17-654/17-754
Analysis of Software Artifacts

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Testing

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**Primary source: Kaner, Falk, Nguyen.
Testing Computer Software (2nd Edition).**

Context: Software Quality Assurance

Design intent: Validation and Verification

Sources of flaws

For software: **"flaw" = "defect" = "fault" = "bug"**

- Flaws in *understanding of intent*
  - ***Validation*** *– Does the system do the right thing?*
  - *Have we correctly **analyzed the problem**?*

Specifications in use
Formal
Declarations
Stories
Models
Implicit
Test cases
Reference code
etc

  - Flaws in specification – incorrect capture of requirements
  - Intent
    - What the system does—its *functionality*
    - How the system accomplishes its task—*performance*
    - How the system responds to unexpected situations—*robustness*
    - What services are provided by system infrastructure—*environment*
      - Libraries, frameworks, hardware, etc.

- Flaws in *realization of intent*
  - ***Verification*** *– Does the system do the thing right?*
  - *Have we correctly **implemented a solution**?*

Primary focus of this course

  - Flaws in design and architecture
    - Incorrect high-level development decisions
  - Flaws in code implementation
  - Flaws in infrastructure implementation

Find that bug!

- A published (Mathematica) version of binary search :

```
BinarySearch[l_List, k_Integer,
                low_Integer, high_Integer, f_] :=
Module[{mid = Floor[ (low + high)/2 ]},
  If [low > high, Return[low - 1/2]];
  If [f[ l[[mid]] ] == k, Return[mid]];
  If [f[ l[[mid]] ] > k,
        BinarySearch[l, k, 1, mid-1, f],
        BinarySearch[l, k, mid+1, high, f] ] ]
```

This library code contains a flaw that was not detected for *five years*.

- The first recursive call to BinarySearch should read:

```
BinarySearch[l, k, low, mid-1, f]
```

- Turns a logarithmic algorithm into a linear one

Moral: not all defects cause incorrect output

- How would you test for this?

Mathematica Journal v5i4; DiscreteMath`Combinatorica` package error

Software quality assurance and testing

- A critical software engineering challenge

- **Difficulties**
  - **Expense**: Testing and evaluation typically consume more time and cost in the software engineering process than design and code development
    - Typically 50% of total cost is attributable to quality assurance.
  - **Precision**: Almost impossible to completely succeed in testing and QA
    - “Very high quality” is rarely achieved, even for critical systems
    - Major gaps in testing and inspection
  - **Consequential**: The consequences (downside, upside) are considerable
    - NIST report: $60B lost
    - Developers: Holding back features and new capability

- **Trends**
  - There is rapid evolution in technology and practice (*more later*)
    - Important new techniques are emerging
      - Technical tools
      - Language
  - Engineering for “assurability” or “testability”
    - Requirements
    - Architecture, design, and other models
    - Implementation practices, languages, tools
  - Process
    - Metrics and measurement

Principal Evaluative Techniques

- **Testing**
  - **Direct execution of code on test data in a controlled environment**
    - **Functional and performance attributes**
      - Component-level
      - System-level
  - Identify and locate faults – no assurance of complete coverage

- **Inspection**
  - **Human evaluation of code, design documents (specs and models)**
    - **Structural attributes**
      - Design and architecture
      - Coding practices
      - Algorithms and design elements
  - Creation and codification of understanding

- **Static analysis**
  - **Tool-supported direct static evaluation of formal software artifacts**
    - **Non-functional attributes**
      - Null references
      - Unexpected exceptions
      - Memory usage
  - Can yield partial positive assurance

Other techniques
  Dynamic analysis
  Model checking
  Verification

Software quality methods – a survey

Evaluative techniques

- **Testing**
  - System and integration
  - Unit
  - Performance
  - Function
  - Usability
- **Test management**
  - Strategy
  - Coverage
  - Fault introduction
  - Resource management
- **Inspection**
  - Requirements
  - Design
  - Code
- **Static analysis**
  - Walk tree of code text
  - Follow control paths
  - Follow data paths
- **Dynamic analysis**
  - Monitoring and runtime checking
  - Instrumentation of code
  - Simulation of code

Preventive techniques

- **Requirements**
  - Quality stakeholders
  - Non-functional attributes
- **Process**
  - Measurement and feedback
    - CMM, TSP, etc.
  - Testers and their role
    - E.g., S&S, agile
  - Risk mgmt
- **Architecture**
  - Robustness and self-healing
- **Design**
  - Robustness patterns
  - Safe APIs
  - Analysis
- **Coding**
  - Safe languages
  - Safe coding practices
  - Encapsulation / sandboxing
- **Specific practices**
  - Use of tools
  - Defect tracking
  - Root cause analysis

Criteria for evaluating techniques

- Cost
  - Ease of use
  - Resource requirements: people, time, computing
- Timeliness: when we get answers
  - E.g., unit test with scaffold
  - E.g., mock-up and prototyping
- Accuracy
  - False positives
  - False negatives
- Development value
  - E.g., Easier to modify code, add features
  - Risks of adoption
- Metrics: observability of outcomes
- Scope: What kinds of defects it addresses
  - System scale and complexity
  - Error vs. fault focus
  - Non-functional attributes: performance, usability, security, safety, etc.
  - Functionality
- Integration and value during development
  - Defect prevention support
  - Architecture design
  - Code management
  - Modeling and design intent capture

Faults, Errors, Failures, and Hazards

Faults, Errors, Failures, Hazards

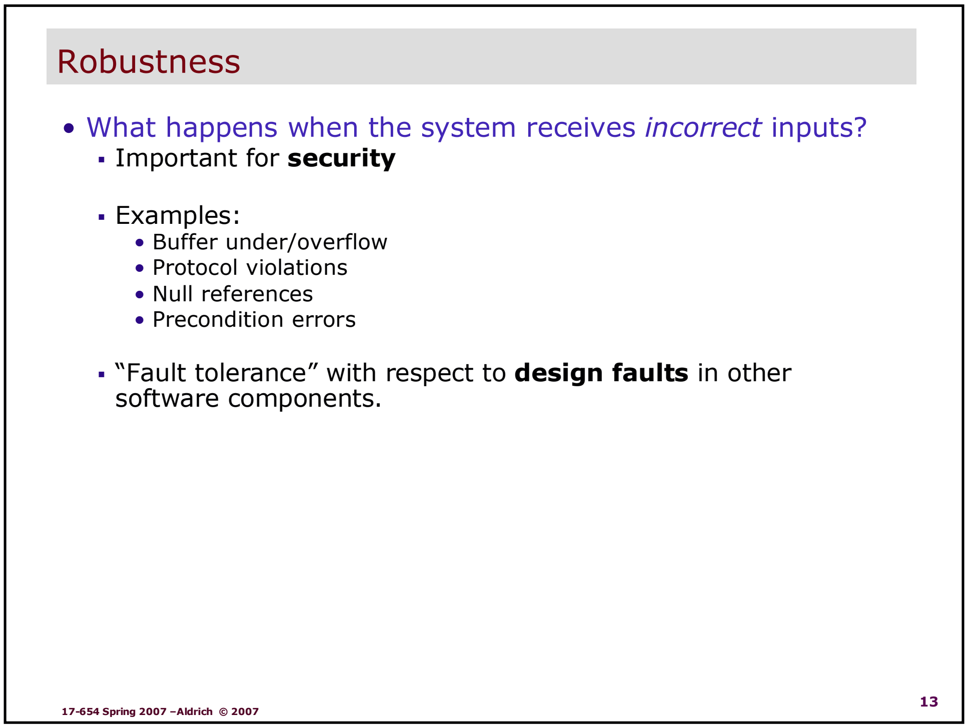
- **Fault**
  - **Type 1 – a flaw in an attached physical component**
    - Traditional notion of a fault in hardware reliability theory (physical parts wearing out)
  - **Type 2 – a static flaw in software code**
    - Syntactically local in code or structurally pervasive
    - Software faults cause errors only when triggered by use.
- **Error – incorrect state at execution time caused by a fault**
  - E.g., buffer overflow, race condition, deadlock, corrupted data
- **Failure – effect of an error on system capability**
  - E.g., program crashes, attacker gains control, program becomes unresponsive, incorrect output
- **Severity – cost of failure to stakeholders**
  - E.g., Loss of life, privacy compromise
- **Hazard – product of failure probability and severity**
  - Equivalent to risk exposure

Relating faults, errors, failures, hazards

- The unconstrained situation (black box)
  - *Any* fault can potentially lead to *any* failure
  - Dependability and security challenges cannot be prioritized
- Commitment to **mission profile**
  - Mission profile defines hazards
    - It determines relative priorities for action
    - Which faults/errors/failures have greatest hazard/risk?
- Commitments to **design and structure**
  - Design commitments constrain the mapping
  - An ideal design fully mitigates faults without affecting system functionality
  - Examples
    - Architecture and structure
      - E.g., self-healing, autonomic architectures
      - E.g., domain-specific architectures
    - Coding practice and patterns
      - E.g., state estimators, robustness tests, etc.
      - E.g., tools, patterns, anti-patterns
      - E.g., measurements of potential fault sites and mitigations
    - Tools and measurements

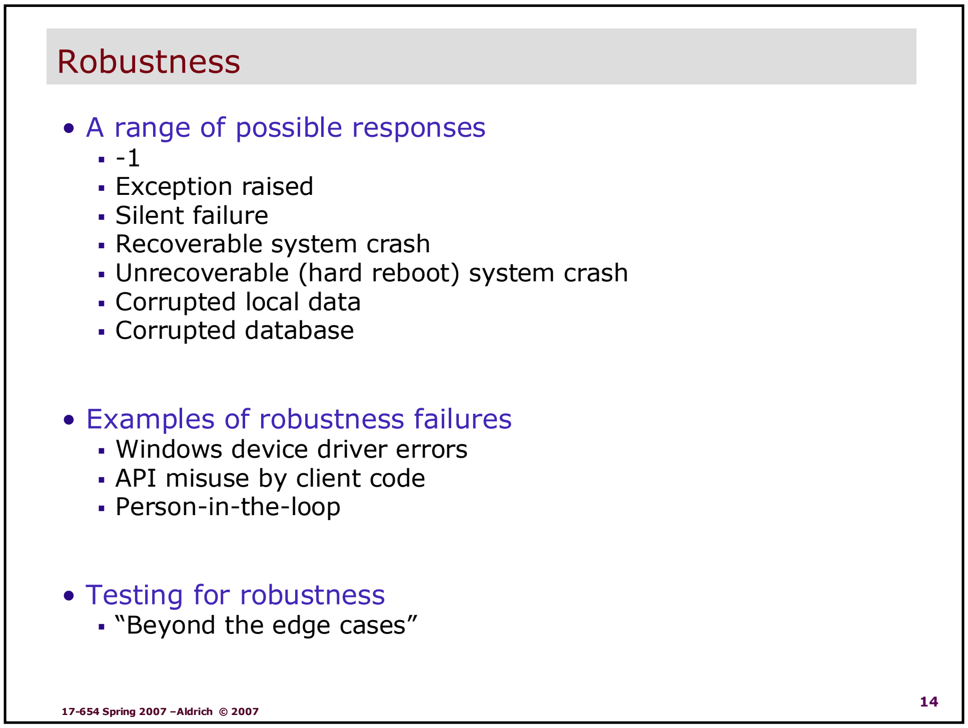
Fault Tolerance

- How does the system behave in the presence of errors in the environment
- Tolerating the faults of sensors, affectors, other physical components in a system
  - "Tolerating" means diminishing the likelihood or severity of **failure** in response to the **fault**
- Examples
  - Memory parity errors
  - Network transient faults
  - Sensor failures
  - Actuator anomalies
  - Processor transient faults



Robustness

- What happens when the system receives *incorrect* inputs?
  - Important for **security**
  - Examples:
    - Buffer under/overflow
    - Protocol violations
    - Null references
    - Precondition errors
  - “Fault tolerance” with respect to **design faults** in other software components.



Robustness

- A range of possible responses
  - -1
  - Exception raised
  - Silent failure
  - Recoverable system crash
  - Unrecoverable (hard reboot) system crash
  - Corrupted local data
  - Corrupted database
- Examples of robustness failures
  - Windows device driver errors
  - API misuse by client code
  - Person-in-the-loop
- Testing for robustness
  - “Beyond the edge cases”

Buffer overflow errors / exploits

```
#include
#define BUF_LEN 40
void main(int argc, char **argv)  {
    char buf[BUF_LEN];
    if (argv > 1)  {
        printf(“buffer length: %d \n parameter length: %d”,
                           BUF_LEN,              strlen(argv[1]) );
        strcpy(buf, argv[1]);
    }
}
```

```
% bad.exe   AAAABBBBCCCC
```

```
% bad.exe   AAAABBBBCCCCDDDDEEEEFFFFGGGGHHHHIIIIJJJJKKKKLLLLMMMM
```

What are the results of an input that is too long?

www.windowsecurity.com

Java buffer overflow

```
public class Bad {
  static final int bufLen = 40;
  public static void main (String argv[]) {
      char[] buf = new char[bufLen];
      if (argv.length >0) {
          int len = argv[0].length();
          char[] tmp = argv[0].toCharArray();

          System.out.println("buffer length: " + bufLen +
                             " parameter length: " + len);
          System.arraycopy(tmp, 0, buf, 0, len);
      }
  }
}
```

```
% java Bad AAAABBBBCCCCDDDDEEEEFFFFGGGGHHHHIIIIJJJJKKKKLLLLMMMM
```

```
buffer length: 40 parameter length: 52
java.lang.ArrayIndexOutOfBoundsException
   at java.lang.System.arraycopy(Native Method)
   at Bad.main(Bad.java:16)
Exception in thread "main"
```

Severity of failure is decreased relative to C

API and Framework Usage Errors

- Related to robustness errors

- **Aspects** of API and framework usage
  - Method call protocol (order of calls and state management)
  - Respect for callbacks (library is only caller)
  - Required set up and tear down
  - Aliasing (inappropriate object references)
  - Effects (inappropriate access or update to state)
  - Locking roles (e.g., caller must acquire a lock)
  - Use of threads (e.g., Java AWT)
  - Exception handling (e.g., correct handling of library exceptions)

- Key point
  - Many developers have difficulty in understanding and respecting the "bureaucracy" of an API

  - How to model?

  - How to assure?

API: Hello World MFC: "Easy as 1, 2, 3"

```
  int APIENTRY WinMain(<<CUT>>)
  {
    <<CUT>>
    // Perform application initialization:
❶   if (!InitInstance (hInstance, nCmdShow)) return FALSE;
❷   hAccelTable = LoadAccelerators(hInstance, (LPCTSTR)IDC_HELLO);
    // Main message loop:
❸   while (GetMessage(&msg, NULL, 0, 0))
    if (!TranslateAccelerator(msg.hwnd, hAccelTable, &msg)) {
      TranslateMessage(&msg); DispatchMessage(&msg);
    }
    <<CUT>>
  }
```

Program runs fine

API: Hello World MFC: or 2, 1, 3

Hello World!

```
  int APIENTRY WinMain(<<CUT>>)
  {
    <<CUT>>
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      TranslateMessage(&msg); DispatchMessage(&msg);
    }
    <<CUT>>
  }
```

Program runs fine

API: Hello World MFC: but not 2, 3, 1

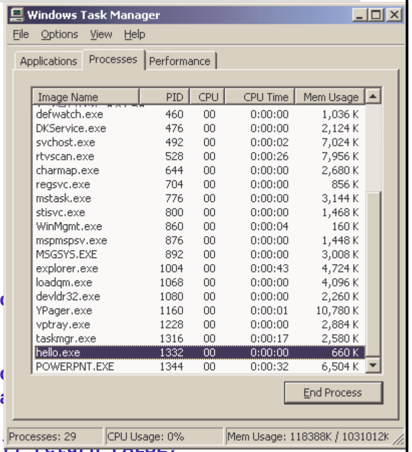

Image Name	PID	CPU	CPU Time	Mem Usage
defwatch.exe	460	00	0:00:00	1,036 K
DKService.exe	476	00	0:00:00	2,124 K
svchost.exe	492	00	0:00:02	7,024 K
rtvscan.exe	528	00	0:00:26	7,956 K
charmap.exe	644	00	0:00:00	2,680 K
regsvc.exe	704	00	0:00:00	856 K
mstask.exe	776	00	0:00:00	3,144 K
stisvc.exe	800	00	0:00:00	1,468 K
WinMgmt.exe	860	00	0:00:04	160 K
mspmspsv.exe	876	00	0:00:00	1,448 K
MSGSYS.EXE	892	00	0:00:00	3,008 K
explorer.exe	1004	00	0:00:43	4,724 K
loadqm.exe	1068	00	0:00:00	4,096 K
devldr32.exe	1080	00	0:00:00	2,260 K
YPager.exe	1160	00	0:00:01	10,780 K
vptray.exe	1228	00	0:00:00	2,884 K
taskmgr.exe	1316	00	0:00:17	2,580 K
hello.exe	1332	00	0:00:00	660 K
POWERPNT.EXE	1344	00	0:00:32	6,504 K

Processes: 29 | CPU Usage: 0% | Mem Usage: 118388K / 1031012k

```
  int APIENTRY WinMain(<<CUT>>)
  {
    <<CUT>>
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❷  hAccelTable = LoadAccelerators(hInstanc
    // Main message loop:
❸  while (GetMessage(&msg, NULL, 0, 0))
    if (!TranslateAccelerator(msg.hwnd, hAc
      TranslateMessage(&msg); DispatchMessa
    }
❶  if (!InitInstance (hInstance, nCmdShow)) return FALSE;
    <<CUT>>
  }
```

Lost process that must be killed from the Task Manager…
MFC Framework gives <u>no compile or runtime</u> help to identify this error

API: Hello World MFC: but not 2, 3, 1

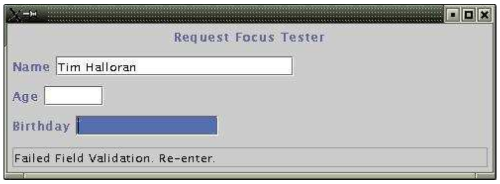
- Could MFC detect the incorrect use of the API?
  - Instead of:
```
hello.exe - 0 error(s), 0 warning(s)
```
  - We should get:
```
Error: GetMessage() called before InitInstance() – Illegal API use
hello.exe - 1 error(s), 0 warning(s)
```
  - Or at least:
```
Warning: GetMessage() called before InitInstance() – API warning
hello.exe - 0 error(s), 1 warning(s)
```

- Call order is a critical property for the API client
  - Typically verified by inspection
  - Model checking, typestate are emerging approaches

- A more robust design reduces severity of failure
  - In this case, by making it easier to identify the fix

API Bureaucracy *and* Usability

```
public void focusLost(FocusEvent fevt) {
  <<CUT>>
  if (fieldName.equals(AGE)) {
    try {
      int i = Integer.parseInt(val);
      status.setText("Age is Valid.");
    }
    catch (NumberFormatException nfe) {
      // FAILED VALIDATION
      // empty field
      tf.setText("");
      // get the focus back to try again
      tf.requestFocus();
      status.setText("Failed Field Validation. Re-enter.");
    }
  <<CUT>>
}
```



Request Focus Tester

Name: Tim Halloran

Age:

Birthday:

Failed Field Validation. Re-enter.

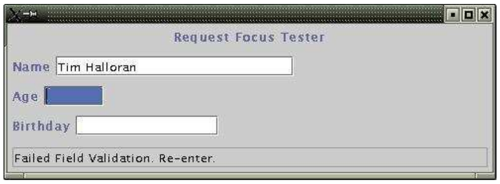
When a bad **age** is typed focus is not sent back to the “Age” field as the code requests. It goes to **birthday**.

Example from: http://www.javaworld.com/javaworld/jw-06-2001/jw-0622-traps.html?

API Bureaucracy *and* Usability

```
// get the focus back to try again
new FocusRequester(c); // c is the JTextField

class FocusRequester implements Runnable {
  private Component comp;
  public FocusRequester(Component comp) {
    this.comp = comp;
    try {
      SwingUtilities.invokeLater(this);
    }
    catch(Exception e) {
      e.printStackTrace();
    }
  }
  public void run() { comp.requestFocus(); }
}
```



Request Focus Tester

Name: Tim Halloran

Age:

Birthday:

Failed Field Validation. Re-enter.

Swing utility method invokeLater() used to "re-invoke" the **age** event correctly

Example from: http://www.javaworld.com/javaworld/jw-06-2001/jw-0622-traps.html?

Testing – The Big Questions

1. **What is testing?**
   - And why do we test?
2. **What do we test?**
   - Levels of structure: unit, integration, system…
3. **How do we select a set of good tests?**
   - Value-driven testing
   - Functional (black-box) testing
   - Structural (white-box) testing
4. **How do we assess our test suites?**
   - Coverage, Mutation, Capture/Recapture…
5. **Practices for testability**
   - What are known best test practices?
   - How does testing integrate into lifecycle and metrics?
6. **What are the limits of testing?**
   - What are complementary approaches?
     - *Inspections*
     - *Static and dynamic analysis*

1. Testing: What and Why

- What is testing?
  - Direct execution of code on test data in a controlled environment

- Goals of testing
  - To reveal failures
    - Most important goal of testing
  - To assess quality
    - Difficult to quantify, but still important
  - To clarify the specification
    - Always test with respect to a spec
    - Testing shows inconsistency
      - Either spec or program could be wrong
  - To learn about program
    - How does it behave under various conditions?
    - Feedback to rest of team goes beyond bugs
  - To verify contract
    - Includes customer, legal, standards

Testing is NOT to show correctness

- Theory: “Complete testing” is impossible
  - For realistic programs there is always untested input
  - The program may fail on this input

- Psychology: Test to find bugs, not to show correctness
  - Showing correctness: you fail when program does
  - Psychology experiment
    - People look for blips on screen
    - They notice more if rewarded for finding blips than if penalized for giving false alarms
  - Testing for bugs is more successful than testing for correctness
    - [Teasley, Leventhal, Mynatt & Rohlman]

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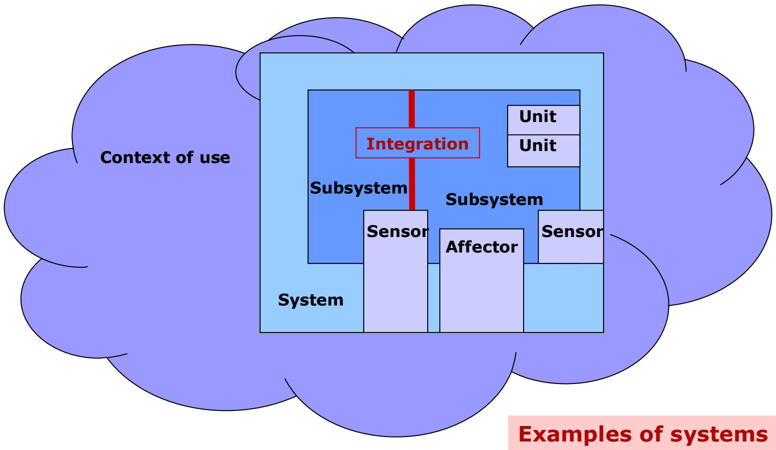
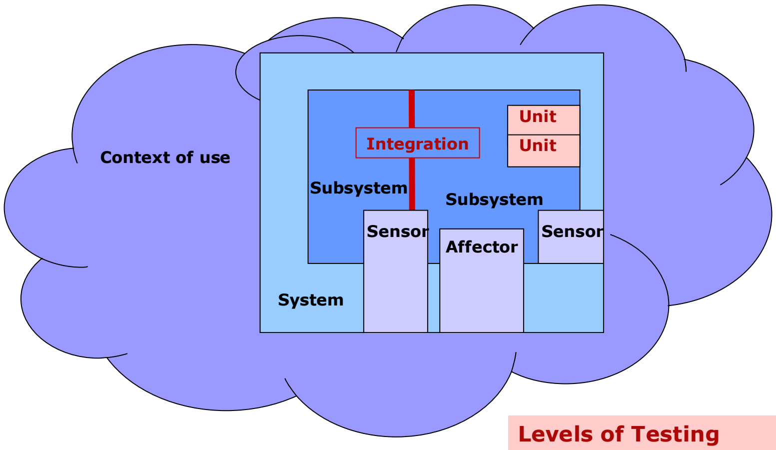
2. What do we test – the Focus of Concern



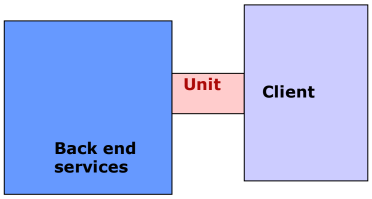
Examples of systems in context
- Mars rover
- Cell phone
- Clothes washing machine
- Point of sale system
- Telecom switch
- Software development tool

The Focus of Concern

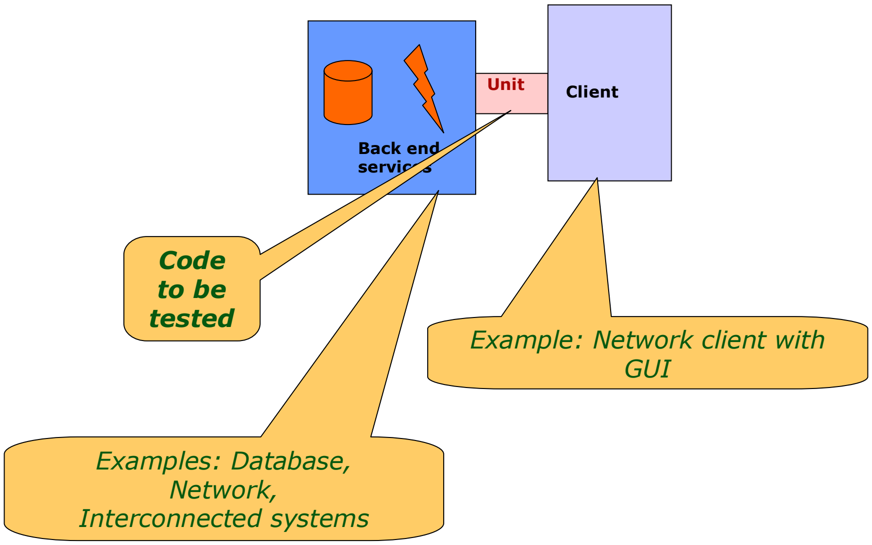


Levels of Testing
- User testing, field testing
- System testing
    - With or without hardware
- Integration testing
- Unit testing

Unit Test and Scaffolding



Unit Test and Scaffolding

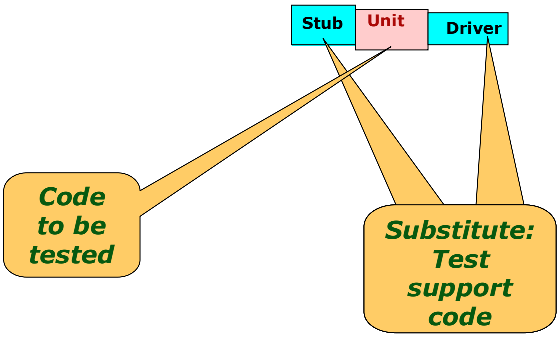


Code to be tested

Example: Network client with GUI

Examples: Database, Network, Interconnected systems

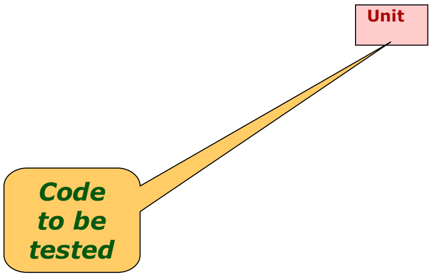
Unit Test and Scaffolding



Code to be tested

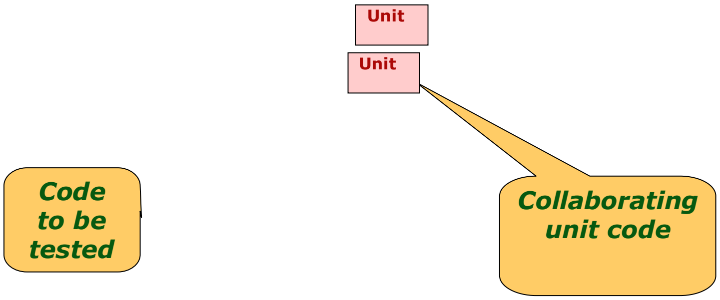
Substitute: Test support code

Unit Test and Scaffolding



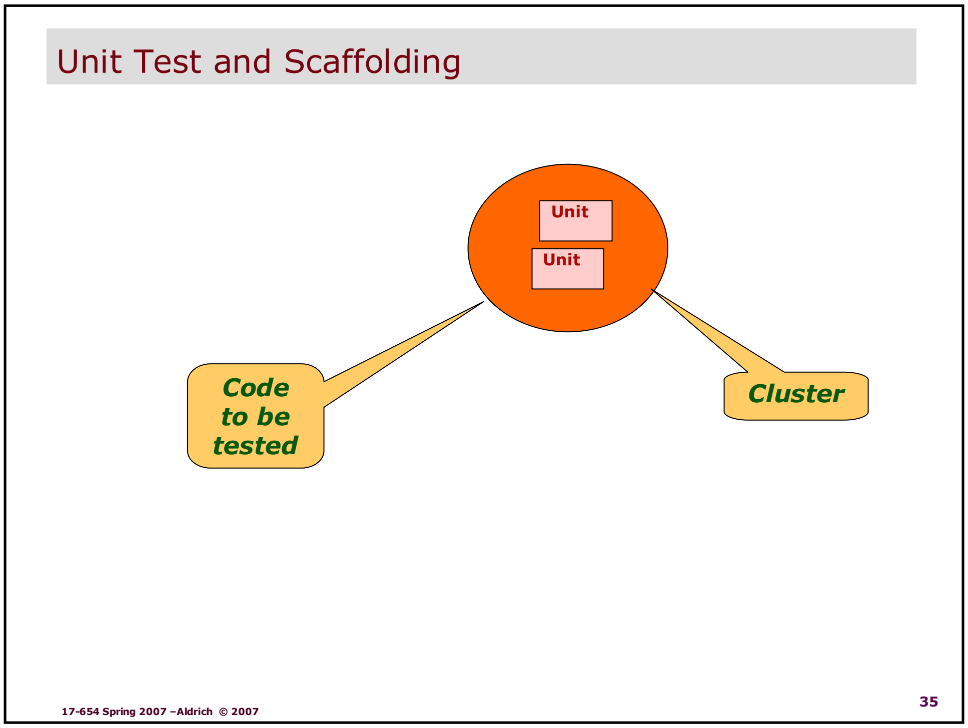
Code to be tested

Unit Test and Scaffolding



Code to be tested

Collaborating unit code



Unit Test and Scaffolding

Unit

Unit

Code to be tested

Cluster

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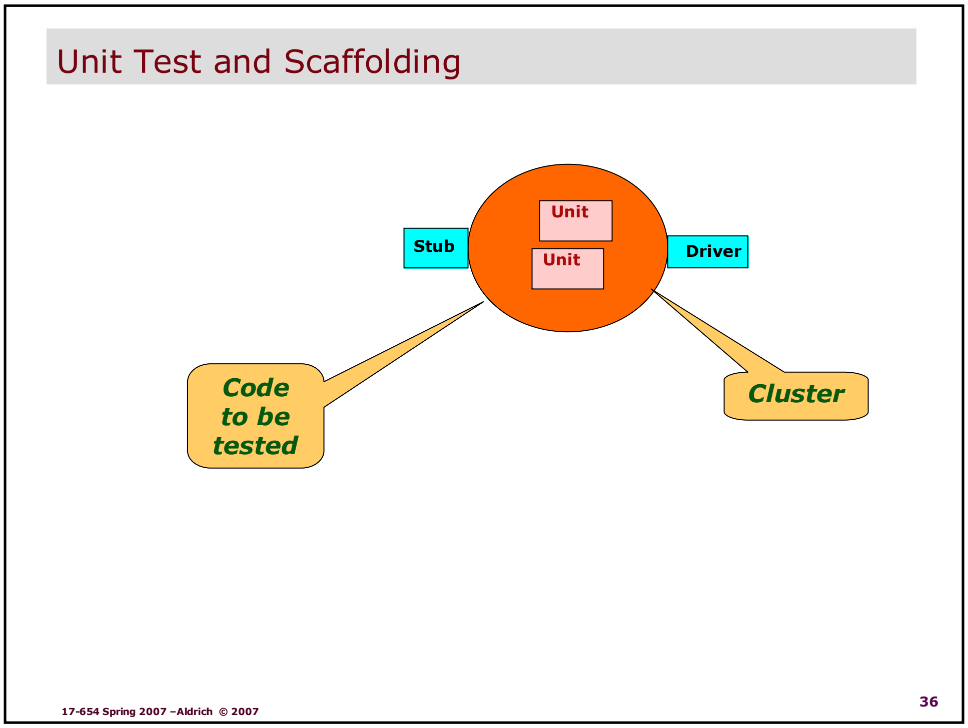

Unit Test and Scaffolding

Stub

Unit

Unit

Driver

Code to be tested

Cluster

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Unit Test for Components

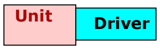
- Unit testing
  - Separate testing of individual components of a system
- Purpose
  - Catch bugs early
  - Improve coverage
  - Validate internal interface/API designs
  - Catch bugs before code is written
    - Use test suites to guide implementation
    - Test components before client/service code is available
- Done by development teams
  - Original component developer
  - Tester / collaborator
- Integration testing
  - Test groups of interacting components
    - Exercise interactions among code components
    - Test in context of portions of the real environment
  - Same techniques and tools as for unit testing

Techniques for Unit Testing 1: Scaffolding

- Use “scaffold” to simulate external code
- External code – scaffold points
  1. Client code
  2. Underlying service code

1. Client API
   - Model the software client for the service being tested
   - Create a **test driver**
   - Object-oriented approach:
     - Test individual calls and sequences of calls

Testers write driver code



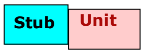
Techniques for Unit Testing 1: Scaffolding

- Use “scaffold” to simulate external code

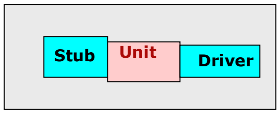
- External code – scaffold points
  1. Client code
  2. Underlying service code

2. Service code
   - Underlying services
     - Communication services
       - Model behavior through a communications i
       - Database queries and transactions
     - Network/web transactions
     - Device interfaces
       - Simulate device behavior and failure modes
     - File system
       - Create file data sets
       - Simulate file system corruption
     - *Etc*
   - Create a set of **stub** services or **mock** objects
     - *Minimal* representations of APIs for these services

Testers write stub code



Scaffolding



- Purposes
  - Catch bugs early
    - Before client code or services are available
  - Limit the scope of debugging
    - Localize errors
  - Improve coverage
    - System-level tests may only cover 70% of code [Massol]
    - Simulate unusual error conditions – test internal robustness
  - Validate internal interface/API designs
    - Simulate clients in advance of their development
    - Simulate services in advance of their development
  - Capture developer intent (in the absence of specification documentation)
    - A test suite formally captures elements of design intent
    - Developer documentation
  - Enable division of effort
    - Separate development / testing of service and client
  - Improve low-level design
    - Early attention to ability to test – “testability”

Testing – The Big Questions

1. **What is testing?**
   - And why do we test?
2. **What do we test?**
   - Levels of structure: unit, integration, system…
3. **How do we select a set of good tests?**
   - Value-driven testing
   - Functional (black-box) testing
   - Structural (white-box) testing
4. **How do we assess our test suites?**
   - Coverage, Mutation, Capture/Recapture…
5. **Practices for testability**
   - What are known best test practices?
   - How does testing integrate into lifecycle and metrics?
6. **What are the limits of testing?**
   - What are complementary approaches?
     - *Inspections*
     - *Static and dynamic analysis*

What makes a test case valuable?

- Value-driven testing
  - Focus on tests that have biggest benefit per unit cost
- Value is driven by quality improvement
  - Some value of information as well
- Value Factors
  - Does it find a bug?
  - How severe is the bug?
  - How common is the bug?
  - How easy is it to fix the bug?
  - Is it distinct from other tests?
    - Unique bug? Unique code? Unique domain coverage?
  - How general is it?
  - What did we learn about the program?
- Much of this is hard to predict in advance!

3. How do we select a set of good tests

- **Test coverage**
  - Why “coverage”?
    - All inputs cannot be tested.
  - Consider strategy for testing these systems:
    - Visual Studio, Eclipse, etc.
    - Automotive navigation/communication system – with many configurations
    - An operating system
    - An e-commerce container framework (J2EE, .net) and its components
  - Only very rarely can we test exhaustively.
    - Deterministic embedded controllers

Test coverage – Ideal and Real

- An **Ideal** Test Suite
  - Uncovers all errors in code
    - That are detectable through testing
  - Uncovers all errors in requirements capture
    - All scenarios covered
    - Non-functional attributes: performance, code safety, security, etc.
  - Minimum size and complexity
  - Uncovers errors early in the process
    - Ideally when code is being written (“test cases first”)

- A **Real** Test Suite
  - Uncovers some portion of errors in code
  - Has errors of its own
  - Assists in exploratory testing for validation
  - Does not help very much with respect to non-functional attributes
  - Includes many regression tests
    - Inserted after errors are repaired to ensure they won’t reappear

Ways of analyzing coverage

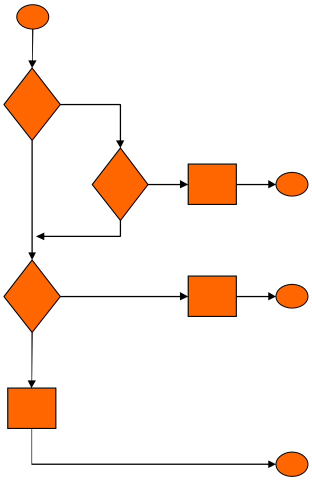
- Code visibility – **glass box** *or* **white box**
  - Visibility to internal code elements – better for non-functional attributes
  - *Can use design information to guide creation and analysis of test suites*
  - Can test internal elements directly

  - **Code coverage analysis**

- Code visibility – **black box**
  - Cannot see internal code elements of the service being tested
  - Test through the public API – better for functional attributes

  - **Domain coverage analysis**

White Box: Statement Coverage

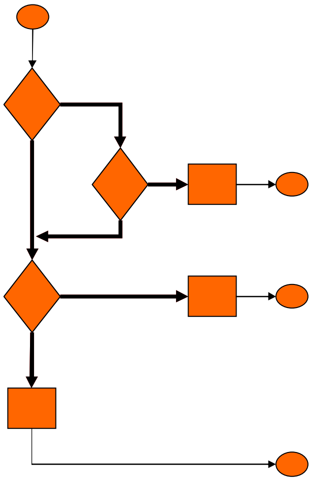


- **Statement coverage**
  - What portion of program statements (nodes) are touched by test cases

- Advantages
  - Test suite size linear in size of code
  - Coverage easily assessed

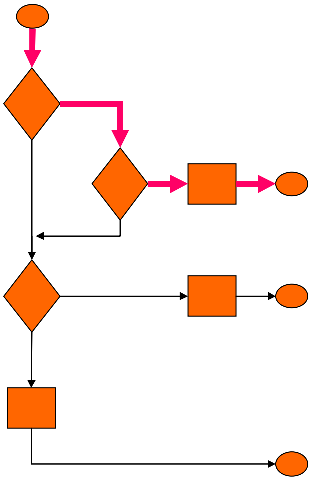
- Issues
  - Dead code is not reached
  - May require some sophistication to select input sets (McCabe basis paths)
  - Fault-tolerant error-handling code may be difficult to "touch"
  - Metric: Could create incentive to *remove* error handlers!

White Box: Branch Coverage



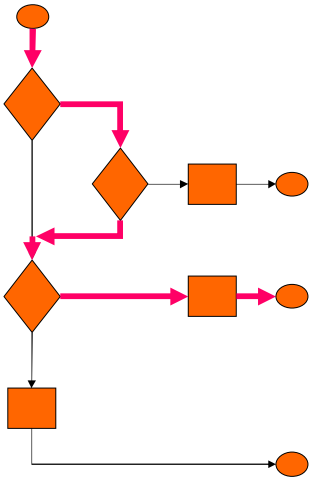
- **Branch coverage**
  - What portion of condition branches are covered by test cases?
  - *Or:* What portion of relational expressions and values are covered by test cases?
    - Condition testing (Tai)
  - **Multicondition coverage** – all boolean combinations of tests are covered
- Advantages
  - Test suite size and content derived from structure of boolean expressions
  - Coverage easily assessed
- Issues
  - Dead code is not reached
  - Fault-tolerant error-handling code may be difficult to "touch"

White Box: Path Coverage



- **Path coverage**
  - What portion of all possible paths through the program are covered by tests?
  - Loop testing: Consider representative and edge cases:
    - Zero, one, two iterations
    - If there is a bound n: n-1, n, n+1 iterations
    - Nested loops/conditionals from inside out
- Advantages
  - Better coverage of logical flows
- Disadvantages
  - Not all paths are possible, or necessary
    - What are the *significant* paths?
  - Combinatorial explosion in cases unless careful choices are made
    - E.g., sequence of *n* **if** tests can yield up to 2^n possible paths
  - Assumption that program structure is basically sound

White Box: Path Coverage



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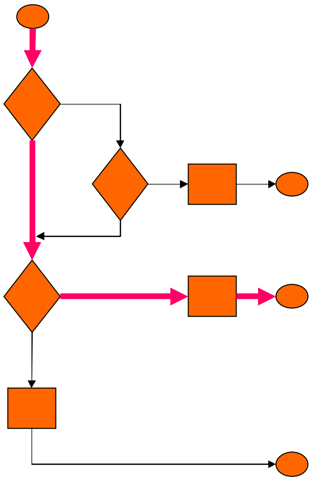

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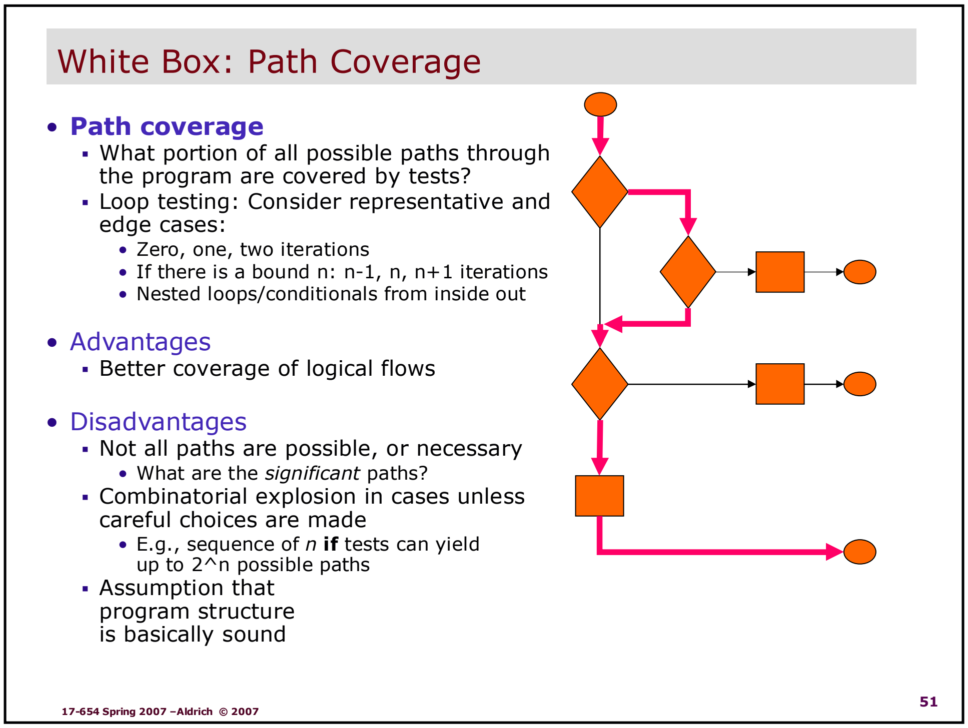

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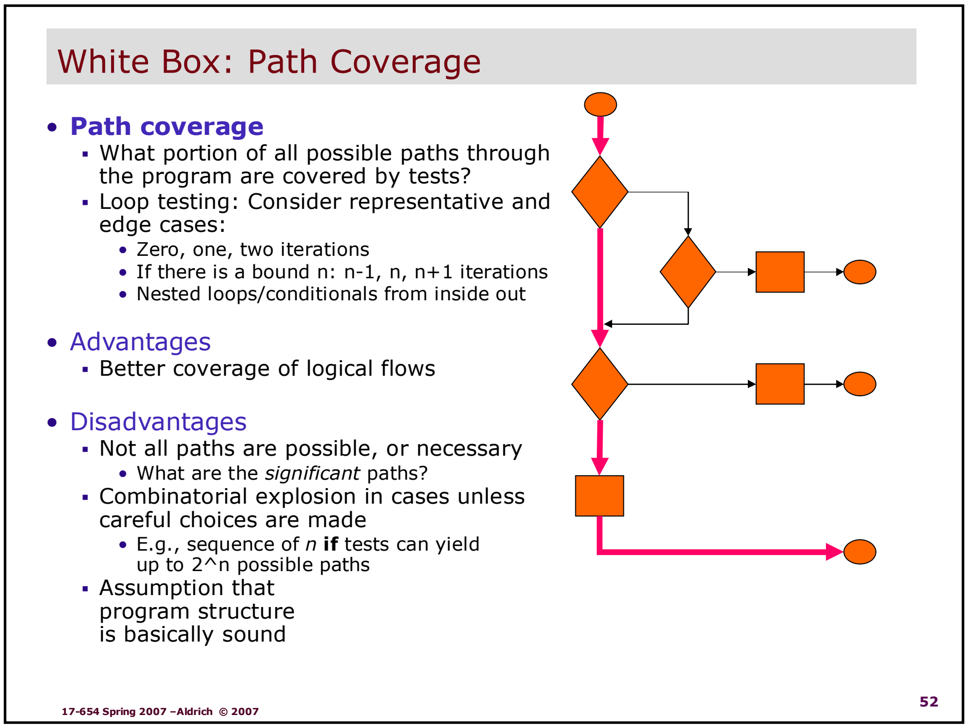

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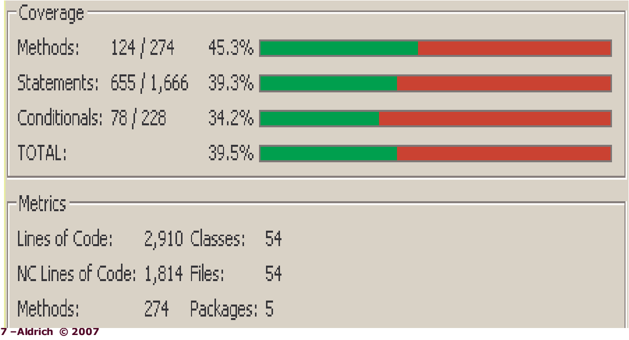
White Box: Assessing structural coverage

- Coverage assessment tools
  - Track execution of code by test cases
  - Techniques
    - Modified runtime environment (e.g., special JVM)
    - Source code transformation
- Count visits to statements
  - Develop reports with respect to specific coverage criteria
- Example: Clover tool for JUnit tests



Coverage

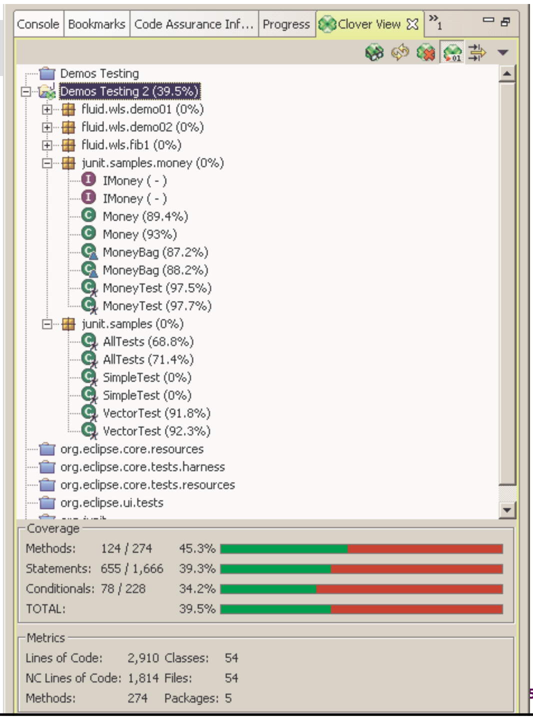
Methods:	124 / 274	45.3%	
Statements:	655 / 1,666	39.3%	
Conditionals:	78 / 228	34.2%	
TOTAL:		39.5%	

Metrics

Lines of Code:	2,910	Classes:	54
NC Lines of Code:	1,814	Files:	54
Methods:	274	Packages:	5

Clover in Eclipse

- Breakdown by package and class
- Coverage
  - Methods
  - Statements
  - Conditionals
- Some metric data
  - LOC
  - Class count
  - Method count



Demos Testing
Demos Testing 2 (39.5%)
  fluid.wls.demo01 (0%)
  fluid.wls.demo02 (0%)
  fluid.wls.fib1 (0%)
  junit.samples.money (0%)
    IMoney (-)
    IMoney (-)
    Money (89.4%)
    Money (93%)
    MoneyBag (87.2%)
    MoneyBag (88.2%)
    MoneyTest (97.5%)
    MoneyTest (97.7%)
  junit.samples (0%)
    AllTests (68.8%)
    AllTests (71.4%)
    SimpleTest (0%)
    SimpleTest (0%)
    VectorTest (91.8%)
    VectorTest (92.3%)
org.eclipse.core.resources
org.eclipse.core.tests.harness
org.eclipse.core.tests.resources
org.eclipse.ui.tests

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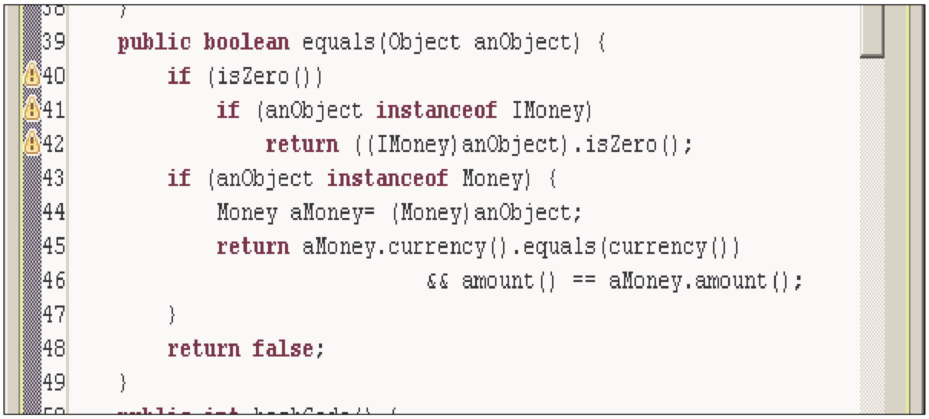
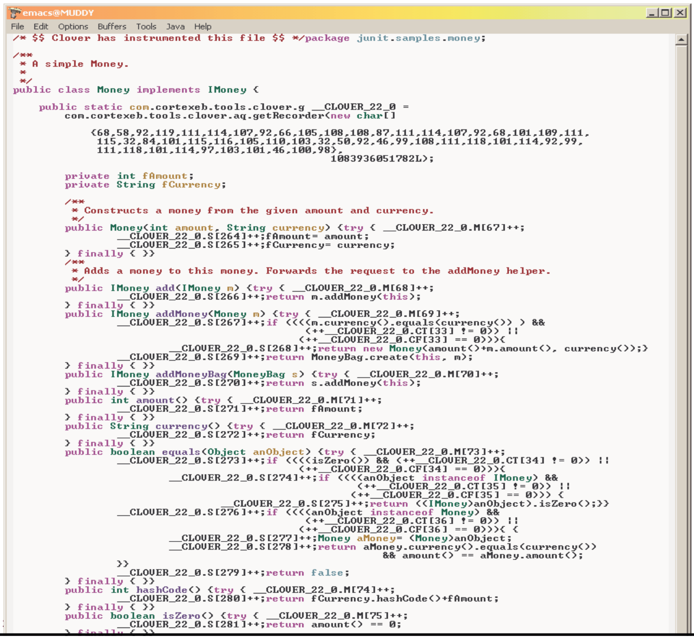
Clover in Eclipse

- Coverage report in editor window
  - Warning for statements not covered by test cases



```
    }
    public boolean equals(Object anObject) {
        if (isZero())
            if (anObject instanceof IMoney)
                return ((IMoney)anObject).isZero();
        if (anObject instanceof Money) {
            Money aMoney= (Money)anObject;
            return aMoney.currency().equals(currency())
                                && amount() == aMoney.amount();
        }
        return false;
    }
    public int hashCode() {
```

Transformed Source Code



```
/* $$ Clover has instrumented this file $$ */package junit.samples.money;

/**
 * A simple Money.
 *
 */
public class Money implements IMoney {

    public static com.cortexeb.tools.clover.g __CLOVER_22_0 =
        com.cortexeb.tools.clover.aq.getRecorder(new char[]

            {68,58,92,119,111,114,107,92,66,105,108,108,87,111,114,107,92,68,101,109,111,
             115,32,84,101,115,116,105,110,103,32,50,92,46,99,108,111,118,101,114,92,99,
             111,118,101,114,97,103,101,46,100,98},
                                                     1083936051782L);

        private int fAmount;
        private String fCurrency;

        /**
         * Constructs a money from the given amount and currency.
         */
        public Money(int amount, String currency) {try { __CLOVER_22_0.M[67]++;
                __CLOVER_22_0.S[264]++;fAmount= amount;
                __CLOVER_22_0.S[265]++;fCurrency= currency;
        } finally { }}
        /**
         * Adds a money to this money. Forwards the request to the addMoney helper.
         */
        public IMoney add(IMoney m) {try { __CLOVER_22_0.M[68]++;
                __CLOVER_22_0.S[266]++;return m.addMoney(this);
        } finally { }}
        public IMoney addMoney(Money m) {try { __CLOVER_22_0.M[69]++;
                __CLOVER_22_0.S[267]++;if ((((m.currency().equals(currency()) ) &&
                                             (++__CLOVER_22_0.CT[33] != 0)) ||
                                            (++__CLOVER_22_0.CF[33] == 0))){
                        __CLOVER_22_0.S[268]++;return new Money(amount()+m.amount(), currency());}
                __CLOVER_22_0.S[269]++;return MoneyBag.create(this, m);
        } finally { }}
        public IMoney addMoneyBag(MoneyBag s) {try { __CLOVER_22_0.M[70]++;
                __CLOVER_22_0.S[270]++;return s.addMoney(this);
        } finally { }}
        public int amount() {try { __CLOVER_22_0.M[71]++;
                __CLOVER_22_0.S[271]++;return fAmount;
        } finally { }}
        public String currency() {try { __CLOVER_22_0.M[72]++;
                __CLOVER_22_0.S[272]++;return fCurrency;
        } finally { }}
        public boolean equals(Object anObject) {try { __CLOVER_22_0.M[73]++;
                __CLOVER_22_0.S[273]++;if ((((isZero()) && (++__CLOVER_22_0.CT[34] != 0)) ||
                                            (++__CLOVER_22_0.CF[34] == 0))){
                        __CLOVER_22_0.S[274]++;if ((((anObject instanceof IMoney) &&
                                                     (++__CLOVER_22_0.CT[35] != 0)) ||
                                                    (++__CLOVER_22_0.CF[35] == 0))) {
                                __CLOVER_22_0.S[275]++;return ((IMoney)anObject).isZero();}}
                __CLOVER_22_0.S[276]++;if ((((anObject instanceof Money) &&
                                             (++__CLOVER_22_0.CT[36] != 0)) ||
                                            (++__CLOVER_22_0.CF[36] == 0))){ {
                        __CLOVER_22_0.S[277]++;Money aMoney= (Money)anObject;
                        __CLOVER_22_0.S[278]++;return aMoney.currency().equals(currency())
                                                         && amount() == aMoney.amount();
                }}
                __CLOVER_22_0.S[279]++;return false;
        } finally { }}
        public int hashCode() {try { __CLOVER_22_0.M[74]++;
                __CLOVER_22_0.S[280]++;return fCurrency.hashCode()+fAmount;
        } finally { }}
        public boolean isZero() {try { __CLOVER_22_0.M[75]++;
                __CLOVER_22_0.S[281]++;return amount() == 0;
        } finally { }}
```

White Box Testing: Checkpoints

- Use “checkpoints” in code
  - Access to intermediate values
  - Enable checks *during* execution

Three approaches

- Logging
  - Create a log record of internal events
  - Tools to support
    - java.util.Logging
    - org.apache.log4j
  - Log records can be analyzed for patterns of events
    - Listener events
    - Protocol events
    - *Etc.*
- Assertions
  - Logical statements explicitly checked during test runs
  - (No side effects on program variables)
  - Check data integrity
    - Absence of null pointer
    - Array bounds
    - *Etc.*
- Breakpoints
  - Provide interactive access to intermediate state when a condition is raised

Benefits of White-Box

- Tool support can measure coverage
  - Helps to evaluate test suite (careful!)
  - Can find untested code
- Can test program one part at a time
- Can consider code-related boundary conditions
  - If conditions
  - Boundaries of function input/output ranges
    - e.g. switch between algorithms at data size=100

White Box: Limitations

- Is it possible to achieve 100% coverage?

- Can you think of a program that has a defect, even though it passes a test suite with 100% coverage?

- Exclusive focus on coverage focus misses important bugs
  - Missing code
  - Incorrect boundary values
  - Timing problems
  - Configuration issues
  - Data/memory corruption bugs
  - Usability problems
  - Customer requirements issues

- Coverage is not a good adequacy criterion
  - Instead, use to find places where testing is *inadequate*

Black-Box (Functional) Testing

- Verify each piece of functionality of the system
  - Black-box: don’t look at the code
  - More common in practice than white-box
- Benefit: finds bugs white-box doesn’t
  - Think like a user, not a programmer
    - The programmer already checked the code!
  - Timing, unanticipated errors, UI, concurrency, configuration issues, performance, hardware failures
- Drawbacks
  - No insight into code structure
  - But good testers will guess anyway!

Black Box: Representative Values

- *Test cases have a statistical distribution similar to expected inputs*
  - Keep generating random inputs until coverage criterion is met
  - Challenge: Do we have a model for the expected input set?

Black Box: Equivalence Class Testing

- Equivalence classes
  - A partition of a set
    - Usually the input domain of the program
  - Based on some equivalence relation
    - Intuition: all inputs in an equivalence class will fail or succeed in the same way

Equivalence Class Example

- Program Specification
    - Given 3 numbers, output whether a triangle formed from these number is equilateral, isosceles, or scalene
- Equivalence classes?

Finding Equivalence Classes

- Intuition that test cases are similar
    - This is useful, but can be incomplete
- Use cases in the specification
    - Impractical if you don’t have the spec
    - What if the spec is incomplete?
- One class per code path
    - Impractical if you don’t have code
- Risk-based
    - Consider a possible error as a risk
    - Given that error, what test cases will produce the same result?

Equivalence Class Hueristics

- Invalid inputs
- Ranges of numbers
- Membership in a group
- Equivalent outputs
  - Can you force the program to output an invalid or overflow value?
- Error messages
- Equivalent operating environments

What value to choose from an Equivalence Class?

- **Risk-based**
  - *Consider the cost of consequences*
    - Vs. frequency of occurrence
    - Focus test data around potential high-impact failures

Risk = (cost of consequence) * (probability of occurrence)

  - Challenge: How to model this set of high-consequence failures?
  - Selection heuristic – consider boundary values
    - Extreme or unique cases at or around "boundaries" with respect to preconditions or program decision points
      - *Examples*: zero-length inputs, very long inputs, null references, etc.
    - Will usually find errors that are present in any other member of the equivalence class, but may find off-by-one errors as well
  - Suited to **black box** and **white box**
  - **Input**: Information regarding fault/failure relationships
  - **Input**: Information regarding boundary cases
    - Requirements
    - Implementation

Robustness Testing

- *Test erroneous inputs and boundary cases*
    - Assess consequences of misuse or other failure to achieve preconditions

Java

```
public static int binsrch (int[] a, int key) {

    int low  = 0;
    int high = a.length - 1;

    while (true) {

        if ( low > high ) return -(low+1);

        int mid = (low+high) / 2;

        if      ( a[mid] < key )  low  = mid + 1;
        else if ( a[mid] > key )  high = mid - 1;
        else    return mid;
    }
}
```

What if the array reference a is null?

Robustness Testing

- *Test erroneous inputs and boundary cases*
    - Assess consequences of misuse or other failure to achieve preconditions
    - Bad use of API
    - Bad program input data
    - Bad files (e.g., corrupted) and bad communication connections
    - Buffer overflow (security exploit) is a robustness failure
        - Triggered by deliberate misuse of an interface.
- Test apparatus needs to be able to catch and recover from crashes and other hard errors
    - Sometimes multiple inputs need to be at/beyond boundaries
- The question of responsibility
    - Is there external assurance that preconditions will be respected?
    - *This is a design commitment that must be considered explicitly*

`a[mid]`

What if the array reference a is null?

Triangle Example

- Program Specification
  - Given 3 numbers, output whether a triangle formed from these number is equilateral, isosceles, or scalene
- Boundary tests?
- Robustness tests?

Combination Testing

- Some errors might be triggered only if two or more variables are at boundary values
- Test combinations of boundary values
  - Combinations of valid input
  - One invalid input at a time
    - In many cases no added value for multiple invalid inputs
- Subtlety required
  - What are the boundary cases for an application that deals with months and days?

Protocol Testing

- **Object protocols**
  - Develop test cases that involve representative sequence of operations on objects
    - Example: Dictionary structure
      - Create, AddEntry*, Lookup, ModifyEntry*, DeleteEntry, Lookup, Destroy
    - Example: IO Stream
      - Open, Read, Read, Close, Read, Open, Write, Read, Close, Close
  - Test concurrent access from multiple threads
    - Example: FIFO queue for events, logging, etc.

Create	**Put**	**Put**	**Get**	**Get**		
	Put	**Get**	**Get**	**Put**	**Put**	**Get**

- Approach
  - Develop representative sequences – based on use cases, scenarios, profiles
  - Randomly generate call sequences
    - Example: Account
      - Open, Deposit, Withdraw, Withdraw, Deposit, Query, Withdraw, Close
  - Coverage: Conceptual states
- Also useful for protocol interactions within distributed designs

Testing example

```
public static int binsrch (int[] a, int key) {

    int low  = 0;
    int high = a.length - 1;

    while (true) {

        if ( low > high ) return -(low+1);

        int mid = (low+high) / 2;

        if      ( a[mid] < key )  low  = mid + 1;
        else if ( a[mid] > key )  high = mid - 1;
        else    return mid;
    }
}
```

- Test **preparation**
  - Client scaffold
  - Failure recovery: exceptions
- Test case **selection**
  - *Expected* cases
    - key found
    - key not found
  - *Extreme* cases
    - empty array
    - singleton array
    - large array
  - *"Sub-unit" testing*
    - ordering relation over domain (…)
  - *Non-functional* testing
    - Performance measurement
      - Expectation: algorithmic analysis
      - Broken code: can yield a linear-time implementation vs. log-time
        - E.g., 1m elements: 20 steps vs. 1,000,000 steps
- **Coverage** analysis
  - Statement, branch, path coverage
  - Data coverage
- **Static analysis** and **inspection**
  - Initialization; array bounds; arithmetic exceptions; coding style

Testing – The Big Questions

1. **What is testing?**
   - And why do we test?
2. **What do we test?**
   - Levels of structure: unit, integration, system…
3. **How do we select a set of good tests?**
   - Value-driven testing
   - Functional (black-box) testing
   - Structural (white-box) testing
4. **How do we know when we're done?**
   - Coverage, Mutation, Capture/Recapture…
5. **Practices for testability**
   - What are known best test practices?
   - How does testing integrate into lifecycle and metrics?
6. **What are the limits of testing?**
   - What are complementary approaches?
     - *Inspections*
     - *Static and dynamic analysis*

When are you done testing?

When are you done testing?

- Coverage criterion
  - Must reach X% coverage
    - Legal requirement to have 100% coverage for avionics software
    - Drawback: focus on 100% coverage can distort the software so as to avoid any unreachable code
- Can look at historical data
  - How many bugs are remaining, based on matching current project to past experience?
  - Key question: is the historical data applicable to a new project?
- Can use statistical models
  - Test on a realistic distribution of inputs, measure % of failed tests
    - Ship product when quality threshold is reached
  - Only as good as your characterization of the input
    - Usually, there’s no good way to characterize this
    - Exception: stable systems for which you have empirical data (telephones)
    - Exception: good mathematical model (avionics)
- Rule of thumb: when error detection rate drops
  - Implies diminishing returns for testing investment

When are you done testing?

- **Mutation testing**
  - *Perturb code slightly in order to assess sensitivity*
  - Focus on low-level design decisions
    - Examples:
      - Change “<“ to “>”
      - Change “0” to “1”
      - Change “≤“ to “<“
      - Change “argv” to “argx”
      - Change “a.append(b)” to “b.append(a)”
- Assess effectiveness of test suite
  - How many seeded defects are found?
    - coverage metric
  - Principle: % of mutants not found ~ % of errors not found
    - Is this really true?
    - Depends on how well mutants match real errors
      - Some evidence of similarity (e.g. off by one errors) but clearly imperfect

When are you done inspecting?

- Capture/Recapture assessment
  - Most applicable for assessing inspections
  - Measure overlap in defects found by different inspectors
  - Use overlap to estimate number of defects not found
- Example
  - Inspector A finds n1=10 defects
  - Inspector B finds n2=8 defects
  - m = 5 defects found by both A and B
  - N is the (unknown) number of defects in the software
- Lincoln-Petersen analysis [source: Wikipedia]
  - Consider just the 10 (total) defects found by A
  - Inspector B found 5 of these 10 defects
  - Therefore the probability that inspector B finds a given defect is 5/10 or 50%
  - So, inspector B should have found 50% of the N defects in the software, so

N = n1 * n2 / m = 10 * 8 / 5 = 20 defects

- Assumptions
  - All defects are equally easy to find
  - All inspectors are equally effective at finding defects
  - Are these realistic?

When are you done testing?

- Most common
  - Run out of time or money
- Ultimately a judgment call
  - Resources available
  - Schedule pressures
  - Available estimates of quality

Testing – The Big Questions

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   - Value-driven testing
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   - Coverage, Mutation, Capture/Recapture…
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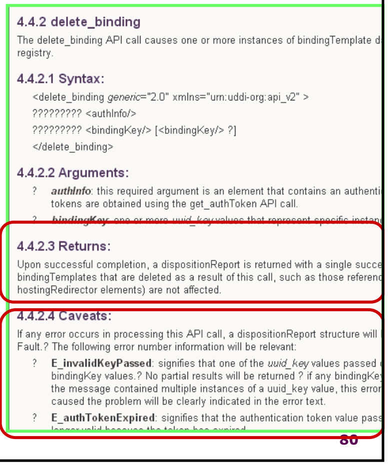
   - What are known best test practices?
   - How does testing integrate into lifecycle and metrics?
6. **What are the limits of testing?**
   - What are complementary approaches?
     - *Inspections*
     - *Static and dynamic analysis*

5a. Practices for testability

1. Document interfaces
   - Write down explicit "rules of the road" at interfaces, APIs, etc

- Design by contract
  - Specify a contract between service **client** and its **implementation**
    - System works if both parties fulfill their contract
    - Use pre- and post-conditions, etc
- Testing
  - Verify pre- and post-conditions during execution
    - Important Limitation
      - Not all logical formulas can be evaluated directly (forall x in S…)
  - Assign responsibility based on contract expectations
  - Executions become a set of unit tests



4.4.2 delete_binding

The delete_binding API call causes one or more instances of bindingTemplate d
registry.

4.4.2.1 Syntax:

```
<delete_binding generic="2.0" xmlns="urn:uddi-org:api_v2" >
????????? <authInfo/>
????????? <bindingKey/> [<bindingKey/> ?]
</delete_binding>
```

4.4.2.2 Arguments:

? ***authInfo***: this required argument is an element that contains an authenti
tokens are obtained using the get_authToken API call.

? ***bindingKey***: one or more *uuid_key* values that represent specific instanc

4.4.2.3 Returns:

Upon successful completion, a dispositionReport is returned with a single succe
bindingTemplates that are deleted as a result of this call, such as those referenc
hostingRedirector elements) are not affected.

4.4.2.4 Caveats:

If any error occurs in processing this API call, a dispositionReport structure will
Fault.? The following error number information will be relevant:

? **E_invalidKeyPassed**: signifies that one of the *uuid_key* values passed
bindingKey values.? No partial results will be returned ? if any bindingKey
the message contained multiple instances of a uuid_key value, this error
caused the problem will be clearly indicated in the error text.

? **E_authTokenExpired**: signifies that the authentication token value pass
longer valid because the token has expired.

5a. Integration/System Testing

2. Do incremental integration testing
    - Test several modules together
    - Still need scaffolding for modules not under test

- Avoid "big bang" integrations
    - Going directly from unit tests to whole program tests
    - Likely to have many big issues
    - Hard to identify which component causes each

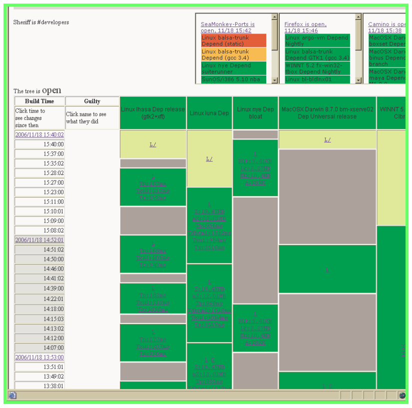
- Test interactions between modules
    - Ultimately leads to end-to-end system test

- Used focused tests
    - Set up subsystem for test
    - Test specific subsystem- or system-level features
        - no "random input" sequence
    - Verify expected output

5a. Frequent (Nightly) Builds

3. Build a release of a large project every night
    - Catches integration problems where a change "breaks the build"
        - Breaking the build is a BIG deal—may result in midnight calls to the responsible engineer
    - Use test automation
        - Upfront cost, amortized benefit
        - Not all tests are easily automated – manually code the others

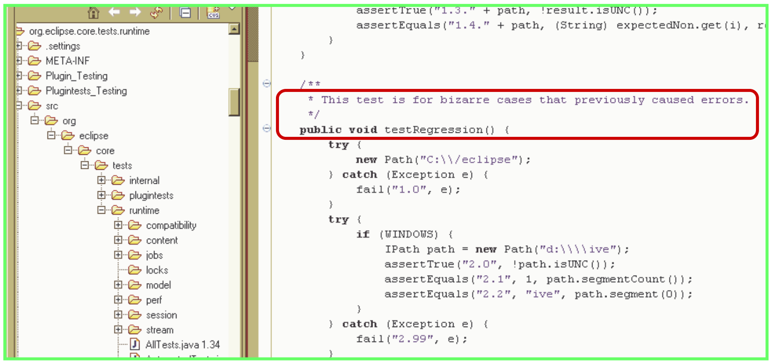
- Run simplified "smoke test" on build
    - Tests basic functionality and stability
    - Often: run by programmers before check-in
    - Provides rough guidance prior to full integration testing



Practices –Regressions

4. Use regression tests
    - Regression tests: run every time the system changes

- Goal: catch new bugs introduced by code changes
    - Check to ensure fixed bugs stay fixed
        - New bug fixes often introduce new issues/bugs
    - Incrementally add tests for new functionality



```
                assertTrue("1.3." + path, !result.isUNC());
                assertEquals("1.4." + path, (String) expectedNon.get(i), r
            }
    }

    /**
     * This test is for bizarre cases that previously caused errors.
     */
    public void testRegression() {
        try {
            new Path("C:\\/eclipse");
        } catch (Exception e) {
            fail("1.0", e);
        }
        try {
            if (WINDOWS) {
                IPath path = new Path("d:\\\\ive");
                assertTrue("2.0", !path.isUNC());
                assertEquals("2.1", 1, path.segmentCount());
                assertEquals("2.2", "ive", path.segment(0));
            }
        } catch (Exception e) {
            fail("2.99", e);
        }
```

Practices – Acceptance, Release, Integrity Tests

5. Acceptance tests (by customer)
    - Tests used by customer to evaluate quality of a system
    - Typically subject to up-front negotiation

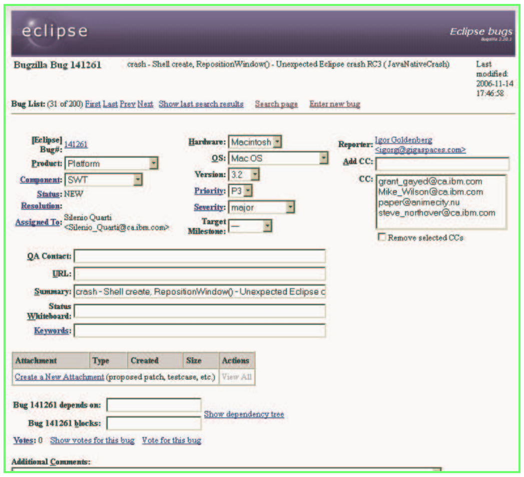
6. Release Test (by provider, vendor)
    - Test release CD
        - Before manufacturing!
    - Includes configuration tests, virus scan, etc
    - Carry out entire install-and-run use case

7. Integrity Test (by vendor or third party)
    - Independent evaluation before release
    - Validate quality-related claims
    - Anticipate product reviews, consumer complaints
    - Not really focused on bug-finding

Practices: Reporting Defects

8. Develop good defect reporting practices

- Reproducible defects
  - Easier to find and fix
  - Easier to validate
    - Built-in regression test
  - Increased confidence
- Simple and general
  - More value doing the fix
  - Helps root-cause analysis
- Non-antagonistic
  - State the problem
  - Don't blame



Bugzilla Bug 141261 crash - Shell create, RepositionWindow() - Unexpected Eclipse crash RC3 (JavaNativeCrash)

Last modified: 2006-11-14 17:46:58

Bug List: (31 of 200) First Last Prev Next Show last search results Search page Enter new bug

[Eclipse] Bug#: 141261
Product: Platform
Component: SWT
Status: NEW
Resolution:
Assigned To: Silenio Quarti <Silenio_Quarti@ca.ibm.com>

Hardware: Macintosh
OS: Mac OS
Version: 3.2
Priority: P3
Severity: major
Target Milestone: —

Reporter: Igor Goldenberg <igorg@gigaspaces.com>
Add CC:
CC: grant_gayed@ca.ibm.com
Mike_Wilson@ca.ibm.com
paper@animecity.nu
steve_northover@ca.ibm.com
☐ Remove selected CCs

QA Contact:
URL:
Summary: crash - Shell create, RepositionWindow() - Unexpected Eclipse c
Status Whiteboard:
Keywords:

Attachment	Type	Created	Size	Actions
Create a New Attachment (proposed patch, testcase, etc.)				View All

Bug 141261 depends on:
Bug 141261 blocks:
Show dependency tree

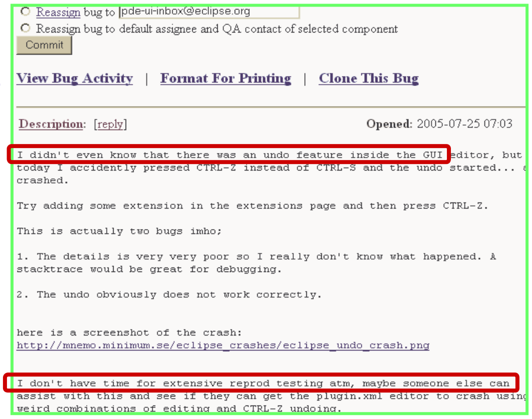
Votes: 0 Show votes for this bug Vote for this bug

Additional Comments:

Practices: Social Issues

9. Respect social issues of testing

- There are differences between developer and tester culture
- Acknowledge that testers often deliver bad news
- Avoid using defects in performance evaluations
  - Is the defect real?
  - Bad will within team
- Work hard to detect defects before integration testing
  - Easier to narrow scope and responsibility
  - Less adversarial
- Issues vs. defects



○ Reassign bug to pde-ui-inbox@eclipse.org
○ Reassign bug to default assignee and QA contact of selected component

Description: [reply] **Opened:** 2005-07-25 07:03

```
I didn't even know that there was an undo feature inside the GUI editor, but
today I accidently pressed CTRL-Z instead of CTRL-S and the undo started...
crashed.

Try adding some extension in the extensions page and then press CTRL-Z.

This is actually two bugs imho;

1. The details is very very poor so I really don't know what happened. A
stacktrace would be great for debugging.

2. The undo obviously does not work correctly.


here is a screenshot of the crash:
http://mnemo.minimum.se/eclipse_crashes/eclipse_undo_crash.png


I don't have time for extensive reprod testing atm, maybe someone else can
assist with this and see if they can get the plugin.xml editor to crash usin
weird combinations of editing and CTRL-Z undoing.
```

Practices: Root cause analysis

10. How can defect analysis help prevent later defects?

- Identify the “root causes” of frequent defect types, locations
  - Requirements and specifications?
  - Architecture? Design? Coding style? Inspection?
- Try to find all the paths to a problem
  - If one path is common, defect is higher priority
  - Each path provides more info on likely cause
- Try to find related bugs
  - Helps identify underlying root cause of the defect
  - Can use to get simpler path to problem
    - This can mean easier to fix
- Identify the most serious consequences of a defect

Testing – The Big Questions

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   - And why do we test?
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   - What are complementary approaches?
     - *Inspections*
     - *Static and dynamic analysis*

5b. Testing and Lifecycle Issues

1. Testing issues should be addressed at every lifecycle phase

- Initial negotiation
  - Acceptance evaluation: evidence and evaluation
  - Extent and nature of specifications

- Requirements
  - Opportunities for early validation
  - Opportunities for specification-level testing and analysis
  - Which requirements are testable: functional and non-functional

- Design
  - Design inspection and analysis
  - Designing for testability
    - Interface definitions to facilitate unit testing

- Follow both top-down and bottom-up unit testing approaches
  - Top-down testing
    - Test full system with stubs (for undeveloped code).
    - Tests design (structural architecture), when it exists.
  - Bottom-up testing
    - Units → Integrated modules → system

Lifecycle issues

2. Favor unit testing over integration and system testing

- Unit tests find defects earlier
  - Earlier means less cost and less risk

  - During design, make API specifications specific
    - Missing or inconsistent interface (API) specifications
    - Missing representation invariants for key data structures
    - What are the unstated assumptions?
      - Null refs ok?
      - Pass out this exception ok?
      - Integrity check responsibility?
      - Thread creation ok?

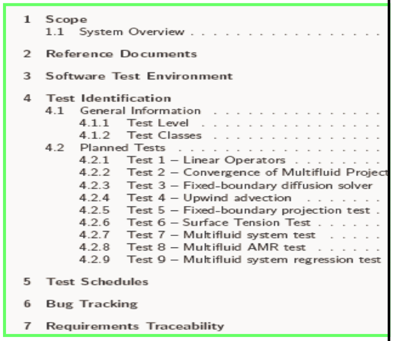
- Over-reliance on system testing can be risky
  - Possibility for finger pointing within the team
  - Difficulty of mapping issues back to responsible developers
  - Root cause analysis becomes blame analysis

Test Plan

3. Create a QA plan document

- Which quality techniques are used and for what purposes

- Overall system strategy
  - Goals of testing
    - Quality targets
    - Measurements and measurement goals
  - What will be tested/what will not
    - Don’t forget quality attributes!
  - Schedule and priorities for testing
    - Based on hazards, costs, risks, etc.
  - Organization and roles: division of labor and expertise
  - Criteria for completeness and deliverables



1 Scope
1.1 System Overview . . . .

2 Reference Documents

3 Software Test Environment

4 Test Identification
4.1 General Information . . . .
4.1.1 Test Level . . . .
4.1.2 Test Classes . . . .
4.2 Planned Tests . . . .
4.2.1 Test 1 – Linear Operators . . . .
4.2.2 Test 2 – Convergence of Multifluid Projec
4.2.3 Test 3 – Fixed-boundary diffusion solver
4.2.4 Test 4 – Upwind advection . . . .
4.2.5 Test 5 – Fixed-boundary projection test .
4.2.6 Test 6 – Surface Tension Test . . . . . .
4.2.7 Test 7 – Multifluid system test . . . . .
4.2.8 Test 8 – Multifluid AMR test . . . . . .
4.2.9 Test 9 – Multifluid system regression test

5 Test Schedules

6 Bug Tracking

7 Requirements Traceability

- Make decisions regarding when to unit test
  - There are differing views
    - **CleanRoom**: Defer testing. Use separate test team
    - ✓ **Agile**: As early as possible, even before code, integrate into team

Test Strategy Statement

- Examples:
  - We will release the product to friendly users after a brief internal review to find any truly glaring problems. The friendly users will put the product into service and tell us about any changes they’d like us to make.

  - We will define use cases in the form of sequences of user interactions with the product that represent … the ways we expect normal people to use the product. We will augment that with stress testing and abnormal use testing (invalid data and error conditions). Our top priority is finding fundamental deviations from specified behavior, but we will also use exploratory testing to identify ways in which this program might violate user expectations.

  - We will perform parallel exploratory testing and automated regression test development and execution. The exploratory testing will focus on validating basic functions (capability testing) to provide an early warning system for major functional failures. We will also pursue high-volume random testing where possible in the code.

[adapted from Kaner, Bach, Pettichord, Lessons Learned in Software Testing]

Why Produce a Test Plan?

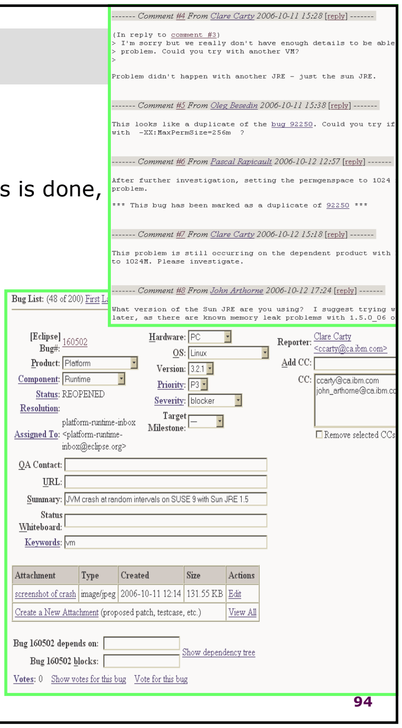
4. Ensure the test plan addresses the needs of stakeholders

- Customer: may be a required product
  - Customer requirements for operations and support
  - Examples
    - Government systems integration
    - Safety-critical certification: avionics, health devices, etc.
- A separate test organization may implement part of the plan
  - "IV&V" – Independent verification and validation
- May benefit development team
  - Set priorities
    - Use planning process to identify areas of hazard, risk, cost
- Additional benefits – the plan is a team product
  - Test quality
    - Improve coverage via list of features and quality attributes
    - Analysis of program (e.g. boundary values)
    - Avoid repetition and check completeness
  - Communication
    - Get feedback on strategy
    - Agree on cost, quality with management
  - Organization
    - Division of labor
    - Measurement of progress

Defect Tracking

5. Track defects and issues

- Issue: Bug, feature request, or query
  - May not know which of these until analysis is done, so track in the same database (Issuezilla)
- Provides a basis for measurement
  - Defects reported: which lifecycle phase
  - Defects repaired: time lag, difficulty
  - Defect categorization
  - Root cause analysis (more difficult!)
- Provides a basis for division of effort
  - Track diagnosis and repair
  - Assign roles, track team involvement
- Facilitates communication
  - Organized record for each issue
  - Ensures problems are not forgotten
- Provides some accountability
  - Can identify and fix problems in process
    - Not enough detail in test reports
    - Not rapid enough response to bug reports
  - Should not be used for HR evaluation



------- Comment #4 From Clare Carty 2006-10-11 15:28 [reply] -------

```
(In reply to comment #3)
> I'm sorry but we really don't have enough details to be able
> problem. Could you try with another VM?
>

Problem didn't happen with another JRE - just the sun JRE.
```

------- Comment #5 From Oleg Besedin 2006-10-11 15:38 [reply] -------

```
This looks like a duplicate of the bug 92250. Could you try if
with  -XX:MaxPermSize=256m  ?
```

------- Comment #6 From Pascal Rapicault 2006-10-12 12:57 [reply] -------

```
After further investigation, setting the permgenspace to 1024
problem.

*** This bug has been marked as a duplicate of 92250 ***
```

------- Comment #7 From Clare Carty 2006-10-12 15:18 [reply] -------

```
This problem is still occurring on the dependent product with
to 1024M. Please investigate.
```

------- Comment #8 From John Arthorne 2006-10-12 17:24 [reply] -------

```
What version of the Sun JRE are you using?  I suggest trying w
later, as there are known memory leak problems with 1.5.0_06 o
```

Bug List: (48 of 200) First La

[Eclipse] Bug#: 160502
Product: Platform
Component: Runtime
Status: REOPENED
Resolution:
Assigned To: platform-runtime-inbox <platform-runtime-inbox@eclipse.org>
Hardware: PC
OS: Linux
Version: 3.2.1
Priority: P3
Severity: blocker
Target Milestone: —
Reporter: Clare Carty <ccarty@ca.ibm.com>
Add CC:
CC: ccarty@ca.ibm.com john_arthorne@ca.ibm.co
☐ Remove selected CCs
QA Contact:
URL:
Summary: JVM crash at random intervals on SUSE 9 with Sun JRE 1.5
Status Whiteboard:
Keywords: vm

Attachment	Type	Created	Size	Actions
screenshot of crash	image/jpeg	2006-10-11 12:14	131.55 KB	Edit
Create a New Attachment (proposed patch, testcase, etc.)				View All

Bug 160502 depends on:
Bug 160502 blocks:
Show dependency tree
Votes: 0 Show votes for this bug Vote for this bug

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     - *Static and dynamic analysis*

---

6. What are the limits of testing?

- **What we can test**
  - Attributes that can be directly evaluated externally
    - *Examples*
      - **Functional** properties: result values, GUI manifestations, etc.
  - Attributes relating to resource use
      - Many well-distributed **performance** properties
      - Storage use
- **What is difficult to test?**
  - Attributes that **cannot easily be measured externally**

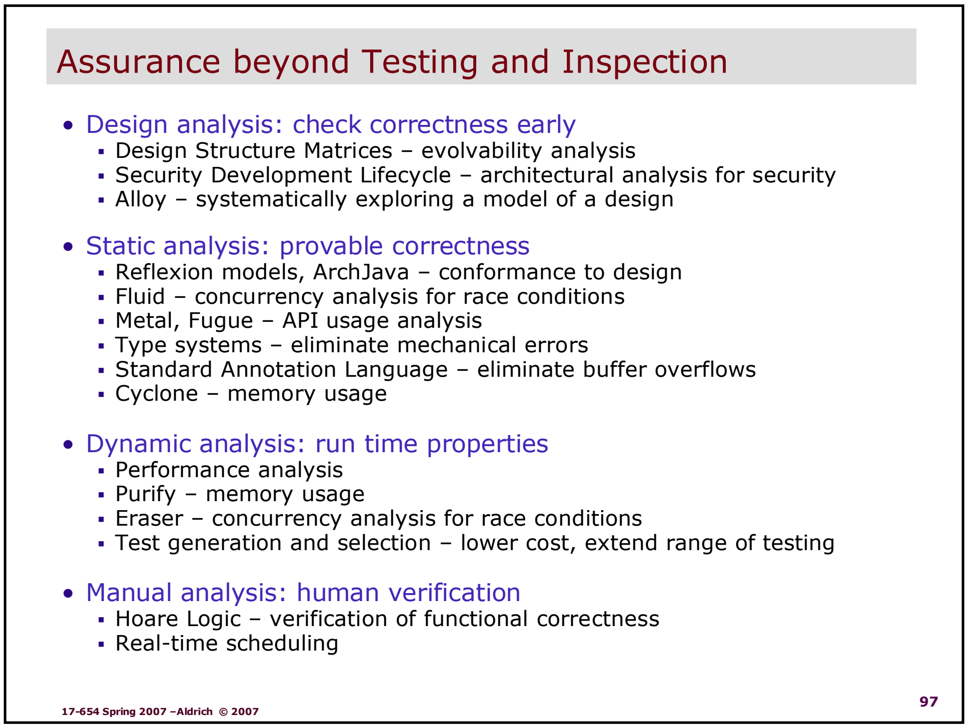
Is a design evolvable?	Design Structure Matrices
Is a design secure?	Secure Development Lifecycle
Is a design technically sound?	Alloy; see also Models
Does the code conform to a design?	ArchJava; Reflexion models; Framework usage
Where are the performance bottlenecks?	Performance analysis
Does the design meet the user’s needs?	Usability analysis

  - Attributes for which **tests are nondeterministic**

Real time constraints	Rate monotonic scheduling
Race conditions	Analysis of locking

  - Attributes relating to the **absence of a property**

Absence of security exploits	Microsoft’s Standard Annotation Language
Absence of memory leaks	Cyclone, Purify
Absence of functional errors	Hoare Logic
Absence of non-termination	Termination analysis



Assurance beyond Testing and Inspection

- Design analysis: check correctness early
  - Design Structure Matrices – evolvability analysis
  - Security Development Lifecycle – architectural analysis for security
  - Alloy – systematically exploring a model of a design
- Static analysis: provable correctness
  - Reflexion models, ArchJava – conformance to design
  - Fluid – concurrency analysis for race conditions
  - Metal, Fugue – API usage analysis
  - Type systems – eliminate mechanical errors
  - Standard Annotation Language – eliminate buffer overflows
  - Cyclone – memory usage
- Dynamic analysis: run time properties
  - Performance analysis
  - Purify – memory usage
  - Eraser – concurrency analysis for race conditions
  - Test generation and selection – lower cost, extend range of testing
- Manual analysis: human verification
  - Hoare Logic – verification of functional correctness
  - Real-time scheduling