Take Your C# Skills to the Next Level

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Ignore the number of slides in this deck. These are primarily for your reference.

Most of our time will be spent in code.

Schedule

• Class Hours	8:30 a.m. – 4:30 p.m.
• Break	10:00 a.m. – 10:15 a.m.
• Lunch	12:00 p.m. – 1:00 p.m.
• Break	3:00 p.m. – 3:15 p.m.

Additional breaks and Q&A throughout the day

All Times are Central Daylight Time

Overview

- What we want from software
- Principles that help
- Tools to get there
  - Interfaces
  - Delegates
  - Dependency Injection
  - Unit Tests

Workshop Materials

https://github.com/jeremybytes/csharp-workshop-2025

Topics (in no particular order)

- What & Why?
  - Interfaces
  - Delegates
  - Dependency Injection (DI)
  - Unit Tests
- Explicit Interface Implementation
- Interface Inheritance
- Interface Granularity
- Func<T, TResult>
- Constructor Injection
- Lambda Expressions
- Using a DI Container
- Adding a Cache
- Injecting Behavior
- Testing DateTime.Now
- Test Fakes and Mocks
- SOLID Principles

What We Want from Software

As Developers and Users

As a user, I want software…

- That works
- That is delivered quickly
- That does what I need it to do
- That can be fixed quickly
- That can change as my needs change

As a developer, I want software…

- With no bugs
- Easy to write
- Fulfills the use cases
- Easy to fix when there are bugs
- Easy to change when the use cases change

We want the same things

What users want

- That works
- That is delivered quickly
- That does what I need it to do
- That can be fixed quickly
- That can change as my needs change

What developers want

- With no bugs
- Easy to write
- Fulfills the use cases
- Easy to fix when there are bugs
- Easy to change when the use cases change

Helpful Practice

- **S** Single Responsibility Principle
- **O** Open/Closed Principle
- **L** Liskov Substitution Principle
- **I** Interface Segregation Principle
- **D** Dependency Inversion Principle

“Best” Practices

No “Best” Practices

Helpful practices are a good place to start, but don’t use them if they don’t fit your situation.

Tools

- Interfaces
  - Add “seams” to code
  - Modification points
  - Interception points
  - Testing points
- Delegates
  - Inject custom behavior
- Dependency Injection
  - Assemble the pieces
  - Containers automate assembly
- Unit Tests
  - Proof code works
  - Proof that I didn’t break something

Interfaces

Adding seams to code

An interface contains definitions for a group of related functionalities that a non-abstract class or struct must implement.

https://learn.microsoft.com/en-us/dotnet/csharp/fundamentals/types/interfaces

An interface describes
a set of capabilities
on an object.

“I have these functions.”

Interface	Abstract Class
Defines a contract	Shared Implementation
Implement any number of interfaces	Inherit from a single base class
Limited implementation code	Unconstrained implementation code
No automatic properties	Can have automatic properties
Properties Methods Events Indexers	Properties Methods Events Indexers Fields Constructors Destructors

Recommendation

Program to an abstraction rather than a concrete type.

Recommendation

Program to an interface rather than a concrete class.

Various Data Sources

Microsoft SQL Server

MongoDB

CSV

WebAPI

Amazon RDS

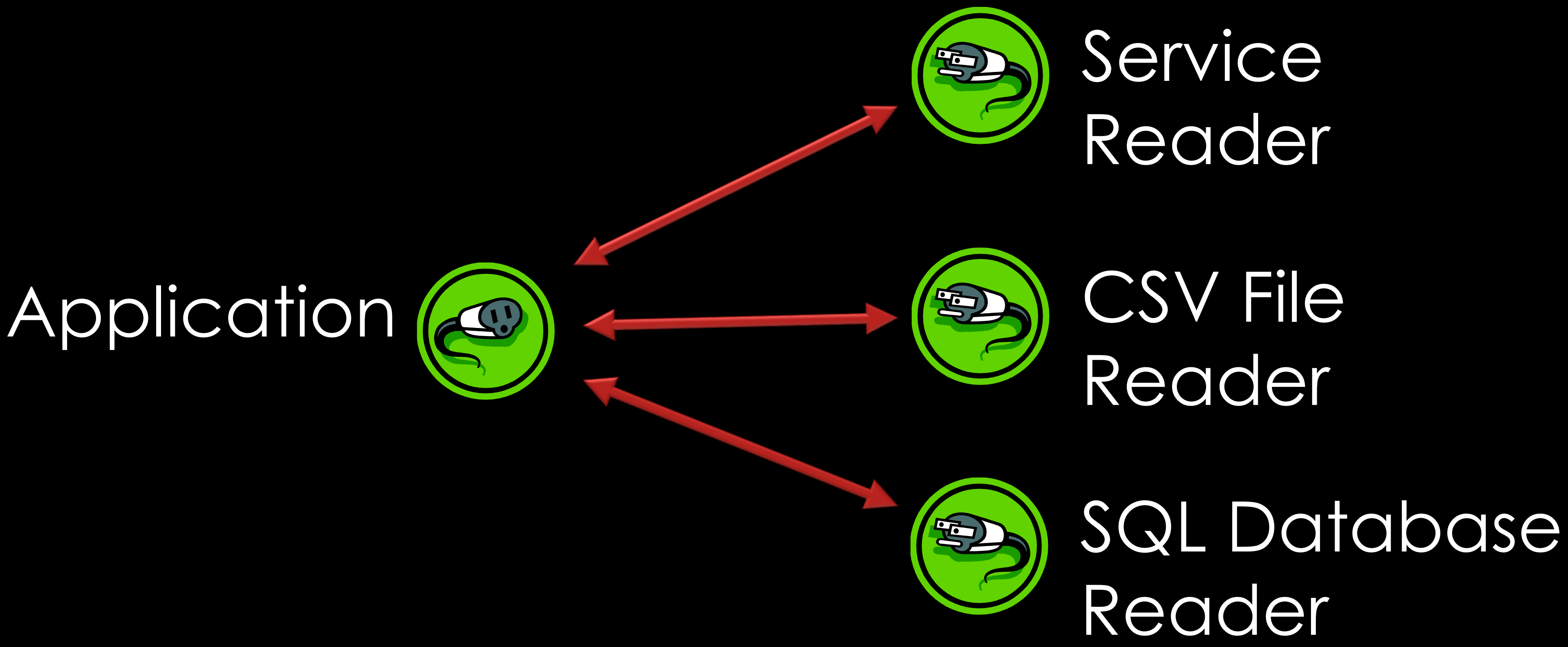
Oracle

JSON

Hadoop

Azure Cosmos DB

Pluggable Data Readers



Application

Service Reader

CSV File Reader

SQL Database Reader

Data Reader Interface

```
public interface IPersonReader
{
    Task<IReadOnlyCollection<Person>> GetPeople();
    Task<Person?> GetPerson(int id);
}
```

Interfaces and Flexible Code

Resilience in the face of change

Insulation from implementation details

Dynamic Factory

- Check configuration
- Create an assembly load context
- Load the assembly
- Look for the type
- Create the data reader
- Return the data reader

Other Benefits

Interfaces help us isolate code for easier unit testing.

Other Benefits

Interfaces can make dependency injection easier.

Interfaces: What & Why?

- An interface describes a set of capabilities of an object.
- Program to an abstraction (interface) rather than a concrete type (class).
- Resilience in the face of change.
- Insulation from implementation details.
- Easier unit testing.
- Easier dependency injection.

Explicit Implementation

An explicitly implemented member belongs to the interface rather than the class.

Class with No Interface

Declaration

```
public class Catalog
{
  public string Save()
  {
    return "Catalog Save";
  }
}
```

Usage

```
Catalog catalog = new();
string result = catalog.Save();
// result = "Catalog Save"
```

Standard Interface Implementation

Declaration

```
public interface ISaveable
{
  public string Save();
}

public class Catalog : ISaveable
{
  public string Save()
  {
    return "Catalog Save";
  }
}
```

Usage

```
Catalog catalog = new();
string result = catalog.Save();
// result = "Catalog Save"

ISaveable saveable = new Catalog();
result = saveable.Save();
// result = "Catalog Save"
```

Explicit Implementation

Declaration

```
public interface ISaveable
{
    public string Save()
}
public class Catalog : ISaveable
{
    public string Save()
    {
        return "Catalog Save";
    }

    string ISaveable.Save()
    {
        return "Interface Save";
    }
}
```

Usage

```
Catalog catalog = new();
string result = catalog.Save();
// result = "Catalog Save"

ISaveable saveable = new Catalog();
result = saveable.Save();
// result = "Interface Save"

result = ((ISaveable)catalog).Save();
// result = "Interface Save"
```

Explicit Implementation

Declaration

```
public interface ISaveable
{
    public string Save()
}
public class Catalog : ISaveable
{
    // Save() method deleted
    string ISaveable.Save()
    {
        return "Interface Save";
    }
}
```

Usage

```
Catalog catalog = new();
string result = catalog.Save();
// **COMPLIER ERROR**

ISaveable saveable = new Catalog();
result = saveable.Save();
// result = "Interface Save"

saveable = (ISaveable)catalog;
result = saveable.Save();
// result = "Interface Save"
```

Interface Inheritance

```
public interface IEnumerable<T> : IEnumerable
```

- IEnumerable<T> inherits IEnumerable
- When a class implements IEnumerable<T>, it must also implement IEnumerable

IEnumerable<T> / IEnumerable

```
public interface IEnumerable<T> : IEnumerable
{
    IEnumerator<T> GetEnumerator();
}
public interface IEnumerable
{
    IEnumerator GetEnumerator();
}
```

When a class implements IEnumerable<T>,
it must also implement IEnumerable

IEnumerable<T> / IEnumerable

```
public class FibonacciSequence : IEnumerable<double>
{
  public IEnumerator<double> GetEnumerator()
  { // implementation }

  public IEnumerator GetEnumerator()
  { // implementation }
}
```

NOT ALLOWED

Methods cannot be overloaded
only on different return types.

IEnumerable<T> / IEnumerable

```
public class FibonacciSequence : IEnumerable<double>
{
  public IEnumerator<double> GetEnumerator()
  { // implementation }

  IEnumerator IEnumerable.GetEnumerator()
  {
    return this.GetEnumerator();
  }
}
```

SOLUTION: Explicit Implementation.

Interface Segregation Principle

```
public class List<T> : IList<T>, IList,
  ICollection<T>, ICollection,
  IEnumerable<T>, IEnumerable,
  IReadOnlyCollection<T>, IReadOnlyList<T>
```

Clients should not be forced to depend upon methods that they do not use.
Interfaces belong to clients,
not hierarchies.

Interface Segregation Principle

```
public class List<T> : IList<T>, IList,
  ICollection<T>, ICollection,
  IEnumerable<T>, IEnumerable,
  IReadOnlyCollection<T>, IReadOnlyList<T>
```

We should have granular interfaces that only include the members that a particular function needs.

List<T> Interfaces

```
public class List<T> : IList<T>, IList,
  ICollection<T>, ICollection,
  IEnumerable<T>, IEnumerable,
  IReadOnlyCollection<T>, IReadOnlyList<T>
```

IEnumerable<T>

GetEnumerator()

IEnumerable

GetEnumerator()

List<T> Interfaces

```
public class List<T> : IList<T>, IList,
  ICollection<T>, ICollection,
  IEnumerable<T>, IEnumerable,
  IReadOnlyCollection<T>, IReadOnlyList<T>
```

ICollection<T>

Count
IsReadOnly
Add()
Clear()
Contains()
CopyTo()
Remove()

Plus
Everything in
IEnumerable<T>
and
IEnumerable

List<T> Interfaces

```
public class List<T> : IList<T>, IList,
  ICollection<T>, ICollection,
  IEnumerable<T>, IEnumerable,
  IReadOnlyCollection<T>, IReadOnlyList<T>
```

IList<T>

Item / Indexer
IndexOf()
Insert()
RemoveAt()

Plus
Everything in
ICollection<T>,
IEnumerable<T>,
and
IEnumerable

Granular Interfaces

- **If We Need to**
  - Iterate over a Collection / Sequence
  - Data Bind to a List Control
  - Use LINQ functions

→ **IEnumerable<T>**

- **If We Need To**
  - Add/Remove Items in a Collection
  - Count Items in a Collection
  - Clear a Collection

→ **ICollection<T>**

- **If We Need To**
  - Control the Order Items in a Collection
  - Get an Item by the Index

→ **IList<T>**

Single Responsibility Principle

A class should have only one reason to change.

Gather together the things that change for the same reasons. Separate those things that change for different reasons.

Open-Closed Principle

Software entities should be open for extension, but closed for modification.

Ex. Injecting behavior through a delegate or other entity.

Liskov Substitution Principle

Substitutability: an object (such as a class) may be replaced by a sub-object without breaking the program.

Violation example: Rectangle vs. Square

Interface Segregation Principle

Clients should not be forced to depend upon methods that they do not use. Interfaces belong to clients, not hierarchies.

Dependency Inversion Principle

High-level modules should not import anything from low-level modules; both should depend on abstractions.

Abstractions should not depend on details. Details (concrete implementations) should depend on abstractions.

Delegates

Inserting behavior

What Is A Delegate?

Definition

A type that defines a method signature

Why Delegates?

- Decoupling Code
- Methods as Parameters
- Multicasting Support
- Callbacks and Event Handlers
- LINQ
- ASP.NET Core Minimal APIs

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Ex. Injecting behavior through a delegate or other entity.

Dependency Injection

Assembling the pieces

Dependency Injection

The fine art of making things someone else’s problem.

Typical Introduction

```csharp
private void BuildMainWindow()
{
    var builder = new ContainerBuilder();
    builder.RegisterType<SQLReader>().As<IPersonReader>()
        .SingleInstance();
    builder.RegisterSource(
        new AnyConcreteTypeNotAlreadyRegisteredSource());
    IContainer Container = builder.Build();
    Application.Current.MainWindow =
        Container.Resolve<PeopleViewerWindow>();
}
```

What Is Dependency Injection?

- Dependency Injection is a software design pattern that allows a choice of component to be made at run-time rather than compile time.
  - Wikipedia 2012

What Is Dependency Injection?

- Dependency injection is a software design pattern that allows the removal of hard-coded dependencies and makes it possible to change them, whether at run-time or compile-time.
  - Wikipedia 2013

What Is Dependency Injection?

- Dependency injection is a software design pattern that implements inversion of control and allows a program design to follow the dependency inversion principle. The term was coined by Martin Fowler.
  - Wikipedia 2014

What Is Dependency Injection?

- In software engineering, dependency injection is a software design pattern that implements inversion of control for software libraries, where the caller delegates to an external framework the control flow of discovering and importing a service or software module. Dependency injection allows a program design to follow the dependency inversion principle where modules are loosely coupled. With dependency injection, the client part of a program which uses a module or service doesn't need to know all its details, and typically the module can be replaced by another one of similar characteristics without altering the client.

  - Wikipedia 2015

What Is Dependency Injection?

- In software engineering, dependency injection is a software design pattern that implements inversion of control for resolving dependencies. A dependency is an object that can be used (a service). An injection is the passing of a dependency to a dependent object (a client) that would use it. The service is made part of the client's state.[1] Passing the service to the client, rather than allowing a client to build or find the service, is the fundamental requirement of the pattern.

  - Wikipedia 2016

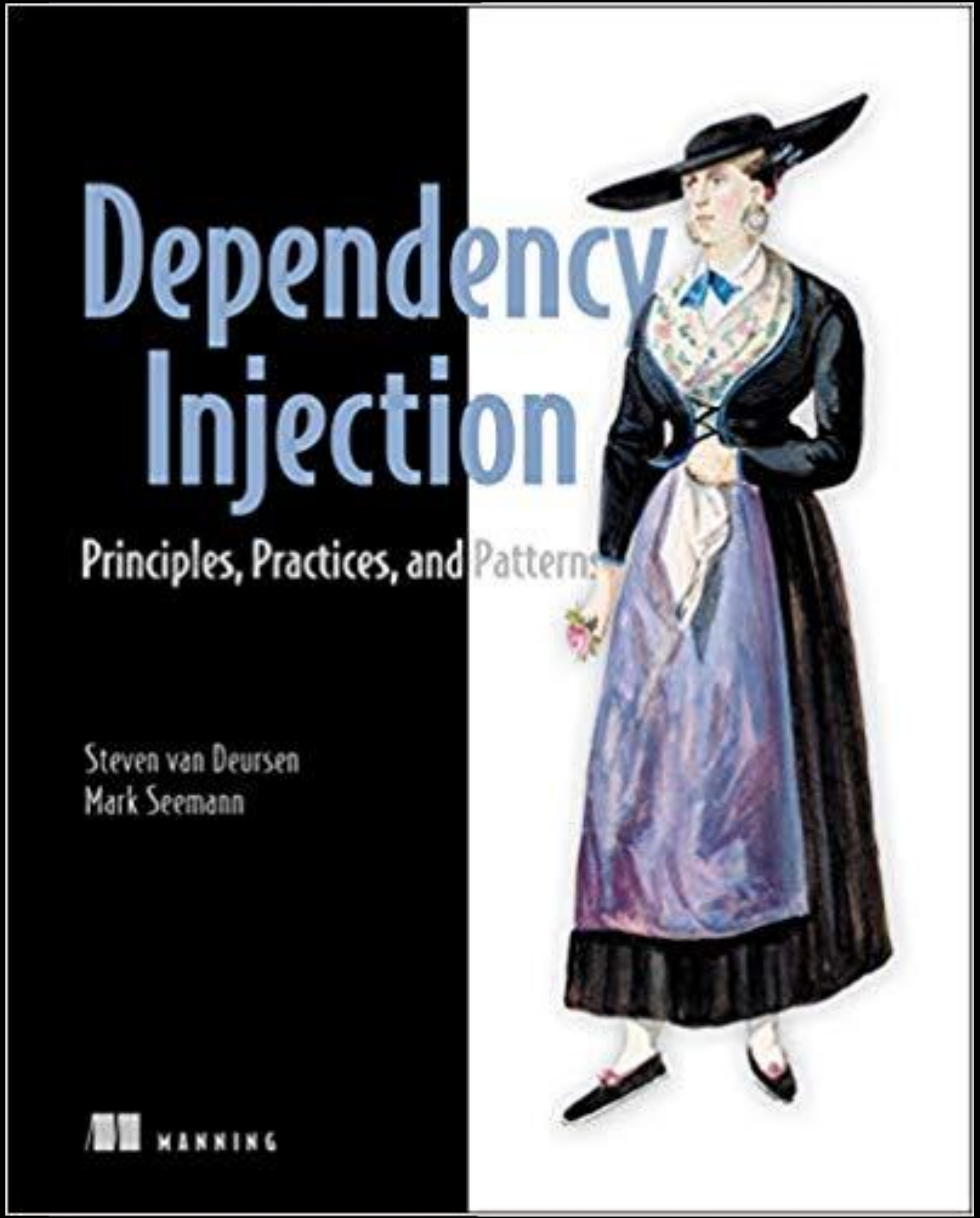
What Is Dependency Injection?

- Dependency Injection is a set of software design principles and patterns that enable us to develop loosely coupled code.

  - Mark Seemann

Dependency Injection
Principles, Practices, and Patterns

- Mark Seemann
- Steven van Deursen



Primary Benefits

- Extensibility
- Parallel Development
- Maintainability
- Testability
- Late Binding

- Adherence to S.O.L.I.D. Design Principles.

Benefits – Extensibility

Code can be extended in ways not explicitly planned for.

Benefits – Parallel Development

Code can be developed in parallel with less chance of merge conflicts.

Benefits – Maintainability

Classes with clearly defined responsibilities are easier to maintain.

Benefits – Testability

Classes can be unit tested,
i.e., easily isolated from other classes
and components for testing.

Benefits – Late Binding

Services can be swapped with other services without recompiling code.

Dependency Injection Concepts

- DI Design Patterns
  - Constructor Injection
  - Property Injection
  - Method Injection
  - Ambient Context
  - Service Locator

- Dimensions of DI
  - Object Composition
  - Interception
  - Lifetime Management

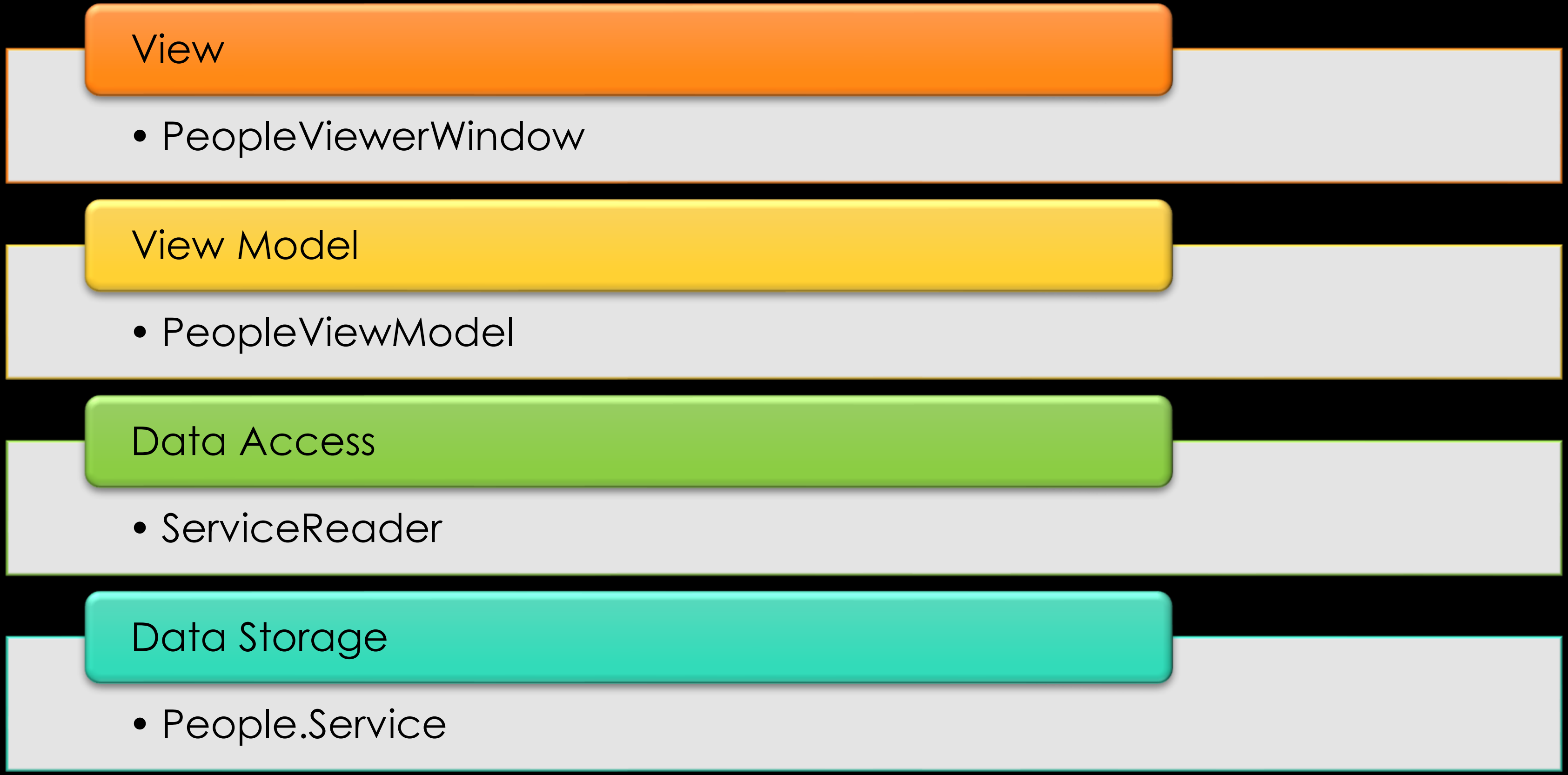
Dependency Injection Containers

- C# Containers
  - Autofac
  - Ninject

- Frameworks w/ Containers
  - ASP.NET Core
  - Angular
  - Prism

  and many others

Application Layers



View

- PeopleViewerWindow

View Model

- PeopleViewModel

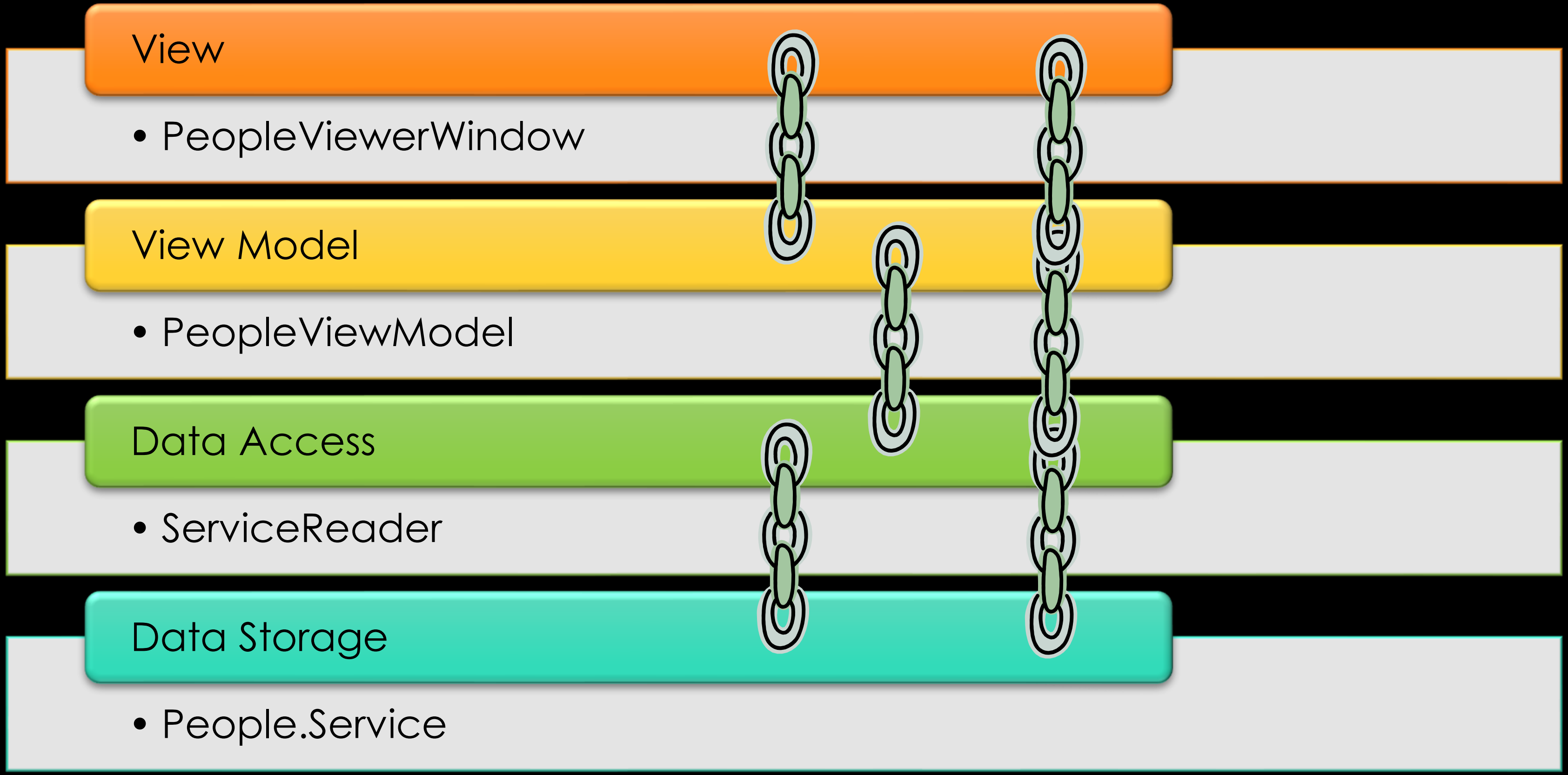
Data Access

- ServiceReader

Data Storage

- People.Service

Tight Coupling



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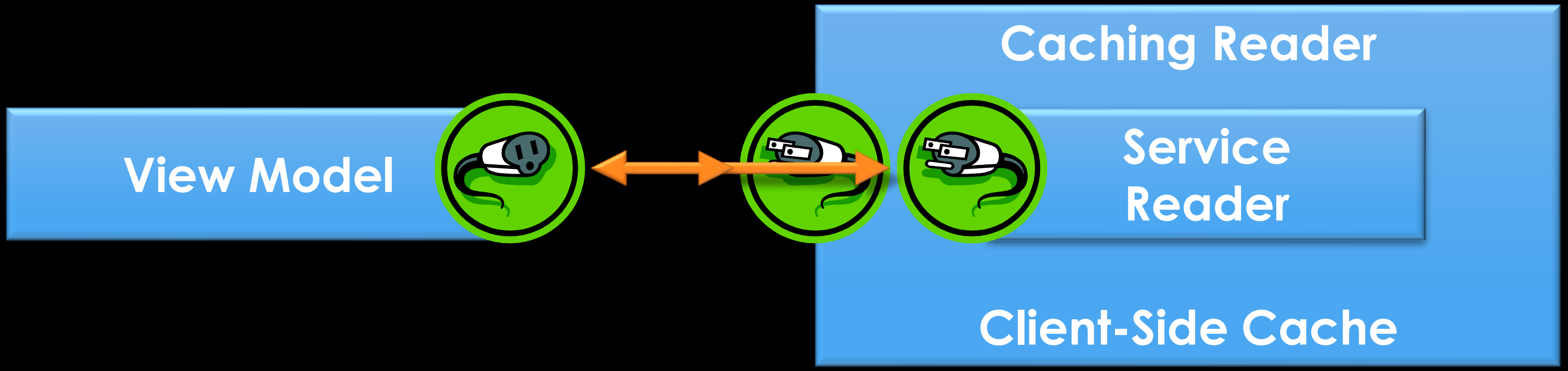
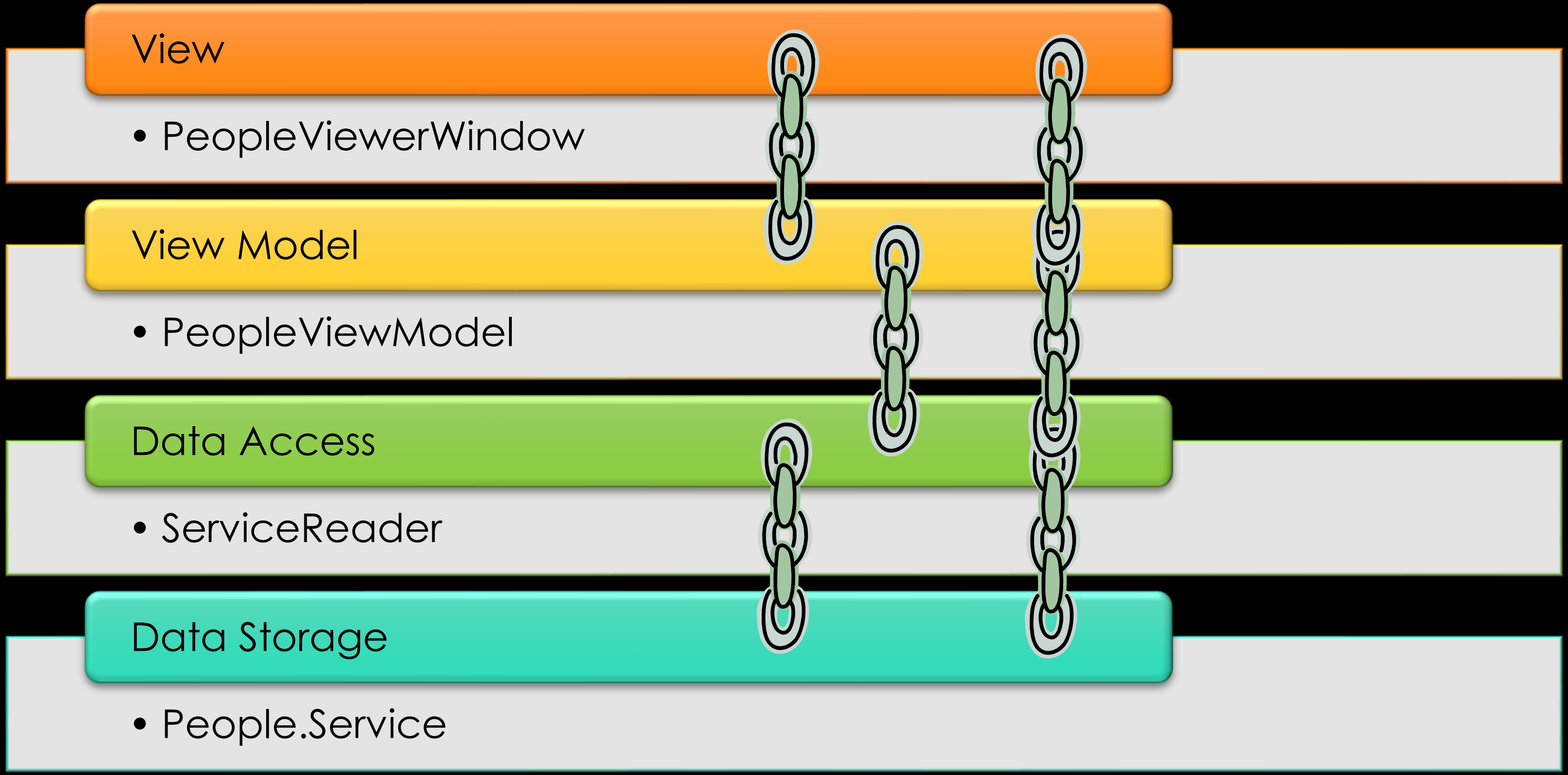
Creating a Caching Reader

The Decorator Pattern



Loose(r) Coupling



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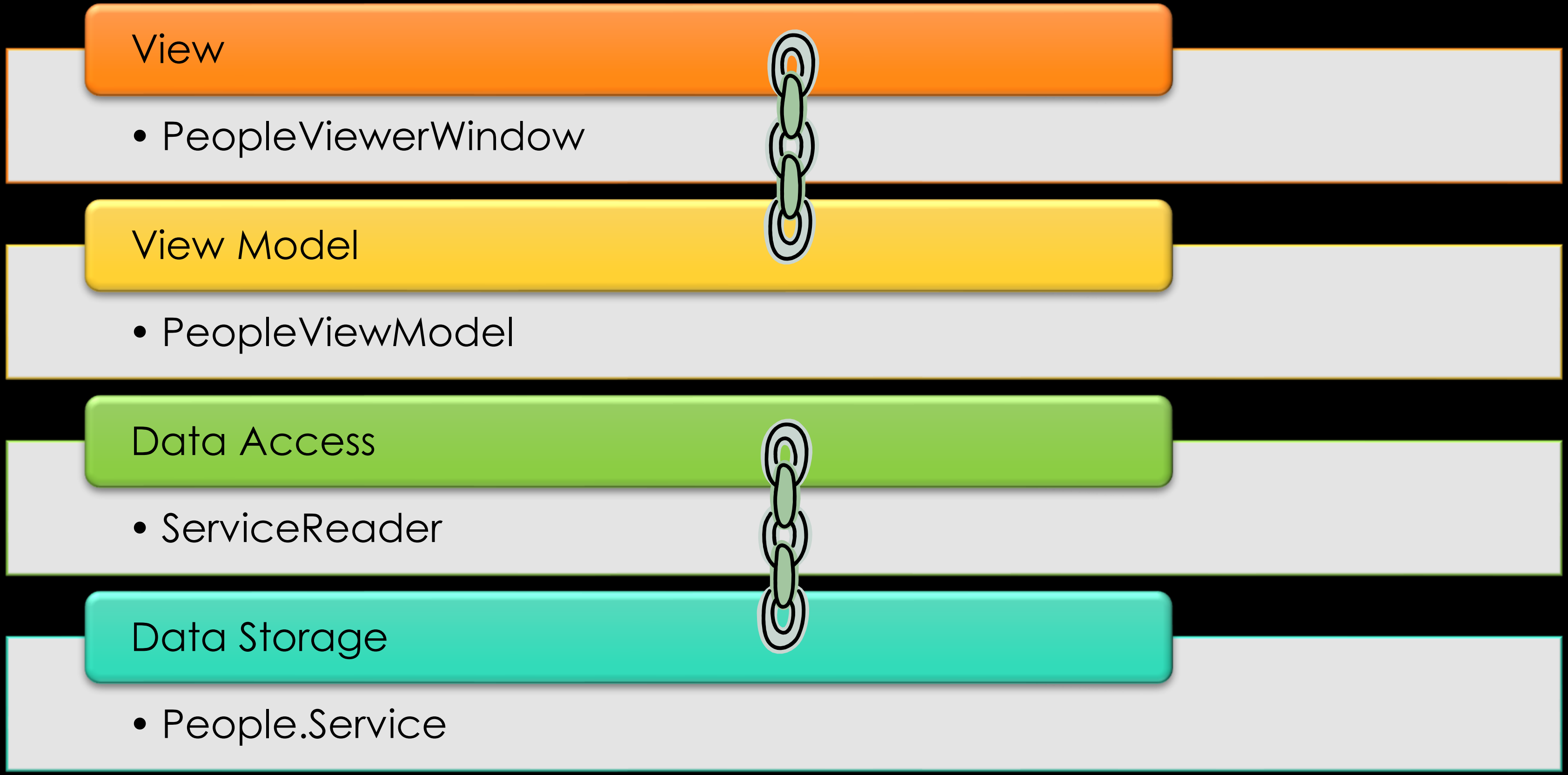

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  - Ambient Context
  - Service Locator

- Dimensions of DI
  - Object Composition
  - Interception
  - Lifetime Management

Constructor Injection

The dependency is injected into the class through a constructor parameter.

Where to use Constructor Injection

- A dependency will be used/re-used at the class level.
- A non-optional dependency must be provided.

- Advantage: it keeps dependencies obvious. Code will not compile if the dependency is not provided

Primary Constructors

- When using a primary constructor, the constructor parameter can either initialize a field (or property) or be used directly.
- When initializing a property, the parameter is given an "unspeakable" name (like a field for an automatic property).
- When used directly, the parameter is class-level and modifiable.

Property Injection

The dependency is injected into the class by setting a property on that class.

Where to use Property Injection

- A dependency will be used/re-used at the class level.
- A dependency is optional.
- A dependency has a good default value that can be used if a separate implementation is not provided.
- Advantage: we do not need to supply a dependency if we want to use the default behavior
- Disadvantage: the dependency is hidden. It may not be obvious to developers that a separate behavior can be provided.

Method Injection

The dependency is injected into a method through a method parameter.

Where to use Method Injection

- A dependency will only be used by a specific method – i.e., it will not be stored by the class and used in other methods.
- A dependency varies for each call of a method.

Stable and Volatile Dependencies

- A stable dependency is one that is not likely to change over the life of the application. For example, classes in the .NET Base Class Library (BCL)
- A volatile dependency is one that is likely to change or needs to be swapped out for fake behavior in unit tests.

Criteria for Stable Dependencies

- The class or module already exists
- You expect that new versions won’t contain breaking changes
- The types in question contain deterministic algorithms
- You never expect to have to replace, wrap, decorate, or intercept the class or module with another

Criteria for Volatile Dependencies

- The dependency introduces a requirement to set up or configure a runtime environment for the application
  - Web services, databases, network calls
- The dependency doesn’t yet exist or is still in development

Criteria for Volatile Dependencies

- The dependency isn’t installed on all machines in the development organization
  - Expensive 3rd party library
- The dependency contains non-deterministic behavior
  - Random number generator
  - DateTime.Now

Tips / Techniques

- Read-Only / init-Only Properties
  (for Constructor Injection)
- Guard Clauses (prevent unintended nulls)

Read-Only / init-Only Properties

- Properties marked as “readonly” or with “init” for a setter are settable only during object construction. This prevents the property from being inadvertently changed during the lifetime of the object.
- This is applicable to Constructor Injection; for obvious reasons, this would be a problem for Property Injection.

Guard Clauses

- Guard clauses (null checks) should be used in constructors, methods, and property setters to ensure that dependencies are not set to null.
- If a “null behavior” is required, consider using the Null Object pattern. This provides a valid implementation with no actual behavior.

Unit Testing

Code faster

Different Kinds of Tests

- Unit Testing
- Integration Testing
- Performance Testing
- Exploratory Test
- Penetration Testing
- User Acceptance Testing (UAT)

What are Unit Tests?

A unit test is an automated piece of code that invokes a unit of work in the system and then checks a single assumption about the behavior of that unit of work.

The Art of Unit Testing by Roy Osherove

Non-Threatening Text Here

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Threatening Text Here

©Jeremy Clark 2025

What are Unit Tests?

A unit test is an automated piece of code that invokes a unit of work in the system and then checks a single assumption about the behavior of that unit of work.

automated piece of code

a unit of work

checks a single assumption

The Art of Unit Testing by Roy Osherove

Assertions

- The Assert class throws exceptions when the assertion fails
  - https://learn.microsoft.com/en-us/dotnet/api/microsoft.visualstudio.testtools.unittesting.assert?view=visualstudiosdk-2022

- xUnit provides a custom Assert class with similar functionality
  - https://xunit.net/docs/comparisons

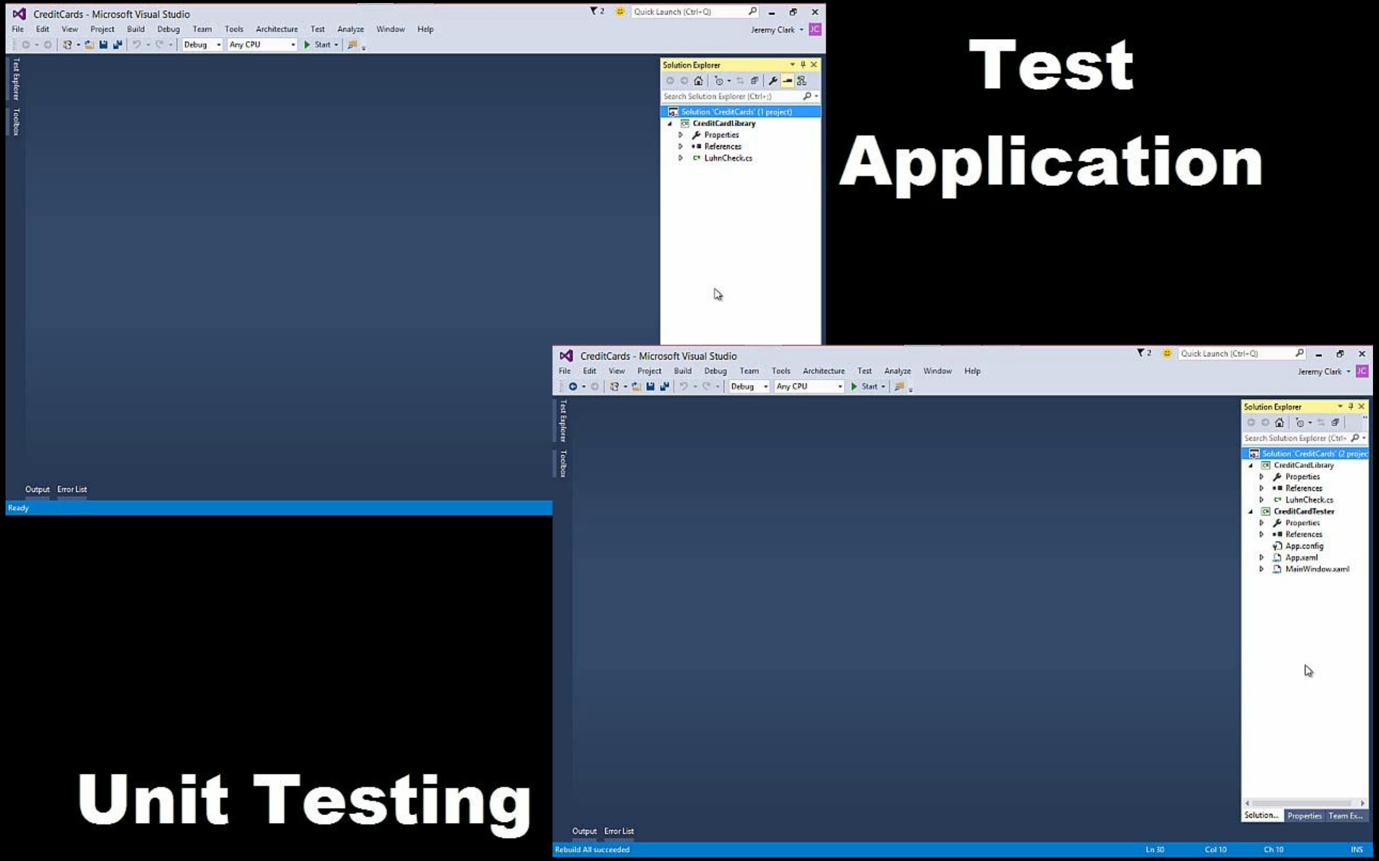
Benefits

- Confirming Functionality
- Checking Regression
- Pinpointing Bugs
- Documenting Functionality

Confirming Functionality

Unit Tests are ***proof*** that my code does what I ***think*** it does

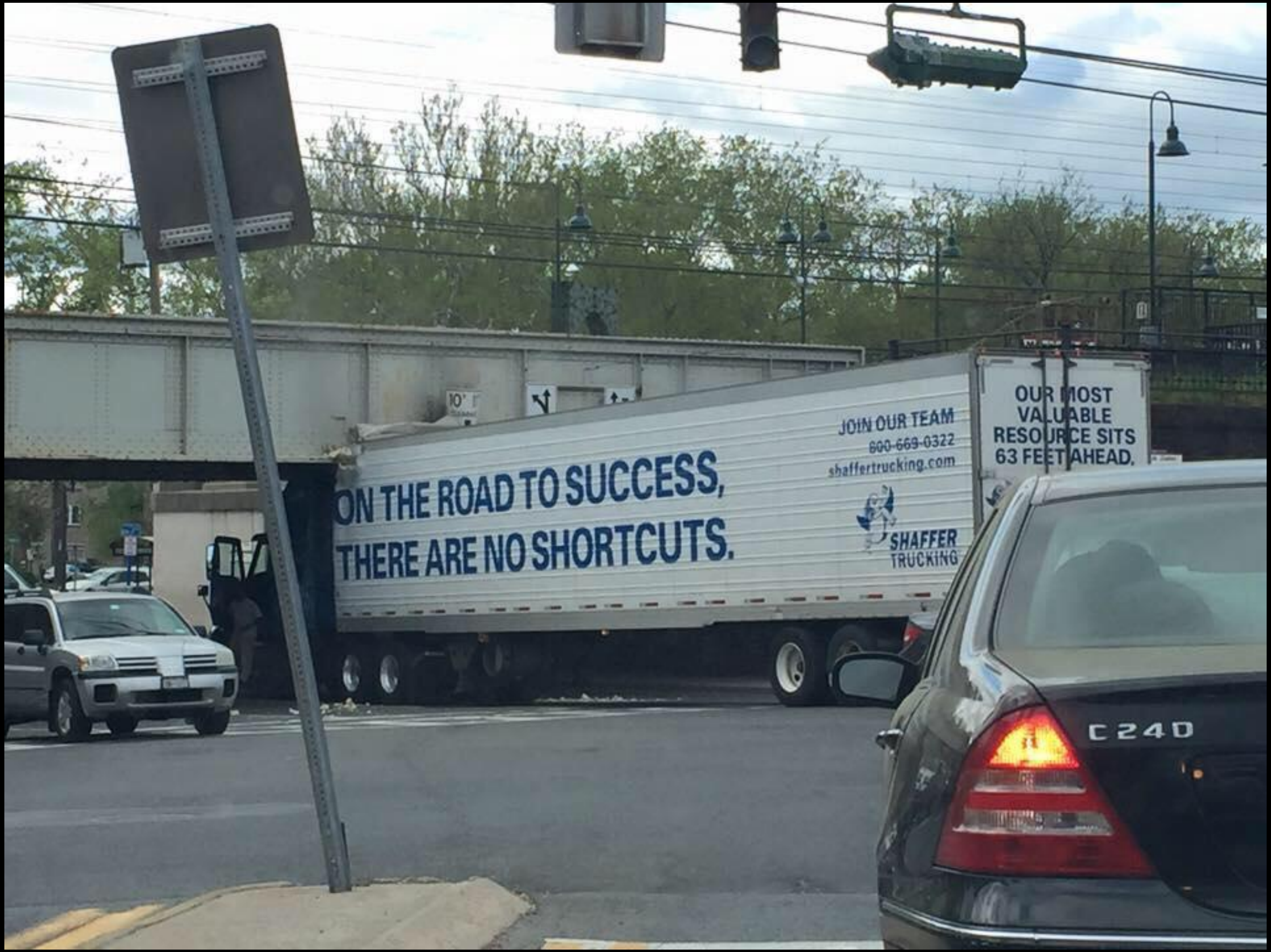
Build Time Comparison



Disclaimer

We get these advantages when we are ***comfortable*** writing ***good*** tests.

Realistic Expectations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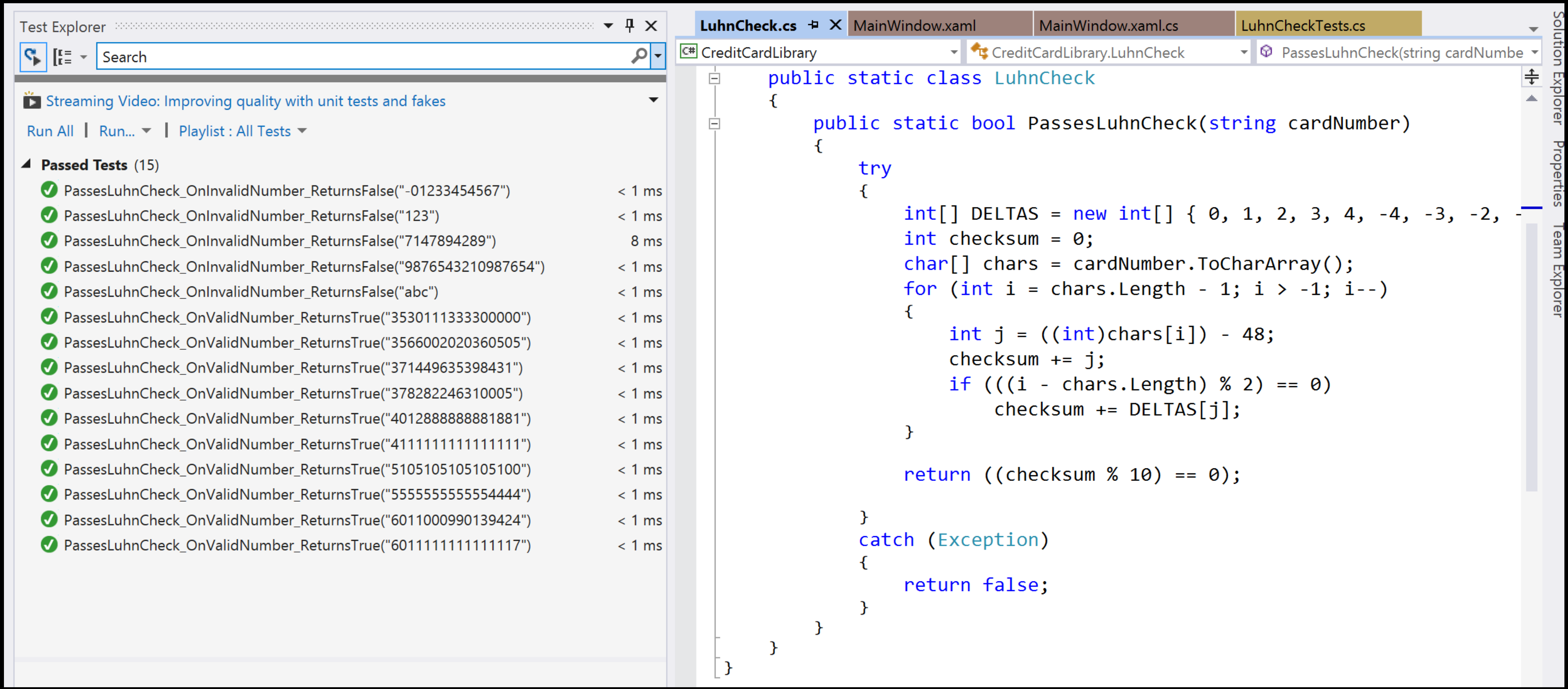
Checking Regression


Test Explorer
Search
Streaming Video: Improving quality with unit tests and fakes
Run All | Run... | Playlist : All Tests
LuhnCheck.cs
MainWindow.xaml
MainWindow.xaml.cs
LuhnCheckTests.cs
CreditCardLibrary
CreditCardLibrary.LuhnCheck
PassesLuhnCheck(string cardNumbe
Solution Explorer
Properties
Team Explorer

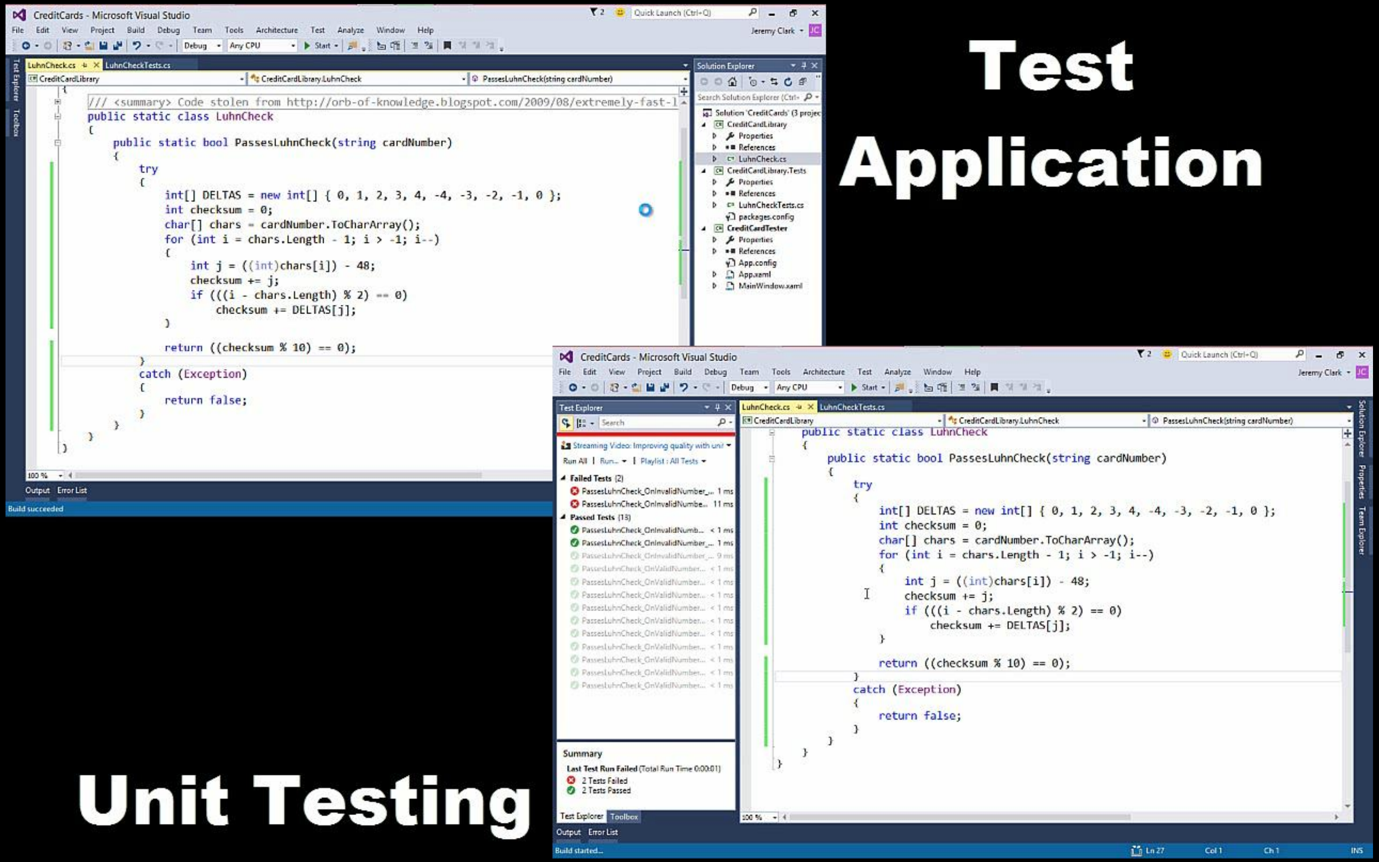
Passed Tests (15)

PassesLuhnCheck_OnInvalidNumber_ReturnsFalse("-01233454567")	< 1 ms
PassesLuhnCheck_OnInvalidNumber_ReturnsFalse("123")	< 1 ms
PassesLuhnCheck_OnInvalidNumber_ReturnsFalse("7147894289")	8 ms
PassesLuhnCheck_OnInvalidNumber_ReturnsFalse("9876543210987654")	< 1 ms
PassesLuhnCheck_OnInvalidNumber_ReturnsFalse("abc")	< 1 ms
PassesLuhnCheck_OnValidNumber_ReturnsTrue("3530111333300000")	< 1 ms
PassesLuhnCheck_OnValidNumber_ReturnsTrue("3566002020360505")	< 1 ms
PassesLuhnCheck_OnValidNumber_ReturnsTrue("371449635398431")	< 1 ms
PassesLuhnCheck_OnValidNumber_ReturnsTrue("378282246310005")	< 1 ms
PassesLuhnCheck_OnValidNumber_ReturnsTrue("4012888888881881")	< 1 ms
PassesLuhnCheck_OnValidNumber_ReturnsTrue("4111111111111111")	< 1 ms
PassesLuhnCheck_OnValidNumber_ReturnsTrue("5105105105105100")	< 1 ms
PassesLuhnCheck_OnValidNumber_ReturnsTrue("5555555555554444")	< 1 ms
PassesLuhnCheck_OnValidNumber_ReturnsTrue("6011000990139424")	< 1 ms
PassesLuhnCheck_OnValidNumber_ReturnsTrue("6011111111111117")	< 1 ms

```csharp
    public static class LuhnCheck
    {
        public static bool PassesLuhnCheck(string cardNumber)
        {
            try
            {
                int[] DELTAS = new int[] { 0, 1, 2, 3, 4, -4, -3, -2, -
                int checksum = 0;
                char[] chars = cardNumber.ToCharArray();
                for (int i = chars.Length - 1; i > -1; i--)
                {
                    int j = ((int)chars[i]) - 48;
                    checksum += j;
                    if (((i - chars.Length) % 2) == 0)
                        checksum += DELTAS[j];
                }

                return ((checksum % 10) == 0);

            }
            catch (Exception)
            {
                return false;
            }
        }
    }
}
```

Regression Comparison

Test Application



```
/// <summary> Code stolen from http://orb-of-knowledge.blogspot.com/2009/08/extremely-fast-l
public static class LuhnCheck
{
    public static bool PassesLuhnCheck(string cardNumber)
    {
        try
        {
            int[] DELTAS = new int[] { 0, 1, 2, 3, 4, -4, -3, -2, -1, 0 };
            int checksum = 0;
            char[] chars = cardNumber.ToCharArray();
            for (int i = chars.Length - 1; i > -1; i--)
            {
                int j = ((int)chars[i]) - 48;
                checksum += j;
                if (((i - chars.Length) % 2) == 0)
                    checksum += DELTAS[j];
            }

            return ((checksum % 10) == 0);
        }
        catch (Exception)
        {
            return false;
        }
    }
}
```

CreditCards - Microsoft Visual Studio
File Edit View Project Build Debug Team Tools Architecture Test Analyze Window Help
Debug
Any CPU
Start
Jeremy Clark
Test Explorer
Search
Streaming Video: Improving quality with unit
Run All | Run... | Playlist : All Tests
LuhnCheck.cs
LuhnCheckTests.cs
CreditCardLibrary
CreditCardLibrary.LuhnCheck
PassesLuhnCheck(string cardNumber)
Solution Explorer
Properties
Team Explorer
Test Explorer
Toolbox
100 %
Output
Error List
Build started...
Ln 27
Col 1
Ch 1
INS

Failed Tests (2)
- PassesLuhnCheck_OnInvalidNumber_... 1 ms
- PassesLuhnCheck_OnInvalidNumbe... 11 ms

Passed Tests (13)
- PassesLuhnCheck_OnInvalidNumb... < 1 ms
- PassesLuhnCheck_OnInvalidNumber_... 1 ms
- PassesLuhnCheck_OnInvalidNumber_... 9 ms
- PassesLuhnCheck_OnValidNumber... < 1 ms
- PassesLuhnCheck_OnValidNumber... < 1 ms
- PassesLuhnCheck_OnValidNumber... < 1 ms
- PassesLuhnCheck_OnValidNumber... < 1 ms
- PassesLuhnCheck_OnValidNumber... < 1 ms
- PassesLuhnCheck_OnValidNumber... < 1 ms
- PassesLuhnCheck_OnValidNumber... < 1 ms
- PassesLuhnCheck_OnValidNumber... < 1 ms
- PassesLuhnCheck_OnValidNumber... < 1 ms
- PassesLuhnCheck_OnValidNumber... < 1 ms

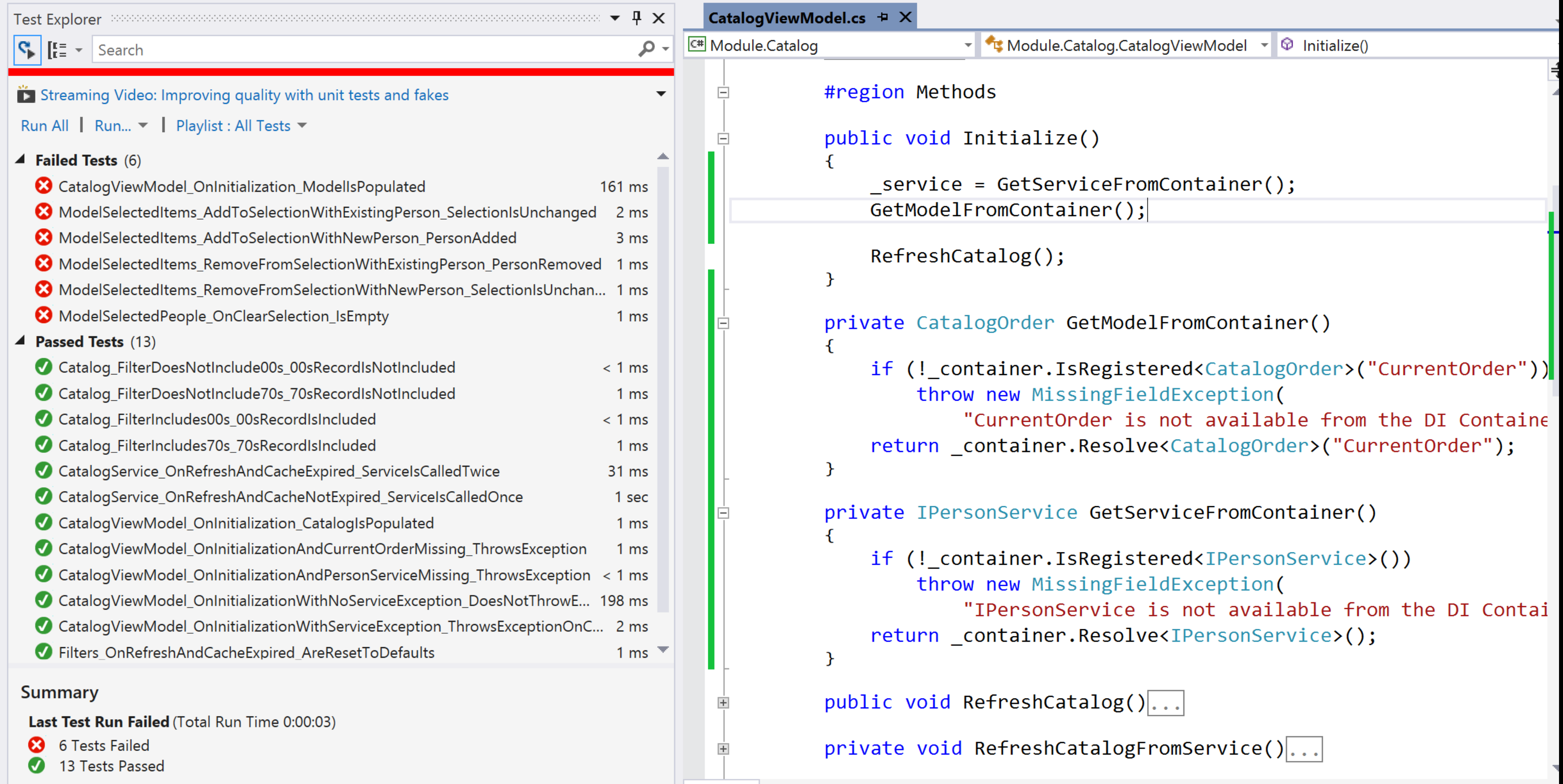
Summary

Last Test Run Failed (Total Run Time 0:00:01)
- 2 Tests Failed
- 2 Tests Passed

```
public static class LuhnCheck
{
    public static bool PassesLuhnCheck(string cardNumber)
    {
        try
        {
            int[] DELTAS = new int[] { 0, 1, 2, 3, 4, -4, -3, -2, -1, 0 };
            int checksum = 0;
            char[] chars = cardNumber.ToCharArray();
            for (int i = chars.Length - 1; i > -1; i--)
            {
                int j = ((int)chars[i]) - 48;
                checksum += j;
                if (((i - chars.Length) % 2) == 0)
                    checksum += DELTAS[j];
            }

            return ((checksum % 10) == 0);
        }
        catch (Exception)
        {
            return false;
        }
    }
}
```

Unit Testing

Pinpointing Bugs



Test Explorer
Search
Streaming Video: Improving quality with unit tests and fakes
Run All | Run... | Playlist : All Tests

Failed Tests (6)

✗ CatalogViewModel_OnInitialization_ModelIsPopulated	161 ms
✗ ModelSelectedItems_AddToSelectionWithExistingPerson_SelectionIsUnchanged	2 ms
✗ ModelSelectedItems_AddToSelectionWithNewPerson_PersonAdded	3 ms
✗ ModelSelectedItems_RemoveFromSelectionWithExistingPerson_PersonRemoved	1 ms
✗ ModelSelectedItems_RemoveFromSelectionWithNewPerson_SelectionIsUnchan...	1 ms
✗ ModelSelectedPeople_OnClearSelection_IsEmpty	1 ms

Passed Tests (13)

✓ Catalog_FilterDoesNotInclude00s_00sRecordIsNotIncluded	< 1 ms
✓ Catalog_FilterDoesNotInclude70s_70sRecordIsNotIncluded	1 ms
✓ Catalog_FilterIncludes00s_00sRecordIsIncluded	< 1 ms
✓ Catalog_FilterIncludes70s_70sRecordIsIncluded	1 ms
✓ CatalogService_OnRefreshAndCacheExpired_ServiceIsCalledTwice	31 ms
✓ CatalogService_OnRefreshAndCacheNotExpired_ServiceIsCalledOnce	1 sec
✓ CatalogViewModel_OnInitialization_CatalogIsPopulated	1 ms
✓ CatalogViewModel_OnInitializationAndCurrentOrderMissing_ThrowsException	1 ms
✓ CatalogViewModel_OnInitializationAndPersonServiceMissing_ThrowsException	< 1 ms
✓ CatalogViewModel_OnInitializationWithNoServiceException_DoesNotThrowE...	198 ms
✓ CatalogViewModel_OnInitializationWithServiceException_ThrowsExceptionOnC...	2 ms
✓ Filters_OnRefreshAndCacheExpired_AreResetToDefaults	1 ms

Summary

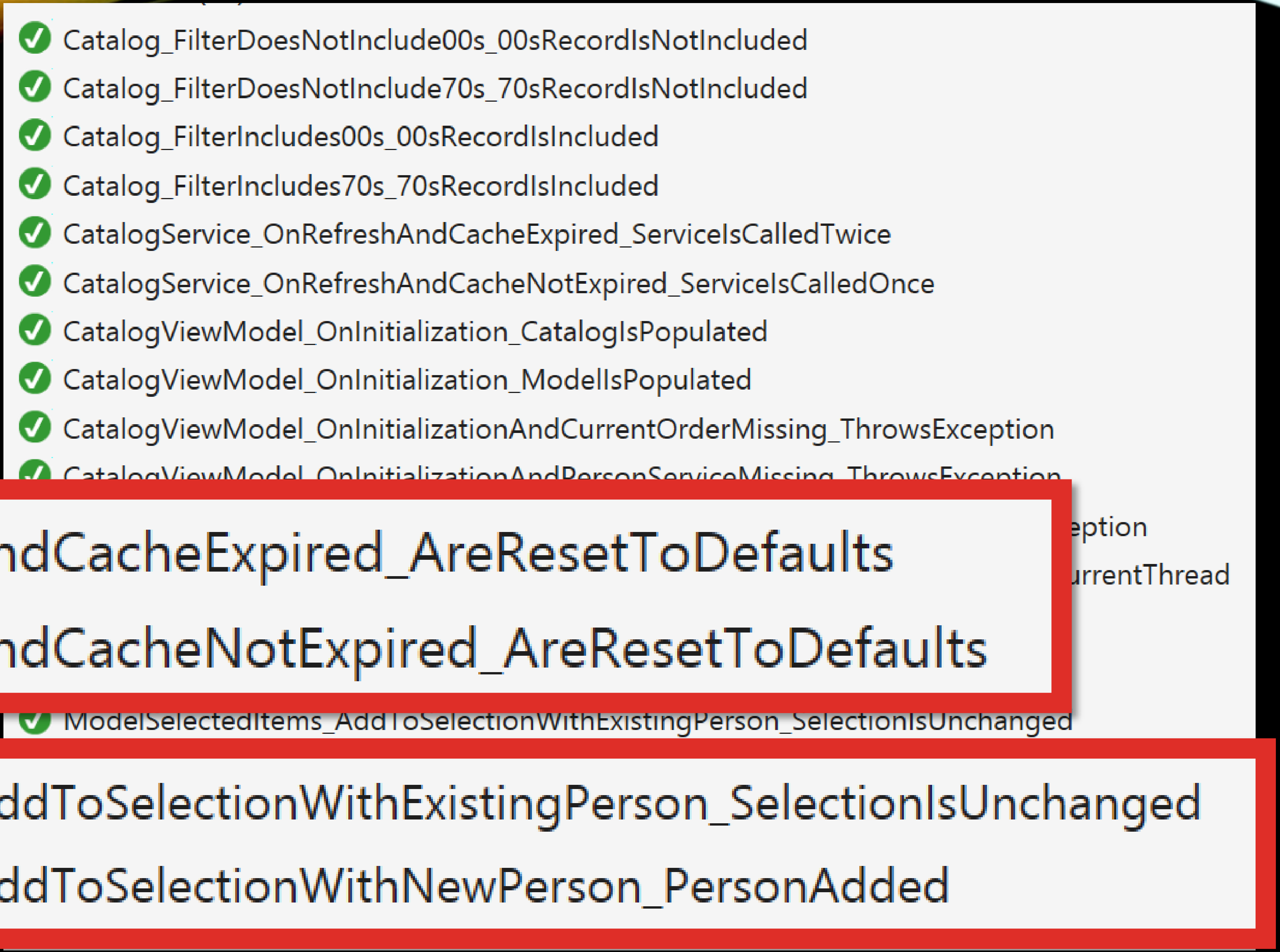
Last Test Run Failed (Total Run Time 0:00:03)

✗ 6 Tests Failed

✓ 13 Tests Passed

```
#region Methods

public void Initialize()
{
    _service = GetServiceFromContainer();
    GetModelFromContainer();

    RefreshCatalog();
}

private CatalogOrder GetModelFromContainer()
{
    if (!_container.IsRegistered<CatalogOrder>("CurrentOrder"))
        throw new MissingFieldException(
            "CurrentOrder is not available from the DI Containe
    return _container.Resolve<CatalogOrder>("CurrentOrder");
}

private IPersonService GetServiceFromContainer()
{
    if (!_container.IsRegistered<IPersonService>())
        throw new MissingFieldException(
            "IPersonService is not available from the DI Contai
    return _container.Resolve<IPersonService>();
}

public void RefreshCatalog()...

private void RefreshCatalogFromService()...
```

Documenting Functionality



✓ Catalog_FilterDoesNotInclude00s_00sRecordIsNotIncluded

✓ Catalog_FilterDoesNotInclude70s_70sRecordIsNotIncluded

✓ Catalog_FilterIncludes00s_00sRecordIsIncluded

✓ Catalog_FilterIncludes70s_70sRecordIsIncluded

✓ CatalogService_OnRefreshAndCacheExpired_ServiceIsCalledTwice

✓ CatalogService_OnRefreshAndCacheNotExpired_ServiceIsCalledOnce

✓ CatalogViewModel_OnInitialization_CatalogIsPopulated

✓ CatalogViewModel_OnInitialization_ModelIsPopulated

✓ CatalogViewModel_OnInitializationAndCurrentOrderMissing_ThrowsException

✓ CatalogViewModel_OnInitializationAndPersonServiceMissing_ThrowsException

eption

urrentThread

✓ Filters_OnRefreshAndCacheExpired_AreResetToDefaults

✓ Filters_OnRefreshAndCacheNotExpired_AreResetToDefaults

✓ ModelSelectedItems_AddToSelectionWithExistingPerson_SelectionIsUnchanged

✓ ModelSelectedItems_AddToSelectionWithExistingPerson_SelectionIsUnchanged

✓ ModelSelectedItems_AddToSelectionWithNewPerson_PersonAdded

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Disclaimer

We get these advantages when we are ***comfortable*** writing ***good*** tests.

Good Unit Tests

- Maintainable
- Dependable
- Runnable

Qualities of a Good Test

Maintainable

- Not Tricky
- Easy to Read
- Easy to Write
- Well-Named

Dependable

- Consistent Results
- Isolated
- Continued Relevance
- Tests the Right Things

Runnable

- FAST

Michael C. Feathers on Speed

“A unit test that takes 1/10th of a second to run is a slow unit test.”

“Unit tests run fast. If they don’t run fast, they aren’t unit tests.”

Working Effectively with Legacy Code by Michael C. Feathers

Qualities of a Good Test

Maintainable

- Not Tricky
- Easy to Read
- Easy to Write
- Well-Named

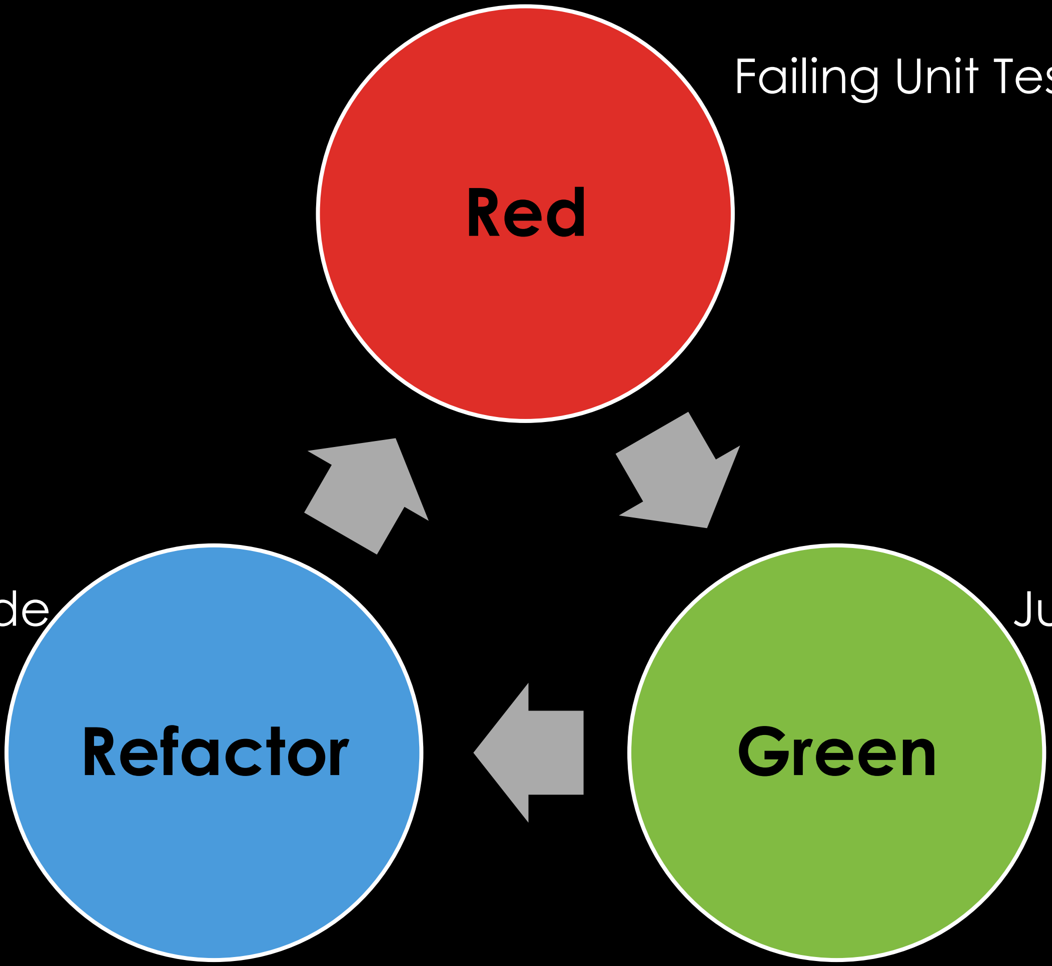
Dependable

- Consistent Results
- Isolated
- Continued Relevance
- Tests the Right Things

Runnable

- FAST
- Single Click
- Repeatable
- Failure Points to the Problem

Test Driven Development



Failing Unit Test

Just Enough Code to Pass Test

Clean Up Code

Fizz Buzz

- Print Numbers 1 to 100
- If divisible by 3 replace with "Fizz"
- If divisible by 5 replace with "Buzz"
- If divisible by 3 and 5 replace with "FizzBuzz"

- 1
- 2
- Fizz
- 4
- Buzz
- Fizz
- 7
- 8
- Fizz

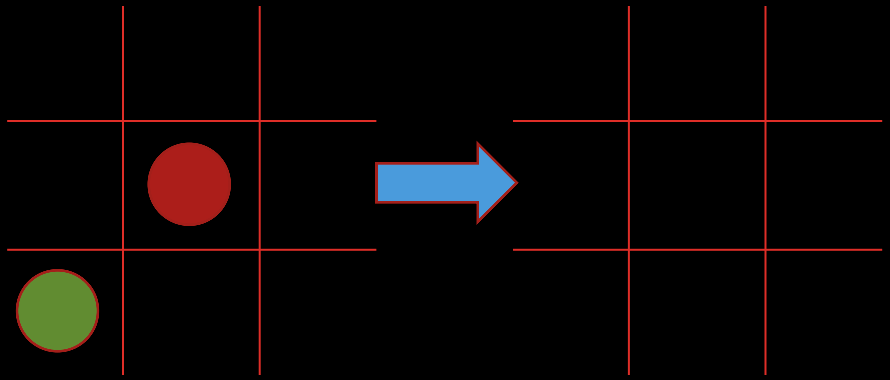
- Buzz
- 11
- Fizz
- 13
- 14
- FizzBuzz
- 16
- 17
- Fizz

Conway’s Game of Life

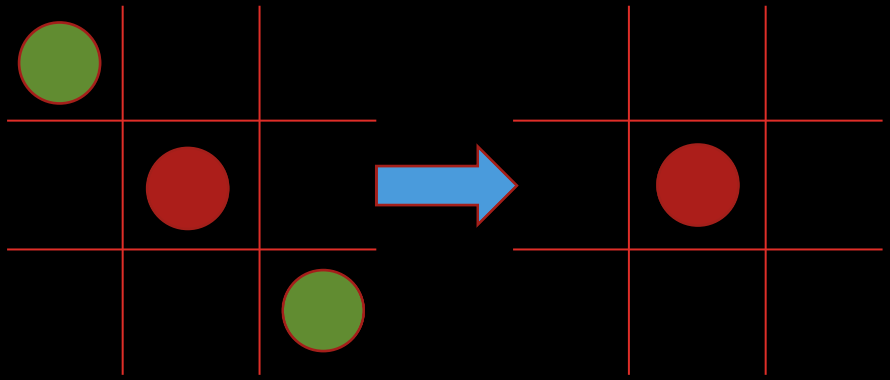
- Any live cell with fewer than two live neighbours dies.
- Any live cell with two or three live neighbours lives.
- Any live cell with more than three live neighbours dies.
- Any dead cell with exactly three live neighbours becomes a live cell.

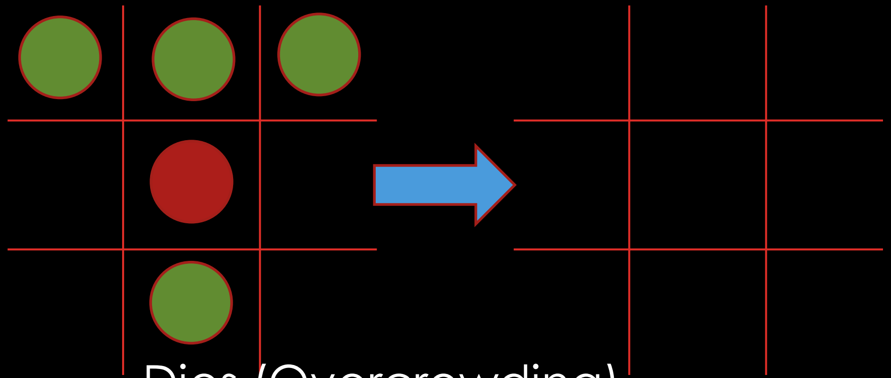
Conway’s Game of Life

Dies (Loneliness)

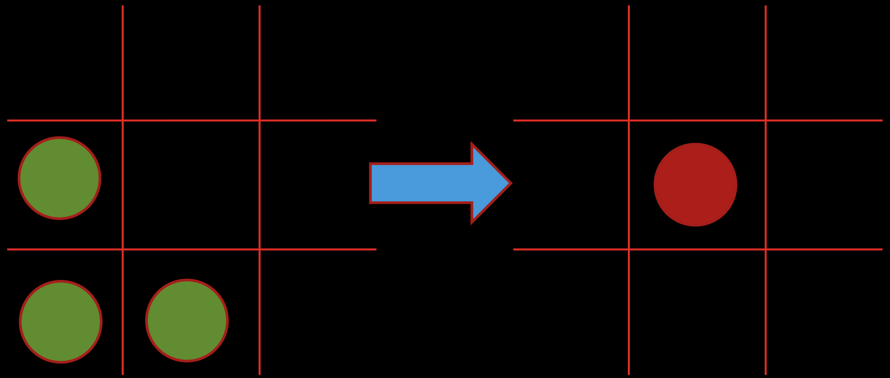


Lives (Happy)





Dies (Overcrowding)



Lives (Reproduction)

Code Coverage

100% Code Coverage is not a guarantee

Conversations about Code Coverage

“What parts of your application are okay ***not*** to test?”

The Stahl Standard

"What parts of your application do your users ***not*** care about?"

-Barry Stahl

Twitter: @bsstahl http://www.cognitiveinheritance.com/

Know the Goals

- Don’t do the right thing for the wrong reason.
- Unit testing will not fix bad development practices.

http://www.jenders.com/2012/01/08/thief-almost-caught-on-camera-stealing-thin-lg-television/

Martin Fowler on Fear

“Don’t let the fear that testing
can’t catch ***all*** bugs
stop you from writing the tests
that will catch ***most*** bugs.”

Refactoring by Martin Fowler et al.

Handling Dependencies

- Create Interfaces to add “seams” to our code
- Use Dependency Injection for loose-coupling
- Use Mocking to inject dependencies for testing

Mocking

- Create “Placeholder” Objects
  - In-Memory
  - Only Implement Behavior We Care About

- Mocking Frameworks
  - NSubstitute
  - Moq

Moq

- Available in NuGet
- Documentation
  - https://github.com/Moq/moq4/wiki/Quickstart

Simple Setup

```
public IPersonReader GetTestReader()
{
    List<Person> testData = [ new Person... ];
    var result = Task.FromResult(testData);
    var mockReader = new Mock<IPersonReader>();
    mockReader.Setup(r => r.GetPeople()).Returns(result);
    return mockReader.Object;
}
```

Setup with Parameters

```
public IPersonReader GetTestReader()
{
    List<Person> testData = [ new Person... ];
    var result = Task.FromResult(testData);
    var mockReader = new Mock<IPersonReader>();

    mockReader.Setup(r => r.GetPeople()).Returns(result);

    mockReader.Setup(r => r.GetPerson(It.IsAny<int>()))

        .Returns((int id) => testData.First(p => p.Id == id));

    return mockReader.Object;

}
```

Setup vs. Factory Methods

- Setup Methods in unit tests are run automatically before any test is invoked.
- Setup Methods can be used for object initialization.

HOWEVER

- Factory Methods are not automatically run.
- Factory Methods are explicitly called within the test.
- Readability of tests can be increased by using Factory Methods instead of Setup Methods.

Sample with Setup Method

```
IPersonReader _reader;


[Initialize]
public IPersonReader GetTestReader()
{
    List<Person> testData = [ new Person... ];
    var result = Task.FromResult(testData);
    var mockReader = new Mock<IPersonReader>();
    mockReader.Setup(r => r.GetPeople())
        .Returns(result);
    _reader = mockReader.Object;
}
```

```
[Fact]
public async Task People_OnRefresh_IsPopulated()
{
    var viewModel = new PeopleViewModel(_reader)
    await viewModel.RefreshPeople();
    Assert.NotNull(viewModel.People);
    Assert.Equal(2, viewModel.People.Count());

}
```

Sample with Factory Method

```
public IPersonReader GetTestReader()
{
    List<Person> testData = [ new Person... ];
    var result = Task.FromResult(testData);
    var mockReader = new Mock<IPersonReader>();
    mockReader.Setup(r => r.GetPeople()).Returns(result);

    return mockReader.Object;
}
```

```
[Fact]
public async Task People_OnRefresh_IsPopulated()
{
    var reader = GetTestReader();
    var viewModel = new PeopleViewModel(reader);
    await viewModel.RefreshPeople();
    Assert.NotNull(viewModel.People);
    Assert.Equal(2, viewModel.People.Count());
}
```

xUnit Parameterization

[Theory]
[InlineData(…)]

- Marking a test as “Theory” allows you to include data that is used as test parameters.
  - https://xunit.net/docs/getting-started/v2/netfx/visual-studio#write-first-theory

[Theory] & [InlineData] Attributes

```
[Theory]
[InlineData(2)]
[InlineData(3)]
public void LiveCell_2or3LiveNeighbors_Lives(int neighbors)
{
    CellState currentState = CellState.Alive;
    var newState = LifeRules.GetState(currentState, neighbors);
    Assert.Equal(CellState.Alive, newState);
}
```

xUnit Parameterization

[ClassData] & [MemberData]

These options can be used instead of [InlineData] when data is more complex, needs to be calculated, or comes from a database or file.

Testing for Exceptions

- Manual Testing:
  - Create method with try/catch block.
  - “Assert.Fail()” if no exception is thrown.
  - Catch block can check exception for specific type/properties.

Testing for Exceptions

- xUnit Testing
  - Use “Assert.Throws()” method to check a block of code.
  - Return value is the exception and can be checked for specific properties.
  - Other testing frameworks offer similar assertions.

xUnit Exception Assertion

```
[Fact]
public void InvalidCellState_ThrowsException()
{
    CellState currentState = (CellState)2;
    int neighbors = 3;

    Assert.Throws<ArgumentOutOfRangeException>(
        "currentState",
        () => LifeRules.GetNewState(currentState, neighbors));
}
```

Thank You!

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https://github.com/jeremybytes/csharp-workshop-2025