Windows Exploit Mitigations

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Windows Exploit Mitigations

Some statements:

- “Windows is insecure”
- “Firefox is more secure than IE”

In respect of memory corruptions – Are these statements (still) true?

Windows Exploit Mitigation

Stack Canaries

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Windows: Stack Canary

Stack Canaries

- Integrated in Visual Studio
- **/gs**
- Since Visual Studio 2002
- Deployed in: XP SP2

Version

- GS v1 (2002)
- GS v1.1 (2003)
- GS v2 (2005)
- GS v3 (2010)

Windows Exploit

SEH / AntiSEH

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Windows: SEH

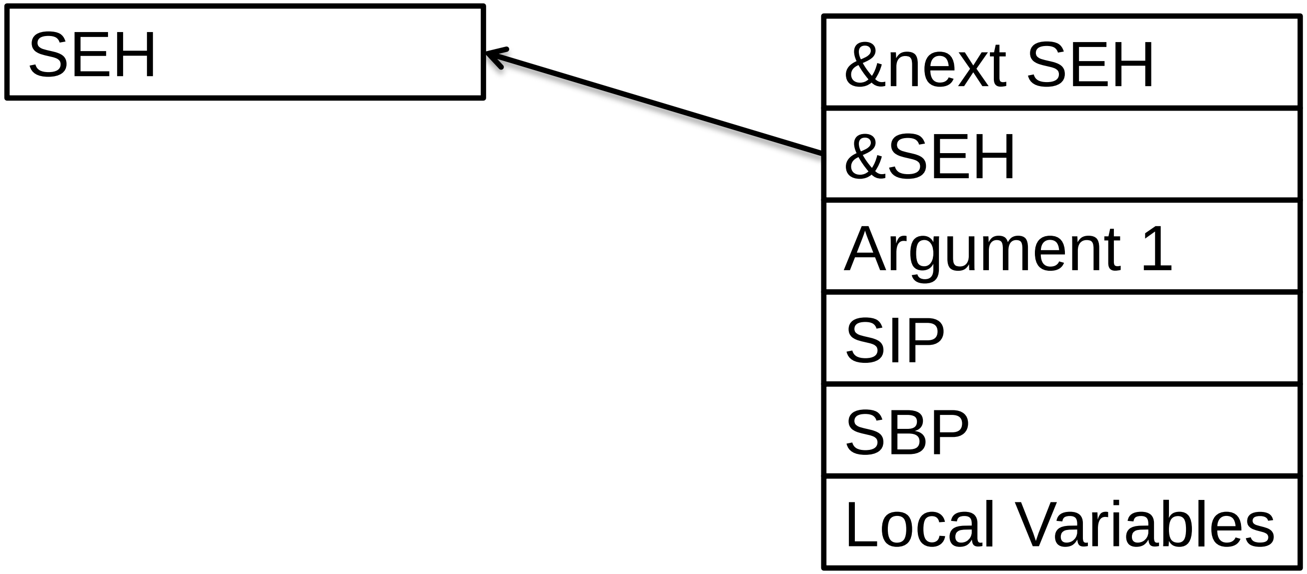
SEH Overwrite

- **S**tructured **E**xception **H**andler
- Located on the stack
- To handle exceptions

Favorite target for Windows exploits for years

https://blogs.technet.microsoft.com/srd/2009/02/02/preventing-the-exploitation-of-structured-exception-handler-seh-overwrites-with-sehop/

Windows: SEH



SEH

&next SEH

&SEH

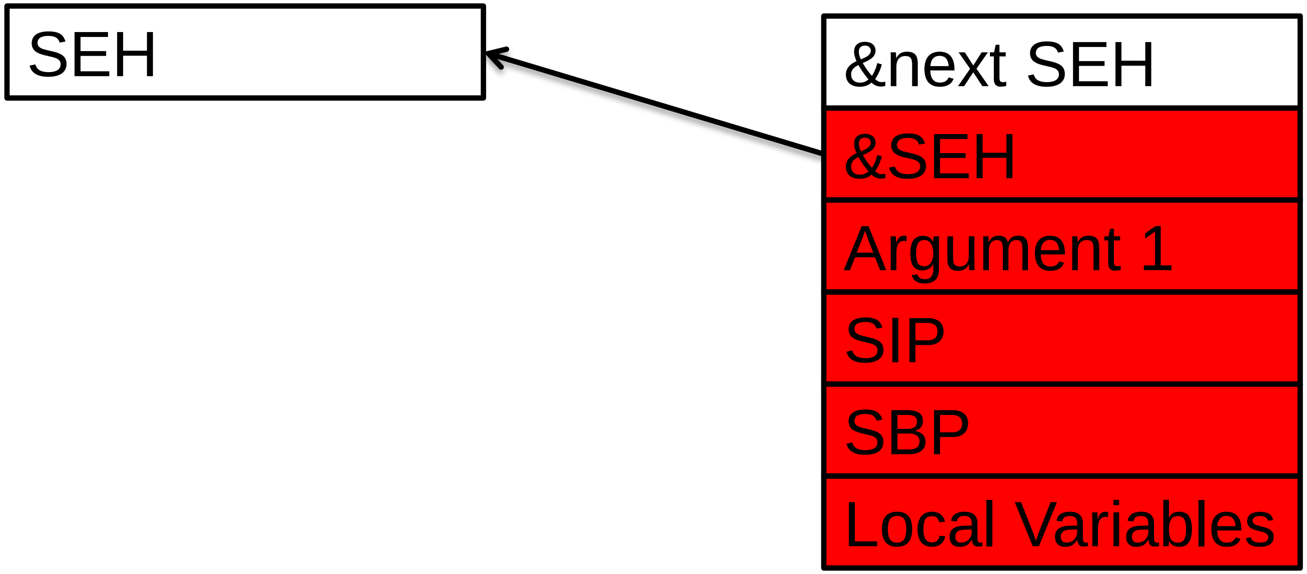
Argument 1

SIP

SBP

Local Variables

Windows: SEH



Windows: SEH

Mitigation: SafeSEH

- VS2003: /SafeSEH
- Whitelist of safe exception handlers

Mitigation: Dynamic SafeSEH

- End of SEH List has a validation frame
- The complete SEH list has to be valid (*next)

Mitigation: SEHOP

- Default active in Windows Server 2008, Vista SP2 (?)
- SEH Overwrite Protection

Windows Exploits

Ret2libc

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Windows: Call convention

Call convention:

- “Stdcall” call convention
  - Caller pushes arguments
  - Callee pops arguments (unlike linux!)

Can call Windows library functions

- E.g: VirtualProtect()
- Changes the permission of a memory region
- Can make it executable again (removing DEP)

Windows: ret2libc

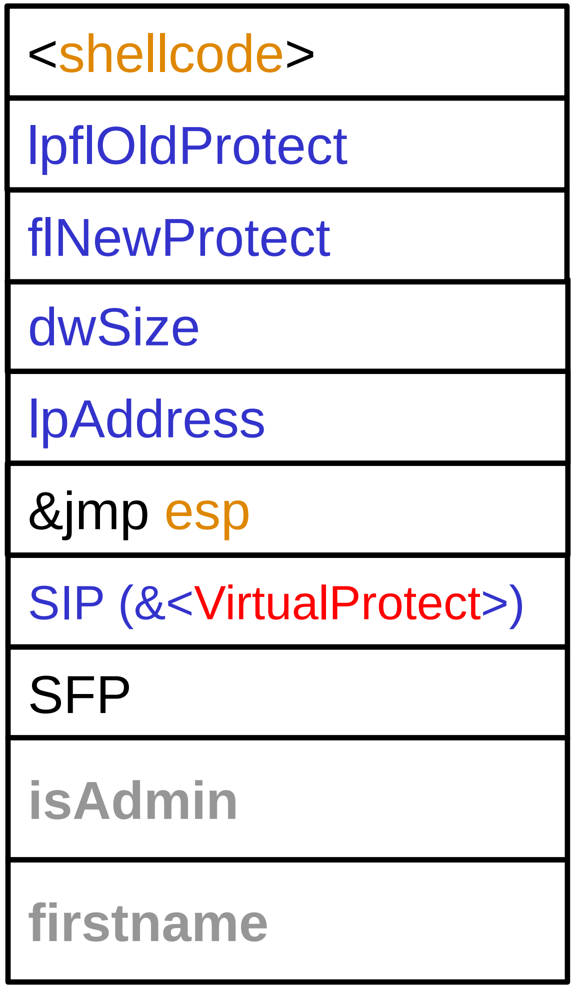
VirtualProtect: Set memory protection bits

```
BOOL WINAPI VirtualProtect(
  _In_  LPVOID lpAddress,
  _In_  SIZE_T dwSize,
  _In_  DWORD  flNewProtect,
  _Out_ PDWORD lpflOldProtect
);
```

Windows: ret2libc

Ret2libc chaining:

```
BOOL WINAPI VirtualProtect(
   _In_   LPVOID lpAddress,
   _In_   SIZE_T dwSize,
   _In_   DWORD  flNewProtect,
   _Out_  PDWORD lpflOldProtect
);
```



<shellcode>

lpflOldProtect

flNewProtect

dwSize

lpAddress

&jmp esp

SIP (&<VirtualProtect>)

SFP

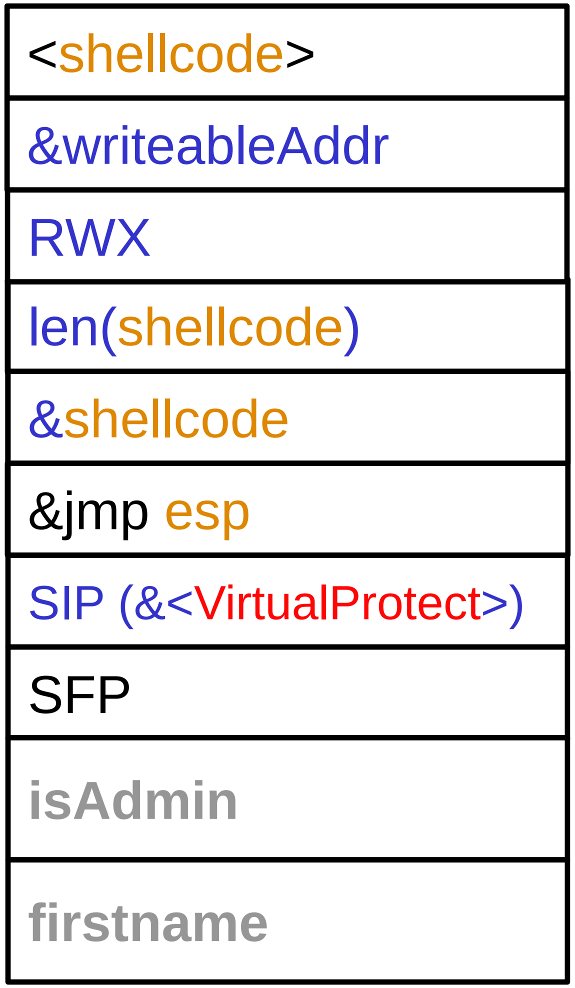
isAdmin

firstname

Windows: ret2libc

Ret2libc chaining:

```
BOOL WINAPI VirtualProtect(
  _In_  LPVOID lpAddress,
  _In_  SIZE_T dwSize,
  _In_  DWORD  flNewProtect,
  _Out_ PDWORD lpflOldProtect
);
```



<shellcode>

&writeableAddr

RWX

len(shellcode)

&shellcode

&jmp esp

SIP (&<VirtualProtect>)

SFP

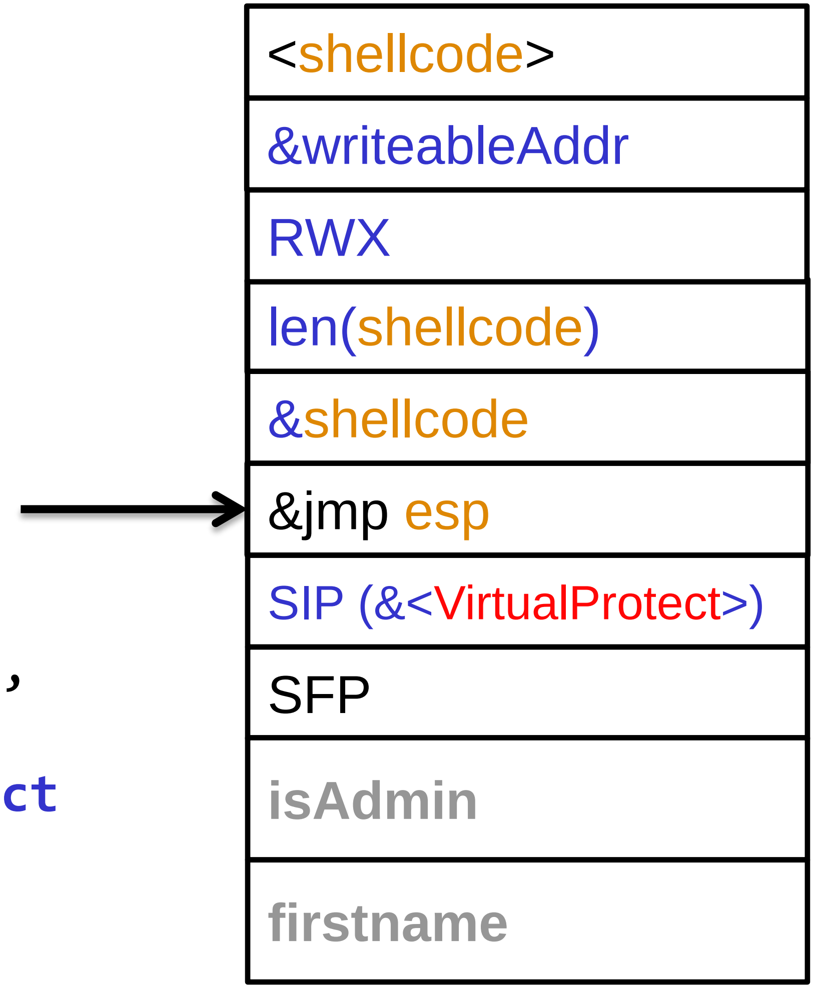
isAdmin

firstname

Windows: ret2libc

Ret2libc chaining:

```
BOOL WINAPI VirtualProtect(
  _In_  LPVOID lpAddress,
  _In_  SIZE_T dwSize,
  _In_  DWORD  flNewProtect,
  _Out_ PDWORD lpflOldProtect
);
```



<shellcode>

&writeableAddr

RWX

len(shellcode)

&shellcode

&jmp esp

SIP (&<VirtualProtect>)

SFP

isAdmin

firstname

Windows: ret2libc

Conclusion:

Possible to chain library calls

Like ROP, just for function calls

Can defeat DEP (or be used for other things)

Windows Exploit Mitigation

ASLR

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Windows: ASLR

ASLR in Windows

- Introduced in Windows Vista

Windows 7

- Randomized: Heap and Stack
- Not randomized: VirtualAlloc, MapViewOfFile
- A little randomized: PEBs, TEPBs

Windows 8

- Opt-in:
- More things are randomized
- A little bit more randomized: PEBs, TEPBs
- High entropy ASLR for 64 bit processes
  - Anti heap-spray

Windows: ASLR

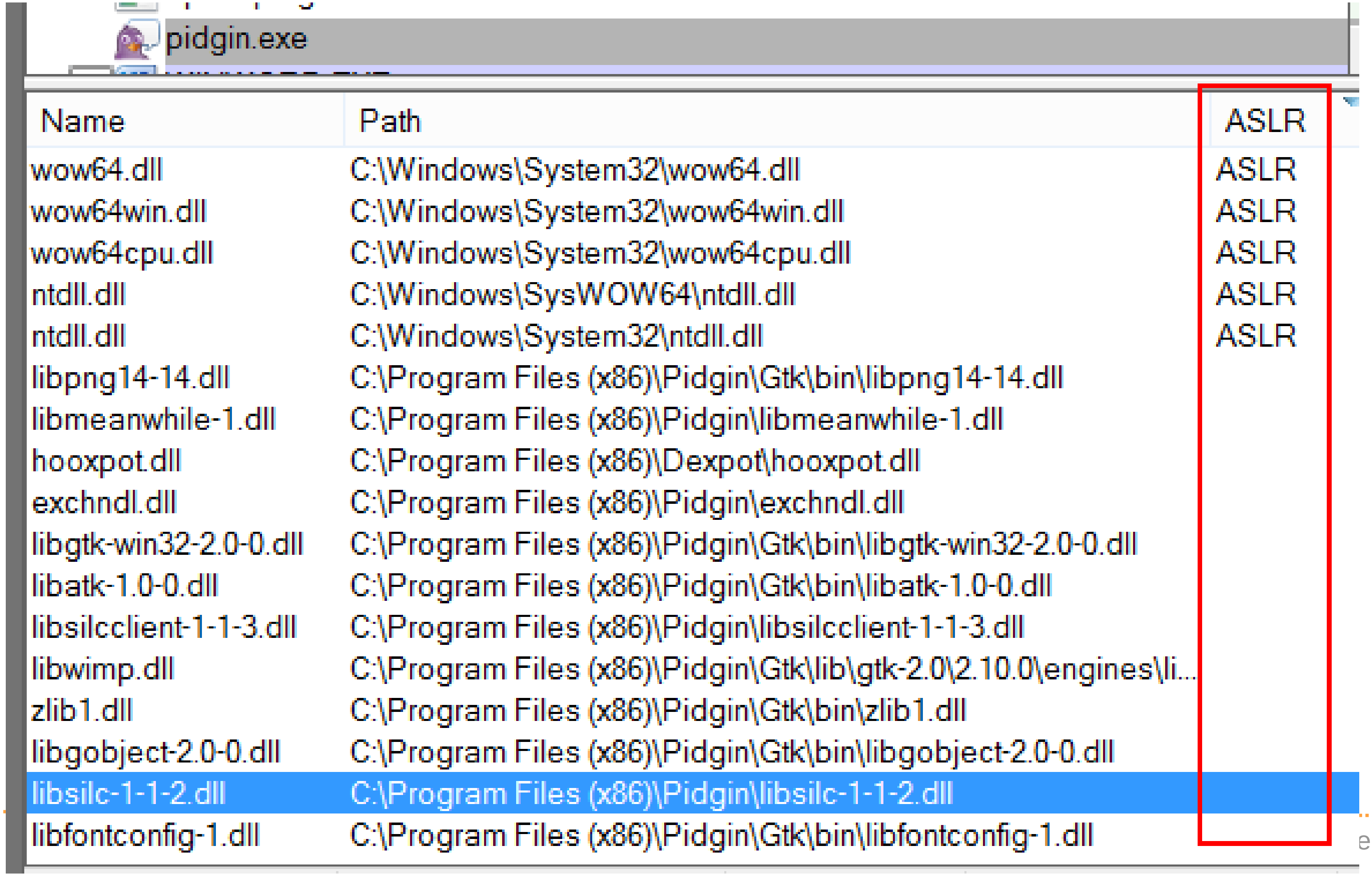
Windows ASLR problems

- Not all binaries are compiled with relocation
- Windows Vista: Relocation on Boot
  - Brute force able
- Heap spraying

- Not all libraries are compiled with relocation!
  - Adobe Flash…
  - Adobe PDF…
  - Java…
  - Some Antivirus inject(ed) DLLs
    - On every process
    - On static addresses…

Windows: ASLR

Pidgin DLL ASLR status:

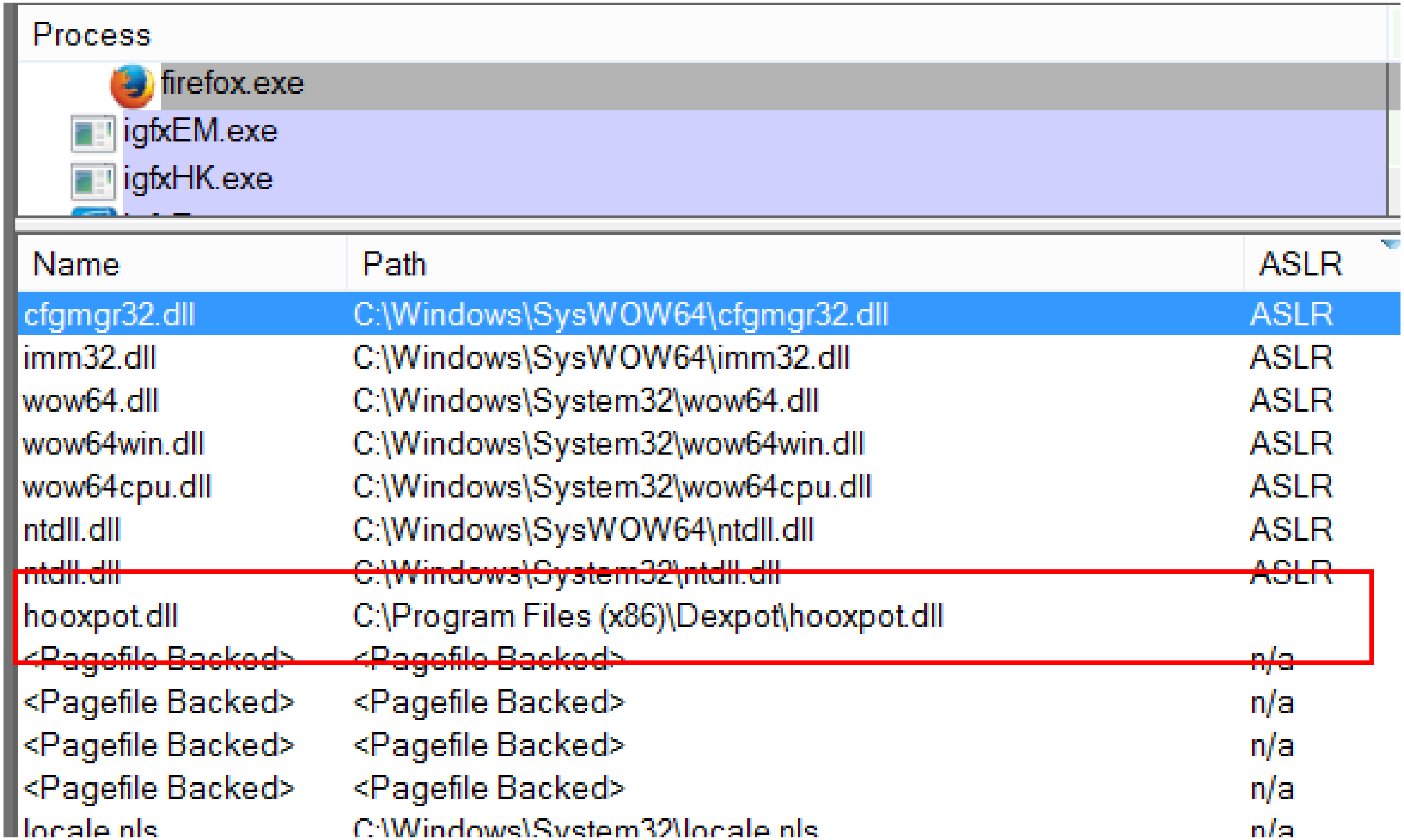


pidgin.exe

Name	Path	ASLR
wow64.dll	C:\Windows\System32\wow64.dll	ASLR
wow64win.dll	C:\Windows\System32\wow64win.dll	ASLR
wow64cpu.dll	C:\Windows\System32\wow64cpu.dll	ASLR
ntdll.dll	C:\Windows\SysWOW64\ntdll.dll	ASLR
ntdll.dll	C:\Windows\System32\ntdll.dll	ASLR
libpng14-14.dll	C:\Program Files (x86)\Pidgin\Gtk\bin\libpng14-14.dll	
libmeanwhile-1.dll	C:\Program Files (x86)\Pidgin\libmeanwhile-1.dll	
hooxpot.dll	C:\Program Files (x86)\Dexpot\hooxpot.dll	
exchndl.dll	C:\Program Files (x86)\Pidgin\exchndl.dll	
libgtk-win32-2.0-0.dll	C:\Program Files (x86)\Pidgin\Gtk\bin\libgtk-win32-2.0-0.dll	
libatk-1.0-0.dll	C:\Program Files (x86)\Pidgin\Gtk\bin\libatk-1.0-0.dll	
libsilcclient-1-1-3.dll	C:\Program Files (x86)\Pidgin\libsilcclient-1-1-3.dll	
libwimp.dll	C:\Program Files (x86)\Pidgin\Gtk\lib\gtk-2.0\2.10.0\engines\li...	
zlib1.dll	C:\Program Files (x86)\Pidgin\Gtk\bin\zlib1.dll	
libgobject-2.0-0.dll	C:\Program Files (x86)\Pidgin\Gtk\bin\libgobject-2.0-0.dll	
libsilc-1-1-2.dll	C:\Program Files (x86)\Pidgin\libsilc-1-1-2.dll	
libfontconfig-1.dll	C:\Program Files (x86)\Pidgin\Gtk\bin\libfontconfig-1.dll	

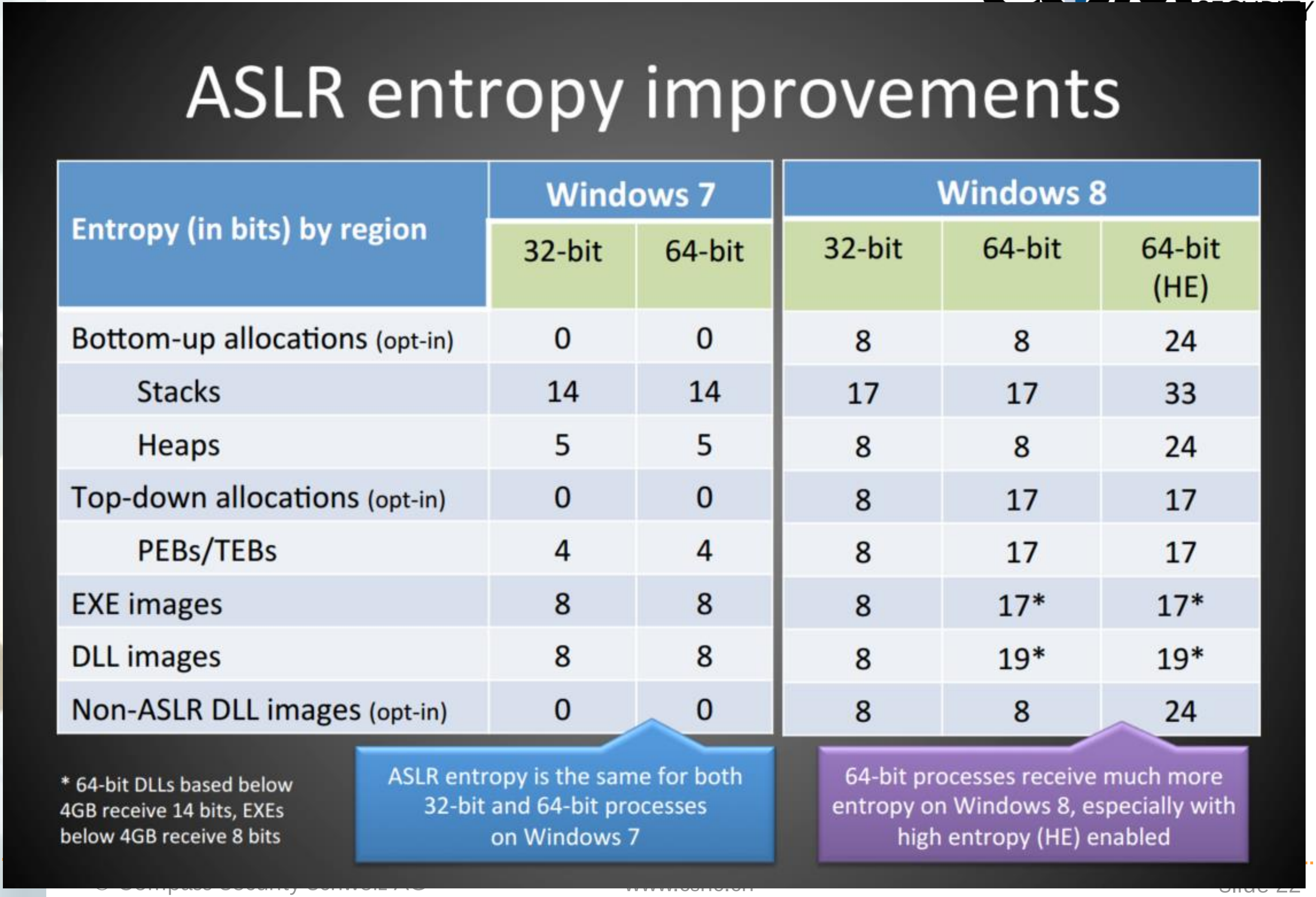
Windows: ASLR

Dexpot DLL injection



Name	Path	ASLR
cfgmgr32.dll	C:\Windows\SysWOW64\cfgmgr32.dll	ASLR
imm32.dll	C:\Windows\SysWOW64\imm32.dll	ASLR
wow64.dll	C:\Windows\System32\wow64.dll	ASLR
wow64win.dll	C:\Windows\System32\wow64win.dll	ASLR
wow64cpu.dll	C:\Windows\System32\wow64cpu.dll	ASLR
ntdll.dll	C:\Windows\SysWOW64\ntdll.dll	ASLR
ntdll.dll	C:\Windows\System32\ntdll.dll	ASLR
hooxpot.dll	C:\Program Files (x86)\Dexpot\hooxpot.dll	
<Pagefile Backed>	<Pagefile Backed>	n/a
<Pagefile Backed>	<Pagefile Backed>	n/a
<Pagefile Backed>	<Pagefile Backed>	n/a
<Pagefile Backed>	<Pagefile Backed>	n/a
locale.nls	C:\Windows\System32\locale.nls	n/a

Windows: ASLR



ASLR entropy improvements

Entropy (in bits) by region	Windows 7		Windows 8		
	32-bit	64-bit	32-bit	64-bit	64-bit (HE)
Bottom-up allocations (opt-in)	0	0	8	8	24
Stacks	14	14	17	17	33
Heaps	5	5	8	8	24
Top-down allocations (opt-in)	0	0	8	17	17
PEBs/TEBs	4	4	8	17	17
EXE images	8	8	8	17*	17*
DLL images	8	8	8	19*	19*
Non-ASLR DLL images (opt-in)	0	0	8	8	24

* 64-bit DLLs based below 4GB receive 14 bits, EXEs below 4GB receive 8 bits

ASLR entropy is the same for both 32-bit and 64-bit processes on Windows 7

64-bit processes receive much more entropy on Windows 8, especially with high entropy (HE) enabled

Windows Exploit Mitigation

HEAP

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Windows: Heap

Heap Protections:

2004: Safe unlinking

2006: Vista heap hardening

Win8:

- Additional Heap metadata structure improvements
- Guard pages
- Allocation order randomization
  - Makes HEAP massaging more difficult

Windows Exploit Mitigations

EMET

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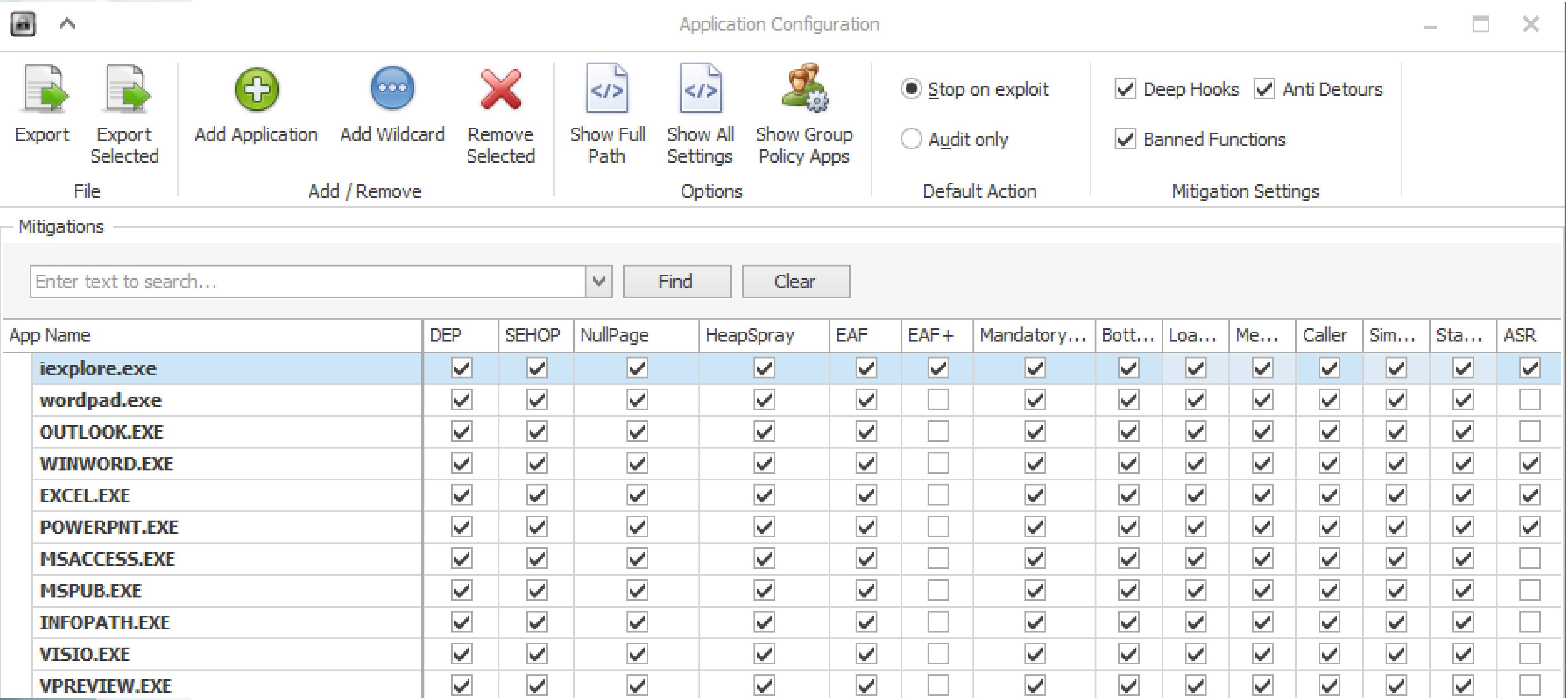
Windows: EMET

Enhanced Mitigation Experience Toolkit

- DEP
- SEHOP
- NullPage
- HeapSpray
- EAF, EAF+ (Export Address Filtering)
- ASLR
- ROP Caller check
- Stack Pivot
- ASR (Attack Surface Reduction)

Windows: EMET

EMET Settings example



Default Action:
● Stop on exploit
○ Audit only

Mitigation Settings:
☑ Deep Hooks ☑ Anti Detours
☑ Banned Functions

App Name	DEP	SEHOP	NullPage	HeapSpray	EAF	EAF+	Mandatory...	Bott...	Loa...	Me...	Caller	Sim...	Sta...	ASR
iexplore.exe	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
wordpad.exe	☑	☑	☑	☑	☑	□	☑	☑	☑	☑	☑	☑	☑	□
OUTLOOK.EXE	☑	☑	☑	☑	☑	□	☑	☑	☑	☑	☑	☑	☑	□
WINWORD.EXE	☑	☑	☑	☑	☑	□	☑	☑	☑	☑	☑	☑	☑	☑
EXCEL.EXE	☑	☑	☑	☑	☑	□	☑	☑	☑	☑	☑	☑	☑	☑
POWERPNT.EXE	☑	☑	☑	☑	☑	□	☑	☑	☑	☑	☑	☑	☑	☑
MSACCESS.EXE	☑	☑	☑	☑	☑	□	☑	☑	☑	☑	☑	☑	☑	□
MSPUB.EXE	☑	☑	☑	☑	☑	□	☑	☑	☑	☑	☑	☑	☑	□
INFOPATH.EXE	☑	☑	☑	☑	☑	□	☑	☑	☑	☑	☑	☑	☑	□
VISIO.EXE	☑	☑	☑	☑	☑	□	☑	☑	☑	☑	☑	☑	☑	□
VPREVIEW.EXE	☑	☑	☑	☑	☑	□	☑	☑	☑	☑	☑	☑	☑	□

Windows: EMET

Use it

No really, use it

- 0-Day Protection
- Automatic configuration is OK
- Protect every program which is handling untrusted data
  - All network services
  - Tools like PDF readers, Chat programs, Photoshop etc.

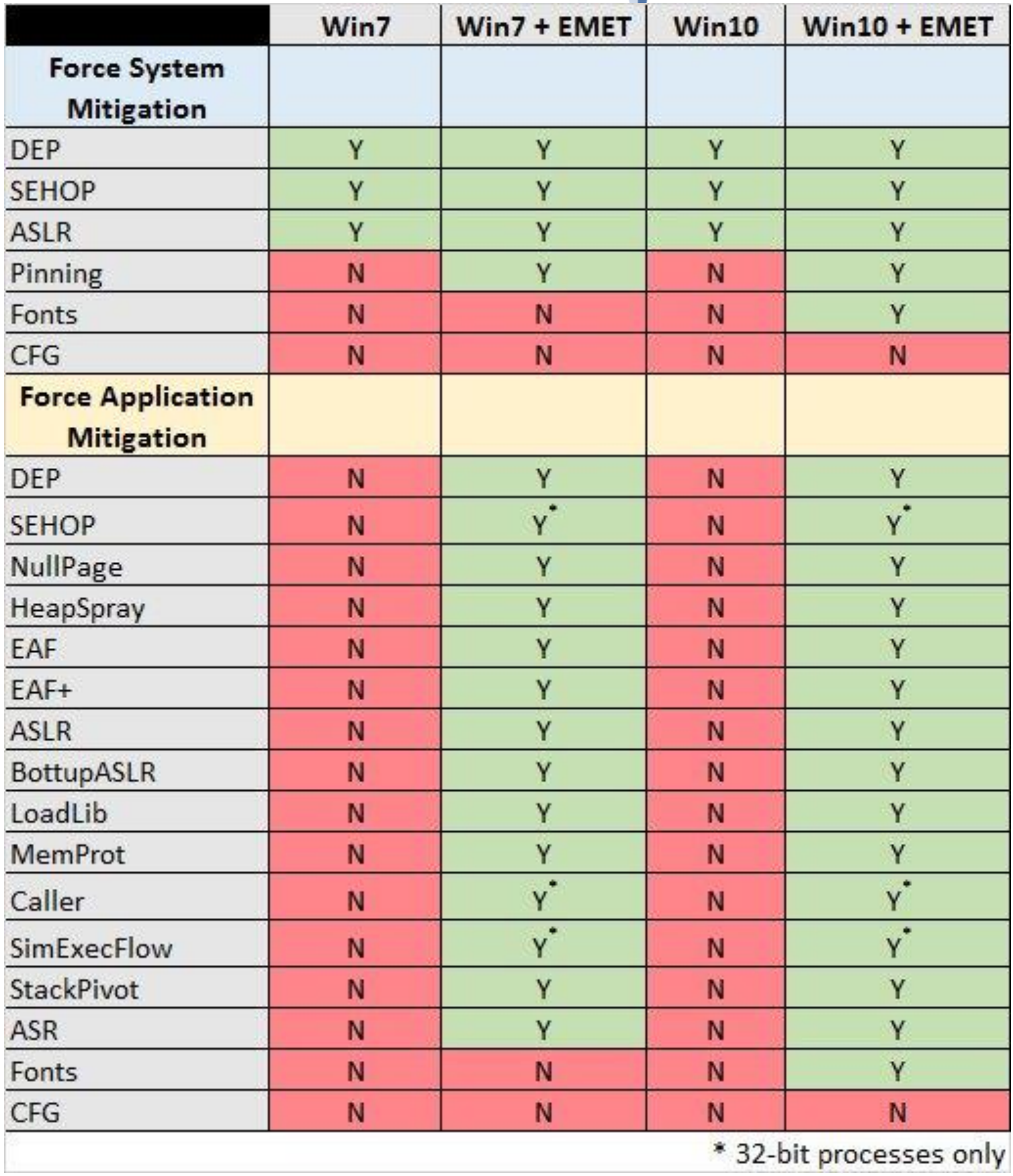
Downsides:

- Download manually…
- Not updated via windows update
- Not localized (…)
- Incompatible programs will crash
- It may confuse users

Windows: EMET

Update 2017: EMET is dead?

- EOL July 31, 2018



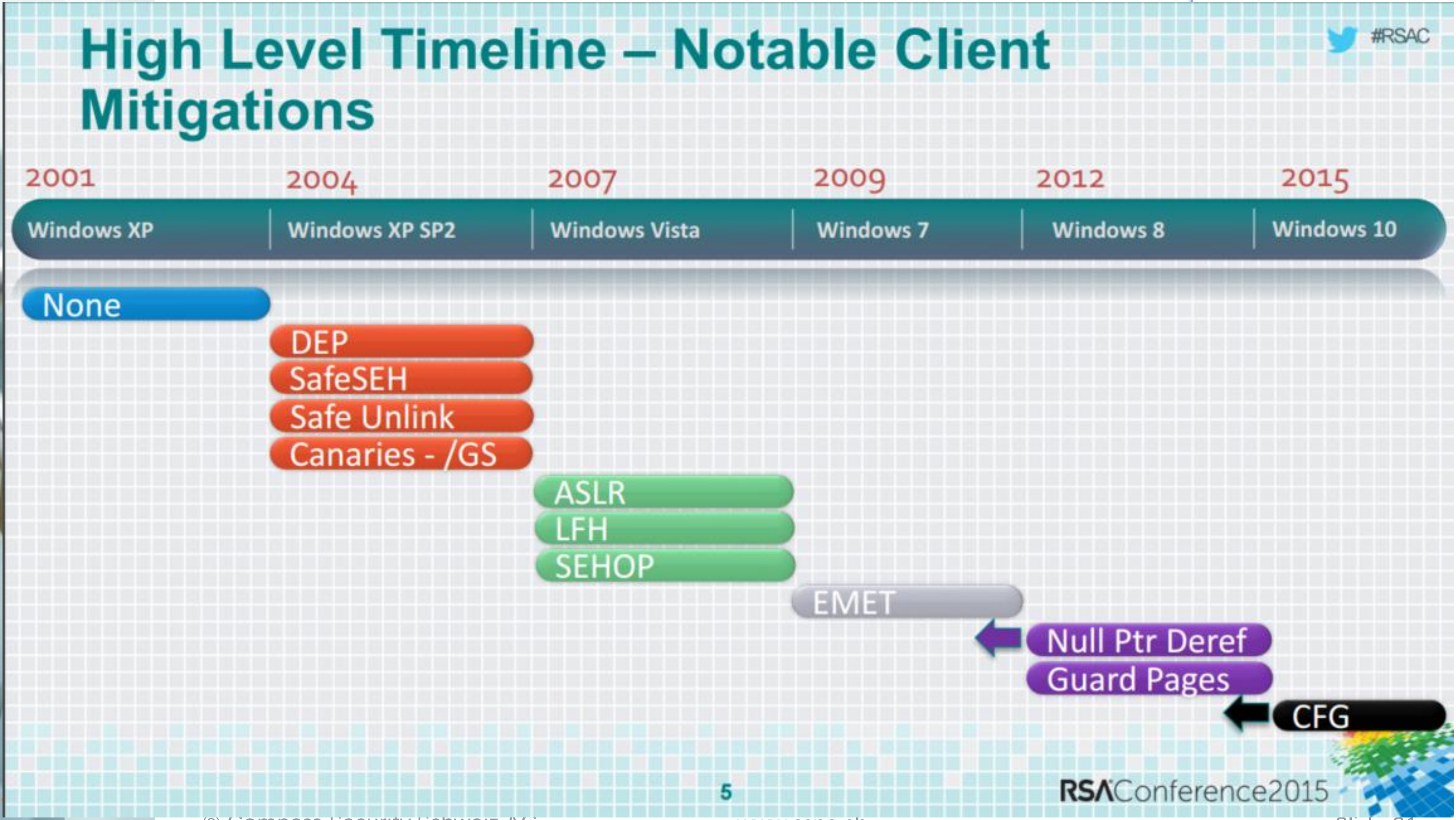
	Win7	Win7 + EMET	Win10	Win10 + EMET
Force System Mitigation				
DEP	Y	Y	Y	Y
SEHOP	Y	Y	Y	Y
ASLR	Y	Y	Y	Y
Pinning	N	Y	N	Y
Fonts	N	N	N	Y
CFG	N	N	N	N
Force Application Mitigation				
DEP	N	Y	N	Y
SEHOP	N	Y*	N	Y*
NullPage	N	Y	N	Y
HeapSpray	N	Y	N	Y
EAF	N	Y	N	Y
EAF+	N	Y	N	Y
ASLR	N	Y	N	Y
BottupASLR	N	Y	N	Y
LoadLib	N	Y	N	Y
MemProt	N	Y	N	Y
Caller	N	Y*	N	Y*
SimExecFlow	N	Y*	N	Y*
StackPivot	N	Y	N	Y
ASR	N	Y	N	Y
Fonts	N	N	N	Y
CFG	N	N	N	N

* 32-bit processes only

Windows Exploit Mitigation

History

Windows History



High Level Timeline – Notable Client Mitigations

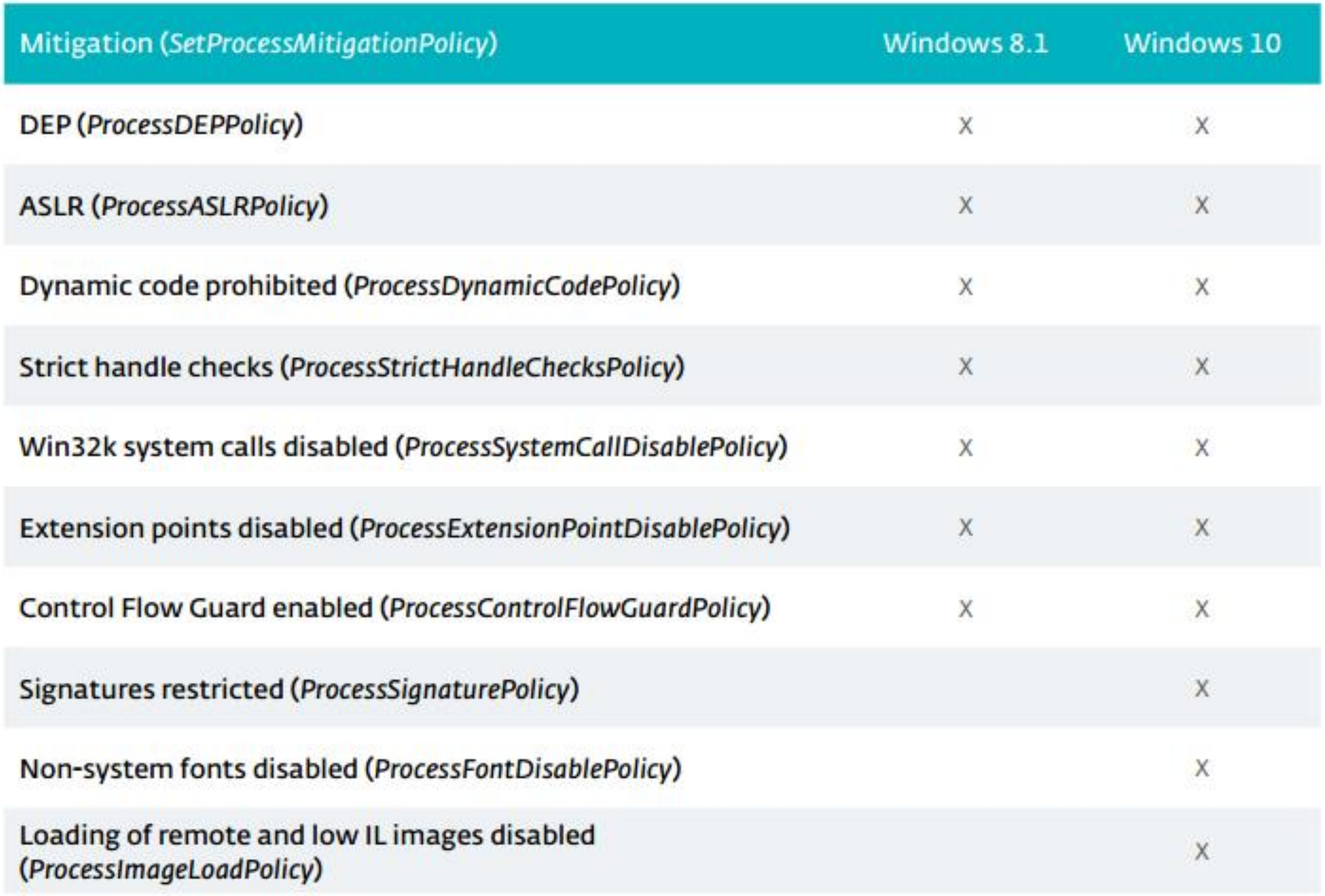
#RSAC

2001	2004	2007	2009	2012	2015
Windows XP	Windows XP SP2	Windows Vista	Windows 7	Windows 8	Windows 10
None	DEP SafeSEH Safe Unlink Canaries - /GS	ASLR LFH SEHOP	EMET	Null Ptr Deref Guard Pages	CFG

5

RSAConference2015

Windows History



Mitigation (*SetProcessMitigationPolicy*)	Windows 8.1	Windows 10
DEP (*ProcessDEPPolicy*)	X	X
ASLR (*ProcessASLRPolicy*)	X	X
Dynamic code prohibited (*ProcessDynamicCodePolicy*)	X	X
Strict handle checks (*ProcessStrictHandleChecksPolicy*)	X	X
Win32k system calls disabled (*ProcessSystemCallDisablePolicy*)	X	X
Extension points disabled (*ProcessExtensionPointDisablePolicy*)	X	X
Control Flow Guard enabled (*ProcessControlFlowGuardPolicy*)	X	X
Signatures restricted (*ProcessSignaturePolicy*)		X
Non-system fonts disabled (*ProcessFontDisablePolicy*)		X
Loading of remote and low IL images disabled (*ProcessImageLoadPolicy*)		X

Table 6. List of mitigations that are available for applications to use to improve their own security.

http://www.welivesecurity.com/wp-content/uploads/2017/01/Windows-Exploitation-2016-A4.pdf

Windows History

Bill Gates’ “Trustworthy Compting Memo” from 2012

Aka “Stop the fuck you are doing right now, get 6 months of education on how to do things securely”

Security: *The data our software and services store on behalf of our customers should be protected from harm and used or modified only in appropriate ways. Security models should be easy for developers to understand and build into their applications.*

https://news.microsoft.com/2012/01/11/memo-from-bill-gates/

Windows History

The move was reportedly prompted by the fact that they *"...had been under fire from some of its larger customers–government agencies, financial companies and others–about the security problems in Windows, issues that were being brought front and center by a series of self-replicating worms and embarrassing attacks."* such as Code Red, Nimda and Klez.

Windows History

Virus:

- Self replicating
- File based
- Requires some user interaction

Worm:

- Self replicating
- Network based
- Requires no user interaction

Trojan:

- Fake some good functionality
- But perform evil actions

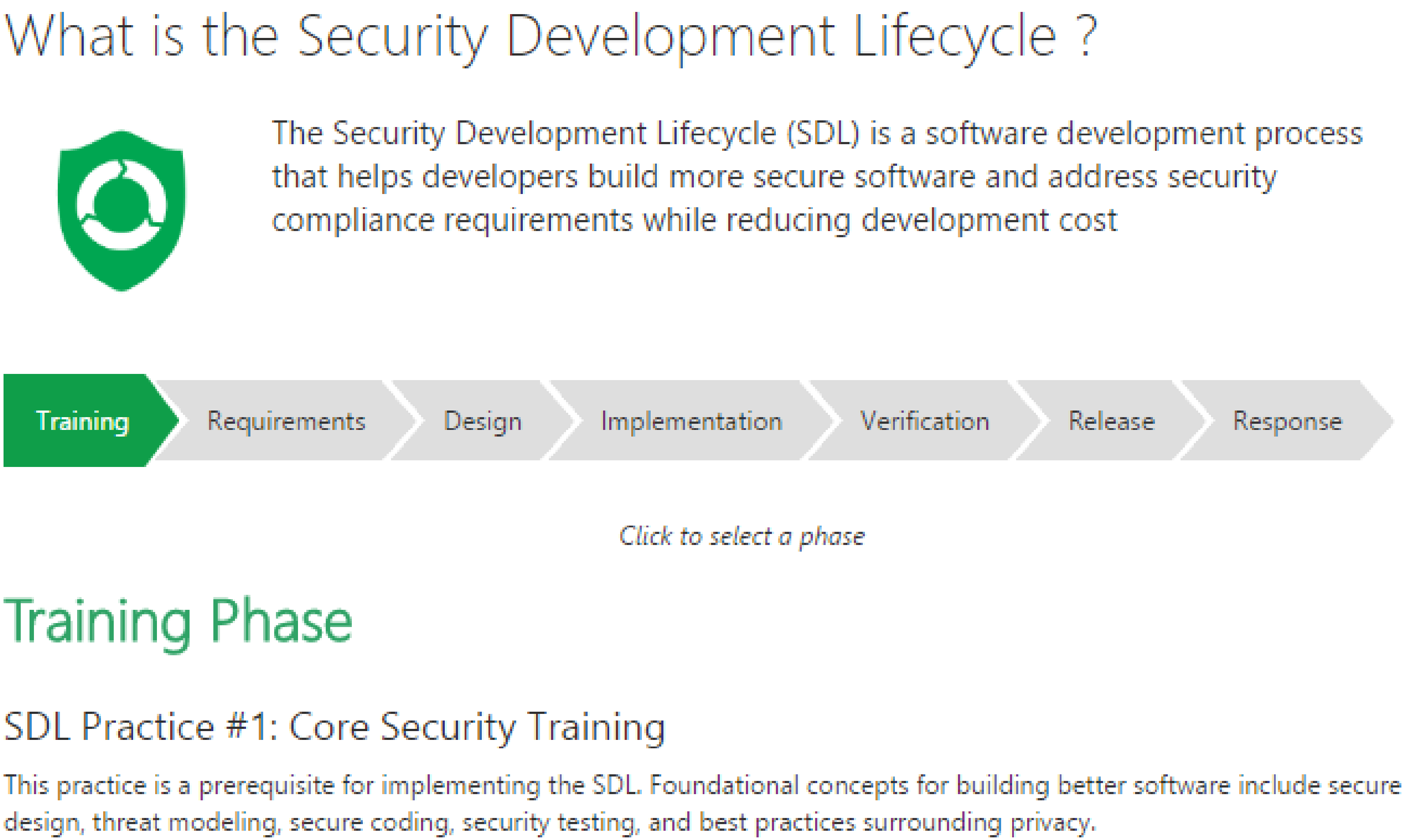
Backdoor:

- Bypass authentication/authorization

Malware!

Windows History

SDL: Security Development Lifecycle



What is the Security Development Lifecycle ?

The Security Development Lifecycle (SDL) is a software development process that helps developers build more secure software and address security compliance requirements while reducing development cost

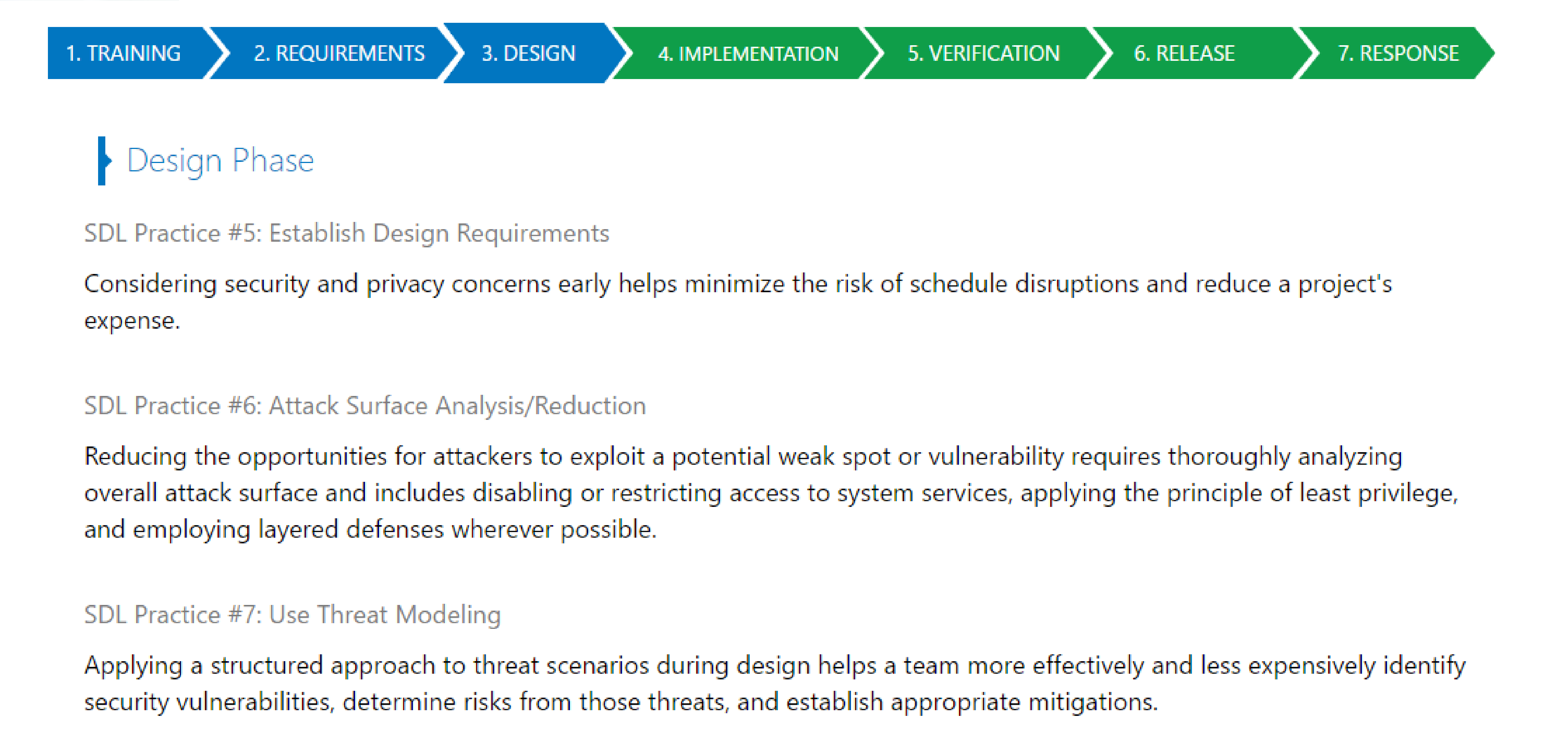
Training Phase

SDL Practice #1: Core Security Training

This practice is a prerequisite for implementing the SDL. Foundational concepts for building better software include secure design, threat modeling, secure coding, security testing, and best practices surrounding privacy.

Windows History

SDL: Security Development Lifecycle



Design Phase

SDL Practice #5: Establish Design Requirements

Considering security and privacy concerns early helps minimize the risk of schedule disruptions and reduce a project's expense.

SDL Practice #6: Attack Surface Analysis/Reduction

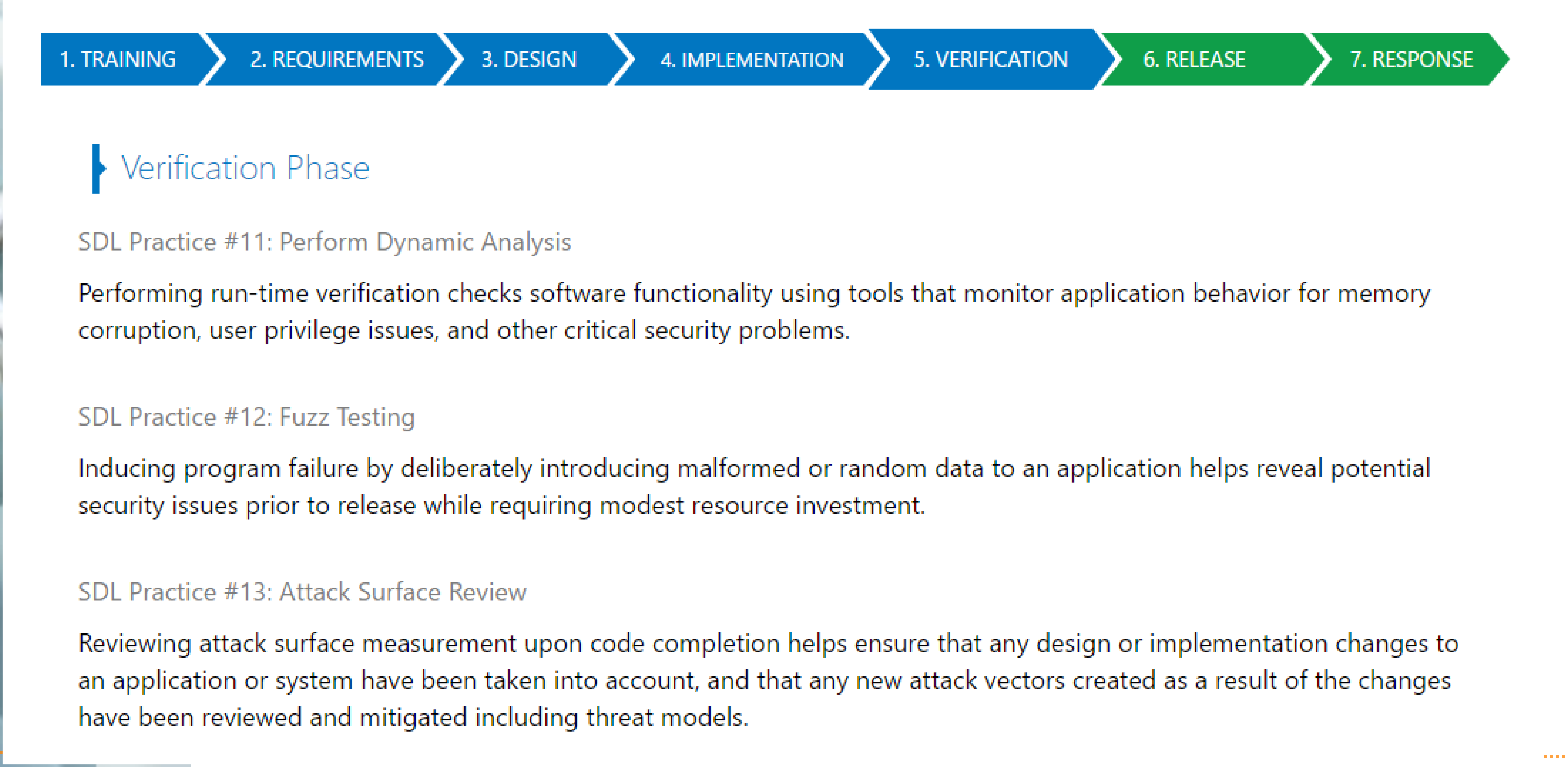
Reducing the opportunities for attackers to exploit a potential weak spot or vulnerability requires thoroughly analyzing overall attack surface and includes disabling or restricting access to system services, applying the principle of least privilege, and employing layered defenses wherever possible.

SDL Practice #7: Use Threat Modeling

Applying a structured approach to threat scenarios during design helps a team more effectively and less expensively identify security vulnerabilities, determine risks from those threats, and establish appropriate mitigations.

Windows History

SDL: Security Development Lifecycle



1. TRAINING 2. REQUIREMENTS 3. DESIGN 4. IMPLEMENTATION 5. VERIFICATION 6. RELEASE 7. RESPONSE

Verification Phase

SDL Practice #11: Perform Dynamic Analysis

Performing run-time verification checks software functionality using tools that monitor application behavior for memory corruption, user privilege issues, and other critical security problems.

SDL Practice #12: Fuzz Testing

Inducing program failure by deliberately introducing malformed or random data to an application helps reveal potential security issues prior to release while requiring modest resource investment.

SDL Practice #13: Attack Surface Review

Reviewing attack surface measurement upon code completion helps ensure that any design or implementation changes to an application or system have been taken into account, and that any new attack vectors created as a result of the changes have been reviewed and mitigated including threat models.

Windows History

Windows XP SP2

- First big step in anti-exploiting
- Compiled with /GS /SAFESEH
- DEP

Windows Vista

- ASLR

Windows History

Windows 8

/GS:

- Better heuristics
- VS now performs bounds checks on array

ASLR:

- Force ASLR on all DLLs of a process (Force ASLR option)

Windows History

Windows 10

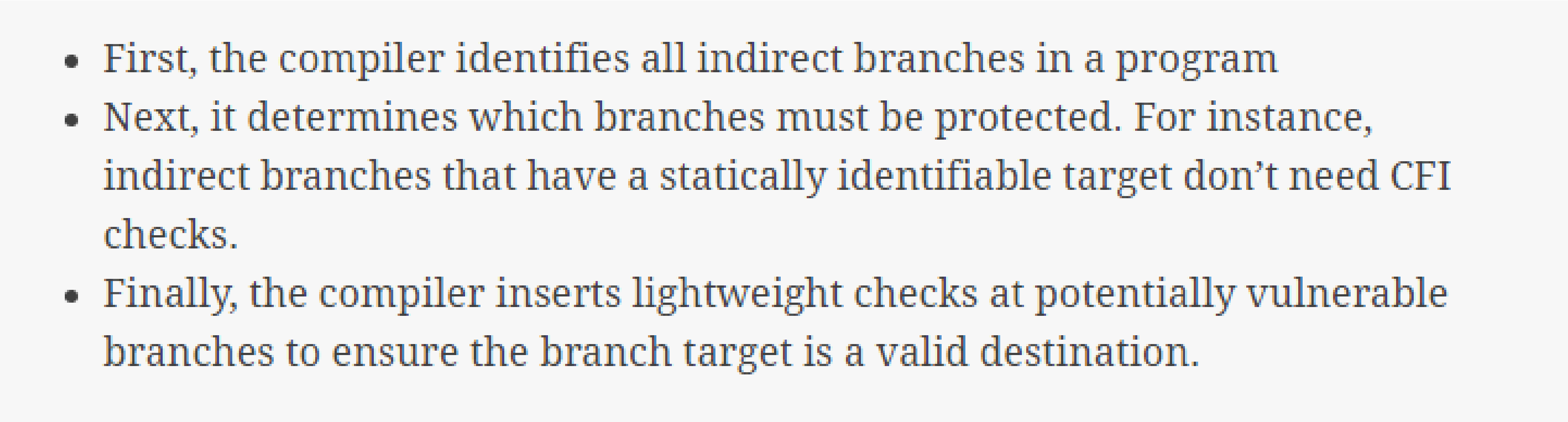
- Control Flow Guard (CFG)
  - Anti ROP
  - Needs help from compiler (Visual studio)
  - Pretty damn awesome
  - IE11 @Win8 Update 3
  - Edge
- EDGE: MemGC
  - Use-After-Free exploit mitigation
- Improved Kernel ASLR
- EPM (Enhanced Protected Mode, Sandbox for IE)

Windows History

Control Flow Integrity (CFI)

`/guard:cf`

- Control Flow Guard



- First, the compiler identifies all indirect branches in a program
- Next, it determines which branches must be protected. For instance, indirect branches that have a statically identifiable target don’t need CFI checks.
- Finally, the compiler inserts lightweight checks at potentially vulnerable branches to ensure the branch target is a valid destination.

https://blog.trailofbits.com/2016/12/27/lets-talk-about-cfi-microsoft-edition/

Windows History

Example: Windows 10 IE11 + EPM + EMET exploit;

- Find UAF
- Heap massage
- Overwrite arraybuffer length for write-what-where
- Re-enable God-Mode (Compiler fail…)
- Without ROP (because of CFI)
- Execute ActiveX
- -> Still in EPM Sandbox
  - Create local web server via ActiveX
  - Netbios DNS spoof/bruteforce to fake hostname so website is in trusted zone
  - Perform above exploit again in 32bit
  - Full RCE

Windows 10

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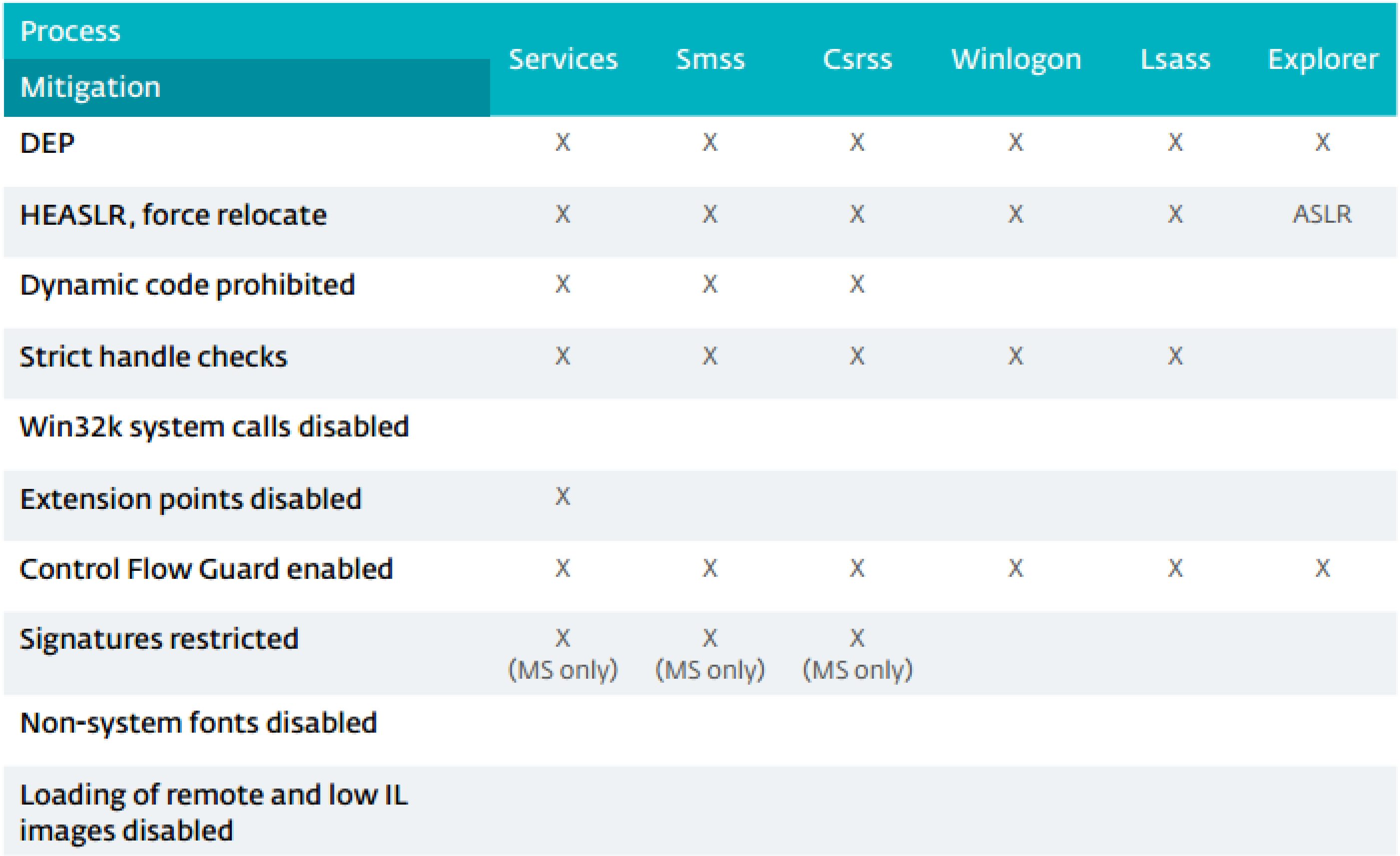
Windows 10 Protections



Process Mitigation	Services	Smss	Csrss	Winlogon	Lsass	Explorer
DEP	X	X	X	X	X	X
HEASLR, force relocate	X	X	X	X	X	ASLR
Dynamic code prohibited	X	X	X			
Strict handle checks	X	X	X	X	X	
Win32k system calls disabled						
Extension points disabled	X					
Control Flow Guard enabled	X	X	X	X	X	X
Signatures restricted	X (MS only)	X (MS only)	X (MS only)			
Non-system fonts disabled						
Loading of remote and low IL images disabled						

Table 7. Mitigations that are applied by default for important processes (Windows 10).

http://www.welivesecurity.com/wp-content/uploads/2017/01/Windows-Exploitation-2016-A4.pdf

Windows 10 Protections

Hypervisor based security

- DeviceGuard, Credential Guard, Hypervisor Code Integrity (HVCI)
- Use separate VM's for sensitive tasks

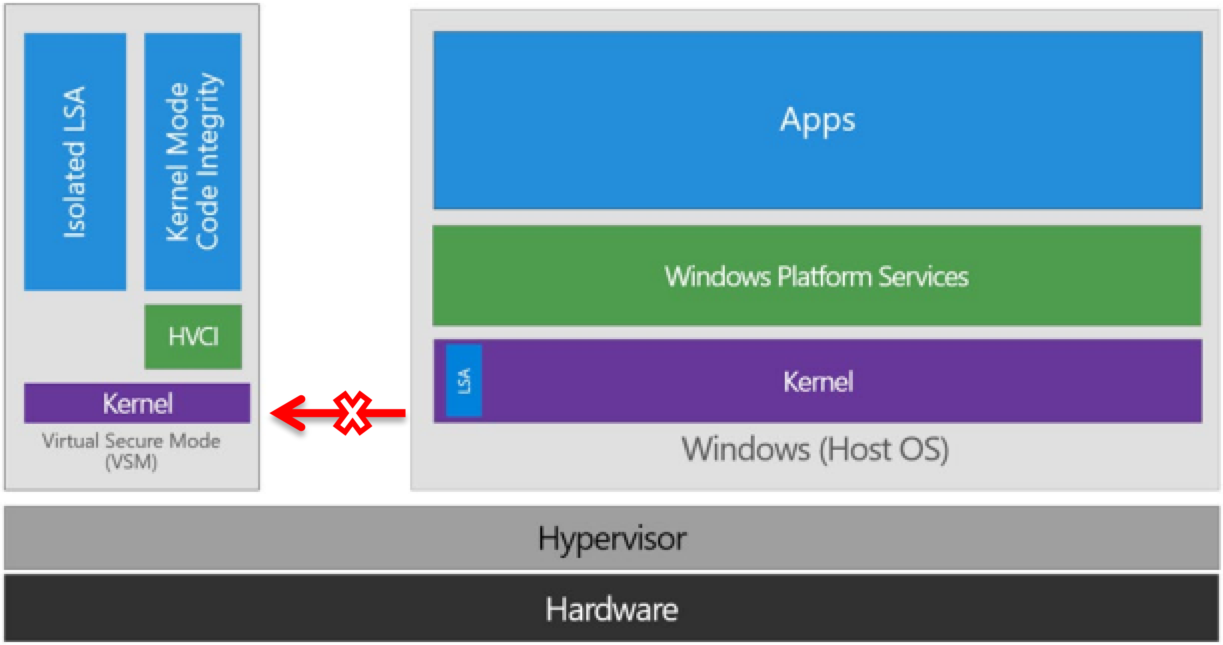

Isolated LSA
Kernel Mode Code Integrity
HVCI
Kernel
Virtual Secure Mode (VSM)
Apps
Windows Platform Services
LSA
Kernel
Windows (Host OS)
Hypervisor
Hardware

Figure 6. Hyper-V architecture with VSM as it is *described* by the Microsoft security guys.

Windows 10 Protections

Hypervisor based security

- Windows Defender Application Guard

not

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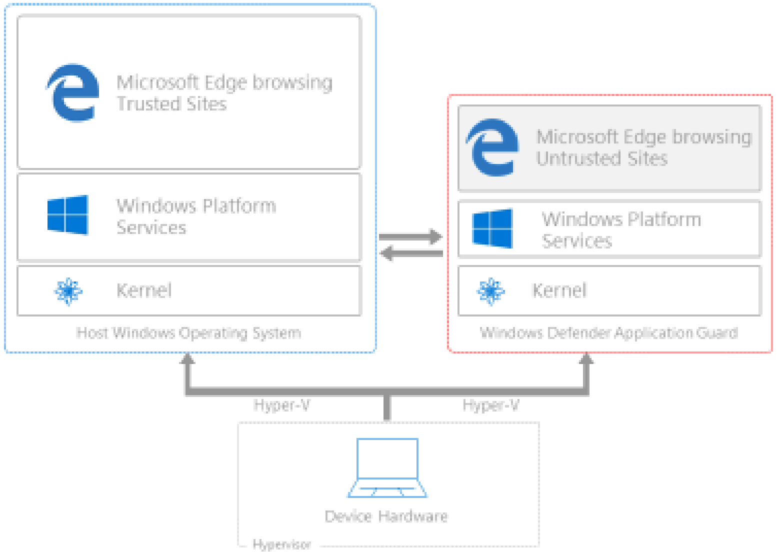
Microsoft Edge browsing Trusted Sites
Windows Platform Services
Kernel
Host Windows Operating System
Microsoft Edge browsing Untrusted Sites
Windows Platform Services
Kernel
Windows Defender Application Guard
Hyper-V
Hyper-V
Device Hardware
Hypervisor

https://blogs.windows.com/msedgedev/2016/09/27/application-guard-microsoft-edge/#SI3kumwvwgYoTPiL.97

Windows Exploit Mitigations Conclusion

Windows: Conclusion

Its not 2001 anymore…

- We don’t need to reboot Windows to change IP address anymore
- We don’t have IE6 anymore (IE7 was a partial rewrite after the Bill Gates Memo)

- Current Windows versions have anti exploiting techniques, which:
  - Are superiour to Linux one’s
  - Enabled by default
  - But still not complete

Windows: Conclusion

Main problems:

- Backwards compatibility / technical depth
  - Parts of UI in Kernelspace
  - Pass the hash / Kerberos…
- 3rd party programs
  - Adobe (Flash, PDF Reader)
  - Oracle (Java)
  - Cisco (Webex)
  - HP (Data “Protector”)
- Monocolture (everybody has the same Windows version)
- Unsavy users
- Worse: Unsavy administrators

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References

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