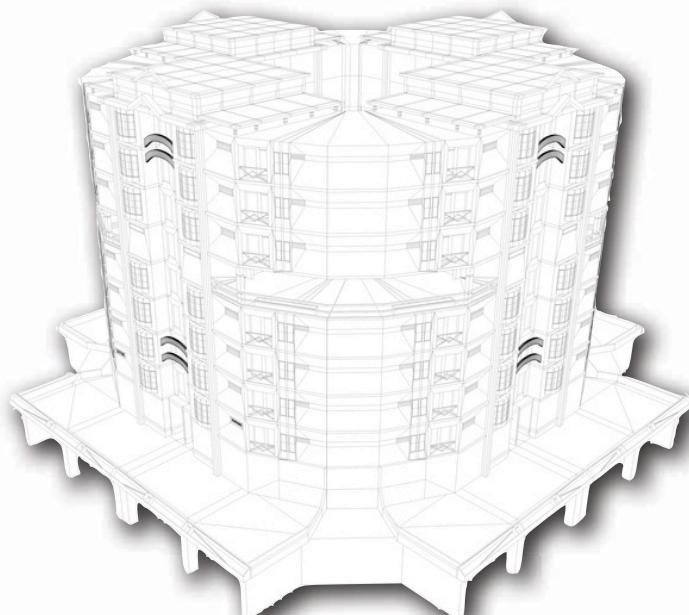


tdd: test-driven *design*



N

NEAL FORD software architect / meme wrangler

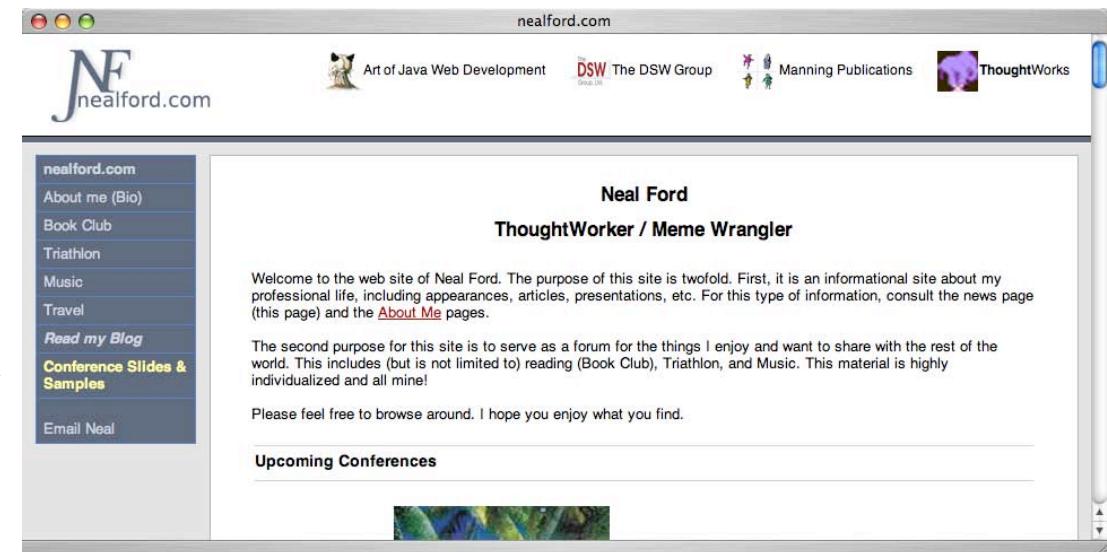
ThoughtWorks

nford@thoughtworks.com
3003 Summit Boulevard, Atlanta, GA 30319
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www.thoughtworks.com
memeagora.blogspot.com

housekeeping

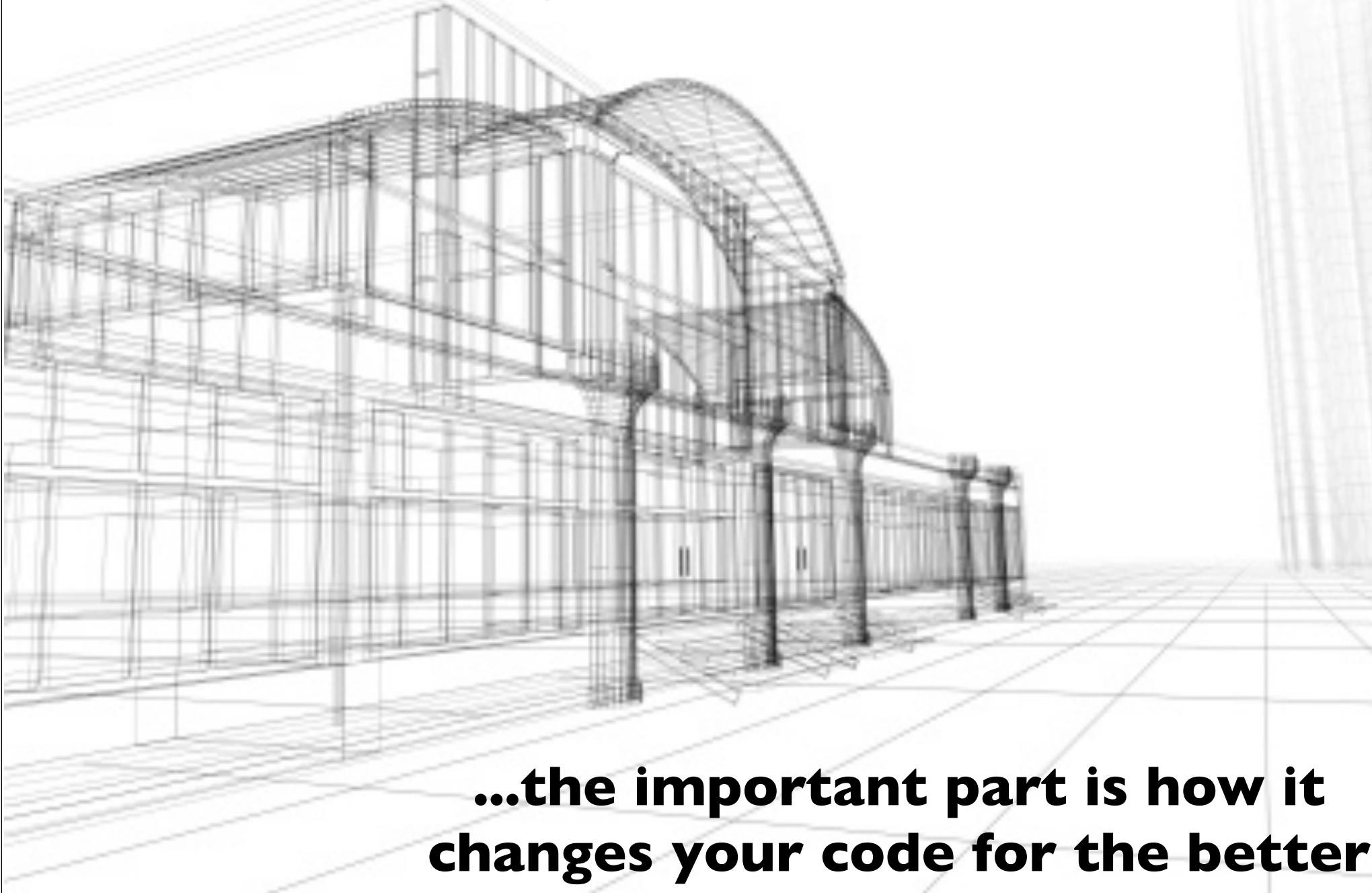
ask questions anytime

download slides from
nealford.com



download samples from github.com/nealford

testing is only a side effect of tdd...



**...the important part is how it
changes your code for the better**

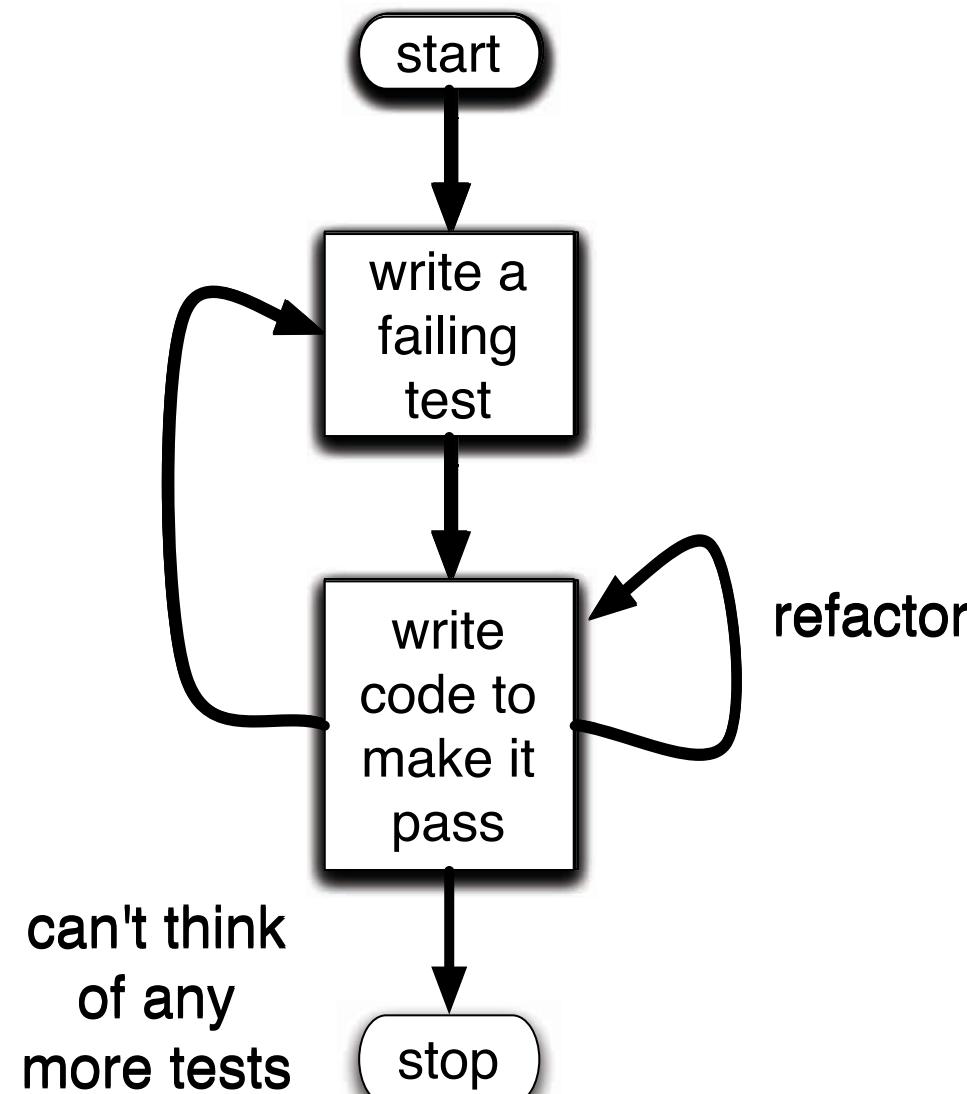
what i cover:

measuring code quality

the evolution of design

test-driven unit testing

testing what's hard to test



red

green

refactor

why watch it fail?

```
@Test public void sum() {  
    Classifier6 c = new Classifier6(20);  
    calculateFactors(c);  
    int expected = 1 + 2 + 4 + 5 + 10 + 20;  
    assertThat(expected, is(expected));  
}
```

design benefits of tdd

think about how the rest of the world uses this class

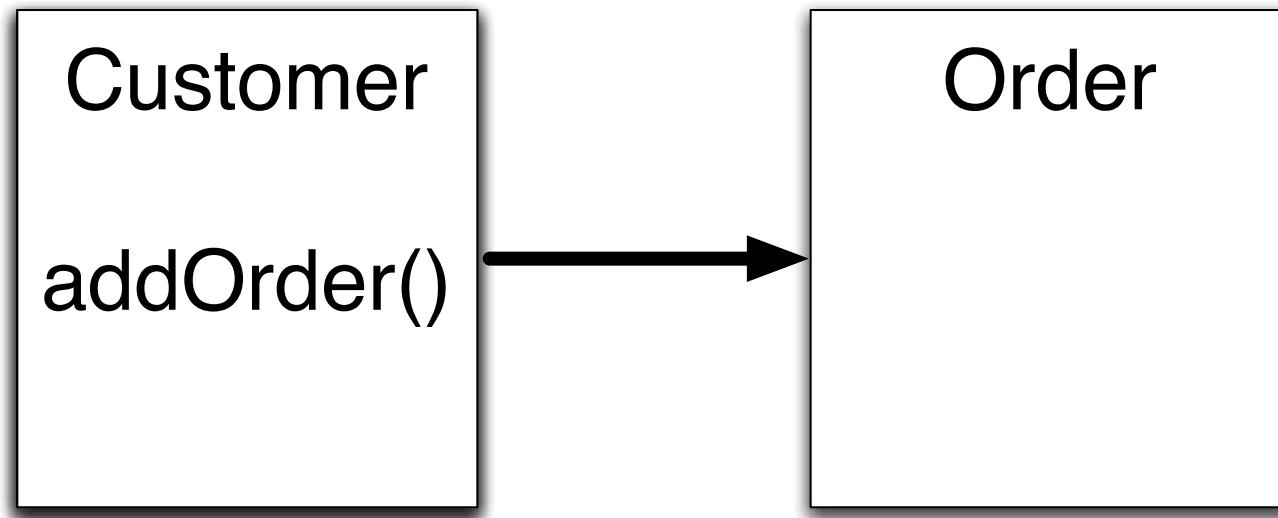
creates *consumption awareness*

design benefits of tdd

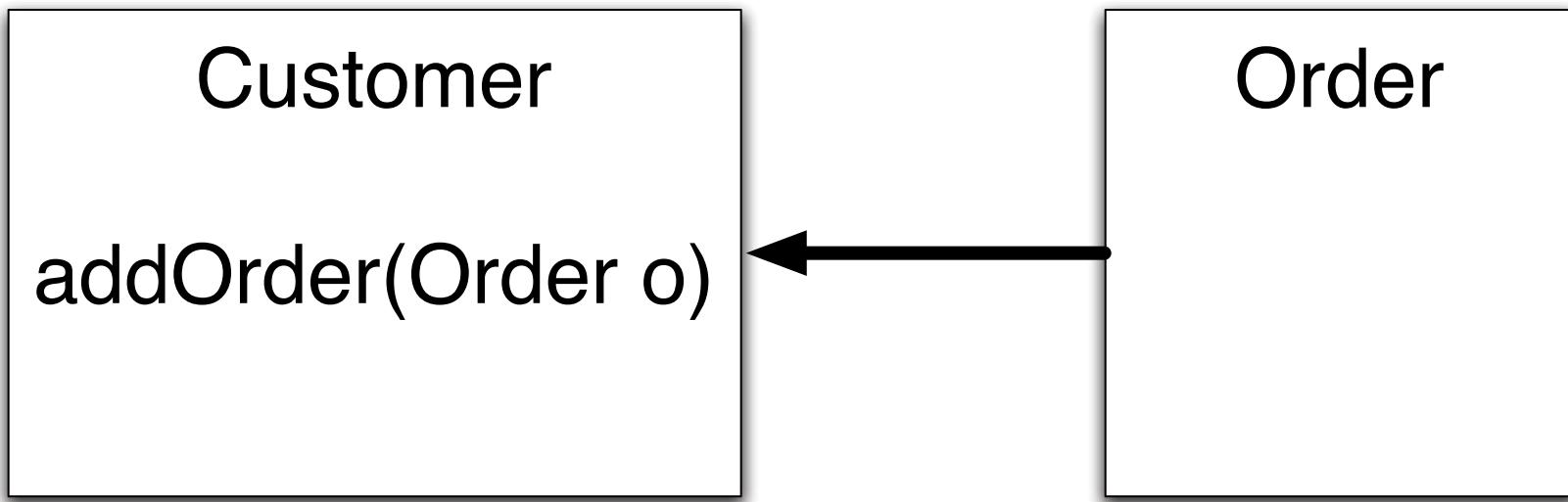
forces mocking of dependent objects

earliest possible object interaction decisions

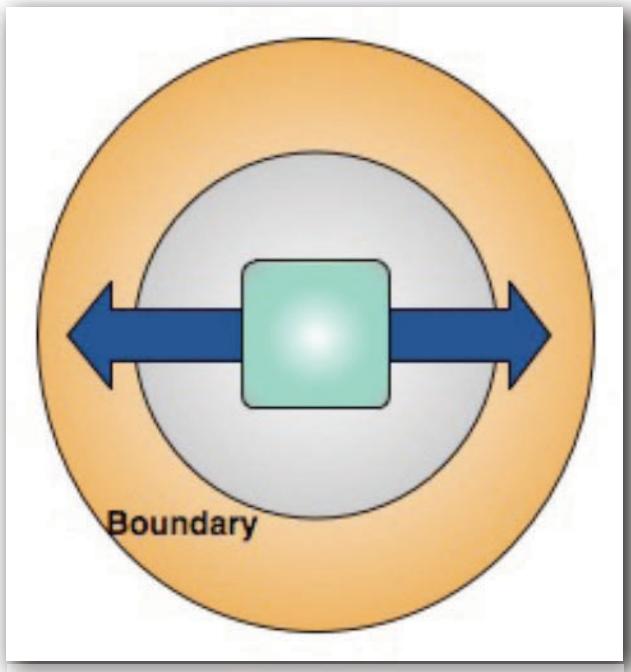
discourages embedded object creation



extroverted object



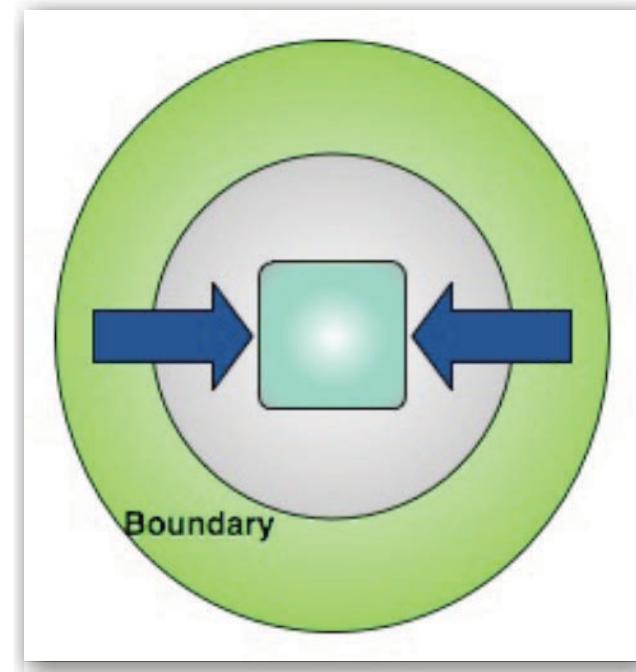
introverted object



extroverted objects

“reach out” to create objects

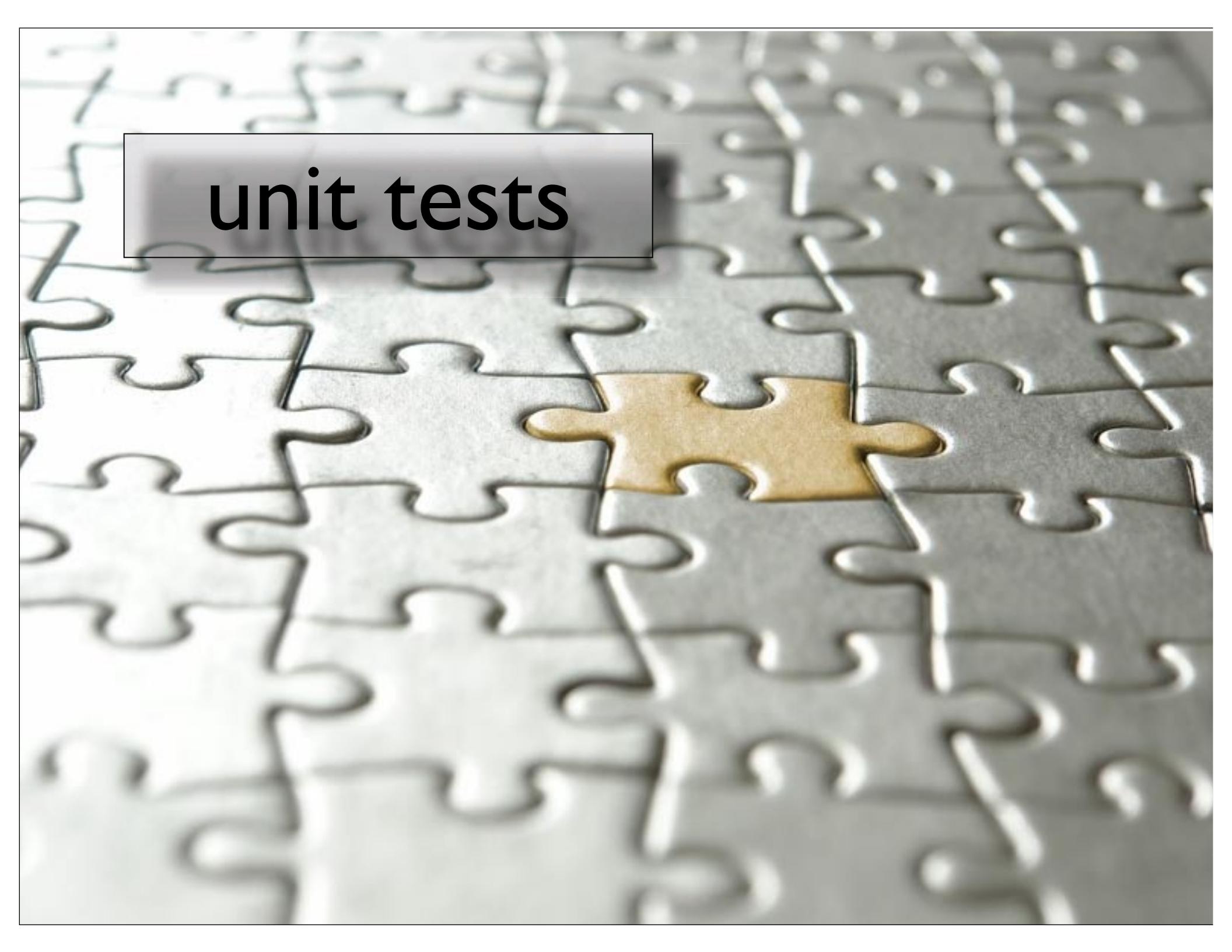
scattered construction



introverted objects

cleaner dependencies

moves object construction to
a few simple places



unit tests

technology stack

java 5

junit 4.4

hamcrest matchers

```
assertThat(c.getFactors(), is(expected));
```



perfect
numbers

perfect number:

\sum of the factors == number
(not including the number)

\sum of the factors - # == #

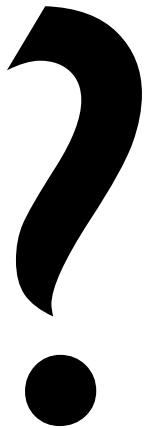
```
public class PerfectNumberFinder1 {  
    public static boolean isPerfect(int number) {  
        // get factors  
        List<Integer> factors = new ArrayList<Integer>();  
        factors.add(1);  
        factors.add(number);  
        for (int i = 2; i < number; i++)  
            if (number % i == 0)  
                factors.add(i);  
  
        // sum factors  
        int sum = 0;  
        for (int n : factors)  
            sum += n;  
  
        // decide if it's perfect  
        return sum - number == number;  
    }  
}
```

```
private static Integer[] PERFECT_NUMS = {6, 28, 496, 8128, 33550336};

@Test public void test_perfection() {
    for (int i : PERFECT_NUMS)
        assertTrue(PerfectNumberFinder1.isPerfect(i));
}

@Test public void test_non_perfection() {
    List<Integer> expected = new ArrayList<Integer>(
        Arrays.asList(PERFECT_NUMS));
    for (int i = 2; i < 100000; i++) {
        if (expected.contains(i))
            assertTrue(PerfectNumberFinder1.isPerfect(i));
        else
            assertFalse(PerfectNumberFinder1.isPerfect(i));
    }
}
```

```
public static boolean isPerfect(int number) {  
    // get factors  
    List<Integer> factors = new ArrayList<Integer>();  
    factors.add(1);  
    factors.add(number);  
    for (int i = 2; i < number; i++)  
        if (number % i == 0)  
            factors.add(i);  
  
    // sum factors  
    int sum = 0;  
    for (int n : factors)  
        sum += n;  
  
    // decide if it's perfect  
    return sum - number == number;  
}
```



```
public class PerfectNumberFinder2 {  
    public static boolean isPerfect(int number) {  
        // get factors  
        List<Integer> factors = new ArrayList<Integer>();  
        factors.add(1);  
        factors.add(number);  
        for (int i = 2; i <= sqrt(number); i++)  
            if (number % i == 0) {  
                factors.add(i);  
                factors.add(number / i);  
            }  
  
        // sum factors  
        int sum = 0;  
        for (int n : factors)  
            sum += n;  
  
        // decide if it's perfect  
        return sum - number == number;  
    }  
}
```

whole number
square roots

```
public class PerfectNumberFinder2 {  
    public static boolean isPerfect(int number) {  
        // get factors  
        List<Integer> factors = new ArrayList<Integer>();  
        factors.add(1);  
        factors.add(number);  
        for (int i = 2; i <= sqrt(number); i++)  
            if (number % i == 0) {  
                factors.add(i);  
                // account for whole-number square roots  
                if (number / i != i)  
                    factors.add(number / i);  
            }  
  
        // sum factors  
        int sum = 0;  
        for (int n : factors)  
            sum += n;  
  
        // decide if it's perfect  
        return sum - number == number;  
    }  
}
```

what's wrong?

the simplest thing?

`isPerfect()`

go back to definition:

factors

is a number a factor

sum factors

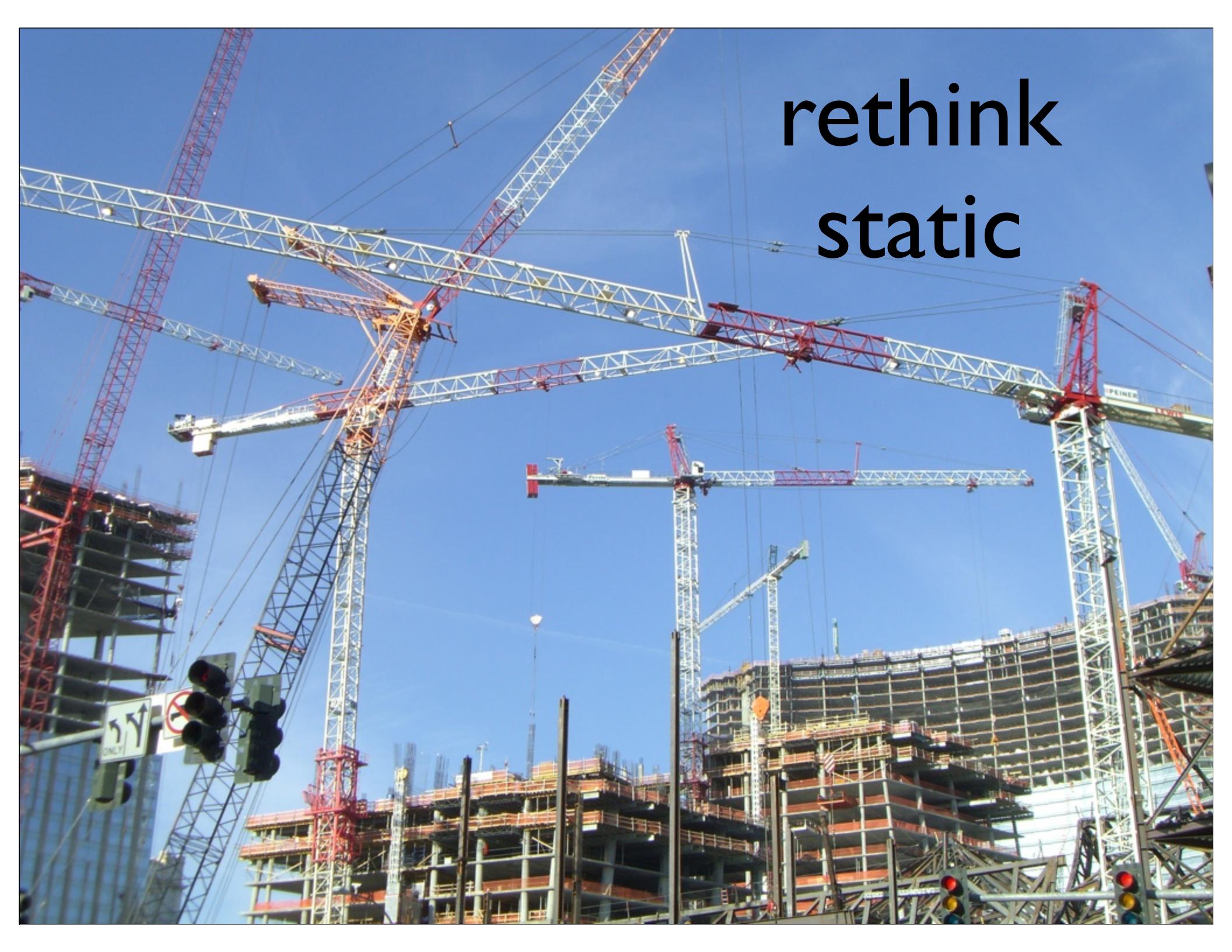
first test

```
@Test public void is_factor() {  
    assertTrue(Classifier1.isFactor(1, 10));  
}  
  
public class Classifier1 {  
    public static boolean isFactor(int factor, int number) {  
        return number % factor == 0;  
    }  
}
```

next test

```
@Test public void factors_for() {  
    int[] expected = new int[] {1};  
    assertThat(Classifier1.factorsFor(1), is(expected));  
}
```

```
public static int[] factorsFor(int number) {  
    return new int[] {number};  
}
```

A photograph of a large-scale construction project, likely a skyscraper, under a clear blue sky. Numerous construction cranes of various sizes and colors (red, white, yellow) are visible, some with their booms extended over the building's structure. The building itself is a multi-story frame with exposed steel beams and concrete floors. In the foreground, there are traffic lights and a road sign indicating a one-way street.

rethink
static

static tends to propagate

```
public class Classifier1 {  
    public static boolean isFactor(int factor, int number) {  
        return number % factor == 0;  
    }  
  
    public static int[] factorsFor(int number) {  
        return new int[] {number};  
    }  
}
```

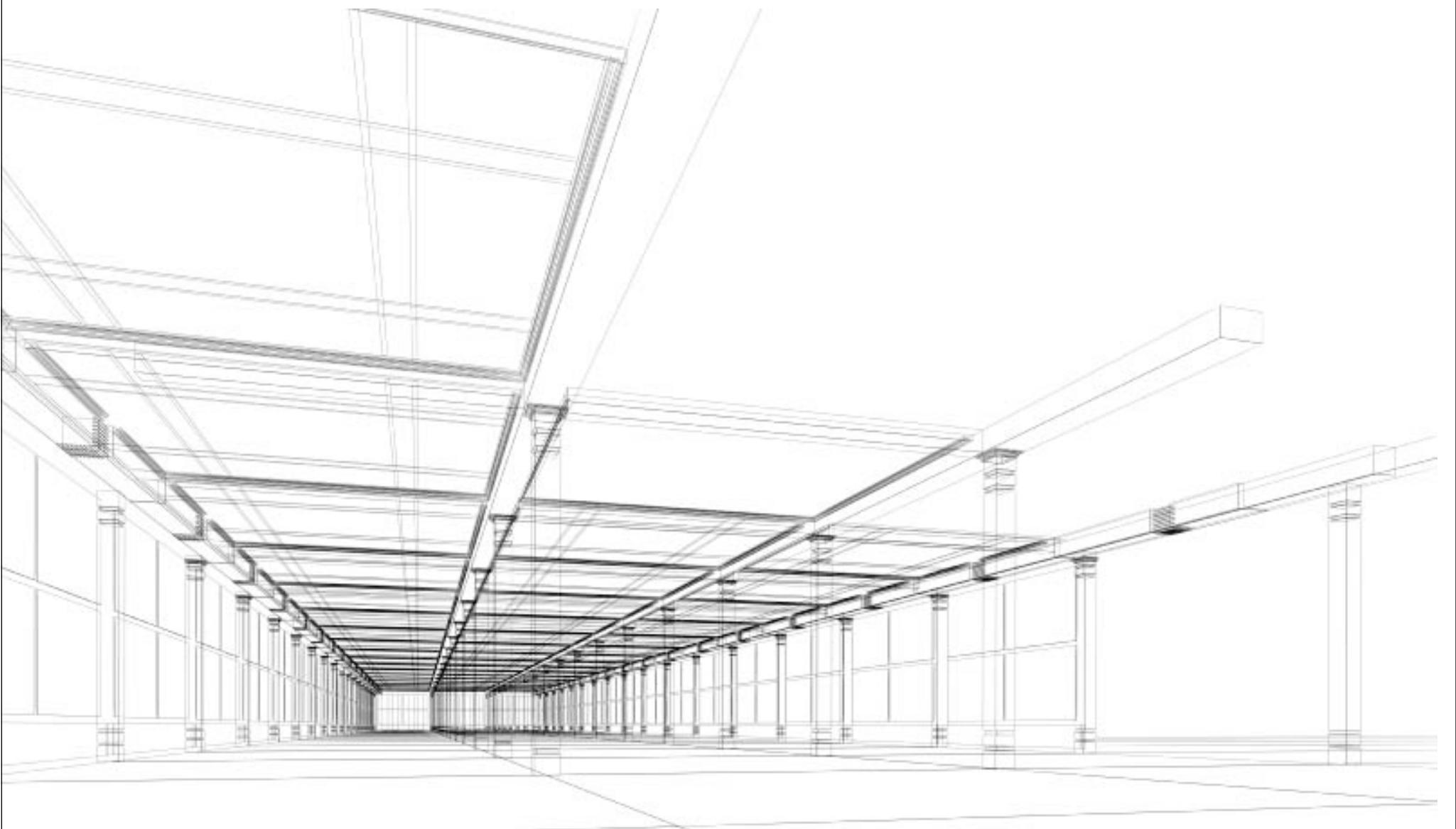
this code is starting to feel very procedural

take 2

```
@Test public void is_1_a_factor_of_10() {  
    Classifier2 c = new Classifier2(10);  
    assertTrue(c.isFactor(1));  
}
```

```
public class Classifier2 {  
    private int _number;  
  
    public Classifier2(int number) {  
        _number = number;  
    }  
  
    public boolean isFactor(int factor) {  
        return _number % factor == 0;  
    }  
}
```

```
@Test public void is_1_a_factor_of_10() {  
    Classifier2 c = new Classifier2(10);  
    assertTrue(c.isFactor(1));  
}  
  
@Test public void is_5_a_factor_of_25() {  
    Classifier2 c = new Classifier2(25);  
    assertTrue(c.isFactor(5));  
}  
  
@Test public void is_3_not_a_factor_of_7() {  
    Classifier2 c = new Classifier2(7);  
    assertFalse(c.isFactor(3));  
}
```



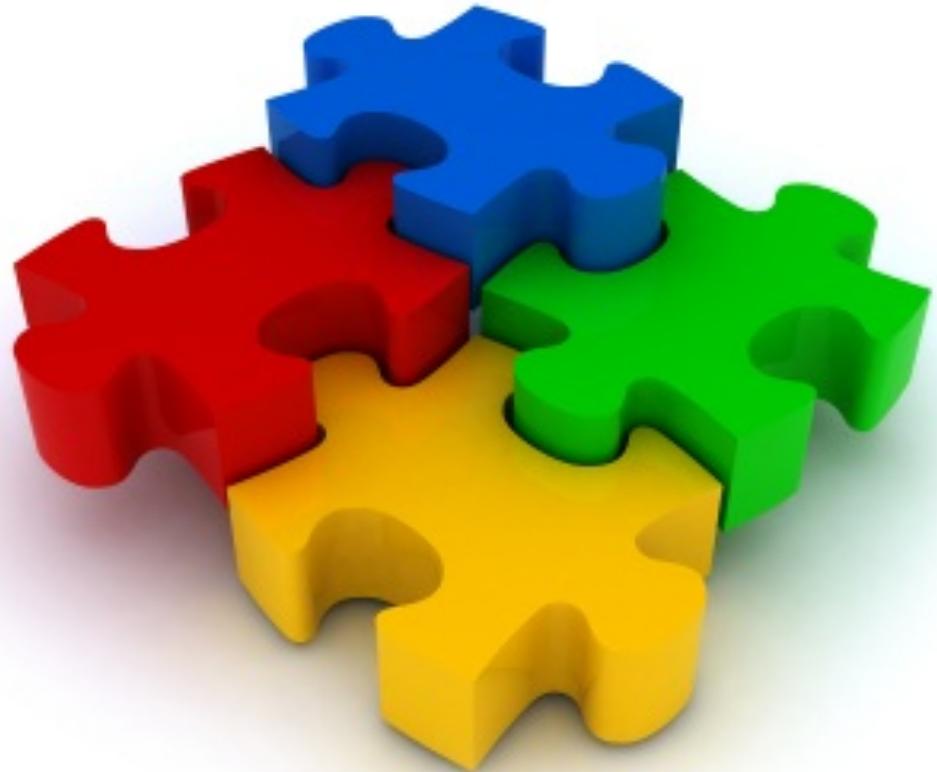
**objects are the keepers of
state**

should we keep this test?

```
@Test public void is_1_a_factor_of_10() {  
    Classifier2 c = new Classifier2(10);  
    assertTrue(c.isFactor(1));  
}
```



you've really
screwed up now!



writing insanely trivial
tests allows you to get
the interactions right

keep
trivial
tests as
canaries



next test

```
@Test public void factors_for_6() {  
    int[] expected = new int[] {1, 2, 3, 6};  
    Classifier2 c = new Classifier2(6);  
    assertThat(c.getFactors(), is(expected));  
}
```

yuck!

```
public int[] getFactors() {
    List<Integer> factors = new ArrayList<Integer>();
    factors.add(1);
    factors.add(_number);
    for (int i = 2; i < _number; i++) {
        if (isFactor(i))
            factors.add(i);
    }
    int[] intListOfFactors = new int[factors.size()];
    int i = 0;
    for (Integer f : factors)
        intListOfFactors[i++] = f.intValue();
    return intListOfFactors;
}
```

problems:

1. too much code!
2. switching from `List<Integer>` to `int[]` is noisy
3. more than one thing happening

promote factors to
internal variable

```
public int[] getFactors() {  
    List<Integer> factors = new ArrayList<Integer>();  
    factors.add(1);  
    factors.add(_number);  
    for (int i = 2; i < _number; i++) {  
        if (isFactor(i))  
            factors.add(i);  
    }  
    int[] intListOfFactors = new int[factors.size()];  
    int i = 0;  
    for (Integer f : factors)  
        intListOfFactors[i++] = f.intValue();  
    return intListOfFactors;  
}
```

adding implicit factors

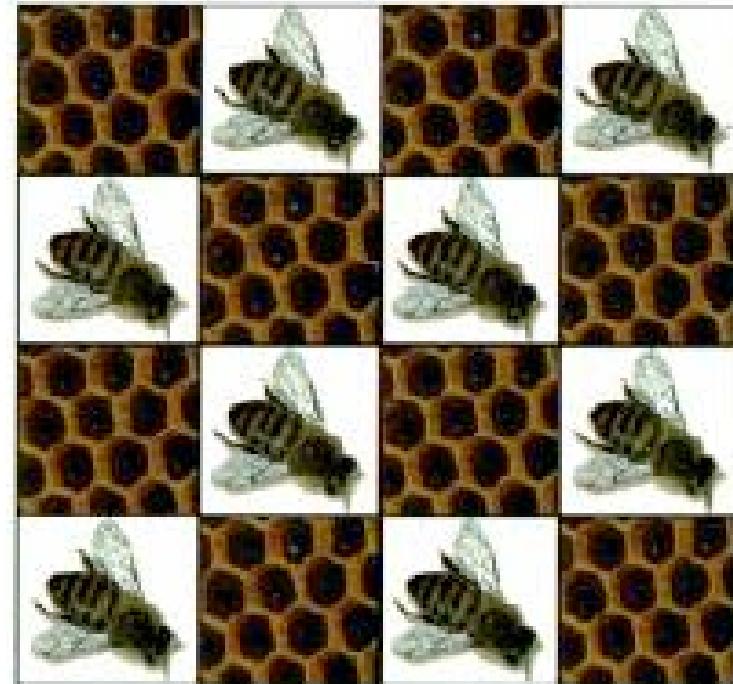
determining factors

converting to int[]

return
List<Integer>

composed method

SMALLHALK BEST PRACTICE PATTERNS



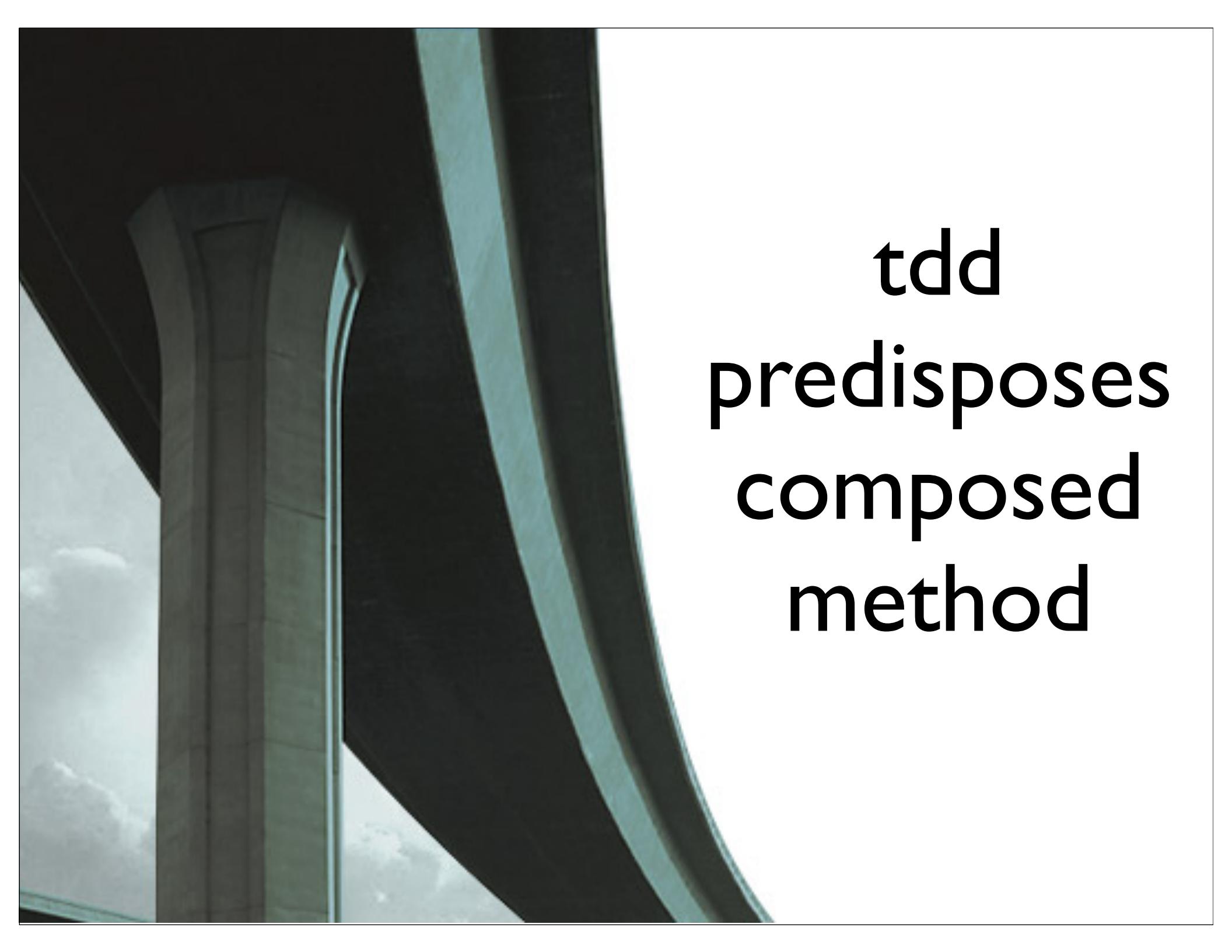
KENT BECK

composed method

Divide your program into methods that perform one identifiable task.

Keep all of the operations in a method at the same level of abstraction.

This will naturally result in programs with many small methods, each a few lines long.

The background of the slide features a photograph of a modern architectural structure, possibly a bridge or a series of panels, with dark, curved, metallic or glass-like surfaces set against a bright, overexposed sky.

tdd
predisposes
composed
method



I test generates lots of ?'s:
should factors be internal
state?
what should it return?

I test...



leads to
another...

and
another...

next test: **addFactors()**

```
@Test public void add_factors() {  
    Classifier3 c = new Classifier3(6);  
    c.addFactor(2);  
    c.addFactor(3);  
    assertThat(c.getFactors(), is(Arrays.asList(1, 2, 3, 6)));  
}
```

```
public class Classifier3 {  
    private int _number;  
    private List<Integer> _factors;  
  
    public Classifier3(int number) {  
        _number = number;  
        _factors = new ArrayList<Integer>();  
        this._factors.add(1);  
        this._factors.add(number);  
    }  
  
    public boolean isFactor(int factor) {  
        return _number % factor == 0;  
    }  
  
    public List<Integer> getFactors() {  
        return _factors;  
    }  
  
    public void addFactor(int factor) {  
        _factors.add(factor);  
    }  
}
```

Done: 1 of 1 Failed: 1(0.035 s)

Output Statistics

```
java.lang.AssertionError:  
Expected: is <[1, 2, 3, 6]>  
      got: <[1, 6, 2, 3]>  
  
at org.junit.Assert.assertThat(Assert.java:502)  
at org.junit.Assert.assertThat(Assert.java:492)  
at com.nealford.conf.tdd.perfectnumbers.Classifier3Test  
at sun.reflect.NativeMethodAccessorImpl.invoke0(Native Method)  
at sun.reflect.NativeMethodAccessorImpl.invoke(NativeMethod)  
at sun.reflect.DelegatingMethodAccessorImpl.invoke(Dele  
at org.junit.internal.runners.TestMethod.invoke(TestMethod)  
at org.junit.internal.runners.MethodRoadie.runTestMethod(MethodRo  
at org.junit.internal.runners.MethodRoadie$2.run(MethodRoadie\$2)  
at org.junit.internal.runners.MethodRoadie$2.run(MethodRoadie\$2)
```

!

rethink the abstraction:

`java.util.List` is ordered

are factors ordered?

looking for the set of factors

refactor!

```
@Test public void add_factors() {  
    Set<Integer> expected =  
        new HashSet(Arrays.asList(1, 2, 3, 6));  
    Classifier4 c = new Classifier4(6);  
    c.addFactor(2);  
    c.addFactor(3);  
    assertThat(c.getFactors(), is(expected));  
}
```

next: calculateFactors()

```
@Test public void factors_for_6() {  
    Set<Integer> expected =  
        new HashSet(Arrays.asList(1, 2, 3, 6));  
    Classifier4 c = new Classifier4(6);  
    c.calculateFactors();  
    assertThat(c.getFactors(), is(expected));  
}  
  
public void calculateFactors() {  
    for (int i = 2; i < _number; i++)  
        if (isFactor(i))  
            addFactor(i);  
}
```

ok for tests to be moist...



...but not drenched



refactor

```
private Set<Integer> expectationSetWith(Integer... numbers) {  
    return new HashSet<Integer>(Arrays.asList(numbers));  
}  
  
@Test public void factors_for_6() {  
    Set<Integer> expected = expectationSetWith(1, 2, 3, 6);  
    Classifier4 c = new Classifier4(6);  
    c.calculateFactors();  
    assertThat(c.getFactors(), is(expected));  
}
```

more tests

```
@Test public void factors_for_12() {  
    Classifier4 c = new Classifier4(12);  
    c.calculateFactors();  
    assertThat(c.getFactors(),  
               is(expectationSetWith(1, 2, 3, 4, 6, 12)));  
}  
  
@Test public void factors_for_100() {  
    Classifier4 c = new Classifier4(100);  
    c.calculateFactors();  
    assertThat(c.getFactors(),  
               is(expectationSetWith(1, 100, 2, 50, 4, 25, 5, 20, 10)));  
}
```

boundary conditions

```
@Test public void factors_for_1() {  
    Classifier5 c = new Classifier5(1);  
    c.calculateFactors();  
    assertThat(c.getFactors(), is(expectationSetWith(1)));  
}  
  
@Test(expected = InvalidNumberException.class)  
public void cannot_classify_negative_numbers() {  
    new Classifier5(-20);  
}  
  
@Test public void factors_for_max_int() {  
    Classifier5 c = new Classifier5(Integer.MAX_VALUE);  
    c.calculateFactors();  
    assertThat(c.getFactors(), is(expectationSetWith(1, 2147483647)));  
}
```

**consumption awareness
encourages exploration of
boundary conditions**

```
public class Classifier5 {  
    private Set<Integer> _factors;  
    private int _number;  
    private static final String NEGATIVE_NUMBER_ERROR =  
        "Can't classify negative numbers";  
  
    public Classifier5(int number) {  
        if (number < 1)  
            throw new InvalidNumberException(NEGATIVE_NUMBER_ERROR);  
        _number = number;  
        _factors = new HashSet<Integer>();  
        _factors.add(1);  
        _factors.add(_number);  
    }  
}
```

next test: sumOfFactors()

```
@Test public void sum() {  
    Classifier5 c = new Classifier5(20);  
    c.calculateFactors();  
    int expected = 1 + 2 + 4 + 5 + 10 + 20;  
    assertThat(c.sumOfFactors(), is(expected));  
}  
  
public int sumOfFactors() {  
    int sum = 0;  
    for (int i : _factors)  
        sum += i;  
    return sum;  
}
```

next test: perfection!

```
@Test public void perfection() {  
    int[] perfectNumbers =  
        new int[] {6, 28, 496, 8128, 33550336};  
    for (int number : perfectNumbers)  
        assertTrue(classifierFor(number).isPerfect());  
}  
  
public boolean isPerfect() {  
    calculateFactors();  
    return sumOfFactors() - _number == _number;  
}
```

what about
a negative test?



```
private static final Integer[] PERFECT_NUMS =
    {6, 28, 496, 8128, 33550336};

@Test public void test_a_bunch_of_numbers() {
    Set<Integer> expected = new HashSet<Integer>(
        Arrays.asList(PERFECT_NUMS));
    for (int i = 2; i < 33550340; i++) {
        if (expected.contains(i))
            assertTrue(classifierFor(i).isPerfect());
        else
            assertFalse(classifierFor(i).isPerfect());
    }
}
```

*optimize
now!*



unoptimized

```
public void calculateFactors() {  
    for (int i = 2; i < _number; i++)  
        if (isFactor(i))  
            addFactor(i);  
}
```

optimized

```
public void calculateFactors() {  
    for (int i = 2; i < sqrt(_number) + 1; i++)  
        if (isFactor(i))  
            addFactor(i);  
}  
  
public void addFactor(int factor) {  
    _factors.add(factor);  
    _factors.add(_number / factor);  
}
```

design implications

remember this?

```
for (int i = 2; i <= sqrt(number); i++)
    if (number % i == 0) {
        factors.add(i);
        // account for whole-number square roots
        if (number / i != i)
            factors.add(number / i);
    }
```

perfect
number
finder

classifier

VS.

```
for (int i = 2; i <= sqrt(number); i++)
    if (number % i == 0) {
        factors.add(i);
        // account for whole-number square roots
        if (number / i != i)
            factors.add(number / i);
    }

private void calculateFactors() {
    for (int i = 2; i < sqrt(_number) + 1; i++)
        if (isFactor(i))
            addFactor(i);
}

private void addFactor(int factor) {
    _factors.add(factor);
    _factors.add(_number / factor);
}
```

tdd vs test-after

test after doesn't expose design flaws early

because you think at the wrong abstraction level

tdd forces you to think about every little thing

and encourages refactoring what's not right



if its hard to test,
something's wrong

```
public class Classifier5 {  
    private Set<Integer> _factors;  
    private int _number;  
    private static final String NEGATIVE_NUMBER_ERROR =  
        "Can't classify negative numbers";  
  
    public Classifier5(int number) {...  
  
    public boolean isFactor(int factor) {...  
  
    public Set<Integer> getFactors() {...  
  
    public void calculateFactors() {...  
  
    public void addFactor(int factor) {...  
  
    public int sumOfFactors() {...  
  
    public boolean isPerfect() {...  
}
```

t d d
generates
cohesive
methods



```
public static boolean isPerfect(int number) {  
    // get factors  
    List<Integer> factors = new ArrayList<Integer>();  
    factors.add(1);  
    factors.add(number);  
    for (int i = 2; i < sqrt(number); i++) {  
        if (number % i == 0) {  
            factors.add(i);  
            if (number / i != i)  
                factors.add(number / i);  
        }  
  
        // sum factors  
        int sum = 0;  
        for (int n : factors)  
            sum += n;  
  
        // decide if it's perfect  
        return sum - number == number;  
    }  
}
```

```
public class Classifier5 {  
    public Classifier5(int number) {  
        calculateFactors();  
    }  
  
    public boolean isFactor(int factor) {  
        return getFactors().contains(factor);  
    }  
  
    public Set<Integer> getFactors() {  
        return factors;  
    }  
  
    public void calculateFactors() {  
        factors = new HashSet<Integer>();  
        factors.add(1);  
        factors.add(number);  
        for (int i = 2; i < sqrt(number); i++) {  
            if (number % i == 0) {  
                factors.add(i);  
                if (number / i != i)  
                    factors.add(number / i);  
            }  
        }  
    }  
  
    public void addFactor(int factor) {  
        factors.add(factor);  
    }  
  
    public int sumOfFactors() {  
        int sum = 0;  
        for (int n : factors)  
            sum += n;  
        return sum;  
    }  
  
    public boolean isPerfect() {  
        return sumOfFactors() - number == number;  
    }  
}
```

refactor comments to methods



**new requirement:
handle abundant &
deficient numbers**

```
public class PerfectNumberFinder2 {  
    public static boolean isPerfect(int number) {  
        // get factors  
        List<Integer> factors = new ArrayList<Integer>();  
        factors.add(1);  
        factors.add(number);  
        for (int i = 2; i < sqrt(number); i++)  
            if (number % i == 0) {  
                factors.add(i);  
                if (number / i != i)  
                    factors.add(number / i);  
            }  
  
        // sum factors  
        int sum = 0;  
        for (int n : factors)  
            sum += n;  
  
        // decide if it's perfect  
        return sum - number == number;  
    }  
}
```

```
public class Classifier6 {  
    private Set<Integer> _factors;  
    private int _number;  
  
    public Classifier6(int number) {  
    }  
  
    private boolean isFactor(int factor) {  
    }  
  
    public Set<Integer> getFactors() {  
    }  
  
    private void calculateFactors() {  
    }  
  
    private void addFactor(int factor) {  
    }  
  
    private int sumOfFactors() {  
    }  
  
    public boolean isPerfect() {  
    }  
  
    public boolean isAbundant() {  
    }  
  
    public boolean isDeficient() {  
    }  
}
```

abundant & deficient

```
public boolean isAbundant() {  
    calculateFactors();  
    return sumOfFactors() - _number > _number;  
}  
  
public boolean isDeficient() {  
    calculateFactors();  
    return sumOfFactors() - _number < _number;  
}
```

**composed method
yields reusable code**

red - green - refactor

```
public boolean isPerfect() {  
    calculateFactors();  
    return sumOfFactors() - _number == _number;  
}  
  
public boolean isAbundant() {  
    calculateFactors();  
    return sumOfFactors() - _number > _number;  
}  
  
public boolean isDeficient() {  
    calculateFactors();  
    return sumOfFactors() - _number < _number;  
}
```

```
private int sumOfFactors() {
    calculateFactors();
    int sum = 0;
    for (int i : _factors)
        sum += i;
    return sum;
}

public boolean isPerfect() {
    return sumOfFactors() - _number == _number;
}

public boolean isAbundant() {
    return sumOfFactors() - _number > _number;
}

public boolean isDeficient() {
    return sumOfFactors() - _number < _number;
}
```

Classifier

```
public class Classifier6 {  
    private Set<Integer> _factors;  
    private int _number;  
  
    public Classifier6(int number) {  
        if (number < 1)  
            throw new InvalidNumberException(  
                "Can't classify negative numbers");  
        _number = number;  
        _factors = new HashSet<Integer>();  
        _factors.add(1);  
        _factors.add(_number);  
    }  
  
    private boolean isFactor(int factor) {  
        return _number % factor == 0;  
    }  
}
```

```
public Set<Integer> getFactors() {
    return _factors;
}

private void calculateFactors() {
    for (int i = 2; i < sqrt(_number) + 1; i++)
        if (isFactor(i))
            addFactor(i);
}

private void addFactor(int factor) {
    _factors.add(factor);
    _factors.add(_number / factor);
}

private int sumOfFactors() {
    calculateFactors();
    int sum = 0;
    for (int i : _factors)
        sum += i;
    return sum;
}
```

```
public boolean isPerfect() {
    return sumOfFactors() - _number == _number;
}

public boolean isAbundant() {
    return sumOfFactors() - _number > _number;
}

public boolean isDeficient() {
    return sumOfFactors() - _number < _number;
}

public static boolean isPerfect(int number) {
    return new Classifier6(number).isPerfect();
}
```

complete tests

```
public class Classifier6Test {  
    private static final Integer[] PERFECT_NUMS =  
        {6, 28, 496, 8128, 33550336};  
  
    @Test  
    public void is_1_a_factor_of_10() {  
        Classifier6 c = new Classifier6(10);  
        assertTrue(isFactor(c, 1));  
    }  
  
    @Test public void is_5_a_factor_of_25() {  
        Classifier6 c = new Classifier6(25);  
        assertTrue(isFactor(c, 5));  
    }  
}
```

```
@Test public void is_3_not_a_factor_of_7() {
    Classifier6 c = new Classifier6(7);
    assertFalse(isFactor(c, 3));
}

@Test public void add_factors() {
    Set<Integer> expected =
        new HashSet<Integer>(Arrays.asList(1, 2, 3, 6));
    Classifier6 c = new Classifier6(6);
    addFactor(c, 2);
    addFactor(c, 3);
    assertThat(c.getFactors(), is(expected));
}

@Test public void factors_for_6() {
    Set<Integer> expected = expectationSetWith(1, 2, 3, 6);
    Classifier6 c = new Classifier6(6);
    calculateFactors(c);
    assertThat(c.getFactors(), is(expected));
}
```

```
@Test public void factors_for_12() {
    Classifier6 c = new Classifier6(12);
    calculateFactors(c);
    assertThat(c.getFactors(),
               is(expectationSetWith(1, 2, 3, 4, 6, 12)));
}

@Test public void factors_for_100() {
    Classifier6 c = new Classifier6(100);
    calculateFactors(c);
    assertThat(c.getFactors(),
               is(expectationSetWith(1, 100, 2, 50, 4, 25, 5, 20, 10)));
}

@Test public void factors_for_prime() {
    Classifier6 c = new Classifier6(23);
    calculateFactors(c);
    assertThat(c.getFactors(), is(expectationSetWith(1, 23)));
}
```

```
@Test public void test_a_bunch_of_numbers() {
    Set<Integer> expected = new HashSet<Integer>(
        Arrays.asList(PERFECT_NUMS));
    for (int i = 2; i < 33550340; i++) {
        if (expected.contains(i))
            assertTrue(classifierFor(i).isPerfect());
        else
            assertFalse(classifierFor(i).isPerfect());
    }
}

@Test(expected = InvalidNumberException.class)
public void cannot_classify_negative_numbers() {
    new Classifier6(-20);
}

@Test public void sum() {
    Classifier6 c = new Classifier6(20);
    calculateFactors(c);
    int expected = 1 + 2 + 4 + 5 + 10 + 20;
    assertThat(sumOfFactors(c), is(expected));
}
```

```
@Test public void perfection() {
    Integer[] perfectNumbers = PERFECT_NUMS;
    for (int number : perfectNumbers)
        assertTrue(classifierFor(number).isPerfect());
}

@Test public void abundance() {
    int[] abundantNumbers = new int[] {12, 18, 20, 24, 30};
    for (int i : abundantNumbers)
        assertTrue(new Classifier6(i).isAbundant());
}

@Test public void deficiency() {
    int[] deficientNumbers = new int[] {3, 5, 7, 9, 10, 11};
    for (int i : deficientNumbers) {
        assertTrue(new Classifier6(i).isDeficient());
    }
}
```

helpers

```
private Set<Integer> expectationSetWith(Integer... numbers) {  
    return new HashSet<Integer>(Arrays.asList(numbers));  
}  
  
private Classifier6 classifierFor(int number) {  
    Classifier6 c = new Classifier6(number);  
    calculateFactors(c);  
    return c;  
}
```

measuring code quality



cyclomatic complexity

measures method complexity

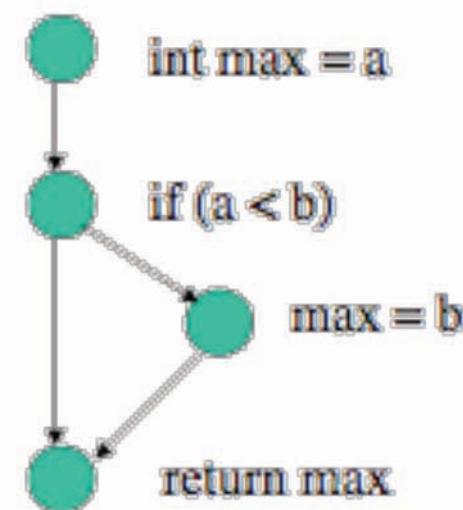
$$V(G) = e - n + 2$$

$V(G)$ = cyclomatic complexity of G

e= # edges

n= # of nodes

```
int max (int a, int b) {  
    int max = a;  
    if (a < b) {  
        max = b;  
    }  
    return max;  
}
```

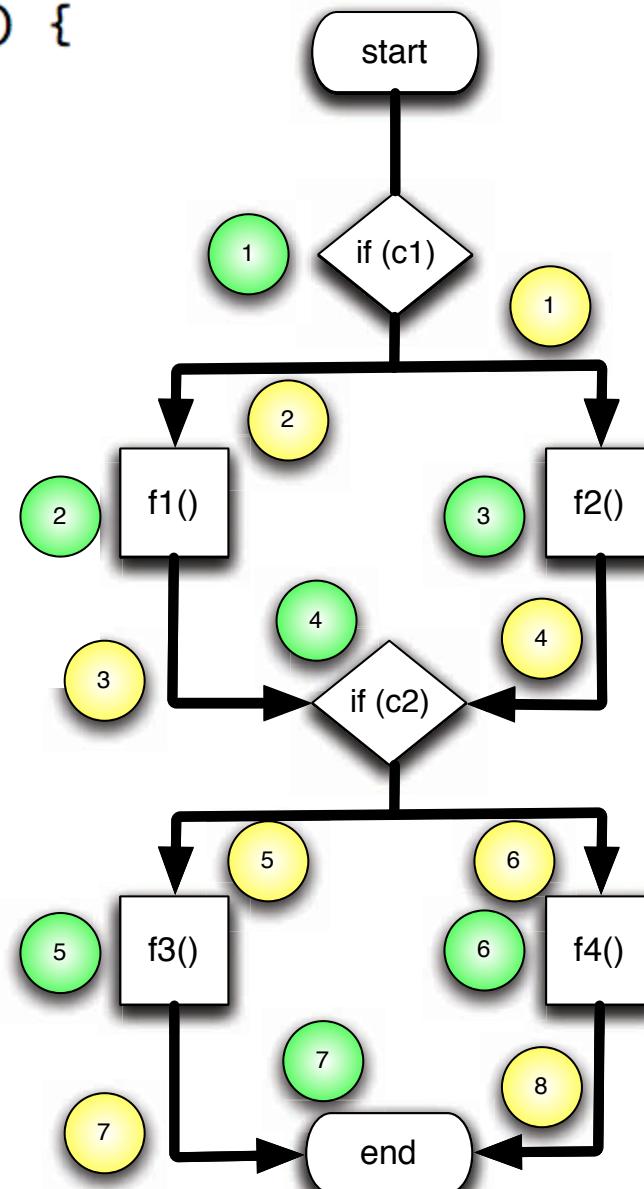


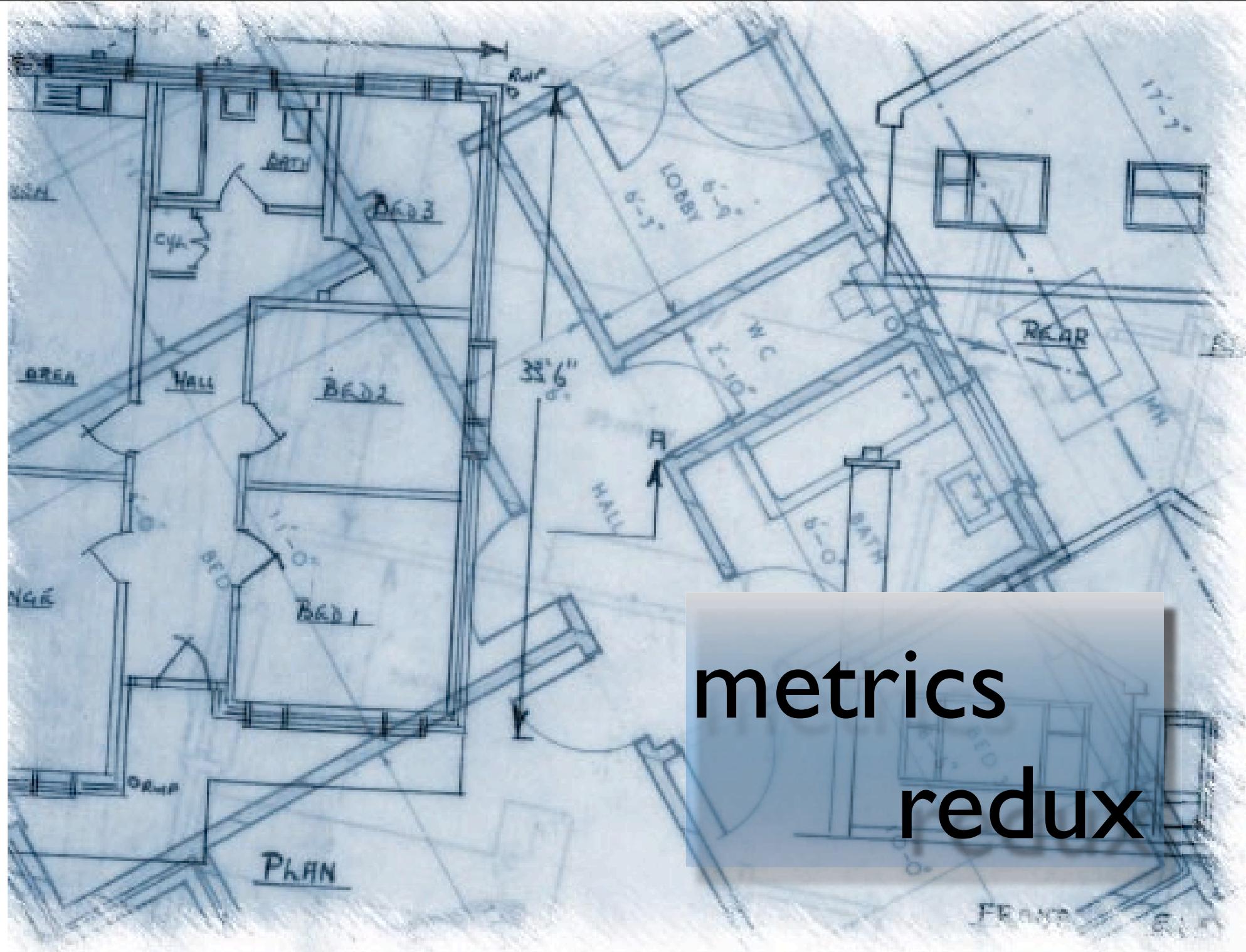
```

public void doIt() {
    if (c1) {
        f1();
    } else {
        f2();
    }
    if (c2) {
        f3();
    } else {
        f4();
    }
}

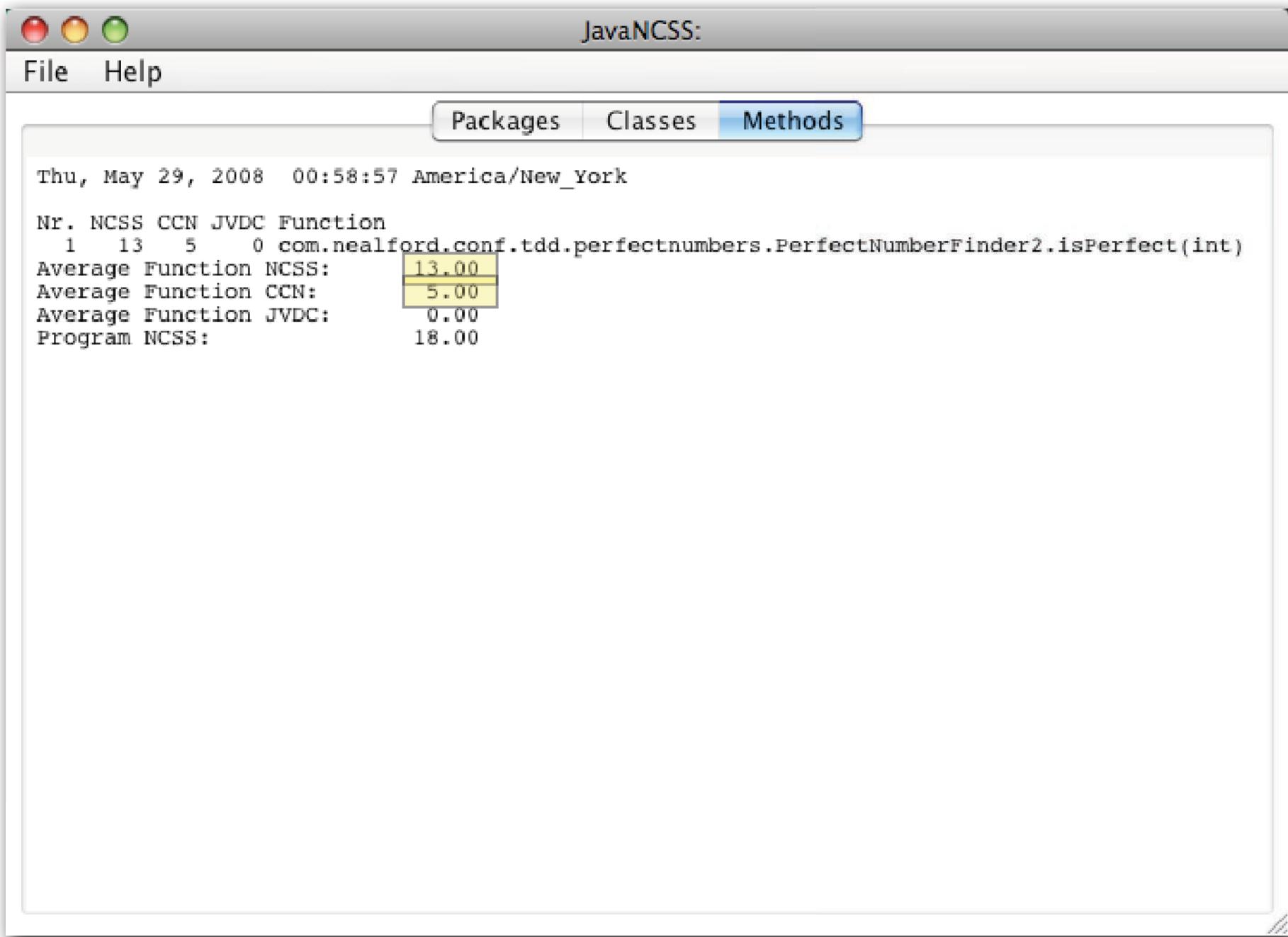
```

nodes
 edges





metrics
redux



 JavaNCSS:

File Help

Packages Classes Methods

Thu, May 29, 2008 00:55:08 America/New_York

Nr.	NCSS	CCN	JVDC	Function
1	7	3	0	com.nealford.conf.tdd.perfectnumbers.Classifier6.Classifier6(int)
2	2	1	0	com.nealford.conf.tdd.perfectnumbers.Classifier6.isFactor(int)
3	2	1	0	com.nealford.conf.tdd.perfectnumbers.Classifier6.getFactors()
4	4	3	0	com.nealford.conf.tdd.perfectnumbers.Classifier6.calculateFactors()
5	3	1	0	com.nealford.conf.tdd.perfectnumbers.Classifier6.addFactor(int)
6	5	2	0	com.nealford.conf.tdd.perfectnumbers.Classifier6.sumOfFactors()
7	3	1	0	com.nealford.conf.tdd.perfectnumbers.Classifier6.isPerfect()
8	3	1	0	com.nealford.conf.tdd.perfectnumbers.Classifier6.isAbundant()
9	3	1	0	com.nealford.conf.tdd.perfectnumbers.Classifier6.isDeficient()

Average Function NCSS: 3.56

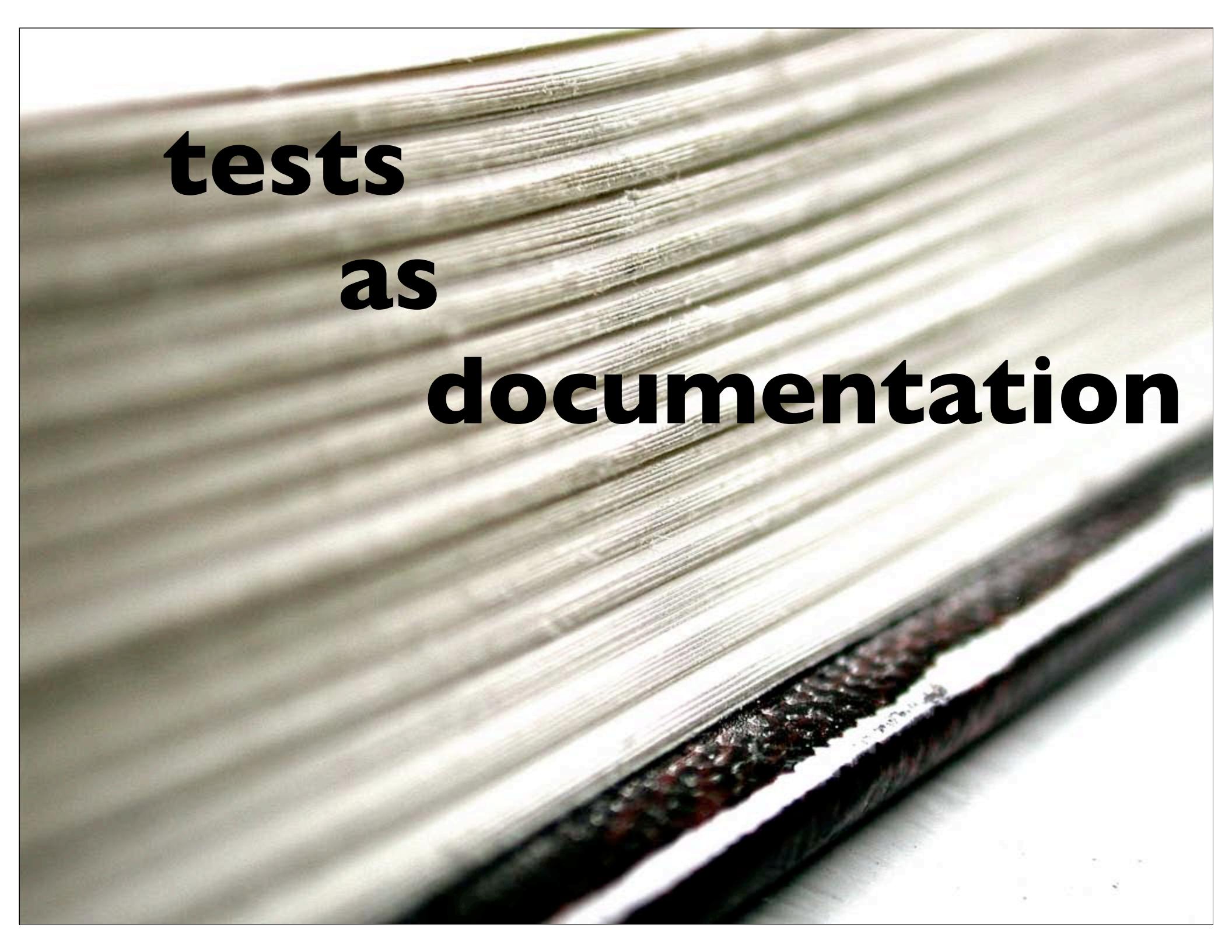
Average Function CCN: 1.56

Average Function JVDC: 0.00

Program NCSS: 39.00

are these number
sustainable for a large
project?

stay tuned!



**tests
as
documentation**

```
@Test public void is_1_a_factor_of_10() {  
    ...  
}  
  
@Test public void is_5_a_factor_of_25() {  
    ...  
}  
  
@Test public void is_3_not_a_factor_of_7() {  
    ...  
}  
  
@Test public void add_factors() {  
    ...  
}  
  
@Test public void factors_for_6() {  
    ...  
}  
  
@Test public void factors_for_12() {  
    ...  
}  
  
@Test public void factors_for_100() {  
    ...  
}  
  
@Test public void factors_for_1() {  
    ...  
}  
  
@Test(expected = InvalidNumberException.class)  
public void cannot_classify_negative_numbers() {  
    ...  
}  
  
@Test public void factors_for_max_int() {  
    ...  
}  
  
@Test public void sum() {  
    ...  
}  
  
@Test public void perfection() {  
    ...  
}
```

**executable requirements
beat paper any day**



testing what's hard to test





tdd private methods?

```
private void calculateFactors() {
    for (int i = 2; i < sqrt(_number) + 1; i++)
        if (isFactor(i))
            addFactor(i);
}

private void addFactor(int factor) {
    _factors.add(factor);
    _factors.add(_number / factor);
}

private int sumOfFactors() {
    int sum = 0;
    for (int i : _factors)
        sum += i;
    return sum;
}
```

solution #1:
make them all public
(or package) scope



solution #2:
use reflection

reflection helpers

```
@Test
public void is_1_a_factor_of_10() {
    Classifier6 c = new Classifier6(10);
    assertTrue(isFactor(c, 1));
}

private boolean isFactor(Classifier6 c, int factor) {
    try {
        Method m = Classifier6.class.getDeclaredMethod(
            "isFactor", int.class);
        m.setAccessible(true);
        return (Boolean) m.invoke(c, factor);
    } catch (Throwable t) {
        fail();
    }
    return false;
}
```



groovy
groovy



reflection

```
@Test public void is_factor_via_reflection() {  
    def m = Classifier6.class.getDeclaredMethod("isFactor", int.class)  
    m.accessible = true  
    assertTrue m.invoke(new Classifier6(10), 10)  
    assertTrue m.invoke(new Classifier6(25), 5)  
    assertFalse m.invoke(new Classifier6(25), 6)  
}
```



dirty secret: private is ignored!

```
@Test public void is_factor() {  
    assertTrue new Classifier6(10).isFactor(1)  
    assertTrue new Classifier6(25).isFactor(5)  
    assertFalse new Classifier6(25).isFactor(6)  
}
```

technically, a bug...

...no great hurry to fix it (insanely useful!)



mocking



mocking in



technology stack



java 5

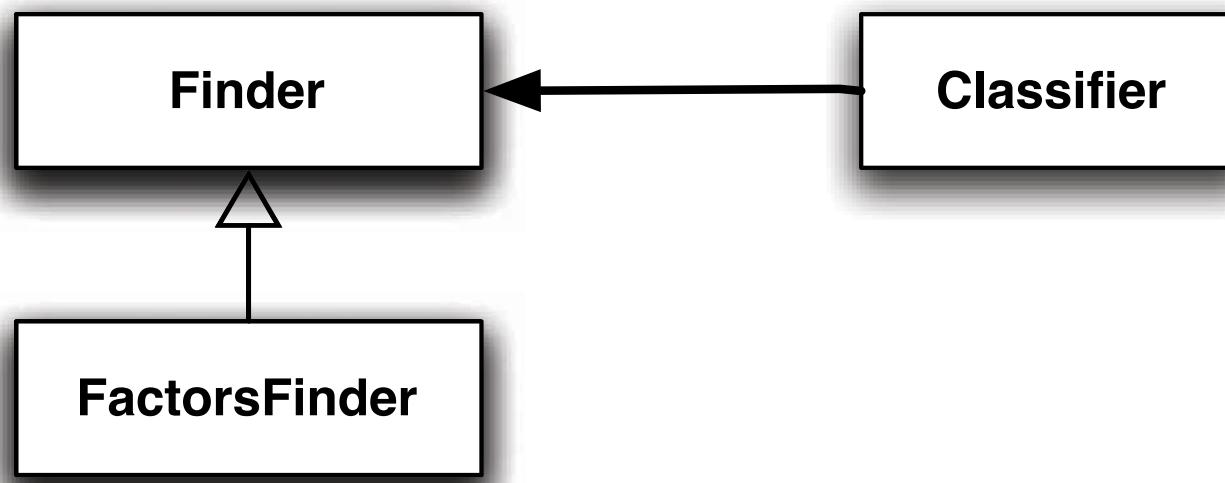
junit 4.x

hamcrest matchers

jmock 2.4

changes:

added a **FactorsFinder** class which harvests factors



refactored **Classifier** to use external factors

```
public class Classifier7 {  
    private int _number;  
    private Finder _factors;  
  
    public Classifier7(int number, Finder factors) {  
        _number = number;  
        _factors = factors;  
    }  
  
    public boolean isPerfect() {  
        return sumOfFactors() - _number == _number;  
    }  
  
    public int sumOfFactors() {  
        int sum = 0;  
        for (int i : _factors.factors())  
            sum += i;  
        return sum;  
    }  
}
```

```
public class FactorsFinder implements Finder {
    private int _number;
    private Set<Integer> _factors = new HashSet<Integer>();

    public FactorsFinder(int number) {
        _number = number;
    }

    public Set<Integer> factors() {
        calculateFactors();
        return _factors;
    }

    private boolean isFactor(int factor) {
        return _number % factor == 0;
    }

    public void calculateFactors() {
        for (int i = 2; i < sqrt(_number) + 1; i++)
            if (isFactor(i))
                addFactor(i);
    }

    private void addFactor(int factor) {
        _factors.add(factor);
        _factors.add(_number / factor);
    }
}
```

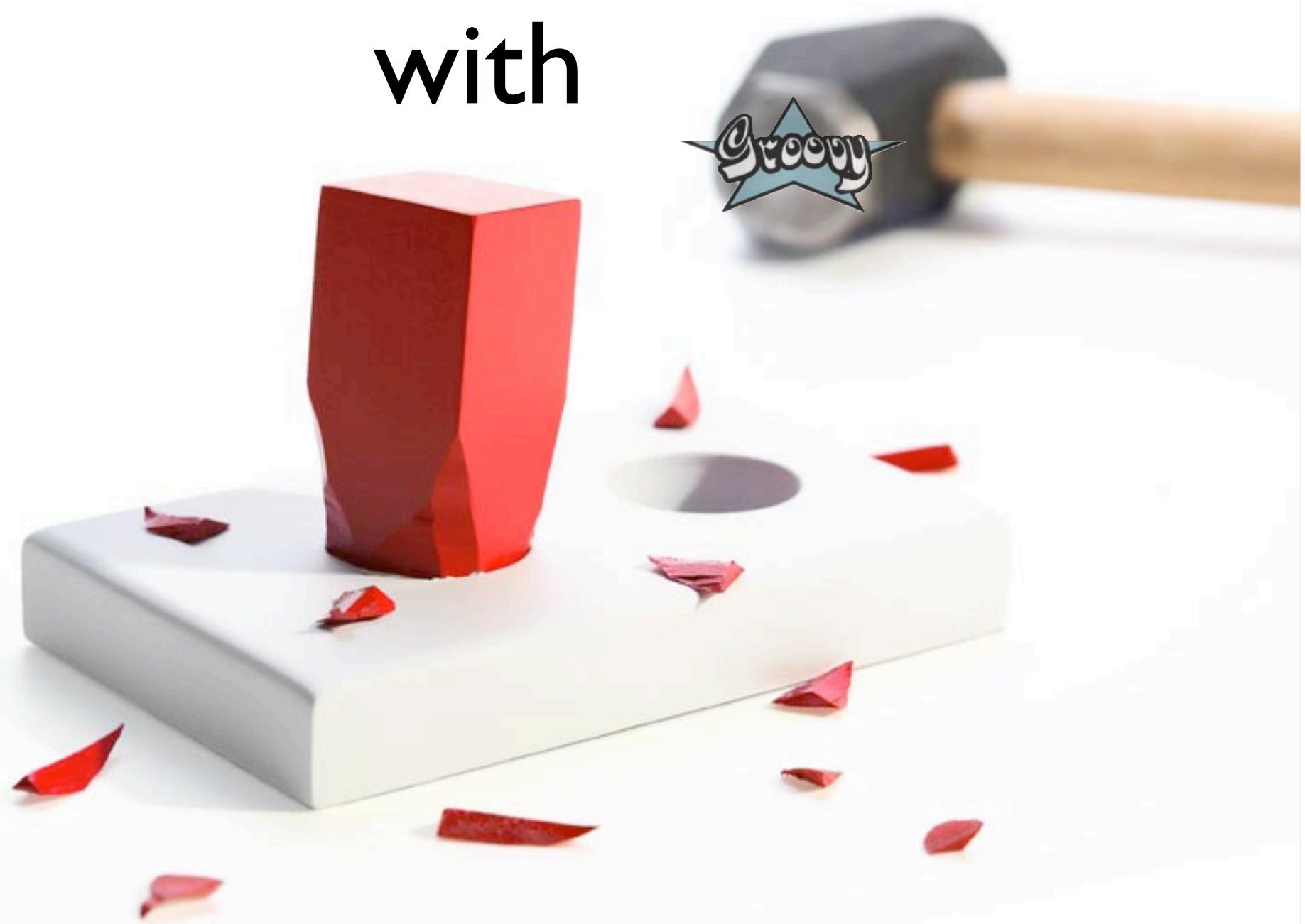


jmock

```
@RunWith(JMock.class)
public class ClassifierWithMockTest {
    Mockery context = new JUnit4Mockery() {{
        setImposteriser(ClassImposteriser.INSTANCE);
   ));

    @Test public void external_factors() {
        final Finder facts = context.mock(Finder.class);
        Classifier7 c = new Classifier7(42, facts);
        final Set<Integer> expected =
            new HashSet(Arrays.asList(1, 2, 3, 6, 7, 21, 14, 42));
        context.checking(new Expectations() {{
            one(facts).factors(); will(returnValue(expected));
       }});
        assertThat(c.sumOfFactors(), is(1 + 2 + 3 + 6 + 7 + 21 + 14 + 42));
        context.assertIsSatisfied();
    }
}
```

mocking with



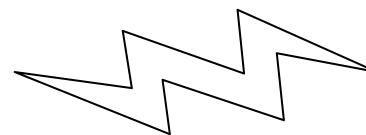
java-like syntax

```
@Test public void test_mock_with_simple_syntax() {  
    Set<Integer> expected = new HashSet<Integer>(Arrays.asList(1, 2, 3, 6, 7, 21, 14, 42))  
    def facts = [factors: {expected}] as Finder  
    Classifier7 c = new Classifier7(42, facts)  
    def sumOfFactors = 0  
    expected.each { num ->  
        sumOfFactors += num  
    }  
    assertThat(c.sumOfFactors(), is(sumOfFactors))  
}
```

```
def facts = [factors: {expected}] as Finder
```

factors

:



Finder

factors()



idiomatic



```
@Test public void test_mock_with_simple_syntax() {  
    Set<Integer> expected = new HashSet<Integer>(Arrays.asList(1, 2, 3, 6, 7, 21, 14, 42))  
    def facts = [factors: {expected}] as Finder  
    Classifier7<Integer> c = new Classifier7<Integer>(42, facts)  
    def sumOfFactors = 0  
    expected.each { num ->  
        sumOfFactors += num  
    }  
    assertThat(c.sumOfFactors(), is(sumOfFactors))  
}
```

```
@Test public void test_mock_with_factors_finder() {  
    def expected = [1, 2, 3, 6, 7, 21, 14, 42]  
    def facts = [factors: {expected as Set<Integer>}] as Finder  
    Classifier7<Integer> c = new Classifier7<Integer>(42, facts)  
    assertThat(c.sumOfFactors(),  
               is(expected.inject(0) { sum, n -> sum += n}))  
}
```

```
@Test public void test_mock_with_factors_finder() {  
    def expected = [1, 2, 6, 7, 23, 46]  
    def facts = [factors: {expected as Set}] as Finder  
    Classifier7 c = new Classifier7(46, facts)  
    assertThat c.sumOfFactors(),  
        is(expected.inject(0) { sum, n -> sum += n})  
}
```



JAVA

```
@Test public void external_factors() {  
    final Finder facts = context.mock(Finder.class);  
    Classifier7 c = new Classifier7(46, facts);  
    final Set<Integer> expected =  
        new HashSet(Arrays.asList(1, 2, 6, 7, 23, 46));  
    context.checking(new Expectations() {{  
        one(facts).factors(); will(returnValue(expected));  
    }});  
    assertThat(c.sumOfFactors(), is(1 + 2 + 6 + 7 + 23 + 46));  
    context.assertIsSatisfied();  
}
```

ceremony

essence



```
@Test public void test_mock_with_factors_finder() {  
    def expected = [1, 2, 6, 7, 23, 46]  
    def facts = [factors: {expected as Set}] as Finder  
    Classifier7 c = new Classifier7(46, facts)  
    assertThat c.sumOfFactors(),  
        is(expected.inject(0) { sum, n -> sum += n})  
}
```

it is professionally
irresponsible to not
write tests

it is professionally
irresponsible to use the
most cumbersome
tools

how ide's help



```
@Test public void abundance() {  
    int[] abundantNumbers = new int[] {12, 18, 20, 24, 30};  
    for (int i : abundantNumbers)  
        assertTrue(Classifier2.isAbundant(i));  
}
```

```
@Test public void abundance() {  
    int[] abundantNumbers = new int[] {12, 18, 20, 24, 30};  
    for (int i : abundantNumbers)  
        assertEquals(true, Classifier2.isAbundant(i));
```

? Create Method 'isAbundant'

- 💡 Add Braces to 'for' statement
- 💡 Replace 'assertTrue()' with 'assertEquals(true, ...)'
- 💡 Replace 'assertTrue()' with 'assertFalse()'

```
    }  
    public void testDeficiency() {  
        int[] deficientNumbers = new int[] {3, 5, 7, 9, 10, 11};  
        for (int i : deficientNumbers)  
            assertFalse(Classifier2.isAbundant(i));  
    }
```

```
public static boolean isAbundant(int i) {  
}
```

```
public static boolean isAbundant(int i) {  
    return false;  
}
```

```
public static boolean isAbundant(int i) {  
    return sumOfFactorsFor(i) - i > i;  
}
```

```
public static boolean isAbundant(int number) {  
    return sumOfFactorsFor(number) - number > number;  
}
```

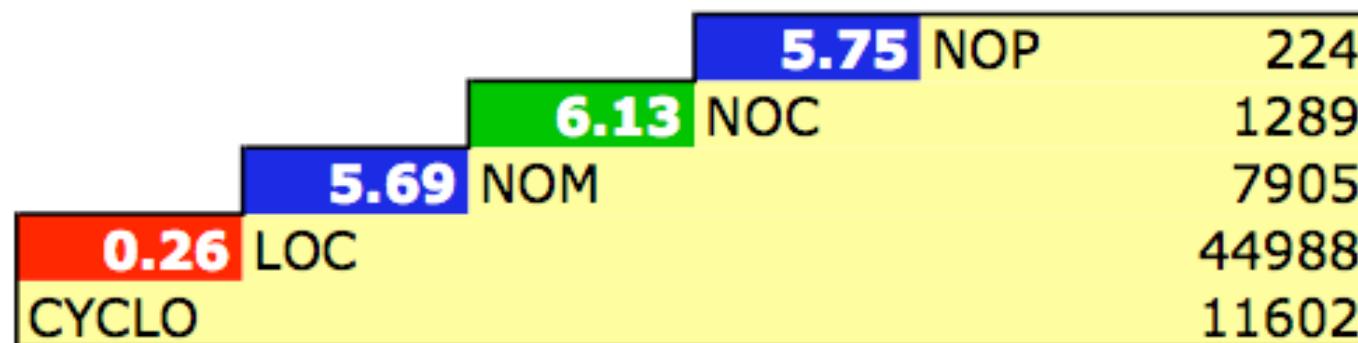
case study

rigorously applied over the life of a real project

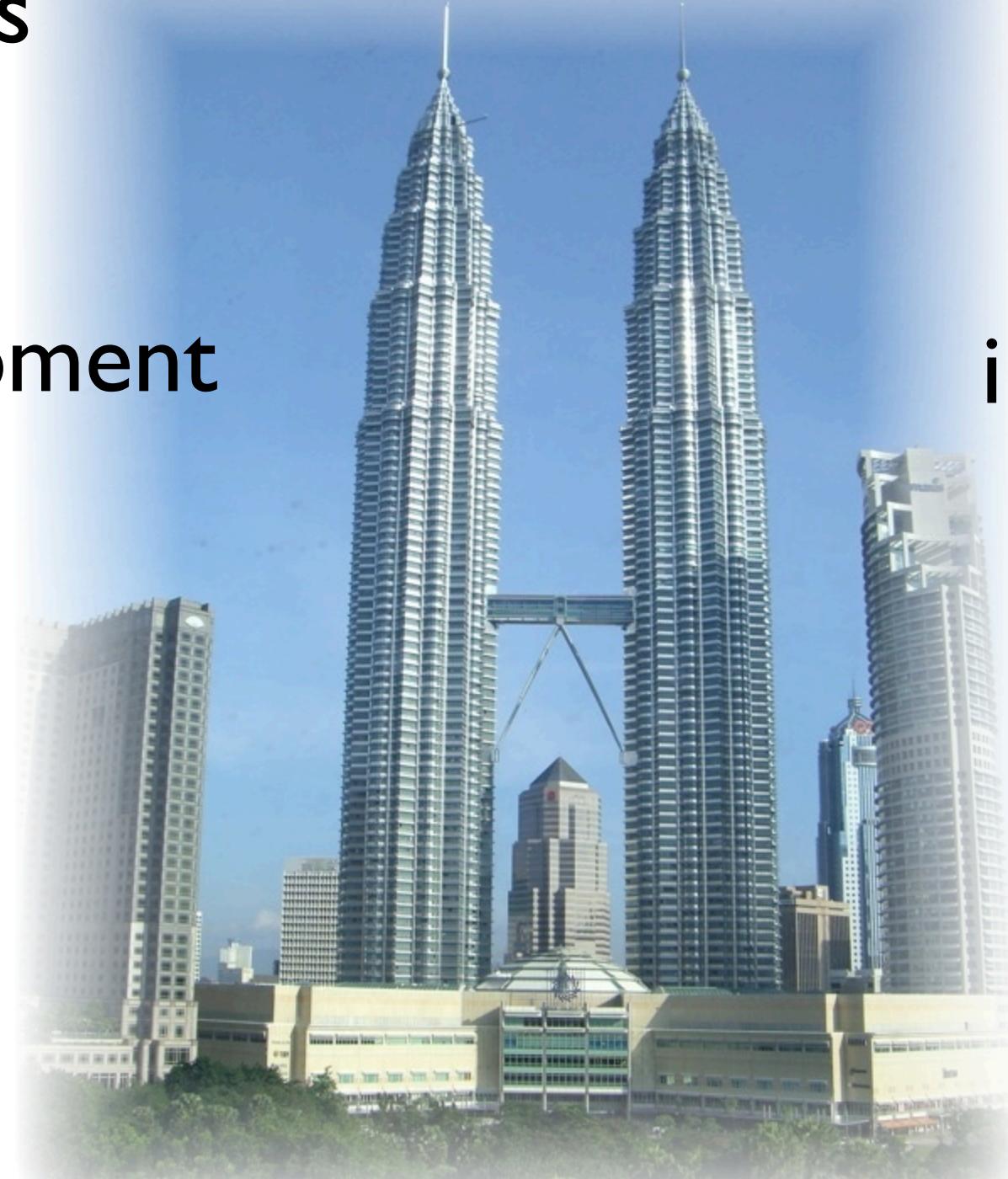
tech lead diligent about metrics

every line of code t d d

results



rigorous
test-
driven
development



improves
the
design
of
your
code

? , S

please fill out the session evaluations
samples at github.com/nealford



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NEAL FORD software architect / meme wrangler

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