Java™

Java is a trademark of Sun Microsystems, Inc.

JavaOne℠

Defective Java Code: Mistakes That Matter

William Pugh
Univ. of Maryland

University of Maryland 1856

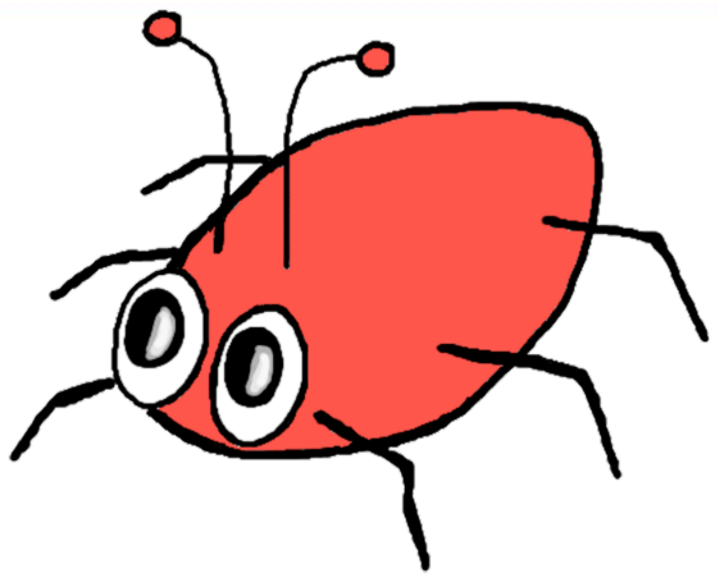
FindBugs

Defective Java Code

Learning from mistakes

- I'm the lead on FindBugs
  - static analysis tool for defect detection
- Visiting scientist at Google for the past 10 months
  - learned a lot about coding mistakes, which ones matter, how to catch them, how to allow a community to review them
- A little like programming puzzlers
  - but no quiz
  - and lots of interspersed commentary

Static analysis



- Analyzes code without running it
- FindBugs is an open source static analysis tool, developed at the University of Maryland
  - with a number of additional contributors
  - Looks for bug patterns, inspired by real problems in real code
- Held FindBugs fixit at Google May 13-14th
  - 300 engineers provided 8,000 reviews of 4,000 issues
    - 75+% were marked should fix or must fix
  - more than 1,500 of the issues have already been removed

Learned wisdom

- Static analysis typically finds mistakes
  - but some mistakes don’t matter
  - need to find the intersection of stupid and important
- The bug that *matter* depend on context
- Static analysis, *at best*, might catch 5-10% of your software quality problems
  - 80+% for certain specific defects
  - but overall, not a magic bullet
- Used effectively, static analysis is cheaper than other techniques for catching the same bugs

Null bug

- From Eclipse, 3.5RC3:
  org.eclipse.update.internal.ui.views.FeatureStateAction

```
if (adapters == null && adapters.length == 0)
    return;
```

- Clearly a mistake
  - First seen in Eclipse 3.2
  - but in practice, adapters is probably never null
- Is there any impact from this?
  - we would probably notice a null pointer exception
  - we don’t immediately return if length is 0

Cost when a mistake causes a fault/failure

- How quickly/reliability would you notice?
- What is the impact of the misbehavior caused by the mistake?
- How easily could you diagnose the problem and the fix?
- What is the cost to deliver a fix?

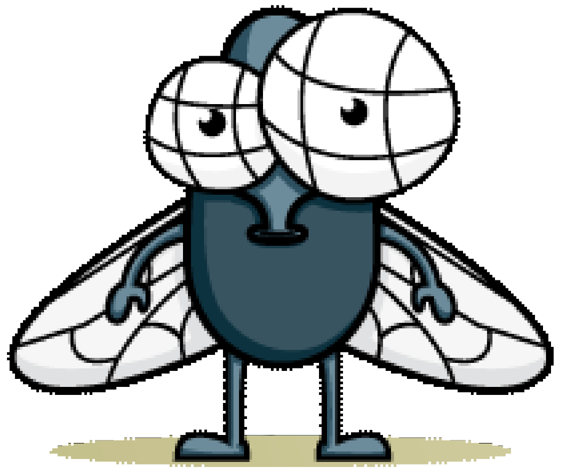
Mistakes in web services

- Some mistakes would manifest themselves by throwing a runtime exception
  - Should be logged and noticed
- If it isn't happening now, a change might cause it to start happening in the future
  - But if it does, the exception will likely pinpoint the mistake
  - And pushing a fix into production is cheaper than pushing a fix to desktop or mobile applications

Expensive mistakes (your results may vary)

- Mistakes that might cost millions of dollars on the first day they manifest
- Mistakes that silently cause the wrong answer to be computed
  - might be going wrong now, millions of times a day
  - or might be OK now, but when it does go wrong, it won’t be noticed until somewhere downstream of mistake
- Mistakes that are expensive or impossible to fix

Using reference equality rather than `.equals`



from Google’s code (no one is perfect)

```
class MutableDouble {
  private double value_;
  public boolean equals(final Object o) {
    return o instanceof MutableDouble &&
      ((MutableDouble)o).doubleValue()
        == doubleValue();
  }
  public Double doubleValue() {
    return value_;
  }
```

Using == to compare objects rather than .equals

- For boxed primitives, == and != are computed using pointer equality, but <, <=, >, >= are computed by comparing unboxed primitive values
- Sometimes, equal boxed values are represented using the same object
  - but only sometimes
- This can bite you on other classes (e.g., **`String`**)
  - but boxed primitives is where people get bit

Heisenbugs vs. deterministic bugs

- A Heisenbug is a mistake that only sometimes manifests itself (e.g., a data race)
- Testing not likely to show error
  - if a test fails, rerunning the test may succeed
- Can be very nasty to track down, impossible to debug
- But how dangerous is a bug that only bites once out of 4 billion times?

Ignoring the return value of putIfAbsent

org.jgroups.protocols.pbcast.NAKACK

```
ConcurrentMap<Long,XmitTimeStat>
      xmit_time_stat = ...;
.....
XmitTimeStat stat = xmit_time_stats.get(key);
if(stat == null) {
 stat = new XmitTimeStat();
 xmit_time_stats.putIfAbsent(key, stat);
}
stat.xmit_reqs_received.addAndGet(rcvd);
stat.xmit_rsps_sent.addAndGet(sent);
```

misusing putIfAbsent

- ConcurrentMap provides putIfAbsent
    - atomically add key → value mapping
        - but only if the key isn't already in the map
    - if non-null value is returned, put failed and value returned is the value already associated with the key
- Mistake:
    - ignore return value of putIfAbsent, and
    - reuse value passed as second argument, and
    - matters if two callers get two different values

Fixed in revision 1.179

org.jgroups.protocols.pbcast.NAKACK

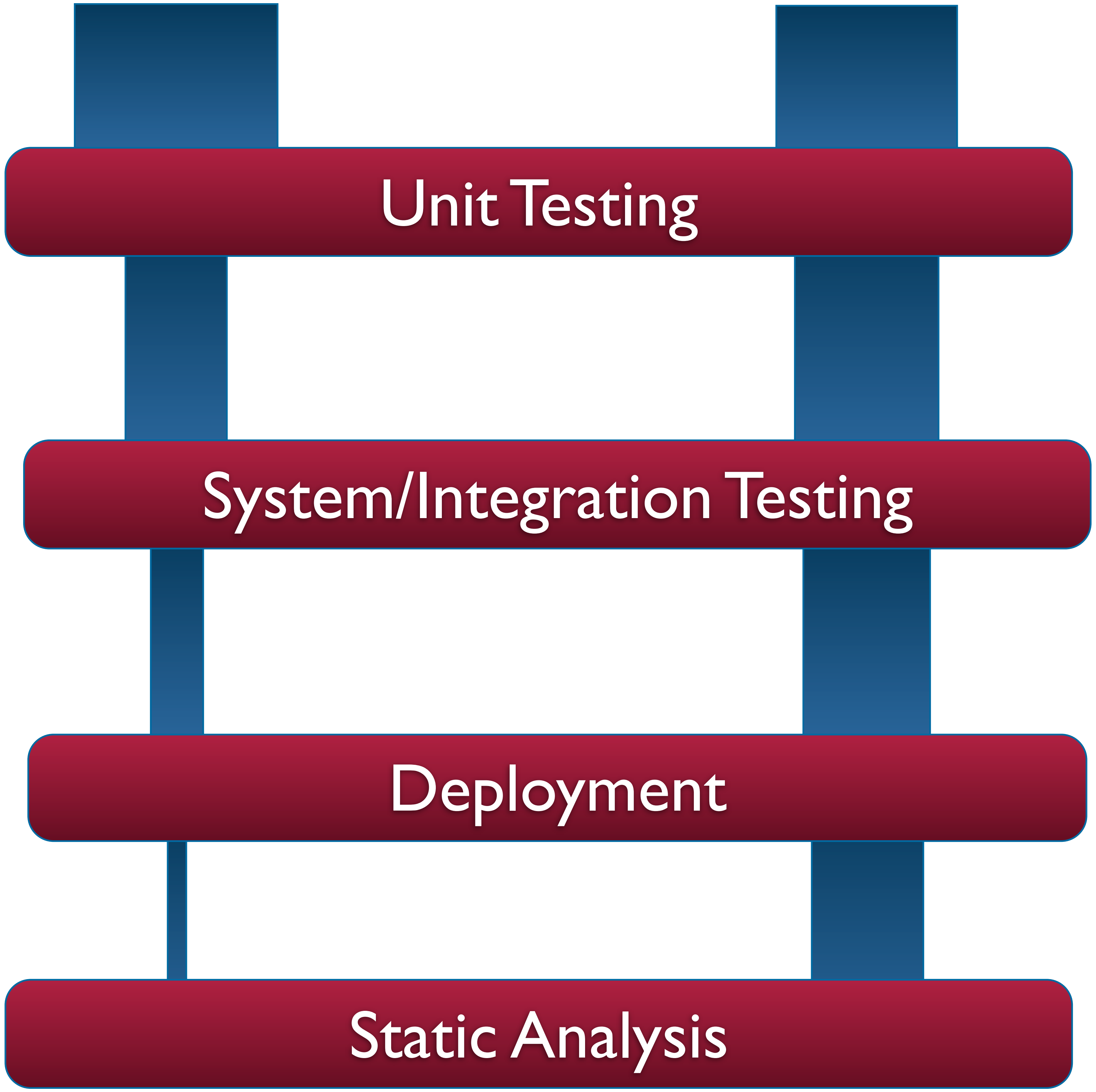
```
XmitTimeStat stat=xmit_time_stats.get(key);
if(stat == null) {
 stat=new XmitTimeStat();
 XmitTimeStat stat2
   = xmit_time_stats.putIfAbsent(key, stat);
  if (stat2 != null)
    stat = stat2;
}
stat.xmit_reqs_received.addAndGet(rcvd);
stat.xmit_rsps_sent.addAndGet(sent)
```

Some lessons

- Concurrency is tricky
- **`putIfAbsent`** is tricky to use correctly
  - engineers at Google got it wrong more than 10% of the time
- Unless you need to *ensure* a single value, just use **`get`** followed by **`put`** if not found
- If you need to ensure a single unique value shared by all threads, use **`putIfAbsent`** and check return value

Mistakes That Matter

Mistakes That Don't



Unit Testing

System/Integration Testing

Deployment

Static Analysis

Static analysis earlier is better

- Find mistakes detected by static analysis before that are detected using more expensive techniques
- Get them to developers while the code is still fresh in developers heads, before anyone else is depending on it or using it
  - Fixing a mistake in code last touched 6 months or 6 years ago isn’t fun
- Of course, this only applies if your mistakes are generally caught by other steps in your quality assurance process at reasonable cost

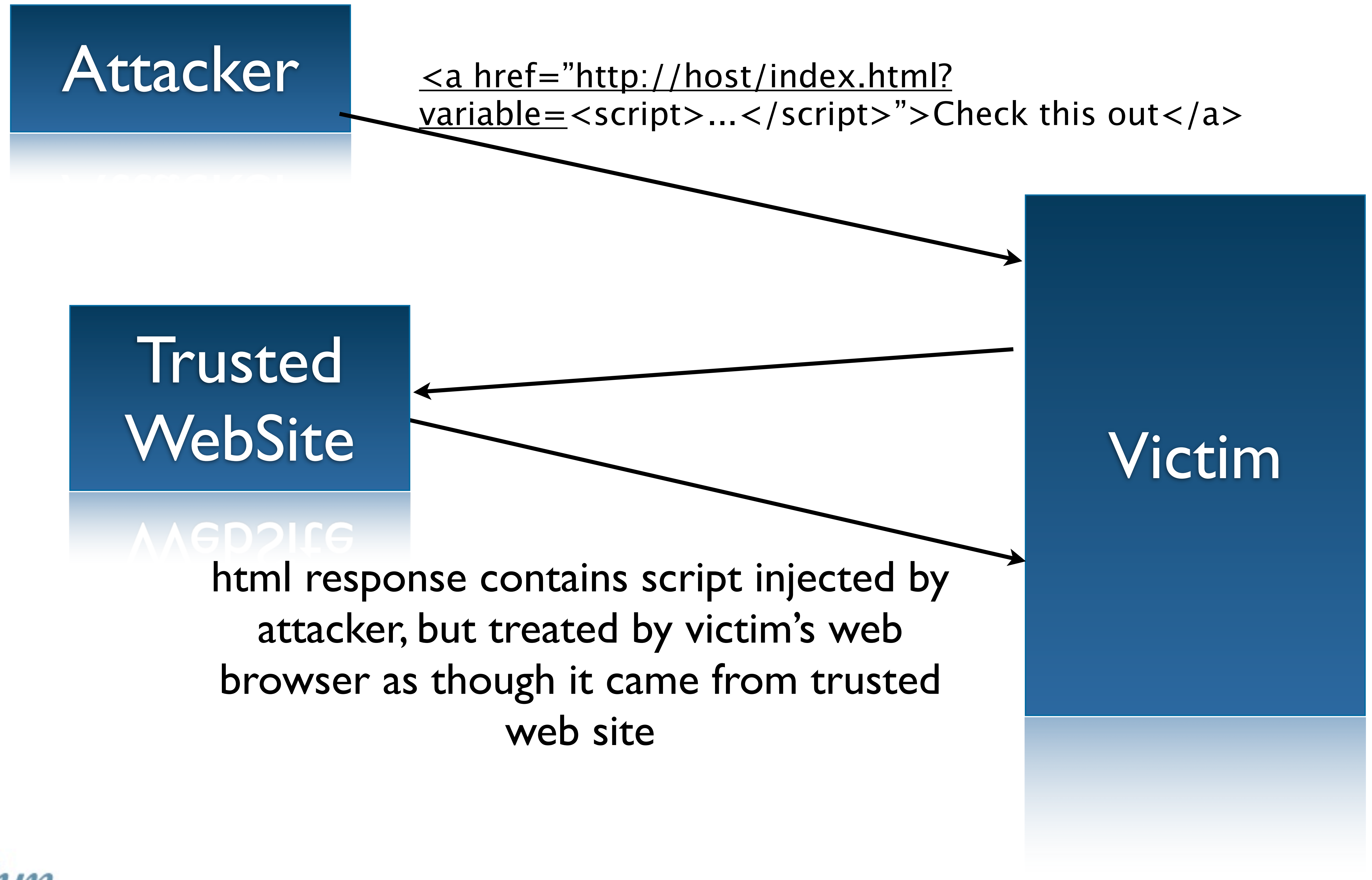
Cross-site scripting

```
public void doGet(HttpServletRequest req,
     HttpServletResponse res) {
  ...
  String target = req.getParameter("url");
  InputStream in = this.getClass()
    .getResourceAsStream("META-INF/resources/"
        + target;
  if (in == null) {
    res.getWriter().println(
      "<p>Unable to locate resource: "
             + target);
    return;
    }
```

Cross-site scripting

- Putting untrusted/unchecked data directly into generated html
  - can contain Javascript, which gets executed in your context
  - untrusted input can be injected into your database, or through a URL query parameter
    - via a link sent from attacker to victim

Cross site scripting



Attacker

<a href=”http://host/index.html?variable=<script>...</script>”>Check this out</a>

Trusted WebSite

Victim

html response contains script injected by attacker, but treated by victim’s web browser as though it came from trusted web site

Security vulnerabilities

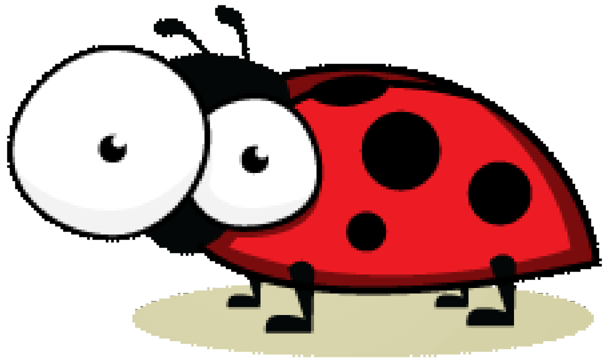
- Not exposed by normal/expected use cases
- Need some combination of:
  - architectural risk analysis
  - careful design
  - static analysis
  - dynamic testing and analysis
- FindBugs only does simple, shallow analysis for network security vulnerabilities

Returning references to internal mutable state

jdk1.7.0-b59

sun.security.x509.InvalidityDateExtension:

```
private Date date;
public Object get(String name) {
    if (name.equalsIgnoreCase(DATE)) {
        return date;
    } else {...}
}
```



Vulnerability to malicious code

- In some cases, your code should preserve certain safety guarantees even if untrusted code is running in the same JVM
    - An issue for the JDK, not an issue for most web services
- Many cases are easy to check for
- I’ve complained about vulnerabilities in Sun’s JDK at JavaOne every year for several years
    - why stop now?

JDK 7 status report

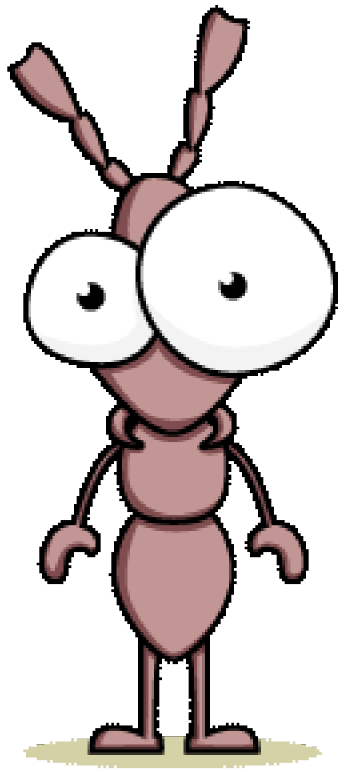
- Overall, *good* progress over JDK 6
  - 188 warnings about mutable static fields in JDK 6
  - 133 warnings in JDK 7
    - 14 new ones, 119 retained from JDK 6
- Some of the new issues ones are trivial to fix
  - **`com.sun.xml.internal.stream.util.BufferAllocator.LARGE_SIZE_LIMIT`** is public, static and non-final
- I can suggest tools to help you with this...

Incomparable equality

org.eclipse.jdt.internal.debug.eval.ast.engine.AstInstructionCompiler

```
SimpleType simpleType = (SimpleType) type;
if ("java.lang.String".equals(simpleType.getName()))
   return Instruction.T_String;
```

- SimpleType.getName() returns a org.eclipse.jdt.core.dom.Name
- In Eclipse since 2.0 (June 2002)



Many variations, assisted by weak typing in APIs

- Using .equals to compare incompatible types
- Using .equals to compare arrays
  - only checks if the same array
- Checking to see if a **`Set<Long>`** contains an **`Integer`**
  - never found, even if the same integral value is contained in the map
- Calling **`get(String)`** on a **`Map<Integer,String>`**

Silent, nasty bugs

- Very hard to find these bugs by inspection
  - types not always visible/explicit
- In some cases, could be introduced by refactoring
  - Change the key type of a **`Map`** from **`Integer`** to **`Long`**
  - Fix all the places where you get type errors
  - Leave behind bugs
- Google had an issue with a refactoring that changed a method to return **`byte[]`** rather than **`String`**
  - introduced silent errors

Bug introduced between Eclipse 3.5RC1 and RC2

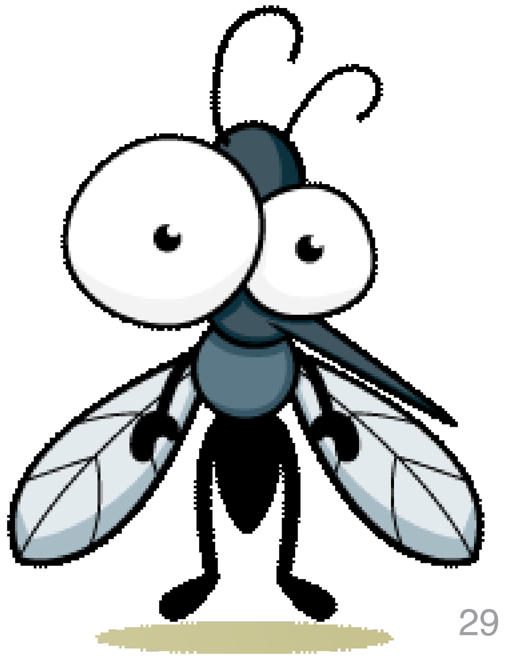
org.eclipse.pde.internal.build.BrandingIron

```
File rootFolder
 = getCanonicalFile(new File(initialRoot));
if (!rootFolder.equals(target)) {
     rootFolder.delete();
     ...
     }
```

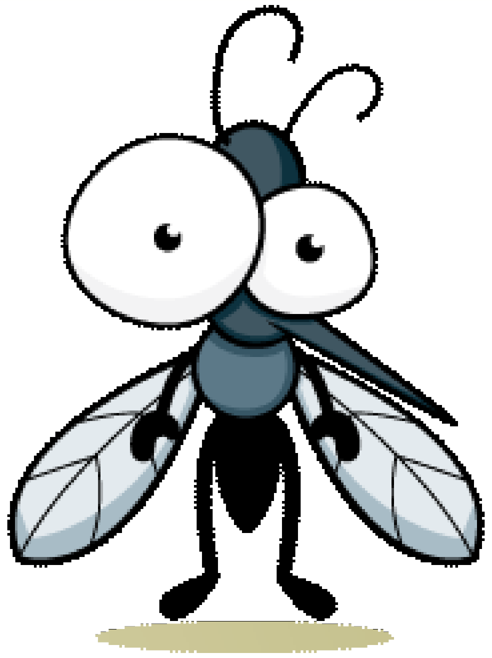
Lost logger

```
void initLogger() {
 Logger logger = Logger.getLogger("edu.umd.cs");
 logger.addHandler(new FileHandler());
 logger.setUseParentHandlers(false);
 }
```

- Loggers are retained by weak references
  - always allowed by spec, recent change to OpenJDK implementation
- If GC happens immediately after the call to **`initLogger`**, changes to logger will be lost



Lost Loggers at Google



- This bug pattern was contributed by Ulf Ochsenfahrt and Eric Fellheimer at Google
  - had manually tracked down a dozen or so instances, came to static analysis team
  - in 30 minutes, I wrote something that found 200+ instances of this problem in Google’s code base
  - Decision was made to fix all of them

Is this change compatible?

- You can argue that this change in the implementation is a bad idea
  - but it is allowed by the spec
- Perhaps if a change is made to a logger, the **`LogManager`** should store a strong reference to the logger
  - a quality of service improvement, even if spec not changed

Listen to your bug stories

- In Joshua Bloch’s talk, he said that his #1 takeaway message was don’t lock on **`ConcurrentMaps`**
  - My reaction was “Really?”
  - Clearly wrong and a bug, but surely that so obviously wrong it would be exceptionally rare
  - But I wrote a detector for FindBugs

JBoss 5.1.0-GA

- 22 synchonizations on **`ConcurrentHashMap`**
- 9 synchronizations on **`CopyOnWriteArrayList`**
  - In Java 5, **`COWAL`** implementation using **`synchronized(this)`**
  - in Java 6+ **`COWAL`** implementation synchronizes on internal **`Lock`** object
- 3 synchronizations on **`AtomicBoolean`**

Improving software quality

- Many different things can catch mistakes and/or improve software quality
  - Each technique more efficient at finding some mistakes than others
  - Each subject to diminishing returns
  - No magic bullet
  - Find the right combination for you and for the mistakes that matter to you

Test, test, test...

- Many times FindBugs will identify bugs
  - that leave you thinking “Did anyone test this code?”
    - And you find other mistakes in the same vicinity
  - FindBugs might be more useful as an untested code detector than as a bug detector
- Overall, testing is far more valuable than static analysis
  - I’m agnostic on unit tests vs. system tests
  - But *no one* writes code so good you don’t need to check that it does the right thing
    - I’ve learned this from personal painful experience

Dead code

> Many projects contain lots of dead code
  - abandoned packages and classes
  - classes that implement 12 methods; only 3 are used

> Code coverage is a very useful tool
  - but pushing to very high code coverage may not be worthwhile
  - you'd have to cover lots of code that never gets executed in production

Code coverage from production

- If you can sample code coverage from production, great
  - look for code executed in production but not covered in unit or system test
- Note: enforce coding standard that body of **`if`** statement must be on separate line than **`if`** statement guard
  - Most statement level code coverage tools need this to tell you whether body of **`if`** statement executed

Cool idea

- If you can't get code coverage from production
- Just get list of loaded classes
  - just your code, ignoring classes loaded from core classes or libraries
  - Very light weight instrumentation
- Log the data
  - could then ask queries such as "Which web services loaded the **`FooBar`** class this month?"

Leveraging class initialization logging

- You’ve got class initialization logging
- But want to know if a particular method or statement is reached
- Define a nested class with a static method with an empty body

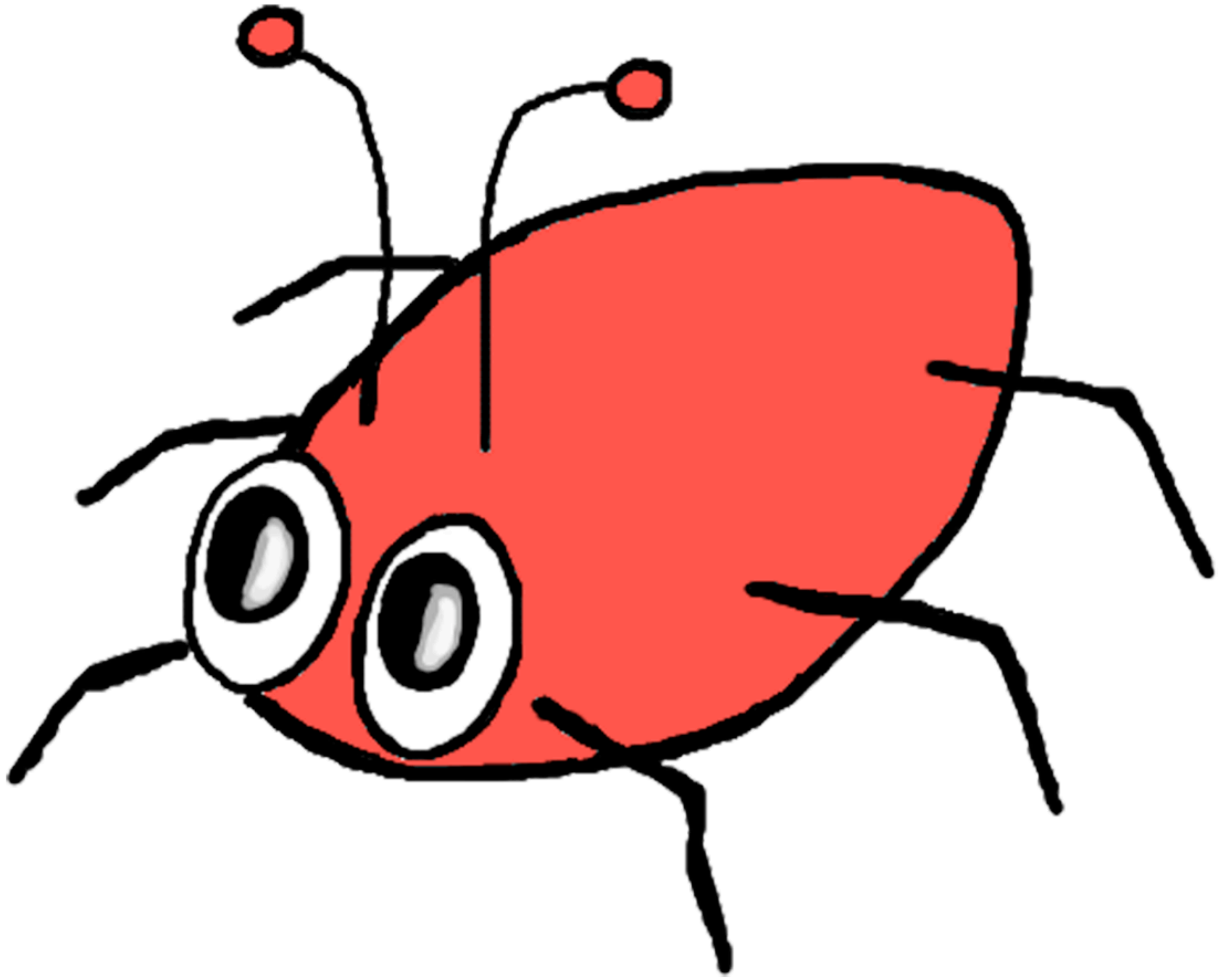
```
static class Foo {
   static void loadClass() {};
   }
```

Using FindBugs to find mistakes

- FindBugs is accurate at finding coding mistakes
  - 75+% evaluated as a mistake that should be fixed
- But many mistakes have low costs
  - memory/type safety lowers cost of mistakes
  - If applied to existing production code, many expensive mistakes have already been removed
    - perhaps painfully
- Need to lower cost of using FindBugs to sell to some projects/teams

FindBugs 1.x

- First research paper published in 2004
- FindBugs 1.0 released in 2006
- 850,000+ downloads from 160+ countries
- Released 1.3.8 in March



FindBugs 2.0

FindBugs 2.0

- FindBugs analysis engine continues to improve, but only incrementally
- Focus on efficiently incorporating static analysis into the large scale software development
  - Review of issues done by a community
  - Once issue is marked as “not a bug”, never forget
  - Integration into bug tracking and source code version control systems

Bug ranking

- FindBugs reported a priority for an issue, but it was only meaningful when comparing instances of the same bug pattern
  - a medium priority X bug might be more important than a high priority Y bug
- Now each issue receives a bug rank (a score, 1-20)
  - Can be customized according to your priorities
  - Grouped into Scariest, Scary, Troubling, and Of Concern

FindBugs community review

- Whenever / where ever you run FindBugs, after completing or loading an analysis
  - it talks to the cloud
  - sees how we’ve been seeing this issue
  - sees if anyone has marked the issue as “should fix” or “not a bug”
- As soon you classify an issue or enter text about the issue, that is sent to the cloud

More cloud integration

- Integration with bug tracking systems
  - One click to bring up pre-populated web page in bug tracker describing issue
  - If bug already filed against issue, click shows you existing issue in bug tracker
- Integration with web based source viewers, such as FishEye
  - Allow viewing of file history, change lists, etc.

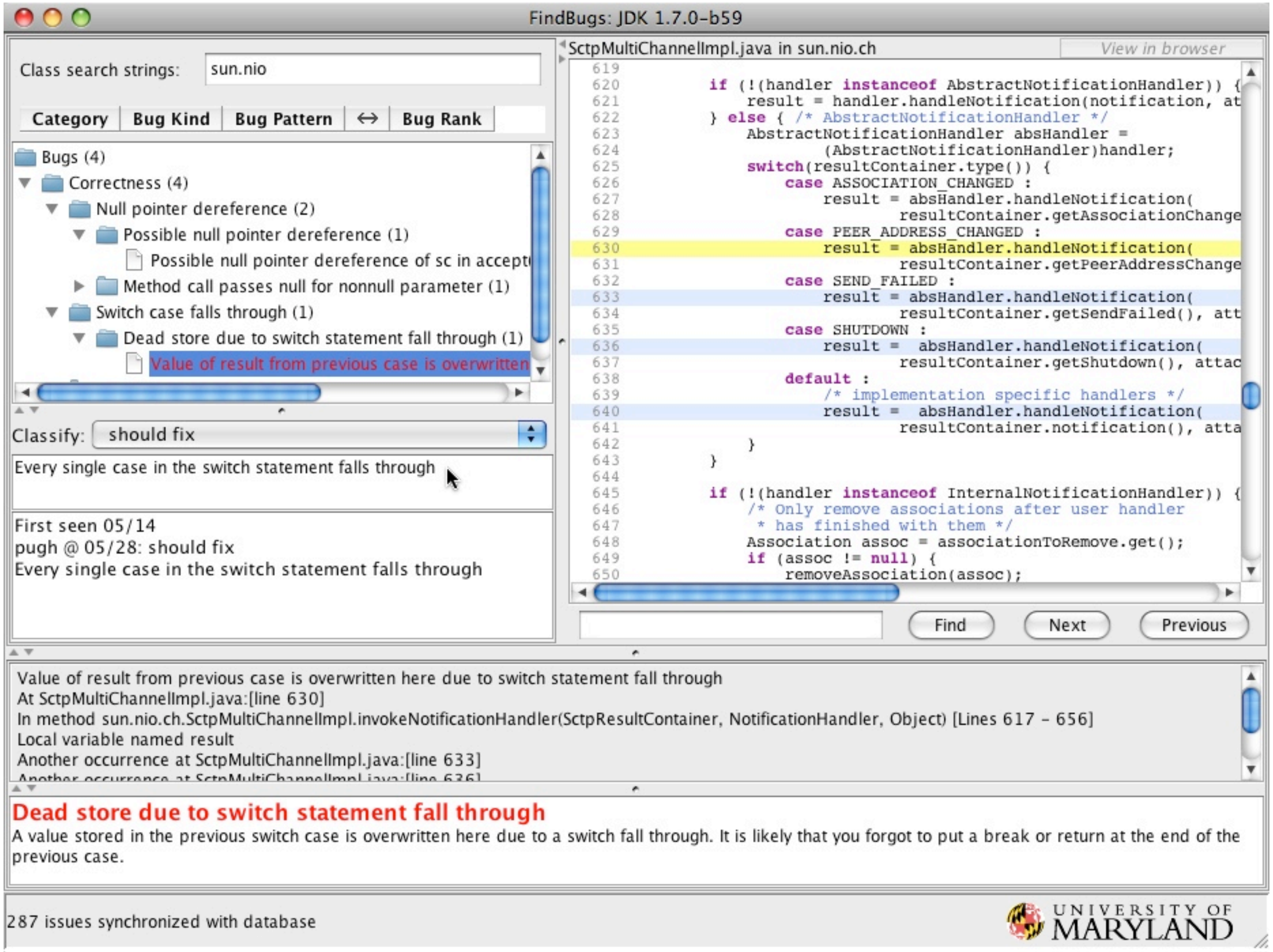
General availability Fall 2009

- Already in use at Google
  - need to also provide hooks into other bug tracking and web source viewers
- Cloud storage needs to be made more robust and scalable
- Needs to be integrated into Eclipse plugin
- Need to replace bubble gum and duct tape with something more stable

FindBugs community review

- Go to http://findbugs.sourceforge.net/review
- Launch FindBugs GUI via webstart
- Review issues in
  - jdk1.7.0
  - Glassfish-v3
  - Eclipse 3.5
- Everyone welcome
  - very much a beta
  - no integration with bug tracking systems yet

Demo



Class search strings: sun.nio

```
Bugs (4)
▼ Correctness (4)
  ▼ Null pointer dereference (2)
    ▼ Possible null pointer dereference (1)
        Possible null pointer dereference of sc in accept
    ▶ Method call passes null for nonnull parameter (1)
  ▼ Switch case falls through (1)
    ▼ Dead store due to switch statement fall through (1)
        Value of result from previous case is overwritten
```

Classify: should fix

Every single case in the switch statement falls through

First seen 05/14
pugh @ 05/28: should fix
Every single case in the switch statement falls through

SctpMultiChannelImpl.java in sun.nio.ch

```
619
620             if (!(handler instanceof AbstractNotificationHandler)) {
621                 result = handler.handleNotification(notification, at
622             } else { /* AbstractNotificationHandler */
623                 AbstractNotificationHandler absHandler =
624                         (AbstractNotificationHandler)handler;
625                 switch(resultContainer.type()) {
626                     case ASSOCIATION_CHANGED :
627                         result = absHandler.handleNotification(
628                                 resultContainer.getAssociationChange
629                     case PEER_ADDRESS_CHANGED :
630                         result = absHandler.handleNotification(
631                                 resultContainer.getPeerAddressChange
632                     case SEND_FAILED :
633                         result = absHandler.handleNotification(
634                                 resultContainer.getSendFailed(), att
635                     case SHUTDOWN :
636                         result =  absHandler.handleNotification(
637                                 resultContainer.getShutdown(), attac
638                     default :
639                         /* implementation specific handlers */
640                         result =  absHandler.handleNotification(
641                                 resultContainer.notification(), atta
642                 }
643             }
644
645             if (!(handler instanceof InternalNotificationHandler)) {
646                 /* Only remove associations after user handler
647                  * has finished with them */
648                 Association assoc = associationToRemove.get();
649                 if (assoc != null) {
650                     removeAssociation(assoc);
```

Value of result from previous case is overwritten here due to switch statement fall through
At SctpMultiChannelImpl.java:[line 630]
In method sun.nio.ch.SctpMultiChannelImpl.invokeNotificationHandler(SctpResultContainer, NotificationHandler, Object) [Lines 617 - 656]
Local variable named result
Another occurrence at SctpMultiChannelImpl.java:[line 633]
Another occurrence at SctpMultiChannelImpl.java:[line 636]

Dead store due to switch statement fall through

A value stored in the previous switch case is overwritten here due to a switch fall through. It is likely that you forgot to put a break or return at the end of the previous case.

287 issues synchronized with database

JavaOne℠

Thank You

William Pugh
pugh@cs.umd.edu

http://findbugs.sourceforge.net/