Getting Saucy with APFS!

The State of Apple's New File System

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Apple File System History

Apple File Systems – Let's Reminisce

1984

Macintosh File System (MFS)

1985

Hierarchical File System

- HFS or Mac OS Standard
- System 2.1

1998

Hierarchical File System Plus

- HFS+ or Mac OS Extended
- System 8.1

2017

Apple File System

- APFS
- iOS 10.3, macOS 10.13

Rich Trouton - Storing our Digital Lives: Mac filesystems from MFS to APFS https://youtu.be/IHZK30h8x4w

APFS Timeline

June 26, 2016

- Announced at WWDC

September 20, 2016

- macOS 10.12
- "Experimental Support"

March 27, 2017

- iOS 10.3
- tvOS 10.2
- watchOS 3.2

September 25, 2017

- macOS 10.13

APFS Gist

- New default file system for iOS 10.3, macOS 10.13 (with caveats), watchOS 3.2, & tvOS 10.2
  - Some basic APFS functionality available with Sierra (10.12)
  - iOS upgrade to APFS transparently in 10.3 update
  - Fusion Drives & HDDs not automatically converted to APFS
  - High Sierra (10.13) install performs in-place upgrade to APFS from HFS+
- 64-bit File System
- Optimized for Flash/SSD Drives
  - Can be used on HDDs
  - Internal & External - Bootable & Data Drives
  - Can be used across multiple drives (ie: RAID-ish, CoreStorage-ish)
- Nanosecond Timestamp Granularity
- Implements TRIM

Acquisition

iOS Acquisition

```
-bash-3.2# uname -a
Darwin miPhoneX 17.2.0 Darwin Kernel Version 17.2.0: Fri Sep 29 18:14:51 PDT 2017; root:xnu-4570.20.62~4/
RELEASE_ARM64_T8015 iPhone10,6
-bash-3.2# cat /etc/fstab
/dev/disk0s1s1 / apfs ro 0 1
/dev/disk0s1s2 /private/var apfs rw,nosuid,nodev 0 2
/dev/disk0s1s3 /private/var/wireless/baseband_data apfs rw,nosuid,nodev,nobrowse 0 2
/dev/disk0s1s4 /private/var/hardware apfs rw,nosuid,nodev,nobrowse 0 2
```

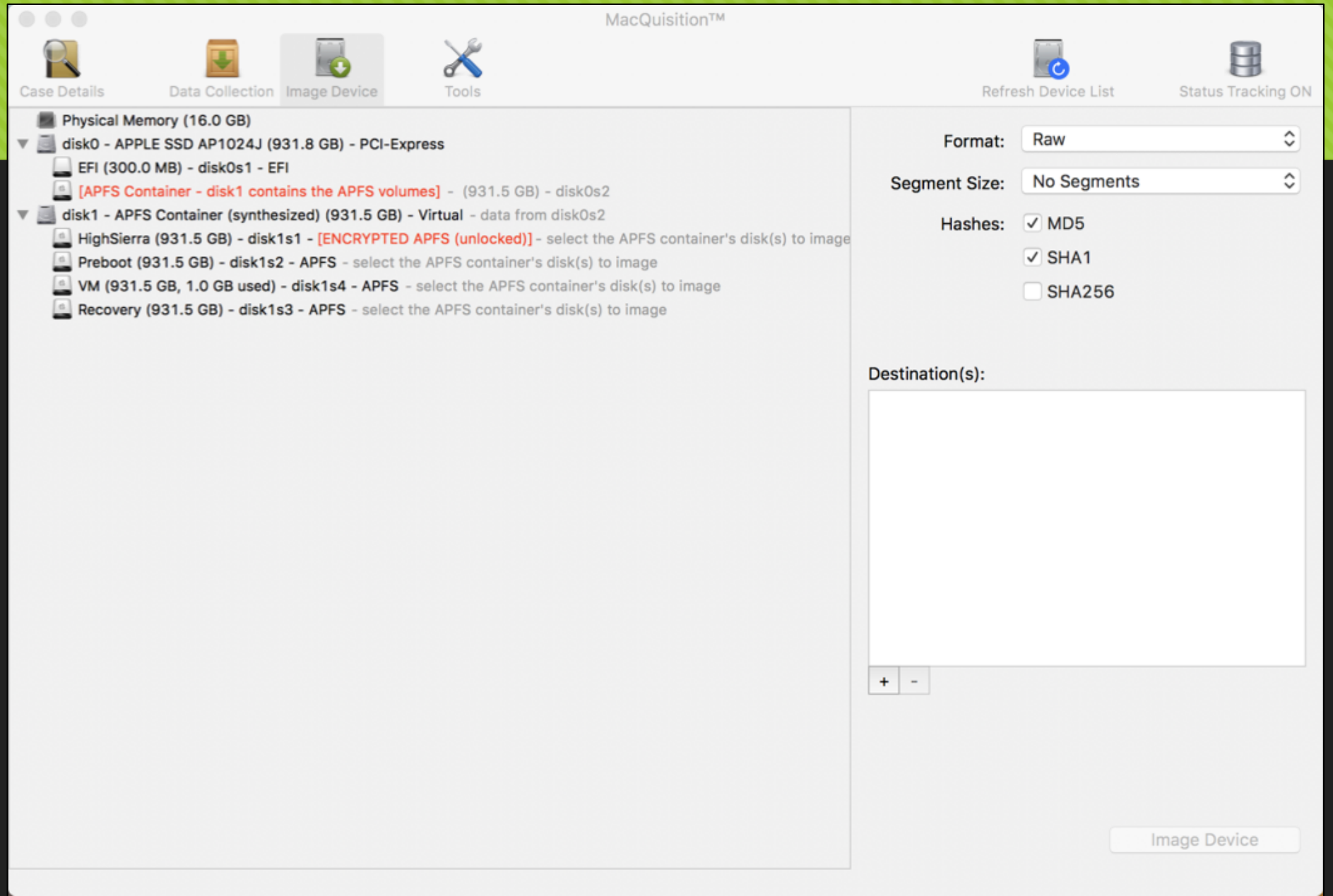
```
-bash-3.2# xxd /dev/disk0
xxd: /dev/disk0: Operation not permitted
-bash-3.2# xxd /dev/disk0s1s1
xxd: /dev/disk0s1s1: Operation not permitted
-bash-3.2# xxd /dev/disk0s1s2
xxd: /dev/disk0s1s2: Operation not permitted
```

- Assumes physical/jailbroken access
- Disk Layout: /etc/fstab
- ‘dd’ system partition imaging limited by permissions = ”Operation not permitted”
- “Logical/Physical” Acquisition – Tar bundle of logical files from physical partitions
- https://www.mac4n6.com/blog/2018/1/7/ios-imaging-on-the-cheap-part-deux-for-ios-10-11

macOS Acquisition

- macOS
  - Turn off SIP (System Integrity Protection)
  - Reboot into Recovery Mode and run '`csrutil disable`'
  - Can re-enable after imaging by rebooting into recovery mode and '`csrutil enable`'
  - SIP Status – '`csrutil status`'
- Encryption
  - Password or Recovery Key Required
- Physical Disk (/dev/disk0) - For single drive APFS implementation
- Logical Container (/dev/disk1) - For systems using spanning data across multiple physical disks (Converted Fusion drives, multiple SSDs, etc.)
- Tools
  - dd/dcfldd/dc3dd
  - Access Data FTK CLI Imager
  - BlackBag MacQuisiton
  - Sumuri Recon Imager

BlackBag MacQuisition



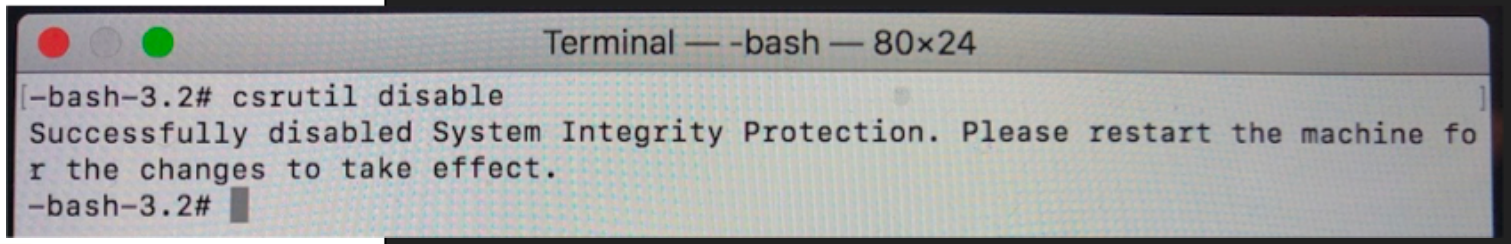
SIP Acquisition Errors

```
MacBook-Pro:~ oompa$ diskutil list
/dev/disk0 (internal):
   #:                       TYPE NAME                    SIZE       IDENTIFIER
   0:      GUID_partition_scheme                        1.0 TB     disk0
   1:                        EFI EFI                     314.6 MB   disk0s1
   2:                 Apple_APFS Container disk1         1.0 TB     disk0s2

/dev/disk1 (synthesized):
   #:                       TYPE NAME                    SIZE       IDENTIFIER
   0:      APFS Container Scheme -                      +1.0 TB    disk1
                                 Physical Store disk0s2
   1:                APFS Volume HighSierra             680.2 GB   disk1s1
   2:                APFS Volume Preboot                27.4 MB    disk1s2
   3:                APFS Volume Recovery               517.8 MB   disk1s3
   4:                APFS Volume VM                     1.1 GB     disk1s4

MacBook-Pro:~ oompa$ dd if=/dev/disk0 of=/tmp/test.dd
dd: /dev/disk0: Operation not permitted
MacBook-Pro:~ oompa$ sudo !!
sudo dd if=/dev/disk0 of=/tmp/test.dd
Password:
dd: /dev/disk0: Operation not permitted
MacBook-Pro:~ oompa$ sudo dd if=/dev/disk1 of=/tmp/test.dd
dd: /dev/disk1: Operation not permitted
MacBook-Pro:~ oompa$ sudo dd if=/dev/disk1s1 of=/tmp/test.dd
dd: /dev/disk1s1: Operation not permitted
```

- Devices not available with SIP enabled
  - Even with root!
- Disable SIP using `csrutil` in Recover Mode
  - Reboot, CMD+R
  - `csrutil disable`



macOS Disks & Partitions
diskutil list

```
Sarahs-MBP-6:~ oompa$ diskutil list
/dev/disk0 (internal):
   #:                       TYPE NAME                    SIZE       IDENTIFIER
   0:      GUID_partition_scheme                        1.0 TB     disk0
   1:                        EFI EFI                     314.6 MB   disk0s1
   2:                 Apple_APFS Container disk1         1.0 TB     disk0s2

/dev/disk1 (synthesized):
   #:                       TYPE NAME                    SIZE       IDENTIFIER
   0:      APFS Container Scheme -                      +1.0 TB    disk1
                                 Physical Store disk0s2
   1:                 APFS Volume HighSierra            650.4 GB   disk1s1
   2:                 APFS Volume Preboot               27.4 MB    disk1s2
   3:                 APFS Volume Recovery              517.8 MB   disk1s3
   4:                 APFS Volume VM                    4.3 GB     disk1s4
```

GPT Partitions
`gpt –r show /dev/disk0`

- EFI Partition GUID - `C12A7328-F81F-11D2-BA4B-00A0C93EC93B`
- APFS Partition GUID - `7C3457EF-0000-11AA-AA11-00306543ECAC`
- FYI: `gpt` command can only be run with SIP disabled

```
Sarahs-MBP-6:~ oompa$ sudo gpt -r show /dev/disk0
      start        size  index  contents
          0           1         PMBR
          1           1         Pri GPT header
          2           4         Pri GPT table
          6       76800      1  GPT part - C12A7328-F81F-11D2-BA4B-00A0C93EC93B
      76806   244199454      2  GPT part - 7C3457EF-0000-11AA-AA11-00306543ECAC
  244276260           4         Sec GPT table
  244276264           1         Sec GPT header
```

APFS Containers
`diskutil ap list`

APFS Container

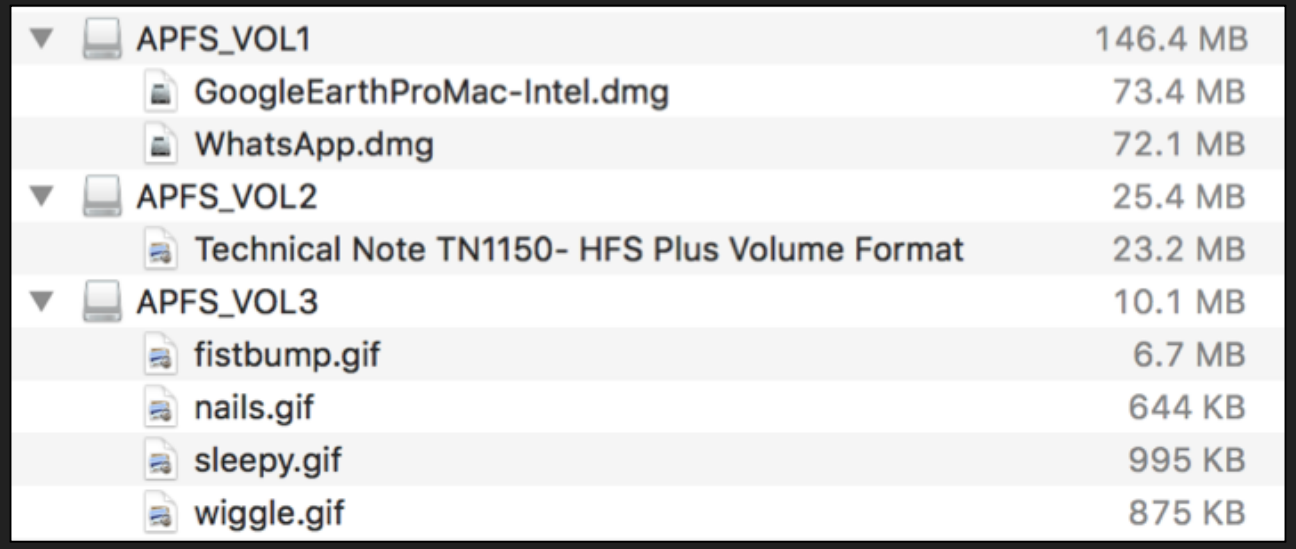
Container Disk

Physical Store

Volumes
- Roles (“None” (User/OS), PreBoot, Recovery, VM)
- Encryption Status - “HighSierra” uses FileVault

```
Sarahs-MBP-6:~ oompa$ diskutil ap list
APFS Containers (3 found)
|
+-- Container disk1 7AB09481-C4B7-4A1D-B551-6ADAA5D8ED24
|   ==================================================
|   APFS Container Reference:     disk1
|   Size (Capacity Ceiling):      1000240963584 B (1.0 TB)
|   Minimum Size:                 1000655269888 B (1.0 TB)
|   Capacity In Use By Volumes:   656089354240 B (656.1 GB) (65.6% used)
|   Capacity Not Allocated:       344151609344 B (344.2 GB) (34.4% free)
|   |
|   +-< Physical Store disk0s2 FC80FCEE-E44F-4F25-BA57-F303E87FB108
|   |   ----------------------------------------------------------
|   |   APFS Physical Store Disk:   disk0s2
|   |   Size:                       1000240963584 B (1.0 TB)
|   |
|   +-> Volume disk1s1 1D19162C-518C-3A34-A02C-2D428A4BC44E
|   |   ----------------------------------------------------
|   |   APFS Volume Disk (Role):   disk1s1 (No specific role)
|   |   Name:                      HighSierra (Case-insensitive)
|   |   Mount Point:               /
|   |   Capacity Consumed:         651046686720 B (651.0 GB)
|   |   FileVault:                 Yes (Unlocked)
|   |
|   +-> Volume disk1s2 670CBB6D-1FE7-446D-A76A-C549A159F34F
|   |   ----------------------------------------------------
|   |   APFS Volume Disk (Role):   disk1s2 (Preboot)
|   |   Name:                      Preboot (Case-insensitive)
|   |   Mount Point:               Not Mounted
|   |   Capacity Consumed:         27398144 B (27.4 MB)
|   |   FileVault:                 No
|   |
|   +-> Volume disk1s3 30817573-A0CE-4CF7-AC2B-D7C7E921B424
|   |   ----------------------------------------------------
|   |   APFS Volume Disk (Role):   disk1s3 (Recovery)
|   |   Name:                      Recovery (Case-insensitive)
|   |   Mount Point:               Not Mounted
|   |   Capacity Consumed:         517754880 B (517.8 MB)
|   |   FileVault:                 No
|   |
|   +-> Volume disk1s4 38B6B6EE-C683-4FF1-8100-EE6C1A551668
|       ----------------------------------------------------
|       APFS Volume Disk (Role):   disk1s4 (VM)
|       Name:                      VM (Case-insensitive)
|       Mount Point:               /private/var/vm
|       Capacity Consumed:         4295012352 B (4.3 GB)
|       FileVault:                 No
```

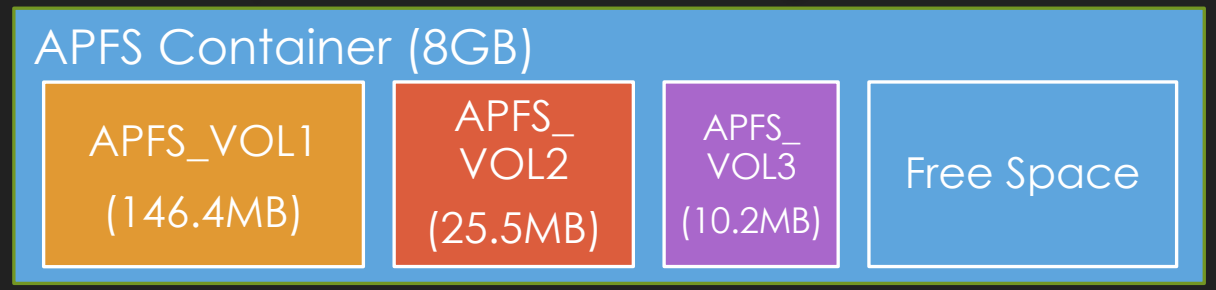
Pooled Storage or “Space Sharing”




```
Sarahs-MBP-6:~ oompa$ df -h /Volumes/APFS_VOL1
Filesystem     Size   Used  Avail Capacity iused                ifree %iused  Mounted on
/dev/disk5s1  7.2Gi  140Mi  7.0Gi     2%      79 9223372036854775728    0%   /Volumes/APFS_VOL1
Sarahs-MBP-6:~ oompa$ df -h /Volumes/APFS_VOL2
Filesystem     Size   Used  Avail Capacity iused                ifree %iused  Mounted on
/dev/disk5s2  7.2Gi   24Mi  7.0Gi     1%     100 9223372036854775707    0%   /Volumes/APFS_VOL2
Sarahs-MBP-6:~ oompa$ df -h /Volumes/APFS_VOL3
Filesystem     Size   Used  Avail Capacity iused                ifree %iused  Mounted on
/dev/disk5s3  7.2Gi  9.7Mi  7.0Gi     1%      88 9223372036854775719    0%   /Volumes/APFS_VOL3
```

“Space Sharing”

- APFS Containers may contain multiple volumes
- Disk spaced is shared amongst other volumes




```
/dev/disk2 (external, physical):
   #:                       TYPE NAME                    SIZE       IDENTIFIER
   0:      GUID_partition_scheme                        *7.9 GB     disk2
   1:                        EFI EFI                     209.7 MB   disk2s1
   2:                 Apple_APFS Container disk3         7.7 GB     disk2s2

/dev/disk3 (synthesized):
   #:                       TYPE NAME                    SIZE       IDENTIFIER
   0:      APFS Container Scheme -                      +7.7 GB     disk3
                                 Physical Store disk2s2
   1:                APFS Volume APFS_VOL1               146.4 MB   disk3s1
   2:                APFS Volume APFS_VOL2               25.5 MB    disk3s2
   3:                APFS Volume APFS_VOL3               10.2 MB    disk3s3
```

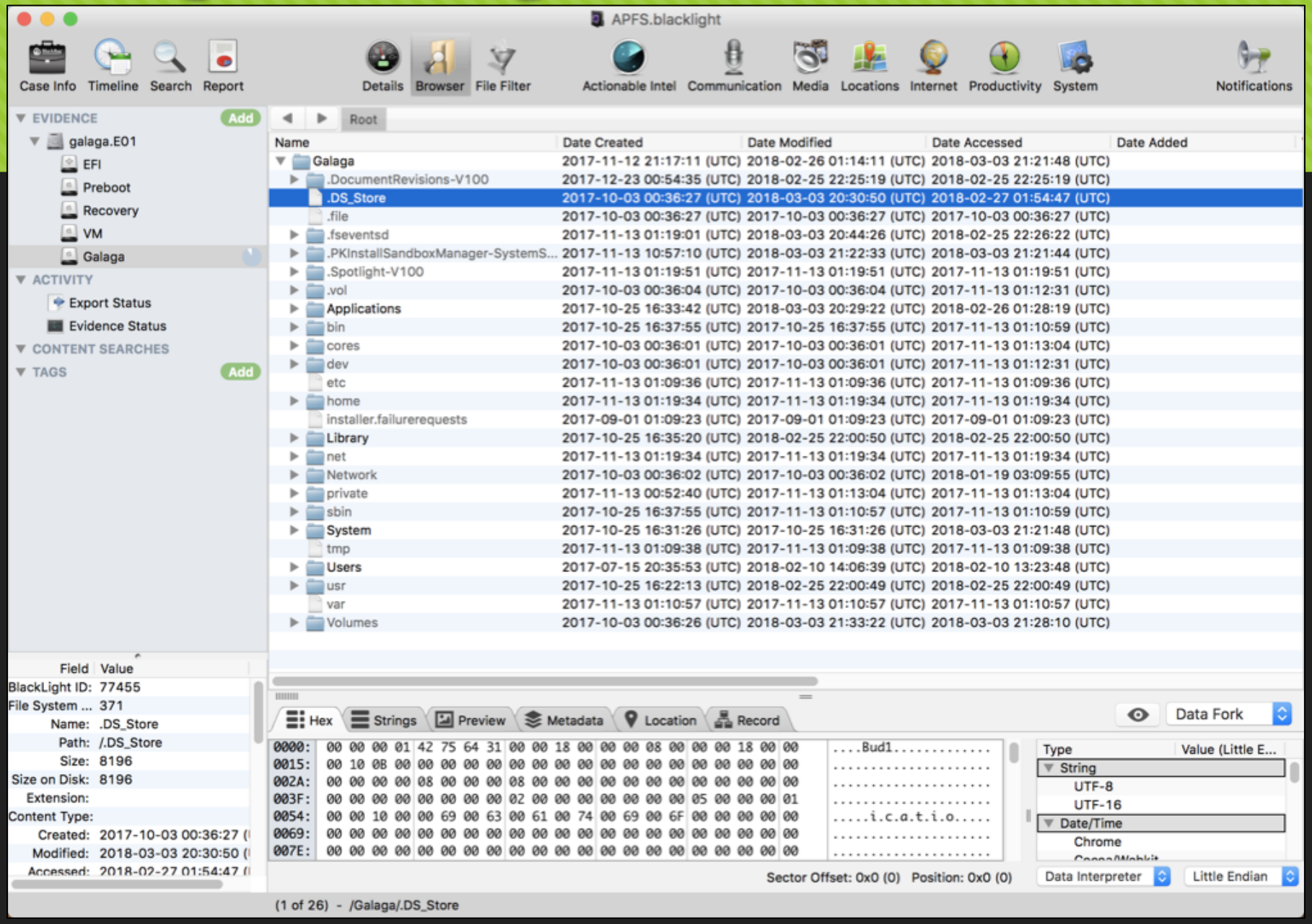
```
Sarahs-MBP-6:~ oompa$ diskutil ap list disk3
|
+-- Container disk3 387F97D2-84FA-46A1-9DD6-042E9C6124FD
    ================================================
    APFS Container Reference:     disk3
    Size (Capacity Ceiling):      7709089792 B (7.7 GB)
    Minimum Size:                 228675584 B (228.7 MB)
    Capacity In Use By Volumes:   207392768 B (207.4 MB) (2.7% used)
    Capacity Not Allocated:       7501697024 B (7.5 GB) (97.3% free)
    |
    +-< Physical Store disk2s2 D91E2996-2C76-4E20-B5BD-E8CEE9F83EE4
    |   ----------------------------------------------------------
    |   APFS Physical Store Disk:   disk2s2
    |   Size:                       7709093376 B (7.7 GB)
    |
    +-> Volume disk3s1 7708D723-0592-4509-A497-8BA01EC8BA64
    |   ----------------------------------------------------
    |   APFS Volume Disk (Role):   disk3s1 (No specific role)
    |   Name:                      APFS_VOL1 (Case-insensitive)
    |   Mount Point:               /Volumes/APFS_VOL1
    |   Capacity Consumed:         146432000 B (146.4 MB)
    |   FileVault:                 No
    |
    +-> Volume disk3s2 B2551185-8A61-42A8-BB05-C8974147E8DE
    |   ----------------------------------------------------
    |   APFS Volume Disk (Role):   disk3s2 (No specific role)
    |   Name:                      APFS_VOL2 (Case-insensitive)
    |   Mount Point:               /Volumes/APFS_VOL2
    |   Capacity Consumed:         25513984 B (25.5 MB)
    |   FileVault:                 No
    |
    +-> Volume disk3s3 7C6F51AE-D751-4F27-B23A-1BECCE4889AA
        ----------------------------------------------------
        APFS Volume Disk (Role):   disk3s3 (No specific role)
        Name:                      APFS_VOL3 (Case-insensitive)
        Mount Point:               /Volumes/APFS_VOL3
        Capacity Consumed:         10186752 B (10.2 MB)
        FileVault:                 No
```

Forensic Tool Analysis Support

Forensic Tool Analysis Support

Tool	Support	Notes
AccessData FTK	No	
BlackBag BlackLight	Yes	FileVault Support
macOS 10.13	Yes	Native via Image Mounting, FileVault Support
Magnet Axiom	No	
Nuix	No	
OpenText EnCase	Meh.	Logical L01 File – No full native support.
SANS SIFT	Yes	Via Image Mounting, 3rd Party Driver, No FileVault Support
Sleuthkit	No	Soon? DFRWS US 2018, Paper by Joe Sylve
Sumuri Recon	Yes	FileVault Support
XWays	Yes	Unencrypted APFS Support

BlackBag BlackLight



Mounting

MacOS – w/ or w/o FileVault Encryption 10.13 Host Required

1. $ sudo mkdir /Volumes/apfs_image/
2. $ sudo mkdir /Volumes/apfs_mounted/
3. $ sudo xmount --in ewf apfs.E01 --out dmg /Volumes/apfs_image/
4. $ hdiutil attach –nomount /Volumes/apfs_image/apfs.dmg
5. *$ diskutil ap list*
6. *$ diskutil ap unlockVolume <Disk GUID> –nomount*
7. $ sudo mount_apfs –o rdonly,noexec,noowners /dev/disk# /Volumes/apfs_mounted/

Windows & Linux Mounting Options

- APFS drivers from Paragon (paragon-software.com)
  - Windows – Free, Currently no support for FileVault
  - Linux – Price and FileVault Support Unknown – "Contact Us"
- Open Source APFS Driver by sgan81 – APFS-fuse
  - https://github.com/sgan81/apfs-fuse
  - FileVault Encryption Supported (with password)
- Fantastic Tutorials from Mari DeGrazia
  - http://az4n6.blogspot.com/2018/01/how-to-mount-mac-apfs-images-in-windows.html
    - Using Arsenal Image Mounter
  - http://az4n6.blogspot.com/2018/01/mounting-apfs-image-in-linux.html

APFS Features

Clones

Name	Size
GoogleEart...c-Intel.dmg	73.4 MB
WhatsApp copy.dmg	72.1 MB
WhatsApp.dmg	72.1 MB

- Instant copy of files/directories
- No redundant use of space
- New/modified data to files saved in separate blocks
- File changes saved as deltas

```
Sarahs-MBP-6:APFS_VOL1 oompa$ stat -x WhatsApp*
  File: "WhatsApp copy.dmg"
  Size: 72061030     FileType: Regular File
  Mode: (0644/-rw-r--r--)     Uid: (  501/   oompa)  Gid: (   20/   staff)
Device: 1,20   Inode: 201   Links: 1
Access: Sun Apr 22 20:16:08 2018
Modify: Thu Nov 23 13:22:54 2017
Change: Sun Apr 22 20:34:35 2018
  File: "WhatsApp.dmg"
  Size: 72061030     FileType: Regular File
  Mode: (0644/-rw-r--r--)     Uid: (  501/   oompa)  Gid: (   20/   staff)
Device: 1,20   Inode: 192   Links: 1
Access: Sun Apr 22 20:16:08 2018
Modify: Thu Nov 23 13:22:54 2017
Change: Sun Apr 22 20:16:14 2018
```

```
Sarahs-MBP-6:~ oompa$ df -h /Volumes/APFS_VOL1
Filesystem      Size   Used  Avail Capacity iused               ifree %iused  Mounted on
/dev/disk5s1   7.2Gi   140Mi  7.0Gi     2%      79 9223372036854775728     0%   /Volumes/APFS_VOL1
Sarahs-MBP-6:~ oompa$ df -h /Volumes/APFS_VOL1
Filesystem      Size   Used  Avail Capacity iused               ifree %iused  Mounted on
/dev/disk5s1   7.2Gi   140Mi  7.0Gi     2%      80 9223372036854775727     0%   /Volumes/APFS_VOL1
```

Snapshots

```
Snapshot – An APFS Snapshot represents a read-only copy of its parent APFS
Volume, frozen at the moment of its creation.  An APFS Volume can have zero or
more associated APFS Snapshots.

APFS Snapshots are neither listed nor discoverable when their Volume is not
mounted. Snapshots are uniquely identified within their parent Volume's names-
pace by either a numeric identifier (preferred) or by their name; Snapshots
can be renamed, but APFS will never allow duplication of names (within a Vol-
ume) to occur.

APFS Snapshots are mountable; when this occurs, its mount point (separate from
and simultaneous with its parent Volume) provides a read-only historic version
of the Volume content at Snapshot creation time.
```

- Read-only snapshot of the file system
- Efficient Backups (Time Machine)
- Time Machine Local Snapshots created: Once an hour & before macOS updates
- Time Machine Local Snapshots kept for 24 hours
- Create on-demand snapshot '`tmutil localsnapshot`'
- 10.12 had command apfs_snapshot
  - Use `tmutil` and `apfs_mount` on live system
  - Still trying to determine how to use forensically from dead image
- About Time Machine local snapshots - https://support.apple.com/en-us/HT204015

Snapshots Live List

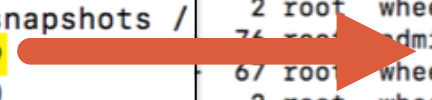
- `diskutil ap listsnapshots <mountpoint>`
  - ...or `listsnaps` (for the millennials)
- `tmutil listlocalsnapshots <mountpoint>`

```
Sarahs-MBP-6:/ oompa$ tmutil listlocalsnapshots /
com.apple.TimeMachine.2018-04-22-114609
com.apple.TimeMachine.2018-04-22-214754
com.apple.TimeMachine.2018-04-22-232139
com.apple.TimeMachine.2018-04-23-005036
com.apple.TimeMachine.2018-04-23-025303
com.apple.TimeMachine.2018-04-23-045139
com.apple.TimeMachine.2018-04-23-064924
com.apple.TimeMachine.2018-04-23-102309
com.apple.TimeMachine.2018-04-23-122205
com.apple.TimeMachine.2018-04-23-161716
com.apple.TimeMachine.2018-04-23-174736
com.apple.TimeMachine.2018-04-23-192417
com.apple.TimeMachine.2018-04-23-195016
```

```
Sarahs-MBP-6:/ oompa$ diskutil ap listsnaps /
Snapshots for disk1s1 (13 found)
|
+-- Name: com.apple.TimeMachine.2018-04-22-114609
|   XID:  10964731
|   NOTE: This snapshot sets the minimal allowed size of APFS Container disk1
|
+-- Name: com.apple.TimeMachine.2018-04-22-214754
|   XID:  10969408
|
+-- Name: com.apple.TimeMachine.2018-04-22-232139
|   XID:  10969977
|
+-- Name: com.apple.TimeMachine.2018-04-23-005036
|   XID:  10970513
|
+-- Name: com.apple.TimeMachine.2018-04-23-025303
|   XID:  10971224
|
+-- Name: com.apple.TimeMachine.2018-04-23-045139
|   XID:  10972023
|
+-- Name: com.apple.TimeMachine.2018-04-23-064924
|   XID:  10972688
|
+-- Name: com.apple.TimeMachine.2018-04-23-102309
|   XID:  10973910
|
+-- Name: com.apple.TimeMachine.2018-04-23-122205
|   XID:  10974578
|
+-- Name: com.apple.TimeMachine.2018-04-23-161716
|   XID:  10975986
|
+-- Name: com.apple.TimeMachine.2018-04-23-174736
|   XID:  10976469
|
+-- Name: com.apple.TimeMachine.2018-04-23-192417
|   XID:  10977049
|
+-- Name: com.apple.TimeMachine.2018-04-23-195016
    XID:  10978281
```

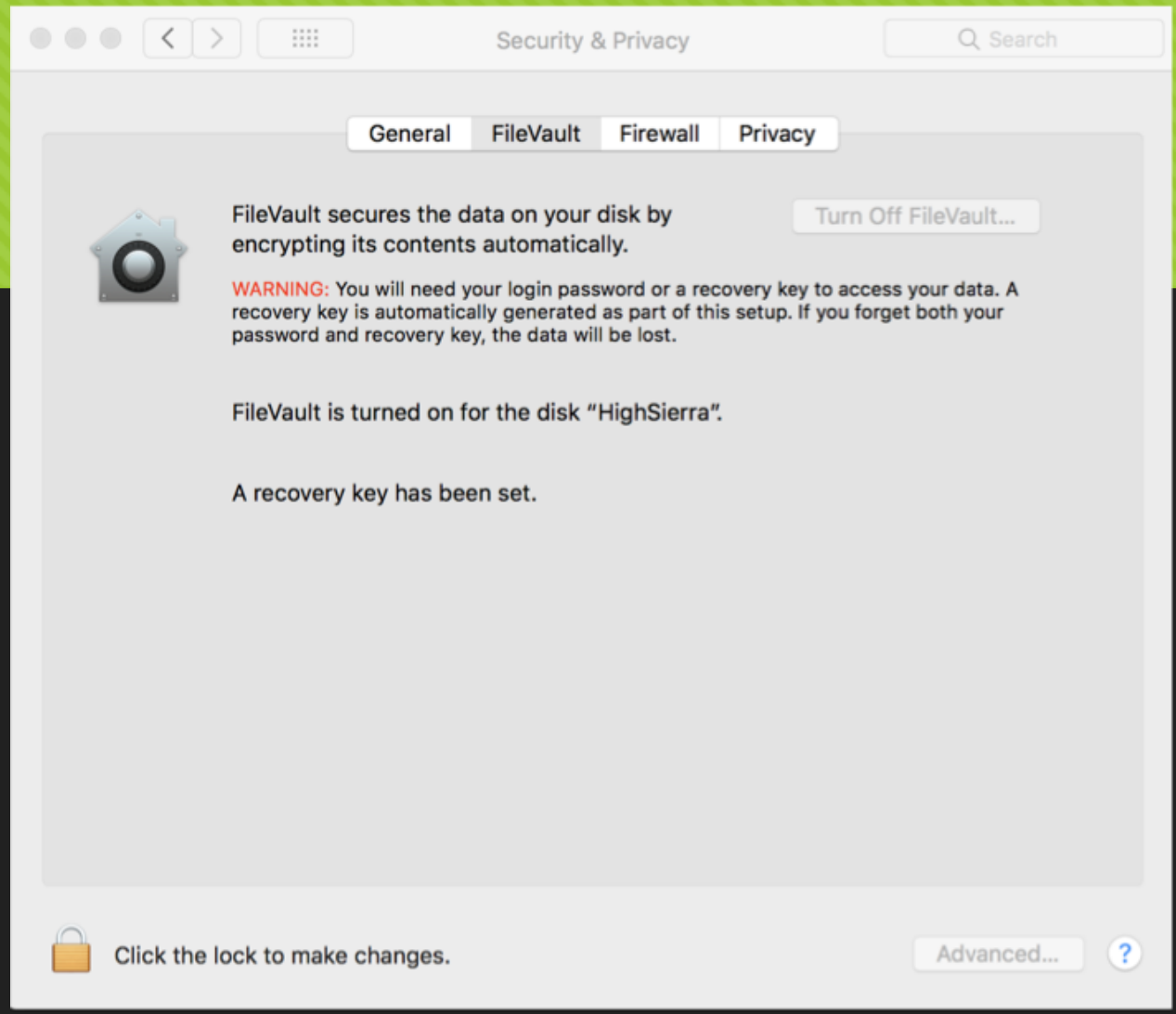
Snapshot Mounting – Live System

```
Sarahs-MBP-6:/ oompa$ tmutil listlocalsnapshots /
com.apple.TimeMachine.2018-04-22-114609
com.apple.TimeMachine.2018-04-22-195720
com.apple.TimeMachine.2018-04-22-202457
com.apple.TimeMachine.2018-04-22-204859
com.apple.TimeMachine.2018-04-22-205540
```



```
Sarahs-MBP-6:/ oompa$ sudo mkdir /Volumes/snapshot_mounted
Sarahs-MBP-6:/ oompa$ sudo mount_apfs -s com.apple.TimeMachine.2018-04-22-114609 / /Volumes/snapshot_mounted
mount_apfs: snapshot implicitly mounted readonly
Sarahs-MBP-6:/ oompa$ ls -la /Volumes/snapshot_mounted/
total 40
drwxr-xr-x@  29 root  wheel    928 Apr 16 22:24 .
drwxr-xr-x+  11 root  wheel    352 Apr 22 21:22 ..
-rw-rw-r--    1 root  admin  14340 Apr 15 10:31 .DS_Store
d--x--x--x    9 root  wheel    288 Apr 16 22:24 .DocumentRevisions-V100
dr-xr-xr-t@   2 root  wheel     64 Nov 11 12:56 .HFS+ Private Directory Data?
drwxr-xr-x@   2 root  wheel     64 Apr 12 19:34 .PKInstallSandboxManager-SystemSoftware
drwx------    5 root  wheel    160 Nov 11 13:18 .Spotlight-V100
srwxrwxrwx    1 root  wheel      0 Apr 16 22:24 .dbfseventsd
----------    1 root  admin      0 Jul 25  2017 .file
drwx------  242 root  wheel   7744 Apr 22 10:26 .fseventsd
              2 root  wheel     64 Jul 25  2017 .vol
              admin   2432 Apr 15 10:31 Applications
              67 root wheel   2144 Apr  1 17:56 Library
              2 root  wheel     64 Jul 25  2017 Network
              4 root  wheel    128 Sep 21  2017 System
              8 root  admin    256 Mar 24 21:22 Users
              7 root  wheel    224 Apr 22 10:26 Volumes
drwxr-xr-x@  38 root  wheel   1216 Apr 10 18:25 bin
drwxrwxr-t    2 root  admin     64 Jul 25  2017 cores
dr-xr-xr-x    2 root  wheel     64 Jul 25  2017 dev
lrwxr-xr-x@   1 root  wheel     11 Nov 11 13:12 etc -> private/etc
dr-xr-xr-x    2 root  wheel     64 Nov 11 13:18 home
-rw-r--r--    1 root  wheel    313 Aug 10  2017 installer.failurerequests
dr-xr-xr-x    2 root  wheel     64 Nov 11 13:18 net
drwxr-xr-x    6 root  wheel    192 Nov 11 13:13 private
drwxr-xr-x@  63 root  wheel   2016 Apr 10 18:25 sbin
lrwxr-xr-x@   1 root  wheel     11 Nov 11 13:12 tmp -> private/tmp
drwxr-xr-x@  10 root  wheel    320 Nov 11 16:58 usr
lrwxr-xr-x@   1 root  wheel     11 Nov 11 13:13 var -> private/var
```

Encryption



- Encryption, built in.

  HFS+ required CoreStorage wrapper
- Encryption per Volume
- Modes:
  - No Encryption
  - Single-key
  - Multi-key
    - Per-file keys for data
    - Key for sensitive metadata
- AES-XTS, AEX-CBC (depends on hardware)
- https://www.blackbagtech.com/blog/2018/04/02/ask-expert-apfs-encryption/

APFS Password Bug – Unified Logs & install.log

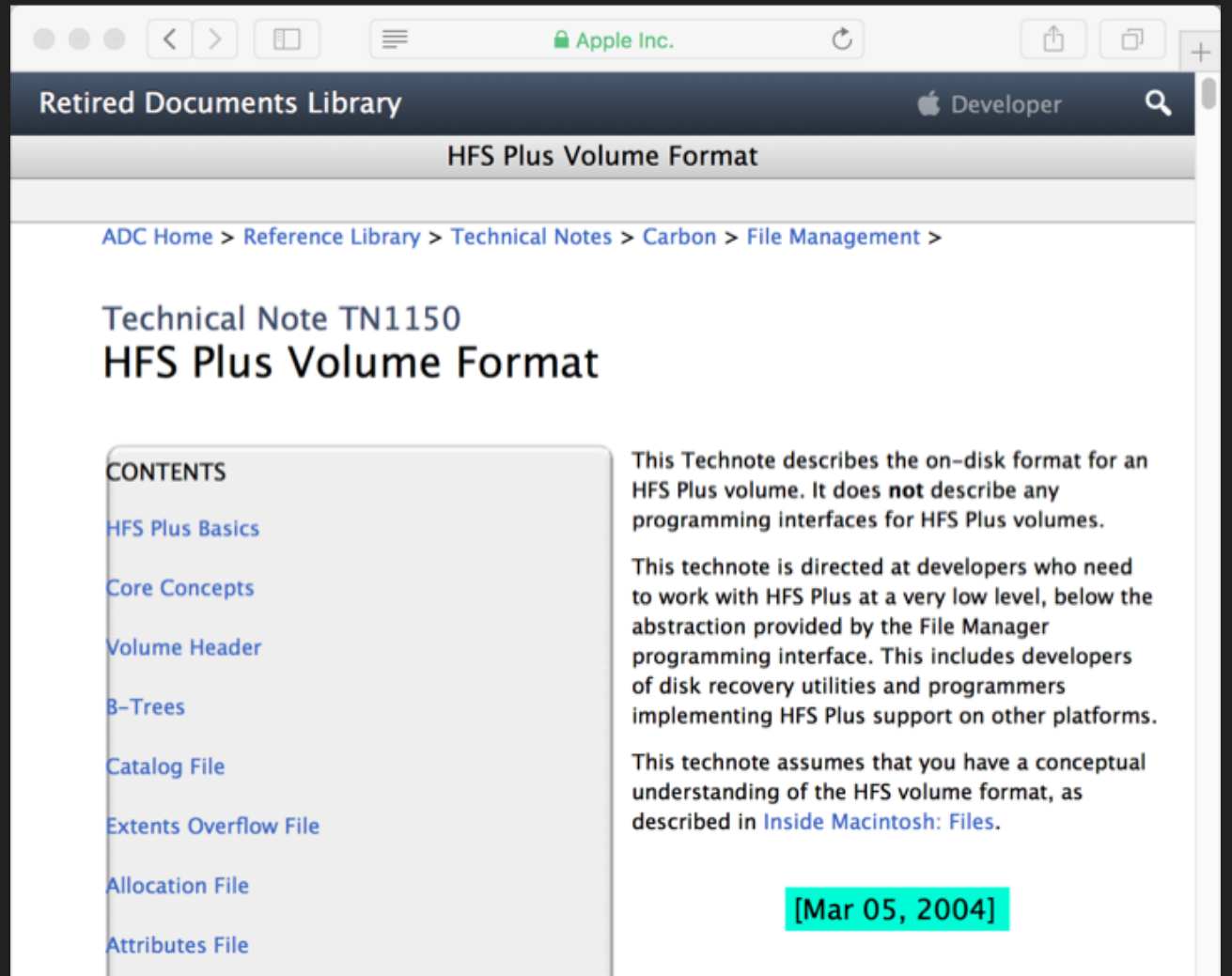
```
Sarahs-MBP:FOR518 oompa$ log show galaga.logarchive/ --info --predicate 'eventMessage contains "SEKRET"' --style syslog
==========
/Users/oompa/FOR518/galaga.logarchive
==========
log: warning: The log archive contains partial or missing metadata
Filtering the log data using "eventMessage CONTAINS "SEKRET""
Skipping debug messages, pass --debug to include.
Timestamp                       (process)[PID]
2018-02-25 20:48:58.712365-0500  localhost diskmanagementd[1257]: diskmanagement: execve(2) pid=1257 /System/Library/Filesystems/hfs.fs/Contents/Resources/newfs_hfs -J -v
 SEKRET /dev/rdisk4s2 .
2018-02-25 20:49:04.466414-0500  localhost kernel[0]: (HFS) hfs: mounted SEKRET on device disk4s2
2018-02-25 20:49:04.518324-0500  localhost fseventsd[47]: could not open <</Volumes/SEKRET/.fseventsd/fseventsd-uuid>> (No such file or directory)
2018-02-25 20:49:04.518334-0500  localhost fseventsd[47]: Failed to load UUID.  Removing all old log files in /Volumes/SEKRET/.fseventsd
2018-02-25 20:49:04.518433-0500  localhost fseventsd[47]: log dir: /Volumes/SEKRET/.fseventsd getting new uuid: 72FEB7BC-BF24-43DE-9D71-54056CECB33E
2018-02-25 20:49:04.668388-0500  localhost deleted[414]: [com.apple.cache_delete:daemon] Purgeable Result: 0 bytes on: "/Volumes/SEKRET"
2018-02-25 20:49:04.722366-0500  localhost fseventsd[47]: Events arrived for /Volumes/SEKRET after an unmount request! Re-initializing.
2018-02-25 20:49:04.722376-0500  localhost fseventsd[47]: creating a dls for /Volumes/SEKRET but it already has one...
2018-02-25 20:49:06.473078-0500  localhost kernel[0]: (HFS) hfs: unmount initiated on SEKRET on device disk4s2
2018-02-25 20:49:06.602182-0500  localhost fseventsd[47]: disk logger: failed to open output file /Volumes/SEKRET/.fseventsd/000000000027b06e (No such file or directory).
 mount point /Volumes/SEKRET/.fseventsd
2018-02-25 20:49:06.602361-0500  localhost fseventsd[47]: disk logger: failed to open output file /Volumes/SEKRET/.fseventsd/000000000027b06e (No such file or directory).
 mount point /Volumes/SEKRET/.fseventsd
2018-02-25 20:49:08.719840-0500  localhost diskmanagementd[1276]: diskmanagement: execve(2) pid=1276 /System/Library/Filesystems/apfs.fs/Contents/Resources/newfs_apfs -A
-i -E -S frogger13 -v SEKRET disk5 .
2018-02-25 20:49:09.741614-0500  localhost kernel[0]: (apfs) apfs_vfsop_mount:1368: mounted volume: SEKRET
2018-02-25 20:49:09.794588-0500  localhost fseventsd[47]: could not open <</Volumes/SEKRET/.fseventsd/fseventsd-uuid>> (No such file or directory)
2018-02-25 20:49:09.794596-0500  localhost fseventsd[47]: Failed to load UUID.  Removing all old log files in /Volumes/SEKRET/.fseventsd
2018-02-25 20:49:09.794711-0500  localhost fseventsd[47]: log dir: /Volumes/SEKRET/.fseventsd getting new uuid: AD6ECA53-6EDE-4FC8-9B21-D9BA10C3C6A9
2018-02-25 20:49:09.798644-0500  localhost deleted[414]: [com.apple.cache_delete:daemon] Purgeable Result: 0 bytes on: "/Volumes/SEKRET"
2018-02-25 20:49:09.816415-0500  localhost storagekitd[1220]: Erase Complete, Mount Point: /Volumes/SEKRET
2018-02-25 20:49:09.830160-0500  localhost deleted[414]: [com.apple.cache_delete:daemon] Purgeable Result: 0 bytes on: "/Volumes/SEKRET"
2018-02-25 20:49:09.858039-0500  localhost storagekitd[1220]: Recache Complete, Mount Point: /Volumes/SEKRET
2018-02-25 20:49:58.326722-0500  localhost deleted[414]: [com.apple.cache_delete:daemon] Purgeable Result: 0 bytes on: "/Volumes/SEKRET"
2018-02-27 18:20:25.719892-0500  localhost kernel[0]: (apfs) apfs_vfsop_mount:1368: mounted volume: SEKRET
2018-02-27 18:20:25.828215-0500  localhost deleted[414]: [com.apple.cache_delete:daemon] Purgeable Result: 0 bytes on: "/Volumes/SEKRET"
2018-02-27 18:22:13.848939-0500  localhost deleted[414]: [com.apple.cache_delete:daemon] Purgeable Result: 0 bytes on: "/Volumes/SEKRET"
2018-02-28 18:58:39.652188-0500  localhost kernel[0]: (apfs) apfs_vfsop_mount:1368: mounted volume: SEKRET
2018-02-28 18:58:39.784029-0500  localhost deleted[414]: [com.apple.cache_delete:daemon] Purgeable Result: 0 bytes on: "/Volumes/SEKRET"
```

https://www.mac4n6.com/blog/2018/4/1/ok-internet-lets-test-this-apfs-password-bug-properly

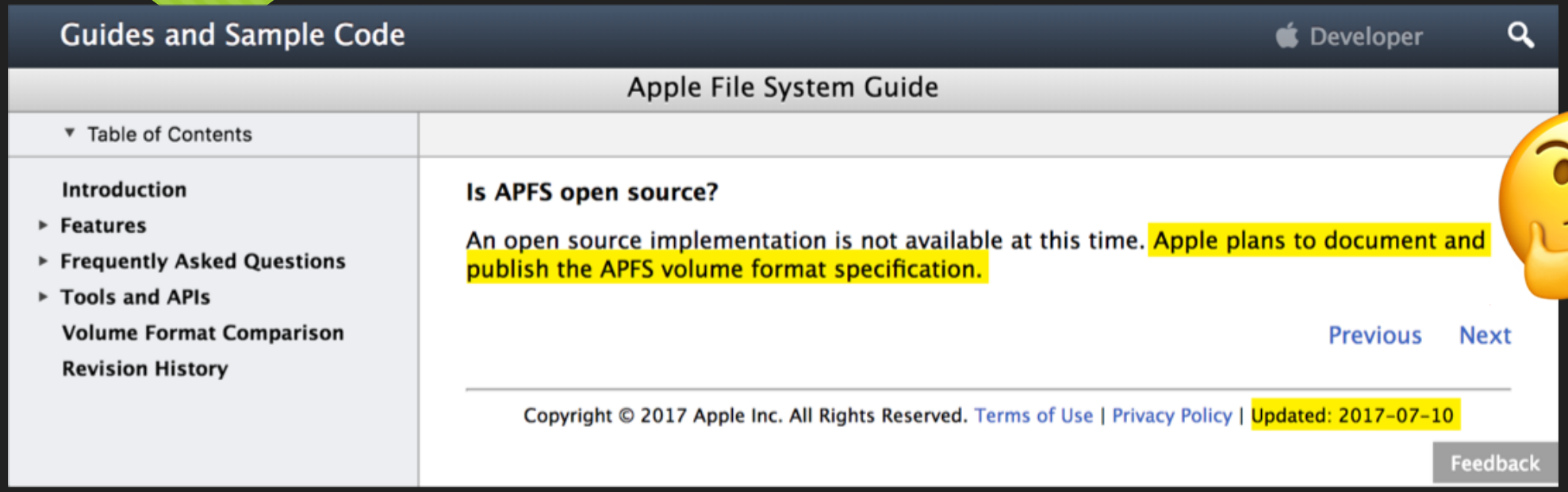
The Future of APFS Forensics

HFS+ Documentation – TechNote 1150

- HFS+ first implemented in 1998
- Published 1999
- Last Updated in 2004!
  - "Reserved for future use."



In-Depth Analysis & Tools
File System Documentation Resources



- Kaitai Struct from cugu - https://github.com/cugu/apfs.ksy
- 'Decoding the APFS file system' by Kurt H. Hansen & Fergus Toolan
  - https://www.researchgate.net/publication/319573636_Decoding_the_APFS_file_system
- ENRW Whitepaper 65 - APFS Internals for Forensic Analysis by Andreas Dewald & Jonas Plum
  - https://static.ernw.de/whitepaper/ERNW_Whitepaper65_APFS-forensics_signed.pdf

References & Links

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- https://www.blackbagtech.com/blog/2018/04/02/ask-expert-apfs-encryption/
- https://www.blackbagtech.com/blog/2018/04/11/apple-file-system-apfs-mac-forensic-imaging-analysis/
- https://www.mac4n6.com/blog/2017/11/26/mount-all-the-things-mounting-apfs-and-4k-disk-images-on-macos-1013
- https://www.blackbagtech.com/blog/2018/04/11/apple-file-system-apfs-mac-forensic-imaging-analysis/
- https://www.paragon-software.com/home/apfs-windows/
- https://www.paragon-software.com/business/apfs-linux/
- https://github.com/sgan81/apfs-fuse
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- http://az4n6.blogspot.com/2018/01/mounting-apfs-image-in-linux.html
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