



FragFS: An Advanced Data Hiding Technique

Irby Thompson and Mathew Monroe
ATRC – Lockheed Martin
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Overview

- History and Analysis of Data Hiding Methods
- Exploring NTFS
- FragFS Implementation
- Demonstration
- Detection
- Future Considerations
- Q&A



History of Data Hiding

- Information Hiding is an Ancient Art
 - Writing a hidden message with invisible ink
- Hiding data on computers is often just the modern day application of existing principles
- Three major categories of data hiding:
 - Out-of-Band
 - In-Band
 - Application Layer



History of Data Hiding

Out-of-Band

- Definition:
 - The portion of a medium which is outside the format specification for that medium
- Examples:
 - Slack space beyond the end of a partition
 - Slack space at the end of files
 - Example: *slacker.exe*
 - Sectors marked as bad
 - Host Protected Area



History of Data Hiding In-Band

- **Definition:**
 - The portion of a medium which is inside the format specification for that medium
 - Hidden data must not break the format of the specification
- **Examples:**
 - Alternative File Streams
 - File-System Journal Logs
 - Reserved but unallocated sectors



History of Data Hiding

Application Layer

- **Definition:**
 - Hiding in a higher-level format specification
 - Often a subset of In-Band Data Hiding viewed at a different level of granularity
- **Examples:**
 - Steganography (hiding data within data)
 - Hidden text within documents
 - Example: extra white space, tabs, new-line characters
 - Virus hiding within EXE's code (.text) section
 - Hydran uses redundancies in i386 code to hide data



Analysis of Hiding Methods

- Well known to Forensic Tools
 - Forensic tools will specifically look for known hiding methods
 - Alternative File Streams
 - Slack space at the end of files
 - A *strings* search over a raw disk will find textual results wherever they are located
- Experienced Analysts will detect anomalies not directly identified by Forensic Tools



Out-of-Band Analysis

- *"Coloring Outside the Lines"*
- Strengths
 - Being outside the boundaries usually results in being overlooked
 - There is sometimes a large amount of space available
 - Hard to discover without special tools
 - Resilient
- Weaknesses
 - Hard to access without special tools
 - Hard to hide from plain-sight analysis of the out-of-band area



In-Band Analysis

- *"Coloring in the Nooks and Crannies"*
- Strengths
 - Usually easy to access with existing tools
 - Follows the specifications – does not break anything
- Weaknesses
 - Storage space is often small
 - Relies on security through obscurity – easy to detect once method is known
 - Specifications may change



Application Layer Analysis

- *"Splatter-Painting the Canvas"*
- Strengths
 - Hiding in plain sight
 - Often hard to detect
- Weaknesses
 - Storage quantity varies with the size of underlying data, but must be relatively small to remain hidden
 - Difficult to access without special tools
 - Complex algorithms to hide/retrieve data
 - Not resilient



EnCase – Slacker.exe

The screenshot displays the EnCase Forensic application window. The main area shows a hex dump of a file. The left pane shows a file tree with folders like \$Extend, Config.Mst, cygwin, bin, etc, home, lib, PuttyCyg, tmp, usr, var, Documents and Settings, Program Files, RECYCLER, System Volume Information, WINDOK, WINDOWS, and Lost Files. The hex dump shows the following data:

Address	Hex	ASCII
117490	64 6C 65 41 00 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00	dleA.....
117521	10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00
117552	00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05
117583	00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10 05 00 00 10cygwinl.dll...E...KERNE
117614	05 00 00 10 05 00 63 79 67 77 69 6E 31 2E 64 6C 6C 00 00 10 45 00 14 10 05 00 4B 45 52 4E 45	L32.dll.....
117645	4C 33 32 2E 64 6C 6C 00
117676	00 00
117707	00 00
117738	00 00
117769	00 00
117800	00 00
117831	00 00
117862	00 00
117893	00 00
117924	00 00
117955	00 00
117986	00 00
118017	00 00
118048	00 00
118079	00 00
118110	00 00
118141	00 00
118172	00 00
118203	00 00
118234	00 00
118265	00 00 00 00 00 00 00 54 68 69 73 20 69 73 20 6F 75 72 20 75 62 65 72 2D 73 65 63 72 65 74 20This is our uber-secret
118296	68 69 64 64 65 6E 20 64 61 74 61 21 21 21 0D 0A 6E 5C 5C 76 61 72 5C 72 75 6E 5C 75 74 6D 70	hidden data!!! n\\var\run\utmp



Finding New Places to Hide

- Determine constraints
 - How much space is needed?
 - What type of access is required?
 - How sensitive is hidden data?
- Decide which hiding category best fits the constraints
- Look for previously-unknown hiding methods in that category
 - Analyze an existing specification
 - May require reverse-engineering
 - Study existing data hiding techniques
 - Find unused reserved or slack space



An NTFS Overview

- Standard file system on Windows NT, Windows 2000, Windows XP, and upcoming Windows Vista
- Master File Table (MFT)
 - Every file or directory is an entry in the table
 - Stores all file system metadata in one place
 - Can grow, but not shrink
 - Not well documented or understood



MFT Entries

- Each entry is of fixed size
 - Defined in the boot sector
- Each file and directory usually requires one entry but can span multiple entries if needed
- Information about an entry is stored as attributes
 - Each entry has multiple attributes
 - Most files have a few common attributes
 - Attributes can be stored in any order
- Has per sector fix up bytes to detect defects
 - Last two bytes of each sector stored in header and fixed up on every read and write



MFT Attributes

- Attributes have different types
- Some attribute types can be repeated
 - Duplicate \$DATA attributes commonly called Alternate File Streams
 - Directories entries stored as individual attributes
- Each attribute can be named, compressed, encrypted, etc
- Each attribute is either resident or non-resident
 - Resident attributes stored within MFT entry
 - Non-resident attributes stored as data run (extent)



MFT Attribute Examples

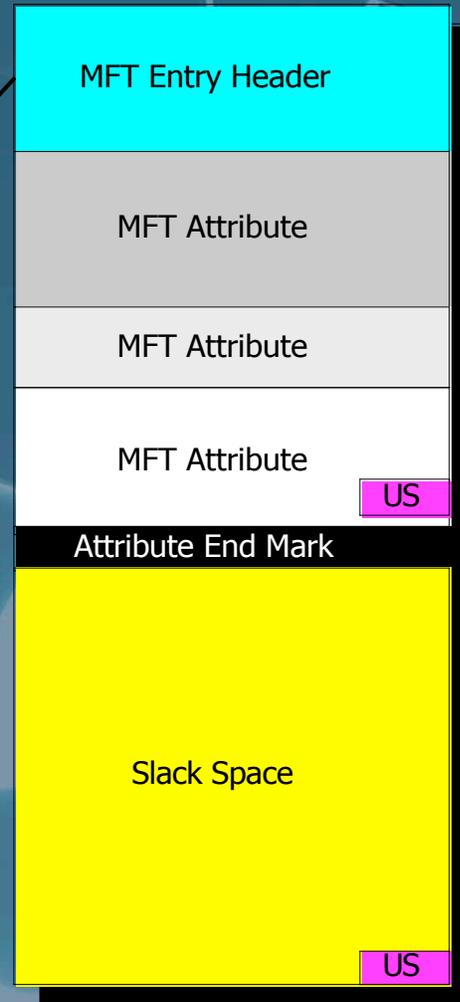
- All entries have
 - `$STANDARD_INFORMATION`
 - Stores timestamps, owner ID, security ID, etc
 - `$FILE_NAME`
 - Name by which an entry is known, size, and create/rename timestamp
- All files have `$DATA` attribute
- Directories use several attributes-
 - Each entry in a directory is stored as a `$FILE_NAME` attribute
 - DOS 8.3 name stored in a second `$FILE_NAME` attribute
 - Directories have additional indexing attributes to improve filename lookup performance
- End of attributes in an entry is marked by `0xFFFFFFFF`
- Most attribute types are kept for backward compatibility



MFT Entry

MFT Entry Header

Magic
US Offset
US Size
LSN
Sequence Number
Hard Links
Attribute Offset
Flags
Real Size
Allocated Size
Base Entry Number
Next Attribute ID
Reserved
Entry Number
US Data



Resident Attribute

Type
Length
Resident Flag
Name Length
Name Offset
Flags
ID
Attribute Length
Attribute Offset
Reserved
Attribute Name
Attribute Data

Non-Resident Attribute

Type
Length
Resident Flag
Name Length
Name Offset
Flags
ID
...
Data Run Offset
...
Attribute Name
Data Run



Usable Space in MFT entries

- **Reserved space within entries**
 - Many small unused areas
 - 2 bytes reserved in every entry header
 - 4 byte reserved in resident attributes
 - Up to 14 bytes are reserved in non-resident attributes
 - All attributes are 8 bytes aligned
 - Each file typically has 32 usable bytes
 - Each directory typically has 64 usable bytes
- **Slack space after entry attributes**
 - Files and directories typically have less than 450 bytes of attributes
 - Default NTFS file systems allocate 1024 bytes per MFT entry
 - Almost 600 bytes per entry!



Usage Concerns

- **Common concerns**
 - Entries may be deleted
 - Entries zeroed on allocation
- **Reserved Space**
 - Might change in future versions of NTFS
 - Normally these bytes are zeroed
- **After-attribute slack space**
 - Attributes might expand or be added
 - Commonly zero but not always
 - Attributes shrink due to going from resident to non-resident, but can't go back to being resident
 - All directories start as resident and go to non-resident, but can't go back to being resident
 - Attributes can be removed



Avoiding Pitfalls

- How do we find "safe" entries?
- Many files are rarely modified or deleted
 - Operating system files (drivers, .inf, font, and help files)
 - Most installed application files are only read
 - If it has never been modified it most likely never will be
 - Files that have been around for a long time are rarely deleted
- Non-resident attributes can never become resident
- Directories are rarely deleted
 - Non-resident directories in particular
- Summary - Choose entries that are
 - Non-resident
 - Have never been modified
 - Old



Putting It All Together

- How much space is available?
 - Base Windows XP Professional install has over 12,000 MFT entries
 - Typical systems have over 100,000 MFT entries
 - Not all entries are safe to use, but testing has shown ~60% of MFT entries are "safe" to use
 - $100,000 \text{ entries} \times 60\% \times 600 \text{ bytes/entry} = 36,000,000 \text{ bytes!}$



Additional Issues

Chunking

- Small scattered chunks are not very useful
- The mapping problem
 - Need an interface that can map large blocks or streams across many chunks
 - No matter what space is being used it should look like one contiguous block to higher-level applications
- Mapping should be dynamic
 - Users will delete old files and directories and add new ones
 - Might lose data or need to use additional entries



Additional Issues

Encryption

- Data can be found by searching the raw device
- Detected data can still be protected
- How good is good enough?
 - XOR
 - Blowfish
 - LRW-AES (Narrow-block Encryption)
- Good encryption systems are hard
 - Good encryption is easy to misapply or misuse
 - Finding publicly available implementations is not easy
- Key management is hard
 - Static forensic analysis can be made difficult
 - Dynamic forensic analysis can always find the keys



Additional Issues

Change Tracking/Redundancy

- What happens when Windows updates an entry you are using?
 - NTFS only changes what it needs to change
 - Might lose some but not all of your data
- Keep extra copies
 - How much redundancy is enough?
- Do your changes get noticed by NTFS?
- Watch for NTFS changing an entry



Additional Issues

Usability

- How is the data presented to the user?
- How is the data presented to the OS?
- Use standard interfaces
 - Prevent the need to rewrite applications
- Reading and writing data files is easy
- Files execution is hard
 - Windows will only execute files from a file system that it understands



FragFS

On-Disk Implementation

- Format
 - Scan MFT Table for suitable entries
 - Non-resident files that have not been modified within the last year
 - Calculate how much space is available in each entry
 - Divide space into 16 byte chunks
 - Store book keeping information in last 8 bytes of each entry
 - First Logical Chunk Number
 - Number of chunks
 - CRC-16 checksum
- No index of chunks on disk
 - Must scan for chunks



FragFS

On-Disk Implementation

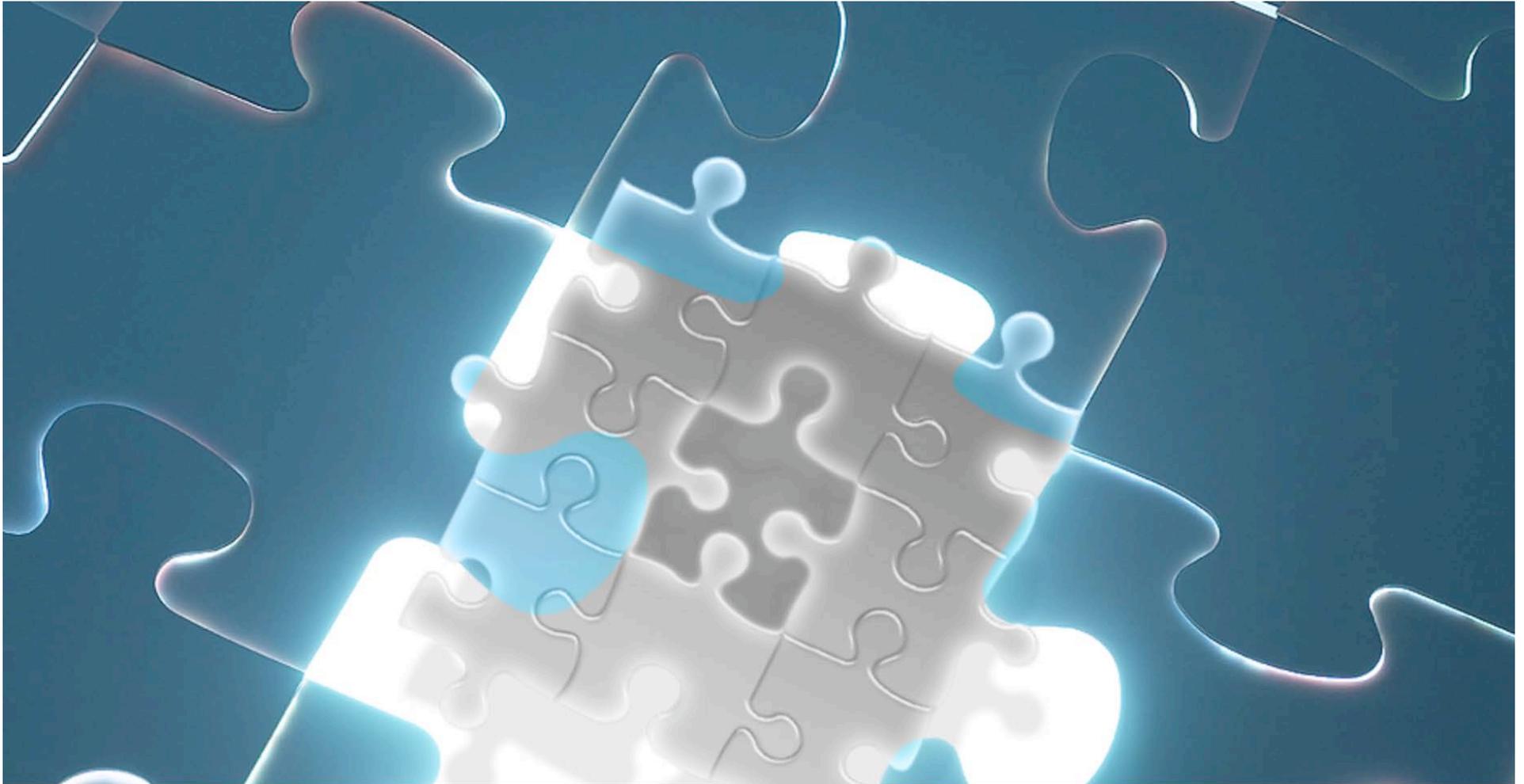
- Advantages
 - Unlimited redundancy
 - Modification detection
 - Localization of data corruption
 - Easy to relocate or replicate individual chunks of data
- Disadvantages
 - Must scan entire MFT to make updates
 - Bookkeeping information can be detected



FragFS

In-Memory Implementation

- Stackable block device interface
 - Easy to update and add new features
 - On disk format can easily change
- User-space Application Library
 - Can be linked to and used by any application
 - Built-in mini file system
- Kernel Device Driver
 - Creates a virtual disk
 - Can execute files directly from it!



FragFS Proof of Concept Demonstration



Detecting NTFS Anomalies

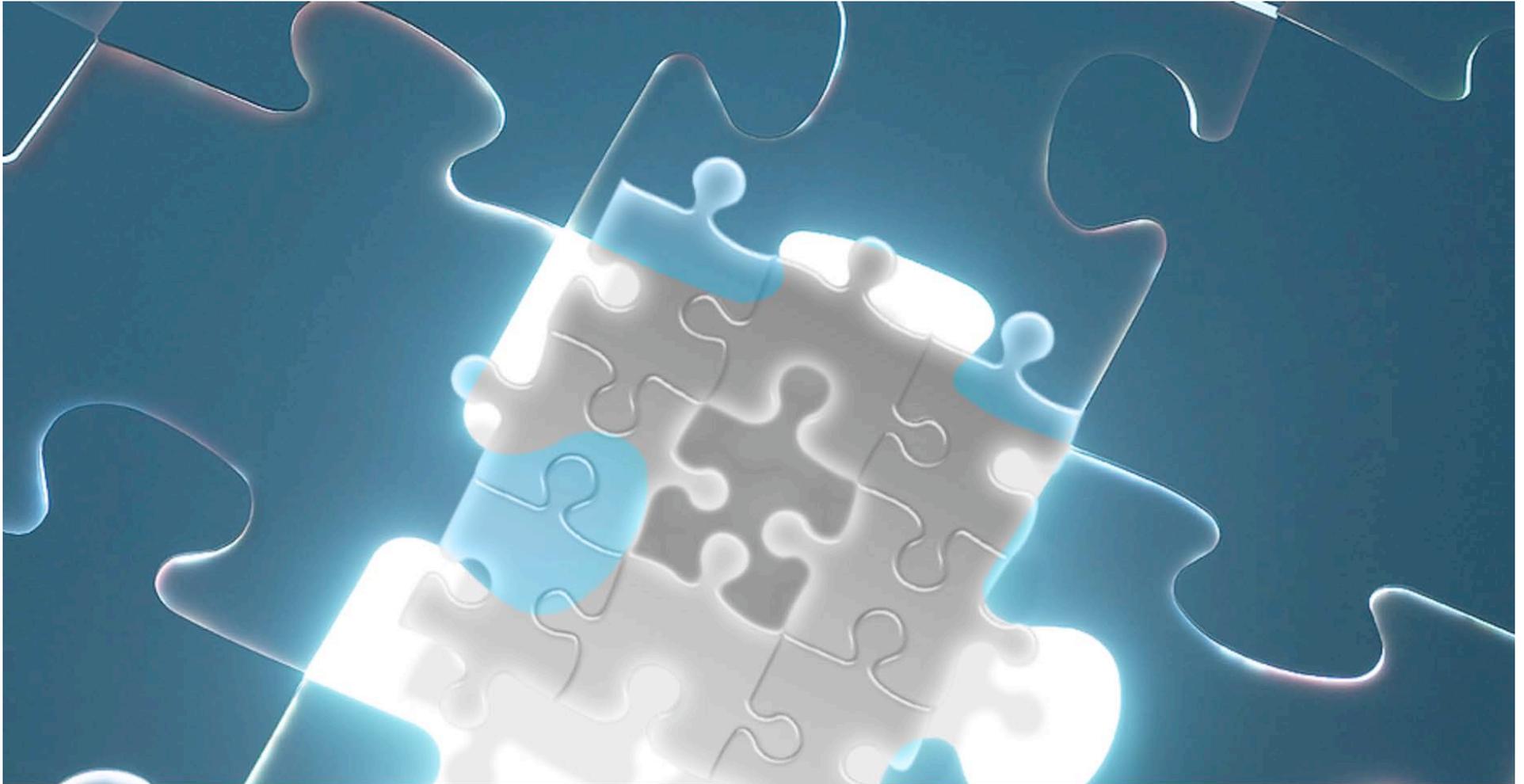
- Current forensic tools treat the MFT as a black box
 - There is a need for forensic tools to better understand file system structures
 - Forensic Analysts do not often have the time to comb through hex dumps
- We have developed a detection tool for data hidden in MFT entry slack space
 - Any data beyond the End-of-Attribute marker is considered suspicious



Encase - FragFS

Name	Filter	In Report	File Ext	File Type	File Category	Signature	Description
3	Folder						Folder, System, Re...
4	Folder						Folder
5	Folder						Folder, Hidden, Sys...
6	\$MFT						File, Internal
7	\$MFTMirr						File, Internal
8	\$LogFile						File, Internal
9	\$Volume						File, Internal

```
050176 46 49 4C 45 30 00 03 00 A2 16 12 00 00 00 00 01 00 02 00 38 00 01 00 C0 01 00 00 FILE0...c.....g...A...
050204 00 04 00 00 00 00 00 00 00 00 00 00 05 00 00 31 00 00 00 03 00 00 00 FC 97 00 00 .....1.....w...
050232 10 00 00 00 60 00 00 00 00 00 00 00 00 00 00 48 00 00 00 18 00 00 00 D0 92 93 8A .....H.....
050260 63 1D C6 01 40 5F 83 67 81 1C C6 01 40 5F 83 67 81 1C C6 01 D0 92 93 8A 63 1D C6 01 c..E.._og..E.._og..E..D000c..E..
050288 20 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 09 01 00 00 00 00 00 .....
050316 00 00 00 00 00 00 00 00 00 00 00 00 30 00 00 68 00 00 00 00 00 00 00 00 00 02 .....0...h.....
050344 50 00 00 00 18 00 01 00 30 00 00 00 00 00 01 00 D0 92 93 8A 63 1D C6 01 D0 92 93 8A P.....0.....D000c..E..D000
050372 63 1D C6 01 D0 92 93 8A 63 1D C6 01 D0 92 93 8A 63 1D C6 01 00 00 00 00 00 00 00 c..E..D000c..E..D000c..E.....
050400 00 00 00 00 00 00 20 00 00 00 00 00 00 00 00 07 01 2E 00 62 00 61 00 73 00 68 00 .....b..a..s..h..
050428 72 00 63 00 30 00 00 00 70 00 00 00 00 00 00 00 00 03 00 52 00 00 00 18 00 01 00 r..e..0...p.....R.....
050456 30 00 00 00 00 01 00 D0 92 93 8A 63 1D C6 01 D0 92 93 8A 63 1D C6 01 D0 92 93 8A 0.....D000c..E..D000c..E..D000
050484 63 1D C6 01 D0 92 93 8A 63 1D C6 01 D0 92 93 8A 63 1D C6 01 00 00 00 00 00 00 00 c..E..D000c..E.....
050512 20 00 00 00 00 00 08 02 42 00 41 00 53 00 48 00 52 00 43 00 7E 00 31 00 00 00 00 .....B..A..S..H..R..C...1...
050540 00 00 00 80 00 00 48 00 00 00 01 00 00 00 00 00 04 00 00 00 00 00 00 00 00 00 .....Q...H.....
050568 05 00 00 00 00 00 40 00 00 00 00 00 00 00 00 00 0C 00 00 00 00 00 DF 0A 00 00 .....@.....B...
050596 00 00 00 DF 0A 00 00 00 00 00 00 00 31 06 47 D6 01 00 01 00 FF FF FF FF 82 79 47 11 .....B.....1..C0.....yyyYyC..
050624 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
050652 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
050680 00 00 00 00 00 03 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
050708 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
050736 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 .....
050764 00 00 00 00 00 00 00 00 00 00 DD 01 7E 95 65 35 09 D0 46 84 9D 6D 51 F2 F2 F1 .....Y...-0e5 DF00mQ00Z
050792 DC 79 09 0D 6F A3 EA E9 84 E2 3F DA 51 D0 8F D8 4A 12 ED CA 6A 2D C9 7F B9 53 9B E0 0y oSae0*?U0000J.iRj-R0'S0*
050820 2B 23 0E 38 0F 40 6E AB E3 19 A7 31 5C A3 6E AC 50 03 47 D8 CC 8D 83 45 C0 56 7A C7 +#*8*@n0A*$1/n-P*00I00RAVz0
050848 9C 0E D7 DE 13 F6 06 44 21 74 D2 11 2D 7F 33 38 AF E6 9C C7 6C 17 2A 63 9A C5 2B 14 0..x*0..D!t0..-038-ad01..*c0A+..
050876 9C 49 7F F4 E4 B4 13 AD 66 69 39 50 75 83 7B BE 15 DC 0B 71 86 D9 C8 D6 11 43 CB B1 0000a'..-f19Pu0(4*U..00U00.CI+
050904 1F 56 82 2C 17 0E 52 FA BC 39 30 5A D7 DF 29 A2 BD 4D 5E AD A6 3C CD 1A 24 C1 5C 73 ..V0...Ru4902x0)e4M^~!<I..fA\s
050932 4F 3C D4 8C 48 C3 4E 53 73 F4 BF 69 17 A4 DE 08 48 28 75 D5 6F F5 B9 0E C1 03 9C 6A 0<00HANS=0;..xP.H(u000*..A..0j
050960 80 41 77 84 D1 71 AA F0 AA 62 44 17 1C CF 65 5F 14 C8 72 91 07 7D 80 9E 81 F3 1A 83 0Aw0Nq*8*bD..Te..E..x0.)a006.0
```



Detection Demonstration



Future Considerations

- “Hiding through Obscurity” only buys you time
- Many other unexplored data storage areas
- Hiding access tools is still a problem
 - Bootstrap out of the hidden space?
- Should file system standards be open?
 - Forensic tools could better detect hidden data
 - File systems will be easier to exploit

Q&A





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Contact Information

Irby Thompson
lantholin (at) gmail.com

Mathew Monroe
mathew.monroe (at) gmail.com