



EECS 499

Introduction to Malware Analysis



UNPACKING FREECELL

project 3

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Basic Executable Analysis

This section contains basic information obtained from a variety of tools and services that helped me form a preliminary about the nature of this binary.

MD5:	E95998D23233476FCC61A1FECA6D02A2
SHA1:	A5847314E89A0B335F583803D29D4BF753EB9174
Created:	Tuesday, November 10, 2015 4:07:28 AM
Size:	82944

VirusTotal Most of the engine hits seemingly came from AV engines that equate a packed binary with malware (names reported like Gen.Packer.PESpin and Pascked.Win32.MNSP.Gen).

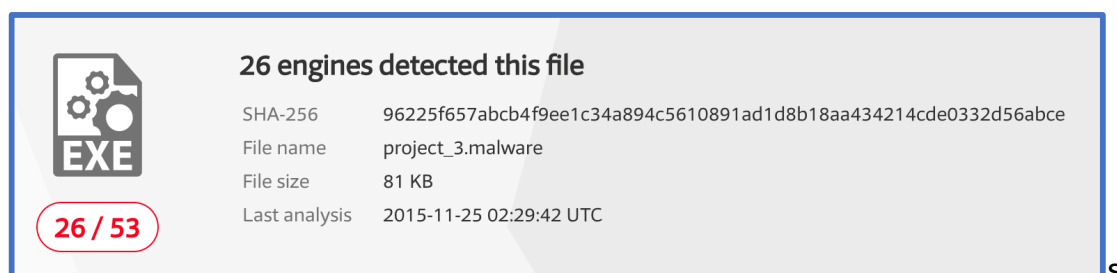


Figure 1 VirusTotal report for the original project_3.malware binary.

PEiD The binary is packed with a version of PESpin ranging from 0.3 to 1.x. Not much could be found about PESpin online except for the programs website and a few manual unpacking tutorials.

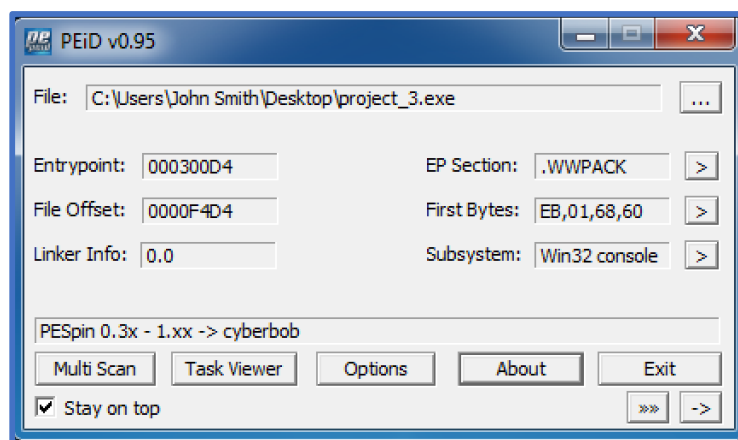


Figure 2 PEiD scan of the original project_3.malware binary.

ProcMon Since the imports for this PE are not evident through static analysis, we must use dynamic analysis tools like Process Monitor to see what libraries the binary needs.

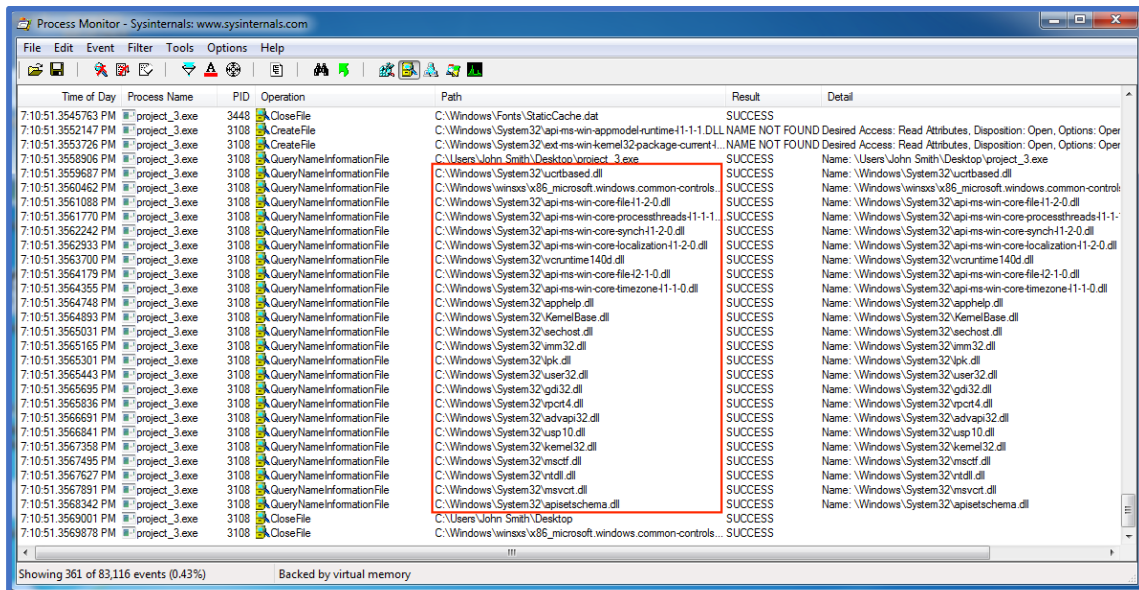


Figure 3 Procmon showing the DLL imports by project_3.malware

When run, the executable simply shows a message box warning the user they need to insert a CD to continue.

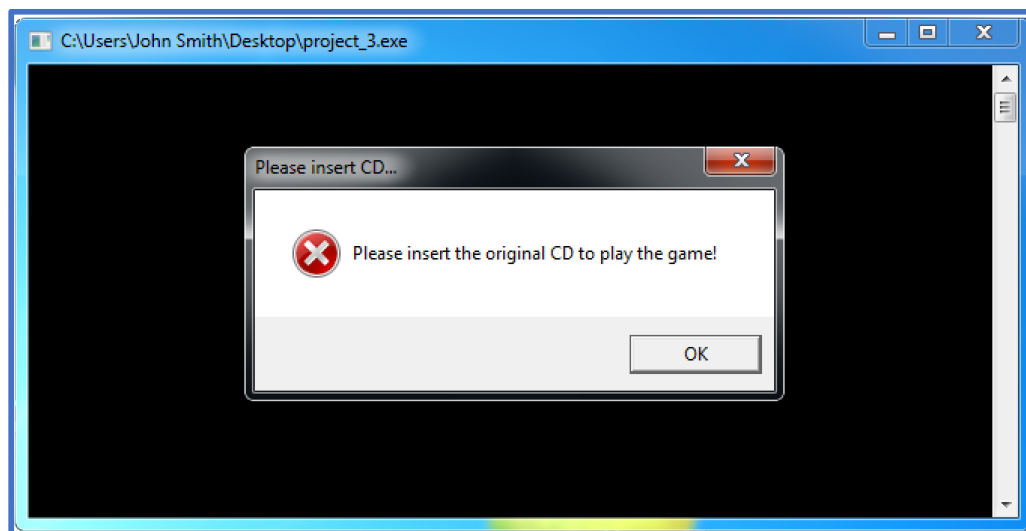


Figure 4 The message that appears when the binary runs.

OllyDbg Observing the executable in OllyDbg is difficult because the program transfers control to threads using *ntdll.ZwContinue*, which switches thread contexts.

Address	Hex dump	Disassembly
77996BD0	6A 00	PUSH 0
77996BDF	51	PUSH ECX
77996BE0	E8 4BE5FFFF	CALL ntdll.ZwContinue
77996BE5	EB 0B	JMP SHORT ntdll.77996BF2

Figure 5 A call to *ntdll.ZwContinue*.

Looking back at ProcMon shows us the malware is actually creating a second process.

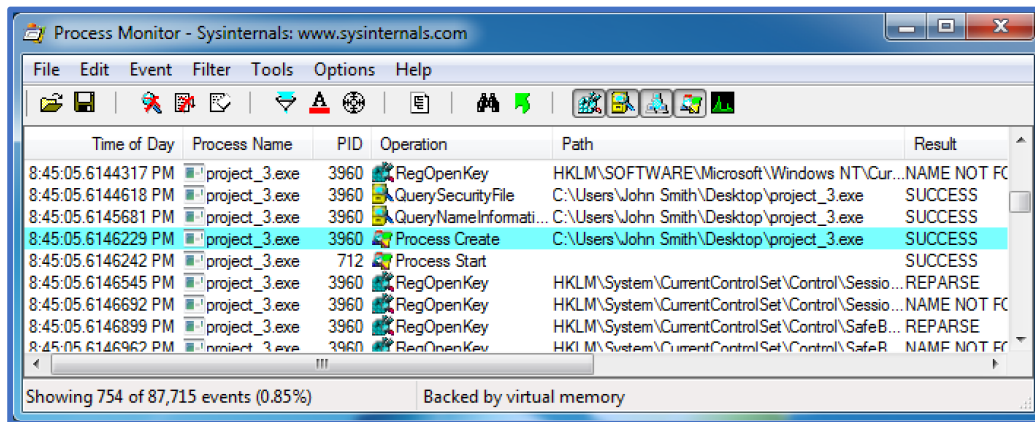


Figure 6 The second process creation.

ProcExp If we observe that child process in Process Explorer we can see the strings loaded in memory, which seem to indicate the program is a game called “FreeCell”.

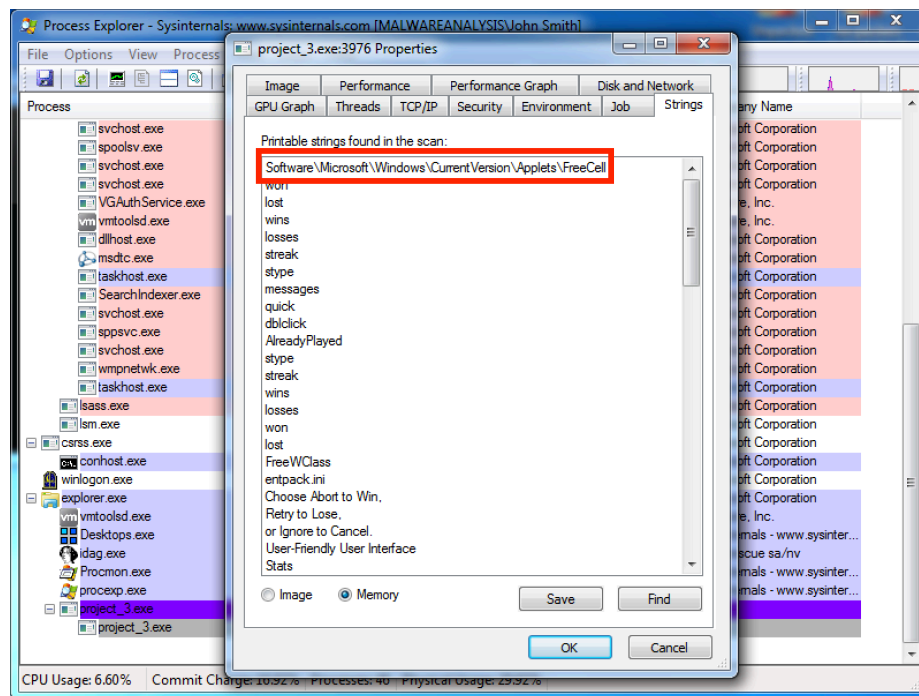


Figure 7 The unpacked strings in memory.

Conclusion It seems as if this binary is a packed version of a game called “FreeCell.” The game (supposedly) cannot be played unless the user has a CD. In order to patch out this CD check, we first need to unpack the executable.

Unpacking

Stage 1 (PESpin)

Because this binary seems to deploy advanced anti-debug and anti-analysis techniques, I decided to use the OllyDbg plugin ScyllaHide, which has numerous anti-anti-debug features (see references section for GitHub page). Particularly useful for this binary was the RunPE dump feature.

RunPE is another packer that tends to modify malware so that the malware duplicates itself in a suspended process shortly after launch. The malware then injects code into the suspended process and resumes it. The ScyllaHide plugin hooks this process creation and dumps the new process into an executable instead of resuming it. PESpin uses a similar technique, so the ScyllaHide feature works for PESpin as well.

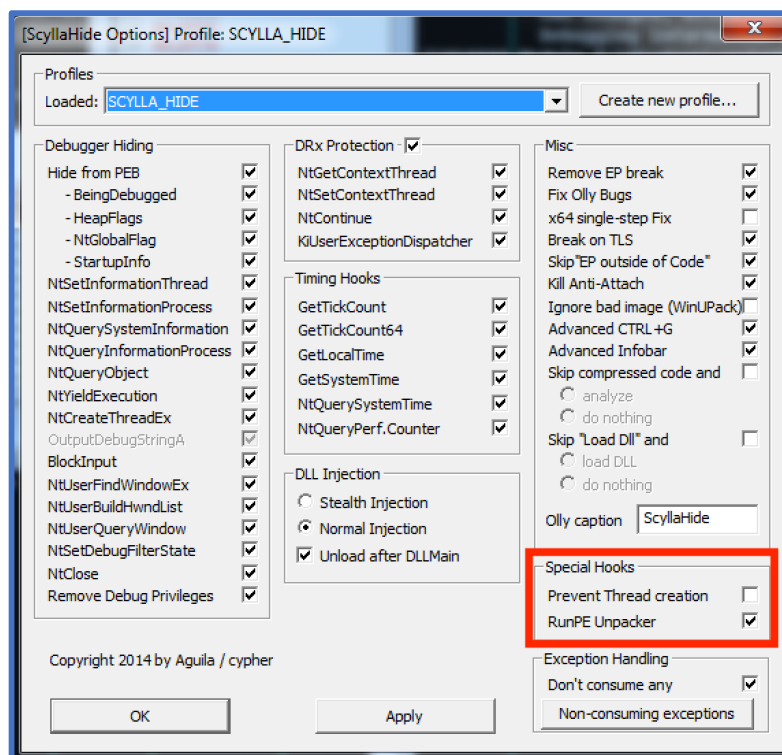


Figure 8 ScyllaHide features.

This option hooks `NtResumeThread`. If the malware creates a new process, ScyllaHide terminates and dumps any newly created process. If you are unpacking malware, enable and try it. Should be only used inside a VM.

A typical RunPE workflow:

1. Create a new process of any target in suspended state.
(Process flag `CREATE_SUSPENDED: 0x00000004`)
2. Replace the original process PE image with a new (malicious) PE image.
This can involve several steps and various windows API functions.
3. Start the process with the windows API function `ResumeThread`(or `NtResumeThread`).

Figure 9 The description of the RunPE Unpacker feature.

Running the executable in OllyDbg after enabling this feature creates the unpacked executable on the Desktop called “Unpacked.” This specific executable successfully loaded the icon from its resources section.



Figure 10 FreeCell icon on Desktop.

If we load the unpacked executable into Dependency Walker, we see that the only imports are *LoadLibraryA* and *GetProcAddress*.

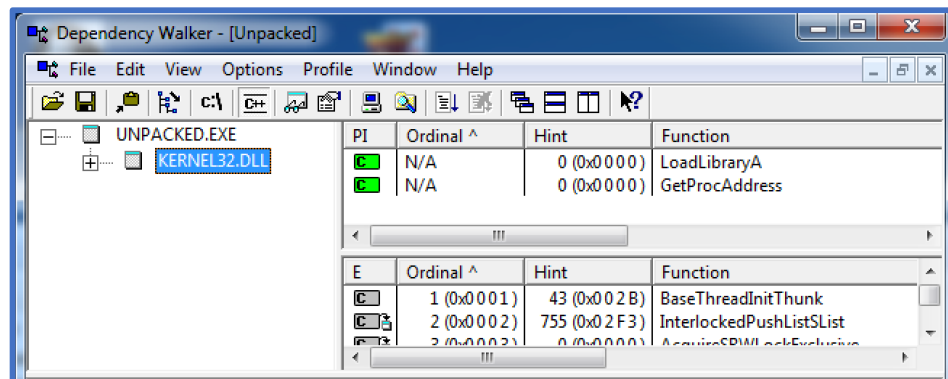


Figure 11 Imports of executable produced by RunPE dump.

This is a strong indicator that the executable is still packed, which likely means the creator ran the binary through more than one packer. PEiD recognizes that the second packer used is YodaProt (Yoda’s Protector).

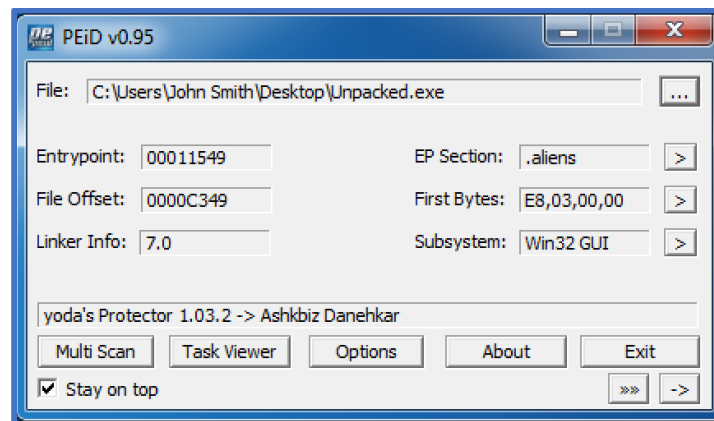


Figure 12 PEiD showing how the RunPE dump executable still is packed.

Stage 2 (YodaProt)

I couldn't find any automatic unpackers for YodaProt online, so manual unpacking is necessary. I ran the program in OllyDbg until the message box appeared asking for the CD. I then used OllyDbg's search feature to search memory for the string "Please insert," knowing that it had to be present in memory for the *MessageBox* function to work.

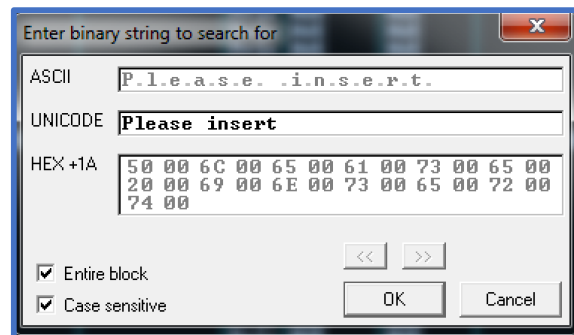


Figure 13 Searching for the MessageBox text in OllyDbg.

Sure enough, I found the string in the .data section of the executable. Shortly below that I found the MessageBox function which contains the CD "check."

Address	Hex	dump	Disassembly	Comment
0100620A	.	00		
0100620B	.	6A 10	PUSH 10	
0100620D	.	68 7D610001	PUSH Unpacked.0100617D	Style = MB_OK!MB_ICONHAND!MB_APPLMODAL
01006212	.	68 A8610001	PUSH Unpacked.010061A8	Title = "Please insert CD..."
01006217	.	6A 00	PUSH 0	Text = "Please insert the original CD to play the game!"
01006219	.	FF15 14110000	CALL [1001114]	hOwner = NULL
0100621F	.	6A 00	PUSH 0	MessageBoxW
01006221	.	FF15 CC110000	CALL [10011CC]	status = 0
01006227	^	E9 0CF2FFFF	JMP Unpacked.01005438	exit
0100622C		00		
0100622D		00		

Figure 14 MessageBox and CD check assembly code.

If we set an execution breakpoint at this line in OllyDbg, it will not register because the section is initially marked as data before the unpacking routine. However, if we mark it as a memory breakpoint, OllyDbg can stop execution at this point, and we can dump the process from memory using OllyDump.

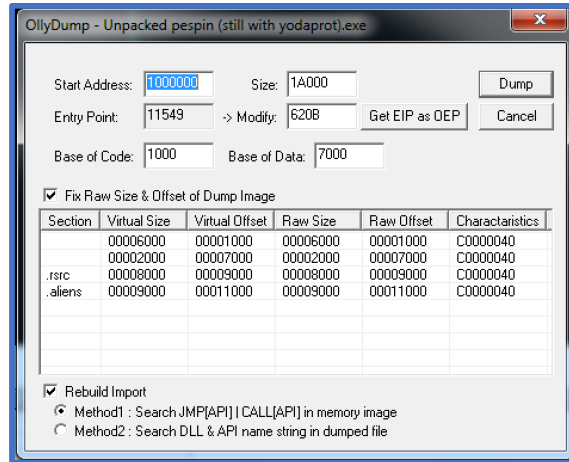


Figure 15 OllyDump settings to dump the executable from the OEP.

We now have the fully unpacked program. We can check this by scanning it with PEiD to see if it detects a packer.

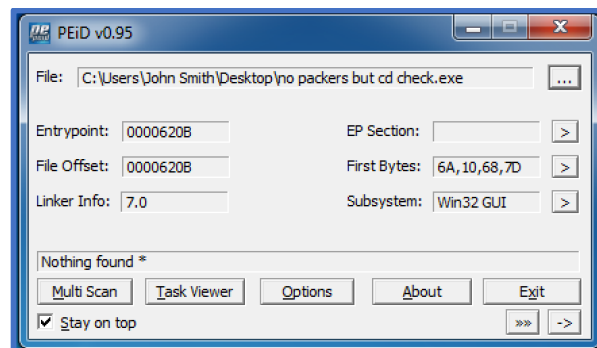


Figure 16 PEiD showing how the executable isn't packed anymore.

The "check" isn't much of a check at all. In fact, all it does is deliver the message to the user, then immediately call *exit(0)*.

Patching

Patching out the CD Check

The CD “check” isn’t much of a check at all. In fact, all it does is deliver the message to the user, then immediately call `exit(0)`. If we simply NOP out the `exit(0)` call, the program will proceed with its normal flow and the game window will pop up.

Address	Hex dump	Disassembly	Comment
0100620A	00	DB 00	
0100620B	5 6A 10	PUSH 10	
0100620D	68 7D610001	PUSH no_packed.0100617D	Style = MB_OK!MB_ICONHAND!MB_APPLMODAL
01006212	68 A8610001	PUSH no_packed.010061A8	Title = "Please insert CD..."
01006217	6A 00	PUSH 0	Text = "Please insert the original CD to play the game!"
01006219	FF15 14110000	CALL [1001114]	hOwner = NULL
0100621F	90	NOP	MessageBoxW
01006220	90	NOP	rstatus
01006221	90	NOP	
01006222	90	NOP	
01006223	90	NOP	
01006224	90	NOP	
01006225	90	NOP	
01006226	90	NOP	
01006227	E9 0CF2FFFF	JMP no_packed.01005438	
0100622C	00	DB 00	
0100622D	00	DB 00	
0100622E	00	DB 00	

Figure 17 The CD check `exit(0)` call is patched out with NOPs.

Additionally, I decided to change the arguments so that `MessageBox` function doesn’t ask the user for a CD, but rather informs them they are playing a patched version of the game.

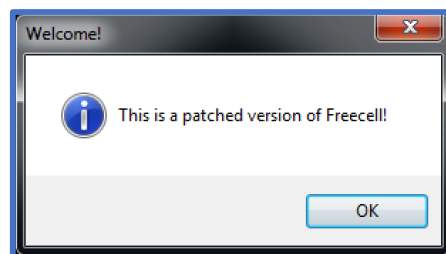


Figure 18 New message box.

Once the user clicks “OK,” the FreeCell game pops up. According to Wikipedia, “FreeCell is a solitaire-based card game played with a 52-card standard deck.”

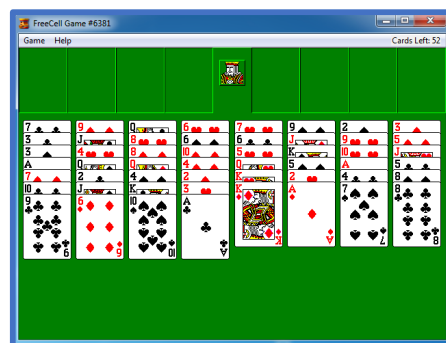


Figure 19 FreeCell game.

Adding an Easter Egg

There is an option to select a random seed for each new game of FreeCell, presumably to change the initial card layout.

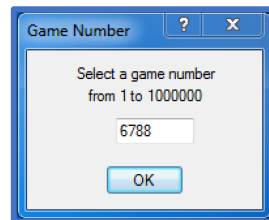


Figure 20 Random seed selection.

I decided to add an easter egg in this section of the game. If the user enters 499 as the random seed, they will receive a special notification. (499 is the EECS department code for an undergraduate, senior, independent study).

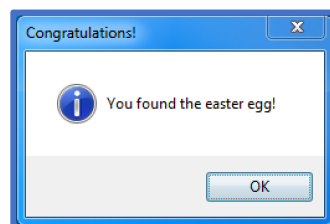


Figure 21 Easter egg message.

In order to achieve this, I had to patch the `cmp` (compare) instruction that checks if the random seed value is less than 10001, which is the max random seed. I patched this instruction to jump to a section of the executable filled with zeroes. The jump destination first checks if the value entered (saved at 0x100834C) is 0x1F3 (499 in decimal). If it is, it calls the `MessageBox` function. If the value is anything but 499, it compares it to 10001 to replace the instruction it patched, and then returns to the instruction right below the patch to resume normal flow.

0100622E	00	DB 00	
01006230	813D 4C830001 F3010000	CMP DWORD PTR [100834C], 1F3	checking if equal to 499
0100623A	74 60	JE SHORT Full_Pat.010062B9	jumping to msgbox
0100623C	813D 4C830001 41420F00	CMP DWORD PTR [100834C], 0F4241	replaced patched command
01006246	E9 70CFFFFFFF	JMP Full_Pat.010081C8	return to regular control flow
0100624B	00	DB 00	
0100624D	00	DB 00	
0100624E	00	DB 00	
0100624F	4300 6F00 6E00 6700 7200 6100	UNICODE "Congratu"	MessageBox title
0100625F	6000 6100 7400 6900 6F00 6E00	UNICODE "lations!"	
0100626F	00	DB 00	
01006270	00	DB 00	
01006271	00	DB 00	
01006272	5900 6F00 7500 2000 6A00 6F00	UNICODE "You Foun"	MessageBox message
01006282	6400 2000 7400 6E00 6500 2000	UNICODE "d the ea"	
01006292	7300 7400 6500 7200 2000 6500	UNICODE "ster egg"	
010062A2	2100 0000	UNICODE "!",0	
010062A6	00	DB 00	
010062A7	00	DB 00	
010062A8	00	DB 00	
010062A9	6A 40	PUSH 40	
010062AB	68 4F620001	PUSH Full_Pat.0100624F	UNICODE "Congratulations!"
010062B0	68 72620001	PUSH Full_Pat.01006272	UNICODE "You found the easter egg!"
010062B5	6A 00	PUSH 0	
010062B7	FF15 14110001	CALL [1001114]	USER32.MessageBoxW
010062B0	E9 06CFFFFFFF	JMP Full_Pat.010081C8	
010062C2	00	DB 00	
010062C3	00	DB 00	

Figure 22 Easter egg assembly code.

Deliverables

Automation Scripts

auto_oeplib.txt – OllyScript script

The first script that a user can use to help automate the process of unpacking this binary is an OllyScript script. OllyScript is a “plugin meant to let you automate OllyDbg by writing scripts in an assembly-like language.”

The following script ensures the user has downloaded ScyllaHide (the anti-anti-debug plugin), and then sets a breakpoint at OEP for the user. After running this script, all the user has to do is run OllyDump to produce the fully-unpacked executable.

```
var breakpoint

MSGYN "Is ScyllaHide installed?"
cmp $RESULT,1
jne no_scylla
jmp start:

start:
rtu                                     // Runs till SEH takes over, which means code section is unpacked
mov breakpoint, 01001000 // Store OEP to hardware breakpoint local variable
bprm breakpoint, 6000
run
cmt eip, "~~~~~ THIS IS OEP ~~~~~"
msg "EIP is now at the OEP! Dump the file using OllyDump's default settings (method 1 for IAT rebuild)"
ret

no_scylla:
msg "Please download it from https://github.com/x64dbg/ScyllaHide"
ret
```

patcher.py – Python 3 script

The second script I wrote is a Python script that takes in a single command line argument, a PE filename. It then reads in this PE, finds the CD check, patches it out, and replaces the message box text informing the user it has been patched out.

```
#!/usr/bin/python

import sys

# REQUIRES: 'replacement' is new bytes
#           'bytes' is the entire byte stream (whole file)
#           'position' is location of original
def patch(replacement, bytes, position):
    first_part = bytes[:position]
    second_part = replacement + bytes[(position+len(replacement)):]
    return first_part + second_part

original =
bytearray(b'\x50\x00\x6C\x00\x65\x00\x61\x00\x73\x00\x65\x00\x20\x00\x69\x00\x6E\x00\x73\x00\x65\x00\x72\x00\x74\x00\x20')

replacement =
bytearray(b'\x57\x00\x65\x00\x6C\x00\x63\x00\x6F\x00\x6D\x00\x65\x00\x21\x00\x00\x00\x73\x00\x65\x00\x72\x00\x74\x00\x20\x00\x43\x00\x44\x00\x2E\x00\x2E\x00\x2E\x00\x00\x00\x00\x00\x54\x00\x68\x00\x69\x00\x73\x00\x20\x00\x69\x00\x73\x00\x20\x00\x61\x00\x20\x00\x70\x00\x61\x00\x74\x00\x63\x00\x68\x00\x65\x00\x64\x00\x20\x00\x76\x00\x65\x00\x72\x00\x73\x00\x69\x00\x6F\x00\x6E\x00\x20\x00\x6F\x00\x66\x00\x20\x00\x46\x00\x72\x00\x65\x00\x65\x00\x63\x00\x65\x00\x6C\x00\x6C\x00\x21\x00\x00\x00\x68\x00\x65\x00\x20\x00\x67\x00\x61\x00\x6D\x00\x65\x00\x21\x00\x00\x00\x00\x00\x6A\x40\x68\x7D\x61\x00\x01\x68\xA8\x61\x00\x01\x6A\x00\xFF\x15\x14\x11\x00\x01\x6A\x00\x90\x90\x90\x90\x90\x90')

bytes = 0
with open(sys.argv[1], "rb") as cd_check_exe:
    bytes = bytearray(cd_check_exe.read())
    bytes = patch(replacement, bytes, bytes.find(original))

with open("patched_cd_check.exe", "wb") as output_exe:
    output_exe.write(bytes)
```

Instructions

The following instructions will allow someone in possession of the original, packed binary to retrieve the fully-unpacked, CD-patched binary.

1. Download and install OllyDbg, and the ScyllaHide, OllyScript, and OllyDump plugins (the latter two are probably installed by default).
2. Open the PE in OllyDbg and check "RunPE dump" in the ScyllaHide options.
3. Run the executable.
4. Reopen OllyDbg with the executable produced by ScyllaHide (should be titled "Unpacked" and placed on the Desktop).
5. Run the OllyScript auto_oep.txt.
6. Open OllyDump and dump the process from memory. Ensure method 1 is selected as the import rebuilding method.
7. Run patcher.py on the executable produced in step 6.

References

<https://github.com/nihilus/ScyllaHide>

<https://sourceforge.net/projects/odbgscript/files/English%20Version/>

<http://www.pespin.com/> (Chrome warns this site is malicious)



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