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www.ensilo.com

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  - Low Level Researcher
  - Author on BreakingMalware

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Agenda

- User-Mode Injections
  - Classic Code Injection Methods
  - Advanced Injections - PowerLoader
  - PowerLoaderEx
  - PowerLoaderEx64
- Kernel-Mode Injections
  - Common Injection Methods
  - Introducing Trap Frame Injection
  - Codeless Code Injection
  - Demo
- Summary

User-Mode Code Injections

Classic Code Injection Methods

- Vanila Injection - OpenProcess/ VirtualAllocEx/CreateRemoteThread/LoadLibrary
- GetThreadContext / SetThreadContext
- SetWindowsHookEx
- AppInit_DLLs and APPCERTDLLs
- ShimEng (InjectDll Tag)
- SetWindowLong
- QueueUserApc
- Replace Dependency DLL
- …

PowerLoader – POP/POP/INJECT

- Loader used in many different dropper families (Gapz / Redyms / Carberp / Vabushky ...)
- Technique was leaked with Carberp source code leak.
- First injection technique via Return Oriented Programming technique (ROP).
- “explorer.exe” is injected using Shell_TrayWnd / NtQueueApcThread (32bit / 64bit)
- Successfully bypassed most HIPSs solutions

1. http://www.welivesecurity.com/2013/03/19/gapz-and-redyms-droppers-based-on-power-loader-code/
2. http://www.slideshare.net/matrosov/advanced-evasion-techniques-by-win32gapz
3. https://www.virusbtn.com/virusbulletin/archive/2012/10/vb201210-code-injection
4. http://www.malwaretech.com/2013/08/powerloader-injection-something-truly.html

➢ Samples and valuable info - http://www.kernelmode.info/forum/

PowerLoader – Abusing Shared Sections

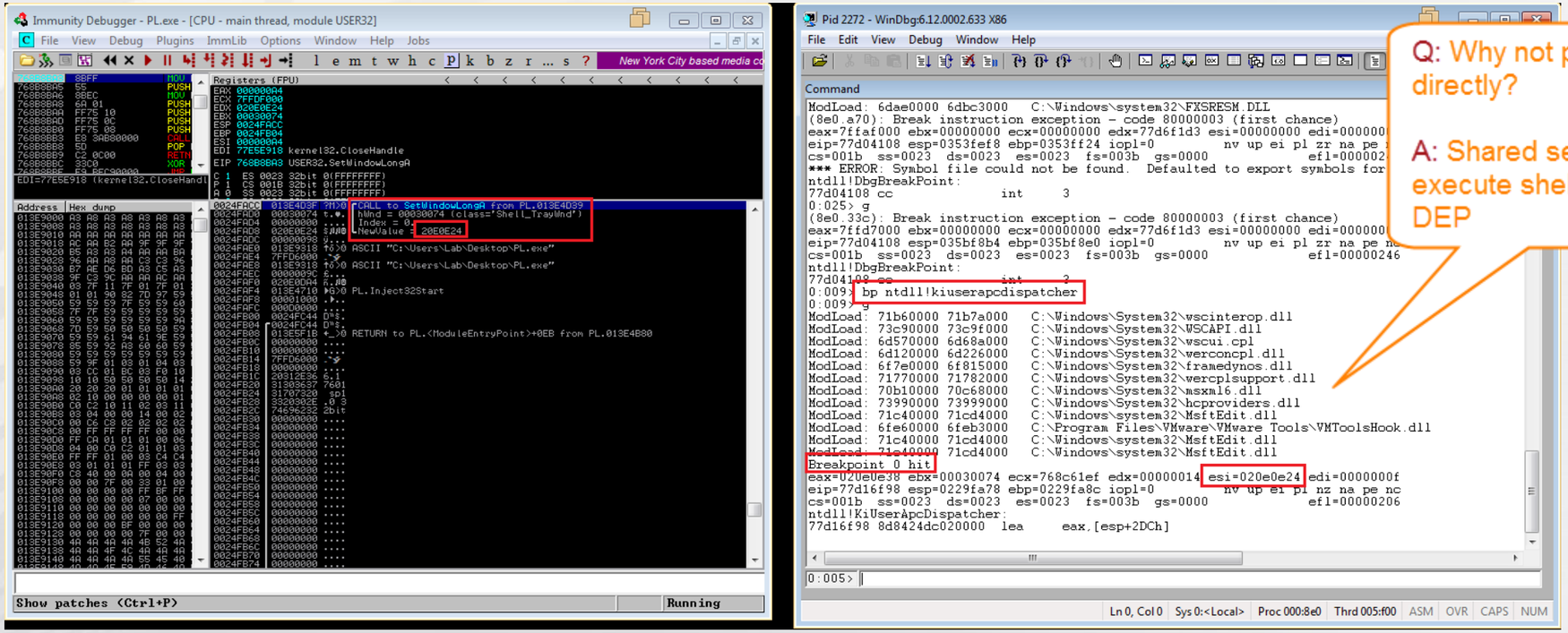
- Explorer.exe has several shared memory sections it uses:

```
.rdata:00407430 aBasenamedobjec:                        ; DATA XREF: sub_404790+C↑o
.rdata:00407430                 unicode 0, <\BaseNamedObjects\ShimSharedMemory>,0
.rdata:00407476                 align 4
.rdata:00407478 aBasenamedobj_0:                        ; DATA XREF: sub_404790+1A↑o
.rdata:00407478                 unicode 0, <\BaseNamedObjects\windows_shell_global_counters>,0
.rdata:004074D8 aBasenamedobj_1:                        ; DATA XREF: sub_404790+21↑o
.rdata:004074D8                 unicode 0, <\BaseNamedObjects\MSCTF.Shared.SFM.MIH>,0
.rdata:00407526                 align 4
.rdata:00407528 aBasenamedobj_2:                        ; DATA XREF: sub_404790+28↑o
.rdata:00407528                 unicode 0, <\BaseNamedObjects\MSCTF.Shared.SFM.AMF>,0
.rdata:00407576                 align 4
.rdata:00407578 aBasenamedobj_3:                        ; DATA XREF: sub_404790+2F↑o
.rdata:00407578                 unicode 0, <\BaseNamedObjects\UrlZonesSM_Administrator>,0
.rdata:004075CE                 align 10h
.rdata:004075D0 aBasenamedobj_4:                        ; DATA XREF: sub_404790+36↑o
.rdata:004075D0                 unicode 0, <\BaseNamedObjects\UrlZonesSM_SYSTEM>,0
```

- By calling NtOpenSection and ZwMapViewOfSection PowerLoader maps one of the shared sections to its own address space
- PowerLoader finds the address of the shared section in explorer by calling VirtualQueryEx / ReadProcessMemory / RtlCompareMemory combination
- The shellcode is than written to the shared section. There is no need for VirtualAllocEx / WriteProcessMemory which is monitored by many HIPS

PowerLoader - Triggering Code Execution

- One of the Windows in Explorer.exe is Shell_TrayWnd
- The Shell_TrayWnd window has a pointer to CTray class object which handles messages to the window
- Once the Shell_TrayWnd window is found PowerLoader uses SetWindowLongPtr to replace the CTray object with a malicious CTray Object in the shared section
- The shared section is not executable thus ROP is needed
- The virtual table of the malicious CTray object point to KiUserApcDispatcher routine which eventually trigger the ROP execution
- To trigger code execution SendNotifyMessage is called with WM_PAINT message



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PowerLoader - ROP n’ Roll

- PowerLoader uses a complex ROP chain
- Basic steps by the ROP chain (High-Level):
  - Direction Flag Set
  - Copy ROP chain to stack
  - Direction Flag Clear
  - Use WriteProcessMemory to overwrite ntdll!atan function (this function is probably not used in the context of explorer.exe)
  - Pass control to the overwritten ntdll!atan function

PowerLoader - Quick Summary

- Advanced Injection technique
- Completely bypassed most HIPS at the time
- Using Exploit-Like techniques:
  - The first Injection technique to use ROP (to our knowledge)
  - Overwrites atan function using WriteProcessMemory
  - No similar 64-bit version (to our knowledge)
  - Try to run vs EMET and see what happens…
- Very application specific:
  - Targets Shell_TrayWnd of explorer.exe
  - Uses specific shared sections
- Doesn’t use direct code injections

Introducing PowerLoaderEx

Goals:

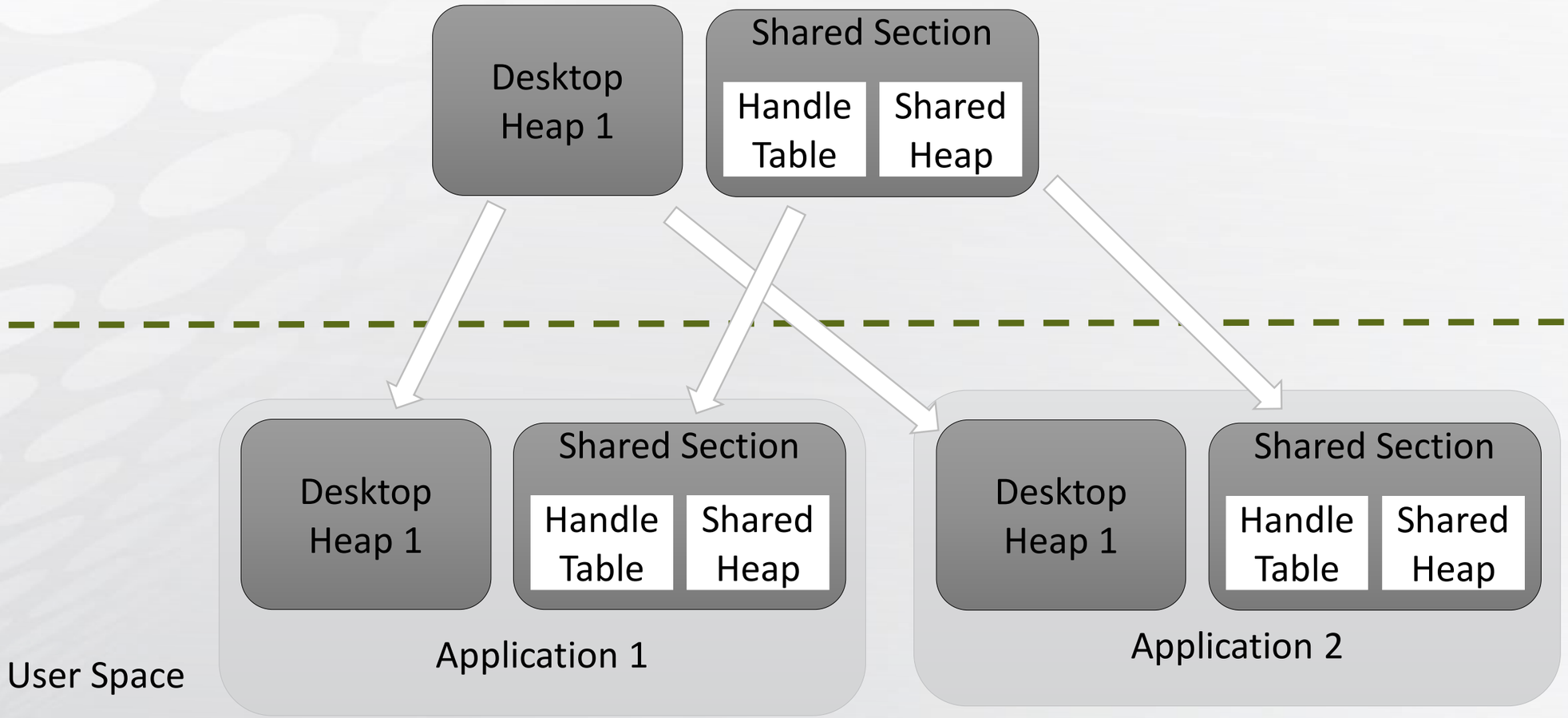
- Remove dependency in Explorer.exe shared sections (more generic)
- Make a 64-bit version
- Bonus: Do it without reading memory from the target process

UI Shared Memory - Reminder

- UI Objects are stored in one of three places:
  - Session Pool – Allocated per user logon
  - Desktop Heap – Stores objects specific to a given Desktop
  - Shared Heap – Handle Table and object relevant to all Desktops
- The heaps are visible to user-mode via shared-memory
- Commonly used for exploiting privilege escalation vulnerabilities
- Extensively documented in:
  “Windows Hooks Of Death: Kernel Attacks through User-Mode Callbacks” – By Tareji Mandt

UI Shared Memory

Kernel Space



User Space

PowerLoaderEx – Desktop Heap as Shared Section

- Desktop Heaps are better as shared section because they are mapped to any process on a given desktop
- Writing arbitrary data to the Desktop Heap is easy:
  - Create a window with enough extra bytes
  - Use SetWindowLongPtr to write the payload
- But how do know where it resides in a target process?

Finding Target Process's Desktop Heap

- Find the Desktop Heap in our process and find its region size
- Enumerate explorer.exe memory regions by calling VirtualQuery.
- The target's Desktop Heap is found if the region characteristics are:
  - State: MEM_COMMIT
  - Type: MEM_MAPPED
  - Protect: PAGE_READ_ONLY
  - RegionSize is equal to the previously obtained heapSize.

Double Check – Avoiding False Positives

- We had **NO** false positives in finding the shared desktop heap (local process and target process)
- The following check will remove any false-positive:

```
while (VirtualQueryEx(ProecssHandle, Addr, &MemInfo, sizeof(MemInfo)))
{
    if (MemInfo.Protect = PAGE_READONLY && MemInfo.Type == MEM_MAPPED && MemInfo.State == MEM_COMMIT && MemInfo.RegionSize == HeapSize)
    {
        // Double check.
        if (!VirtualProtectEx(ProecssHandle, Addr, 0x1000, PAGE_READWRITE, &OldProt))
        {
            // return section information.
            return MemInfo.BaseAddress;
        }
        else
        {
            VirtualProtectEx(ProecssHandle, Addr, 0x1000, OldProt, &OldProt);
        }
    }
    Addr += MemInfo.RegionSize;
}
```

The call will fail if it's the desktop heap and otherwise will succeed.

* Note: using the double check version will require calling NtOpenProcess with QUERY_INFORMATION and PROCESS_VM_OPERATION

Finding The Gadgets

- We do the gadget lookup in our own process
- Load and scan only modules that we know that are always loaded in the target process (i.e. explorer.exe)
- Use only modules that are very likely to have the same base in both processes:
  - ntdll.dll
  - Kernel32.dll
  - Kernelbase.dll
  - User32.dll
  - Shell32.dll

PowerLoaderEx - Look Ma, No Read!

1. Create a window and find it in the shared desktop heap
2. Find the target process (Explorer.exe) and find where the desktop heap is mapped, requires only PROCESS_QUERY_INFORMATION privileges
3. Scan for the required gadgets
4. Write the payload to the shared desktop heap using SetWindowLongPtr
5. Continue like normal PowerLoader

* Note: If a different target process has more than one Desktop Heap mapped read will be needed

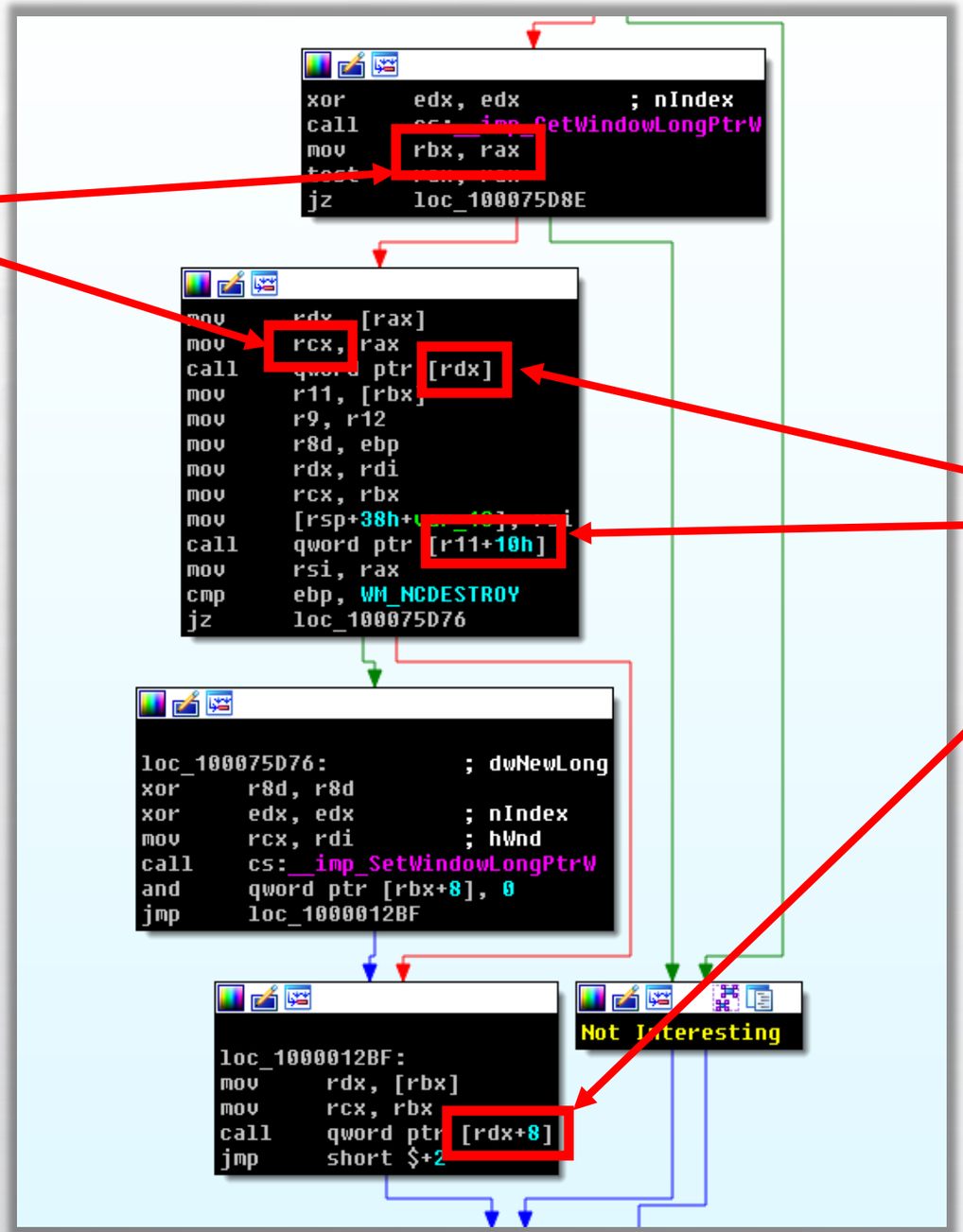
PowerLoaderEx64 - What About 64-bit?

- Challenges:
  - Much harder to find useful gadgets
  - No code writing allowed
  - No reads allowed

PowerLoaderEx64 – Remember the CTray Object?

CImpWndProc::s_WndProc

The Controlled
Ctray Object



Virtual Calls

PowerLoaderEx64 - Strategy

- Find some function that can be manipulated to call LoadLibrary with controlled first argument
- Make sure no crashes occur after/during library loading
- To make things simple point 2 of the 3 virtual calls to “Do Nothing” functions (Ret opcode)

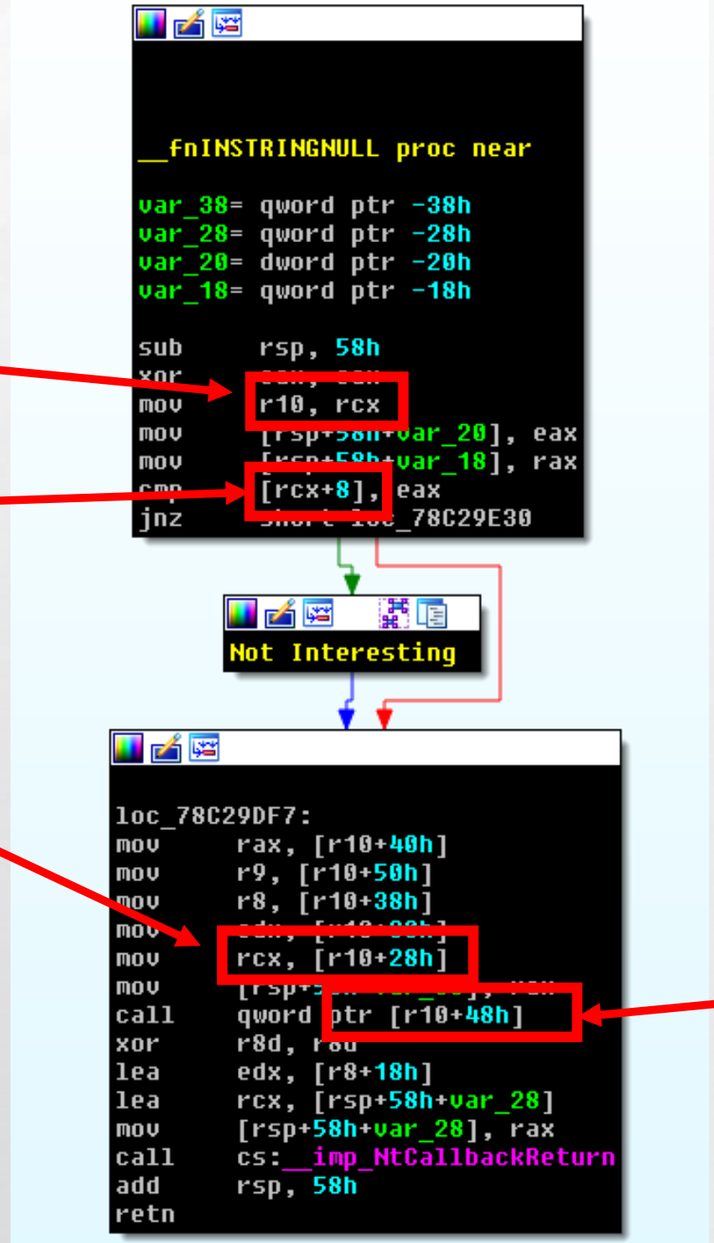
PowerLoaderEx64 – User32 Callbacks To Rescue

The Controlled Ctray Object

Should be NULL

Pointer to DLL Path

Pointer to LoadLibraryA



PowerLoaderEx64 - Recap

1. Create a window and find it in the shared desktop heap
2. Find the target process (Explorer.exe) and find where the desktop heap is mapped, requires only PROCESS_QUERY_INFORMATION privileges
3. Write the malicious CTray object to the shared desktop heap using SetWindowLongPtr
4. Replace the Shell_TrayWnd window's CTray object using SetWindowLongPtr
5. Use SendNotifyMessage to trigger LoadLibrary

PowerLoaderEx64 source code will be on BreakingMalware

http://BreakingMalware.com

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Kernel-To-User Code Injections

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Introduction - Kernel-To-User Code Injections

- Mainly used for:
  - Injecting DLLs
  - Sandbox escapes – After exploiting privilege escalation vulnerability
  - Injecting to protected processes
- Fewer techniques exist than user-mode
- Less documented than user-mode techniques
- Used by both Malware and Software/Security vendors

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Common Injection Methods – User APC

- The most common Kernel-To-User injection method
- Used by lots of malwares:
  - TDL
  - ZERO ACCESS
  - Sandbox escape shellcodes
  - …
- Also used by lots of security products:
  - AVG
  - Kaspersky Home Edition
  - Avecto
  - …
- Documented:
  - Blackout: What Really Happened
  - Much more in forums and leaked source codes

Common Injection Methods – User APC

Basic Steps (There are several variations):

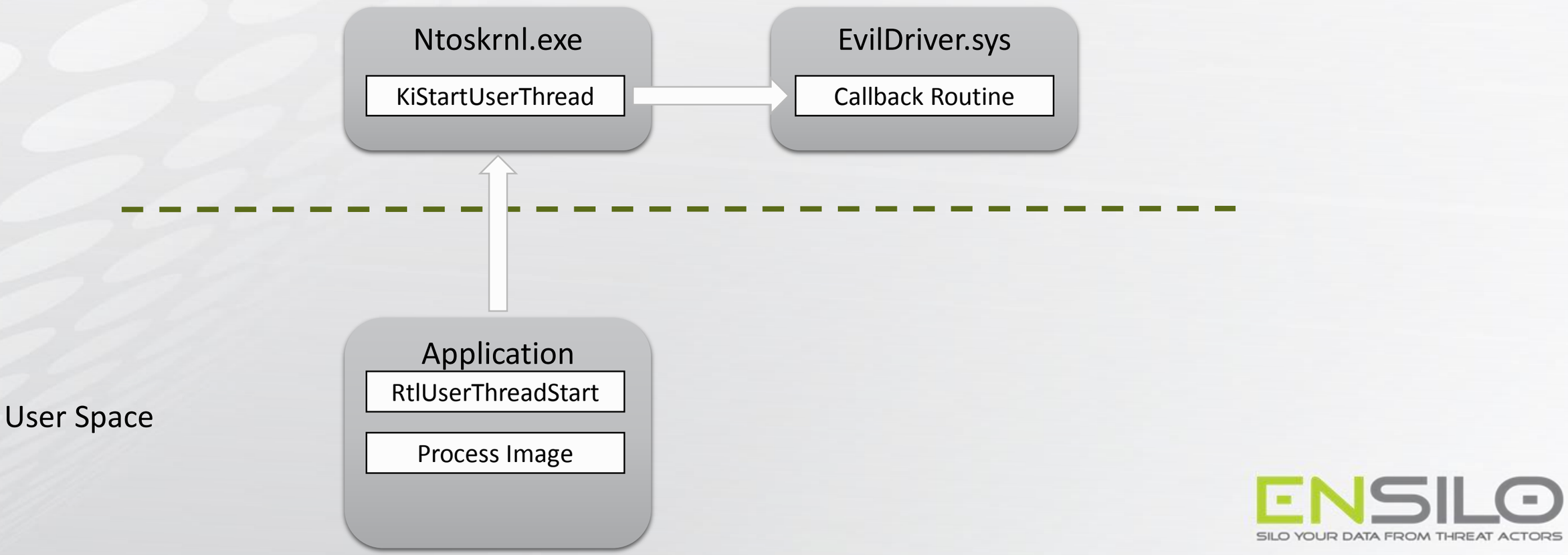
1. Register load image callback using PsSetLoadImageNotifyRoutine and wait for main module to load
2. Write payload that injects a dll using LdrLoadDll
   (Other variations use LoadLibrary)
3. Insert User APC using KeInsertQueueApc

Common Injection Methods – Entry Point Patching

- Not really common but worth mentioning
- Used by Duqu
- Fully documented in:
  http://binsec.gforge.inria.fr/pdf/Malware2013-Analysis-Diversion-Duqu-paper.pdf

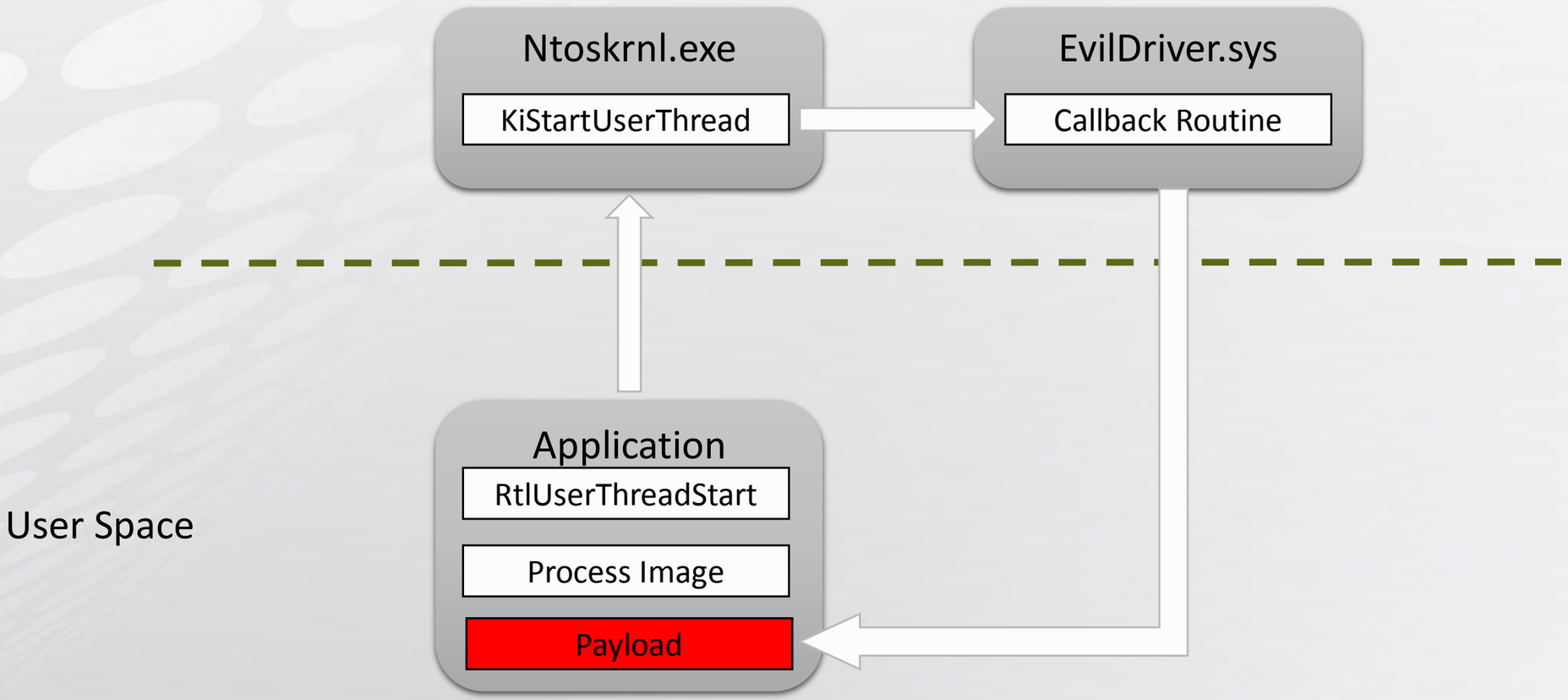
Common Injection Methods – Entry Point Patching

- Register load image callback using PsSetLoadImageNotifyRoutine and wait for main module to load



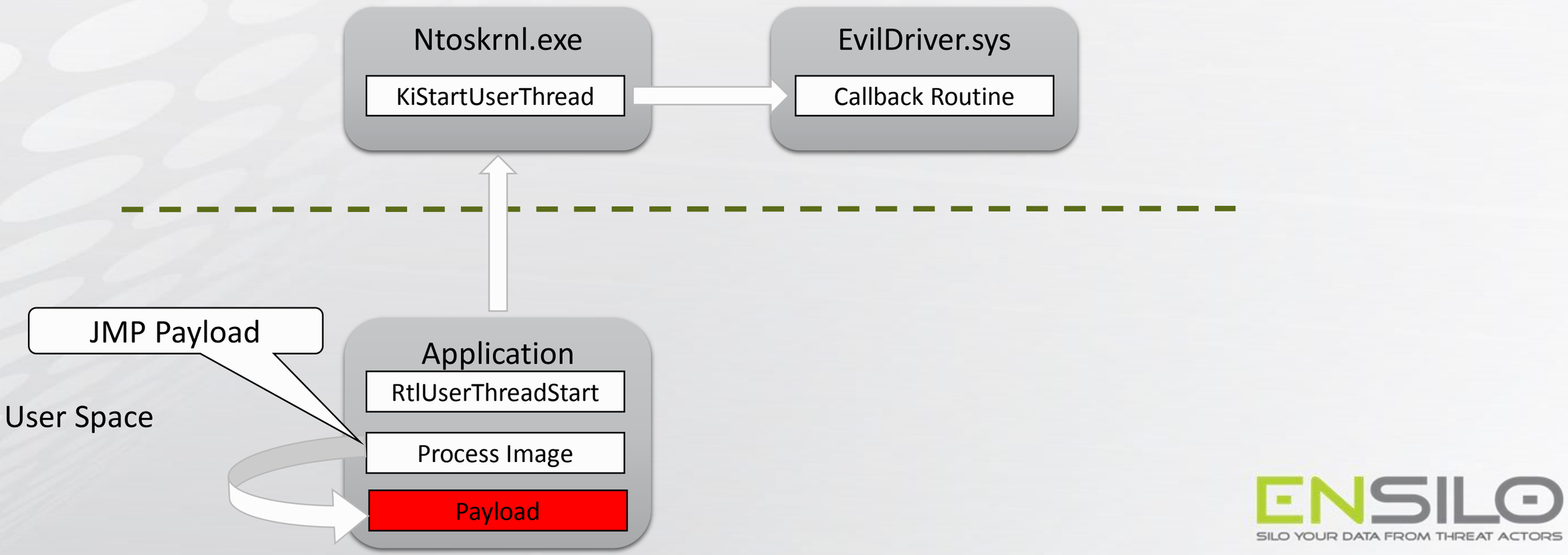
Common Injection Methods – Entry Point Patching

- Write the payload to the process address space



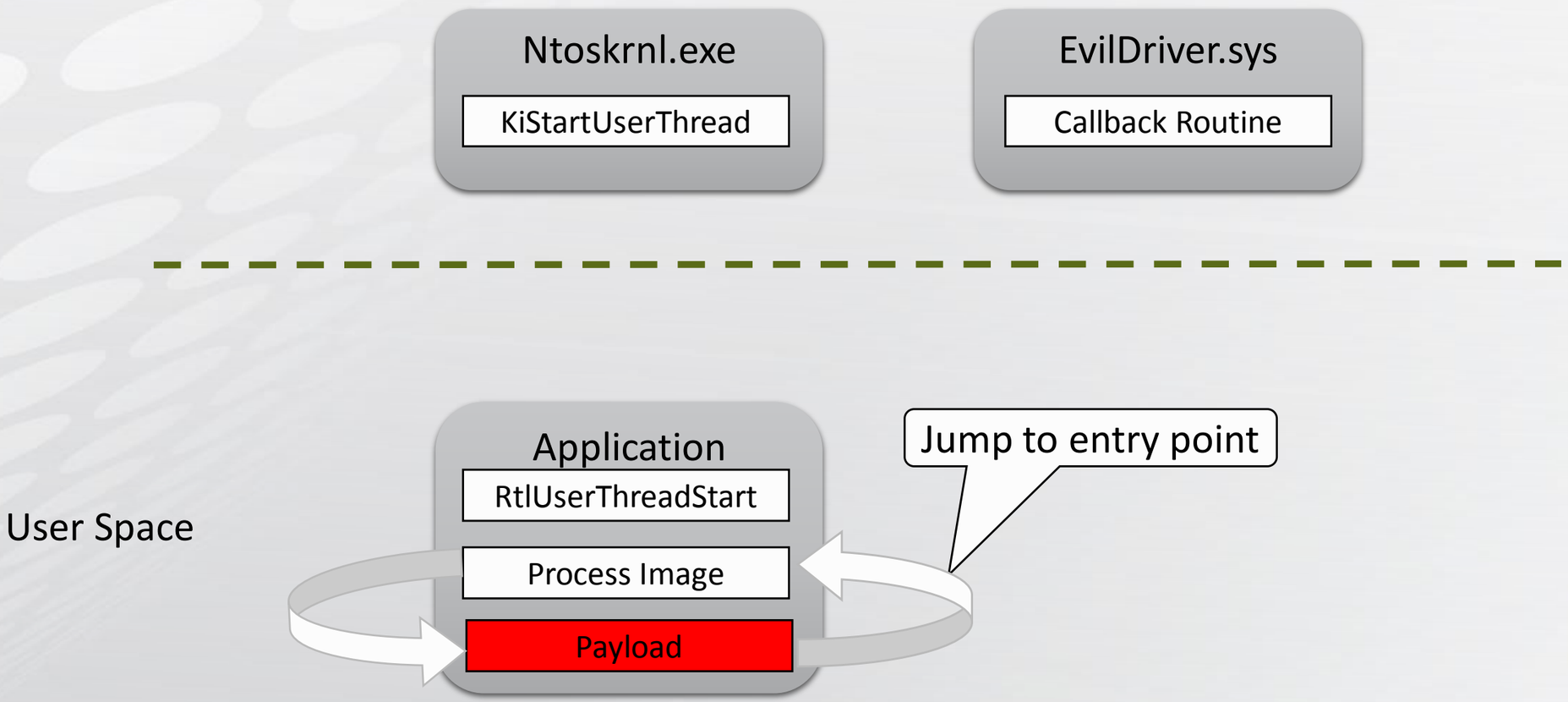
Common Injection Methods – Entry Point Patching

- Replace the image entry point with **JMP** to the new code



Common Injection Methods – Entry Point Patching

- The payload executes, fixes the entry point and jumps to it

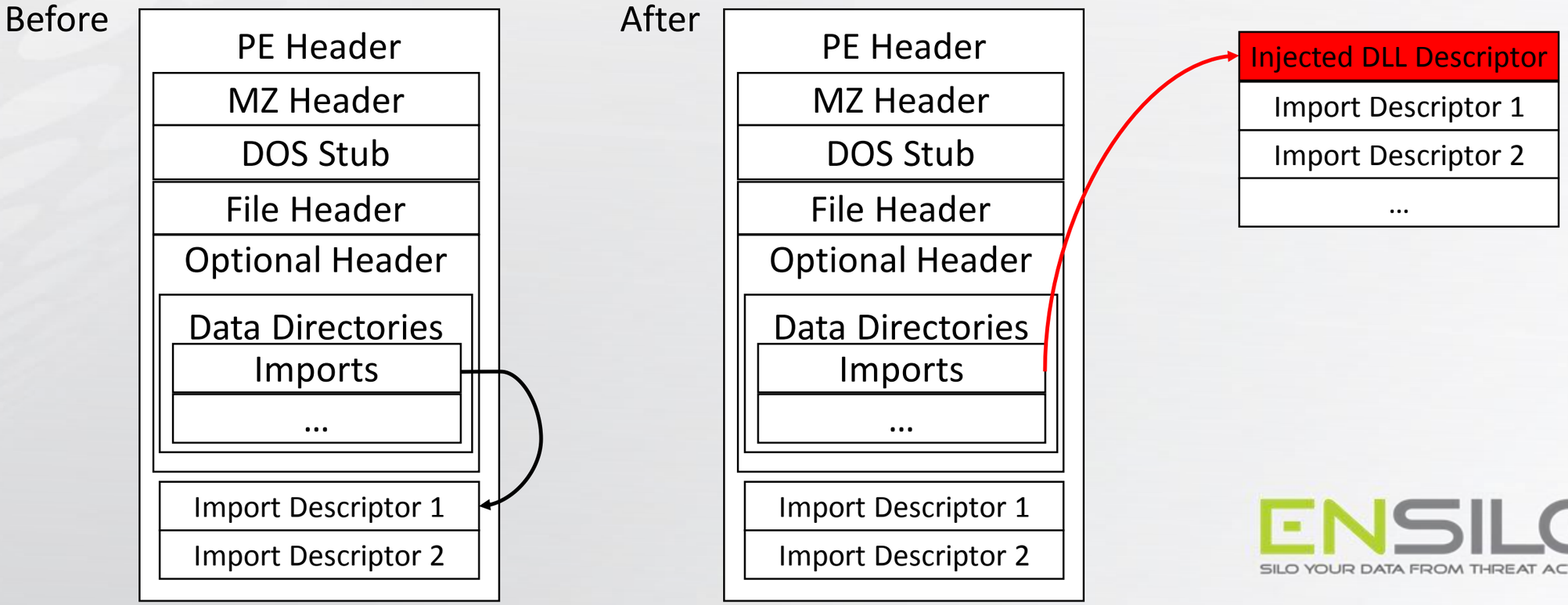


Common Injection Methods – Import Table Patching

- Undocumented (to our knowledge)
- Never been used by malware (to our knowledge)
- Used by software and security vendors:
  - Symantec
  - Trusteer
  - Microsoft App-V
- Similar method could probably use TLS data directory

Common Injection Methods – Import Table Patching

1. Register load image callback using PsSetLoadImageNotifyRoutine and wait for main module to load
2. Allocate memory for the new import table and copy old table with a new record for the injected DLL
3. Point the import data directory to the new table
4. When the DLL is loaded the original PE header is restored



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Common Injection Methods – Quick Summary

- Kernel-To-User Injections are extensively used by both malware and security/software vendors
- Kernel injections are mainly used to inject a DLL to target(or all) processes
- All these methods require injection of some payload to user mode (except for Import Table Patching)
- All use PsSetLoadImageNotifyRoutine

Introducing Trap Frame Injection

- A new kernel-to-user injection technique
- Trap frames save the CPU user-mode state during exceptions or interrupt handling
- A Trap frame is created each time a system call is made and stored on the kernel stack
- The kernel structure used for trap frames is _KTRAP_FRAME
- The user-mode state is restored when the system call returns
- Current frame is stored in the TrapFrame field of _KTHREAD

KTRAP_FRAME

32-Bit

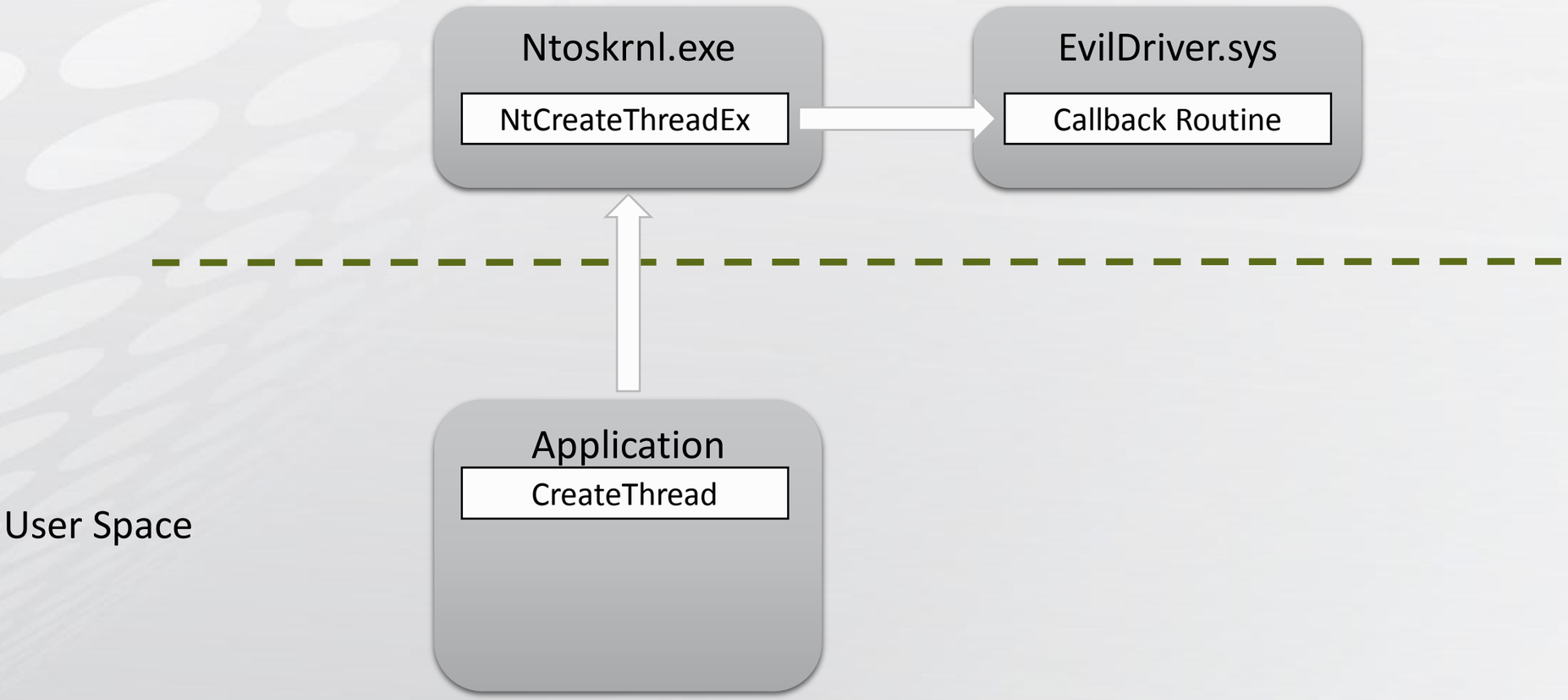
```
kd> dt _ktrap_frame
nt!_KTRAP_FRAME
   +0x000 DbgEbp           : Uint4B
   +0x004 DbgEip           : Uint4B
   +0x008 DbgArgMark       : Uint4B
   +0x00c DbgArgPointer    : Uint4B
   +0x010 TempSegCs        : Uint2B
   +0x012 Logging          : UChar
   +0x013 Reserved         : UChar
   +0x014 TempEsp          : Uint4B
   +0x018 Dr0              : Uint4B
   +0x01c Dr1              : Uint4B
   +0x020 Dr2              : Uint4B
   +0x024 Dr3              : Uint4B
   +0x028 Dr6              : Uint4B
   +0x02c Dr7              : Uint4B
   +0x030 SegGs            : Uint4B
   +0x034 SegEs            : Uint4B
   +0x038 SegDs            : Uint4B
   +0x03c Edx              : Uint4B
   +0x040 Ecx              : Uint4B
   +0x044 Eax              : Uint4B
   +0x048 PreviousPreviousMode : Uint4B
   +0x04c ExceptionList    : Ptr32 _EXCEPTION_REGISTRATION_RECORD
   +0x050 SegFs            : Uint4B
   +0x054 Edi              : Uint4B
   +0x058 Esi              : Uint4B
   +0x05c Ebx              : Uint4B
   +0x060 Ebp              : Uint4B
   +0x064 ErrCode          : Uint4B
   +0x068 Eip              : Uint4B
   +0x06c SegCs            : Uint4B
   +0x070 EFlags           : Uint4B
   +0x074 HardwareEsp      : Uint4B
   +0x078 HardwareSegSs    : Uint4B
   +0x07c V86Es            : Uint4B
   +0x080 V86Ds            : Uint4B
   +0x084 V86Fs            : Uint4B
   +0x088 V86Gs            : Uint4B
```

64-Bit

```
kd> dt _ktrap_frame
nt!_KTRAP_FRAME
   ...
   +0x030 Rax              : Uint8B
   +0x038 Rcx              : Uint8B
   +0x040 Rdx              : Uint8B
   +0x048 R8               : Uint8B
   +0x050 R9               : Uint8B
   +0x058 R10              : Uint8B
   +0x060 R11              : Uint8B
   +0x068 GsBase           : Uint8B
   +0x068 GsSwap           : Uint8B
   ...
   +0x0d0 FaultAddress     : Uint8B
   +0x0d0 ContextRecord    : Uint8B
   +0x0d0 TimeStampCKCL    : Uint8B
   +0x0d8 Dr0              : Uint8B
   ...
   +0x130 SegDs            : Uint2B
   +0x132 SegEs            : Uint2B
   +0x134 SegFs            : Uint2B
   +0x136 SegGs            : Uint2B
   +0x138 TrapFrame        : Uint8B
   +0x140 Rbx              : Uint8B
   +0x148 Rdi              : Uint8B
   +0x150 Rsi              : Uint8B
   +0x158 Rbp              : Uint8B
   ...
   +0x168 Rip              : Uint8B
   +0x170 SegCs            : Uint2B
   ...
   +0x180 Rsp              : Uint8B
   ...
```

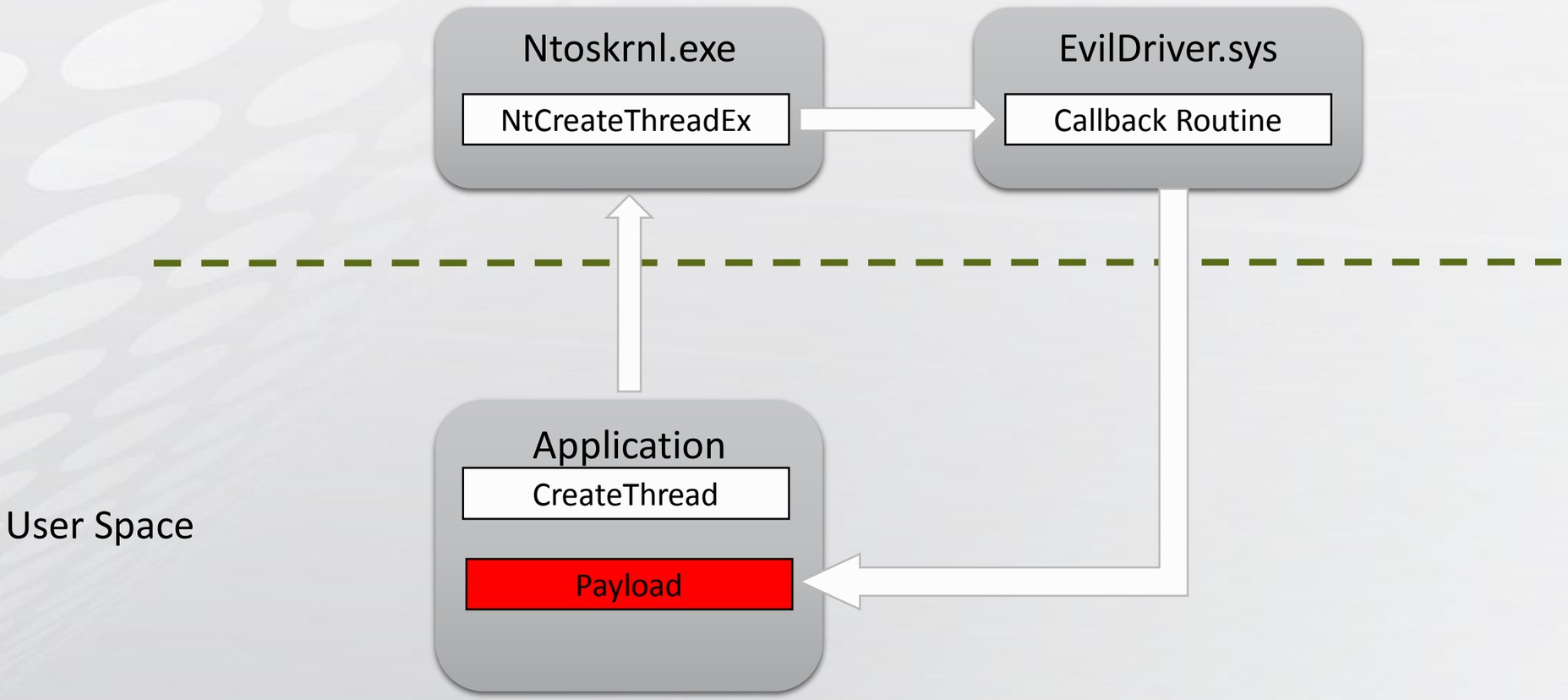
The Trivial Injection

- Wait for some callback that runs in context of a system call (Thread Creation, Registry Access,…)



The Trivial Injection

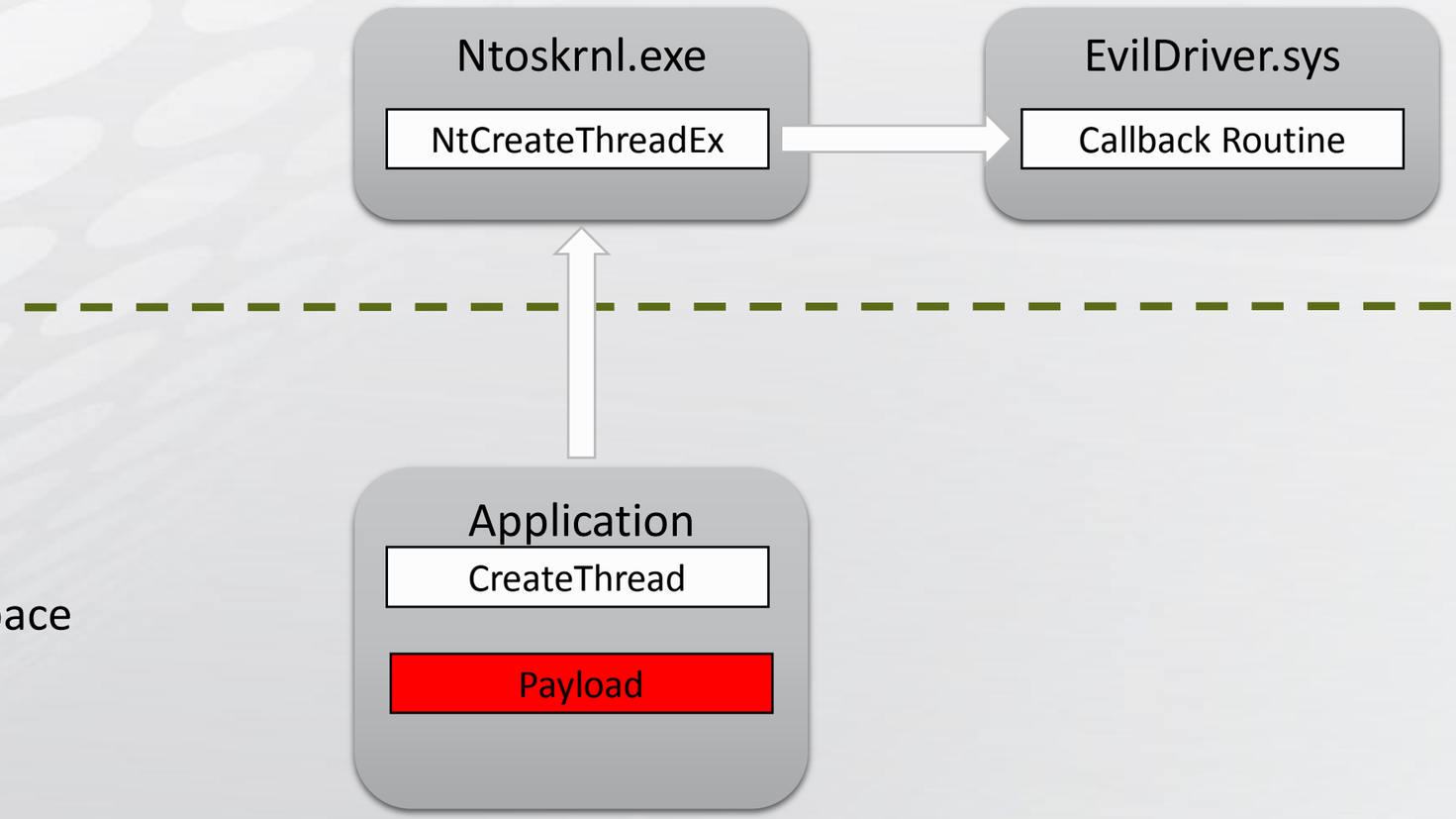
- Allocate payload in the target application



The Trivial Injection

- Fix the trap frame's saved RIP/EIP to the payload

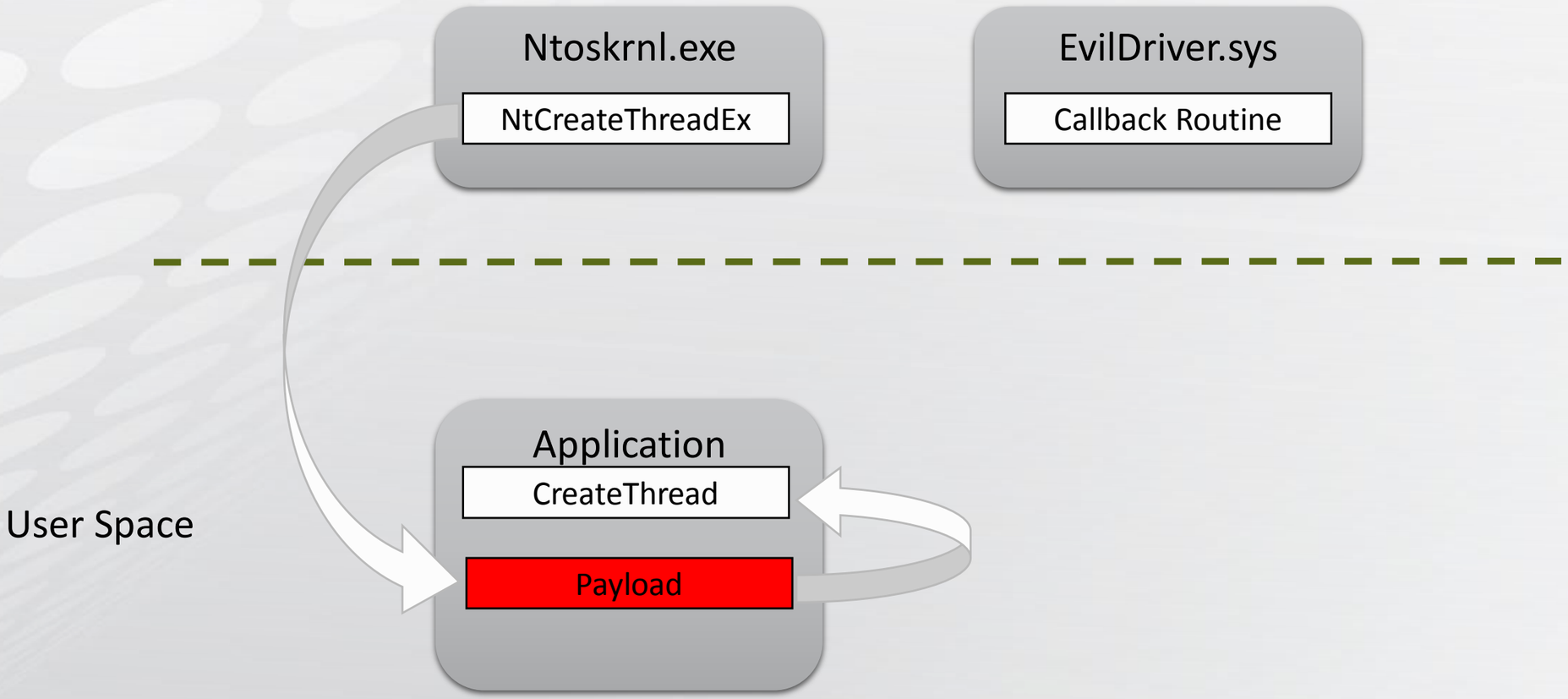
Kernel Space



User Space

The Trivial Injection

- The payload runs and restores normal execution



But We Promised a Codeless Code Injection…

Goals:

- Run code in the context of an arbitrary process:
  - Force IExplore.exe to send POST
  - Open remote shell
  - …
- Easy to write

Limitation:

- No code injections to the process

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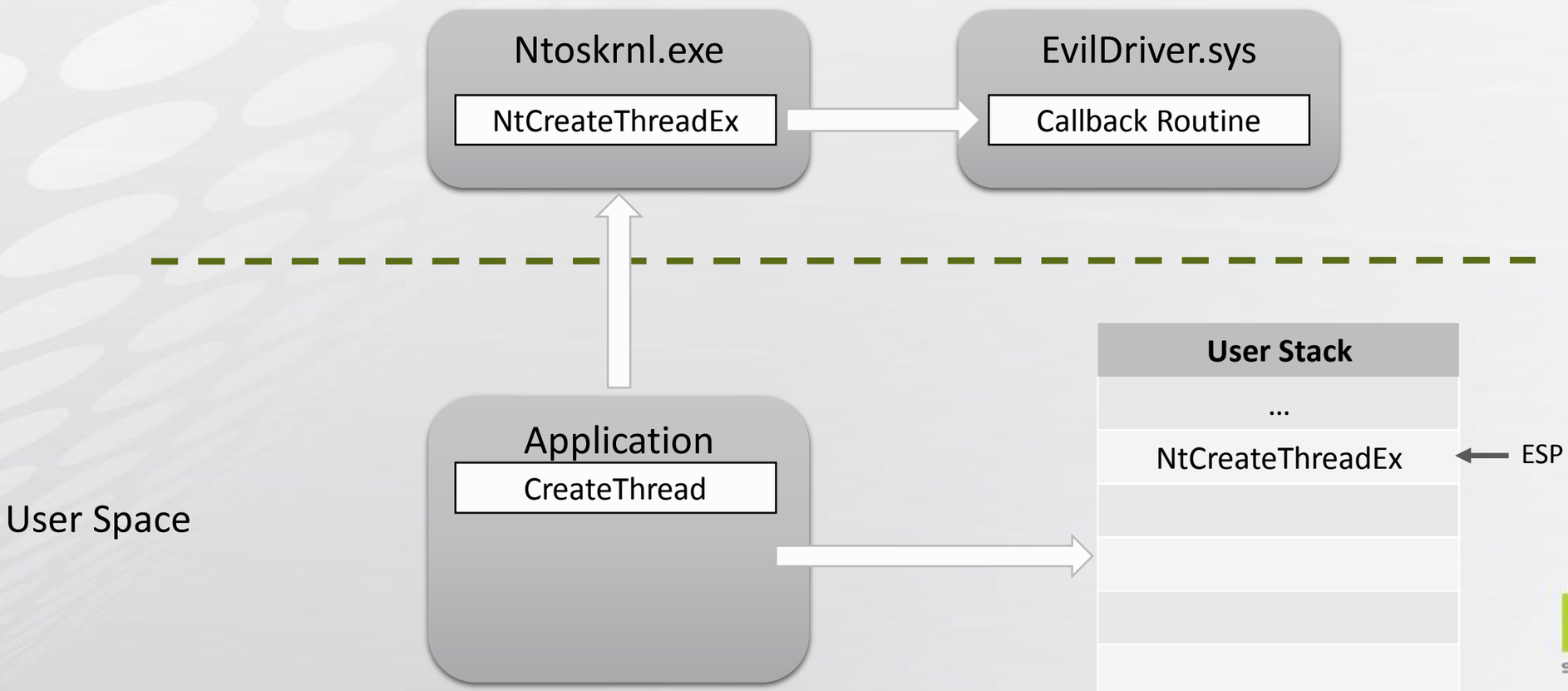
Codeless Code Injection

- Wait for some callback that runs in context of a system call (Thread Creation, Registry Access,…)



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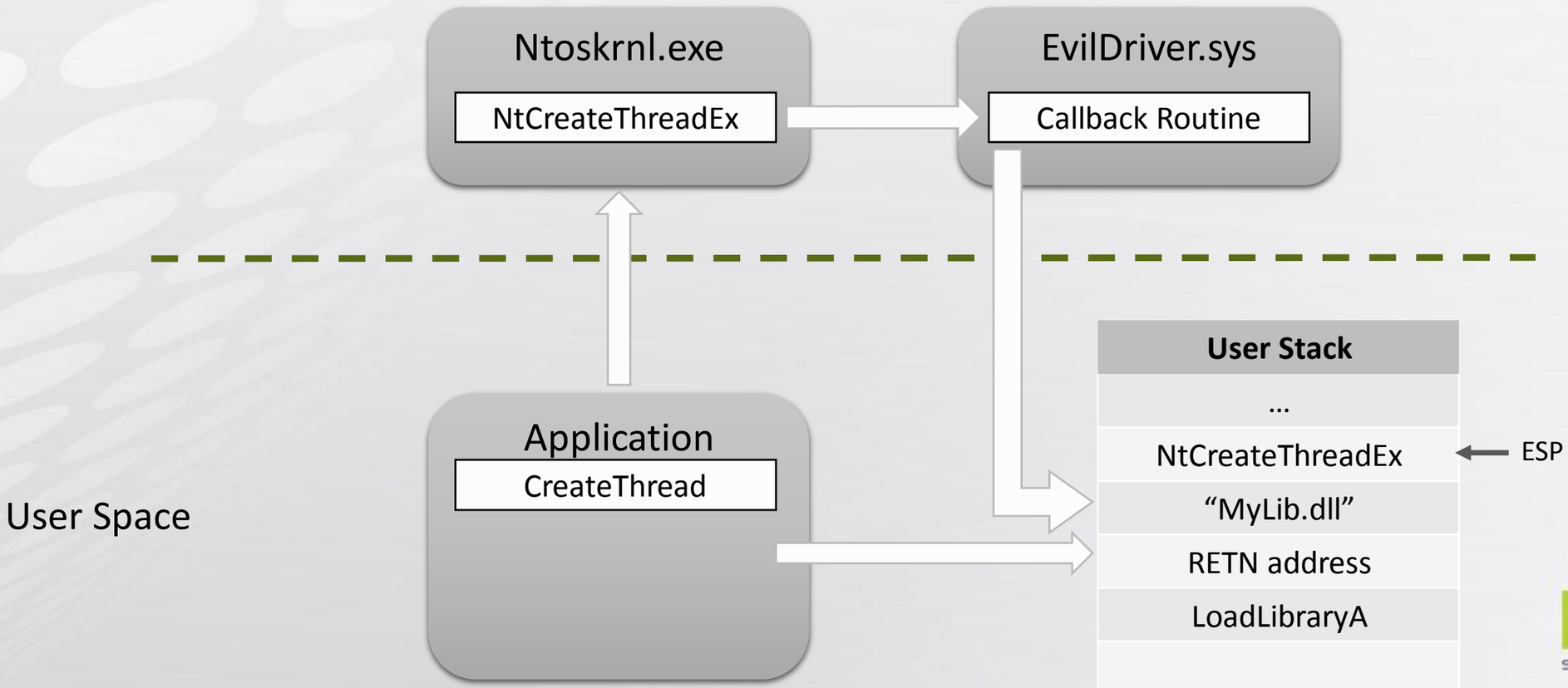
Codeless Code Injection

- Build ROP Chain on the user stack



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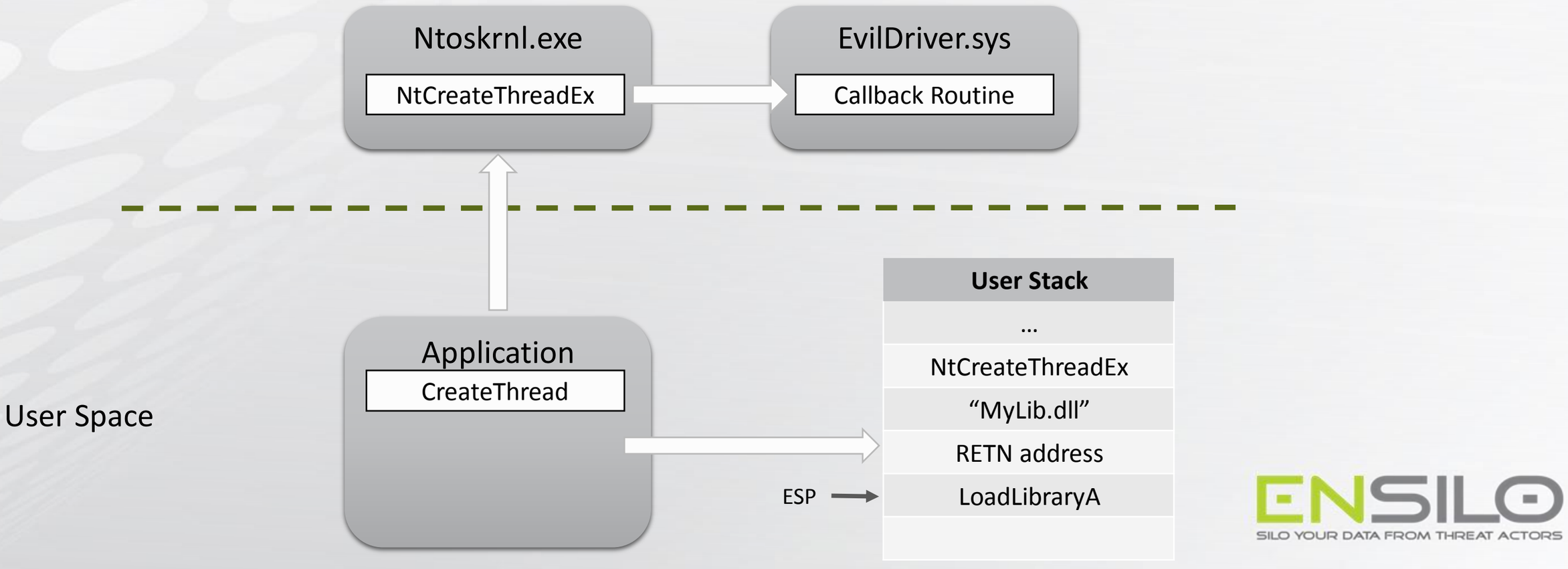
Codeless Code Injection

- Set the stack pointer to the start of the ROP chain



Codeless Code Injection - Challenges

- Getting Return Values – how do we get return values back to kernel mode
  - Solution 1: Use device handle to get notifications (deep dive coming up)
  - Solution 2: Save return value somewhere and trigger some hook-able event (Such as registry access)
- Deadlocks – if the user mode caller holds a lock that our injected function needs
  - Solution: Use a dedicated thread
- Callback – What if we need to a user-mode callback function
  - Solution 1: Use a function that always triggers some hook-able event and fix the context
  - Solution 2: Just don't use such functions ☺

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Codeless Code Injection - NtClose as a callback

- Create a device using IoCreateDevice
- Whenever we require a callback, create a handle for the device in the target process
- Build the following ROP chain:

User Stack
…
Device Handle
RETN address
NtClose
MOV [EDX], EAX Gadget
Writable Location
POP EDX Gadget
…

ESP →

=

MOV EDX, ADDRESS
MOV [EDX], EAX
NtClose(DeviceHandle)

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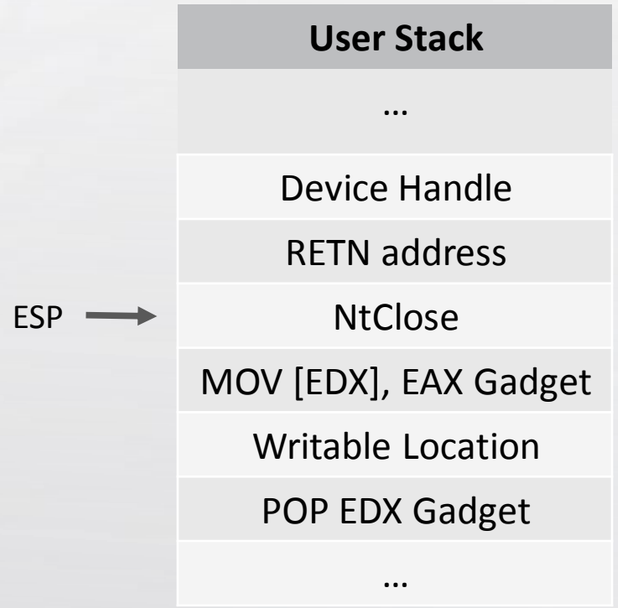
Codeless Code Injection - NtClose as a callback

- When NtClose(Device Handle) is executed then the IRP_MJ_CLEANUP handler will be called
- The required data will reside in the target address



* moving EAX to some register is not safe because of WOW64

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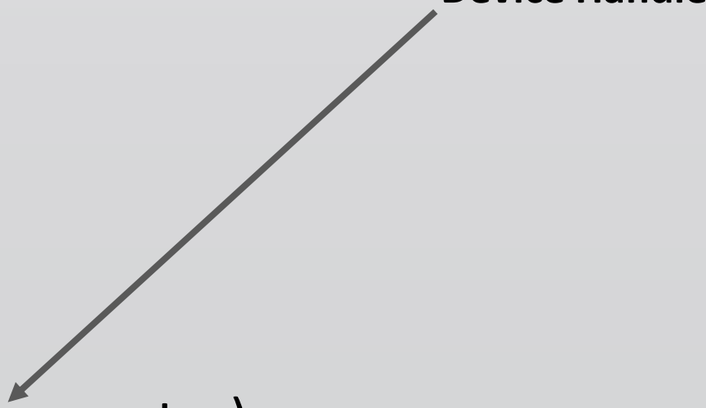
Codeless Code Injection – Creating dedicated thread

```
HANDLE WINAPI CreateThread(
  _In_opt_  LPSECURITY_ATTRIBUTES  lpThreadAttributes,
  _In_      SIZE_T                 dwStackSize,
  _In_      LPTHREAD_START_ROUTINE lpStartAddress,
  _In_opt_  LPVOID                 lpParameter,
  _In_      DWORD                  dwCreationFlags,
  _Out_opt_ LPDWORD                lpThreadId
);

DWORD WINAPI ThreadProc(_In_ LPVOID lpParameter);
```

NtClose

Device Handle



Codeless Code Injection – Creating a Dedicated Thread

- Wait for some callback that runs in context of a system call (Thread Creation, Registry Access,…)
- Build the following ROP Chain

User Stack
…
0
0
Device Handle
NtClose
0
NULL
RETN address
ESP → CreateThread
…

=

```
CreateThread(NULL,
             0,
             NtClose,
             Device Handle,
             0,
             0);
```

- When Handle cleanup is triggered start injecting ROP chains to the new thread

Codeless Code Injection – API

```
ROProgram *CreateProgram(CHAR* TargetName)–
```
Creates a ROP program that's to be run in a target process

```
AddStep(ROProgram* Program, ROProgramStepProc StepProc)–
```
Adds a step to the program. A Single ROP chain that ends in callback(NtClose)

```
RunProgram(ROProgram* Program) –
```
Wait's for the target process to create a thread and starts a new dedicated thread

```
UserLibrary OpenUserLibrary(CHAR* LibName)–
```
Finds a DLL in the target process memory

```
Call(ROPChain* RopChain, UserLibrary Module, CHAR* Function, u32 NumberOfArgs, ...) –
```
Add a call to a ROP chain

```
LoadLibrary(ROPChain* RopChain, char* Name) –
```
Load a Library into the target process

```
WriteToUser(ROPChain* RopChain, u8* Buf, u32 BufSize) –
```
Writes a buffer of data to user-mode

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Codeless Code Injection – API Example

Load a new library to the target process:

```
ROProgram* Program = CreateProgram("iexplore.exe“);
AddStep(Program, LoadSomeLibrary);
RunProgram(Program);

…
bool LoadSomeLibrary(ROProgram* Program, ROPChain* Chain){
     return LoadLibrary(Chain, “MyLibrary.dll”);
}
```

Demo

Reverse Shell from WINLOGON

Summary

- Code injection remains an important capability for both malware and security/software vendors
- Like exploits, techniques are becoming less generic (PowerLoader)
- New User and Kernel injection techniques are constantly being invented
- We can probably expect new advanced injection methods in the near future
- Slides and Source-code will be available on BreakingMalware in a few days

Thank You!

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