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Test run failed Results: 1/3 passed; Item(s) checked: 2

Result	Test Name	Project	Error Message
Passed	SumTestTypicalCase	TestSumator	
Failed	SumTestNullArray	TestSumator	Test method SumatorTest.SumT
Failed	SumTestOverflow	TestSumator	Test method SumatorTest.SumT

Unit Testing

Building Rock-Solid Software

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Learning & Development
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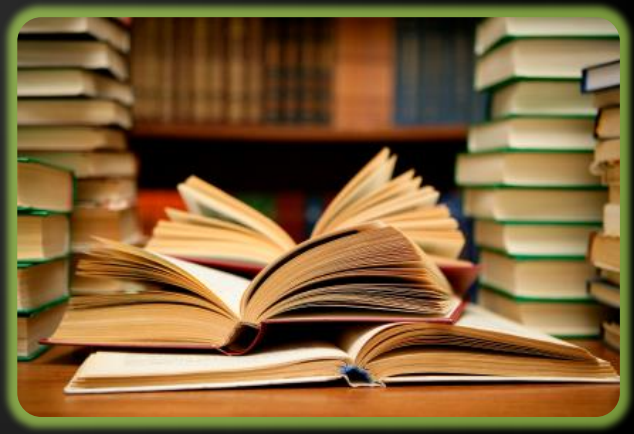

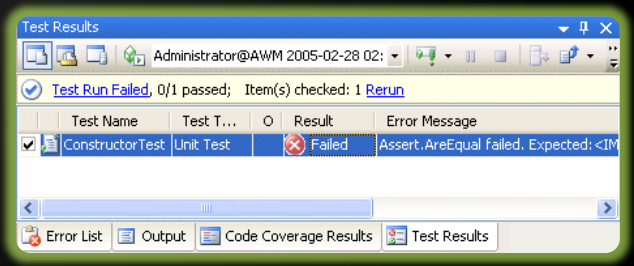

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What is Unit Testing?

Unit Test – Definition

A unit test is a piece of code written by a developer that exercises a very small, specific area of functionality of the code being tested.

"Program testing can be used to show the presence of bugs, but never to show their absence!"

Edsger Dijkstra, [1972]

Manual Testing

- You have already done unit testing
  - Manually, by hand
- Manual tests are less efficient
  - Not structured
  - Not repeatable
  - Not on all your code
  - Not easy to do as it should be

Unit Test – Example

```
int Sum(int[] array)
{
  sum = 0;
  for (int i=0; i<array.Length; i++)
    sum += array[i];
  return sum;
}

void TestSum()
{
 if (Sum(new int[]{1,2}) != 3)
    throw new TestFailedException("1+2 != 3");
 if (Sum(new int[]{-2}) != -2)
    throw new TestFailedException("-2 != -2");
 if (Sum(new int[]{}) != 0)
    throw new TestFailedException("0 != 0");
}
```

Unit Testing – Some Facts

- Tests are specific pieces of code
- In most cases unit tests are written by developers, not by QA engineers
- Unit tests are released into the code repository (TFS / SVN / Git) along with the code they test
- Unit testing framework is needed
  - Visual Studio Team Test (VSTT)
  - NUnit, MbUnit, Gallio, etc.

Unit Testing – More Facts

- All classes should be tested
- All methods should be tested
  - Trivial code may be omitted
    - E.g. property getters and setters
  - Private methods can be omitted
    - Some gurus recommend to never test private methods → this can be debatable
- Ideally all unit tests should pass before check-in into the source control repository

Why Unit Tests?

- Unit tests dramatically decrease the number of defects in the code
- Unit tests improve design
- Unit tests are good documentation
- Unit tests reduce the cost of change
- Unit tests allow refactoring
- Unit tests decrease the defect-injection rate due to refactoring / changes

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Unit Testing Frameworks

Unit Testing Frameworks

- JUnit
  - The first popular unit testing framework
  - Based on Java, written by Kent Beck & Co.
- Similar frameworks have been developed for a broad range of computer languages
  - NUnit – for C# and all .NET languages
  - cppUnit, jsUnit, PhpUnit, PerlUnit, …
- Visual Studio Team Test (VSTT)
  - Developed by Microsoft, integrated in VS

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Visual Studio Team Test (VSTT)

Visual Studio Team Test – Features

- Team Test (VSTT) is very well integrated with Visual Studio
  - Create test projects and unit tests
  - Execute unit tests
  - View execution results
  - View code coverage

- Located in the assembly `Microsoft.VisualStudio.QualityTools.UnitTestFramework.dll`

Visual Studio Team Test – Attributes

- Test code is annotated using custom attributes:
  - `[TestClass]` – denotes a class holding unit tests
  - `[TestMethod]` – denotes a unit test method
  - `[ExpectedException]` – test causes an exception
  - `[Timeout]` – sets a timeout for test execution
  - `[Ignore]` – temporary ignored test case
  - `[ClassInitialize]`, `[ClassCleanup]` – setup / cleanup logic for the testing class
  - `[TestInitialize]`, `[TestCleanup]` – setup / cleanup logic for each test case

Assertions

- Predicate is a true / false statement
- Assertion is a predicate placed in a program code (check for some condition)
  - Developers expect the predicate is always true at that place
  - If an assertion fails, the method call does not return and an error is reported
  - Example of VSTT assertion:

```
Assert.AreEqual(
  expectedValue, actualValue, "Error message.");
```

VSTT – Assertions

- Assertions check a condition
  - Throw exception if the condition is not satisfied
- Comparing values for equality

```
AreEqual(expected_value, actual_value [,message])
```

- Comparing objects (by reference)

```
AreSame(expected_object, actual_object [,message])
```

- Checking for `null` value

```
IsNull(object [,message])
```

```
IsNotNull(object [,message])
```

VSTT – Assertions (2)

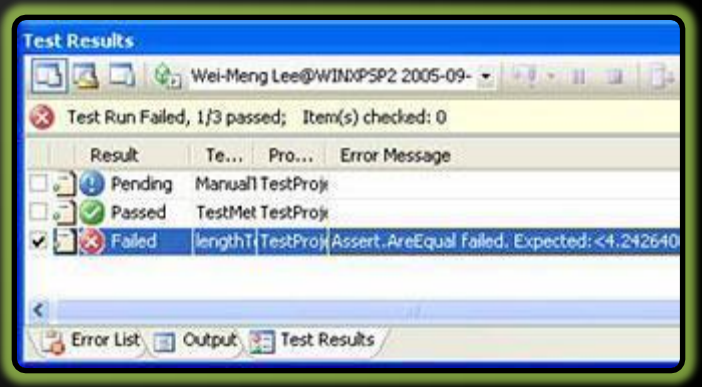
- Checking conditions

```
IsTrue(condition)
```

```
IsFalse(condition)
```

- Forced test fail

```
Fail(message)
```



The 3A Pattern

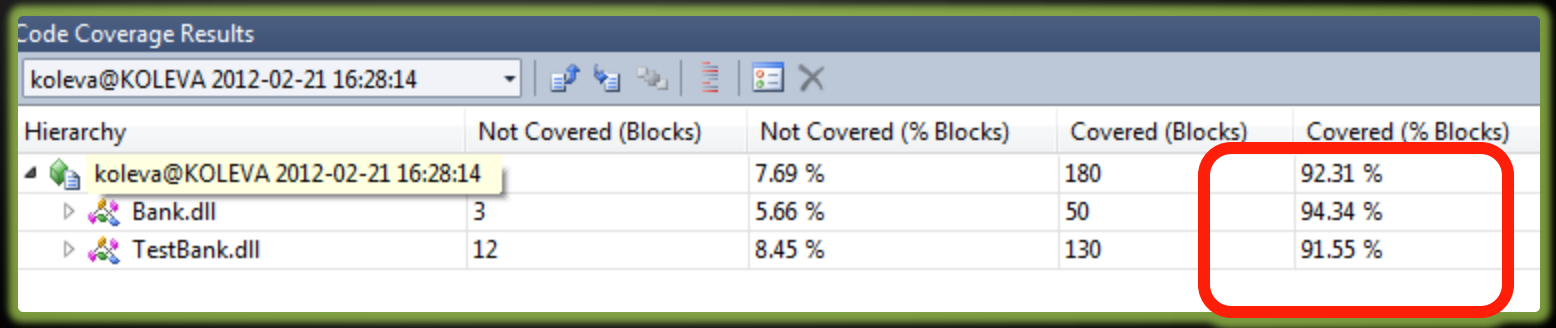
- Arrange all necessary preconditions and inputs
- Act on the object or method under test
- Assert that the expected results have occurred

```
[TestMethod]
public void TestDeposit()
{
  BankAccount account = new BankAccount();
  account.Deposit(125.0);
  account.Deposit(25.0);
  Assert.AreEqual(150.0, account.Balance,
    "Balance is wrong.");
}
```

The 3A Pattern

Code Coverage

- Code coverage
  - Shows what percent of the code we've covered
  - High code coverage means less untested code
  - We may have pointless unit tests that are calculated in the code coverage
- 70-80% coverage is excellent



VSTT – Example

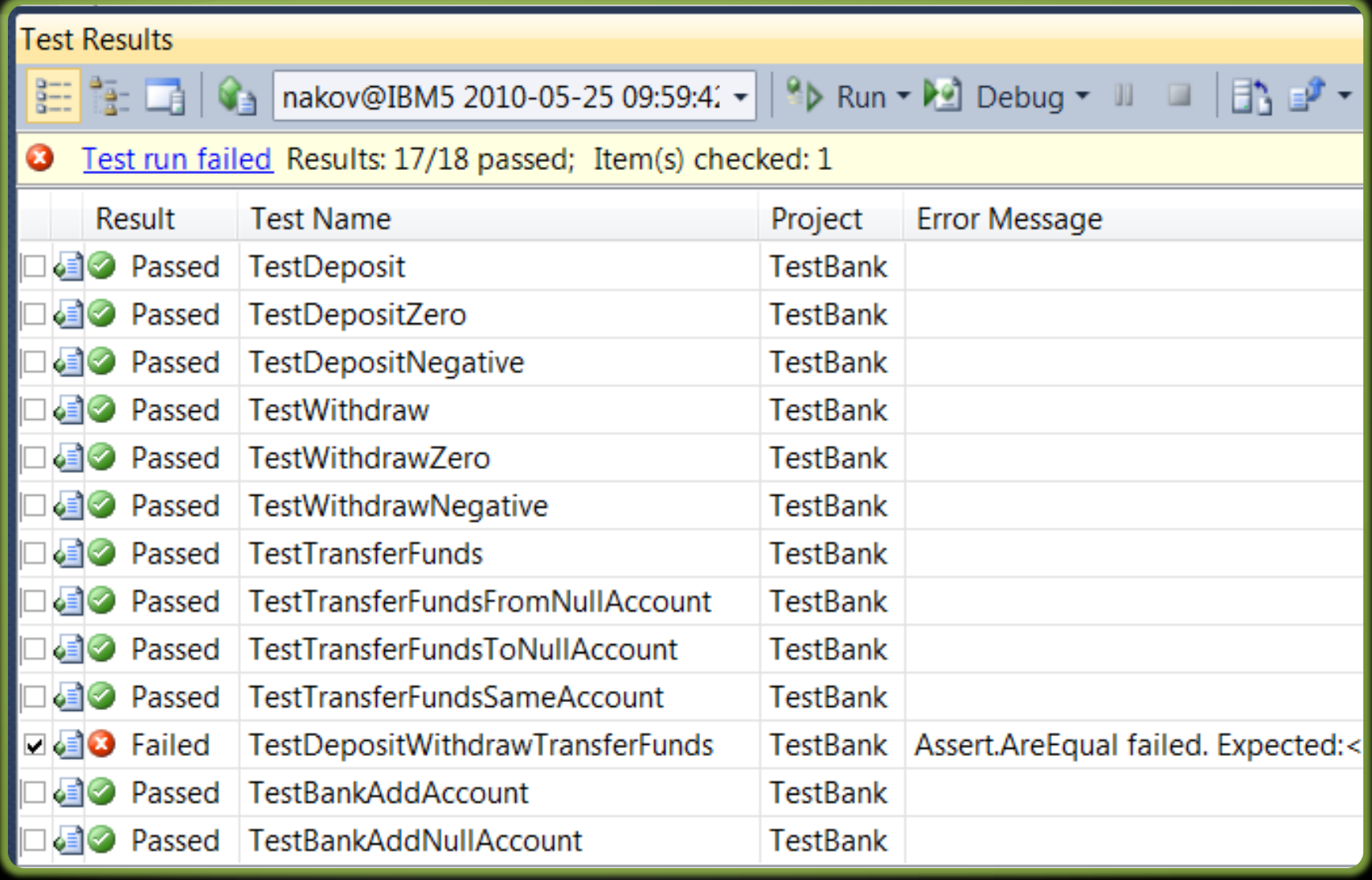
```
public class Account
{
  private decimal balance;
  public void Deposit(decimal amount)
  {
    this.balance += amount;
  }
  public void Withdraw(decimal amount)
  {
    this.balance -= amount;
  }
  public void TransferFunds(
    Account destination, decimal amount)
  { … }
  public decimal Balance
  { … }
}
```

VSTT – Example (2)

```
using Microsoft.VisualStudio.TestTools.UnitTesting;

[TestClass]
public class AccountTest
{
  [TestMethod]
  public void TransferFunds()
  {
    Account source = new Account();
    source.Deposit(200.00M);
    Account dest = new Account();
    dest.Deposit(150.00M);
    source.TransferFunds(dest, 100.00M);
    Assert.AreEqual(250.00M, dest.Balance);
    Assert.AreEqual(100.00M, source.Balance);
  }
}
```

VSTT – Screenshot



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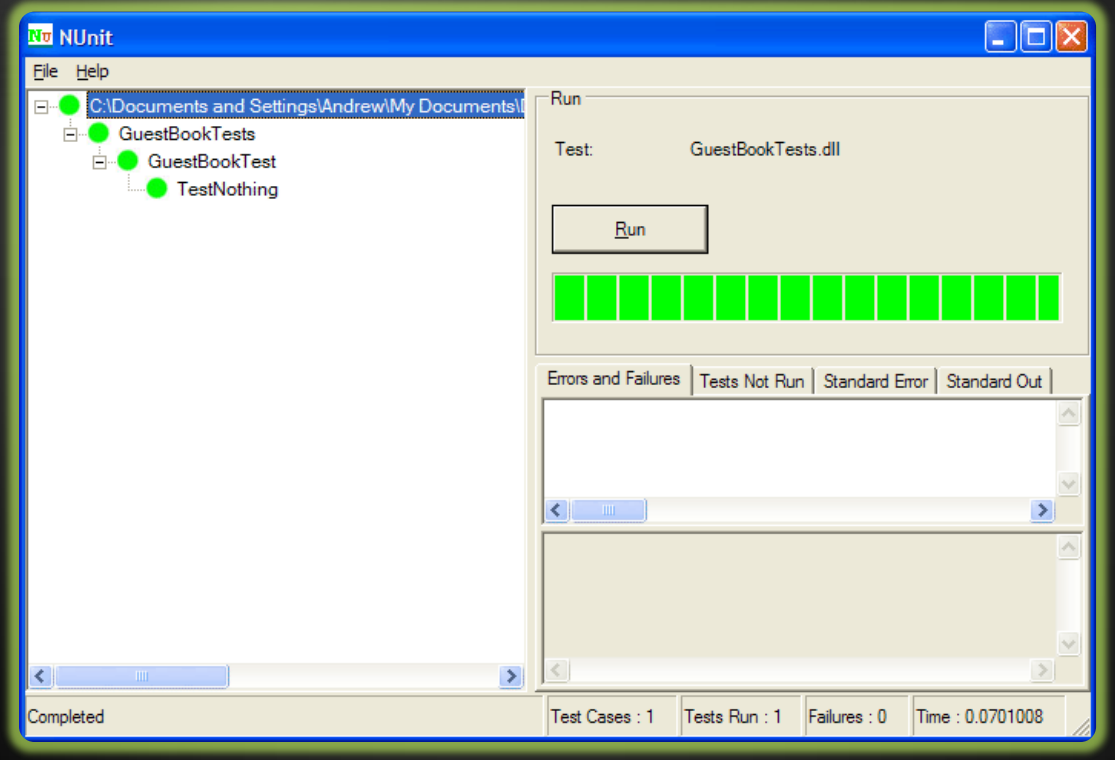
Visual Studio Team Test

Live Demo

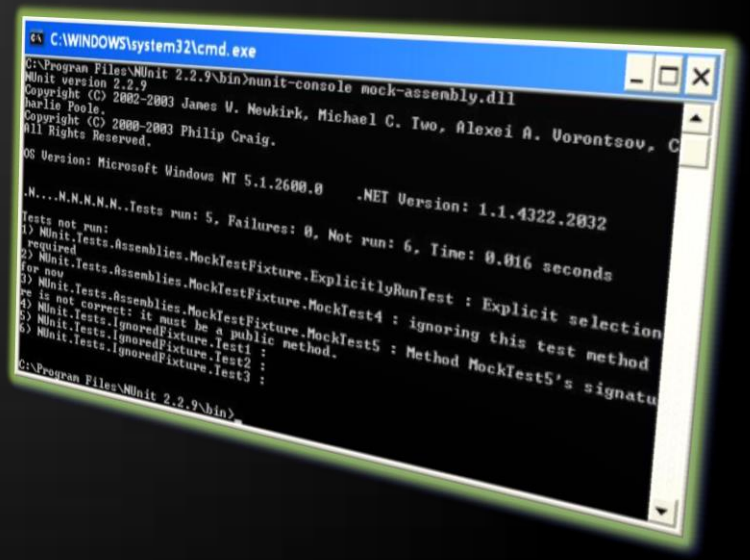


NUnit

http://www.nunit.org/index.php?p=download

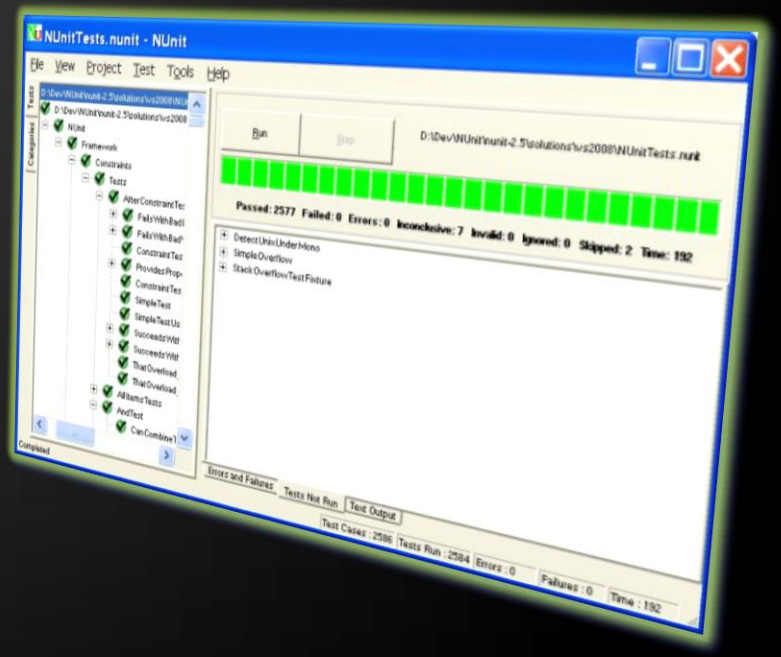
NUnit – Features

- Test code is annotated using custom attributes
- Test code contains assertions
- Tests organized as multiple assemblies
- Two execution interfaces
  - GUI
    - `nunit-gui.exe`
  - Console
    - `nunit-console.exe`



NUnit – Features (2)

- NUnit provides:
  - Creating and running tests as NUnit Test Projects
  - Visual Studio support

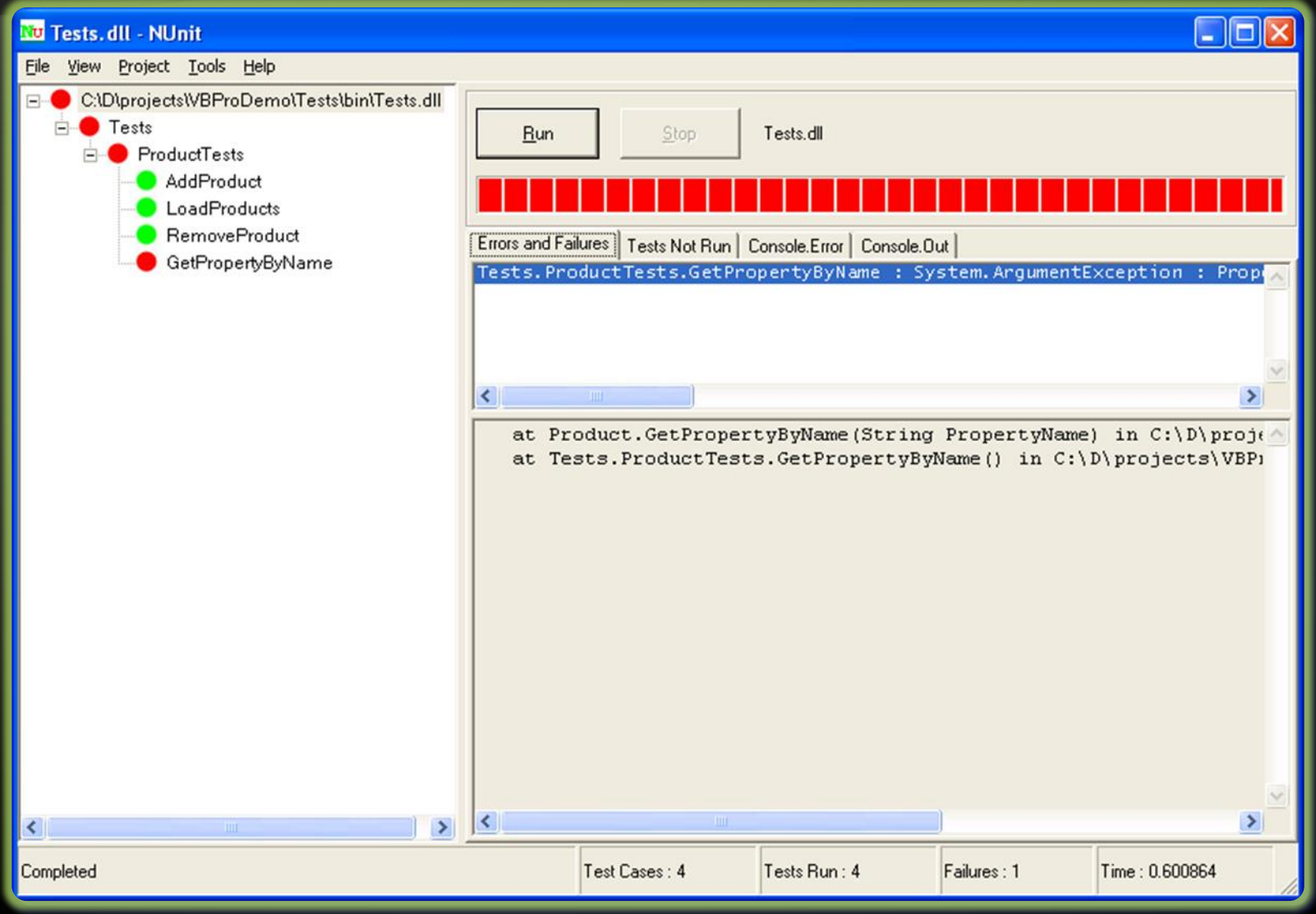


NUnit – Example: Test

```
using NUnit.Framework;

[TestFixture]
public class AccountTest
{
  [Test]
  public void TransferFunds()
  {
    Account source = new Account();
    source.Deposit(200.00F);
    Account dest = new Account();
    dest.Deposit(150.00F);
    source.TransferFunds(dest, 100.00F);
    Assert.AreEqual(250.00F, dest.Balance);
    Assert.AreEqual(100.00F, source.Balance);
  }
}
```

NUnit – Screenshot



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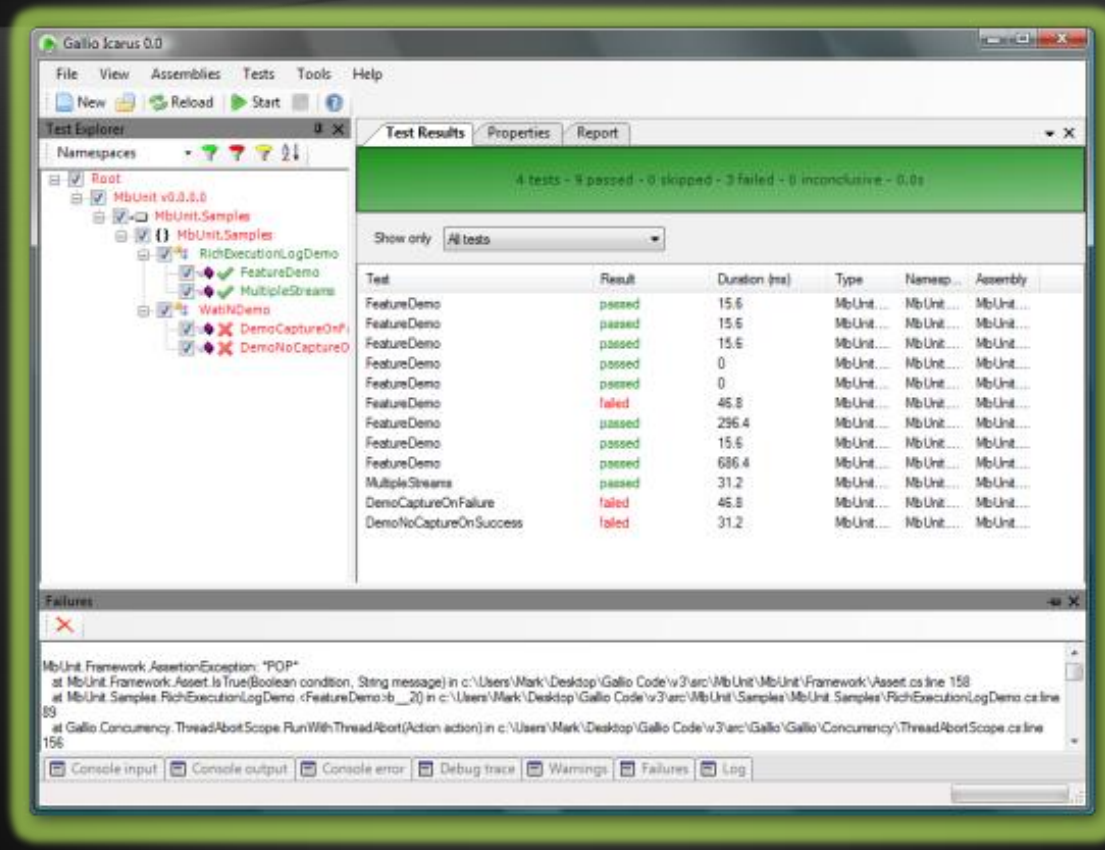


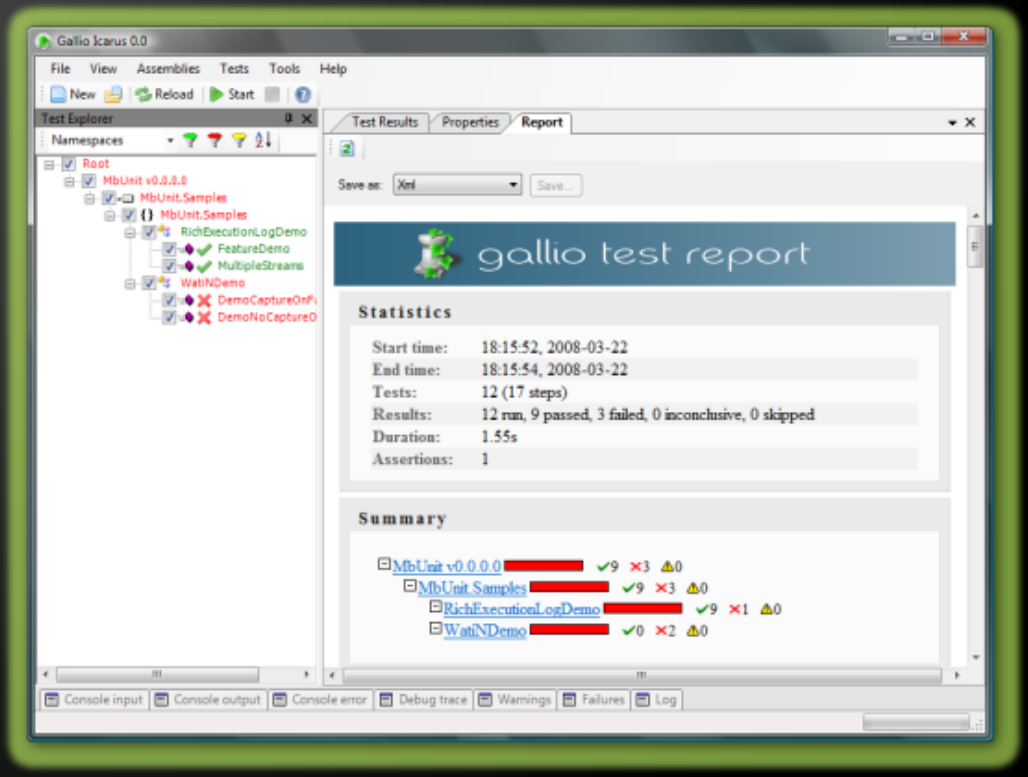
Gallio

The Gallio Automation Platform

- The Gallio Automation Platform
  - An open, extensible, and neutral system for using many .NET test frameworks
  - Gallio can run tests from MbUnit, MSTest, NUnit, xUnit.Net, csUnit, and RSpec
  - Provides a common object model, runtime services and tools (such as test runners)
    - May be leveraged by any number of test frameworks
  - www.gallio.org

Interfaces

- Gallio includes its own interfaces:
  - Echo
    - Command-line runner
  - Icarus
    - Windows GUI



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Unit Testing Best Practices

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Naming Standards for Unit Tests

- The test name should express a specific requirement that is tested
  - Usually prefixed with `[Test]`
  - E.g. `TestAccountDepositNegativeSum()`
- The test name should include
  - Expected input or state
  - Expected result output or state
  - Name of the tested method or class

Naming Standards for Unit Tests – Example

- Given the method:

```
public int Sum(params int[] values)
```

with requirement to ignore numbers greater than 100 in the summing process

- The test name could be:

```
TestSum_NumberIgnoredIfGreaterThan100
```

When Should a Test be Changed or Removed?

- Generally, a passing test should never be removed
  - These tests make sure that code changes don't break working code
- A passing test should only be changed to make it more readable
- When failing tests don't pass, it usually means there are conflicting requirements

When Should a Test be Changed or Removed? (2)

- Example:

```
[ExpectedException(typeof(Exception),
  "Negatives not allowed")]
void TestSum_FirstNegativeNumberThrowsException()
{
  Sum (-1,1,2);
}
```

- New features allow negative numbers

When Should a Test be Changed or Removed? (3)

- New developer writes the following test:

```
void TestSum_FirstNegativeNumberCalculatesCorrectly()
{
  int sumResult = sum(-1, 1, 2);
  Assert.AreEqual(2, sumResult);
}
```

- Earlier test fails due to a requirement change

When Should a Test be Changed or Removed? (4)

- Two course of actions:
  1. Delete the failing test after verifying it is invalid
  2. Change the old test:
     - Either testing the new requirement
     - Or test the older requirement under new settings

Tests Should Reflect Required Reality

```
int Sum(int a, int b) -> returns sum of a and b
```

- What's wrong with the following test?

```
public void Sum_AddsOneAndTwo()
{
    int result = Sum(1,2);
    Assert.AreEqual(4, result, "Bad sum");
}
```

- A failing test should prove that there is something wrong with the production code
  - Not with the unit test code

What Should Assert Messages Say?

- Assert message in a test could be one of the most important things
  - Tells us what we expected to happen but didn't, and what happened instead
  - Good assert message helps us track bugs and understand unit tests more easily
- Example:
  - *"Withdrawal failed: accounts are not supposed to have negative balance."*

What Should Assert Messages Say? (2)

- Express what should have happened and what did not happen
  - *"`Verify()` did not throw any exception"*
  - *"`Connect()` did not open the connection before returning it"*
- Do not:
  - Provide empty or meaningless messages
  - Provide messages that repeat the name of the test case

Avoid Multiple Asserts in a Single Unit Test

```
void TestSum_AnyParamBiggerThan1000IsNotSummed()
{
  Assert.AreEqual(3, Sum(1001, 1, 2);
  Assert.AreEqual(3, Sum(1, 1001, 2);
  Assert.AreEqual(3, Sum(1, 2, 1001);
}
```

- Avoid multiple asserts in a single test case
  - If the first assert fails, the test execution stops for this test case
  - Affect future coders to add assertions to test rather than introducing a new one

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Unit Testing – The Challenge

- The concept of unit testing has been around the developer community for many years
- New methodologies in particular Scrum and XP, have turned unit testing into a cardinal foundation of software development
- Writing good & effective unit tests is hard!
  - This is where supporting integrated tools and suggested guidelines enter the picture
- The ultimate goal is tools that generate unit tests automatically

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Unit Testing

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Exercises

1. Write three classes: `Student`, `Course` and `School`. Students should have name and unique number (inside the entire `School`). Name can not be empty and the unique number is between 10000 and 99999. Each course contains a set of students. Students in a course should be less than 30 and can join and leave courses.
2. Write VSTT tests for these two classes
   - Use 2 class library projects in Visual Studio: `School.csproj` and `TestSchool.csproj`
3. Execute the tests using Visual Studio and check the code coverage. Ensure it is at least 90%.

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