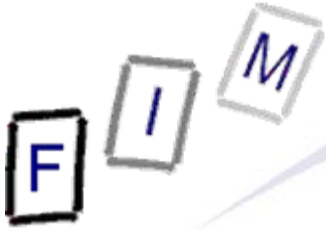


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# File system investigation

## Computer forensics

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# Agenda

- Acquiring a forensic copy
- Preliminary stages
  - → Image hashing
  - → Partition/file system information
- Removing known files
- Identifying file types
  - → Hash databases
- Creating a timeline

# Acquiring a forensic copy: Write blockers

- Never work on the original media
  - → Anything going wrong → The evidence is gone!
    - » Even just a suspicion of that may be enough in a process!
- So we need a copy…
  - → But during copying the media is accessed as well!
  - → Additionally, we don't want a copy of the files … we want a copy of the media!
    - » This is not the same: Unallocated clusters are e.g. not copied when transferring (all) files through a share
- Result: Create a binary copy of the source media while applying some kind of write-protection to the original
  - → This may be quite easy: Floppy disks/USB sticks do have a "write-protect" "switch"
    - » But can we trust it? And what about media without them, e.g. normal hard disks?

# Acquiring a forensic copy: Write blockers

- Therefore we need a separate write blocker
  - → Which is under the control of the person performing the copy!
- Use a trusted hardware write blocker
  - → Exist for all kind of media: IDE, SATA, flash-disks, SCSI, …
    - » Note: More "exotic" or high-performance → Expensive
      - – This is not a mainstream hardware sold in thousands!
- Alternatively use a software write blocker
  - → Problem: Many things can go wrong, e.g. configuring it for the wrong device, bugs etc.
  - → Additionally, it should only be used on a trusted computer
    - » Not: Installing/Running a write-blocker on the source machine
      - – You don't know what else is installed there and whether this will actually work or not!
  - → Typical example: USB write blocker
  - → Potential problem: Reboot may be required

# Hardware write blockers: How they work

- Two kinds exists
  - → Same interface on both sides: IDE – IDE
  - → Different interfaces: IDE/SATA – USB/Firewire
    - » The typical computer-side is USB and/or Firewire
    - » Advantage: USB and Firewire are hot-swappable!
- Basic work process
  - → Intercept commands writing to the disk
    - » Problem: Custom extensions!
      - – Best approach: Don't allow anything not explicitly know to no modify the data and block everything else
      - – Note: This may break compatibility with exotic systems!
    - » Return OK/Failure depending on configuration
  - → Pass all other , i.e. read-only, commands
- See http://www.cftt.nist.gov/hardware_write_block.htm for tested appliances!

# Hardware write blockers: Examples

- Examples:
  - → FastBloc
    - » http://www.encase.com/products/ee_hardware.aspx
  - → ICS DriveLock
    - » http://www.icsforensic.com/index.cfm/action/catalog.browse/category/DriveLock/id_category/c14d69f1-dcb6-47ab-8be6-1b13217f5b84
  - → WiebeTech Forensic ComboDock v4
    - » http://wiebetech.com/products/ForensicComboDock.php
  - → Tableau
    - » http://tableau.com/index.php?pageid=products&category=forensic_bridges
  - → MyKey NoWrite FPU (owns a patent on write-blocking)
    - » http://www.mykeytech.com/



# Software write blockers: How they work

- Basic principle: Access the media without passing on write requests; only allow read requests
  - → I.e., on Linux do not mount it in read/write mode, or just "refrain from writing" (USB)
    - » "Not writing" will still change access time
    - » Attention on journaling file systems!
- Not recommended: Setting the USB-write-protection Flag in the Windows registry
  - → This requires a reboot and is not guaranteed to work!
- In general, SW blockers do the same as Hardware ones
- Comparing Hardware and Software blockers:
  - → SW +: Cheaper and flexible (all devices)
  - → SW -: Platform specific, working not immediately apparent
  - → HW +: Hot-swap, interface conversion, easier to verify
  - → HW -: Expensive, only for selected devices

# Software write blockers: Examples

- Digital Intelligence PDBlock
  - → http://www.digitalintelligence.com/software/disoftware/pdblock/
- Linux:
  - → Disable auto-mounting
  - → Mount drive as read-only
  - → Example: mount –t <fs-type> –o ro,loop,noexec,noatime <image> <directory>
    - » ro: Do not write to disk, not even for root
    - » loop: Loopback device, i.e. opening an image as a file system
    - » noexec: Do not execute files from this disk
    - » noatim: Do not change access time on access
- See http://www.cftt.nist.gov/software_write_block.htm for test reports of dedicated software!

# Duplication issues

- Read errors: What to do when encountering erroneous sectors on the source media
  - → Try to get the data nevertheless (several retries)
  - → If really not accessible, then it wasn't for the suspect as well!
    - » When still suspected → Hardware investigation (platter surface)
  - → Write zeros ('0x00') to the destination instead
    - » This will cause the least harm and not introduce other material
    - » Additionally, mark it as "BAD" externally or within
- Wiped destination disk
  - → Ideally, the destination disk should be wiped before acquiring
    - » This means all zeros, not just a complete formatting!
    - » Reason: Read errors, larger size, … precaution
  - → Not needed when acquiring to an image file
- Large disks may require multiple destination volumes
  - → Splitting the image into several image files
  - → Care required on analyzing: Seams!

# Forensic duplication file formats

- EnCase: "Standard" in law enforcement (".E01")
  - → Proprietary file format, certain metadata
  - → Supports compression
    - » Requires more CPU power to work with, but less space
- Raw: Bit-by-bit copy of the source
  - → Every program can work with this format
  - → There is no compression and no metadata
    - » Compression only for transfer possible, not for working with it!
  - → Integrity check must be external (separate file with hash)
- AFF: Advanced Forensic Format (".AFF", ".AFD")
  - → Open format: Documented, no royalties, BSD-licensed code
  - → Supports arbitrary metadata
  - → Includes metadata, compression, chain-of-custody recording
    - » In future should also support encryption
- Several other exist: http://www.forensicswiki.org/wiki/Forensic_file_formats

# Creating a forensic duplication: dd

- dd = Data Dump; Used to create binary copies
- Example: dd if=/dev/hdb of=SuspectHD.bin conv=notrunc,noerror,sync bs=1024
  - → if: Input device
  - → of: Output device; just a normal file here
  - → notrunc: Don't truncate output on errors
  - → noerror: Do not stop on read errors
  - → sync: Write zeros on read errors instead of skipping sector
  - → bs: Block size. Default = 512; better performance with larger values, but read errors always affect complete block
    - » Use the physical size if possible; usually 512
  - → count: Number of blocks to copy
    - » Must be multiplied by "bs" value to get bytes!
  - → skip: Number of blocks skipped before copying starts
- Make sure that "of" is mounted, but "if" is **not**!

# Creating a hash of the whole image

- Important to assure the identity of the image and the source
- Therefore two hashes should theoretically be built
  - → One of the source drive
  - → One of the image
- Actually, usually only a single one is calculated, as reading the source again would not be different from image creation!
  - → Still important: Later modifications of the image can be detected easily
  - → Additionally, in case of doubt, the original can be read and hashed and compared to the image which as analyzed
    - » Helps against swapping images or malicious modifications
- Typically SHA-1, SHA-256 or MD5 is used
  - → MD5 should not be used any more, as it is known to be susceptible to attacks (not yet broken)

# Creating a hash of the whole image: Example

- Example for creating a MD5 hash:
  - → chmod 444 SuspectHD.bin
  - → md5sum –b SuspectHD.bin >md5sum.txt
  - → chmod 444 md5sum.txt
- Example for checking:
  - → md5sum–c md5sum.txt
    - » File need not be specified – stated in md5sum.txt!
- Content of md5sum.txt:
  - → 3be6330d9da0db04d45ef96c86bd7afc SuspectHD.bin

See "sha1sum" for calculating SHA-1 hashes

- → "shasum" calculates other versions as well
  - » Algorithm: 1, 224, 256, 384, 512

- Note: chmod is only there for "security": Read-only files!

# Duplication + Hashing: dcfldd

- Slight enhancement of "dd", the disk duplication SW
  - → Open source program
  - → Created by the DoD Computer Forensics Lab (DCFL)
- Features:
  - → Hashing of the data on the fly (=during duplication)
    - » Not only for whole file but also for smaller blocks
  - → Status output (progress bar)
  - → Supports disk wipes with special patterns (not just zeros)
  - → Multiple and split output possible
  - → Produces raw images only

# Duplication + Hashing: dcfldd

- Example: dcfldd if=/dev/had of=/mnt/evidence/disk_a.dd conv=sync,noerror hashwindow=1024 hashlog=hash.txt
  - → Parameters similar to dd
    - » if: Input device
    - » of: Output device
    - » sync: Write zeros on read errors instead of skipping sector
    - » noerror: Do not stop on read errors
    - » bs: Block size. Default = 512; better performance with larger values, but read errors always affect complete block
      - – Use the physical size if possible; usually 512
  - → Additional parameters (hashing):
    - » hashwindow=1024: Separate hash for every 1024 bytes
    - » hashlog=hash.txt: Where to write the hash values
- Windows:
  - → if=\\.\PhysicalDrive3

# Partition and file system information

- "Volume": Careful, it can mean many things!
  - → Collection of addressable sectors
    - » Not necessarily on one physical device or consecutive sectors
    - » Must only look to the OS/application as if it were cons. sectors!
  - → Single accessible storage area within a single file system
    - » Typically within a partition
  - → An entity that has a drive letter mapped to it
    - » Therefore applicable only to Windows, not Unix
- Physical disk organization can be complex
  - → Several disks can be grouped to create a single "volume"
    - » Example: RAID-0 (Striping)
  - → This volume can then be split in several partitions
    - » Within an partition there can be more partitions
  - → Each partition has a single file system
  - → Not the whole disk need be assigned to partitions

# Partition and file system information
# Forensic considerations

- On complex or uncommon systems, copying the physical disk may not be very useful
  - → String search is always possible, unless partitions are compressed or encrypted
  - → But recreating the file systems may be impossible
    - » Depends on the OS used, which may not be available
- Sometimes it may therefore be better to do a "live" copy
  - → Start the system and copy all files to another computer with a "common" file system
  - → Note: All slack space, deleted files etc. are lost!
- Best, but most expensive/time-consuming approach:
  - → Create two full physical copies
    - » One for physical-drive-analysis
    - » Original as evidence
  - → Boot from one copy and create a file system duplicate

# DOS partitions

- The most common type of disk organization
  - → DOS, Windows, Linux, BSD; most multi-boot systems
    - » 32 Bit versions only; 64 Bit versions are often different!
- Basic layout: See file systems!
- A DOS partitioned hard disk can only contain 4 partitions
    - » These are called "primary partitions"
  - → But one can also be an "extended partition"
    - » This can contain several "logical" ("secondary") partitions
      - – In theory, only two: A normal and again an extended one, …
  - → Any of the sub-partitions could be from a different OS and be organized differently within!
  - → One partition may be marked as "active" or "bootable"
    - » This will be the one the system boots from
    - » Note: The code in the MBR record may decide otherwise, perhaps based on user input, or change the markings!

# MBR / Partition table example

- MBR = Master Boot Record
  - → 0-445: Boot code (to be executed on booting the system)
    - » 440-443: Windows ≥ NT: NT Drive Serial Number
      - – Also used by Linux 2.6 to determine boot volume location
  - → 446-509: Partition table (space for describing 4 partitions)
  - → 510-511: Magic number: 0x55, 0xAA
- Partition table:
  - → 0: Bootable Flag (0x80 = Boot partition)
  - → 1-3: Start CHS address
    - » Cylinder-Head-Sector; Only for old/small hard disks
  - → 4: Partition type
    - » E.g. 0x06 (FAT16, 32MB-2GB, CHS), 0x0c (FAT32 LBA), 0x83 (Linux), 0x84 (Hibernation), 0x86 (NTFS Volume Set), …
  - → 5-7: Ending CHS address
  - → 8-11: Starting LBA address
  - → 12-15: Size in sectors

# MBR example

| Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 000000000 | 33 | C0 | 8E | D0 | BC | 00 | 7C | FB | 50 | 07 | 50 | 1F | FC | BE | 1B | 7C |
| 000000010 | BF | 1B | 06 | 50 | 57 | B9 | E5 | 01 | F3 | A4 | CB | BD | BE | 07 | B1 | 04 |
| 000000020 | 38 | 6E | 00 | 7C | 09 | 75 | 13 | 83 | C5 | 10 | E2 | F4 | CD | 18 | 8B | F5 |
| 000000030 | 83 | C6 | 10 | 49 | 74 | 19 | 38 | 2C | 74 | F6 | A0 | B5 | 07 | B4 | 07 | 8B |
| 000000040 | F0 | AC | 3C | 00 | 74 | FC | BB | 07 | 00 | B4 | 0E | CD | 10 | EB | F2 | 88 |
| 000000050 | 4E | 10 | E8 | 46 | 00 | 73 | 2A | FE | 46 | 10 | 80 | 7E | 04 | 0B | 74 | 0B |
| 000000060 | 80 | 7E | 04 | 0C | 74 | 05 | A0 | B6 | 07 | 75 | D2 | 80 | 46 | 02 | 06 | 83 |
| 000000070 | 46 | 08 | 06 | 83 | 56 | 0A | 00 | E8 | 21 | 00 | 73 | 05 | A0 | B6 | 07 | EB |
| 000000080 | BC | 81 | 3E | FE | 7D | 55 | AA | 74 | 0B | 80 | 7E | 10 | 00 | 74 | C8 | A0 |
| 000000090 | B7 | 07 | EB | A9 | 8B | FC | 1E | 57 | 8B | F5 | CB | BF | 05 | 00 | 8A | 56 |
| 0000000A0 | 00 | B4 | 08 | CD | 13 | 72 | 23 | 8A | C1 | 24 | 3F | 98 | 8A | DE | 8A | FC |
| 0000000B0 | 43 | F7 | E3 | 8B | D1 | 86 | D6 | B1 | 06 | D2 | EE | 42 | F7 | E2 | 39 | 56 |
| 0000000C0 | 0A | 77 | 23 | 72 | 05 | 39 | 46 | 08 | 73 | 1C | B8 | 01 | 02 | BB | 00 | 7C |
| 0000000D0 | 8B | 4E | 02 | 8B | 56 | 00 | CD | 13 | 73 | 51 | 4F | 74 | 4E | 32 | E4 | 8A |
| 0000000E0 | 56 | 00 | CD | 13 | EB | E4 | 8A | 56 | 00 | 60 | BB | AA | 55 | B4 | 41 | CD |
| 0000000F0 | 13 | 72 | 36 | 81 | FB | 55 | AA | 75 | 30 | F6 | C1 | 01 | 74 | 2B | 61 | 60 |
| 000000100 | 6A | 00 | 6A | 00 | FF | 76 | 0A | FF | 76 | 08 | 6A | 00 | 68 | 00 | 7C | 6A |
| 000000110 | 01 | 6A | 10 | B4 | 42 | 8B | F4 | CD | 13 | 61 | 61 | 73 | 0E | 4F | 74 | 0B |
| 000000120 | 32 | E4 | 8A | 56 | 00 | CD | 13 | EB | D6 | 61 | F9 | C3 | 55 | 6E | 67 | 81 |
| 000000130 | 6C | 74 | 69 | 67 | 65 | 20 | 50 | 61 | 72 | 74 | 69 | 74 | 69 | 6F | 6E | 73 |
| 000000140 | 74 | 61 | 62 | 65 | 6C | 6C | 65 | 00 | 46 | 65 | 68 | 6C | 65 | 72 | 20 | 62 |
| 000000150 | 65 | 69 | 6D | 20 | 4C | 61 | 64 | 65 | 6E | 20 | 64 | 65 | 73 | 20 | 42 | 65 |
| 000000160 | 74 | 72 | 69 | 65 | 62 | 73 | 73 | 79 | 73 | 74 | 65 | 6D | 73 | 00 | 42 | 65 |
| 000000170 | 74 | 72 | 69 | 65 | 62 | 73 | 73 | 79 | 73 | 74 | 65 | 6D | 20 | 6E | 69 | 63 |
| 000000180 | 68 | 74 | 20 | 76 | 6F | 72 | 68 | 61 | 6E | 64 | 65 | 6E | 00 | 00 | 00 | 00 |
| 000000190 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 0000001A0 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 0000001B0 | 00 | 00 | 00 | 00 | 00 | 2C | 48 | 6E | BE | C0 | BE | C0 | 00 | 00 | 80 | 01 |
| 0000001C0 | 01 | 00 | 07 | FE | FF | FF | 3F | 00 | 00 | 00 | 0E | E3 | CA | 04 | 00 | 00 |
| 0000001D0 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 0000001E0 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 0000001F0 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 55 | AA |

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```

- Boot code
- Error messages
- NT Drive Serial Number
- Partition table
- Magic number (Signature ID)

- Text for error messages is at the end of the code
- The three bytes before the serial number are the relative offsets of the individual messages
  - Allows translations of different length without changing the code

See http://www.geocities.com./thestarman3/asm/mbr/Win2kmbr.htm

# NTFS Partition Boot Record example

0x0B – 0x054: BIOS parameter block

```
0000: EB 52 90 4E 54 46 53 20 20 20 20 00 02 08 00 00   .R.NTFS    .....
0010: 00 00 00 00 00 F8 00 00 3F 00 FF 00 3F 00 00 00   ........?...?...
0020: 00 00 00 00 80 00 80 00 0D E3 CA 04 00 00 00 00   ................
0030: 00 00 0C 00 00 00 00 00 10 00 00 00 00 00 00 00   ................
0040: F6 00 00 00 01 00 00 00 9E D1 A3 28 0A A4 28 AC   ...........(..(.
0050: 00 00 00 00 FA 33 C0 8E D0 BC 00 7C FB B8 C0 07   .....3.....|....
0060: 8E D8 E8 16 00 B8 00 0D 8E C0 33 DB C6 06 0E 00   ..........3.....
0070: 10 E8 53 00 68 00 0D 68 6A 02 CB 8A 16 24 00 B4   ..S.h..hj....$..
0080: 08 CD 13 73 05 B9 FF FF 8A F1 66 0F B6 C6 40 66   ...s......f...@f
0090: 0F B6 D1 80 E2 3F F7 E2 86 CD C0 ED 06 41 66 0F   .....?.......Af.
00A0: B7 C9 66 F7 E1 66 A3 20 00 C3 B4 41 BB AA 55 8A   ..f..f. ...A..U.
00B0: 16 24 00 CD 13 72 0F 81 FB 55 AA 75 09 F6 C1 01   .$...r...U.u....
00C0: 74 04 FE 06 14 00 C3 66 60 1E 06 66 A1 10 00 66   t......f`..f...f
00D0: 03 06 1C 00 66 3B 06 20 00 0F 82 3A 00 1E 66 6A   ....f;. ...:..fj
00E0: 00 66 50 06 53 66 68 10 00 01 00 80 3E 14 00 00   .fP.Sfh.....>...
00F0: 0F 85 0C 00 E8 B3 FF 80 3E 14 00 00 0F 84 61 00   ........>.....a.
0100: B4 42 8A 16 24 00 16 1F 8B F4 CD 13 66 58 5B 07   .B..$.......fX[.
0110: 66 58 66 58 1F EB 2D 66 33 D2 66 0F B7 0E 18 00   fXfX..-f3.f.....
0120: 66 F7 F1 FE C2 8A CA 66 8B D0 66 C1 EA 10 F7 36   f......f..f....6
0130: 1A 00 86 D6 8A 16 24 00 8A E8 C0 E4 06 0A CC B8   ......$.........
0140: 01 02 CD 13 0F 82 19 00 8C C0 05 20 00 8E C0 66   ........... ...f
0150: FF 06 10 00 FF 0E 0E 00 0F 85 6F FF 07 1F 66 61   ..........o...fa
0160: C3 A0 F8 01 E8 09 00 A0 FB 01 E8 03 00 FB EB FE   ................
0170: B4 01 8B F0 AC 3C 00 74 09 B4 0E BB 07 00 CD 10   .....<.t........
0180: EB F2 C3 0D 0A 41 20 64 69 73 6B 20 72 65 61 64   .....A disk read
0190: 20 65 72 72 6F 72 20 6F 63 63 75 72 72 65 64 00    error occurred.
01A0: 0D 0A 4E 54 4C 44 52 20 69 73 20 6D 69 73 73 69   ..NTLDR is missi
01B0: 6E 67 00 0D 0A 4E 54 4C 44 52 20 69 73 20 63 6F   ng...NTLDR is co
01C0: 6D 70 72 65 73 73 65 64 00 0D 0A 50 72 65 73 73   mpressed...Press
01D0: 20 43 74 72 6C 2B 41 6C 74 2B 44 65 6C 20 74 6F    Ctrl+Alt+Del to
01E0: 20 72 65 73 74 61 72 74 0D 0A 00 00 00 00 00 00    restart........
01F0: 00 00 00 00 00 00 00 00 83 A0 B3 C9 00 00 55 AA   ..............U.
```

- Jump to code start + NOP
- Producer and/or type name+version
- Bytes per sector
- Sectors per cluster
- Reserved sector count
- Media descriptor
- Sectors per track
- Number of read/write heads
- Hidden sectors (start of volume)
- Disc unit number
- Signature byte (Magic number)
- Sectors in volume
- Start cluster of MFT
- Start cluster of MFT mirror
- Clusters per MFT record
- Clusters per index Block
- NTFS volume serial number
- Boot code
- Error messages



See: http://www.geocities.com./thestarman3/asm/mbr/NTFSBR.htm
and http://homepages.tesco.net/J.deBoynePollard/FGA/bios-parameter-block.html

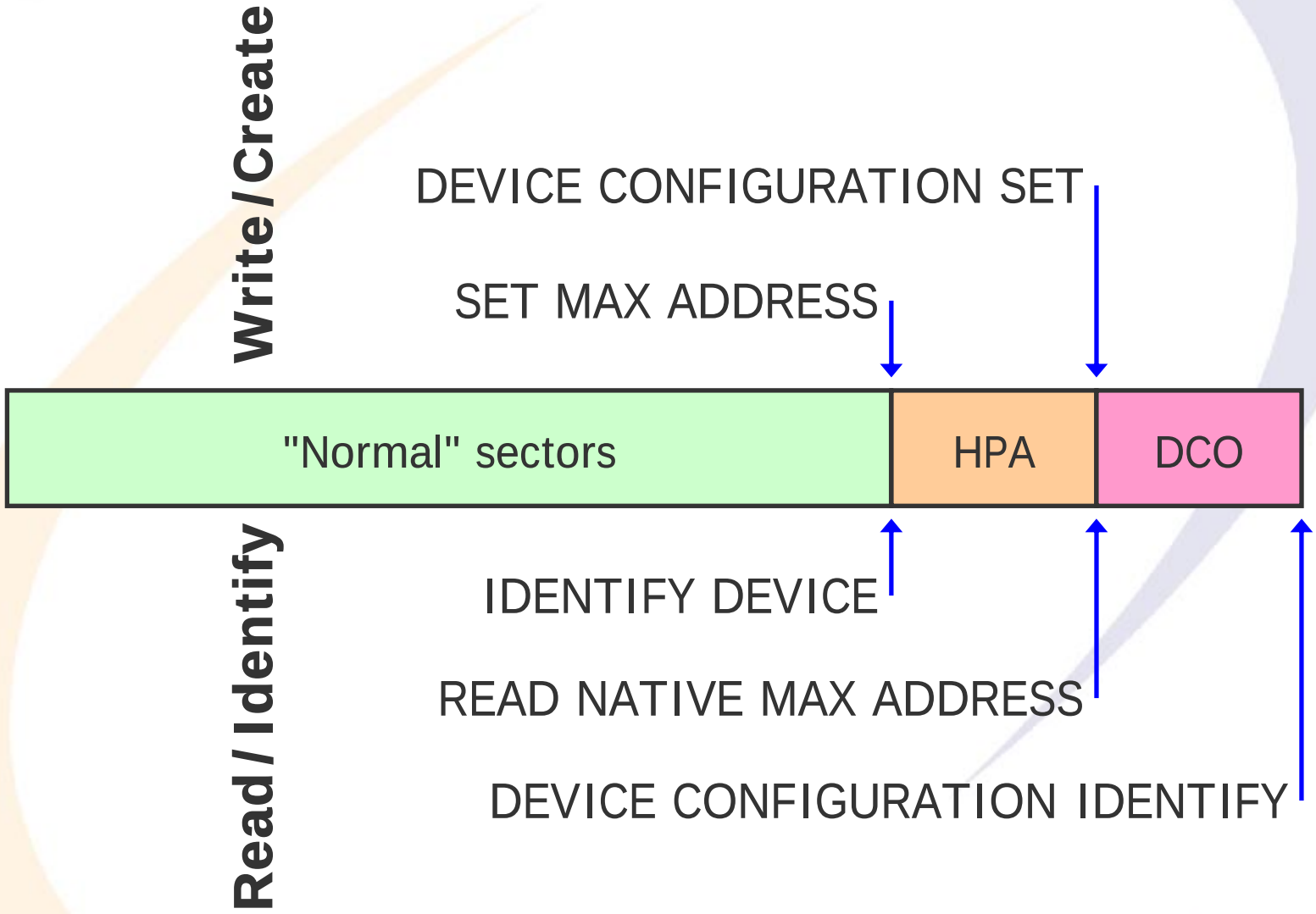
# HPA – Host Protected Area

- Hidden area on the disk invisible to the OS
  - → Partition with repair info for OS (copy of installation DVD)
  - → Theft recovery and monitoring services
  - → Reducing capacity of disks to match existing ones
  - → Introduced with ATA-4 standard
- Properties:
  - → Survives formatting the disk
  - → No access by user, OS or BIOS
  - → Accessible through directly issuing ATA commands
    - » "READ NATIVE MAX ADDRESS (EXT)": Read physical size
    - » "SET MAX ADDRESS (EXT)": Set maximum addressable size
  - → "Volatile" bit: Changes revert on next power up/reboot
    - » Useful for imaging: The disk itself remains unchanged!
      - – Careful with write blockers: They may block the necessary ATA commands as they change the disk, although only temporarily!

# DCO – Device Configuration Overlay

- Modifications/hidden area invisible to the OS
  - → Reduce disk capacity to exactly match existing ones
  - → Remove special (optional) features of the controller
  - → Introduced with ATA-6 standard
- Properties:
  - → Survives formatting the disk
  - → No access by user, OS or BIOS
  - → Modifications are always permanent
- DCO and HPA can exist on the same disk
  - → First set DCO, then reduce size through HPA!
    - » READ NATIVE MAX ADDRESS will return the reduced size!
    - » DEVICE CONFIGURATION IDENTIFY shows the actual size

# Combining HPA and DCO



# HPA + DCO vs. computer forensics

- Both are simple to detect:
  - → Read number of sectors from physical drive (Internet, sticker)
    - » Label on drive need not necessarily be the original one!
  - → Compare to information obtained on the computer
- HPA can also be detected through software
  - → Retrieving physical size and comparing it to the maximum addressable sector
- Changing the DCO is always permanent!
  - → No "volatile" bit → Image first, the remove DCO and image again/the rest. **The disk is modified through this!**
- Imaging without HPA/DCO will produce incomplete copies
  - → And return different hashes than copies including them!
- Good forensic programs handle HPA (automatically), but DCO seems to be still a problem
  - → This applies to disk wiping programs as well …

# Removing know files

- Usually a disk under investigation will contain an operating system, i.e. several thousands of uninteresting files
  - → But you can't be sure, that everything in "C:\Windows" is from Microsoft and completely unchanged!
  - → Applies to any other "known" files as well
- Simple approach: Compare file names and contents with installation media and securely downloaded updates
- Better: Create hash values of all files and compare them to public libraries of hash values of known files
  - → These exist for OS, applications, malware etc.
  - → Private libraries also exist for illegal files, e.g. child porn
    - » This is legal: Only the hash value is stored, not the file!
  - → md5deep calculates hash values on numerous files, esp. also recursively (has some other nice features as well)!

# Hash libraries

- National Software Reference Library
  - → Contains has values of known, traceable software applications, but none of illegal data
  - → Currently 12.296.529 hash values (1.9.2007)
- Four CDs:
  - → Non-English software
  - → English software (OS)
  - → Application software
  - → Images and graphics
- File format: CSV
  - → SHA-1, MD5, CRC32, Filename, Filesize, Product + OS code
  - → "0000004DA6391F7F5D2F7FCCF36CEBDA60C6EA02", "0E53C14A3E48D94FF596A2824307B492","AA6A7B16", "00br2026.gif",2226,228,"WIN",""
    - » Corel Gallery 750.000, English, Windows

# Identifying file types

- Important to identify files intentionally misnamed
  - → Changing the name from "drugs.doc" to "cmd.com"
  - → See also temporary office files: ".doc", ".xls" → ".tmp"
- Also important after undelete or file carving
  - → The filename may no longer be available, but the content is
- How it works:
  - → Most file formats include some kind of header or footer with specific value at certain positions: "Magic numbers"
  - → Linux: "file" command
- Example:
  - → `# MS Access database`
  - → `4  string  Standard\ Jet\ DB Microsoft  Access Database`
  - → At position 4 the string "Standard Jet DB" is expected
  - → Format: Position  Type  Value  Document-type

# "Magic number" examples

- "JFIF" JPEG images

| Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00000000 | FF | D8 | FF | E0 | 00 | 10 | 4A | 46 | 49 | 46 | 00 | 01 | 02 | 01 | 00 | 48 | ÿØÿà JFIF H |
| 00000010 | 00 | 48 | 00 | 00 | FF | ED | 0B | D8 | 50 | 68 | 6F | 74 | 6F | 73 | 68 | 6F | H ÿí ØPhotosho |
| 00000020 | 70 | 20 | 33 | 2E | 30 | 00 | 38 | 42 | 49 | 4D | 03 | ED | 00 | 00 | 00 | 00 | p 3.0 8BIM í |

Note: Not immediately at the start of the file!

- "GIF8" GIF images

| Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00000000 | 47 | 49 | 46 | 38 | 39 | 61 | EE | 00 | D3 | 00 | F7 | 00 | 00 | 00 | 00 | 00 | GIF89aî Ó ÷ |
| 00000010 | 80 | 00 | 00 | 00 | 80 | 00 | 80 | 80 | 00 | 00 | 00 | 80 | 80 | 00 | 80 | 00 | ▌ ▌ ▌▌ ▌▌ ▌ |
| 00000020 | 80 | 80 | C0 | C0 | C0 | C0 | DC | C0 | A6 | CA | F0 | 04 | 04 | 04 | 08 | 08 | ▌▌ÀÀÀÀÜÀ¦Êð |

- 0x89"PNG" PNG images

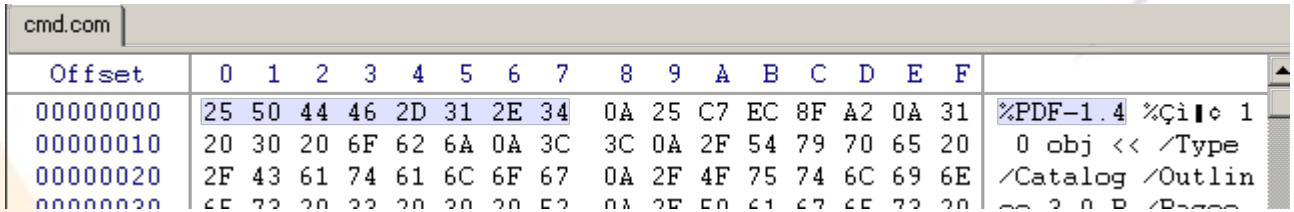
| Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00000000 | 89 | 50 | 4E | 47 | 0D | 0A | 1A | 0A | 00 | 00 | 00 | 0D | 49 | 48 | 44 | 52 | ▌PNG IHDR |
| 00000010 | 00 | 00 | 02 | 80 | 00 | 00 | 01 | E0 | 08 | 06 | 00 | 00 | 00 | 35 | D1 | DC | ▌ à 5ÑÜ |
| 00000020 | E4 | 00 | 00 | 00 | 09 | 70 | 48 | 59 | 73 | 00 | 00 | 0B | 13 | 00 | 00 | 0B | ä pHYs |

- MS Access Database

| Offset | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00000000 | 00 | 01 | 00 | 00 | 53 | 74 | 61 | 6E | 64 | 61 | 72 | 64 | 20 | 4A | 65 | 74 | Standard Jet |
| 00000010 | 20 | 44 | 42 | 00 | 01 | 00 | 00 | 00 | B5 | 6E | 03 | 62 | 60 | 09 | C2 | 55 | DB µn b` ÂU |
| 00000020 | E9 | A9 | 67 | 72 | 40 | 3F | 00 | 9C | 7E | 9F | 90 | FF | 85 | 9A | 31 | C5 | é©gr@? ▌~▌▌ÿ▌▌1Å |

# Identification example

- Example file: "cmd.com"
  - → Note: Both "command.com" and "cmd.exe" do exist in "C:\Windows\System32" (Windows command line)!
- Output on a Linux machine:
  [user@host ~]# file cmd.com
  cmd.com: PDF document, version 1.4
- Suggested actions:
  - → Make a copy to a different disk
    - » Keep original disk and file unchanged!
  - → Rename extension to PDF
  - → Open with Acrobat Reader



# Creating a timeline

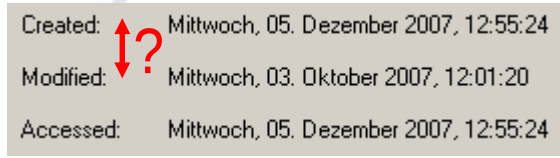
- Timeline: When any/certain actions were taken
  - → Take care: Usually all you get is computer local time!
- May contain various elements
  - → When the computer was started/stopped
    - » Use of company resources outside working hours
  - → When certain files were created/deleted/modified/accessed
    - » Creation: E.g. rootkit installation
    - » Modification: Modification date past the date stated within
      - – Example: Backdating letters, modifying balance sheets, …
    - » Deletion: After notice of proceedings → Evidence destruction
  - → When a certain user was logged in/active

# Creating a timeline

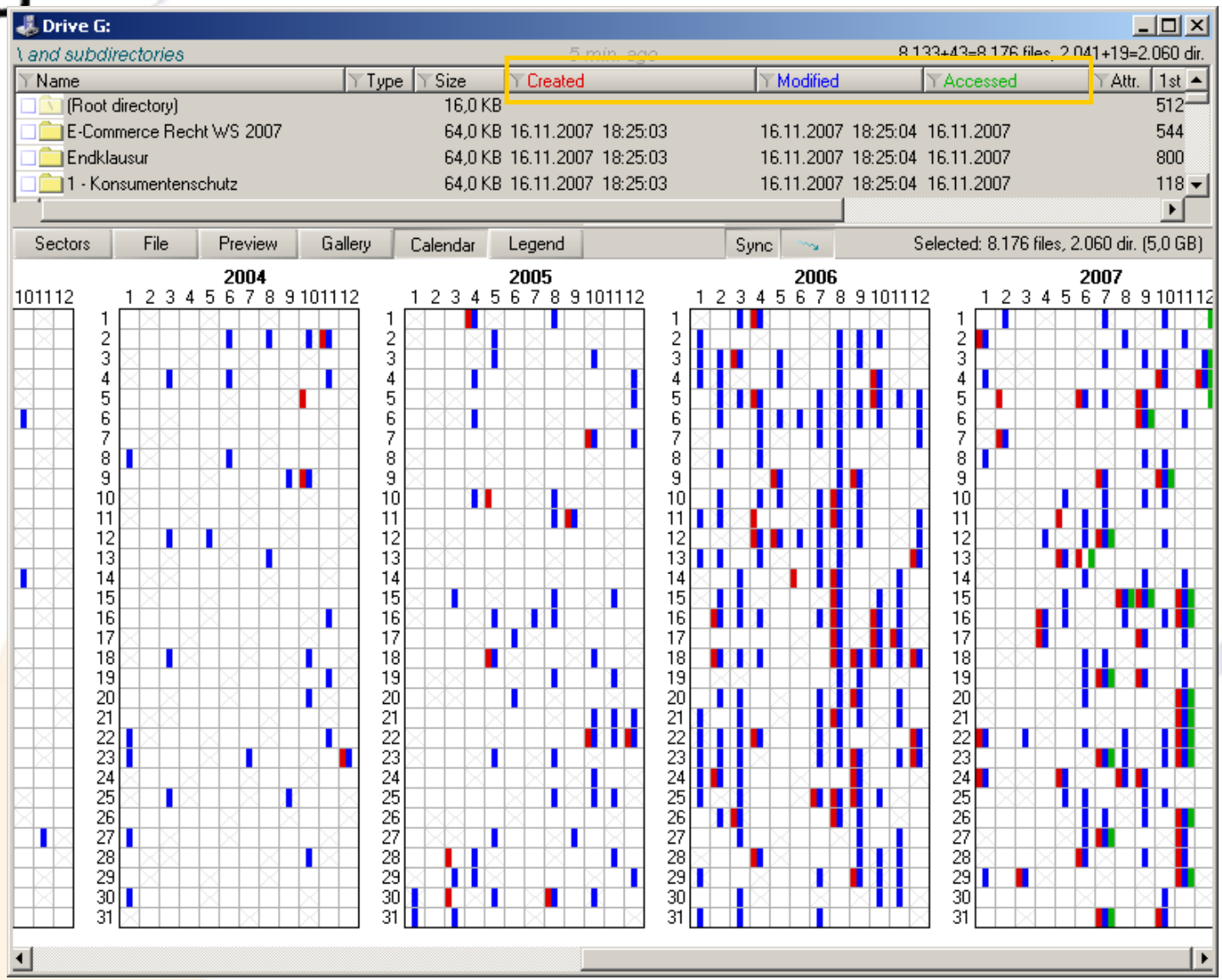
- Sources: MAC time of files, log files / Registry
  - → HKLM\System\CurrentControlSet\Control\Windows\ShutdownTime: 64 Bit Hex datetime value
- Hints:
  - → Compare e.g. web cache files to their timestamps to detect clock skew!
  - → Look for inconsistencies in the naming of System restore points (which are created in increasing numbering and are timestamps, as they are files, directories, etc.)

# MAC

- MAC = Modification, Access, Creation time
  - → Some file systems have other metadata as well!
  - → Access time is fragile: Most actions on a file will change it!
    - » Usually not: appearing in a directory list
    - » Should: Open for display, copy (source & destination)
  - → Modification: When the file was written to
- Note: Modifying these values depends on the OS
  - → On most systems changes can be forbidden
    - » HKLM\SYSTEM\CurrentControlSet\Control\FileSystem\NtfsDisableLastAccessUpdate → 1 (Claimed to be default in Vista!)
    - » Linux: mount –o noatime
- Windows specialty: Copying files retains M, but sets new C!
  - → Creation after modification:
    A hint, that file was copied here
  - → Not reset on extracting files from an archive

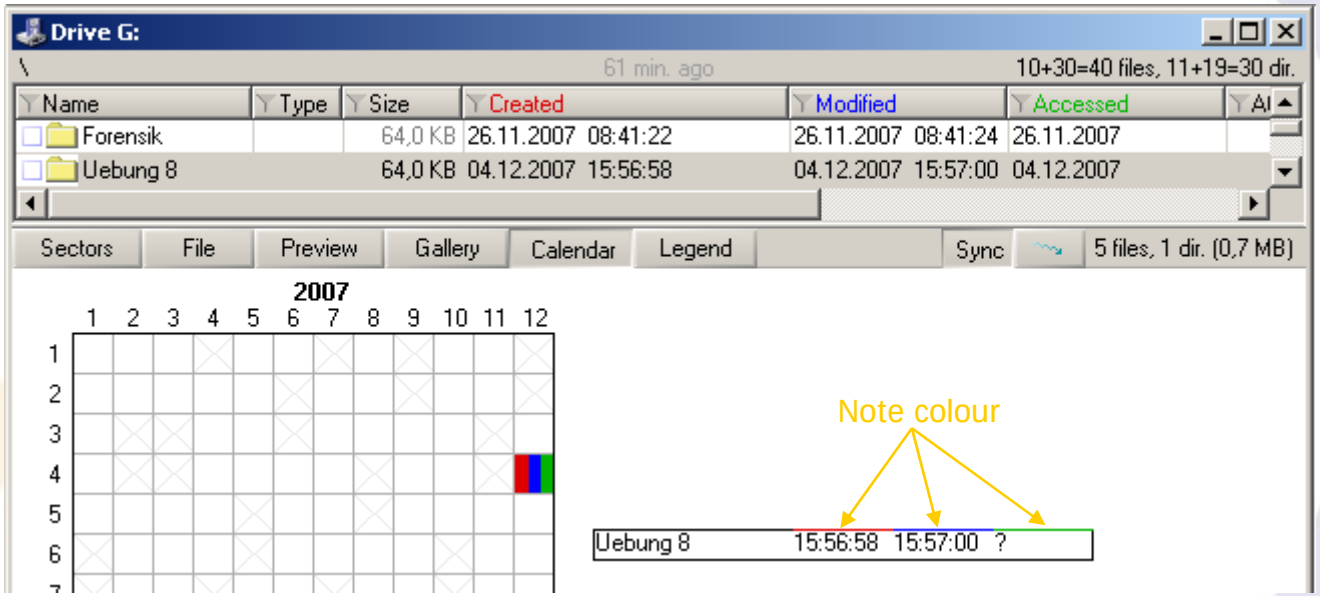


# Timeline based on MAC: Example




- Access dates only after 13.6.2007
- Creation dates are rather recent, compared to modification dates
- Files must have been copied there
- Older C dates: Probably extracted from ZIP files!
- Notice the "blue line" in 8/2006: Continuous work over the weekends!
- Gray crosses: Weekends!

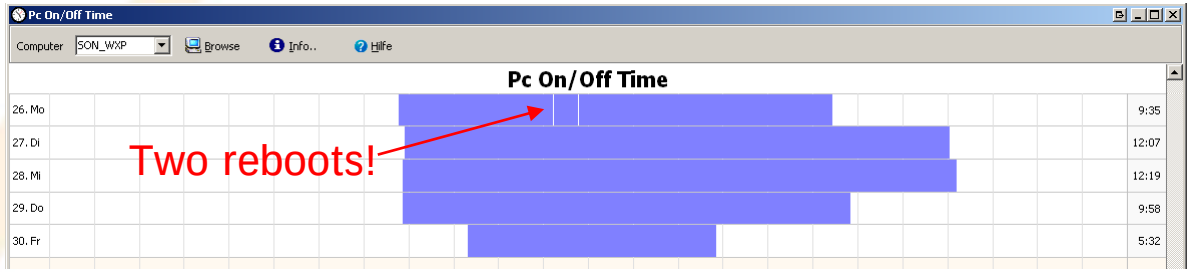
# Timeline based on MAC: Example




- File information on hovering the mouse
  - → Note: The hovering is not quite correct: The access date is not shown in the popup, although marked in the calendar and shown in the directory view above!

# Startup and shutdown information

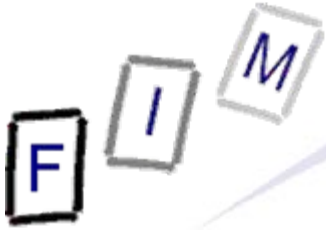
- Recorded in the system log: Detailed time
  - → When this is cleared, the information is gone!
    - » Traces may remain on disk → partial information




- Based on MAC times of all files and all log entries
  - → Results only in vague times: When the computer was definitely on (single last shutdown time: Registry time)
    - » But it might have been on at other times as well …
- Manipulating the local clock allows falsifying such data
  - → But this is difficult: All file times must match these values too!
- Linux is similar to Windows: Specific entries/MAC+whole log

# Conclusions

- The first and most important aspects of forensic are the
  Three "P's" of evidence: "preserve, package, protect"
  - → This especially includes using write blockers
- Computer forensics is not only undeleting files
  - → There are many small but important areas as well, e.g.
    - » Partition table examination
    - » E-Mail / Web browser forensics
    - » Recognizing files
    - » Creating timelines
    - » Investigating the Windows registry
    - » Recycle bins, LNK files, …
- What is therefore needed: Caution
  - → And a good list of where what information might be found, to acquire knowledge/expertise in this area if needed!




# Questions?

**Thank you for your attention!**

# Links

- http://tech.groups.yahoo.com/group/hashkeeper/
- http://www.nsrl.nist.gov/
- http://www.utica.edu/academic/institutes/ecii/publications/articles/EFE36584-D13F-2962-67BEB146864A2671.pdf
- http://www.foi.se/upload/rapporter/foi-computer-forensics.pdf