



# iOS 6 Kernel Security: A Hacker's Guide

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# Introduction

- iOS 6 recently released
- Large focus on security improvements – particularly kernel hardening
- Primarily targets strategies employed in “jailbreaks”
- This talk provides an overview of the new kernel-based mitigations
- Explores new techniques for attacking iOS 6

# Topics Covered

- Part 1 – Defense
  - Heap Hardening Strategies
  - Stack Cookies
  - Information Leaking Mitigations
  - Address Space Layout Randomization (ASLR)
  - User/Kernel address space hardening
- Part 2 – Offense
  - Information Leaking
  - Heap Strategies

# Randomization Algorithm

- First, a word on randomness...
- Used to derive random numbers for stack cookie, heap cookies, kernel map ASLR, and pointer obfuscation
- Random seed generated (or retrieved) during boot loading (iBoot)
- Combined with current time to get random value

# Randomization Algorithm

```
unsigned long long
GetRandomValue(unsigned long long time, unsigned long long seed)
{
    unsigned int time_low      = time & 0xFFFFFFFF;
    unsigned int time_high     = (time >> 32) & 0xFFFFFFFF;
    unsigned int result_low;
    unsigned int result_high;
    unsigned int tmp;

    // calculate low DWORD of output

    tmp = (time_low & 0xFF) << 8;
    result_low = (time_low ^ tmp) ^ (time_low << 16);

    // calculate high DWORD of output

    tmp = (seed & 0xFF) << 16;
    result_high = tmp ^ (result_low ^ time_high);

    tmp = (result_low >> 8) ^ 0xFF;
    result_high = ROTATE_RIGHT(result_high, tmp);

    // done

    return (result_high << 32) | result_low;
}
```

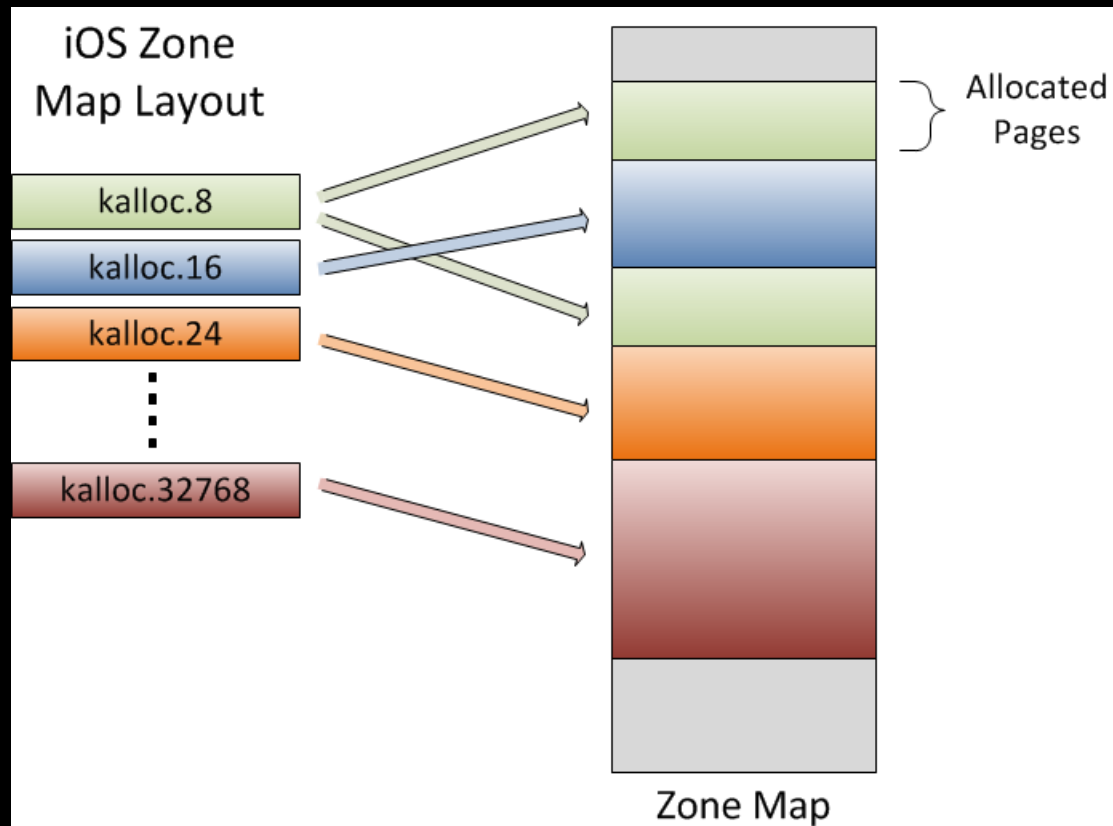
# Heap Hardening

- Heap has been hardened to prevent well-known attack strategies
- Three mitigations put in place
  - Pointer validation
  - Block poisoning
  - Freelist integrity verification
- Specific to the zone allocator (`zalloc( )`, used by `kalloc( )`, `MALLOC( )`, `MALLOC_ZONE( )`)

# Heap Hardening - Recap

- Quick recap of old exploitation techniques required
  - Covered in the past extensively by Stefan Esser, Nemo, probably others
- Zone allocations divided in to fixed-size zones (kalloc.8, kalloc.16, ... kalloc.32768)
  - Specialized zones also utilized for specific tasks (eg. Pmap\_zone, vm\_map\_copy\_zone, etc)
- Zone allocates more pages on demand

# Heap Hardening - Recap

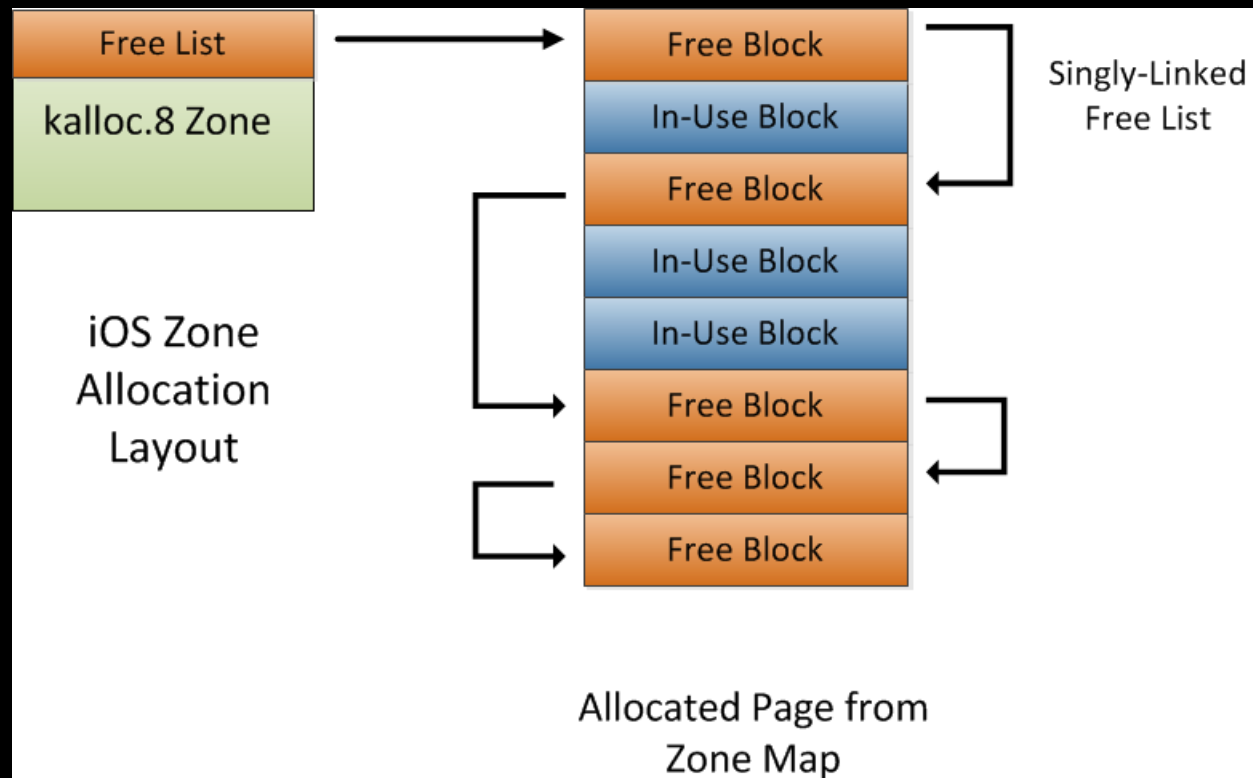




# Heap Hardening - Recap

- Zone allocates blocks of pages on demand
  - Divides memory in to element-size blocks
  - All blocks initially added to zone's free list
- Zone free list maintained as singly linked list
  - First DWORD of free block overwritten with “next” pointer when it is freed
- Allocations simply remove elements from the free list

# Heap Hardening - Recap



# Heap Hardening - Recap

- Previous exploitation techniques rely on overwriting free list pointers in free blocks
  - Future allocation can return arbitrary memory block
- Typical strategy: Add a pointer to sysent
  - Add new system call
  - Invoke new system call
  - Profit

# Heap Hardening – Pointer Validation

- Goal: Prevent invalid pointers being entered in to `kalloc( )` zone's freelist
- Additional checks performed on pointers passed to `zfree( )`
  - Also performed as part of validation on pointers in freelist during allocation (`zalloc( )`)

# Heap Hardening – Pointer Validation

- Pointer verified to be in kernel memory ( $0x80000000 < \text{ptr} < 0xFFFFEFFF$ )
- If `allows_foreign` is set in zone, no more validation performed
  - Currently `event_zone`,  
`vm_map_entry_reserved_zone`, `vm_page_zone`
- If pointer is within kernel image, allow (??)
- Otherwise, ensure pointer is within `zone_map`

# Heap Hardening – Block Poisoning

- Goal: Prevent UAF-style attacks
- Strategy involves filling blocks with sentinel value (0xdeadbeef) when being freed
  - Performed by `add_to_zone( )` called from `zfree( )`
- Only performed on selected blocks
  - Block sizes smaller than cache line size of processor (e.g. 32 bytes on A5/A5X devices)
  - Can override with “-zp”, “-no-zp”, “zp-factor” boot parameters

# Heap Hardening – Freelists

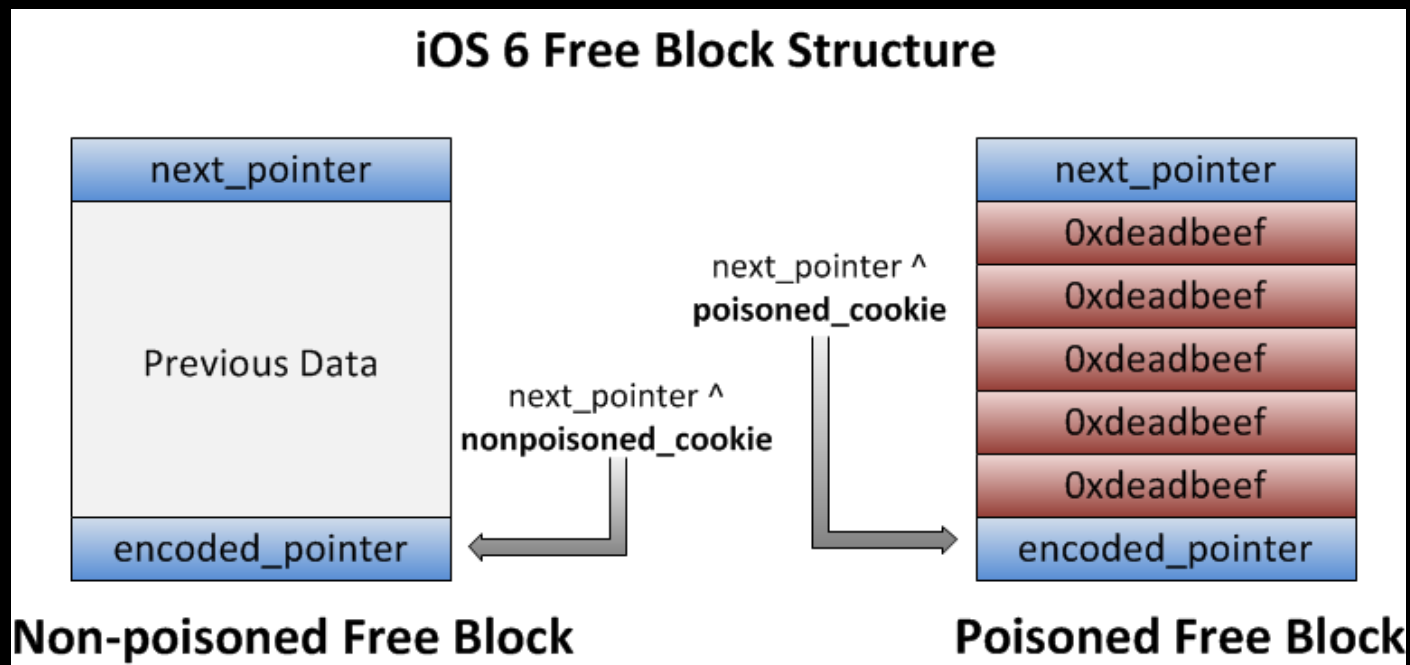
- Goal: Prevent heap overwrites from being exploitable
- Two random values generated at boot time (`zone_bootstrap( )`)
  - 32-bit cookie for “poisoned blocks”
  - 31-bit cookie for “non-poisoned blocks”
    - Low bit is clear
- Values serve as validation cookies

# Heap Hardening – Freelists

- Freelist pointers at the top of a free block are now validated by `zalloc( )`
  - Work performed by `alloc_from_zone( )`
- Encoded next pointer placed at end of block
  - XOR'd with `poisoned_cookie` or `nonpoisoned_cookie`



# Heap Hardening – Freelists



# Heap Hardening – Freelists

- `zalloc( )` ensures `next_pointer` matches encoded pointer at end of block
  - Tries both cookies
  - If poisoned cookie matches, check whole block for modification of sentinel (0xdeadbeef) values
  - Cause kernel panic if either check fails
- Next pointer and cookie replaced by 0xdeadbeef when allocated
  - Possible information leak protection

# Heap Hardening – Primitives

- `OSUnserializeXML( )` could previously be used to perform kernel heap feng shui
  - Technique presented by Stefan Esser in «iOS Kernel Heap Armageddon» at SyScan 2012
- Allowed precise allocation and freeing of kalloc zone data
- Also possible to force persistent allocations by wrapping the reference count

# Heap Hardening - Primitives

```
<plist version="1.0">
<dict>
  <key>AAAA</key>
  <array ID="1" CMT="IsNeverFreedTooManyReferences">...</array>
  <key>REFS</key>
<array>
  <x IDREF="1"/><x IDREF="1"/><x IDREF="1"/><x IDREF="1"/>
  <x IDREF="1"/><x IDREF="1"/><x IDREF="1"/><x IDREF="1"/>
  <x IDREF="1"/><x IDREF="1"/><x IDREF="1"/><x IDREF="1"/>
  ...
  <x IDREF="1"/><x IDREF="1"/><x IDREF="1"/><x IDREF="1"/>
</array>
</dict>
</plist>
```

# Heap Hardening - Primitives

- Duplicate dictionary keys no longer result in freeing of the original key/value
- Dictionary entries can no longer be pinned to memory using multiple references
- In both cases, the plist dictionary is considered invalid

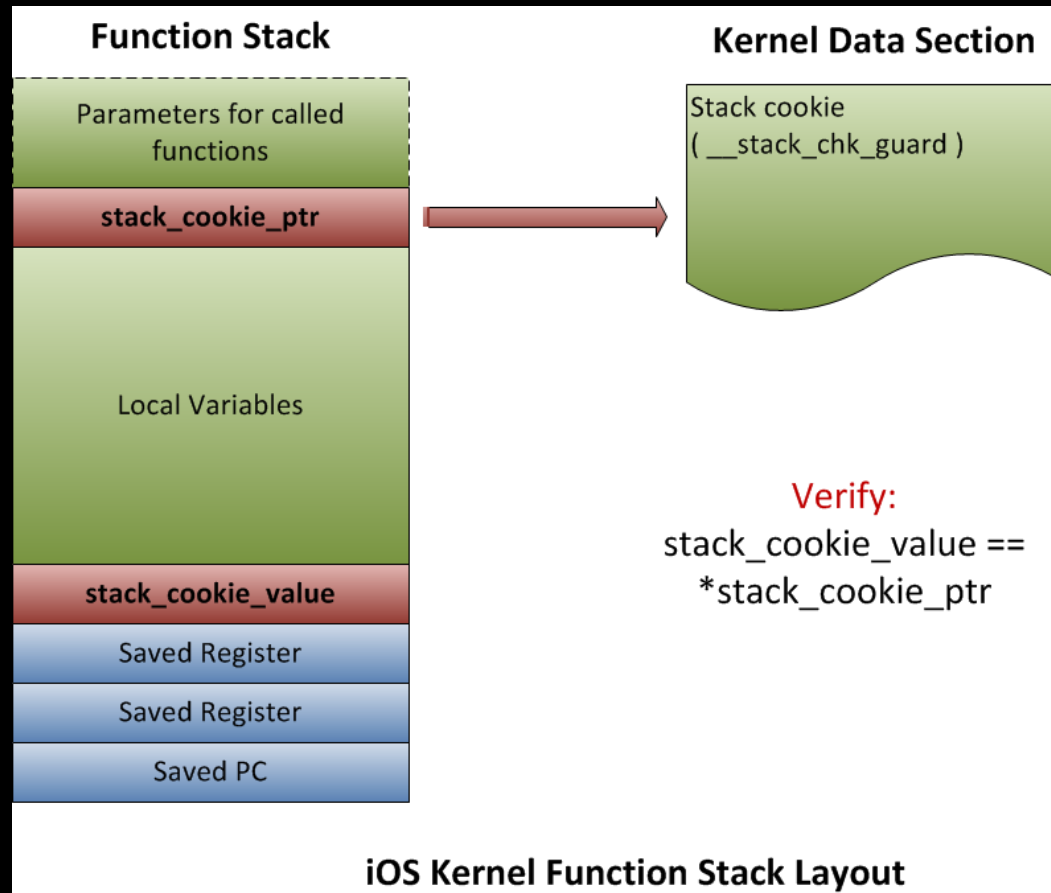
# Stack Cookies

- Goal: Prevent stack overflow exploitation
- Only applied to functions with structures/buffers
- Random value generated during early kernel initialization (`arm_init( )`)
- 24-bit random value
  - 32-bit value really, but 2<sup>nd</sup> byte zeroed out
  - Presumably string copy prevention

# Stack Cookies

- Generated stack cookie placed directly after saved registers at bottom of stack frame
- Pointer to cookie saved at top of stack frame
  - Or in a register if convenient
  - Space above stack cookie pointer used for called functions if necessary

# Stack Cookies





# Stack Cookies

- Function epilog verifies saved stack cookie
  - Generated value found by following saved pointer
- Verification failure results in kernel panic

```
--TEXT: __text:800051FC __epilog ; CODE XREF: sub_80004F98+2B4↓j
--TEXT: __text:800051FC ; sub_80004F98+486↓j
--TEXT: __text:800051FC LDR R0, [SP,#0x2CC+stack_cookie_ptr]
--TEXT: __text:800051FE LDR R0, [R0]
--TEXT: __text:80005200 LDR R1, [SP,#0x2CC+stack_cookie]
--TEXT: __text:80005202 CMP R0, R1 ; check stack cookie validity
--TEXT: __text:80005204 ITTTT EQ
--TEXT: __text:80005206 MOVEQ R0, R4
--TEXT: __text:80005208 ADDEQ.W SP, SP, #0x2B4
--TEXT: __text:8000520C POPEQ.W {R8,R10,R11}
--TEXT: __text:80005210 POPEQ {R4-R7,PC}
--TEXT: __text:80005212 BL ___stack_chk_fail
```

# Information Leaking Mitigations

- Goals:
  - Prevent disclosure of kernel base
  - Prevent disclosure of kernel heap addresses
- Strategies:
  - Disables some APIs
  - Obfuscate kernel pointers for some APIs
  - Zero out pointers for others

# Information Leaking Mitigations

- Previous attacks relied on zone allocator status disclosure
  - `host_zone_info( )` / `mach_zone_info( )`
  - Stefan Esser described using this for heap “feng shui” ([https://media.blackhat.com/bh-us-11/Esser/BH\\_US\\_11\\_Esser\\_Exploiting\\_The\\_iOS\\_Kernel\\_Slides.pdf](https://media.blackhat.com/bh-us-11/Esser/BH_US_11_Esser_Exploiting_The_iOS_Kernel_Slides.pdf))
- APIs now require `PE_i_can_has_debugger()` access

# Information Leaking Mitigations

- Several APIs disclose kernel object pointers
  - `mach_port_kobject( )`
  - `mach_port_space_info( )`
  - `vm_region_recurse( ) / vm_map_region_recurse( )`
  - `vm_map_page_info( )`
  - `proc_info( PROC_PIDREGIONINFO, PROC_PIDREGIONPATHINFO, PROC_PIDFDPIPEINFO, PROC_PIDFDSOCKETINFO, PROC_PIDFILEPORTSOCKETINFO )`
  - `fstat( )` (when querying pipes)
  - `sysctl( net.inet.*.pcblist )`

# Information Leaking Mitigations

- Need these APIs for lots of reasons
  - Often, underlying APIs rather than exposed ones listed previously
- Strategy: Obfuscate pointers
  - Generate 31 bit random value at boot time
    - lowest bit always 1
  - Add random value to real pointer

# Information Leaking Mitigations

```
int
fill_pipeinfo(struct pipe * cpipe, struct pipe_info * pinfo)
{
    ... code ...

    pinfo->pipe_handle = (uint64_t)((uintptr_t)cpipe);
    pinfo->pipe_peerhandle = (uint64_t)((uintptr_t)(cpipe->pipe_peer));
    pinfo->pipe_status = cpipe->pipe_state;

    PIPE_UNLOCK(cpipe);

    return (0);
}
```

# Information Leaking Mitigations

```
__TEXT:__text:801EC942      MOV      R1, (heap_random_value_ptr - 0x801EC94E) ; heap_random_value_ptr
__TEXT:__text:801EC94A      ADD      R1, PC ; heap_random_value_ptr
__TEXT:__text:801EC94C      LDR      R1, [R1]
__TEXT:__text:801EC94E      STR      R3, [R5,#0x20]
__TEXT:__text:801EC950      ASRS     R6, R3, #0x1F
__TEXT:__text:801EC952      STR      R6, [R5,#0x24]
__TEXT:__text:801EC954      STMIA.W  R4, {R0,R2,R3,R6}
__TEXT:__text:801EC958      ADD.W    R4, R5, #0x38
__TEXT:__text:801EC95C      STMIA.W  R4, {R0,R2,R3,R6}
__TEXT:__text:801EC960      MOVS     R0, #0
__TEXT:__text:801EC962      LDR      R2, [R1] ; R2 = heap_random_value
__TEXT:__text:801EC964      ADD.W    R6, R2, R8 ; R6 = (unsigned long) cpipe + heap_random_value;
__TEXT:__text:801EC968      STR.W    R6, [R5,#0x88] ; set pipe_handle to cpipe + heap_random_value
__TEXT:__text:801EC96C      STR.W    R0, [R5,#0x8C] ; set pipe_handle_peer to NULL
__TEXT:__text:801EC970      LDR.W    R2, [R8,#0x30]
```

# Information Leaking Mitigations

- Other APIs disclose pointers unnecessarily
  - Zero them out
- Used to mitigate some leaks via sysctl
  - Notably, known proc structure infoleak



# Kernel ASLR

- Goal: Prevent attacker's from modifying/utilizing data at known (fixed) addresses
- Strategy is two-fold
  - Randomize kernel image base
  - Randomize base of kernel\_map (sort of)

# Kernel ASLR – Kernel Image

- Kernel base randomized by boot loader (iBoot)
  - Random data generated
  - SHA-1 hash of data taken
  - Byte from SHA-1 hash used to calculate kernel “slide”
- Kernel is rebased using the formula:  
$$0x01000000 + (\text{slide\_byte} * 0x00200000)$$
  - If slide is 0, static offset of 0x21000000 is used

# Kernel ASLR – Kernel Image

```
ROM:5FF19CF8
ROM:5FF19CF8 loc_5FF19CF8 ; CODE XREF: Image3_RelocateImage+3A↑j
ROM:5FF19CF8 ADD R0, SP, #0x3C+slide ; address of output buffer
ROM:5FF19CFA MOVS R4, #0
ROM:5FF19CFC MOVS R1, #1 ; number of random bytes required
ROM:5FF19CFE STRB.W R4, [SP,#0x3C+slide]
ROM:5FF19D02 MOV R5, R9
ROM:5FF19D04 BL iBoot_GetRandomBytes
ROM:5FF19D08 CBZ R0, loc_5FF19D10
ROM:5FF19D0A LDR R0, =0x5FF44EB8
ROM:5FF19D0C STR R4, [R0] ; failed to generate random bytes, just make slide 0
ROM:5FF19D0E B loc_5FF19D28
ROM:5FF19D10 ; -----
ROM:5FF19D10
ROM:5FF19D10 loc_5FF19D10 ; CODE XREF: Image3_RelocateImage+54↑j
ROM:5FF19D10 LDR R2, =0x5FF44EB8
ROM:5FF19D12 MOV.W R0, #0x21000000
ROM:5FF19D16 LDRB.W R1, [SP,#0x3C+slide]
ROM:5FF19D1A CMP R1, #0
ROM:5FF19D1C ITT NE
ROM:5FF19D1E MOUNE.W R0, #0x1000000
ROM:5FF19D22 ADDNE.W R0, R0, R1, LSL#21 ; slide = (slide_byte << 21) + 0x00100000
ROM:5FF19D26 STR R0, [R2] ; store slide value for later use
```

# Kernel ASLR – Kernel Image

- Calculated value added to kernel preferred base later on
- Result:
  - Kernel can be rebased at 1 of 256 possible locations
  - Base addresses are 2MB apart
    - Example: 0x81200000, 0x81400000, ... 0xA1000000
- Adjusted base passed to kernel in boot args structure (offset 0x04)

# Kernel ASLR – Kernel Map

- Used for kernel allocations of all types
  - `kalloc( )`, `kernel_memory_allocate( )`, etc
- Spans all of kernel space (0x80000000 -> 0xFFFFEFFFF)
- Kernel-based maps are submaps of `kernel_map`
  - `zone_map`, `ipc_kernel_map`, etc

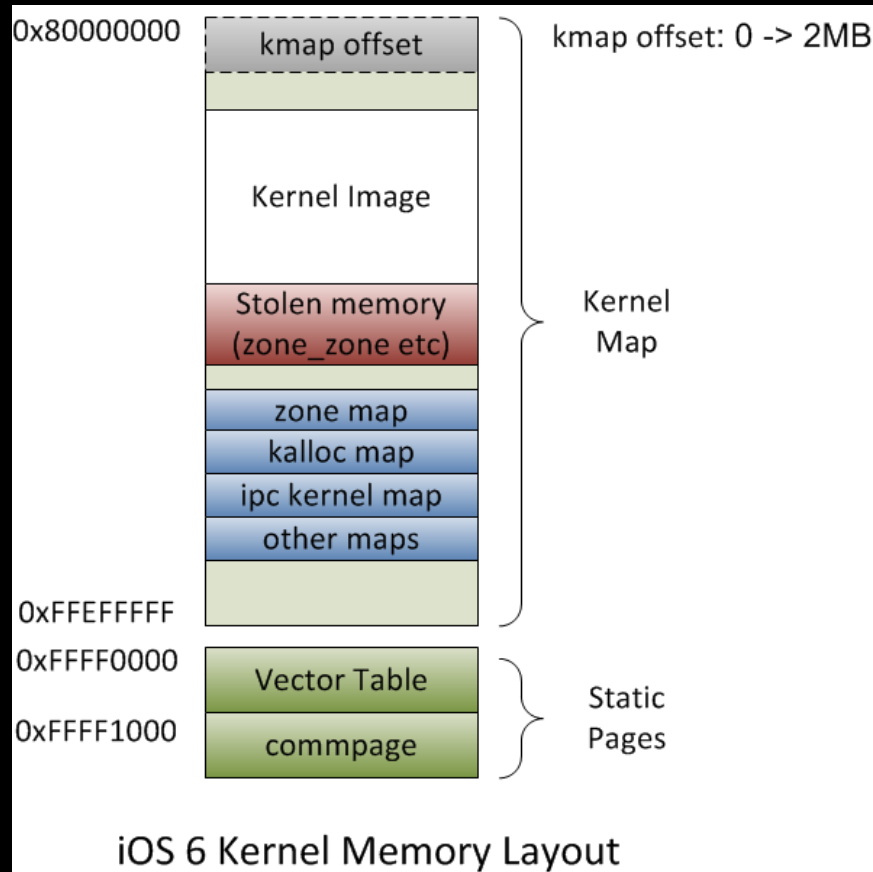
# Kernel ASLR – Kernel Map

- Strategy involves randomizing the base of `kernel_map`
  - Random 9-bit value generated right after `kmem_init( )` (which establishes `kernel_map`)
  - Multiplied by page size
  - Resulting value used as size for initial `kernel_map` allocation
  - 9 bits = 512 different allocation size possibilities

# Kernel ASLR – Kernel Map

- Future kernel\_map (including submap) allocations pushed forward by random amount
  - Allocation silently removed after first garbage collection (and reused)
- Behavior can be overridden with “kmapoff” boot parameter

# Kernel ASLR – Kernel Map





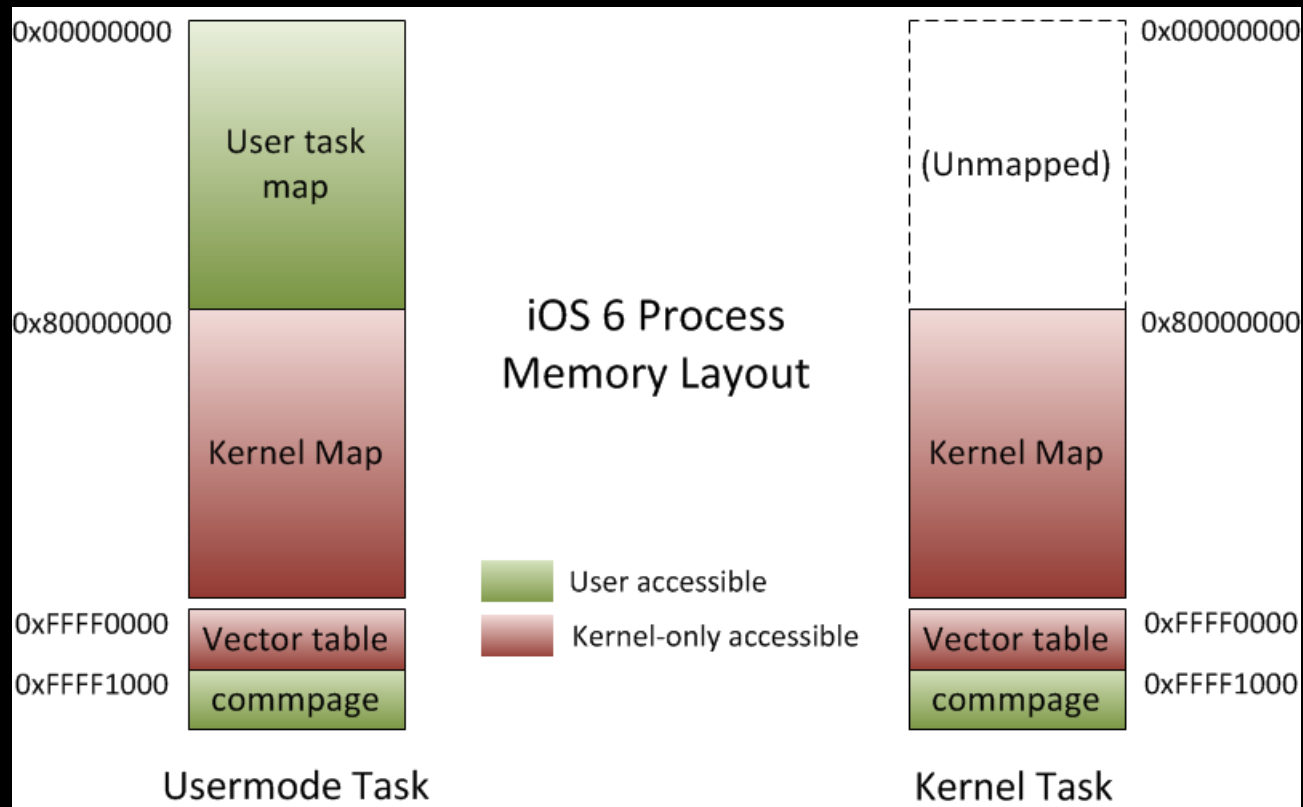
# Kernel Address Space Protection

- Goal: Prevent NULL/offset-to-NULL dereference vulnerabilities
- Previously, kernel mapped in to user-mode address space
- NULL-dereferences were prevented by forcing binaries to have `__PAGE_ZERO` section
  - Does not prevent offset-to-NULL problems

# Kernel Address Space Protection

- kernel\_task now has its own address space while executing
  - Transitioned to with interrupt handlers
  - Switched between during `copyin( )` / `copyout( )`
- User-mode pages therefore not accessible while executing in kernel mode
- Impossible to accidentally access them

# Kernel Address Space Protection



# Kernel Address Space Protection

- BUG – iOS 5 and earlier had very poor user/kernel validation in `copyin( )` / `copyout( )`
  - Only validation: usermode pointer < 0x80000000
  - Length not validated
- Pointer + length can be > 0x80000000 (!)
  - Can potentially read/write to kernel memory
- Limitation: Device must have > 512M to map 0x7FFFF000
  - iPad 3 / iPhone 5

# Kernel Address Space Protection

```
EXPORT _copyout
_copyout
; CODE XREF: sub_8000D64C+C↑p
; __TEXT:__text:800132F6↑p ...

CMP      R2, #0
MOVEQ    R0, #0
BXEQ     LR
CMP      R1, #0x80000000
BCS      _error
STMFD    SP!, {R4}
ADR      R3, fault_handler_routine
MRC      p15, 0, R12,c13,c0, 4
LDR      R4, [R12,#0x220]
STR      R3, [R12,#0x220]
CMP      R2, #0x10
BLT      bytearray_copy
ORR      R3, R0, R1
TST      R3, #3
BNE      bytearray_copy
SUB      R2, R2, #8
```

# Kernel Address Space Protection

- iOS 6 added security checks
  - Integer overflow/signedness checks
  - Conservative maximum length
  - $\text{Pointer} + \text{length} < 0x80000000$
- iOS 6 still vulnerable!
  - If copy length  $\leq 0x1000$ , pointer + length check not performed
  - Can read/write to first page of kernel memory

# Kernel Address Space Protection

```
_copyout                                ; CODE XREF: sub_8000E490+C↑p  
                                        ; __mach_trap_vm_allocate+4A↑p ...  
  
var_8                                  = -8  
  
    CMP                                R2, #0  
    MOVEQ                               R0, #0  
    BXEQ                               LR  
    CMP                                R1, #0x80000000  
    BCS                                loc_80088278  
    CMP                                R2, #0x1000  
    BLS                                do_copy  
    STMFD                               SP!, {R4-R7,LR}  
    MOV                                R4, R0  
    MOV                                R5, R1  
    MOV                                R6, R2  
    ADD                                R7, SP, #0x14+var_8  
    BLX                                copy_validate  
    CMP                                R0, #0  
    LDMNEFD                             SP!, {R4-R7,PC}  
    MOV                                R0, R4  
    MOV                                R1, R5  
    MOV                                R2, R6  
    LDMFD                               SP!, {R4-R7,LR}
```

# Kernel Address Space Protection

- Is anything in the first page of memory?
  - Initially contains kmap offset allocation, but that is removed after first garbage collection
  - Some things allocate to kernel map directly
    - HFS
    - kalloc() blocks of  $\geq 256k$
- Create a pipe, specify buffers  $> 0x7FFFFFF000$
- Bonus: If memory is not mapped, kernel will not panic (safely return EFAULT)



# Kernel Address Space Protection

- Memory is no longer RWX
  - Kernel code cannot be directly patched
  - Heap is non-executable
  - Stack is non-executable

# Kernel Attacks: Overview

- Protections kill most of the known attack strategies
  - Syscall table overwrites
  - Patching kernel code
  - Attacking key data structures (randomized locations)
- Need something new!

# Kernel Attacks: Overview

- Generally, exploit will require information leaking followed by corruption
- Corruption primitives dictate strategy
  - Write in to adjacent buffer (overflow)
  - Write to relative location from buffer
  - Write to arbitrary location
- Different types of primitives will be considered separately

# Kernel Attacks: KASLR

- Leaking the kernel base is really useful
- `kext_request( )` allows applications to request information about kernel modules
  - Divided into active and passive operations
- Active operations (load, unload, start, stop, etc.) require privileged (root) access
  - Secure kernels (i.e. iOS) remove ability to load kernel extensions

# Kernel Attacks: KASLR

- Passive operations were originally unrestricted in < iOS 6
  - Allowed unprivileged users to query kernel and module base addresses

```
result = kOSKextReturnNotPrivileged;
if (hostPriv == HOST_PRIV_NULL) {
    if (!predicate->isEqualTo(kKextRequestPredicateGetLoaded) &&
        !predicate->isEqualTo(kKextRequestPredicateGetKernelImage) &&
        !predicate->isEqualTo(kKextRequestPredicateGetKernelLoadAddress)) {
        goto finish;
    }
}
```

# Kernel Attacks: KASLR

- iOS 6 inadvertently removed some limitations
  - Only load address requests disallowed

```
result = kOSKextReturnNotPrivileged;
if (hostPriv == HOST_PRIV_NULL) {
    if (sPrelinkBoot) {
        hideTheSlide = true;

        /* must be root to use these kext requests */
        if
(predicate->isEqualTo(kKextRequestPredicateGetKernelLoadAddress) ) {
            OSKextLog(/* kext */ NULL,
                    kOSKextLogErrorLevel |
                    kOSKextLogIPCFlag,
                    "Access Failure - must be root user.");
            goto finish;
        }
    }
}
```

# Kernel Attacks: KASLR

- We can use `kKextRequestPredicateGetLoaded`
  - Returns load addresses and mach-o header dumps (base64 encoded)
  - Load address / Mach-O segment headers are obscured to hide ASLR slide
  - Mach-O section headers are not!
  - Reveals virtual addresses of loaded kernel sections

# Kernel Attacks: KASLR

Request

```
<dict><key>Kext Request Predicate</key><string>Get Loaded Kext Info</string></dict>
```

Response

```
<dict ID="0"><key>__kernel__</key></dict>
ID="1"><key>OSBundleMachOHeaders</key><data
ID="2">zvrt/gwAAAAJAAAAAgA...AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAMhQ
CIAAAAAAJgAAABAAAAAwPDIAwEUAAA==</data>
...
<key>OSBundleLoadAddress</key><integer size="64" ID="9">0x80001000</integer>
```

0000h:	CE FA ED FE	0C 00 00 00	09 00 00 00	02 00 00 00	îúíp.....
0010h:	0F 00 00 00	24 09 00 00	01 00 20 00	01 00 00 00	....\$. ....
0020h:	48 01 00 00	5F 5F 54 45	58 54 00 00	00 00 00 00	H...__TEXT....
0030h:	00 00 00 00	00 10 00 80	00 E0 2C 00	00 00 00 00	.....e.à,....
0040h:	00 00 00 00	05 00 00 00	05 00 00 00	04 00 00 00	.à,.....
0050h:	00 00 00 00	00 5F 5F 74 65	78 74 00 00	00 00 00 00	...._text.....
0060h:	00 00 00 00	00 5F 5F 54 45	58 54 00 00	00 00 00 00	...._TEXT.....
0070h:	00 00 00 00	00 00 20 60 9A	18 3C 28 00	00 10 00 00	...._s.<{.....
0080h:	0C 00 00 00	00 00 00 00	00 00 00 00	00 04 00 80	.....e

Decoded kernel macho header

Real \_\_text section address



# Kernel Attacks: Heap Corruption

- Standard heap overflow tricks no longer work
  - Overwriting freelist pointer results in validation step failing
- Exploitation requires new strategies
  - Information leak to find heap address/cookies
  - Control structure manipulation
- Depends on corruption primitives

# Kernel Attacks: Heap Overflows

- Overflowing metadata is useful
  - Various control structures can be targeted instead
  - Requires some heap grooming (may or may not be difficult depending on block size)
- Various heap attacking primitives can be combined to gain code execution

# Kernel Attacks: Heap Overflows

- Introducing vm\_map\_copy\_t

```
struct vm_map_copy {
    int            type;
#define VM_MAP_COPY_ENTRY_LIST      1
#define VM_MAP_COPY_OBJECT         2
#define VM_MAP_COPY_KERNEL_BUFFER  3
    vm_object_offset_t  offset;
    vm_map_size_t      size;
    union {
        struct vm_map_header  hdr;      /* ENTRY_LIST */
        vm_object_t           object;    /* OBJECT */
        struct {
            void              *kdata;    /* KERNEL_BUFFER */
            vm_size_t         kalloc_size; /* size of this copy_t */
        } c_k;
    } c_u;
};
```

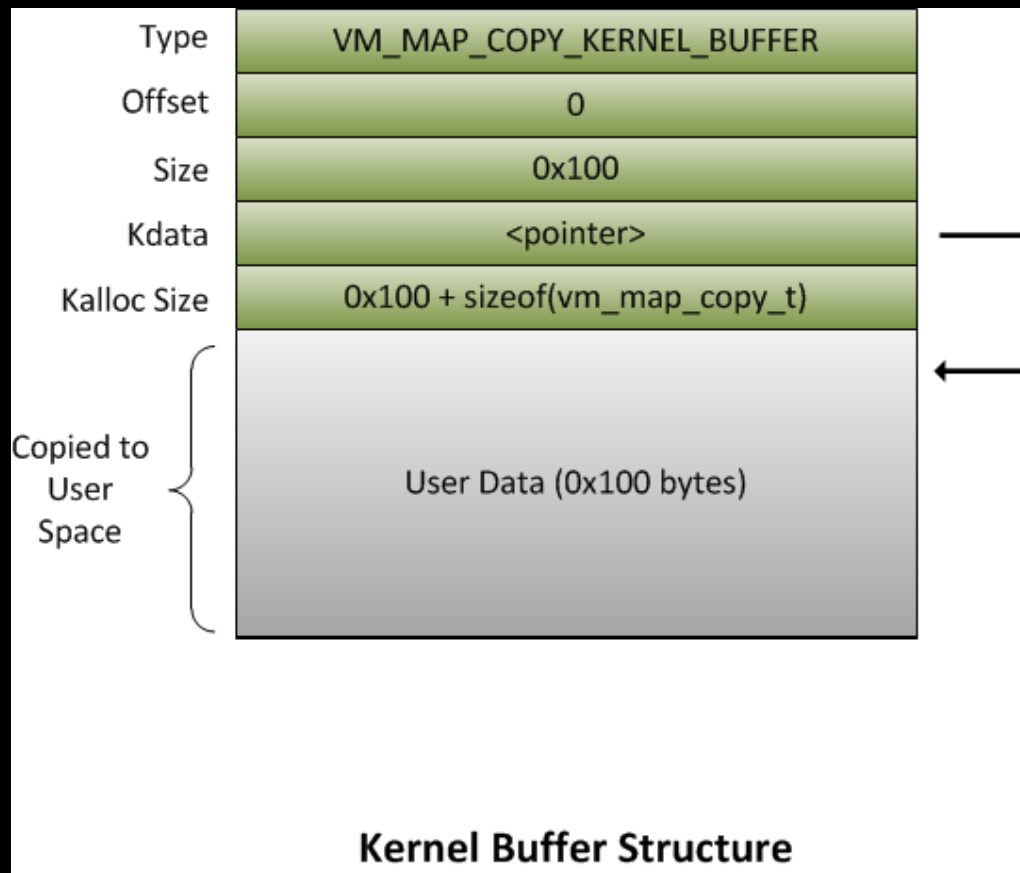
# Kernel Attacks: Heap Overflows

- Kernel buffers allocated by `vm_map_copyin()` if size < 4096
- Creating them is easy
  - Send messages to a mach port with ool\_descriptors in them
  - They are persistent until the message is received
- Corrupting these structures are useful for information leaking and exploitation

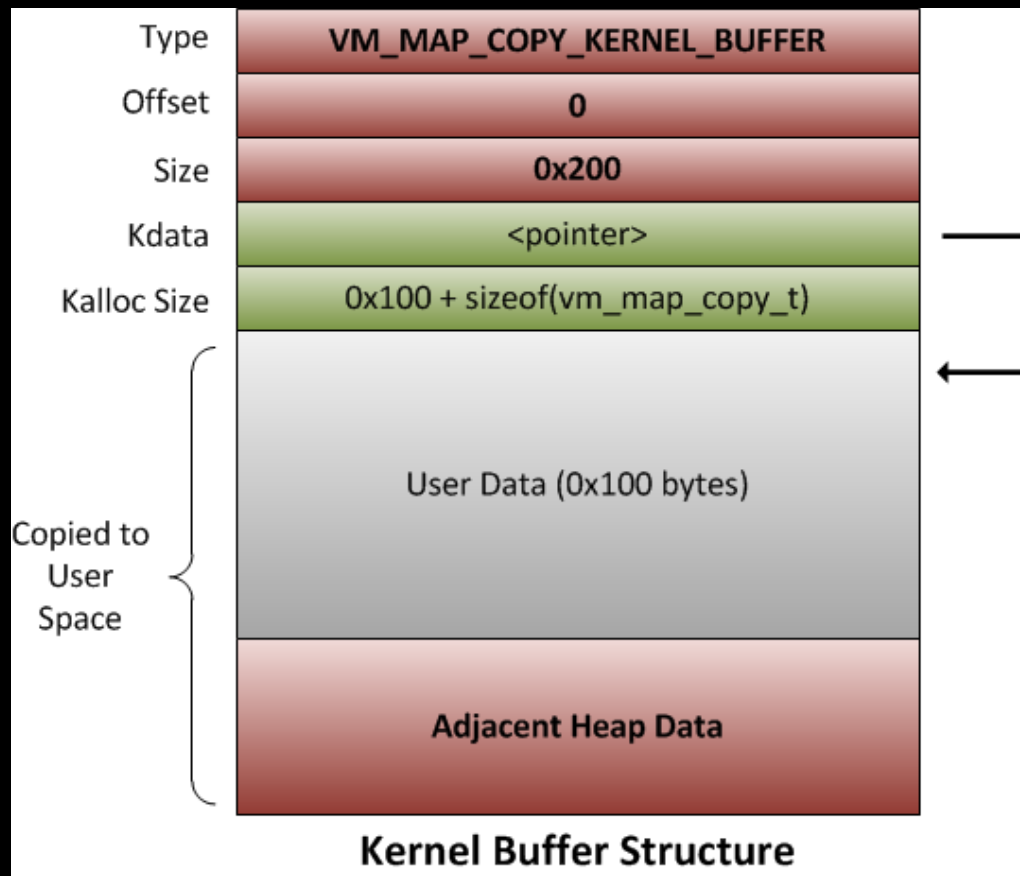
# Kernel Attacks: Heap Overflows

- Primitive 1: Adjacent Disclosure
  - Overwrite size parameter of `vm_map_copy_t`
  - Receive the message corresponding to the map
  - Returns memory past the end of your allocated buffer
- Bonus: Overwritten size is not used in `kfree()`
  - No side effects

# Kernel Attacks: Heap Overflows



# Kernel Attacks: Heap Overflows



# Kernel Attacks: Heap Overflows

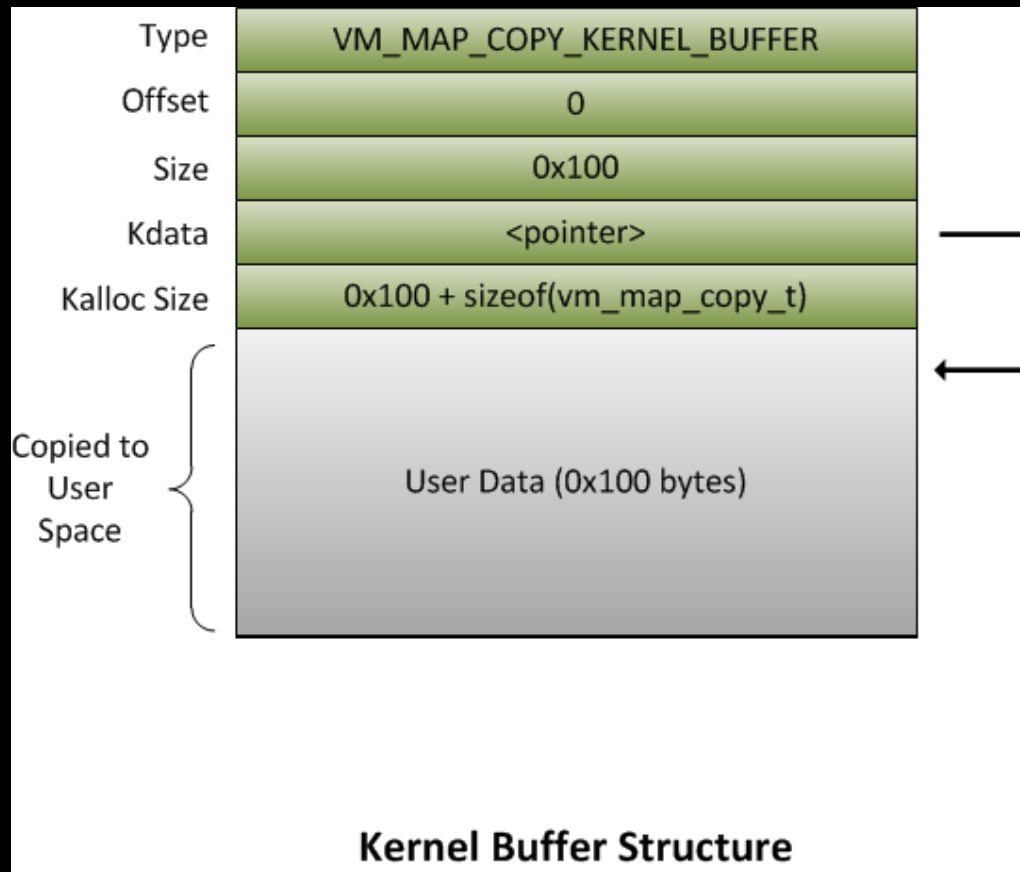
- Primitive 2: Arbitrary Memory Disclosure
  - Overwrite size and pointer of adjacent `vm_map_copy_t`
  - Receive message, read arbitrary memory from kernel
- No side effects
  - Data pointer (`cpy_kdata`) is never passed to `kfree()` (the `vm_map_copy_t` is)
  - Leave `kalloc_size` alone!



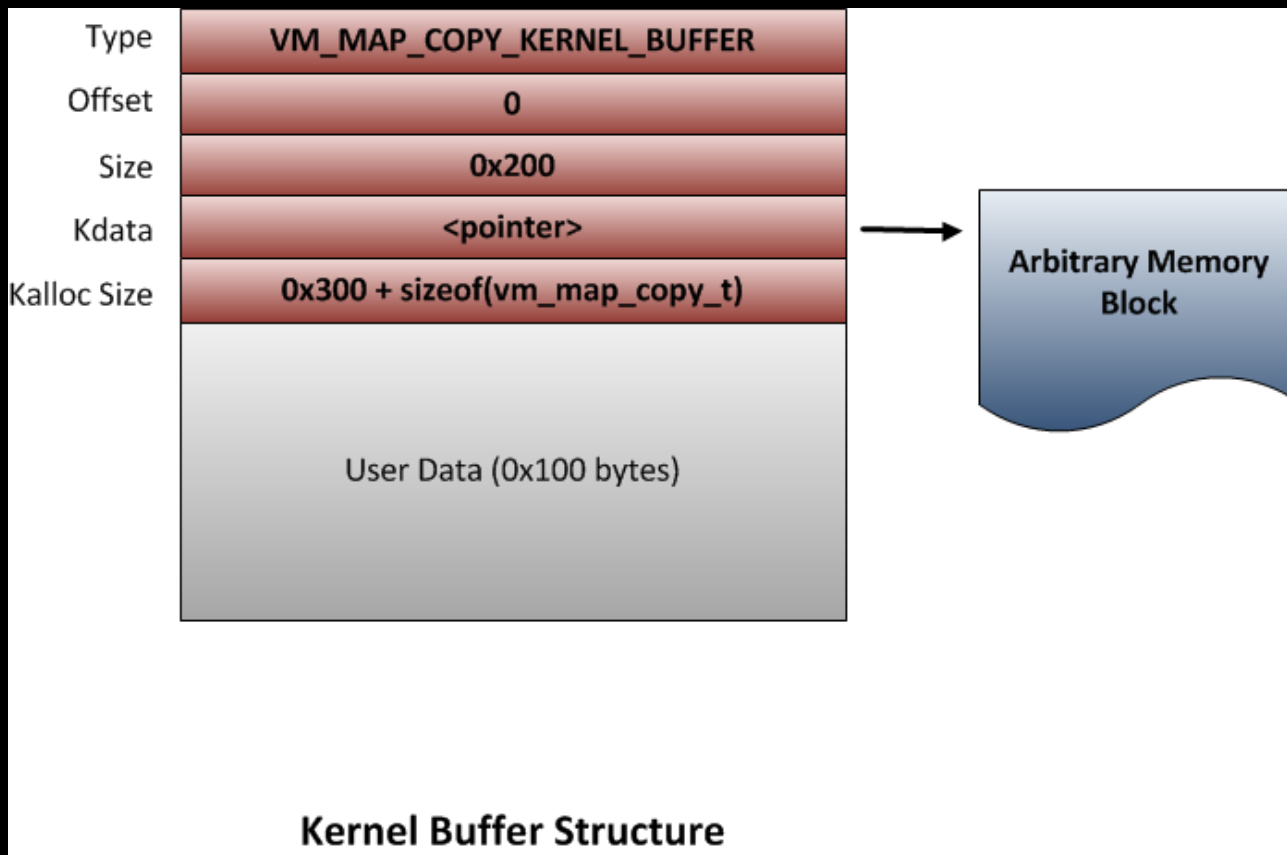
# Kernel Attacks: Heap Overflows

- Primitive 3: Extended Overflow
  - Overwrite `kalloc_size` with larger value
  - Passed to `kfree()` – block entered in to wrong zone (eg. `kalloc.256` instead of `kalloc.128`)
  - Allocate block from poisoned zone
  - Profit

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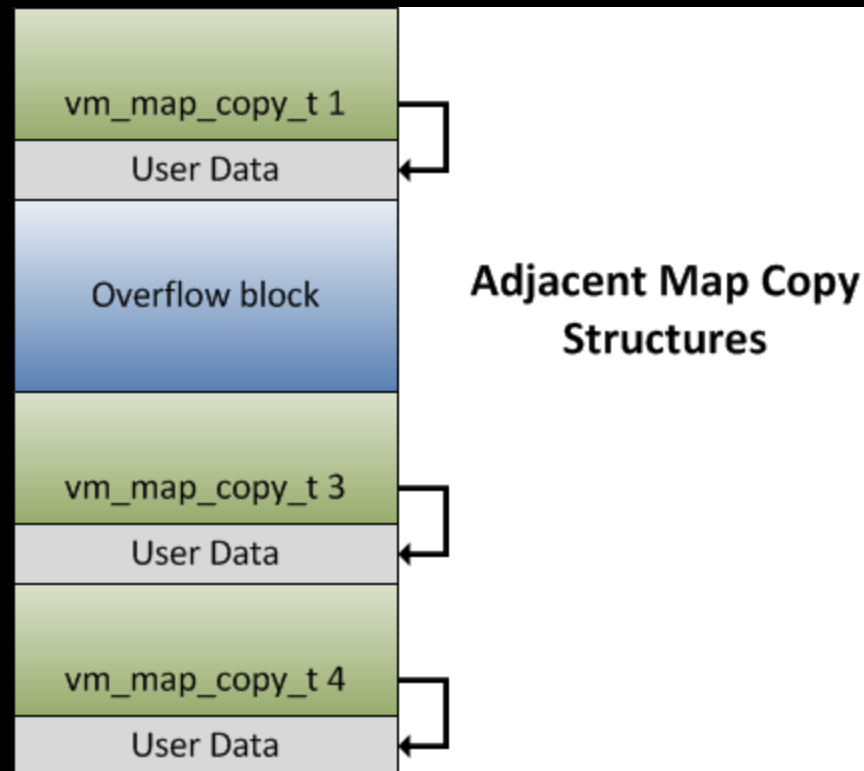
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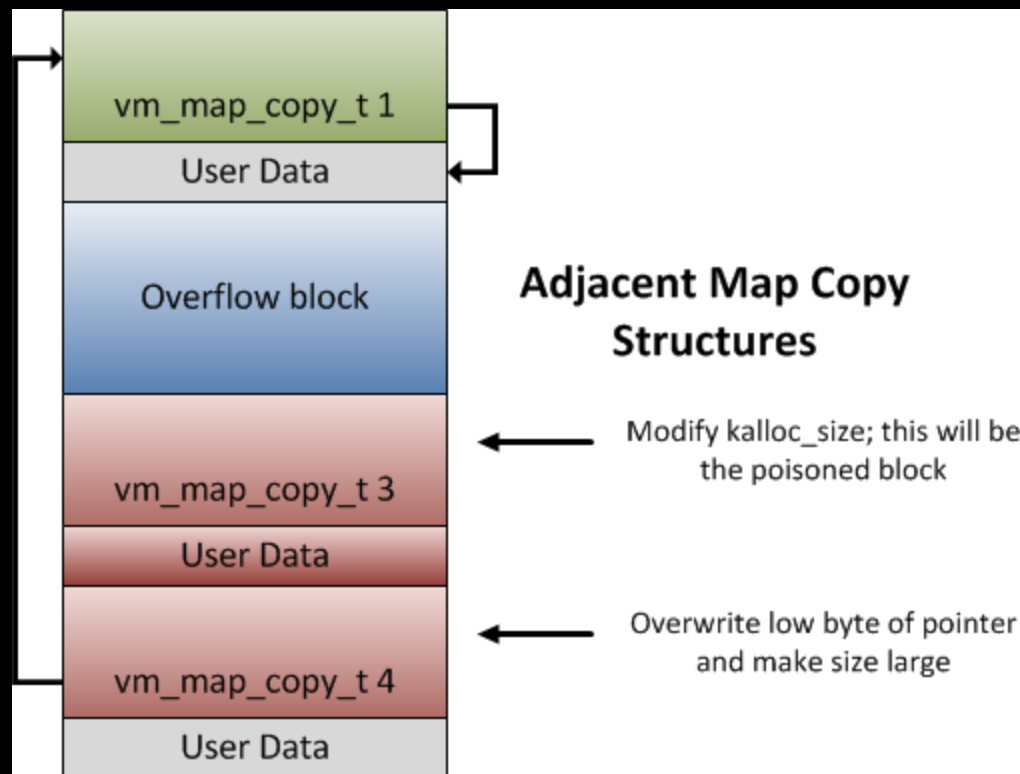
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- Primitive 4: Find our own address + Overflow
  - Mix and match primitive 1 and 3
  - Overwrite one whole `vm_map_copy_t`, changing `kalloc_size` to be suitably large
  - Overflow in to adjacent `vm_map_copy_t`, partially overwriting pointer / length
  - Free second copy (revealing pointers to itself)
  - Free first copy, creating poisoned `kalloc` block at known location

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# Conclusion

- iOS 6 mitigations significantly raise the bar
  - Many of the old tricks don't work
  - A variety of bugs likely to be (reliably) unexploitable now
- Presented strategies provide useful mechanisms for exploiting iOS 6
- Thanks!