# Exploit Mitigation Improvements in Windows 8

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# Windows 8 Security Overview

## Secure Development

The development of Windows 8 followed the Security Development Lifecycle (SDL) which defines best practices for secure software design, implementation, and testing.

## Securing the Boot

Windows 8 includes new protections against root and boot kits. UEFI systems prevent malware from starting before Windows and protects the remainder of the boot process, including early launch antimalware software.

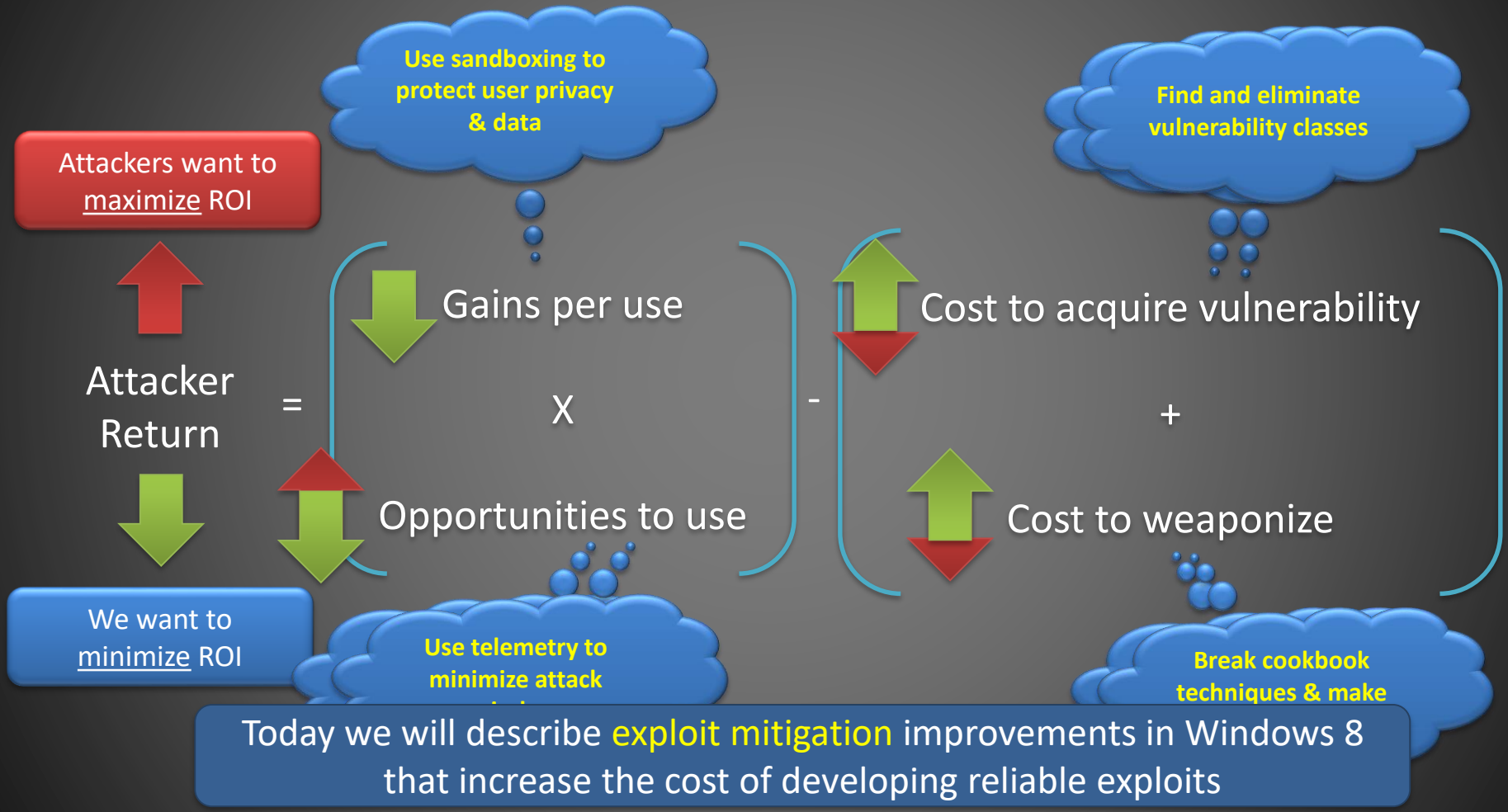
## Securing the Core

Windows 8 includes numerous security features, such as mitigations, that make it difficult and costly for malware authors to develop reliable exploits for vulnerabilities.

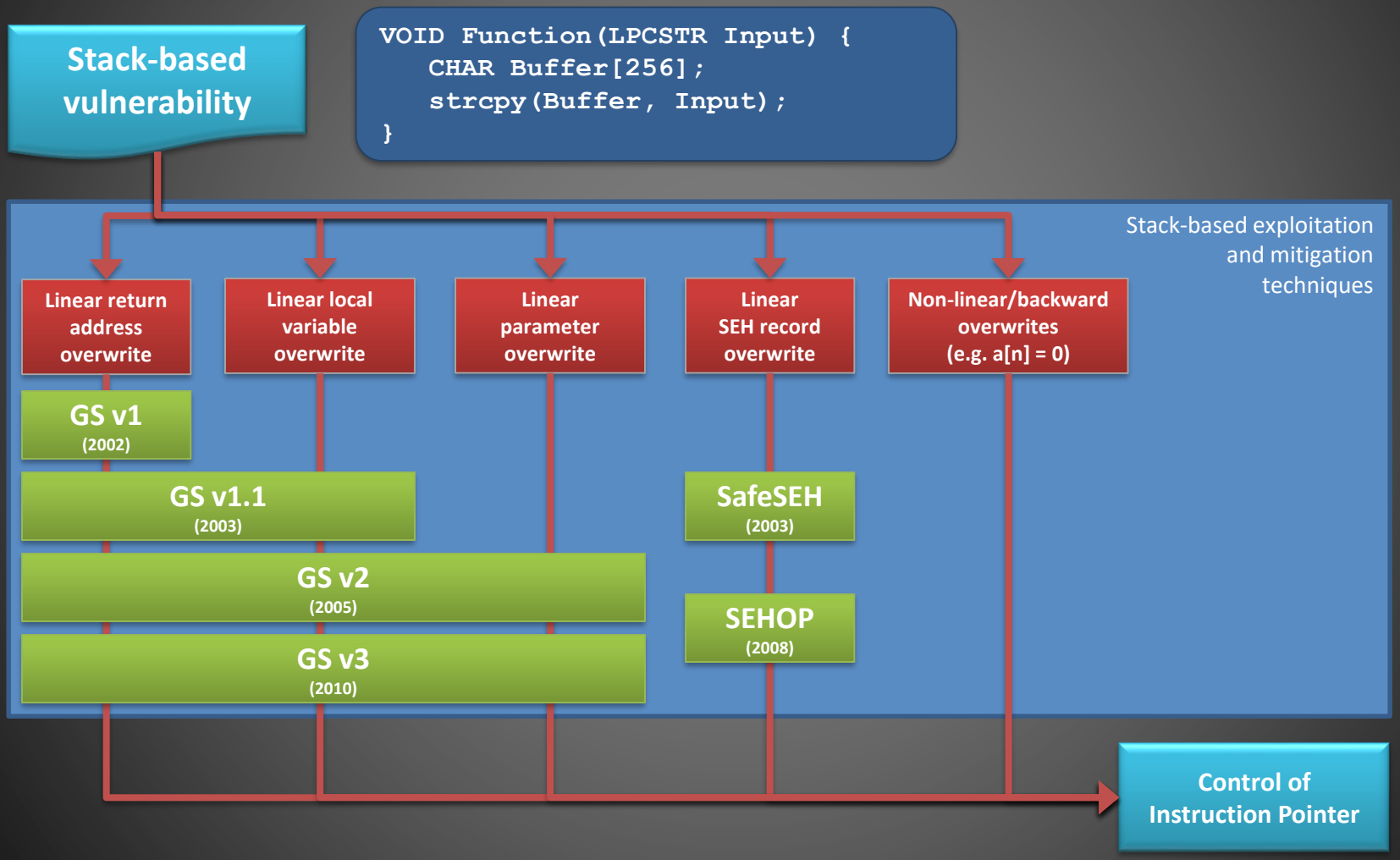
## Securing After the Boot

Windows Defender is shipped with every edition of Windows 8 and Internet Explorer's Application reputation features have been moved into the platform such that users are protected regardless of the browser they use.

# Framing the problem with exploit economics



# History of exploit mitigations on Windows



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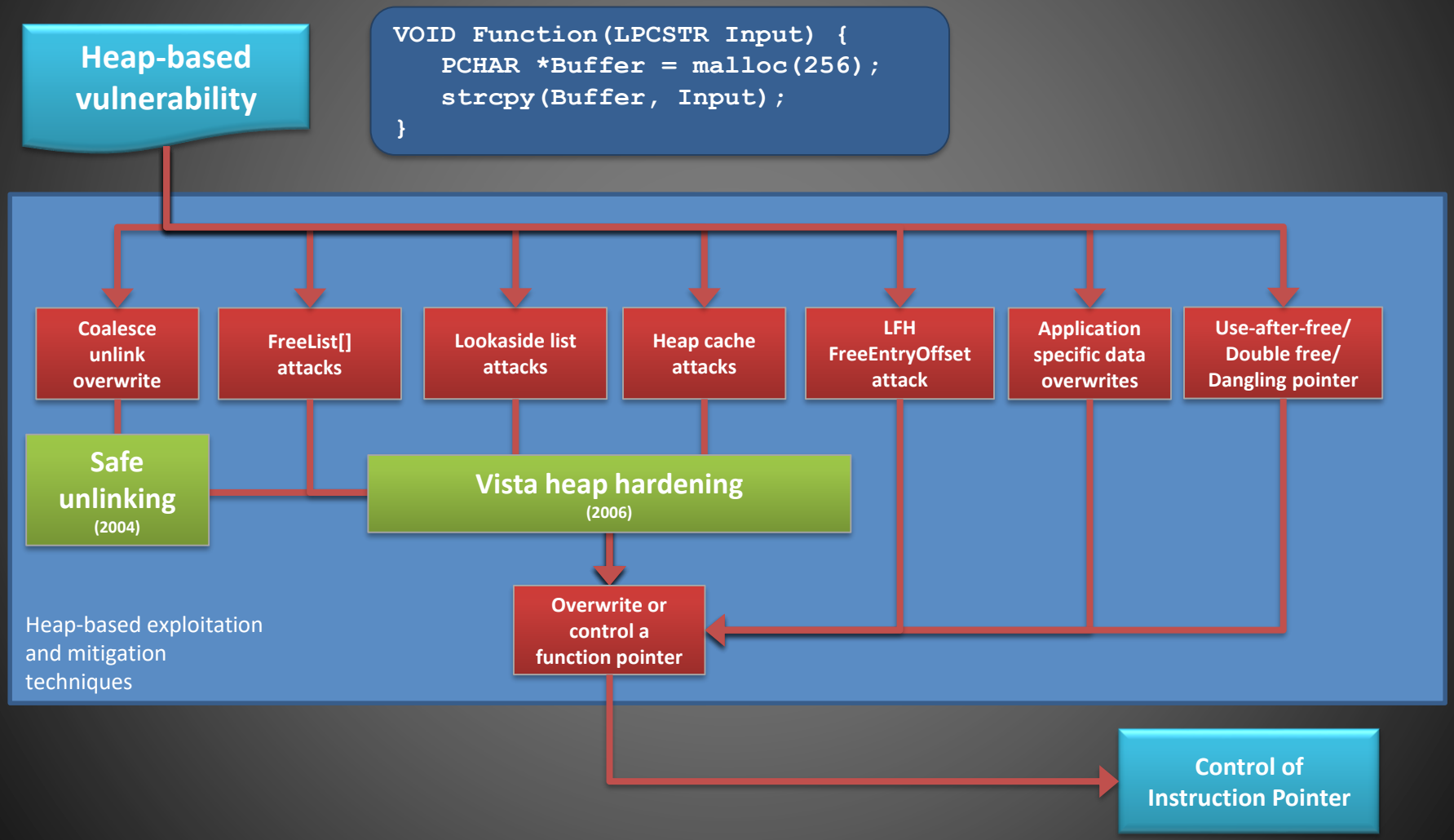

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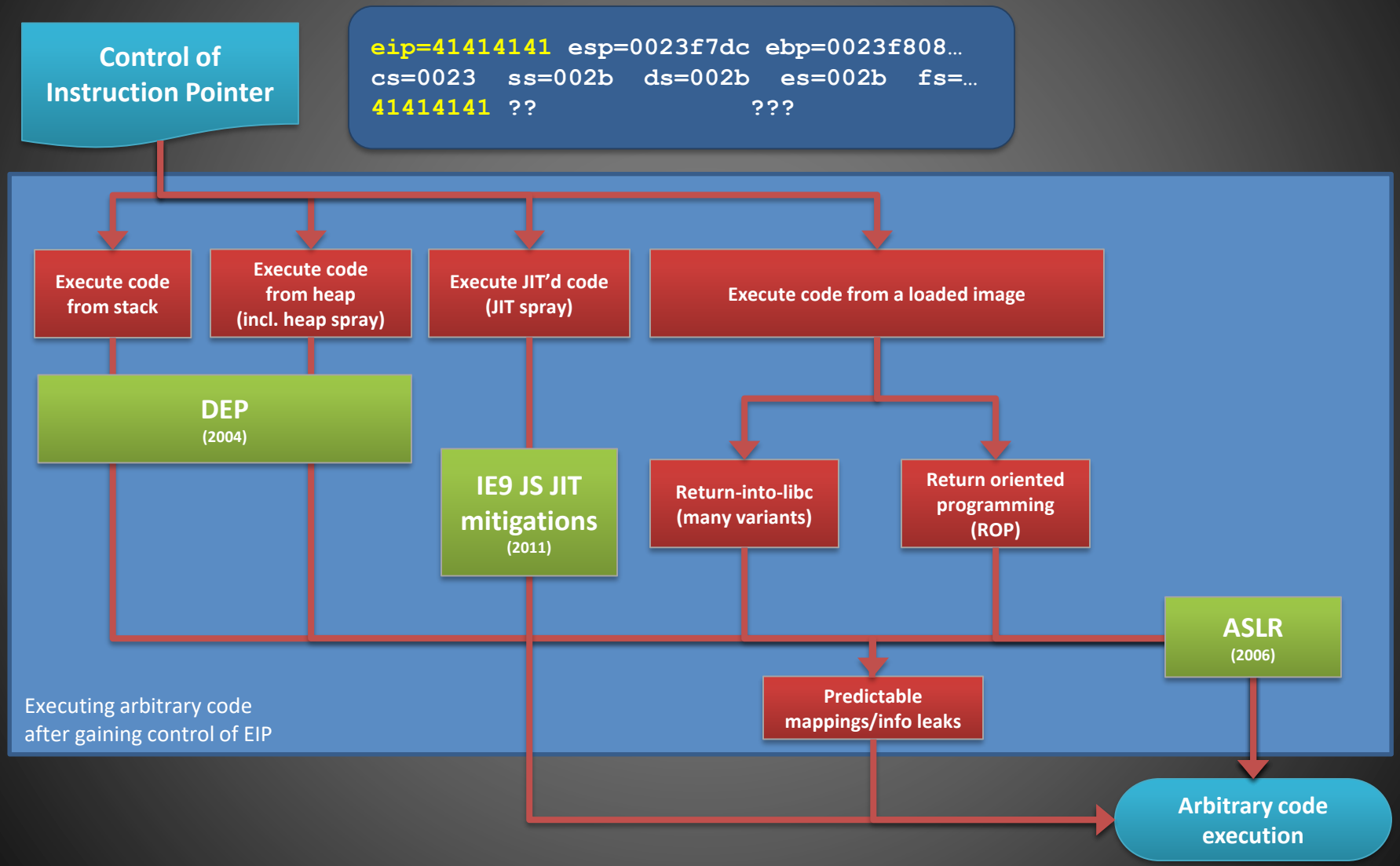


# The state of memory safety exploits

| | |
|---|---|
| Most systems are not compromised by exploits | • About 6% of MSRT detections were likely caused by exploits [29]<br>• Updates were available for more than a year for most of the exploited issues [29] |
| Most exploits target third party applications | • 11 of 13 CVEs targeted by popular exploit kits in 2011 were for issues in non-Microsoft applications [27] |
| Most exploits target older versions of Windows (e.g. XP) | • Only 5% of 184 sampled exploits succeeded on Windows 7 [28]<br>• ASLR and other mitigations in Windows 7 make exploitation costly [30] |
| Most exploits fail when mitigations are enabled | • 14 of 19 exploits from popular exploit kits fail with DEP enabled [27]<br>• 89% of 184 sampled exploits failed with EMET enabled on XP [28] |
| Exploits that bypass mitigations & target the latest products do exist | • Zero-day issues were exploited in sophisticated attacks (Stuxnet, Duqu)<br>• Exploits were written for Chrome and IE9 for Pwn2Own 2012 |

Bottom line: we must continue to increase the cost of exploitation for attackers

# Objectives & focus areas in Windows 8

**Objectives**

Mitigate entire classes of vulnerabilities

Break known exploitation techniques

Increase the cost of exploitation in key domains

- Code Generation Security
- Address Space Layout Randomization
- Windows Heap
- Windows Kernel
- Default Settings

Enhanced /GS, range checks, sealed optimization, and virtual table guard

# CODE GENERATION

# Enhanced /GS

- Enhanced GS stack buffer overrun protection
  - Released with Visual Studio 2010 [1]
  - Windows 8 is built with this enabled
- GS heuristics now protect more functions
  - Non-pointer arrays and POD structures
- GS optimization removes unnecessary checks
  - Safety proof means no check is needed
- Closes gaps in protection
  - MS04-035, MS06-054, MS07-017 (ANI)

# Range Checks

- Compiler-inserted array bounds check (via /GS)

```
CHAR Buffer[256];
UINT i; // possibly attacker controlled

if (i >= ARRAYSIZE(Buffer)) {     ← compiler inserted
   __report_rangecheckfailure();
}

Buffer[i] = 0;
```

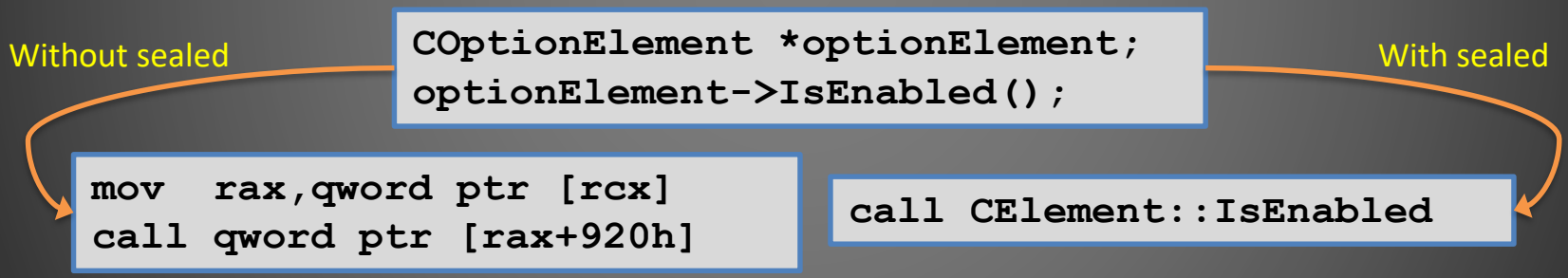
- Completely mitigates certain vulnerabilities
  - CVE-2009-2512, CVE-2010-2555
- Bounds check insertion is limited to specific scenarios
  - Assignment of NUL to a fixed-size stack/global array

# Sealed optimization

- Optimization for “sealed” C++ types & methods

```
class COptionElement sealed : public CElement
{
    DECLARE_CLASS_TYPES(COptionElement, CElement)
```

- Virtual method calls become direct calls



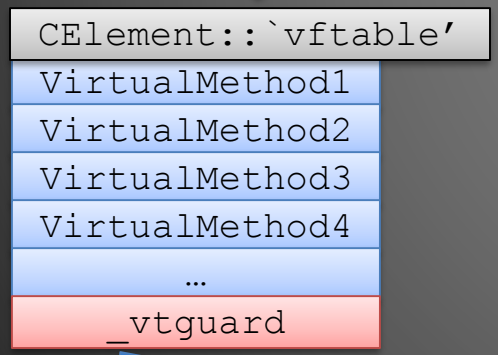

- Eliminating indirect calls reduces exploitation attack surface
  - Helps mitigate vulnerabilities like CVE-2011-1996
  - Devirtualized ~4,500 calls in mshtml.dll and ~13,000 in mso.dll

# Virtual Table Guard

Probabilistic mitigation for vulnerabilities that enable vtable ptr corruption

IE10 has enabled this for a handful of key classes in mshtml.dll

Enabled by adding an annotation to a C++ class




```
mshtml!CElement::Doc:
63700e70 mov     eax,dword ptr [ecx]
63700e72 cmp     [eax+1B8h],offset mshtml!_vtguard
63700e7c jne     mshtml!CElement::Doc+0x18 (63700e88)
63700e7e call    dword ptr [eax+0ACh]
63700e84 mov     eax,dword ptr [eax+0Ch]
63700e87 ret
63700e88 call    mshtml!__report_gsfailure
```

Extra entry added to vtable. ASLR makes this entry's value unknown to the attacker.

Check added at virtual method call sites. If vtable[vtguard_vte] != vtguard then terminate the process.

Force ASLR, bottom-up/top-down randomization, and high entropy

# ADDRESS SPACE LAYOUT RANDOMIZATION

# Retrospective: ASLR

- ASLR was first introduced in Windows Vista
  - Led to a big shift in attacker mentality
- Attackers now depend on gaps in ASLR
  - EXEs/DLLs not linked with /DYNAMICBASE [2]
  - Address space spraying (heap/JIT) [3]
  - Predictable memory regions [4]
  - Information disclosures [5]
- ASLR has been substantially improved in Windows 8

# Force ASLR

- Many exploits depend on non-ASLR DLLs

```
0:000> !dh dirapi
...
4B4C111C time date stamp Mon Jan 11 22:05:16 2010
...
    1000 base of code
         ----- new -----
68000000 image base
    1000 section alignment
...
00001000 size of heap commit
       0  DLL characteristics
  187A80 [    402F] address [size] of Export Directory
  1869F4 [      C8] address [size] of Import Directory
  19B000 [   12178] address [size] of Resource Directory
```

Images are not randomized unless the DYNAMIC_BASE bit is set

- Processes can now force non-ASLR images to be randomized
  - Behaves as if an image's preferred base is not available
  - Bottom-up randomization provides entropy for these images
- Processes must opt-in to receive this behavior
  - Also supported on Windows 7 with KB2639308 installed

Outcome: attackers can no longer rely on non-ASLR images

# Bottom-up & top-down randomization


## Windows 7

- Heaps and stacks are randomized
- PEBs/TEBs are randomized, but with limited entropy
- VirtualAlloc and MapViewOfFile are not randomized
- Predictable memory regions can exist as a result

## Windows 8

- All bottom-up/top-down allocations are randomized
- Accomplished by biasing start address of allocations
- PEBs/TEBs now receive much more entropy
- Both are opt-in (EXE must be dynamicbase)

Outcome: predictable memory regions have been eliminated

# High entropy ASLR for 64-bit processes

ASLR in Windows 8 takes advantage of the large address space (8TB) of 64-bit processes

| | |
|---|---|
| High entropy bottom-up randomization | • 1 TB of variance in bottom-up start address<br>• Breaks traditional address space spraying (heap/JIT)<br>• Processes must opt-in to receive this behavior |
| High entropy top-down randomization | • 8 GB of variance in top-down start address<br>• Automatically enabled if top-down randomization is on |
| High entropy image randomization | • Images based above 4 GB receive more entropy<br>• All system images have been moved above 4 GB |

Outcome: probability of guessing an address is decreased and disclosures of memory addresses must include more than the low 32 bits

# 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

# Removal of information disclosure vectors

- Information disclosures can be used to bypass ASLR
- Disclosure via an arbitrary read is now less reliable
  - Predictable mappings have been eliminated
- SharedUserData is still predictable, but less useful
  - Image pointers have been removed, breaking known techniques [4,6]

```
0:000> u ntdll!NtWriteVirtualMemory L6
ntdll!NtWriteVirtualMemory:
6a214724 b802000000      mov     eax,2
6a214729 e803000000      call    ntdll!NtWriteVirtualMemory+0xd (6a214731)
6a21472e c21400          ret     14h
6a214731 8bd4            mov     edx,esp
6a214733 0f34            sysenter
6a214735 c3              ret
0:000> dd 7ffe0300 L1
7ffe0300  00000000
```

Integrity checks, guard pages, and allocation order randomization

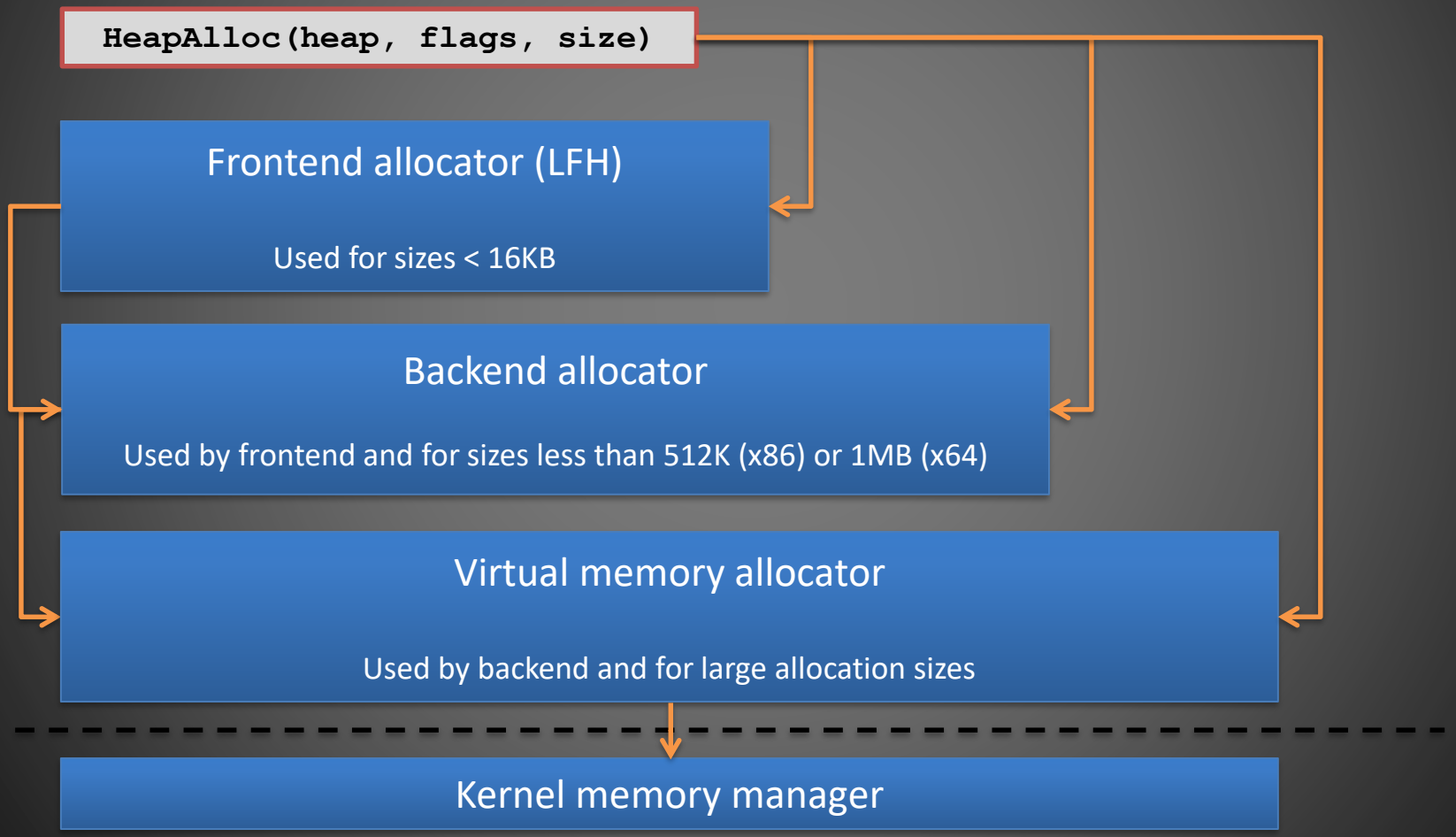
# WINDOWS HEAP

# Retrospective: Windows Heap

- Windows Vista heap hardening was very effective [11]
  - Only one documented exploit that corrupts metadata [9]
- New attacks have been proposed by researchers
  - Corrupting the HEAP data structure [7]
  - LFH bucket overwrite [7]
  - LFH FreeEntryOffset corruption and depth desync [8,12]
- Real-world exploits target app data on the heap [10]
  - No heap safeguards exist today for this

# Windows 8 heap architecture

The general design of the Windows heap is unchanged in Windows 8



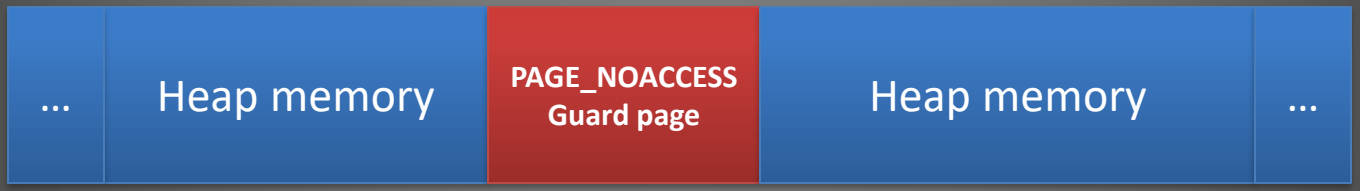
# LFH design changes & integrity checks

| Change in Windows 8 | Impact |
|---|---|
| LFH is now a bitmap-based allocator | LinkOffset corruption no longer possible [8] |
| Multiple catch-all EH blocks removed | Exceptions are no longer swallowed |
| HEAP handle can no longer be freed | Prevents attacks that try to corrupt HEAP handle state [7] |
| HEAP CommitRoutine encoded with global key | Prevents attacks that enable reliable control of the CommitRoutine pointer [7] |
| Validation of extended block header | Prevents unintended free of in-use heap blocks [7] |
| Busy blocks cannot be allocated | Prevents various attacks that reallocate an in-use block [8,11] |
| Heap encoding is now enabled in kernel mode | Better protection of heap entry headers [19] |

Outcome: attacking metadata used by the heap is now even more difficult

# Guard pages

- Guard pages are now used to partition the heap
  - Designed to prevent & localize corruption in some cases
  - Touching a guard page results in an exception




- Insertion points for guard pages are constrained
  - Large allocations
  - Heap segments
  - Max-sized LFH subsegments (probabilistic on 32-bit)

# Allocation order randomization

- Allocation order is now nondeterministic (LFH only)
  - Exploits often rely on surgical heap layout manipulation [10]
  - Randomization makes heap normalization unreliable

Windows 7 LFH block allocation behavior


Windows 8 LFH block allocation behavior


- Maximizing reliability is more challenging
  - Application-specific and vulnerability-specific
  - May require corrupting more data (increasing instability)
  - May require allocating more data (triggering guard pages)

DEP, ASLR, SMEP/PXN, NULL dereference protection, and pool integrity checks

# WINDOWS KERNEL

# Retrospective: Windows Kernel

- Kernel vulnerabilities have been less targeted
  - Relatively few remote kernel exploits exist
  - User mode exploitation is better researched
- Attack focus is shifting more toward the kernel
  - Interest in sandbox escapes is increasing
  - Local kernel exploitation techniques well-understood
  - New kernel pool attacks have been proposed [13]
  - Sophisticated remote kernel exploits exist [14,21]

# DEP is broadly enabled in the Windows 8 kernel

Many kernel memory regions were unnecessarily executable in Windows 7 and prior

| | x86 (PAE) | | x64 | | ARM |
|---|---|---|---|---|---|
| | Win7 | Win8 | Win7 | Win8 | Win8 |
| Paged pool | X | X | NX | NX | NX |
| Non-paged pool | X | X | X | X | X |
| Non-paged pool (NX) | N/A | NX | N/A | NX | NX |
| Session pool | X | X | NX | NX | NX |
| Image data sections | X | X | NX | NX | NX |
| Kernel stacks | NX | NX | NX | NX | NX |
| Idle/DPC/Initial stacks | X | NX | X | NX | NX |
| Page table pages | X | NX | X | NX | NX |
| PFN database | X | NX | X | NX | NX |
| System cache | X | NX | X | NX | NX |
| Shared user data | X | NX | X | NX | NX |
| HAL heap | X | NX | X | NX | NX |

X = executable NX = non-executable

**Windows 8 introduces NonPagedPoolNx for non-executable non-paged pool allocations (default on ARM)**

**NX HAL heap and NonPagedPoolNx break the assumptions of exploits for MS09-050**

# Kernel ASLR improvements

- Kernel ASLR was first added in Server 2008 RTM
  - 4 bits of entropy for drivers, 5 bits for NTOS/HAL
  - Driver entropy was improved in Windows 7
- Entropy has been further improved in Windows 8
  - Biasing of kernel segment base
  - NTOS/HAL receive 22 bits (64-bit) and 12 bits (32-bit)
  - Various boot regions also randomized (P0 idle stack)

# Support for SMEP/PXN

- New processor security feature
  - Prevents supervisor from executing code in user pages
  - Most exploits for local kernel EOPs rely on this today
  - Requires Intel Ivy Bridge or ARM with PXN support
- SMEP/PXN + DEP make exploitation more difficult
  - Strong mitigation for some issues (CVE-2010-2743 from Stuxnet)
  - Attackers need to leverage code in kernel images [15]

# NULL dereference protection

- Kernel NULL dereferences are a common issue
  - Examples include MS08-025, MS08-061, MS09-001
- Local exploitation is generally straightforward
  - NULL is part of the user mode address space
  - Kernel currently allows user processes to map NULL page
- Windows 8 prohibits mapping of the first 64K
  - All kernel NULL dereferences become a DoS (not EoP)
  - NTVDM has been disabled by default as well
  - Enabling NTVDM will disable NULL dereference protection

# Kernel pool integrity checks

- The kernel pool allocator is similar to the heap
  - Implementation is very different, though
- New integrity checks block various attacks [13]
  - Process quota pointer encoding
  - Lookaside, delay free, and pool page cookies
  - PoolIndex bounds check
  - Additional safe unlinking checks

# Other improvements

- Safe unlinking has been enabled globally
  - Previously only used in the heap and kernel pool
  - Now applies to all usage of LIST_ENTRY, closing known gaps [16]
  - New “FastFail” mechanism enables rapid & safe process termination
- Improved entropy for GS and ASLR
  - Use of PRNG seeded by TPM/RDRAND/other sources
  - Hardcoded GS initialization is overridden by the OS
  - Addresses weaknesses described in attack research [17,18]
- Object manager hardened against reference count overflows
- Resolved kernel information disclosure via certain system calls [22]

ARM, Inbox, Windows 8 style apps, IE 10, the new Office, and other applications

# DEFAULT SETTINGS

# ARM default settings

All applicable mitigations are enabled on ARM

| | |
|---|---|
| DEP | On |
| ASLR (images) | On |
| ASLR (force relocate) | N/A (all images are ASLR) |
| ASLR (bottom-up) | On |
| ASLR (top-down) | On |
| ASLR (high entropy) | N/A (not 64-bit) |
| SEHOP | N/A (not needed) |
| Heap termination | On |
| Kernel NULL dereference | On |
| Kernel SMEP | On |

ARM PE images must opt-in to DEP and ASLR

Kernel will fail to load images that do not

Lack of application compatibility concerns enables us to be more aggressive

# Application default settings

All applicable mitigations are enabled for Windows 8 UI style apps

| Default settings for Windows 8 client | 32 bit (x86) | | | | 64 bit (x64) | | | |
|---|---|---|---|---|---|---|---|---|
| | Win8 UI apps | Inbox | IE10 | Default | Win8 UI apps | Inbox | IE10 | Default |
| DEP | On | On | On | OptIn | On | On | On | OptIn |
| ASLR (images) | On | On | On | OptIn | On | On | On | OptIn |
| ASLR (force relocate) | On | OptIn | On | OptIn | On | OptIn | On | OptIn |
| ASLR (bottom-up) | On | On | On | OptIn | On | On | On | OptIn |
| ASLR (top-down) | On | On | On | OptIn | On | On | On | OptIn |
| ASLR (high entropy) | N/A | N/A | N/A | N/A | On | On | On | OptIn |
| SEHOP | On | On | On | OptIn | N/A | N/A | N/A | N/A |
| Heap termination | On | On | On | OptIn | On | On | On | On |

Internet Explorer 10 and the new Office also enable all applicable mitigations

# Enabling opt-in mitigations

Opt-in methods

- "MitigationOptions" Image File Execution Option (IFEO)
- Process creation attribute (via UpdateProcThreadAttribute)
- SetProcessMitigationPolicy API
- Linker flag

| Opt-in mitigation | IFEO | Proc Attr | API | Linker flag |
|---|---|---|---|---|
| Bottom-up randomization | Yes | Yes | No | /DYNAMICBASE (on EXE) |
| Top-down randomization | No | No | No | /DYNAMICBASE (on EXE) |
| Bottom-up randomization (high entropy) | Yes | Yes | No | /HIGHENTROPYVA (on EXE) |
| ASLR | No | No | No | /DYNAMICBASE |
| Force ASLR | Yes | Yes | Yes | None |
| DEP | Yes | Yes | Yes | /NXCOMPAT (on EXE) |
| SEHOP | Yes | Yes | No | None* |
| Heap termination | Yes | Yes | Yes | None* |

* EXEs with a subsystem version >= 6.2 will automatically enable these mitigations

# Expectations for exploits on Windows 8

- Writing exploits for Windows 8 will be very costly
  - Some vulnerability classes are now entirely mitigated
  - Many attack techniques are now broken or unreliable
- Attackers will likely focus their attention on
  - Desktop apps that do not enable all applicable mitigations
  - Desktop apps running on previous versions of Windows
  - Refining methods of disclosing address space information
  - Researching new exploitation techniques [20]
- We will continue to evolve our mitigation technologies

# Call to action

- Upgrade to Windows 8 and IE 10 ☺
  - 64-bit is best from a mitigations perspective
  - Enable "Enhanced Protected Mode" for IE 10
- Software vendors
  - Build your applications with Visual Studio 2012 [31]
  - Enable new opt-in mitigations
- Driver writers
  - Port your drivers to use NonPagedPoolNx

# Questions?

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# References


1. Enhanced GS in Visual Studio 2010. Tim Burrell. March, 2009. http://blogs.technet.com/b/srd/archive/2009/03/20/enhanced-gs-in-visual-studio-2010.aspx
2. Adobe CoolType SING Table "uniqueName" Stack Buffer Overflow Exploit. Metasploit. Sep, 2010. http://dev.metasploit.com/redmine/projects/framework/repository/revisions/master/entry/modules/exploits/windows/browser/adobe_cooltype_sing.rb
3. Interpreter Exploitation: Pointer Inference and JIT Spraying. Dionysus Blazakis. Black Hat Federal, 2010. http://www.semantiscope.com/research/BHDC2010/BHDC-2010-Paper.pdf
4. Defeat Windows 7 Browser Memory Protection. XiaBo Chen, Jun Xie. XCon 2010.
5. Memory Retrieval Vulnerabilities. Derek Soeder. 2006. http://www.eeye.com/eEyeDigitalSecurity/media/ResearchPapers/eeyeMRV-Oct2006.pdf
6. Win32 ASLR round 2. Justin Ferguson, March, 2010. http://nietmenja.blogspot.com/2010/03/win32-aslr-round-2.html
7. Attacking the Vista Heap. Ben Hawkes. Nov, 2008. http://www.lateralsecurity.com/downloads/hawkes_ruxcon-nov-2008.pdf
8. Understanding the Low Fragmentation Heap. Chris Valasek. July, 2010. http://illmatics.com/Understanding_the_LFH_Slides.pdf.
9. Modern Heap Exploitation using the Low Fragmentation Heap. Chris Valasek. 2011.
10. Heap Feng Shui in JavaScript. Alex Sotirov. 2007. http://www.phreedom.org/research/heap-feng-shui/heap-feng-shui.html
11. Preventing the exploitation of user mode heap corruption vulnerabilities. Matt Miller. 2009. http://blogs.technet.com/b/srd/archive/2009/08/04/preventing-the-exploitation-of-user-mode-heap-corruption-vulnerabilities.aspx
12. Ghost in the Windows 7 Allocator. Steven Seeley, 2012. http://conference.hitb.org/hitbsecconf2012ams/materials/D2T2%20-%20Steven%20Seeley%20-%20Ghost%20In%20the%20Windows%207%20Allocator.pdf

# References


13. Kernel Pool Exploitation on Windows 7. Tarjei Mandt. Black Hat DC, 2011. https://media.blackhat.com/bh-dc-11/Mandt/BlackHat_DC_2011_Mandt_kernelpool-wp.pdf.
14. 351 packets from trampoline. Piotr Bania. October, 2009. http://blog.piotrbania.com/2009/10/351-packets-from-trampoline.html.
15. SMEP: What is it, and how to beat it on Windows. Mateusz Jurczyk, Gynvael Coldwind. June, 2011. http://j00ru.vexillium.org/?p=783.
16. VEH. Ben Hawkes. 2011. http://sota.gen.nz/veh/.
17. Windows Kernel-mode GS Cookies and 1 bit of entropy. Mateusz Jurczyk, Gynvael Coldwind. January, 2011. http://j00ru.vexillium.org/?p=690.
18. Reducing the effective entropy of GS cookies. Skape. May, 2007. http://www.uninformed.org/?v=7&a=2&t=sumry.
19. Kernel Attacks through User-Mode Callbacks. Tarjei Mandt. Black Hat USA, 2011. http://mista.nu/research/mandt-win32k-slides.pdf.
20. Windows 8 Heap Internals. Chris Valasek and Tarjei Mandt. Black Hat USA, 2012.
21. More information on MS11-087. Chengyun Chu, Jonathan Ness. December, 2011. http://blogs.technet.com/b/srd/archive/2011/12/13/more-information-on-ms11-087.aspx.
22. Subtle information disclosure in win32k.sys syscall return values. Mateusz Jurczyk. May, 2011. http://j00ru.vexillium.org/?p=762.

# References


26. On the effectiveness of DEP and ASLR. Microsoft. December, 2010. http://blogs.technet.com/b/srd/archive/2010/12/08/on-the-effectiveness-of-dep-and-aslr.aspx.
27. The Exploit Intelligence Project v2. Dan Guido. December, 2011. http://vimeo.com/31548167.
28. Microsoft Security Intelligence Report (SIR): Volume 12. Microsoft. April, 2012. http://www.microsoft.com/en-us/download/details.aspx?id=29569.
29. Microsoft Security Intelligence Report (SIR): Volume 11. Microsoft. October, 2011. http://www.microsoft.com/en-us/download/details.aspx?id=27605.
30. Mitigating Software Vulnerabilities. Microsoft. July, 2011. http://www.microsoft.com/en-us/download/details.aspx?id=26788.
31. Compiler Security Enhancements in Visual Studio 11. Tim Burrell. December, 2011. http://blogs.msdn.com/b/sdl/archive/2011/12/02/security.aspx.