unix Commands

cut -f 1 -d \ \	cut the first column from a file. Consider space () as delimiter
df	check free disk space
du	list disk usage of each directory
find	find files
grep -a "needle" file	same, but treat binary file like ASCII
grep -c "needle" file	count lines that contain "needle"
grep -v "needle" file	return lines that DO NOT contain "needle"
grep "needle" file	extract all lines that contain "needle" from file
history	review recent commands
id	who am I?
ls	directory listing
sort	sort a file line by line
sort -u	sort, and only show unique lines
strings	extract printable strings from file
uniq	unique lines from sorted file

Bring Out the Big Guns

Top 10 sources from a tcpdump capture:

```
tcpdump -nr dumpfile | cut -f3 -d' \ ' | cut -f1-4 -d'.' |
sort | uniq -c | sort -nr | head -10
```

Top 10 referrers from Apache access log:

```
cat access_log | cut -d' \ ' -f11 | cut -d '/' -f3 | sort |
uniq -c | sort -nr | head -10
```

Windows Commands

(Not all commands are available in all windows versions) runas: run a program as a different user

assoc	associate programs with extensions
netsh	Network configuration tool (type "?" to get help)
sc	control services (startup/shutdown/auto-start on boot)
sigverify	Verify driver signatures
find large files	find . -size +5000k -xdev -print
Kill Process	wmic process [pid] delete wmic process where name='cmd.exe' delete
List local users	wmic useraccount list full
Startup Programs	wmic startup list full
use wmic on remote system: wmic /user:userID /password:password /node:hostname share list full	
More:	http://blogs.technet.com http://isc.sans.org/diary.html?storyid=1229

Frequently Scanned Ports

Also see [http://isc.sans.org/port.html?port=\[portnumber\]](http://isc.sans.org/port.html?port=[portnumber])

PORT	SERVICE	PORT	SERVICE
21	FTP	1028	Windows RPC
23	telnet	1080	Proxy Server
25	SMTP (Sendmail)	1433	SQL Server (connect)
53	DNS	1434	SQL Server (Slammer Worm)
67, 68	DHCP	2967	Symantec System Center
80	WEB	3128	Squid Proxy
113	authd/ident	3306	MYSQL
135	Windows Name Resolution	3389	MS Terminal Services
137	Windows File Sharing	4662	eMule P2P file sharing
139	Windows File Sharing	4672	remote access server
143	IMAP	4899	remote admin
161	SNMP	5060	SIP (VoIP)
443	HTTPS	5900	VNC
445	Common Internet File System	6881	Bittorrent
1026	Windows RPC	8000	irdmi/http
1027	Windows RPC	8010	Wingate / HTTP

IPv4 Header															
Byte 0				Byte 1				Byte 2				Byte 3			
0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7
Version		Length		TOS				Total Packet Length							
IP ID / Fragment ID															
TTL				Protocol				Checksum							
Source Address															
Destination Address															

IPv6 Header															
Byte 0				Byte 1				Byte 2				Byte 3			
0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7
Version		Traffic Class				Flow Label									
Payload Length								Next Header				Hop Limit			
Source Address (128 bits, 16 bytes)															
Destination Address (128 bits, 16 bytes)															

ASCII/HEX Lookup																
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	TAB	LF	VT	FF	CR	SO	SI
1	DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
2	SPC	!	"	#	\$	%	&	(	)	*	+	,	-	.	/	
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z	{		}	~	DEL

HEX/DEC Conversion																
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
3	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
4	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
5	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
6	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111
7	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127
8	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143
9	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159
A	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175
B	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191
C	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207
D	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223
E	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239
F	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255

Protocols			
1	ICMP	51	AH
2	IGMP	55	IP Mobility
4	IP in IP	58	IPv6 ICMP
6	TCP	60	IPv6 no header
8	EGP	88	EIGRP
9	IGP	89	OSPF
17	UDP	111	IPX in IP
41	IPv6 in IPv4	115	L2TP
43	IPv6 Routing	133	FC
44	IPv6 Fragment	135	Mobility
47	GRE	255	Reserved
50	ESP		

<http://www.iana.org/assignments/protocol-numbers>

Compare Unix to Windows Shell Commands		
DOS	Unix	
assign	ln -s	create symbolic link
attrib	chmod	change file permissions
chdir	pwd	display current directory
chdisk	du	disk usage
cls	clear	clear screen
comp /fc	diff	compare files
copy	cp	
date/time	date	show date or time
del/erase	rm	delete file
dir	ls	directory listing
doskey /h	history	get recent commands
find	grep	find matching lines
format	mke2fs	format a disk
help	man	get help
ipconfig	ifconfig	check network configuration
mem	free/top	check memory usage
mkdir/md	mkdir	create directory
netstat	netstat	network info
pkzip	zip	compress a file with ZIP
reboot	shutdown -r now	reboot system
rename/move	mv	rename file or move file
route print	route -n	check routing configuration
tasklist	ps	list of running programs
tracert	tracert	trace route
type	cat	print file content
ver	uname -a	OS version

http://www.yolinux.com/TUTORIALS/unix_for_dos_users.html

Convert Windows text files to Unix (remove CR and ^Z):
| tr -d '\15\32' < windows.txt > unix.txt |

Convert Unix text file to Windows:
| awk 'sub("\$", "\r")' unix.txt > windows.txt |

Note: Unix variation vary. Not all commands are available on all flavors of Unix. Use “man” and “info” to explore.

Outshare the bad guys!

Submit your observations at <https://isc.sans.org/contact.html>

Purpose

This cheat sheet supports the SANS **FOR508: Advanced Incident Response, Threat Hunting, and Digital Forensics** course. It is not intended to be an exhaustive resource for Volatility™ or other highlighted tools. Volatility™ is a trademark of Verizon. The SANS Institute is not sponsored, approved by or affiliated with Verizon.

How To Use This Document

Memory analysis is one of the most powerful tools available to forensic examiners. This guide hopes to simplify the overwhelming number of available options.

Analysis can generally be accomplished in six steps:

1. Identify Rogue Processes
2. Analyze Process DLLs and Handles
3. Review Network Artifacts
4. Look for Evidence of Code Injection
5. Check for Signs of a Rootkit
6. Extract Processes, Drivers, and Objects

We outline the most useful Volatility™ plugins supporting these six steps here. Further information is provided for:

- Memory Acquisition
- Alternate Memory Locations
- Converting Hibernation Files and Crash Dumps
- Memory Artifact Timelining
- Registry Analysis Plugins

Getting Started with Volatility™

Getting Help

```
# vol.py -h          Show options and supported plugins
# vol.py plugin -h    Show plugin usage
# vol.py plugin --info Show available OS profiles
```

Sample Command Line

```
# vol.py -f image --profile=profile plugin
```

Identify System Profile

```
imageinfo Display memory image metadata
# vol.py -f mem.img imageinfo
```

Using Environment Variables

```
Set name of memory image Takes place of -f
# export VOLATILITY_LOCATION=file:///images/mem.img
Set profile type           Takes place of --profile=
# export VOLATILITY_PROFILE=Win10x64_14393
```

Identify Rogue Processes

```
pslist High-level view of running processes
# vol.py pslist

psscan Scan memory for EPROCESS blocks
# vol.py psscan

pstree Display parent-process relationships
# vol.py pstree
```

Identify Rogue Processes

```
dlllist List of loaded dlls by process
-p      Show information only for specific processes (PIDs)
# vol.py dlllist -p 1022,868

getsids Print process security identifiers
-p      Show information only for specific PIDs
# vol.py getsids -p 868

handles List of open handles for each process
-p      Show information only for specific PIDs
-t      Display only handles of a certain type
        {Process, Thread, Key, Event, File, Mutant, Token, Port}
# vol.py handles -p 868 -t File,Key
```

Review Network Artifacts

```
netscan Scan for TCP connections and sockets
# vol.py netscan
Note: Use connscan and sockscan for XP systems
```

Look for Evidence of Code Injection

```
malfind Find injected code and dump sections
-p      Show information only for specific PIDs
-v      Verbose: show full paths from three DLL lists
# vol.py ldrmodules -p 868 -v

hollowfind Detect process hollowing techniques
-p      Show information only for specific PIDs
-D      Directory to save suspicious memory sections
# vol.py hollowfind -D ./output_dir
```

Check for Signs of a Rootkit

```
psxview Find hidden processes using cross-view
# vol.py psxview

modscan Scan memory for loaded, unloaded, and
        unlinked drivers
# vol.py modscan

apihooks Find API/DLL function hooks
-p      Operate only on specific PIDs
-Q      Only scan critical processes and DLLs
# vol.py apihooks

ssdt Hooks in System Service Descriptor Table
# vol.py ssdt | egrep -v '(ntoskrnl|win32k)'

driverirp Identify I/O Request Packet (IRP) hooks
-r      Analyze drivers matching REGEX name pattern
# vol.py driverirp -r tcpip

idt Display Interrupt Descriptor Table
# vol.py idt
```

Extract Processes, Drivers, and Objects

dllldump Extract DLLs from specific processes

- p Dump DLLs only for specific PIDs
- b Dump DLL using base offset
- r Dump DLLs matching REGEX name

```
# vol.py dllldump --dump-dir ./output -r metsrv
```

modddump Extract kernel drivers

- b Dump driver using offset address (from modscan)
- r Dump drivers matching REGEX name

```
--dump-dir Directory to save extracted files
# vol.py modddump --dump-dir ./output -r gaopdx
```

procdump Dump process to executable sample

- p Dump only specific PIDs
- o Specify process by physical memory offset
- n Use REGEX to specify process

```
--dump-dir Directory to save extracted files
# vol.py procdump --dump-dir ./output -p 868
```

memdump Extract every memory section into one file

- p Dump memory sections from these PIDs
- n Use REGEX to specify process

```
--dump-dir Directory to save extracted files
# vol.py memdump --dump-dir ./output -p 868
```

filesan Scan memory for FILE_OBJECT handles

```
# vol.py filesan
```

dumpfiles Extract FILE_OBJECTs from memory

- Q Dump using physical offset of FILE_OBJECT
- r Extract using a REGEX (add -i for case insensitive)
- n Add original file name to output name

```
--dump-dir Directory to save extracted files
# vol.py dumpfiles -n -i -r \\.\exe --dump-dir=.
```

svcsan Scan for Windows Service record structures

- v Show service DLL for svchost instances

```
# vol.py svcsan -v
```

cmdscan Scan for COMMAND_HISTORY buffers

```
# vol.py cmdscan
```

consoles Scan for CONSOLE_INFORMATION output

```
# vol.py consoles
```

Memory Acquisition

Remember to open command prompt as Administrator

winpmmem

- o Output file location
- p <path to pagefile.sys> Include page file
- e Extract raw image from AFF4 file
- l Load driver for live memory analysis

```
C:\> winpmmem <version>.exe -o F:\mem.aff4
C:\> winpmmem <version>.exe F:\mem.aff4 -e
PhysicalMemory -o mem.raw
```

DumpIt

- /f Output file location
- /s <value> Hash function to use
- /t <addr> Send to remote host (set up listener with /l)

```
C:\> DumpIt.exe /f F:\mem.raw /s 1
```

Alternate Memory Locations

Hibernation File

Compressed RAM Image; available in Volume Shadow Copies
%SystemDrive%\hiberfil.sys

Page and Swap Files

%SystemDrive%\pagefile.sys
%SystemDrive%\swapfile.sys (Win8+ \2012+)

Memory Dump

%WINDIR%\MEMORY.DMP

Converting Hibernation Files and Crash Dumps

imagecopy Convert alternate memory sources to raw

- f Name of source file
- o Dump DLL using base offset
- profile Source OS from imageinfo

```
# vol.py imagecopy -f hiberfil.sys -O hiber.
raw --profile=Win7SP1x64
# vol.py imagecopy -f MEMORY.DMP -O crashdump.
raw --profile=Win2016x64_14393
```

How To Use This Document

The **timeliner** plugin parses time-stamped objects found in memory images. Output is sorted by:

- Process creation time
- Thread creation time
- Driver compile time
- DLL/EXE compile time
- Network socket creation time
- Memory resident registry key last write time
- Memory resident event log entry creation time

timeliner

- output-file Optional file to write output
- output=body Bodyfile format (also **text**, **xlsx**)
- type=Registry Extract registry key last write times

```
# vol.py -f mem.img timeliner --output-file out.
body --output=body --profile=Win10x64
```

Registry Analysis Plugins

hivelist Find and list available registry hives

```
# vol.py hivelist
```

hivedump Print all keys and subkeys in a hive

- o Offset of registry hive to dump (virtual offset)

```
# vol.py hivedump -o 0xe1a14b60
```

printkey Output a registry key, subkeys, and values

- K Registry key path

```
# vol.py ol.py printkey -K "Microsoft\Windows\
CurrentVersio
```

dumpregistry Extract all available registry hives

- o Extract using virtual offset of registry hive
- dump-dir Directory to save extracted files

```
# vol.py printkey -K "Microsoft\Windows\
CurrentVersion\Run"
```

hashdump Dump user NTLM and Lanman hashes

```
# vol.py hashdump
```

autoruns Map ASEPs to running processes

- v Show everything

```
# vol.py autoruns -v
```

Purpose

The Rekall Memory Forensic Framework is a collection of memory acquisition and analysis tools implemented in Python under the GNU General Public License. This cheat sheet provides a quick reference for memory analysis operations in Rekall, covering acquisition, live memory analysis and parsing plugins used in the 6-Step Investigative Process. For more information on this tool, visit rekall-forensic.com.

Rekall Memory Forensic Framework

Memory analysis is one of the most powerful investigation techniques available to forensic examiners. Rekall auto-detects the target system's profile, using a repository of more than 100 kernel versions available either online or stored locally.

When launching Rekall, you can run single commands or drop into an interactive session to take advantage of caching, preventing the need to obtain the same data with subsequent plugin runs. This cheat sheet shows command line examples using both techniques for Rekall version 1.5.3+

Getting Started with Rekall

Single Command Example

```
$ rekall -f be.aff4 pslist
```

Starting an Interactive Session

```
$ rekall -f be.aff4
```

Starting an Interactive Session (sends output to specified tool)

```
$ rekall -f be.aff4 --pager=gedit
```

session # current image local system time

Memory Analysis Basics

GETTING HELP

```
[1] be.aff4 11:14:35> plugins.<tab>
(lists plugins applicable for use for this image)
[1] be.aff4 11:14:35> pslist?
(lists options available for specific plugin)
```

COMMON OPTIONS IN INTERACTIVE SESSION

```
describe(<plugin>) Print the output fields of a plugin verbosity=#
Specify amount of output (1-10, default=1)
proc_regex="process name"
Regex to select process by name <pid>
Positional Argument: Filter by process PID
dump_dir="path to directory"
Path to output directory
output="path to output dir\file"
Required if outputting to file quit
Exit interactive session
```

IMAGE DETAILS (list OS version, physical layout, uptime)

```
[1] be.aff4 11:14:35> imageinfo
```

ARTIFACT COLLECTOR (Carving for defined artifacts)

```
[] Live (API) 16:52:10> artifact_list
>[] Live (API) 16:52:10> artifact_collector
["WMIProcessList", "WMILoggedOnUsers", "WMIDrivers"],
output_path="c:\\cases\\exercises"
```

Step 1. Enumerating Processes

PSLIST – Enumerate Processes

```
[1] be.aff4 11:14:35> pslist
```

Customize pslist output with efilters

```
[1] be.aff4 11:14:35> describe(pslist)
[1] be.aff4 11:14:35> select
EPROCESS,ppid,process_create_time from pslist()
order by process_create_time
```

PSTREE (WITH VERBOSITY) – List Processes with path and command line

```
[1] be.aff4 11:14:35> describe(pstree)
[1] be.aff4 11:14:35> select _EPROCESS,ppid,cmd,path
from pstree()
```

PEINFO Display detailed process & PE info

```
[1] be.aff4 11:14:35> procinfo <PID>
```

DESKTOPS Enumerate desktops and desktop threads

```
[1] be.aff4 11:14:35> desktops verbosity=<#>
```

SESSIONS Enumerate sessions and associated processes

```
[1] be.aff4 11:14:35> sessions
```

Step 2. Analyze Process DLLs and Handles

DLLLIST – List of loaded dlls by process.

Filter on specific process(es) by including the process identifier <PID> as a positional argument

```
[1] image.img 11:14:35> dlllist [1580,204]
```

THREADS – Enumerates process threads

```
[1] be.aff4 11:14:35> threads proc_regex= "chrome"
```

HANDLES List of open handles for each process Include pid or array of pids separated by commas

```
object_types="TYPE" – Limit to handles of a certain type
{Process, Thread, Key, Event, File, Mutant, Token, Port}
[1] image.img 11:14:35> handles 868, object_types="Key"
```

FILES CAN – Scan memory for _FILE_OBJECT handles

```
[1] image.img 11:14:35> filescan output="filescan.txt"
```

DUMPFILLES – Extract memory mapped files

```
[1] image.img 11:14:35> dumpfiles 1484,dump_dir="."
```

Step 3. Review Network Artifacts

NETSCAN -Scan for connections and sockets in Vista-Win7

```
[1] memory.aff4 11:14:35> netscan
```

NETSTAT -ID active TCP connections in Vista-Win7

```
[1] memory.aff4 11:14:35> netstat
```

DNS_CACHE- Dumps dns resolver cache

```
[1] memory.aff4 11:14:35> dns_cache
```

Step 4. Look for Evidence of Code Injection

MALFIND analysis	Find injected code and dump sections by VAD
<pid> Positional Argument:	Show information only for specific PIDs
phys_eprocess=	Provide physical offset of process to scan
eprocess=	Provide virtual offset for process to scan
dump_dir=	Directory to save memory sections [1] be.aff4 11:14:35> malfind eprocess=0x853cf460, dump_dir="/cases"
LDRMODULES	Detect unlinked DLLs
verbosity=	Verbose: show full paths from three DLL lists [1] be.aff4 11:14:35> ldrmodules 1936
MESSAGEHOOKS	Enumerates desktop and thread windows message hooks to aid in spotting SetWindowsHookEx code injection

Step 5. Check for Signs of a Rootkit

PSXVIEW MODSCAN	Find hidden processes using cross-view Scan memory for loaded, unloaded, and unlinked drivers
SERVICES	Enumerates services from in-memory registry hive
SVCSCAN	Scans for _SERVICE_RECORD objects
HOOKS_INLINE	Detects API hooks
eprocess=	Filters by virtual address EProcess
phys_eprocess=	Filters by physical address of EProcess
HOOKS_EAT	Detects Export Address Table hooks [1] be.aff4 11:14:35> hooks_eat 6764
HOOKS_IAT	Detects Import Address Table hooks
SSDT	Hooks in System Service Descriptor Table
DRIVERIRP	Identify I/O Request Packet (IRP) hooks
regex="drivername"	Filter on REGEX name pattern
OBJECT_TREE	Tracks named objects [1] be.aff4 11:15:35> object_tree type_regex="Driver"
CALLBACKS	Enumerates registered system event callbacks

Step 6. Dump Suspicious Processes and Drivers

DUMP	Hexdump data starting a specified offset [1] be.aff4 11:14:35> dump <virtual offset>
COMMON OPTIONS FOR EXTRACTION	
<pid>	Positional Argument: Filter by process
PID proc_regex="process name"	Regex to select process by name
offset=	Specify process by physical memory offset
dump_dir=	Directory to save extracted files [1] be.aff4 11:14:35> dlldump 1004, dump_dir="."
DLLDUMP	Extract DLLs from specific processes
MODDUMP	Extract kernel drivers [1] be.aff4 11:14:35> moddump regex="tcpip", dump_dir="/tmp"
PROCDUMP	Dump process to executable sample [1] be.aff4 11:14:35> procdump proc_regex="csrss", dump_dir="/tmp"
MEMDUMP	Dump every memory section into a single file [1] be.aff4 11:15:35> memdump 1004, dump_dir="/output"

Windows Memory Acquisition (winpmem)

CREATING AN AFF4 (Open cmd.exe as Administrator)
C:\> winpmem_<version>.exe -o output.aff4

*INCLUDE PAGE FILE
C:\> winpmem_<version>.exe -p c:\pagefile.sys -o output.aff4

EXTRACTING TO RAW MEMORY IMAGE FROM AFF4
C:\> winpmem_<version>.exe output.aff4 --export PhysicalMemory -o memory.img

EXTRACTING TO RAW USING REKALL
\$ rekall -f win7.aff4 imagecopy --output-image="/cases/win7.img"

Live Windows Memory Analysis

(Open cmd.exe as Administrator)
CREATING LIVE REKALL SESSION VIA MEMORY
C:\Program Files\Rekall> Rekall --live

CREATING LIVE REKALL SESSION VIA API ANALYSIS
C:\Program Files\Rekall> Rekall --live API

**LIVE WMI COMMANDS
[] Live (API) 16:52:10> wmi
"select SID, Disabled from Win32_UserAccount"

**LIVE GLOB SEARCH
[] Live (API) 16:52:10> select *
from glob("c:\windows*.exe")

MacOS Memory Live Analysis & Acquisition

MAC OSXPMMEM (Run commands with Root privileges)
Extract osxpmem.zip and ensure file/dir permissions are root:wheel

CREATING AN AFF4
\$ sudo kextload MacPmem.kext
\$ sudo ./osxpmem --output test.aff4
\$ sudo kextunload MacPmem.kext/
<clean up by removing driver>

LIVE OSX MEMORY ANALYSIS
\$ sudo kextload MacPmem.kext/
\$ rekall -f /dev/pmem
<begin interactive session>
\$ sudo kextunload MacPmem.kext/
<clean up by removing driver>

Registry Analysis Plugins

ENUMERATE AND EXTRACT REGISTRY HIVES

HIVES Find and list available registry hives
\$ rekall -f be.aff4 hives

REGDUMP Extracts target hive

--hive_regex Regex Pattern Matching

-D "<dir>" Dump directory
\$ rekall -f be.aff4 regdump --hive_regex="SAM"
-D "/cases"

PRINTKEY Output a registry key, subkeys, and values

-K "Registry key path"
[1] be.aff4 11:14:35> printkey -K
"Software\Microsoft\Windows\CurrentVersion\Run"

USERASSIST Find and parse userassist key values

Additional Functionality

ANALYZE_STRUCT	Interprets and identifies windows memory structures when given a virtual offset [1] be.aff4 11:15:35> analyze_struct 0x8180e6f0
DT	Displays Specific Kernel Data Structures [1] be.aff4 11:14:35> dt "_EPROCESS",offset=<virtual offset>
PTOV	Determine owning process with physical to virtual address translation (decimal offset shown below) \$ rekal -f test.img ptov 21732272
VMSCAN	Allows for the identification of virtual machines
CERTSCAN	Dumps RSA private and public keys
dump_dir=	Dumps output to a specified directory
MIMIKATZ	Extracts and decrypts credentials from lsass

Linux Memory Acquisition

LINUX PMEM (TO CREATE PROFILE)

```
# tar vxzf linux_pmem_1.0RC1.tgz
# cd linux
# make
```

LINPMEM (TO CREATE IMAGE VIA /proc/kcore)

```
# gzip -d linpmem_2.0.1.gz
# chmod 755 linpmem_2.0.1
# ./linpmem_2.0.1 -o linux.aff4
# cd linux
# rekal convert_profile 3.11.0-26-generic.zip
Ubuntu.zip # rekal --profile=Ubuntu.zip -f ../linux.aff4
```

Purpose

Forensic analysts are on the front lines of computer investigations and this guide aims to support them in their quest to uncover the truth.

How To Use This Document

When performing an investigation, it is helpful to be reminded of the powerful options available to the investigator. This document is aimed to be a reference to the tools that could be used.

The key to successful forensics is minimizing your data loss, accurate reporting, and a thorough investigation.

awk

awk is an extremely useful tool, especially for parsing data structured in columns. It is straightforward to use for simple purposes. Its basic use is to select some particular columns from the output: column 1 is referred to as \$1, column 2 as \$2, etc.

The space is the default awk separator. However if you want to be able to parse data separated by some other character, e.g., ":", you can use the -F flag.

Example: `echo "hello:goodbye" | awk -F: '{print $2}'`

Would return "goodbye" as an output

sed

sed is an excellent command for character substitution. Example: if you want to substitute the first occurrence of the 'a' character by an 'e':

`echo "hallo" | sed 's/a/e/'`

The output would be: `hello`

You can use the `g` modifier to substitute all instances:

`echo "Hallo Janny" | sed 's/a/e/g'`

The output would be: `Hello Jenny`

uniq

The `uniq` command reads the input and compares adjacent lines. If two or more adjacent lines are identical, all but one is removed.

Here is a list of the most common options used with `uniq`:

- `-c` Prefix line with number of occurrence
- `-f` Avoid comparing the first N fields
- `-i` Ignore case
- `-s` Avoid comparing the first N characters
- `-u` Only print unique lines

Consider this input file:

a
b
c
d

Now run `uniq` on it:
`sort testfile | uniq`

a
b
c

Now run `uniq -c` on it:

1 a
2 b
3 c

Date

Check the date man page for more options.

Returns the real date from epoch time:

`date -d @1284127201`

Return an epoch time of 1288756800:

`date +%s -d "2010-11-03"`

Return a 2 days old date:

`date --date="-2 days" +"%Y-%m-%d"`

Return 20:00 hours:

`date -d @1288310401 +%k:%M`

Windows findstr

The Windows `findstr` has one interesting feature that differs from `grep`. If you need to search for multiple strings, you need to separate them with a space.

For example, you want or need to look for a match for WHITE or GREEN in a text file, you write your command like this:

`findstr "WHITE GREEN" testfile`

To make the search case insensitive, add the `/I` to print all variant of WHITE or GREEN.

Windows findstr Command List

- `/B` Matches pattern if at the beginning of a line
- `/E` Matches pattern if at the end of a line
- `/L` Uses search strings literally
- `/R` Uses search strings as regular expressions
- `/S` Searches for matching files in the current directory and all subdirectories
- `/I` Specifies that the search is not to be case-sensitive
- `/X` Prints lines that match exactly
- `/V` Prints only lines that do not contain a match
- `/N` Prints the line number before each line that matches
- `/M` Prints only the filename if a file contains a match
- `/O` Prints character offset before each matching line
- `/P` Skip files with non-printable characters

Hex File Header and ASCII Equivalent

File headers are used to identify a file by examining the first 4 or 5 bytes of its hexadecimal content.

File Type	Start	Start ASCII Translation
ani	52 49 46 46	RIFF
au	2E 73 6E 64	snd
bmp	42 4D F8 A9	BM
bmp	42 4D 62 25	BMp%
bmp	42 4D 76 03	BMv
cab	4D 53 43 46	MSCF
dll	4D 5A 90 00	MZ
Excel	D0 CF 11 E0	
exe	4D 5A 50 00	MZP (inno)
exe	4D 5A 90 00	MZ
flv	46 4C 56 01	FLV
gif	47 49 46 38 39 61	GIF89a
gif	47 49 46 38 37 61	GIF87a
gz	1F 8B 08 08	
ico	00 00 01 00	
jpeg	FF D8 FF E1	
jpeg	FF D8 FF E0	JFIF
jpeg	FF D8 FF FE	JFIF
Linux bin	7F 45 4C 46	ELF
png	89 50 4E 47	PNG
msi	D0 CF 11 E0	
mp3	49 44 33 2E	ID3
mp3	49 44 33 03	ID3
OFT	4F 46 54 32	OFT2
PPT	D0 CF 11 E0	
PDF	25 50 44 46	%PDF
rar	52 61 72 21	Rar!
sfw	43 57 53 06/08	cws
tar	1F 8B 08 00	
tgz	1F 9D 90 70	
Word	D0 CF 11 E0	
wmv	30 26 B2 75	
zip	50 4B 03 04	PK

grep/egrep

grep's strength is extracting information from text files. grep operates on one or multiple files when provided with a command line argument(s) that can also include wildcards:

Example: **grep "John" addressbook**

Would return the lines that contained the "John" string in the addressbook text file

Some useful flags:

- A Print number of lines after the match
- B Print number of lines before match
- c Report number of occurrences
- f Reads one or more patterns from a file – pattern is terminated by a newline
- h Suppress the file names on the output
- i Ignore case
- l Report matching files, not matching lines
- P Interpret pattern as a Perl Regex
- v Reverse operation: return the lines **not** matching the string

The **egrep** (extended **grep**) utility can be useful to match several possible strings at the same time (in an OR mode):

egrep "John|Peter" addressbook

grep "John\|Peter" addressbook

Purpose

Incident responders are on the front lines of intrusion investigations and this guide aims to support them in their quest to uncover the truth.

IT'S TIME TO GO HUNTING!

Lnk files with LECmd

Type of artifact: Document creation and opening

Basic usage

```
LECmd.exe -f <file>
LECmd.exe -d <directory>
```

Key data

Target timestamps, Volume information, Absolute file path, Target ID information

Advanced usage

Use the `--all` switch to process all files in a directory vs. only those ending in `.lnk`.

Prefetch Files with PECmd

Type of artifact: Evidence of execution

Basic usage

```
PECmd.exe -f <file>
PECmd.exe -d <directory>
```

Default output is to standard out. Data can be exported to several formats such as csv, json, HTML, etc.

```
PECmd.exe -d <directory> --csv c:\temp
```

Key data

Execution timestamps, total number of executions, and files/directories referenced

Advanced usage

To display higher precision timestamps, use the `--mp` switch. When `--mp` is used, the higher precision timestamps will be reflected in any exported data as well.

Jump Lists with JLECmd

Type of artifact: Document creation and opening

Basic usage

```
JLECmd.exe -f <file>
JLECmd.exe -d <directory>
```

Key data

Same as `LECmd` key data plus Application ID and DestList entry information (for automaticDestinations jump lists)

Advanced usage

The `--ld` and `--fd` switch can be used to display more information about each embedded lnk file.

Use the `--appIDs` switch to supply a list of application IDs that will be added to the internal list of over 375 appIDs.

In some cases, an automaticDestinations jump list can contain additional lnk files tracked in its Directory that are not accounted for in DestList entries. When this happens, a warning will be given and the `--withDir` switch can be used to process all available lnk files regardless of them being present in the DestList.

`JLECmd` also allows for exporting out all available lnk files from a jump list to a directory via the `--dumpTo` switch. Once lnk files have been dumped from a jump list, they can be investigated using any parser that understands lnk files (`LECmd` for example).

String Searching with bstrings

Type of artifact: Any

Basic usage

```
bstrings -f <file>
```

To search for specific strings, use `--ls`

```
bstrings -f <file> --ls "forensics"
```

Use the `-x` and `-m` switches to set maximum and minimum string lengths

Use `--off` to show the offset for each search hit

Advanced usage

In addition to Unicode strings, `bstrings` looks for strings encoded using Western (1252) code page. Use the `--cp` switch to search in any other code page supported by .net. A full listing of available code pages is available at <https://goo.gl/ig6DxW>

`bstrings` also supports regular expression searches via the `--lr` switch. `bstrings` also contains over a dozen built in regular expression patterns for things like credit card numbers, social security numbers, IP addresses, email addresses, and more. To see a list of all built-in regular expressions, use the `-p` switch. When using a built-in expression, use the value in the Name column. For example, to look for email addresses, use this command:

```
bstrings -f <some file> --lr email
```

`bstrings` also allows searching for several strings or regular expressions at once using the `--fr` and `--fs` switches

Filtering: Just the Field You Want

Type of artifact: Evidence of execution

Basic usage

```
AppCompatCacheParser.exe -f <path to>\SYSTEM --csv c:\temp
```

Output file is a tab separated file that can be imported into Timeline Explorer or Excel.

Key data

Full path for executable and execution flag

Advanced usage

```
AppCompatCacheParser.exe --csv c:\temp
```

Omitting `-f` switch pulls AppCompatCache data from the Registry hive loaded into memory.

The `-d` switch can be used to inspect all available details for an entry

Common Functionality

Most tools have common options for exporting data, displaying higher precision timestamps, using custom date formats, etc.

When `--mp` is used, higher precision timestamps are displayed and will also be reflected in any exported data.

Data can be exported to several formats such as csv, json, HTML, etc. at the same time.

```
PECmd.exe -d <directory> --csv c:\temp --html c:\temp\html
```

Amcache.hve with AmcacheParser

Type of artifact: Evidence of execution

Basic usage

`AmcacheParser.exe -f <path to>\Amcache.hve -csv c:\temp`

Output file is a tab separated file that can be imported into Timeline Explorer or Excel.

Key data

FullPath: The full path to the executed file

SHA-1: The SHA-1 hash of the file FileIDLastWriteTimestamp: First executed timestamp MFTEntryNumber: NTFS entry number from FILE record

MFTSequenceNumber: NTFS sequence number from FILE record

Advanced usage

Use the `-b` and `-w` switches to blacklist or whitelist SHA-1 hashes to further reduce the amount of data to review

Use `-i` to generate a list of associated program/file entries

Download Location

Individual tools are available at <https://ericzimmerman.github.io/>.

Chocolatey packages for each are also available.

To get all tools at once, use chocolatey to install the EricZimmermanTools package

Purpose

This guide is a supplement to the SANS [FOR572: Advanced Network Forensics: Threat Hunting, Analysis, and Incident Response](#) course. It covers the basics of JSON and some of the fundamentals of the `jq` utility. The `jq` utility filters, parses, formats, and restructures JSON—think of it as `sed`, `awk`, and `grep`, but for JSON. Given the trend toward logs being generated in JSON, easily accessing and molding that data is increasingly important for the forensicator. This document is not intended to replace `jq`'s extensive documentation. It is only a quick reference resource.

Acquiring the jq Utility

Stephan Dolan is the developer of `jq`, which is free and open-source software. You can install `jq` in most *NIX-based operating systems using the distribution's software/package management system, or you can download the binary for your operating system or the source code from the main project page. Visit for572.com/jq for details, as well as to learn how to contribute to the project through the author's GitHub repository.

A web-based version of `jq` is hosted at jqplay.org. This is especially helpful while learning `jq`, as you can experiment with filters and options in a graphical interface. The jqplay.org web implementation can also be hosted in your own environment, making it suitable for air-gapped networks.

JSON: Structure for Humans and Machines

JSON (JavaScript Object Notation) is an open standard data interchange format, which is both machine-parsable and (mostly) human-readable. JSON is built on two primary structures: Key/value pairs and ordered lists of values. Data types for values can consist of strings, numbers, booleans, nested JSON objects, or the null value.

A single-field JSON object might look like this:

```
{ "name": "Lance" }
```

A more complex JSON object might look like this:

```
{ "name": "Lance", "age": 42,
  "active": true, "tags": [ "tag1",
    "tag2" ], "address": { "street":
    "123 Main", "city": "Lewes",
    "state": "DE", "postalCode":
    "19958"}, "pet": null }
```

JSON can be represented in compact form, as shown above with one object per line, or expanded as shown below – both formats are considered equivalent. Note that `tags` is an array and `address` is a nested JSON object.

```
{
  "name": "Lance",
  "age": 42,
  "active": true,
  "tags": [
    "tag1",
    "tag2"
  ],
  "address": {
    "street": "123 Main",
    "city": "Lewes",
    "state": "DE",
    "postalCode": "19958"
  },
  "pet": null
}
```

Sample JSON Record

The following JSON object will be used for all examples. This reflects a single entry from a `dns.log` file created by the [Zeek Network Security Monitoring](#) platform. All examples assume the compact version of this record in a file named `dns.log`. If you'd like to test on your own, download the sample record from for572.com/dnslog-sample.

```
{
  "ts": 1602265824.123071,
  "uid": "CHFRflzsgM15k9et4",
  "id.orig_h": "192.168.75.169",
  "id.orig_p": 58506,
  "id.resp_h": "192.168.75.1",
  "id.resp_p": 53,
  "proto": "udp",
  "trans_id": 50763,
  "rtt": 0.022633075714111328,
  "query": "www.sansgear.com",
  "qclass": 1,
  "qclass_name": "C_INTERNET",
  "qtype": 1,
  "qtype_name": "A",
  "rcode": 0,
  "rcode_name": "NOERROR",
  "AA": false,
  "TC": false,
  "RD": true,
  "RA": true,
  "Z": 0,
  "answers": [
    "vhost1.identityvector.com",
    "70.32.97.206"
  ],
  "TTLs": [
    3600,
    3600
  ],
  "rejected": false
}
```

To learn what these fields mean, see for572.com/dnslog-fields

Fundamental Usage: Pretty Print

In its simplest usage, `jq` will format compact JSON objects into their expanded form, as shown in the panels to the left. There are several fundamental command line options that will help you as well. The `'.'` filter represents the root of each JSON object and will simply display all fields in the object when used.

```
jq      Format, filter, and transform JSON data
$ jq [options] <filter> <input_file>
-c      Compact output instead of "pretty-printed"
-r      Raw output instead of quoted JSON text
-s      Sort output lexically based on key names
```

For example, to print the sample `dns.log` entry shown in expanded form on the left:

```
$ jq '.' dns.log
```

Filtering: Just the Field You Want

Many times, the user only needs to display specific fields from each JSON object instead of the entire set. This requires a more detailed filter statement.

To display the value for just one field, identify the field with the `'.<fieldname>'` syntax (note the leading dot).

```
$ jq '.query' dns.log
"www.sansgear.com"
```

To display resulting values in their non-quoted raw form, use the `-r` option to the `jq` command.

```
$ jq -r '.query' dns.log
www.sansgear.com
```

When referencing a field name that contains any non-alphanumeric character, double quotation marks must be used. This is common with the dot character, which designates nested JSON objects. However, some JSON logs such as Zeek's use it as a part of the field name which then requires double quoting.

```
$ jq '."'id.orig_h"' dns.log
"192.168.75.169"
```

Accessing Array Elements

To access a particular element from an array, familiar `[<element_number>]` notation is used. Remember that array indices are zero-based.

Accessing Nested JSON Objects

Nested objects can be accessed by using the dot separator. While the sample Zeek `dns.log` entry does not contain these, the below example uses the original JSON object from this handout with the shell's pipe operator to show that like many other command-line tools, `jq` can be used with data on STDIN instead of a file.

```
$ echo '{ "name": "Lance",
  "age": 42, "active": true,
  "tags": [ "tag1", "tag2" ],
  "address": { "street": "123 Main",
    "city": "Lewes", "state": "DE",
    "postalCode": "19958"},
  "pet": null }' | jq '.address.city'
"Lewes"
```

Complex Filtering: Build New JSON Objects

To select more than one field, the syntax reflects assembling a new JSON object. No leading dot is used in this filter syntax. Note that the `-r` option has no effect.

```
$ jq '{ "id.orig_h", query }' dns.log
{
  "id.orig_h": "192.168.75.169",
  "query": "www.sansgear.com"
}
```

Selecting Records Based on Content

By default, `jq` will process all JSON objects in the input data set. Using the select operator allows you to limit the records processed based on their values.

```
$ jq 'select(.rcode_name == "NOERROR")'
```

This command will produce all records with a value of `"NOERROR"` in the `rcode_name` field.

The additional operators `contains`, `startswith`, and `endswith` are also useful ways to select records.

```
$ jq 'select(.query |
  contains("sans"))' dns.log
$ jq 'select(.query |
  endswith(".com"))' dns.log
```

Note however, that the `select()` operator can be very slow, especially on large data sets. Using a preprocessor such as `grep` (or `zgrep` for `gzip`-compressed JSON) can provide a dramatic performance improvement.

Chaining jq Operations

The pipe symbol, `|`, can be used in the filter statement to pass the output of one operation to the input of the next.

```
$ jq 'select(.rcode_name == "NOERROR")
| .query' dns.log
www.sansgear.com
```

Reformatting Time Stamps

Many logs use a form of the UNIX Epoch timestamp. Rather than use external conversion utilities, `jq` can convert these natively. (The `|` operator passes output from one part of the filter as input to the next and `|=` replaces a field's value in place.)

```
$ jq '.ts |= todate | .ts' dns.log
"2020-10-09T17:50:24Z"
```

Purpose

This guide is a supplement to SANS FOR572: Advanced Network Forensics: Threat Hunting, Analysis, and Incident Response. It covers some of what we consider the more useful Linux shell primitives and core utilities. These can be exceedingly helpful when automating analysis processes, generating output that can be copied and pasted into a report or spreadsheet document, or supporting quick-turn responses when a full tool kit is not available.

Remember: If you can make it happen in a shell over a lag-ridden SSH connection, there is a better chance of being the lethal forensicator when it really matters!

How To Use This Document

Linux has been around since 1991, and its *NIX parents since 1969. This handout cannot begin to scratch the surface of the great and powerful things you can do with nothing more than a shell prompt and some moxie. Use this document as a “memory jog” for some of the capabilities of the more commonly used tools in this course and in the forensic workflow in general.

Dig into the details of each tool’s features through its manual pages (aka “man pages”) and other online and offline references. We think you will find the shell to be as powerful as the GUI, and in some cases a far superior alternative – especially for scalability and automation.

No Packets, No Party

tcpdump – Dump network traffic

```
$ sudo tcpdump -n -s 0 -i eth0 '<BPF filter>'
```

```
$ tcpdump -n -r input.pcap -w output.pcap '<BPF filter>'
```

- n Prevent DNS lookups on IP addresses. Use twice to also prevent port-to-service lookups
- r Read from pcap file instead of the network
- w Write packet data to a file
- D Enumerate network interfaces
- i Specify the network interface on which to capture
- s Number of bytes per packet to capture
- C Number of megabytes to save in a capture file before starting a new file
- G Number of seconds to save in each capture file (requires time format in output filename)
- W Used with the -C or -G options, limit the number of rotated files (see man page for detailed usage)
- x Display packet contents in hex

tcpdump requires root privileges to capture network traffic promiscuously. User-level permissions are sufficient for manipulating existing capture files.

See the **pcap-filter** man page for information on building BPFs to control captured traffic.

Index That pcap File!

nfcapd – Generate **nfdump**-compatible NetFlow records from **pcap** file

```
$ nfcapd -r in.pcap -l ./netflow/ -S 1 -z
```

- r pcap file to read
- l Output directory
- s Output directory format (0=flat, 1=yr/mo/day; see **nfcapd** man page for more)
- z Compress output flows

Fundamental Usage: Pretty Print

nfdump – Process NetFlow data from files on disk

```
$ nfdump -R ./ -O tstart -o extended
```

- R Recursively read data from the specified directory
 - r Read data from a single nfcapd file
 - a Aggregate by src+dst IP, src+dst port, protocol
 - A Specify custom aggregation
 - t Time window, in “YYYY/MM/DD.hh:mm:ss” format (See man page for additional details)
 - s Generate “TopN” statistics
 - O Specify output ordering
 - o Specify output format (**line**, **long**, **extended**, or custom). Custom formatting uses “**fmt:<format string>**” syntax, where “**<format string>**” defines values displayed (see man page for full list).
- | | | | |
|------|------------------|------|---------------------|
| %ts | Start time | %te | End time |
| %td | Duration | %pr | Protocol |
| %sa | Source address | %da | Destination address |
| %sap | Source IP:port | %dap | Destination IP:port |
| %sp | Source port | %dp | Destination port |
| %sas | Source ASN | %das | Destination ASN |
| %pkt | Packet count | %byt | Byte count |
| %fl | Flow count | %flg | TCP flags |
| %bps | Bits per second | %pps | Packets per second |
| %bpp | Bytes per packet | | |

What’s in a Name?

passivedns – Generate normalized records for all DNS queries and responses

```
$ passivedns -r input.pcap ↵
-l pdnslog.txt -I pdns_nxdomain.txt
```

- r Specify pcap file to read
- l Log for normal (non-error) queries
- I Log for SRC error queries
- i Specify interface for live DNS observation

GUI-less Packet Spelunking

tshark – Dump and analyze network traffic (aka “Wireshark in the shell”)

```
$ tshark -n -r in.pcap -Y '<disp filter>'
-n      Prevent DNS and port lookups
-r      Read from pcap file instead of the network
-w      Write output to a pcap file instead of the terminal
-T      Output format ( text, fields, etc.)
-e      With “-T fields”, add a field to the output
-Y      Protocol-aware display filter to apply
-z      Statistical output modes – see man page
```

See the **wireshark-filter** man page for information on building protocol-aware display filters.

Bring Out the Big Guns

awk – Pattern scanning and processing language
Seriously powerful stuff™!

```
$ awk -F ' ' '{ print $1,$6,$3 }' in.txt
-F      Specify input field separator (default is space)

Input and output field separators can be specified in the awk script
itself with the FS and OFS variables:

$ awk '{ FS = ","; OFS = "\t"; print $2,$4 }' in.txt
```

For More About These Fine Commands...

Use the built-in reference manual:

```
man      Interface to the on-line reference manuals
$ man find
-k      Perform keyword search through all man pages
```

Use inline command help where available – many commands provide brief usage statements with the “**--help**” or “**-h**” options

```
$ tcpdump --help
```

The Grymoire - home for UNIX wizards:

<http://www.grymoire.com/Unix/>

Use the Force

BASH provides many functions to improve your accuracy, speed, and efficiency – know and use them!

Tab Completion

Hit the <TAB> key to expand the first few characters of a command, directory name, filename, or variable name. If there is more than one possible option, it will complete as far as possible. Press <TAB> again to see the possible completion options.

Standard Variables

```
~      An alias for the current user's home directory (also available
      as $HOME)
$PATH  The command search path
$?     The exit value of the previous command
$PWD   The current working directory
```

Command History

Cycle through previous commands by pressing the up and down arrows. Use the **history** command to see a list of the command history buffer. (BASH writes this buffer is **~/.bash_history** upon exiting, overwriting any existing contents.) Press **Ctrl-R** to search through history for commands that match a search string.

Searching: Where For Art Thou?

grep – Print lines matching a pattern

```
$ grep pattern input.txt
-i      Case-insensitive pattern matching
-v      Print lines that do not match
-c      Count matching lines instead of printing them
-l      Print filenames containing matching lines
-h      Do not include filenames when searching multiple input files
      (e.g., output*.txt)
```

Working on the Chain Gang

Linux prefers small, single-purpose functions and utilities. Chain them together with the “pipe”, which sends the output of one command into the next as input.

```
$ grep pattern input.txt | sort | uniq -c
```

Iteratively build a series of commands to create output that definitively addresses your requirements.

Order in the Court

sort – Sort lines alphabetically or numerically

```
$ sort input.txt
-n      Sort numerically (5 before 10)
-r      Reverse sort order
-k      Specify an alternate sort field
-t      Specify a field delimiter for -k
```

De-Duplication and De-Duplication

uniq – Only print consecutive matching lines once

```
$ grep pattern input.txt | uniq
-c      Print the count of consecutive lines
```

Remember: Only finds consecutive matching lines! Most useful with input piped from the sort command.

```
$ grep pattern input.txt | sort | uniq
```

Redirect Output: I Don't Want to Hear You

Redirect output to a file instead of the shell itself with the “greater than” character. (Warning: It overwrites any existing contents!)

```
$ grep pattern1 input.txt > results.txt
```

Append to existing files with “double greater than”

```
$ grep pattern2 input.txt >> results.txt
```

Purpose

DFIR Forensic Analysts are on the front lines of computer investigations and this guide aims to support them in their quest to uncover the truth.

How To Use This Document

When performing an investigation it is helpful to be reminded of the powerful options available to the investigator. This document is aimed to be a reference to the tools that could be used. Each of these commands runs locally on a system.

TIME TO GO HUNTING

Mounting DD Images

mount -t fstype [options] image mountpoint

The *image* can be a disk partition or a dd image file

Useful options:

ro mount as read only
loop mount on a loop device
noexec do not execute files
offset=<BYTES> logical drive mount
show_sys_files show ntfs metafiles
streams_interface=windows use ADS

Example: Mount an image file at mount_location

```
# mount -o
loop,ro,show_sys_files,streams_interface=windows
imagefile.dd /mnt/windows_mount
```

Mounting E01 Images

```
# ewfmount image.E01 mountpoint
```

```
# mount -o
loop,ro,show_sys_files,streams_interface=windows
/mnt/ewf/ewf1 /mnt/windows_mount
```

Mounting Volume Shadow Copies

Stage 1 – Attach local or remote system drive:

```
# ewfmount system-name.E01 /mnt/ewf
```

Stage 2 – Mount raw image VSS:

```
# vshadowmount ewf1 /mnt/vss/
```

Stage 3 – Mount all logical filesystem of snapshot:

```
# cd /mnt/vss
# for i in vss*; do mount -o
ro,loop,show_sys_files,streams_interface= windows $i
/mnt/shadow_mount/$i; done
```

Creating Super Timelines

```
# log2timeline -r -p -z <system-timezone> -f
<type-input> /mnt/windows_mount -w timeline.csv
```

```
file|dir ..... artifact target
-f <TYPE-INPUT> ..... input format
-o <TYPE-OUTPUT> ..... output format: default csv file
-w <FILE> ..... append to log file
-z <SYSTEM TIMEZONE>
-Z <OUTPUT TIMEZONE>
-r ..... recursive mode
-p ..... preprocessors
```

```
# mount -o
loop,ro,show_sys_files,streams_interface=windows
imagefile.dd /mnt/windows_mount
```

```
# log2timeline -z EST5EDT -p -r -f win7
/mnt/windows_mount -w /cases/bodyfile.txt
```

```
# l2t_process -b /cases/bodyfile.txt -w whitelist.txt
04-02-2012 > timeline.csv
```

Stream Extraction

```
# bulk_extractor <options> -o output_dir image
```

Useful options:

```
-o outdir
-f <regex> ..... regular expression term
-F <rfile> ..... file of regex terms
-Wn1:n2 ..... extract words between n1 and n2 in length
-q nn ..... quiet mode
-e scanner ..... enables a scanner
-e wordlist ..... enable scanner wordlist
-e aes ..... enable scanner aes
-e net ..... enable scanner net
```

```
# bulk_extractor -F keywords.txt -e net -e aes -e
wordlist -o /cases/bulk-extractor-memory-output /
cases/memory-raw.001
```

Registry Parsing – Regripper

```
# rip.pl -r <HIVEFILE> -f <HIVETYPE>
```

Useful options:

```
-r ..... Registry hive file to parse <HIVEFILE>
-f ..... Use <HIVEFILE> (e.g., sam, security,
software, system, ntuser)
-l ..... List all plugins
```

```
# rip.pl -r
/mnt/windows_mount/Windows/System32/config/SAM -f sam
/cases/windowsforensics/SAM.txt
```

Recover Deleted Registry Keys

```
# deleted.pl <HIVEFILE>

# deleted.pl
/mnt/windows_mount/Windows/System32/config/SAM >
/cases/windowsforensics/SAM_DELETED.txt
```

Recovering Data

Create Unallocated Image Using dls (for FAT and NTFS)

```
# blkls imagefile.dd >
unallocated_imagefile.blkls
```

Create Slack Image (deleted data) using blkls

```
# blkls -s imagefile.dd >
imagefile.slack
```

```
foremost Carves out files based on headers and footers
data_file.img = raw data, slack space, memory, unallocated space
# foremost -o outputdir -c
/path/to/foremost.conf data_file.img
```

```
sigfind Search for a binary value at a given offset (-o)
-o <offset> Start search at byte <offset>
# sigfind <hexvalue> -o <offset>
```

Shadow Timeline Creation

Step 1 – Attach Local or Remote System Drive

```
# ewfmount system-name.E01 /mnt/ewf
```

Step 2 – Mount VSS Volume

```
# cd /mnt/ewf
# vshadowmount ewf1 /mnt/vss
```

Step 3 – Run fls across ewf1 mounted image

```
# cd /mnt/ewf
# fls -r -m C: ewf1 >> /cases/vss-bodyfile
```

Step 4 – Run fls Across All Snapshot Images

```
# cd /mnt/vss
# for i in vss*; do fls -r -m C: $i >>
/cases/vss-bodyfile; done
```

Step 5 – De-Duplicate Bodyfile using sort and uniq

```
# sort /cases/vss-bodyfile | uniq >
/cases/vss-dedupe-bodyfile
```

Step 6 – Run mactime Against De-Duplicated Bodyfile

```
# mactime -d -b /cases/vss-dedupe-bodyfile -z EST5EDT
MM-DD-YYYY..MM-DD-YYYY > /cases/vss-timeline.csv
```

Memory Analysis

```
vol.py command -f
/path/to/windows_xp_memory.img
--profile=WinXPSP3x86
```

Supported commands:

```
connscan..... Scan for connection objects
files..... List of open files process
imagecopy ..... Convert hibernation file
procdump..... Dump process
pslist..... List of running processes
sockscan..... Scan for socket objects
```

Sleuthkit Tools

File System Layer Tools (Partition Information)

```
fsstat..... Displays details about the file system
# fsstat imagefile.dd
```

Data Layer Tools (Block or Cluster)

```
blkcat..... Displays the contents of a disk block
# blkcat imagefile.dd block_num
blkls ..... Lists contents of deleted disk blocks
# blkls imagefile.dd > imagefile.blkls
blkcalc..... Maps between dd images and blkls results
# blkcalc imagefile.dd -u blkls_num
blkstat..... Displays allocation status of block
# blkstat imagefile.dd cluster_number
```

MetaData Layer Tools (Inode, MFT, or Directry Entry)

```
ils..... Displays inode details
# ils imagefile.dd
istat..... Displays information about a specific inode
# istat imagefile.dd inode_num
icat..... Displays contents of blocks allocated to an inode
# icat imagefile.dd inode_num
ifind..... Determines which inode contains a specific block
# ifind imagefile.dd -d block_num
```

Filename Layer Tools

```
fls..... Displays deleted file entries in a directory inode
# fls -rpd imagefile.dd
ffind ..... Finds the filename that's using the inode
# ffind imagefile.dd inode_num
```

Purpose

This guide is a supplement to the SANS FOR518: Mac and iOS Forensic Analysis and Incident Response and FOR585: Smartphone Forensic Analysis In-Depth courses, and enhances concepts covered in other courses. It covers some of the core methods to extracting data from SQLite databases. Definitions, sample queries, and SQLite terminology will help you conduct manual extractions from databases of interest found on Macs, smartphones, and PCs. *Commercial tools will only get you so far. Manual recovery and extracting contents **is** what really matters!*

How To Use This Document

SQLite databases are used to store a vast amount of data recovered from digital media. This handout cannot begin to scratch the surface of the great and powerful things you can do with SQL queries. Use this document as a “memory jog” for some of the queries, tools available and examples for normalizing data formats recovered from databases.

We think you will find this reference as a place to start or simply help remember which operators and queries will assist you in your investigation. The tools listed provide support for CLI and GUI.

SQLite References & Tutorials

- **Official SQLite Documentation:** <https://sqlite.org>
- **Great Tutorials:**
 - <https://www.tutorialspoint.com/sqlite/>
 - <http://www.sqlitetutorial.net/>
 - <http://zetcode.com/db/sqlite/>
 - <http://sandersonforensics.com/forum/content.php?275-How-NOT-to-examine-SQLite-WAL-files>
- **FOR518: Mac and iOS Forensic Analysis and Incident Response** – FOR518.com
- **FOR585: Smartphone Forensic Analysis In-Depth** – FOR585.com

Table Joins

Taking data from two (or more!) tables that have a column in common and joining them into one table. Identify tables of interest that contain unique values.

LEFT JOIN – Resulting rows are returned from the **LEFT** table even if there are no matches in the right. Using the **LEFT JOIN** produced all the text messages including those with and without attachments.

```
SELECT
ZVIBERMESSAGE.ZTEXT AS "Message Text",
ZATTACHMENT.ZNAME AS "Attachment Filename",
datetime(ZVIBERMESSAGE.ZDATE+978307200,'unixepoch',
'localtime') AS "Message Date",
ZVIBERMESSAGE.ZSTATE AS "Message Direction/State"
FROM
ZVIBERMESSAGE
LEFT JOIN ZATTACHMENT on
ZATTACHMENT.Z_PK=ZVIBERMESSAGE.ZATTACHMENT
```

INNER JOIN – Resulting rows are returned when both items are a match. Using the **INNER JOIN** (also achieved by typing “JOIN” in the query) returned just the messages that included attachments.

Useful Stuff

Column Renaming:

```
A_TABLE.ZAWKWARDCOLUMNNAME AS "Chat Messages"
```

Counting:

```
SELECT COUNT(*) FROM A_TABLE;
```

Aggregating with GROUP BY and COUNT

(Count chat messages per contact):

```
SELECT MESSAGES,COUNT(*) FROM CHAT GROUP BY CONTACT;
```

Sorting with ORDER BY:

```
SELECT * FROM CHAT ORDER BY A_TIMESTAMP ASC
```

ASC = Ascending

DESC = Descending

Searching with WHERE and LIKE:

```
SELECT CONTACT, MESSAGE FROM CHAT WHERE CONTACT LIKE
'%Hank%'
```

Timestamp Conversion

Timestamps are stored in the databases as one of several numerical representations. (Timestamps are assumed to be stored in UTC, you may need to verify this.)

UNIX Epoch (10-digit number - number of seconds since 01/01/1970 00:00:00):

- `SELECT datetime(TS_COLUMN,'unixepoch')`
Or in **local time** as suggested by the device settings (this can be done for all the following timestamps):
- `SELECT datetime(TS_COLUMN,'unixepoch','localtime')`

UNIX Epoch MILLISECONDS (13-digit number - number of milliseconds since 01/01/1970 00:00:00):

- `SELECT datetime(TS_COLUMN/1000,'unixepoch');`

Mac Absolute time, number of seconds since 01/01/2001 00:00:00. To correctly convert this timestamp, first, add the number of seconds since UNIXEPOCH time to Mac Absolute Time (978307200), then convert.

- `SELECT datetime(TS_COLUMN + 978307200,'unixepoch');`

Chrome time accounts for time accurate to the MICROSECOND, which requires dividing the number by 1,000,000:

- `SELECT datetime(TS_COLUMN/1000000 + (strftime('%s','1601-01-01')), 'UNIXEPOCH');`

sqlite3 CLI Options

Use the command line version of the **sqlite3** program (sqlite.org/cli.html) either in a SQLite shell, or just query via CLI:

```
$ sqlite3 <db_file>
$ sqlite3 <db_file> 'select * from a_table'
```

- **.help** – Provides a list of these ‘dot-commands’
- **.tables** – Show the table names in the database
- **.headers on** – Show the column names in the output
- **.mode column** – Show left-aligned columns
- **.mode tabs** – Show tab separated columns
- **.output <filename>** – Send output to file
- **.dump** – Dump database contents (use with .output)
- **.quit** – Quit sqlite3 shell

Is the Database Using WAL or Journaling

The SQLite header for every database will contain offsets enabling you to differentiate if a journal or WAL is being used to support the database.

- File Offset 18 (1 byte) = x01 = Journaling
- File Offset 19 (1 byte) = x01 = Journaling
OR
- File Offset 18 (1 byte) = x02 = WAL
- File Offset 19 (1 byte) = x02 = WAL

SQLite Deletion

Examine the table to determine if data is moved to the free pages or a Boolean value is entered to mark the data deleted.

Use a SQLite Editor to examine the free pages in a Hex view to carve for deleted artifacts.

Use scripts and tools available to conduct a cursory scan of the free pages for deleted SQLite entries.

SQLite Deleted Records Parser – Python script and GUI to parse deleted data from SQLite databases – https://github.com/mdegrazia/SQLite-Deleted-Records-Parser/tree/master/Old_Versions/sqlparse_v1_1

SQLite Database Basics

SQLite databases are a self-contained database stored as a file system file (but may have a few supporting files that will also be needed for analysis!) Files have the magic number “**SQLite format 3**”. SQLite files correspond to a database that contains tables. **Tables** contain **rows** of data with corresponding columns that describe the data in the row.

Tables		Columns			
		ZUSER	ZRECEIVEDTIMESTAMP	ZTIMESTAMP	ZBODY
FOKATTACHMENT (184)					
FOKATTACHMENTEXTRA (178)					
FOKATTRIBUTION (3)					
FOKCHAT (5)					
FOKCHATEXTRA (5)					
FOKMESSAGE (558)					
FOKMESSAGEEXTRA (4062)					
FOKPUBLICGROUPS (1)					
FOKUSER (292)					
FOKUSEREXTRA (292)					
L_MESSAGES (558)					
L_MESSAGESINVERSE (1)					
L_SHARINGSINVERSE (0)					
L_MEMBERS (32)					
L_METADATA (1)					
L_MODEL_CACHE (1)					

Some temporary files may also be created, including **Journal files** and **Write Ahead Logs**. **Journal files** store original data before a transaction change so the database can be restored to a known state if an error occurs. They are created by default.

Write Ahead Logs (WAL) contain new data changes, leaving original database untouched. After a set number of page changes, the WAL is used to update the actual database. Write ahead logs are optional. Journal files – stores original data before a transaction change so the database can be restored to a known state if an error occurs. (created by default)

SQLite Analysis Tools

- **DB Browser for SQLite** – Free GUI utility available for Mac/Windows/*nix – sqlitebrowser.org
- **sqlite3** – Free CLI utility available for (or native to) Mac/iOS/Android/*nix/Windows – sqlite.org/cli.html
- **SQLite Spy** – Free GUI utility for Windows – <https://www.yunqa.de/delphi/products/sqlitespy/index>
- **Sanderson Forensic Toolkit for SQLite** – Commercial GUI utility for Windows – sandersonforensics.com
- **SQLite Miner** – Free script to extract blobs from databases – https://github.com/threeplanetssoftware/sqlite_miner
- **Commercial tools and Browser Plug-ins** – A SQLite editor is available in most forensic tool suites

Basic Analysis Query Structure

Get everything from a single table:

```
SELECT * FROM A_TABLE;
```

Get two columns from a single table:

```
SELECT COLUMN_A, COLUMN_B FROM A_TABLE;
```

Data Types

- **NULL** – NULL Value
- **INTEGER** – Signed Integer
- **REAL** – Floating Point Number
- **TEXT** – Text String (UTF-8, UTF-16BE or UTF-16LE)
- **BLOB** – (Binary Large Objects) to store large chunks of data. This data may be a picture, video, audio, or archive (Gzip) files. This data is not defined in the database, it may contain anything an app developer desires. This data is often overlooked but may contain forensic nuggets of gold!

Operators

Arithmetic:

- Addition [+]
- Subtraction [-]
- Multiplication [*]
- Division [/]
- Modulus [%]

Comparison:

- Equal [==] or [=], Not Equal [!=] or [<>]
- Greater Than [>] or Greater Than or Equal [>=]
- Less Than [<] or Less Than or Equal [<=]

Logic:

- **IS/IS NOT** – Equal/Not Equal
- **IN/NOT IN** – Is value in (or not) a list of values?
- **LIKE (Case Insensitive)/GLOB (Case Sensitive)** – Is value like this other value? Uses wildcards.
- **AND/OR** – Use with WHERE clause to create complex logic.
- **BETWEEN** – Look for values between two values.

Purpose

SOF-ELK is a VM appliance with a preconfigured, customized installation of the Elastic Stack. It was designed specifically to address the ever-growing volume of data involved in a typical investigation, as well as to support both threat hunting and security operations components of information security programs. The SOF-ELK customizations include numerous log parsers, enrichments, and related configurations that aim to make the platform a ready-to-use analysis appliance. The SOF-ELK platform is a free and open-source appliance, available for anyone to download. The configuration files are publicly available in a GitHub repository and the appliance is designed for upgrades in the field. The latest downloadable appliance details are at for572.com/sof-elk-readme.

What is “ELK” and the “Elastic Stack”?

The Elastic Stack consists of the Elasticsearch search and analytics engine, the Logstash data collection and enrichment platform, and the Kibana visualization layer. It is commonly known as “ELK”, named for these three components.

The broader Elastic Stack includes other components such as the Elastic Beats family of log shippers, and various security and performance monitoring components.

All of the ELK components and the Beats log shippers are free and open-source software. Some other components of the Elastic Stack are commercially-licensed.

Booting and Logging into SOF-ELK

The SOF-ELK VM is distributed in ready-to-boot mode. You may want to add additional CPU cores and RAM if available. Do not decrease the CPU or RAM. After the VM boots, its IP address is displayed on the pre-authentication screen. This IP address is needed for both remote shell access (SSH) and web access to the Kibana interface.

Log in with the “**elk_user**” user account and password “**forensics**”. The elk_user has administrative access using the sudo utility. The password should be changed after first login using local preferences or policies. The SSH server is running on the default port, 22. Access this with your preferred SSH/SCP/SFTP client software. The Kibana interface is running on port 5601. Access this with your preferred web browser. (Note that Microsoft Edge is known to be problematic.)

Updating With Git

The SOF-ELK VM uses a clone of the GitHub-based repository containing all configuration files. This allows the user to update an operational install's configuration files without needing to download a new copy of the VM itself. ALWAYS check the current GitHub repository for any notes or special instructions before updating an operational SOF-ELK platform.

To update the VM, ensure it has Internet connectivity and run the following command:

```
$ sudo sof-elk_update.sh
```

Clearing and Re-Parsing Data

Removing data from SOF-ELK's Elasticsearch indices as well as forcing the platform to re-parse source data on the filesystem itself have both been automated with a shell script. Removal is done by index, and optionally allows a single source file to be removed. The index name is required.

Get a list of currently-loaded indices:

```
$ sof-elk_clear.py -i list
```

Remove all data from the netflow index:

```
$ sof-elk_clear.py -i netflow
```

Remove all data from the syslog index and reload all source data:

```
$ sudo sof-elk_clear.py -i syslog -r
```

Remove all data from the index that was originally loaded from the /logstash/httpdlog/access_log file:

```
$ sof-elk_clear.py ↵  
-f /logstash/httpdlog/access_log
```

Kibana Query Language Syntax

The Kibana user interface uses the Kibana Query Language (KQL) syntax for searching the data contained in Elasticsearch. Below are some of the basic syntaxes that will help you search data that has been loaded to SOF-ELK.

Basic Searching

The most basic search syntax is “**fieldname:value**”, which will match all documents with a “**fieldname**” field set to a value of “**value**”. Searches can be negated by prefixing them with “**not**”. Some examples:

- **hostname:webserver**
- **not querytype:AAAA**

Logical Construction

Multiple searches can be combined using “**and**” and “**or**”.

- **destination_geo.asn:Amazon.com and in_bytes > 1000000**

Numerical Ranges

Fields containing numerical values can be searched with standard range operators.

- **total_bytes > 1000000**
- **return_code >= 200 and return_code <300**

Partial String Searches

The “*****” is used as a wildcard character.

- **username:*admin***
- **query:*.*.cz.cc**

IP Addresses and CIDR Blocks

IP address fields can be searched for specific values or can use CIDR notation for netblocks.

- **source_ip:172.16.7.11**
- **destination_ip:172.16.6.0/24**

Loading Data to SOF-ELK

SOF-ELK can ingest several data formats, including:

- Syslog (many different log types supported)
- HTTP server access logs
- NetFlow
- Selected Zeek logs
- Selected EZ Tools JSON files

More sources are being tested and added to the platform and can be activated through the GitHub repository. See the “Updating With Git” section for more details on how to do this.

All source data can be loaded from existing files (DFIR Model) as well as from live sources (Security Operations Model).

DFIR Model

Place source data onto the SOF-ELK VM under the `/logstash/` directory tree.

Syslog data: `/logstash/syslog/`

Since syslog entries often do not include the year, subdirectories for each year can be created in this location – for example, `/logstash/syslog/2018/`

HTTP server logs: `/logstash/httpd/`

Supports common, combined, and related formats

PassiveDNS logs: `/logstash/passivedns/`

Raw logs from the `passivedns` utility

NetFlow from nfcapd-collected data stores:

`/logstash/nfarch/`

Use the included `nfdump2sof-elk.sh` or `vpcflow2sof-elk.sh` scripts to create SOF-ELK-compatible NetFlow ASCII files.

Zeek NSM logs: `/logstash/zeek/`

Supports multiple different log types, based on default Zeek NSM filenames

EZ Tools JSON Files: `/logstash/kape/`

Supports multiple files from the KAPE family of Eric Zimmerman’s tools in JSON format. Open the necessary firewall port(s) to allow your preferred network-based ingest to occur.

Security Operations Model

Syslog: TCP and UDP syslog protocol

```
$ sudo fw_modify.sh -a open -p 5514 -r tcp
```

```
$ sudo fw_modify.sh -a open -p 5514 -r udp
```

Syslog: Elastic Filebeat shipper

```
$ sudo fw_modify.sh -a open -p 5044 -r tcp
```

NetFlow: NetFlow v5 and v9 protocols

```
$ sudo fw_modify.sh -a open -p 9995 -r udp
```

HTTP Server logs: TCP and UDP syslog protocol

```
$ sudo fw_modify.sh -a open -p 5515 -r tcp
```

```
$ sudo fw_modify.sh -a open -p 5515 -r udp
```

Configure the log shipper or source to send data to the port indicated above.

SOF-ELK Dashboards

Several Kibana dashboards are provided, each designed to address basic analysis requirements. Open the Kibana interface in a web browser using the SOF-ELK VM’s IP address on port 5601.

The following dashboards are included:

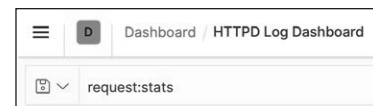
- SOF-ELK VM Introduction Dashboard • HTTPD Log Dashboard
- Syslog Dashboard • NetFlow Dashboard

Additional dashboards will be distributed through the GitHub repository. (See the “Updating With Git” section.)

The Kibana dashboards allow the analyst to interact with and explore the data contained in the underlying Elasticsearch engine. Several features provide a level of interactivity that allows dynamic analysis across vast volumes of data.

Querying Available Data

The top of each dashboard allows the user to input KQL queries, detailed in the “Kibana Query Language Syntax” section. Elasticsearch determines how well its documents match, including a “`_score`” field that indicates how well each document matches the query.



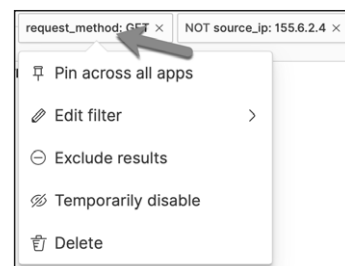
Filtering

Filters can also be applied in the Kibana interface. These are similar to queries, but are a binary match/non-match search without a “`_score`” field. Elasticsearch caches frequently-used filters to optimize their performance.

Kibana shows filters as boxes below the query field. “Must have” and “must not have” are differentiated with the red “NOT” text.

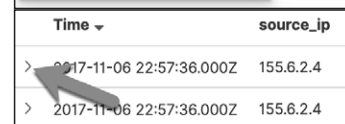


Filters can be modified with the drop-down menu displayed after clicking on a filter.

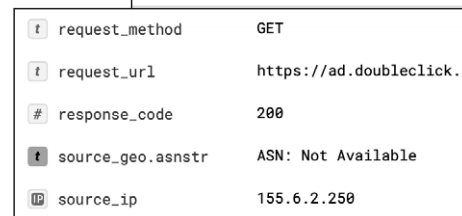


Document Expansion

When a dashboard includes a document listing panel, each document can be expanded by clicking the triangle icon on the left.



This will show all fields for the document.



Interactive Filter Generation

Each field displayed in the record details can be interactively built into a filter with the magnifying glass icons displayed when hovering over the field. The plus sign magnifying glass creates a “must have” filter, the minus sign magnifying glass creates a “must not have” filter. The table icon adds the field to the document listing panel and the final icon creates a “field must be present” filter.



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Assessment

Basic/Intermediate Levels

BootUp CTF

- Beginner to intermediate levels
- A wide spectrum of cybersecurity disciplines
- Individual or team-based
- Self-paced
- 1 to 2 days, scheduled a week in advance

Event/Competition

Basic/Intermediate/Expert/Pro Levels

NETWARS

- Cutting-edge challenges
- Compelling integrated storyline
- Led by SANS instructors and teaching assistants
- Individual or team-based
- Multiple versions: Core, Cyber Defense, DFIR, ICS and Power Grid
- One day, two days, or four months – scheduled a month in advance

Simulation

Intermediate/Expert Levels

Expert/Pro Levels



- Built for cybersecurity leaders and managers
- Real-world decision-making scenarios
- Play as an individual or team
- Compete to build your security capabilities

NETWARS CYBERCITY

- 1:87 scale miniature physical city
- Real-world ICS assets
- Emulates commercial/residential power, transportation, water, and defense sectors
- Individual or team-based
- One to five days – scheduled a month in advance



- Real-world simulation of enterprise environment
- Expert-level penetration test/offensive skill development
- Individual or team-based
- Self-paced
- One to two days – scheduled a month in advance

Cyber STX

- Red-on-blue range emulating an advanced persistent threat
- Protect IT & OT infrastructure under active attack
- Teams of 25 to 100+ people
- One week, but can be customized
- Please schedule six months in advance



For custom Cyber Range options and the schedule of upcoming Community CTF events and NetWars Tournaments, visit sans.org/cyber-ranges

Security Analyst Gabriel B. has some advice.

"As someone with a Master's in Cybersecurity, I would say that the course content at SANS is way better than what I learned at my school. If I had known SANS offered accredited degree programs, it would have saved me a ton of heartache and money. I also would have learned more. I wish I could have done things differently, but maybe I can convince others to take the SANS.edu academic path."

- Gabriel B., Security Analyst
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Blog – Cybersecurity Blog



Newsletters – Newsbites; @Risk; OUCH!



Webcasts – Live and Archived



Posters – Job-Focused Resources



SANS Holiday Hack Challenge



Critical Security Controls – Recommended Actions for Cyber Defense



Podcasts – Internet Storm Center Daily Stormcast; Trust Me, I'm Certified; Blueprint

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