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 3rd question:

  3) How to detect the effect by answering the 1st and 2nd.

  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

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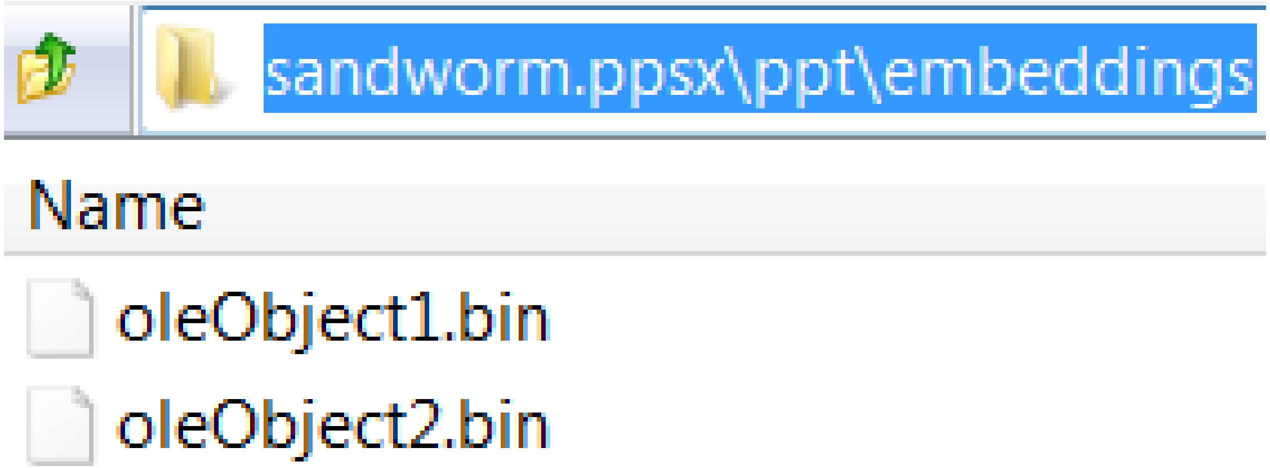
OLE-related Zero Days in History

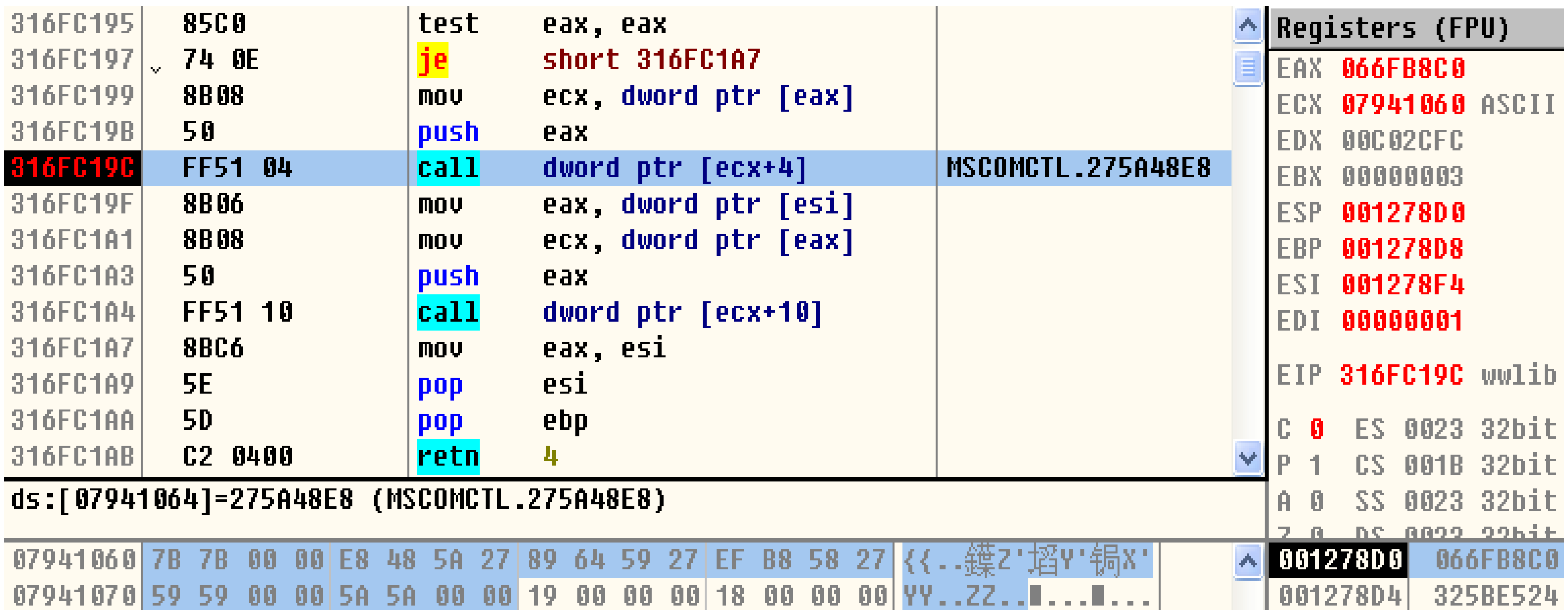
- Almost all previous critical Office/WordPad zero days actually involve OLE
- CVE-2014-4114/6352 (a.k.a. “Sandworm” zero day)
  - Reported in October 2014. Logic fault, really serious
  - 2 OLE objects found in the original sample
  - *Microsoft failed to fix it in the initial patch*



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
```



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

CVE-2013-3906.docx\word\activeX

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
01050000020000001B0000004D53436F6D63746C4C69622E4C697374566965774374726C2E32
```

- 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

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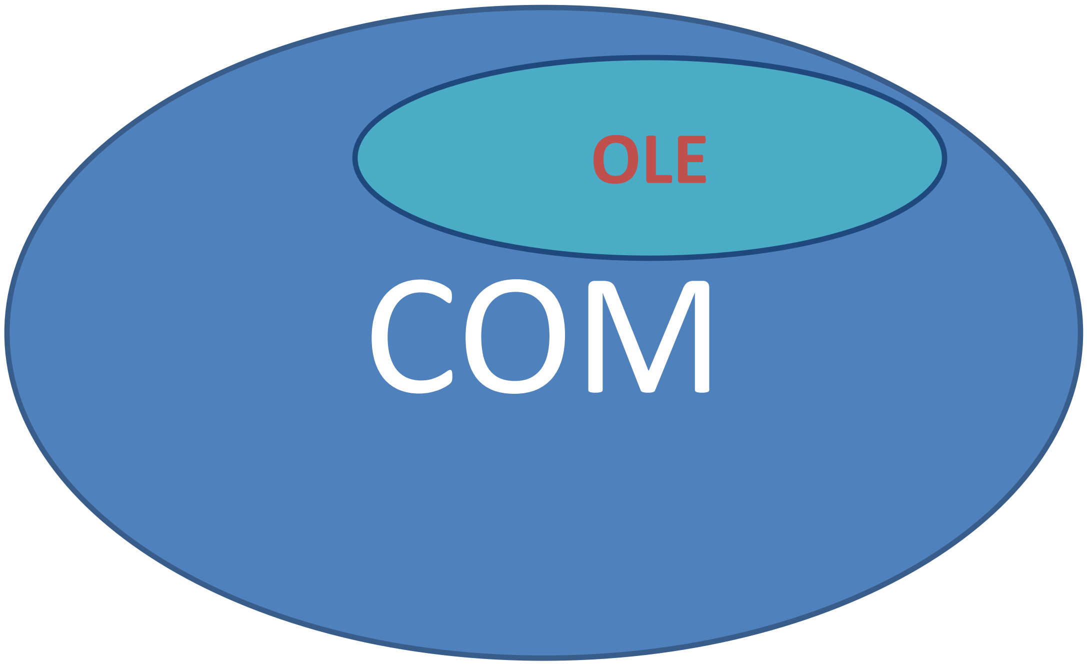
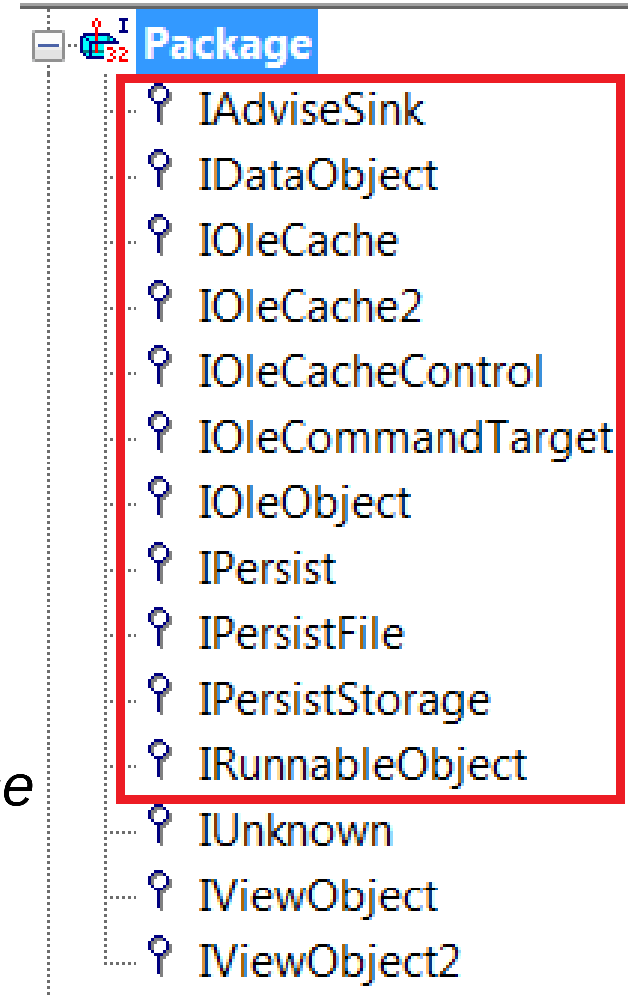
Previous Related Work

- 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
    - 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



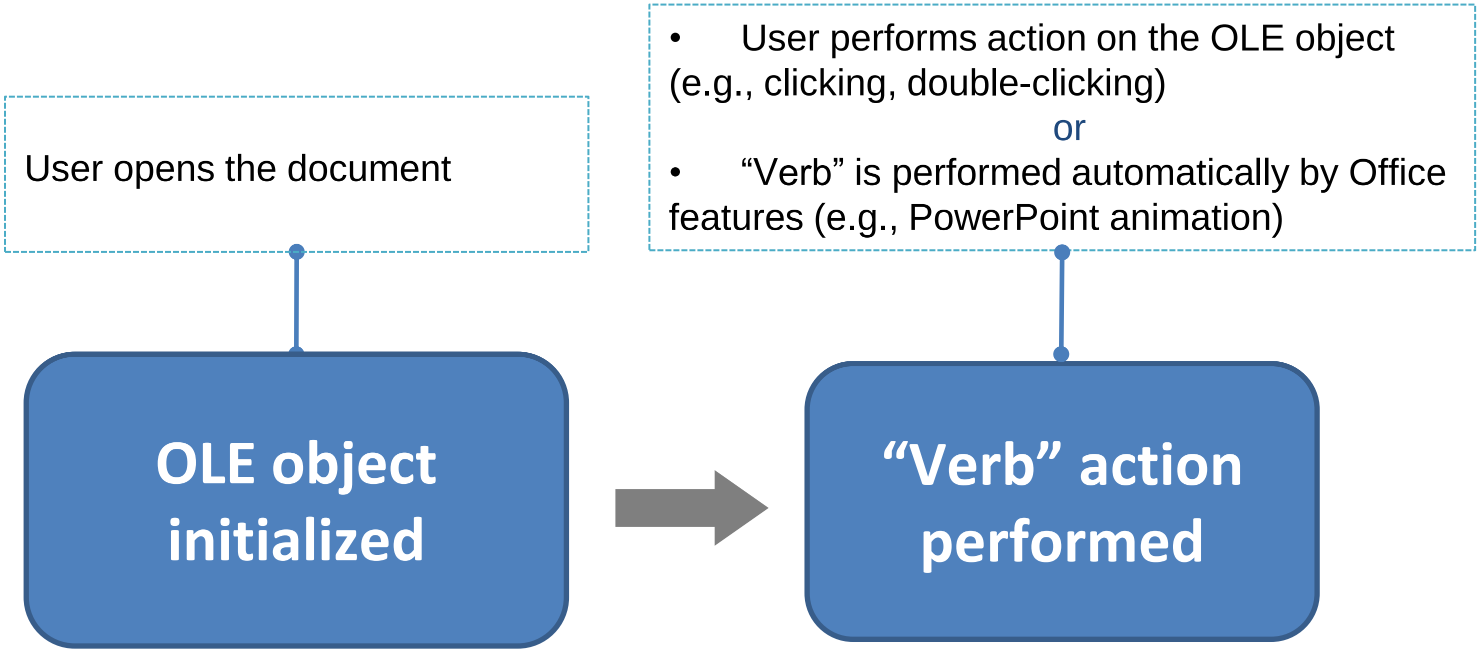


OLE objects are COM objects that expose specific Interfaces. Must have:

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 00

CoCreateInstance(CLSID,
NULL,
CLSCTX_INPROC_SERVER |
CLSCTX_INPROC_HANDLER |
CLSCTX_NO_CODE_DOWNLOAD,
IID(IOleObject))

Where Does CLSID Come From?

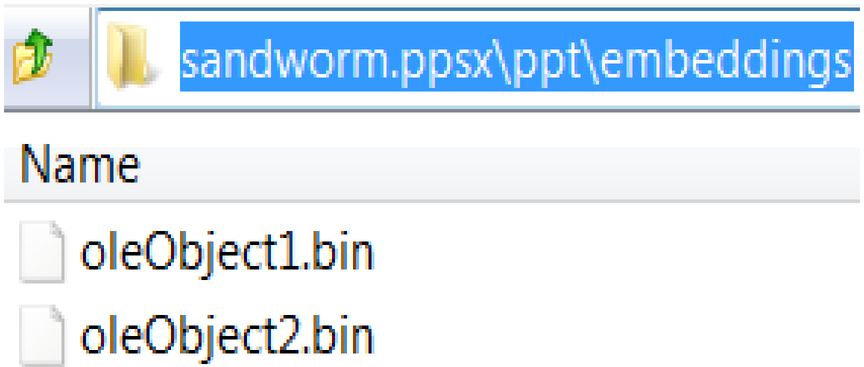
- The CLSID comes from the document, indicating which OLE object the user wants to initialize

- 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



00000440	16	00	05	00	FF	FF	FF	FF	FF	FF	FF	FF	01	00	00	00
00000450	02	26	02	00	00	00	00	00	C0	00	00	00	00	00	00	46
00000460	00	00	00	00	00	00	00	00	00	00	00	00	F0	75	FD	41

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
- 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
);
```

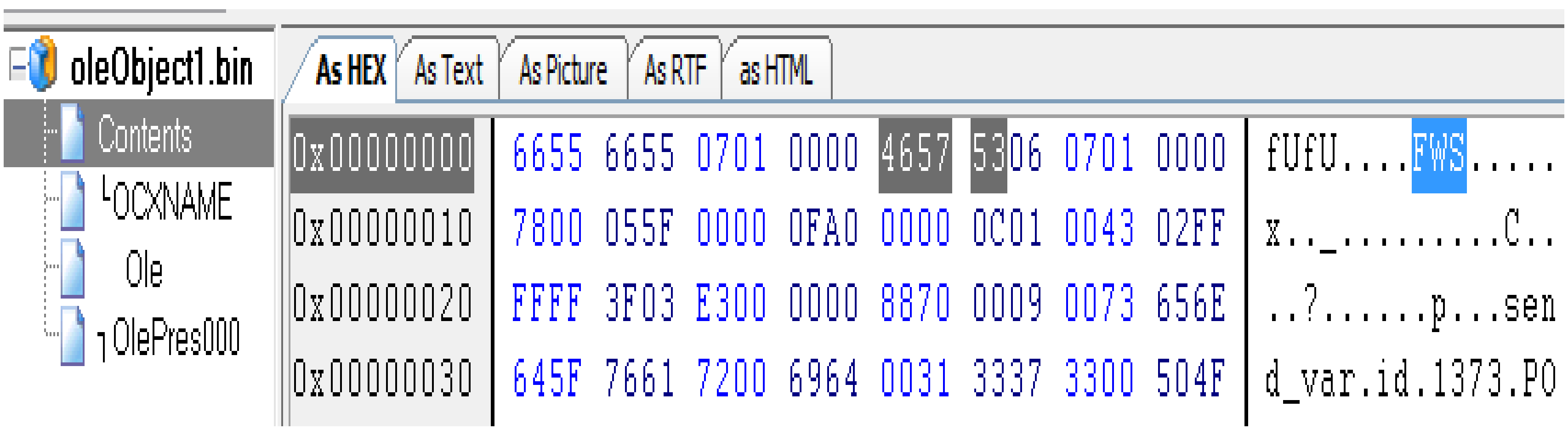
Load the initial "status" for the OLE object when it's being initialized

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



Storage Data in RTF

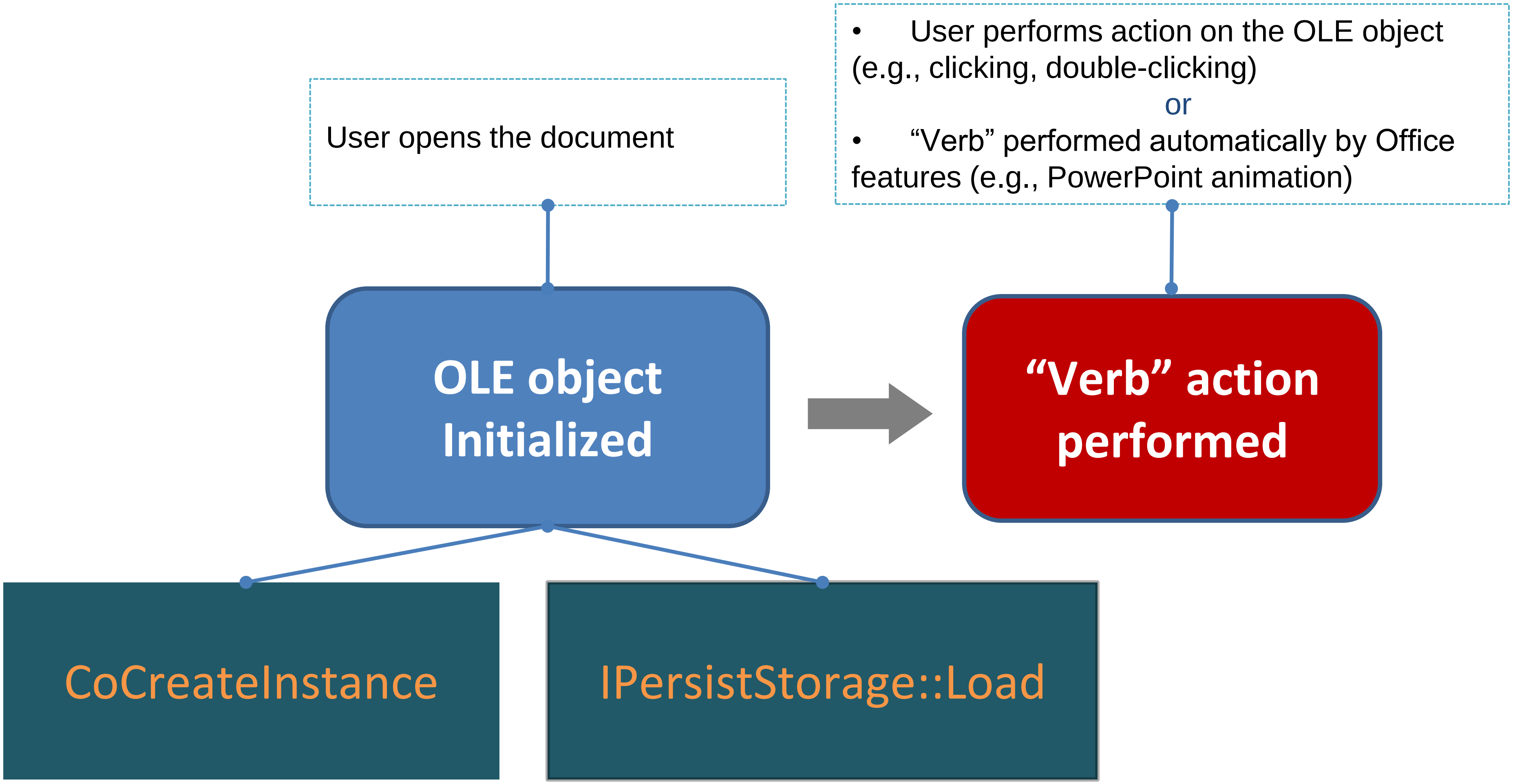
- Represented in OLE1 Native Data
- Described here: https://msdn.microsoft.com/en-us/library/dd942053.aspx

```
{\*\objdata
01050000        //OLE version
02000000        //Format ID, EmbeddedObject
1B000000        //ProgID
4D53436F6D63746C4C69622E4C697374566965774374726C2E3200
00000000
00000000

000E0000        //OLE1 Native Data (length + data)
D0CF11E0A1B11AE10000000000000000000000000000000003E00030
10000002000000001000000FEFFFFFF0000000000000000FFFFFFFF
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
```

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
  - 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 ***FFFFFFFD*** *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>
```

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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

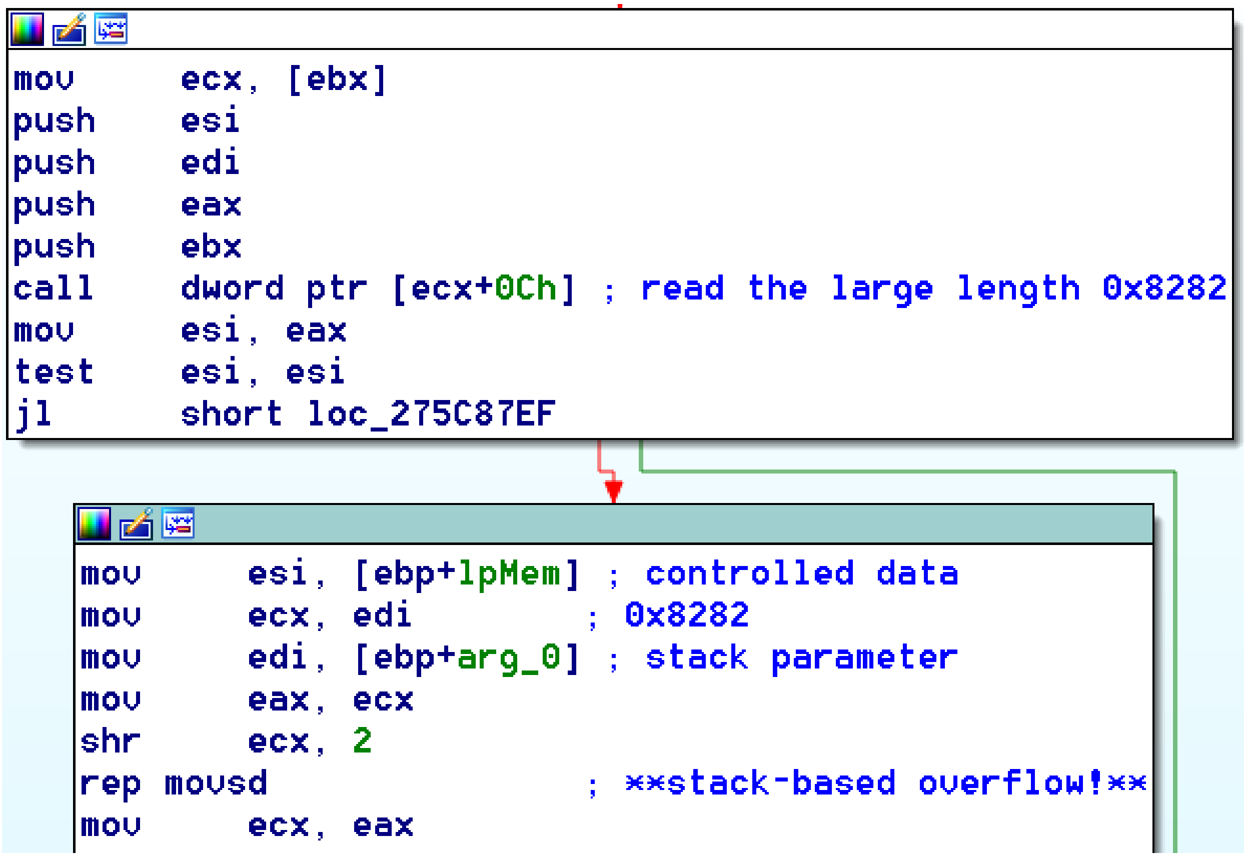
- It's the most obvious one
  - You want to parse some data; I give you the crafted data
  - Sometimes it will result in memory corruptions; sometimes it may be a logic bug

- 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



- 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:275903E0↑o
.text:276008D9                                         ; .text:275906D8↑o ...
.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, 0FFFFFFFCh
.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_vtable 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

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 &,voi
.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(IOl
.text:02FA1510                dd offset ?GetClientSite@CPackage@@UAGJPAPAUIOleClientSite@@@Z ; CPackage::GetClientSite(I
.text:02FA1514                dd offset ?SetHostNames@CPackage@@UAGJPBG0@Z ; CPackage::SetHostNames(ushort const *,ushor
.text:02FA1518                dd offset ?Close@CPackage@@UAGJK@Z ; CPackage::Close(ulong)
.text:02FA151C                dd offset ?Save@CPackage@@UAGJPBGH@Z ; CPackage::Save(ushort const *,int)
.text:02FA1520                dd offset ?InitFromData@CPackage@@UAGJPAUIDataObject@@HK@Z ; CPackage::InitFromData(IData
.text:02FA1524                dd offset ?InitFromData@CPackage@@UAGJPAUIDataObject@@HK@Z ; CPackage::InitFromData(IData
.text:02FA1528                dd offset ?GetClipboardData@CPackage@@UAGJKPAPAUIDataObject@@@Z ; CPackage::GetClipboardDa
.text:02FA152C                dd offset ?DoVerb@CPackage@@UAGJJPAUtagMSG@@PAUIOleClientSite@@JPAUHWND__@@PBUtagRECT@@@Z
.text:02FA1530                dd offset ?EnumVerbs@CPackage@@UAGJPAPAUIEnumOLEVERB@@@Z ; CPackage::EnumVerbs(IEnumOLEVER
.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 *,ulo
.text:02FA1550                dd offset ?Unadvise@CPackage@@UAGJK@Z ; CPackage::Unadvise(ulong)
.text:02FA1554                dd offset ?EnumAdvise@CPackage@@UAGJPAPAUIEnumSTATDATA@@@Z ; CPackage::EnumAdvise(IEnumSTA
.text:02FA1558                dd offset ?GetMiscStatus@CPackage@@UAGJKPAK@Z ; CPackage::GetMiscStatus(ulong,ulong *)
.text:02FA155C                dd offset ?SaveCompleted@CPackage@@UAGJPBG@Z ; CPackage::SaveCompleted(ushort const *)
```

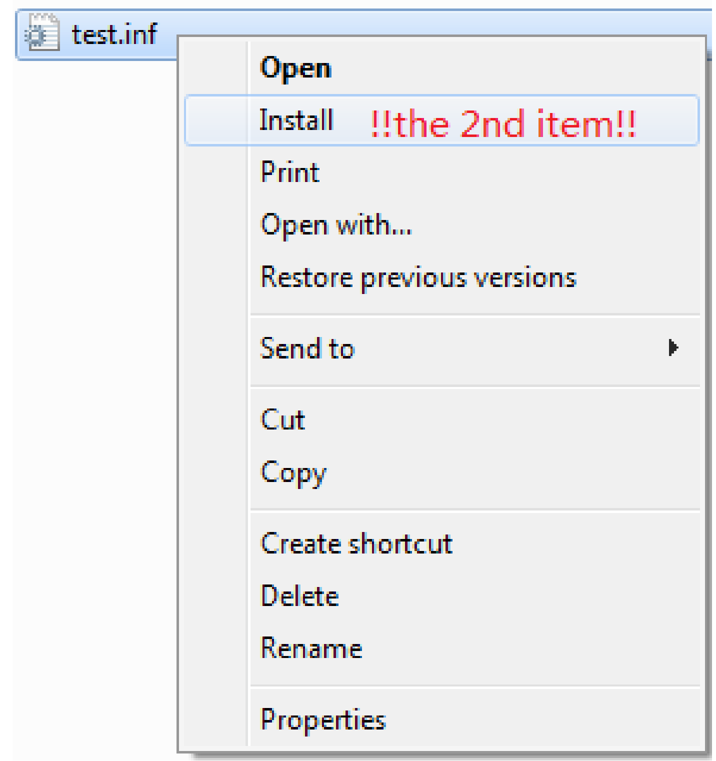
When “verb” is 3

Performing “context-menu” actions!

```
                                                //
v20 = (a1 - 8);                                 // come here for iVerb=3
v23 = CPackage::GetContextMenu(&v21);
if ( v23 >= 0 )
{
  hMenu = CreatePopupMenu();
  if ( hMenu )
  {
    v23 = (*(*v21 + 12))(v21, hMenu, 0, 2, 0xFFFFu, 0);// CDefFolderMenu::QueryContextMenu
    if ( v23 >= 0 )
    {
      mii.cbSize = 48;
      mii.fMask = 2;
      if ( GetMenuItemInfoW(hMenu, v_iVerb - 2, 1, &mii) )// position = 3 -2 = 1
                                                // means the 2nd item on the menu.
      {
        if ( *(a1 + 48) == 3 )
          v23 = CPackage::CreateTempFile(0);
        if ( v23 >= 0 )
        {
          v16 = mii.wID - 2;
          v13 = 36;
          v14 = 0;
          v15 = 0;
          v17 = 0;
          v18 = 0;
          v19 = 1;
          v23 = (*(*v21 + 16))(v21, &v13);    // CDefFolderMenu::InvokeCommand
                                                // Do the real job: "clicking" the 2nd item on the menu.
        }
      }
      else
      {
        v23 = 0x40181u;
      }
    }
    DestroyMenu(hMenu);
  }                                             //
                                                //
```

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

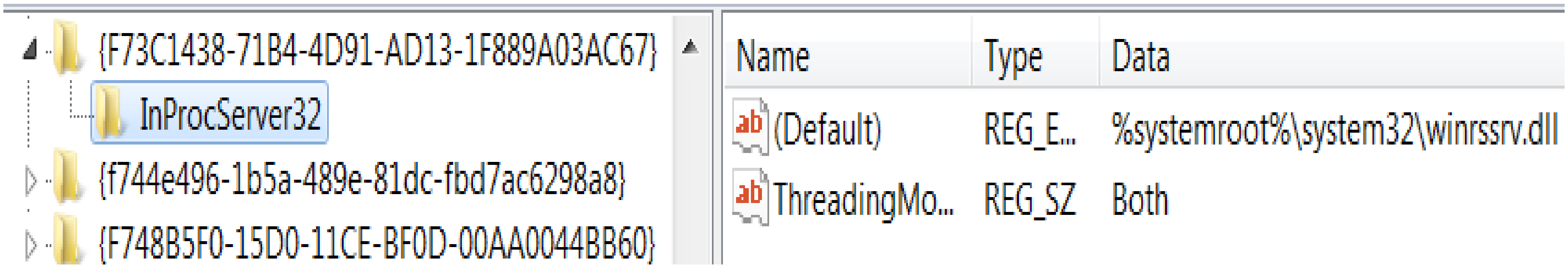
- So, we have discussed two important attack vectors for OLE: IPersistStorage::Load and IOleObject::DoVerb
- Are there any more?
  - Definitely
- Let's review the very first step of loading an OLE object
  - *Calling the CoCreateInstance trying to initialize the OLE objects, the OLE object is specified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

  CoGetClassObject(rclsid, dwClsContext, NULL, IID_IClassFactory, &pCF);
  hresult = pCF->CreateInstance(pUnkOuter, riid, ppvObj)
  pCF->Release();

- CoGetClassObject 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



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**

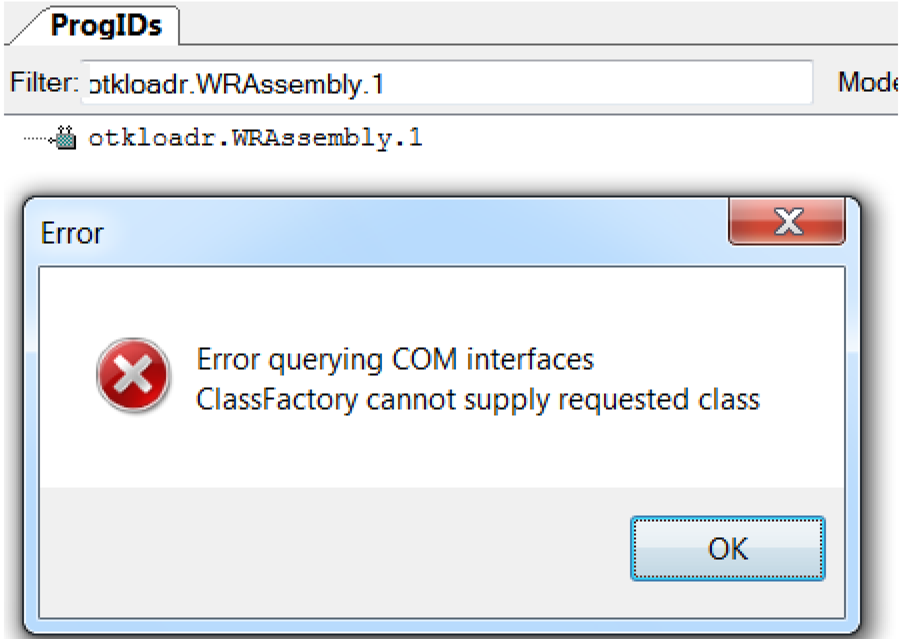
Consequence 1: Non-ASLR DLL

- 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: CDDBCC7C-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

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

https://wikileaks.org/hackingteam/emails/emailid/49815

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.

DLL-Preloading Example: OLE Loading

- CVE-2015-2369 is a good example we reported, fixed just in July Patch Tuesday

- Minimal PoC in less than one tweet (140 bytes) ☺

  {\rt\object\objocx{\objdata 0105000002000000140000000574D444D434553502E574D444D434553502E3100000000000000000001000000410105000000000000}}

- CLSID-associated DLL
  - ProgID: WMDMCESP.WMDMCESP.1
  - CLSID: {067B4B81-B1EC-489f-B111-940EBDC44EBE}
  - DLL: %systemroot%\System32\cewmdm.dll

- Will result in loading a DLL named “rapi.dll” from the current working directory

- Demo!

Demo

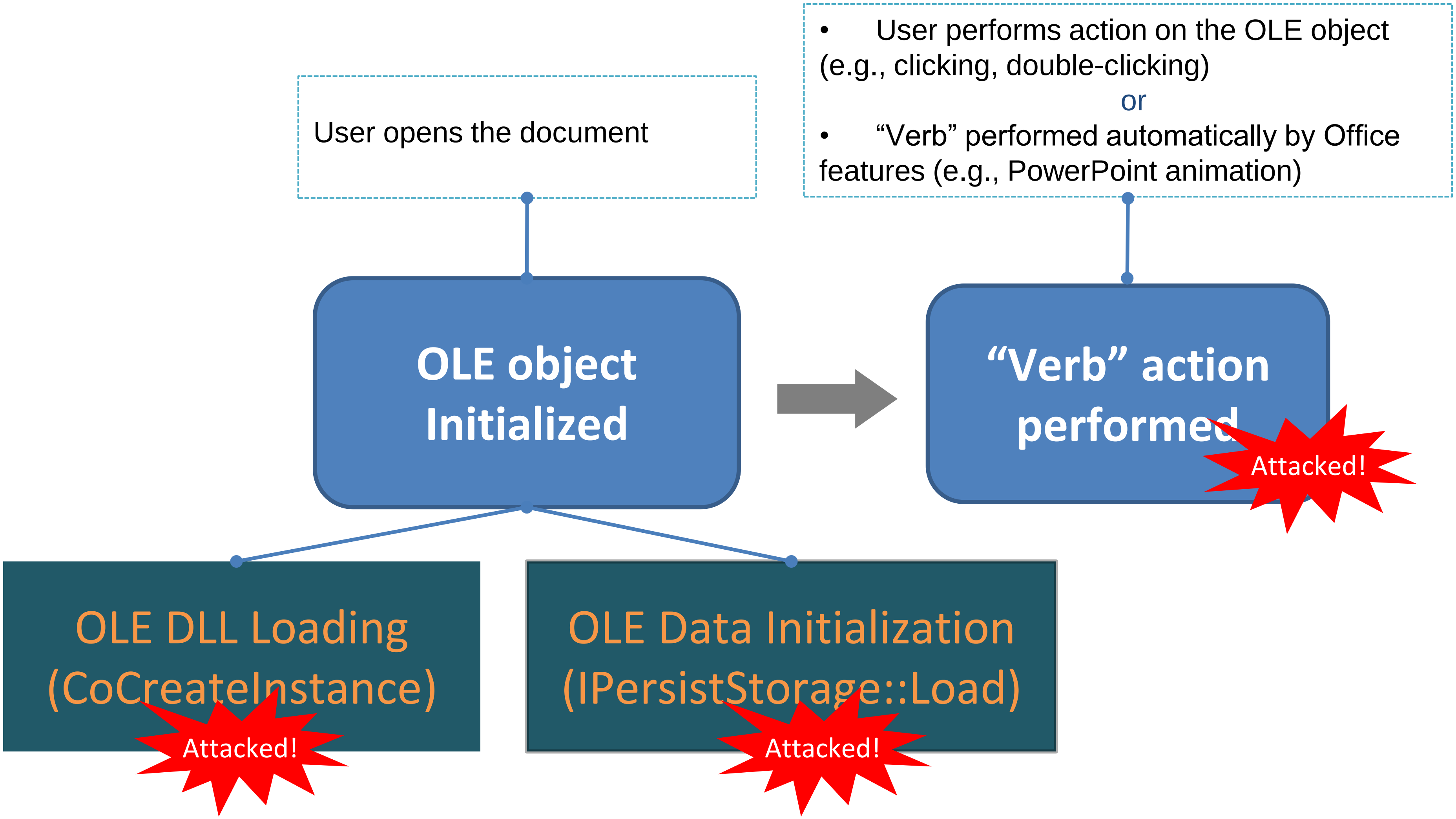
Summary of Attacking Vectors

- 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

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Thank You!

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