TDD for Embedded C

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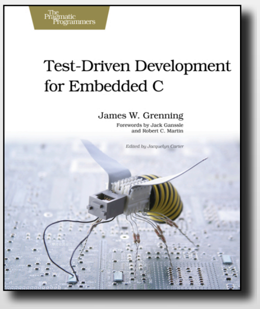
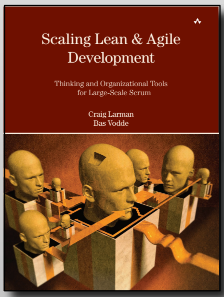
http://www.renaissancesoftware.net
http:// www.jamesgrenning.com
http://www.odd-e.com

Come to a full version of James' TDD for Embedded C
October 2012. Phoenix, AZ


The Pragmatic Programmers
Test-Driven Development for Embedded C
James W. Grenning
Forewords by Jack Ganssle and Robert C. Martin
Edited by Jacquelyn Carter


Scaling Lean & Agile Development
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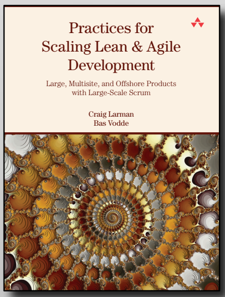
Practices for Scaling Lean & Agile Development
Large, Multisite, and Offshore Products with Large-Scale Scrum
Craig Larman
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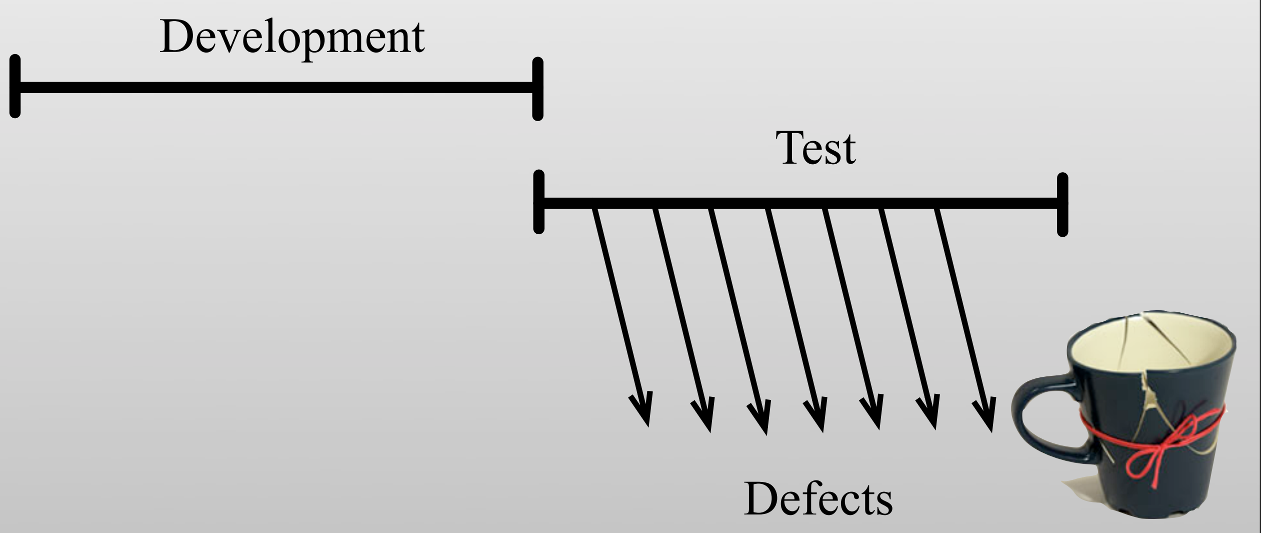
Topics

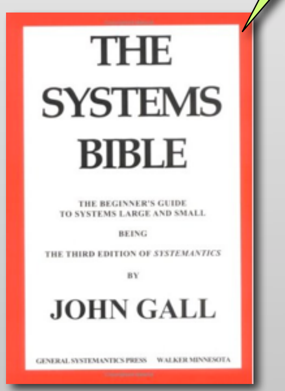
- The why and what of TDD
- Embedded adaptation
- Abstracting HW and OS
- Mocking the silicon
- Test-double substitution options
- Function pointer substitution
- Preprocessor substitution
- TDD next to an RTOS

Why TDD?
What is TDD?

This Work Flow is Designed to Allow Defects



Your program will have bugs. And they will surprise you when you find them.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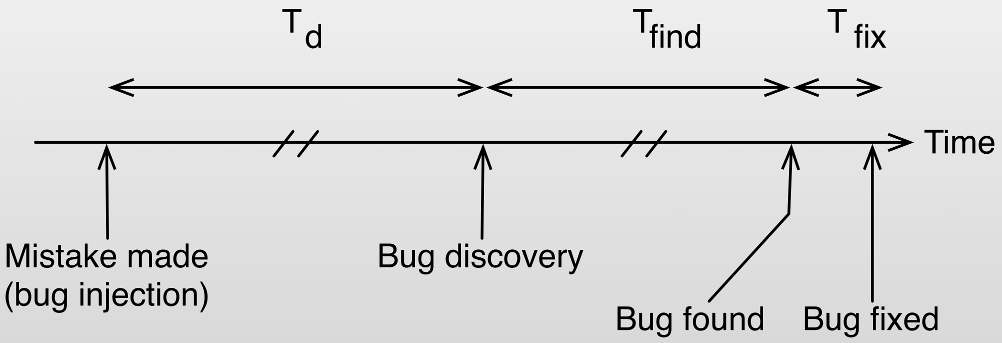
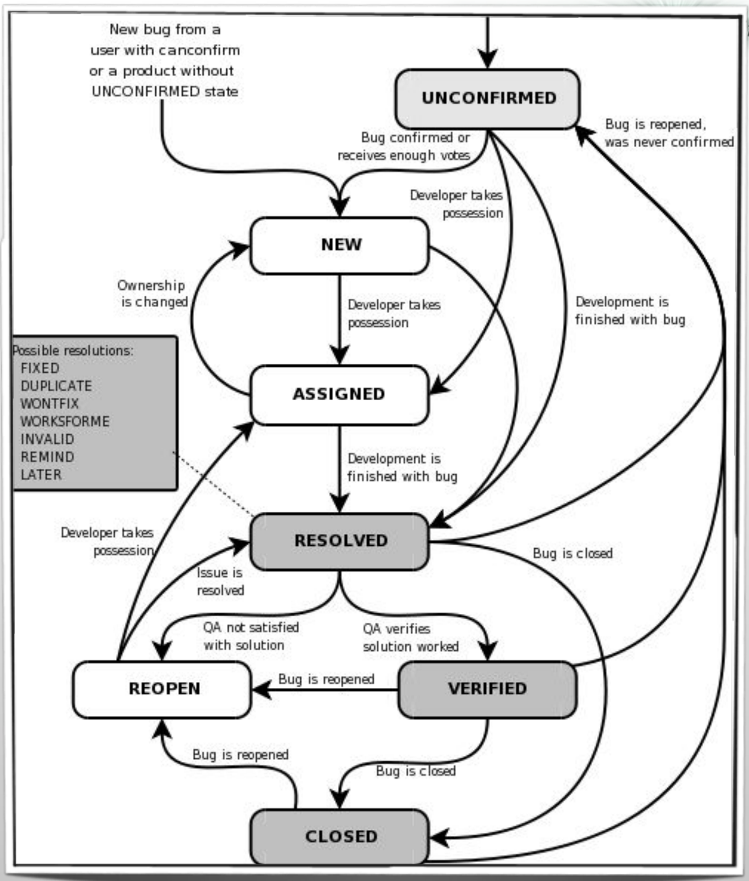
The Physics of Debug Later Programming (DLP)



- As T_d increases, T_{find} increases dramatically
- T_{fix} is usually short, but can increase with T_d

A Bug's Life



New bug from a user with canconfirm or a product without UNCONFIRMED state

UNCONFIRMED

Bug confirmed or receives enough votes

Bug is reopened, was never confirmed

Developer takes possession

NEW

Ownership is changed

Developer takes possession

Development is finished with bug

Possible resolutions:
FIXED
DUPLICATE
WONTFIX
WORKSFORME
INVALID
REMIND
LATER

ASSIGNED

Development is finished with bug

Developer takes possession

RESOLVED

Bug is closed

Issue is resolved

QA not satisfied with solution

QA verifies solution worked

REOPEN

Bug is reopened

VERIFIED

Bug is reopened

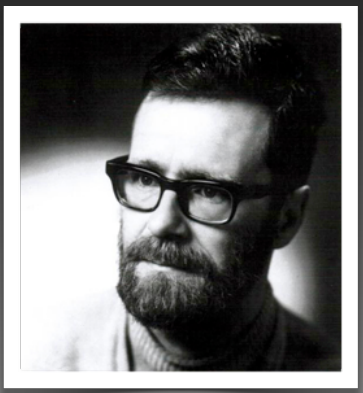
Bug is closed

CLOSED

From http://www.softwaretestinghelp.com/bug-life-cycle/

Edsger Dijkstra

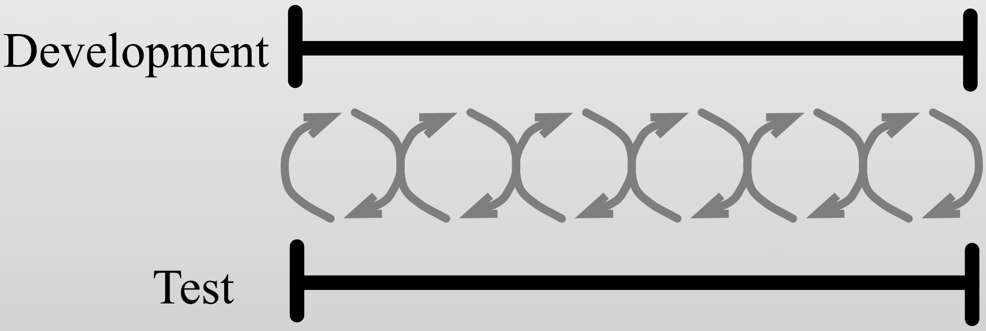
Those who want really reliable software will discover that they must find means of avoiding the majority of bugs to start with, and as a result, the programming process will become cheaper. If you want more effective programmers, you will discover that they should not waste their time debugging, they should not introduce the bugs to start with.



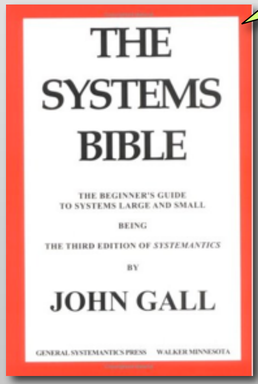
Can we Realize Dijkstra's Dream and Prevent Defects with Test Driven Development?

Being good at chasing bugs is not Technical Excellence

Development and Test Work Together Preventing Defects



A Complex system that works is invariably found to have evolved from a simple system that worked.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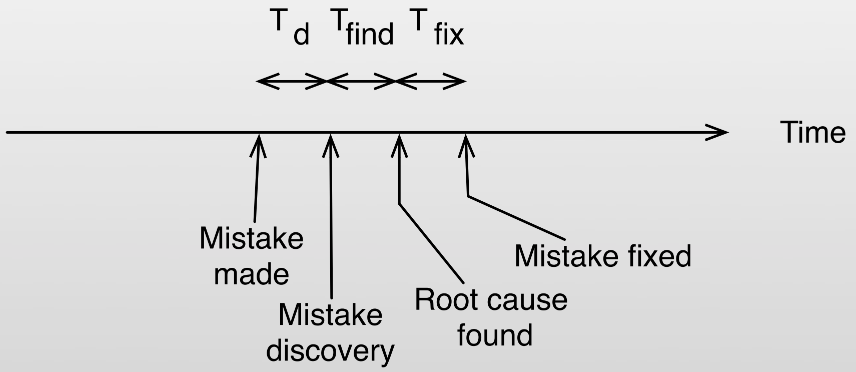
The Physics of Test Driven Development



- When T_d approaches zero, T_{find} approaches zero
- In many cases, bugs are not around long enough to be considered bugs.
- See: http://www.renaissancesoftware.net/blog/archives/16

Why is it difficult to sustain?

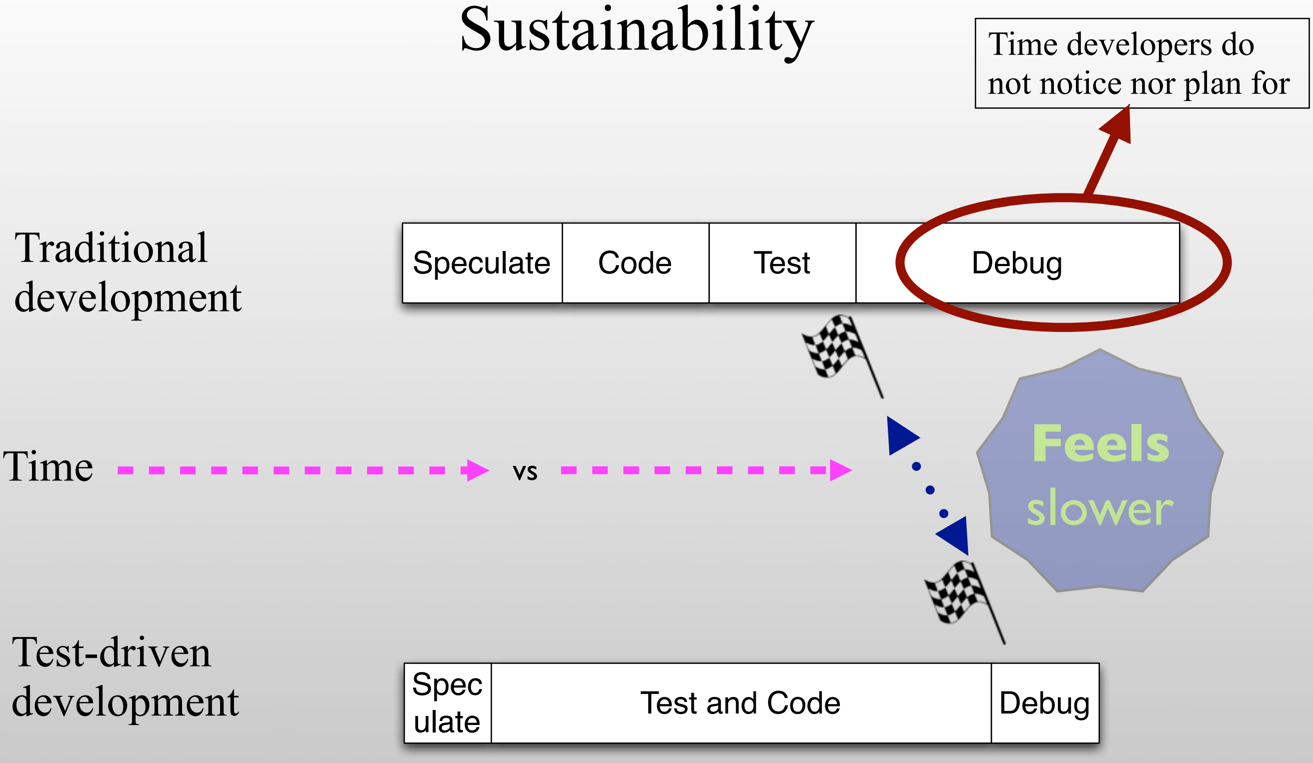
TDD:

- Steady pace
- Speed limits
- No traffic lights (bugs)
- Might feel slow!!

Traditional:

- Spurts
- Fast when no problems!
- Debugging
- Feels fast! But often slow

Sustainability



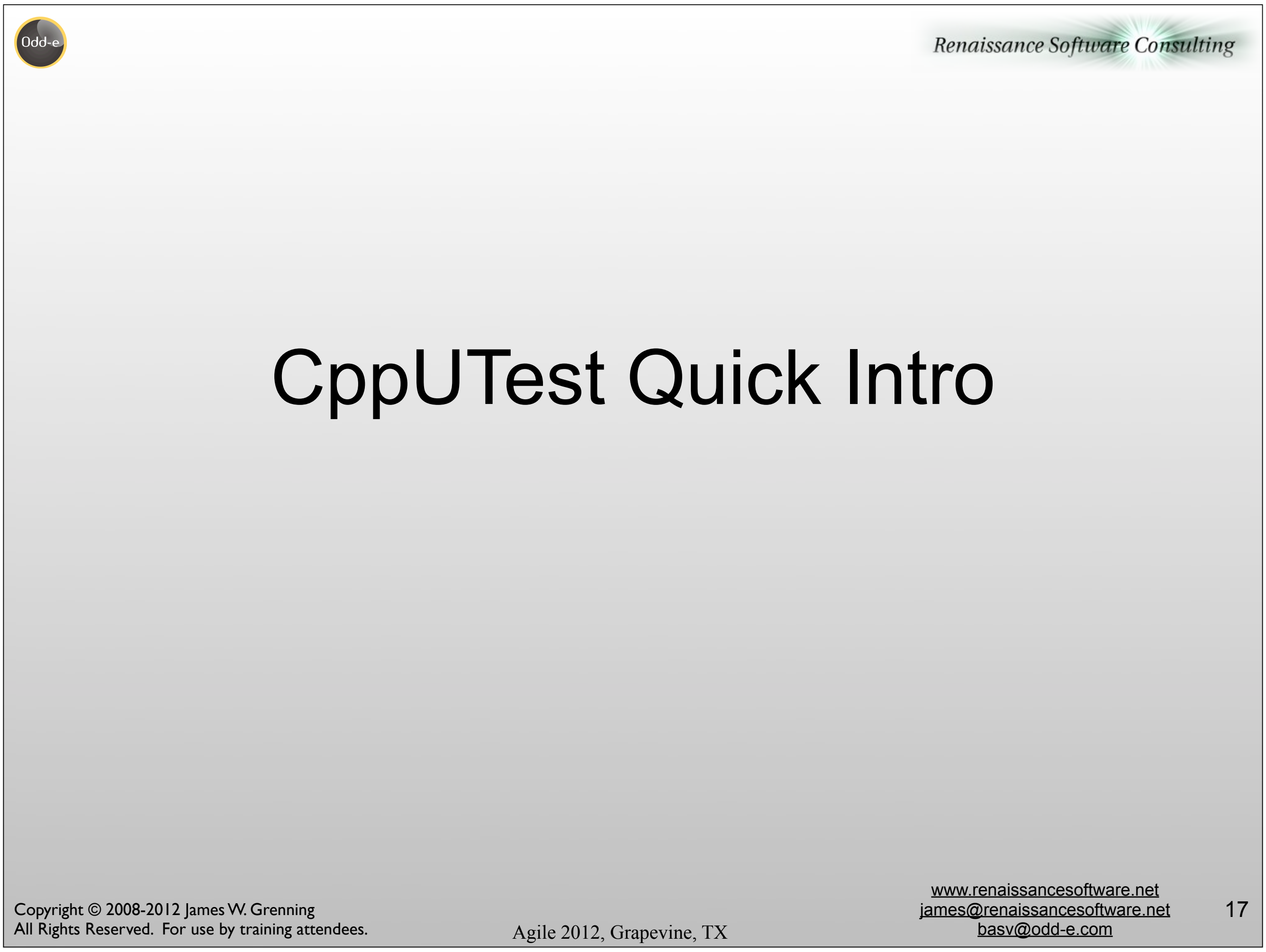
Time developers do not notice nor plan for

Traditional development

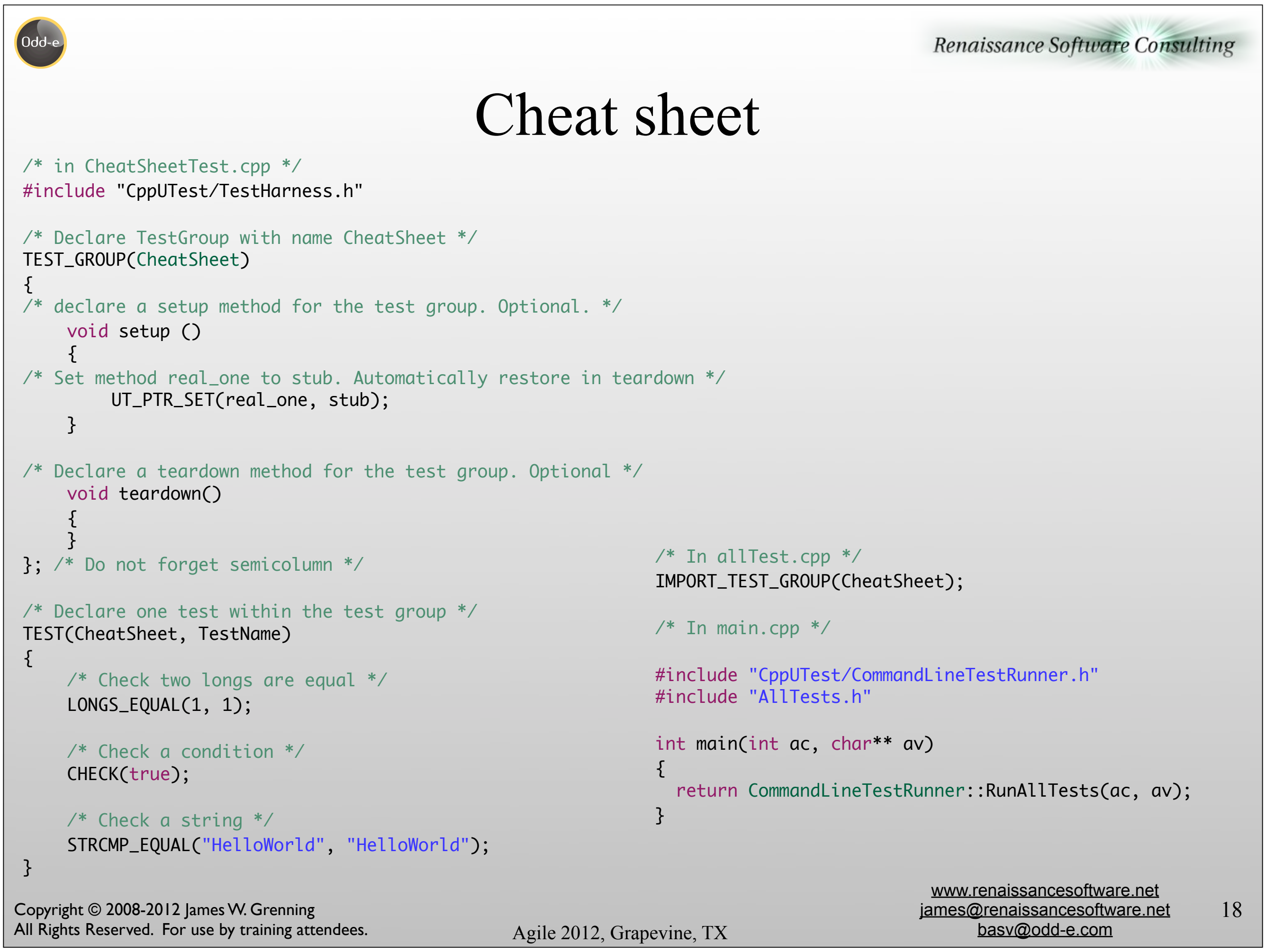
Time vs

Test-driven development

Demo and Exercise



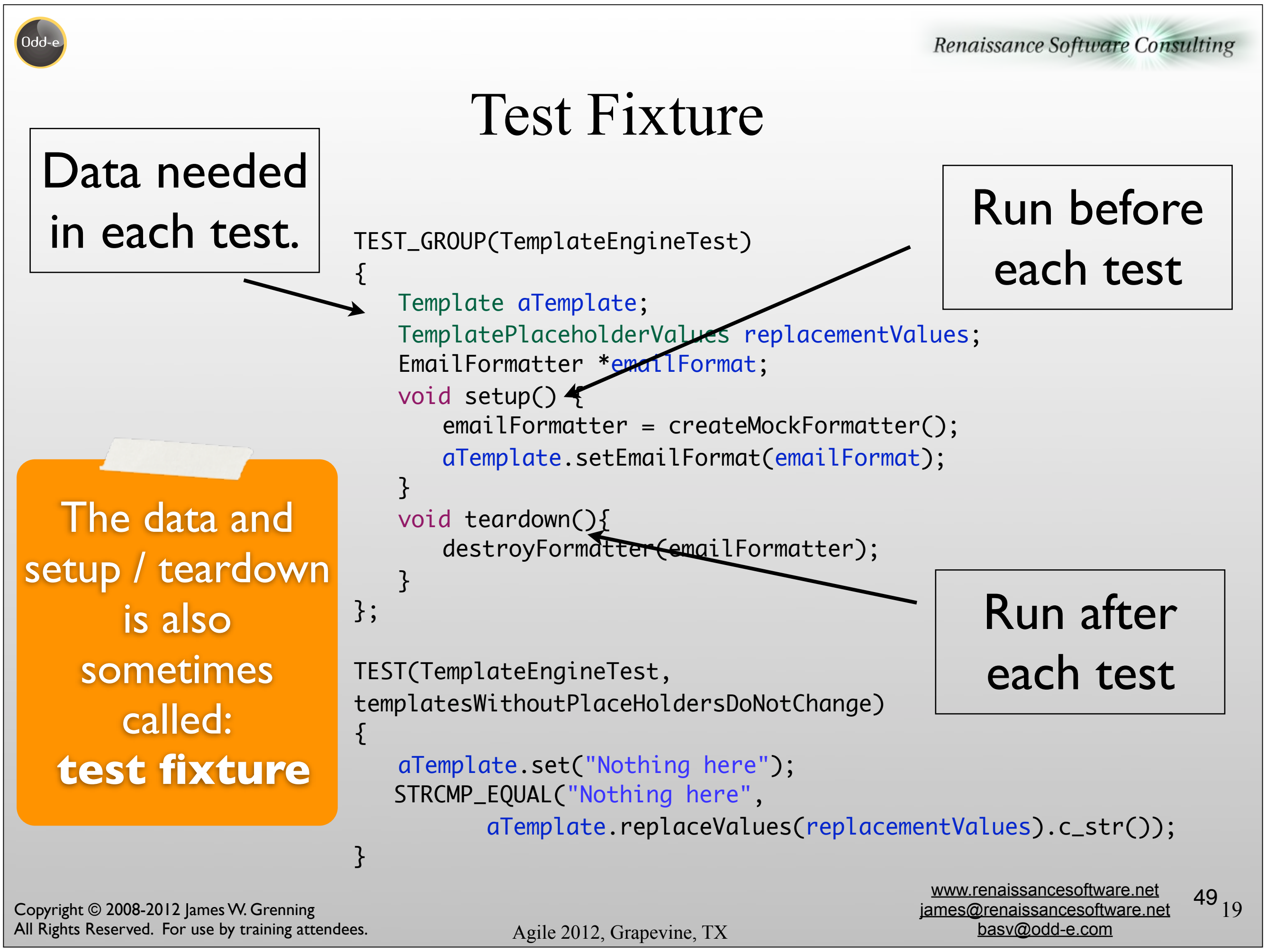
CppUTest Quick Intro



Cheat sheet

```
/* in CheatSheetTest.cpp */
#include "CppUTest/TestHarness.h"

/* Declare TestGroup with name CheatSheet */
TEST_GROUP(CheatSheet)
{
/* declare a setup method for the test group. Optional. */
    void setup ()
    {
/* Set method real_one to stub. Automatically restore in teardown */
        UT_PTR_SET(real_one, stub);
    }

/* Declare a teardown method for the test group. Optional */
    void teardown()
    {
    }
}; /* Do not forget semicolumn */

/* Declare one test within the test group */
TEST(CheatSheet, TestName)
{
    /* Check two longs are equal */
    LONGS_EQUAL(1, 1);

    /* Check a condition */
    CHECK(true);

    /* Check a string */
    STRCMP_EQUAL("HelloWorld", "HelloWorld");
}
```

```
/* In allTest.cpp */
IMPORT_TEST_GROUP(CheatSheet);

/* In main.cpp */

#include "CppUTest/CommandLineTestRunner.h"
#include "AllTests.h"

int main(int ac, char** av)
{
  return CommandLineTestRunner::RunAllTests(ac, av);
}
```



Test Fixture

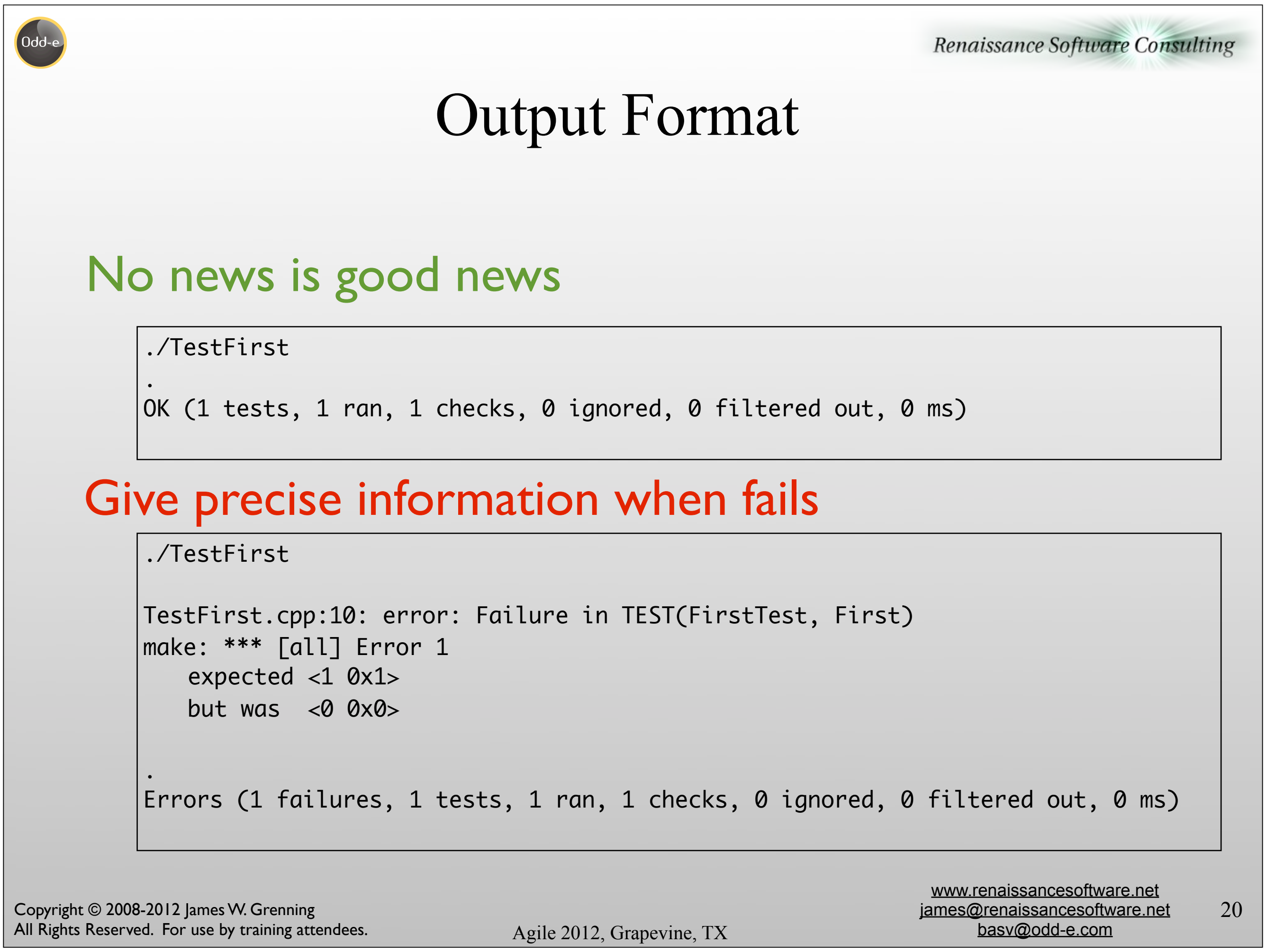
Data needed in each test.

Run before each test

Run after each test

```
TEST_GROUP(TemplateEngineTest)
{
    Template aTemplate;
    TemplatePlaceholderValues replacementValues;
    EmailFormatter *emailFormat;
    void setup() {
        emailFormatter = createMockFormatter();
        aTemplate.setEmailFormat(emailFormat);
    }
    void teardown(){
        destroyFormatter(emailFormatter);
    }
};

TEST(TemplateEngineTest,
templatesWithoutPlaceHoldersDoNotChange)
{
    aTemplate.set("Nothing here");
    STRCMP_EQUAL("Nothing here",
           aTemplate.replaceValues(replacementValues).c_str());
}
```

The data and setup / teardown is also sometimes called: **test fixture**



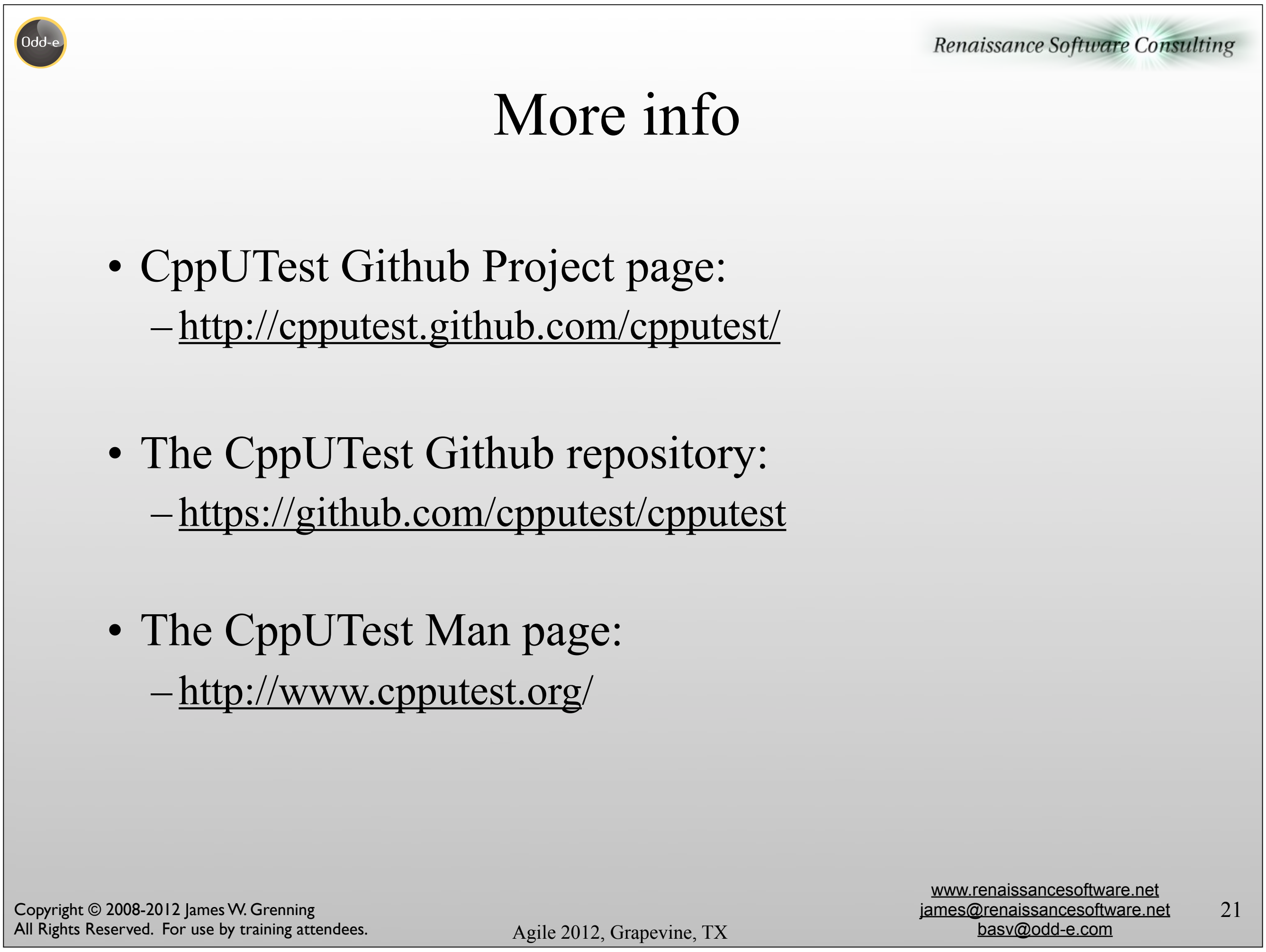
Output Format

No news is good news

```
./TestFirst
.
OK (1 tests, 1 ran, 1 checks, 0 ignored, 0 filtered out, 0 ms)
```

Give precise information when fails

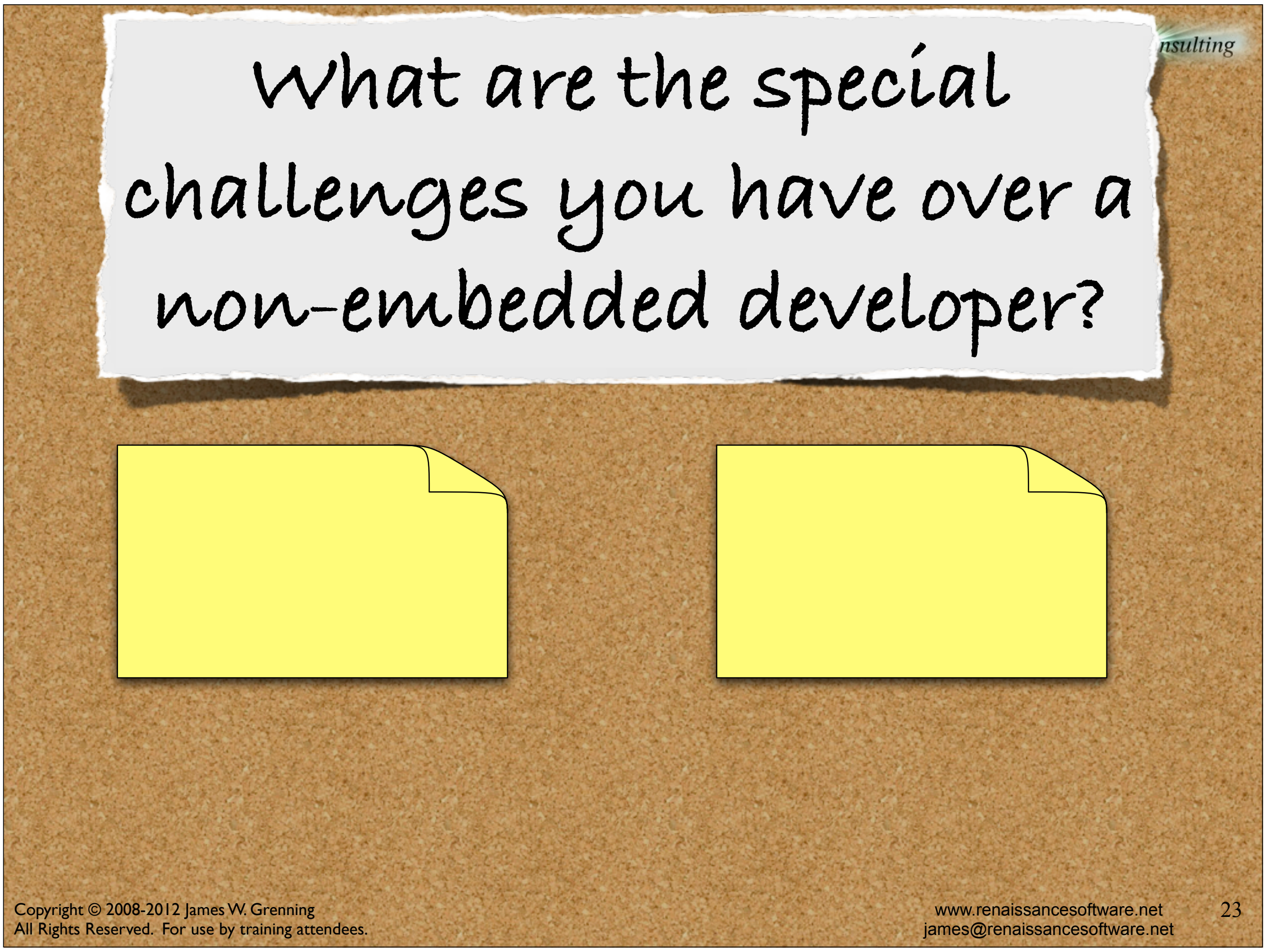
```
./TestFirst

TestFirst.cpp:10: error: Failure in TEST(FirstTest, First)
make: *** [all] Error 1
    expected <1 0x1>
    but was  <0 0x0>

.
Errors (1 failures, 1 tests, 1 ran, 1 checks, 0 ignored, 0 filtered out, 0 ms)
```



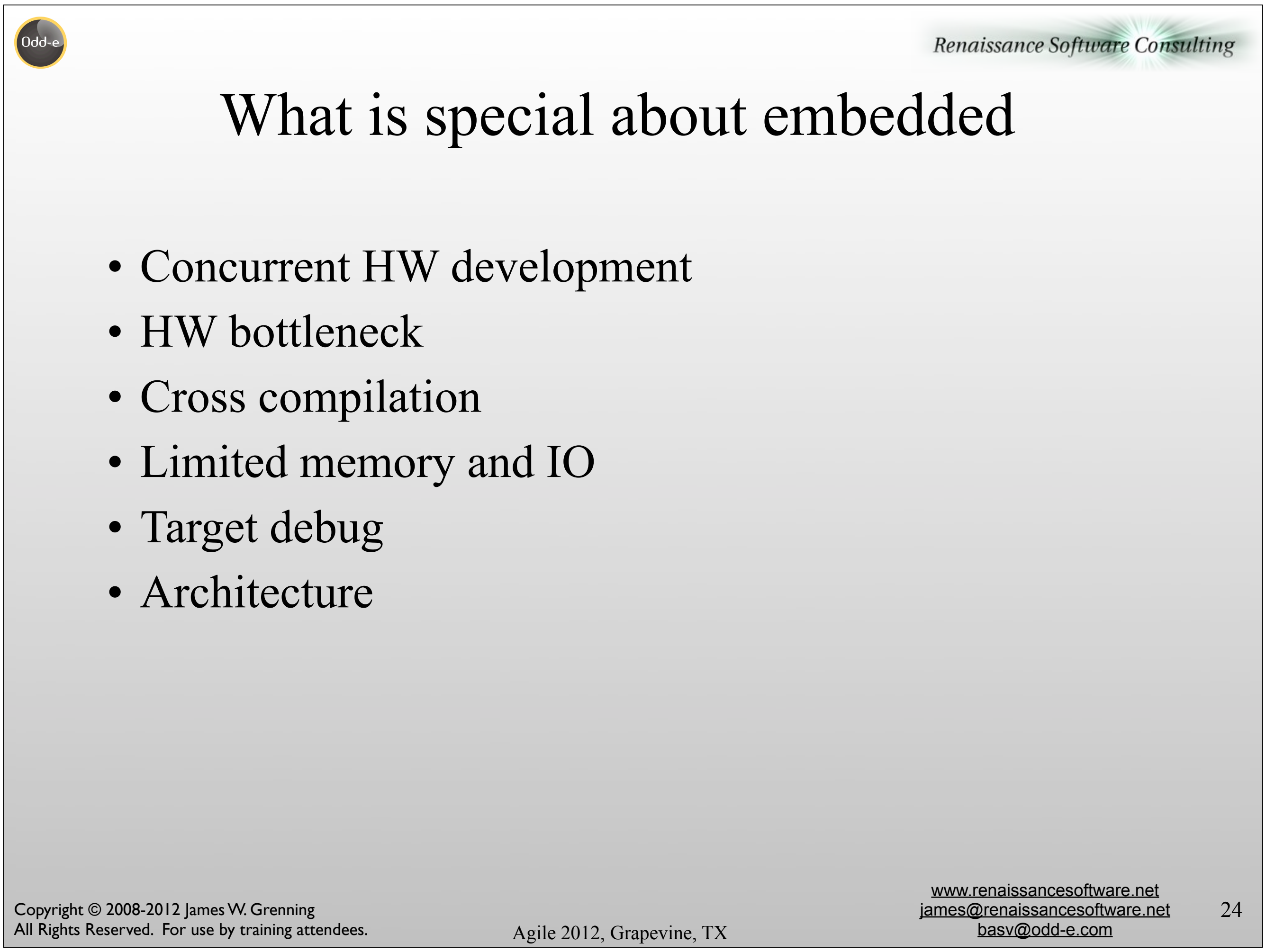
More info

- CppUTest Github Project page:
  - http://cpputest.github.com/cpputest/
- The CppUTest Github repository:
  - https://github.com/cpputest/cpputest
- The CppUTest Man page:
  - http://www.cpputest.org/

Adaptation for Embedded Software



What are the special challenges you have over a non-embedded developer?



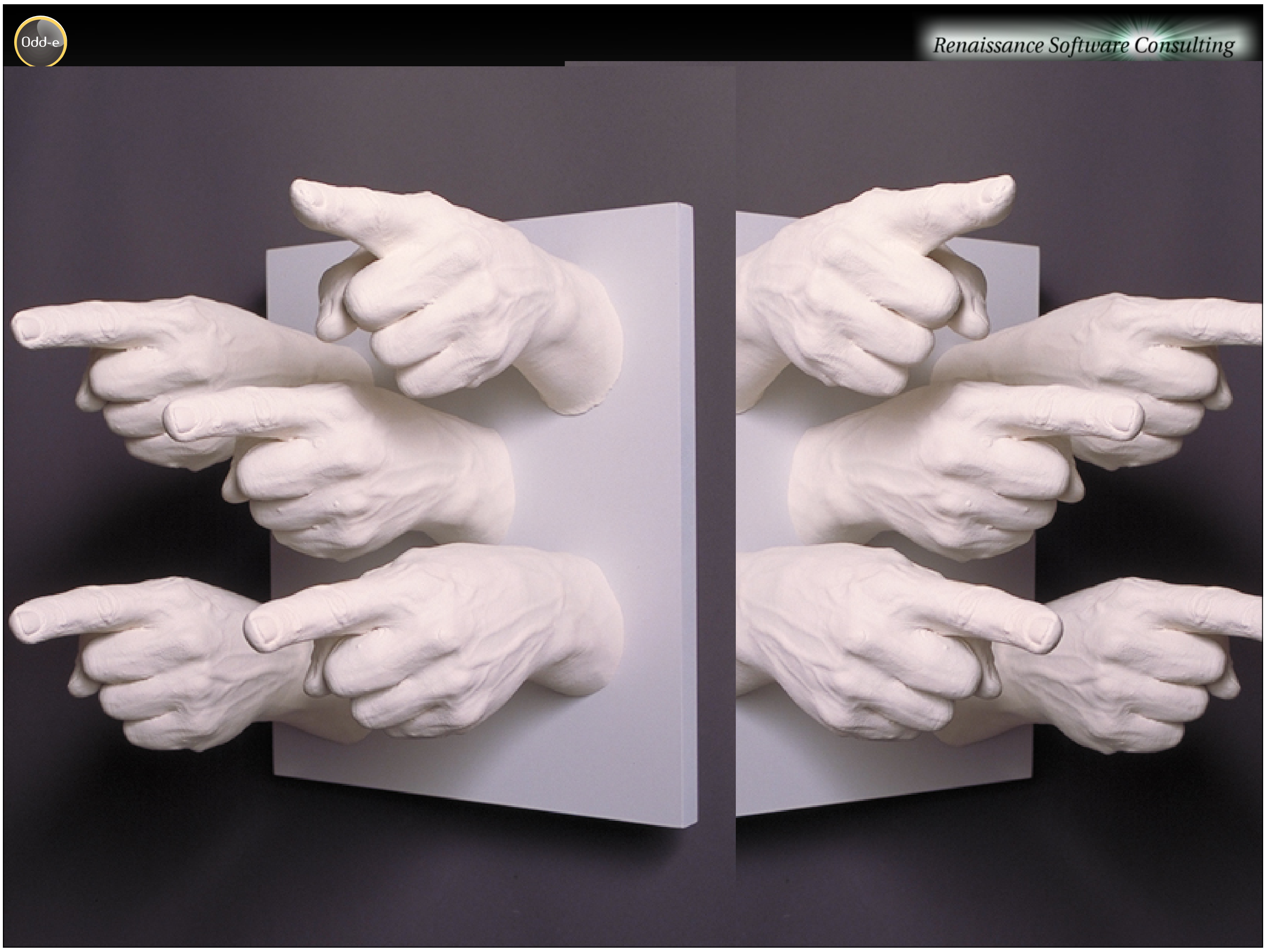
What is special about embedded

- Concurrent HW development
- HW bottleneck
- Cross compilation
- Limited memory and IO
- Target debug
- Architecture

Hardware is Scarce!

- It does not exist.
- It is being used by someone else.
- It has bugs of its own.

[illegible]



Minimize

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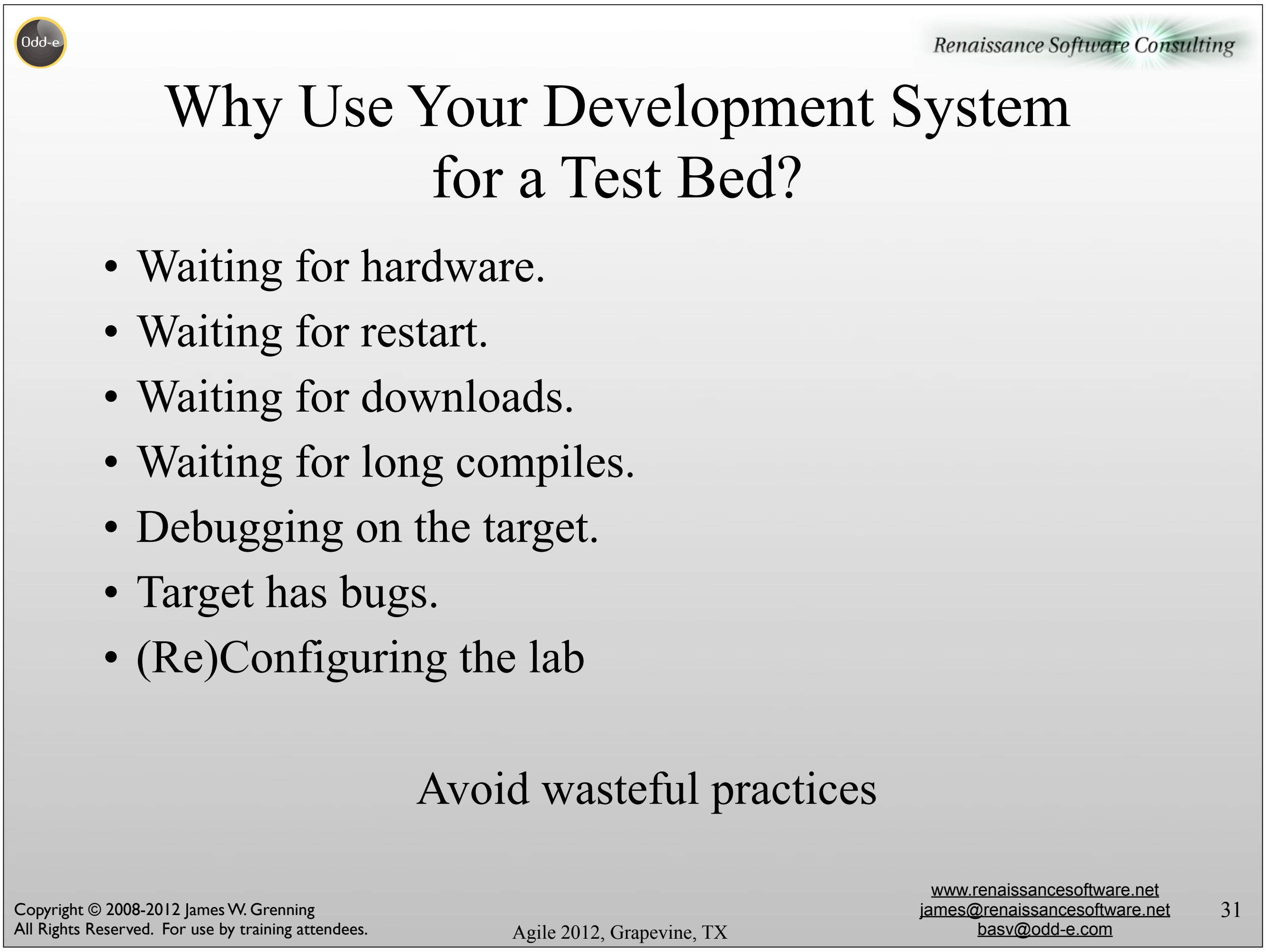
Debug

On

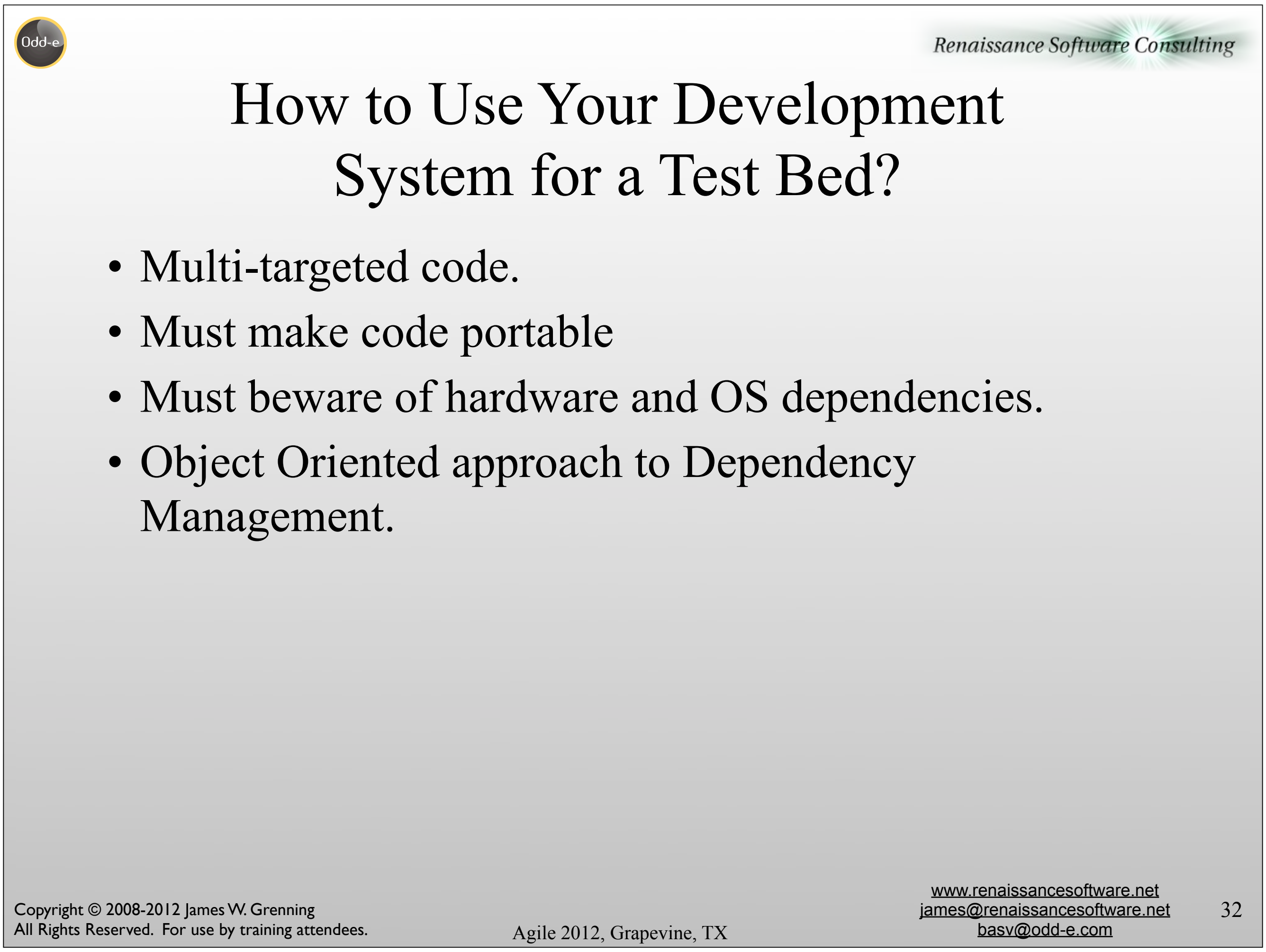
Hardware



Why Use Your Development System for a Test Bed?

- Waiting for hardware.
- Waiting for restart.
- Waiting for downloads.
- Waiting for long compiles.
- Debugging on the target.
- Target has bugs.
- (Re)Configuring the lab

Avoid wasteful practices



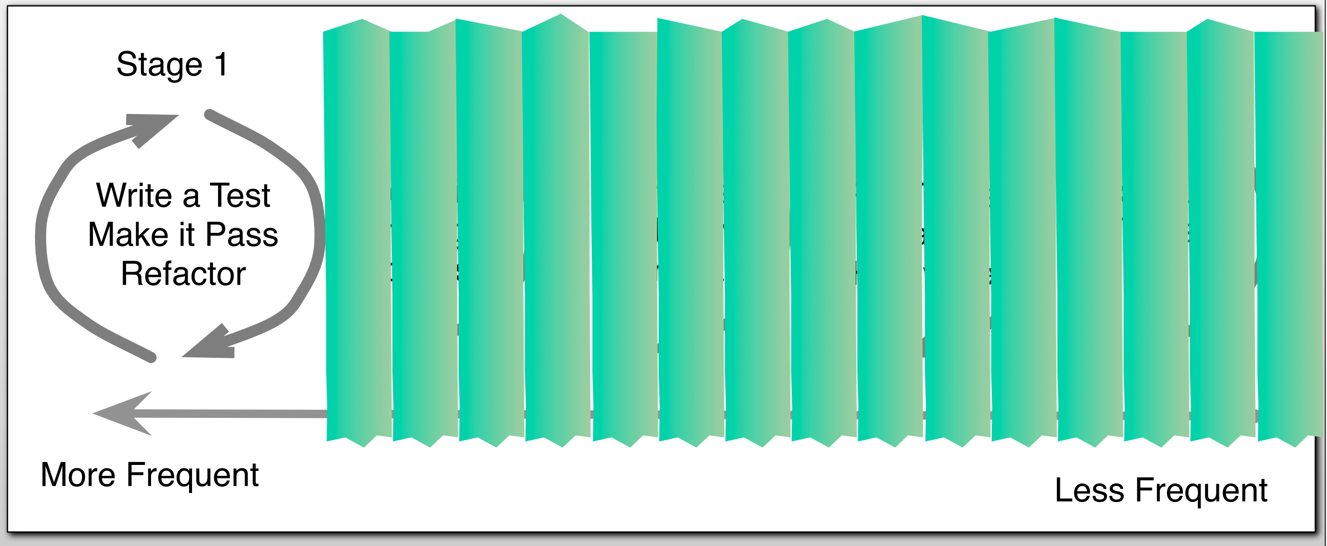
How to Use Your Development System for a Test Bed?

- Multi-targeted code.
- Must make code portable
- Must beware of hardware and OS dependencies.
- Object Oriented approach to Dependency Management.

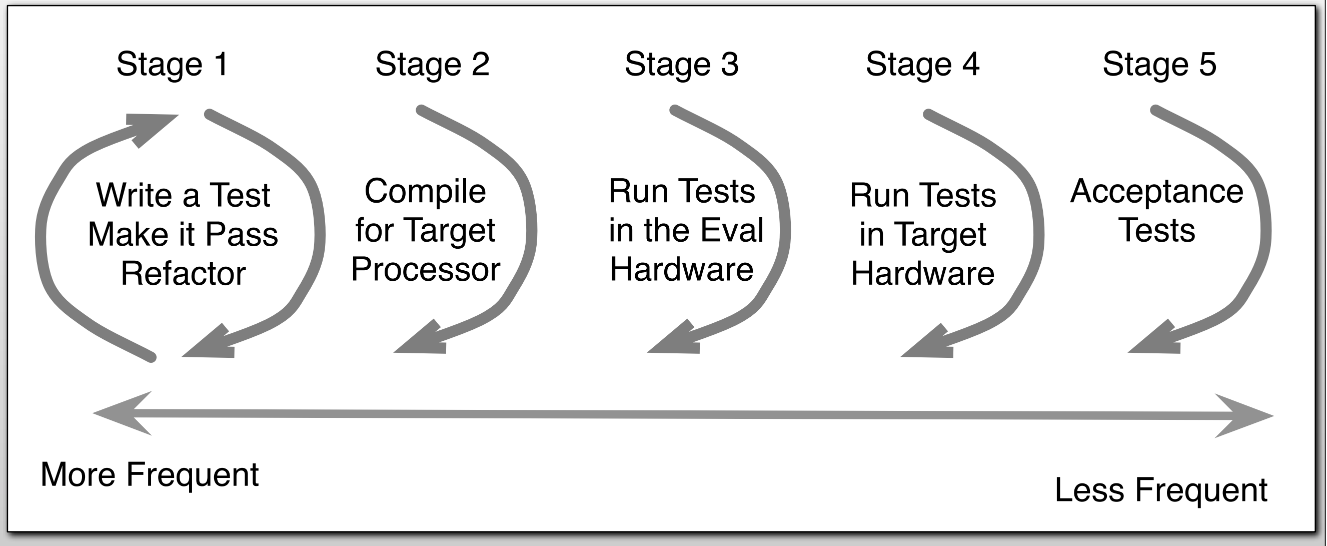
But There are Risks with Development System Tests

- Architecture differences
  - Word size
  - Big-endian Little-endian
  - Alignment
- Compiler differences
- Library differences
- Execution differences

TDD Adaptation for Embedded Development



TDD Adaptation for Embedded Development



Stage 1

Write a Test
Make it Pass
Refactor

Stage 2

Compile
for Target
Processor

Stage 3

Run Tests
in the Eval
Hardware

Stage 4

Run Tests
in Target
Hardware

Stage 5

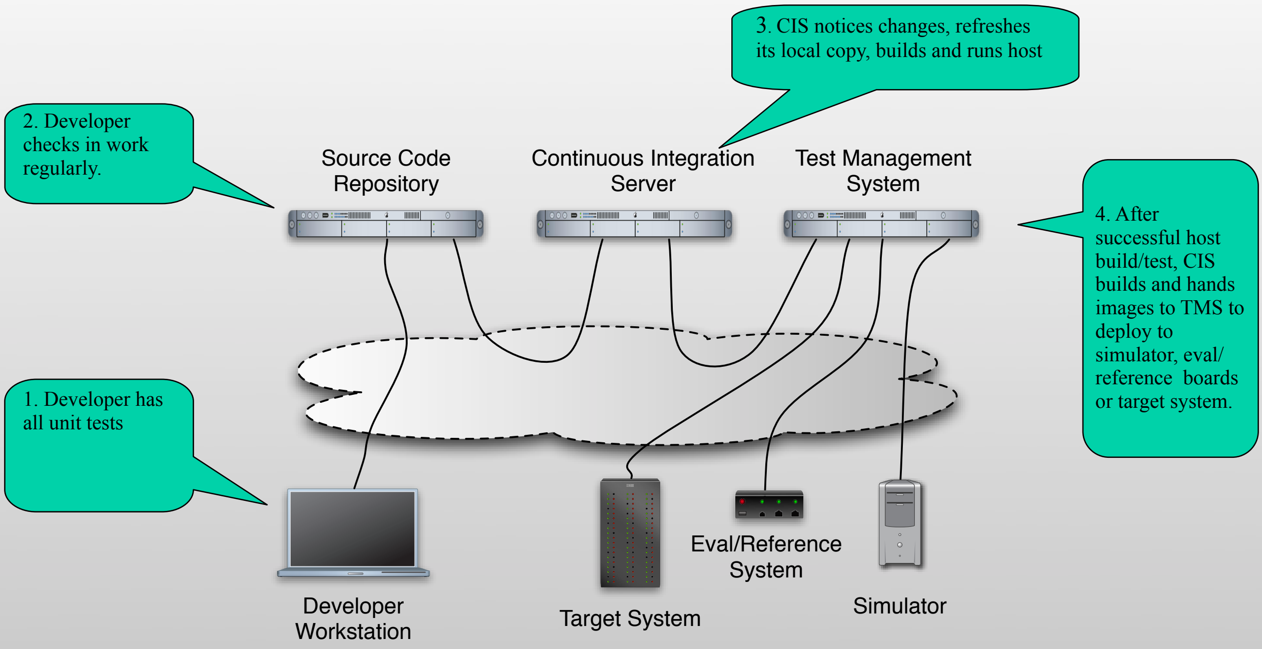
Acceptance
Tests

More Frequent

Less Frequent

See : http://renaissancesoftware.net/files/articles/ProgressBeforeHardware.pdf

Continuous Integration - Embedded



3. CIS notices changes, refreshes its local copy, builds and runs host

2. Developer checks in work regularly.

Source Code Repository

Continuous Integration Server

Test Management System

4. After successful host build/test, CIS builds and hands images to TMS to deploy to simulator, eval/ reference boards or target system.

1. Developer has all unit tests

Developer Workstation

Target System

Eval/Reference System

Simulator

The SCR, CIS and TMS are not necessarily separate hardware systems.

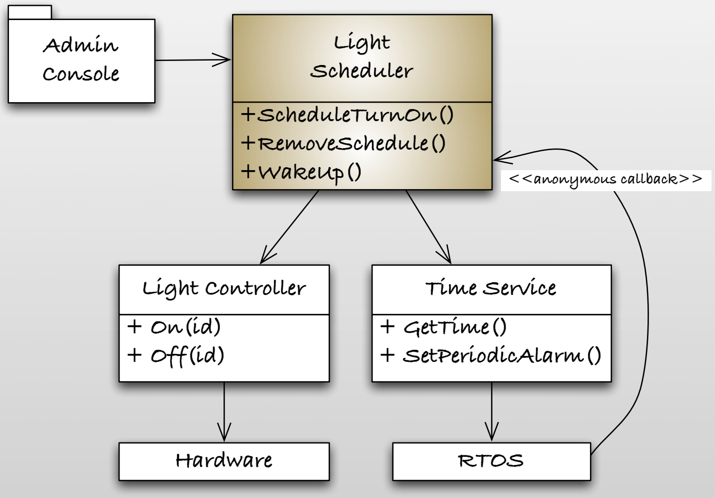
Problems Found at Appropriate Stage

Stage	Problems Likely to Find in Stage
1	Logic, design, modularity, interface, boundary conditions
2	Compiler compatibility (language features) Library compatibility (header files, declarations)
3	Processor executions problems (compiler and library bugs) Portability problems (word size, alignment, endian)
4	Ditto stage 3 Hardware integration problems Misunderstood hardware specifications
5	Ditto stage 4 Misunderstood feature specification

Hardware and OS Abstraction

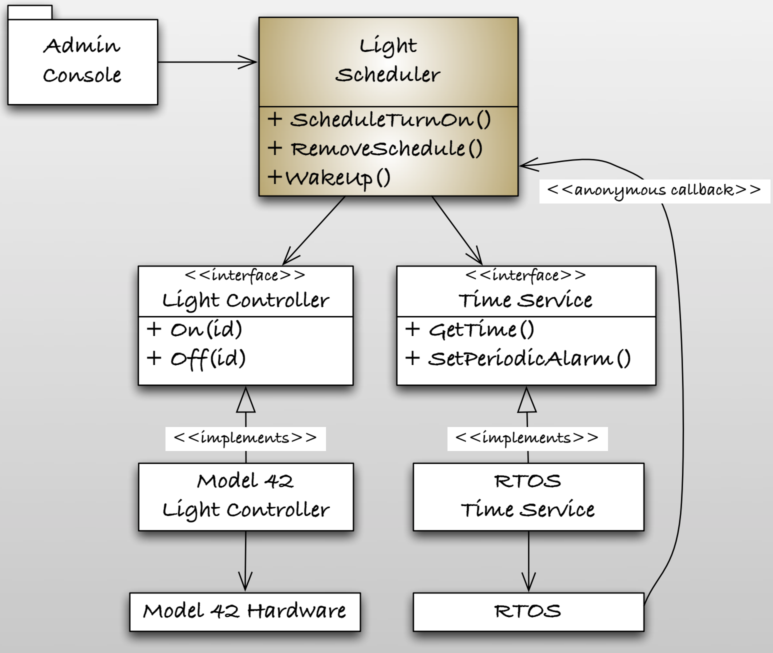
Separation of Responsibilities

- Every minute, the RTOS wakes up the Light Scheduler.
- If it is time for one of the lights to be controlled, the LightController is told to turn on/off the light.



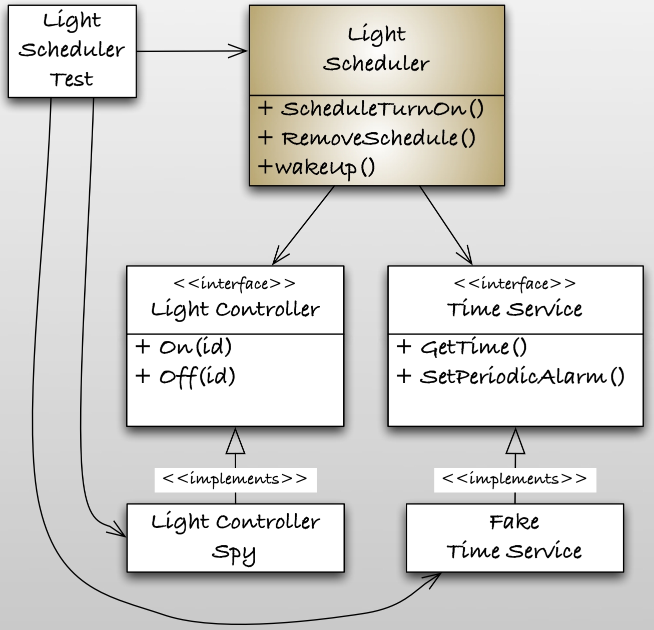
Light Scheduler Design

- Program to Interfaces
- Separate interface and implementation as separate entities.
- This design has good separation of responsibilities



LightScheduler Test Fixture Design

- Use the real collaborators if you can.
- Use fakes when you must.



Testing the Scheduler

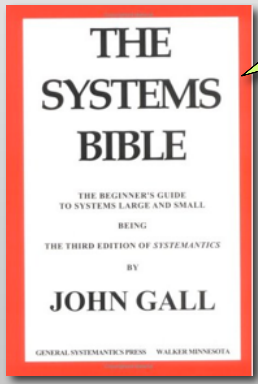
```
TEST(LightScheduler, light_not_changed_at_the_wrong_time)
{
    LightScheduler_ScheduleTurnOn(3, EVERYDAY, 1200);
    FakeTimeService_SetMinute(1199);
    LightScheduler_Wakeup();
    LONGS_EQUAL(NO_LIGHT_ID, LightControllerSpy_GetLastId());
    LONGS_EQUAL(LIGHT_STATE_UNKNOWN, LightControllerSpy_GetLastState());
}

TEST(LightScheduler, light_changed_at_the_right_time)
{
    LightScheduler_ScheduleTurnOn(3, EVERYDAY, 1200);
    FakeTimeService_SetMinute(1200);
    LightScheduler_Wakeup();
    LONGS_EQUAL(3, LightControllerSpy_GetLastId());
    LONGS_EQUAL(LIGHT_ON, LightControllerSpy_GetLastState());
}
```

Light Scheduler Test List

Light Scheduler Tests

Lights are not changed at initialization
Time is wrong, day is wrong, no lights are changed
Day is right, time is wrong, no lights are changed
Day is wrong, time is right, no lights are changed
Day is right, time is right, the right light is turned on
Day is right, time is right, the right light is turned off
Schedule every day
Schedule a specific day
Schedule all weekdays
Schedule weekend days
Remove scheduled event
Remove non-existent event
Multiple scheduled events at the same time
Multiple scheduled events for the same light
Remove non scheduled light schedule
Schedule the maximum supported number of events (128)
Schedule too many events

A Complex system that works is invariably found to have evolved from a simple system that worked.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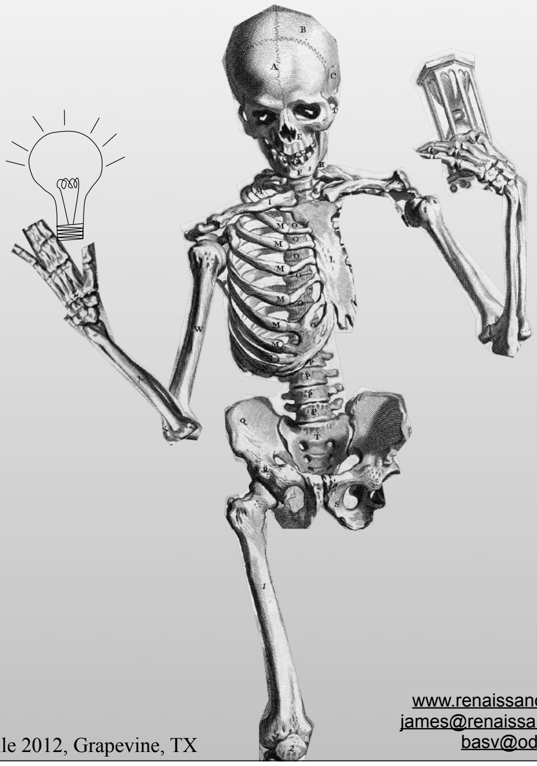
Partial Skeleton Let's Your Try the Design and Test Ideas Early



Copy/Paste THINK

```
TEST(LightScheduler, light_not_changed_at_the_wrong_time)
{
    LightScheduler_ScheduleTurnOn(3, EVERYDAY, 1200);
    TransitionClockTo(SUNDAY, 1199);
   ExpectLightsUnchanged();
}

TEST(LightScheduler, light_changed_at_the_right_time)
{
    LightScheduler_ScheduleTurnOn(3, EVERYDAY, 1200);
    TransitionClockTo(SUNDAY, 1200);
    ExpectLightOn(3);
}
```

Test-Double Substitution Options

Replacing collaborators

- Linker-stubbing
- Function pointer
- Pre-processor

Linker Substitution

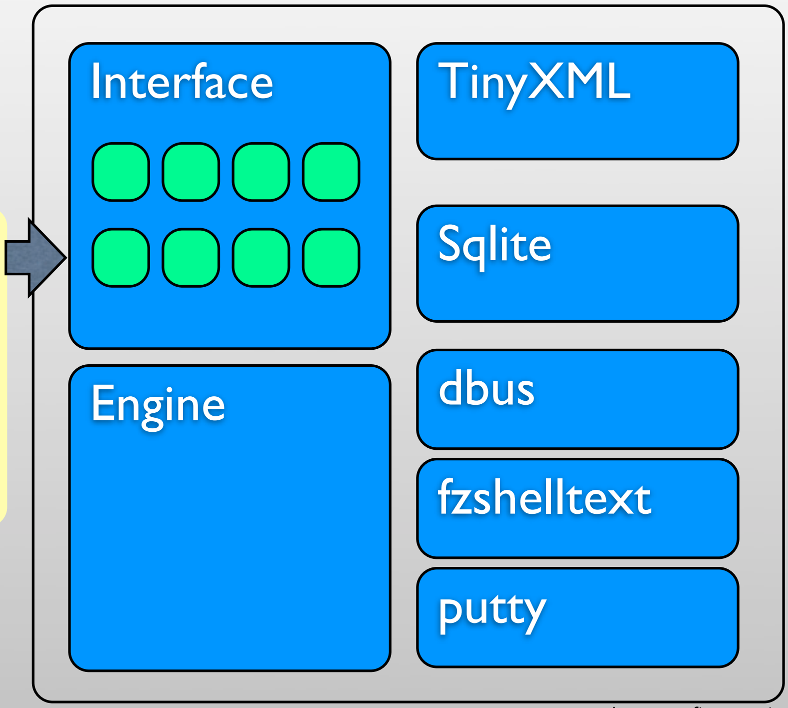
Linker Stubbing

```
#include "sqlite3.h"

int sqlite3_open(const char *filename, sqlite3 **ppDb)
{
    FAIL("sqlite3_open");
    return 0;
}

int sqlite3_step(sqlite3_stmt*)
{
    FAIL("sqlite3_step");
    return 0;
}

int sqlite3_reset(sqlite3_stmt *pStmt)
{
    FAIL("sqlite3_reset");
    return 0;
}

sqlite3_int64 sqlite3_last_insert_rowid(sqlite3*)
{
    FAIL("sqlite3_last_insert_rowid");
    return 0;
}

int sqlite3_bind_int64(sqlite3_stmt*, int, sqlite3_int64)
{
    FAIL("sqlite3_bind_int64");
    return 0;
}
```

Don’t link the real library. Instead provide a fake that does something useful for the test

Use linker stubs across subsystems

- Use linker stubs on other subsystems
- Linker stubs requires no change in code! ✓



Function Pointer Substitution

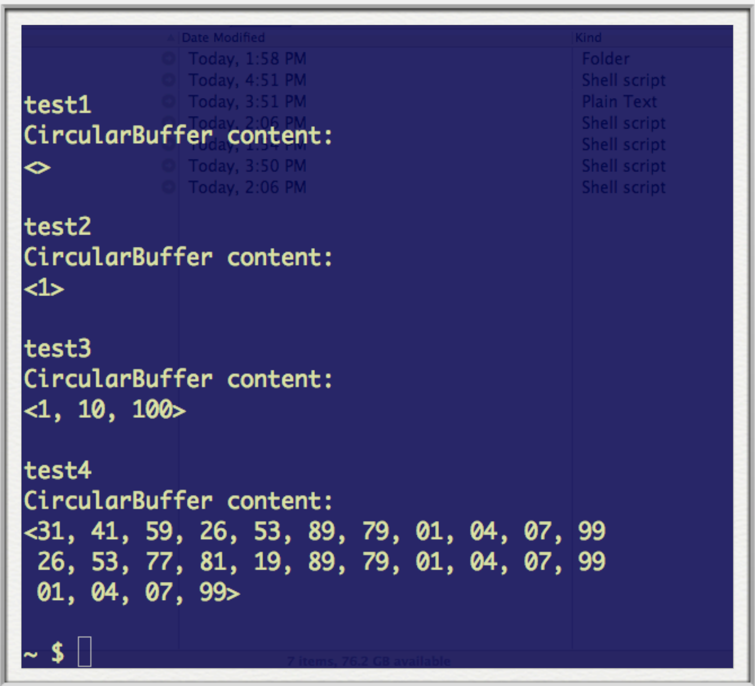
Reasons to Use Function Pointers for Test-Doubles

- When you already use function pointers for other purposes (you have a built-in test hook!)
  - Swappable device drivers
  - Swappable implementations
- You need the production implementation in the test build, and you must substitute a test double in the same test build
  - printf
- You don't want to have too many test builds due to using link-time substitution

Example Usage - Printed Output

- Logs and printed output are helpful for checking program correctness and debugging
- But...
  - They require that you look at the output.
  - They doom you to a lifetime of manually verified tests
- So...
  - Design your code so that printed output can be captured and verified in your unit tests

Manual/Tedious/Error Prone Output Inspection

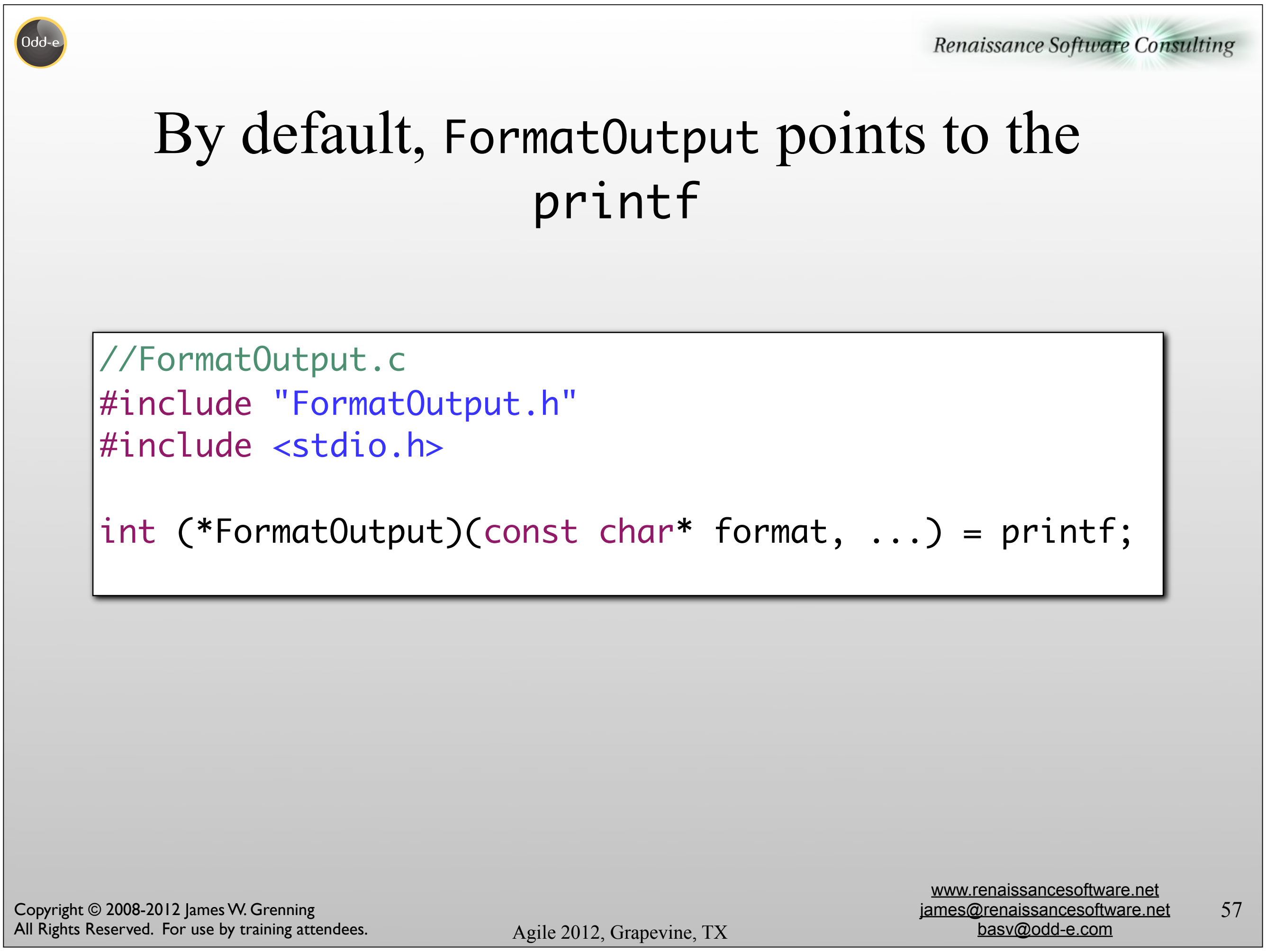


```
test1
CircularBuffer content:
<>

test2
CircularBuffer content:
<1>

test3
CircularBuffer content:
<1, 10, 100>

test4
CircularBuffer content:
<31, 41, 59, 26, 53, 89, 79, 01, 04, 07, 99
 26, 53, 77, 81, 19, 89, 79, 01, 04, 07, 99
 01, 04, 07, 99>

~ $
```

Function Pointer - Runtime Substitution

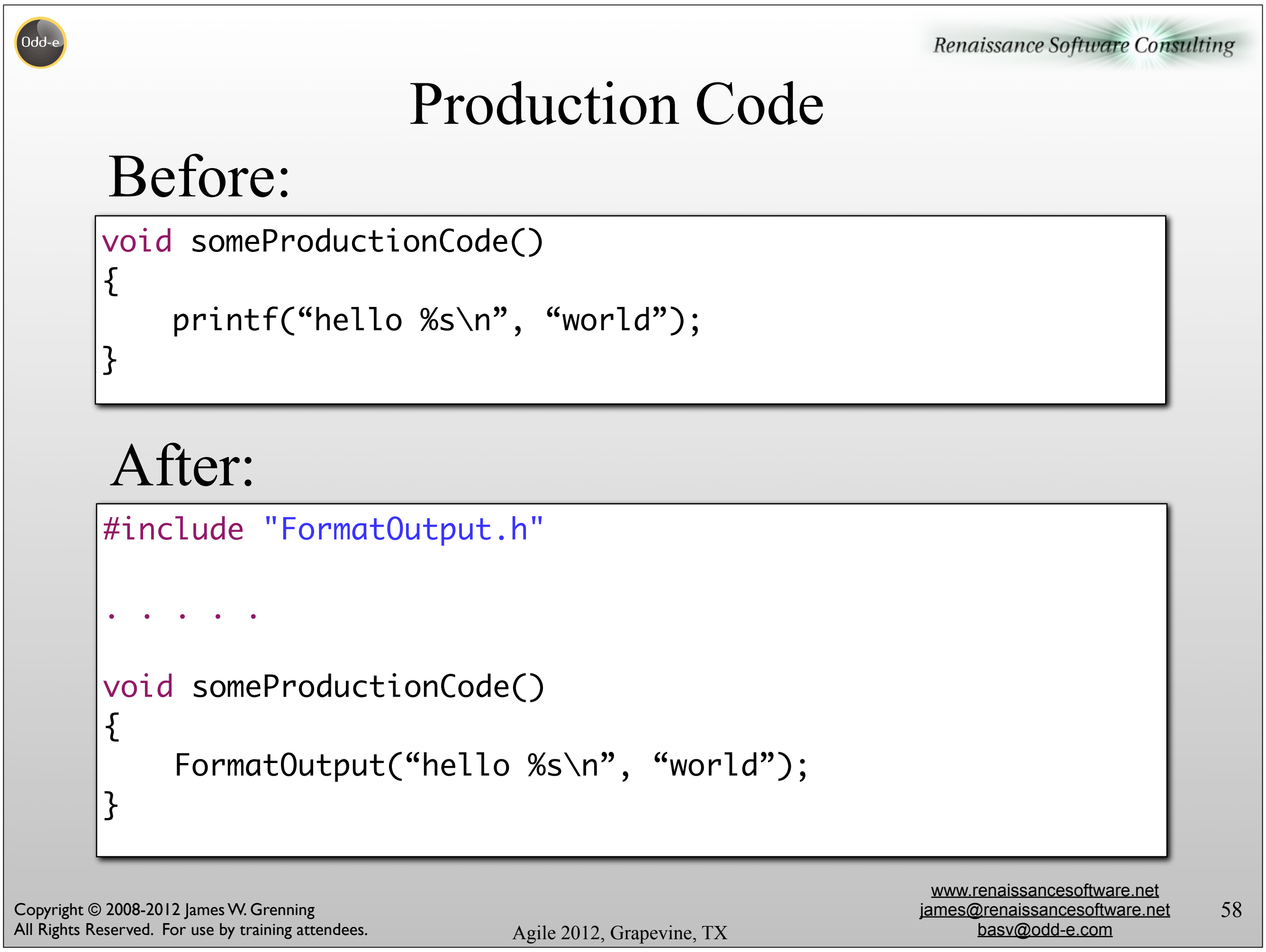
- Sometimes we want to use the real function.
- Sometimes we want to use a test version.
- Define a function pointer that has the same declaration as the function to override, in this case `printf()`

```
#ifndef D_FormatOutput_H
#define D_FormatOutput_H

extern int (*FormatOutput)(const char *, ...);

#endif  // D_FormatOutput_H
```



By default, `FormatOutput` points to the `printf`

```
//FormatOutput.c
#include "FormatOutput.h"
#include <stdio.h>

int (*FormatOutput)(const char* format, ...) = printf;
```



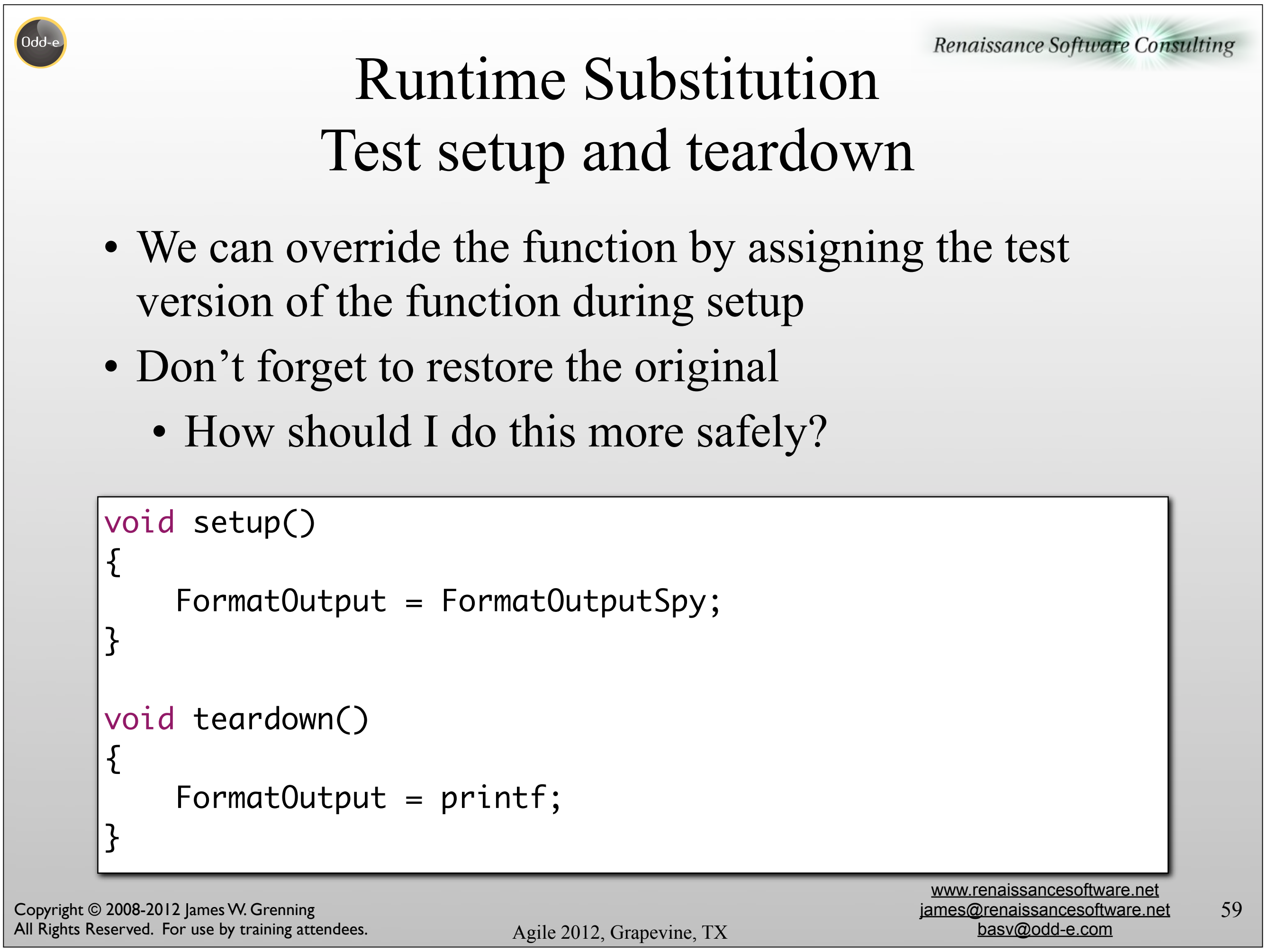
Production Code

Before:

```
void someProductionCode()
{
    printf(“hello %s\n”, “world”);
}
```

After:

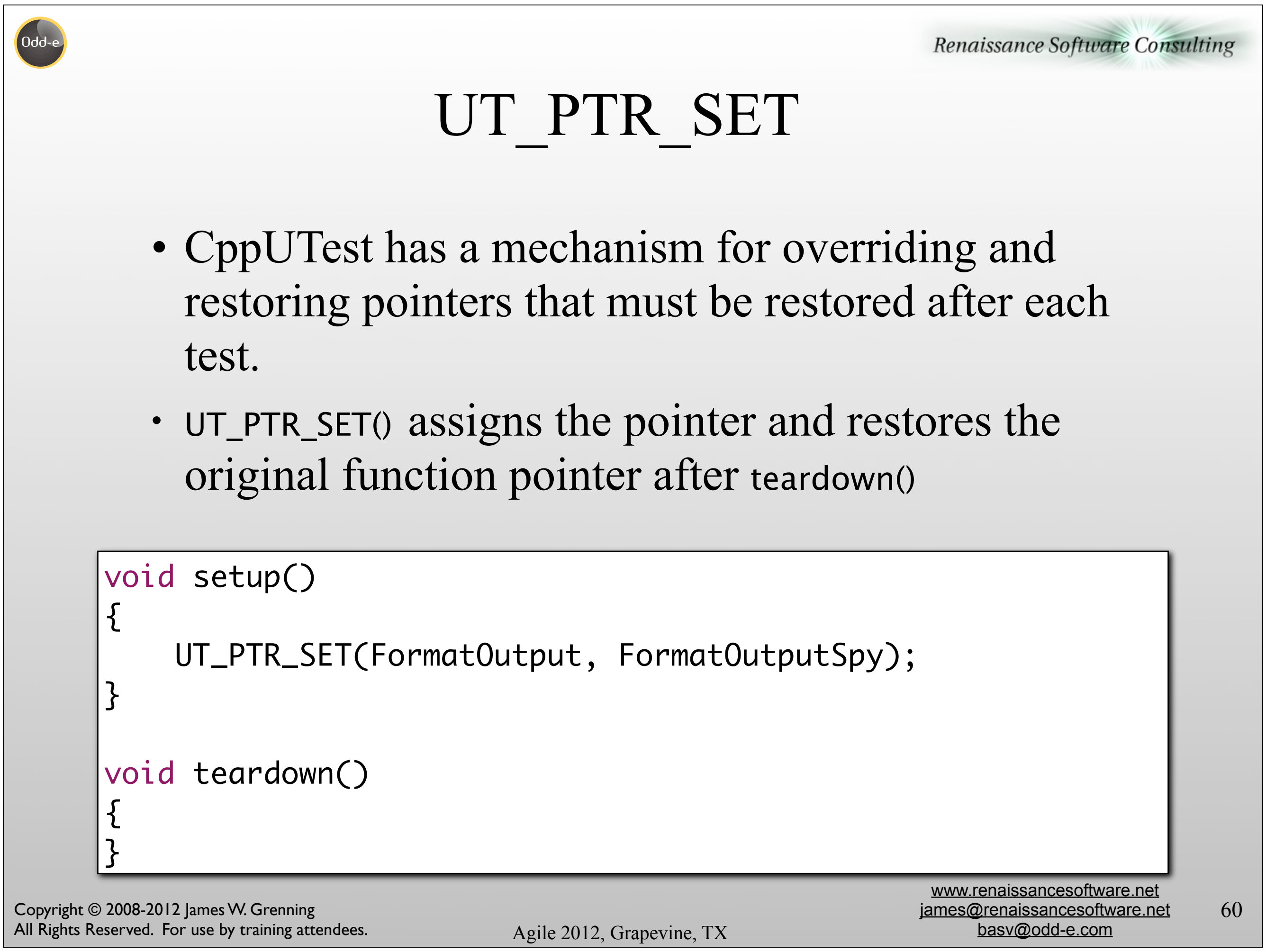
```
#include "FormatOutput.h"

. . . . .

void someProductionCode()
{
    FormatOutput(“hello %s\n”, “world”);
}
```



Runtime Substitution
Test setup and teardown

- We can override the function by assigning the test version of the function during setup
- Don't forget to restore the original
  - How should I do this more safely?

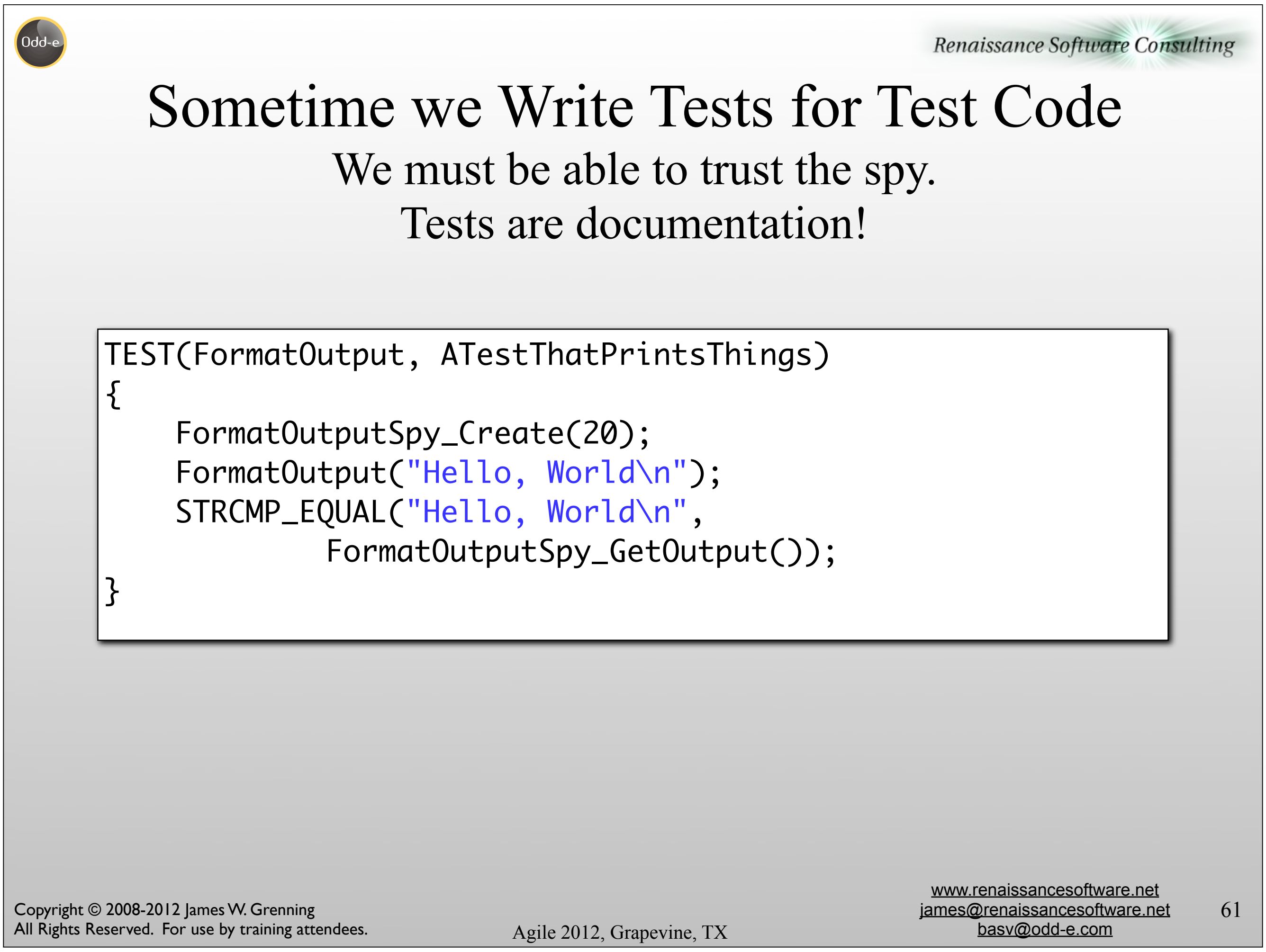
```
void setup()
{
    FormatOutput = FormatOutputSpy;
}

void teardown()
{
    FormatOutput = printf;
}
```



UT_PTR_SET

- CppUTest has a mechanism for overriding and restoring pointers that must be restored after each test.
- UT_PTR_SET() assigns the pointer and restores the original function pointer after teardown()

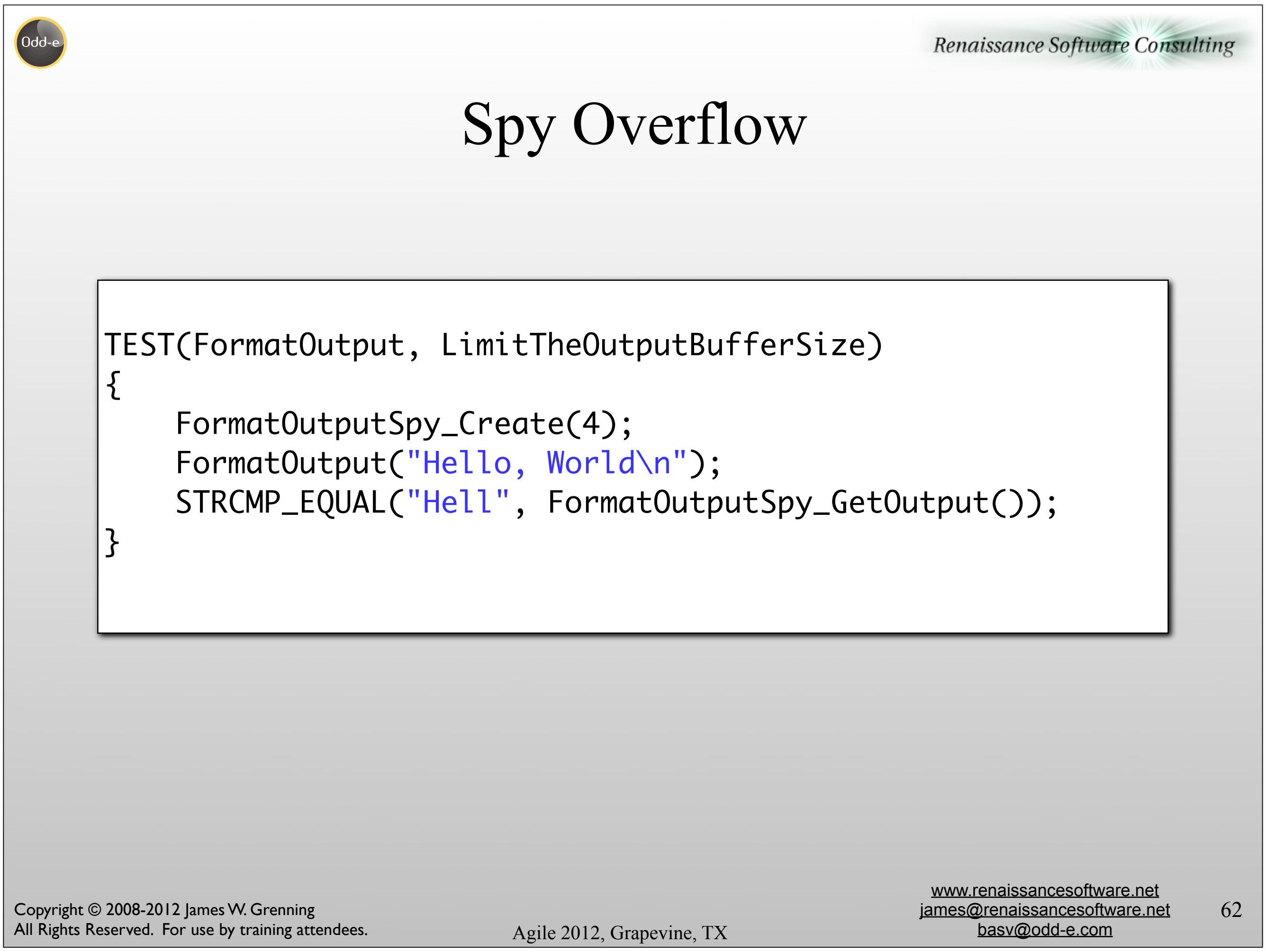
```
void setup()
{
    UT_PTR_SET(FormatOutput, FormatOutputSpy);
}

void teardown()
{
}
```



Sometime we Write Tests for Test Code

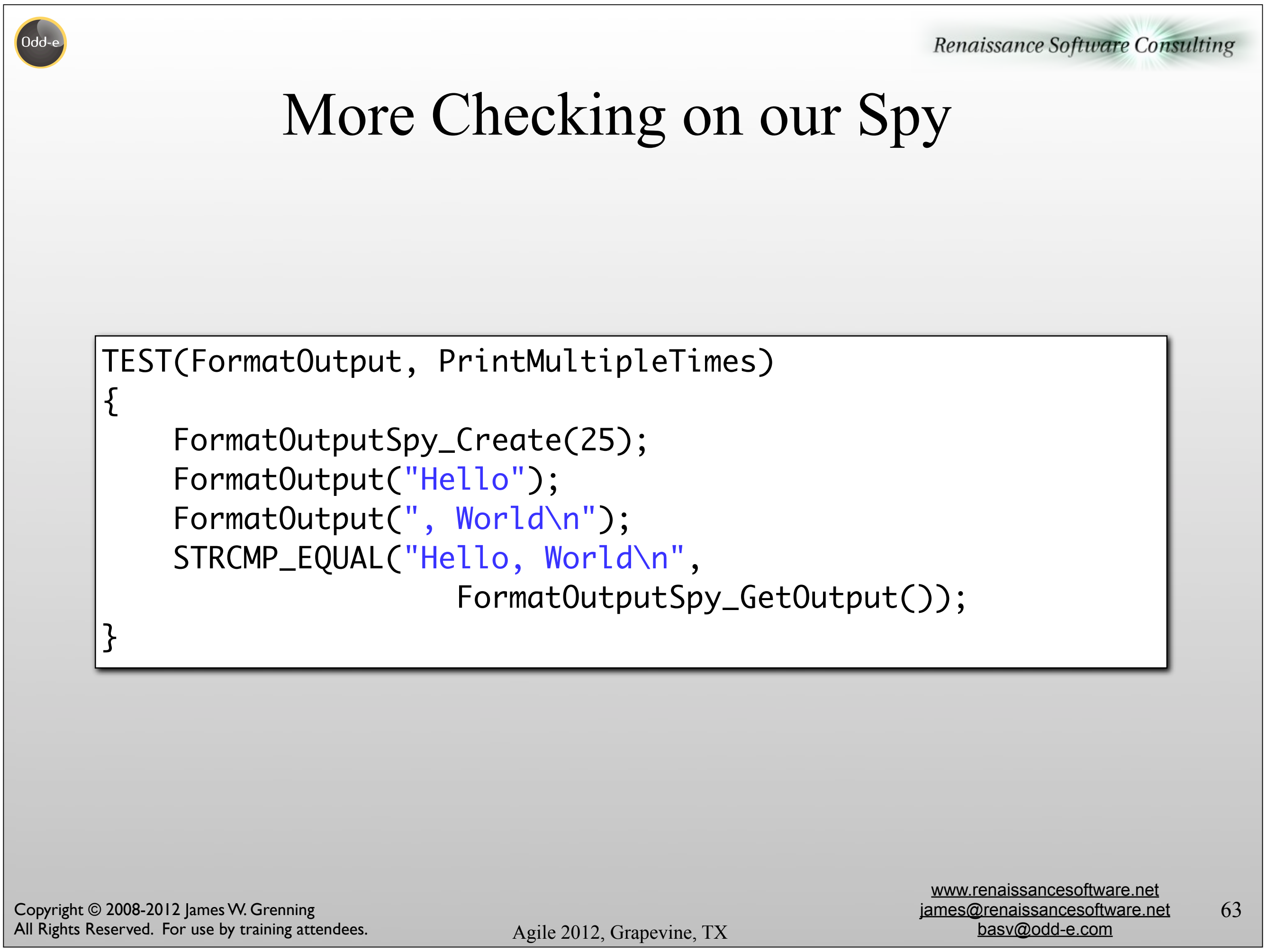
We must be able to trust the spy.
Tests are documentation!

```
TEST(FormatOutput, ATestThatPrintsThings)
{
    FormatOutputSpy_Create(20);
    FormatOutput("Hello, World\n");
    STRCMP_EQUAL("Hello, World\n",
            FormatOutputSpy_GetOutput());
}
```



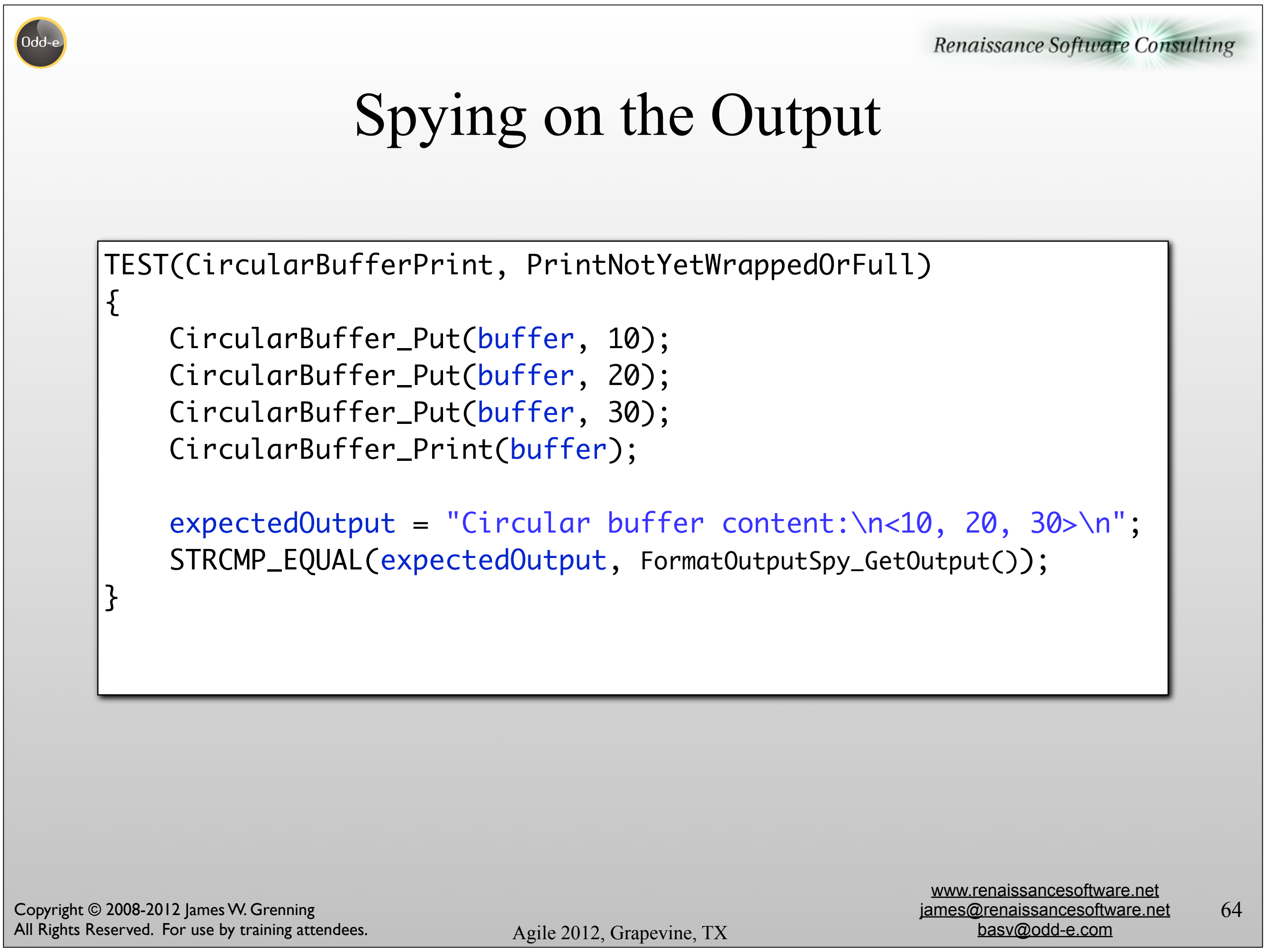
Spy Overflow

```
TEST(FormatOutput, LimitTheOutputBufferSize)
{
    FormatOutputSpy_Create(4);
    FormatOutput("Hello, World\n");
    STRCMP_EQUAL("Hell", FormatOutputSpy_GetOutput());
}
```



More Checking on our Spy

```
TEST(FormatOutput, PrintMultipleTimes)
{
    FormatOutputSpy_Create(25);
    FormatOutput("Hello");
    FormatOutput(", World\n");
    STRCMP_EQUAL("Hello, World\n",
                    FormatOutputSpy_GetOutput());
}
```



Spying on the Output

```
TEST(CircularBufferPrint, PrintNotYetWrappedOrFull)
{
    CircularBuffer_Put(buffer, 10);
    CircularBuffer_Put(buffer, 20);
    CircularBuffer_Put(buffer, 30);
    CircularBuffer_Print(buffer);

    expectedOutput = "Circular buffer content:\n<10, 20, 30>\n";
    STRCMP_EQUAL(expectedOutput, FormatOutputSpy_GetOutput());
}
```

Test Fixture

```
TEST_GROUP(CircularBufferPrint)
{
    CircularBuffer buffer;
    const char * expectedOutput;
    const char * actualOutput;

    void setup()
    {
      UT_PTR_SET(FormatOutput, FormatOutputSpy);
      FormatOutputSpy_Create(100);
      buffer = CircularBuffer_Create(10);
    }

    void teardown()
    {
       CircularBuffer_Destroy(buffer);
       FormatOutputSpy_Destroy();
    }
};
```

Preprocessor Substitution

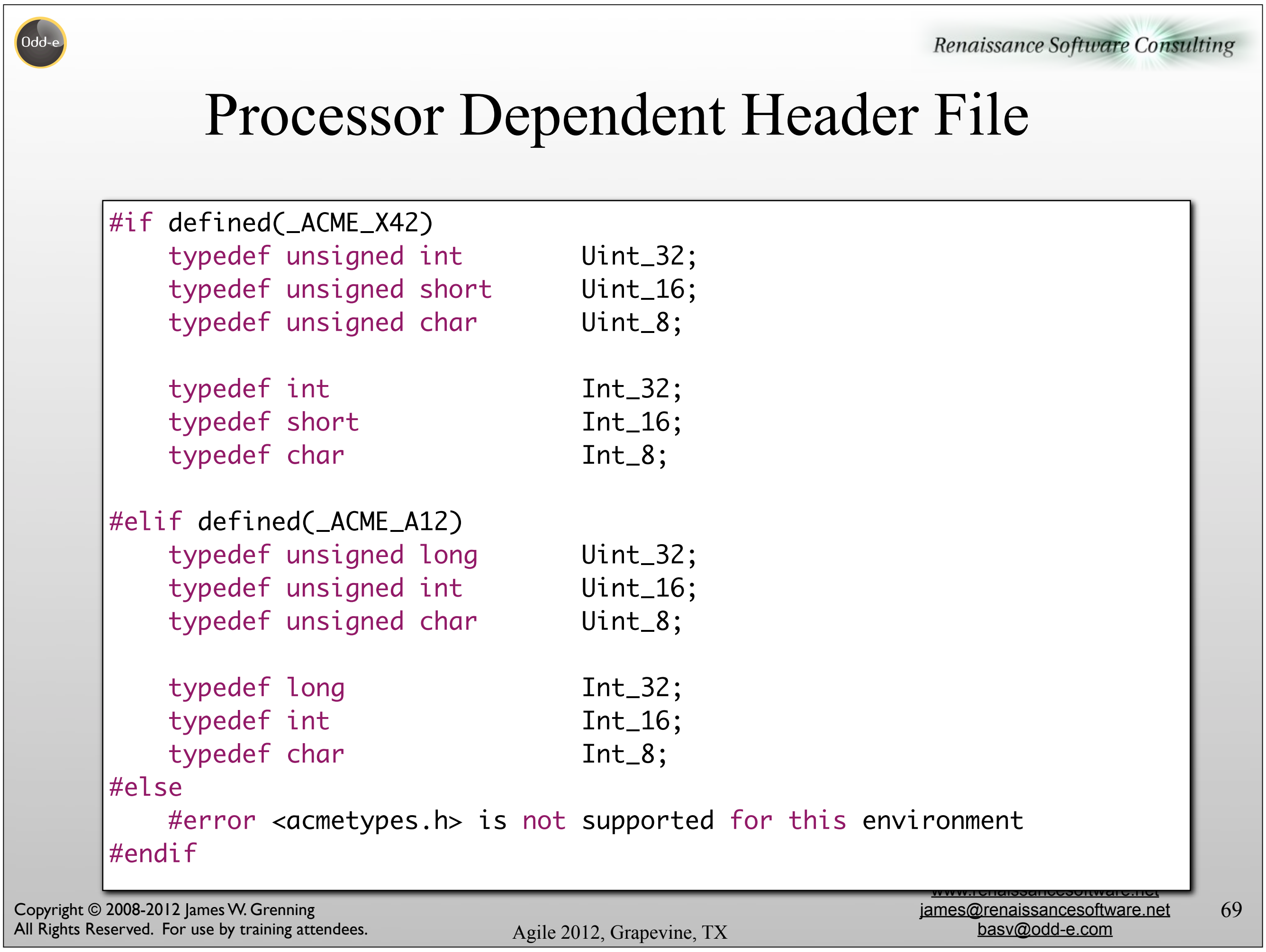
Preprocessor Substitution

- Is the least desirable form of substitution
- Though necessary when
  - Header files won’t compile off-target
  - Header files have are the start to a massive dependency chain
  - A direct function call API cannot be changed and you need to override the direct call and use the direct call in the implementation of the fake

    e.g. **`malloc()`**, **`free()`**

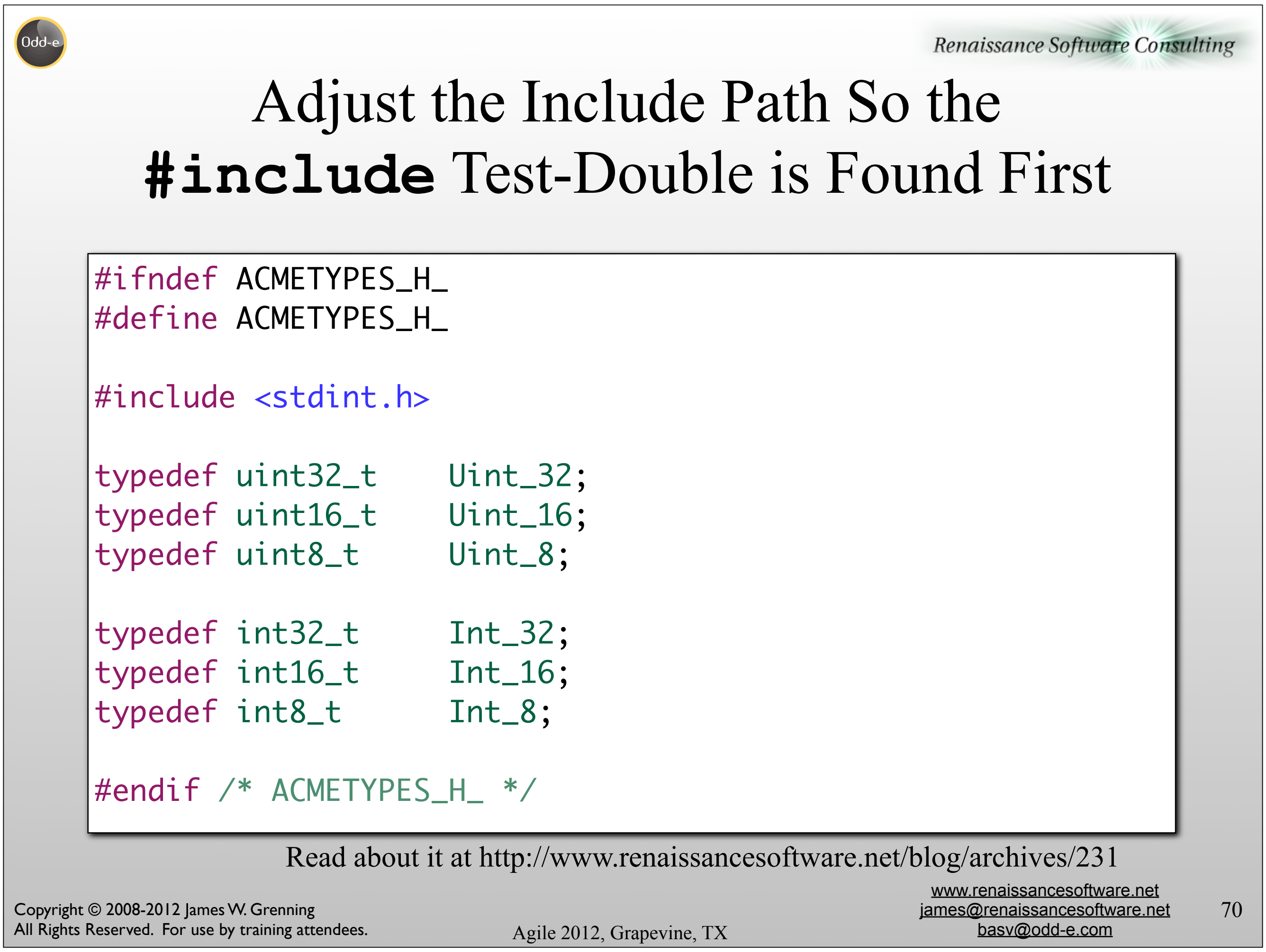
Preprocessor Substitution Variants

- Header file test double
  - Change the include path during test builds
- Force includes
  - Force in a header file that substitutes problem dependencies
- Command line definition
  - Override a symbol one at a time



Processor Dependent Header File

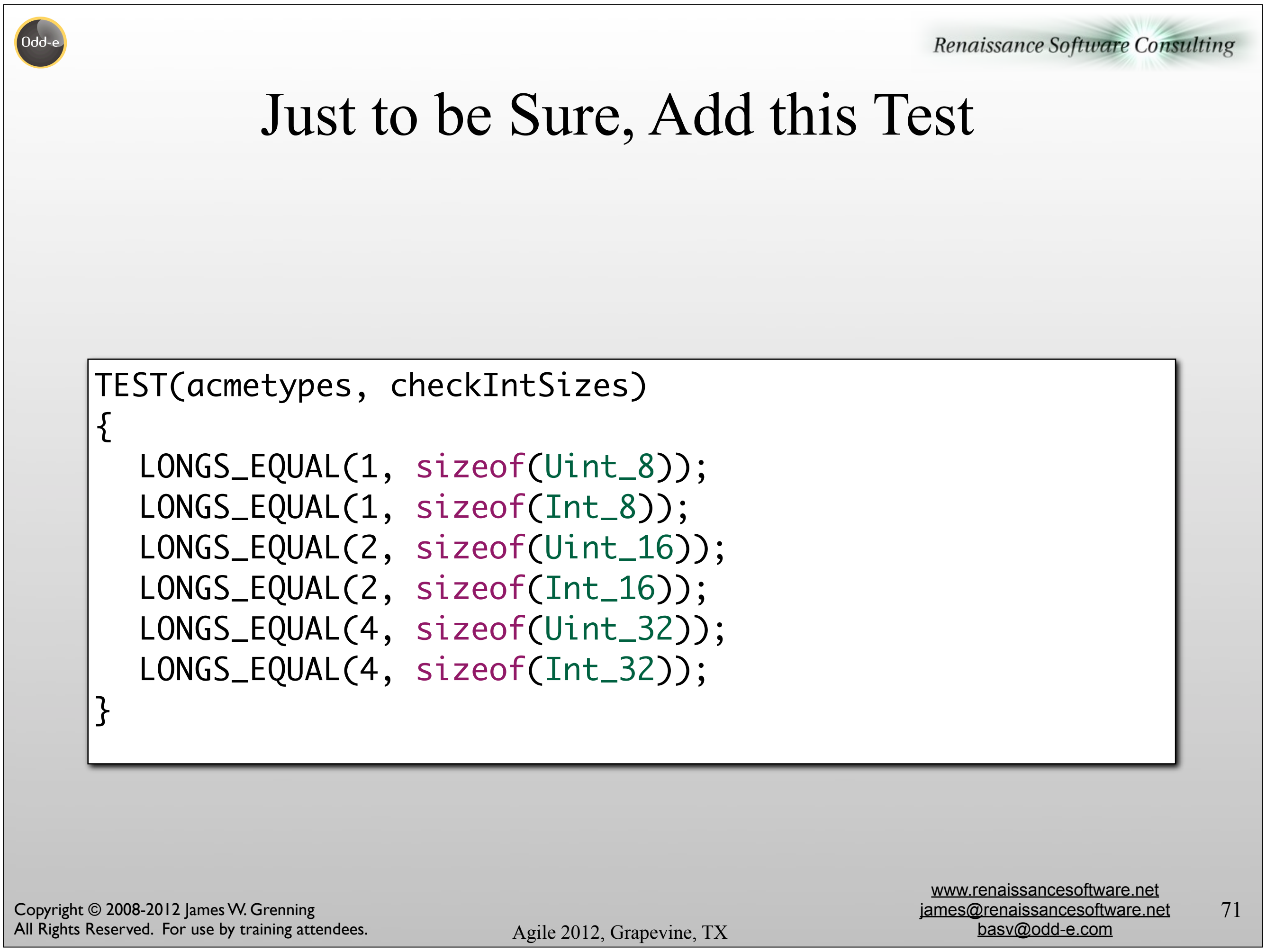
```
#if defined(_ACME_X42)
    typedef unsigned int        Uint_32;
    typedef unsigned short      Uint_16;
    typedef unsigned char       Uint_8;

    typedef int                 Int_32;
    typedef short               Int_16;
    typedef char                Int_8;

#elif defined(_ACME_A12)
    typedef unsigned long       Uint_32;
    typedef unsigned int        Uint_16;
    typedef unsigned char       Uint_8;

    typedef long                Int_32;
    typedef int                 Int_16;
    typedef char                Int_8;
#else
    #error <acmetypes.h> is not supported for this environment
#endif
```



Adjust the Include Path So the **#include** Test-Double is Found First

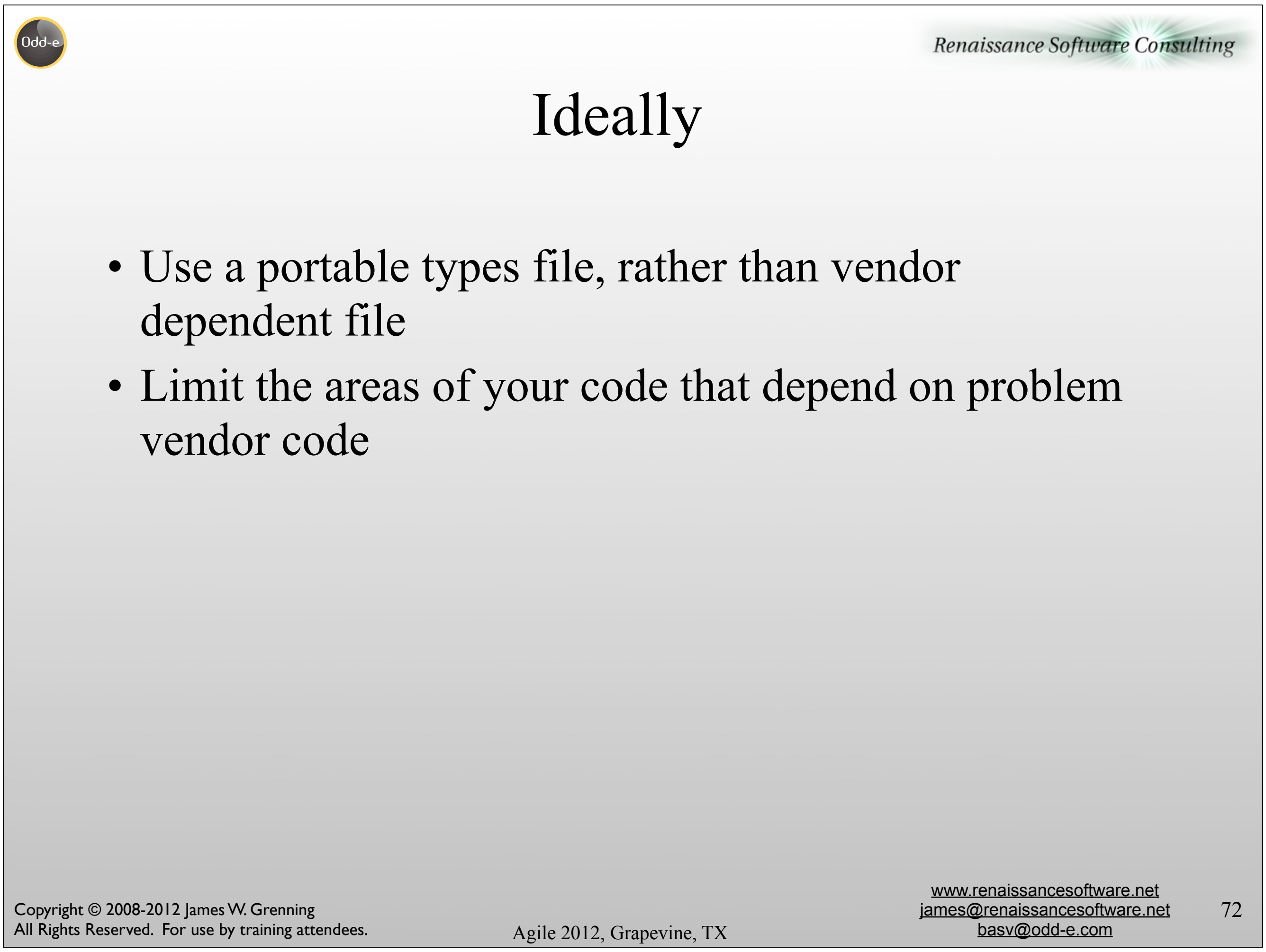
```
#ifndef ACMETYPES_H_
#define ACMETYPES_H_

#include <stdint.h>

typedef uint32_t    Uint_32;
typedef uint16_t    Uint_16;
typedef uint8_t     Uint_8;

typedef int32_t     Int_32;
typedef int16_t     Int_16;
typedef int8_t      Int_8;

#endif /* ACMETYPES_H_ */
```

Read about it at http://www.renaissancesoftware.net/blog/archives/231



Just to be Sure, Add this Test

```
TEST(acmetypes, checkIntSizes)
{
   LONGS_EQUAL(1, sizeof(Uint_8));
   LONGS_EQUAL(1, sizeof(Int_8));
   LONGS_EQUAL(2, sizeof(Uint_16));
   LONGS_EQUAL(2, sizeof(Int_16));
   LONGS_EQUAL(4, sizeof(Uint_32));
   LONGS_EQUAL(4, sizeof(Int_32));
}
```



Ideally

- Use a portable types file, rather than vendor dependent file
- Limit the areas of your code that depend on problem vendor code

See the C that is NOT C

```
/* Chip Vendor Specific Header File     */
...
extern cregister volatile unsigned int AMR;     /* Address Mode Register      */
extern cregister volatile unsigned int CSR;     /* Control Status Register    */
extern cregister volatile unsigned int IFR;     /* Interrupt Flag Register    */
extern cregister volatile unsigned int ISR;     /* Interrupt Set Register     */
extern cregister volatile unsigned int ICR;     /* Interrupt Clear Register   */
extern cregister volatile unsigned int IER;     /* Interrupt Enable Register  */
extern cregister volatile unsigned int ISTP;    /* Interrupt Service Tbl Ptr  */
extern cregister volatile unsigned int IRP;     /* Interrupt Return Pointer   */
extern cregister volatile unsigned int NRP;     /* Non-maskable Int Return Ptr*/
extern cregister volatile unsigned int IN;      /* General Purpose Input Reg  */
extern cregister volatile unsigned int OUT;     /* General Purpose Output Reg */
...
```

Read about it at http://www.renaissancesoftware.net/blog/archives/249

Force Include

```
//OffTargetDefines.h

#define cregister
#define interrupt
...
```

Registers Become Global Variables

```
// FakeRegisters.c
volatile unsigned int AMR;
volatile unsigned int CSR;
volatile unsigned int IFR;
volatile unsigned int ISR;
volatile unsigned int ICR;
volatile unsigned int IER;
volatile unsigned int ISTP;
volatile unsigned int IRP;
volatile unsigned int NRP;
volatile unsigned int IN;
volatile unsigned int OUT;
```

Ideally

- You should limit areas of your code that are vendor specific
- Make a Hardware Abstraction Layer

Command Line Definition

- Compilers all preprocessor symbols to be defined on the command line
- These gcc command line options changes all occurrences of **`malloc()`** to **`cpputest_malloc()`** and **`free()`** to **`cpputest_free()`**

```
-Dmalloc=cpputest_malloc
-Dfree=cpputest_free
```

Undefine the Override So the Original Can be Used

```
#undef malloc
#undef free

void * cpputest_malloc(size_t size)
{
  // do the malloc/free book keeping
   return malloc(size);
}

void cpputest_free(void * mem)
{
  // do the malloc/free book keeping
   return free(mem);
}
```

Problem - asm

The legacy code has **asm** instructions that won't compile off-target

Solution - 1

Make **asm** go away using forced include

Solution - 2

Introduce an **AsmSpy** to capture the instruction stream and check it in a test case

- See http://www.renaissancesoftware.net/blog/archives/136

What is an **AsmSpy**?

```
TEST(AsmSpy, captures_asm_text)
{
   AsmSpy("NOP");
   AsmSpy("GLOP");
   AsmSpy("SLOP");
   STRCMP_EQUAL("NOP;GLOP;SLOP;", AsmSpy_Debrief());
}
```

Read more:
http://www.renaissancesoftware.net/blog/archives/136
http://www.renaissancesoftware.net/blog/archives/143

Force Include AsmSpy.h

```
#ifndef D_AsmSpy_H
#define D_AsmSpy_H

#define asm AsmSpy

void AsmSpy_Create(int size);
void AsmSpy_Destroy(void);
void AsmSpy(const char *);
const char * AsmSpy_Debrief(void);

#endif
```

Problem - **#pragma**

The legacy code has **#pragma** instructions that won’t compile off-target

Solution

Adjust the compiler settings to ignore unknown **#pragmas**

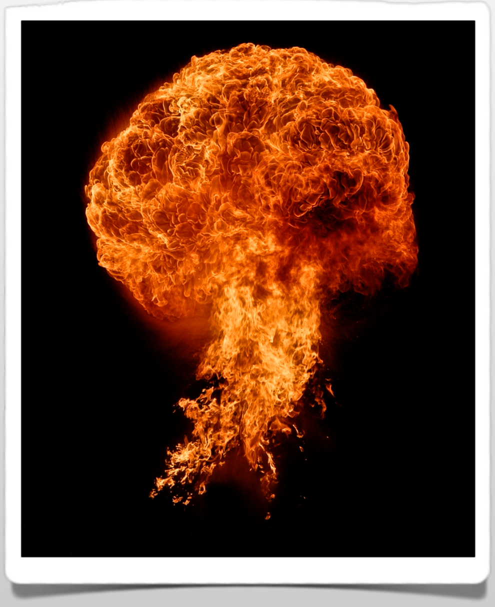
Types of Test-doubles

Test-double types

- Exploding stubs
- Dynamic
- Recording - Mock
- Generic

Exploding stubs

```
sqlite3_int64 sqlite3_last_insert_rowid(sqlite3*)
{
    FAIL("sqlite3_last_insert_rowid");
    return 0;
}
```



Easy and you know when it is used.
Delays more implementation...

Dynamic stub

stubSqlite.cpp

```
sqlite3_int64 sqlite3_last_insert_rowid(sqlite3* lite)
{
    if (sqlite3_last_insert_rowid_stub)
        return sqlite3_last_insert_rowid_stub(lite);

    return 0;
}
```

"Sensible default"

stubSqlite.h

```
extern sqlite3_int64 (*sqlite3_last_insert_rowid_stub)(sqlite3*);
```

Recording ... mock

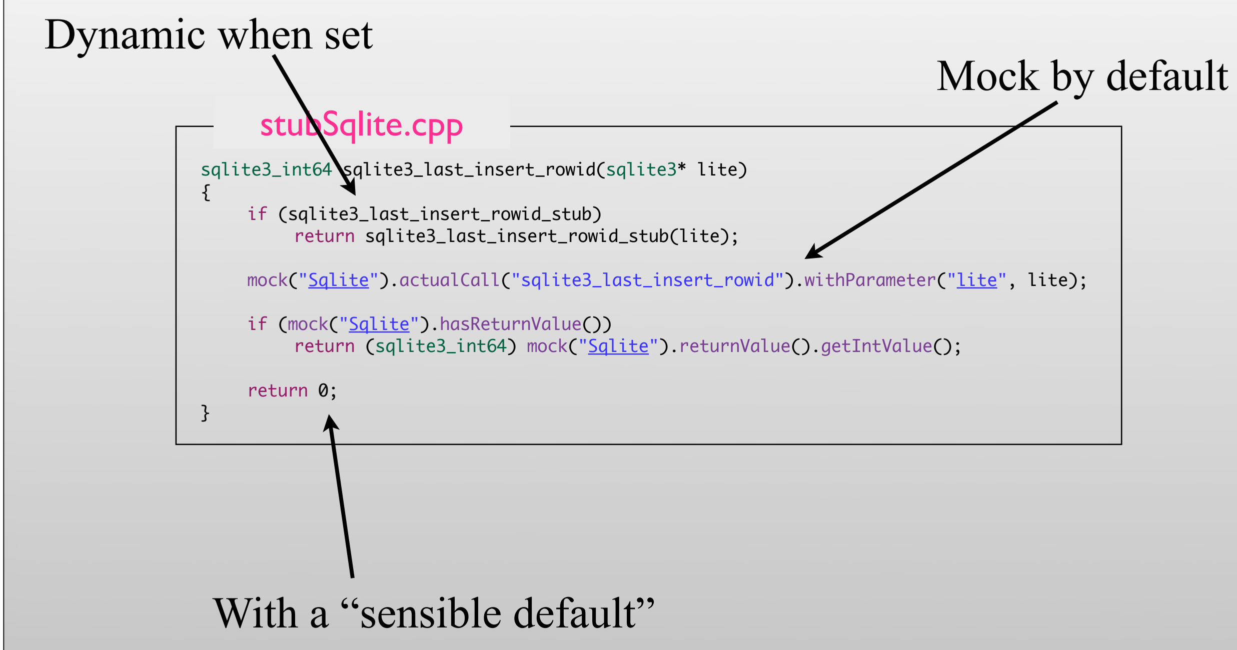
stubSqlite.cpp

```
sqlite3_int64 sqlite3_last_insert_rowid(sqlite3* lite)
{
    mock("Sqlite").actualCall("sqlite3_last_insert_rowid").withParameter("lite", lite);

    if (mock("Sqlite").hasReturnValue())
        return (sqlite3_int64) mock("Sqlite").returnValue().getIntValue();

    return 0;
}
```

testUsingSQL.cpp

```
TEST(ProgramUsingSQLite, InserRowID)
{
    mock("Sqlite").expectOneCall("sqlite3_last_insert_rowid").withParameter("lite", lite)
            .andReturnValue(0);

    ...
    mock("Sqlite").checkExpectations();
    mock("Sqlite").clear();
}
```

Generic stub



Dynamic when set

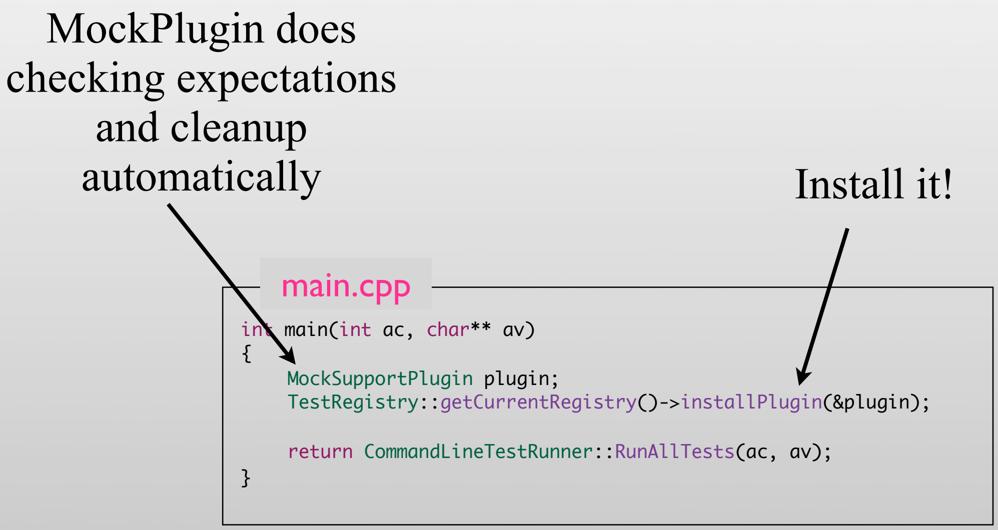
Mock by default

stubSqlite.cpp

```
sqlite3_int64 sqlite3_last_insert_rowid(sqlite3* lite)
{
    if (sqlite3_last_insert_rowid_stub)
        return sqlite3_last_insert_rowid_stub(lite);

    mock("Sqlite").actualCall("sqlite3_last_insert_rowid").withParameter("lite", lite);

    if (mock("Sqlite").hasReturnValue())
        return (sqlite3_int64) mock("Sqlite").returnValue().getIntValue();

    return 0;
}
```

With a “sensible default”

CppUMock MockPlugin



MockPlugin does checking expectations and cleanup automatically

Install it!

main.cpp

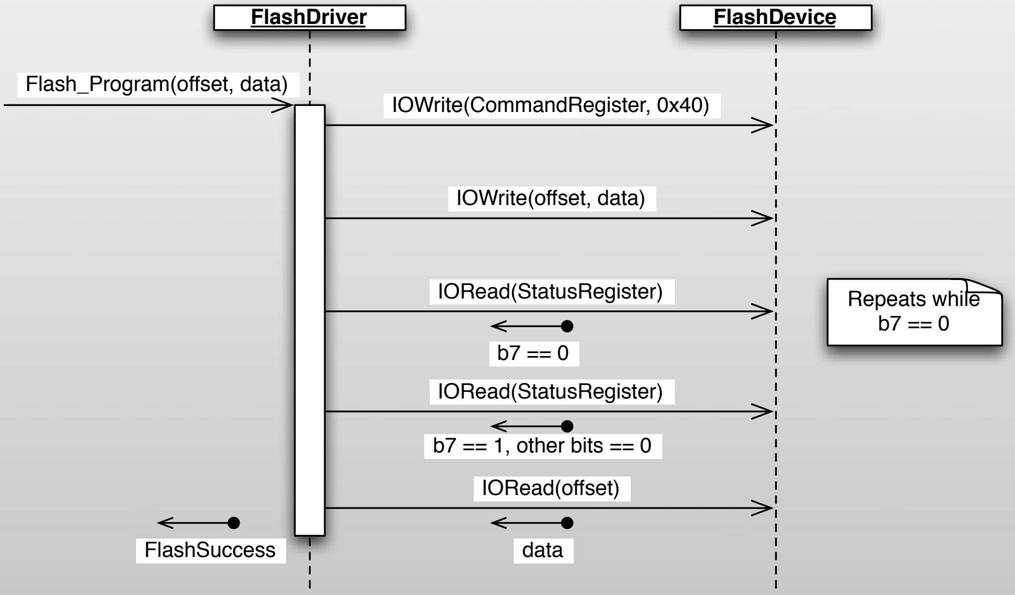
```
int main(int ac, char** av)
{
    MockSupportPlugin plugin;
    TestRegistry::getCurrentRegistry()->installPlugin(&plugin);

    return CommandLineTestRunner::RunAllTests(ac, av);
}
```

Mocking the Silicon

Why a Mock Object?

- Problem - Complex collaborator interactions cannot be captured with a simple spy.
- Solution - Mock Object
  - A Mock Object is a Test Double that verifies that the code being tested interacts with its collaborator properly.
  - The test tells the mock
    - The expected calls
    - In the expected order
    - What to return.

Message Flow for Flash Memory Block Erase with Error



FlashDriver

FlashDevice

Flash_Program(offset, data)

IOWrite(CommandRegister, 0x40)

IOWrite(offset, data)

IORead(StatusRegister)

b7 == 0

Repeats while b7 == 0

IORead(StatusRegister)

b7 == 1, other bits == 0

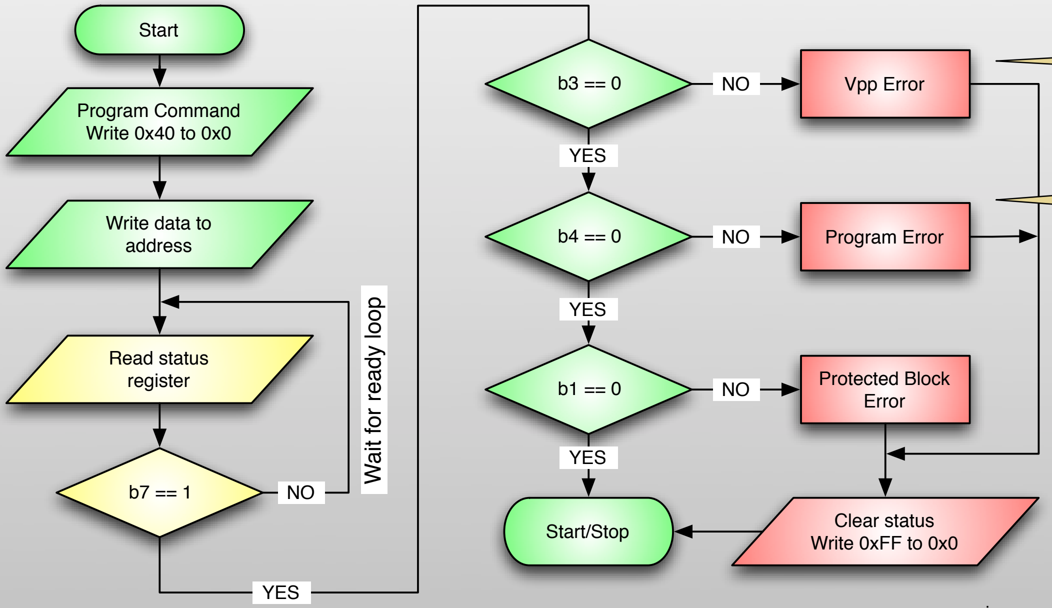
IORead(offset)

data

FlashSuccess

Flash Program Flow Chart

How Many Tests are Needed?



Start

Program Command
Write 0x40 to 0x0

Write data to address

Read status register

b7 == 1

NO

Wait for ready loop

YES

b3 == 0

NO

Vpp Error

YES

b4 == 0

NO

Program Error

YES

b1 == 0

NO

Protected Block Error

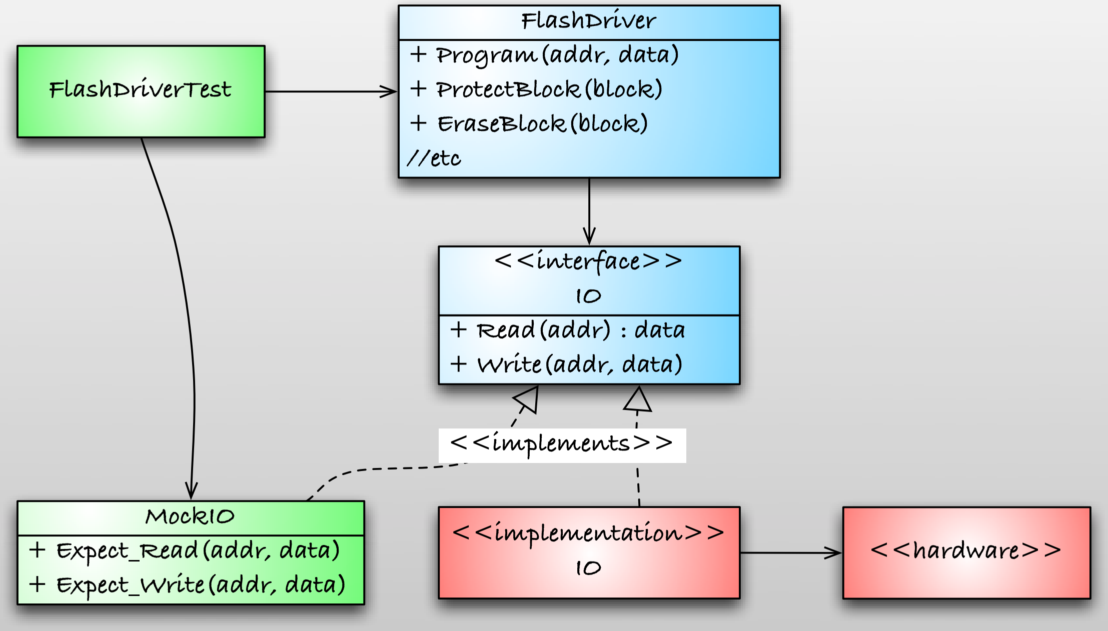
YES

Start/Stop

Clear status
Write 0xFF to 0x0

How do you test these errors in the target?

Flash Driver Test Fixture



FlashDriverTest

FlashDriver
+ Program(addr, data)
+ ProtectBlock(block)
+ EraseBlock(block)
//etc

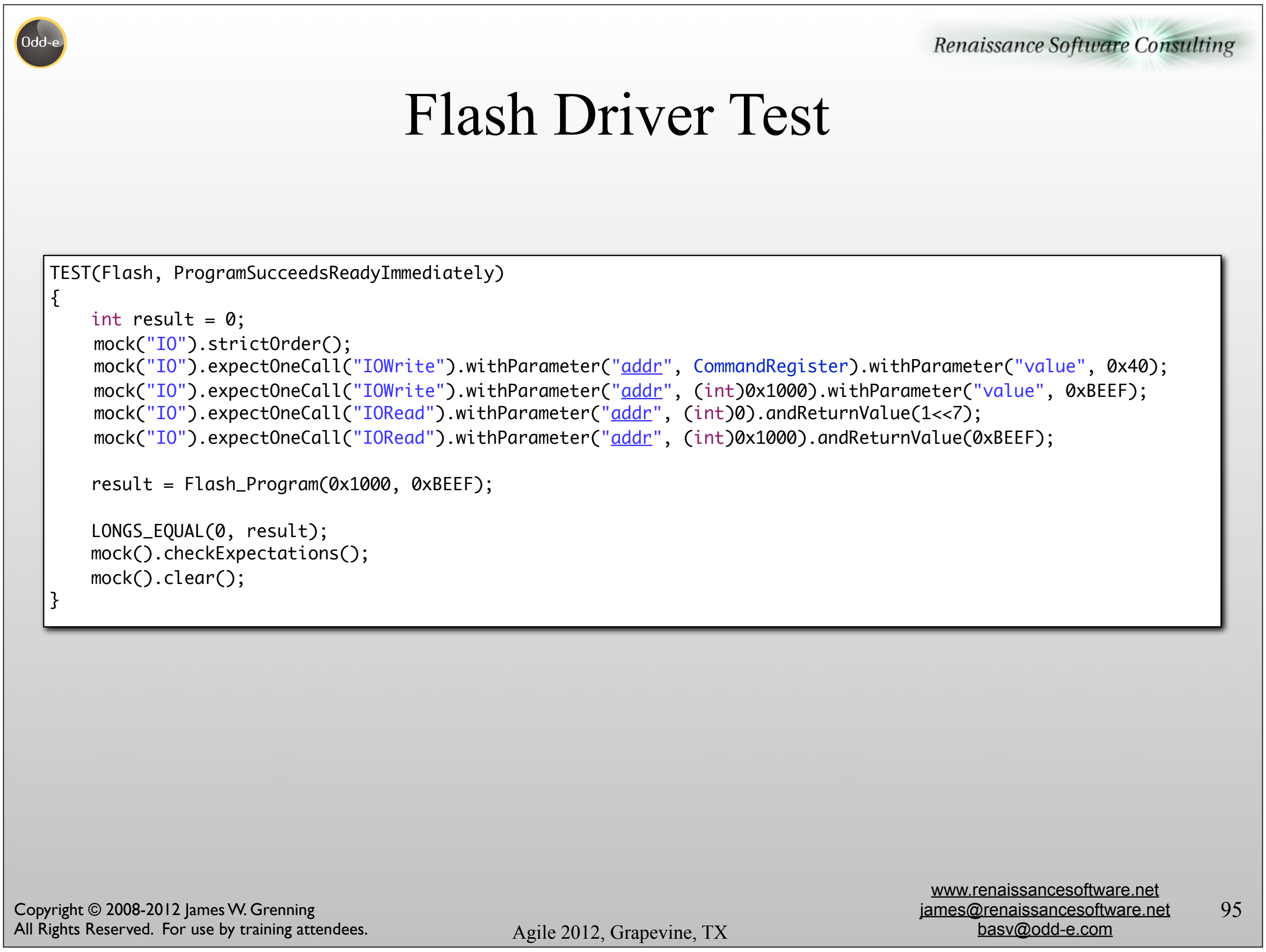
<<interface>>
IO
+ Read(addr) : data
+ Write(addr, data)

<<implements>>

MockIO
+ Expect_Read(addr, data)
+ Expect_Write(addr, data)

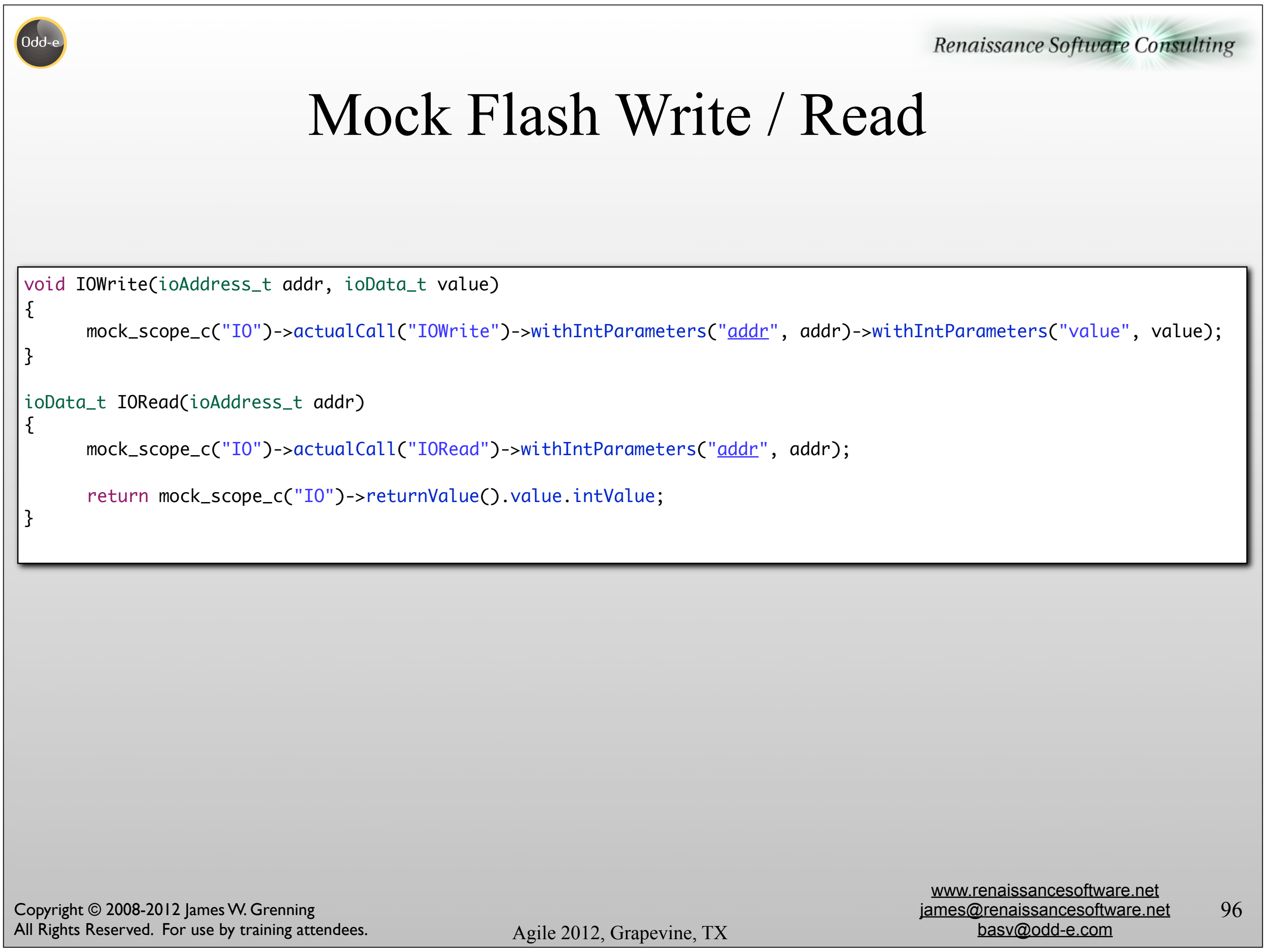
<<implementation>>
IO

<<hardware>>



Flash Driver Test

```
TEST(Flash, ProgramSucceedsReadyImmediately)
{
    int result = 0;
    mock("IO").strictOrder();
    mock("IO").expectOneCall("IOWrite").withParameter("addr", CommandRegister).withParameter("value", 0x40);
    mock("IO").expectOneCall("IOWrite").withParameter("addr", (int)0x1000).withParameter("value", 0xBEEF);
    mock("IO").expectOneCall("IORead").withParameter("addr", (int)0).andReturnValue(1<<7);
    mock("IO").expectOneCall("IORead").withParameter("addr", (int)0x1000).andReturnValue(0xBEEF);

    result = Flash_Program(0x1000, 0xBEEF);

    LONGS_EQUAL(0, result);
    mock().checkExpectations();
    mock().clear();
}
```



Mock Flash Write / Read

```
void IOWrite(ioAddress_t addr, ioData_t value)
{
      mock_scope_c("IO")->actualCall("IOWrite")->withIntParameters("addr", addr)->withIntParameters("value", value);
}

ioData_t IORead(ioAddress_t addr)
{
      mock_scope_c("IO")->actualCall("IORead")->withIntParameters("addr", addr);

      return mock_scope_c("IO")->returnValue().value.intValue;
}
```

What do the Tests Mean?

- Vendor’s driver did not pass my tests
- Undocumented operations (resets) were added in silicon vendor’s solution.
- My driver functions met the spec, but may have encountered integration problems
  - Were the extra resets really needed?

Minimize DoH!

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Debug

On

Hardware

TDD Next to an RTOS

Intro to the Fake Function Framework

Choices When Faking the OS

- For new code, you might choose to create an OS abstraction layer.
- For existing code, or where the layer is not desired, you can create an RTOS test double

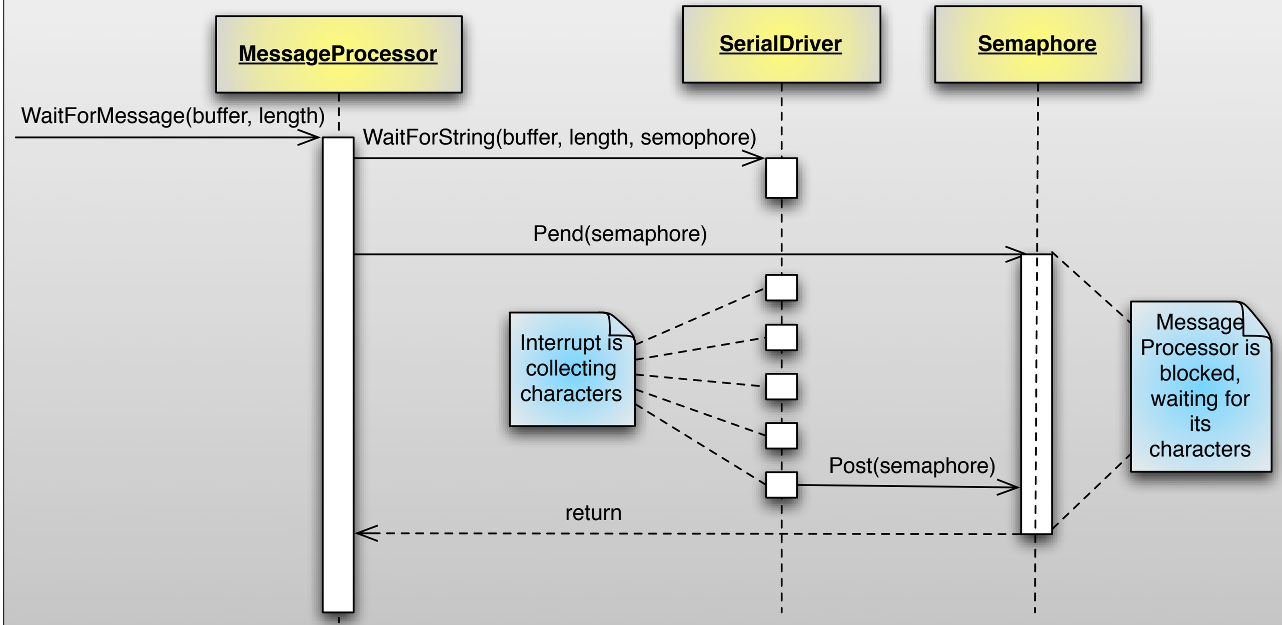
How Do I Test OS Dependent Code Like This?

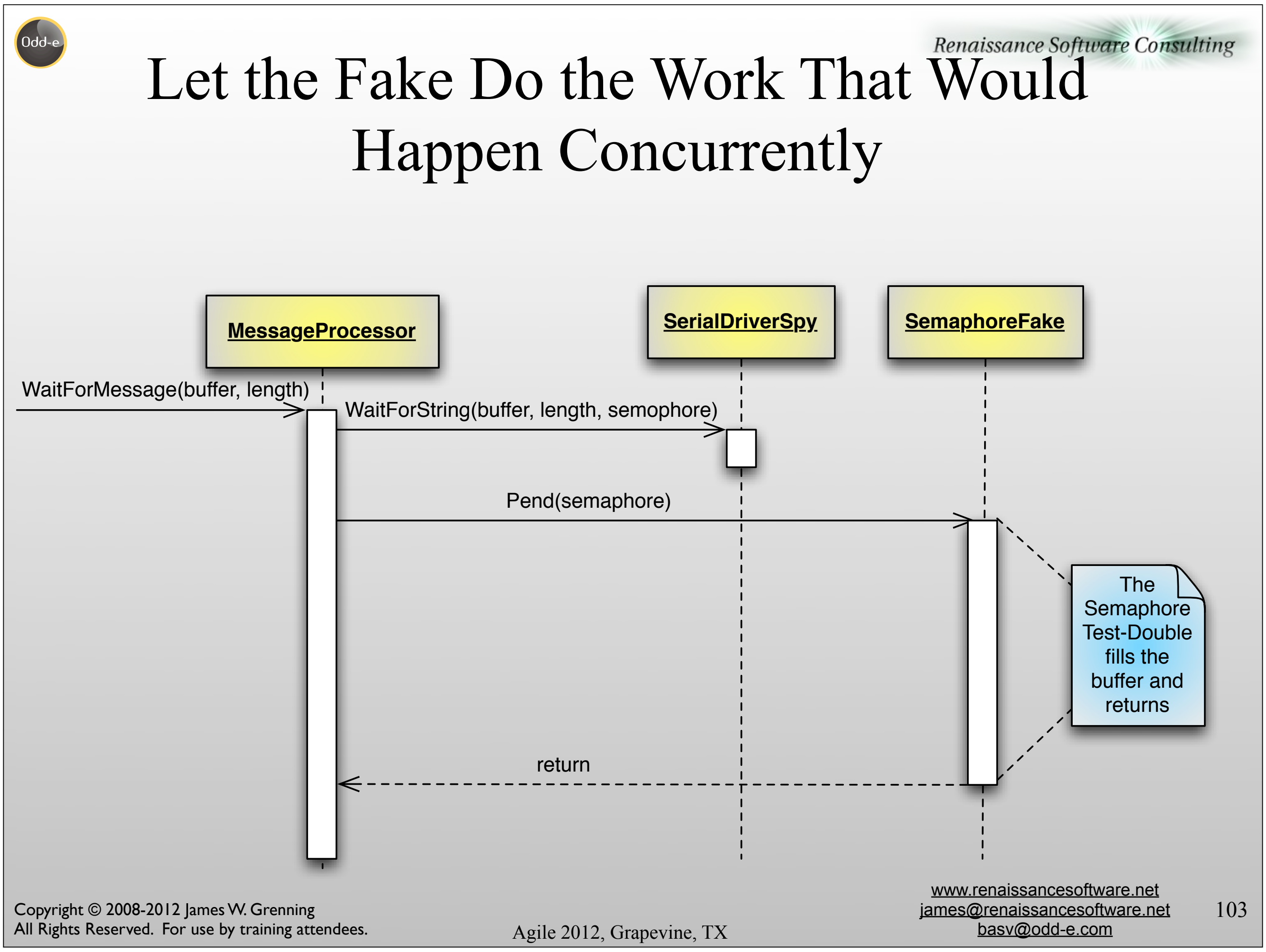
```
int MessageProcessor_WaitForMessage(char * buffer, size_t length)
{
   INT8U error = 0;
   SerialInterrupt_WaitForString(buffer, length, int_sync);
   OSSemPend(int_sync, 1000, &error);
   return error == OS_ERR_NONE;
}
```

I may just fake out WaitForMessage() and manually test the OS dependent code.

But that may not be an option in legacy code Where OS primitives are used more liberally.

The ISR Has to Satisfy the Request

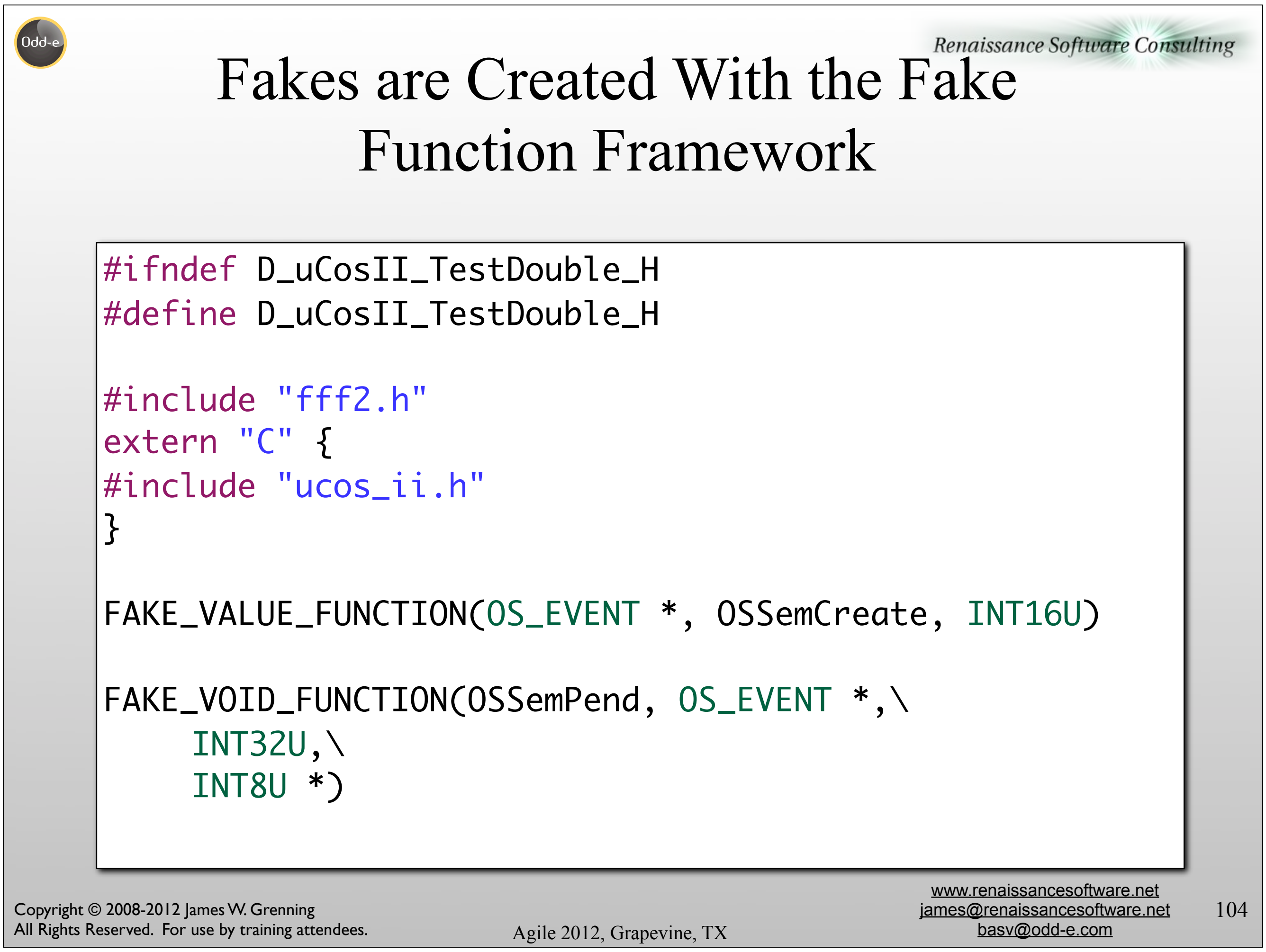

MessageProcessor
SerialDriver
Semaphore
WaitForMessage(buffer, length)
WaitForString(buffer, length, semophore)
Pend(semaphore)
Interrupt is collecting characters
Message Processor is blocked, waiting for its characters
Post(semaphore)
return



Let the Fake Do the Work That Would Happen Concurrently

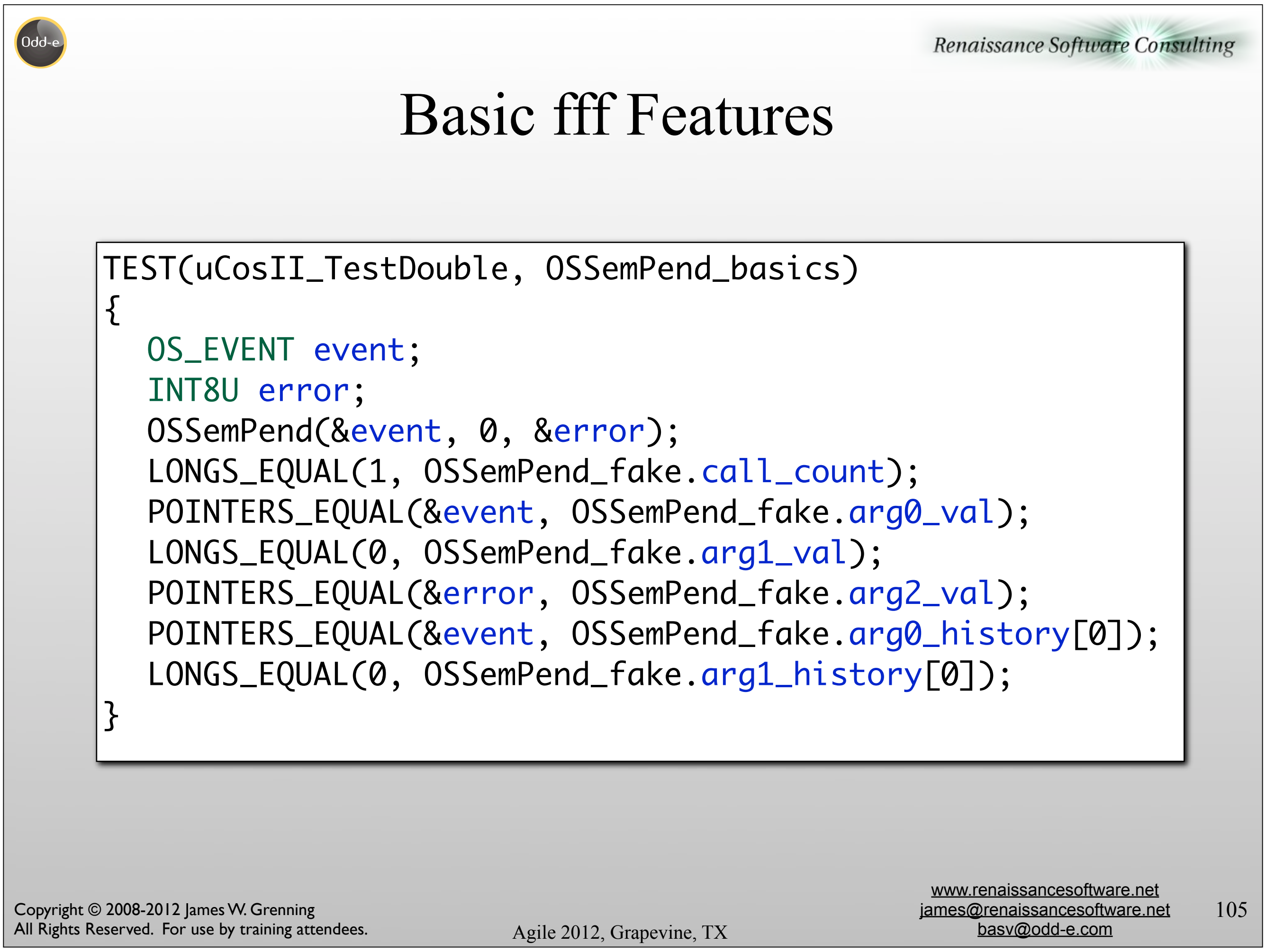
MessageProcessor
SerialDriverSpy
SemaphoreFake
WaitForMessage(buffer, length)
WaitForString(buffer, length, semophore)
Pend(semaphore)
return

The Semaphore Test-Double fills the buffer and returns



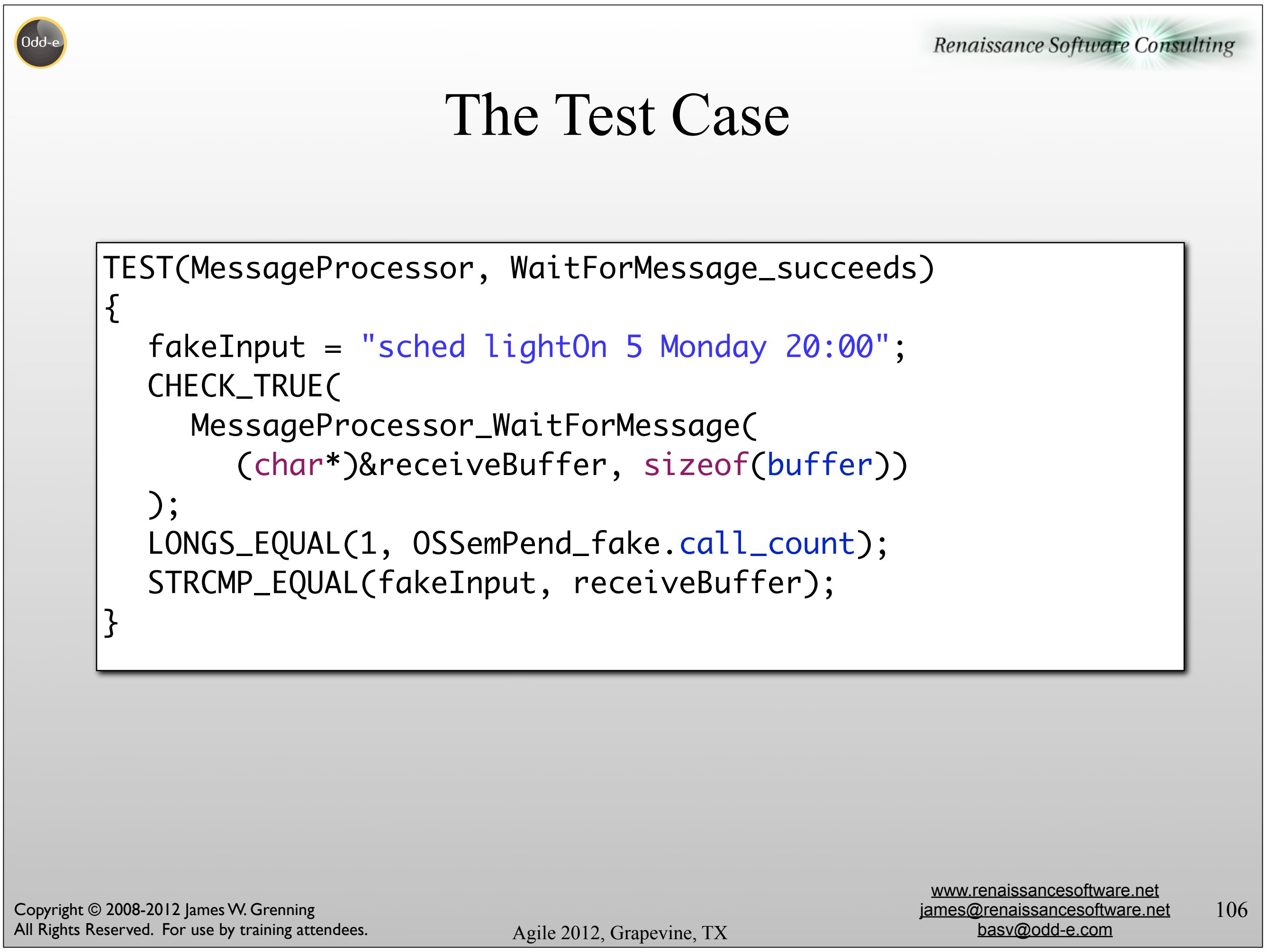
Fakes are Created With the Fake Function Framework

```
#ifndef D_uCosII_TestDouble_H
#define D_uCosII_TestDouble_H

#include "fff2.h"
extern "C" {
#include "ucos_ii.h"
}

FAKE_VALUE_FUNCTION(OS_EVENT *, OSSemCreate, INT16U)

FAKE_VOID_FUNCTION(OSSemPend, OS_EVENT *,\
     INT32U,\
     INT8U *)
```



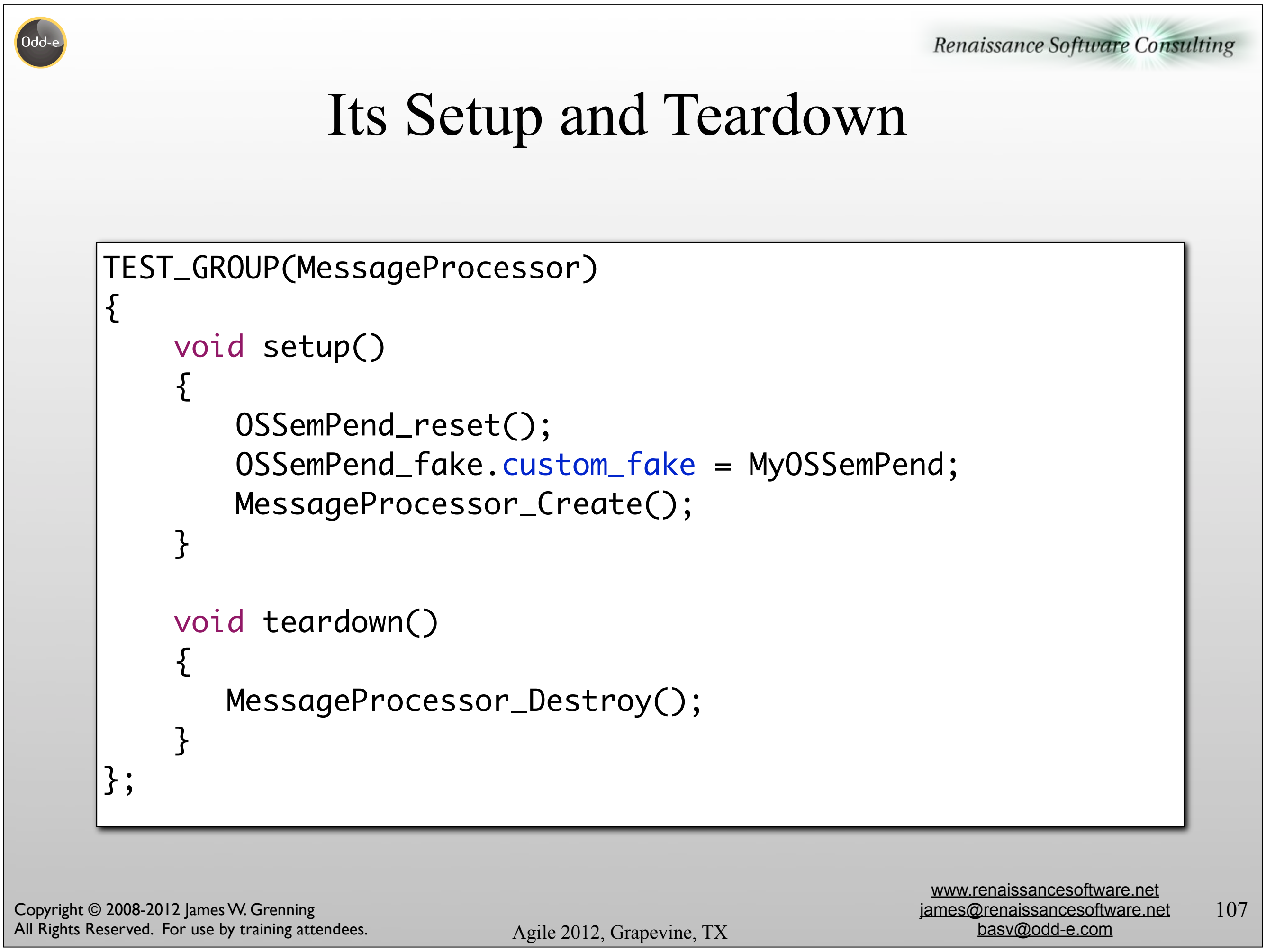
Basic fff Features

```
TEST(uCosII_TestDouble, OSSemPend_basics)
{
   OS_EVENT event;
   INT8U error;
   OSSemPend(&event, 0, &error);
   LONGS_EQUAL(1, OSSemPend_fake.call_count);
   POINTERS_EQUAL(&event, OSSemPend_fake.arg0_val);
   LONGS_EQUAL(0, OSSemPend_fake.arg1_val);
   POINTERS_EQUAL(&error, OSSemPend_fake.arg2_val);
   POINTERS_EQUAL(&event, OSSemPend_fake.arg0_history[0]);
   LONGS_EQUAL(0, OSSemPend_fake.arg1_history[0]);
}
```



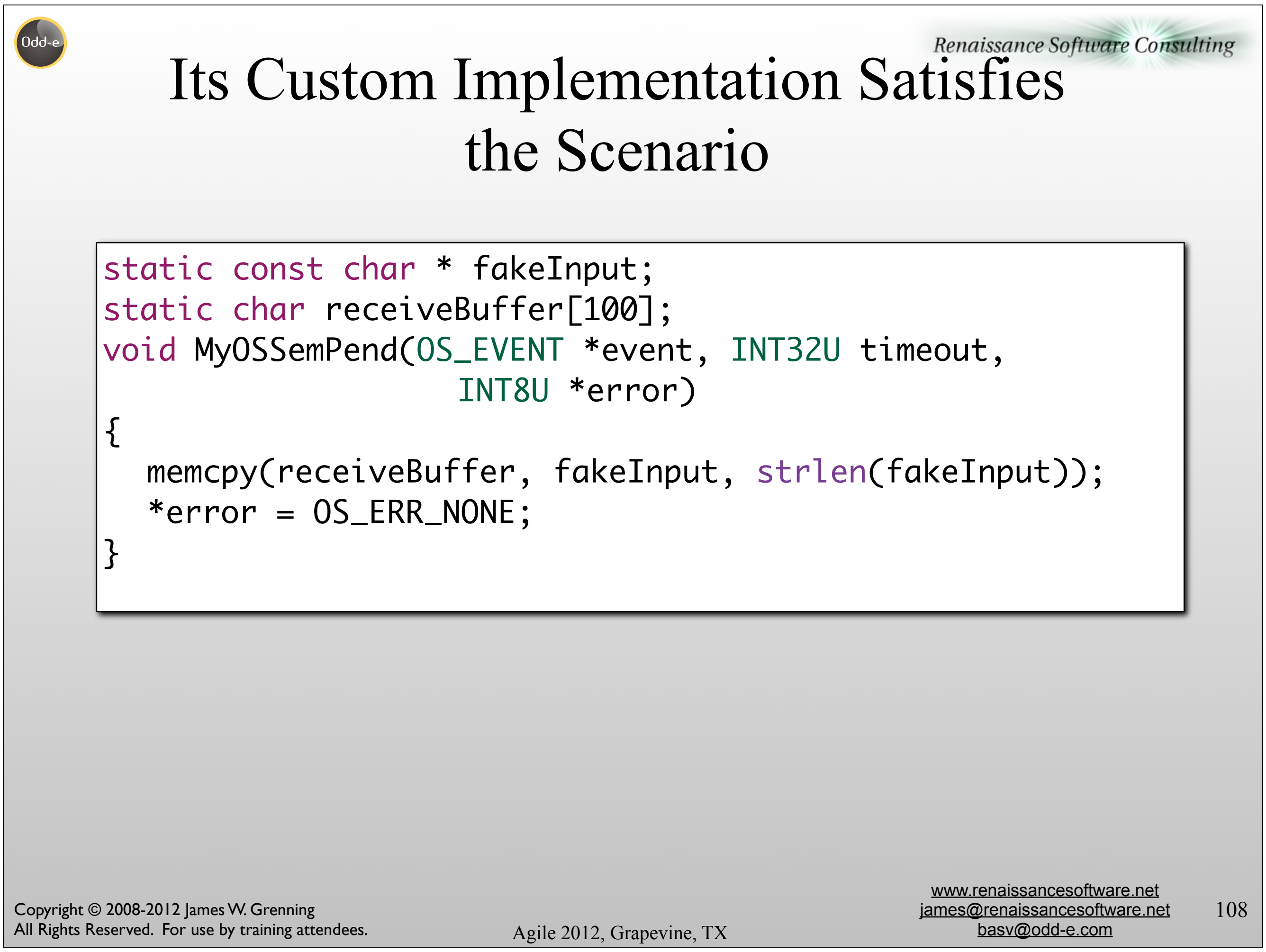
The Test Case

```
TEST(MessageProcessor, WaitForMessage_succeeds)
{
   fakeInput = "sched lightOn 5 Monday 20:00";
   CHECK_TRUE(
      MessageProcessor_WaitForMessage(
         (char*)&receiveBuffer, sizeof(buffer))
   );
   LONGS_EQUAL(1, OSSemPend_fake.call_count);
   STRCMP_EQUAL(fakeInput, receiveBuffer);
}
```



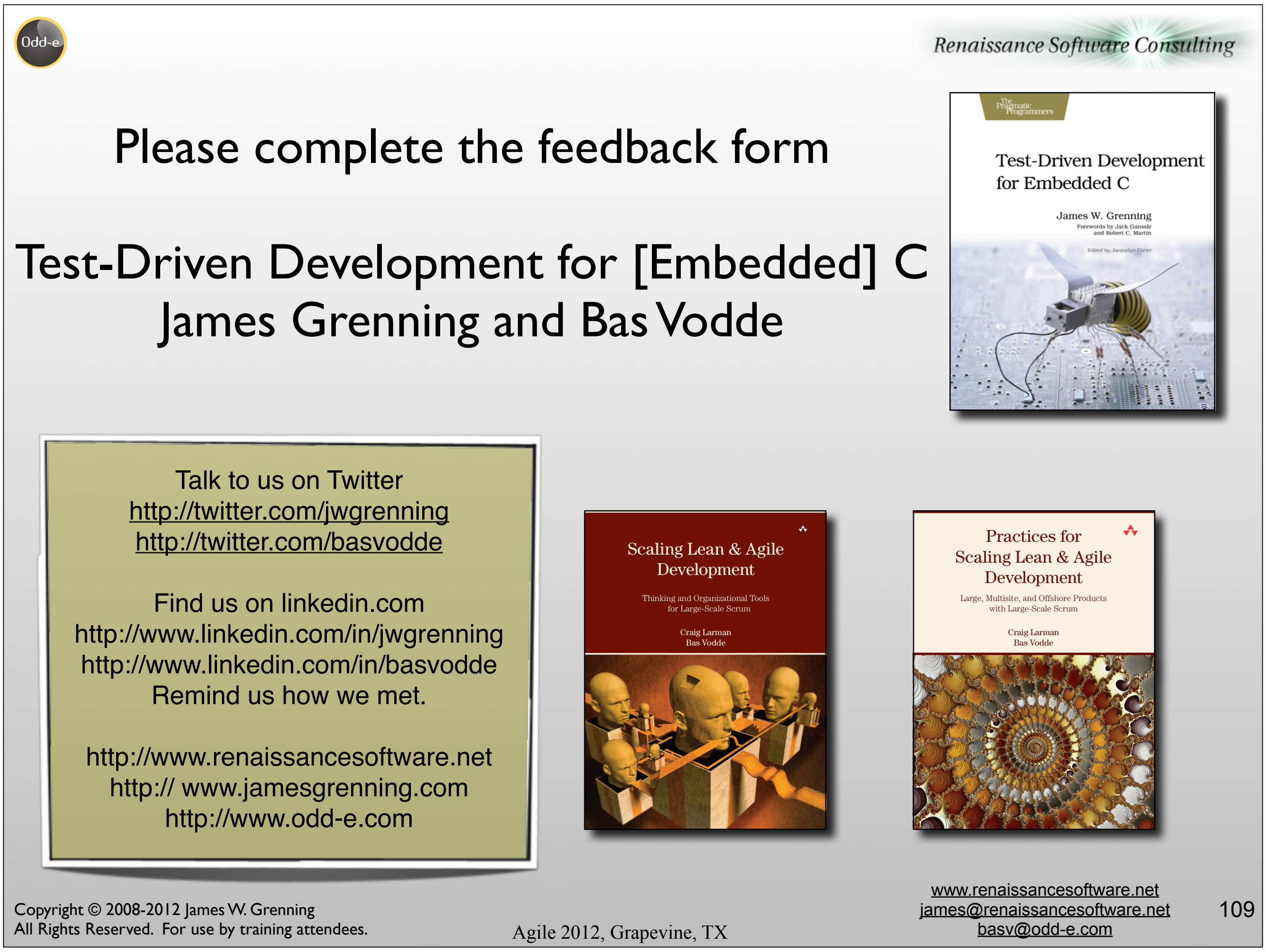
Its Setup and Teardown

```
TEST_GROUP(MessageProcessor)
{
    void setup()
    {
        OSSemPend_reset();
        OSSemPend_fake.custom_fake = MyOSSemPend;
        MessageProcessor_Create();
    }

    void teardown()
    {
       MessageProcessor_Destroy();
    }
};
```



Its Custom Implementation Satisfies the Scenario

```
static const char * fakeInput;
static char receiveBuffer[100];
void MyOSSemPend(OS_EVENT *event, INT32U timeout,
                      INT8U *error)
{
   memcpy(receiveBuffer, fakeInput, strlen(fakeInput));
   *error = OS_ERR_NONE;
}
```



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Edited by Jacquelyn Carter
Scaling Lean & Agile Development
Thinking and Organizational Tools for Large-Scale Scrum
Craig Larman
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Practices for Scaling Lean & Agile Development
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