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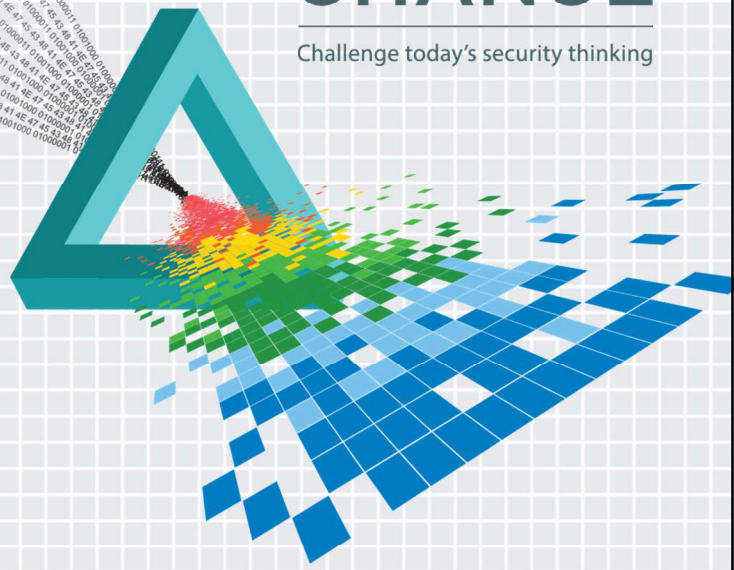
CHANGE

Challenge today's security thinking



SESSION ID: MBS-R01

Code Signing – Hashed Out

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@Technologeeks

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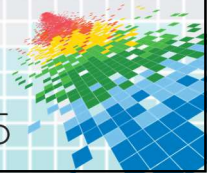
Code Signing in Apple's OSes

- Apple has introduced code signing as far back as OS X 10.5
  - Along with another major feature – then seatbelt, now sandbox
- Other OSes use signatures too, but Apple's use is more advanced:
  - Provides the fulcrum for all system security measures
  - In OS X, creeping in as of 10.8 (via GateKeeper) and Mac App Store
  - In iOS, Mandatory as of day one.

Motivation for Code Signing

- Obvious motivation: Authenticate software origin
  - Greatly mitigates any potential for malware as Apple vets its Devs
- Secondary motivation: Security profiles embedded in signature
  - OS X and iOS declarative security – entitlements – part of signature
- Unexpected bonus: Hegemony over software distribution
  - Only code signature allowed in iOS is Apple's.
  - OS X still allows any signature (or even unsigned code). For how long?



Battle Plan

- Document technical specification of signature
  - Quick refresher on the Mach-O binary format a prerequisite
- Explain Enforcement mechanisms (in iOS)
  - Come Face-to-Face with the adversary - AppleMobileFileIntegrity
- Examine bypass techniques up to and including iOS 8.1.2

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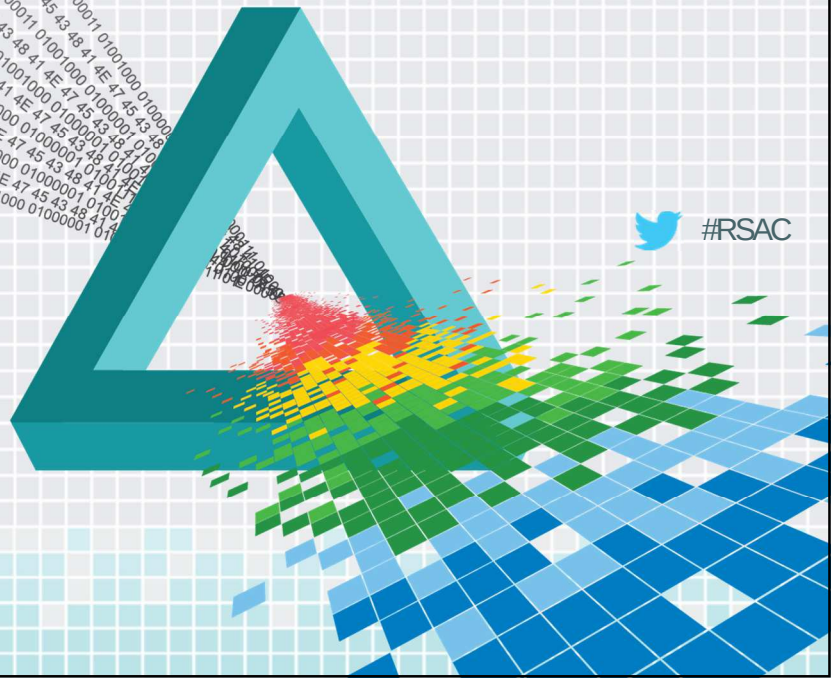
Refresher: Mach-O binaries



Mach-O and Code Signatures

- Apple uses Mach-O as its binary format
  - Old binfmt tracing back to its NeXTSTEP origins
  - Many modifications introduced throughout OS X 10.x and iOS
  - No longer compatible with GNU HURD Mach-O
  - Never was and/or will be in any way compatible with ELF

Mach-O Cheat Sheet

- For those familiar with ELF parlance:

Mach-O...	Is ELF's..
Segment	Section
Section	N/A
/usr/lib/dyld	/usr/bin/ld
dylib (dynamic library)	so (Shared object)

Mach-O and Code Signatures

- Mach-O header consists of `ncmds` "Load commands":

Load command	Defines
`LC_SEGMENT[_64]`	Memory regions with same r/w/x protection. Further contains sections. fileaddr [+ filesize] mapped to vmaddr [+vmsize]
`LC_DYLD_INFO[_ONLY]`	Map of LINKEDIT for dynamic linker (DYLD)
`LC_[DY]SYMTAB`	Symbol tables
`LC_LOAD_DYLINKER`	Which dynamic linker to use (`/usr/lib/dyld`)
`LC_MAIN` (pre 10.8:UNIXTHREAD)	Entry point of executable
`LC_LOAD_DYLIB`	Dynamic library dependencies

Mach-O and Code Signatures

- Simple example: (/bin/ls from an ARMv8 iOS8)

```
Phontifex:/root #jtool -l -v /bin/ls
LC 00: LC_SEGMENT_64          Mem: 0x000000000-0x100000000      File: Not Mapped        ---/--- __PAGEZERO
LC 01: LC_SEGMENT_64          Mem: 0x100000000-0x100008000      File: 0x0-0x8000        r-x/r-x __TEXT
  Mem: 0x100003cc8-0x100007288    File: 0x00003cc8-0x00007288     __TEXT.__text   (Normal)
  Mem: 0x100007288-0x10000760c    File: 0x00007288-0x0000760c     __TEXT.__stubs  (Symbol Stubs)
  Mem: 0x10000760c-0x1000079a8    File: 0x0000760c-0x000079a8     __TEXT.__stub_helper    (Normal)
  Mem: 0x1000079a8-0x100007b68    File: 0x000079a8-0x00007b68     __TEXT.__const
  Mem: 0x100007b68-0x100007fb7    File: 0x00007b68-0x00007fb7     __TEXT.__cstring (C-String Literals)
  Mem: 0x100007fb8-0x100008000    File: 0x00007fb8-0x00008000     __TEXT.__unwind_info
LC 02: LC_SEGMENT_64          Mem: 0x100008000-0x10000c000      File: 0x8000-0xc000     rw-/rw- __DATA
  Mem: 0x100008000-0x100008038    File: 0x00008000-0x00008038     __DATA.__got    (Non-Lazy Symbol Ptrs)
  Mem: 0x100008038-0x100008290    File: 0x00008038-0x00008290     __DATA.__la_symbol_ptr  (Lazy Symbol Ptrs)
  Mem: 0x100008290-0x1000084b8    File: 0x00008290-0x000084b8     __DATA.__const
  Mem: 0x1000084c0-0x1000084f0    File: 0x000084c0-0x000084f0     __DATA.__data
  Mem: 0x1000084f0-0x1000085a8    Not mapped to file              __DATA.__bss    (Zero Fill)
  Mem: 0x1000085a8-0x100008634    Not mapped to file              __DATA.__common (Zero Fill)
LC 03: LC_SEGMENT_64          Mem: 0x10000c000-0x10000e000      File: 0xc000-0xd2f0     r--/r-- __LINKEDIT
   ...
LC 17: LC_DYLIB_CODE_SIGN_DRS   Offset: 50656, Size: 40 (0xc5e0-0xc608)
   Library Dependency blob (36 bytes) Internal: 3000000
LC 18: LC_CODE_SIGNATURE        Offset: 53552, Size: 448 (0xd130-0xd2f0)
```

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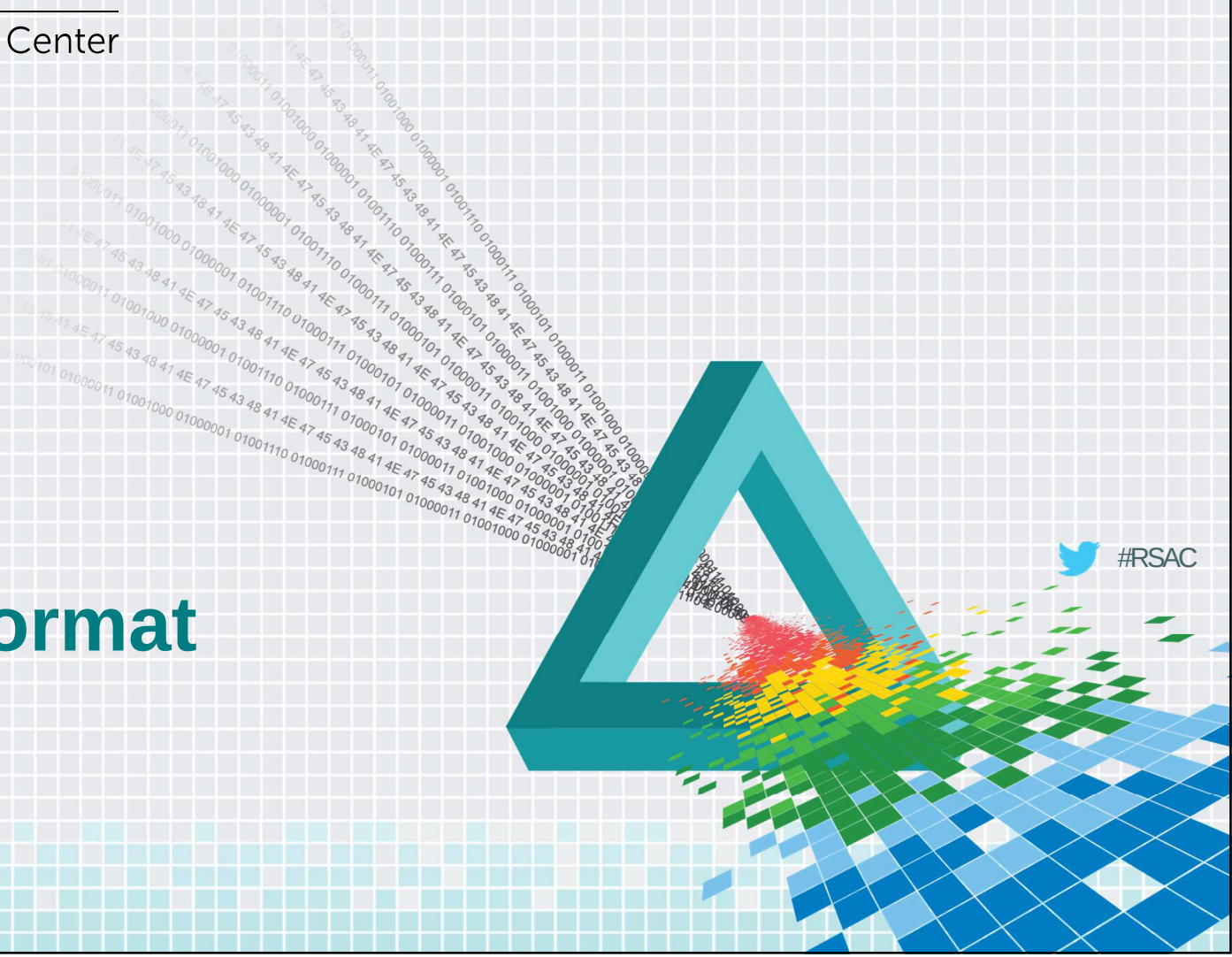

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Code Signature Format

LC_CODE_SIGNATURE

- `LC_CODE_SIGNATURE` format is largely undocumented
  - That is, unless you go to the source: Security/libsecurity_codesigning
  - Enforcement (on OS X and XNU core) partially open source
- Apple provides two tools:
  - `codesign(1)`: Generates, validates, and partially dumps signatures
  - `codesign_allocate(1)`: Reserves space for load command in header
- Free, advanced tool: Jtool (http://NewOSXBook.com/files/jtool.tar)
  - `otool(1)` clone with many more options, esp. relevant to code signing

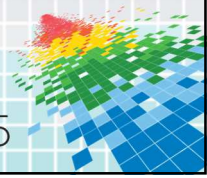
LC_CODE_SIGNATURE

- `LC_CODE_SIGNATURE` command points to a code signature “blob”
- Key component of blob is the “Code Directory”
  - Version: 20100
  - Flags: none, or “adhoc”
  - Identifier: reverse DNS notation unique ID
  - CDHash: SHA-1 or other “mega-hash” of code slots
- Code signature can also be “detached”, i.e. separate from binary

Code Slots

- File pages are individually hashed into “slots”, at indices 0+
- Ancillary data also hashed into “special slots”, at negative indices:

Index	Contains
-1	Bound Info.plist (Manifest)
-2	Internal requirements
-3	Resource Directory (_CodeResources)
-4	Application Specific (largely unused)
-5	Entitlements (bound in code signature)



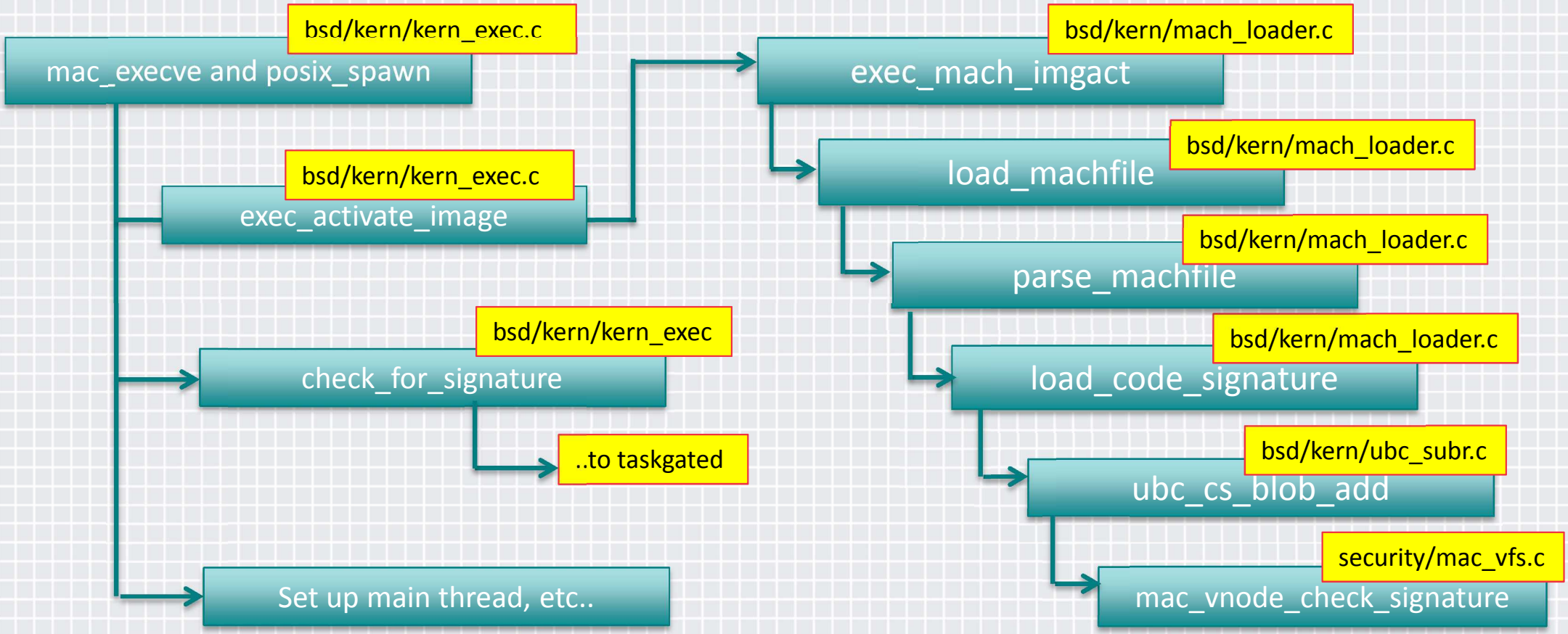
Code Signature Format (OS X)

```
morpheus@Boreas (~)$ jtool --sig -v /bin/ls
Blob at offset: 29232 (5488 bytes) is an embedded signature of 4549 bytes, and 3 blobs
      Blob 0: Type: 0 @36: Code Directory (261 bytes)
            Version:     20100
            Flags:       none (0x0)
            Identifier:  com.apple.ls
            CDHash:      e8e766ea872cf682d5a5da3176f57ed140dfa75f
            # of Hashes: 8 code + 2 special
            Hashes @101 size: 20 Type: SHA-1
                  Requirements blob:      34a9b54a874a8a0992f450a4d9a13f6bf3ee9edf (OK)
                  Bound Info.plist: Not Bound
                  Slot   0 (File page @0x0000): 75e0c5f20a84694cde3247b56ee1103a931d286a (OK)
                  Slot   1 (File page @0x1000): ad20db05d1744ea7746baabb4da1d516ff91ae30 (OK)
                  Slot   2 (File page @0x2000): f74b63f857ba9a44172352a146f8c213ea55afc9 (OK)
                  Slot   3 (File page @0x3000): 532f0362c18af792becd2447aad5fef07a05109f (OK)
                  Slot   4 (File page @0x4000): 234b0c4fc286483a73eed2aff135ea1696ad5371 (OK)
                  Slot   5 (File page @0x5000): 1de73e5f3b2587afd89ce3d14c90f6e40f0eb173 (OK)
                  Slot   6 (File page @0x6000): b0c138b5d7dffc104edb223cb4494759fb447898 (OK)
                  Slot   7 (File page @0x7000): 6300feb2aa97d8956596264a64f047cad3c2f638 (OK)
      Blob 1: Type: 2 @297: Requirement Set (180 bytes) with 2 requirements:
            0: Designated Requirement (@28): Ident("com.apple.ls") AND Apple Anchor
            1: Library Requirement (@68): Ident("com.apple.libutil1") AND Apple Anchor OR
                                          Ident("libncurses.5") AND Apple Anchor OR
                                          Ident("libSystem.B") AND Apple Anchor
      Blob 2: Type: 10000 @477: Blob Wrapper (4072 bytes) (0x10000 is CMS (RFC3852) signature)
```

Code Signature Format (iOS)

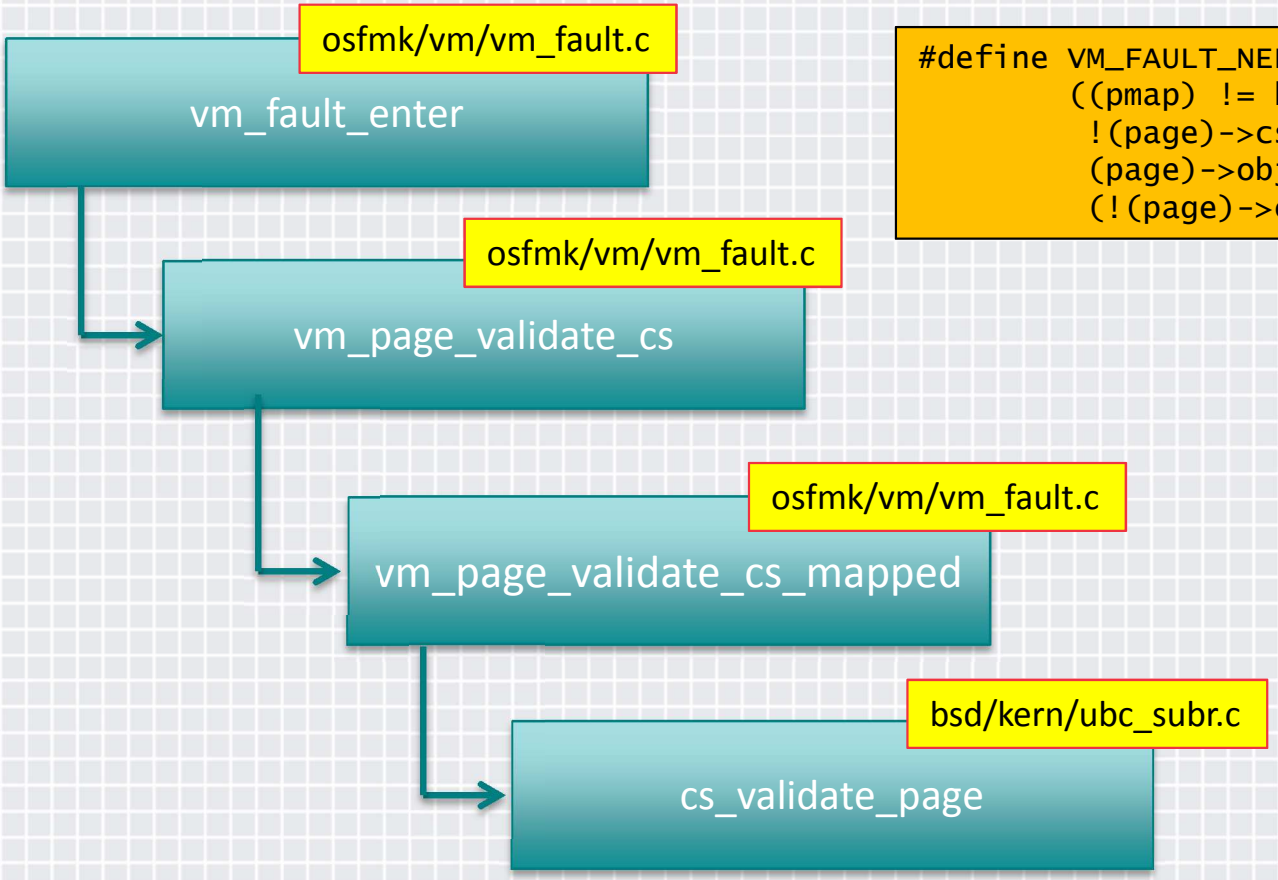
```
Phontifex:/ root# jtool -v --sig /bin/ls
Blob at offset: 53552 (448 bytes) is an embedded signature of 437 bytes, and 3 blobs
        Blob 0: Type: 0 @36: Code Directory (381 bytes)
                Version:     20100
                Flags:       adhoc (0x2)
                Identifier:  com.apple.ls
                CDHash:      bb98100b1aea8bc76f0384094542b6a1c802e742
                # of Hashes: 14 code + 2 special
                Hashes @101 size: 20 Type: SHA-1
                        Requirements blob:      3a75f6db058529148e14dd7ea1b4729cc09ec973 (OK)
                        Bound Info.plist:       Not Bound
                        Slot   0 (File page @0x0000):   4ea36bd97bfe568c38bee510bcaf3b5b4baafa99 (OK)
                        Slot   1 (File page @0x1000):   1ceaf73df40e531df3bfb26b4fb7cd95fb7bff1d (OK)
                        Slot   2 (File page @0x2000):   1ceaf73df40e531df3bfb26b4fb7cd95fb7bff1d (OK)
                        Slot   3 (File page @0x3000):   f0b6158041cb2df9f9269d1490af9dbe7850d5f1 (OK)
                        Slot   4 (File page @0x4000):   89dd50a17ad26ecd5290b0588027d87a8159855a (OK)
                        Slot   5 (File page @0x5000):   8f402084bddce6a837e9e0297a3590d8e2554dcc (OK)
                        Slot   6 (File page @0x6000):   9203c7ca528a8f133586e95e94c257786fa808dc (OK)
...
                        Slot  11 (File page @0xb000):   1ceaf73df40e531df3bfb26b4fb7cd95fb7bff1d (OK)
                        Slot  12 (File page @0xc000):   fbeff9126c1c8de8079bbc9c30f68d54c295c8fa (OK)
                        Slot  13 (File page @0xd000):   d8a6e4163274866d4fe943b8887213b18650ecac (OK)
        Blob 1: Type: 2 @417: Empty requirement set
        Blob 2: Type: 10000 @429: Blob Wrapper (8 bytes) (0x10000 is CMS (RFC3852) signature)
        Superblob ends @36
```

Code Signature validation in XNU: on load



Code directory hash is validated in its entirety – no individual hashes checked yet

Code Signature validation in XNU: page faults




```
#define VM_FAULT_NEED_CS_VALIDATION(pmap, page)                 \
        ((pmap) != kernel_pmap /*1*/ &&                         \
         !(page)->cs_tainted /*2*/ &&                           \
         (page)->object->code_signed /*3*/ &&                   \
         (!(page)->cs_validated || (page)->wpmapped /*4*/))
```

Individual hashed checked on corresponding page's page fault – if VM_FAULT_NEED_CS_VALIDATION

Code Signature Blob Handling

- Entire signature blob copied to kernel space
  - Once verified, inaccessible by own process (loaded into UBC)

- Applications can use undocmented `csops`(#169) syscall
  - Used extensively by dyld
  - Wrapped by `Security.Framework` `KSecTask*` APIs
    - (primarily used for entitlements blob portion of code signature)
    - Even on jailbroken iOS binaries must be (pseudo)-signed

CSOPS (#169)

Flag (CS_OPS_*)	Effect
_STATUS _SETSTATUS	Return or set status of code signing for process
_MARKINVALID	Invalidate sig, possibly killing process on spot
_MARKKILL	Kill process
_CDHASH	Return Code Directory Hash
_ENTITLEMENTS_BLOB	Retrieve Entitlements
_MARKRESTRICT	(dyld) restrict library loading (like __RESTRICT segment)
_BLOB	Retrieve entire blob
SIGPUP_INSTALL/DROP	10.9+: Used for CSR codesigning

LC_DYLIB_CODE_SIGN_DRS

- `LC_DYLIB_CODE_SIGN_DRS` added in iOS 5.1 and OS X 10.8
  - Resulting from a hack by Charlie Miller
    - Demonstrated arbitrary loading of unsigned dylibs by patching dyld
  - Specifies Internal Requirements which must be satisfied on loading:
    - Basically, logical OR of (foreach library_identifier and anchor apple)
    - Requirement language supports certificates, entitlements, and much more

iOS: Text is always read-only

- In iOS (unlike OS X) `mmap(2)/mprotect(2)` are intentionally "broken"
  - Setting +w is disallowed on a +x segment (and vice versa)
- Apple provides an exception to this rule for JIT generated code
  - `VM_FLAGS_MAP_JIT` allows `+wx` simultaneously
  - Code "leaked"* in XNU-1699 (iOS5/OS X 10.7)
- Exception requires special `dynamic-codesigning` entitlement
  - Only exception is MobileSafari (iOS5+) with "nitro" javascript engine

* Code was `#ifdef`'ed as `CONFIG_EMBEDDED`. Apple has consistently (*knowingly*) leaked iOS code up to 1699. Why? Good question.

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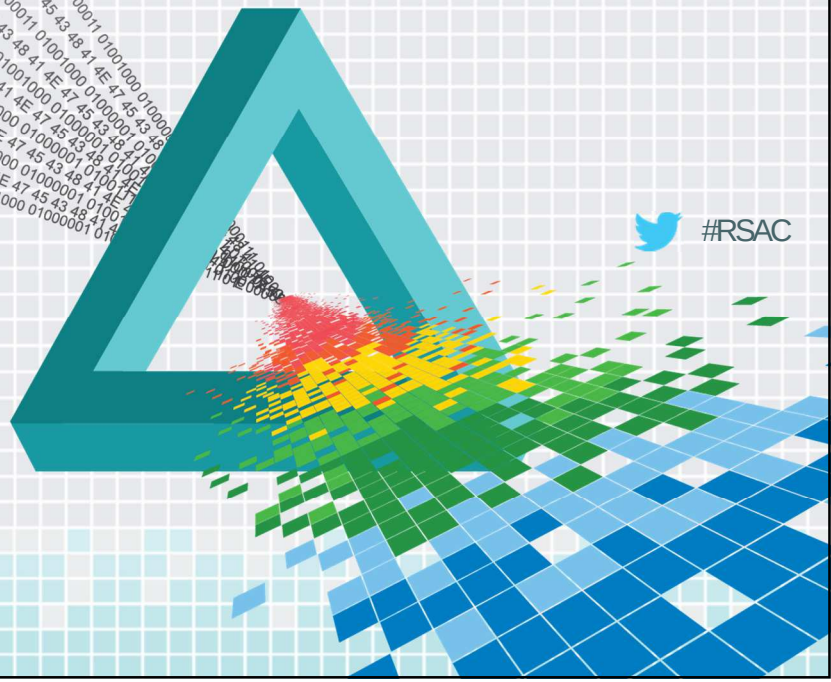
Enforcement



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Substrate: The MAC* framework

- Apple borrows/inherits the MAC Framework of Trusted BSD
- XNU is laced with `#if CONFIG_MACF` callouts (true in both iOS/OS X)
- Policy modules can call `mac_policy_register` to receive callouts
  - `nm/jtool -S|grep mac_policy_register` on `/System/Library/Extensions`
  - Can also check `kextstat(8)`, for dependency on `com.apple.kpi.dsep`

```
morpheus@Zephyr (~)$ kextstat | grep "2 1>"
   19  2 0xffffff7f80f9e000 0xd000   0xd000   com.apple.driver.AppleMobileFileIntegrity (1.0.5) <7 6 5 4 3 2 1>
   21  0 0xffffff7f80f9b000 0x2000   0x2000   com.apple.security.TMSafetyNet (8) <7 6 5 4 2 1>
   23  1 0xffffff7f80fb0000 0x17000  0x17000  com.apple.security.sandbox (300.0) <22 19 7 6 5 4 3 2 1>
   24  0 0xffffff7f80fc7000 0x9000   0x9000   com.apple.security.quarantine (3) <23 22 7 6 5 4 2 1>
   31  5 0xffffff7f810ac000 0x76000  0x76000  com.apple.iokit.IOHIDFamily (2.0.0) <14 7 6 5 4 3 2 1>
   60  0 0xffffff7f8279a000 0x5000   0x5000   com.apple.AppleFSCompression.AppleFSCompressionTypeZlib (1.0.0d1)
<6 4 3 2 1>
   61  0 0xffffff7f827a1000 0x3000   0x3000   com.apple.AppleFSCompression.AppleFSCompressionTypeDataless
(1.0.0d1) <7 6 4 3 2 1>
```

* Mandatory Access Control: Linux/Android has similar (though incompatible) functionality in SELinux

Enter: AppleMobileFileIntegrity

- The AppleMobileFileIntegrity* kernel extension enforces codesigning
  - Also protects Mach task ports
  - Provides in-kernel entitlement support
- Works in cahoots with sandbox.kext
- Extremely paranoid (literally – panics kernel on unload or on failures)
- Very chatty (easy to decompile – plenty of verbose strings)

* Known to its friends – and enemies alike – as “AMFI” (uppercase). Lowercase (amfid) is used for daemon, discussed later

AMFI as a MAC Policy

- MPOs have some 330 (or so) callouts. AMFI cares about a dozen:

Callout	Called by MACF when:
mpo_cred_check_label_update_execve	MAC Label* needs to be updated as a result of process launching (exec)
mpo_cred_label_init/associate/destroy	MAC Label* lifecycle
mpo_proc_check_interit_ipc_ports	resets task/thread ports for setuid/setgid programs
mpo_proc_check_mprotect	mprotect(2) invoked (iOS prevents r-x from ever getting +w)
mpo_proc_check_map_anon	mmap(2) invoked with MAP_ANON
mpo_proc_check_get_task	task_for_pid trap (the holy grail of debugging/tracing/pwning) invoked
mpo_vnode_check_exec	exec(2) is invoked
mpo_proc_check_cpumon	CPU Usage Monitoring parameters
mpo_proc_check_run_cs_invalid	**Code Signature is invalid – AMFI gets a chance to save process**
mpo_vnode_check_signature	**Signature blob is added to Unified Buffer Cache**

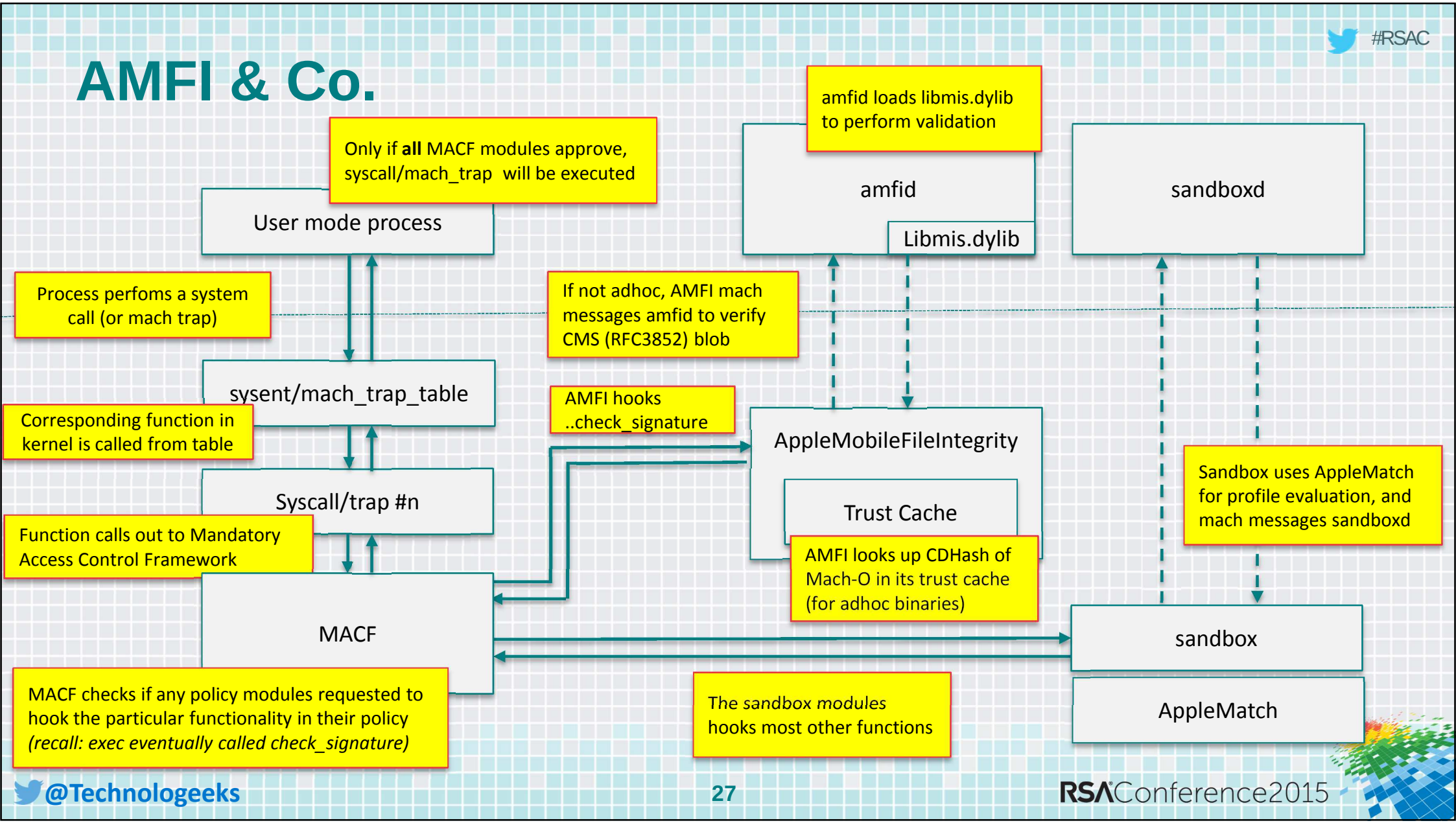
* MAC Labels are used in the implementation of sandboxing – but that's for another presentation (and the book)

In Cache We Trust

- AMFI has a built-in “trust cache” with CDHashes of all iOS binaries
  - Used in “adhoc” (certificate-less) model – compares hashes only
  - Additional cache can be loaded from user mode, under some conditions
    - Loading process requires `com.apple.private.amfi.can-load-trust-cache`
    - Loaded cache must be a signed IMG3/IMG4 (encrypted/certified by Apple*)
- For all other binaries (read: App-store Apps) it uses amfid

* Loading the trust cache (via the UserClient) actually performs PKI in kernel mode, parsing DER and using corecrypto for PKCS#1

AMFI & Co.


Only if **all** MACF modules approve, syscall/mach_trap will be executed
amfid loads libmis.dylib to perform validation
User mode process
amfid
Libmis.dylib
sandboxd
Process perfoms a system call (or mach trap)
If not adhoc, AMFI mach messages amfid to verify CMS (RFC3852) blob
sysent/mach_trap_table
AMFI hooks ..check_signature
AppleMobileFileIntegrity
Corresponding function in kernel is called from table
Trust Cache
Sandbox uses AppleMatch for profile evaluation, and mach messages sandboxd
Syscall/trap #n
Function calls out to Mandatory Access Control Framework
AMFI looks up CDHash of Mach-O in its trust cache (for adhoc binaries)
MACF
sandbox
MACF checks if any policy modules requested to hook the particular functionality in their policy *(recall: exec eventually called check_signature)*
The sandbox modules hooks most other functions
AppleMatch

amfid

- User mode lackey of `AppleMobileFileIntegrity.kext`
- Communicates over host special port #18 (`HOST_AMFID_PORT`)
  - Mach port maintained by launchd, making it hard* to MiM
- Itself only a half-empty shell over libmis.dylib, which provides logic
  - Dylib handles “provisioning profiles”, allowing developer/enterprise apps
  - Boils down to `MISValidateSignature` and friends

* Hard – but not impossible

Reining in AMFI

- Can be disabled with several boot-args to XNU, including:

Boot-Arg	Means
`amfi_allow_any_signature`	Allow self-signed
`cs_enforcement_disable`	Invalid binaries may be loaded, won't be killed
`amfi_get_out_of_my_way`	Disables AMFI altogether
`cs_debug`	Diagnostic IOLog() messages from AMFI

- iBoot no longer passes boot-args (as of iOS 5 on release devices)
  - boot-args can still be overwritten in memory (if you can exploit iBoot)

AMFI: Coming to an OS X near you

- AMFI.kext and `amfid` make their OS X debut in 10.10
- Presently securing kernel extensions by offering APIs
  - `LC_CODE_SIGNATURE` for kexts was introduced in 10.9 – but that's `kextd`*
  - Main use: enforce entitlements at kernel levels
    - e.g **AppleMobileFileIntegrity::AMFIEntitlementGetBool(proc*, char const*, bool*)**
      AppleMobileFileIntegrity::copyEntitlements(proc*)
- May very likely enforce everything in 10.11, or 11.0, etc.
  - Likely coming soon: entitlement support in OS X

* That kernel extension signatures are validated in user mode makes for ***many*** ways to bypass

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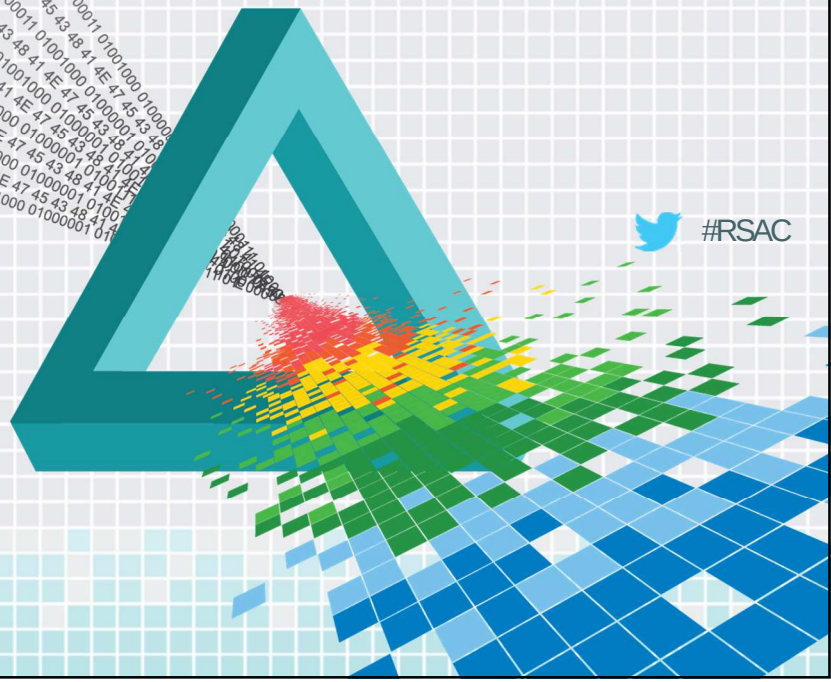
Defeating Code Signing



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A Brief History of Time (à la code signing)

- Apple's code signature mechanism has evolved considerably
  - Some modifications introduced to support new security features
  - Most modifications coerced by successful hacks (reactive, not proactive)

- Presently (iOS 8.1.3, 8.2b3+, 8.3b+) – no publicly known faults
  - But you never know about 0-days, now, do you?

Tried and True: Return Oriented Programming

- Originally devised by SolarDesigner (return to libc)
- Perfected as “Return Oriented Programming” to include:
  - Set up of dummy stack frames (on 32-bit) or just return addresses
  - Jump back into “gadgets” achieving assembly code snippets
  - Gadgets **are validly signed code** – just used out of order!
- `dyld_shared_cache` (prelinked libraries) supplies plenty of gadgets
  - Even more so on Intel architectures (instructions are variable length)
  - Apple tries to secure framework code (SDK stubs), but just can’t do so.

Tried and True: Return Oriented Programming

- Wang, et. Al presented “Jekyll Apps” in USENIX ’13
  - Idea: App contains alternate code path to trigger deliberate ROP
  - Submitted to Apple, app passes code review, gets signature
  - Deployed on devices, phones home, then subverts (“hacks” itself)

- Solution: Tighter entitlements, white list model only
  - iOS 8 brings an explosive growth in entitlements, and move to XPC

Low hanging fruit: sysctl proc/vnode enforce

- Originally, the sysctl MIBs controlling code signings were read/write

```
morpheus@Zephyr(~)$ sysctl  -a | grep enforce
..
security.mac.proc_enforce: 1
security.mac.vnode_enforce: 1
```

- Root arbitrary code execution via ROP, then `sysctl -w` disables

- Solution: Apple made the MIB variables read only as of iOS 5
  - Can still be overwritten if a kernel memory overwrite is found

Forbidden fruit: stolen enterprise/dev certificates

- Apple willingly signs certains certificates, adding to chain of trust
  - Developer certificates (to deploy on device)
  - Enterprise certificates (to allow for org-internal apps)
    - Some jailbreaks set the i-Device date, which bypasses certificate expiration
- Apple can’t vet all the code that gets arbitrarily signed
  - Solution: Use restrictive entitlements, embedded in certificate
  - Problem: Still allows arbitrary code execution, within entitlement bounds
    - Allows for “failbreaks” and conducive to eventual jailbreaks

Rotten fruit: DYLD_INSERT_LIBRARIES

- Dyld's equivalent of LD_PRELOAD
  - Just as powerful, just as nasty (especially if coupled with interposing)
- Several jailbreaks would force inject trojan libraries into processes
  - Apple got sick of that and introduced dyld restricting (ignoring variables)

sRestrictedReason	Means
restrictedBySetGUid	u+s or g+s
restrictedBySegment	`__RESTRICT/__restrict` section (e.g. amfid)
restrictedByEntitlements	code signed binaries with entitlements

- Plus, any injected library would have to be code signed.. Right?

Evasi0n (6/7): There is no TEXT

- Trojan `libmis.dylib` with an empty `__TEXT.__text`
  - No Text = No signature

```
morpheus@Zephyr(~)$ ARCH=armv7 jtool -l ~/iOS/JB/evasi0n7/libmis.dylib
LC 00: LC_SEGMENT                Mem: 0x00000000-0x00001000    __TEXT
      Mem: 0x00001000-0x00001000           __TEXT.__text     (Normal)
LC 01: LC_SEGMENT                Mem: 0x00001000-0x00002000    __LINKEDIT
LC 02: LC_ID_DYLIB               /usr/lib/libmis.dylib
..
```

- Redirect symbols:

```
morpheus@Zephyr(~)$ jtool -S -v ~/iOS/JB/evasi0n7/libmis.dylib
0xa2a4    I _MISValidateSignature (indirect for _CFEqual)
0xa2b0    I _kMISValidationInfoEntitlements (indirect for _kCFUserNotificationTokenKey)
0xa2bc    I _kMISValidationInfoSignerCertificate (indirect for _kCFUserNotificationTokenKey)
0xa2c8    I _kMISValidationInfoSigningID (indirect for _kCFUserNotificationTokenKey)
0xa2d4    I _kMISValidationInfoValidatedByProfile (indirect for _kCFUserNotificationTokenKey)
0xa2e0    I _kMISValidationOptionAllowAdHocSigning (indirect for _kCFUserNotificationTokenKey)
0xa2ec    I _kMISValidationOptionExpectedHash (indirect for _kCFUserNotificationTimeoutKey)
0xa2f8    I _kMISValidationOptionLogResourceErrors (indirect for _kCFUserNotificationTokenKey)
0xa304    I _kMISValidationOptionUniversalFileOffset (indirect for _kCFUserNotificationTokenKey)
0xa310    I _kMISValidationOptionValidateSignatureOnly (indirect for _kCFUserNotificationTokenKey)
0xa31c    U _CFEqual
```

Evasi0n (6): Overlapping Segments (Round I)

- Deliberately set two `LC_SEGMENT` commands to overlap
  - First command sets R-X (for executable code)
  - Second command sets R-- (not text)
  - Both commands have same vmaddr/vmsize

- `mmap(2)` called twice, and second mapping helps bypass check
  - Note segment overlap check is performed by dyld, not kernel
  - Kernel doesn't care – code signature is only for text (+x) pages

- rdar://13145644

CVE-2013-0977: Fixed in iOS 6.1.3

Pangu (7): Overlapping Segments (Round II)

- Apple checks vmaddr + vmsize... But fails on an integer overflow!

```
morpheus@Zephyr (.../Pangu7)$ jtool -l -v -arch arm libmis.dylib

LC 00: LC_SEGMENT              Mem: 0xfffff000-0x00000000    File: 0x0-0x1000         r-x/r-x     __FAKE_TEXT
LC 01: LC_SEGMENT              Mem: 0xfffff000-0x00000000    File: 0x2000-0x3000      r--/r--     __TEXT
LC 02: LC_SEGMENT              Mem: 0x00001000-0x00002000    File: 0x1000-0x10bb      r--/r--     __LINKEDIT
LC 03: LC_SYMTAB
      Symbol table is at offset 0x0 (0), 0 entries
      String table is at offset 0x0 (0), 0 bytes
...
         Export info: 576   bytes at offset 4096 (0x1000-0x1240)
LC 06: LC_ID_DYLIB              /usr/lib/libmis.dylib (compatibility ver: 1.0.0, current ver: 1.0.0)
LC 07: LC_LOAD_DYLIB            /System/Library/Frameworks/CoreFoundation.framework/CoreFoundation
(compatibility ver: 65535.255.255, current ver: 0.0.0)
```

- Deliberately malformed negative vmaddr bypasses check!

CVE unknown, but (sort of) fixed in 8

Pangu (8): Overlapping segments (Round III)

- Apple only checks first segment.. (< 8.1.2) So Pangu8 fakes second:

```
Pademonium:/ root# ARCH=armv8 jtool -v -l libmisPangu.dylib  | more
LC 00: LC_SEGMENT_64          Mem: 0x000000000-0xc0000  File: 0x0-0xc0000       r-x/r-x __TEXT
        Mem: 0x000000000-0x000000000    File: 0x00004000-0x00004000              __TEXT.__text
LC 01: LC_SEGMENT_64          Mem: 0xfffffffffffc000-0x0       File: 0xc0000-0x184000  rw-/rw- __TEXT1
LC 02: LC_SEGMENT_64          Mem: 0x0000c8000-0xcc000  File: 0xc8000-0xc8794   r--/r-- __LINKEDIT
LC 03: LC_ID_DYLIB              /usr/lib/libmis.dylib (compatibility ver: 1.0.0, current ver: 255.0.0)...
```

- Note the first segment is still technically empty (no code in section)

CVE-2014-4455: Fixed in iOS 8.1.2

Pangu (8): Overlapping segments (Round III)

- Binary is loaded, __TEXT1 segment overlaps, and “resets” protection

```
Pademonium:/ root# ARCH=armv8 jtool -v -l libmisPangu.dylib  | more
LC 00: LC_SEGMENT_64          Mem: 0x000000000-0xc0000  File: 0x0-0xc0000       r-x/r-x __TEXT
        Mem: 0x000000000-0x000000000    File: 0x00004000-0x00004000             __TEXT.__text
LC 01: LC_SEGMENT_64          Mem: 0xfffffffffffc000-0x0       File: 0xc0000-0x184000  rw-/rw- __TEXT1
LC 02: LC_SEGMENT_64          Mem: 0x0000c8000-0xcc000  File: 0xc8000-0xc8794   r--/r-- __LINKEDIT
LC 03: LC_ID_DYLIB              /usr/lib/libmis.dylib (compatibility ver: 1.0.0, current ver: 255.0.0)...
```

```
Pademonium:/ root# DYLD_INSERT_LIBRARIES=/usr/lib/libmisPangu.dylib DYLD_PRINT_SEGMENTS=1 ls > /dev/null
dyld: Main executable mapped /bin/ls
        __PAGEZERO at 0x00000000->0x100000000
            __TEXT at 0x100068000->0x100070000
            __DATA at 0x100070000->0x100074000
        __LINKEDIT at 0x100074000->0x100076000
...
dyld: Mapping /usr/lib/libmisPangu.dylib (slice offset=557056)
            __TEXT at 0x10008C000->0x10014BFFF with permissions r.x
           __TEXT1 at 0x100088000->0x10014BFFF with permissions rw.
        __LINKEDIT at 0x100154000->0x100154793 with permissions r..
```

CVE-2014-4455: Fixed in iOS 8.1.2

TaiG: Overlapping segments (Round IV)

- Apple adds checks for vmsize and filesize all over, but not vmaddr...

```
morpheus@Zephyr(~)$ ARCH=armv7 jtool -l -v ~/iOS/JB/TaiG/libmis.dylib
LC 00: LC_SEGMENT                Mem: 0x00000000-0x00001000 File: 0x0-0x1000      __TEXT
       Mem: 0x00001000-0x00001000  File: 0x00001000-0x00001000   __TEXT.__text   (Normal)
LC 01: LC_SEGMENT                Mem: 0x00001000-0x00002000      __LINKEDIT
LC 02: LC_ID_DYLIB               /usr/lib/libmis.dylib
..
LC 16: LC_SEGMENT                Mem: 0xfffff000-0x1ffff000  File: 0xa000-0xc000     __DATA
```

```
morpheus@Zephyr(~)$ ARCH=armv8 jtool -v -l ~/iOS/JB/TaiG/libmis.dylib
LC 00: LC_SEGMENT_64          Mem: 0x000000000-0x4000  File: 0x0-0x1000  __TEXT
       Mem: 0x000004000-0x000004000    File: 0x00001000-0x00001000   TEXT.__text   (Normal)
LC 01: LC_SEGMENT_64  Mem: 0x000004000-0x8000 File: 0xa000-0xa618  __ __LINKEDIT
LC 02: LC_ID_DYLIB    /usr/lib/libmis.dylib
...
LC 16: LC_SEGMENT_64  Mem: 0xfffffffffffffc000-0x1fffc000 File: 0xc000-0x14000  r--/r-- __DATA
```

CVE-2014-4455: Really Fixed in iOS 8.1.3

TaiG: Overlapping segments (Round IV)

- Once again, overlap occurs.

```
morpheus@Zephyr(~)$ ARCH=armv8 jtool -v -l ~/iOS/JB/TaiG/libmis.dylib
LC 00: LC_SEGMENT_64          Mem: 0x000000000-0x4000   File: 0x0-0x1000   __TEXT
       Mem: 0x000004000-0x000004000    File: 0x00001000-0x00001000   TEXT.__text   (Normal)
LC 01: LC_SEGMENT_64  Mem: 0x000004000-0x8000 File: 0xa000-0xa618  __ __LINKEDIT
LC 02: LC_ID_DYLIB    /usr/lib/libmis.dylib
...
LC 16: LC_SEGMENT_64  Mem: 0xfffffffffffffc000-0x1fffc000 File: 0xc000-0x14000  r--/r-- __DATA

Phontifex:/ root# DYLD_PRINT_SEGMENTS=1 DYLD_INSERT_LIBRARIES=/tmp/libmis.taig.dylib ls > /dev/null
dyld: Main executable mapped /bin/ls
...
dyld: Mapping /tmp/libmis.taig.dylib (slice offset=65536)
            __TEXT at 0x40000000->0x40000FFF with permissions r.x
       __LINKEDIT at 0x40001000->0x40001617 with permissions r..
            __DATA at 0x3FFFF000->0x40000FFF with permissions r..
```

CVE-2014-4455: Really Fixed in iOS 8.1.3

Hypotheticals (?)

- SHA-1 2nd Preimage will entirely defeat signatures, but ..
  - We don't have that yet(?)
  - Signatures decoupled from Algorithms, and could migrate to 256 or NG
- Any kernel memory overwrite – even 32-bits - will defeat enforcement
  - XNU is getting more secure, but there's always IOKit and IOHID/IOUSB ☺

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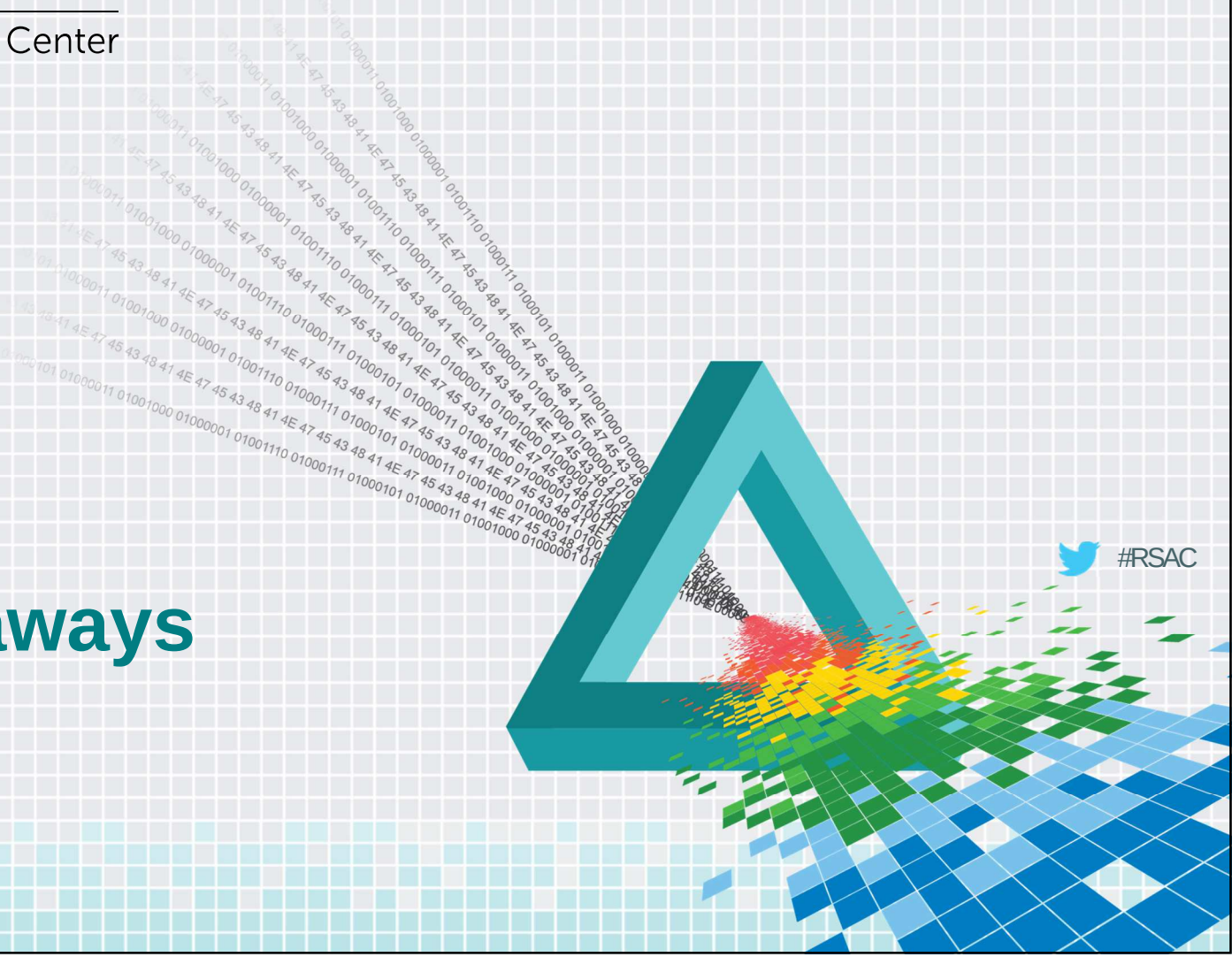

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Summary & Takeaways

Apple clearly thought out code signatures..

- Elegant, cryptographically secure mechanism
  - Uses hash-of-hashes technique
  - Implementation decoupled from hash specifics
  - SHA-1 (still) secure, hash easily upgradeable to SHA-256 or NG
- Used as subtrate for overall system security
  - Intricately tied to entitlements and sandboxing

But elegant design makes for multiple fractures

- User mode components are inherently weak
  - Can't fully validate daemon identity and integrity
  - Dynamically linked binary prone to library injection/replacement
  - Loader (dyld) *still* has bugs aplenty, amfid too critical a component
- Even pure kernel mode implementation can be broken
  - Kernel arbitrary memory overwrite can disable KEXT
- Implementation faults, implementation faults, implementation faults!

For more information

- Pangu's CANSEC-West Talk 2015 – Covers their jailbreaks in depth
  - Awesome talk straight from the horse's mouth
- Mac OS X and iOS Internals (1st) – With 2nd Edition (vol I) due summer '15
  - Still open for last minute requests: http://NewOSXBook.com/TOC2.html
- http://NewOSXBook.com – Book's Web site, lots of free tools/articles
  - Open forum at http://NewOSXBook.com/forum/index.php
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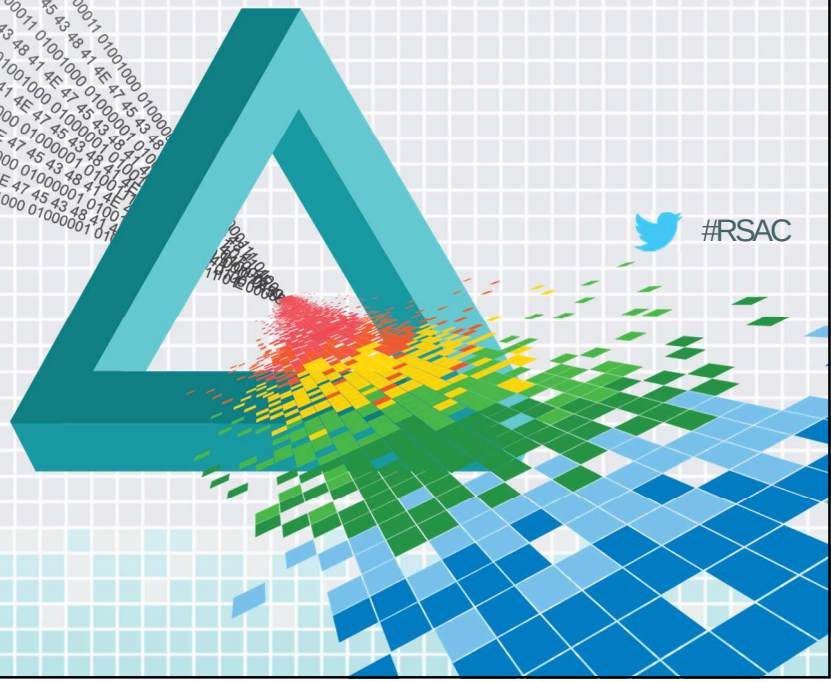
Questions? Comments?



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