Static Malware Detection

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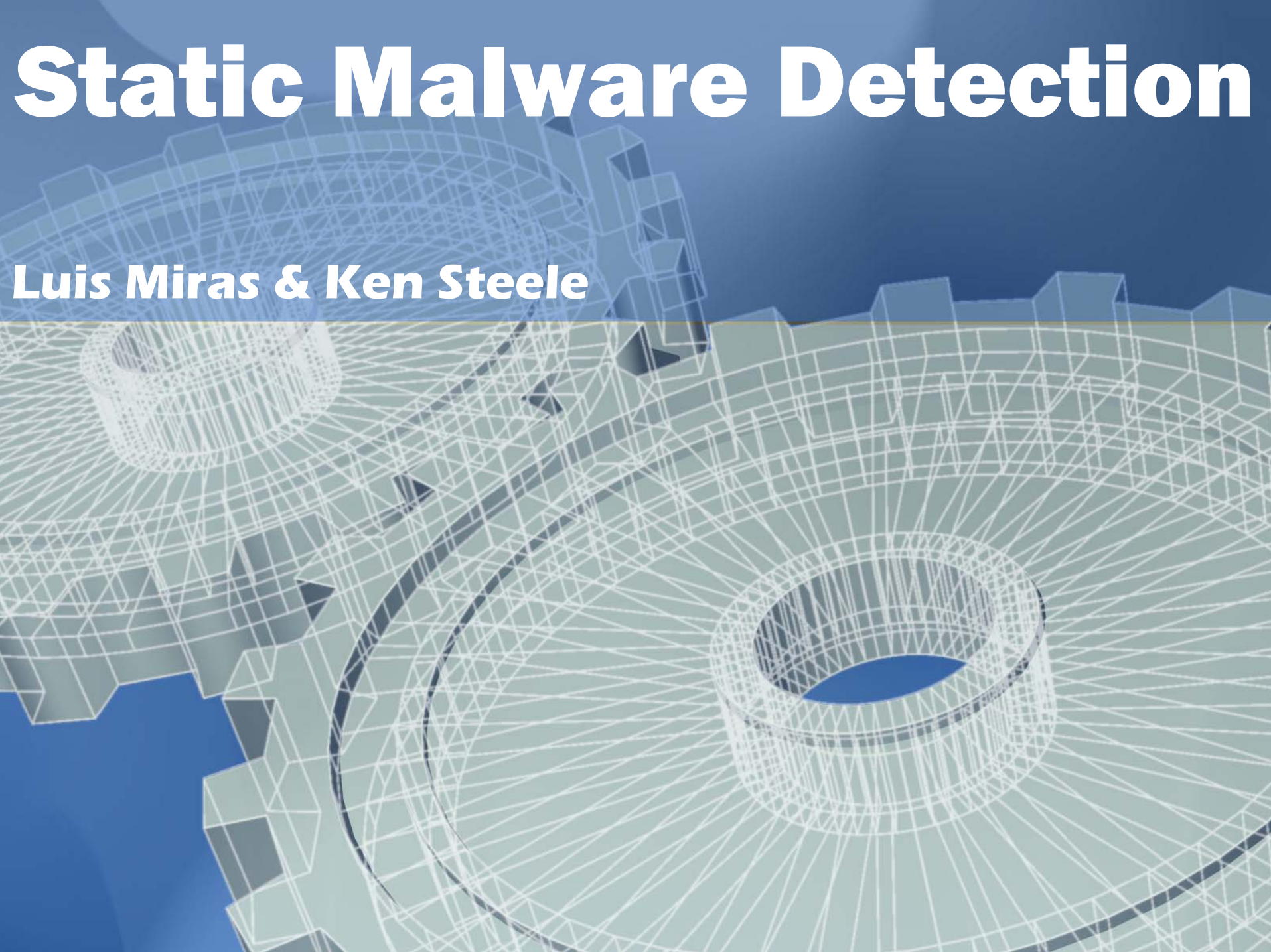


Goals

- Stimulate research in static binary analysis for malware detection purposes
- Provide a toolset for exploration of Portable Executables
- Show consequences of not blocking packed/compressed executables at the gateway.
- Provide a mechanism to aid in mitigating 0day "mass mailer" worms.

Philosophy of Detection

- Signature based
  - Pros
    - Concise
  - Cons
    - Update game
- Heuristics
  - Pros
    - Adaptable to new attacks
  - Cons
    - False positives

Our Approach

- Python PE parsing library
- Why Python?
- Packer Detection
  - Signature (complete)
  - Heuristics (in progress)
- Block "mass mailer" worms at the MTA
  - Scan all attachments (extensions don't matter)
    - Exit when not PE
  - No patch for stupidity

Agenda

- Email Worm Overview
- PE File Format Overview
- Packer Overview
- Packer Detection
- Library and Tools
- Demos
- Future Roadmap
- Other Research
- Resources
- Questions

Email Worm Overview

What is an Email Worm?

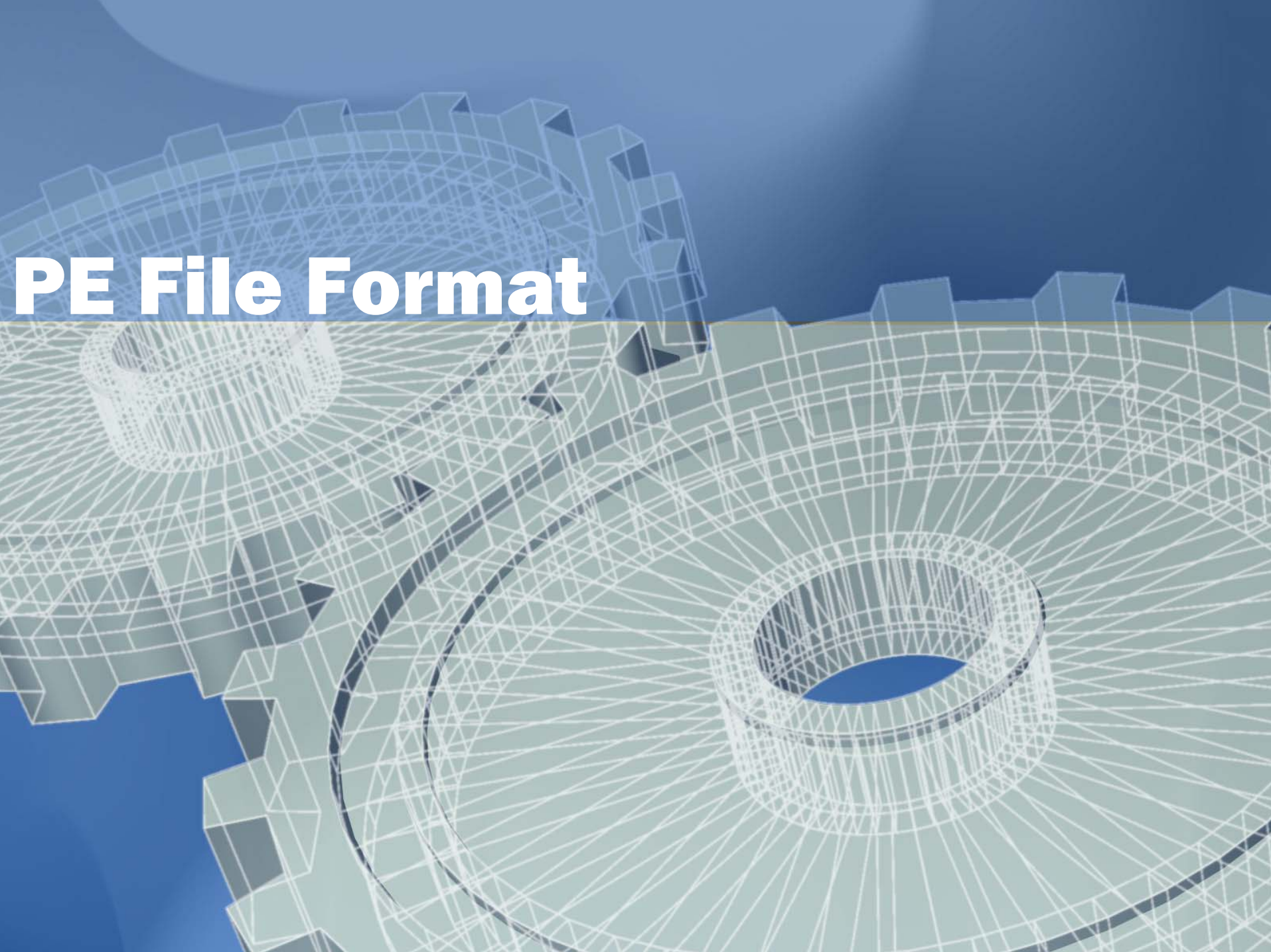
- Also known as "mass mailing" worms
- Propagate via tempting users to execute email attachments
  - Does not generally involve exploiting vulnerabilities
- Some email worms open backdoors
- Iterates through user contact lists and redistributes itself
- Today's worms have evolved to use sophisticated obfuscation techniques

Example Email Worms

- Bagle(Beagle)
  - Backdoors on high TCP ports
  - Variants: 28 (as of 6/04)
- Netsky
  - Functions varied between virus strains
  - Beeping sounds on specific dates
  - Variants: 29 (as of 6/04)
- MyDoom
  - DoS SCO (awww.. poor SCO)
  - Broke the record for the fastest spreading "mass mailing" worm
  - Variants: 10 (as of 6/04)

(thanks wikipedia!)

PE File Format



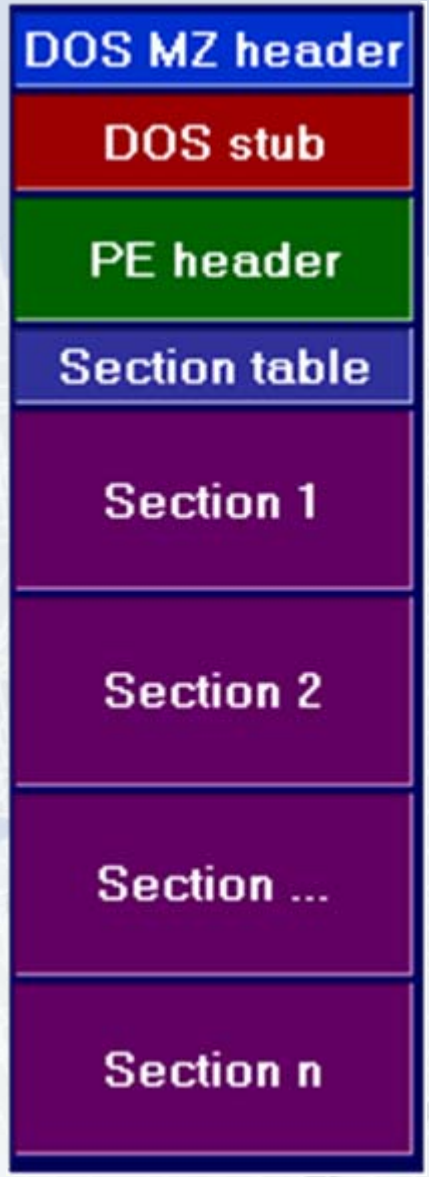
PE File Format Overview

- PE stands for Portable Executable
- It is the standard executable binary format for all win32 OS.
- It contains a DOS header and stub code for compatibility purposes.

PE File Format Diagram

- DOS Header must contain MZ
- DOS Stub
  - "This program cannot be run in DOS mode"
- PE Header
  - File Header
  - Optional Header
    - Data Directory
  - Section Table
  - Sections

Image from Iczelion PE tutorial (http://win32assembly.online.fr/pe-tut1.html)



IMAGE_DOS_HEADER

```
typedef struct _IMAGE_DOS_HEADER {
  WORD e_magic;      // Magic number
  WORD e_cblp;       // Bytes on last page of file
  WORD e_cp;         // Pages in file
  WORD e_crlc;       // Relocations
  WORD e_cparhdr;    // Size of header in paragraphs
  WORD e_minalloc;   // Minimum extra paragraphs needed
  WORD e_maxalloc;   // Maximum extra paragraphs needed
  WORD e_ss;         // Initial (relative) SS value
  WORD e_sp;         // Initial SP value
  WORD e_csum;       // Checksum
  WORD e_ip;         // Initial IP value
  WORD e_cs;         // Initial (relative) CS value
  WORD e_lfarlc;     // File address of relocation table
  WORD e_ovno;       // Overlay number
  WORD e_res[4];     // Reserved words
  WORD e_oemid;      // OEM identifier (for e_oeminfo)
  WORD e_oeminfo;    // OEM information; e_oemid specific
  WORD e_res2[10];   // Reserved words
  LONG e_lfanew;     // File address of new exe header
} IMAGE_DOS_HEADER, *PIMAGE_DOS_HEADER;
```

IMAGE_NT_HEADERS

```
typedef struct _IMAGE_NT_HEADERS {
  DWORD Signature;
  IMAGE_FILE_HEADER FileHeader;
  IMAGE_OPTIONAL_HEADER32
 OptionalHeader;
} IMAGE_NT_HEADERS32,
  *PIMAGE_NT_HEADERS32;
```

IMAGE_FILE_HEADERS

```
typedef struct _IMAGE_FILE_HEADER{
  WORD  Machine;
  WORD  NumberOfSections;
  DWORD TimeDateStamp;
  DWORD PointerToSymbolTable;
  DWORD NumberOfSymbols;
  WORD  SizeOfOptionalHeader;
  WORD  Characteristics;
} IMAGE_FILE_HEADER,
  *PIMAGE_FILE_HEADER;
```

IMAGE_OPTIONAL_HEADER32

```
typedef struct _IMAGE_OPTIONAL_HEADER {
 WORD  Magic;
 BYTE  MajorLinkerVersion;
 BYTE  MinorLinkerVersion;
 DWORD SizeOfCode;
 DWORD SizeOfInitializedData;
 DWORD SizeOfUninitializedData;
 DWORD AddressOfEntryPoint;
 DWORD BaseOfCode;
 DWORD BaseOfData;
 DWORD ImageBase;
 DWORD SectionAlignment;
 DWORD FileAlignment;
 WORD  MajorOperatingSystemVersion;
 WORD  MinorOperatingSystemVersion;
 WORD  MajorImageVersion;
 WORD  MinorImageVersion;
 WORD  MajorSubsystemVersion;
 WORD  MinorSubsystemVersion;
 DWORD Win32VersionValue;
 DWORD SizeOfImage;
 DWORD SizeOfHeaders;
 DWORD CheckSum;
 WORD  Subsystem;
 WORD  DllCharacteristics;
 DWORD SizeOfStackReserve;
 DWORD SizeOfStackCommit;
 DWORD SizeOfHeapReserve;
 DWORD SizeOfHeapCommit;
 DWORD LoaderFlags;
 DWORD NumberOfRvaAndSizes; // number of members in the data directory
 IMAGE_DATA_DIRECTORY DataDirectory[IMAGE_NUMBEROF_DIRECTORY_ENTRIES]; // array of data dirs
} IMAGE_OPTIONAL_HEADER32, *PIMAGE_OPTIONAL_HEADER32;
```

DATA DIRECTORIES

```
IMAGE_DIRECTORY_ENTRY_EXPORT          equ 0
IMAGE_DIRECTORY_ENTRY_IMPORT          equ 1
IMAGE_DIRECTORY_ENTRY_RESOURCE        equ 2
IMAGE_DIRECTORY_ENTRY_EXCEPTION       equ 3
IMAGE_DIRECTORY_ENTRY_SECURITY        equ 4
IMAGE_DIRECTORY_ENTRY_BASERELOC       equ 5
IMAGE_DIRECTORY_ENTRY_DEBUG           equ 6
IMAGE_DIRECTORY_ENTRY_ARCHITECTURE    equ 7
IMAGE_DIRECTORY_ENTRY_GLOBALPTR       equ 8
IMAGE_DIRECTORY_ENTRY_TLS             equ 9
IMAGE_DIRECTORY_ENTRY_LOAD_CONFIG     equ 10
IMAGE_DIRECTORY_ENTRY_BOUND_IMPORT    equ 11
IMAGE_DIRECTORY_ENTRY_IAT             equ 12
IMAGE_DIRECTORY_ENTRY_DELAY_IMPORT    equ 13
IMAGE_DIRECTORY_ENTRY_COM_DESCRIPTOR equ 14
```

IMAGE_SECTION_HEADER

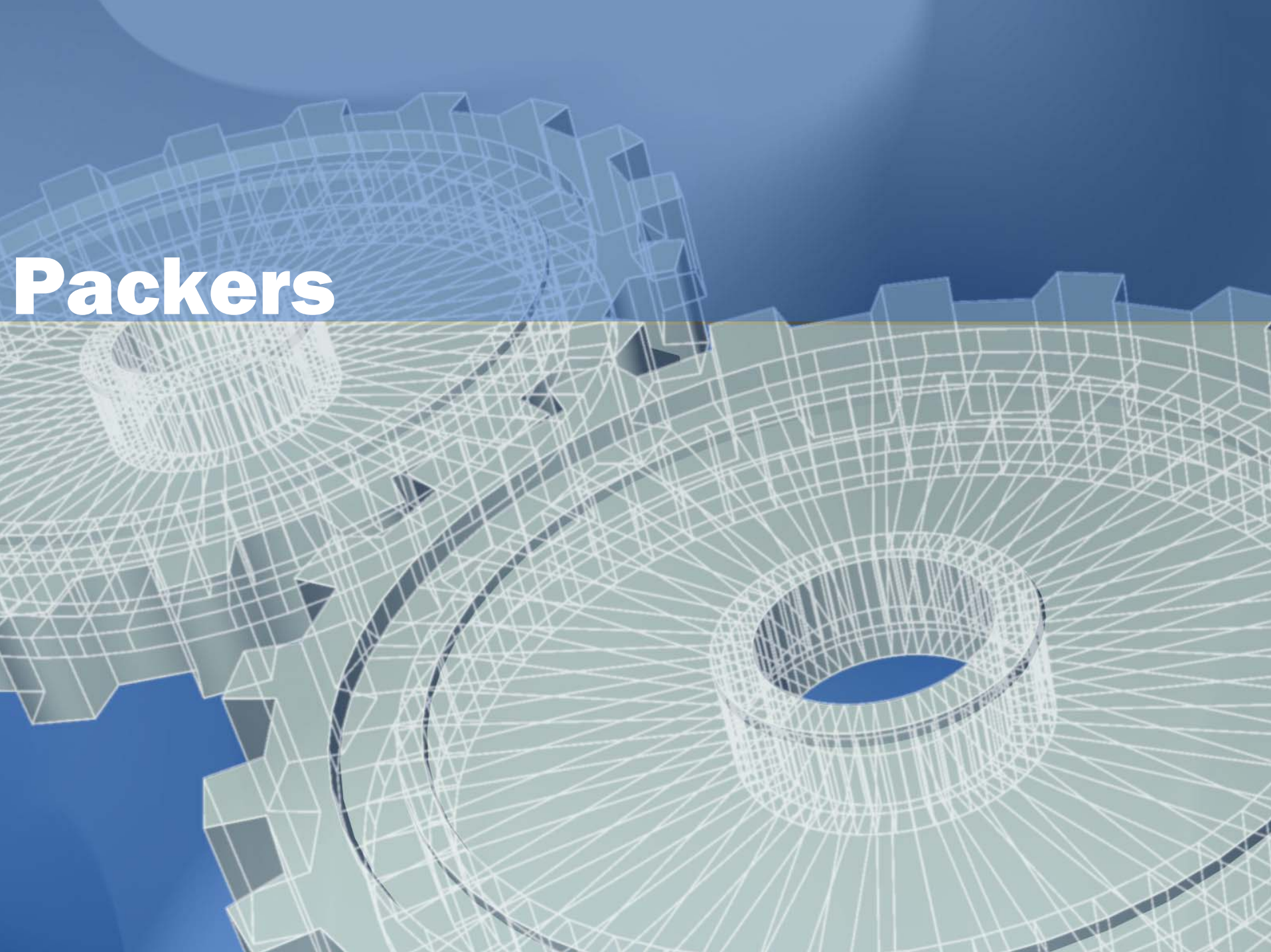
```
IMAGE_SECTION_HEADER STRUCT
  Name1 db IMAGE_SIZEOF_SHORT_NAME dup(?)
  union Misc
    PhysicalAddress    dd ?
    VirtualSize        dd ?
  ends
  VirtualAddress       dd ?
  SizeOfRawData        dd ?
  PointerToRawData     dd ?
  PointerToRelocations dd ?
  PointerToLinenumbers dd ?
  NumberOfRelocations  dw ?
  NumberOfLinenumbers  dw ?
  Characteristics      dd ?
IMAGE_SECTION_HEADER ENDS

IMAGE_SIZEOF_SHORT_NAME equ 8
```

IMAGE_IMPORT_DESCRIPTOR

```
IMAGE_IMPORT_DESCRIPTOR STRUCT
  union
    Characteristics        dd ?
    OriginalFirstThunk     dd ?
  ends
  TimeDateStamp            dd ?
  ForwarderChain           dd ?
  Name1                    dd ?
  FirstThunk               dd ?
IMAGE_IMPORT_DESCRIPTOR ENDS
```

Packers



Packer Overview

- Packers are executable compressors
- Usually consist of a decompression stub and compressed data
- They originated in an effort to make reverse engineering more difficult.
- Primary users of packers are shareware authors and malware authors.
- Some popular packers are UPX, ASPack, PEcompact, and Armadillo.

Packer Features

- Packers are intended to decompress the executable during loading.
- Anti-debugging is built-in.
- Junk code is inserted in order to overwhelm the reverse engineer.
- Exception handling is abused
- Jumps into the middle of longer instructions are used to fool disassemblers.

Packer Example

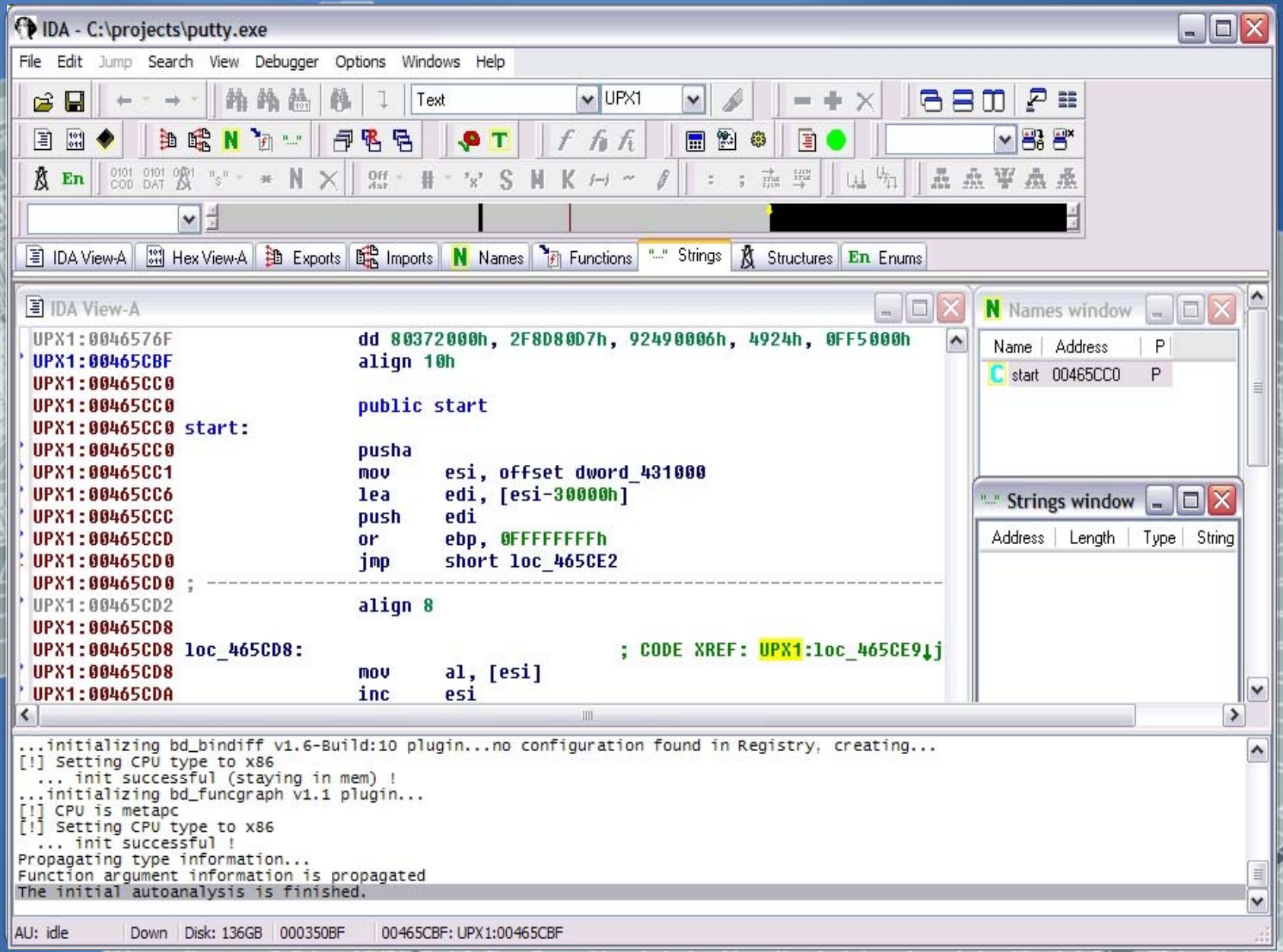
- Below is putty.exe original and packed with UPX 1.25

223,744 putty.exe – packed

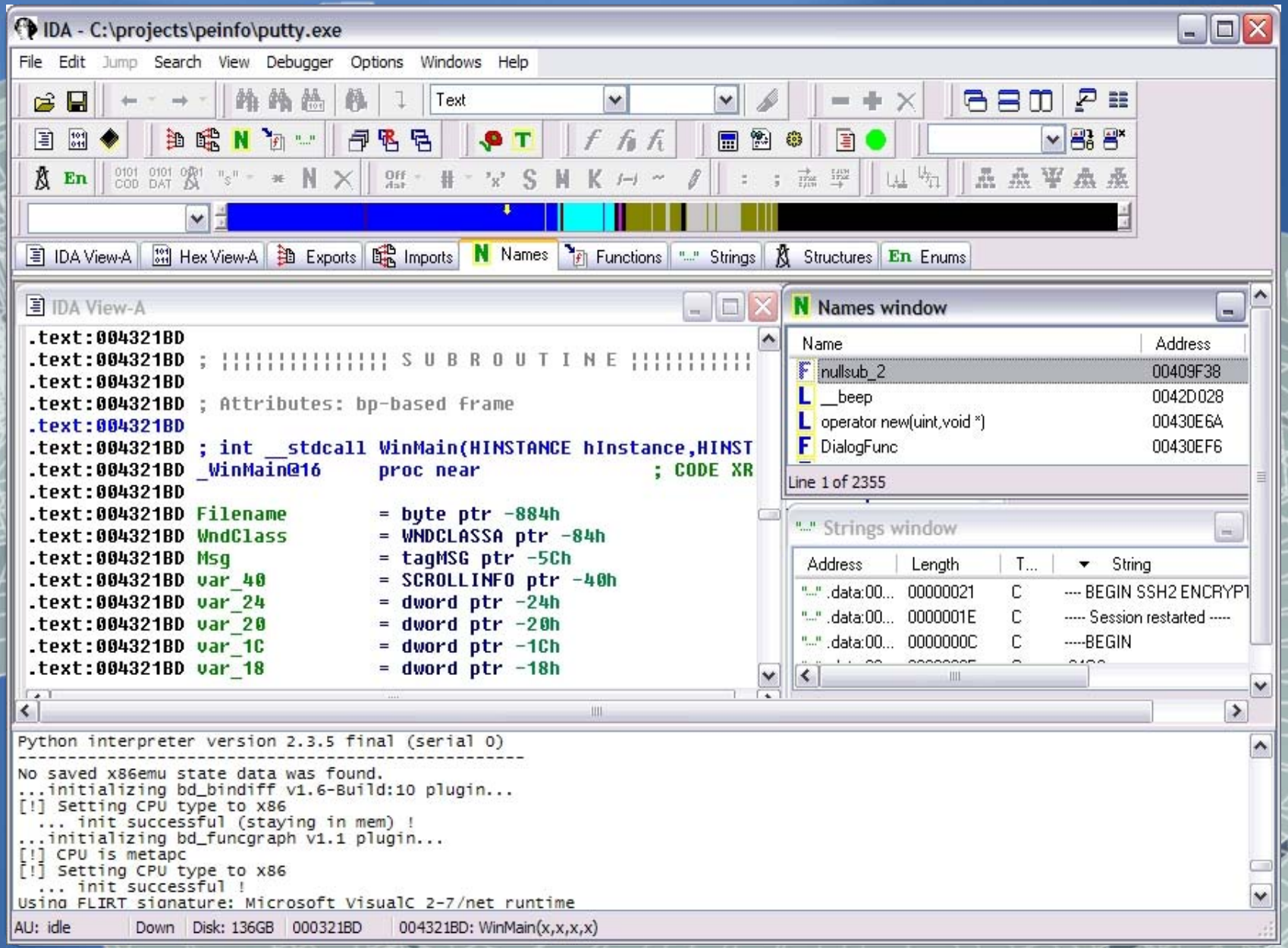
380,928 putty.exe – original

Packed Imports (11)	Original Imports(251)
LoadLibraryA	RegEnumKeyA
GetProcAddress	RegCloseKey
ExitProcess	RegCreateKeyA
RegEnumKeyA	RegSetValueExA
ChooseFontA	RegOpenKeyA
LineTo	[...]
ImmGetContext	FindNextFileA
ShellExecuteA	FindClose
GetDC	VirtualFree
PlaySoundA	SetFilePointer
OpenPrinterA	SetStdHandle

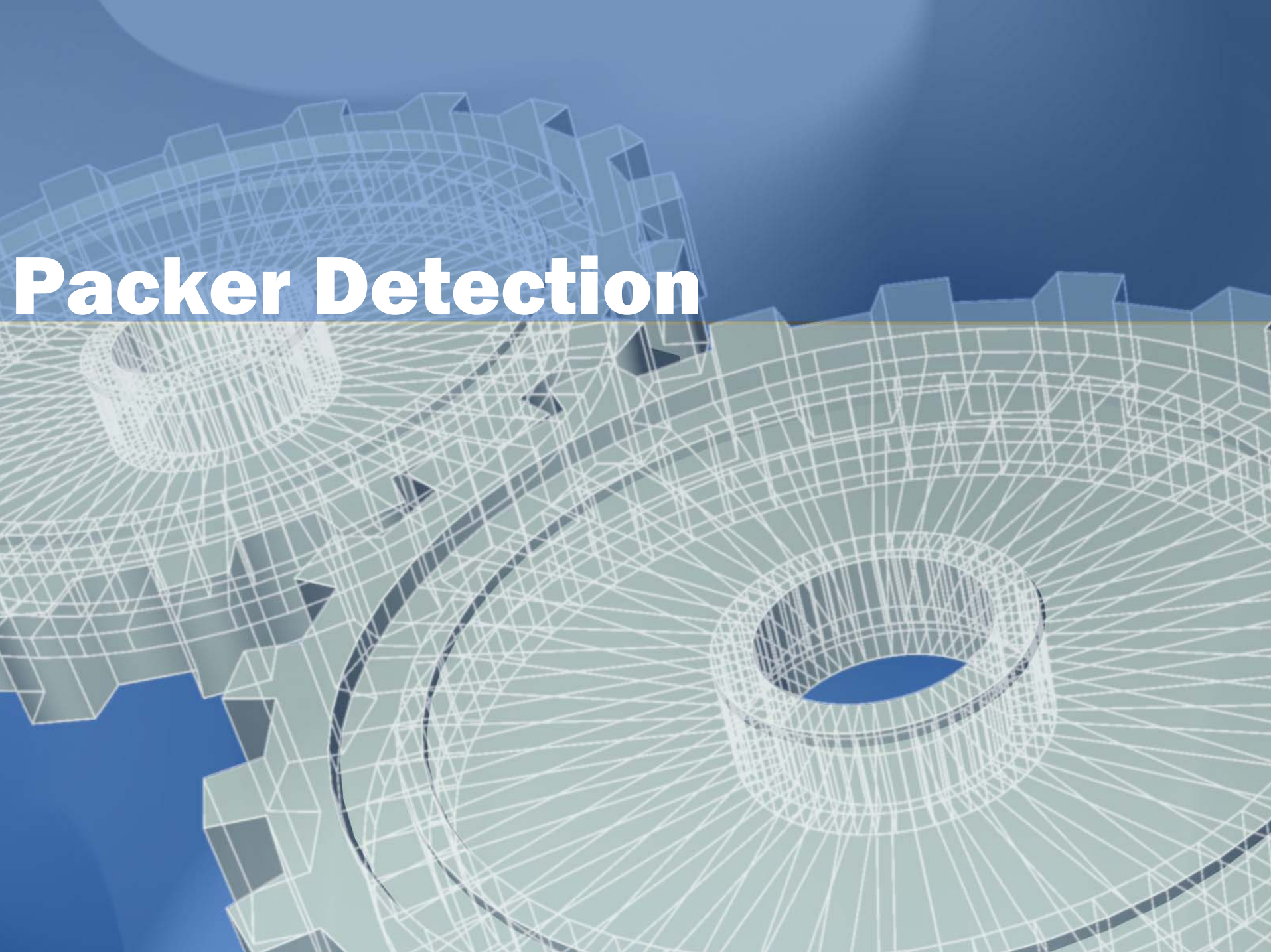
Packed File in IDA Pro



Original File in IDA Pro



Packer Detection



Packer Detection Methods

- Signature based
  - Executable code signatures
- Heuristics
  - Entropy Checks
  - IMPORT ADDRESS TABLE
  - Other Checks (not exclusive to packers)

Executable Code Signatures

- There are many signature based tools in use by the RE/Cracking community. The best one is PEiD. http://peid.has.it
- This method compares bytes at the program entry point against a database.
- Signatures are designed so that they ignore non-opcode bytes.

Signature Example

- **Below is a signature for a Borland C++ DLL:**

```
[Borland C++ DLL]
signature = A1 ?? ?? ?? ?? C1 E0 02 A3
ep_only = true
```

- **The following assembly matches the signature:**

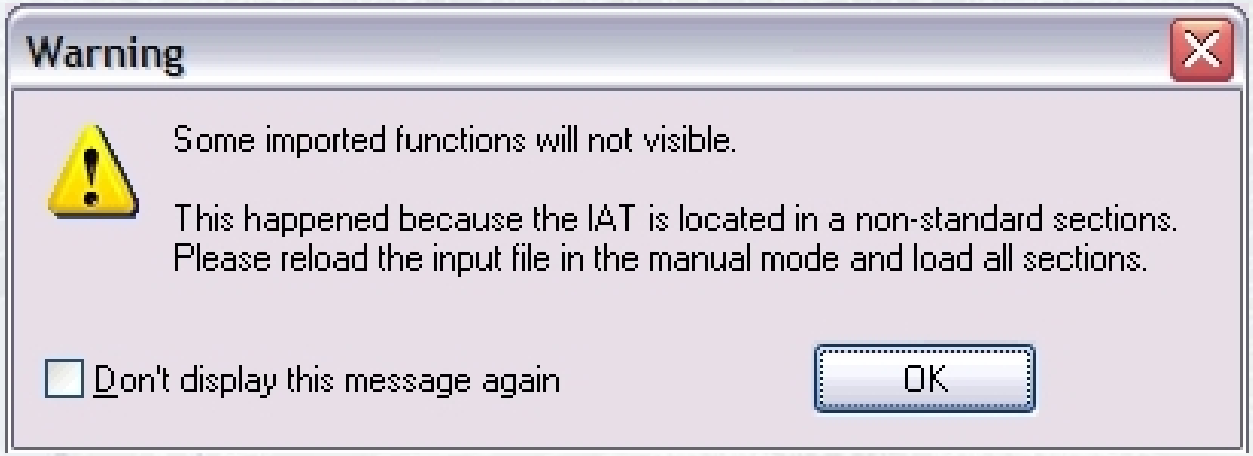
```
A1 37130300     MOV EAX,DWORD PTR DS:[31337]
C1E0 02         SHL EAX,2
A3 37130300     MOV DWORD PTR DS:[31337],EAX
```

Entropy Checks

- Byte distribution or entropy is changed by packers
- Sections as well as Import tables can be checked

Import Address Table

- IAT is in non-standard section
- IMAGE_IMPORT_DIRECTORY inconsistencies



Other Checks

- Strings
- Very few Imports
- Differences between section's VirtualSize and SizeofRawData
- Non standard NumberOfRvaAndSizes


Library and Tools

Library and Tools

- PELP
  - pelp.py — PE Library (Python)
- Tools
  - pelpUtil.py — Performs packer detection and dumps Dependencies, Imports and Sections.
  - smdScan.py — Qmail Scanner plugin

PELP – PE Library (Python)

- Portable Executable Library written in Python.
- Parses PE header, sections and imports
- Construct PE Object
- Where can I get it?
  - http://sourceforge.net/projects/pelp

PELP Example

- *The following will print out DLL dependencies:*

```
peFile = pelp.PE( fileName )
for dll in peFile.File.IMPORT_TABLE:
   print "[%s]" % dll.dllName
```

pelpUtil.py

- pelpUtil is a command line tool
- Uses the PELP library
- similar to Microsoft's dumpbin
- It also provides packer detection

```
Usage: pelpUtil.py -f <filename>
                   [ -i|--imports
                     -d|--depends
                     -s|--sections
                     -p|--packscan
                     -u|--userdb <userdb> ]
```

Packer Detection at the MTA

- Goal is to block packed executables at the MTA
- Choosing an MTA
  - Open Source
  - Good Security Record
  - Extensible through plugins
  - High market penetration

QMail and QMail Scanner

- QMail
  - Good alternative to Sendmail
  - Security track record
  - Extensible with QMail Scanner
  - Large userbase to help us test ☺
  - Available from http://www.qmail.org
- Qmail Scanner
  - Content scanner for Qmail
  - Forwards email content to 3rd party tools
  - Available from http://qmail-scanner.sf.net

smdScan

- smdScan is a tool that provides packer detection for Qmail
- Design goals
  - Low CPU utilization
  - Easy to add new signatures
  - Basic policy management
  - Works well with others

smdScan Usage

```
Usage:
smdScan.py (  -f <filename> |
              -d <directory> )
           [  -q|--quiet
              –u|--userdb <userdb> ]
```

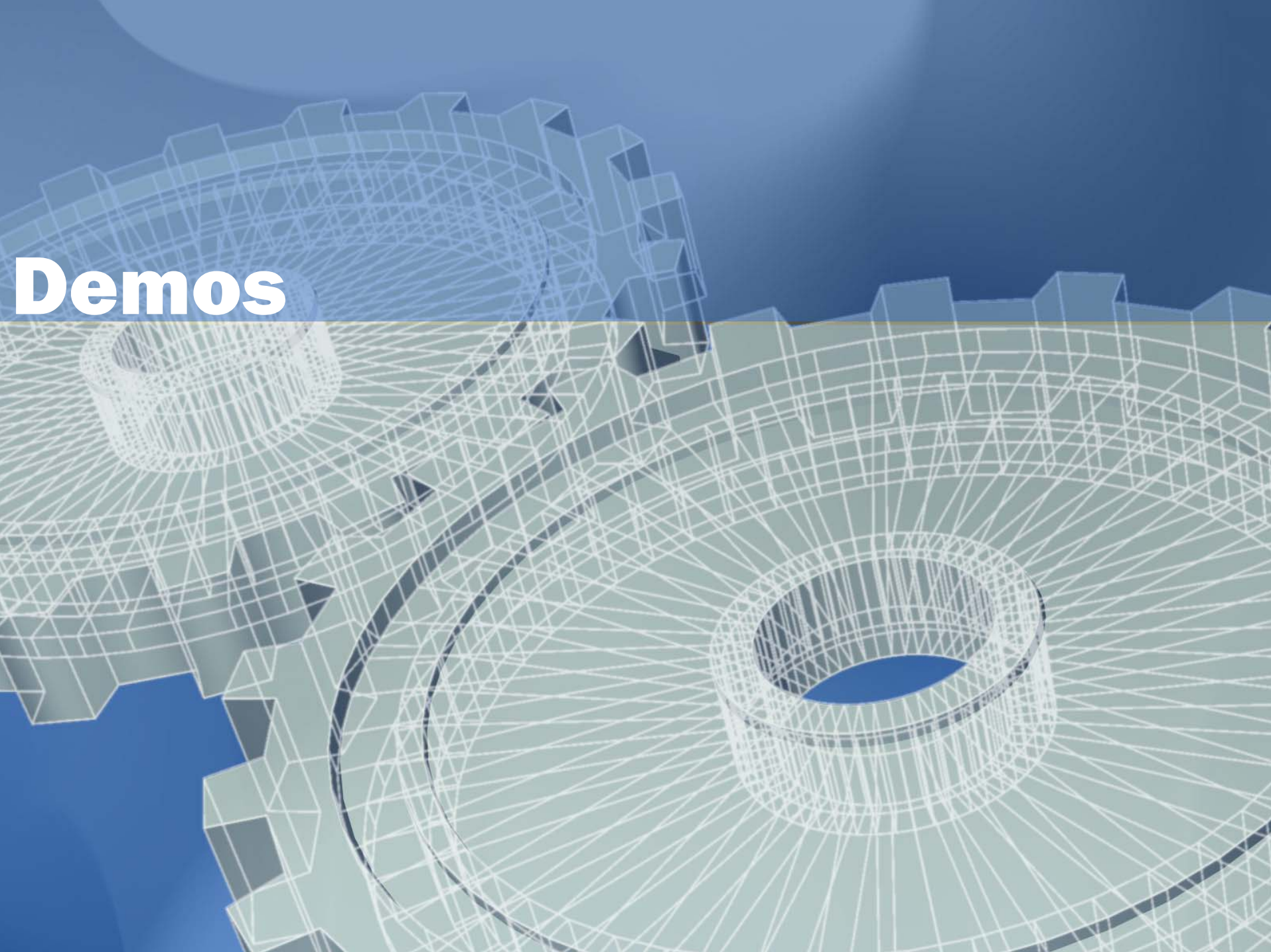
SMD Packer Detection DB

- Scanning over 750 signatures
- Example SMD database entries:

```
[Microsoft Visual C++ v6.0]
signature = 55 8B EC 83 EC 50 53 56 57 BE
   ?? ?? ?? ?? 8D 7D F4 A5 A5 66 A5 8B
ep_only = true
action = allow

[PECompact v1.4x+]
signature = EB 06 68 ?? ?? ?? ?? C3 9C 60
   E8 02 ?? ?? ?? 33 C0 8B C4 83 C0 04 93
   8B E3 8B 5B FC 81
ep_only = true
action = deny
```

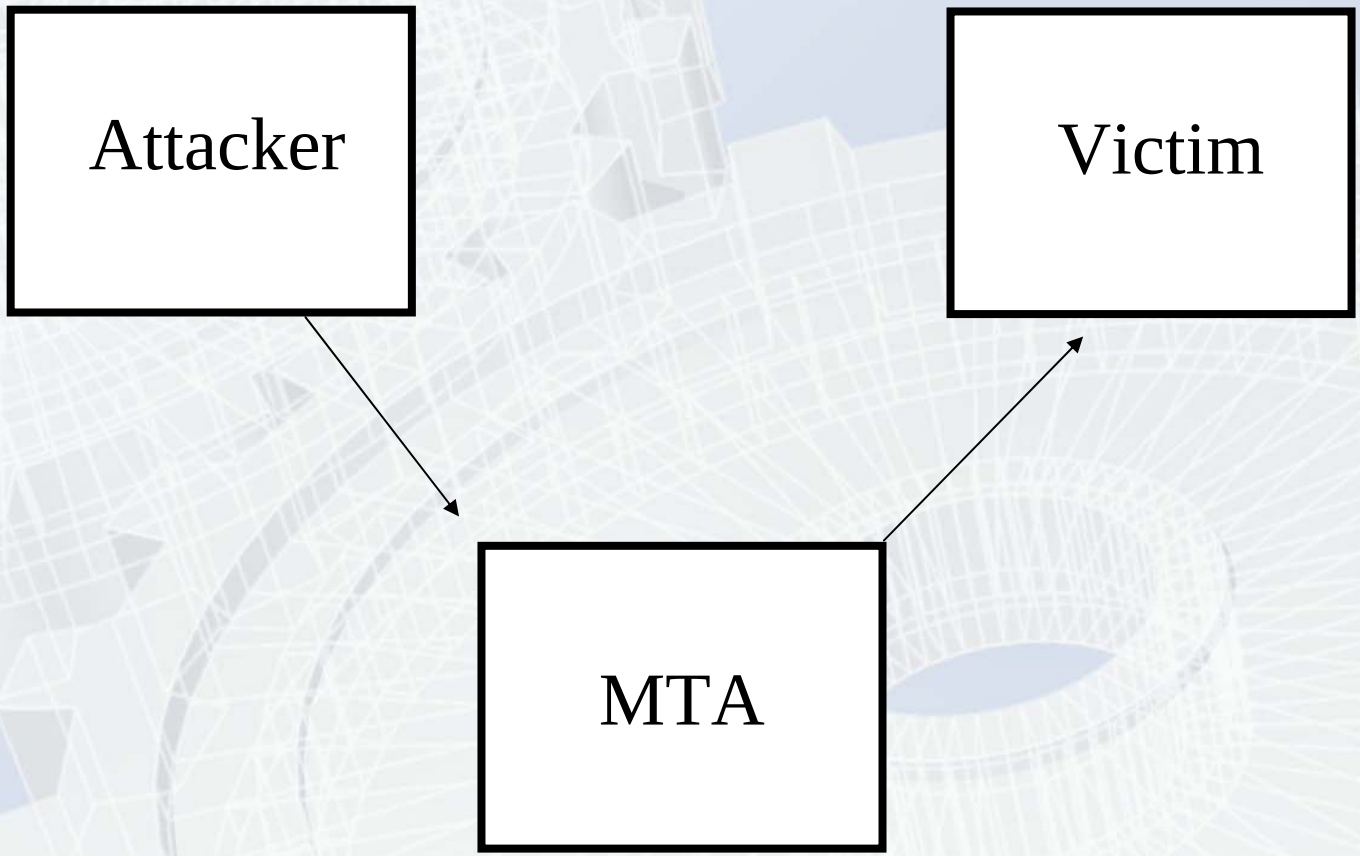
Demos



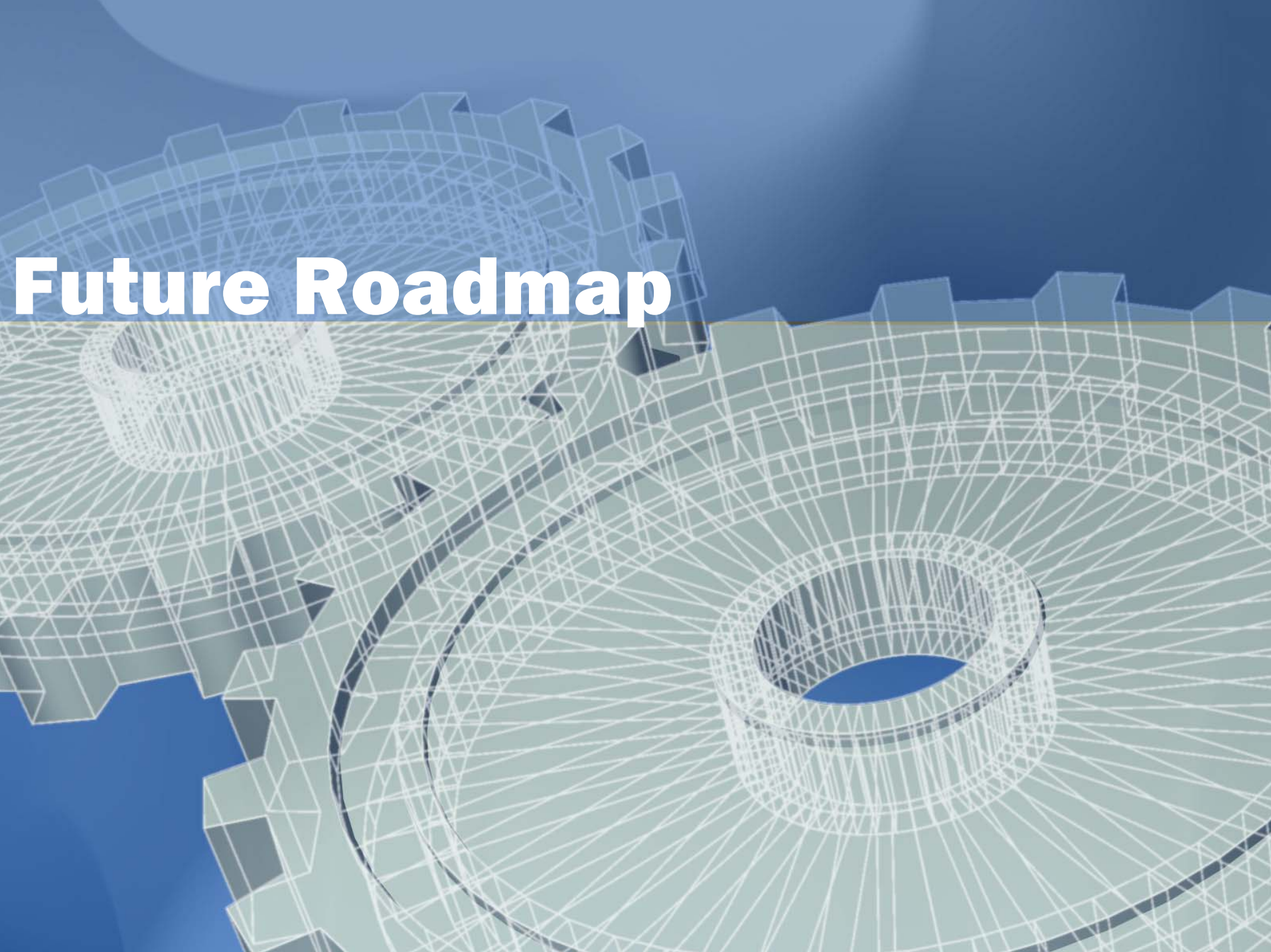
Demo Configuration

- Fedora Core 4 VMWare image
  - Qmail
  - Qmail Scanner
  - ClamAV
  - smdScan
- Windows XP Host OS
  - Thunderbird

Demo Diagram



Future Roadmap

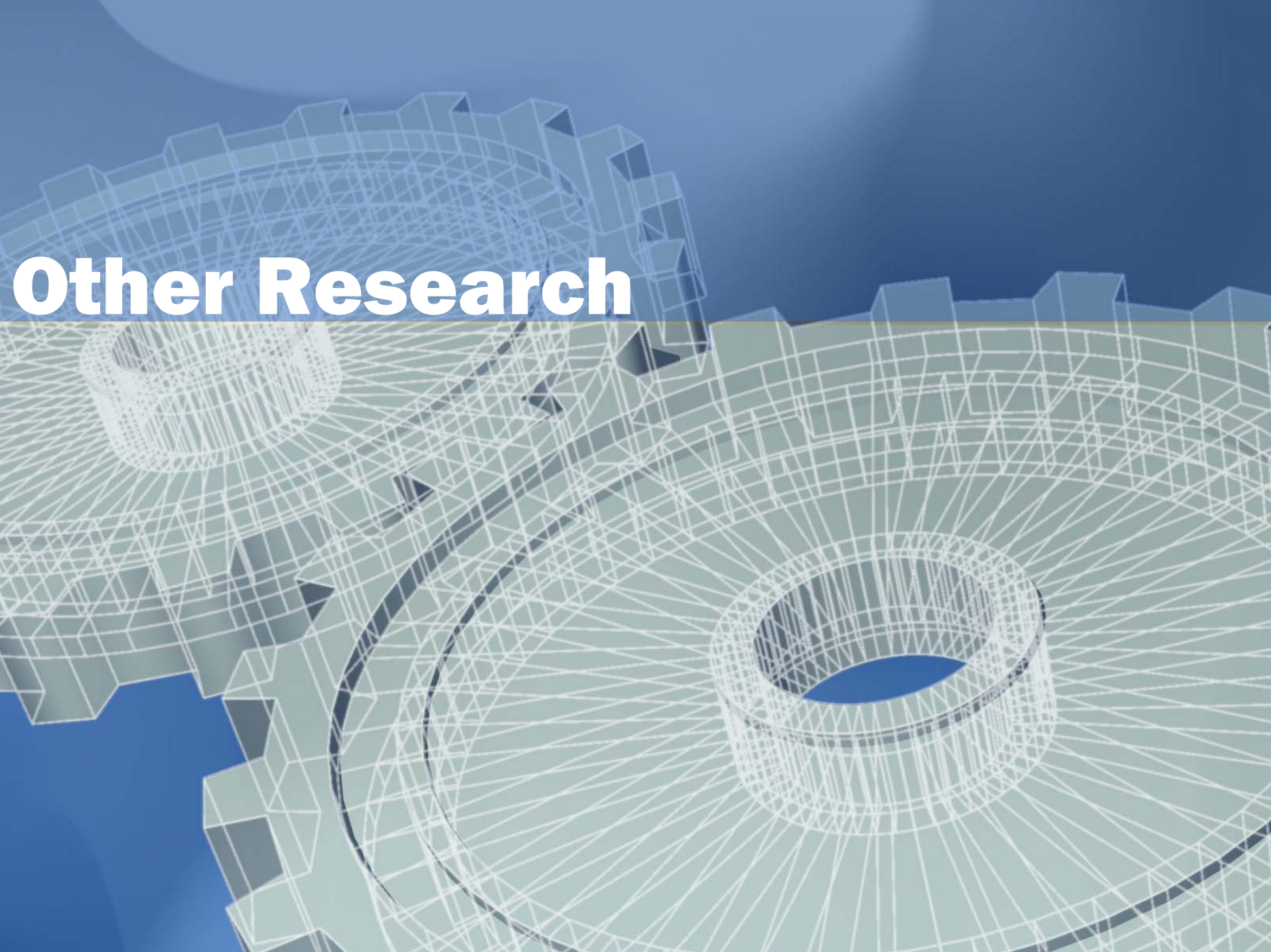


Short Term Goals

- SMD
  - Add MD5/SHA1 support for allow/deny actions
  - Finish PE level analysis checks.
  - Implement disassembly library
- PELP
  - Support for modifying PE files (adding sections, imports, etc.)
  - Microsoft .NET support
- OllyDbg plugin

Long Term Goals

- Plugins for MTAs other than QMail
- Develop plugin framework
  - Custom unpackers
  - Third party modules
- Deep analysis via static disassembly and emulation
- Advanced heuristics
  - Cyclomatic Complexity


Other Research

Other Research

- pype - http://dkbza.org/pype/pype.html
- Cyclomatic Complexity - http://www.openrce.org/articles/full_view/11

Resources

- PEiD - http://peid.has.it/
- IDA Pro - http://datarescue.com/idabase/
- Iczelion PE tutorial - http://win32assembly.online.fr/pe-tut1.html
- 0x90.exe - http://www.honeynet.org/scans/scan33/
- UPX – http://upx.sf.net
- ASPack - http://www.aspack.com
- EXE Shield – http://www.exeshield.com
- QMail – http://www.qmail.org
- QMail Scanner – http://qmail-scanner.sf.net
- ClamAV – http://www.clamav.net
- Signatures compiled from various sources including - http://www.exetools.com

Questions ?

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http://sf.net/projects/pelp
http://sf.net/projects/smd