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# Attacking Interoperability: An **OLE** Edition

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TM

# About Us: Haifei

- Security Researcher at Intel Security (formerly McAfee)
  - Previously: Microsoft, Fortinet
- Work on several questions (for good purposes):
  - 1) How to find vulnerabilities
  - 2) How to exploit them

*At McAfee my interests have been extended to a 3<sup>rd</sup> question:*

  - 3) How to detect the effect by answering the 1<sup>st</sup> and 2<sup>nd</sup>.

*Work on research-backed projects aiming at detecting the most stealthy exploits or zero-days (e.g., the Advanced Exploit Detection System)*
- Presented at BlackHat Europe 2010, REcon 2012, Syscan360 2012, CanSecWest 2011/2014/2015)

# About Us: Bing

- Security Research Manager of IPS security research team at Intel Security Group (formerly McAfee)
- Focus:
  - 1) Advanced vulnerability exploitation and detection
  - 2) Rootkits techniques and detection
  - 3) Firmware security
  - 4) Virtualization security
- Presented at BlackHat EU 2007, Syscan 2007, CanSecWest 2008, Xcon 2006/2007/2009

# Declaration

- Even though we are going to talk about OLE, for Object **Linking** and **Embedding**, we will cover only **Embedding** in this presentation.
  - *Due to the length of our presentation*
  - *This is a really big area*

# Agenda

- What Is OLE?
- Historical Zero Days Involving OLE
- OLE Internals
- Attack Surface
- Conclusion



# What Is OLE?

- Object Linking and Embedding
  - Based on Component Object Model (COM)
- It serves the majority of interoperability on Office/WordPad
  - Working with default/third-party applications to provide rich documentation features to Office/WordPad users

# What Is OLE in Our Lives, Really?

- Embedding a document in another document

To Employees: Benefits Enrollment and Payroll Set-up  
ACTION REQUIRED

PAYROLL SETUP			
WHAT YOU HAVE TO DO	DESCRIPTION	HOW YOU GET IT DONE	DEADLINE
Read	Payroll Schedule, Tips.	 Payroll Information	N/A
A/R	Complete and submit Benefits Summary Enrollment Form	 Summary Enrollment Form.pdf	7/01/2015

- By double-clicking on the “Checklist” document readers will be able to open another document
  - Very convenient for Office users

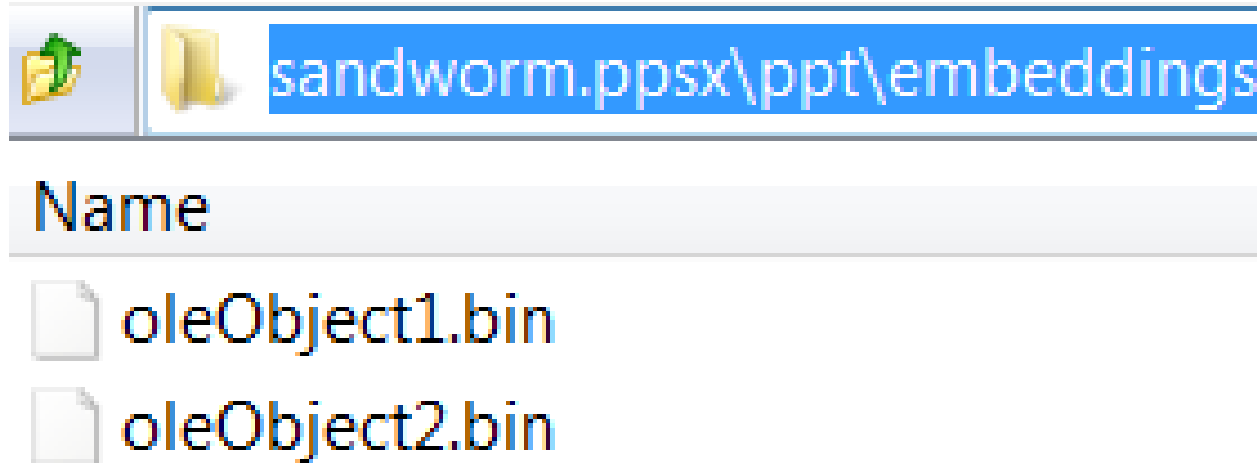
# Agenda

- What Is OLE?
- **Historical Zero Days Involving OLE**
- OLE Internals
- Attack Surface
- Conclusion



# OLE-related Zero Days in History

- Almost all previous critical Office/WordPad zero days actually involve OLE
- **CVE-2014-4114/6352 (a.k.a. “Sandworm” zero day)**
  - Reported in October 2014. Logic fault, really serious
  - 2 OLE objects found in the original sample
  - *Microsoft failed to fix it in the initial patch*



# OLE-related Zero Days in History

## ➤ CVE-2014-1761

- Reported in March 2014 by Google, highly targeted attack
- RTF format-handling fault, not a vulnerability in OLE object, but leverages OLE mechanism to load a non-ASLR module, “MSCOMCTL.OCX”, to bypass ASLR

```
\objh749{\*\objclass MSComctlLib.ImageComboCtl.2}\*\objdata
```

Address	Disassembly	Comment	Registers (FPU)
316FC195	85C0	test eax, eax	EAX 066FB8C0
316FC197	74 0E	je short 316FC1A7	ECX 07941060 ASCII
316FC199	8B08	mov ecx, dword ptr [eax]	EDX 00C02CFC
316FC19B	50	push eax	EBX 00000003
316FC19C	FF51 04	call dword ptr [ecx+4]	ESP 001278D0
316FC19F	8B06	mov eax, dword ptr [esi]	EBP 001278D8
316FC1A1	8B08	mov ecx, dword ptr [eax]	ESI 001278F4
316FC1A3	50	push eax	EDI 00000001
316FC1A4	FF51 10	call dword ptr [ecx+10]	EIP 316FC19C wwlib
316FC1A7	8BC6	mov eax, esi	C 0 ES 0023 32bit
316FC1A9	5E	pop esi	P 1 CS 001B 32bit
316FC1AA	5D	pop ebp	A 0 SS 0023 32bit
316FC1AB	C2 0400	ret 4	7 0 DS 0023 32bit

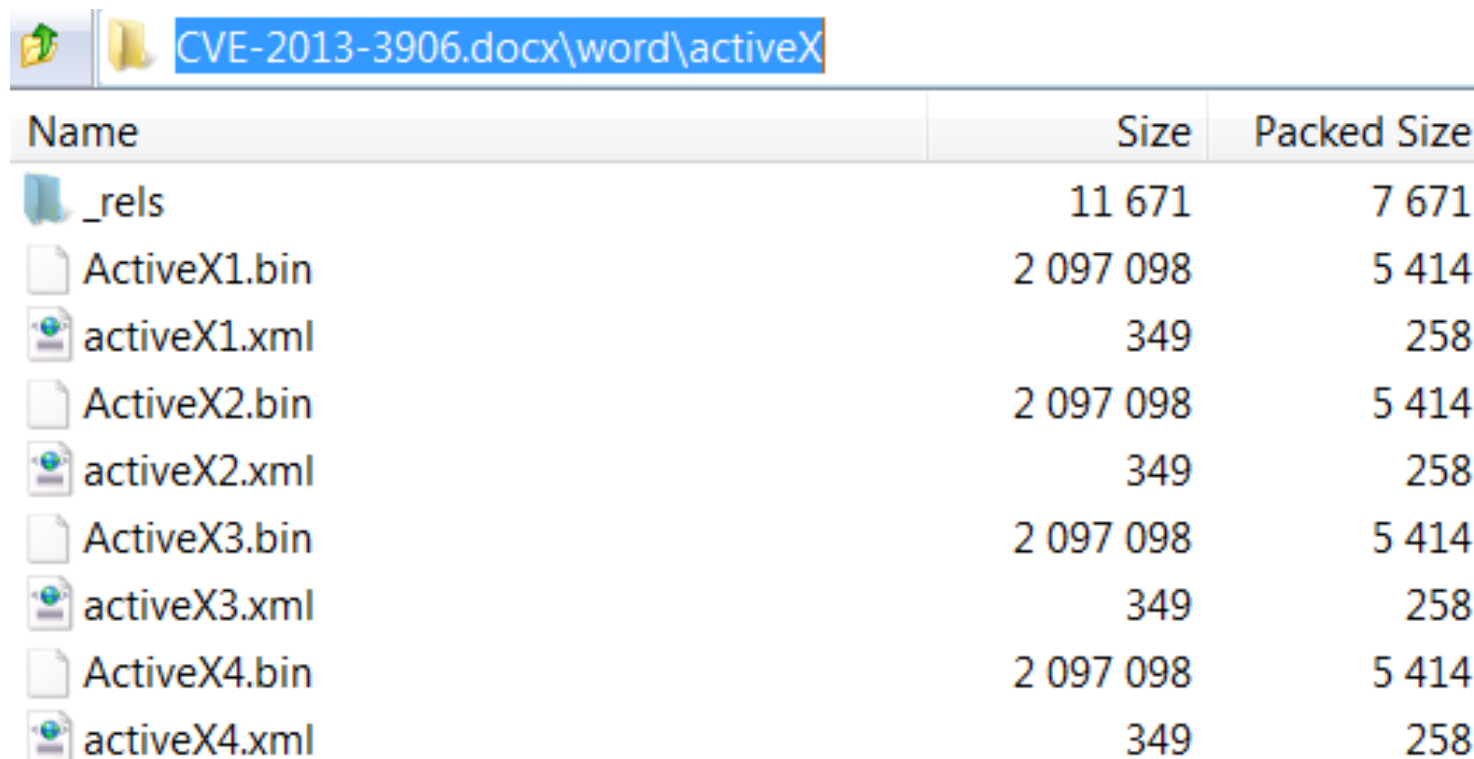
ds:[07941064]=275A48E8 (MSCOMCTL.275A48E8)










Address	Hex	ASCII
07941060	7B 7B 00 00 E8 48 5A 27	<<..鏢Z'培Y'锅X'
07941070	59 59 00 00 5A 5A 00 00	YY..ZZ.. ... ...

# OLE-related Zero Days in History

## ➤ CVE-2013-3906

- Detected and reported by us in October 2013
- Microsoft Graphics Component fault, not a vulnerability in OLE object, but leverages ActiveX/OLE mechanism to perform a heap spray in Office



Name	Size	Packed Size
 _rels	11 671	7 671
 ActiveX1.bin	2 097 098	5 414
 activeX1.xml	349	258
 ActiveX2.bin	2 097 098	5 414
 activeX2.xml	349	258
 ActiveX3.bin	2 097 098	5 414
 activeX3.xml	349	258
 ActiveX4.bin	2 097 098	5 414
 activeX4.xml	349	258

# OLE-related Zero Days in History

- **CVE-2012-0158 / CVE-2010-3333**
  - Years-old vulnerabilities in MSCOMCTL.OCX
  - Classic OLE vulnerabilities
  - Still see samples in the wild today. :P

```
\par{\object\*-\\\objocx{\*\objdata  
010500000200000001B00000004D53436F6D63746C4C69622E4C697374566965774374726C2E32'
```

- Just in: A similar zero-day attack in MSCOMCTL.OCX (**CVE-2015-2424**)
  - Disclosed on July 15 by iSIGHT Partners
  - <http://www.isightpartners.com/2015/07/microsoft-office-zero-day-cve-2015-2424-leveraged-by-tsar-team>

# A Short Summary

- OLE objects not only produce critical zero-day vulnerabilities, but also help greatly on Office/WordPad vulnerability exploitation
  - Loading non-ASLR modules
  - Heap-spray in Office process
  - ...
- Bug class through memory corruption to logic bugs

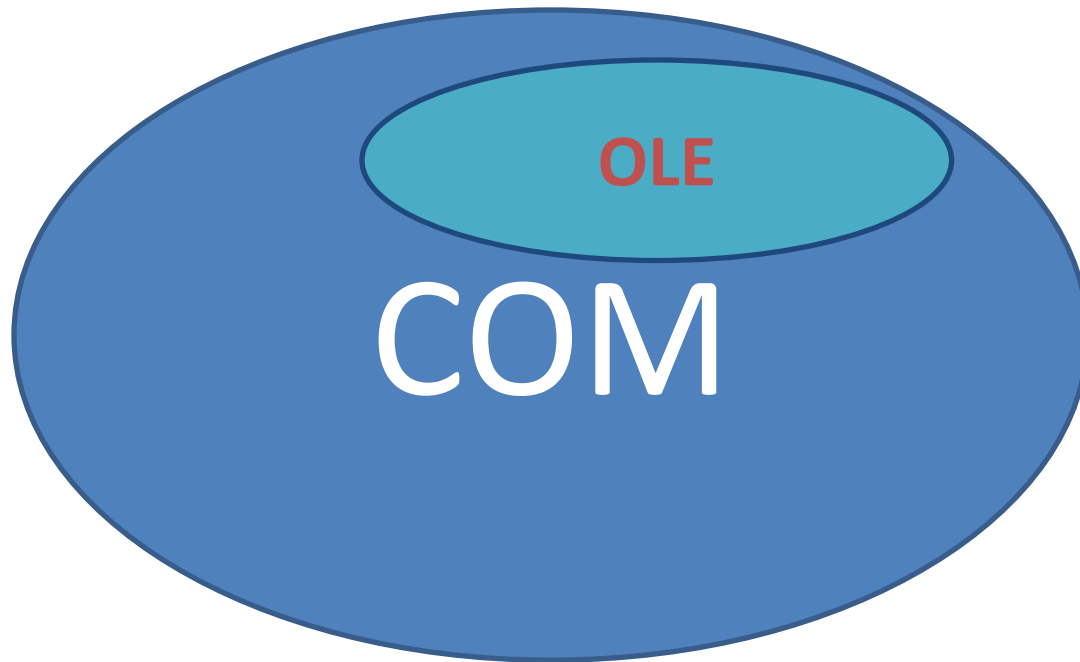
# Agenda

- What Is OLE?
- Historical Zero Days Involving OLE
- **OLE Internals**
- Attack Surface
- Conclusion

# Previous Related Work

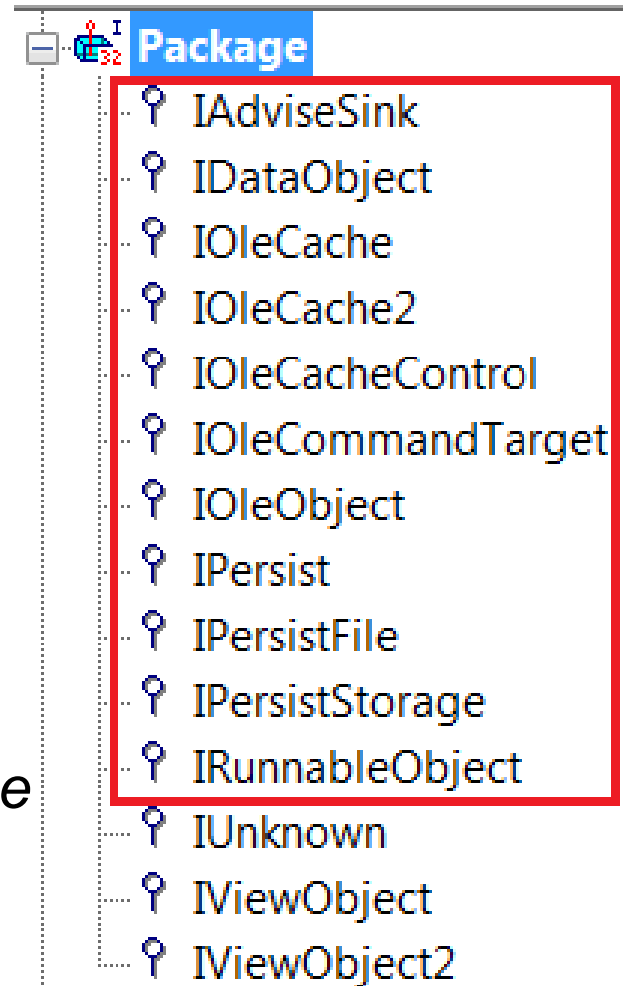
- There is barely no previous research focusing on OLE internals, but we will mention two:
  - “Attacking Interoperability”
    - [http://hustlelabs.com/stuff/bh2009\\_dowd\\_smith\\_dewey.pdf](http://hustlelabs.com/stuff/bh2009_dowd_smith_dewey.pdf)
    - by Mark Dowd, Ryan Smith, and David Dewey in 2009
    - *We named our presentation in honor of the great work done in this paper*
  - Parvez Anwar’s blog site has some work related to Office/OLE
    - <https://www.greyhathacker.net>

# OLE Is a Subset of COM



*OLE objects are COM objects that expose specific Interfaces. Must have:*

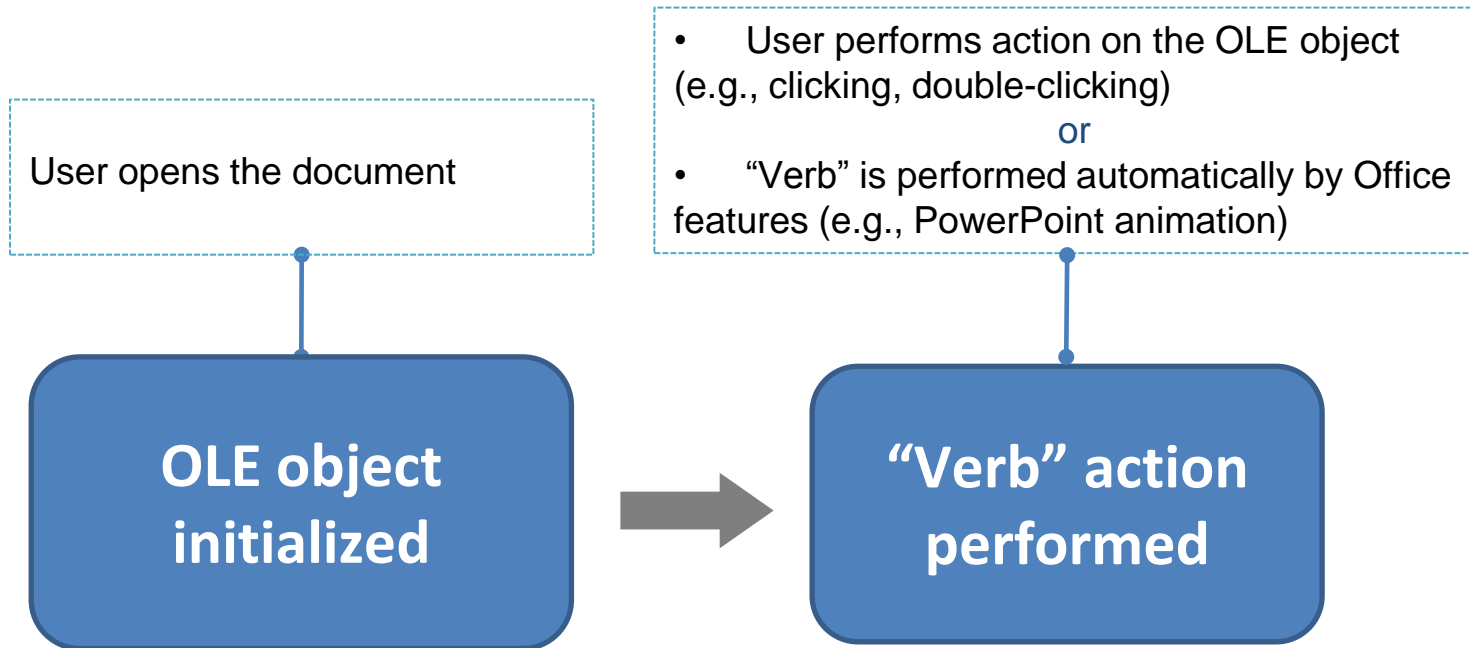
**IPersistStorage**  
**IOleObject**





# OLE Internals

- To explain the OLE internals, first we need to understand what happens when a user opens a document containing OLE objects.



# OLE Initialization

- Initializing/loading an OLE object can be done simply via the **ole32!OleLoad()** API

```
HRESULT OleLoad(  
    _In_ LPSTORAGE           pStg,  
    _In_ REFIID             riid,  
    _In_ LPOLECLIENTSITE   pClientSite,  
    _Out_ LPVOID            *ppvObj  
);
```

The **OleLoad** function performs the following steps:

- If necessary, performs an automatic conversion of the object (see the **OleDoAutoConvert** function).
- Gets the CLSID from the open storage object by calling the **IStorage::Stat** method.
- Calls the **CoCreateInstance** function to create an instance of the handler. If the handler code is not available, the default handler is used (see the **OleCreateDefaultHandler** function).
- Calls the **IOleObject::SetClientSite** method with the *pClientSite* parameter to inform the object of its client site.
- Calls the **QueryInterface** method for the **IPersistStorage** interface. If successful, the **IPersistStorage::Load** method is invoked for the object.
- Queries and returns the interface identified by the *riid* parameter.

# OLE Initialization

- We focus on the two major steps
  - **Step 1: calling CoCreateInstance to initialize the OLE object**
  - **Step 2: calling IPersistStorage to initialize the OLE object's initial status (data)**
- Next let's analyze the two steps in detail

# Step 1: CoCreateInstance

*ole32!wCreateObject+0x101:*

*75b41553 e8b387feff call ole32!CoCreateInstance (75b29d0b)*

*0018de38 0018de98 00000000 00000403 64c0c954*

*0:000> k*

*75b3f2af ole32!wCreateObject+0x101*

*75b3f1d4 ole32!OleLoadWithoutBinding+0x9c*

*632c4eb4 ole32!OleLoad+0x37*

*0:000> db poi(esp)*

*0018de98 02 26 02 00 00 00 00 00-c0 00 00 00 00 00 00 46*

*0:000> db poi(esp+4\*3)*

*64c0c954 12 01 00 00 00 00 00 00-c0 00 00 00 00 00 00*

**CoCreateInstance(CLSID,  
NULL,  
CLSCTX\_INPROC\_SERVER |  
CLSCTX\_INPROC\_HANDLER |  
CLSCTX\_NO\_CODE\_DOWNLOAD,  
IID(IOleObject))**

# Where Does CLSID Come From?

- The CLSID comes from the document, indicating which OLE object the user wants to initialize
- Because Office/WordPad supports a couple of document file types, locating the CLSID varies
  - Office Open-XML format (.docx, .xlsx, .pptx, .ppsx, etc)
  - RTF (.rtf)
  - Office Binary format (.doc, .xls, .ppt, pps, etc)
  - Office even supports HTML format
- We are going to give examples in the Open-XML format and RTF

# CLSID in Open-XML Format

- For Open-XML Format, the CLSID is read from the **“OLESS”** binary data file

sandworm.ppsx\ppt\embeddings		00000440	16 00 05 00 FF FF FF FF FF FF FF FF 01 00 00 00
Name		00000450	02 26 02 00 00 00 00 00 c0 00 00 00 00 00 00 46
oleObject1.bin		00000460	00 00 00 00 00 00 00 00 00 00 00 00 00 F0 75 FD 41

oleObject2.bin

DirectoryEntries[4]		0x00000400	0x00000200	List<OLESSDirectoryEntry>
OLESSDirectoryEntry[0]	\Root Entry	0x00000400	0x00000080	OLESSDirectoryEntry
EleName	Root Entry ...	0x00000400	0x00000040	DataItem_UnicodeString
CbEleName	0x16	0x00000440	0x00000002	DataItem_UInt16
Type	0x5	0x00000442	0x00000001	DataItem_UInt8
TbyFlags	0x0	0x00000443	0x00000001	DataItem_UInt8
sidLeft	0xFFFFFFFF	0x00000444	0x00000004	DataItem_UInt32
sidRight	0xFFFFFFFF	0x00000448	0x00000004	DataItem_UInt32
sidChild	0x1	0x0000044c	0x00000004	DataItem_UInt32
clsidThis		0x00000450	0x00000010	CLSID

# CLSID in RTF

- For RTF, it uses the *outdated* OLE 1.0 format to define an OLE object
  - <https://msdn.microsoft.com/en-us/library/dd942402.aspx>
- Specifying the CLSID is done via specifying the corresponding **ProgID**, in “\objdata” RTF control word\*
  - ProgID will be “translated” to CLSID at runtime via *CLSIDFromProgID*

```
{\rtf1{\object\objocx{\*\objdata  
01050000 //OLEVersion  
02000000 //FormatID, EmbeddedObject
```

```
08000000  
5061636b61676500 //ProgID "Package"
```

```
00000000  
00000000  
D4290000
```

*\*If the ProgID is invalid, and the following native data follows the OLESS format, the CLSID will be read from the OLESS native data*

# Step 2: IPersistStorage::Load

ole32!wCreateObject+0x1f9:

75b3eb41 ff5118 call dword ptr [ecx+18h]

ds:0023:6fb614a8={packager!CPackage::Load (6fb66171)}

0:000> k

75b3f2af ole32!wCreateObject+0x1f9

75b3f1d4 ole32!OleLoadWithoutBinding+0x9c

5c0e4eb4 ole32!OleLoad+0x37

- The container calls the “Load()” method on the OLE object’s IPersistStorage interface to initialize its initial status

```
; __int32 __stdcall CPackage::Load(CPackage *this, LPSTORAGE pStg)
?Load@CPackage@@UAGJPAUIStorage@@@Z proc near
```

```
var_1C= dword ptr -1Ch
NumberOfBytesWritten= dword ptr -18h
pclsid= CLSID ptr -14h
var_4= dword ptr -4
this= dword ptr 8
pStg= dword ptr 0Ch
```

```
mov     edi, edi
push   ebp
mov     ebp, esp
sub     esp, 1Ch
```



# Step 2: IPersistStorage::Load

- [https://msdn.microsoft.com/en-us/library/windows/desktop/ms679731\(v=vs.85\).aspx](https://msdn.microsoft.com/en-us/library/windows/desktop/ms679731(v=vs.85).aspx)
- IID: 0000010a-0000-0000-C000-000000000046

Method	Description
HandsOffStorage	Instructs the object to release all storage objects that have been passed to it by its container and to enter HandsOff mode.
InitNew	Initializes a new storage object.
IsDirty	Determines whether an object has changed since it was last saved to its current storage.
Load	Loads an object from its existing storage.
Save	Saves an object, and any nested objects that it contains, into the specified storage object. The object enters NoScribble mode.
SaveCompleted	Notifies the object that it can write to its storage object.

```
HRESULT Load(  
    [in] IStorage *pStg  
);
```

*Load the initial “status” for the OLE object when it’s being initialized*

# Storage Data

- It really depends on the OLE object for handling the IStorage - loading its initial status
  - As the code for implementing the IPersistStorage interface sits in the OLE provider (OLE object)
- The **Storage Data** (represented in the “IStorage” parameter) is stored in document file
  - Like the “**CLSID**” field, it’s also from the document file (which the attacker supplies)
  - But there are differences
    - OLE container (Office/WordPad) reads the CLSID in order to instantiate the OLE object
    - OLE container reads the Storage Data and passes it to the OLE object, which is responsible for processing the data

# Storage Data in Office Open-XML

- Represented in **OLESS data file**
- The following example shows the Storage Data for Flash Player OLE object
  - CLSID: D27CDB6E-AE6D-11CF-96B8-444553540000
  - Read Storage Data from **OLESS data file** (oleObject1.bin)
  - Read from the “Contents” section

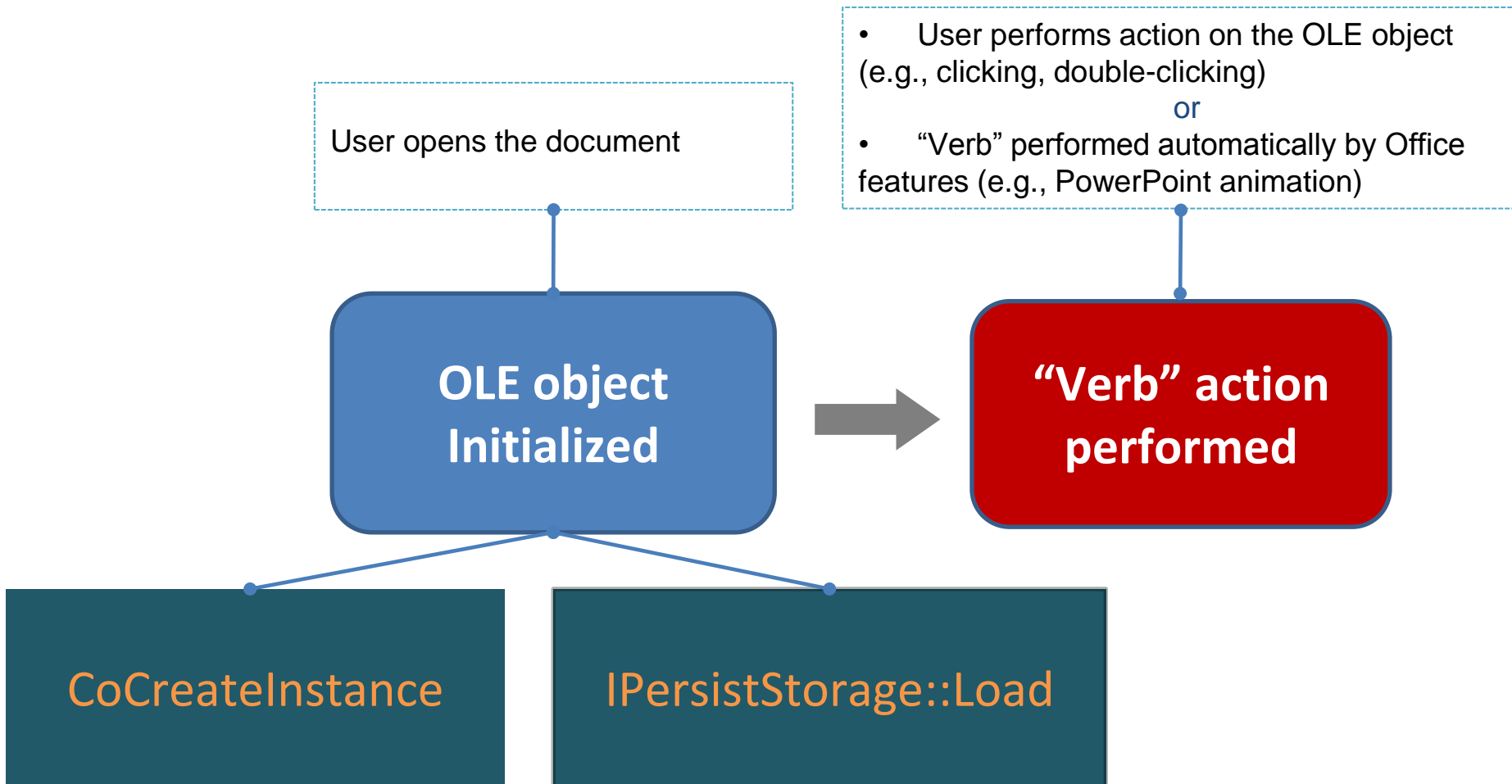
The screenshot shows a hex editor window for the file 'oleObject1.bin'. The 'Contents' section is selected, and the data is displayed in hexadecimal and ASCII. The ASCII column shows the text 'fUfU...EWS...'. The 'EWS' part is highlighted in blue.

Address	Hex	ASCII
0x00000000	6655 6655 0701 0000 4657 5306 0701 0000	fUfU...EWS...
0x00000010	7800 055F 0000 0FA0 0000 0C01 0043 02FF	x.._.....C..
0x00000020	FFFF 3F03 E300 0000 8870 0009 0073 656E	..?.....p...sen
0x00000030	645F 7661 7200 6964 0031 3337 3300 504F	d_var.id.1373.PO



# A Short Break

- We have explained the two key steps in **OLE Initialization**
- Next, let's take a look at the **“Verb” action**



# OLE “Verb” Action

- In essence, performing “verb” action is just calling the **IOleObject::DoVerb** on the OLE object
- IOleObject
  - [https://msdn.microsoft.com/en-us/library/windows/desktop/dd542709\(v=vs.85\).aspx](https://msdn.microsoft.com/en-us/library/windows/desktop/dd542709(v=vs.85).aspx)
  - IID: **00000112-0000-0000-C000-000000000046**
  - 24 methods on this Interface
- There are a few parameters for this **IOleObject::DoVerb** method, but we need to focus only on the first one: the “iVerb,” which under certain scenarios can be controlled by the attacker
  - For example, via PowerPoint Show files (.ppsx, .pps)

# IOleObject::DoVerb

*packager!CPackage::DoVerb:*

```
731e580c 8bff          mov     edi,edi
```

```
0:000> dd esp
```

```
0031c89c 660651c6 0054ec80 FFFFFFFFD 00000000
```

HRESULT DoVerb(

[in] LONG	iVerb,
[in] LPMSG	lpmsg,
[in] IOleClientSite	*pActiveS
[in] LONG	lindex,
[in] HWND	hwndParen
[in] LPCRECT	lprcPosRe

- <p:cmd type="verb" cmd="-3">

- <p:cBhvr>

- <p:cTn id="10" dur="1000" fill="hold">

- <p:stCondLst>

<p:cond delay="0"/>

</p:stCondLst>

</p:cTn>

- <p:tgtEl>

<p:spTgt spid="4"/>

</p:tgtEl>

</p:cBhvr>

</p:cmd>

# Agenda

- What Is OLE?
- Historical Zero Days Involving OLE
- OLE Internals
- **Attack Surface**
- Conclusion



# Attack Surface via Document

- So, what may an attacker possibly perform in a document-based attack via OLE?
- We need to understand what data an attacker may supply from documents
  - Is the attacker able to supply the **CLSID** for **CoCreateInstance** during **OLE Initialization**?
    - Answer: **Yes** (explained)
  - Is the attacker able to supply the **Storage** used in **IPersistStorage::Load()** during **OLE Initialization**?
    - Answer: **Yes** (explained)
  - Is the attacker able to supply the “**verb**” id during OLE “**Verb**” Action?
    - Answer: **Yes** (explained)

# Attack I - IPersistStorage::Load

- It's the most obvious one
  - You want to parse some data; I give you the crafted data
  - Sometimes it will result in memory corruptions; sometimes it may be a logic bug
- In fact, most of the previously disclosed OLE vulnerabilities were actually in the `IPersistStorage::Load()` function
- Let's give some examples

# CVE-2012-0158

- Lots of previous analysis has shown this, in MSCOMCTL.OCX

```
mov     ecx, [ebx]
push   esi
push   edi
push   eax
push   ebx
call   dword ptr [ecx+0Ch] ; read the large length 0x8282
mov     esi, eax
test   esi, esi
jl     short loc_275C87EF
```

```
mov     esi, [ebp+lpMem] ; controlled data
mov     ecx, edi        ; 0x8282
mov     edi, [ebp+arg_0] ; stack parameter
mov     eax, ecx
shr     ecx, 2
rep movsd                ; **stack-based overflow!**
mov     ecx, eax
```

- But, where does the routine really come from?

# CVE-2012-0158

➤ Tracing back, we arrive here

```
.text:276008D9 sub_276008D9 proc near ; DATA XREF: .text:275903E0fo
.text:276008D9 ; .text:275906D8fo ...
.text:276008D9
.text:276008D9 arg_0 = dword ptr 8
.text:276008D9 arg_4 = dword ptr 0Ch
.text:276008D9
.text:276008D9 push ebp
.text:276008DA mov ebp, esp
.text:276008DC mov eax, [ebp+arg_4]
.text:276008DF lea edx, [ebp+arg_4]
.text:276008E2 push edx
.text:276008E3 push 0
.text:276008E5 mov ecx, [eax]
.text:276008E7 push 10h
.text:276008E9 push 0
.text:276008EB push offset aContents ; "Contents"
.text:276008F0 push eax
.text:276008F1 call dword ptr [ecx+10h] ; opening the stream named "CONTENTS"
.text:276008F4 test eax, eax
.text:276008F6 jl short loc_27600916
.text:276008F8 mov eax, [ebp+arg_0]
.text:276008FB push esi
.text:276008FC push [ebp+arg_4]
.text:276008FF add eax, 0FFFFFFCh
.text:27600902 mov ecx, [eax]
.text:27600904 push eax
.text:27600905 call dword ptr [ecx+14h] ; call to 275B66DE
```

➤ What is the function sub\_276008D9 really?

# CVE-2012-0158

- After some REing, we realize this is exactly the “IPersistStorage::Load” method

```
.text:275906C0 IPersistStorage_utable dd offset IPersistStorage__QueryInterface
.text:275906C0                                     ; DATA XREF: sub_27586000
.text:275906C0                                     ; sub_2759453E+50↓o
.text:275906C4                                     dd offset IPersistStorage__AddRef
.text:275906C8                                     dd offset IPersistStorage__Release
.text:275906CC                                     dd offset IPersistStorage__GetRunningClass
.text:275906D0                                     dd offset IPersistStorage__IsDirty
.text:275906D4                                     dd offset IPersistStorage__InitNew
.text:275906D8                                     dd offset IPersistStorage__Load ; 0x276008D9
.text:275906DC                                     dd offset IPersistStorage__Save
.text:275906E0                                     dd offset IPersistStorage__SaveCompleted
.text:275906E4                                     dd offset IPersistStorage__HandsOffStorage
```

- Indeed, the stack-based overflow exists in the IPersistStorage::Load method

# “Package” Temp File Dropping

- Reported in McAfee Labs blog in July 2014
  - <https://blogs.mcafee.com/mcafee-labs/dropping-files-temp-folder-raises-security-concerns>
  - Demo: <http://justhaifei1.blogspot.com/2014/08/demonstration-of-windowsoffice-insecure.html>
  - **Still unpatched!**
  - Recently, James Forshaw leveraged the “feature” in the exploitation of an NTLM Reflection EoP vulnerability he discovered: <https://code.google.com/p/google-security-research/issues/detail?id=325>
- The issue also exists in the “**IPersistStorage::Load**” function

# “Package” Temp File Dropping

0:000> r

packager!CPackage::EmbedReadFromStream+0x2c6:

733c404d call packager!CopyStreamToFile (733c6974)

0:000> du poi(esp+4)

04fdc008 "C:\Users\ADMINI~1\AppData\Local\"

04fdc048 "Temp\dwmapi.dll"

0:000> k

733c4aaa packager!CPackage::EmbedReadFromStream+0x2c6

733c627e packager!CPackage::PackageReadFromStream+0x6b

7749eb44 packager!**CPackage::Load**+0x10d

# Attack II: IOleObject::DoVerb

- This is the “iVerb” param for the **IOleObject::DoVerb**

```
HRESULT DoVerb(  
    [in] LONG          iVerb,  
    [in] LPMSG        lpmsg,  
    [in] IOleClientSite *pActiveSite,  
    [in] LONG         lindex,  
    [in] HWND         hwndParent,  
    [in] LPCRECT      lprcPosRect  
);
```

- The value of the “iVerb” can be defined in some place the attacker can control. For example: PowerPoint

```
Show) - <p:cmd type="verb" cmd="-3">  
    - <p:cBhvr>  
        - <p:cTn id="10" dur="1000" fill="hold">  
            - <p:stCondLst>  
                <p:cond delay="0"/>  
            </p:stCondLst>  
        </p:cTn>  
    - <p:tgtEl>  
        <p:spTgt spid="4"/>  
    </p:tgtEl>  
    </p:cBhvr>  
</p:cmd>
```



# Attack II: IOleObject::DoVerb

- The attacker can supply the “iVerb” value and call the “IOleObject::DoVerb” method automatically
  - For example, via the PowerPoint Show “Animations” feature
- Different values will result in different actions. For example:
  - You give value 0, it performs predefined action 0, maybe opening the object
  - You give value -1, it performs predefined action -1, maybe doing something else

# Attack II: IOleObject::DoVerb

- OLE objects can choose not to implement their own `IOleObject` but use the default/standard interface
  - Thus resulting in some standard “verb” actions
  - See next
- However, there are also a number of OLE objects that chose to implement their own `IOleObject`
  - An action the developer implemented but that may be abused by bad guys
  - Usually logic issues

# Standard “Verb” Actions

- [https://msdn.microsoft.com/en-us/library/windows/hardware/z326sbae\(v=vs.71\).aspx](https://msdn.microsoft.com/en-us/library/windows/hardware/z326sbae(v=vs.71).aspx)

Value	Action
0	The default action for the object.
-1	Activates the object for editing. If the application that created the object supports in-place activation, the object is activated within the OLE container control.
-2	Opens the object in a separate application window. If the application that created the object supports in-place activation, the object is activated in its own window.
-3	For embedded objects, hides the application that created the object.
-4	If the object supports in-place activation, activates the object for in-place activation and shows any user interface tools. If the object doesn't support in-place activation, the object doesn't activate, and an error occurs.
-5	If the user moves the focus to the OLE container control, creates a window for the object and prepares the object to be edited. An error occurs if the object doesn't support activation on a single mouse click.
-6	Used when the object is activated for editing to discard all record of changes that the object's application can undo.

# The Sandworm Zero Day

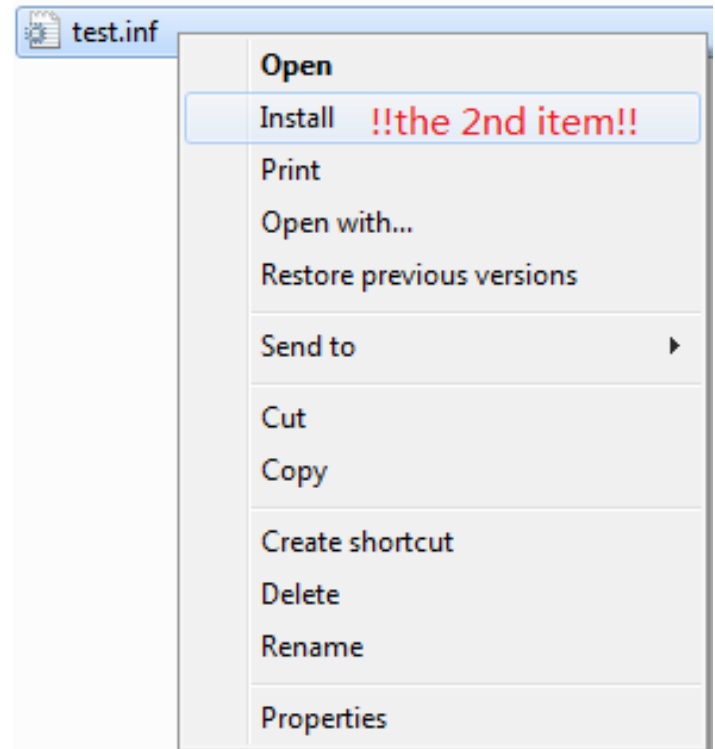
- The “Sandworm” zero-day attack (CVE-2014-4114) was the **first ever** exploit targeting this “**IOleObject::DoVerb**” vector

```
.text:02FA1500 ; const CPackage::~`vftable'{for `IOleObject'}
.text:02FA1500 ??_7CPackage@@6BIOleObject@@ dd offset ?QueryInterface@CPackage@@W7AGJABU_GUID@@PAPAX@Z
.text:02FA1500 ; DATA XREF: CPackage::~~CPackage(void)+13↓o
.text:02FA1500 ; CPackage::CPackage(void)+33↓o
.text:02FA1500 ; [thunk]:CPackage::QueryInterface`adjustor{8}' (_GUID const &,void)
.text:02FA1504 dd offset ?AddRef@CPackage@@W7AGKXZ ; [thunk]:CPackage::AddRef`adjustor{8}' (void)
.text:02FA1508 dd offset ?Release@CPackage@@W7AGKXZ ; [thunk]:CPackage::Release`adjustor{8}' (void)
.text:02FA150C dd offset ?SetClientSite@CPackage@@UAGJPAUIOleClientSite@@@Z ; CPackage::SetClientSite(IOleClientSite *)
.text:02FA1510 dd offset ?GetClientSite@CPackage@@UAGJPAUIOleClientSite@@@Z ; CPackage::GetClientSite(IOleClientSite *)
.text:02FA1514 dd offset ?SetHostNames@CPackage@@UAGJPBG@Z ; CPackage::SetHostNames(ushort const *,ushort const *)
.text:02FA1518 dd offset ?Close@CPackage@@UAGJK@Z ; CPackage::Close(ulong)
.text:02FA151C dd offset ?Save@CPackage@@UAGJPBG@Z ; CPackage::Save(ushort const *,int)
.text:02FA1520 dd offset ?InitFromData@CPackage@@UAGJPAUIDataObject@@HK@Z ; CPackage::InitFromData(IDataObject *)
.text:02FA1524 dd offset ?InitFromData@CPackage@@UAGJPAUIDataObject@@HK@Z ; CPackage::InitFromData(IDataObject *)
.text:02FA1528 dd offset ?GetClipboardData@CPackage@@UAGJKPAPAUIDataObject@@@Z ; CPackage::GetClipboardData(IDataObject *)
.text:02FA152C dd offset ?DoVerb@CPackage@@UAGJPAUtagMSG@@PAUIOleClientSite@@JPAUHWND_@PBUtagRECT@@@Z
.text:02FA1530 dd offset ?EnumVerbs@CPackage@@UAGJPAUIEnumOLEVERB@@@Z ; CPackage::EnumVerbs(IEnumOLEVERB *)
.text:02FA1534 dd offset ?Update@CPackage@@UAGJXZ ; CPackage::Update(void)
.text:02FA1538 dd offset ?Update@CPackage@@UAGJXZ ; CPackage::Update(void)
.text:02FA153C dd offset ?GetUserClassID@CPackage@@UAGJPAU_GUID@@@Z ; CPackage::GetUserClassID(_GUID *)
.text:02FA1540 dd offset ?GetUserType@CPackage@@UAGJKPAPAG@Z ; CPackage::GetUserType(ulong,ushort *)
.text:02FA1544 dd offset ?SetExtent@CPackage@@UAGJKPAUtagSIZE@@@Z ; CPackage::SetExtent(ulong,tagSIZE *)
.text:02FA1548 dd offset ?GetExtent@CPackage@@UAGJKPAUtagSIZE@@@Z ; CPackage::GetExtent(ulong,tagSIZE *)
.text:02FA154C dd offset ?Advise@CPackage@@UAGJPAUIAdviseSink@@PAK@Z ; CPackage::Advise(IAdviseSink *,ulong)
.text:02FA1550 dd offset ?Unadvise@CPackage@@UAGJK@Z ; CPackage::Unadvise(ulong)
.text:02FA1554 dd offset ?EnumAdvise@CPackage@@UAGJPAUIEnumSTATDATA@@@Z ; CPackage::EnumAdvise(IEnumSTATDATA *)
.text:02FA1558 dd offset ?GetMiscStatus@CPackage@@UAGJKPAK@Z ; CPackage::GetMiscStatus(ulong,ulong *)
.text:02FA155C dd offset ?SaveCompleted@CPackage@@UAGJPBG@Z ; CPackage::SaveCompleted(ushort const *)
```



# The Sandworm Zero Day

- What could possibly be wrong?
- The “context-menu” options for different file types are different
- The file content as well as the filename (file type) are controlled via “IPersistStorage::Load”
  - Remember our “Package” Temp File Dropping case study? They are the same!
  - So, this neat zero-day actually leveraged **two** attack vectors
- For example, installing an .inf
  - **Pwned! Logic bug!**



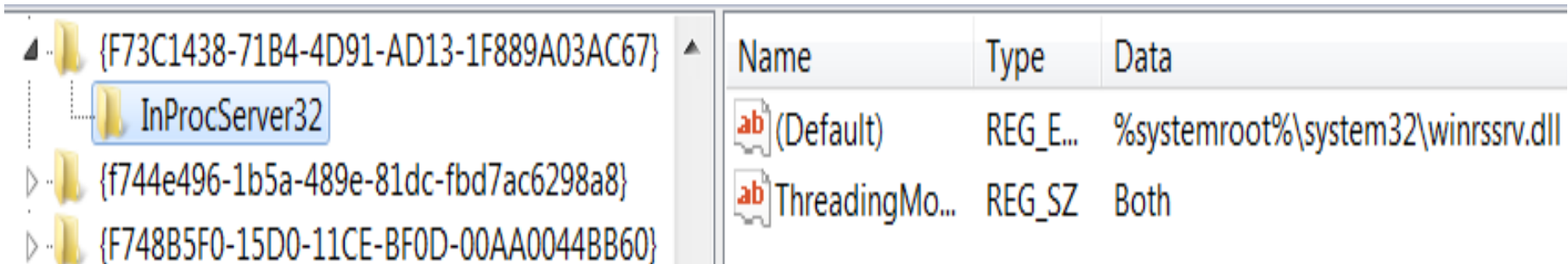
# Attack III: CLSID-Associated DLL Loading

- So, we have discussed two important attack vectors for OLE: **IPersistStorage::Load** and **IOleObject::DoVerb**
- Are there any more?
  - Definitely
- Let's review the very first step of loading an OLE object
  - *Calling the **CoCreateInstance** trying to initialize the OLE objects, the OLE object is specified by CLSID, which is provided in the document file*
- What does **CoCreateInstance** do? The following:

```
CoGetObject(rclsid, dwClsContext, NULL, IID_IClassFactory, &pCF);  
hresult = pCF->CreateInstance(pUnkOuter, riid, ppvObj)  
pCF->Release();
```
- **CoGetObject** needs to first load the DLL associated with the CLSID into the process

# What Is “CLSID-Associated” DLL?

- A DLL has an associated CLSID in your Windows Registry
  - HKEY\_CLASSES\_ROOT\CLSID
  - The “**InprocServer32**” key specifies where the DLL (“server”) is



The screenshot shows the Windows Registry Editor. The left pane displays a tree view of the registry. The path HKEY\_CLASSES\_ROOT\CLSID\{F73C1438-71B4-4D91-AD13-1F889A03AC67}\InProcServer32 is selected. The right pane shows a list of registry values for this key.

Name	Type	Data
(Default)	REG_E...	%systemroot%\system32\winrsv.dll
ThreadingMo...	REG_SZ	Both



# Attack III: CLSID-Associated DLL Loading

- What could possibly be wrong here?
  - From an attacker's perspective?
- As we've discussed, OLE objects are a **subset** of COM objects, which is another **subset** of CLSID-associated objects
  - Many COM objects registered in the OS are not OLE objects
    - **Several hundreds** vs. **several thousands**
  - Sometimes even a DLL that has a CLSID associated in the Windows Registry is not necessarily a COM
- But, **CoCreateInstance** will still load the CLSID-associated DLL in the process
  - Regardless whether it is an "OLE DLL"
  - The loaded DLL won't be unloaded, even if it's determined later not to be an "OLE DLL"

# Attack III: CLSID-Associated DLL Loading

- This is a **\*design\*** problem in the process of initializing OLE objects on Windows, in our opinion
  - **Without loading the DLL first, you won't be able to know whether the COM exposes the interface you want!**
- Let's compare it with its well-known "sister" feature: the ActiveX Controls in Internet Explorer
  - Unlike OLE, IE11 loading an ActiveX Control (say, in IE) will first result in checking the "preapproved" list
    - *HKLM\Software\Microsoft\Windows\CurrentVersion\Ext\PreApproved*
  - So, if the ActiveX CLSID is not in the list, the DLL won't be really loaded into the IE process
    - **No problem for ActiveX in IE**

# Consequences

- What bad things might happen due to the problem we discussed?
  - We can load any DLL into the process as long as the DLL is associated with a CLSID
  - Considering the attack is launched via a document
- There are quite a few
- *Note: Loading OLE DLL may also have the same problems. But, being able to load every CLSID-associated DLL increases the attack surface*  
*\*significantly\**

# Consequence 1: Non-ASLR DLL

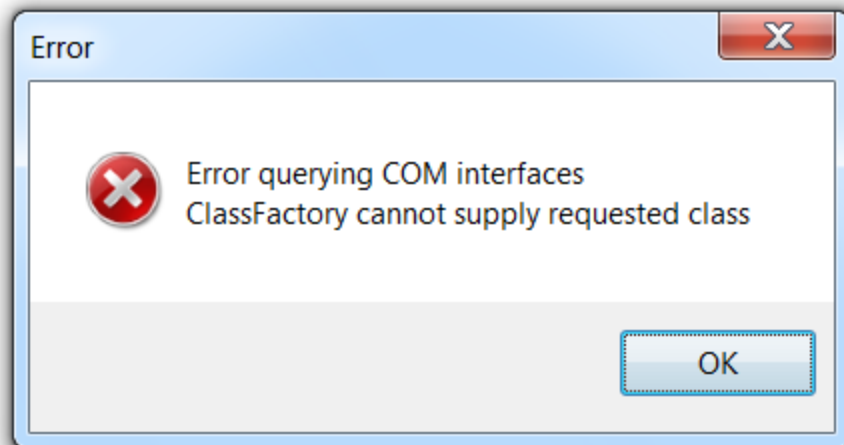
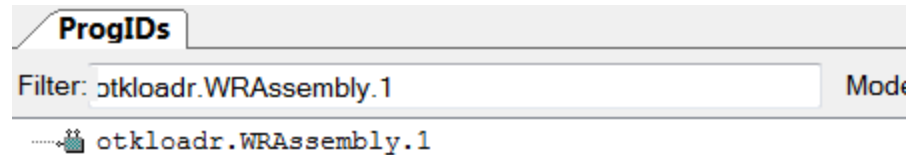
- Loading non-ASLR DLL in container process
  - Namely, Word, PowerPoint, Excel, WordPad
  - Thus used to bypass ASLR for exploitation
- Note, not only the CLSID-associated DLL may be non-ASLR, but sometimes the CLSID-associated DLL could also link to other non-ASLR DLLs (so loaded as well)
- Does not work on Office 2013 and later because they enabled “Force ASLR”
  - <http://blogs.technet.com/b/srd/archive/2013/12/11/software-defense-mitigating-common-exploitation-techniques.aspx>
  - Still works on Office <= 2010 and WordPad 😊

# Example 1: otkloadr.WRAssembly.1

- Trying to load the “COM object” identified by ProgID: `otkloadr.WRAssembly.1`

```
{\rtf1{\object\objocx{\*\objdata
01050000
02000000
16000000 //otkloadr.WRAssembly.1
6f746b6c6f6164722e5752417373656d626c792e3100
00000000
00000000
01000000
41
01050000
00000000
}}}
```

- It's not even a COM!



# Example 1: otkloadr.WRAssembly.1

- Will load “*C:\Program Files\Microsoft Office\Office14\ADDINS\OTKLOADR.DLL,*” which will result in loading linked non-ASLR *MSVCR71.DLL* in the same directory
- Disclosed by Parvez Anwar in June 2014 at <http://www.greyhathacker.net/?p=770>, already fixed by Microsoft

# Example 2: mscormmc.dll

- This non-ASLR DLL is on the default Windows 7
  - C:\Windows\Microsoft.NET\Framework\v1.0.3705\mscormmc.dll
- A couple CLSIDs are associated on this DLL, for example:
  - {18BA7139-D98B-43C2-94DA-2604E34E175D}
- Then make an Office document or RTF containing an OLE object with the CLSID. You will get the non-ASLR DLL loaded into the process
- Still works! Finding non-ASLR DLL made easy; found this in just a few minutes

Name	Path	Base	Image Base	ASLR
mscormmc.dll	C:\Windows\Microsoft.NET\Framework\v1.0.3705\mscormmc.dll	0x10000000	0x10000000	

# Consequence 2: Memory Corruption

- Sometimes, loading an “unprepared” DLL is enough to trigger a memory corruption
- Example: Microsoft Office Uninitialized Memory Use Vulnerability (CVE-2015-1770)
  - CLSID: **CDDDBCC7C-BE18-4A58-9CBF-D62A012272CE**
  - Associated DLL: *C:\Program Files\Microsoft Office\Office15\OSF.DLL*
  - Just trying to load the CLSID-associated DLL will give you a crash (exploitable)!
  - The **OSF.DLL** is certainly **not** designed for you to load as OLE or ActiveX Control
  - Discovered by Yong Chuan Koh of MWR Labs, more details at [https://labs.mwrinfosecurity.com/system/assets/987/original/mwri\\_advisory\\_cve-2015-1770.pdf](https://labs.mwrinfosecurity.com/system/assets/987/original/mwri_advisory_cve-2015-1770.pdf)



# Consequence 3: DLL-Preloading

- There's another attack scenario that hides in the deep
  - Note, this is about document-based attacking
- The **current working directory** is something the attacker can control
- I shouldn't have to explain a DLL-Preloading attack



22. Description. Detail a list of deliverables including documentation.

Microsoft Office 2007, 2010, 2013 Module Remote DLL Hijacking Vulnerability

Microsoft Office contains a module that is vulnerable to DLL hijacking upon referenced from a crafted WebDAV or SMB share containing an Office file.

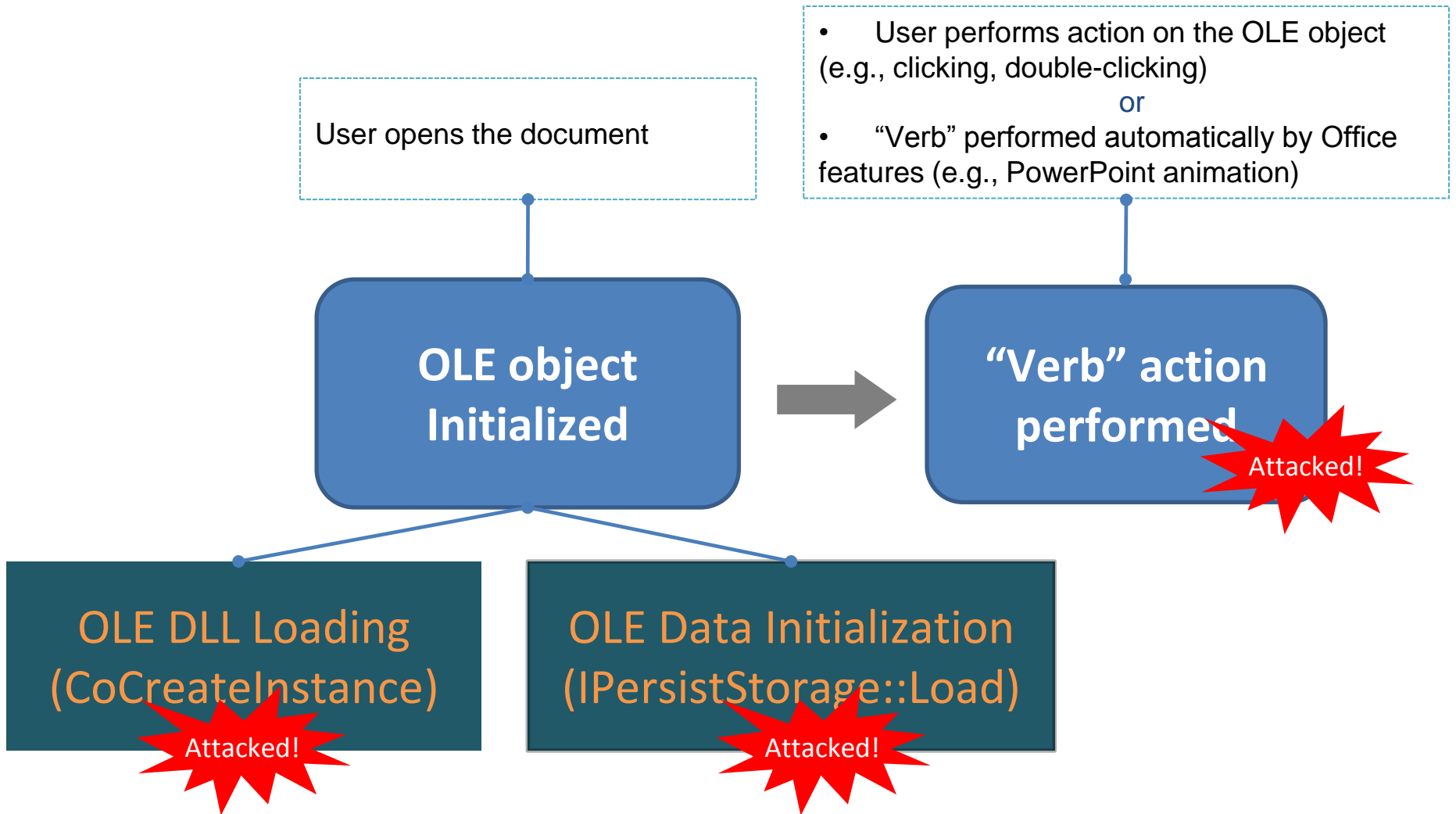


# Demo

# Summary of Attacking Vectors

- Based on the time-flow of a victim opening the document, the attack vectors are:
  - I. Various types of attacks may occur during the “**CLSID-associated DLL Loading**” process—the very first step of “OLE Object Initialization”
    - Non-ASLR DLL loading
    - Memory Corruption
    - DLL preloading
    - ...
  - II. Various types of vulnerabilities may exist in the “**IPersistStorage::Load**” routine, another step of the “OLE Object Initialization”
    - A lot of zero-day attacks focus on this area
  - III. “Verb” action attack via “**IOleObject::DoVerb**”
    - Usually logic bugs, more dangerous

# Every Step Attacked



# Summary of Attack Surface

- The OLE mechanism offers a **huge** attack surface
- Unlike ActiveX, an OLE object is **not** restricted by security enhancement features like “Pre-Approved List,” Safe For Scripting (SFS), or Safe For Initialization (SFI)
- Being able to load any\* CLSID-associated DLL makes the attack surface even much bigger
  - **Hundreds** of OLE objects on default Windows
  - **Thousands** of CLSID-associated DLLs on default Windows
- **Don't forget it's an open area!**
  - The more apps installed, the bigger the surface becomes
  - It's possible one day we'll see a document-based attack targeting specific users having specific software installed on the system

*\*Note that the OLE-loading process honors the IE/Office Killbits, so if a CLSID is killbitted, the associated DLL will not be loaded.*

# Agenda

- What Is OLE?
- Historical Zero Days Involving OLE
- OLE Internals
- Attack Surface
- Conclusion

# Conclusion

- The OLE mechanism serves the majority of Microsoft's documentation interoperability with other components
- A huge attack surface offered
  - New ActiveX?
  - Even though it's not scriptable, it can do much more than we expected
- What to expect next after the preso?
  - Many OLE-related vulnerabilities will probably be discovered
  - Probably more zero-day attacks targeting Office/WordPad
  - Detection and defense need to be improved\*, for both sandboxing and static approaches
    - An OLE-specific detection method is on the way

*\*We have reported some new evasion tech recently (<https://blogs.mcafee.com/mcafee-labs/threat-actors-use-encrypted-office-binary-format-evade-detection>), suggesting the difficulties on detecting Office-based attack correctly.*



# Conclusion

- To vendor (Microsoft)
  - The questionable “OLE Loading” mechanism needs to be revisited, maybe redesigned
    - You can't just load every CLSID-associated DLL into the Office/WordPad process
  - A large-scale internal pentest on the default OS is needed
    - New attacking vectors produce many new vulnerabilities
- Training third-party vendors
  - Just like what you have done before for ActiveX

# Major References

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# Thank You!



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