iOS App Performance

Memory

Session 242

Morgan Grainger
Software Engineer

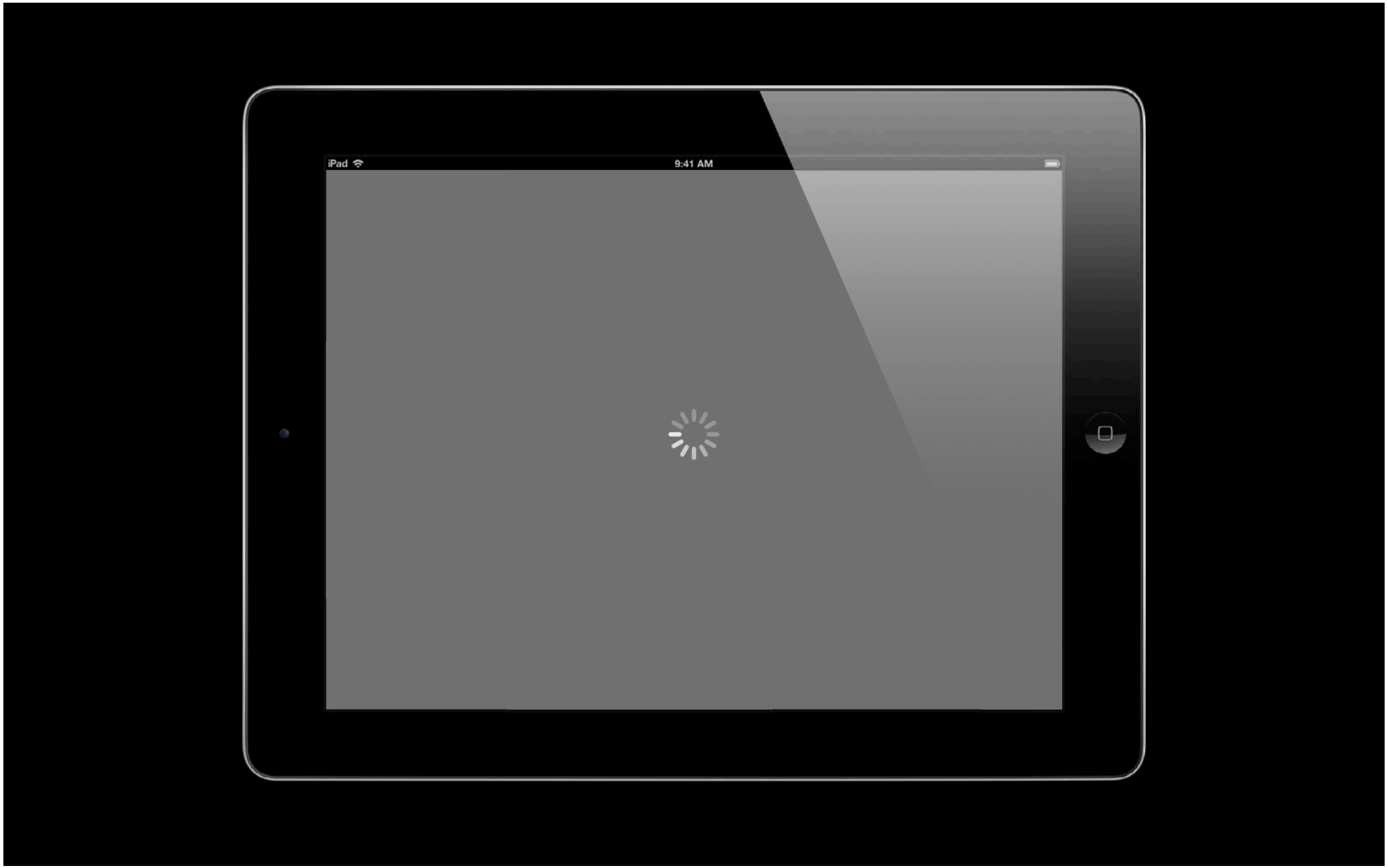
Agenda

- Memory Landscape
- iOS Memory Fundamentals
- Memory Pressure
- Finding Memory Issues
- Tools Tips and Tricks

iOS Memory Landscape

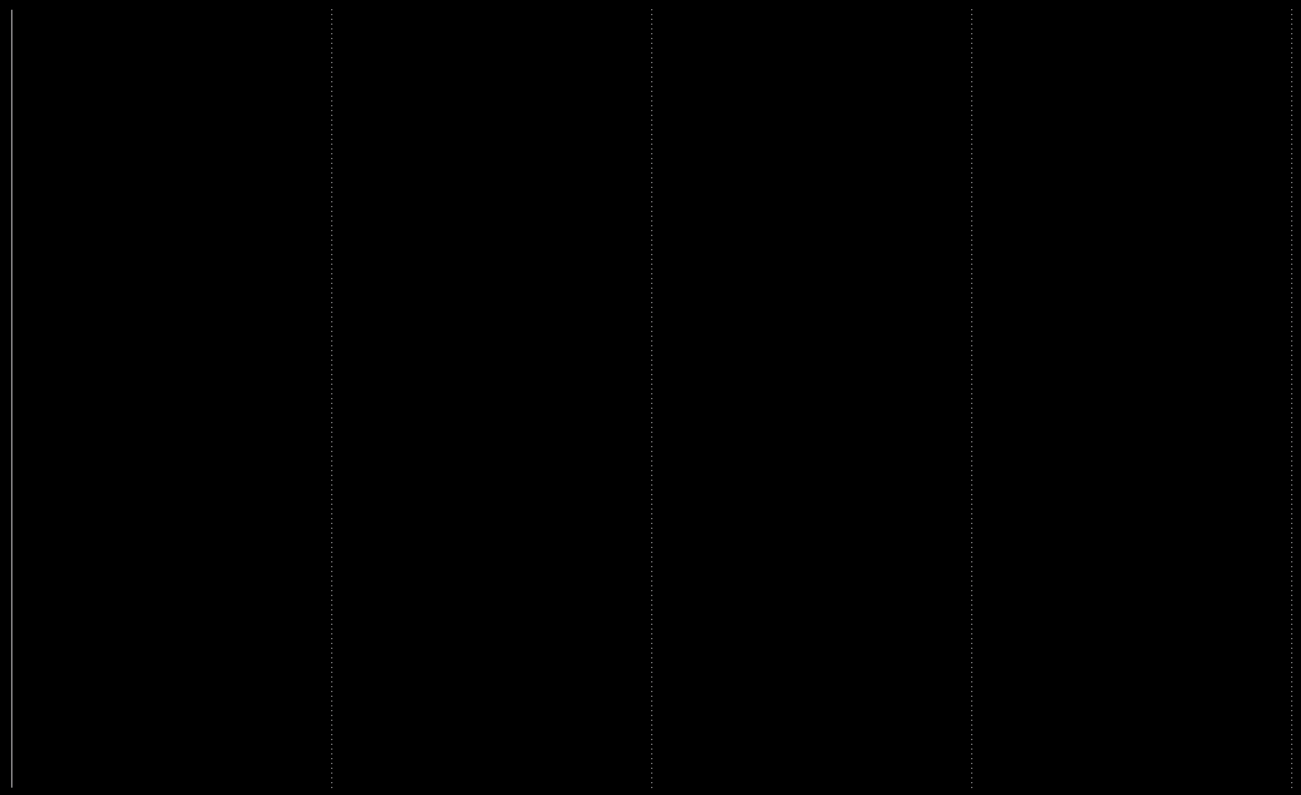

iPad
9:41 AM


iPad
9:41 AM
Messages
FaceTime
Photos
Camera
Maps
YouTube
Clock
Photo Booth
Monday
11
Calendars
Contacts
Notes
Reminders
Newsstand
iTunes
App Store
Game Center
Settings
Safari
Mail
Videos
Music


iPad
9:41 AM

“I love this app, but it always crashes after a few minutes.”

The March of Progress



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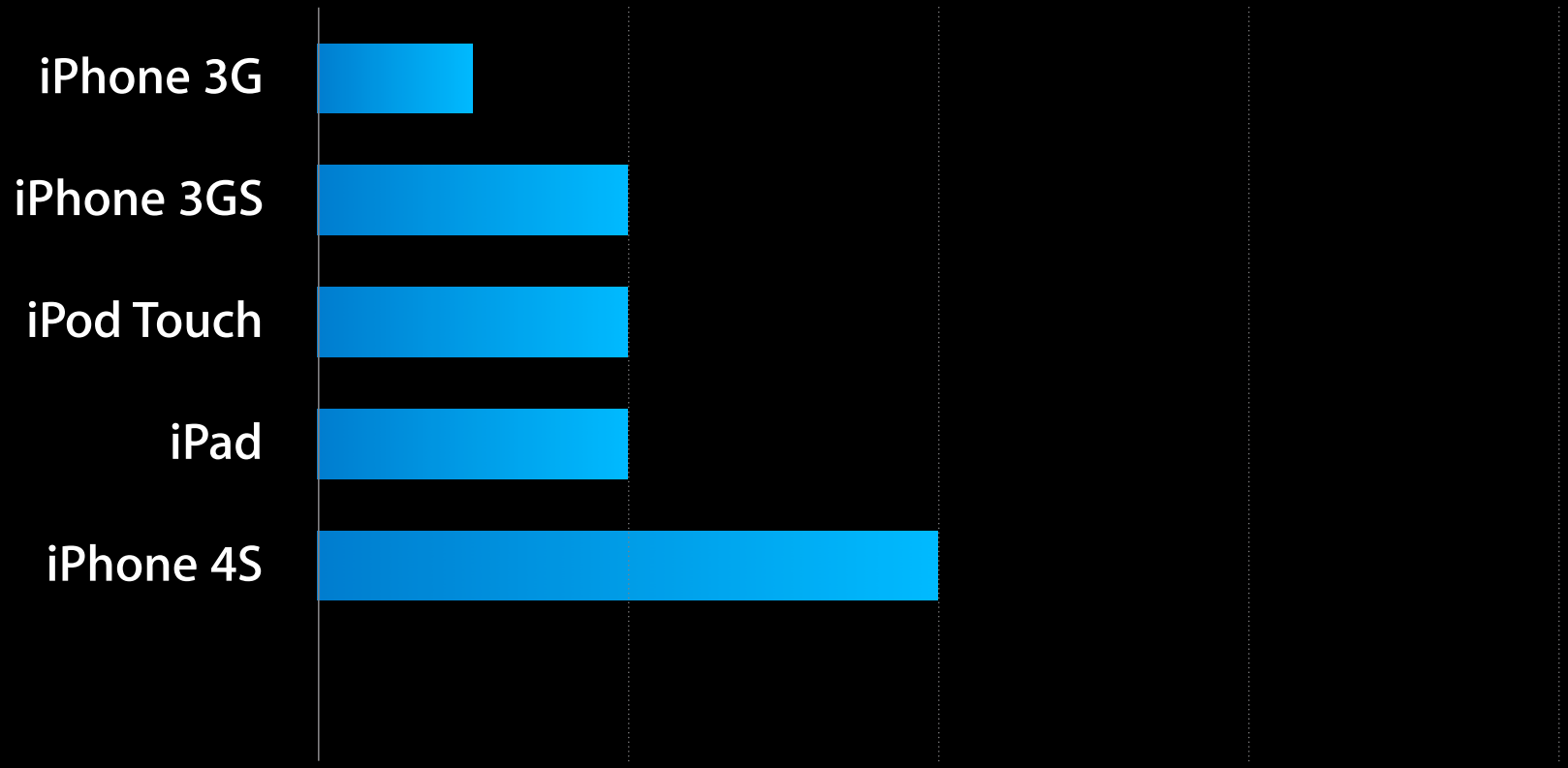

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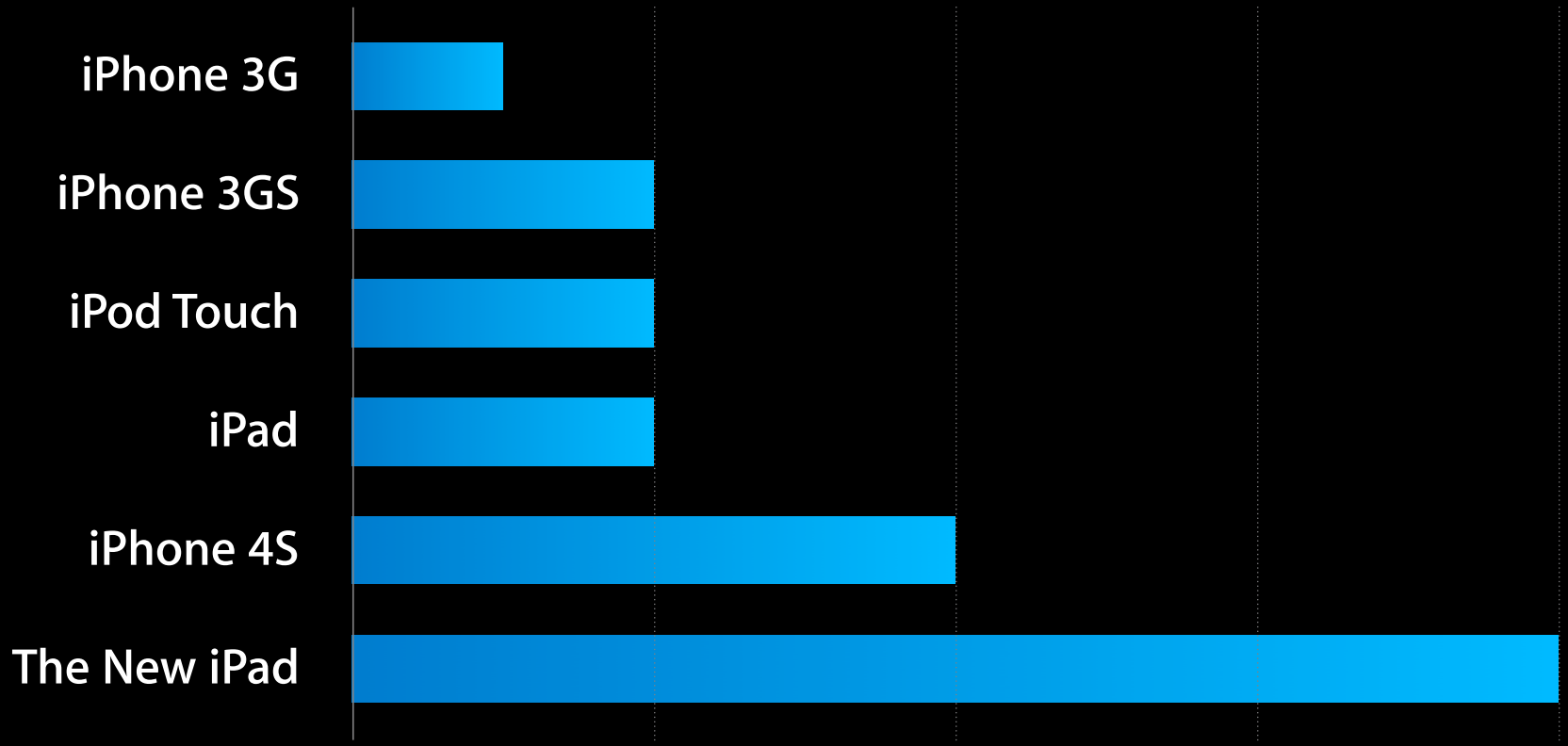


iPad
9:41 AM
Friday
7
Messages
Calendar
Notes
Reminders
Maps
YouTube
Videos
Contacts
Game Center
iTunes
App Store
Newsstand
FaceTime
Camera
Photo Booth
Settings
Safari
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iPad
9:41 AM
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iOS Memory Fundamentals

Understanding Low Memory

Understanding Low Memory

```
Incident Identifier: C6CCECE6-E2B8-4426-B4D1-BE56599AE468
CrashReporter Key:   4b2eb6dfff066742d067aa5d505790a9338464cb
Hardware Model:      iPhone2,1
OS Version:          iPhone OS 6.0
UDID:                e1cbbbfbd5af450138d6c7a144900e62d171d48f
Date:                2012-06-11 09:41:00 -0700

Free pages:        507
Active pages:      1062
Inactive pages:    646
Throttled pages:   47919
Purgeable pages:   0
Wired pages:       14566
Largest process:   YourApp

Processes
Name                        <UUID>                            rpages          [reason]       (state)

      YourApp    <c6bf10738ad63bac97674e0b50d3ba55>          23197            [vm]       (frontmost) (continuous)
         afcd    <cb4f085516ba37c89a093107b0633c31>            114            [vm]       (daemon) (idle)
  MobilePhone    <baac0168db6f30b4917122274bd18450>            944            [vm]       (resume) (continuous)
         tccd    <10049f303aea3df3a4a8f26a9716fb2f>            172            [vm]       (daemon)
          kbd    <ff9db8dd78203f279706712c9d98bb6c>            375            [vm]       (daemon)
         ptpd    <efffd169c8d33a79a4ba5d30ea2962b6>           1682                       (daemon)
     powerlog    <d7555671415f3fd3800623765604b587>            524                       (daemon)
      syslogd    <7477c8ba4f0e356bb3ea615fc9976685>            147                       (daemon)
        wifid    <c84d495dee503822a1ac7d11701c526b>            497                       (daemon)
   aosnotifyd    <ead3ebb514a3339b80ea4ed739ce53c5>            401                       (daemon)
          atc    <8b3cbb041b453e3fa0521c11f52b731c>            778                       (daemon)
iaptransportd    <04a9afc8f43035b58faa81e1b3831bb9>            187                       (daemon)
    locationd    <04d2854a2b6b3a34ab5d0e0330b72e4e>           1067                       (daemon)
  SpringBoard    <ad72e5c25ca43ebbaedf427ee56d153f>           4003
```

iOS Memory Fundamentals

What you'll learn

- How is memory allocated and managed on iOS?
- What types of memory use matter?
  - Clean and dirty
- What happens when iOS runs low on memory?

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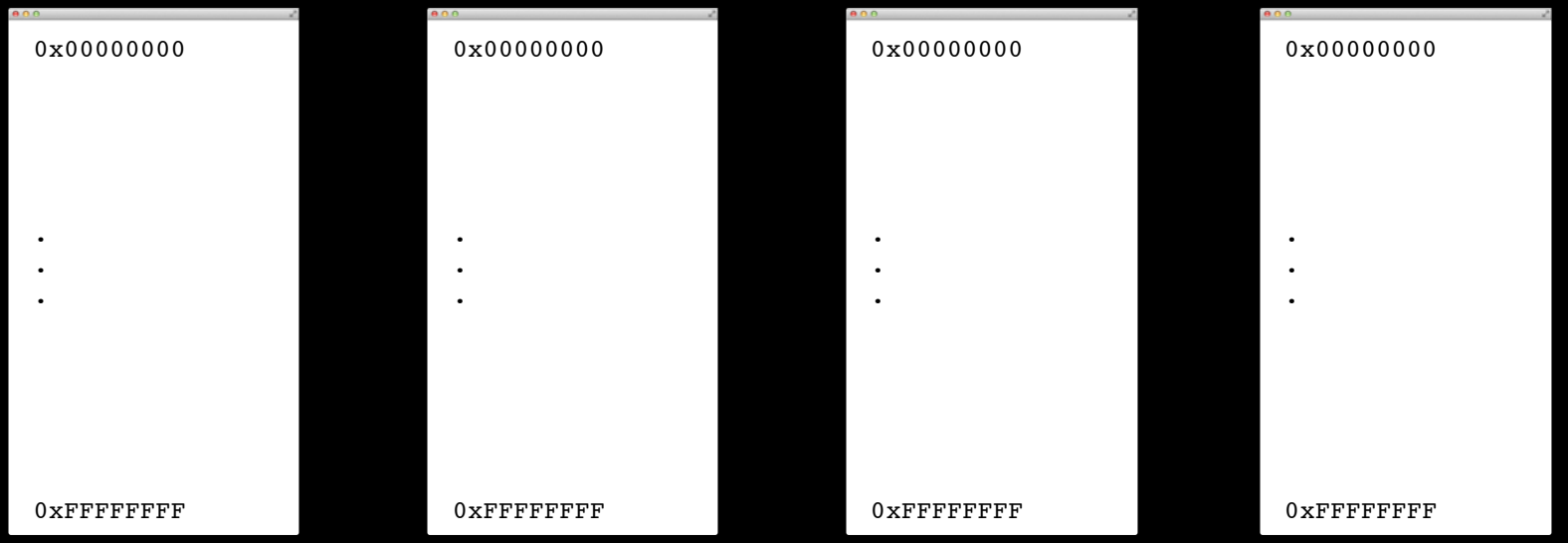
Address Space Fundamentals



Safari Mail Calendar Contacts

Do the Math

Do the Math

$$2^{32} = 4\ GB$$

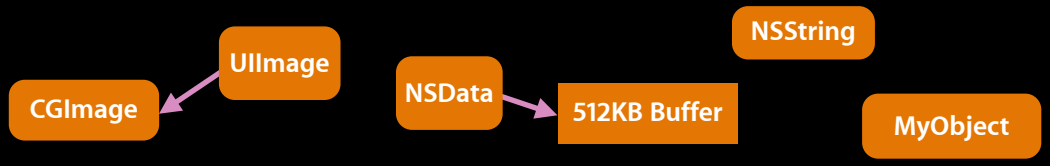
Pointer Range

Virtual Memory

- Physical memory divided into 4 KB pages
- Not all pages in memory at once

Virtual Memory

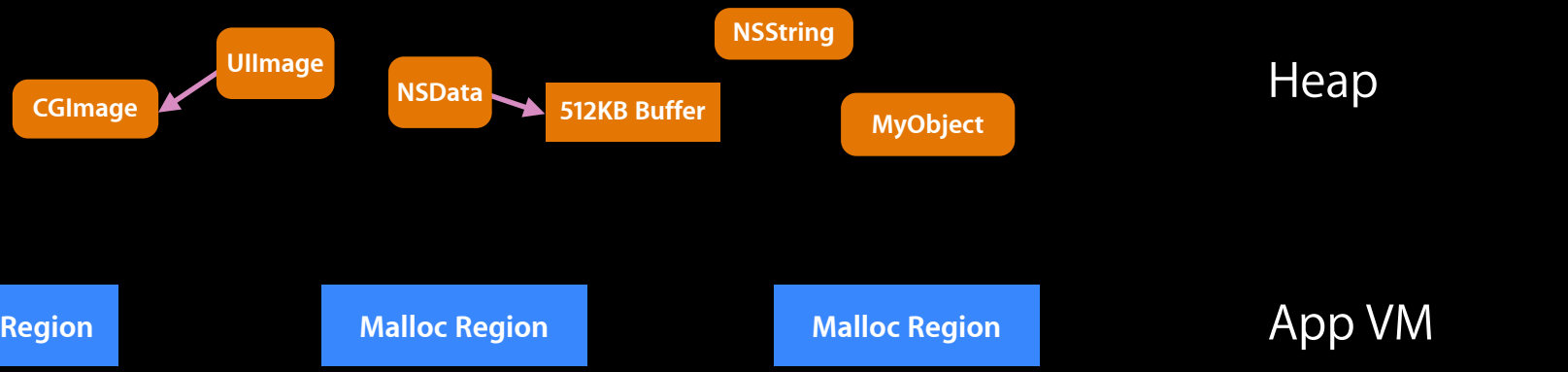
Virtual Memory



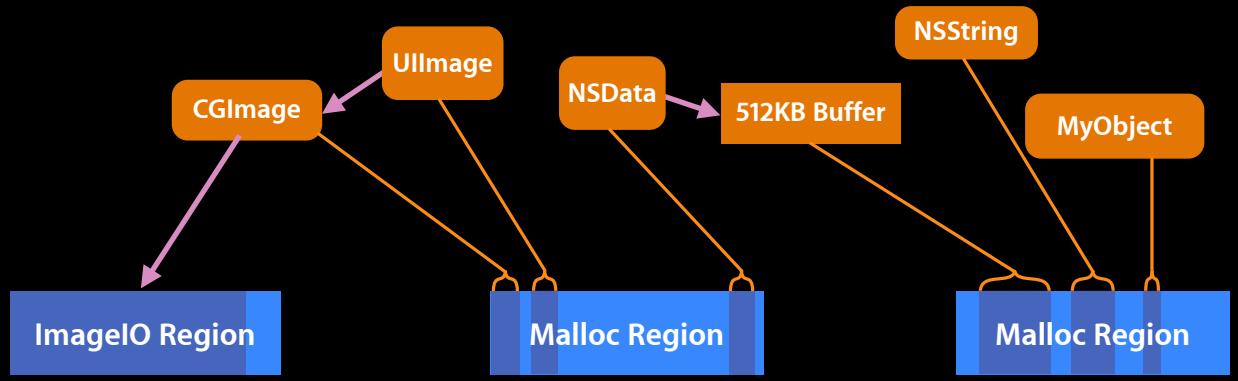
Heap

Physical Mem

Virtual Memory



Virtual Memory

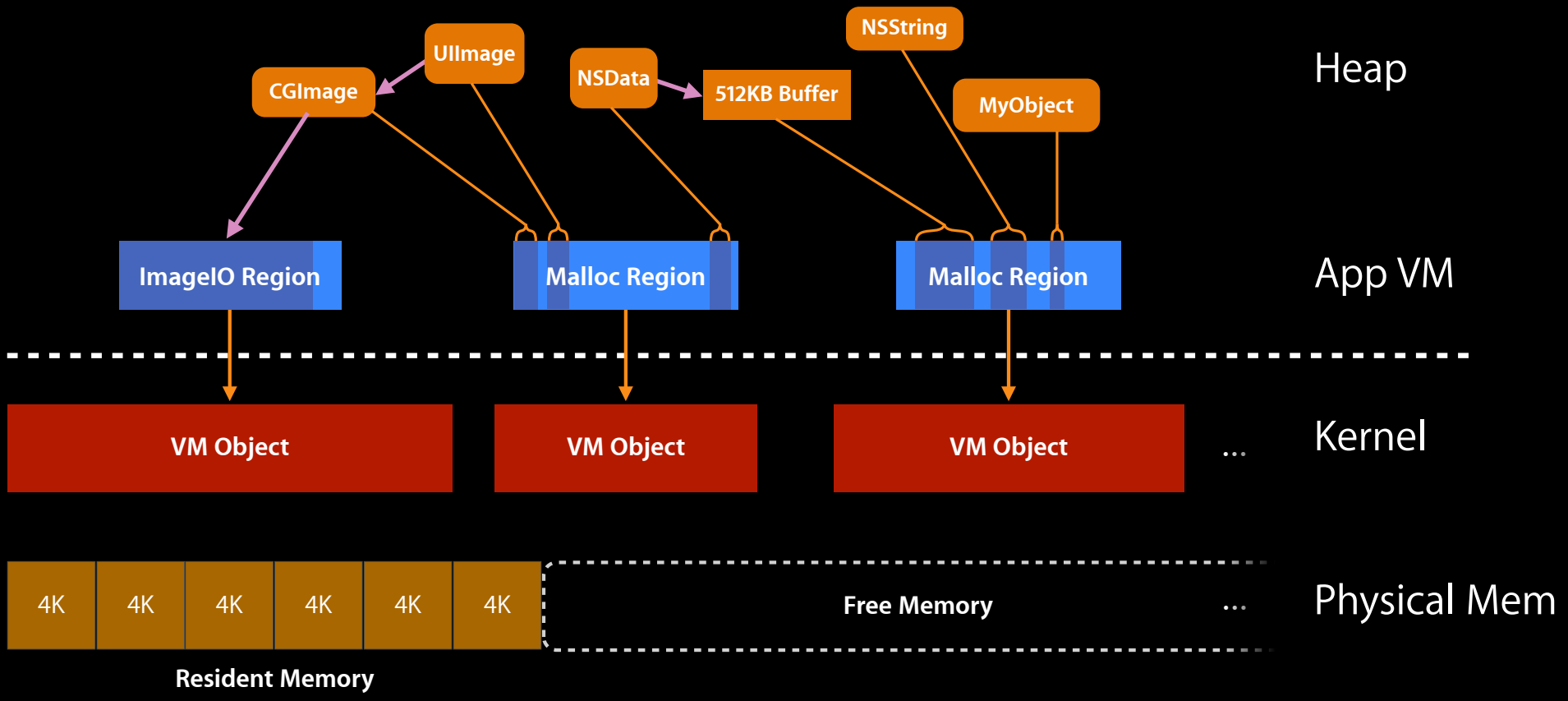


Heap

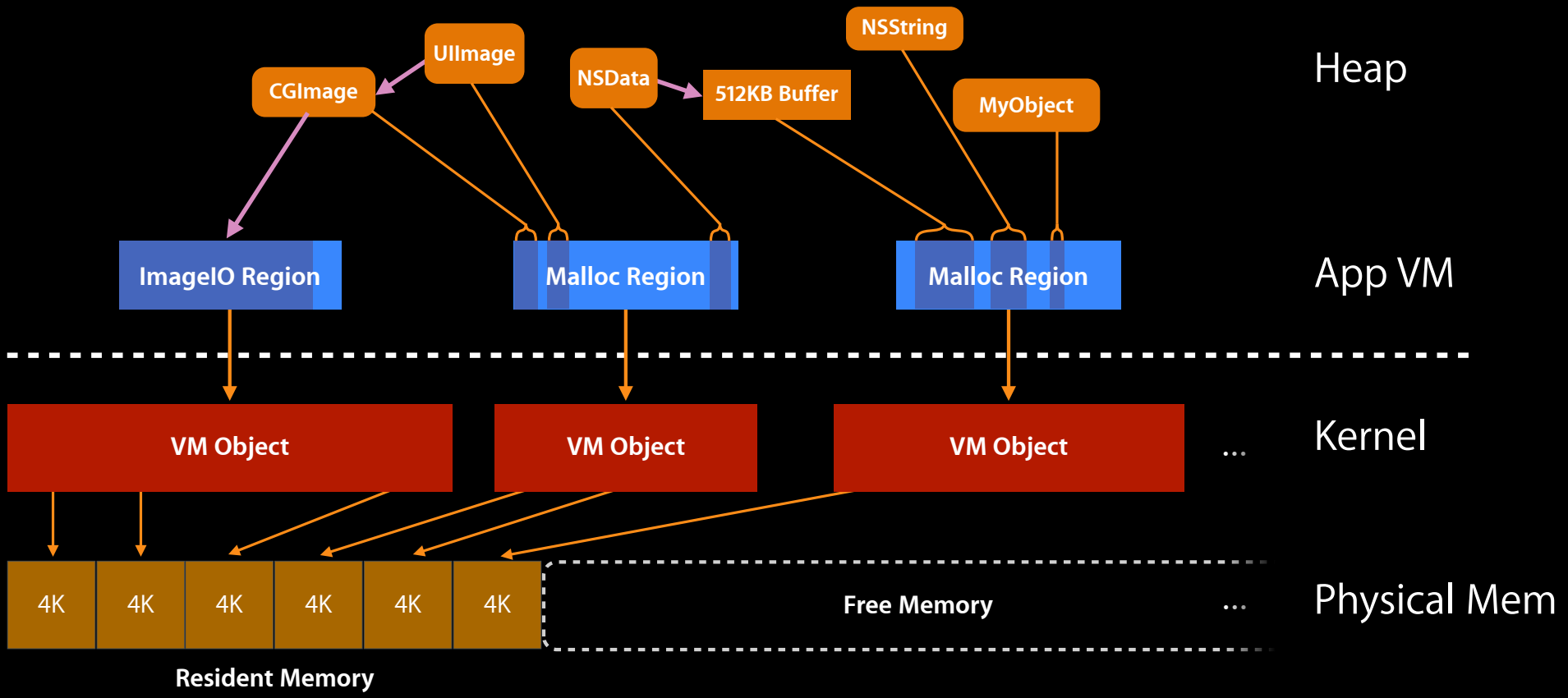
App VM

Physical Mem

Virtual Memory

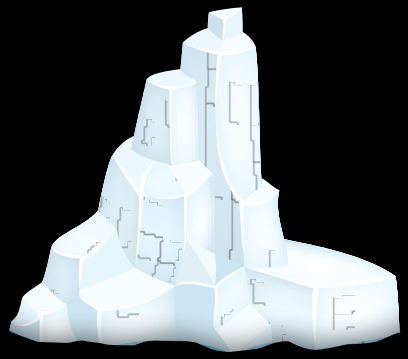


Virtual Memory



Memory Footprint

Heap Memory



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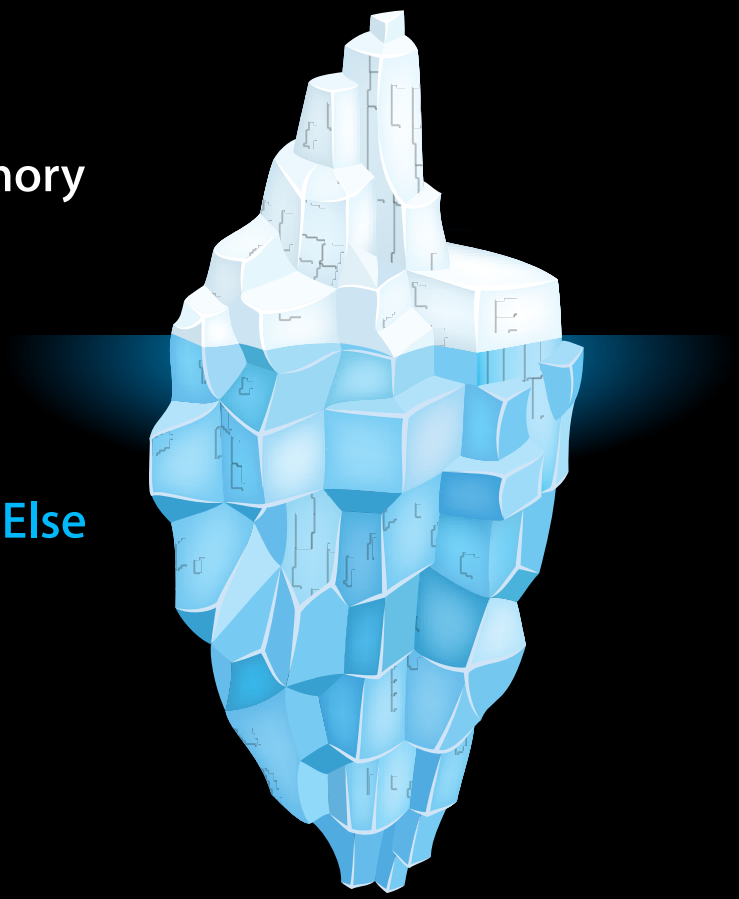
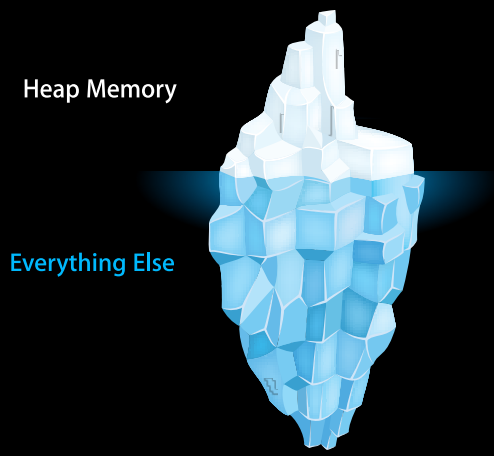


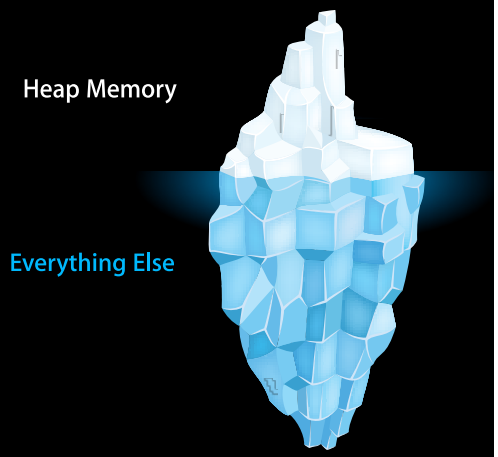
Everything Else

Memory Footprint



More Than Just Objects

- Heap memory
  - +[NSObject alloc]/malloc
  - Objects/buffers allocated by frameworks
- Other memory
  - Code and globals (__TEXT, __DATA)
  - Thread stacks
  - Image data
  - CALayer backing stores
  - Database caches
- Additional memory outside of your application!



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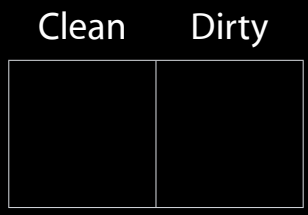
Evicting Memory

- Destructive if memory cannot be retrieved or recreated
  - Only recourse is to terminate the owning process
- *Clean memory:* memory for which a copy exists on disk
  - Code, frameworks, memory-mapped files
- *Dirty memory:* everything else
  - Heap allocations, decompressed images, database caches

Clean or Dirty?

The game show

Clean or Dirty?




```
- (void)displayWelcomeMessage {

    NSString *welcomeMessage = [NSString stringWithUTF8String:
                                    “Welcome to WWDC!”];

    self.alertView.title = welcomeMessage;
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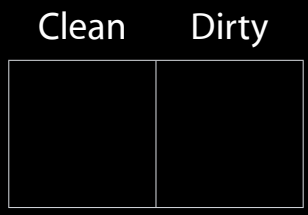


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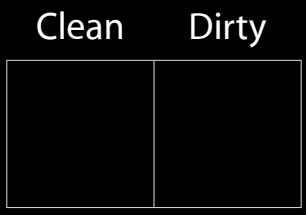


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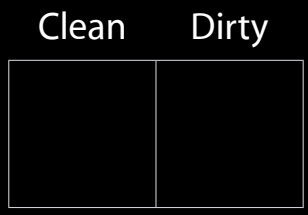


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        buf[i] = (char)random();
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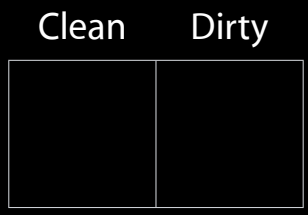


```
UIImage *wwdcLogo = [UIImage imageNamed:@”WWDC12Logo”];
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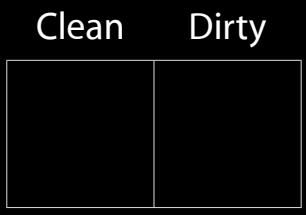
Clean or Dirty?

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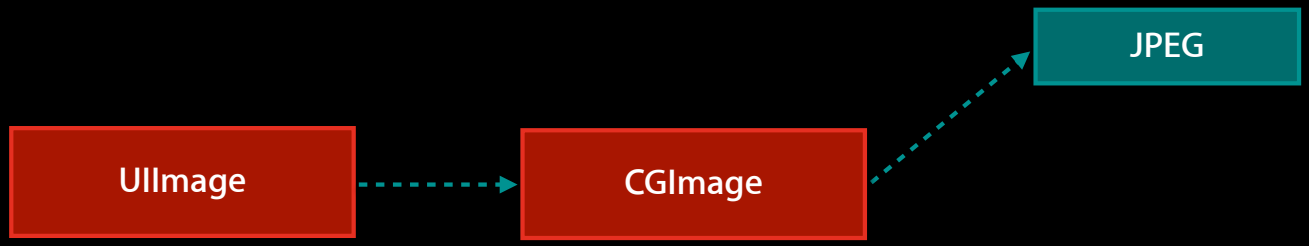

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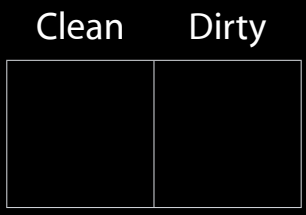


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UIImage *wwdcLogo = [UIImage imageNamed:@"WWDC12Logo"];
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…
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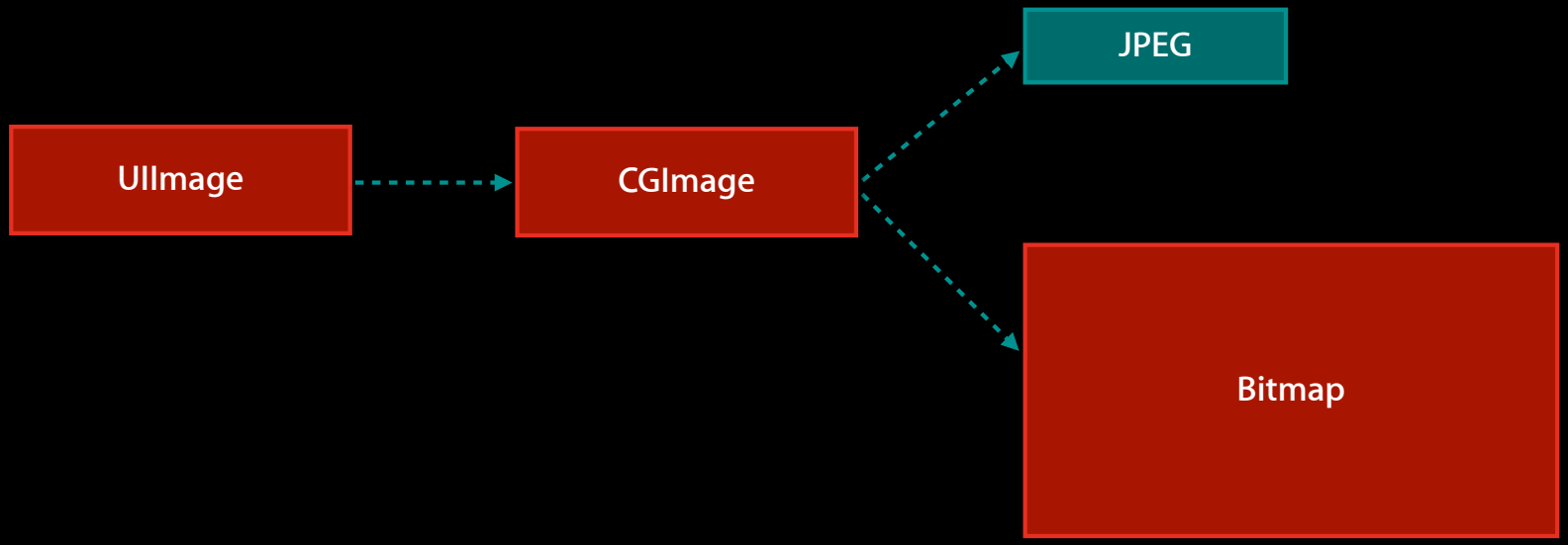

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Clean	Dirty
	✓

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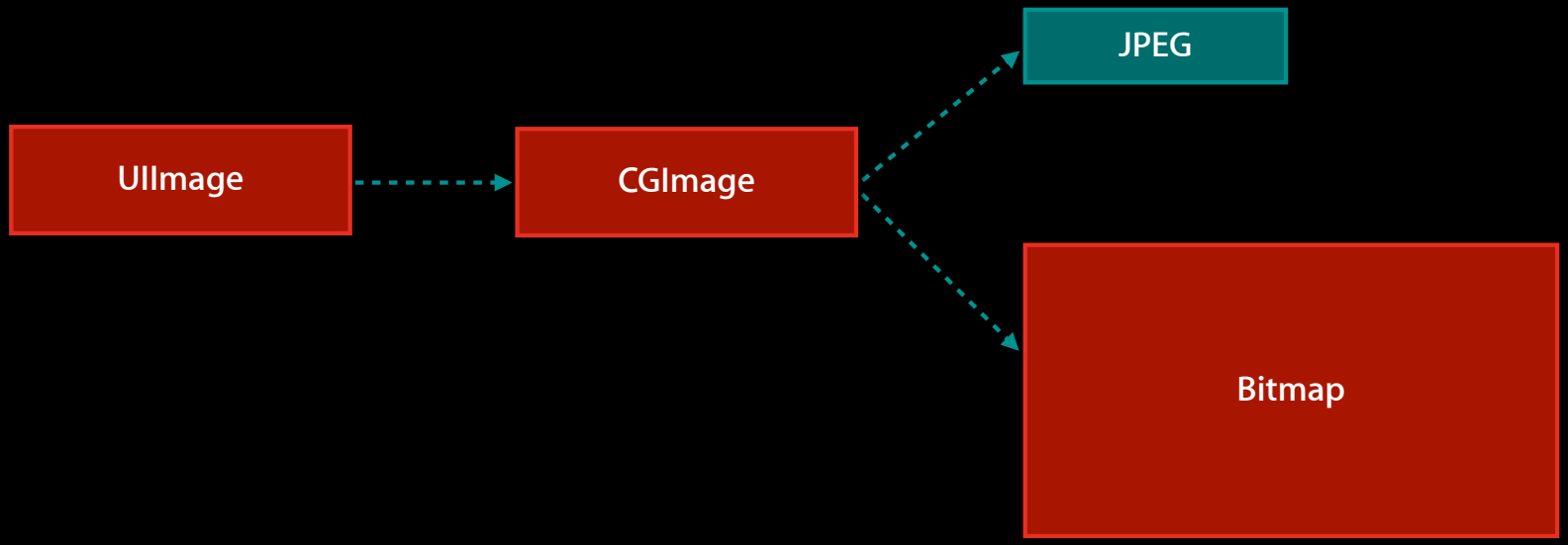
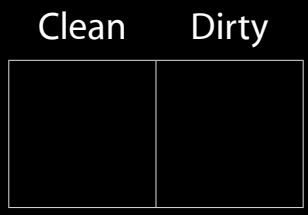


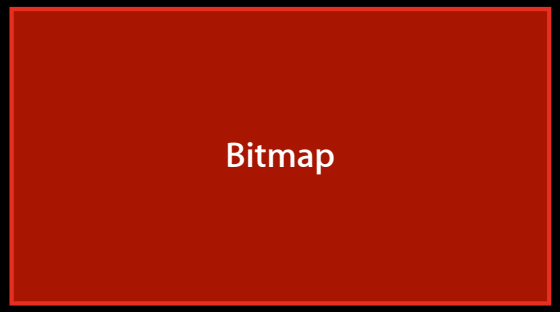
Clean or Dirty?


```
UIGraphicsBeginImageContext();
```

Clean or Dirty?




```
UIGraphicsBeginImageContext();
[[myview layer] renderInContext:UIGraphicsGetCurrentContext()];
```



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UIImage *snapshot = UIGraphicsGetImageFromCurrentImageContext();
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Clean	Dirty
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Most App Allocations are Dirty

iOS Memory Fundamentals

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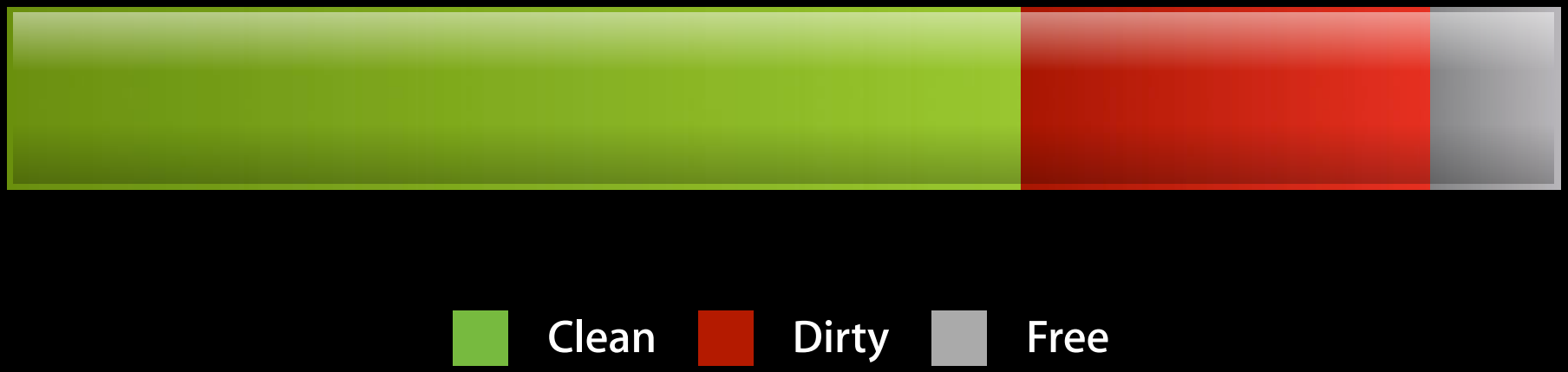
Managing System-Wide Memory



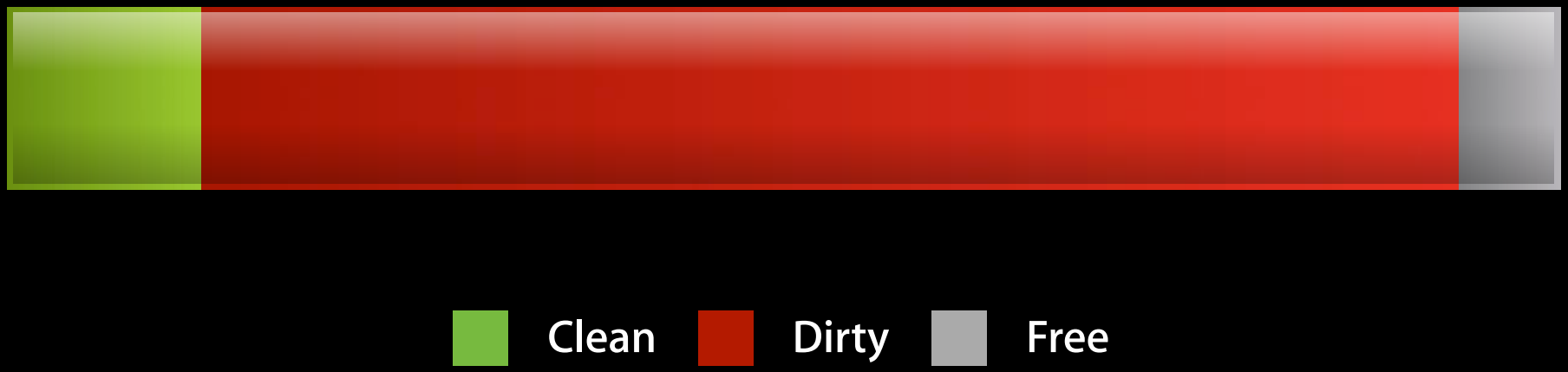
Managing System-Wide Memory

Launch Your App

Clean Dirty Free

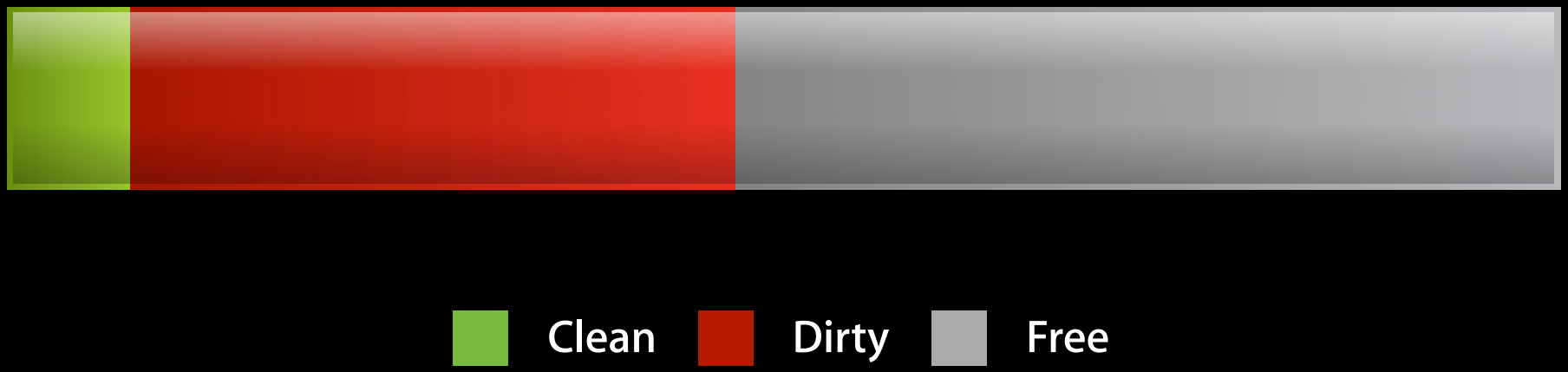
Managing System-Wide Memory

Memory Pressure



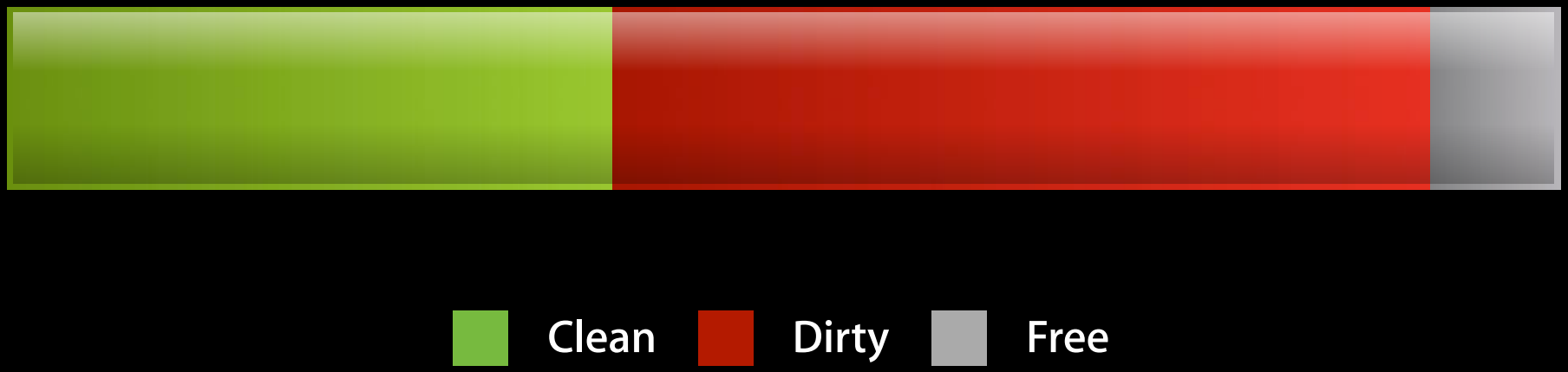
Managing System-Wide Memory

Terminate Background Apps



Managing System-Wide Memory

Run Some Other Apps



Memory Warnings

A challenge

- Fact of life on memory-constrained devices

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- Last chance to preserve user experience

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Memory Warnings

A challenge

- Fact of life on memory-constrained devices
- Last chance to preserve user experience
- Ensure that your application can respond
  - Notifications arrive on main thread
  - Avoid large, rapid allocations
- Stay safe in the background
  - `-[id <UIApplicationDelegate> -applicationDidEnterBackground:]`

Memory Warnings

An opportunity

Memory Warnings

An opportunity

- Free as much as possible
  - But don’t sacrifice user experience

Memory Warnings

An opportunity

- Free as much as possible
  - But don't sacrifice user experience
- Many ways to respond
  - `UIApplicationDidReceiveMemoryWarningNotification`
  - `-[id <UIApplicationDelegate> -applicationDidReceiveMemoryWarning:]`
  - `-[UIViewController didReceiveMemoryWarning]`

Memory Warnings

An opportunity

- Free as much as possible
  - But don't sacrifice user experience
- Many ways to respond
  - `UIApplicationDidReceiveMemoryWarningNotification`
  - `-[id <UIApplicationDelegate> -applicationDidReceiveMemoryWarning:]`
  - `-[UIViewController didReceiveMemoryWarning]`
- No longer necessary or called
  - ~~`-[UIViewController viewDidUnload]`~~

Memory Limits on Devices

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- How much can you use?

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- How much can you use?
- Test on each device

Memory Limits on Devices

- How much can you use?
- Test on each device
- Limit of 650 MB on the new iPad
  - Provides certainty

Memory Limits on Devices

- How much can you use?
- Test on each device
- Limit of 650 MB on the new iPad
  - Provides certainty
- Use less if possible

Demo

VM Tracker

Pay Attention to Dirty Memory!

Avoid Usage Spikes

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- Memory high-water mark matters

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- Memory high-water mark matters
  - Use Allocations and VM Tracker graphs to identify spikes

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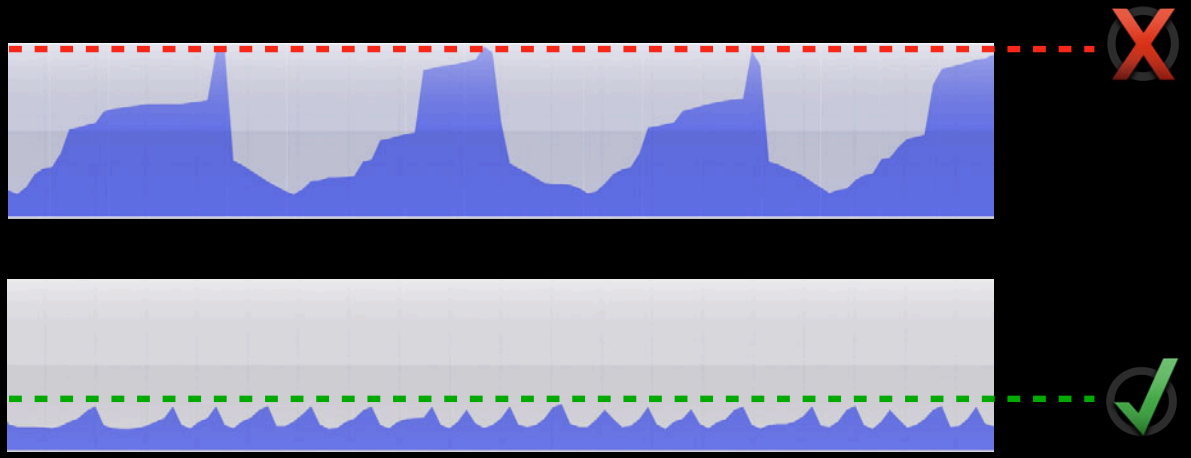
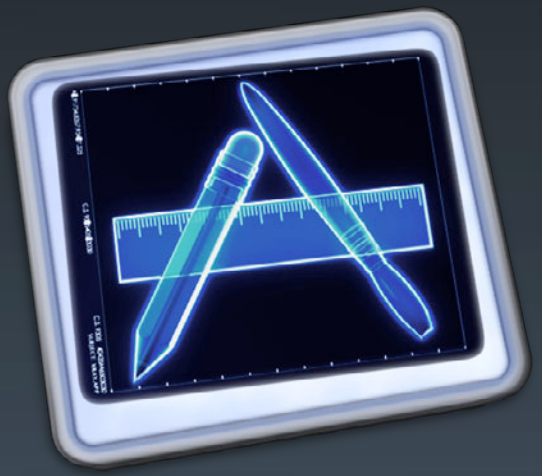
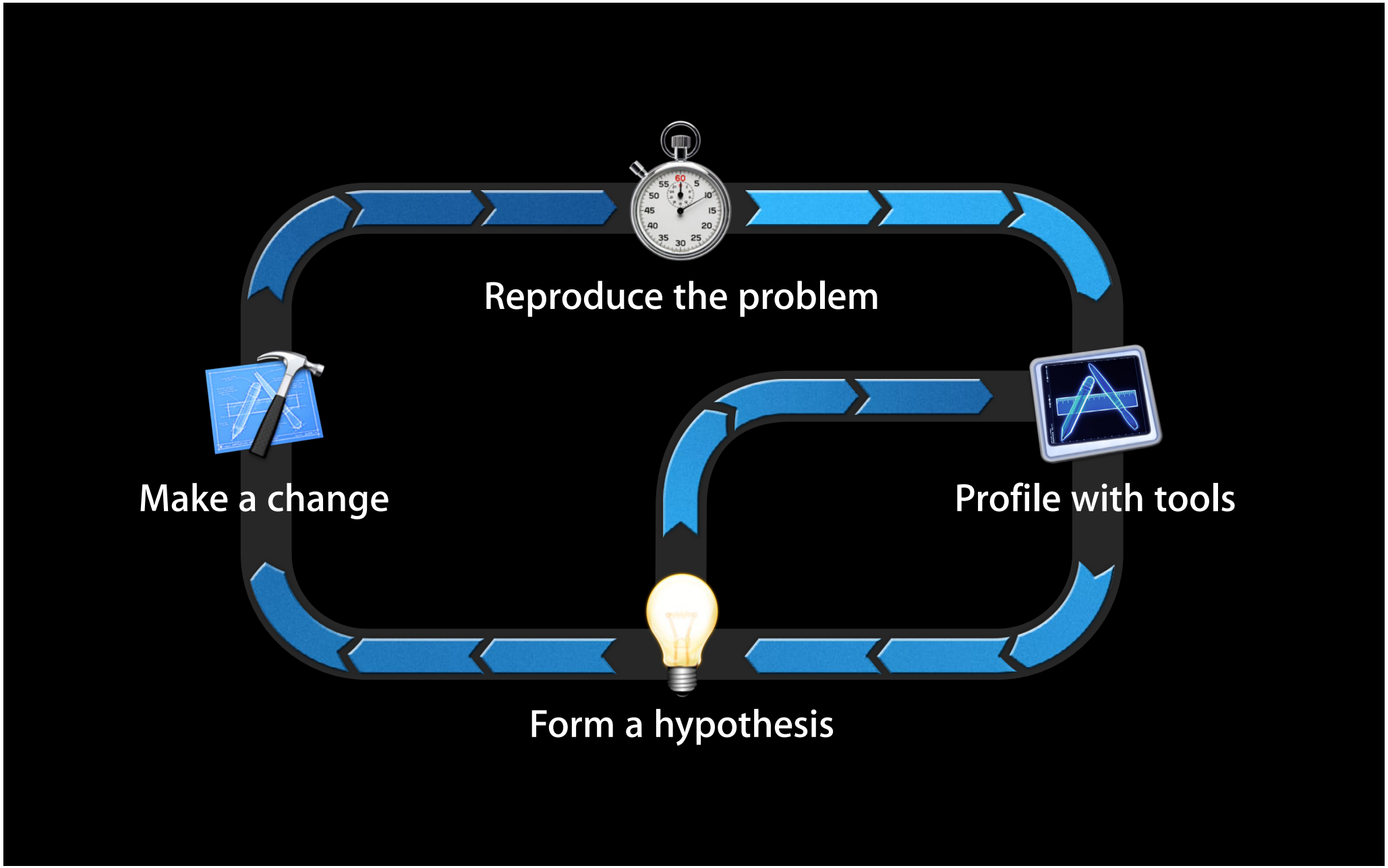


  - @autoreleasepool can help in Objective-C code

Finding Memory Issues

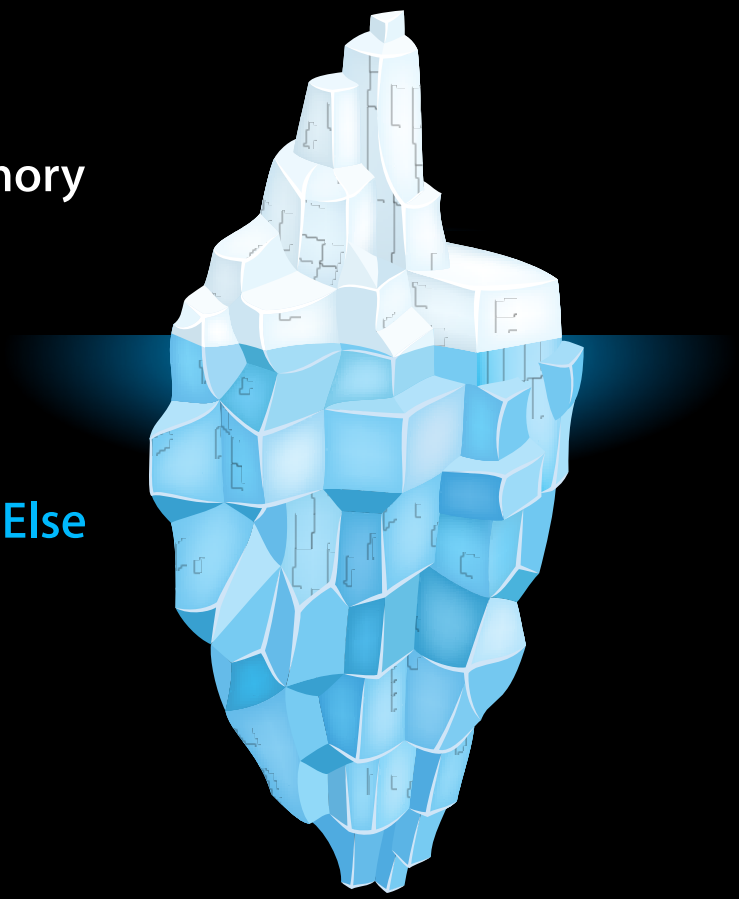


Daniel Delwood
Software Engineer


Reproduce the problem
Profile with tools
Form a hypothesis
Make a change

Memory Footprint

Heap Memory



Everything Else

Most Dirty Memory is
Related to the Heap

Reducing Memory Usage

What you can do

Reducing Memory Usage

What you can do

- Understand your view hierarchy
  - The more pixels you draw…

Reducing Memory Usage

What you can do

- Understand your view hierarchy
  - The more pixels you draw…
- Avoid recurring heap growth
  - Doesn't matter if the objects are small

Avoiding Memory Growth

Top three to look for

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- Leaked memory
  - Inaccessible—no more pointers to it
  - Can't ever be used again

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- Leaked memory
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  - Won't ever be used again
- Cached memory
  - Referenced and waiting
  - May never be used again

Memory Growth

How to detect it

- Memory shouldn't grow without bound when repeating an operation

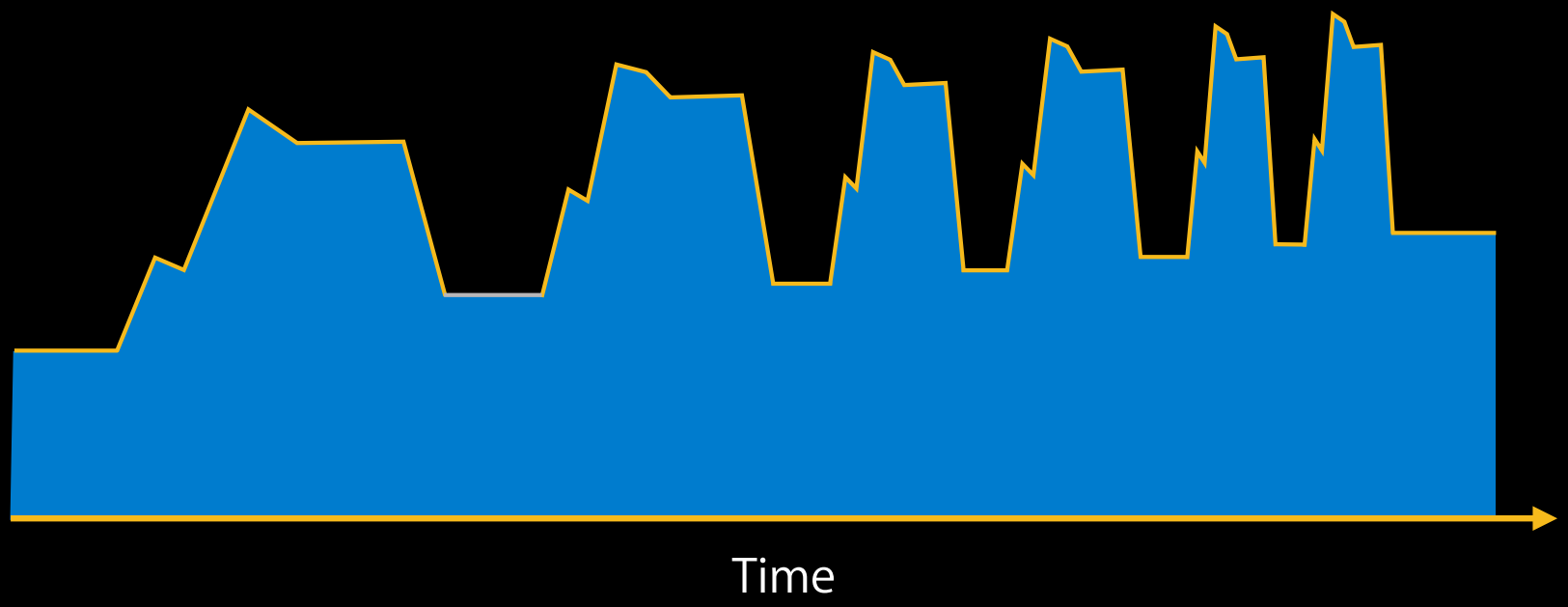
Memory Growth

How to detect it

- Memory shouldn't grow without bound when repeating an operation
  - For example
    - Pushing and popping a view controller
    - Scrolling in a table view
    - Performing a database search

Avoiding Memory Growth

Repetition reveals waste



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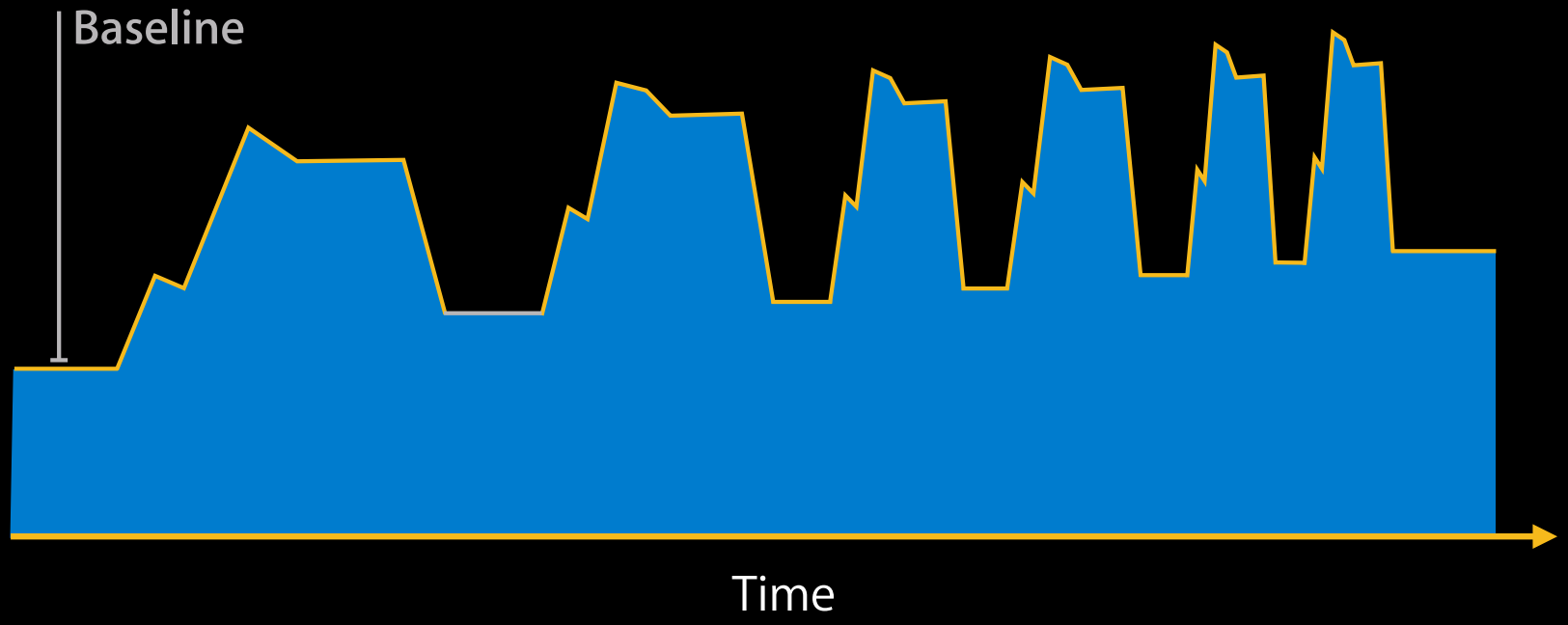

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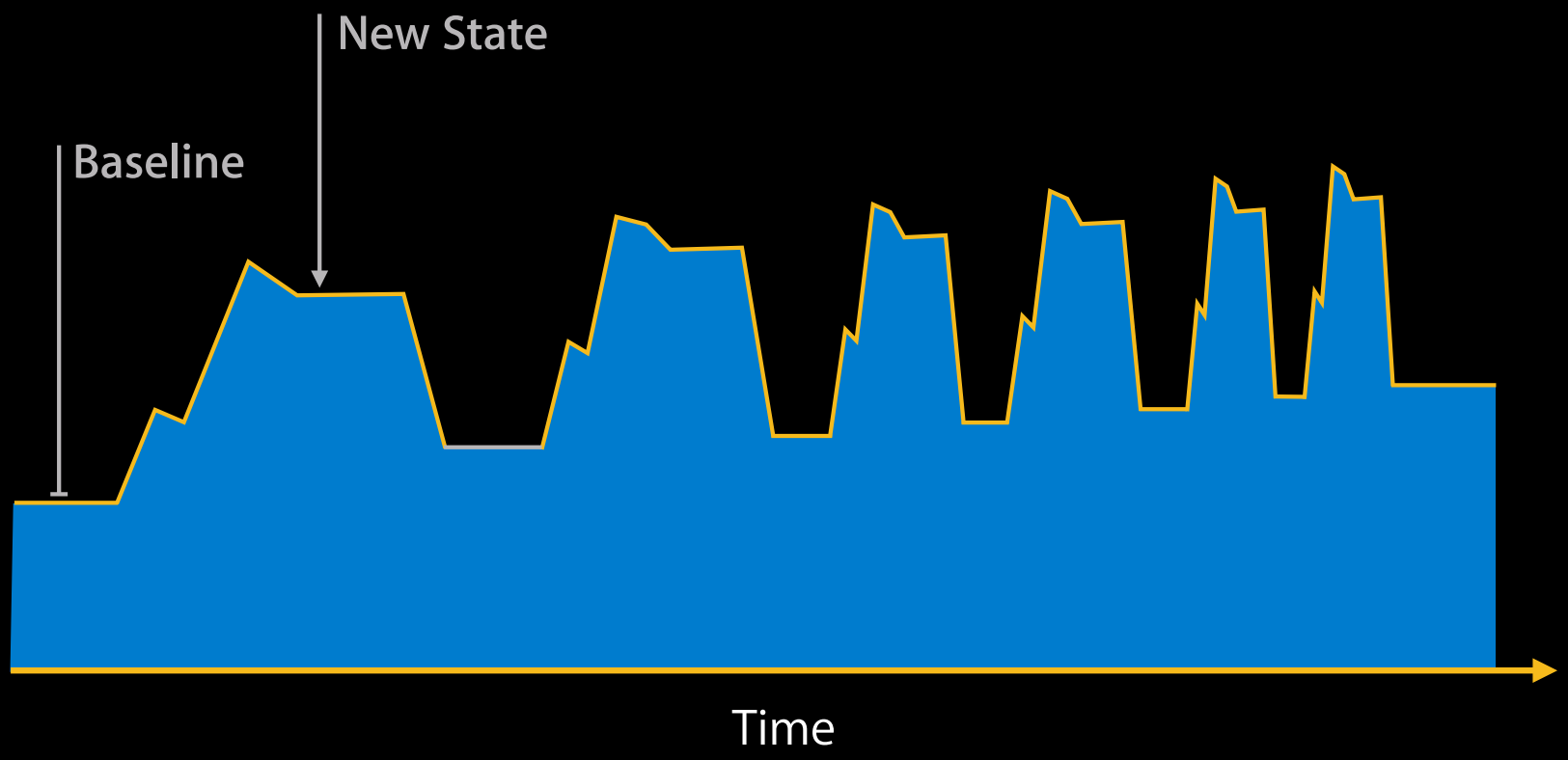

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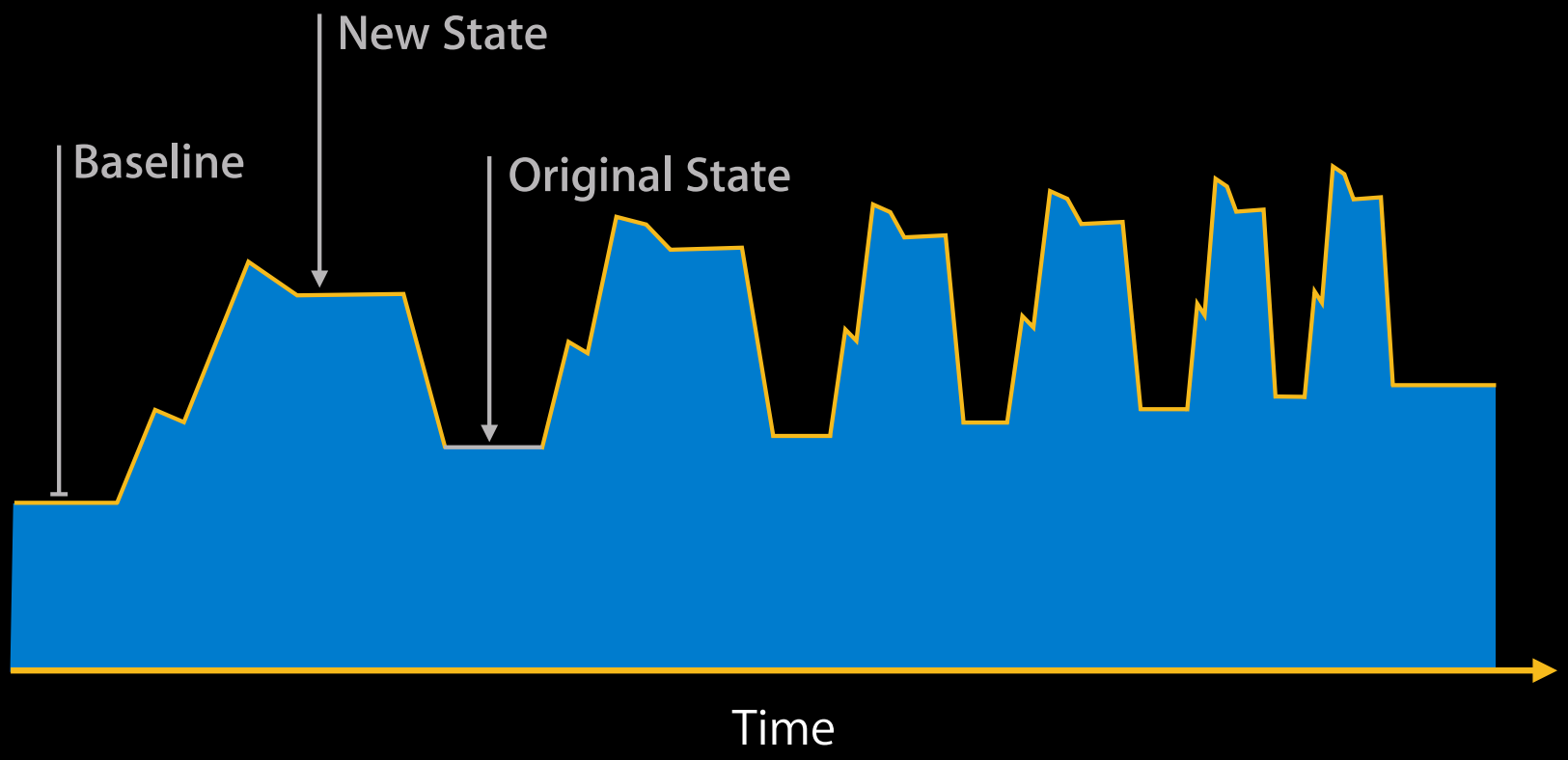

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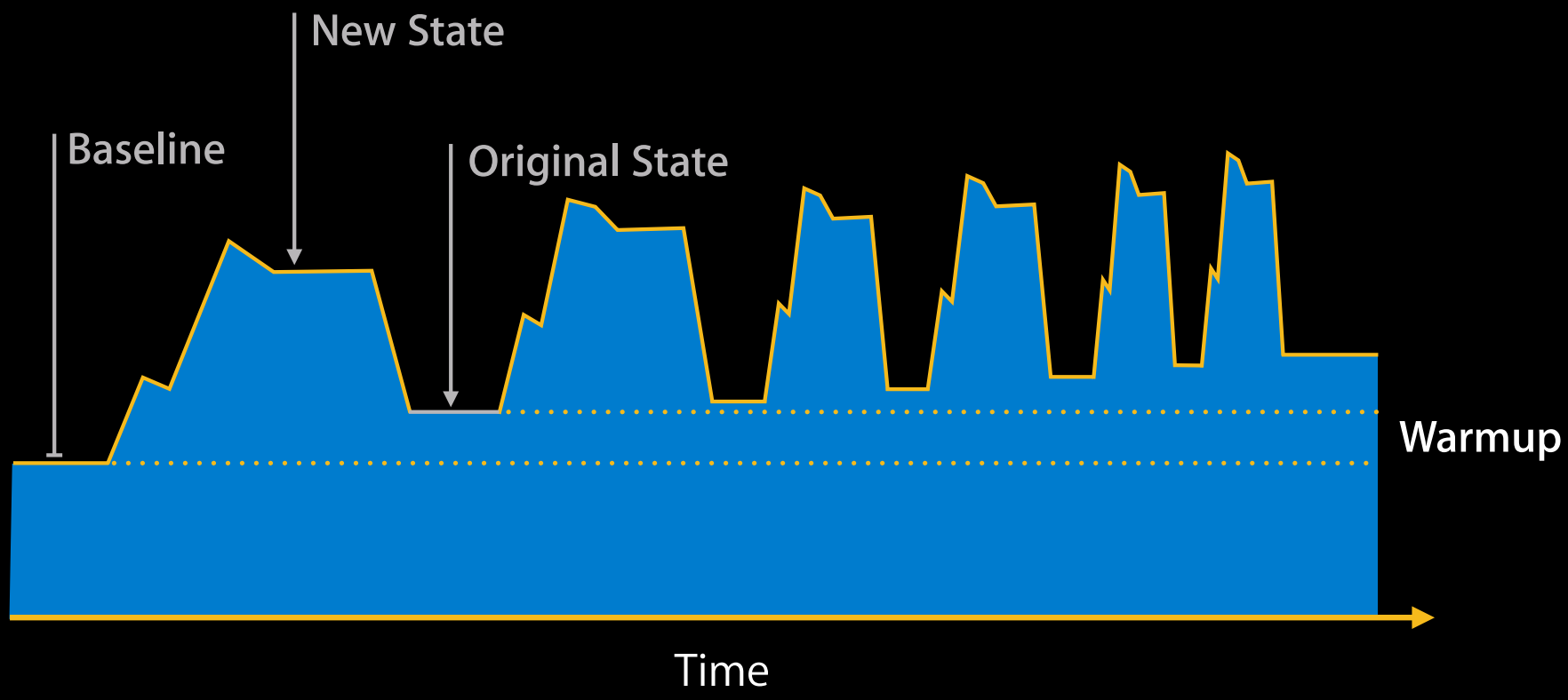

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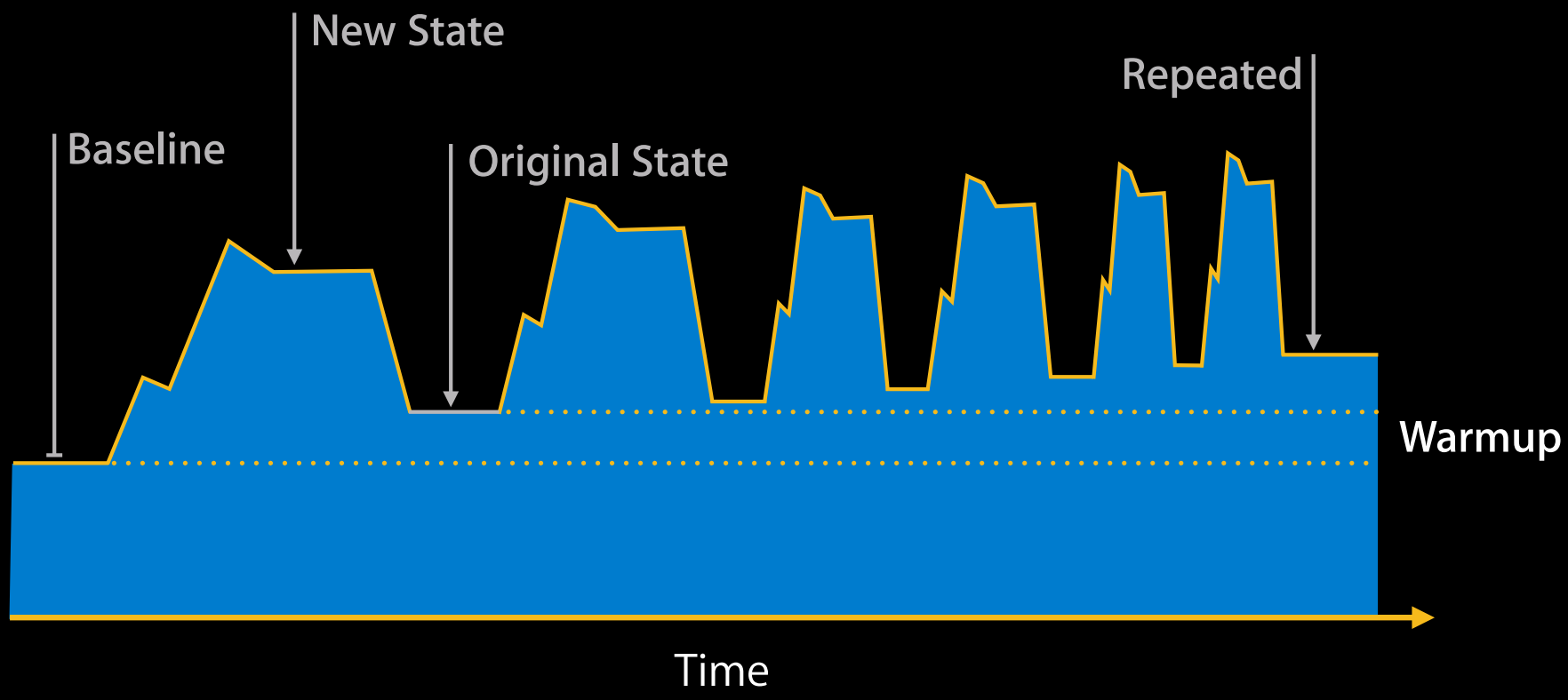

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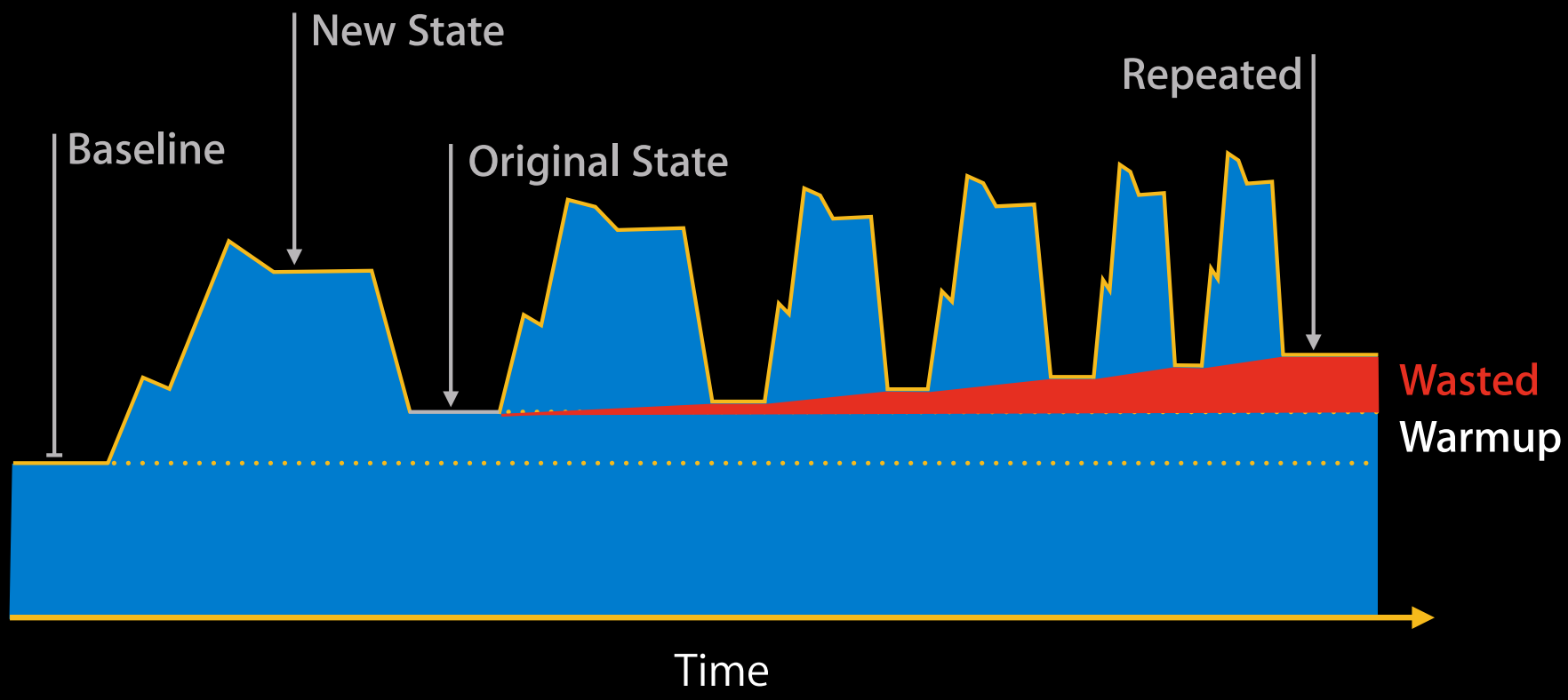
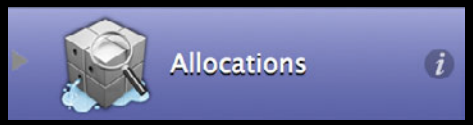


Allocations Instrument

A targeted tool



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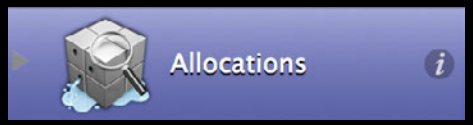

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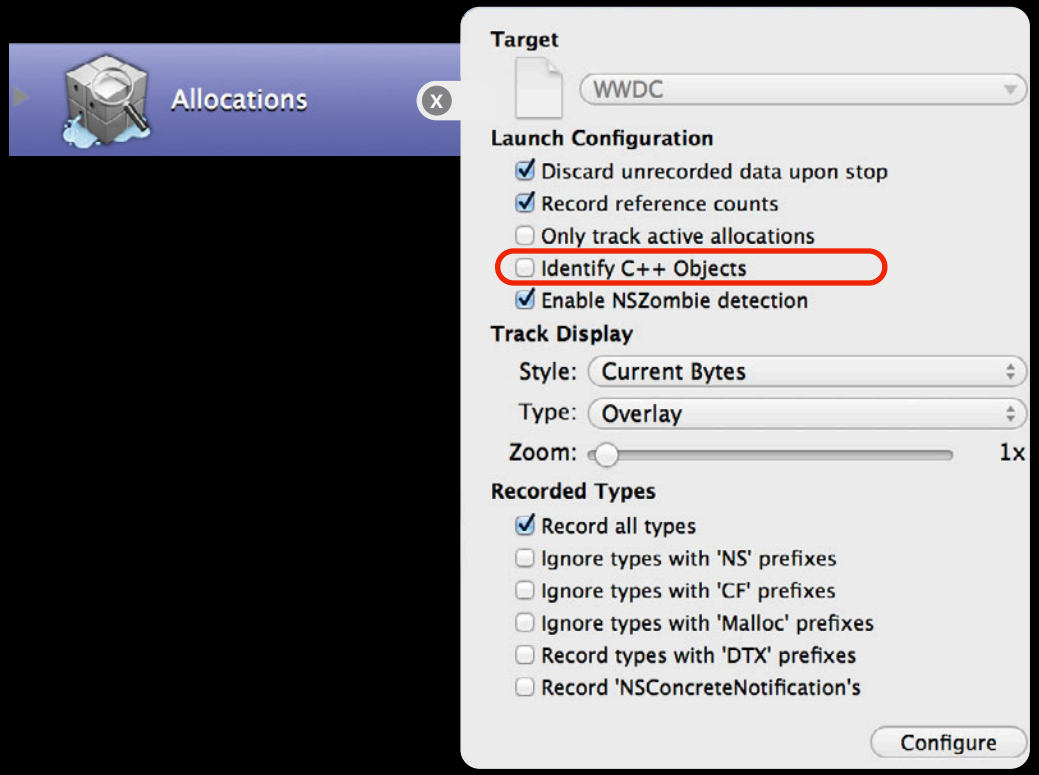

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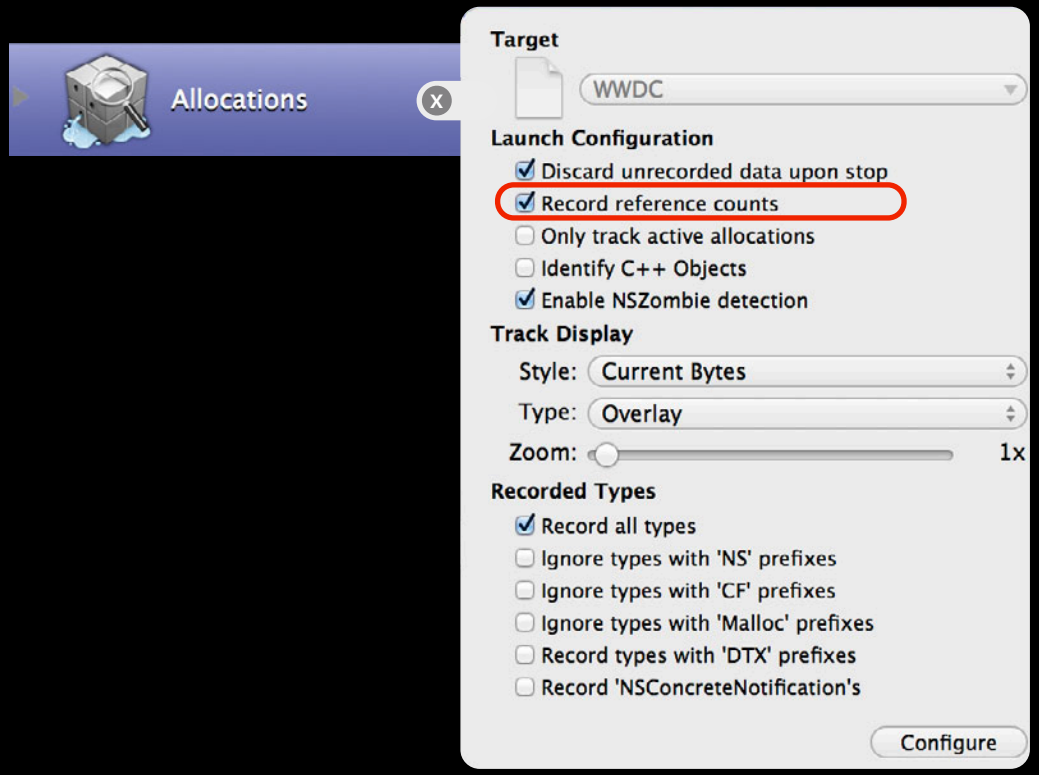

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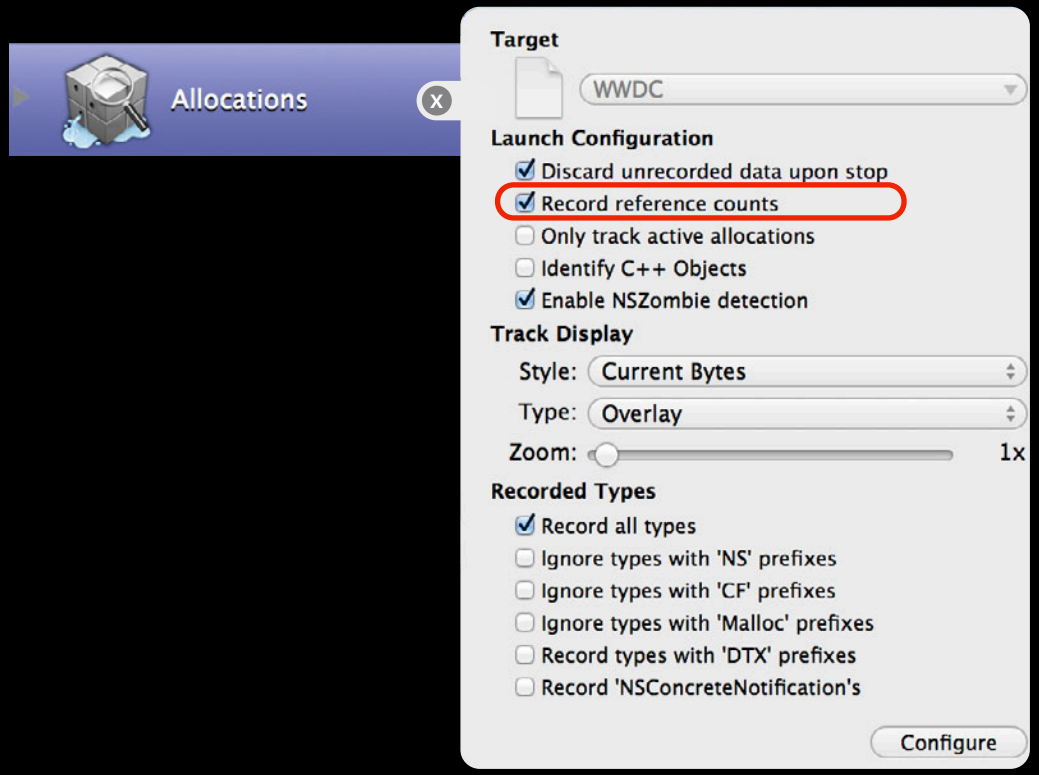

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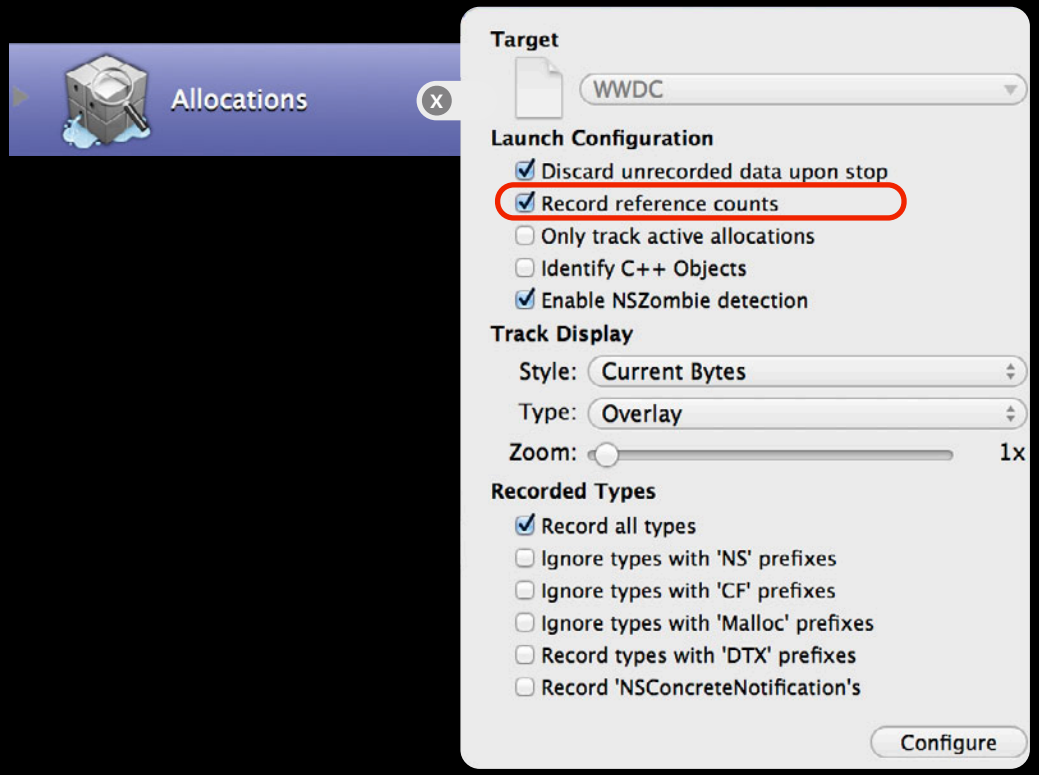

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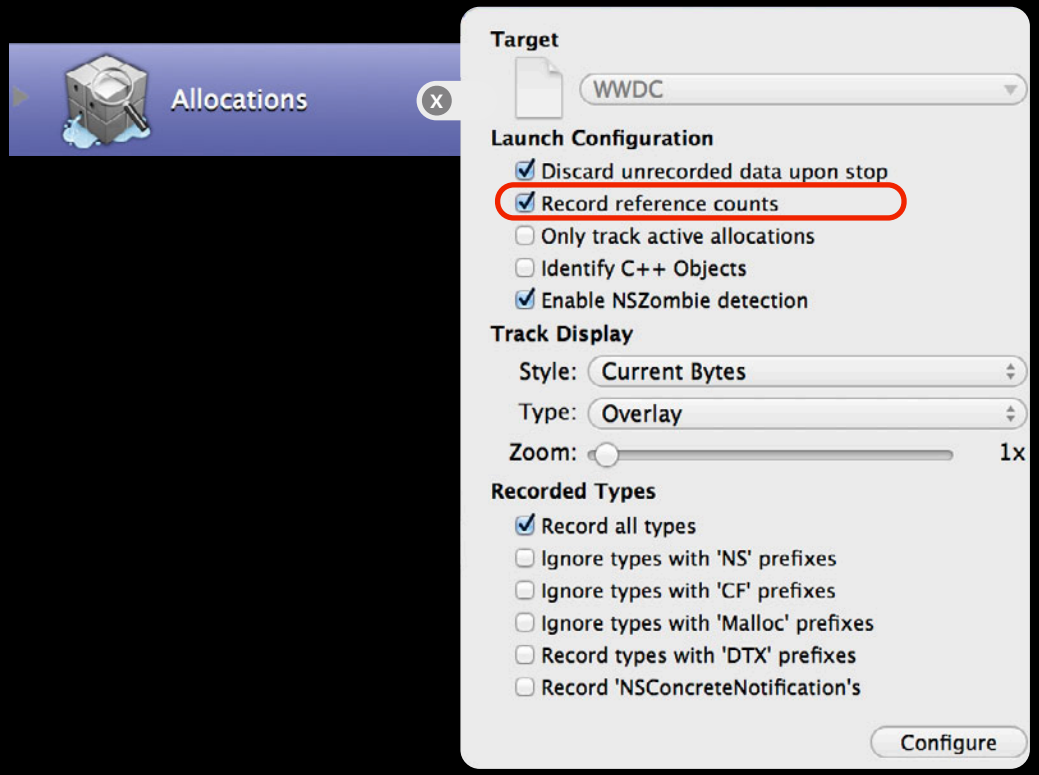

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A practical example

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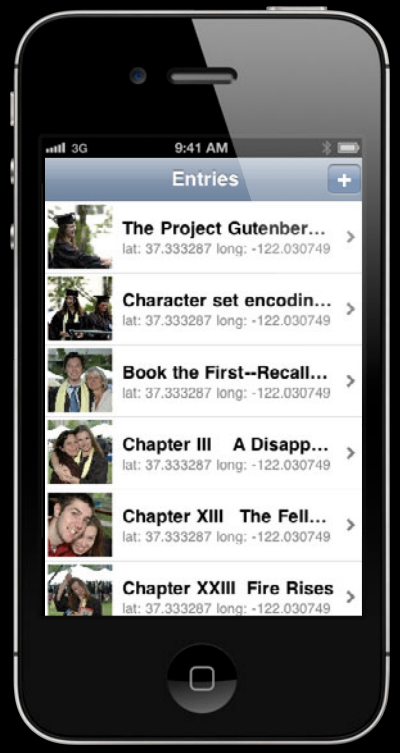

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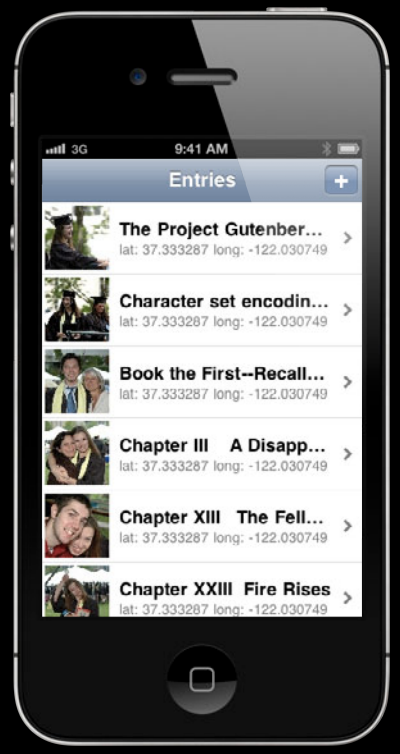

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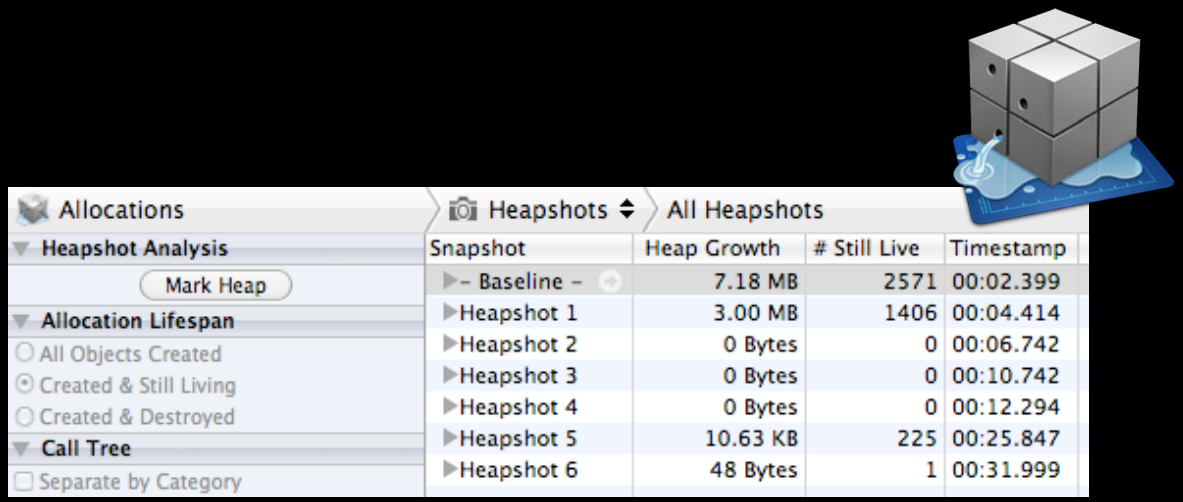

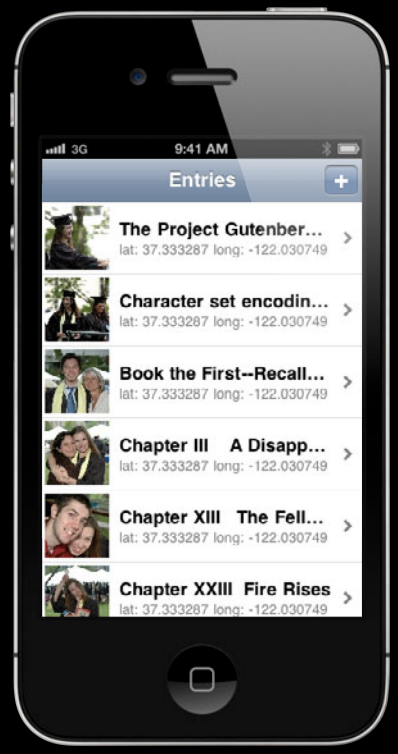

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Repeat!

Allocations | Heapshots | All Heapshots

Heapshot Analysis

Mark Heap

Allocation Lifespan

- All Objects Created
- Created & Still Living
- Created & Destroyed

Call Tree

- Separate by Category

Snapshot	Heap Growth	# Still Live	Timestamp
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Heapshot 1	3.00 MB	1406	00:04.414
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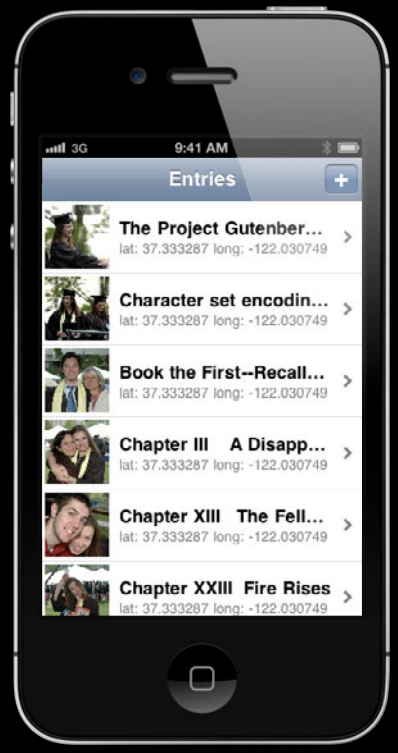

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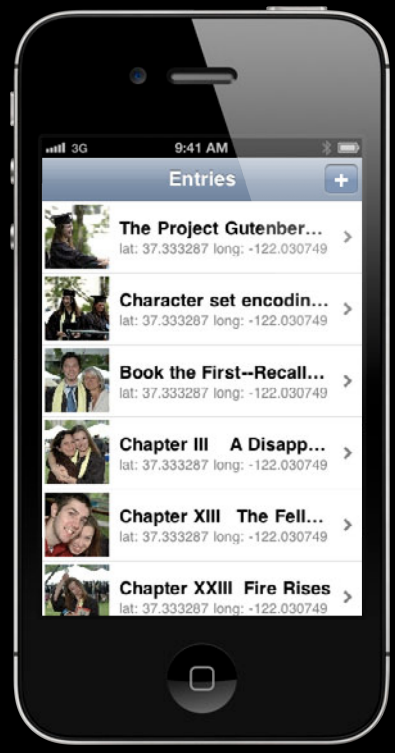

Demo

Detecting and fixing memory growth

Tools Tips and Tricks

Memory Tips

Getting to know your app

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- Pay attention to objects holding resources
  - UIImage, UIViewController, NSOperation, etc.
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Memory bugs are expensive

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- Run the static analyzer
- Use the Leaks instrument
  - Make one fix at a time, re-run

Fixing Leaks

Plugging the holes

- Retain cycles
  - Use the “Cycles & Roots” view
  - Be aware of ^block captures

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Fixing Leaks

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- Incorrect retain/release
  - Possible with incorrect ARC bridging
  - Focus on the reference counting history

__NSMallocBlock__	1	0xb0a3550
NSConcreteMutableData	1	0x9b9acd0
__NSMallocBlock__	1	0xb0a34d0

NSConcreteMutableData	Malloc	1	00:01.893.340
NSConcreteMutableData	Retain	2	00:01.893.342
NSConcreteMutableData	Retain	3	00:01.893.344
NSConcreteMutableData	Release	2	00:01.893.344
NSConcreteMutableData	Release	1	00:01.993.307

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In case of emergency

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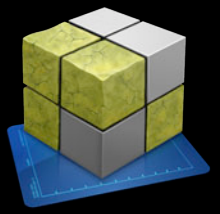

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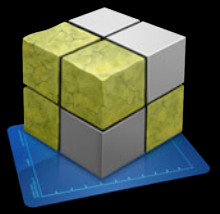

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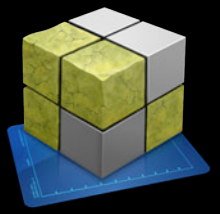

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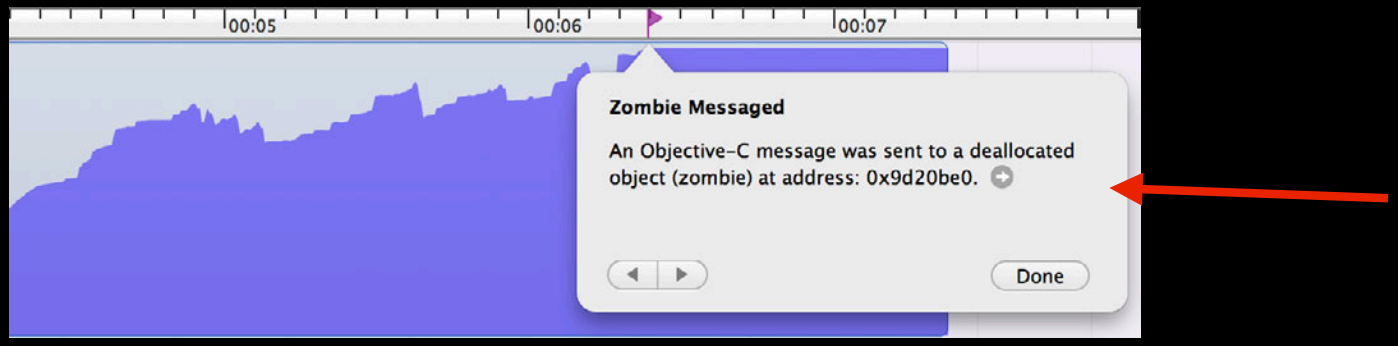
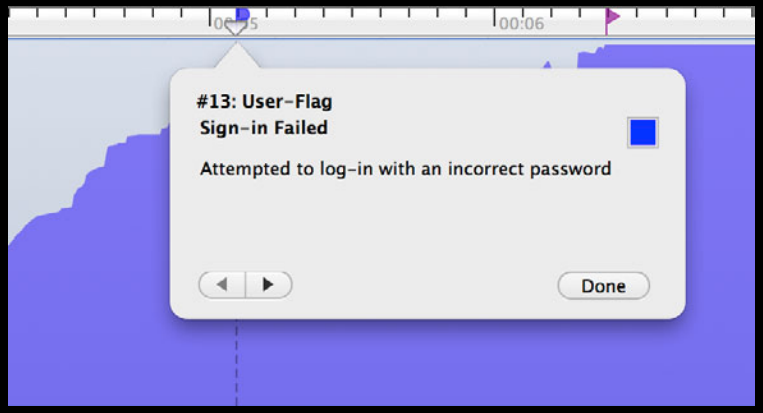


Tracing Tips



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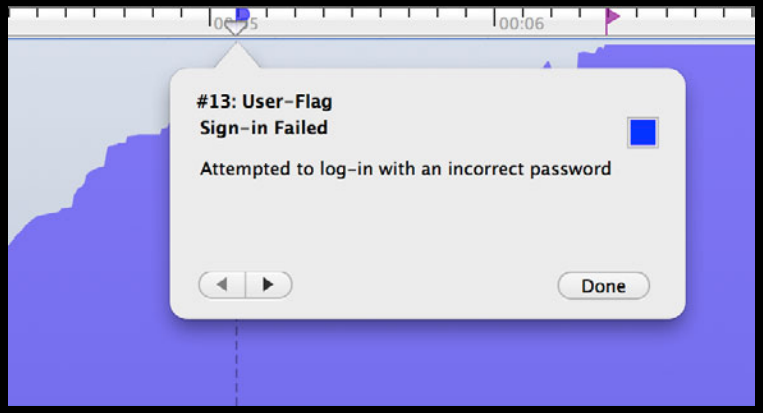

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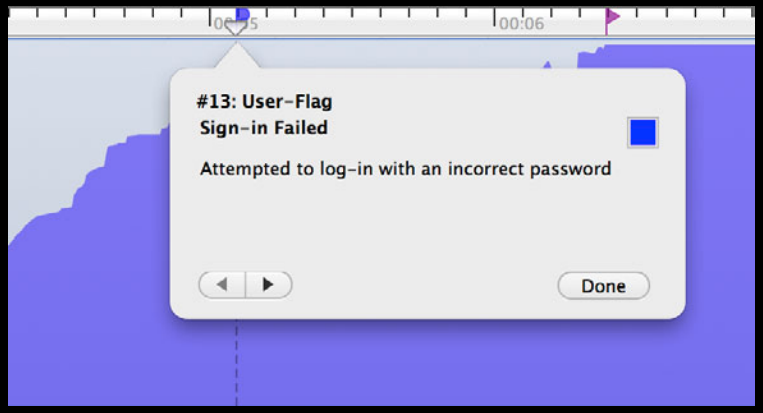

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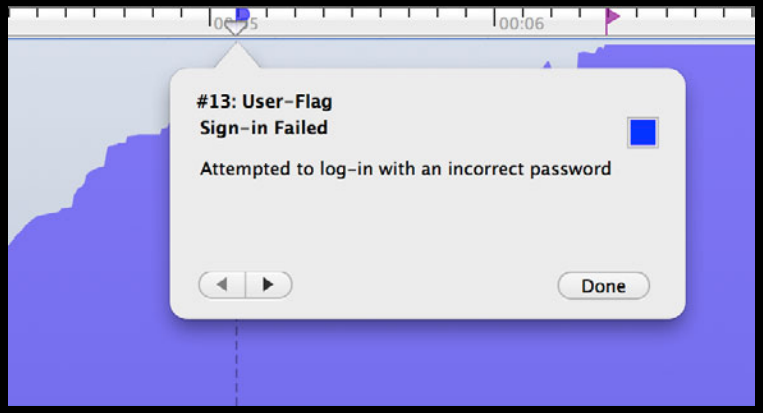

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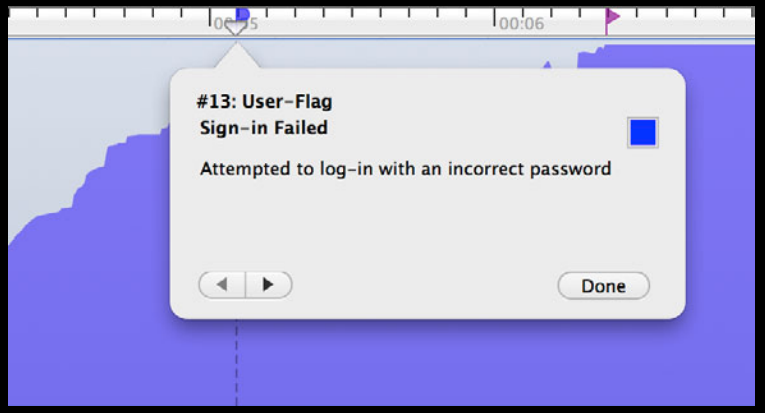

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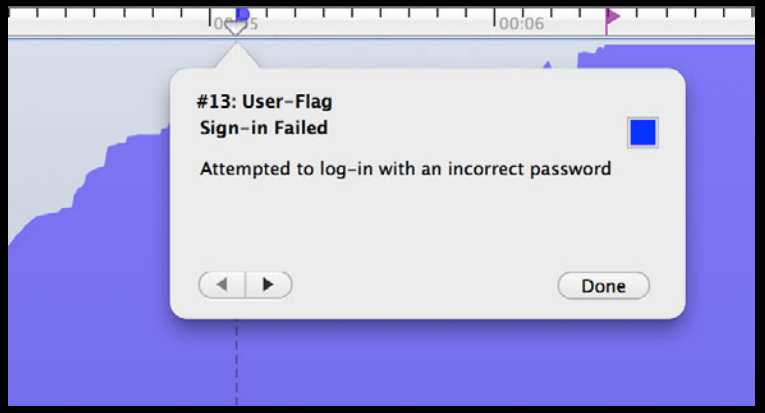
- Be conscious of snapshot intervals
  - Leaks and VM Tracker will cause app pauses



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- Measure, change, and iterate

More Information

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Instruments Documentation
Instruments User Guide
Instruments User Reference
http://developer.apple.com/ "Developer Library"

Apple Developer Forums
http://devforums.apple.com

Related Sessions

Learning Instruments	Presidio Wednesday 4:30PM
iOS App Performance: Responsiveness	Presidio Thursday 11:30AM
iOS App Performance: Graphics and Animations	Presidio Thursday 3:15PM
Polishing Your Interface Rotations	Mission Thursday 4:30PM
Adopting Automatic Reference Counting	Nob HIll Friday 11:30AM
Asynchronous Design Patterns with Blocks, GCD, and XPC	Pacific Heights Friday 9:00AM

Labs

OS X Performance Lab	Developer Tools Lab A Friday 9:00AM


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