RE:Trace – Applied Reverse Engineering on OS X
Tiller Beauchamp
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What Is DTrace™?

DTRACE BACKGROUND

*Dtrace was created by Sun Microsystems, Inc. and released under the Common Development and Distribution License (CDDL), a free software license based on the Mozilla Public License (MPL).

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DTrace Background

- Kernel-based dynamic tracing framework
- Created by Sun Microsystems
- First released with Solaris™ 10 operating System
- Now included with Apple OS X Leopard, QNX
- June 10th, 2008, committed to CURRENT branch of FreeBSD 7, Will be in 8 STABLE (John Birrell)
- OpenBSD, NetBSD, Linux?

*Solaris™ is a trademark of Sun Microsystems, Inc. in the United States and/or other countries.

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DTrace Overview

- DTrace is a framework for performance observability and debugging in real time
- Tracing is made possible by thousands of “probes” placed “on the fly” throughout the system
- Probes are points of instrumentation in the kernel
- When a program execution passes one of these points, the probe that enabled it is said to have fired
- DTrace can bind a set of *actions* to each probe

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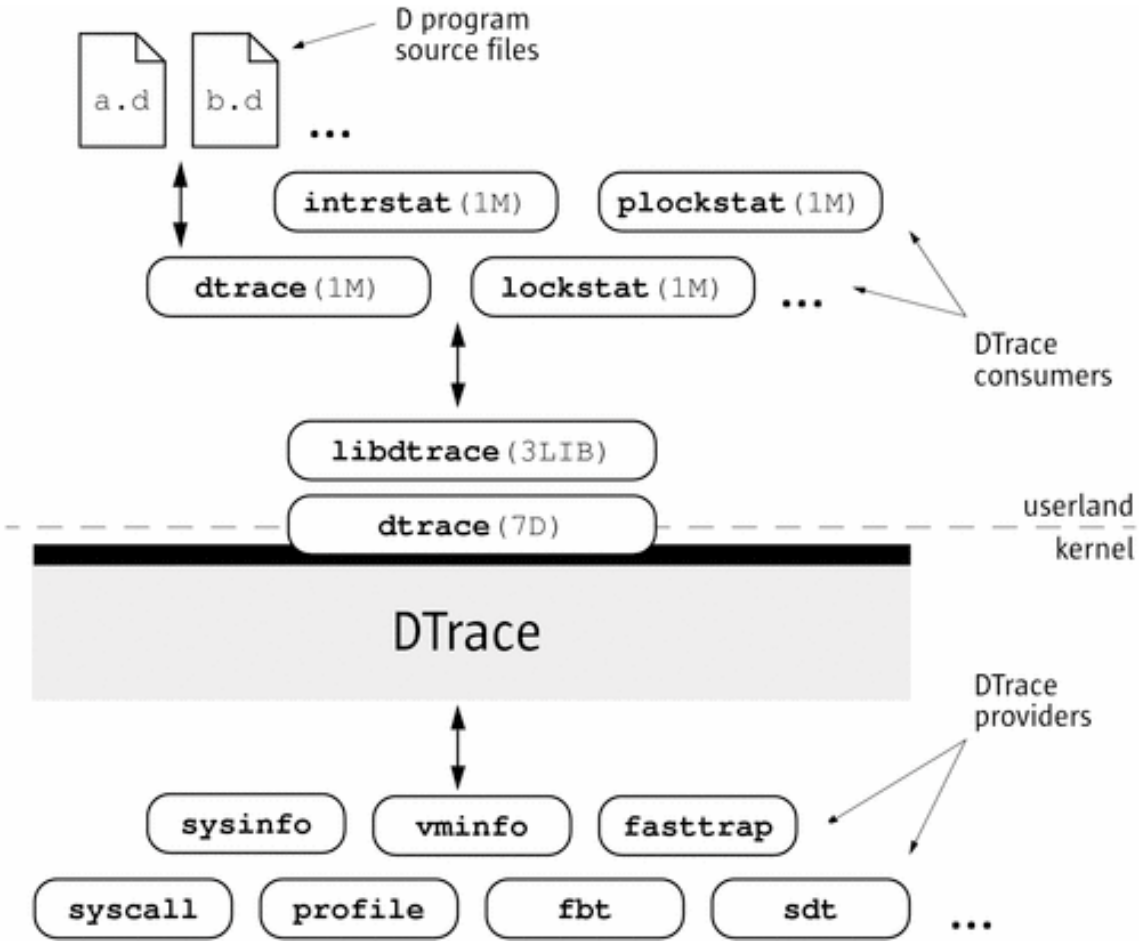
DTrace Architecture



Source: Solaris Dynamic Tracing Guide

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The D Language

- D is an interpreted, block-structured language
- D syntax is a subset of C
- D programs are compiled into intermediate form
- Intermediate form is validated for safety when your program is first examined by the DTrace kernel software
- The DTrace execution environment handles any runtime errors

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The D Language

- D does not use control-flow constructs such as if statements and loops
- D program clauses are written as single, straight-line statement lists that trace an optional, fixed amount of data
- D can conditionally trace data and modify control flow using logical expressions called *predicates*
- *A predicate is tested at probe firing before executing any statements*

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DTrace Performance

- DTrace is dynamic: probes are enabled only when you need them
- No code is present for inactive probes
- There is no performance degradation when you are not using DTrace
- When the `dtrace` command exits, all probes are disabled and instrumentation removed
- The system is returned to its original state

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DTrace Uses

- DTrace takes the power of multiple tools and unifies them with one programmatically accessible interface
- DTrace has features similar to the following:
  - `truss`: tracing system calls, user functions
  - `ptrace`: tracing library calls
  - `prex/tnf`*: tracing kernel functions
  - `lockstat`: profiling the kernel
  - `gdb`: access to kernel/user memory

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DTrace Uses

- DTrace combines system performance statistics, debugging information, and execution analysis into one tight package
- A real “Swiss army knife” for reverse engineers
- DTrace probes can monitor every part of the system, giving “the big picture” or zooming in for a closer look
- Can debug “transient” processes that other debuggers cannot

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Creating DTrace Scripts

- Dozens of ready-to-use scripts are included with Sun's DTraceToolkit; they can be used as templates
- These scripts provide functions such as syscalls by process, reads and writes by process, file access, stack size, CPU time, memory r/w and statistics
- Complex problems can often be diagnosed by a single "one-liner" DTrace script

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Example: Syscall Count

- System calls count by application:

```
dtrace -n 'syscall:::entry{@[execname] = count();}'.
```

```
Matched 427 probes
Syslogd                                           1
DirectoryService                                  2
Finder                                            3
TextMate                                          3
Cupsd                                             4
Ruby                                           4309
vmware-vmx                                     6899
```

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Example: File Open Snoop

```
#!/usr/sbin/dtrace -s

syscall::open*:entry {
  printf("%s %s\n",
         execname,
         copyinstr(arg0));
}
```

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Example: File Snoop Output

vmware-vmx	/dev/urandom
Finder	/Library/Preferences/SystemConfiguration/com.apple.smb.server.plist
iChat	/Library/Preferences/SystemConfiguration/com.apple.smb.server.plist
Microsoft Power	/Library/Preferences/SystemConfiguration/com.apple.smb.server.plist
nmblookup	/System/Library/PrivateFrameworks/ByteRange ... ByteRangeLocking
nmblookup	/dev/dtracehelper
nmblookup	/dev/urandom
nmblookup	/dev/autofs_nowait
Nmblookup	/System/Library/PrivateFrameworks/ByteRange... ByteRangeLocking

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DTrace Lingo

- Probes are points of instrumentation
- Providers are logically grouped sets of probes
- Examples of providers include syscall, lockstat, fbt, io, mib
- Predicates allow actions to be taken only when certain conditions are met
- Actions are taken when a probe fires

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DTrace Syntax

Generic D Script

Probe: provider:module:function:name

Predicate: /some condition that needs to happen/

{

Action: action1;

action2; (ex: printf();)

}

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How Can We Use DTrace?

DTRACE AND REVERSE ENGINEERING (RE)

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DTrace for RE

- DTrace is extremely versatile and has many applications for RE
- It is very useful for understanding the way a process works and interacts with the rest of the system
- DTrace probes work in a manner very similar to debugger “hooks”
- DTrace probes are useful because they can be described generically and focused later

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DTrace for RE

- Think of DTrace as a rapid development framework for RE tasks and tools
- One of DTrace's greatest assets is speed
- DTrace can instrument any process on the system without starting or stopping it
- Complex operations can be understood with a succinct one-line script
- You can refine your script as the process continues to run

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Helpful Features

DTrace gives us some valuable features for free:

- Control flow indicators
- Symbol resolution
- Call stack trace
- Function parameter values
- CPU register values
- Both in kernel space and user space!

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Control Flow

```
1       -> -[AIContentController finishSendContentObject:]
1         -> -[AIAdium notificationCenter]
1         <- -[AIAdium notificationCenter]
1         -> -[AIContentController processAndSendContentObject:]
1           -> -[AIContentController handleFileSendsForContentMessage:]
1           <- -[AIContentController handleFileSendsForContentMessage:]
1           -> -[AdiumOTREncryption willSendContentMessage:]
1             -> policy_cb
1               -> contactFromInfo
1                 -> -[AIAdium contactController]
1                 <- -[AIAdium contactController]
1                 -> accountFromAccountID
```

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Symbol and Stack Trace

```
dyld`strcmp
  dyld`ImageLoaderMachO::findExportedSymbol(char
  dyld`ImageLoaderMachO::resolveUndefined(...
  dyld`ImageLoaderMachO::doBindLazySymbol(unsigned
  dyld`dyld::bindLazySymbol(mach_header const*, ...
  dyld`stub_binding_helper_interface2+0x15
  Ftpd`yylex+0x48
  Ftpd`yyparse+0x1d5
  ftpd`ftp_loop+0x7c
  ftpd`main+0xe46
```

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Function Parameters

DTrace's copyin* functions allow you to copy data from the process space:

```
printf("arg0=%s", copyinstr( arg0 ))
```

Output:

```
1   -> strcmp     arg0=_isspecial_l
```

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CPU Register Values

Uregs array allows access to reading CPU registers

```
printf("EIP:%x", uregs[R_EIP]);
```

Example:

```
EIP: 0xdeadbeef
EAX: 0xffffeae6
EBP: 0xdefacedd
ESP: 0x183f6000
```

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Destructive Examples

```
#!/usr/sbin/dtrace -w -s
syscall::uname:entry { self->a = arg0; }

syscall::uname:return{
        copyoutstr("Windows", self->a, 257);
        copyoutstr("PowerPC", self->a+257, 257);
        copyoutstr("2010.b17", self->a+(257*2), 257);
        copyoutstr("fud:2010-10-31", self->a+(257*3), 257);
        copyoutstr("PPC", self->addr+(257*4), 257);
}
```

Adapted from: Jon Haslam, http://blogs.sun.com/jonh/date/20050321

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Snooping

```
syscall::write: entry {
    self->a = arg0;
}
syscall::write: return {
    printf("write: %s",
    copyinstr(self->a);
}
```

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Got Ideas?

Using DTrace:

- Monitor stack overflows
- Code coverage
- Fuzzer feedback
- Monitor heap overflows

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DTrace vs. Debuggers

- Don’t think of DTrace as a debugger
- User mode and kernel mode debuggers allow you to control execution and inspect process information
- DTrace can instrument both the kernel and user land applications at the same time
- To trace execution, debuggers use instructions to pause and resume execution
- DTrace carries out parallel actions in the kernel when a probe is hit

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DTrace vs. Debuggers

- Traditional debuggers also affect the target process's memory layout. DTrace doesn't
- DTrace does not directly perform exception handling
- DTrace can halt process and transfer control to external debugger
- Currently DTrace is not susceptible to traditional anti-debugging techniques (isdebuggerpresent())
- However, Apple has implemented probe blocking with use of the PT_ATTACH_DENY

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DTrace vs. Tracers

- Truss, ltrace, and strace operate one process at a time, with no system-wide capability
- Truss reduces application performance
- Truss stops threads through procfs, records the arguments for the system call, and then restarts the thread
- Valgrind™ is limited to a single process and only runs on Linux
- Ptrace is much more efficient at instruction level tracing but it is crippled on OS X

*Valgrind is Open Source/Free Software and is freely available under the GNU General Public License.

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DTrace Limitations

- The D language does not have conditionals or loops
- The output of many functions is to stdout (i.e., stack(), unstack())
- Lack of loops and use of stdout means DTrace is not ideal for processing data
- We can fix this
- Cannot modify registers :’(epic sad time

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DTrace Cautionaries

A few issues to be aware of:

- DTrace drops probes by design
- Tune options, narrow trace scope to improve performance
- Some libraries and functions behave badly
- overflows can cause violations before function return

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RE:Trace & RE:dbg

RE with Ruby, DTrace and the Mach API

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RE:Trace

- RE:Trace combines Ruby with DTrace
- Ruby gives us the power of OOP, text processing, iteration
- RE:Trace utilizes Ruby libdtrace bindings, written by Chris Andrews
- Can be the glue which combines the power of several existing Ruby RE frameworks (idarub, librub, metasm, MSF3)
- RE:Trace is similar to programmatic frameworks (pyDBG, noxDBG, immDBG)
- Includes script to dump and search memory

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IdaRub

- Wraps IDA interface
- Ruby code is the client
- Server is IDA plugin
- Ruby glues it all together
- IdaRub was released by Spoonm at REcon 2006

```
ida.set_item_color(eip, 3000)
```

More info: http://www.metasploit.com/users/spoonm/idarub/

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RE:Trace and Exploit Dev

- Vulnerability analysis times can be dramatically reduced with RE:Trace
- DTrace probes allow you to track data input flow throughout a process to understand where and why memory corruption took place
- Methods that cause stack and heap corruption can be pinpointed using IDARub to integrate IDA's static analysis features

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RE:Trace and Code Coverage

- DTrace can “hook” every function in a process
- This makes it perfect for implementing a “code coverage aware” fuzzer
- Code coverage is useful for understanding what areas are being fuzzed
- Current RE code coverage monitors are mostly block based (PaiMei)
- We can use IDA to obtain block information or check code coverage at the function or instruction level

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RE:dbg

- RE:dbg picks up where RE:Trace left off
- Programmatic debugger for mach debug API
- Partially exists on OS X in Python (see vtrace and Charlie Miller's pydbg port)

Integrated Ruby based RE Toolset:

- Tracing : RE:Trace
- Disassembly: IDArub
- Debugger reDBG

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RE:dbg

- C code around Mach debugging API with Ruby bindings
- Higher level Ruby class to make everything easy
- Symbol resolution
- Read and write memory
- Walk memory segments
- Modify memory permissions
- Set breakpoints
- Exception handling
- Interface with IDA (... metasm?)

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iPhoto Format String Exploit

- iPhoto format string vuln is a good test for automation
- URL handler bug: iphoto://%dd%n
- What we want to do is trace with RE:Trace until we hit printf with arg1=%25 (URL encoded %n)
- Use idarub to get disassembly info from IDA
- Set a break on RET of the function with reDBG
- When breakpoint is hit, print out stack return address (or whatever you overwrote) to make sure the overflow was correct

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RE:Trace/reDBG/IDArub

```
Progtext = “pid$target::__vfprintf:entry
  /copyinstr(arg2) == "%25n"/ {stop();}”
t = Dtrace.new
p = t.createprocess([ARGV[0]])
prog = t.compile progtext
prog.execute
t.go
p.Continue
ida,sess = IdaRub.auto_client
Func = ida.Get_func(eip)
function[0..4].each  do |line|
  if line == “ret”
  Dbg = reDBG.new
  dbg.attach(pid)
       dbg.setBreak(line)
```

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RE:dbg ASLR

- ASLR analysis
- Start the application, lookup addresses for application and library symbols
- Search through all memory for references to those addresses
- Rinse and repeat

Can you find an address that is always relative to an address of a useful function?

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RE:dbg Soon!

If it’s not up in a week, bug us

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Writing a Stack Overflow Monitor with RE:Trace

MONITORING THE STACK

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Stack Overflow Monitoring

Programmatic control at EIP overflow time allows you to:

- Pinpoint the vulnerable function
- Reconstruct the function call trace
- Halt the process before damage occurs (HIDS)
- Dump and search process memory
- Send feedback to fuzzer
- Attach debugger

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Overflow Detection in One Probe

```
#/usr/sbin/dtrace -w -s

pid$target:::return
    / uregs[R_EIP] == 0x41414141 / {
    printf("Don't tase me bro!!!");
            stop()
            ...
}
```

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First Approach

- Store RETURN value at function entry
- uregs[R_SP], NOT uregs[R_ESP]
- Compare EIP to saved RETURN value at function return
- If different, there was an overflow

Simple enough, but false positives from:

- Tail call optimizations
- Functions without return probes

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DTrace and Tail Calls

- Certain compiler optimizations mess with the standard call/return control flow
- Tail calls are an example of such an optimization
- Two functions use the same stack frame, saves resources, less instruction
- DTrace reports tail calls as a return then a call, even though the return never happens
- EIP on return is not in the original calling function, it is the entry to second
- Screws up simple stack monitor if not aware of it

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New Approach

- Store RETURN value at function entry
- At function return, compare saved RETURN value with CURRENT value
- Requires saving both the original return value and its address in memory
- Fires when saved RETURN ! = current RETURN and EIP = current RETURN

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But Missing Return Probes???

Still trouble with functions that “never return”

- Some functions misbehave
- DTrace does not like function jump tables (dyld_stub_*)
- Entry probe but no exit probe

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Determining Missing Returns

Using DTrace – l flag

- List entry/exit probes for all functions
- Find functions with entry but no exit probe

Using DTrace aggregates

- Run application
- Aggregate on function entries and exits
- Look for mismatches

Exclude these functions with predicates

- / probefunc ! = “everybodyJump” /

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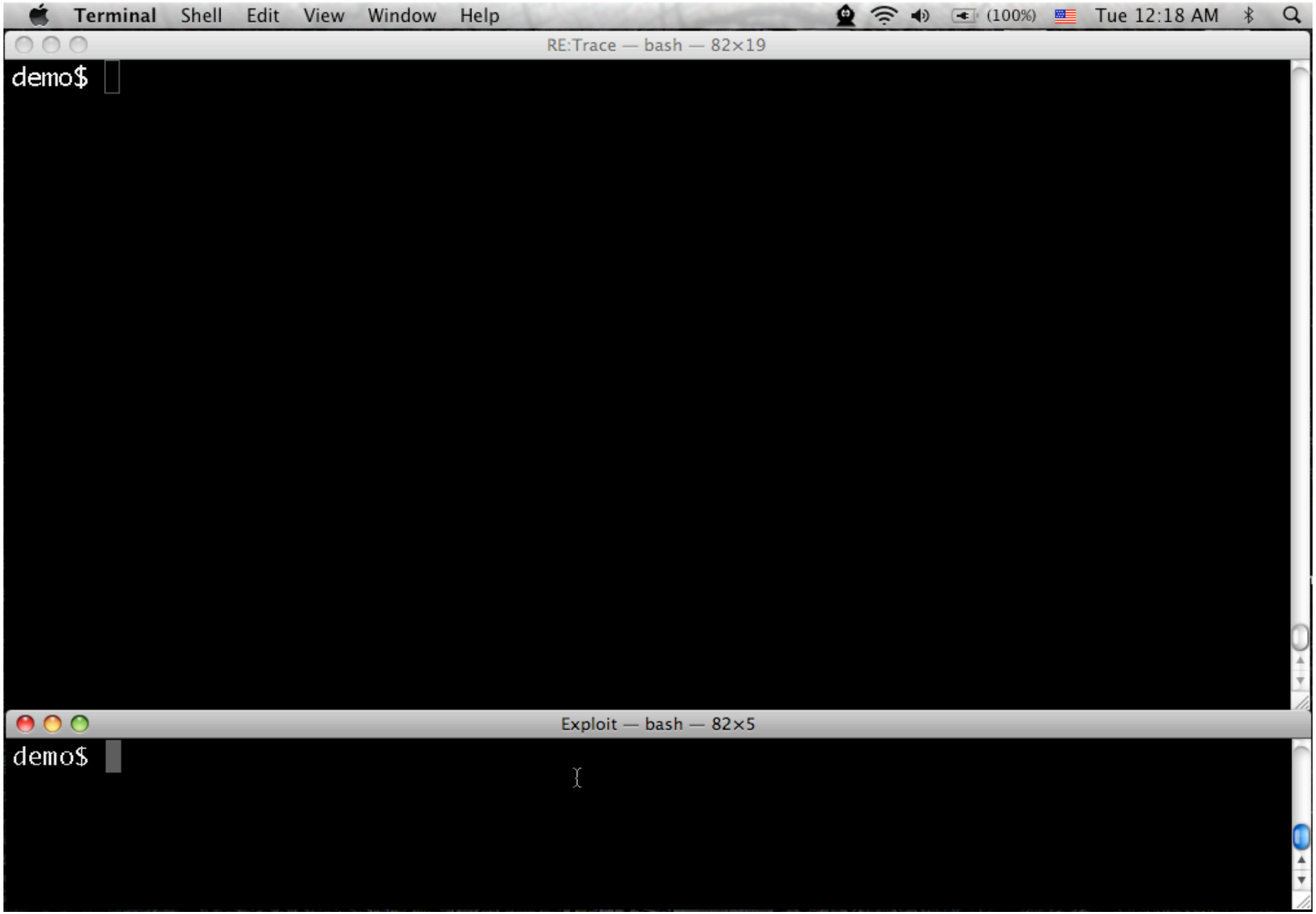
Terminal Shell Edit View Window Help
(100%)
Tue 12:18 AM
RE:Trace — bash — 82×19
demo$
Exploit — bash — 82×5
demo$

Advanced Tracing

Diving in deeper:

- Instruction-level tracing
- Code coverage with IDA Pro and IdaRub
- Profiling idle and GUI code
- Feedback to the fuzzer, smart/evolutionary fuzzing
- Conditional tracing based on function parameters (reaching vulnerable code paths)

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Instruction Tracing

CODE COVERAGE

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Code Coverage Approach

Approach

- Instruction-level tracing using DTrace
- Must properly scope tracing
- Use IdaRub to send commands to IDA
- IDA colors instructions and code blocks
- Can be done in real time, if you can keep up

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Tracing Instructions

- The last field of a probe is the offset in the function
- Entry = offset 0
- Leave blank for every instruction
- Must map static global addresses to function offset addresses

Print address of every instruction:

pid$target:a.out:: { print(“%d”, uregs[R_EIP]); }

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Tracing Instructions (cont.)

- DTrace to print instructions
- Ruby-Dtrace to combined DTrace with Ruby
- Idarub and rublib to combined Ruby with IDA

Tracing libraries

- When tracing libraries, must know memory layout of program
- `vmmap` on OS X will tell you
- Use offset to map runtime library EIPs to decompiled libraries

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Code Coverage with DTrace

Capabilities:

- Associate fuzz runs with code hit
- Visualize code paths
- Record number of times blocks were hit
- Compare idle traces to other traces

Limitations:

- Instruction tracing can be slow for some applications
- Again, tuning and limiting scope

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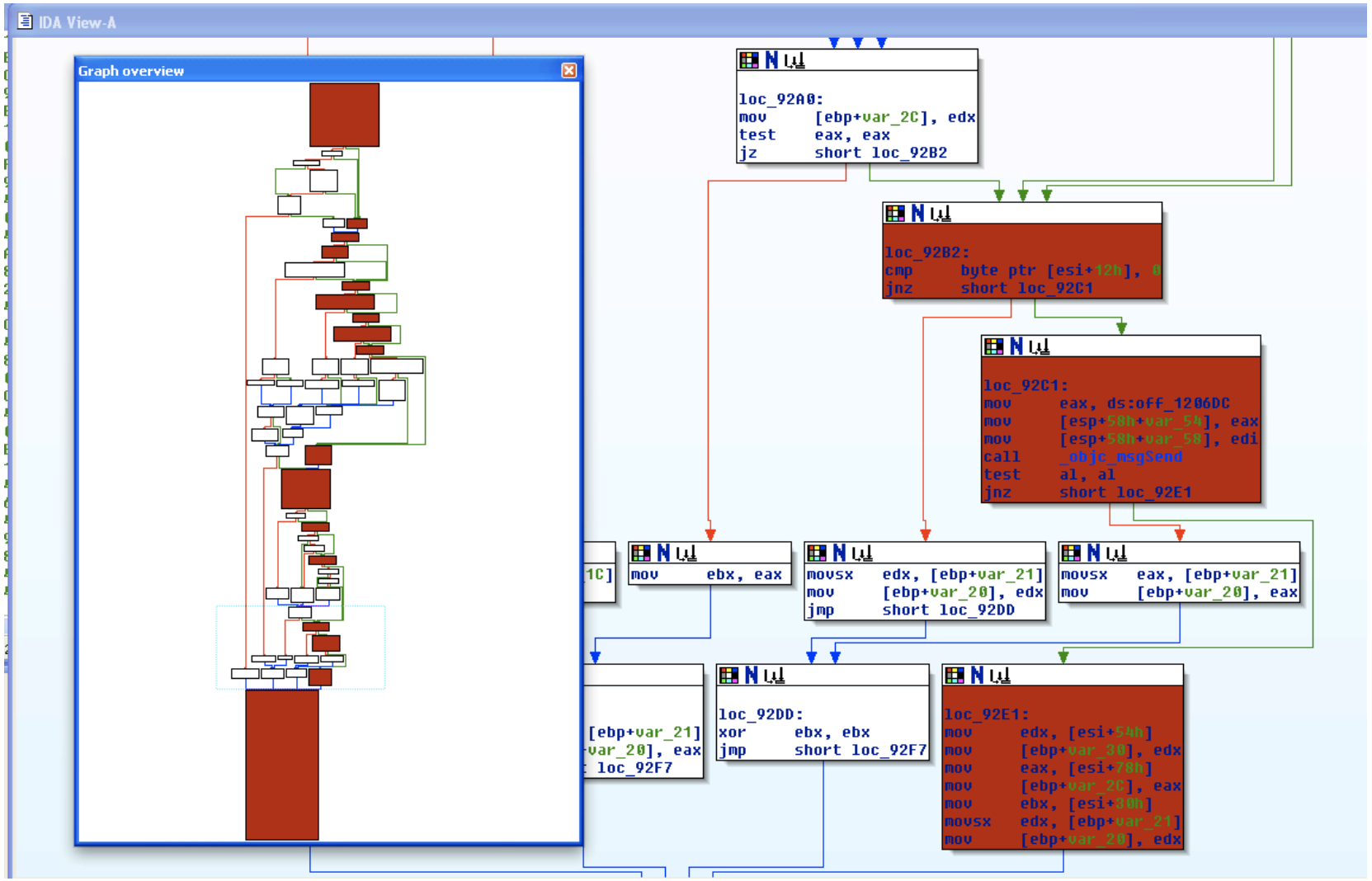
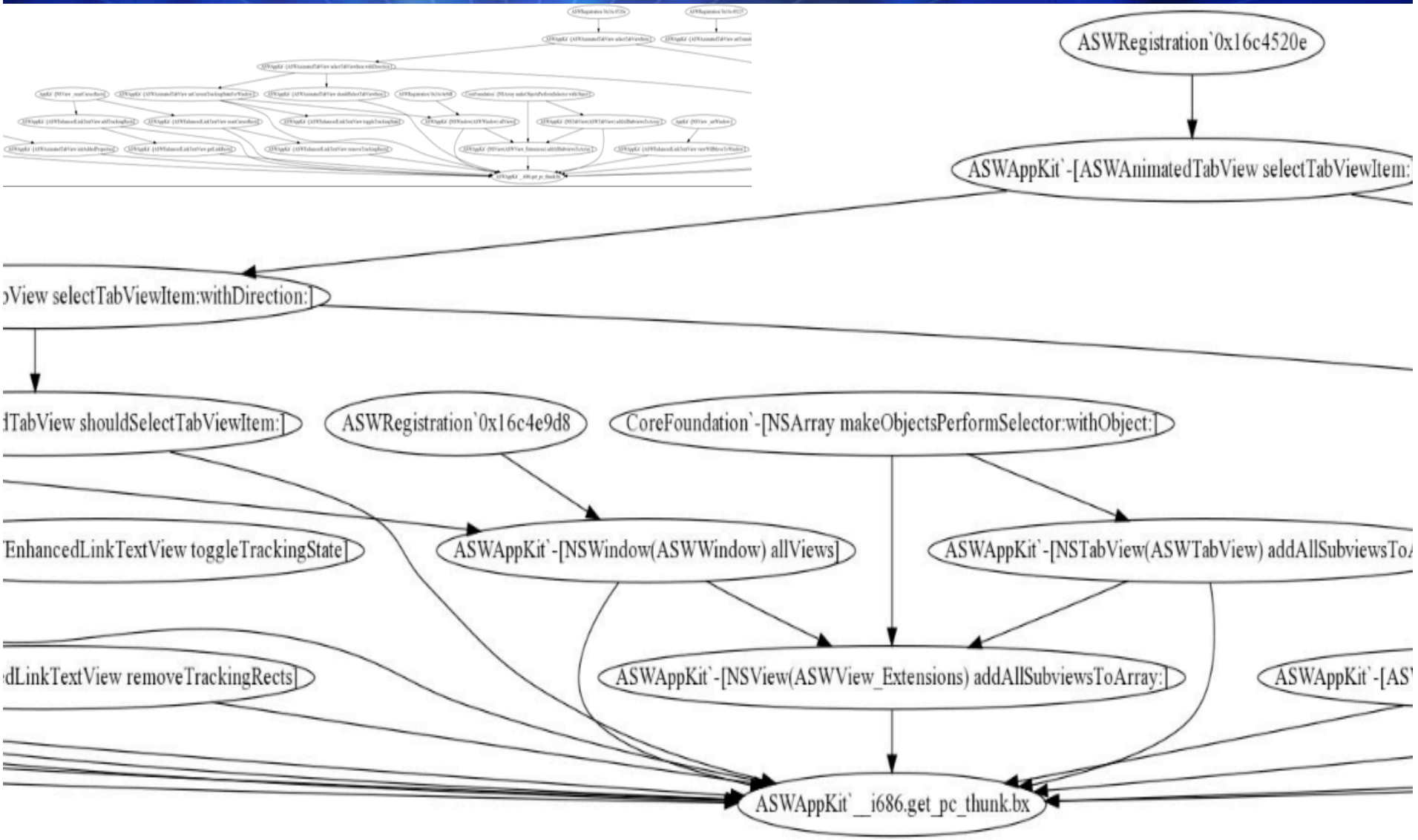
Coverage Visualization



Runtime Call Graphs



Writing a Heap Overflow Monitor

MONITORING THE HEAP

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Hackin' the Heap with RE:Trace

- The heap has become "the" major attack vector replacing stack-based buffer overflows
- Relatively common unlink() write4 primitives are no longer as "easy" to exploit on many platforms
- See Aitel and Waisman's excellent "Debugging with ID" presentation for more details
- As they point out, the key to the "new breed" of heap exploit is understanding the heap layout and allocation patterns
- ImmDBG can help you with this on Win32, and Gerrado Richarte's heap tracer can help you with visualization and double free() on Solaris and Linux

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Hackin' the Heap with RE:Trace

- Many Different ways to use DTrace for heap exploits
- Standard double free(), double malloc(), Leak Detection
- Heap Visualization (Directed Graphs/OpenGL /Instruments)
- Pesky off by one errors
- Spot app specific function pointers to overwrite
- Find heap overflows/corruptions that might not be immediately dereference

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OS X Heap Exploits

- Ltrace = Bonds on the Pirates, DTrace = Bonds on the Giants
- Like Most BSD's OS X does not store metadata "in-band"
- Older techniques such as overwriting initial_malloc_zones function pointers are dead
- You now have to overwrite app specific data
- DTrace already hooks functions to understand heap layout and allocation patterns
- A slew of Heap Tools for OS X (vmmap, MallocScribble, MallocCheckHeap, leaks)

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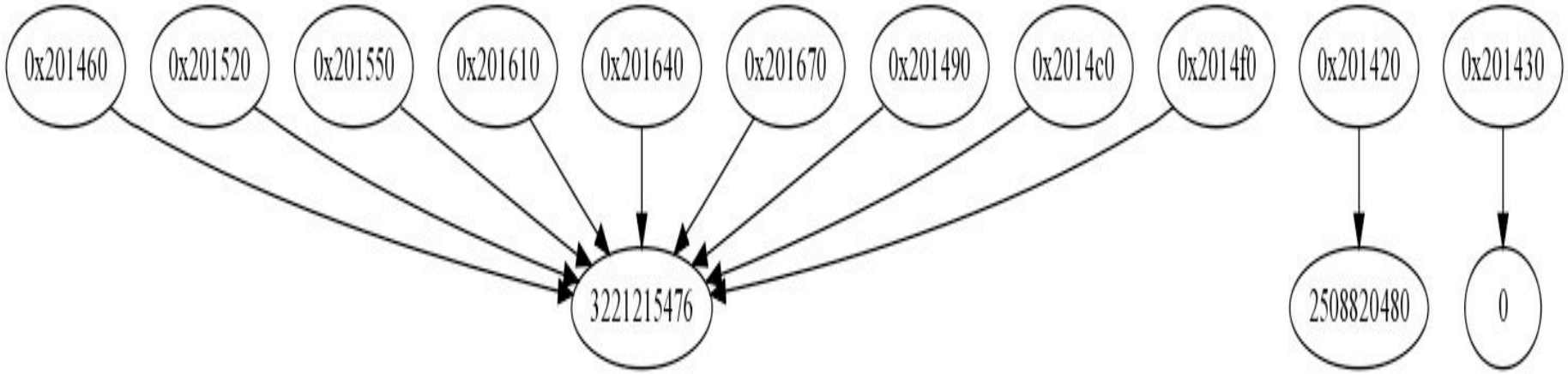
Heap Visualization

Directed Graph of Heap Allocation Sizes:



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RE:Trace Heap Smasher()

Refresher:

- When you malloc() on OS X, you are actually calling the scalable zone allocator, which breaks allocations into different zones by size:

Zone Type	Zone Size	Allocation Size	Allocation Quantum
Tiny	2MB	< 992 Bytes	32 bytes
Small	8MB	993-15-369 bytes	1024 bytes
Large	-	15,360 – 16,773,120 bytes	1 page (4096 bytes)
Huge	-	16,773,121 bytes	1 page (4096 bytes)

Adapted from: *OS X Internals A System Approach*

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RE:Trace Heap Smasher()

- In our heap smash detector, we must keep track of four different “heaps”
- We do this by hooking malloc() calls and storing them to ruby hashes with the pointer as the key and the size allocated as the value
- We break the hashes into tiny, small, large, and huge by allocation size
- We then hook all allocations and determine if the pointer falls in the range of the previous allocations. We can adjust the heap as memory is free()’d or realloc’d()

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RE:Trace Heap Smasher()

- By hooking C functions (strncpy, memcpy, memmove, etc.) we can determine if they are over-allocating to locations in the heap by looking at the arguments and comparing to our heap records

```
pid$target::strncpy:entry {
   self->sizer = arg2;
   printf("copyentry:dst=0x%p|src=0x%p;size=%i", arg0, arg1, arg2);
   self->sizer = 0;
}
```

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RE:Trace Heap Smasher()

- We can check to see if the allocation happens in a range we know about
- If it does, we know the size allocation, and we can tell if a smash will occur
- Compared to our stack smash detector, we need very few probes. A few dozen probes will hook all the functions we need
- We can attach to a live process on and off without disturbing it

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RE:Trace Heap Smasher()

- We also keep a hash with the stack frame, which called the original malloc()
- When an overflow is detected, we know:
  - Who allocated it (stack frame)
  - Who used it (function hook)
  - Where the overflowed memory is
  - How large the overflow was
  - We can find out if its ever free()'d

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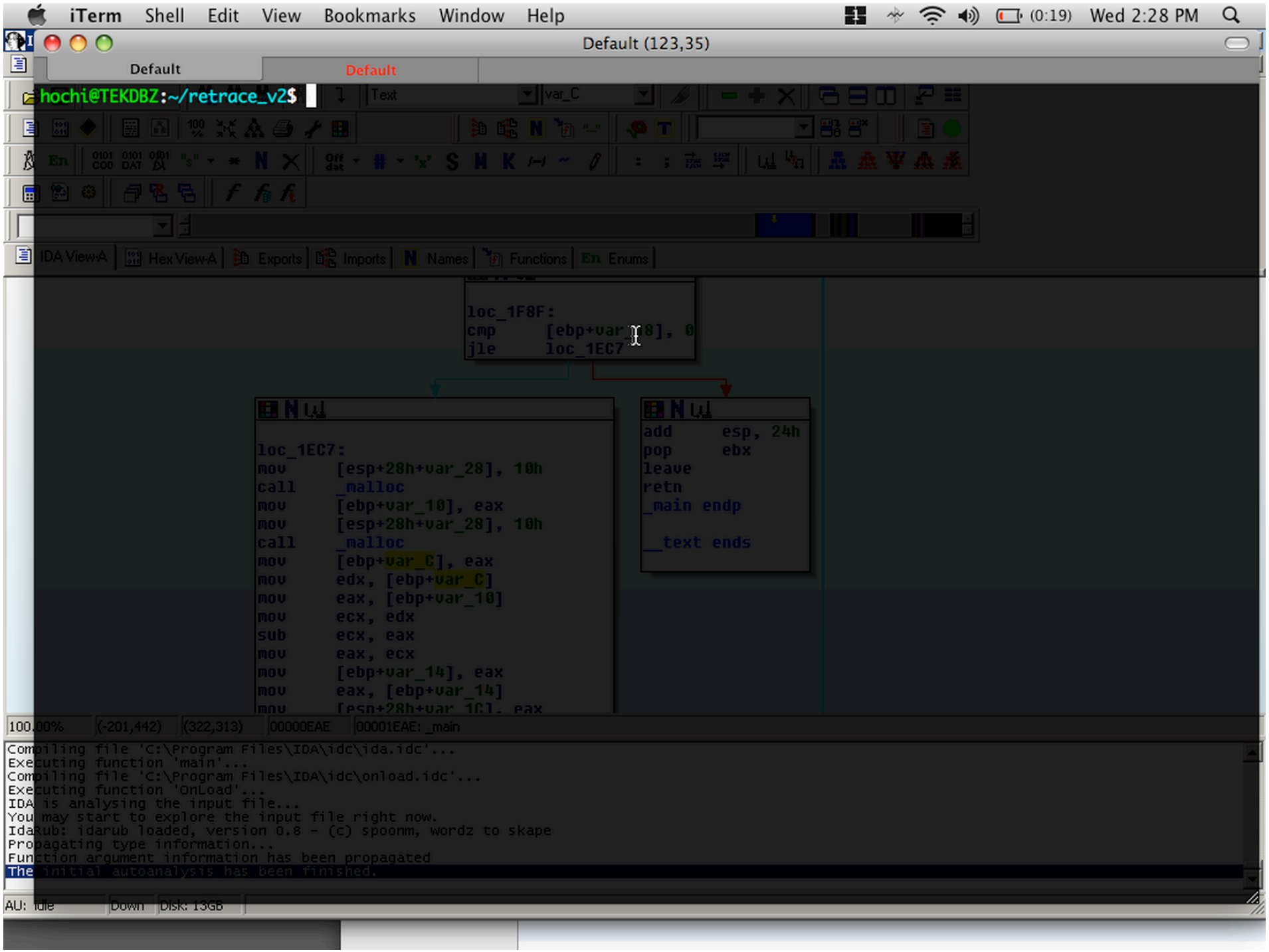
iTerm Shell Edit View Bookmarks Window Help
(0:19) Wed 2:28 PM
Default (123,35)
Default
Default
hochi@TEKDBZ:~/retrace_v2$
IDA View-A
Hex View-A
Exports
Imports
Names
Functions
Enums
loc_1F8F:
cmp [ebp+var_8], 0
jle loc_1EC7
loc_1EC7:
mov [esp+28h+var_28], 10h
call _malloc
mov [ebp+var_10], eax
mov [esp+28h+var_28], 10h
call _malloc
mov [ebp+var_C], eax
mov edx, [ebp+var_C]
mov eax, [ebp+var_10]
mov ecx, edx
sub ecx, eax
mov eax, ecx
mov [ebp+var_14], eax
mov eax, [ebp+var_14]
add esp, 24h
pop ebx
leave
retn
_main endp
__text ends
100.00% (-201,442) (322,313) 00000EAE 00001EAE: _main
Compiling file 'C:\Program Files\IDA\idc\ida.idc'...
Executing function 'main'...
Compiling file 'C:\Program Files\IDA\idc\onload.idc'...
Executing function 'OnLoad'...
IDA is analysing the input file...
You may start to explore the input file right now.
IdaRub: idarub loaded, version 0.8 - (c) spoonm, wordz to skape
Propagating type information...
Function argument information has been propagated
The initial autoanalysis has been finished.
AU: idle Down Disk: 13GB

RE:Trace Heap Smasher()

Future additions:

- Graphviz/OpenGL Graphs
- There is a new version of Firefox which has probes in the JavaScript library
- This would give us functionality to help create tools similar to Alexander Sotirov's HeapLib (Heap Fung Shui) for heap manipulation generically
- Can trigger on high level object creation or action, then trace for mallocs

- You tell me?

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Using DTrace Defensively

DTRACE DEFENSE

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Basic HIDS with DTrace

- Using Dtrace, you can profile your applications basic behavior
- See Stefano Zanero's BH 06 talk on **Anomaly detection through system call argument analysis**
- You should then be able to trace for anomalies with predicates
- This is great for hacking up something to protect a custom application (monitor for return-to-libc)
- Easy to create a rails interface for monitoring with Ruby-DTrace

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Basic HIDS with DTrace

- Problem: "I want to use QuickTime, but it's got a #@#$@# of holes"
- Solution: Make a DTrace script to call stop() when weird stuff happens
- QuickTime probably never needs to call /bin/sh or mprotect() on the stack to make it writable (Houston we have a problem)

*QuickTime® is a registered trademark of Apple Inc. in the United States and/or other countries.

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Basic HIDS with DTrace

```
#!/usr/sbin/dtrace  -q -s

proc:::exec
     /execname == "QuickTime Player" &&
     args[0] == "/bin/sh"/
{
     printf("\n%s Has been p0wned! It tried
to  spawned %s\n”, execname, args[0])
}
```

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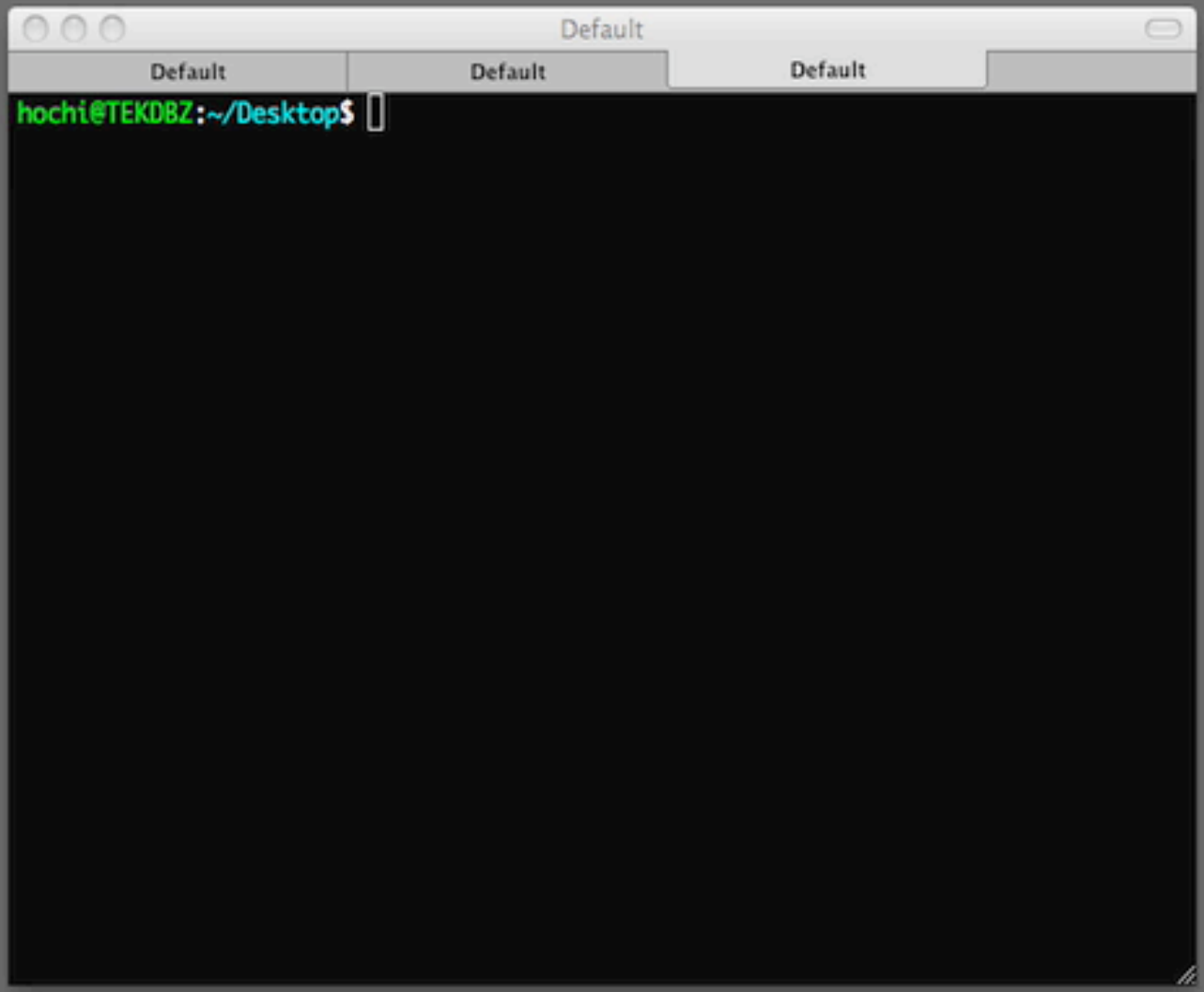
HIDS Video



DTrace and Rootkits

- Check out Archim's paper "B.D.S.M the Solaris 10 Way," from the CCC Conference
- He created the SInAr rootkit for Solaris 10
- Describes a method for hiding a rootkit from DTrace
- DTrace FBT (kernel) provider can spy on all active kernel modules
- Should have the ability to detect rootkits, which don't explicitly hide from DTrace (SInAr is the only one I could find)
- Expect more on this in the future

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DTrace for Malware Analysis

- Very easy to hack up a script to analyze MalWare
- Example: Leopard DNS Changer (**OSX.RSPlug.A)**
- Why the heck is my video codec calling…

```
/usr/sbin/scutil
add ServerAddresses * $s1 $s2
set State:/Network/Service/$PSID/DNS
```

- You can monitor file I/O and syscalls with just two lines
- Scripts to do this now included with OS X by default
- Malware not hiding from DTrace yet
- BUT Apple made that a feature (yayyy!)

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Hiding from DTrace

- In Jan. Core DTrace developer Adam Leventhal discovered that Apple crippled DTrace for Leopard
- On OS X Your application can set the "PT_ATTACH_DENY" flag to hide from DTrace just like you can for GDB
- Leventhal used timing analysis to figure out they are hiding iTunes™ from DTrace
- Very easy to patch in memory or with kext
- Landon Fuller released a kext to do this

http://landonf.bikemonkey.org/code/macosx/Leopard_PT_DENY_ATTACH.20080122.html

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OS X Kernel / Driver

KERNEL DEBUGGING

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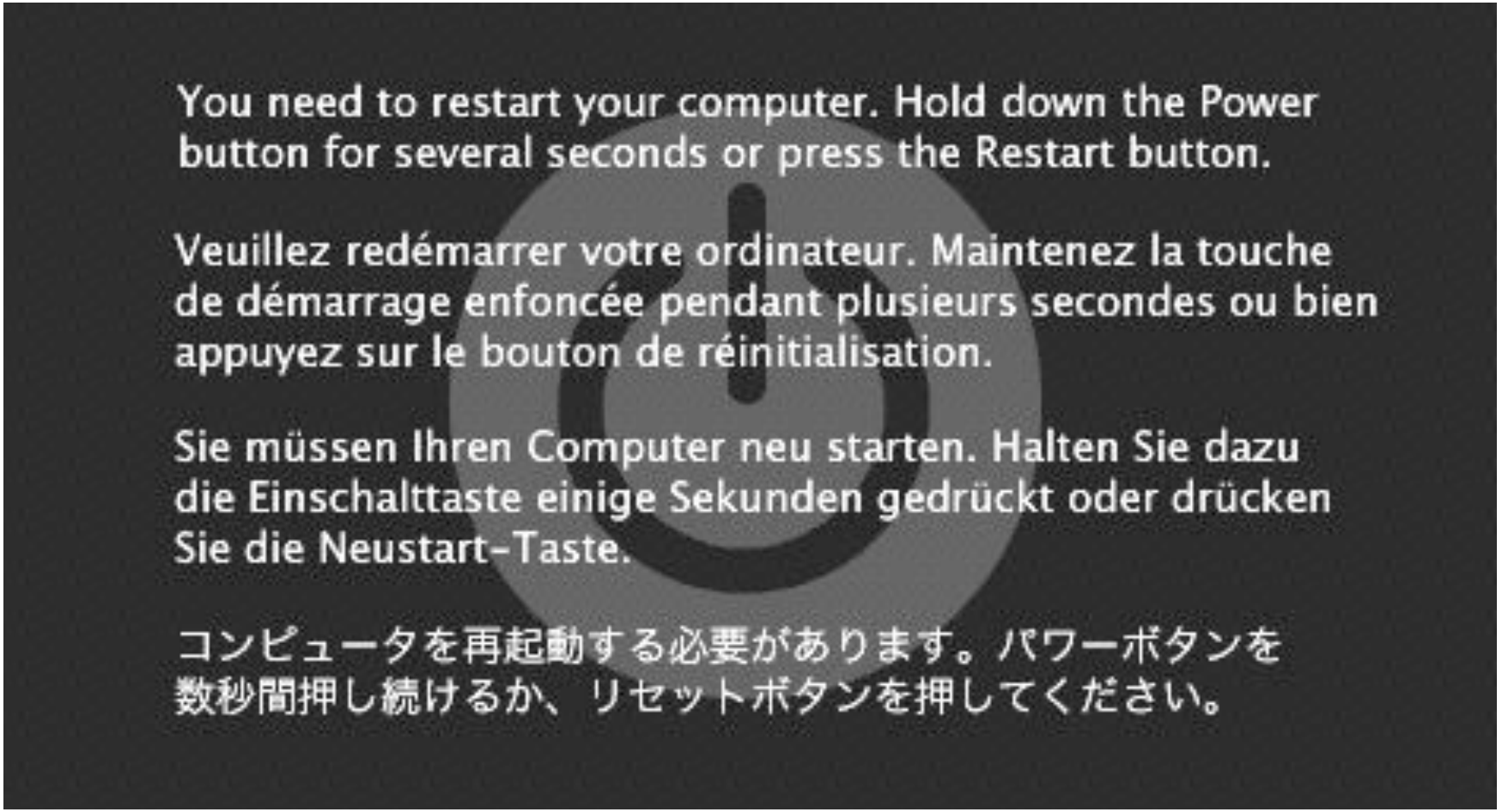
Steve Jobs' BSoD



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Panic Log

/Library/Logs/PanicReporter/

Fri Feb 8 09:30:02 2008
panic(cpu 1 caller 0x001A7BED): Kernel trap at 0x5c3f1cf9, type 14=page fault, registers:
CR0: 0x8001003b, CR2: 0x00000004, CR3: 0x013bd000, CR4: 0x00000660
EAX: 0x00000000, EBX: 0x08d74490, ECX: 0x08d74490, EDX: 0x00000000
CR2: 0x00000004, EBP: 0x7633fd98, ESI: 0xe00002ed, EDI: 0x07038200
EFL: 0x00010202, EIP: 0x5c3f1cf9, CS: 0x00000008, DS: 0x07030010
Error code: 0x00000000

Backtrace, Format - Frame : Return Address (4 potential args on stack)
0x7633fb98 : 0x12b0e1 (0x455670 0x7633fbcc 0x133238 0x0)
0x7633fbe8 : 0x1a7bed (0x45ea20 0x5c3f1cf9 0xe 0x45e1d4)
0x7633fcc8 : 0x19e517 (0x7633fce0 0x9086080 0x7633fd98 0x5c3f1cf9)
0x7633fcd8 : 0x5c3f1cf9 (0xe 0x48 0x10 0x7030010)
0x7633fd98 : 0x612470 (0x8d74490 0x0 0xe00002ed 0x0)
0x7633fdf8 : 0x88a2c7 (0x6eaf000 0x7038200 0xe00002ed 0x0)
0x7633fe68 : 0x88b7ec (0x6eaf000 0x7024240 0x0 0x0)
0x7633fed8 : 0x88b824 (0x6eaf000 0x0 0x0 0x135b0f)
0x7633fef8 : 0x88e705 (0x6eaf000 0x2 0x5366a0 0x6e4686c)
0x7633ff18 : 0x41d149 (0x6eaf000 0x6f21700 0x1 0x19ccc1)
0x7633ff68 : 0x41c2a6 (0x6f21700 0x6d77208 0x7633ff98 0x1368db)
0x7633ff98 : 0x41bf88 (0x6eaa500 0x6d95540 0x7633ffc8 0x7e56998)
0x7633ffc8 : 0x19e2ec (0x6eaa500 0x0 0x1a10b5 0x7726f20)
Backtrace terminated-invalid frame pointer 0
    Kernel loadable modules in backtrace (with dependencies):
      com.keyspan.iokit.usb.KeyspanUSAdriver(2.1)@0x5c3e2000->0x5c436fff
        dependency: com.apple.iokit.IOSerialFamily(9.1)@0x723000
        dependency: com.apple.iokit.IOUSBFamily(3.0.5)@0x60d000
      com.apple.driver.AppleUSBUHCI(3.0.5)@0x884000->0x891fff
        dependency: com.apple.iokit.IOPCIFamily(2.4)@0x63c000
        dependency: com.apple.iokit.IOUSBFamily(3.0.5)@0x60d000
      com.apple.iokit.IOUSBFamily(3.0.5)@0x60d000->0x634fff

BSD process name corresponding to current thread: kernel_task

Mac OS version:
9B18

Kernel version:
Darwin Kernel Version 9.1.0: Wed Oct 31 17:46:22 PDT 2007; root:xnu-1228.0.2~1/RELEASE_I386

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Page Fault

... Kernel trap at 0x5c3f1cf9, type 14=**page fault**, registers:

CR0: 0x8001003b, **CR2: 0x00000004**, CR3: 0x013bd000, CR4: 0x00000660

...

com.keyspan.iokit.usb.KeyspanUSAdriver(2.1)@0x5c3e2000 ->0x5c436fff

- Exception happens at 0x5c3f1cf9
- Keyspan driver is mapped to memory starting at 0x5c3e2000
- Drivers loaded page aligned so - 0x1000
- 0x5c3f1cf9 - 0x5c3e2000 - 0x1000 = 0xecf9

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0xECF9

```
__text:0000ECDD     mov     eax, [ebx+1Ch]
__text:0000ECE0     mov     [esp+28h+var_1C], eax
__text:0000ECE4     mov     eax, [ebx+20h]
__text:0000ECE7     mov     [esp+28h+var_20], eax
__text:0000ECEB     mov     [esp+28h+var_24], 13h
__text:0000ECF3     mov     eax, [ebx+138h]
__text:0000ECF9     mov     eax, [eax+4]    ; CRASH
__text:0000ECFC     mov     [esp+28h+var_28], eax
__text:0000ECFF     call    __ZN12USA28Xdriver8logEventEiiii
__text:0000ED04     mov     esi, eax
```

Registers from panic log:

...

CR0: 0x8001003b, CR2: **0x00000004**, CR3: 0x013bd000, CR4: 0x00000660

EAX: **0x00000000**, EBX: 0x08d74490, ECX: 0x08d74490, EDX: 0x00000000

...

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Kernel Debugging

- All that was done without debugging
- What if we want to inspect memory?
- What if we get different errors and we aren't sure why?
- Further debugging will be necessary

Kernel Debugging is a pain

- Require remote setup
- Need two hosts
- Export and import symbols
- Can DTrace help?

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Kernel References

Apple Technical Note TN2063:

Understanding and Debugging Kernel Panics

Apple Technical Note TN2118:

Kernel Core Dumps

Hello Debugger: Debugging a Device Driver With GDB

http://developer.apple.com/documentation/Darwin/Conceptual/KEXTConcept/KEXTConceptDebugger/hello_debugger.html

Uninformed volume 8 article 4 by David Maynor

http://www.uninformed.org/?v=8&a=4

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Leveraging Custom Application Probes

HIGHER LEVEL TRACING

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Application Probes

- Represent a more abstract action
- Browser example: Page Load, build DOM, DNS request
- Helps for gathering performance metrics
- Also tracing VM languages like Java, Python, Ruby
- Largely still in the works

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Tracing SQL Calls

- fuzz inputs
- hook the database

```
#!/usr/sbin/dtrace -s

pid$target:mysqld:*dispatch_command*:entry {
 printf("%Y %s\n", walltimestamp, copyinstr(arg2))
}
```

Example:

```
2008 Jun 15 01:02:35 INSERT INTO router (prefix,
   lladdr, mac, trusted, address) VALUES
   ('face<script>', 'face''', 'face;--', 1,
   'face"')
```

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Future Work

- Automated feedback and integration with fuzzers
- More experimenting with Kernel tracing
- Improved overflow monitoring
- Memory allocation analysis libraries (will help port Sotirov's HeapLib to ActiveX, DHTML version or other browsers/OSes)
- Garbage collection behavior analysis
- More on utilizing application-specific probes (probes for JS in browsers, MySQL probes, ...)
- New Probes: Network providers, IP send & recv

Your own ideas!

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Conclusion

DTrace can:

- Collect an unprecedented range of data
- Collect very specific measurements
- Scope can be **very broad** or **very precise**

Applied to Reverse Engineering:

- Allows researchers to pinpoint specific situation (overflows)
- Or to understand general behavior (heap growth)

RETRACE + REDBG + IDA!

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Thank You!

See the RE:Trace framework for implementation:

(redbg coming soon!)

http://www.poppopret.org/

Questions?

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