SektionEins
http://www.sektioneins.de

iOS 6

Exploitation
280
Days Later

Stefan Esser <stefan.esser@sektioneins.de>

CanSecWest Vancouver

Who am I?

Stefan Esser

- from Cologne / Germany
- in information security since 1998
- initially did a lot of low level security
- from 2001 to 2010 focused on PHP / web app security
- since mid-2010 focused on iPhone security (ASLR, kernel exploitation)
- Head of Research and Development at SektionEins GmbH

What is this talk about?

- iOS 6 is the new major version of iOS with tons of new security features
- new kernel security mitigations already discussed by Mark Dowd/Tarjei Mandt
- but iOS 6.x has other not yet mentioned new security features
- and some kernel features require commentary
- basically an update to my CSW 2012 talk

- *280 days later because it was about 280 days later when I submitted to Dragos*

Part I

iOS Security Timeline 2012-2013

CanSecWest 2012 - iOS 5 An Exploitation Nightmare?

March 2012

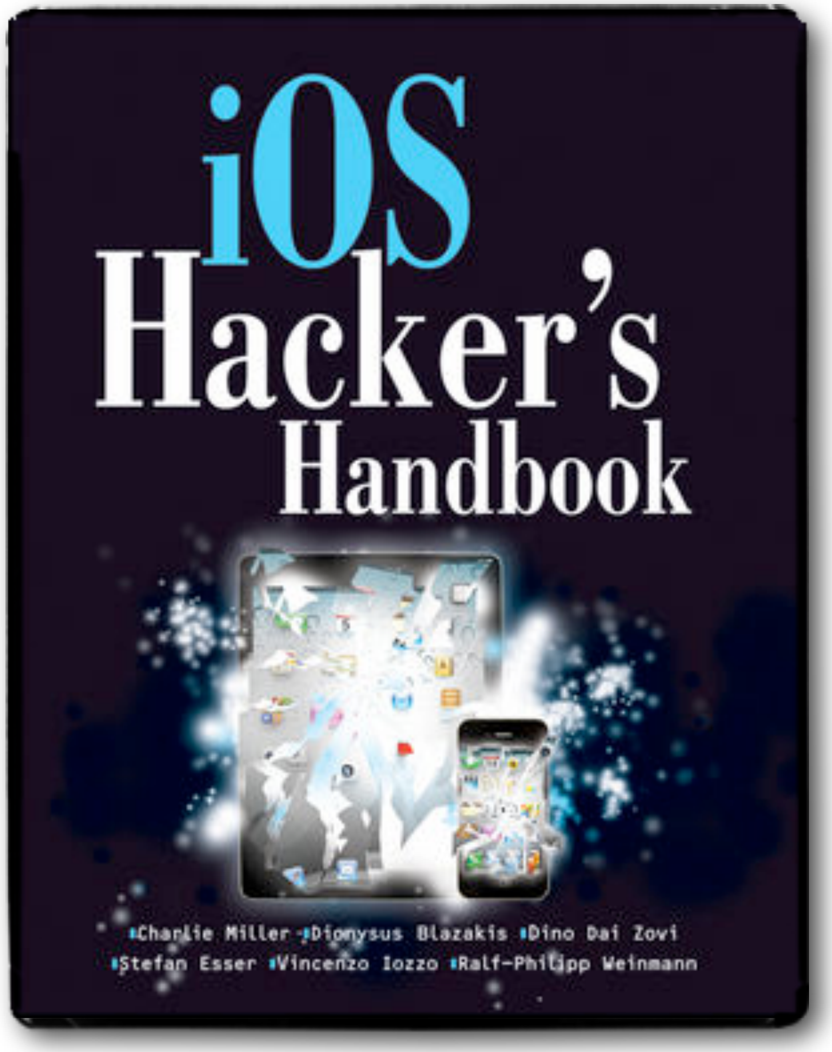
- reasons why iOS 5 jailbreak took so long
- history of some iOS security features
- history of iOS security bugfixes
- getting kernel debugger running on new devices
- abusing BPF as kernel weird machine

URL: http://cansecwest.com/csw12/CSW2012_StefanEsser_iOS5_An_Exploitation_Nightmare_FINAL.pdf

iOS Hacker's Handbook

April 2012

- **Charlie Miller - Dionysius Blazakis - Dino Dai Zovi**
- **Stefan Esser - Vincenzo Iozzo - Ralf-Philipp Weinmann**
- covers iOS 4 to iOS 5
- iOS Security Basics, iOS in the Enterprise
- Encryption, Code Signing and Memory Protection
- Sandboxing, Fuzzing iOS Applications
- Exploitation, Return-Oriented-Programming
- Kernel-Debugging and Exploitation, Jailbreaking, Baseband Attacks



URL: http://ca.wiley.com/WileyCDA/WileyTitle/productCd-1118204123.html

SyScan 2012 - iOS Kernel Heap Armageddon

April 2012

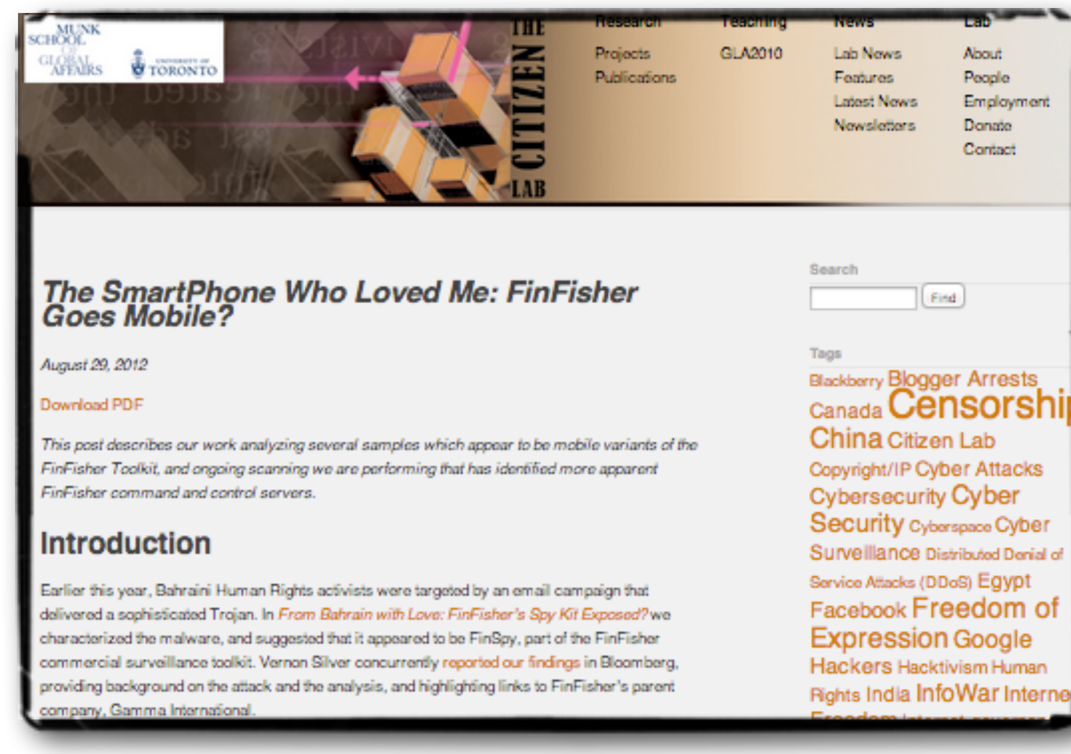
- different iOS kernel heap wrappers
- feasibility of cross zone / memory manager attacks
- attacking IOKit application data / object vtables instead of heap meta data
- using OSUnserializeXML() for generic kernel level heap feng shui
- talk updated for BlackHat USA & XCon 2012

URL 1: http://reverse.put.as/wp-content/uploads/2011/06/SyScan2012_StefanEsser_iOS_Kernel_Heap_Armageddon.pdf

URL 2: http://media.blackhat.com/bh-us-12/Briefings/Esser/BH_US_12_Esser_iOS_Kernel_Heap_Armageddon_WP.pdf

FinFisher Mobile - The Smartphone Who Loved Me

August 2012

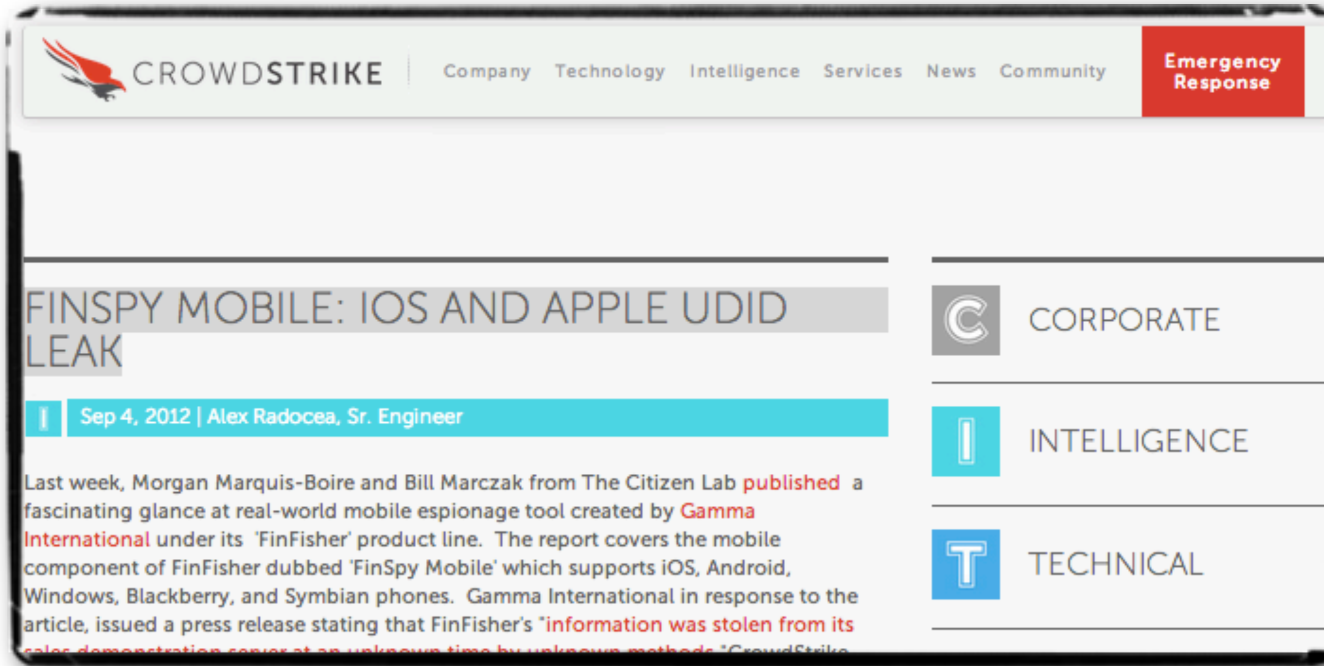


- **by CitizenLab**
- analysis of FinFisher for mobile devices
- samples caught in the wild
- iOS sample compiled for developer phones
- media wrongly assumed developer cert lets you write spy applications

URL: https://citizenlab.org/2012/08/the-smartphone-who-loved-me-finfisher-goes-mobile/

FinSpy Moile: iOS and Apple UDID Leak

September 2012


CROWDSTRIKE | Company Technology Intelligence Services News Community | Emergency Response

FINSPY MOBILE: IOS AND APPLE UDID LEAK

Sep 4, 2012 | Alex Radocea, Sr. Engineer

Last week, Morgan Marquis-Boire and Bill Marczak from The Citizen Lab published a fascinating glance at real-world mobile espionage tool created by Gamma International under its 'FinFisher' product line. The report covers the mobile component of FinFisher dubbed 'FinSpy Mobile' which supports iOS, Android, Windows, Blackberry, and Symbian phones. Gamma International in response to the article, issued a press release stating that FinFisher's "information was stolen from its

CORPORATE

INTELLIGENCE

TECHNICAL

- **by Alex Radocea^Crowdstrike**
- deep analysis of FinFisher for iOS
- revealed that there was no iOS priv escape 0-day in FinFisher iOS - just empty placeholder
- instead seems to heavily rely on being jailbroken with a public jailbreak prior to installation

URL: http://www.crowdstrike.com/blog/finspy-mobile-ios-and-apple-udid-leak/index.html

iOS 6 Released and J/“F“ailbroken on Day 1

September 2012

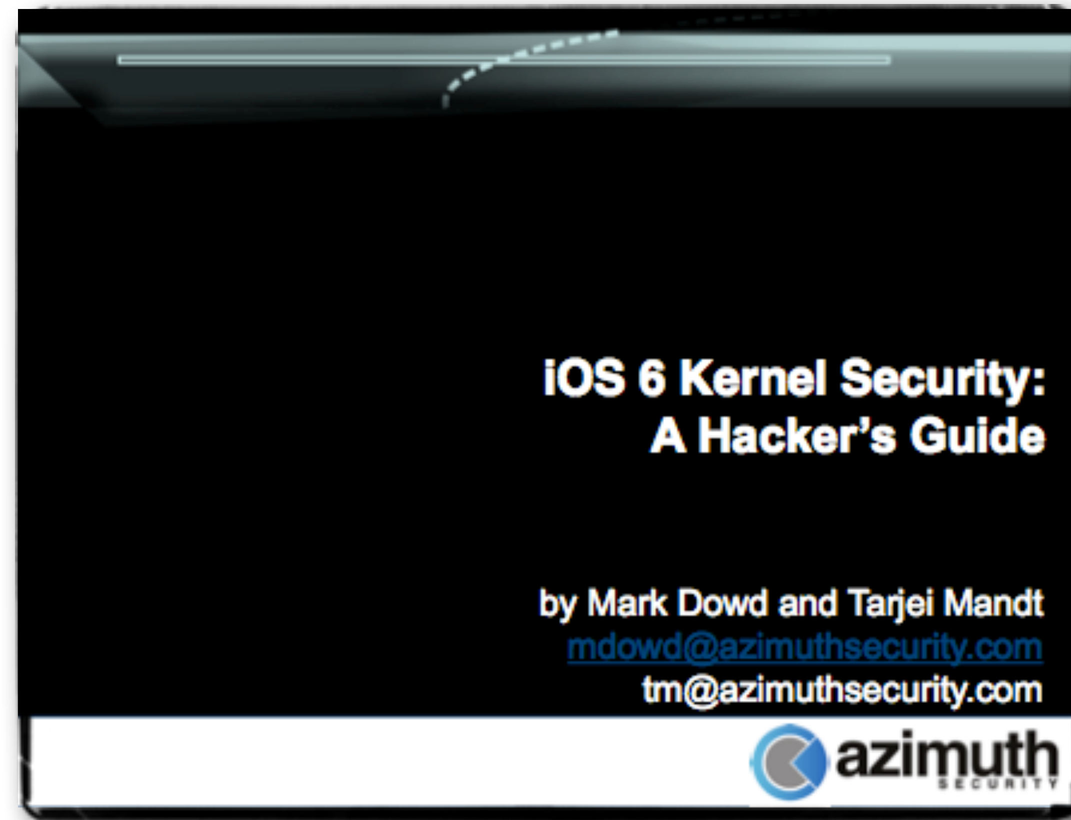
- **by Musclenerd**
- iOS 6 on pre-A5 already tethered jailbroken on day one

- **by CHPWN**
- iOS 6 on iPhone 5 already failbroken on day one
- failbroken means Cydia runs but no kernel payload

URL: https://twitter.com/chpwn/status/249249908094296064

HITB2012 - iOS 6 Kernel Security

October 2012



- **by Mark Dowd and Tarjei Mandt**
- deep analysis of new iOS 6 kernel exploit mitigations
- contained a 0-day kernel info leak vulnerability
- and the vm_map_copy exploitation technique heavily used by latest iOS 6 jailbreak

URL: http://conference.hackinthebox.org/hitbsecconf2012kul/materials/D1T2%20-%20Mark%20Dowd%20&%20Tarjei%20Mandt%20-%20iOS6%20Security.pdf

Video: http://www.youtube.com/watch?v=O-WZinEoki4

POC2012 - Find your own iOS kernel bug

`November 2012`

- **by Xu Hao and Chen Xiaobo**
- analysis of previous IOKit vulnerability
- about fuzzing iOKit for vulnerabilities

- later repeated at SyScan360 in December

URL: http://syscan.org/index.php/download/get/328bf4b37e6ae8b799472ff230465339/XuHao_Chen_Xiaobo_Find_your_own_iOS_kernel_bug.zip

Hackulo.us / Installous shutdown

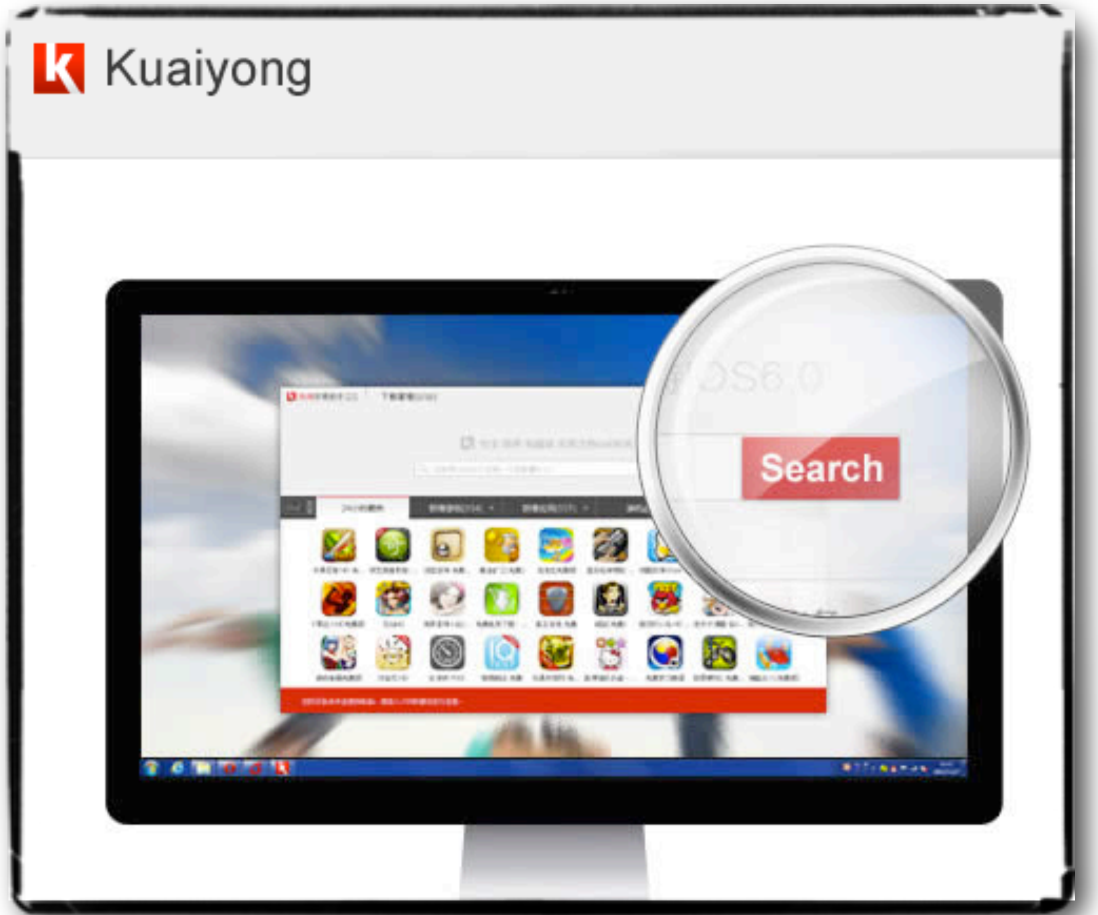
December 2012

- announcement that Hackulo.us shut down
- also took down Installous the notorious application used by iOS application pirates on jailbroken iPhones
- celebrated by media, jailbreak developers and iOS app developers around the world

URL: http://thanks-god-not-anymo.re

kuaiyong, Zeusmos, 25pp, ...

January 2013



- after installous is dead more and more iOS piracy solutions that do not require jailbreak
- solutions reportedly based on account sharing and/or some undisclosed exploit
- still active ?!?

URL 1: http://m.csoonline.com/article/725183/now-pirated-ios-apps-can-be-installed-without-jailbreak

URL 2: http://no.you.dont.get.the.url.you.want

Research Assistant: Marc Rogers

Community Milking and iOS 6 JB Release

February 2013

- **by evad3rs**
- website with donation button and multiple banner ads
- told people repeatedly for about a week to check website for status updates
- about one week later release of iOS 6.0/6.1 jailbreak
- so far the most expensive jailbreak in terms of crowdfunding

URL: http://www.evasi0n.com/

evasi0n Jailbreak's Userland Components

February 2013

- **by Braden Thomas^AccuvantLabs**
- analysis of userland components of evasi0n jailbreak
- covers most of the userland bugs exploited by evasi0n

URL: http://blog.accuvantlabs.com/blog/bthomas/evasi0n-jailbreaks-userland-component

Dissecting the "evasi0n" Kernel Exploit

February 2013

- **by Tarjei Mandt^Azimuth**
- analysis of kernel components of evasi0n jailbreak
- shows how evasi0n is based on techniques discussed in the iOS 6 kernel security talk by azimuth

URL: http://blog.azimuthsecurity.com/2013/02/from-usr-to-svc-dissecting-evasi0n.html

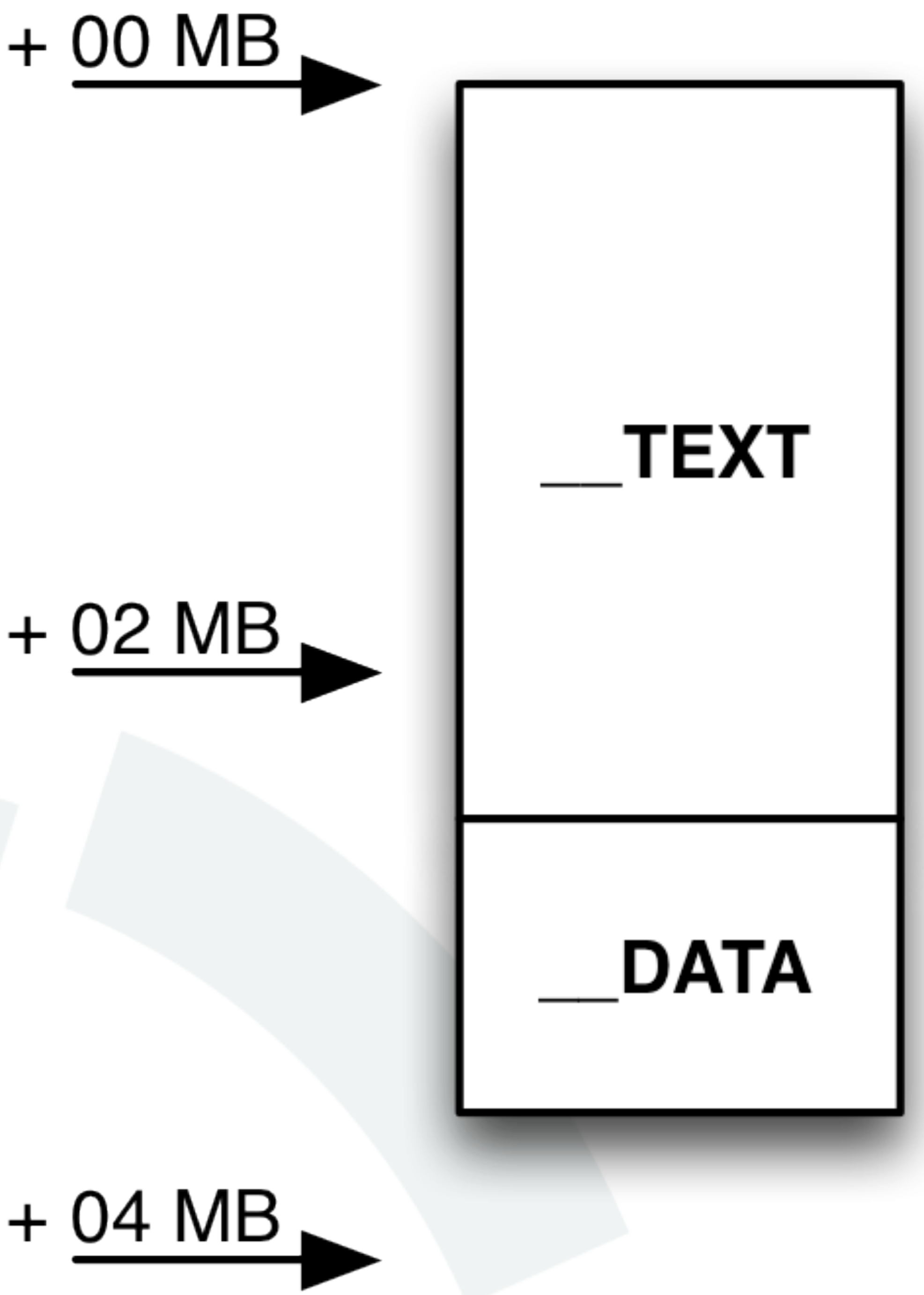
Part II

iOS 6 Kernel Security “Improvements“

KASLR

- iOS 6 introduces KASLR - kernel address space layout randomization
- only 256 possible load addresses
- each 2 MB apart
- starting at **`0x81200000`** ending at **`0xA1000000`**

KASLR: But why 2 MB Aligned?



- 2 MB alignment of KASLR seems arbitrary
- why not smaller alignment?
- big alignment is less secure
- right now:
  - leak any address in __DATA and you know the kernel's base address

    (address - 0x200000) & 0xFFE00000

  - leak any address from first 2 MB of kernel __TEXT and know the kernel's base address

    address & 0xFFE00000

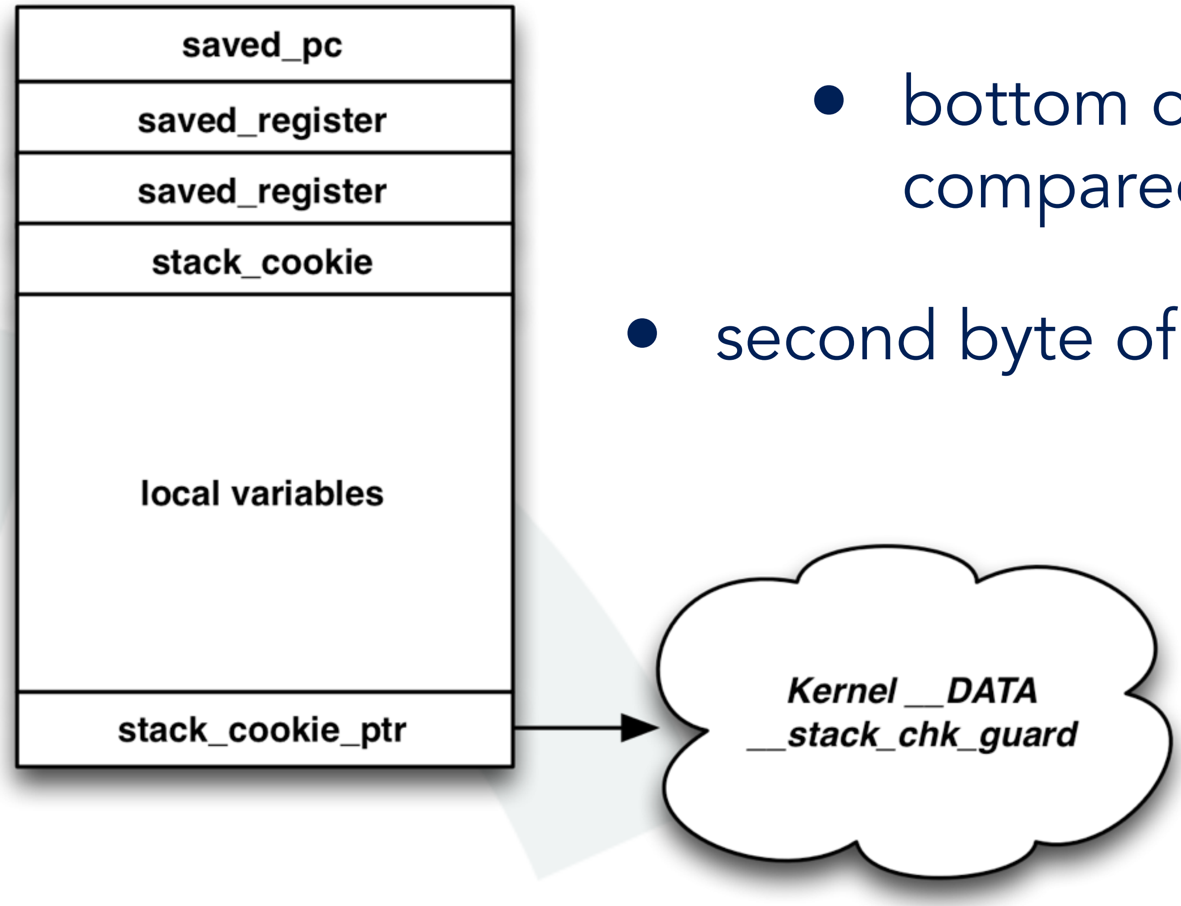
Kernel Address Space Hardening

- kernel __TEXT no longer writable
  - ➡ to stop kernel code hotpatching
- kernel heap no longer executable
  - ➡ to stop just executing kernel data
- kernel address space is separated from user space processes
  - ➡ to stop return into user space code and offset from NULL-deref attacks

SektionEins

Kernel Stack Cookies

- iOS 6 added stack cookies to protect from kernel stack buffer overflows
- implementation is rather unusual
    - stack cookie on top of stack
    - bottom of local stack contains ptr to the value it is compared against
- second byte of stack cookie is forced to **`0x00`**



Kernel Stack Cookie Verification

- stack cookie verification in function epilog
- verification against cookie pointed to
- fact that **`stack_cookie_ptr`** and **`stack_cookie`** are both on stack is a weakness
- wrong cookie value will lead to a kernel panic without message

```
__text:8027AFB0                 LDR             R0, [SP,#0x4C+stack_cookie_ptr]
__text:8027AFB2                 LDR             R0, [R0]
__text:8027AFB4                 LDR             R1, [SP,#0x4C+stack_cookie]
__text:8027AFB6                 CMP             R0, R1
__text:8027AFB8                 ITTT EQ
__text:8027AFBA                 ADDEQ           SP, SP, #0x34
__text:8027AFBC                 POPEQ.W         {R8,R10,R11}
__text:8027AFC0                 POPEQ           {R4-R7,PC}
__text:8027AFC2                 BL              ___stack_chk_fail
```


SektionEins

Kernel Heap Cookies

- iOS 4 and iOS 5 kernel heap exploitation has always attacked the free list
- in iOS 6 Apple introduced heap protection cookies to protect free list
- distinguishes between small poisoned and larger non-poisoned blocks
- two different security cookies are used for this

➡ stops attacks against the free list as used before in public jailbreaks

Kernel Heap Cookies (larger blocks)

- for larger blocks the memory content is kept but end is trashed with cookie
- secret cookie has lowest bit cleared
- if data of freed block leaks this leaks
  - a kernel heap address: **`0x87b46500`**
  - the secret cookie: **`0x6b7769c8 ^ 0x87b46500 = 0xECC30CC8`**

next_pointer

```
87b46480: 00 65 b4 87 00 00 00 00 00 00 00 00 00 00 00 00 .e..............
87b46490: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
87b464a0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
87b464b0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
87b464c0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
87b464d0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
87b464e0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 ................
87b464f0: 00 00 00 00 00 00 00 00 00 00 00 00 c8 69 77 6b .............iwk
```

next_pointer^non_poisoned_cookie

Kernel Heap Cookies (small blocks)

- for small blocks the memory content is overwritten with **`0xdeadbeef`**
- secret cookie has lowest bit set
- if data of freed block leaks this leaks
  - a kernel heap address: **`0x92f1c740`**
  - the secret cookie: **`0x7ec1387b ^ 0x92f1c740 = 0xEC30FF3B`**

next_pointer

```
92f1c700: 40 c7 f1 92 ef be ad de ef be ad de ef be ad de @...............
92f1c710: ef be ad de ef be ad de ef be ad de ef be ad de ................
92f1c720: ef be ad de ef be ad de ef be ad de ef be ad de ................
92f1c730: ef be ad de ef be ad de ef be ad de 7b 38 c1 7e ............{8.~
```

next_pointer^poisoned_cookie

Kernel Heap Cookies after allocation

- on allocation free list pointer and cookie are overwritten with **`0xdeadbeef`**
- most probably as defense in depth against information leaks

```
9072b000: ef be ad de 00 00 00 ff 00 00 00 ff 00 00 00 ff ................
9072b010: 00 00 00 ff 00 00 00 ff 00 00 00 ff 00 00 00 ff ................
9072b020: 00 00 00 ff 00 00 00 ff 00 00 00 ff 00 00 00 ff ................
9072b030: 00 00 00 ff 00 00 00 ff 00 00 00 ff 00 00 00 ff ................
9072b040: 00 00 00 ff 00 00 00 ff 00 00 00 ff 00 00 00 ff ................
9072b050: 00 00 00 ff 00 00 00 ff 00 00 00 ff 00 00 00 ff ................
9072b060: 00 00 00 ff 00 00 00 ff 00 00 00 ff 00 00 00 ff ................
9072b070: 00 00 00 ff 00 00 00 ff 00 00 00 ff ef be ad de ................
```

Kernel Heap Hardening

- previously **mach_zone_info()** and **host_zone_info()** leaked internal state
- both functions now require debugging kernel boot arguments

- previously **OSUnserializeXML()** allowed fine control over kernel heap
- Apple fixed some bugs in it and put some arbitrary limits on it
- only exact methods described at BlackHat / SyScan were killed
- **other ways to abuse this function for kernel heap feng shui still working**

Death to Kernel Info Leaks

- two fold strategy to fight kernel info leaks
  - fix information leak vulnerabilities
  - obfuscate kernel addresses returned to user land
- example of fixed information leaks
  - **BPF** stack data info leak
  - **kern.proc** leak fixed
  - **kern.file** info leak fixed

Kernel Address Obfuscation

- lots of kernel API return kernel addresses to user land processes

  e.g. mach_port_kobject(), mach_port_space_info(), vm_region_recurse(), vm_map_region_recurse(), vm_map_page_info(), proc_info(), fstat(), sysctl()

- protected by adding a random 32 bit cookie `(lowest bit set)`

```
#define VM_KERNEL_ADDRPERM(_v)                          \
        (((vm_offset_t)(_v) == 0) ?                     \
            (vm_offset_t)(0) :                          \
            (vm_offset_t)(_v) + vm_kernel_addrperm)
```

```
iin->iin_urefs = IE_BITS_UREFS(bits);
iin->iin_object = (natural_t)VM_KERNEL_ADDRPERM((uintptr_t)entry->ie_object);
iin->iin_next = entry->ie_next;
iin->iin_hash = entry->ie_index;
```


SektionEins

Kernel Image Address Obfuscation

- some API might even return addresses inside the kernel image
- these addresses are additionally **unslid** to protect against **KASLR** leaks

```
#define VM_KERNEL_UNSLIDE(_v)                                   \
        ((VM_KERNEL_IS_SLID(_v) ||                              \
          VM_KERNEL_IS_KEXT(_v)) ?                              \
            (vm_offset_t)(_v) - vm_kernel_slide :               \
            (vm_offset_t)(_v))
#define VM_KERNEL_SLIDE(_u)                                     \
        ((vm_offset_t)(_u) + vm_kernel_slide)

#define VM_KERNEL_ADDRPERM(_v)                                  \
        (((vm_offset_t)(_v) == 0) ?                             \
            (vm_offset_t)(0) :                                  \
            (vm_offset_t)(_v) + vm_kernel_addrperm)
```

```
if (0 != kaddr && is_ipc_kobject(*typep))
    *addrp = VM_KERNEL_ADDRPERM(VM_KERNEL_UNSLIDE(kaddr));
else
    *addrp = 0;
```

Readonly Syscall Table

- previous jailbreaks used partial syscall table overwrites
- Apple moved syscall table into section `__DATA::__const`
- section is made read only at runtime
- controlled by kernel boot argument `dataconstro`
- stops syscall table corruption ...

Just replace Syscall Table completely?

- kernel linking changes in iOS 6 introduced lots of indirect accesses
- syscall table is no longer accessed directly (also true for lots of other stuff)
- instead pointer to syscall table is used from **`__nl_symbol_ptr`** section
- and guess what - this section is writable

```
text:8021F760    LDR      R10, [R0,#0x30]
text:8021F764    CMP      R10, #0
text:8021F768    LDREQ    R10, [R0]
text:8021F76C    MOV      R2, #(_pNsys - 0x8021F77C) ; _pNsys
text:8021F774    LDR      R2, [PC,R2] ; _pNsys
text:8021F778    MOV      R1, #(_pSysent - 0x8021F78C) ; _pSysent
text:8021F780    UXTH     R5, R10
text:8021F784    LDR      R1, [PC,R1] ; _pSysent
text:8021F788    LDR      R2, [R2]
text:8021F78C    CMP      R5, R2
text:8021F790    BLT      loc_8021F7A0
```

```
nl_symbol_ptr:802D2C7C _pNsys         DCD _nsys
nl_symbol_ptr:802D2C7C
nl_symbol_ptr:802D2C80 _pSysent       DCD _sysent
```


SektionEins

Part III

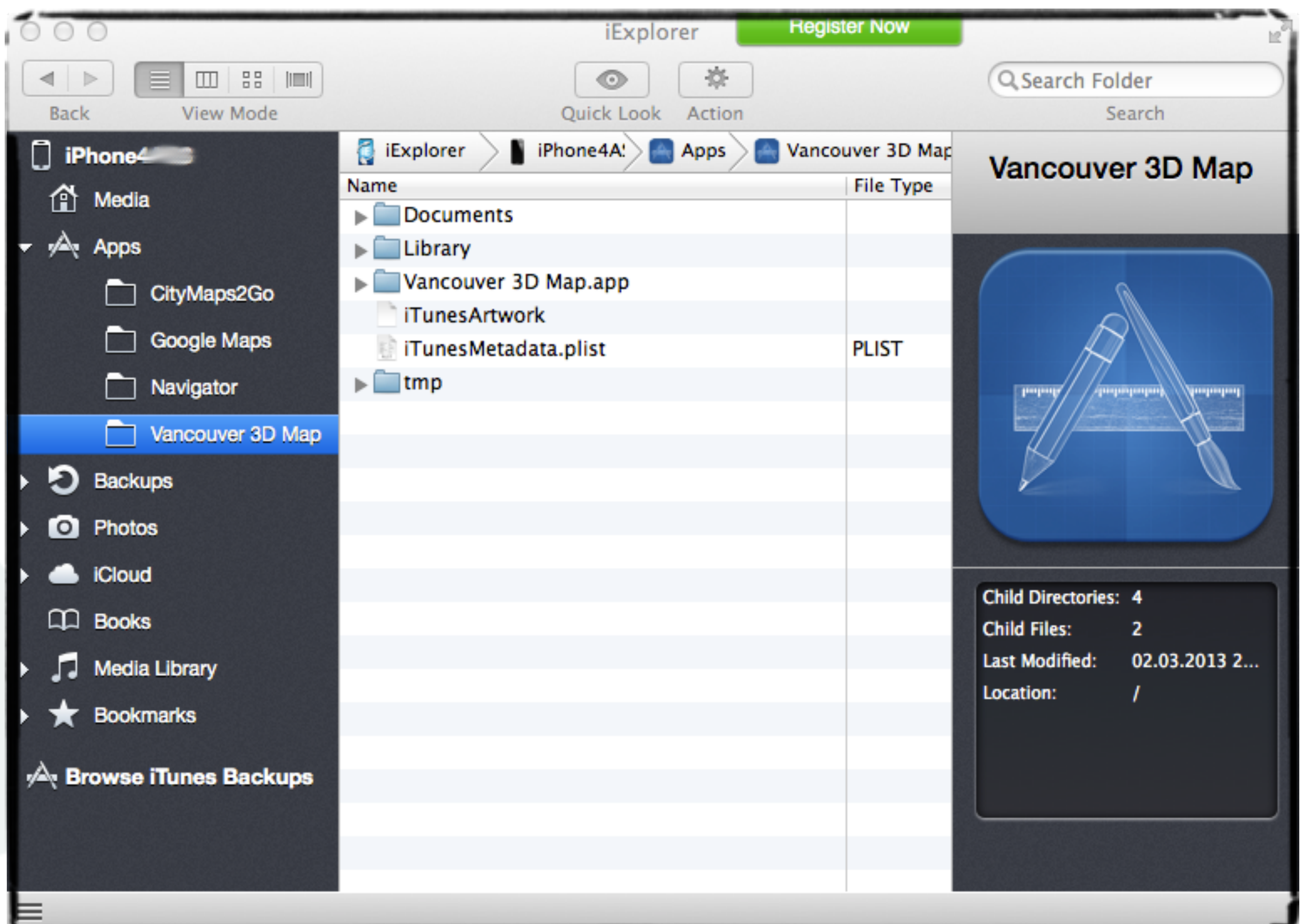
iOS 6 Misc Hardening

BPF not so weird anymore...

- at CSW 2012 BPF was mentioned as weird machine inside the kernel
- in iOS 6.x it is still a machine but not so weird anymore
- Apple added sanity checks inside the function
- access to slack memory is now checked for bounds

mobile_house_arrest - Readonly Code Directory

- lockdown service for reading / writing into app directories
- since iOS 6 application's code directory is no longer writable
- previously it was possible to replace arbitrary application resources



Part IV

User Space ASLR (Address Space Layout Randomization)

ASLR in iOS 4.3-6.x

- randomly slides
  - main binary
  - dyld *(dynamic linker)*
  - dynamic library cache

Position Independent Executables in 2012

```
$ python ipapiescan.py
Adobe Reader                      -       armv7 - PIE    - N/A
Bluefire Reader                   - armv6|armv7 - NO_PIE - 3.0
DiamondDash                       -       armv7 - NO_PIE - 4.2
Ebook Reader                      - armv6|armv7 - NO_PIE - N/A
eBookS Reader                     - armv6|armv7 - NO_PIE - N/A
Facebook                          - armv6|armv7 - NO_PIE - 4.0
Fly With Me                       - armv6|armv7 - NO_PIE - 3.0
FPK Reader                        - armv6|armv7 - NO_PIE - 3.2
Hotels                            - armv6|armv7 - NO_PIE - 3.1
iBooks                            - armv6|armv7 - NO_PIE - 4.2
KakaoTalk                         - armv6|armv7 - NO_PIE - 3.1
Messenger                         - armv6|armv7 - NO_PIE - 4.0
PerfectReader Mini                - armv6|armv7 - NO_PIE - N/A
QR Reader                         - armv6|armv7 - NO_PIE - 4.0
QR Scanner                        - armv6|armv7 - NO_PIE - N/A
QR-Scanner                        -       armv7 - NO_PIE - 4.0
QRCode                            - armv6|armv7 - NO_PIE - N/A
Quick Scan                        - armv6|armv7 - NO_PIE - 4.0
Skype                             - armv6|armv7 - NO_PIE - N/A
Twitter                           - armv6|armv7 - NO_PIE - 4.0
vBookz PDF                        -       armv7 - PIE    - 4.3
VZ-Netzwerke                      - armv6       - NO_PIE - 3.0
Wallpapers                        - armv6|armv7 - NO_PIE - 4.1
WhatsApp                          - armv6|armv7 - NO_PIE - 3.1
Where is                          - armv6|armv7 - NO_PIE - 4.1
```

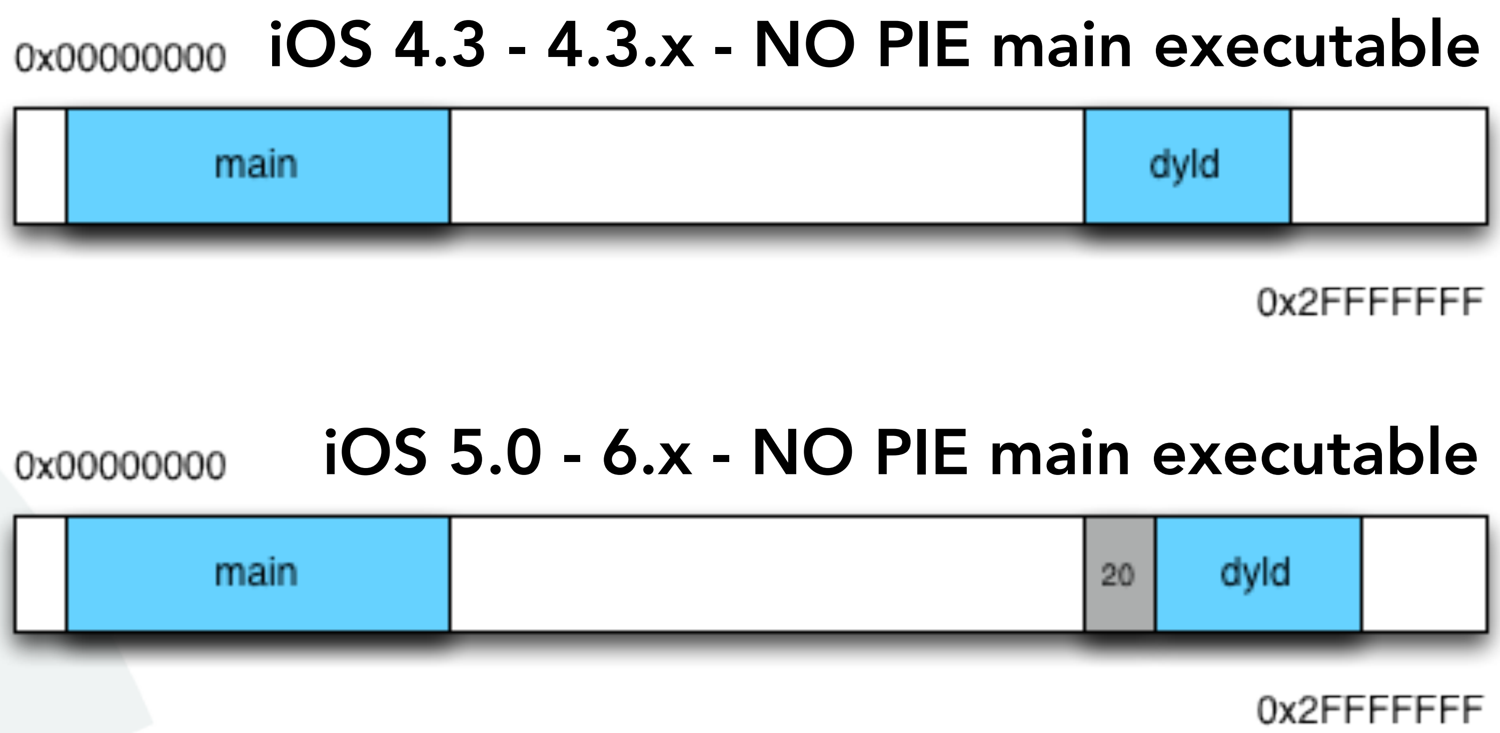
- all system binaries were compiled as PIE
- most 3rd party apps were not compiled as PIE

source code of old **`idapiescan.py`** is available at Github

https://github.com/stefanesser/idapiescan

iOS 4.3-6.x: NO PIE main binary randomization

- dynamic loader is not slid in iOS 4 for NO PIE main executables
- since iOS 5 the dynamic loader is always slid
- randomized by kernel in 256 positions



Position Independent Executables in 2013

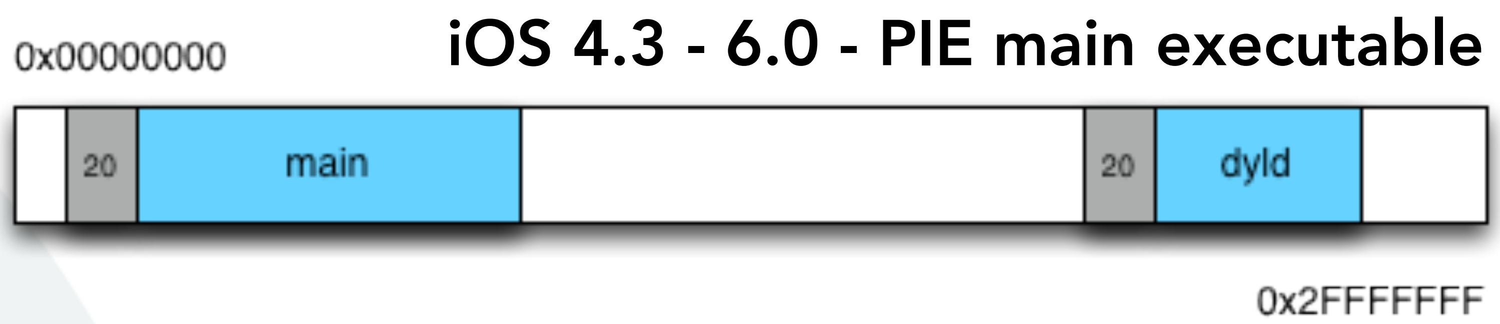
```
$ python ipapiescan.py
Bluefire Reader       -        armv7(s) - PIE    - 4.3
Calendar Pro          -        armv7(s) - PIE    - 4.3
CalenMob              -        armv7(s) - PIE    - 5.0
Chrome                -        armv7    - PIE    - 4.3
CloudOn               -        armv7    - NO_PIE - 5.0
DiamondDash           -        armv7(s) - PIE    - 4.3
Documents             -        armv7(s) - PIE    - 4.3
Ebook Reader          -        armv7    - PIE    - 4.3
eBookS Reader         - armv6|armv7     - NO_PIE - N/A
Facebook              -        armv7    - PIE    - 4.3
G-Whizz!              - armv6|armv7     - NO_PIE - 4.0
Gmail                 -        armv7    - PIE    - 5.0
Google                -        armv7    - PIE    - 4.3
Google Drive          -        armv7    - PIE    - 5.0
Google Earth          -        armv7    - PIE    - 4.3
Google+               -        armv7    - PIE    - 5.0
iBooks                -        armv7    - PIE    - 5.0
IM+                   -        armv7(s) - PIE    - 4.3
Instagram             -        armv7    - PIE    - 4.3
KakaoTalk             -        armv7(s) - PIE    - 4.3
Latitude              - armv6|armv7     - NO_PIE - N/A
Local                 - armv6|armv7     - PIE    - 4.3
Lync 2010             -        armv7    - NO_PIE - 4.3
Messenger             -        armv7    - PIE    - 4.3
MSN World             -        armv7(s) - PIE    - 4.3
SkyDrive              - armv6|armv7     - NO_PIE - 4.0
Skype                 -        armv7    - NO_PIE - 4.3
SmartGlass            -        armv7    - PIE    - 5.0
SSH Mobile Free       -        armv7(s) - PIE    - 4.3
SystemTools           -        armv7(s) - PIE    - 4.3
Translate             - armv6|armv7     - NO_PIE - N/A
Trillian              -        armv7    - PIE    - 4.3
Twitter               -        armv7    - PIE    - 5.0
Usessh                -        armv7(s) - PIE    - 4.3
```

- all system binaries are compiled as PIE
- most 3rd party apps are now compiled as PIE
- NO_PIE mostly unimportant apps
- some high profile exceptions are: Skype, SkyDrive, Google Translate, ...

SektionEins

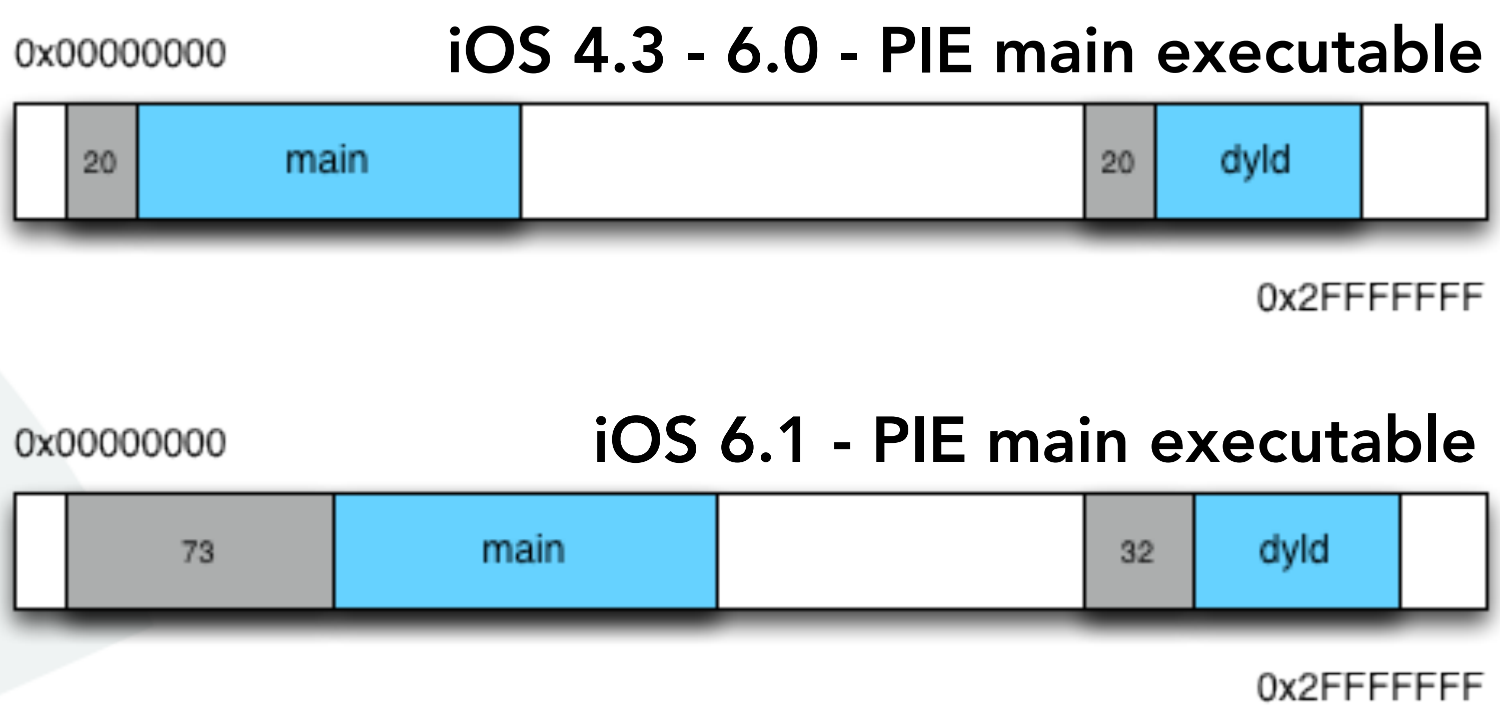
iOS 4.3-6.0: PIE main binary randomization

- for PIE main executables the main binary and dyld are randomized
- main binary and dyld are slid the same amount
- randomized by kernel in 256 positions



iOS 6.1: PIE main binary randomization

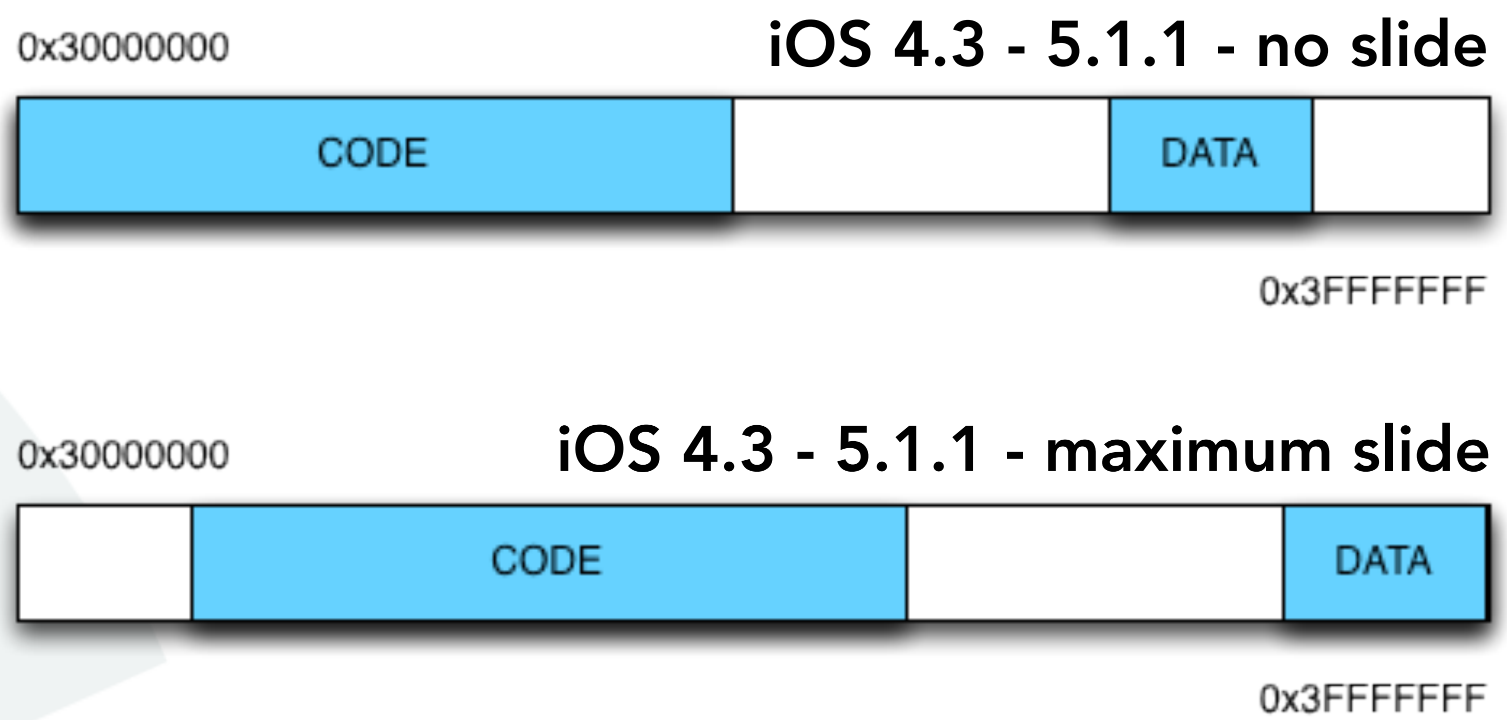
- since iOS 6.1 the kernel finally generates two separate slides
- randomness of both is still limited to 256 positions
- knowing addresses in dyld / main no longer leaks address of other



SektionEins

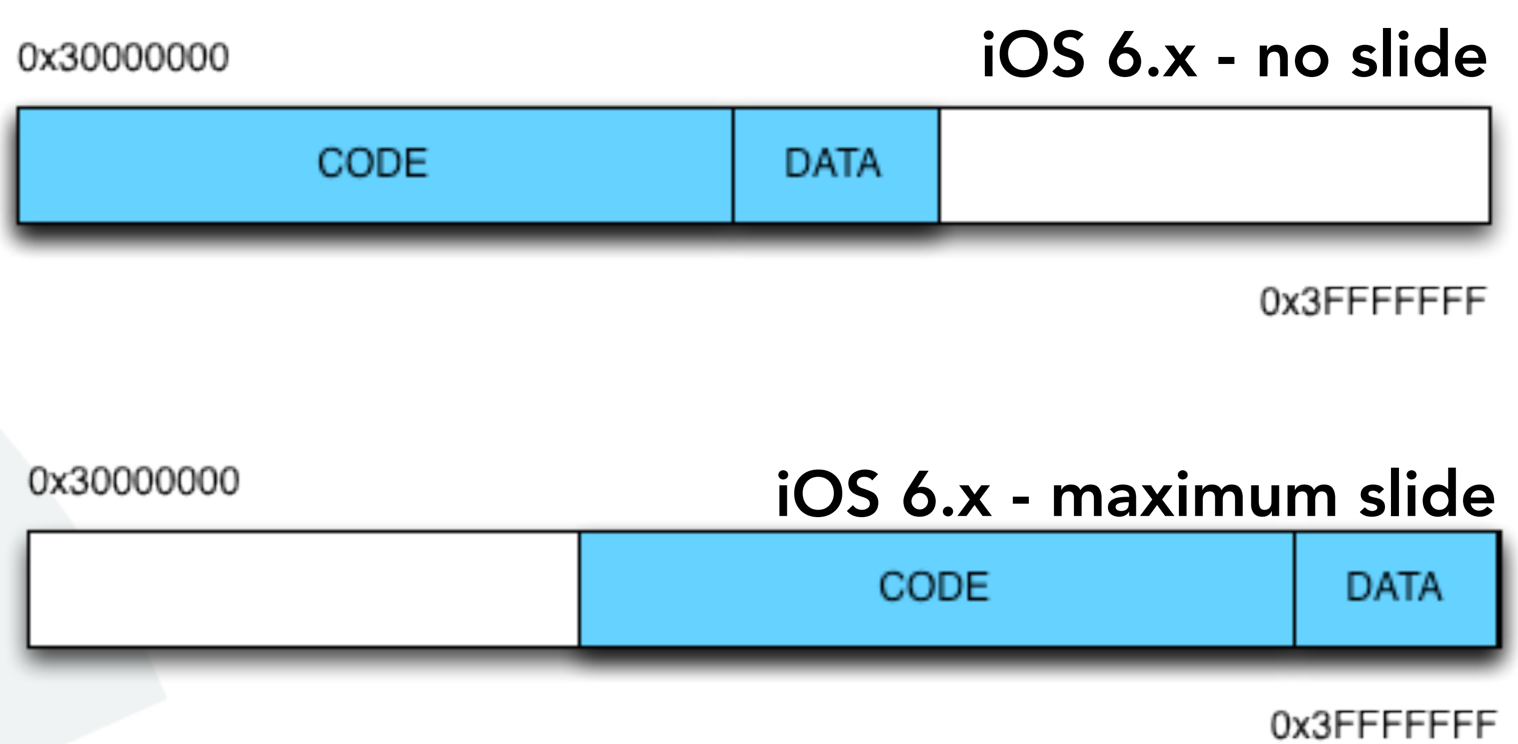
iOS 4.3-5.1.1: dyld_shared_cache randomization

- data and code must slide together *(due to codesigning)*
- hole after code - data usually loaded to 0x3E000000
- max slide determined by difference of end of shared area and end of data
- around 4200 different positions



iOS 6.x: dyld_shared_cache randomization

- code and data loaded right next to each other
- no more hole - no more wasted space
- max slide determined by size of shared area minus size of shared cache
- about 21500 different positions for iPod 4G
  (new devices = more code = less random)



Part V

iOS 6 and the Partial Code-signing Vulnerability

Partial Code-signing Vulnerability (iOS 4)

- in iOS 4.x jailbreaks the method of choice to launch untether exploits
- when a *mach-o* is loaded the kernel will load it as is
- a possible signature will be registered
- missing signature is okay until a not signed executable page is accessed
- dyld was tricked with malformed ***mach-o*** data structures to execute code

sniffLoadCommands (iOS 4.3.4)

- function does pre-handling of mach-o load commands
- iOS 4.3.4 adds protection against partial code signing
  - mach-o load commands must be inside a segment
  - mach-o load commands can only be in R + X segment
  - mach-o load commands may not be partially in a segment

➡ *effect is that once dyld maps the header R+X it can only continue to work on it if there is a valid signature*

Partial Code-signing Vuln (iOS 4.3.4-iOS 5.1.1)

- protection in sniffLoadCommands could be bypassed
  - by having a **`RW-`** ***LC_SEGMENT64*** for ***mach-o*** header
  - and a fake **`R-X`** ***LC_SEGMENT*** for ***mach-o*** header
- disclosed at **CanSecWest 2012** - here on stage
- worked because kernel handles **LC_SEGMENT64** and dyld did not
- magic is that dyld will read mach-o header from from address in memory

sniffLoadCommands (iOS 6.0)

- iOS 6.0 adds protection against CSW 2012 trick to sniffLoadCommands
  - if a LC_SEGMENT64 load command is found an exception is thrown

➡ *CSW 2012 trick was already partially broken after iOS 5.1.1*

- *in iOS 5.1.1 AMFI verified existence of a code signing blob*

Load Command Segment Override (iOS 6.0-6.1.2)

- bug used by evasi0n
- kernel not directly involved in loading dynamic libraries only dyld is
- dyld could be tricked with a malicious dylib
  - contains real R-X segment with load commands in it
  - contains second R-- segment that contains copy of load commands
  - virtual address of both segments is set to same position
  - later segment in mach-o will replace previous in memory
- when dyld accesses header it is in RO memory = no sig needed = bypass

sniffLoadCommands (iOS 6.1.3 beta 2)

- iOS 6.1.3 beta 2 adds additional protections to sniffLoadCommands
  - load commands must now be in one segment only
  - for dynamic libraries a second sniff pass is added
  - all segments must not intersect the R-X segment containing the load commands

➡ evasi0n untether killed

Part VI

iOS 6.1 and Launch-Daemon-Code-Signing

Launch Daemons to launch Untethers

- in iOS 5.x jailbreaks were launched on boot via launch daemons
- launch daemons are plists describing system services

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE plist PUBLIC "-//Apple//DTD PLIST 1.0//EN" "http://
www.apple.com/DTDs/PropertyList-1.0.dtd">
<plist version="1.0">
<dict>
    <key>Label</key>
    <string>jb</string>
    <key>ProgramArguments</key>
    <array>
        <string>/usr/sbin/corona</string>
        <string>-f</string>
        <string>racoon-exploit.conf</string>
    </array>
    <key>WorkingDirectory</key>
    <string>/usr/share/corona/</string>
    <key>RunAtLoad</key>
    <true/>
    <key>LaunchOnlyOnce</key>
    <true/>
    <key>DisableAslr</key>
    <true/>
</dict>
</plist>
```

DisableAslr was removed from iOS 5.1

Launch-Daemon-Code-Signing (I)

- abuse of launch daemons lead to new iOS 6.1 security feature
- launch daemon loading is now code signed
- implemented in **`/bin/launchctl`**
- can be bypassed by setting kernel boot arguments
  (not possible without low-level exploit)

```
bool launchctl_enforce_codesign()
{
  char buffer[1024];
  char *p, *tmp = NULL;
  size_t len;
  int res = 0;

  len = sizeof(buffer);
  if ( !sysctlbyname("kern.bootargs", buffer, &len, 0, 0) )
  {
    p = strnstr(buffer, "cs_enforcement_disable=", len);
    if ( p )
      res = strtoul(p + 23, 0, 10);
    p = strnstr(buffer, "launchctl_enforce_codesign=", len);
    if ( p )
    {
      if (strtoul(p + 27, &tmp, 10) == 0)
        res = 1;
    }
  }
  return res == 0;
}
```

Launch-Daemon-Code-Signing (II)

- without launch-daemon-code-signing
  `/bin/launchctl` scans **`/System/Library/LaunchDaemons`** for defined launch daemons and loads them

- with activated launch-daemon-code-signing
  a big plist with all defined launch daemons is loaded instead

- launch daemon can only be loaded if it is defined in the plist and exists on disk

```
if ( !LaunchDaemonCachePlist )
{
  length = 0;
  xpcd_cache = dlopen("/System/Library/Caches/com.apple.xpcd/xpcd_cache.dylib", 2);
  if ( !xpcd_cache )
  {
    dlerror_msg = dlerror();
    launchctl_log(3, "cache loading failed: dlopen returned %s.", dlerror_msg);
    goto error1;
  }
  __xpcd_cache = dlsym(xpcd_cache, "__xpcd_cache");
  if ( !__xpcd_cache )
  {
    msg = "cache loading failed: failed to find __xpcd_cache symbol in cache.";
    goto LABEL_6;
  }
  if ( !dladdr(__xpcd_cache, &dl_info) )
```

Launch-Daemon-Code-Signing (III)

- big launch daemon plist is loaded from **`/System/Library/Caches/com.apple.xpcd/xpcd_cache.dylib`**
- this dynamic library is within the **dyld_shared_cache** and therefore **code signed**
- symbol **`__xpcd_cache`** must exist
- but binary plist is take from sectiondata of **`__TEXT::__xpcd_cache`**

```
if ( !LaunchDaemonCachePlist )
{
  length = 0;
  xpcd_cache = dlopen("/System/Library/Caches/com.apple.xpcd/xpcd_cache.dylib", 2);
  if ( !xpcd_cache )
  {
    dlerror_msg = dlerror();
    launchctl_log(3, "cache loading failed: dlopen returned %s.", dlerror_msg);
    goto error1;
  }
  __xpcd_cache = dlsym(xpcd_cache, "__xpcd_cache");
  if ( !__xpcd_cache )
  {
    msg = "cache loading failed: failed to find __xpcd_cache symbol in cache.";
    goto LABEL_6;
  }
  if ( !dladdr(__xpcd_cache, &dl_info) )
```

XPCD_CACHE.PLIST

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE plist PUBLIC "-//Apple//DTD PLIST 1.0//EN" "http://www.apple.com/DTDs/PropertyList-1.0.d
<plist version="1.0">
<dict>
  <key>CreationDate</key>
  <date>2013-13-13T13:13:13Z</date>
  <key>LaunchDaemons</key>
  <dict>
    <key>/System/Library/LaunchDaemons/com.apple.AOSNotification.plist</key>
    <dict>
      <key>JetsamProperties</key>
      <dict>
        <key>JetsamMemoryLimit</key>
        <integer>1024</integer>
        <key>JetsamPriority</key>
        <integer>-49</integer>
      </dict>
      <key>KeepAlive</key>
      <dict>
        <key>PathState</key>
        <dict>
          <key>/var/mobile/Library/Preferences/com.apple.AOSNotification.FMFAccounts.plist</key>
          <true/>
          <key>/var/mobile/Library/Preferences/com.apple.AOSNotification.launchd</key>
          <true/>
        </dict>
      </dict>
```

Launch-Daemon-Code-Signing Security

How secure Apple wanted Launch-Daemon-Code-Signing to be...

Launch-Daemon-Code-Signing Security

How secure Launch-Daemon-Code-Signing is right now...

SektionEins

Launch-Daemon-Code-Signing Security

- code signing itself seems to stop loading arbitrary launch daemons
- but Apple forgot / or ignored **`/etc/launchd.conf`**
- **`/etc/launchd.conf`** defines commands **launchctl** executes on start
- attacker can execute arbitrary existing commands

```
bsexec .. /sbin/mount -u -o rw,suid,dev /
setenv DYLD_INSERT_LIBRARIES /private/var/evasi0n/amfi.dylib
load /System/Library/LaunchDaemons/com.apple.MobileFileIntegrity.plist
bsexec .. /private/var/evasi0n/evasi0n
unsetenv DYLD_INSERT_LIBRARIES
bsexec .. /bin/rm -f /private/var/evasi0n/sock
bsexec .. /bin/ln -f /var/tmp/launchd/sock /private/var/evasi0n/sock
```

FAQ: Why not put old launchctl binary on device?

Q: *"If only the newest iOS 6.1* ***launchctl*** *binary implements this code signing. Why not put an iOS 6.0* ***launchctl*** *binary on the device to bypass this protection?"*

A: "System binaries like **launchctl** do not come with a valid code signing signature from Apple. Instead they come only with the table of memory page hashes and entitlements. When the kernel loads such a binary it hashes these tables and checks if the hash is in a whitelist inside the kernel (a.k.a. trust cache). The old **launchctl** binary will not be accepted because it is not in the trust cache of the new kernel."

Final Words

- with iOS 6 Apple has tried to kill all public techniques
- finally kills some stuff that was previously known and ignored for 10 years
- the new mitigations make exploitation a lot harder
- when launch daemon code signing is hardened a bit more, persisting on iDevices will become incredibly hard
- however there are still weaknesses in most of the protections
- ... and tons of kernel information leaks

Questions

?