710.3

Automating Malware Analysis

All reference links are operational in the browser-based delivery of the electronic workbook.

FOR710.3 | Reverse-Engineering Malware: Advanced Code Analysis

SANS DFIR
DIGITAL FORENSICS & INCIDENT RESPONSE

Automating Malware Analysis

Section FOR710.3, also known as Section 3 of the FOR710 course, focuses on discussing approaches to automating malware analysis.

FOR710.3 materials are created and maintained by Anuj Soni. To learn about Anuj's background and expertise, please see https://www.sans.org/instructors/anuj-soni. You can visit his blog at https://malwology.com/ and follow him on Twitter at https://twitter.com/asoni.

Course Roadmap

- FOR710.1: Code Deobfuscation and Execution
- FOR710.2: Encryption in Malware
- FOR710.3: Automating Malware Analysis
- FOR710.4: Correlating Malware and Building Rules

SECTION 3

- ***Python for Malware Analysis***
  - Lab 3.1: Automating Config Extraction with Python
- Malware Analysis with DBI Frameworks
  - Lab 3.2: Automate Payload Extraction with Frida
- Automating Analysis with Ghidra
  - Lab 3.3: Scripting with Ghidra

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Python for Malware Analysis

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Python for Malware Analysis: Module Objectives

- Develop comfort with Python for malware analysis.
- Gain experience using the pefile Python module for parsing PE files.
- Apply our knowledge of the PE file format to programmatically analyze a Windows executable.
- Understand how Python can help automate the results of our prior static code analysis and debugging efforts.
- Create a malware configuration extractor.

This slide describes the objectives of this module.

Consider These Caveats to Calibrate Your Expectations

- This module focuses on introducing Python programming for RE; it does not provide an in-depth introduction to the language in general.
- Consider attending the SANS course titled SEC573: Automating Information Security with Python (sans.org/sec573).
- When writing scripts for malware analysis, your goal is functioning code that produces the expected output—do not worry about code quality.
- If the script you create is of value in future analysis efforts, you will have plenty of opportunity to iteratively improve your code.
- Consider the Pareto principle: time spent optimizing the code will require most of your time if you focus on a 100% solution.

It's worth emphasizing that the purpose of this module is to introduce Python for malware analysis, and not to introduce *all* aspects of the Python programming language. For a thorough discussion of the Python programming language, consider attending the six-section SANS course titled SEC573: Automating Information Security with Python.

Also, scripts created during malware analysis are typically written under time constraints, and scripts created for one malware variant or family may or may not be applicable to future malware. As a result, the goal is simply to write a script that "works" by producing the intended output. Do not focus on code quality and performance, at least initially. If the script you create has value in the future, there will be opportunity to iteratively improve.

Remember the Pareto principle when writing malware analysis scripts (i.e., the 80/20 rule): 80% of the benefit will come from 20% of the work. The remaining 20% may require an unrealistic amount of time, and in most cases is unnecessary. Applying this to writing scripts, the point is that you can produce functional, helpful scripts in a relatively short period of time. However, if you obsess over code quality, performance, and robustness, you will spend most of your time on these details. Write a script that gets the job done and worry about adding polish to your script later.

Python Background

- Python is an interpreted language, which means a .py script is executed by a helper program (i.e., an interpreter).
- To run a Python program on Windows, use `py.exe` or `python.exe`:
  - `python myscript.py`
  - `py myscript.py`
- The Python interpreter:
  - Compiles the source code into platform-independent bytecode.
  - Runs the bytecode in the Python Virtual Machine (PVM), which converts bytecode into machine-executable code.

Python is an interpreted language, which means a helper program called an interpreter is required to run the source code.

Within our Windows VMs, you can run a Python program using the python.exe or py.exe executables. It is not necessary to include ".exe" on the command line. We will use "python" or "python.exe" for clarity and consistency.

The interpreter first converts the source code to byte code, and this byte code is provided to the Python Virtual Machine (PVM) for execution. The PVM converts bytecode to machine code and runs it.

Python 3 Is Installed in Your Windows VMs

- The Python installer is available at python.org.
- Several additional modules are installed in your VMs, including pefile, pycryptodome, and frida-tools.
- Packages were installed using `pip`, the package manager for Python:
  - `pip3 install <package_name>`
  - Using `pip3` ensures the package will be installed into a Python 3 environment.
- Search for other available packages at https://pypi.org/.

We are using Python 3 during this class. If you have prior exposure to Python, you have probably used Python 2 at some point. Python 2 sunset on January 1, 2020. We will not discuss the differences between Python 2 and Python 3 in class but view this resource for a brief summary about the differences: https://for710.com/python2v3.

Python 3 is already installed within your Windows VMs. If you need to install Python on another Windows system, the recommended approach is to download an installer from https://www.python.org/. During the install, it is important to add Python to your PATH variable so you can execute the interpreter from anywhere within a terminal.

Several additional Python modules were installed within your Windows VMs, including pefile, pycryptodome, and frida-tools. All modules will be discussed later in this section. These modules were installed using pip, a package manager for Python. To learn more about pip, see https://for710.com/pip. Using pip3 instead of pip in the install command ensures the specified program is installed into the Python 3 environment. This is an important detail if you have both Python 2 and Python 3 installed on your system.

To explore other available Python packages, browse to https://pypi.org/.

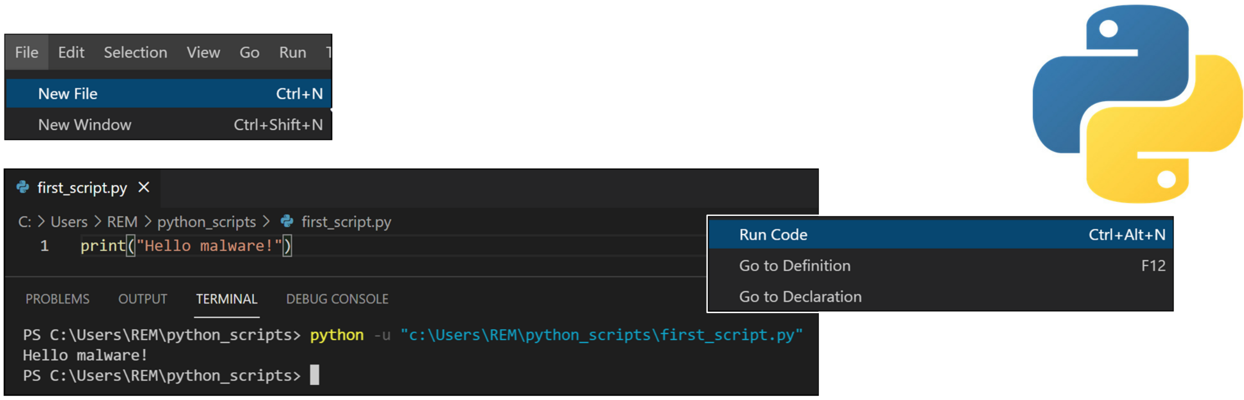
Microsoft's Visual Studio (VS) Code

- Visual Studio Code is a free and open-source Integrated Development Environment (IDE) that accommodates many programming languages.
- Several VS extensions are installed, including:
  - Python
  - Code Runner
  - Vim emulation (disabled)
- PyCharm is another popular IDE, specifically for Python.

There are multiple code editors to choose from. We will use Microsoft's Visual Studio Code, which is free and open source. VS Code is available for macOS, Windows, and Linux. Another popular alternative is PyCharm, an IDE exclusively for Python programing.

VS Code has many extensions available through the Visual Studio Code Marketplace. The VS Code install within your VMs has several modules already installed, including Python, Code Runner, and Vim emulation (disabled by default).

Create and Execute Your First Python Script



Save the file (Ctrl+S) after each modification before running the code.

To get started with Visual Studio Code, first launch the program from your Dynamic VM's desktop.

Then, create a new file by browsing to File > New File.

Then, go to File > Save. Within C:\Users\REM, create a folder named "python_scripts" (right-click > New > Folder). Save your file with the file name first_script.py.

Let's complete our first Python script. Type the text `print("Hello malware!")`.

Then, go to File > Save or use the keyboard shortcut Ctrl+S. A common mistake is to run the code without saving, which will run the code last saved to the file.

To run the code, you can click on the Play symbol on the top-right of the window. Alternatively, you can execute the code via the context menu with a right-click > Run Code. Within the context menu, notice the keyboard shortcut Ctrl + Alt + N (on a Mac this translates to Ctrl + Option + N). This shortcut is provided by the third-party Code Runner extension installed in VS Code. We will use shortcuts often in this class to save time and clicks.

Python Basics

- We use variables to store data:
  - Use descriptive variable names (case-sensitive).
  - Add an underscore ("_") between words.
- Strings are within double or single quotes—we will use double quotes.
- `print():` built-in function to output content (default stdout).
- Use # for a single-line comment and place multi-line comments between triple quotes (`"""`).

```
#My first Python script
text1 = "Hello"
text2 = " malware!"
print(text1 + text2)
```


The next few slides introduce some basic concepts in Python programming.

We will use variables to store data temporarily. The code snipped at the bottom-right of this slide shows two examples of variable assignments. When specifying a variable name, choose terms that are concise and descriptive. If the variable name includes two words, separate those words using an underscore.

In Python, strings are enclosed in quotes. You can use single or double quotes. In this class, we will only use double quotes for consistency.

The built-in `print()` function prints content. We will use `print()` to output content to the terminal. When using `print()`, we can use the add ("+") operator to concatenate strings.

When writing comments, use the pound symbol ("#") for single-line comments and enclose multiple lines between triple quotes.

Three Basic Data Types Are Strings, Numbers, and Booleans

```
#My first Python script

#String example
output_text = “Hello malware!”
print(output_text)

#Number and integer example
num = 1

#Number and float example
num_float = 1.1

#Boolean example
is_dll = True
```

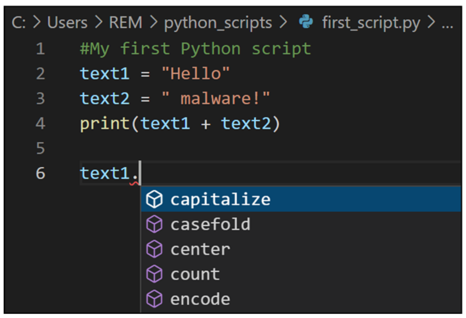

Three basic types in Python you should be familiar with are strings, numbers, and Booleans. We already have a good understanding of what a string is.

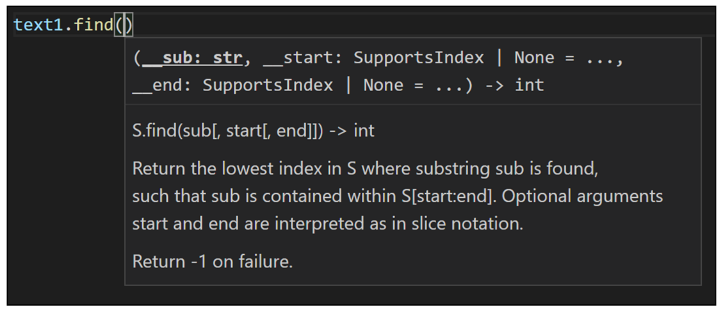
The numbers category can be broken down into integers and floats. Floats are numbers with decimal places included.

Booleans are True or False (they must begin with a capital letter).

A String Is an Object, and Objects Have Methods (i.e., Functions)

- Use a dot (“.”) after an object to view available methods.
- VS Code provides helpful background about a function’s purpose, its parameters, and return value.





A string is an object, and Python provides certain functions that are specific to strings. Functions specific to a certain type of object are called “methods.” You can call a method by typing the object followed by a dot (“.”). VS Code will automatically provide a list of available methods to choose from.

For more additional detail on a method, choose one and type “(”. VS Code will pop up a box with details on the method, its parameters, and return value.

Mathematical, Bitwise, Comparison, and Logical Operations

Mathematical Operators	
Operator	***Description***
+	Add
-	Subtract
/	Division
*	Multiplication
**	Exponent
%	Modulus

Comparison Operators	
Operator	***Description***
==	Equal
!=	Not equal
<	Less than
>	Greater than
<=	Less than or equal to
>=	Greater than or equal to

Bitwise Operators	
Operator	***Description***
&	AND
|	OR
^	XOR
~	NOT
<<	Left shift
>>	Right shift

Logical Operators	
Operator	***Description***
and	True if both statements true
or	True if at least one statement true
not	Reverse the result

This slide lists Python operators that you are likely to encounter and use. This is not a comprehensive list of all operators. See https://for710.com/pyoperators for more information.

Note that when using the bitwise shift operators, any gaps created by shifting bits are replaced with zero bits (i.e., bits do not wrap around from one side to the other).

Use Mathematical Comparison and Logical Operators with "if" Statements to Evaluate a Condition

C: > Users > REM > python_scripts > first_script.py > ...

```python
#Operating on numbers
num1 = 5
num2 = 1

num = num1 + num2
print("The sum is " + str(num))

if num > 1 and num < 10:
    print("The result is within range!")
elif num >= 10:
    print("It's too high!")
else:
    print("It's too low.")

#Comparing text
text = "malware"
if text == "malware":
    print("We have a text match!")
```

PROBLEMS OUTPUT TERMINAL DEBUG CONSOLE

```
PS C:\Users\REM\python_scripts> python -u "c:\Users\REM\python_scripts\first_script.py"
The sum is 6
The result is within range!
We have a text match!
PS C:\Users\REM\python_scripts>
```

- Parentheses are only used in an if-statement to force an order of operations.
- Append a colon (":") at the end of the if-statement.
- Indentation creates blocks of code (i.e., no {}).

The code on this slide shows an example of how operators are used in Python. The first example involves numbers while the second example involves strings.

This slide also uses an if-statement in Python, which allows us to assess a condition. When using an if-statement in Python, there is no need for parenthesis unless you want to force an order of operations. Also, there are no curly braces to delineate code blocks as is common in other programming languages. Instead, indentation is used. If the assessed condition is true, the indented code block below the if-statement is executed.

A List Is a Flexible Data Type That Includes Multiple Values

- Lists are *mutable*, so values can be modified, added, and removed.
- Use bracket notation to access items.
- Use the colon (“:”) slicing operator to access part of a list.
- Use the **`in`** operator:
  - With **for** to iterate through a list.
  - With **if** to check if an item is in the list.

C: > Users > REM > python_scripts > first_script.py > ...

```python
weekdays = ["Monday", "Tuesday", "Wednesday", "Thursday", "Friday"]

#What is the first weekday?
print("The first weekday is " + weekdays[0])
print("*******")

#Print the middle three days
print("Middle three weekdays:")
print(weekdays[1:4])
print("*******")

#Print weekdays
print("All weekdays: ")
for day in weekdays:
    print(day)
print("*******")

#Check today
today = "Saturday"
print("Today is " + today)
if today in weekdays:
    print("It's a weekday!")
else:
    print("It's the weekend!")
```

PROBLEMS OUTPUT TERMINAL DEBUG CONSOLE

```
PS C:\Users\REM> python -u "c:\Users\REM\python_scripts\first_script.py"
The first weekday is Monday
*******
Middle three weekdays:
['Tuesday', 'Wednesday', 'Thursday']
*******
All weekdays:
Monday
Tuesday
Wednesday
Thursday
Friday
*******
Today is Saturday
It's the weekend!
```

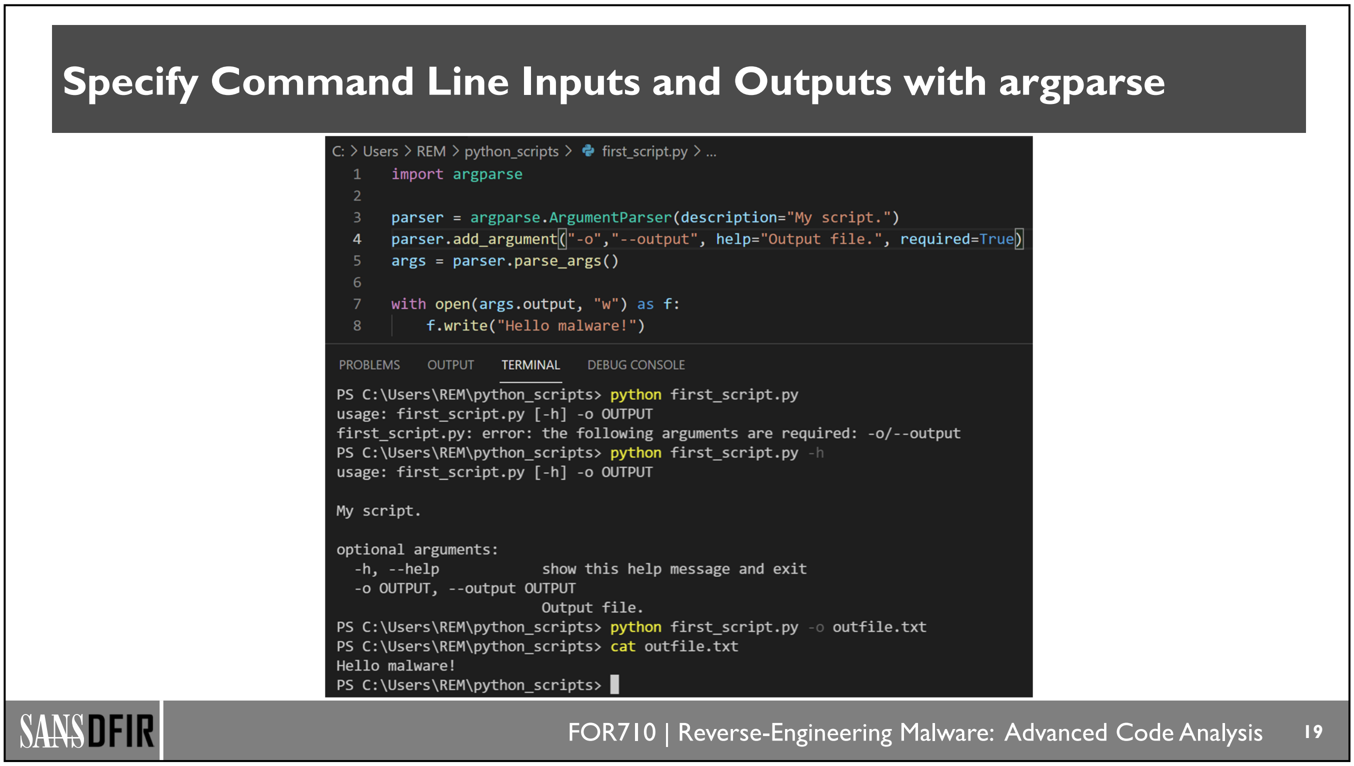

Lists are commonly used to store multiple values. For more information on lists and available methods, see https://for710.com/python-lists.

We can iterate over a list to assess its multiple values. The code on this slide demonstrates the use of a `for` loop to iterate over a list. In the example, “day” is considered a loop variable.

To check if a list contains a certain value, we can use an if-statement and the “`in`” keyword:

To access a subset of values within a list, we can use the colon (“:”) slicing operator. The general format for list slicing is:

- sample_list[start:stop] # includes first element through stop-1
- sample_list[start:] # includes first element through the entire array
- sample_list[:stop] # includes first element through stop-



The argparse module allows us to specify command line arguments for a script. The argparse functionality is not built-in, so the module must be imported. The example on this slide demonstrates how to specify command line arguments.

When using the argparse module, we first create an ArgumentParser object:
`parser = argparse.ArgumentParser(description="My script.").`

We populate the ArgumentParser object with information about relevant arguments using the `add_argument()` method.

Calling `parse_args()` provides access to the supplied command-line arguments. For example, the code on this slide adds an argument called "output". The script then includes the statement:
`args = parser.parse_args()`

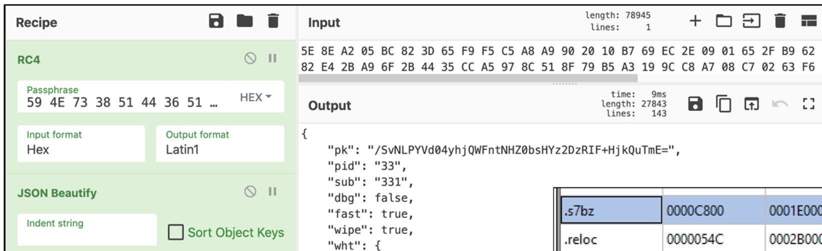
After `parse_args()` is executed, we can access the "output" command-line argument as an attribute of `args` via `args.output`.

The code on this slide uses the command-line argument to write text to the specified file. The `with` keyword is often used for file access because it ensures the file is properly closed without explicitly including code to do so.

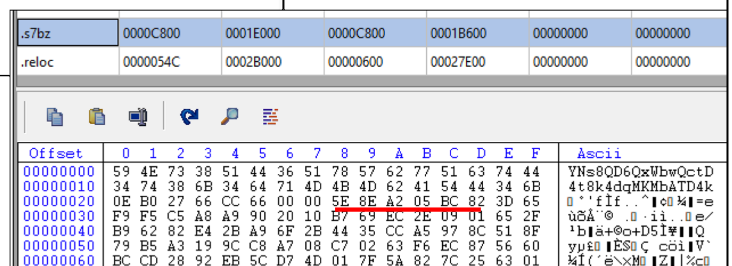
For more information on argparse, see https://for710.com/argparse. For more information on reading and writing files in Python, see https://for710.com/pythonfiles.

Creating a Configuration Extractor for file.exe

- In Section 2, we analyzed file.exe and determined that the function at 004059fc implements RC4 and decrypts configuration data.



- The encrypted data resided in a section with an unusual name.



Now that we understand some Python basics, let's focus on automating a task. Our goal is to extract the encrypted, embedded configuration from file.exe, an executable we discussed in Section 2. As a reminder, this malware sample has SHA-256 hash 6b212864731c131bd095c2537ca14e10338d3ebf997dda59465c5f1ce73d418b. You can find file.exe and other executables referred to during this walk-through within Malware\Section3\file_and_more.zip.

When we performed some initial static file analysis of file.exe, we observed a section with an unusual name that contained unreadable data. This led us to perform some additional debugging, and eventually we arrived at the conclusion that this content was RC4 decrypted to reveal configuration data.

How could we automate this decryption outside of a debugger? Could we create a python script to run against this and similar executables to extract the configuration content?

Document the Script's Requirements before Writing Any Code

Our script must:

- Accept a target file and output file on the command line.
- Parse a PE file.
- Find the section that contains the obfuscated configuration data.
- Extract data from that section.
- Parse the section data and identify the RC4 key, encrypted data, and any related information based on our understanding of how the data is structured.
- RC4-decrypt the encrypted configuration data.
- Write the decrypted configuration to a file.

The target file must be unpacked.

This slide lists the requirements for the Python script we want to write.

Note that we are creating a *static* config extractor intended to be run against a target file on disk. This means the encrypted content is embedded somewhere in the file, and we can extract it for processing. If the encrypted data were only available in memory after an initial executable unpacked itself, we would need to unpack that executable first.

Explore pefile Usage with a Legitimate Program, notepad.exe

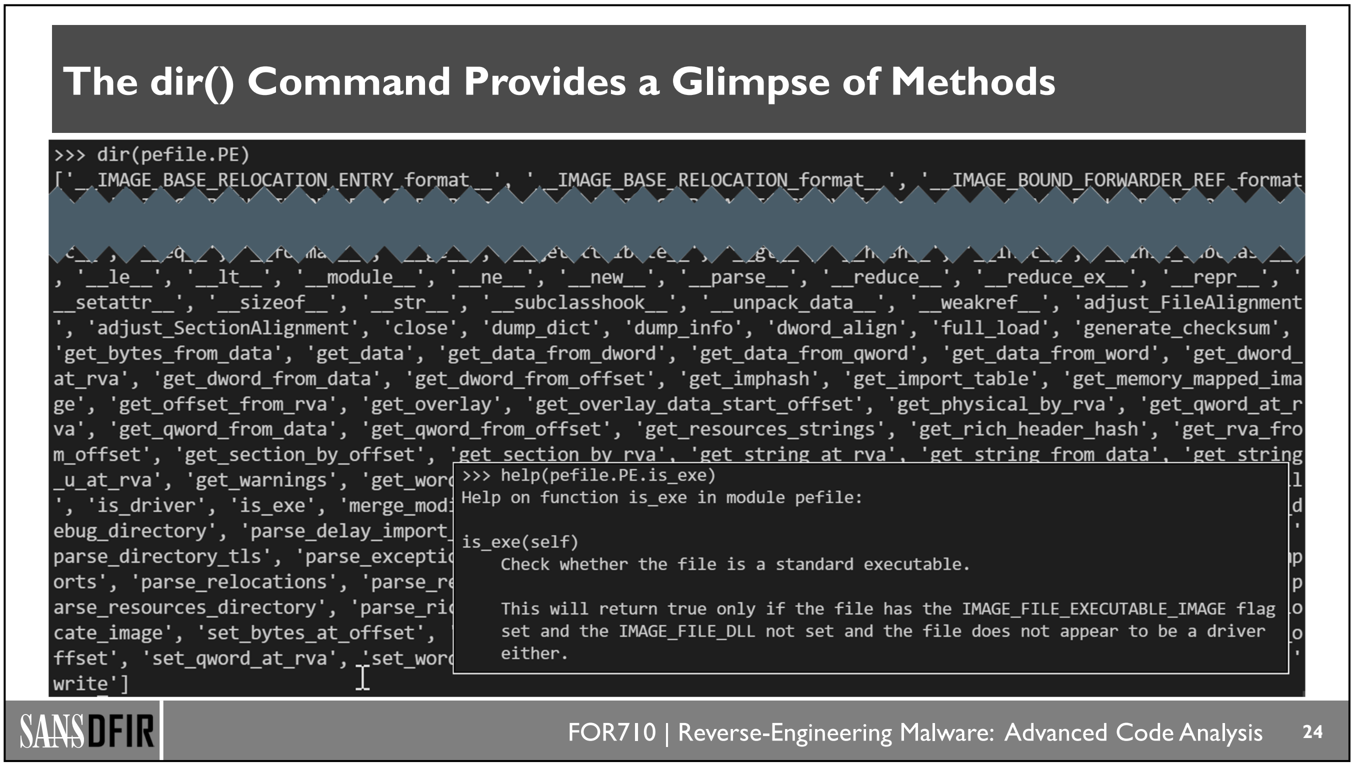
```
PS C:\Users\REM\python_scripts> python
Python 3.9.7 (tags/v3.9.7:1016ef3, Aug 30 2021, 20:19:38) [MSC v.1929 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license" for more information.
>>> import pefile
>>> help(pefile)
```

```
class PE(builtins.object)
 |  PE(name=None, data=None, fast_load=None, max_symbol_exports=8192, max_repeated_symbol=120)
 |
 |  A Portable Executable representation.
 |
 |  This class provides access to most of the information in a PE file.
 |
 |  It expects to be supplied the name of the file to load or PE data
 |  to process and an optional argument 'fast_load' (False by default)
 |  which controls whether to load all the directories information,
 |  which can be quite time consuming.
 |
 |  pe = pefile.PE('module.dll')
```


Since we are exploring a new PE file parsing capability, it's a good idea to use a legitimate program to learn more about the Python module. Malicious programs often have an unusual characteristics and these anomalies may confuse our initial attempts to understand pefile's capabilities.

Within the terminal screen in the lower part of VS Code, type python to launch the interactive shell. Then, load the pefile module with the command `import pefile.` In Python, the "import" statement finds the specified module and provides access to the module's functionality.

Let's explore this module by viewing its help information. Type `help(pefile)`, as shown on this slide. In addition to an overview of the module, we see a description of classes contained within the module. Scrolling down (hit the spacebar) provides information about each class. For now, we will only focus on the PE class. The description tells us that this class will give us access to the structure of a PE file, which is precisely what we need for our Windows file analysis. The output also explains how to create an instance of the PE class and read in a file.



We can return to the help menu to read more about the methods and attributes of the PE class. Alternatively, we can view a summary of this information by typing `dir(pefile.PE)`. An excerpt of this output is shown on this slide.

The dir() command output is a bit cluttered, but a quick scan of the text hints at the module's capabilities. For example, we see references to get_impash, get_overlay, and is_exe. If we want more information about a specific method, we can use the `help()` function.

By the way, functions that begin and end with double underscores are considered "magic methods". They are basically reserved and can be safely ignored for now.

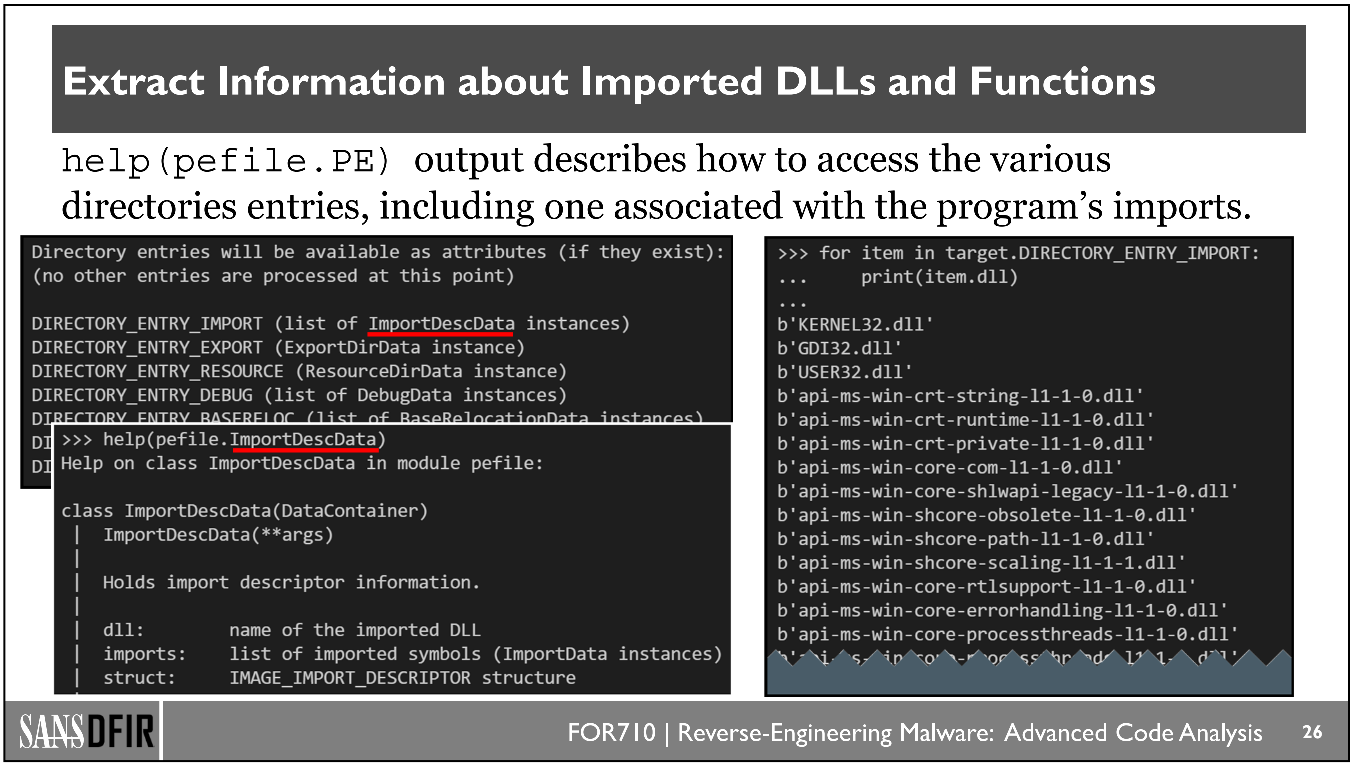
Pefile: Load a Program

- Within a Python interactive shell, type these commands to get started:

```
>>> import pefile
>>> target = pefile.PE("C:\\Windows\\notepad.exe")
>>> target.get_imphash()
'670212bd5fae78855c331eddeffdd4eb'
>>> target.is_exe()
True_
```

- When an executable is loaded, we can begin calling methods to learn about the target program and explore its structure.
- It's helpful to have an interactive shell open while writing a script to test code and review any available documentation.

This slide demonstrates how to use the pefile module to load an executable and begin using available methods.



Although the pefile module includes several function to quickly extract information like an import table hash, obtaining other information may require a bit more work.

For example, let's discuss how to extract an executable's imported DLLs and functions. This is useful data we often consult when performing static file analysis.

The screenshots on this slide show how we can navigate pefile documentation and perform testing to get access to the list of imported DLLs. In this case, we learn that the imports are accessible via the DIRECTORY_ENTRY_IMPORT attribute, which is a list of `ImportDescData` instances. Reviewing documentation on the `ImportDescData` class reveals that the "dll" attribute contains the name of the imported DLL.

The code on the right iterates over the DIRECTORY_ENTRY_IMPORT list and prints out the "dll" attribute for each `ImportDescData` object. The output is a list of imported DLLs.

Iterate over ImportData Instances to Print DLLs and Functions

```
>>> help(pefile.ImportDescData)
Help on class ImportDescData in module pefile:

class ImportDescData(DataContainer)
 |  ImportDescData(**args)
 |
 |  Holds import descriptor information.
 |
 |  dll:        name of the imported DLL
 |  imports:    list of imported symbols (ImportData instances)
 |  struct:     IMAGE_IMPORT_DESCRIPTOR structure
```

```
>>> help(pefile.ImportData)
Help on class ImportData in module pefile:

class ImportData(DataContainer)
 |  ImportData(**args)
 |
 |  Holds imported symbol's information.
 |  ordinal:    Ordinal of the symbol
 |  name:       Name of the symbol
 |  bound:      If the symbol is bound, this contains
 |              the address.
```

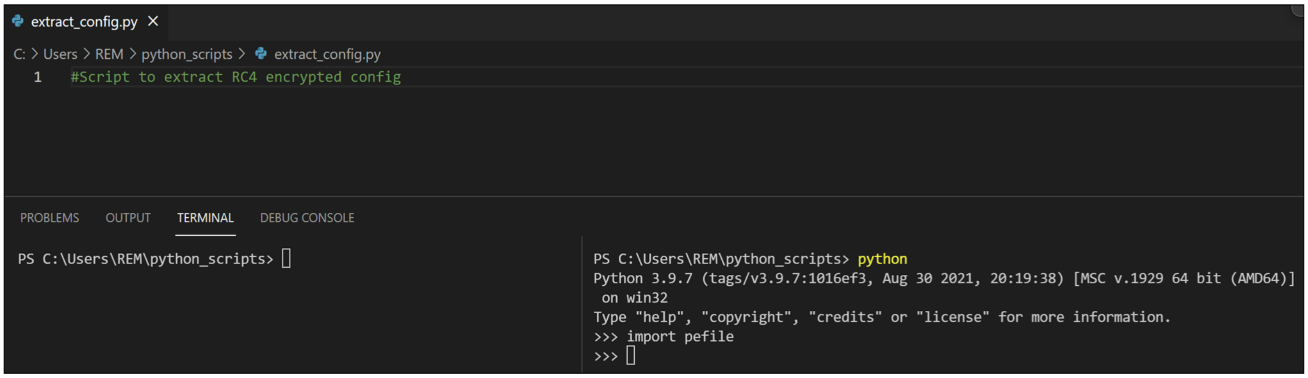
```
>>> for item in target.DIRECTORY_ENTRY_IMPORT:
...     print(item.dll)
...     for function in item.imports:
...             print(function.name)
...
b'KERNEL32.dll'
b'GetProcAddress'
b'CreateMutexExW'
b'AcquireSRWLockShared'
b'DeleteCriticalSection'
b'GetCurrentProcessId'
b'GetProcessHeap'
b'GetModuleHandleW'
```


We can supplement the output on the previous slide by adding the names of functions imported by each DLL. To obtain this additional detail, observe that each `ImportDescData` object contains an attribute "imports" that is a list of `ImportData` instances. Documentation on `ImportData` shows a "name" attribute that specifies the function name.

The code on the right makes use of this detail to iterate over the list of function names to print each one to the terminal.

With a brief introduction to pefile behind us, let's return to building our configuration extractor.

VS Code: Include a Text Editor, Terminal, and Python Shell



This organization allows us to both run our script and interactively explore `pefile` as needed to parse our target file.

Let's get started with building our config extractor. We will also take some time to get more familiar with the pefile Python module. Within VS Code, create a new file and call it extract_config.py. We will also use two terminal windows below the script file. On the left, we have our terminal prompt where we can view the output of running our script. This will help us check for errors and assess if our script produces the expected output. On the right, launch a Python interactive shell. Rather than diving straight into creating a script, the interactive shell is a great way to learn about available modules and perform quick testing.

Within the interactive shell, load pefile with the command `import` pefile. As a reminder, pefile is not included with a default Python install. It was installed within your Windows VMs with the command `pip3 install pefile`.

Our Script Will Import Several Python Modules

- We need to import several libraries:

```
import pefile
import argparse
from Crypto.Cipher import ARC4
```

- The pycryptodome module implements many cryptographic algorithms including RC4, Salsa20, ChaCha20, and various ECC curves.

```
cipher = ARC4.new(key)
decrypted_data = cipher.decrypt(data)
print(decrypted_data)
```

  - Our script must extract the key and data.

Our script needs to import several Python modules to perform its work, including pefile, argparse, and pycryptodome.

As a reminder, the “import” statement in Python finds the specified module and provides access to the module’s functionality. The “import” statement allows access to all functions within a specified module. If you only need access to a subset of functions within a module, consider the “from” statement. As shown on this slide, our script will include the statement:

```
from Crypto.Cipher import ARC4
```

This statement imports functions from ARC4.py located in the Crypto (i.e., pycryptodome) package under the Cipher subdirectory. A “package” is a collection of related modules. You can find ARC4.py within your VM at C:\Users\REM\AppData\Local\Programs\Python\Python39\Lib\site-packages\Crypto\Cipher\ARC4.py.

Next, We Specify Arguments and Load the Target Program

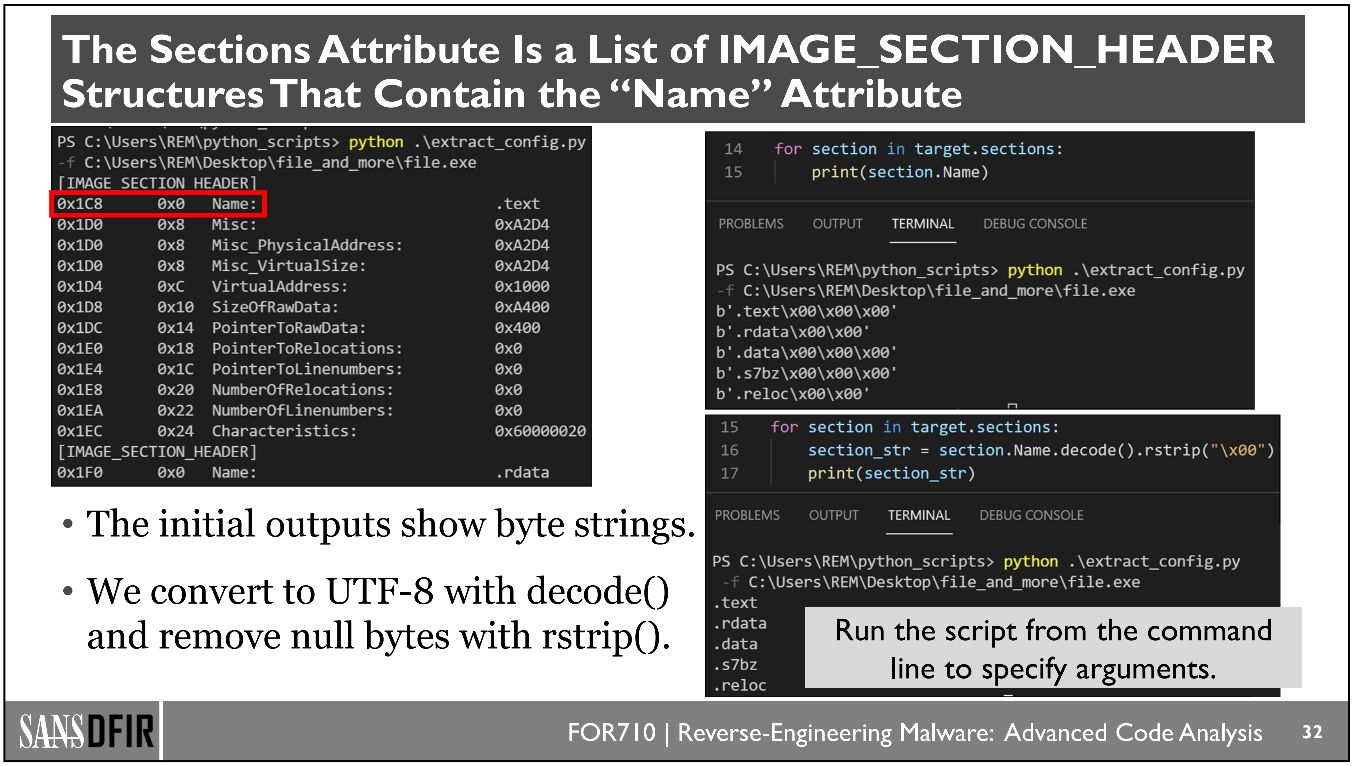
- Arguments will specify the target executable and an optional output file for the extracted config:

```
parser = argparse.ArgumentParser(description="Config extractor")
parser.add_argument("-f","--file", help="File for config
extraction.", required=True)
parser.add_argument("-o","--output", help="Output file for
config.", required=False)
args = parser.parse_args()
```

- Then, we can load the specified target program.

```
target = pefile.PE(args.file)
```


Next, we will use argparse to specify our command line arguments. As a reminder, we want to include arguments to specify the input file (i.e., the target binary) and an output file. We can make the output file option by including `required=False` when we call `parser.add_argument()`.



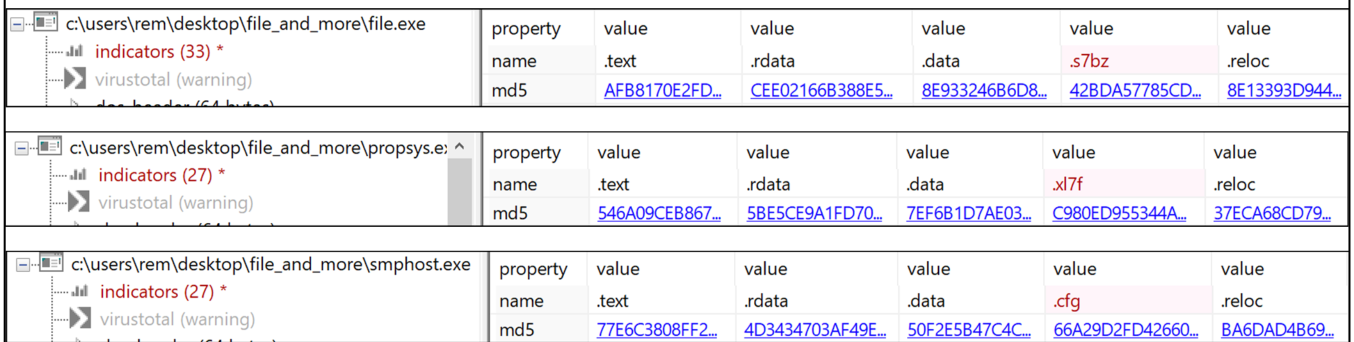
To execute the script on the previous slide and pass arguments, you will need to run it from the command line within the terminal window. The output lists IMAGE_SECTION_HEADER structures. Each structure includes, among other attributes, the "Name" of the section. Let's update our script to print out these names (see top-right screenshot).

The new output prints out the section names as expected, but the format requires explanation. Each section is preceded by "b" because the data is a "binary string". If you printed the type for these values using the built-in type() function, the output describes the values as `<class 'bytes'>`. To convert this data to a string type, we can apply the `decode()` function. When using `decode()`, you can specify the appropriate encoding. UTF-8 is the default, so we do not need to specify the encoding in this case. An alternative to using the `decode()` function is to convert the type with the code `str(section.Name,'utf-8')`. However, `decode()` is more common when operating on byte data. For more information on the `decode()` method, see https://for710.com/decode.

Because the byte data includes null bytes, it is necessary to remove those values. We can accomplish this with the string `rstrip()` method (see https://for710.com/rstrip).

Compare Similar Executables to Identify the Section of Interest

- Brief static analysis indicates all files have a section with an unusual section name, but the name varies.
- In our script, we could check for section names that are non-standard.



Our script must identify the appropriate section within the target PE file to extract the encrypted configuration data. We know the encrypted content is in the section named ".s7bz". One approach is to iterate over the sections within the target file (i.e., file.exe) until we find a section named ".s7bz". However, this section name may change across similar samples, and if the name changes, our script will not work.

The best-case scenario is that our script successfully extracts the configuration data from file.exe *and* similar files (we will discuss how to find similar files more in the next section). Therefore, when deciding how to identify the anomalous section, it is helpful to collect several similar malware samples. This slide shows section data for file.exe and two samples that have similar functionality when compared to file.exe. All three examples have a single anomalous section, but the section name varies. Within our script, perhaps we could iterate over sections and identify the one with an uncommon section name. Let's try this approach.

Create a List of "Good" Sections to Compare Against

- To identify the anomalous section, we define a list that includes multiple string values.
- If a section name is *not* in the list, identify it for further processing.
- Our updated script correctly identifies the single unusual section.

```
good = [".text", ".rdata", ".data", ".reloc"]

for section in target.sections:
    section_str = section.Name.decode().rstrip("\x00")
    if section_str not in good:
        print(section_str)
```

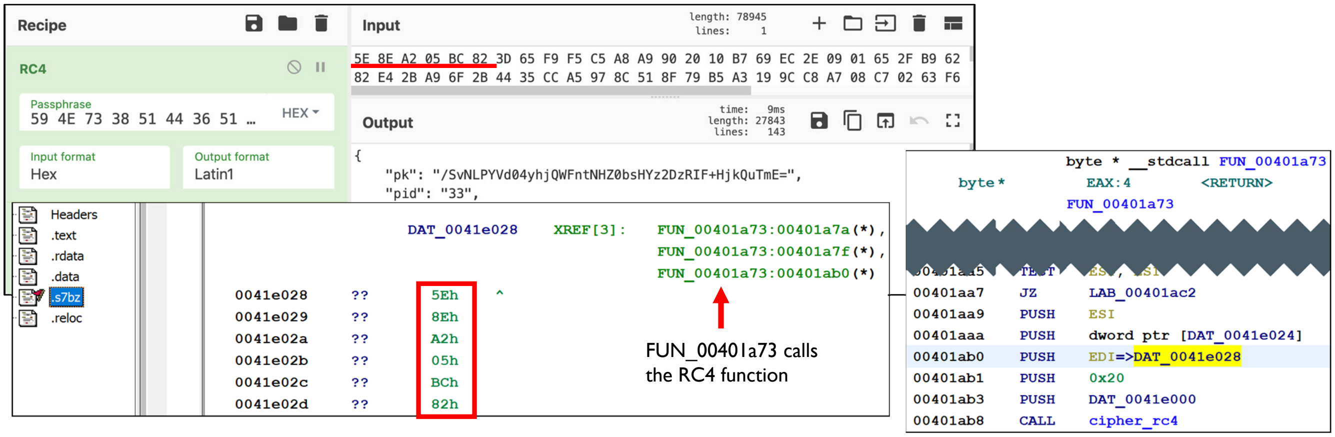
PROBLEMS OUTPUT TERMINAL DEBUG CONSOLE

```
PS C:\Users\REM\python_scripts> python .\extract_config.py
 -f C:\Users\REM\Desktop\file_and_more\file.exe
.s7bz
```


In the code on this slide, we first define a list of standard Windows executable section names. Then, when we iterate over the list of sections, we check each section name against our list. If a section name is not in the list, it must be the anomalous section that contains the encrypted configuration data.

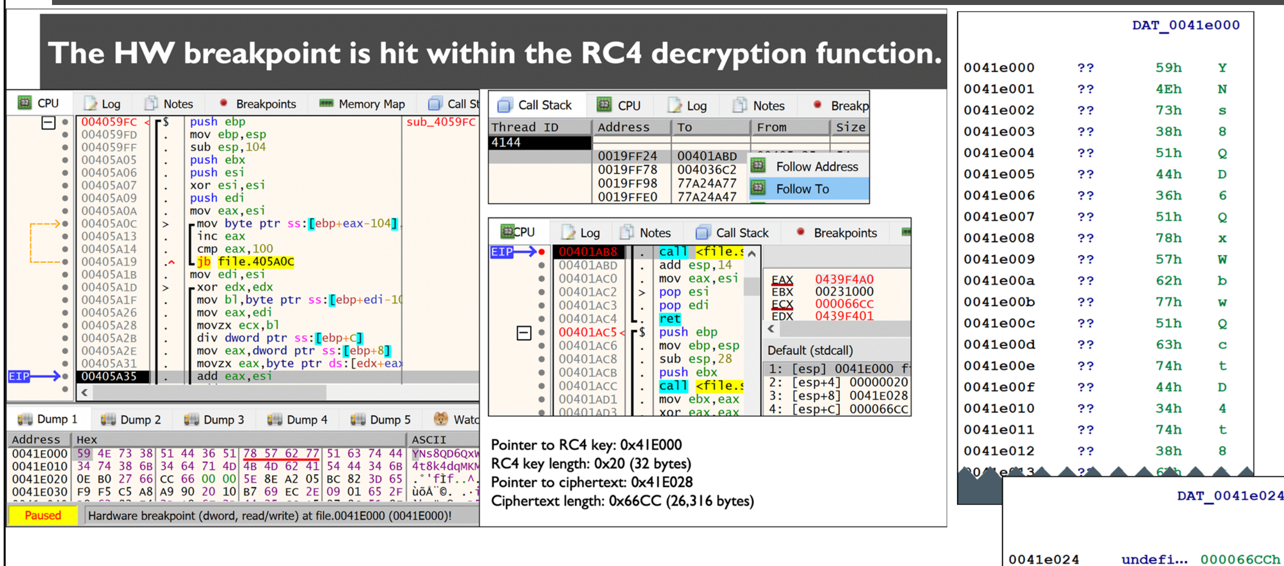
Clarify Where the RC4 Key and Encrypted Data are Located

If we browse to the section name .s7bz within Ghidra, we find several labeled locations including one that corresponds to the encrypted config.



Before proceeding with our script, we must understand the structure of the anomalous PE section and where the encrypted data resides. Within Ghidra, when we jump to the PE section of interest, we find several labeled locations. One labeled location corresponds to the encrypted data. There are three more labeled locations, which we will discuss shortly.

Associate Two Other Labeled Locations with the RC4 Key and Encrypted Data Size



Based on our analysis in Section 2 (see the slide in Section 2 titled "The HW Breakpoint Is Hit within the RC4 Decryption Function"), we can associate two of the remaining three labeled locations with the RC4 key and the encrypted data size.

Rename Labels for Clarity, Leaving One Unknown Label

```
                    rc4_key
0041e000    ??    59h    Y
0041e001    ??    4Eh    N
0041e002    ??    73h    s
0041e003    ??    38h    8
0041e004    ??    51h    Q
0041e005    ??    44h    D
0041e006    ??    36h    6
0041e007    ??    51h    Q
0041e008    ??    78h    x
0041e009    ??    57h    W
0041e00a    ??    62h    b
0041e00b    ??    77h    w
0041e00c    ??    51h    Q
0041e00d    ??    63h    c
0041e00e    ??    74h    t
0041e00f    ??    44h    D
0041e010    ??    34h    4
0041e011    ??    74h    t
```

```
                    DAT_0041e020
0041e020    ??    0Eh
0041e021    ??    B0h
0041e022    ??    27h    '
0041e023    ??    66h    f
                    encrypted_size
0041e024    undefi...  000066CCh
                    encrypted_data
0041e028    ??    5Eh    ^
0041e029    ??    8Eh
0041e02a    ??    A2h
0041e02b    ??    05h
0041e02c    ??    BCh
```

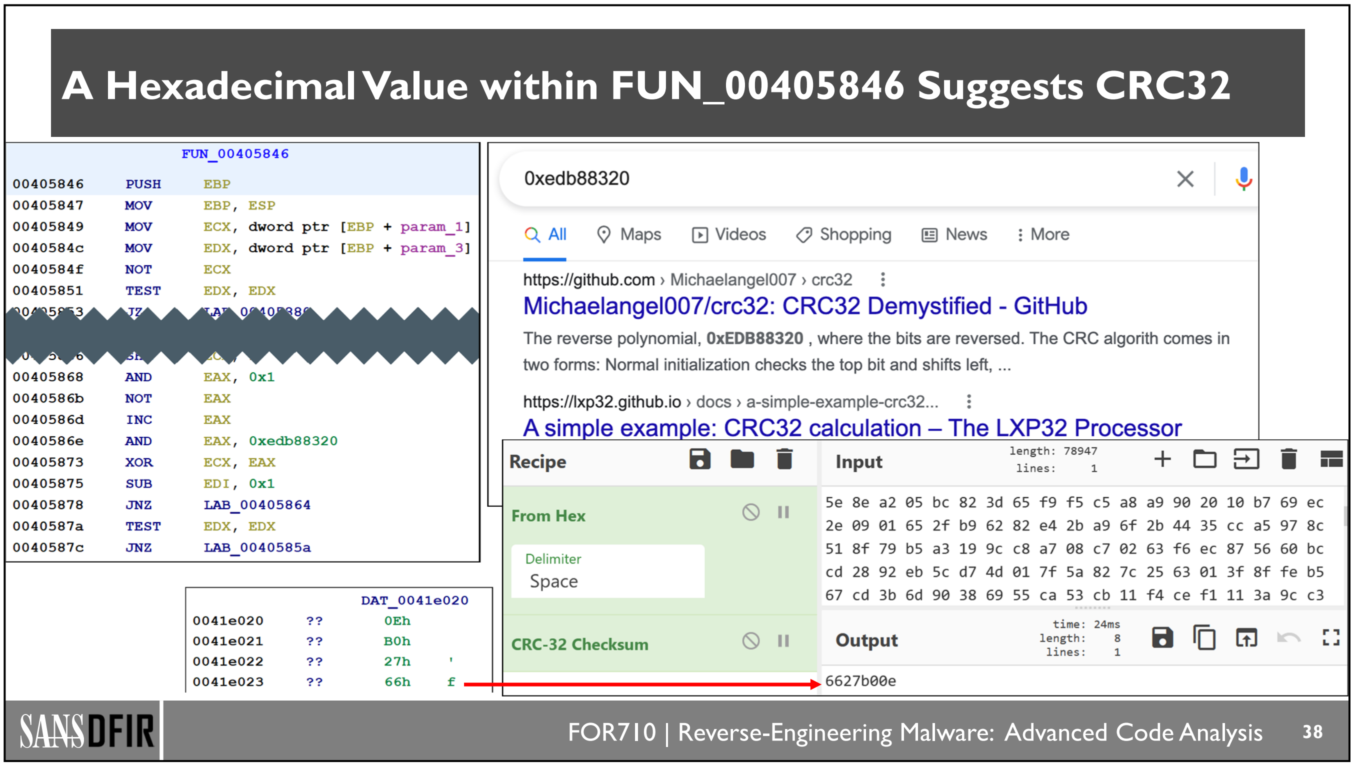
```
                    FUN_00401a73
00401a73    PUSH    EDI
00401a74    PUSH    dword ptr [encrypted_size]
00401a7a    MOV     EDI, encrypted_data
00401a7f    PUSH    EDI=>encrypted_data
00401a80    PUSH    0x0
00401a82    CALL    FUN_00405846

00401a87    ADD     ESP, 0xc
00401a8a    CMP     EAX, dword ptr [DAT_0041e020]
00401a90    JZ      LAB_00401a96
00401a92    XOR     EAX, EAX
00401a94    POP     EDI
00401a95    RET
```

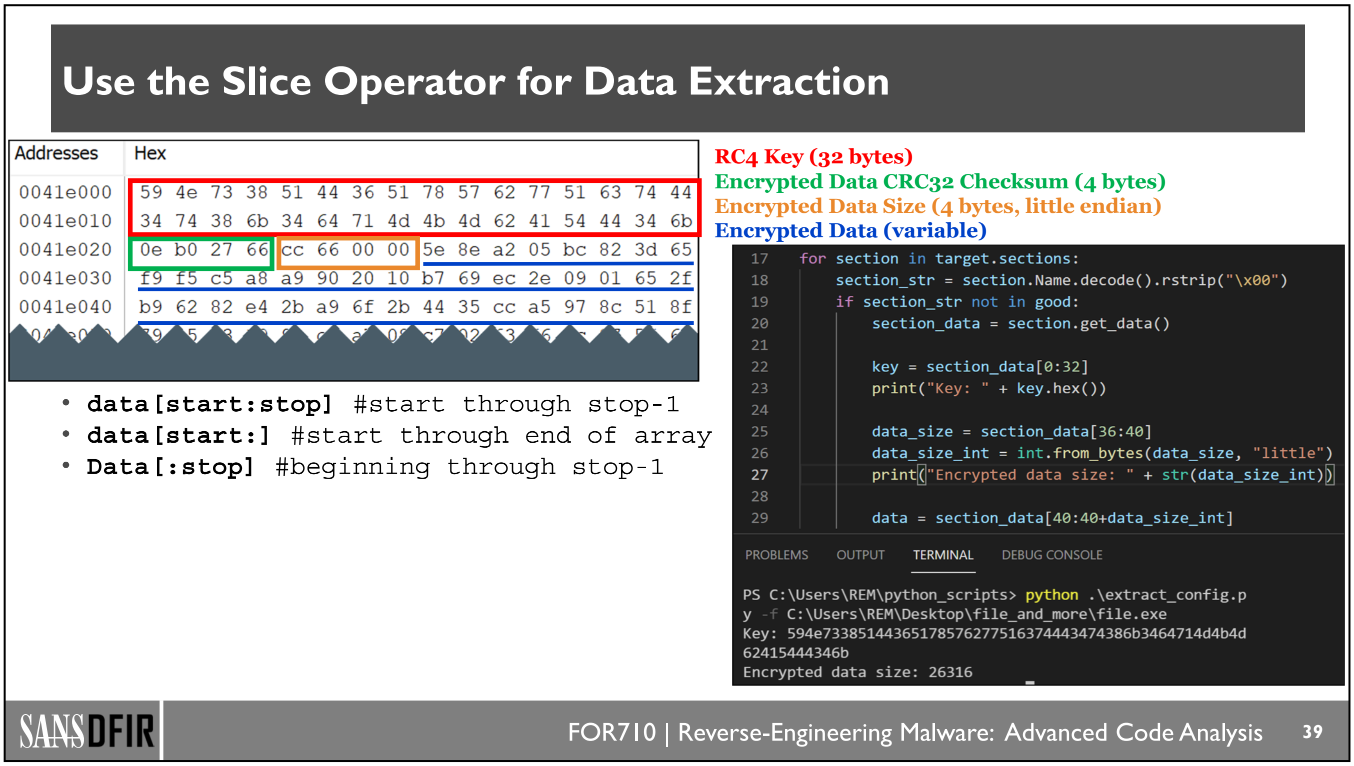
Some code analysis is necessary to understand the remaining labeled data.

Within the PE section of interest, there is one remaining labeled data location. To investigate, let's review the code that references this location.

At 401a8a, the data is compared to the contents of EAX. If the value in EAX is not equal to the 32-bit value at 41e020, the function returns. We know EAX often stores the return value of a function, and we see a function call shortly before this function: at 401a82, FUN_00405846 is executed. Interestingly, arguments passed to FUN_00405846 include the encrypted data size and a pointer to the encrypted data. Let's jump to FUN_00405846 for a closer look.



Within FUN_00405846 we see code that is not immediately identifiable. It includes XOR, SUB, and AND instructions, which may indicate the function implements an algorithm. Within the function, also observe the value 0xedb88320. Online research of this hexadecimal value reveals it is associated with the CRC32 algorithm. Considering the arguments passed to the function, FUN_00405846 likely performs an integrity check of the encrypted data before proceeding with decryption. Using CyberChef, we can confirm the four-byte value located at 41e020 is the CRC32 checksum of the encrypted data.



Based on our recent static code analysis, we can now accurately identify the structure of the PE section where the encrypted configuration resides. This section also contains the RC4 key, a CRC32 checksum of the encrypted data, and the size of the encrypted data.

In our Python script, we can use the slice operator to extract these individual components as shown in the code snippet. Another approach to parsing binary data is to use the Python struct library. While we will not use this approach in class, you can read more about this library here: https://for710.com/pystruct.

The code on this slide also demonstrates the use of the `get_data()` method. When run against a section, this method returns the data contained within the section. This is the data we slice as needed to specify the key, data size, and encrypted data.

This slide also uses the integer method from_bytes(). This function returns the integer represented by an array of bytes (for more information, see https://for710.com/frombytes).

Use the Python json Module for Beautification

extract_config.py > ...

```python
#Script to extract RC4 encrypted config

import argparse
import pefile
from Crypto.Cipher import ARC4
import json
```

```python
decrypted_str = decrypted_data.decode().rstrip("\x00")
config_data = json.loads(decrypted_str)
with open(args.output, "w") as f:
    f.write(json.dumps(config_data, indent=4))
```

config.txt


```
{
    "pk": "/SvNLPYVd04yhjQWFntNHZ0bsHYz2DzRIF+HjkQuTmE=",
    "pid": "33",
    "sub": "331",
    "dbg": false,
    "fast": true,
    "wipe": true,
    "wht": {
        "fld": [
            "boot",
            "msocache",
            "programdata",
            "$windows.~ws",
            "tor browser",
            "program files (x86)",
            "$recycle.bin",
            "google",
            "$windows.~bt",
            "intel",
            "windows",
            "windows.old",
            "mozilla",
            "system volume information",
            "perflogs",
            "application data",
            "appdata",
            "program files"
```


As mentioned on the previous slide, the configuration is in JSON format. We can use the Python json module to beautify the output and add indentation as shown on the right side of this slide.

The `json.load()` method converts the decrypted content to a Python object. The `json.dump()` method generates a JSON formatted string with the specified indentation.

To view the complete config extractor script, see the file `section3.1_extract_config.py` in the Malware\Section3 folder in your Windows VMs.

To learn more about the Python json module, see https://for710.com/python-json.

Course Roadmap

- FOR710.1: Code Deobfuscation and Execution
- FOR710.2: Encryption in Malware
- FOR710.3: Automating Malware Analysis
- FOR710.4: Correlating Malware and Building Rules

SECTION 3

- Python for Malware Analysis
  - ***Lab 3.1: Automating Config Extraction with Python***
- Malware Analysis with DBI Frameworks
  - Lab 3.2: Automate Payload Extraction with Frida
- Automating Analysis with Ghidra
  - Lab 3.3: Scripting with Ghidra

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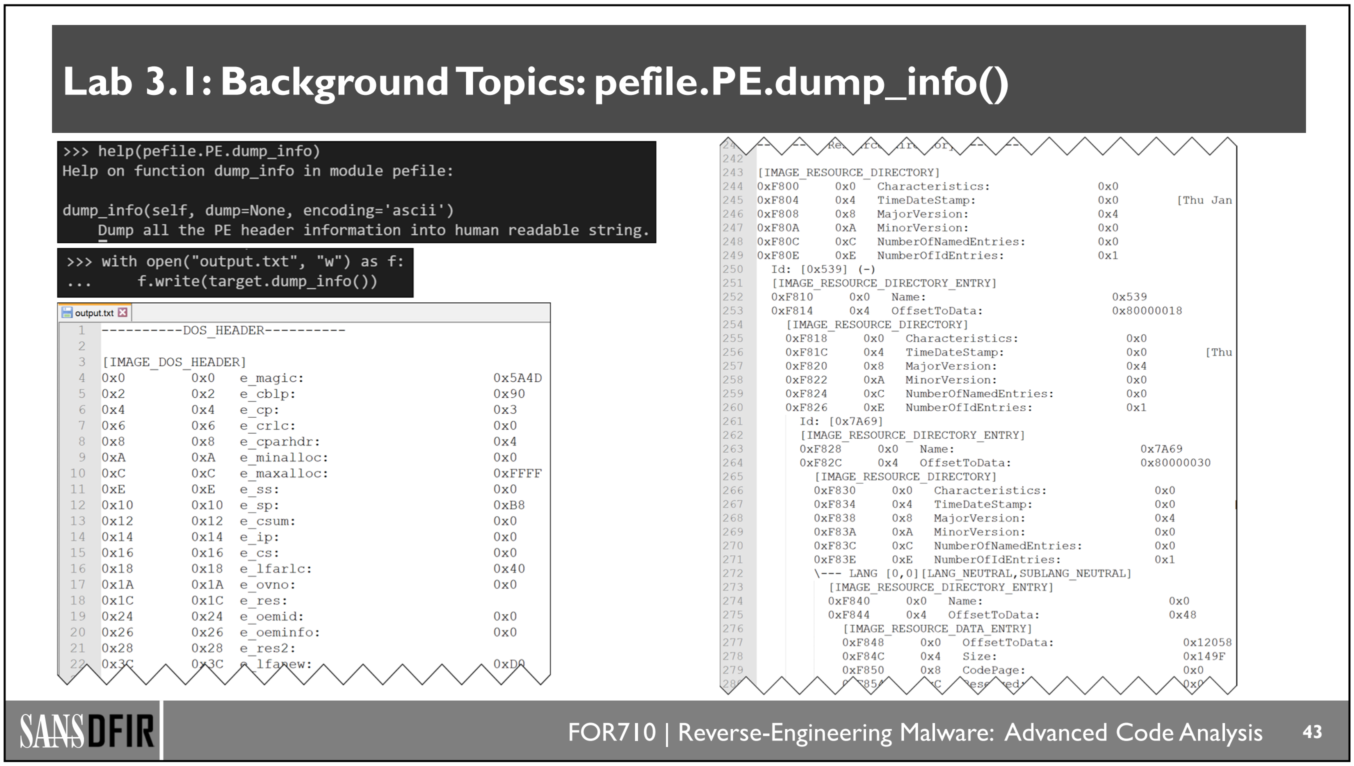

The next few slides provide additional background that is helpful for Lab 3.1.

The walk-through in this module discussed malware that embeds an encrypted configuration in a section. If the encrypted configuration is stored as a resource, however, accessing this data programmatically is a bit more complicated due to the structure of the resource section.

We can use the `pefile dump_info()` method to learn more about the structure of the resource section. This method prints all PE header information. This volume of data is best reviewed in a text editor, so the commands on this slide write the output to a file.

Our goal is to access the IMAGE_RESOURCE_DATA_ENTRY structure, which contains an offset to the resource data in winbio.exe.

Lab 3.1: Background Topics: Access Resources with pefile (1)

```
Directory entries will be available as attributes (if they exist):
(no other entries are processed at this point)

DIRECTORY_ENTRY_IMPORT (list of ImportDescData instances)
DIRECTORY_ENTRY_EXPORT (ExportDirData instance)
DIRECTORY_ENTRY_RESOURCE (ResourceDirData instance)
DIRECTORY_ENTRY_DEBUG (list of DebugData instances)
DIRECTORY_ENTRY_BASERELOC (list of BaseRelocationData instances)
DIRECTORY_ENTRY_TLS
DIRECTORY_ENTRY_BOUND_IMPORT (list of BoundImportData instances)
```

```
>>> help(pefile.ResourceDirData)
Help on class ResourceDirData in module pefile:

class ResourceDirData(DataContainer)
 |  ResourceDirData(**args)
 |
 |  Holds resource directory information.
 |
 |  struct:     IMAGE_RESOURCE_DIRECTORY structure
 |  entries:    list of entries (ResourceDirEntryData instances)
```

```
>>> help(pefile.ResourceDirEntryData)
Help on class ResourceDirEntryData in module pefile:

class ResourceDirEntryData(DataContainer)
 |  ResourceDirEntryData(**args)
 |
 |  Holds resource directory entry data.
 |
 |  struct:     IMAGE_RESOURCE_DIRECTORY_ENTRY structure
 |  name:       If the resource is identified by name this
 |             attribute will contain the name string. None
 |             otherwise. If identified by id, the id is
 |             available at 'struct.Id'
 |  id:         the id, also in struct.Id
 |  directory:  If this entry has a lower level directory
 |             this attribute will point to the
 |             ResourceDirData instance representing it.
 |  data:       If this entry has no further lower directories
 |             and points to the actual resource data, this
 |             attribute will reference the corresponding
 |             ResourceDataEntryData instance.
 |  (Either of the 'directory' or 'data' attribute will exist,
 |  but not both.)
```

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Similar to the approach we used to access a program's IAT, our journey to access resource data begins with a directory entry. On the top-left of this slide, the screenshot shows an excerpt of output from help(pefile.PE). This explains that resources are accessible through the DIRECTORY_ENTRY_RESOURCE attribute. This attribute is an instance of a `ResourceDirData` object.

If we query `help()` to understand the `ResourceDirData` class, we find it includes an attribute named "entries" that is a list of `ResourceDirEntryData` instances.

If we query `help()` to understand the `ResourceDirEntryData` class, we see it includes four attributes. The data attribute points to the actual resource data, but only if there are no lower directories. If there are subdirectories, those are accessible via the directory attribute, which points to additional `ResourceDirData` objects. This means we must traverse any subdirectories before accessing the resource data. As highlighted on this slide, only one of the directory or data attributes may exist.

When we finally reach the resource data, it will be an instance of the `ResourceDataEntryData` class.

Lab 3.1: Background Topics: Access Resources with pefile (2)

```
class ResourceDataEntryData(DataContainer)
 |  ResourceDataEntryData(**args)
 |
 |  Holds resource data entry information.
 |
 |  struct:     IMAGE_RESOURCE_DATA_ENTRY structure
 |  lang:       Primary language ID
 |  sublang:    Sublanguage ID
```

```
>>> help(pefile.PE.get_data)
Help on function get_data in module pefile:

get_data(self, rva=0, length=None)
    Get data regardless of the section where it lies on.

    Given a RVA and the size of the chunk to retrieve, this method
    will find the section where the data lies and return the data.
```

output.txt

```
----------Resource directory----------

[IMAGE_RESOURCE_DIRECTORY]
0xF800     0x0   Characteristics:              0x0
0xF804     0x4   TimeDateStamp:                0x0        [Thu Jan
0xF808     0x8   MajorVersion:                 0x4
0xF80A     0xA   MinorVersion:                 0x0
0xF80C     0xC   NumberOfNamedEntries:         0x0
0xF80E     0xE   NumberOfIdEntries:            0x1
  Id: [0x539] (-)
  [IMAGE_RESOURCE_DIRECTORY_ENTRY]
  0xF810     0x0   Name:                         0x539
  0xF814     0x4   OffsetToData:                 0x80000018
    [IMAGE_RESOURCE_DIRECTORY]
    0xF818     0x0   Characteristics:              0x0
    0xF81C     0x4   TimeDateStamp:                0x0        [Thu
    0xF820     0x8   MajorVersion:                 0x4
    0xF822     0xA   MinorVersion:                 0x0
    0xF824     0xC   NumberOfNamedEntries:         0x0
    0xF826     0xE   NumberOfIdEntries:            0x1
      Id: [0x7A69]
      [IMAGE_RESOURCE_DIRECTORY_ENTRY]
      0xF828     0x0   Name:                         0x7A69
      0xF82C     0x4   OffsetToData:                 0x80000030
        [IMAGE_RESOURCE_DIRECTORY]
        0xF830     0x0   Characteristics:              0x0
        0xF834     0x4   TimeDateStamp:                0x0
        0xF838     0x8   MajorVersion:                 0x4
        0xF83A     0xA   MinorVersion:                 0x0
        0xF83C     0xC   NumberOfNamedEntries:         0x0
        0xF83E     0xE   NumberOfIdEntries:            0x1
        \--- LANG [0,0][LANG_NEUTRAL,SUBLANG_NEUTRAL]
          [IMAGE_RESOURCE_DIRECTORY_ENTRY]
          0xF840     0x0   Name:                         0x0
          0xF844     0x4   OffsetToData:                 0x48
            [IMAGE_RESOURCE_DATA_ENTRY]
            0xF848     0x0   OffsetToData:                 0x12058
            0xF84C     0x4   Size:                         0x149F
            0xF850     0x8   CodePage:                     0x0
            0xF854     0xC   Reserved:                     0x0
```

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Continuing our analysis from the previous slide, we can query `help()` for more information on the `ResourceDataEntryData` class. There, we observe a "struct" attribute. This attribute contains the IMAGE_RESOURCE_DATA_ENTRY structure we saw in our earlier `dump_info()` output (highlighted on the slide). This structure contains `OffsetToData` and Size fields. Passing these values to `get_data()` will return the resource data we desire.

Lab 3.1

Automating Config Extraction with Python

Please begin Lab 3.1 now.

Course Roadmap

- FOR710.1: Code Deobfuscation and Execution
- FOR710.2: Encryption in Malware
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Malware Analysis with DBI Frameworks

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This module discusses how to use Dynamic Binary Instrumentation (DBI) frameworks to help automate malware analysis.

Malware Analysis with DBI Frameworks: Module Objectives

- Gain familiarity with the concept of DBI frameworks.
- Understand how DBI-based tools can help automate reverse engineering.
- Use a DBI-based tool to monitor API calls.
- Use a DBI framework's Python bindings to script a common malware analysis workflow.

This slide describes the objectives of this module.

DBI Frameworks: Run a Program and Interact with Its Internals

- This includes hooking functions, observing API calls, assessing function inputs/outputs, and modifying instructions and data during execution.
- DBI-based tools are often used to assess proprietary programs, evaluate performance, and discover vulnerabilities.
- DBI frameworks are available for both desktop and mobile OSs and most include well documented APIs to facilitate tool development.

Malware reverse engineers perform dynamic code analysis to inspect a program during execution. This typically involves using a debugger to monitor a suspect process. A complementary approach is to interrogate a running process using Dynamic Binary Instrumentation (DBI) frameworks. While a debugger allows you to attach to a process, DBI techniques allow you to inject and execute code within a process to examine its internals.

Well-known DBI frameworks include DynamoRIO, Intel's Pin, and Frida. These frameworks are often used to assess proprietary programs and evaluate program performance, but they can also be applied to accelerate malware analysis. They allow analysts to hook functions to observe API calls, assess their inputs and outputs, and even modify instructions and data during execution. DBI frameworks target both desktop and mobile operating systems (i.e., Windows, macOS, GNU/Linux, iOS, Android™, and QNX) and provide well-documented APIs to facilitate tool development.

DBI Framework Capabilities Complement the RE Process

- Malware reverse engineers debug programs to inspect code and data during execution.
- DBI frameworks can help automate the debugging process.
- With DBI-based tools, we can monitor APIs of interest and automatically extract argument and return values.
- We can use DBI framework capabilities to automate common RE tasks including deobfuscating code, dumping payloads, and decrypting data.

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DBI frameworks are versatile, and one application is to automate common malware analysis tasks. Reverse engineers often find themselves monitoring functions, observing their inputs and outputs, and taking further action based on what is discovered. DBI-based tools can play a key role in automating these tasks, including deobufscating code, dumping payloads, and decrypting data.

Frida Background

- While there are several options to choose from, we will pursue the Frida DBI framework to automate our reverse engineering efforts.
- Frida is a free and open-source DBI framework we can use to rapidly automate malware analysis workflows.
- Frida injects JavaScript into a running program to monitor and/or modify function arguments and return values.
- Frida includes helpful command line tools to get started immediately, but the framework's power is best experienced using its Python bindings.
- The framework is available in your VM, but in another environment you would install Frida with the command: `pip3 install frida-tools`.

This module demonstrates how to use Frida to automate reverse engineering workflows. We will discuss Frida's key features and explain the core components of a Frida Python script. With this knowledge, analysts can rapidly build custom tools to perform binary analysis.

Frida is a free and open-source software created by Ole André V. Ravnås. It allows analysts to inject JavaScript into programs to observe, intercept, and modify the inputs and outputs of function calls during execution. It works on a variety of desktop and mobile operating systems. Frida provides command line tools for those who want immediate access to its benefits, but the framework's functionality and flexibility are best experienced using the available Python bindings.

Frida requires a Python 3 install on a Windows, macOS, or GNU/Linux operating system. To install Frida, run the following command from an internet-connected machine: pip3 install frida-tools.

Python 3 and Frida are already installed within your VMs.

Frida-Trace Provides Benefits of the Frida Framework with Minimal Coding

- With frida-trace, you can quickly intercept APIs of interest.
- Use this command line format:
  - `frida-trace -f <target> -i <module Name>!<functions(s)>`
  - Example: `frida-trace -f run.exe -i KERNEL32.DLL!CreateFile*`
- **`-f`**: Target file to execute
- **`-i`**: Function(s) to intercept
- **`*`**: Wildcard to monitor multiple APIs, but this may include *too* many
- Including the module name is optional but recommended.

Frida-trace is one of several command-line tools in the Frida framework that has clear benefits for malware analysis. Malware analysts often spend time tracing API calls; this tool helps automate tracing by allowing analysts to display and process the inputs and outputs of a specified function. Frida is not an emulator framework, which means it executes the target program. For this reason, frida-trace should be used in an isolated environment when performing malware analysis.

To spawn a process and begin tracing function calls, use the following command line format: frida-trace -f <program name> -i <MODULE NAME>!<Function(s) to monitor>.

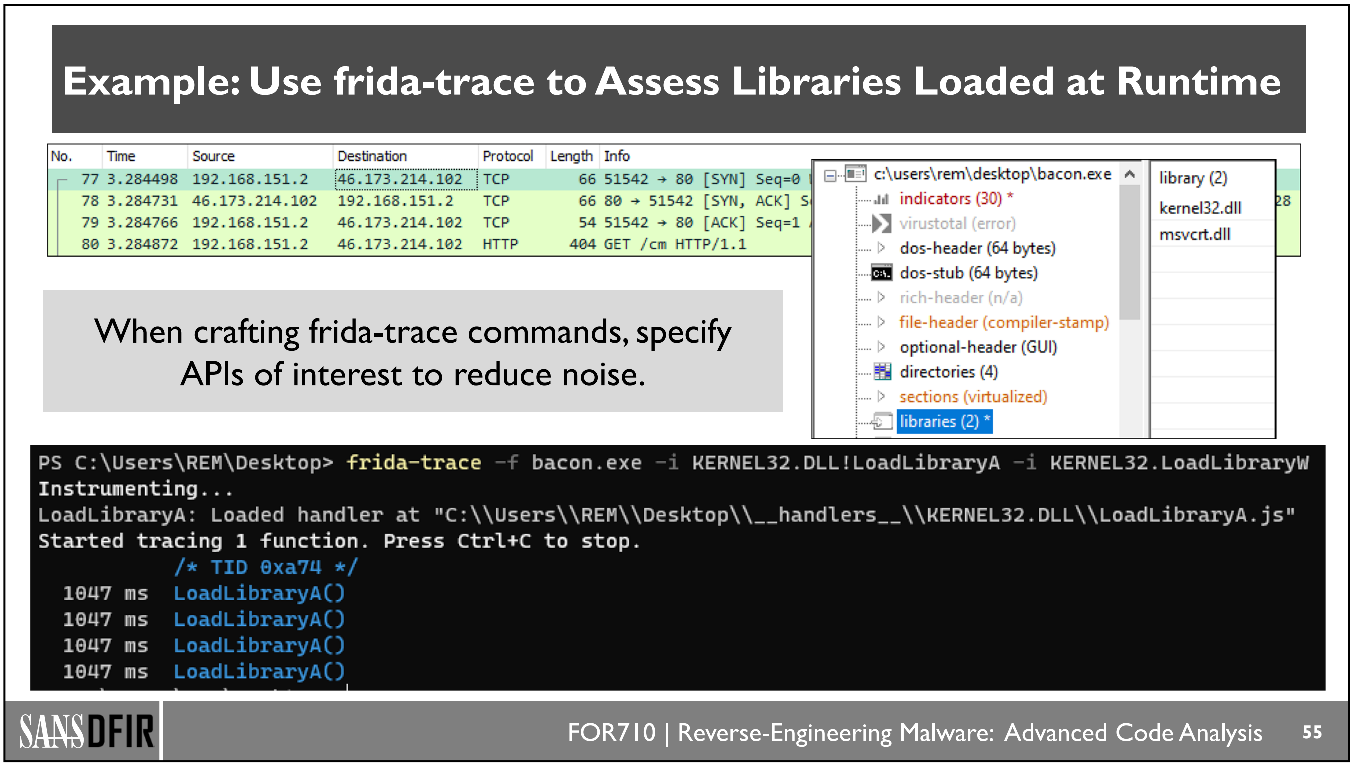
To view the help output, use the "`-h`" command line flag. You can also visit https://for710.com/fridatrace for more information.

There are numerous APIs worth tracing for malware analysis. For example, consider this command:

```
frida-trace -f run.exe -i KERNEL32.DLL!CreateFile*
```

This command line will launch run.exe and monitor calls to any API that begins with "CreateFile" in kernel32.dll. Key details about this command line to note are:

- The `-f` flag specifies the target file to spawn.
- Use `-i` flag specifies the function to monitor.
- Including the module name is optional but yields more concise and targeted output. The module name must be typed in all capital letters.
- The asterisk (*) is a wildcard, and this is helpful to monitor both the wide character and ANSI versions of Windows APIs (e.g., CreateFileW and CreateFileA) or groups of APIs (e.g., all APIs that begin with "Crypto"). However, it is generally best to be as specific as possible to avoid an overwhelming amount of information from too many API calls.



Let's use frida-trace to take a closer look at a malware sample. The screenshots on this slide show analysis of a sample named bacon.exe with SHA-256 hash 866b2c7dc08682cc174c58bf5cfc6ca44af7696b28b8191e7ff003d97639934c. You can find this file in the Malware\Section3 folder within your VMs.

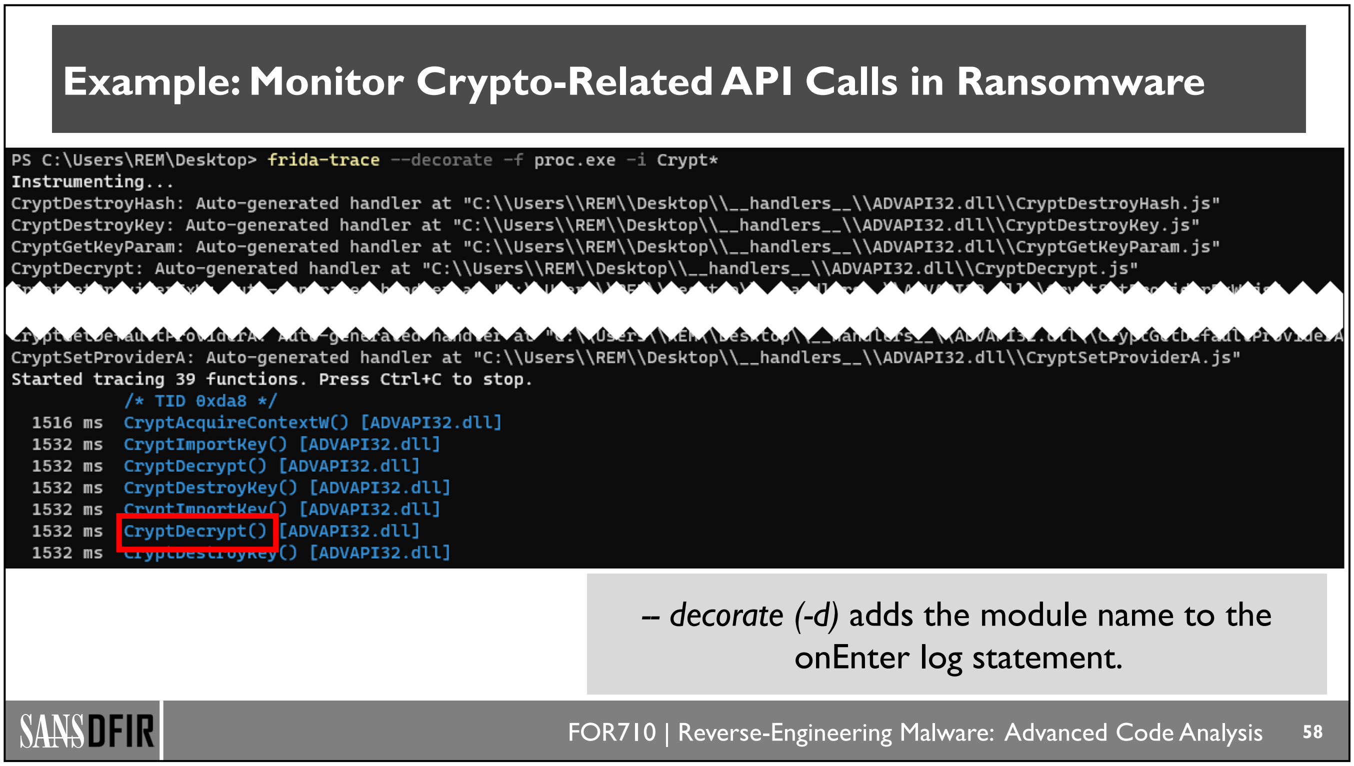
Brief behavioral analysis of bacon.exe indicates an HTTP request. However, looking at the imports, we see only two imported DLL with functions that have no obvious capability to communicate across a network. For example, we might expect to see ws2_32.dll or wininet.dll in the list of imported DLLs, two modules that provide networking functionality. This likely indicates additional libraries are loaded at runtime with APIs resolved during execution. We can use frida-trace to quickly evaluate if `LoadLibrary` variants (i.e., `LoadLibraryW` or `LoadLibraryA`) are called to load additional DLLs. We could monitor a larger group of `LoadLibrary` API variants using "`LoadLibrary*`", but this results in too much noise. Some trial and error is involved in writing targeted commands, but in general, it is best to be as specific as possible when choosing APIs of interest.

The command line from this screen is run from the PowerShell command prompt, but you can use the traditional command prompt as well.

According to the frida-trace output, `LoadLibraryA` is called by the program. This is a good starting point, but we need more detailed output. What DLL do these calls load? To answer this question, we need to modify the "handler" referenced in the Frida output.

The Microsoft documentation for `LoadLibraryA` explains that the first argument points to the file or device to be created or opened. We can direct Frida to output this argument by modifying `onEnter` as shown on this slide. The `readAnsiString()` method reads a null-terminated ANSI string from the pointer passed as the first argument. Other methods to read strings from a pointer include `readCString()`, `readUtf8String()`, and `readUtf16String()`. It's worth nothing that `readAnsiString()`, which is used in this example, only works within the context of the Windows operating system. Again, browse to https://for710.com/fridanativeptr for more detail on available methods.

If we re-run the earlier frida-trace command line, the output now shows which DLLs are loaded during execution. Among the four DLLs are wininet.dll and ws2_32.dll, two modules that contain networking functionality. You will have an opportunity to use a similar command when monitoring calls to `GetProcAddress` in the upcoming lab.



This slide demonstrates the use of frida-trace with a different malware sample. In the screenshots on this slide, we analyzed a ransomware sample named proc.exe with SHA-256 hash d0f212d9f64ed0590919966ba837beb1de95f38d88476406b18490cd4322f21e. You can find this file in the Malware\Section3 folder within your VMs.

As we discussed in Section 2, ransomware may use the Microsoft CryptoAPI to perform encryption and decryption. With the command on this slide, we can quickly assess if this sample uses the CryptoAPI. In this case, we used the "`--decorate`" flag, which adds the name of the API module to the log output. A review of the output confirms this malware uses the CryptoAPI, and the call to CryptDecrypt might pique our interest. What content is decrypted?

Example: Modify a CryptDecrypt Handler to View Decrypted Content (1)

```
/*
 * Auto-generated by Frida. Please modify to match the signature of CryptDecrypt.
 * This stub is currently auto-generated from manpages when available.
 *
 * For full API reference, see: https://frida.re/docs/javascript-api/
 */
{
  /**
   * Called synchronously when about to call CryptDecrypt.
   * @this {object} - Object allowing you to store state for use in onLeave.
   * @param {function} log - Call this function with a string to be presented to the user.
   * @param {array} args - Function arguments represented as an array of NativePointer objects.
   * For example use args[0].readUtf8String() if the first argument is a pointer to a C string encoded as UTF-8.
   * It is also possible to modify arguments by assigning a NativePointer object to an element of this array.
   * @param {object} state - Object allowing you to keep state across function calls.
   * Only one JavaScript function will execute at a time, so do not worry about race-conditions.
   * However, do not use this to store function arguments across onEnter/onLeave, but instead
   * use "this" which is an object for keeping state local to an invocation.
   */
  onEnter(log, args, state) {
    log('CryptDecrypt()');
    this.decData = args[4];
  },
  /**
   * Called synchronously when about to return from CryptDecrypt.
   * See onEnter for details.
   * @this {object} - Object allowing you to access state stored in onEnter.
   * @param {function} log - Call this function with a string to be presented to the user.
   * @param {NativePointer} retval - Return value represented as a NativePointer object.
   * @param {object} state - Object allowing you to keep state across function calls.
   */
  onLeave(log, retval, state) {
    log('Decrypted data: ' + this.decData.readAnsiString());
  }
}
```

```
BOOL CryptDecrypt(
  HCRYPTKEY  hKey,
  HCRYPTHASH hHash,
  BOOL       Final,
  DWORD      dwFlags,
  BYTE       *pbData,
  DWORD      *pdwDataLen
);
```

Use *this* to reference arguments from onLeave.

We can modify the `CryptDecrypt` handler file to print the decrypted content. The fifth argument passed to `CryptDecrypt` specifies the location in memory of the decrypted data. To access this argument from `onLeave`, we use "this" in both `onEnter` and `onLeave` when referring to the `decData` (i.e., pointer to decoded data) variable.

Example: Modify a CryptDecrypt Handler to View Decrypted Content (2)

Windows PowerShell

```
PS C:\Users\REM\Desktop> frida-trace -f proc.exe -i CryptDecrypt -o out.txt
```

out.txt

```
344 ms  CryptDecrypt()
344 ms  Decrypted data:
Kernel32.dll;Wow64DisableWo
dvapi32.dll;CreateProcessWi
344 ms  Decrypted data: Dea
a ransom!

Decryption service is paid

Also from your servers file
to our cloud storage
```

out.txt

```
COMMUNICATION METHOD:

To decrypt your computer, you need to download the TOR browser at
https://www.torproject.org/download/

Install it and visit our website for further action
http://paymen45oxzpnouz.onion/

359 ms  Decrypted data:
ntdll.dll;NtQueryObject;NtQuerySystemInformation;RtlGetVersion;Kernel32.dll
;GetFinalPathNameByHandleW;QueryFullProcessImageNameW;
359 ms  Decrypted data: sc delete vmickvpexchange
sc delete vmicguestinterface
sc delete vmicshutdown
sc delete vmicheartbeat
```


After modifying the `CryptDecrypt` handler, we can run frida-trace to review decrypted content. Note the use of the "`-o`" command line flag to create a log file. The decrypted content includes references to DLLs, APIs, ransom note text, and commands.

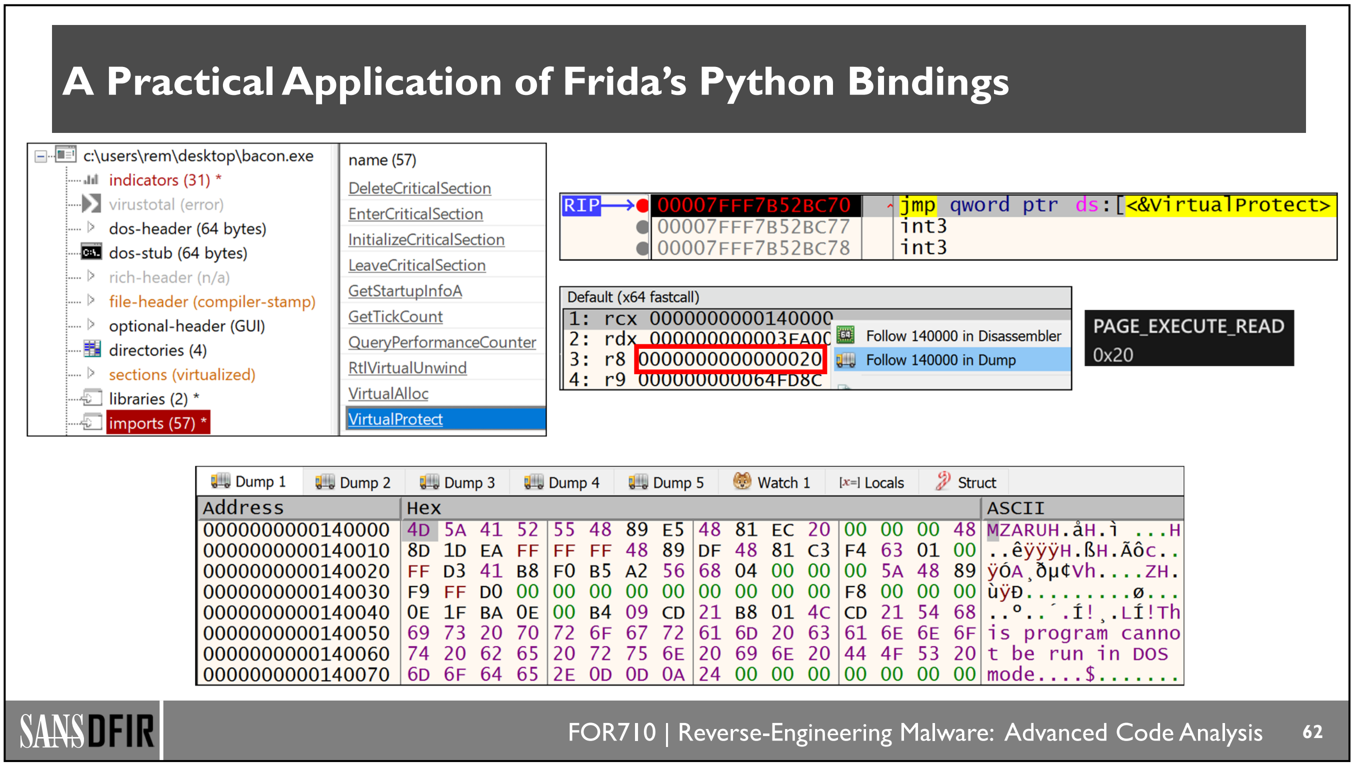
Keep in mind that, in the case of ransomware, generating an output file might be problematic if the text file is immediately encrypted.

Frida-Python

- A Python script will give us more control over execution and make it easier to troubleshoot issues.
- We can intercept multiple APIs and store arguments and variables across function calls to automate analysis.
- Our script will:
  - Accept a target executable on the command line.
  - Execute the program and attach to the spawned process.
  - Include JavaScript, which includes functions to intercept and onEnter/onLeave code.
  - Inject the JavaScript into the target process.
  - Wait to receive any messages from the target process.

Frida-trace is a great way to initially benefit from the framework. However, writing our own script using Frida's Python bindings provides more control and flexibility over API monitoring. In the next part of this module, we will discuss how to harness Frida-Python to automate more complex aspects of our reverse engineering workflow. The goal is to create a script that will perform the following items:

- Accept a target executable on the command line.
- Execute the program.
- Attach to the spawned process.
- Specify JavaScript code to inject into the target process. This will hook `VirtualAlloc` and `VirtualProtect` and include code to send messages from within the target process to the Python process.
- Inject the JavaScript code into the target process.
- Resume the process.
- Wait to receive any messages from the target process.



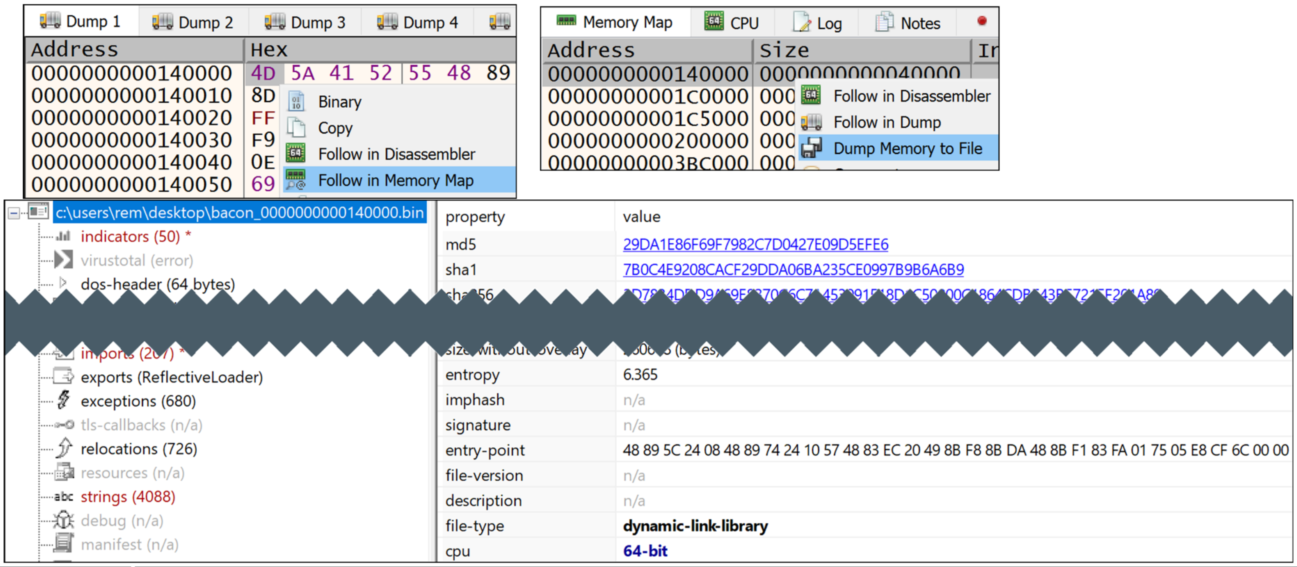
Let's return to bacon.exe and continue our analysis of this file. This analysis will demonstrate an opportunity to automate a common reverse engineering workflow using Frida's Python bindings.

Among bacon.exe's imports is `VirtualProtect`, and this API interests us malware analysis because it is used to change the permissions (e.g., read, write, execute) of a memory region. If a region in memory is updated to be executable, it might include code that was unpacked, decoded, and/or decrypted at runtime. For a similar reason, `VirtualAlloc` is a good API to investigate. You will have an opportunity to trace that API in the upcoming lab.

A common next step is to transition to a debugger to assess what content is present in memory when `VirtualProtect` is called. To this end, we load bacon.exe into x64dbg and set a breakpoint on `VirtualProtect`. Then, we run the program, and each time we encounter a call to `VirtualProtect`, we view its arguments. The first of four arguments passed to `VirtualProtect` specifies the starting address of the memory region whose permissions will change. The third parameter specifies the new permission to be applied (Microsoft refers to this as the "memory protection constant", listed here: https://for710.com/memory-protection-constants).

The first time we encounter `VirtualProtect`, observe the protection constant of 0x20, which includes executable permissions. If we dump the starting address to the dump window, we see a region beginning with "MZ" and the string "This program cannot be run in DOS mode", two indications that this content might be a Windows executable.

Dump the Memory Region to Confirm a Windows Executable



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To confirm the memory region contains a Windows executable, we follow it in the memory map and dump it to disk. Finally, we can load the dumped binary into PeStudio, which confirms this file is a 64-bit DLL.

Automate the Recent Analysis with a Frida-Python Script

Our script should automate our debugging workflow:

- Monitor calls to the VirtualProtect API.
- Evaluate if the memory region specified by the first argument contains a Windows executable (e.g., “MZ”).
- Dump the data if there is a match.
- Optional: Check if the protection constant includes executable permissions.

This slide lists the activities we want our Frida script to automate.

Key Components to a Frida-Python Script (2)

Next, the code below specifies the JavaScript code to be injected:

```
script = session.create_script("""
        Module.load('KERNEL32.DLL');
        var vpFunctionAddress = Module.getExportByName("KERNEL32.DLL",
        ”VirtualProtect");

        Interceptor.attach(vpFunctionAddress,
        {
                onEnter: function (args) {
                        console.log("\\nFunction called");
                },
                onLeave: function (retval) {
                        console.log("\\nFunction returned");
                }
        });
        """)
```


After the target process is launched, we must specify the JavaScript to be injected into the target process. In Python, we execute `session.create_script()` and provide the JavaScript code.

The JavaScript includes several key functions:

- `Module.load():` Loads the specified module.
- `Module.getExportByName ():` Returns the address of the specified API, which is necessary to intercept calls.
- `Interceptor.attach ():` Intercepts calls to the specified address (returned from `Module.getExportByName`) and specifies the previously discussed `onEnter` and `onLeave` functions.
- `Console.log ():` Logs messages to the console during execution.

Key Components to a Frida-Python Script (3)

Finally, the script injects the JavaScript into the target process, resumes the process, and prepares to read any log messages:

```
script.load()
frida.resume(pid)
sys.stdin.read()
session.detach()
```


Lastly, the script loads the injected code into the target process, resumes the process, and receives any logged messages.

Build upon the Basic Script to Dump a Windows Executable (1)

First, we add JavaScript try...catch statements to detect any errors.

```
try {
        Module.load('KERNEL32.DLL');
} catch (err) {
        console.log(err);
}

try {
        var vpExportAddress = Module.getExportByName("KERNEL32.dll", "VirtualProtect");
} catch (err) {
        console.log(err);
}
```


To generate a custom script that dumps a Windows executable referenced by `VirtualProtect`, we must customize the basic script template we just discussed. The code discussed in the upcoming slides is available in your Malware\Section3 folder in the file named section3.2_dump_mz_vp.py.

First, let's add some error detection in case a module does not load properly, or a function is not intercepted as expected. We can use JavaScript try…catch statements for this as shown on the slide above. This is not absolutely necessary, and it does add some bloat to the code, but it helps troubleshoot issues and can save a lot of time.

Build upon the Basic Script to Dump a Windows Executable (2)

- Then, we capture relevant VirtualProtect arguments and log them.
- In addition, we print a hexdump of the memory region referenced.

```
var vpAddress = args[0];
var vpSize = args[1].toInt32();
var vpProtect = args[2];

console.log("\\nVirtualProtect called!");
console.log("\\tAddress: " + vpAddress);
console.log("\\tSize: " + vpSize);
console.log("\\tNew Protection: " + vpProtect)

console.log("\\n" + hexdump(vpAddress));
```


When performing manual debugging of bacon.exe, we paused at each call to `VirtualProtect` and reviewed its arguments. Specifically, we dumped the starting address to a dump window and checked the new permissions applied. In our Frida script, we need to access and print out this information using the code shown. We also access the size of the region, which will be useful when it comes time to dump data to disk.

Note our use of the function `toInt32()`, which converts the second argument (i.e., the size of the region) to an integer. We also take advantage of the `hexdump()` JavaScript function to print both hexadecimal and ASCII output located at the specified memory region.

Build upon the Basic Script to Dump a Windows Executable (3)

Finally, check if the first two bytes are "MZ"; and dump the contents if a match is found.

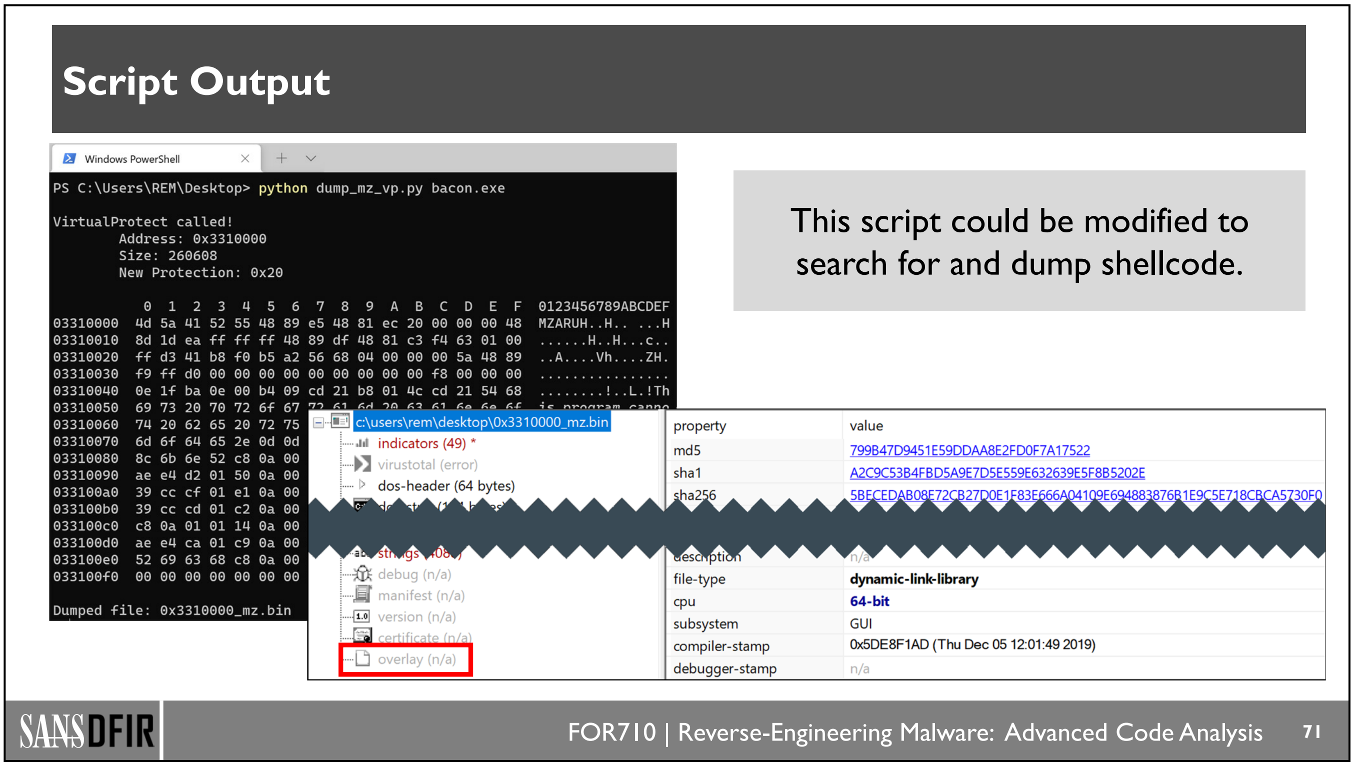
```
if (vpAddress.readAnsiString(2) == "MZ"){

         var someBinData = vpAddress.readByteArray(vpSize);

         var filename = vpAddress + "_mz.bin";
         var file = new File(filename, "wb");
         file.write(someBinData);
         file.flush();
         file.close();

         console.log("\\nDumped file: " + filename);
}
```


This code uses the Frida function `readAnsiString()` to read the first two bytes of the memory region and check if they match "MZ". If so, it uses the function `readByteArray()` to read the memory contents and dump the file to disk. Note that the argument passed to `readByteArray()` uses the size of the region to read in the appropriate number of bytes.



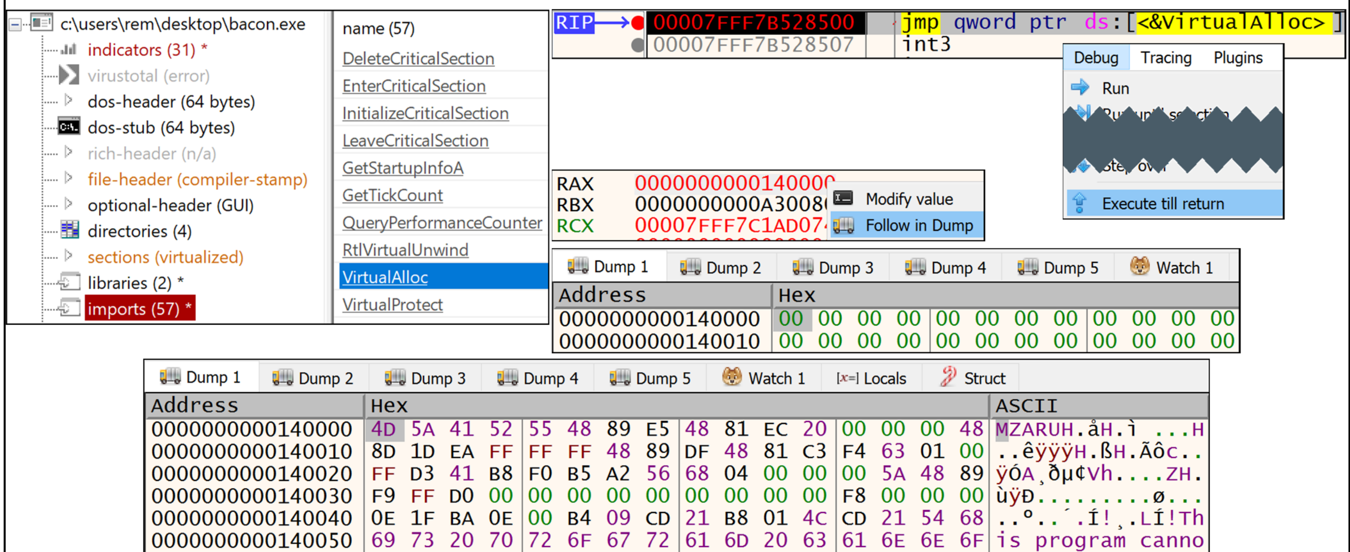
Running the script produces the output shown above. Loading the dumped content into PeStudio confirms it is a 64-bit DLL. Comparing this recently dumped executable with the file we dumped using a debugger reveals that the executable produced via Friday-Python does not have an overlay. This is because our script uses the size passed to VirtualProtect to determine how many bytes to read and dump. The result is that our Frida-Python script is more precise in its approach to dumping deobfuscated content.

To view the complete script, see the file `section3.2_dump_mz_vp.py` in the Malware\Section3 folder in your Windows VMs.

This example script could also be modified to search for and dump shellcode. Instead of searching for “MZ” at the beginning of a memory region, the script could search for common shellcode bytes. We discussed common shellcode bytes in Section 1 of this course.

To view a Frida script that detects and dumps shellcode, see this blog post written by Anuj Soni: https://for710.com/bbfrida.

During Malware Analysis, We Monitor Memory Regions to Identify Interesting Content



In the last example, we identified a Windows executable when looking at analyzing calls to `VirtualProtect`. Sometimes, a more productive approach is to monitor multiple regions allocated via `VirtualAlloc`. For example, when we performed some initial static file analysis of bacon.exe, we noted it imported `VirtualAlloc` in addition to `VirtualProtect`. If we reviewed calls to VirtualAlloc within a debugger, we could dump each region allocated to a dump window and observe if any interesting data appears at that location. Eventually, we would identify the same Windows executable.

Using `VirtualAlloc` as a pivot into the code instead of `VirtualProtect` is sometimes necessary. The challenge with this approach, however, is that it requires us to track multiple regions in memory and repeatedly evaluate if any execute content was placed in one of the allocated regions. Let's explore this approach.

One Approach to Tracking Multiple Allocated Regions

```
Module.load('KERNEL32.DLL');
var vaExportAddress = Module.getExportByName("KERNEL32.dll", "VirtualAlloc");

var memRegions = [];

Interceptor.attach(vaExportAddress,
{
		onEnter: function (args) {
				this.vaSize = args[1].toInt32();

				for(var i = 0; i < memRegions.length; i++)
				{
						var firstBytes = memRegions[i].memBase.readAnsiString(2);

						if (firstBytes == "MZ")
						{
								//Generate hexdump
								//Dump content to disk
						}
				}

		},
		onLeave: function (retval) {
				memRegions.push({memBase:ptr(retval), memSize:this.vaSize});
		}
});
```


To track multiple allocated regions, we could create an array of memory regions to monitor. We could add to this array when a new region is allocated and check previously allocated regions for evidence of code or data. This automates the common malware analysis workflow of monitoring multiple regions in memory during execution.

To track multiple sections, we could use the approach described on this screen. For brevity, previous discussed code is referred to in comments but not included. Try…catch statements are also excluded.

This code declares an array `memRegions` that tracks allocated memory regions. Whenever `VirtualAlloc` returns, it pushes (i.e., adds) to the array. Each element has two properties: the starting address of the region allocated (`memBase`) and the size of the region allocated (`memSize`). We use `ptr()` to convert the return value to a pointer because it is an address. We also refer to the size via "this" because the size is referenced as an argument when the function is first called, and not when it returns.

With this code, anytime `VirtualAlloc` is called, previously allocated regions will be evaluated to determine if they begin with the bytes "MZ". If those bytes are found, the regions are dumped as described earlier in this module.

You'll have an opportunity to implement this approach in the upcoming lab.

Course Roadmap

- FOR710.1: Code Deobfuscation and Execution
- FOR710.2: Encryption in Malware
- FOR710.3: Automating Malware Analysis
- FOR710.4: Correlating Malware and Building Rules

SECTION 3

- Python for Malware Analysis
  - Lab 3.1: Automating Config Extraction with Python
- Malware Analysis with DBI Frameworks
  - ***Lab 3.2: Automating Payload Extraction with Frida***
- Automating Analysis with Ghidra
  - Lab 3.3: Scripting with Ghidra

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Lab 3.2

Automating Payload Extraction with Frida

Please begin Lab 3.2 now.

Course Roadmap

- FOR710.1: Code Deobfuscation and Execution
- FOR710.2: Encryption in Malware
- FOR710.3: Automating Malware Analysis
- FOR710.4: Correlating Malware and Building Rules

SECTION 3

- Python for Malware Analysis
  - Lab 3.1: Automating Config Extraction with Python
- Malware Analysis with DBI Frameworks
  - Lab 3.2: Automate Payload Extraction with Frida
- ***Automating Analysis with Ghidra***
  - Lab 3.3: Scripting with Ghidra

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Automating Analysis with Ghidra

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Scripting with Ghidra: Module Objectives

- Explore how to automate code analysis workflows within Ghidra.
- Use Ghidra's built-in Python interpreter to explore provided APIs.
- Understand best practices for developing Ghidra Python scripts.
- Write a Ghidra Python script to automate analysis.
- Our focus is on script development and not the use of third-party scripts.

This slide describes the objectives of this module.

Extend Ghidra's Functionality with Plugins, Analyzers, Extensions, and Scripts

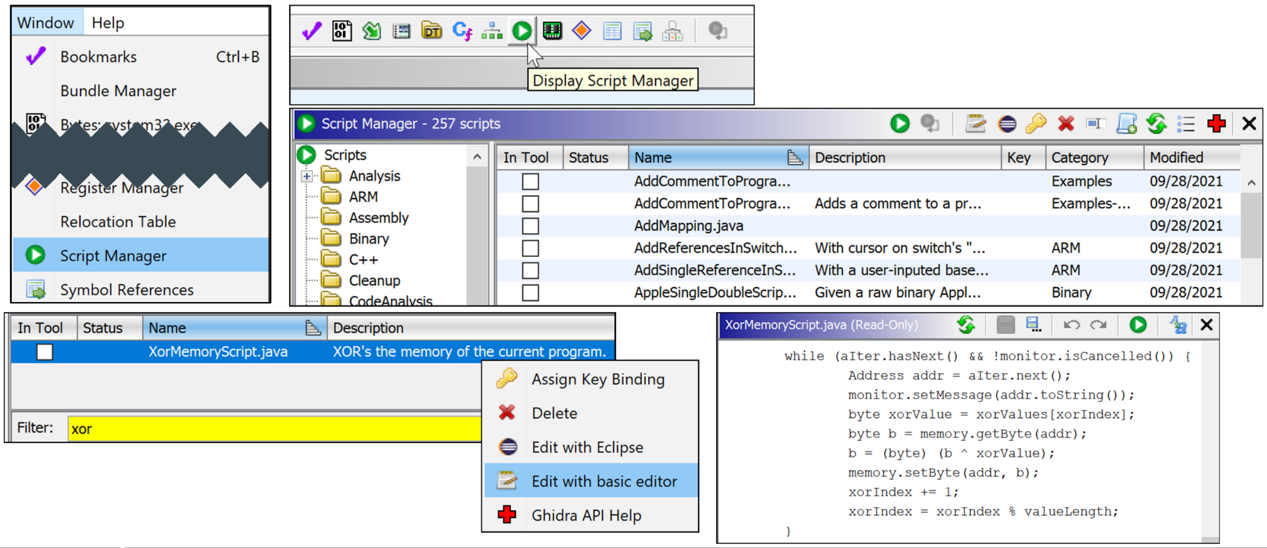
- This course focuses on developing scripts for rapid prototyping.
- Scripts can access disassembly and decompiler output.
- Ghidra supports scripting using both Java and Python—we will continue our focus on Python.
- Python is possible via Jython, which provides complete access to Ghidra's Java API.
- Jython only implements Python 2.7, but we can still accomplish our automation goals despite this shortcoming.

Ghidra can be extended by developing plugins, analyzers, extensions (also referred to as "modules"), and scripts. This module will focus on script development which is relatively lightweight and quick compared to other options mentioned.

Ghidra supports script development using both Java and Python. Due to our focus on Python during the last two modules and the general popularity of the language, it makes sense to build on our existing Python knowledge and use Ghidra's Python scripting capabilities. Python support is provided via Jython, a Java implementation of Python. Jython implements Python 2.7, and there are no public plans for Python 3 support. As a result, any Python development within Ghidra must be supported by Python 2.

Ghidra has hundreds of built-in scripts available to use and review. Although most built-in scripts are written in Java, the API is very similar to that provided via Python. Reading and understanding these scripts is an excellent starting point to understand how to write your own scripts within Ghidra.

Ghidra Includes Hundreds of Functional Built-In Scripts



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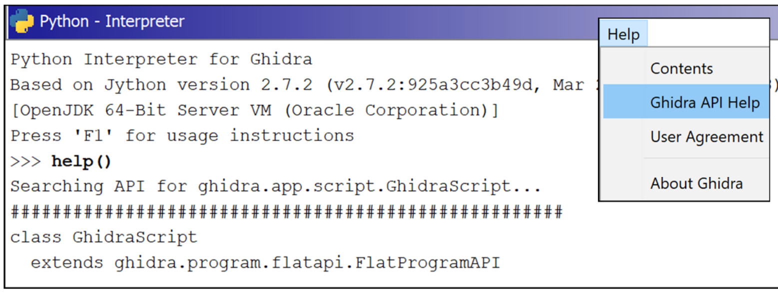
To access Ghidra's Script Manager, you can browse to Window > Script Manager. Alternatively, you can click the green "Play" button located within the toolbar at the top of the Code Browser. The Script Manager contains hundreds of built-in scripts that are ready to use and learn from as we develop our own scripts. These scripts serve as excellent starting points for writing your own scripts. Most provided scripts are written in Java, but as mentioned earlier, Ghidra's scripting APIs are the same regardless of which language you use for script development.

To search for a script, use the Filter field at the bottom of the Script Manager .For example, if we filter by "xor" as shown on this slide, we arrive at a script that performs the XOR operation against each byte in a specified memory location. To view or edit the script, right-click on it and choose "Edit with basic editor". Do not worry if the code in the excerpt on this slide is unclear. We will cover key methods and attributes later in this module.

If you want to try running the scripts and Python commands discussed in the upcoming slides, you will need to load an executable for analysis. For this discussion, we will use system32.exe from Section 2 located at Malware\Section2\system32.zip in your VMs.

Launch the Python Interpreter Via Window > Python

- The Python terminal defaults to an instance of the GhidraScript, which extends the Flat Program API.



- Help is available in the API documentation.
- Also use tab completion in the interpreter, `help()`, `dir()`, and `type()`

The best way to start learning about Python scripting within Ghidra is to dive straight in. To test command and explore various methods, we can use the built-in Python interpreter. You can access the interpreter by browsing to Window > Python from the menu bar.

When typing commands in the Python interpreter, you are operating within an instance of the `GhidraScript` class. This class *extends* the `FlatProgram` api, which means the `GhidraScript` instance has all the methods and properties of the `FlatProgram` API we discussed earlier.

In addition to accessing API documentation using the Firefox shortcuts discussed on the previous slide, you can also browse to Help > Ghidra API help from the menu bar of the Python interpreter.

To learn more about the Ghidra API, use the built-in API help. In addition, take advantage of the Python `help()`, `dir()`, and `type()` functions.

Flat Program API dir() Output

```
>>> dir()
['MAX_REFERENCES_TO', '__builtins__', '__doc__', '__name__', '__package__', 'addEntryPoint', 'addInstructionXref',
[redacted]
'getAnalysisOptionDescriptions', 'getBookmarks', 'getByte', 'getBytes', 'getCategory', 'getCodeUnitFormat',
'getCurrentAnalysisOptionsAndValues', 'getCurrentProgram', 'getDataAfter', 'getDataAt', 'getDataBefore',
'getDataContaining', 'getDataTypes', 'getDefaultLanguage', 'getDemangled', 'getDouble', 'getEOLComment',
'getEOLCommentAsRendered', 'getEquate', 'getEquates', 'getFirstData', 'getFirstFunction', 'getFirstInstruction',
'getFloat', 'getFragment', 'getFunction', 'getFunctionAfter', 'getFunctionAt', 'getFunctionBefore',
'getFunctionContaining', 'getGhidraVersion', 'getGlobalFunctions', 'getInstructionAfter', 'getInstructionAt',
'getInstructionBefore', 'getInstructionContaining', 'getInt', 'getLanguage', 'getLastData', 'getLastFunction',
'getLastInstruction', 'getLong', 'getMemoryBlock', 'getMemoryBlocks', 'getMonitor', 'getNamespace', 'getPlateComment',
'getPlateCommentAsRendered', 'getPostComment', 'getPostCommentAsRendered', 'getPreComment', 'getPreCommentAsRendered',
'getProgramFile', 'getProjectRootFolder', 'getReference', 'getReferencesFrom', 'getReferencesTo', 'getRepeatableComment',
'getRepeatableCommentAsRendered', 'getScriptAnalysisMode', 'getScriptArgs', 'getScriptName', 'getShort', 'getSourceFile',
[redacted]
'setCurrentSelection', 'setDouble', 'setEOLComment', 'setFloat', 'setInt', 'setLong', 'setPlateComment', 'setPostComment',
'setPotentialPropertiesFileLocations', 'setPreComment', 'setPropertiesFile', 'setPropertiesFileLocation',
'setReferencePrimary', 'setRepeatableComment', 'setScriptArgs', 'setServerCredentials', 'setShort', 'setSourceFile',
'setToolStatusMessage', 'show', 'sourceFile', 'start', 'state', 'toAddr', 'toHexString', 'toString', 'writer']
```


Because the built-in Python interpreter defaults to an instance of the `GhidraScript` class, you can view its attributes and methods by typing the `dir()` command. This slide shows an excerpt of available attributes and methods.

Access the Program API with the currentProgram Object

```
>>> help(currentProgram)
Searching API for ghidra.program.database.ProgramDB...
#####################################################
class ProgramDB
  extends ghidra.framework.data.DomainObjectAdapterDB
```

```
...laySpace', 'addSynchronizedDomainObject',
...
...essFactory', 'getAddressMap', 'getAddressSetPropertyMap',
'getBookmarkManager', 'getChangeSet', 'getChangeStatus', 'getChanges', 'getClass', 'getCodeManager', 'getCompiler',
'getCompilerSpec', 'getConsumerList', 'getContentHandler', 'getCreationDate', 'getCurrentTransaction', 'getDBHandle',
'getDataTypeManager', 'getDefaultPointerSize', 'getDescription', 'getDomainFile', 'getEquateTable', 'getExecutableFormat',
'getExecutableMD5', 'getExecutablePath', 'getExecutableSHA256', 'getExternalManager', 'getFunctionManager',
'getGlobalNamespace', 'getImageBase', 'getIntRangeMap', 'getLanguage', 'getLanguageID', 'getListing', 'getLock',
'getMaxAddress', 'getMemory', 'getMetadata', 'getMinAddress', 'getModificationNumber', 'getName', 'getNamespaceManager',
'getOptions', 'getOptionsNames', 'getProgramContext', 'getProgramUserData', 'getRedoName', 'getReferenceManager',
'getRegister', 'getRegisters', 'getRelocationTable', 'getStoredVersion', 'getSymbolTable', 'getSynchronizedDomainObjects',
'getTreeManager', 'getUndoName', 'getUndoStackDepth', 'getUniqueProgramID', 'getUsrPropertyManager', 'globalNamespace',
...
'setExecutableFormat', 'setExecutableMD5', 'setExecutablePath', 'setExecutableSHA256', 'setImageBase', 'setLanguage',
'setName', 'setObjChanged', 'setPropertyChanged', 'setPropertyRangeRemoved', 'setRegisterValuesChanged', 'setTemporary',
'sourceArchiveAdded', 'sourceArchiveChanged', 'startTransaction', 'storedVersion', 'symbolAdded', 'symbolChanged',
'symbolTable', 'synchronizedDomainObjects', 'tagChanged', 'tagCreated', 'temporary', 'toString', 'treeManager', 'undo',
'undoLock', 'undoName', 'undoStackDepth', 'uniqueProgramID', 'unlock', 'usrPropertyManager', 'wait']
```


To access the Program API, refer to the `currentProgram` object. The `currentProgram` object refers to the target program loaded within Ghidra. Type `help(currentProgram)` or `dir(currentProgram)` to view available methods and attributes.

When Scripting within Ghidra, Consider These Types of Content

- Functions:
  - Arguments
  - Return values
  - Function references
- Instructions:
  - Mnemonics
  - Operands
- Addresses:
  - Function location
  - Instruction location
  - Data location
  - Address references
- Comments: Adding notes

To help script an analysis workflow, consider which of the above components are used and in what order.

When performing an analysis workflow, we commonly work with the content listed on this slide. As we attempt to automate an analysis workflow, these are the same components we want to reference. The Ghidra Scripting interface provides access to each of these objects.

Ghidra APIs Provide Methods Associated with Functions

- Flat API:
  - `getFirstFunction():` Returns the first function in the program.
  - `getFunctionContaining(address):` Get the function containing an address.
- Program API:
  - Identify and iterate through all functions:

```
fm = currentProgram.getFunctionManager().getFunctions(True)
for function in fm:
        ep_addr = function.getEntryPoint()
        fn_body = function.getBody()
        fn_name = function.getName()
```


Function analysis is critical to performing effective code analysis. This slide lists examples of methods in both the Flat and Program API that allow us to interact with and learn about functions.

Two helpful functions within the Flat API include:

- `getFirstFunction()` returns the first function in the program. To clarify, the "first" function is the function at the lowest virtual address, not the first function that will be executed.
- `getFunctionContaining()` returns the address of the function containing the address passed to the function.

While the Flat API provides many key methods, it lacks functions to perform some common reverse engineering workflows like reviewing function references. For this, we must use the Program API. The code excerpt at the bottom of this slide demonstrates Program API methods we can use to iterate over function references. Specifically, `currentProgram.getFunctionManager().getFunctions(True)` returns an "iterator" that includes functions within the program. An "iterator" is simply an object with multiple values that we can iterate over.

The for loop in the code excerpt queries each function in the program for key information:

- `getEntryPoint():` Returns the address of the first instruction in the function.
- `getBody():` Returns the set of addresses that comprise the function. You can call `contains()` against the returned value to determine if a specified address is contained within a function.
- `getName():` Returns the name of a function.

For additional detail, search for any of these methods in the API documentation.

Referencing Addresses in a Ghidra Python Script

- Addresses may be passed to a function as an argument or returned from a function after execution.
- `toAddr()`: converts offset (long, int, or string) to an Address object.
- This code iterates through references to an address:

```
decoding_fn = toAddr(0x54a3d0)
fn_refs = getReferencesTo(decoding_fn)

for ref in fn_refs:
        from_addr = ref.getFromAddress()
```


During code analysis, we interact with addresses often. Addresses specify where an instruction, function, or data are located in memory. Addresses are also passed to functions as arguments, and they may be return values. For this reason, it is important we understand how to interact with addresses in a Ghidra Python script.

To convert a value to an address, we use the toAddr() function. This function can take a long (64-bits), int (32-bits), or a string. Examples of acceptable formats include:

toAddr(0x54a3d0)
toAddr("0x54a3d0")
toAddr("54a3d0")

During malware analysis, we often evaluate references to an address, such as the starting address of a function. To accomplish this task, first specify the starting address of a function or obtain the address via the Program API method `getEntryPoint()` shown on the previous slide. Then, use the Flat API method `getReferencesTo()` to return an array of references to the specified address. Finally, use a for loop to iterate through each reference and call `getFromAddress()` to acquire the address of the reference. An example of this code is shown on the slide.

An Address is an instance of the GenericAddress class:

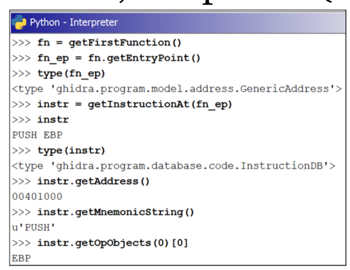
file:///C:/Users/REM/AppData/Local/Ghidra/GhidraAPI_javadoc/10.0.4/api/ghidra/program/model/address/GenericAddress.html

Accessing Instructions in a Ghidra Script

- The Flat API includes several methods that return an instruction:

`getInstructionAfter(Address address)`	Returns the instruction defined after the specified address or null if no instruction exists.
`getInstructionAfter(Instruction instruction)`	Returns the instruction defined after the specified instruction or null if no instruction exists.
`getInstructionAt(Address address)`	Returns the instruction at the specified address or null if no instruction exists.
`getInstructionBefore(Address address)`	Returns the instruction defined before the specified address or null if no instruction exists.
`getInstructionBefore(Instruction instruction)`	Returns the instruction defined before the specified instruction or null if no instruction exists.

- Using an instruction, we can get the address, mnemonic, or operand(s).
  - `getAddress():` Return the instruction address.
  - `getMnemonicString():` Return the mnemonic.
  - `getOpObjects():` Takes the index of the operand and returns an array with the operand value (use `toString()` to convert to a string).



```
Python - Interpreter
>>> fn = getFirstFunction()
>>> fn_ep = fn.getEntryPoint()
>>> type(fn_ep)
<type 'ghidra.program.model.address.GenericAddress'>
>>> instr = getInstructionAt(fn_ep)
>>> instr
PUSH EBP
>>> type(instr)
<type 'ghidra.program.database.code.InstructionDB'>
>>> instr.getAddress()
00401000
>>> instr.getMnemonicString()
u'PUSH'
>>> instr.getOpObjects(0)[0]
EBP
```


This slide discusses methods to acquire an instruction and probe the instruction for its address, mnemonic, or operand(s).

As a reminder, we loaded the file system32.exe into Ghidra for this discussion. This file has the SHA-256 hash eecc969ba17e924093821a7c862da03f8668abe833042b6bd023fbe75fa2e0e8. You can find it in on your VM desktop at Malware\Section2\system32.zip.

Acquiring the address and mnemonic is relatively straightforward, as shown in the example on this slide. Using the method to acquire the operands, however, may be a bit confusing and requires further explanation. The method that returns an instruction's operand is `getOpObjects()`, and the argument passed to it is the index of the operand (i.e., zero for the first operand, one for the second operand). This method returns an array with only one value. Therefore, to obtain the first operand of an instruction stored in the variable "instr", we type `instr.getOpObjects(0)[0]`. Note that the returned operand value is not a string—to convert it to a string, use the `toString()` method. Using the example on this slide, we could acquire the string with the command `instr.getOpObjects(0)[0].toString()`.

For more information on methods related to instructions, search the API documentation for "ghidra.program.database.code.InstructionDB".

Operating on Data at a Specified Address

- `getDataAt(Address)`: Returns data at a specified address.
- `getValue()`: `Returns` the value of the data item.
- Use `try` and `except` clauses to fail gracefully if data is not defined.

Python - Interpreter

```
>>> data = getDataAt(toAddr("411ea0"))
>>> data
unicode u"SOFTWARE\\keys_data\\data"
>>> type(data)
<type 'ghidra.program.database.code.DataDB'>
>>> value = data.getValue()
>>> value
u'SOFTWARE\\keys_data\\data'
>>> type(value)
<type 'unicode'>
```

```
try:
        value = data.getValue()
except:
        print("No defined data at this location")
```


When performing manual code analysis, we often encounter pointers to data. For example, an instruction may have an operand that points to a string. We then double-click on the pointer to view the corresponding data, which may be a string. How can we programmatically perform this same action?

The Ghidra API provides two helpful methods. First, use the Flat API's `getDataAt()` function to return the data at a specified address. Then, to acquire the data content in a format that is easier to work with, call `getValue()` against the previously returned data. In the case that a pointer points to a Unicode string (as shown in the example on this slide), `getValue()` will return the data value as a Unicode string.

Note that if there is no defined data at a specified address, while `getDataAt()` will return successfully, `getValue()` will generate an exception. For that reason, it is recommended to use try and except clauses in Python. If the code in the try clause generates an error, the except clause will be executed, where you can print a detailed message.

Adding Comments and Bookmarks

boolean	`setEOLComment(Address address, java.lang.String comment)`	Sets a EOL comment at the specified address
[redacted]		
boolean	`setPlateComment(Address address, java.lang.String comment)`	Sets a PLATE comment at the specified address
boolean	`setPostComment(Address address, java.lang.String comment)`	Sets a POST comment at the specified address
boolean	`setPreComment(Address address, java.lang.String comment)`	Sets a PRE comment at the specified address

Bookmark	`createBookmark(Address address, java.lang.String category, java.lang.String note)`	Creates a NOTE book mark at the specified address.

During code analysis, we know it is important to document our findings. One way to log observations is to insert comments within the Listing view. An analyst could also use Ghidra's Bookmark feature to add similar notes. The Flat API methods on this slide allow users to add various types of comments or a bookmark.

Renaming Functions

- The Program API's setName() method can rename a specified function:

void	**setName**(java.lang.String name, **SourceType** source)	Set the name of this function.

- This method's second argument specifies a symbolic constant:

Enum Constants

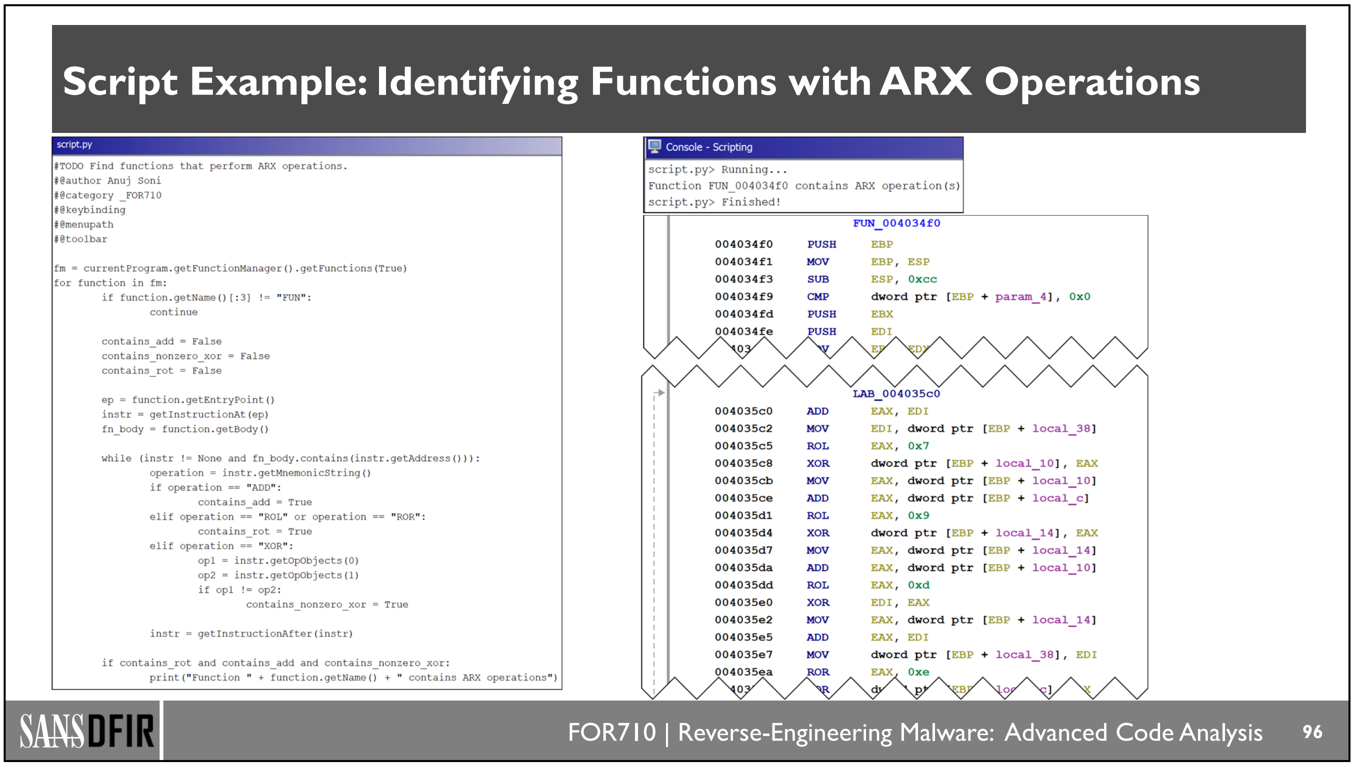
Enum Constant	Description
ANALYSIS	The object's source indicator for an auto analysis.
DEFAULT	The object's source indicator for a default.
IMPORTED	The object's source indicator for an imported.
USER_DEFINED	The object's source indicator for a user defined.

Python - Interpreter

```
>>> fn = getFirstFunction()
>>> fn
FUN_00401000
>>> from ghidra.program.model.symbol import SourceType
>>> fn.setName("first_func", SourceType.USER_DEFINED)
>>> fn
first_func
```


In addition to inserting comments, we also rename functions during code analysis to create more meaningful function names. The Program API's `setName()` method can help with this task. The first argument passed to this method is the new function name, and the second argument is a symbolic constant. Symbolic constant options are shown on the bottom-left of this slide. To find the documentation within your VM, copy and paste this location into your browser within one of the Windows VMs:
file:///C:/Program Files (x86)/Ghidra/docs/GhidraAPI_javadoc/api/ghidra/program/model/symbol/SourceType.html

To reference one of the symbolic constant options, we must import them from ghidra.program.model.symbol.SourceType. The Python statements on the right side of this slide show a sequence of statements that renames the first function in the target program.



This slide discusses an example of a complete Ghidra Python script. This purpose of this script is to identify functions with ARX (i.e., add, rotate, xor) operations. As we discussed in Section 2, functions with ARX operations may implement an algorithm of interest. When this script is run against system32.exe, it identifies FUN_004034f0, and a closer look at this function's code confirms it implements the Salsa symmetric encryption algorithm. In fact, we discussed this same function in Section 2.

To take a closer look at the code on this slide, see the file `section3.3_ghidra_arx.py` in the Malware\Section3 folder in your Windows VMs.

Ghidra's Headless Mode

- In headless mode, you can batch process multiple files.
- Note that to output content to a log file, you must use `println()` instead of `print()` in the Python script.
- Use the format:
  - ```
    "C:\Program Files (x86)\Ghidra\support\analyzeHeadless.bat" <project_location> <project_name> -import <target file> -postScript <full_path_script> -log <process_log> -scriptlog <script_log> -overwrite
    ```


Ghidra provides a headless mode which allows you to control Ghidra via the command line. This may be helpful for processing multiple files without opening each within the GUI. For example, if you are confident in a Python script and its output, you could consider running the script against multiple files using Ghidra's headless mode.

To execute a script in headless mode you must launch analyzeHeadless.bat. This .bat file is located at C:\Program Files (x86)\Ghidra\support\analyzeHeadless.bat

The format of the command line is shown on this slide. Note that the <project location> directory must already exist.

For additional documentation on this feature, copy and paste these locations into Firefox's address bar within the Windows VM:

- file:///C:/Program Files (x86)/Ghidra/docs/GhidraClass/Intermediate/HeadlessAnalyzer.html
- file:///C:/Program%20Files%20(x86)/Ghidra/support/analyzeHeadlessREADME.html

To execute our ARX script on the previous slide, use the command:

"C:\Program Files (x86)\Ghidra\support\analyzeHeadless.bat" projectdir projectname -import system32.exe -postScript C:\Users\REM\ghidra_scripts\script.py -log headlesslog.txt -scriptlog scriptlog.txt -overwrite
    ```

Course Roadmap

- FOR710.1: Code Deobfuscation and Execution
- FOR710.2: Encryption in Malware
- FOR710.3: Automating Malware Analysis
- FOR710.4: Correlating Malware and Building Rules

SECTION 3

- Python for Malware Analysis
  - Lab 3.1: Automating Config Extraction with Python
- Malware Analysis with DBI Frameworks
  - Lab 3.2: Automate Payload Extraction with Frida
- Automating Analysis with Ghidra
  - ***Lab 3.3: Scripting with Ghidra***

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Lab 3.3 Background: Search program.exe for Functions That Perform XOR Operations

```
#@author Anuj Soni
#@category _FOR710
#@keybinding
#@menupath
#@toolbar

from ghidra.program.model.lang import OperandType

fm = currentProgram.getFunctionManager().getFunctions(True)
for function in fm:
        if function.getName()[:3] != "FUN":
                continue
        contains_nonzero_xor = False
        ep = function.getEntryPoint()
        instr = getInstructionAt(ep)
        fn_body = function.getBody()

        while (instr != None and fn_body.contains(instr.getAddress())):
                operation = instr.getMnemonicString()
                if operation == "XOR":
                        op1 = instr.getOpObjects(0)
                        op2 = instr.getOpObjects(1)
                        if op1 != op2 and (instr.getOperandType(0) == OperandType.SCALAR or instr.getOperandType(1) == OperandType.SCALAR):
                                contains_nonzero_xor = True
                instr = getInstructionAfter(instr)

        if contains_nonzero_xor:
                print("Function " + function.getName() + " contains an XOR operation of interest.")
```

Console - Scripting

```
section3.3_ghidra_nonzeroXOR.py> Running...
Function FUN_00408130 contains an XOR operation of interest.
Function FUN_004093f0 contains an XOR operation of interest.
Function FUN_00410950 contains an XOR operation of interest.
Function FUN_00455d30 contains an XOR operation of interest.
Function FUN_0046a1b9 contains an XOR operation of interest.
section3.3_ghidra_nonzeroXOR.py> Finished!
```

```
                  LAB_00409490
00409490  MOV     AL, byte ptr [ESI]
00409492  LEA     ECX=>local_54, [EBP + -0x44]
00409495  XOR     AL, 0x8
00409497  ADD     AL, 0x3
00409499  XOR     AL, 0x54
0040949b  MOVZX   EAX, AL
0040949e  PUSH    EAX
0040949f  CALL    FUN_0040c280
004094a4  INC     ESI
004094a5  CMP     ESI, EDI
004094a7  JNZ     LAB_00409490
```


Earlier in this module, we created a Ghidra Python script to identify functions with add, rotate, and xor (ARX) operations. We could generalize this script and update it to *only* search for xor operations given how frequently this instruction appears in encoding and decoding functions. We might also consider including a check to ensure one xor operand is a scalar (i.e., a number). This is another common occurrence in functions that encode or decode data. A script that includes these updates is called section3.3_ghidra_nonzeroXOR.py, and it is included in the Malware\Section3 folder.

If we run this script against program.exe (located in Malware\Section3), it outputs several functions of interest. This exercise will explore just one of these functions, FUN_004093f0. If we double-click on this function and review its code, we observe the loop shown on this slide, which contains several mathematical operations, including two XORs.

Lab 3.3

Scripting with Ghidra

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Please begin Lab 3.3 now.

Scripting with Ghidra: Module Objectives, Revisited

- ✓Explore how to automate code analysis workflows within Ghidra.
- ✓Use Ghidra's built-in Python interpreter to explore provided APIs.
- ✓Understand best practices for developing Ghidra Python scripts.
- ✓Write a Ghidra Python script to automate analysis.

This slide describes the objectives of the module we just completed.

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