# FragFS: An Advanced Data Hiding Technique

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# Overview

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

# Why is Data Hiding important?

- Do rootkits alleviate the need for data hiding?
  - NO!!
  - Rootkits hide data on a live system
  - Hiding from forensic/offline analysis is much harder
- What if the rootkit is entirely memory-based?
  - Offline disk analysis will not find it
  - No reboot persistence
- Some techniques rely on covert, persistent storage
  - “The patient hacker”

# History of Data Hiding

- Information Hiding is Old News
  - Writing with invisible ink
- Hiding data on computers is often just a 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 that is outside the normal specifications for that medium
  - The *"Media Management"* Layer
- 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 that is inside the normal specifications for that medium
  - The *"File System"* Layer
  - 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 often 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

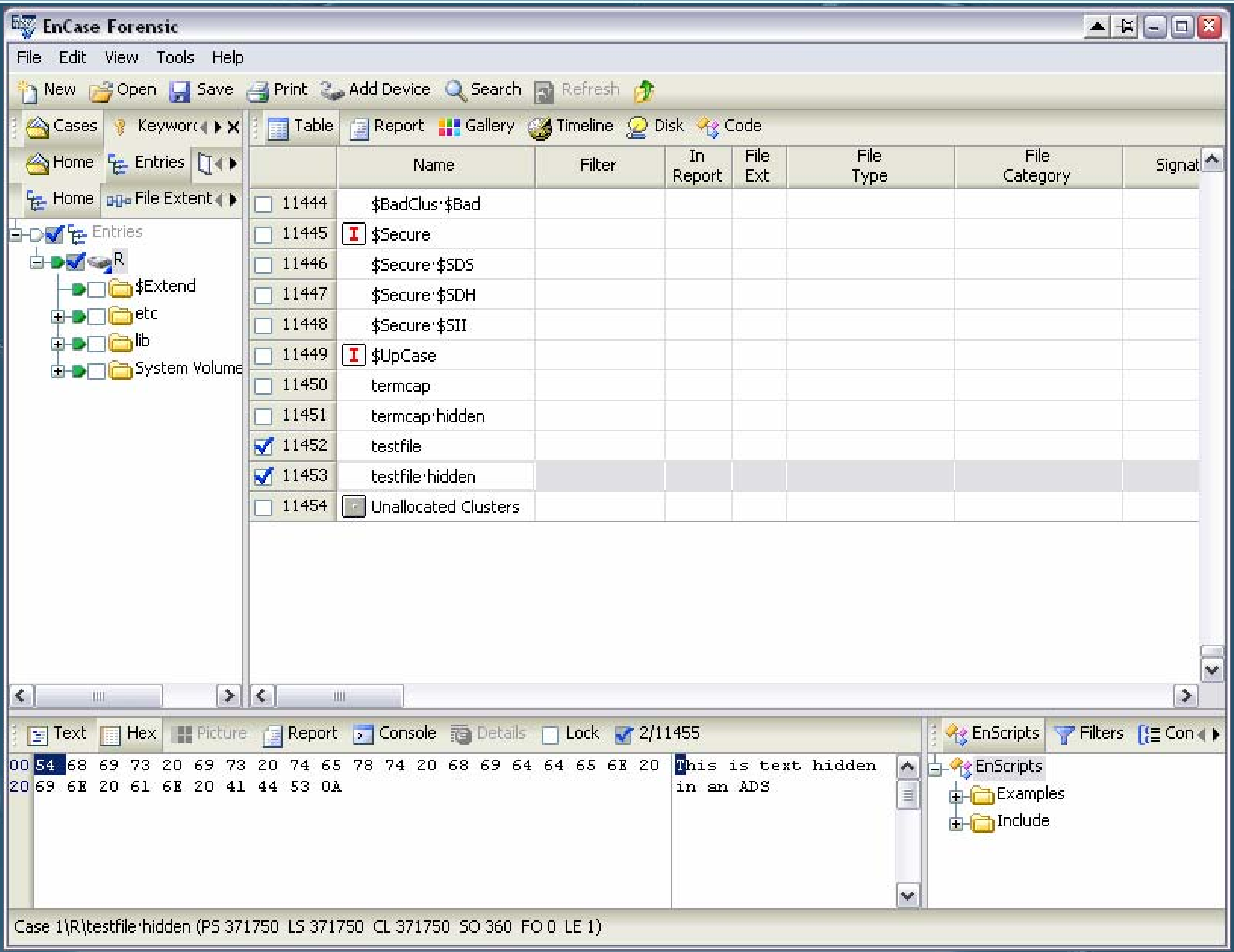
# In-Band Analysis

- *"Coloring in the Nooks and Crannies"*
- Strengths
  - Usually easy to access with existing tools
  - Follows the specifications
    - Less devious?
- Weaknesses
  - Storage space is often small
  - Relies on security through obscurity – easy to detect once method is known
  - Specifications may change

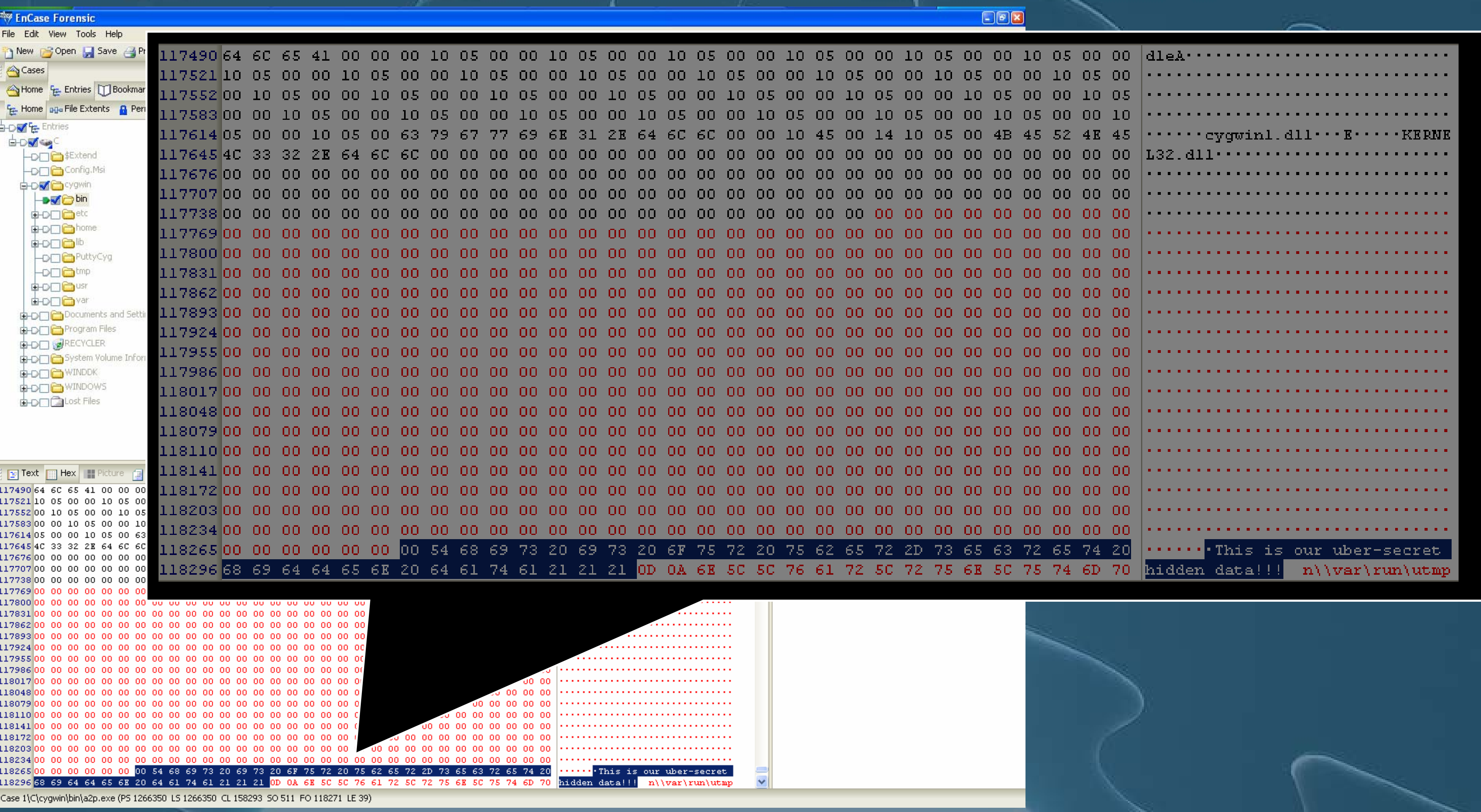
# Application Layer Analysis

- *"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 – Alternate File Streams



# EnCase – Slacker.exe



# 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

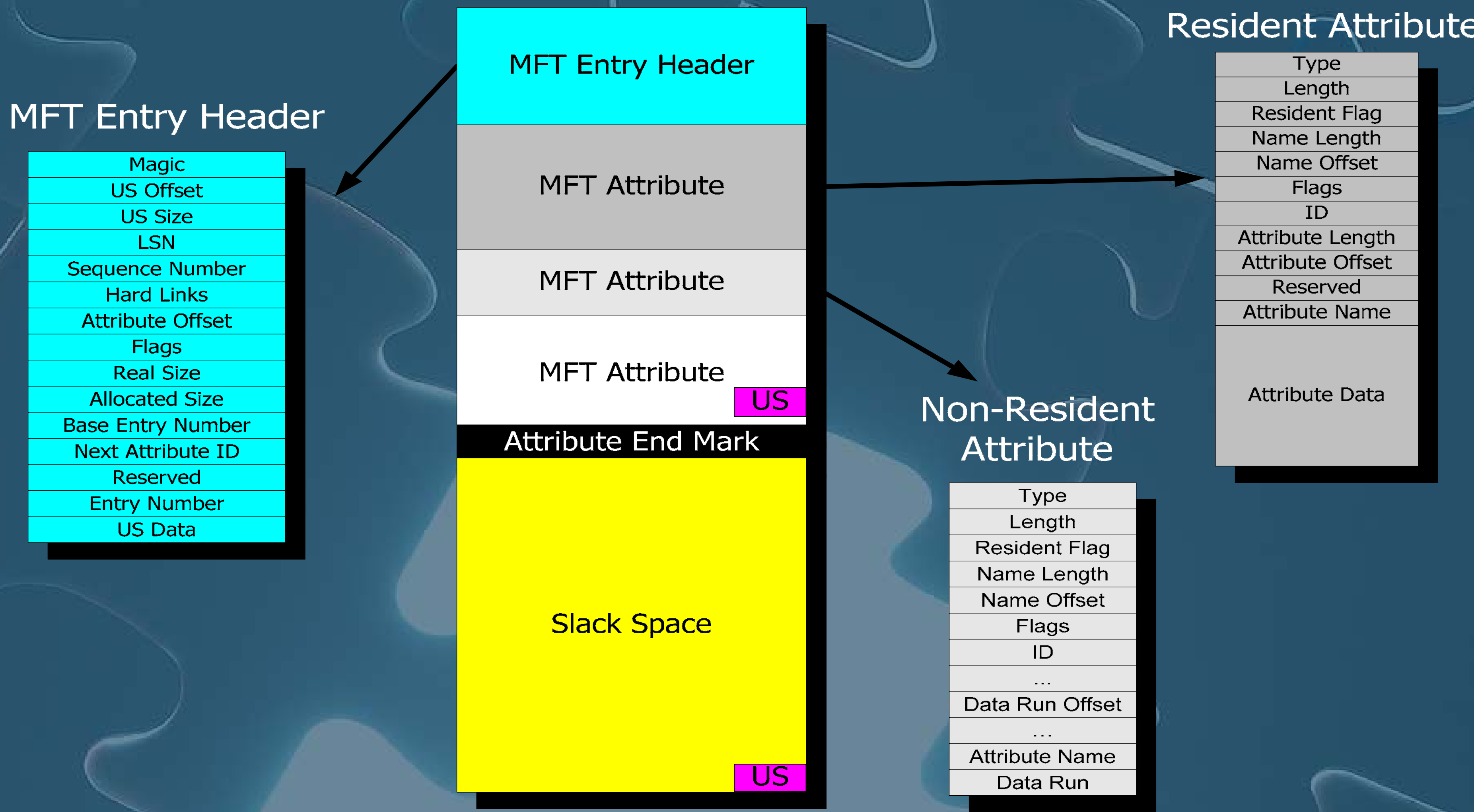
# MFT Attributes

- 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
MFT Entry Header
MFT Attribute
MFT Attribute
MFT Attribute
US
Attribute End Mark
Slack Space
US
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 entries x 60% x 600 bytes/entry = 36,000,000 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)
- Encryption plus Integrity
  - Self-Authenticating encryption is best
- 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

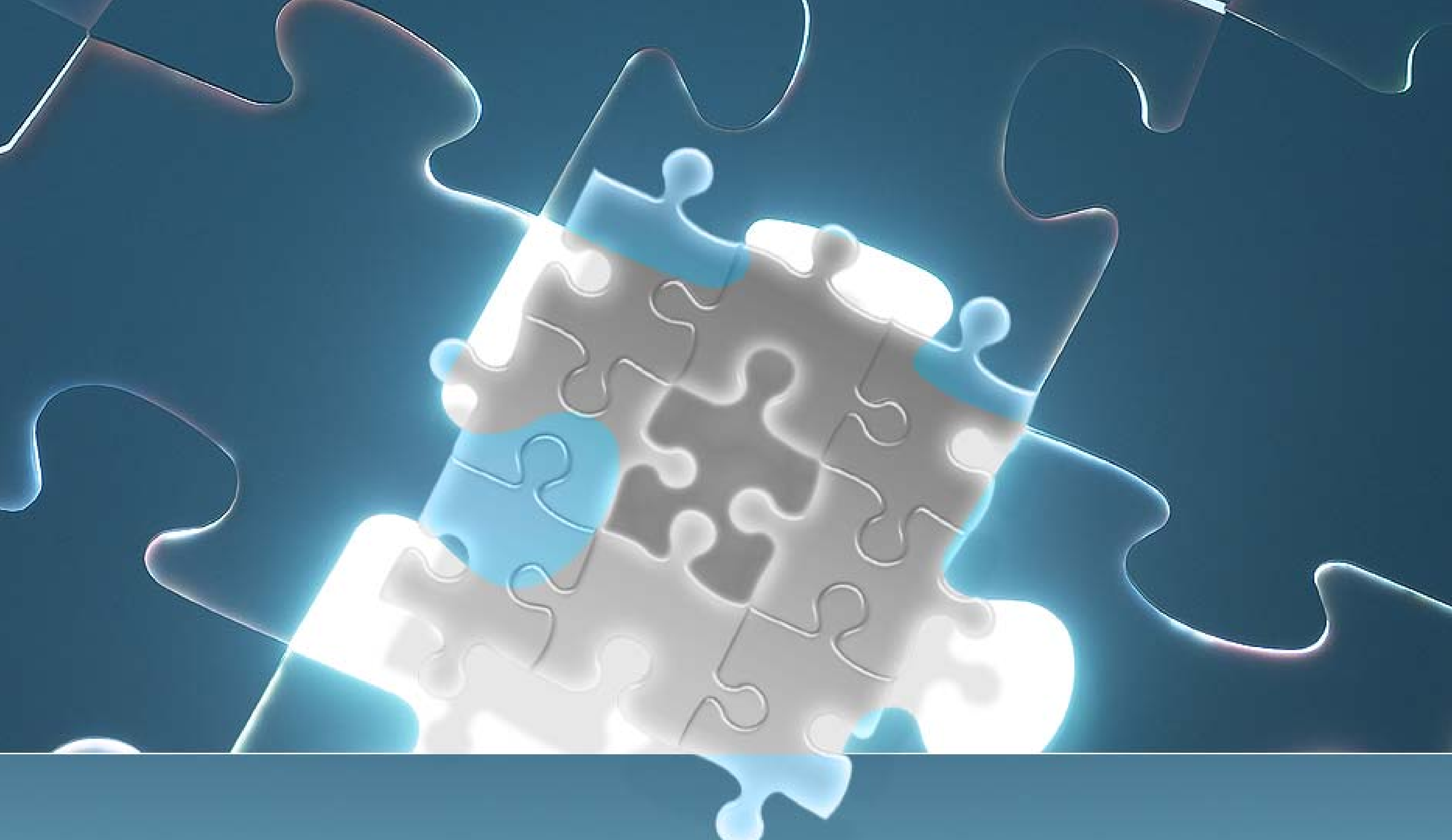
- Format
  - Scan MFT Table for suitable entries
    - Non-resident files that have not been modified within the last year
  - Calculate how much space is available in each entry
  - Divide space into 32 byte chunks
    - 4 bytes for Logical Chunk Number
    - 28 bytes for data
- No book marking or index of chunks on disk
  - Check the last 32 bytes of every entry to see if it is a valid chunk
  - If a chunk is valid then check 32 bytes before it the same entry to see if it is also a valid chunk

# 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

# 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
  - Uses the FAT file system
  - Can execute files directly from it!

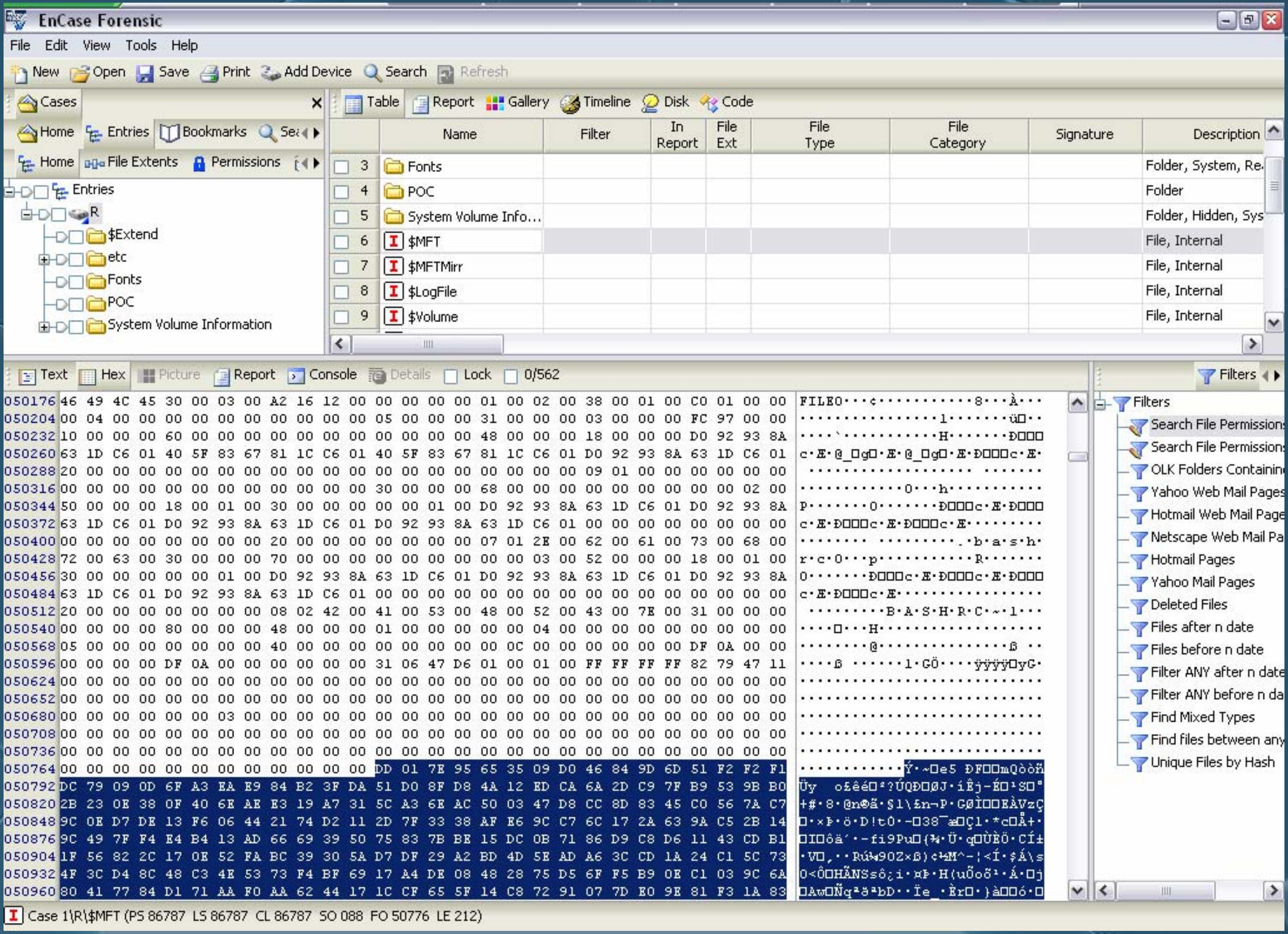


# FragFS Proof of Concept Demonstration

# 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



# 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

FragFS

# Contributors

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  - The Grugq
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