# Metrics & Methodologies for Test Suite Design

Sean Olszewski

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# Hello!

Engineer for Pivotal Labs

Daily TDD Practitioner

Musician & Sound Designer

@__chefski__

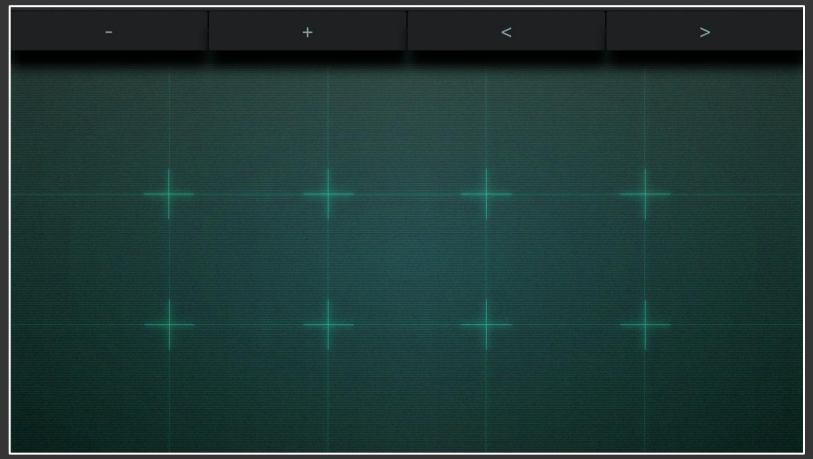
# Session Overview

- **My App - Arper**
  Ground the talk in something concrete
- **Test Suite Engineering**
  Talk about ways to engineer effective test suites
- **Review**
  Go over the topics we went through

# Arper

## Arper

- Music app
- Ambient/drone music
- Entirely test-driven
  - Quick/Nimble
- Under active development



# Arper - Components

### ButtonBankView

Lays out buttons so they can be played. Notifies a delegate that a button is pressed.

### MIDINoteMapping

Determines which button corresponds to a note.

### AudioEngineManager

Handles note routing into the audio engine. Contains logic for interpreting various controls.

### AudioEngine

Handles converting notes into sound.

# Test Suite Engineering

# Concepts

- **Responsibilities**
  The purpose and benefits of a test suite
- **Metrics**
  Measurable and meaningful details for assessing the efficacy of your test suites
- **Patterns**
  Clearly defined and repeatable ways to code test suites
- **Methodologies**
  Ways that you can use patterns & metrics to engineer an effective test suite

# Terminology

- **Test**
  A way to prove something works, usually automatically.
- **Test Subject**
  The component you are interested in proving works.
- **Behavior**
  What a test subject is supposed to do; what we are interested in testing
- **Test Double**
  A component which stands-in for a dependency of the test subject (**mocks**, **spies**, **fakes**, etc)

# Responsibilities

The purpose and benefits of a test suite

# Proving what you're building is coded correctly.

# Showing how your code works by example.

Improving your ability to make changes to your code base.

Create software at a lower cost and a faster rate.

# Metrics

Measurable and meaningful details for assessing the efficacy of your test suites

# Metrics

## Signal-to-Noise Ratio

how clearly a test failure indicates a specific fault or issue in your code base

## Maintenance Cost

how much effort must go into keeping a test or test suite effective

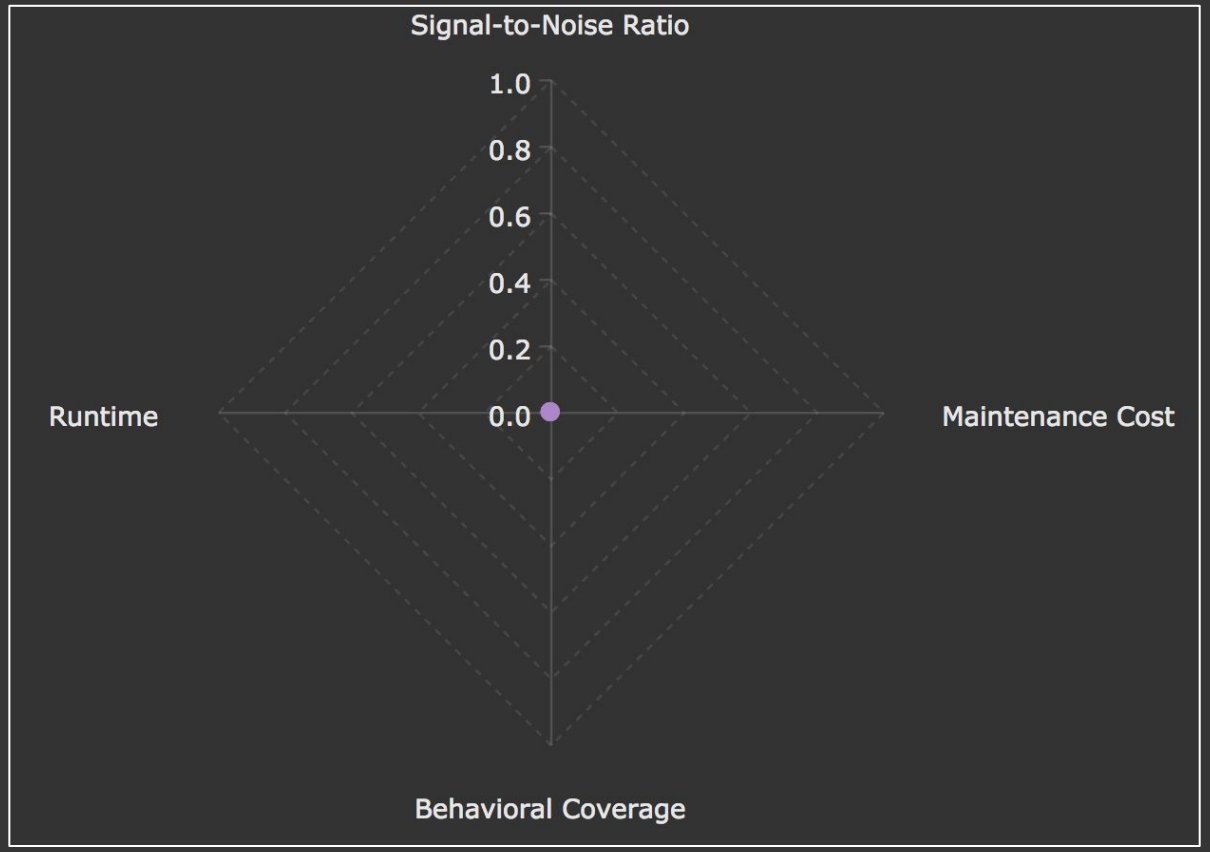
## Behavioral Coverage

how many of the system's behaviors are exercised by the test or test suite

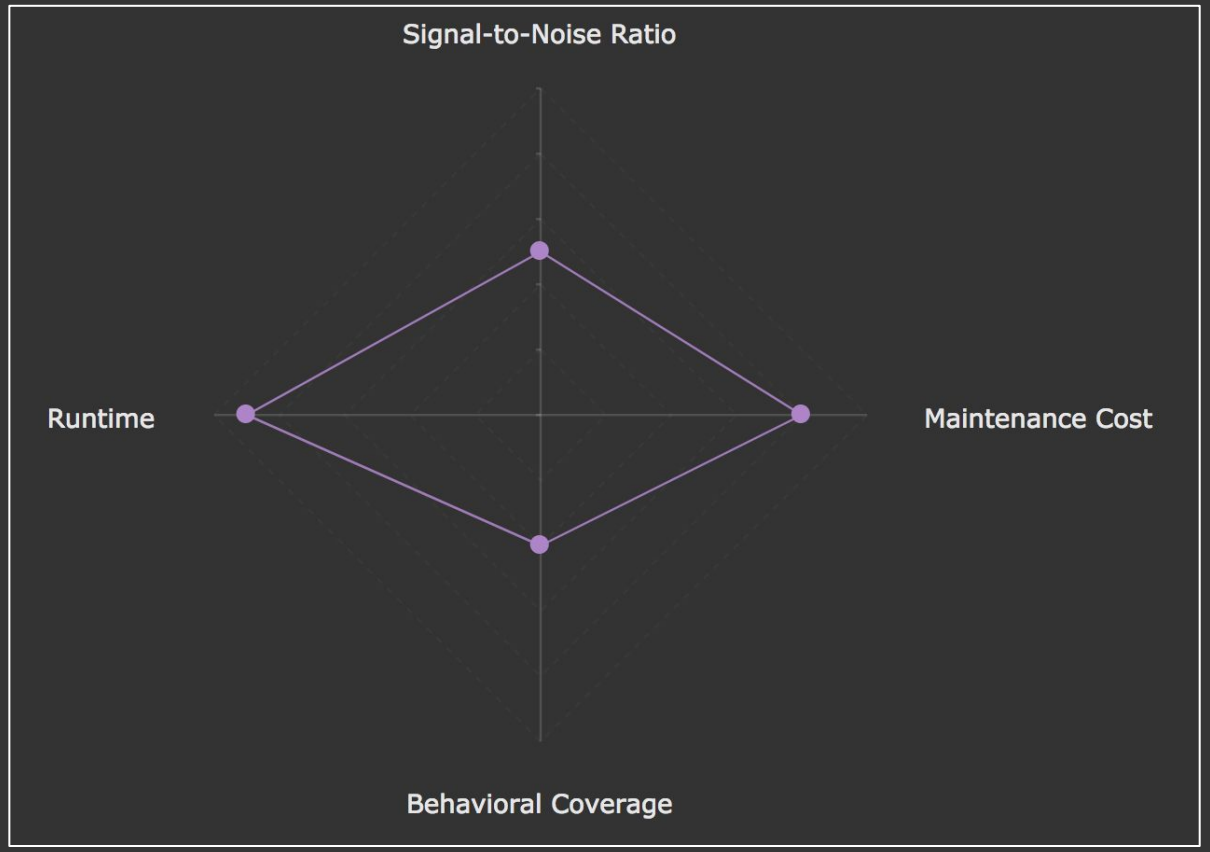
## Runtime

how long a test or test suite must run for before it reveals an issue

# Metrics


Signal-to-Noise Ratio
1.0
0.8
0.6
0.4
0.2
0.0
Runtime
Maintenance Cost
Behavioral Coverage

# Metrics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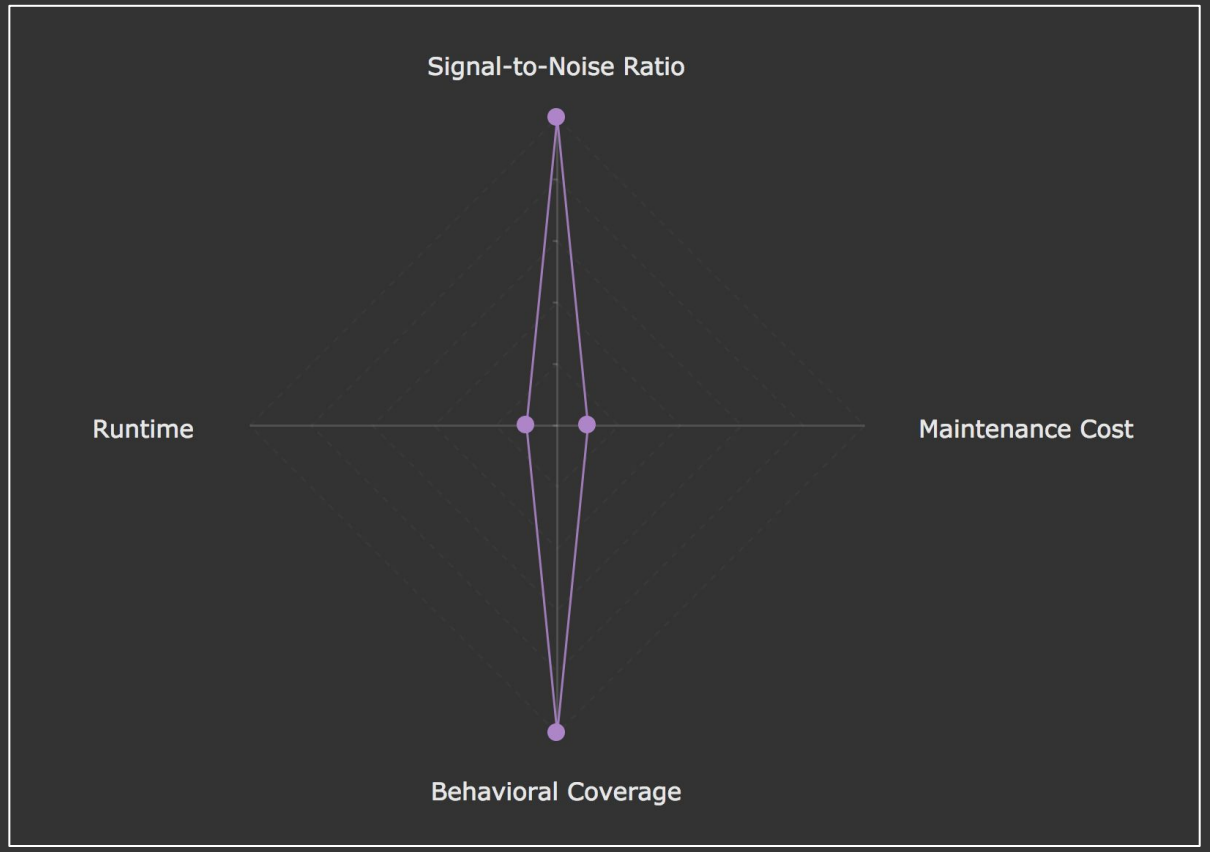

Signal-to-Noise Ratio
Runtime
Maintenance Cost
Behavioral Coverage

# Patterns

Clearly defined and repeatable ways to code test suites

## Patterns
Overview

### Collaboration Test

A test that proves a subject uses a dependency correctly

"Does this method call another method on a passed-in dependency?"

### Functional Test

A test that proves the subject returns a specific output for a specific input

"Does this method return ***y*** when I give it ***x***?"

### Contract Test

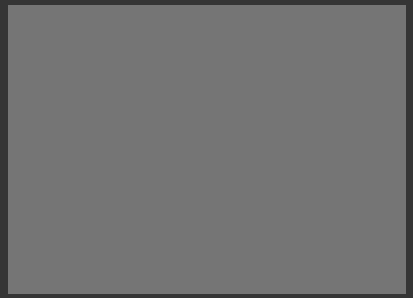
A test of an abstract interface that proves certain behaviors about all the implementers of an interface

"Does every implementation of this method return 15 unique elements?"

# Arper - Components

**ButtonBankView**

Lays out buttons so they can be played. Notifies a delegate that a button is pressed.



# Problem

**A user must be able to press a button so that the synthesizer can know to make a sound**

View layer must not have any other logic

# Solution

**Create a *UIView* which encapsulates handling the buttons**

Delegate out responding to button presses

Use *IndexPaths* to refer to a particular button

```
—

@objc protocol ButtonBankViewDelegate: class {
    func received(noteEvent: NoteEvent, from indexPath: IndexPath)
}

class ButtonBankView: UIView {
  var buttonBank: [[PressureButton]]

  weak var delegate: ButtonBankViewDelegate?

  init(frame: CGRect, delegate: ButtonBankViewDelegate)
}
```

# Collaboration Test

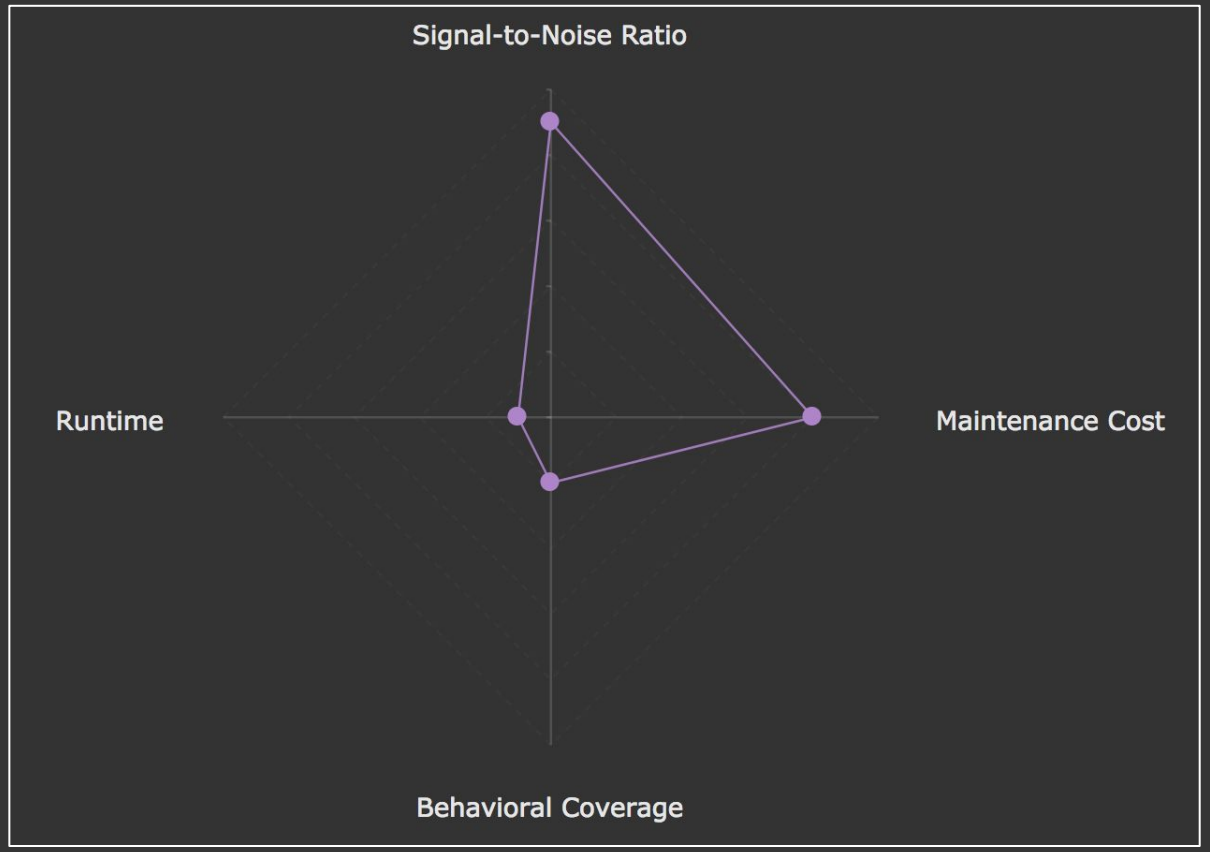
**A test which proves a subject uses a dependency correctly**

Uses test doubles for validation

Not a test of behavior

Effective for testing against non-deterministic or complex dependencies

# Metrics


Signal-to-Noise Ratio
Runtime
Maintenance Cost
Behavioral Coverage

```
class ButtonBankViewSpec: QuickSpec {
  override func spec() {

    var delegateSpy: ButtonBankDelegateSpy! // conforms to ButtonBankViewDelegate
    var subject: ButtonBankView!

    describe("ButtonBankView") {

      beforeEach {
        delegateSpy = ButtonBankDelegateSpy()
        subject = ButtonBankView(frame: .zero, delegate: delegateSpy)
      }

      it("calls its delegate any time a button receives a touch event") {}
  }
}
```

```
delegateSpy = ButtonBankDelegateSpy() // conforms to ButtonBankViewDelegate
subject = ButtonBankView(frame: .zero, delegate: delegateSpy)
```

—

```
protocol Spy {
    var methodCalls: [String] { get }
}

@objc protocol ButtonBankViewDelegate: class {
    func received(noteEvent: NoteEvent, from indexPath: IndexPath)
}
```

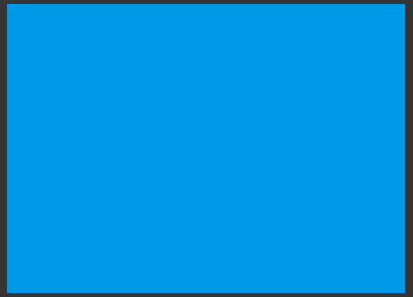
```
class ButtonBankDelegateSpy: Spy, ButtonBankViewDelegate {

    private(set) var methodCalls = [String]()
    private(set) var noteEvents = [NoteEvent]()
    private(set) var indexPaths = [IndexPath]()

    func received(noteEvent: NoteEvent, from indexPath: IndexPath) {
        methodCalls.append(#function)
        noteEvents.append(noteEvent)
        indexPaths.append(indexPath)
    }
}
```

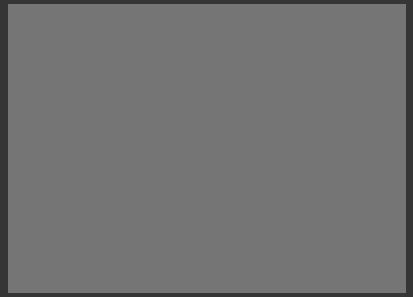
```
it("calls its delegate any time a button receives a touch event") {
  let expectedNoteEvents: [NoteEvent] = [.noteOn, .noteOff]
  let expectedIndexPaths: [IndexPath] = [IndexPath(row: 0, section: 0),
                                         IndexPath(row: 0, section: 0)]

  // subject is an instance of ButtonBankView
  let firstButton = subject.buttonBank.first?.first
  firstButton.sendActions(for: .touchDown)
  firstButton.sendActions(for: .touchUpInside)

  // delegateSpy updates when received(noteEvent:for:) gets called
  expect(delegateSpy.noteEvents).to(equal(expectedNoteEvents))
  expect(delegateSpy.indexPaths).to(equal(expectedIndexPaths))
}
```

# Arper - Components

**MIDINoteMapping**

Determines which button corresponds to a note.





# Problem

**A user must be able to have a button press correspond to a note**

Must support many permutations, as there are many ways to associate buttons with notes

Must use numbers to represent notes

Should use MIDI as inspiration

# Solution

**Create a *MIDINoteMapping* abstraction which encapsulates mapping buttons to note numbers**

Receive an *IndexPath*, return a note number that's valid per MIDI spec

Use *UInt8* to refer to a note number

Support mapping from any note number

```
protocol AnyMIDINoteMapping {
    var baseNote: UInt8 { get }
    init(baseNote: UInt8)
    func noteForButton(at indexPath: IndexPath) -> UInt8
}

struct ChromaticNoteMapping: AnyMIDINoteMapping {
    let baseNote: UInt8
    func noteForButton(at indexPath: IndexPath) -> UInt8
}
```

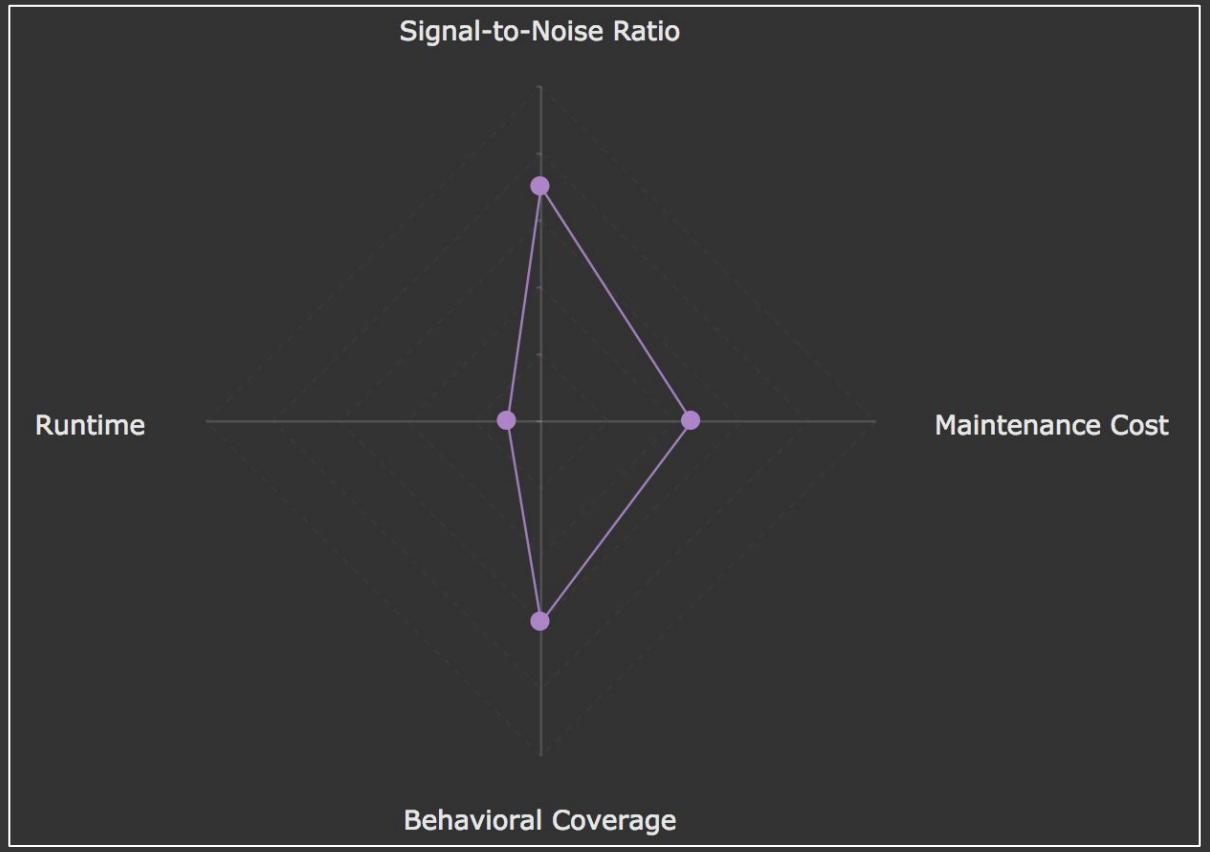
# Functional Test

**A test which proves the subject's interface works, with no validation of how the subject uses its dependencies.**

Proves the subject returns a specific output for specific input

Sometimes called a blackbox test

# Metrics


Signal-to-Noise Ratio
Runtime
Maintenance Cost
Behavioral Coverage

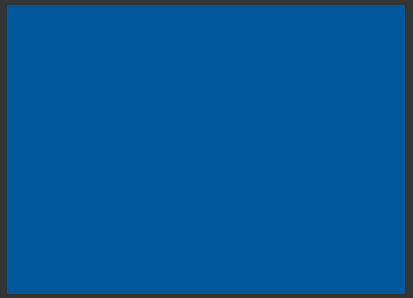
```
describe("ChromaticNoteMapping") {
  it("maps IndexPaths into note numbers using the chromatic scale"){

    let chromaticScale: [UInt8] = [60, 61, 62, 63, 64,
                                   65, 66, 67, 68, 69,
                                   70, 71, 72, 73, 74]

    let chromaticNoteMapping = ChromaticNoteMapping(baseNote: 60)

    // notes(using:) calls noteForButton(at:) 15 times
    expect(notes(using: chromaticNoteMapping)).to(equal(chromaticScale))
  }
}
```

—

```
func notes(using mapping: AnyMIDINoteMapping) -> [UInt8] {
  return (0...2).flatMap { notesForRow(number: $0, using: mapping) }
}


func notesForRow(number: Int, using mapping: AnyMIDINoteMapping) -> [UInt8] {
  return (0...4).map {
    let indexPath = IndexPath(row: number, section: $0)
    return mapping.noteForButton(at: indexPath) // noteForButton(at:) is the test subject
  }
}
```

```
protocol AnyMIDINoteMapping {
    var baseNote: UInt8 { get }
    init(baseNote: UInt8)
    func noteForButton(at indexPath: IndexPath) -> UInt8
}

struct ChromaticNoteMapping: AnyMIDINoteMapping {
    let baseNote: UInt8
    func noteForButton(at indexPath: IndexPath) -> UInt8
}

describe("ChromaticNoteMapping") {
  it("maps IndexPaths into note numbers using the chromatic scale"){

    let chromaticScale: [UInt8] = [60, 61, 62, 63, 64,
                                   65, 66, 67, 68, 69,
                                   70, 71, 72, 73, 74]

    let chromaticNoteMapping = ChromaticNoteMapping(baseNote: 60)

    // notes(using:) calls noteForButton(at:) 15 times
    expect(notes(using: chromaticNoteMapping)).to(equal(chromaticScale))
  }
}
```

# Arper - Components



**AudioEngineManager**

Handles note routing into the audio engine. Contains logic for interpreting various controls.

**AudioEngine**

Handles converting notes into sound.

# Example of Balancing Metrics

SNR, Maintenance Cost,  & Behavioral Coverage

```
class AKAudioEngineManagerSpec: QuickSpec {
    override func spec() {
        // variable declarations are omitted...

        describe("AKAudioEngineManager") {
            beforeEach {
                audioEngineSpy = AudioEngineSpy()
                noteMappings = [ChromaticNoteMapping(baseNote: 0)]
                subject = AKAudioEngineManager(audioEngine: audioEngineSpy,
                                               noteMappings: noteMappings)
            }

            it("routes button presses to the audio engine") {
                subject.received(noteEvent: .noteOn, from: IndexPath(row: 0, section: 0))
                subject.received(noteEvent: .noteOff, from: IndexPath(row: 0, section: 0))

                expect(audioEngineSpy.methodCalls.first).to(equal("render(notesNumbered:)"))
                expect(audioEngineSpy.methodCalls.last).to(equal("stopRendering(of:)"))

                expect(audioEngineSpy.renderedNoteNumbers).to(equal([0]))
                expect(audioEngineSpy.stoppedNoteNumbers).to(equal([0]))
            } // 12 more tests are omitted...
        }
    }
}
```

# Balancing Metrics

# Balancing Metrics

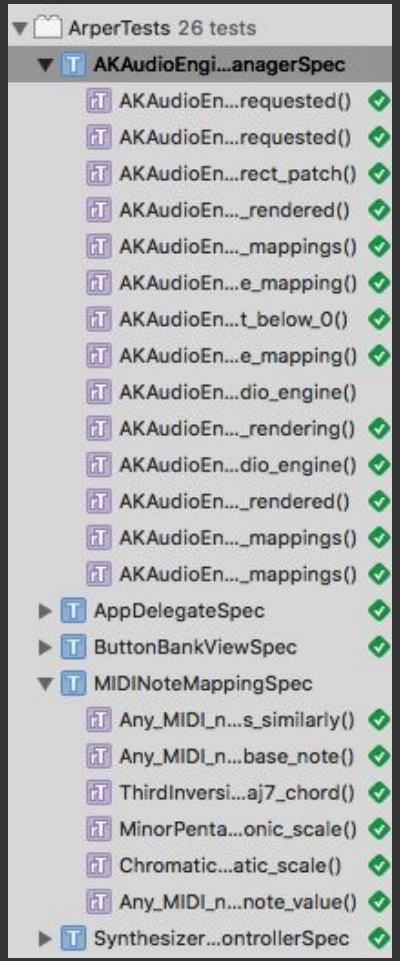
```
describe("AKAudioEngineManager") {
    beforeEach {
        audioEngineSpy = AudioEngineSpy()
        noteMappings = [ChromaticNoteMapping(baseNote: 0)]

        subject = AKAudioEngineManager(audioEngine: audioEngineSpy,
                                       noteMappings: noteMappings)
    }
    // 13 tests omitted...
}
```

# Mutation Testing

The process of intentionally introducing issues into a code base to assess its test suite's efficacy

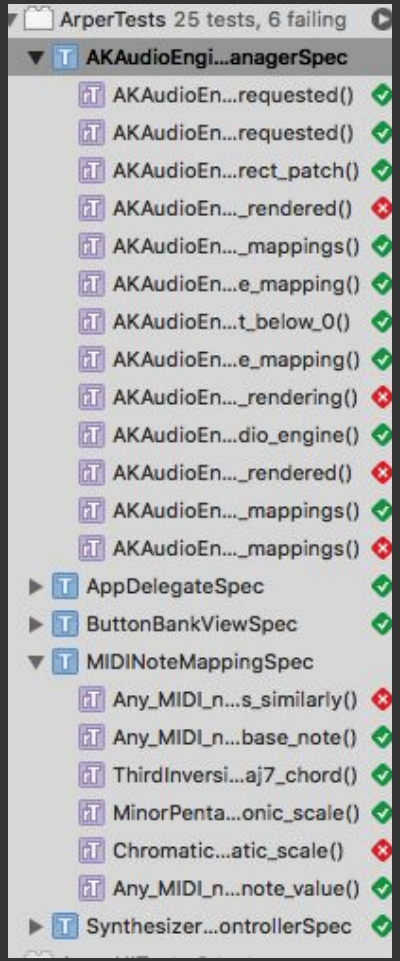
# Balancing Metrics

```
describe("AKAudioEngineManager") {
    beforeEach {
        audioEngineSpy = AudioEngineSpy()
        noteMappings = [ChromaticNoteMapping(baseNote: 0)]

        subject = AKAudioEngineManager(audioEngine: audioEngineSpy,
                                       noteMappings: noteMappings)
    }
    // ...
}
```



# Balancing Metrics

```
// BEFORE
struct ChromaticNoteMapping: MIDINoteMapping {
    let intervals: [UInt8] = [1]
}


// AFTER
struct ChromaticNoteMapping: MIDINoteMapping {
    let intervals: [UInt8] = [0]
}
```



# Possible Solution

Isolate *AudioEngineManager* from changes in *ChromaticNoteMapping* with a test double

# Contract Test

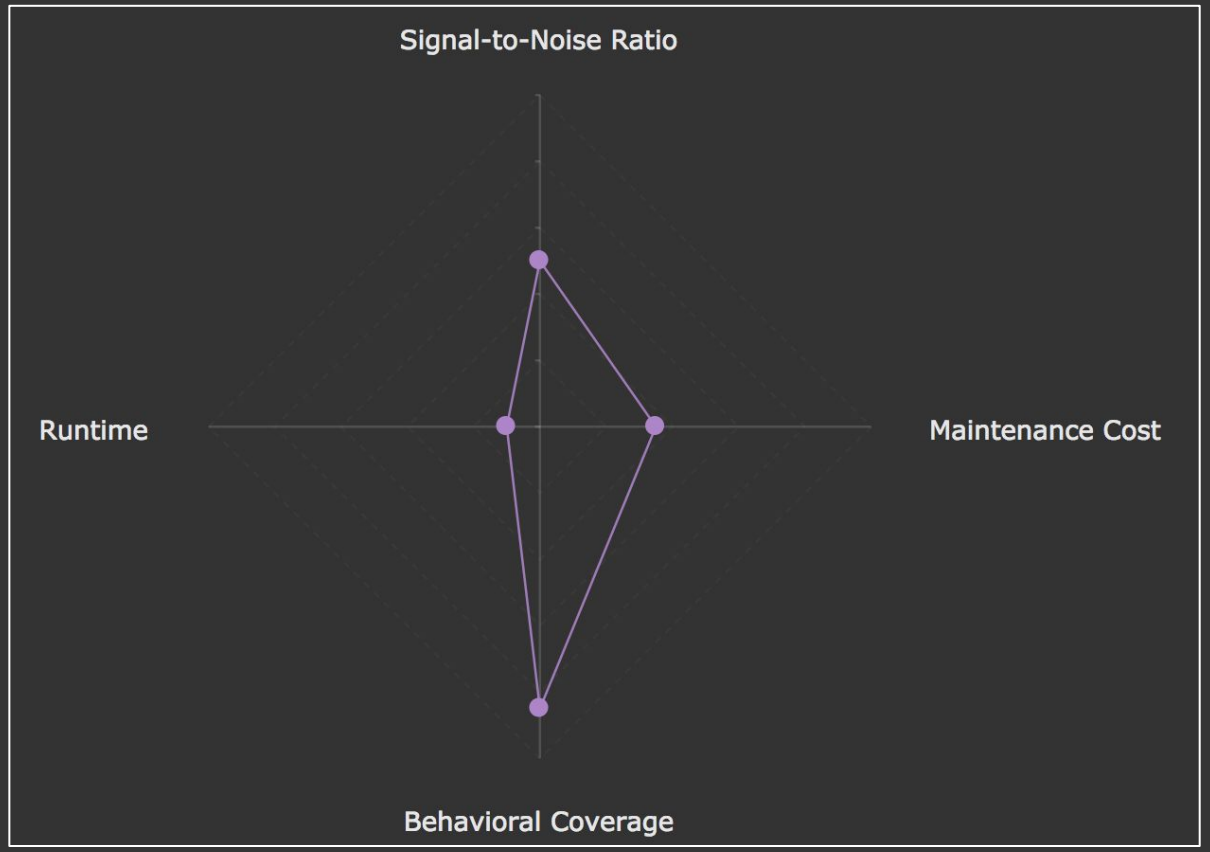
**A test of an abstract interface that proves certain behaviors about all the implementers of an interface.**

In Swift, used for types that conform to protocols or subclass.

Used when a type system doesn't completely cover the behavior of the subject's interface.

Test multiple types at once

# Metrics


Signal-to-Noise Ratio
Runtime
Maintenance Cost
Behavioral Coverage

# Balancing Metrics

```
protocol AnyMIDINoteMapping {
    var baseNote: UInt8 { get }
    init(baseNote: UInt8)
    func noteForButton(at indexPath: IndexPath) -> UInt8
}
```

# Balancing Metrics

```
describe("Any MIDI note mapping") {
  it("maps 15 notes with no repeating notes") {}

  it("maps notes starting from a provided base note") {}

  it("defaults notes above the allowable range to the maximum MIDI note value") {}
}
```

## Balancing Metrics

```
describe("Any MIDI note mapping") {
  it("maps 15 notes with no repeating notes") {
      let mappings = allMIDINoteMappings(usingBaseNote: 60)

      for anyMapping in mappings {
       // ...
      }
  }
}
```

# Balancing Metrics

```
func allMIDINoteMappings(usingBaseNote note: UInt8) -> [AnyMIDINoteMapping] {
    return [ChromaticNoteMapping(baseNote: note),
            // ...
            MIDINoteMappingFake(baseNote: note)]
}
```

# Balancing Metrics

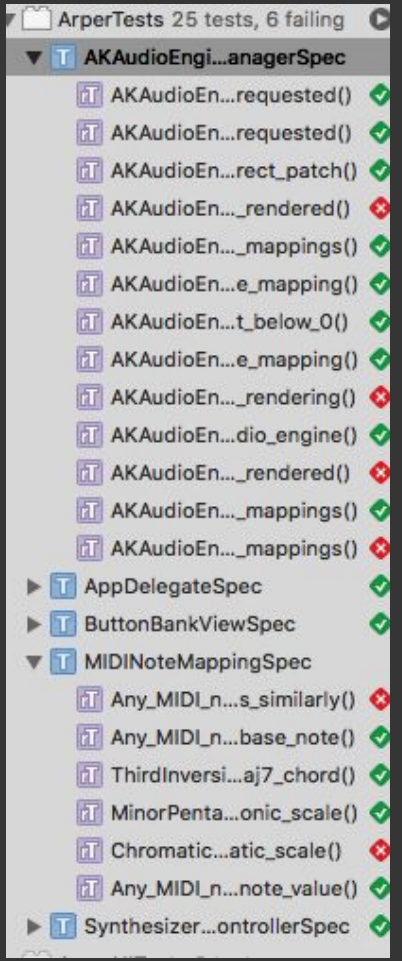
```
it("maps 15 notes with no repeating notes") {
    let mappings = allMIDINoteMappings(usingBaseNote: 60)

    for anyMapping in mappings {

        // notes(using:) calls anyMapping.noteForButton(at:) 15 times
        expect(notes(using: anyMapping)).to(haveCount(15))
        expect(notes(using: anyMapping)).to(haveUniqueElements(15))

        let theFirstNote = anyMapping.noteForButton(at: IndexPath(row: 0, section: 0))
        let theFirstNoteMappedAgain = anyMapping.noteForButton(at: IndexPath(row: 0, section: 0))
        expect(theFirstNote).to(equal(theFirstNoteMappedAgain))
    }
}
```

```swift
class MIDINoteMappingFake: AnyMIDINoteMapping {

    let baseNote: UInt8

    required init(baseNote: UInt8) {
        self.baseNote = baseNote
    }

    func noteForButton(at indexPath: IndexPath) -> UInt8 {
        return noteMapping[indexPath.row][indexPath.section]
    }
}
```

```swift
private extension MIDINoteMappingFake {
     var noteMapping: [[UInt8]] {

        let mapping: [[UInt8]] = (0...2).map { rowNumber in
            return notesForRow(number: rowNumber)
        }

        return mapping
     }

    func notesForRow(number: UInt8) -> [UInt8] {
        return (0...4).map { columnNumber in

            if number == 0 && columnNumber == 0 {
                return min(baseNote, 127)
            }

            let rowOffset = UInt8(number) * 5
            let columnOffset = UInt8(columnNumber)
            let note = baseNote + rowOffset + columnOffset

            return min(note, 127)
        }
    }
}
```

# Balancing Metrics

```
describe("AKAudioEngineManager") {
    beforeEach {
        // ...
        noteMappings = [ChromaticNoteMapping(baseNote: 0)]
        // ...
    }
}
```



# Balancing Metrics

```
describe("AKAudioEngineManager") {
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        noteMappings = [MIDINoteMappingFake(baseNote: 0)]
        // ...
    }
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```
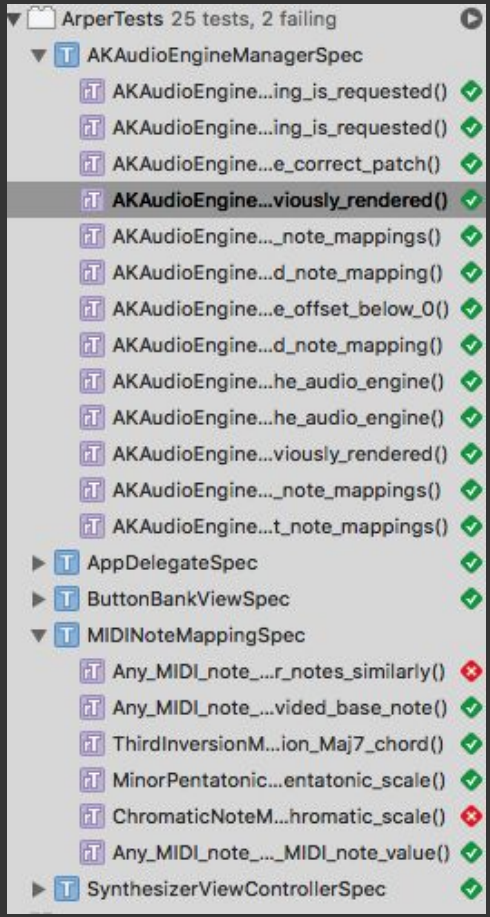



# What was improved?

# Signal-to-Noise Ratio

## Balancing Metrics

# What was worsened?

# Maintenance Cost

# Behavioral Coverage

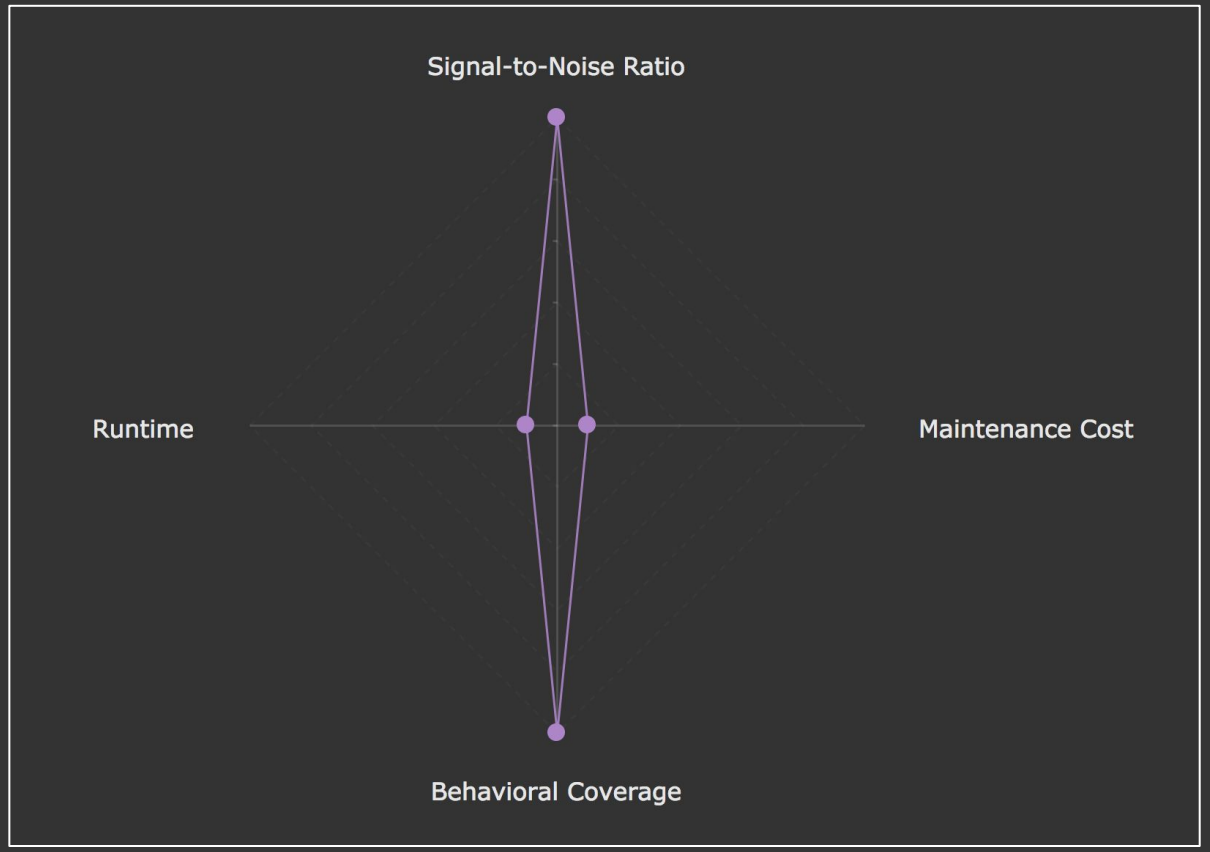
## Balancing Metrics

# Was it the right decision to make?

## Balancing Metrics

# Depends on what you need your test suite to do for you

# Metrics


Signal-to-Noise Ratio
Runtime
Maintenance Cost
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# Review

# Review
Metrics

## Signal-to-Noise Ratio

how clearly a test failure indicates a specific fault or issue in your code base

## Maintenance Cost

how much effort must go into keeping a test or test suite effective

## Behavioral Coverage

how many of the system's behaviors are exercised by the test or test suite

## Runtime

how long a test or test suite must run for before it reveals an issue

# Review

Testing Patterns

## Collaboration Test

A test that proves a subject uses a dependency correctly

"Does this method call another method on a passed-in dependency?"

## Functional Test

A test that proves the subject returns a specific output for a specific input

"Does this method return ***y*** when I give it ***x***?"

## Contract Test

A test of an abstract interface that proves certain behaviors about all the implementers of an interface

"Does every implementation of this method return exactly 15 elements?"

# Review

Testing Methodologies

## Test Doubling

Replacing a subject's dependency with an implementation only meant for testing.

Use sparingly.

## Mutation Testing

Introducing issues into your code to assess how effective your test suite is.

Practice often.

## Behavior Driven Development

Designing components and tests with a focus on what something is supposed to do, without regard for implementation.

Practice always.

# Review

Additional Resources - Books

**Test Driven Development: By Example**

Kent Beck

**Xunit Test Patterns**

Gerard Meszaros

**Working Effectively with Legacy Code**

Michael Feathers

# Review

Additional Resources - Websites/Blogs

**Introducing BDD**

https://dannorth.net/introducing-bdd/

**The Test Double Rule of Thumb**

https://engineering.pivotal.io/post/the-test-double-rule-of-thumb/

**Joe Masilotti's Blog**

http://masilotti.com/

# Thank you!

Sean Olszewski

github.com/SeanROlszewski

@__chefski__