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Unit Test Virtualization with VMVM

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ICSE 2014

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Good news: We have tests!

No judgement on whether they are complete or not,
but we sure have a lot of them

	Number of tests
Apache Tomcat	1,734
Closure Compiler	7,949
Commons I/O	1,022

Bad news: We have to run a lot of tests!

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  - E.g. Wong [ISSRE ’97], Rothermel [ICSM ’99]; Elbaum [ICSE ’01]; Srivastava [ISSTA ’02] and more

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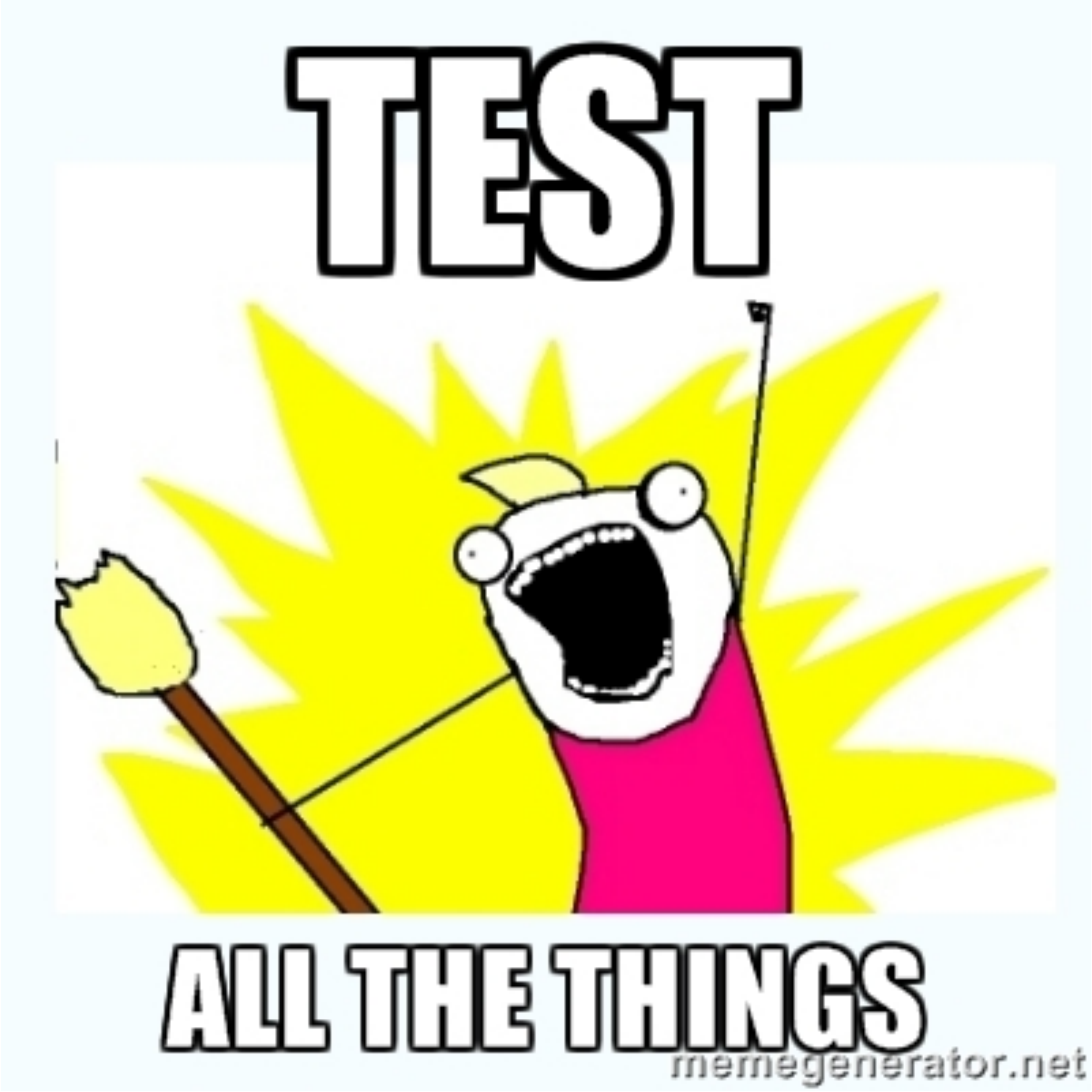
- Test Suite Minimization
  - E.g. Harrold [TOSEM ’93]; Wong [ICSE ’95]; Chen [IST ’98]; Jones [TOSEM ’03]; Tallam [PASTE ’05]; Jeffrey [TSE ’07]; Orso [ICSE ’09] Hao [ICSE ’12] and more

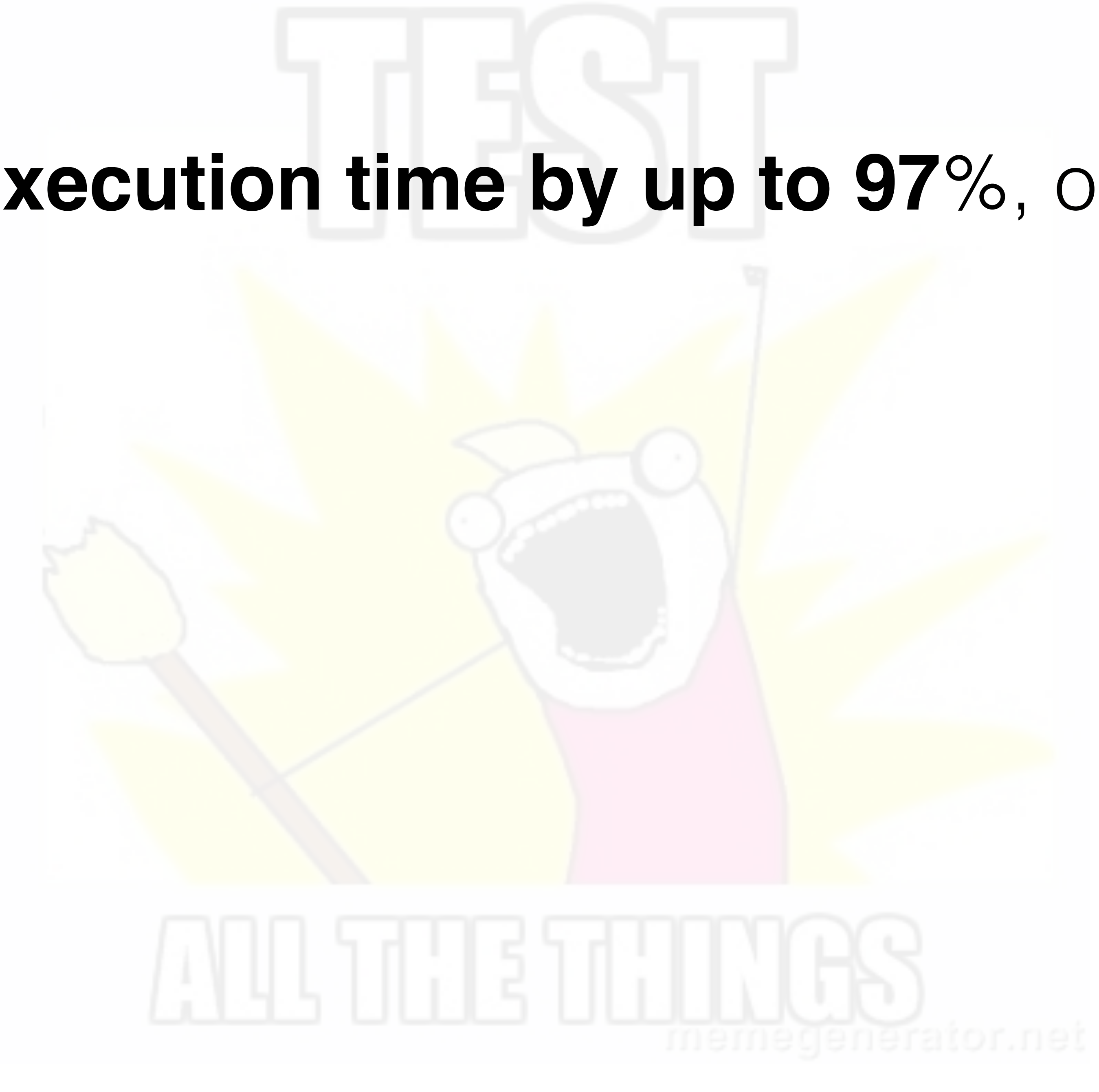
Testing still takes too long.

Our Approach: Unit Test Virtualization



Our Approach:
Unit Test Virtualization

Reduces test execution time by up to 97%, on average 62%



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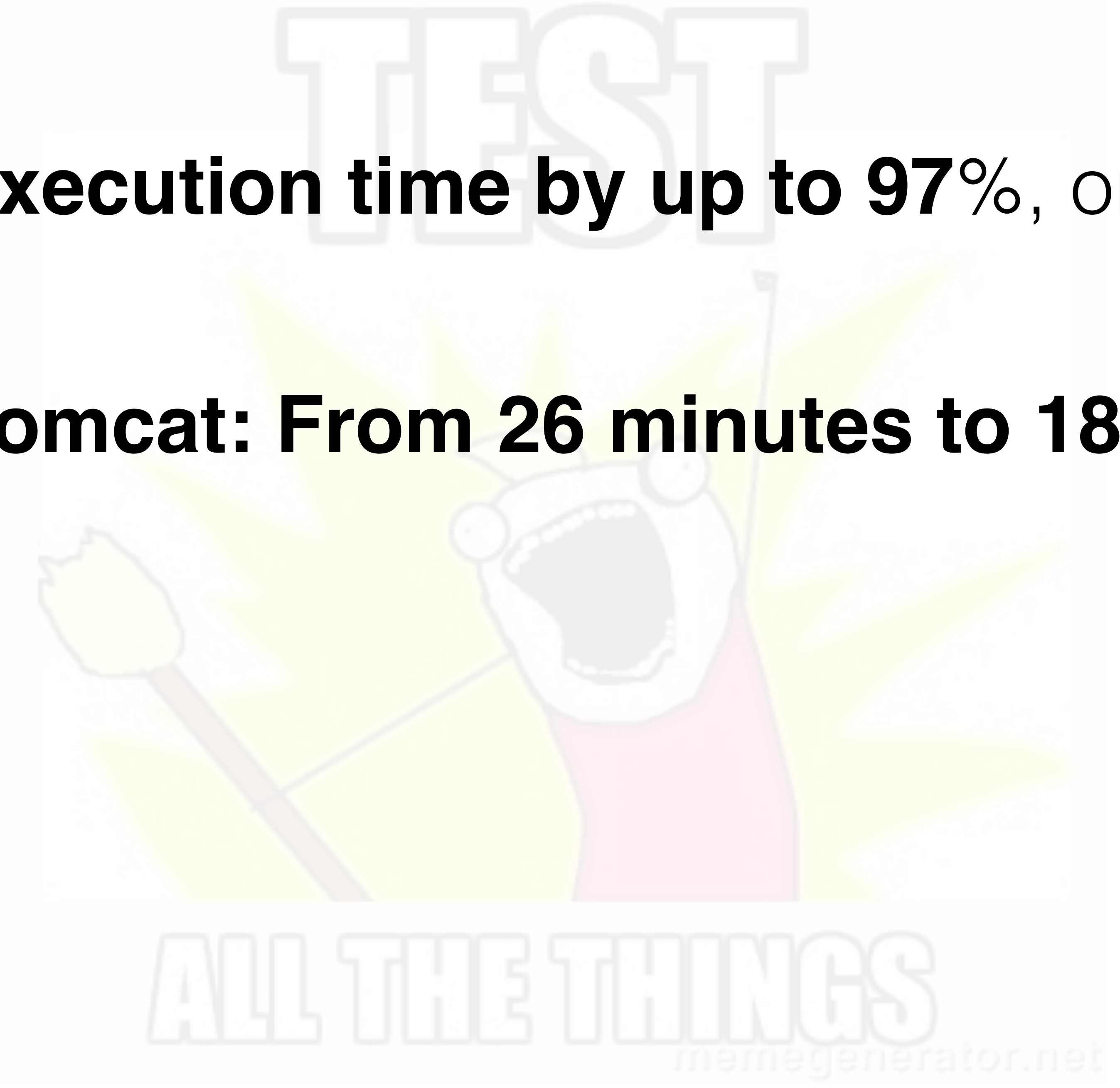

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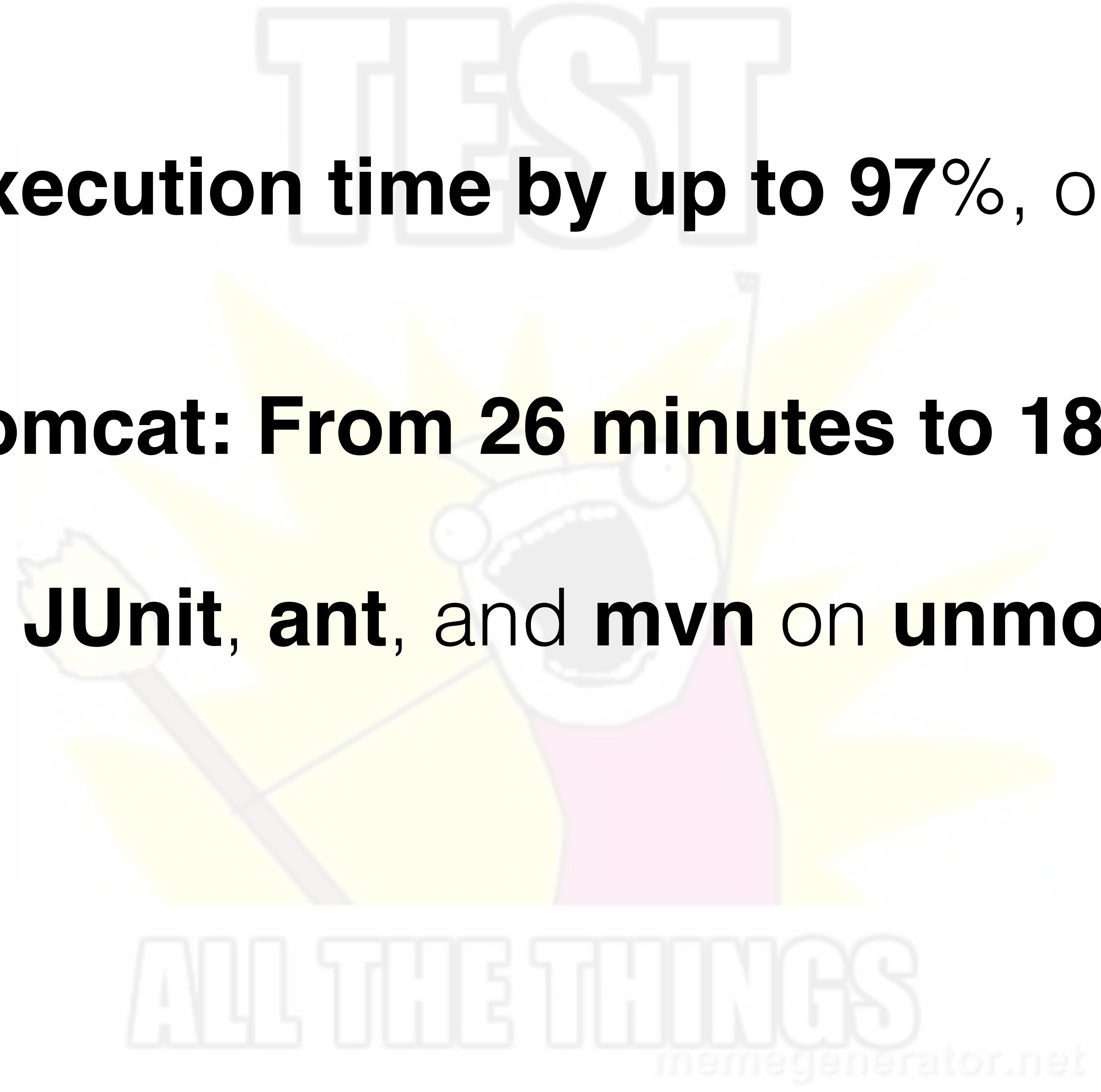

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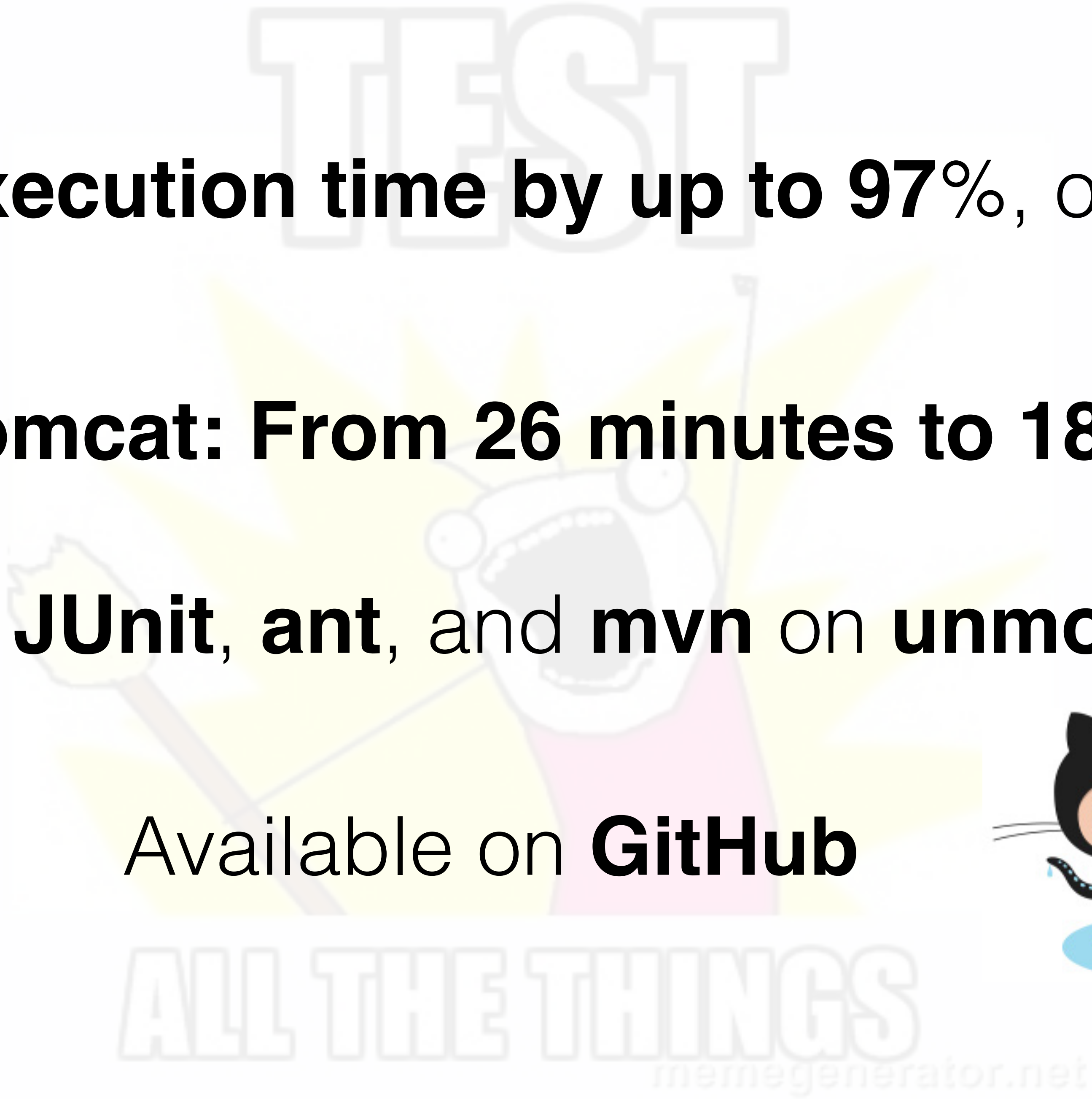

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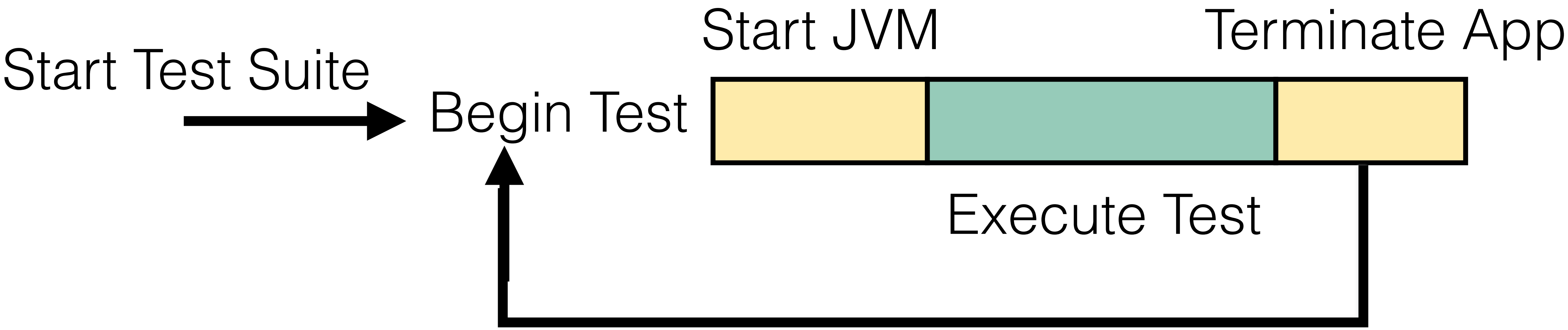
Available on **GitHub**

JUnit Test Execution



Start Test Suite

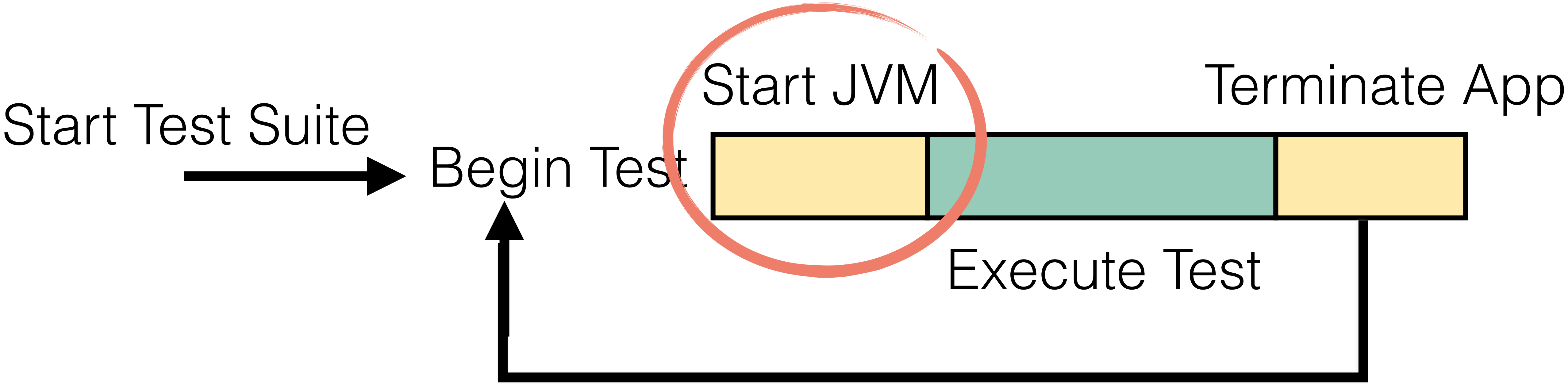
Begin Test

Start JVM

Execute Test

Terminate App

JUnit Test Execution



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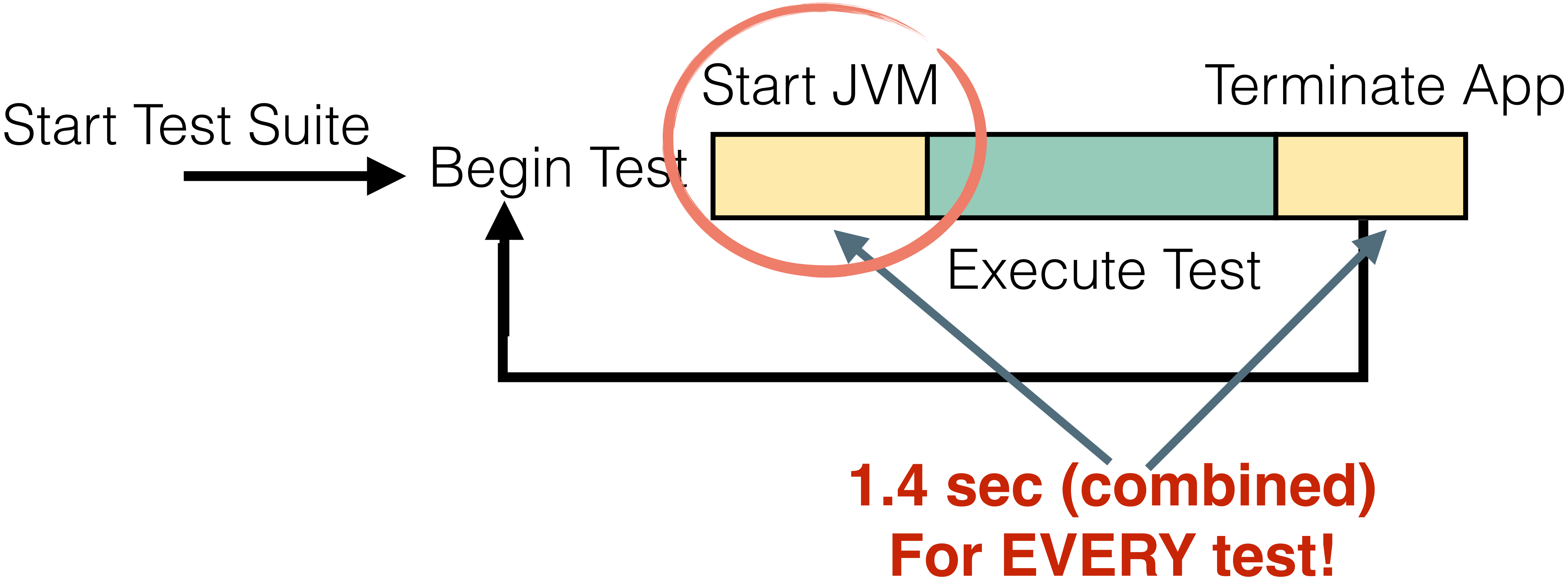
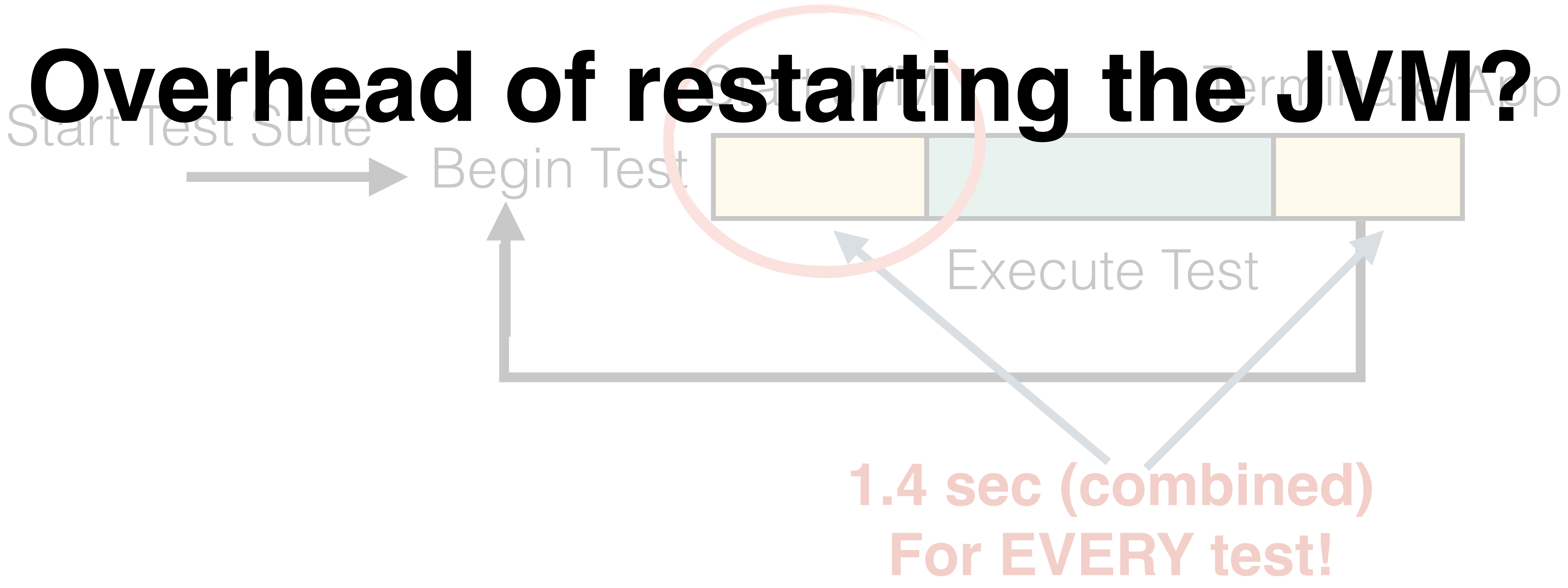


**1.4 sec (combined)
For EVERY test!**

JUnit Test Execution



Overhead of restarting the JVM?

JUnit Test Execution

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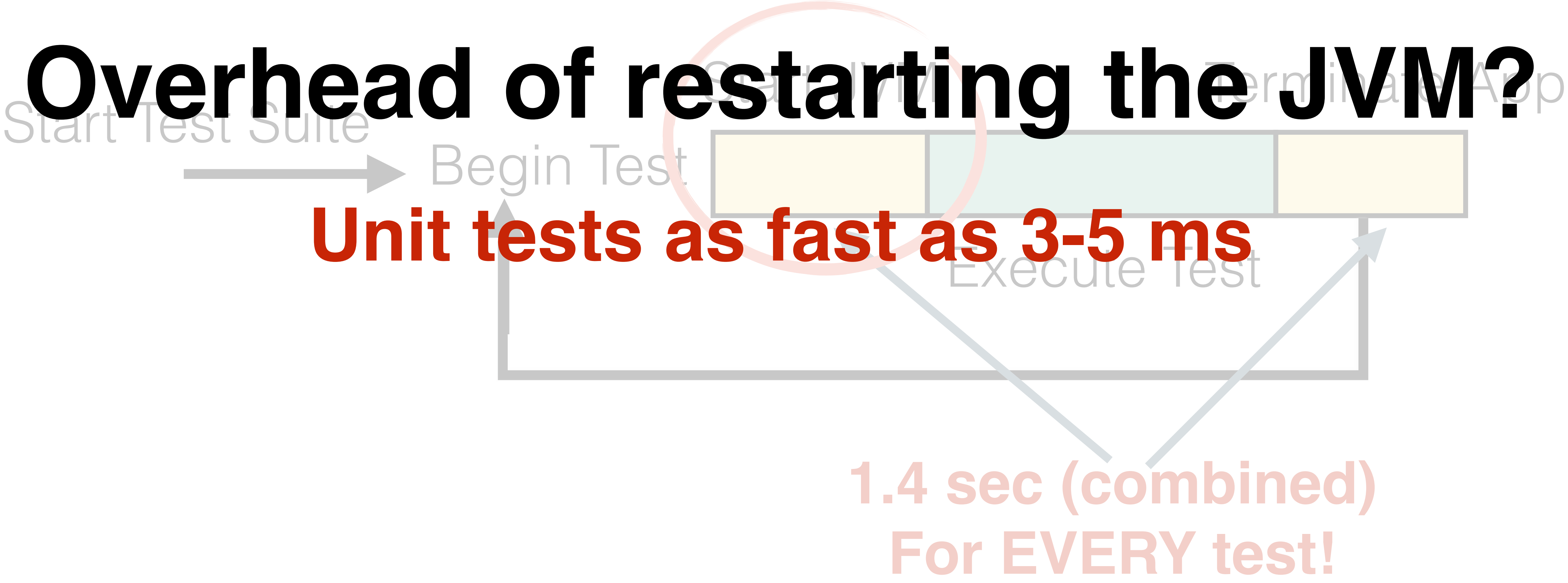
Unit tests as fast as 3-5 ms



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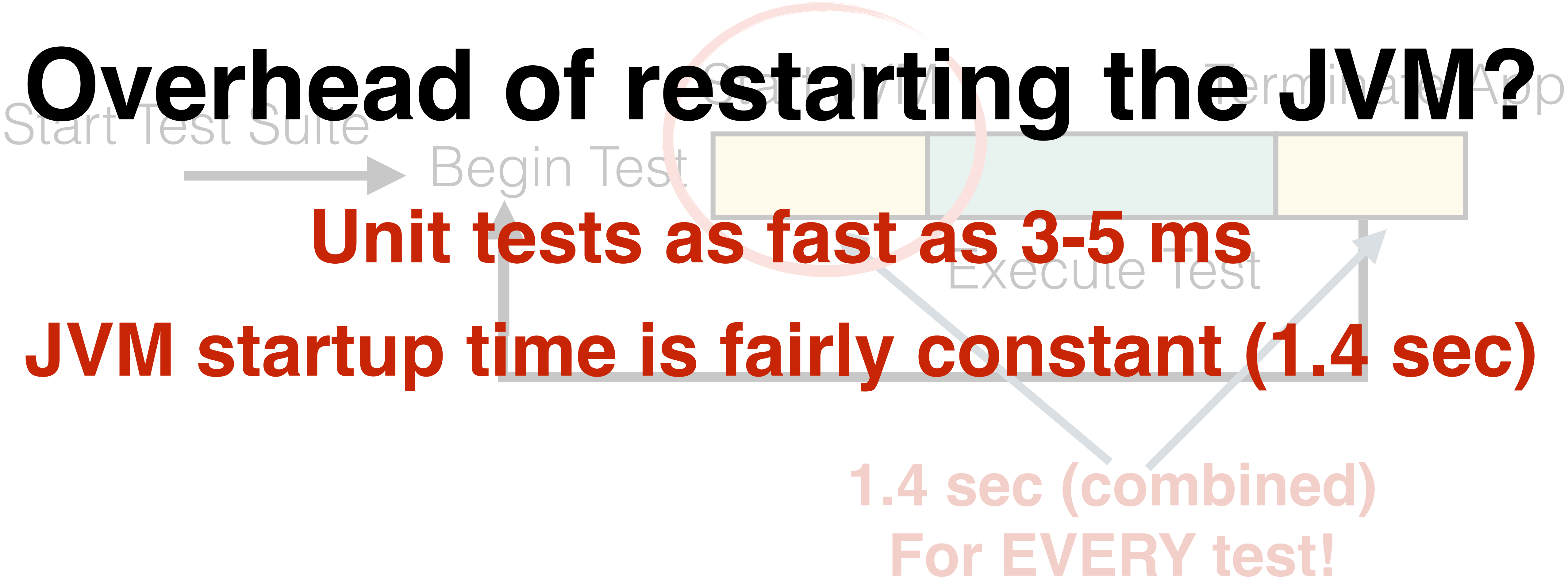

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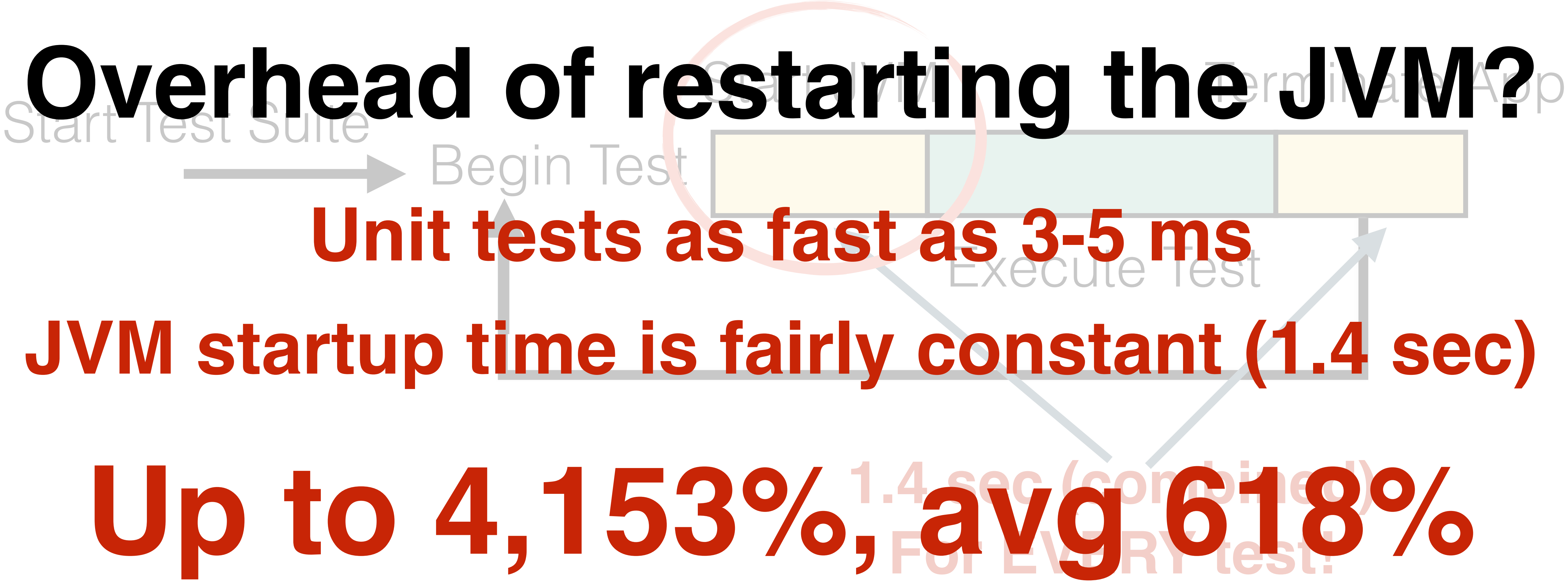

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JVM startup time is fairly constant (1.4 sec)

Up to 4,153%, avg 618%

***From our study of 20 popular FOSS apps**

Do applications really use a new JVM for each test?

- Checked out the 1,000 largest Java projects from Ohloh
- 81% of projects with more than 1,000 tests do it
- 71% of projects with more than 1 million LOC do it
- Overall: 41% of all of the projects do

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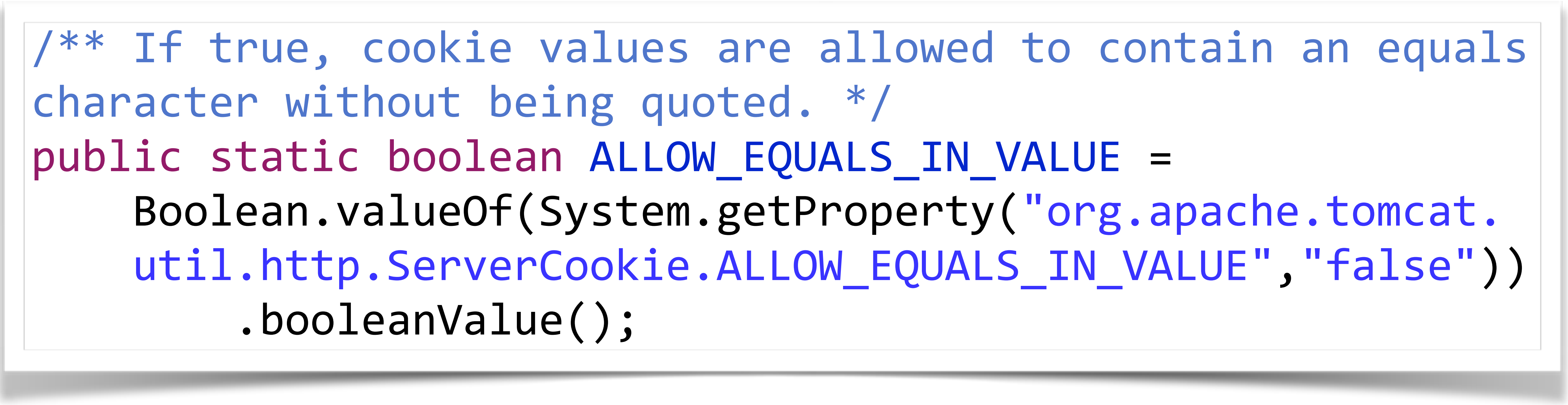
- Dangerous: If wrong, can have false positives or false negatives (Muşlu [FSE ’11], Zhang [ISSTA ’14])

Test Independence



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/** If true, cookie values are allowed to contain an equals
character without being quoted. */
public static boolean ALLOW_EQUALS_IN_VALUE =
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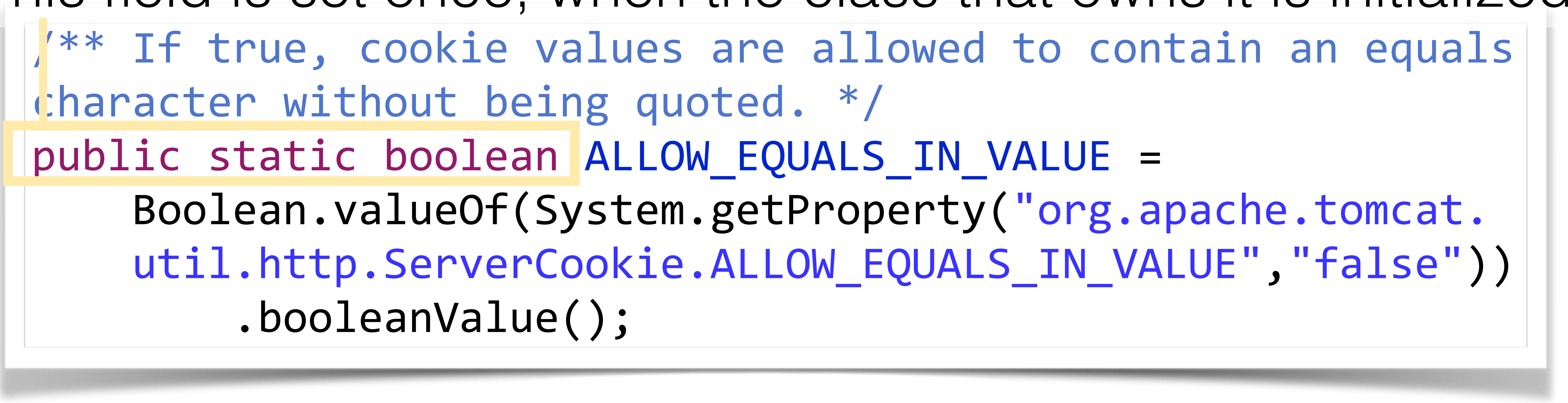
Test Independence

This field is set once, when the class that owns it is initialized



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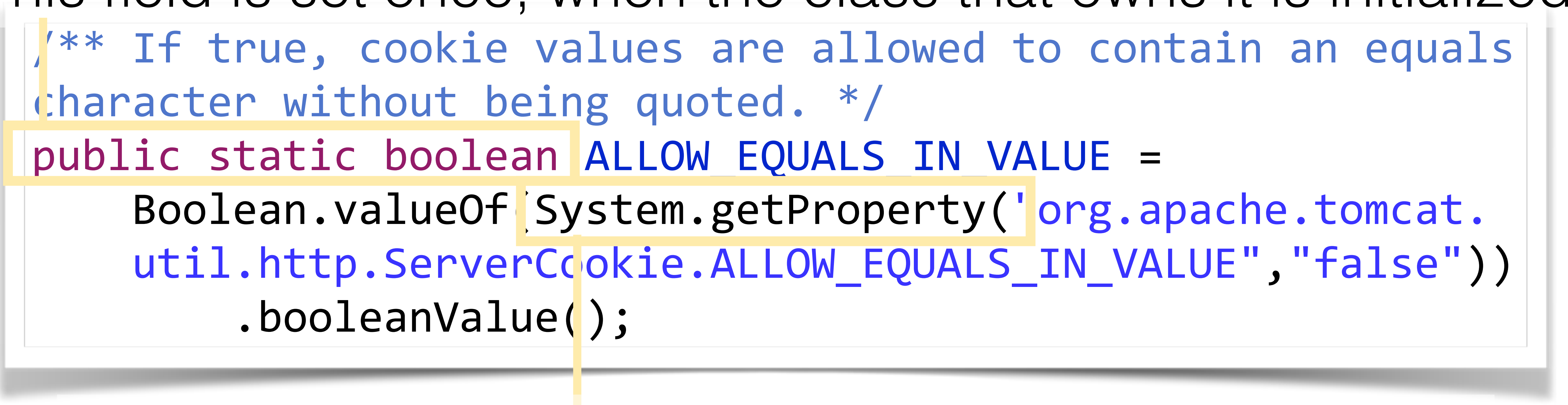

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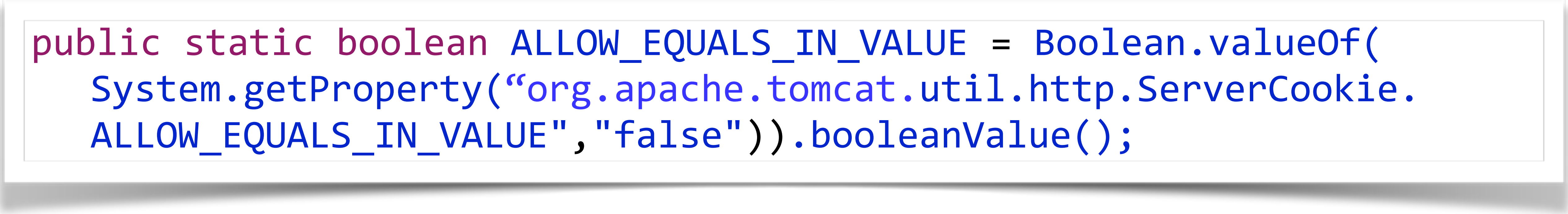
This field's value is dependent on an external property

A Tale of Two Tests



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TestAllowEqualsInValue

TestDontAllowEqualsInValue

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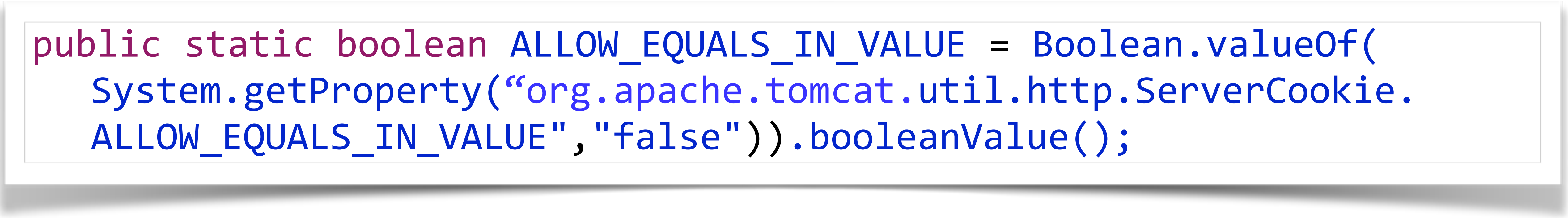

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TestAllowEqualsInValue

TestDontAllowEqualsInValue

Sets environmental variable to `true`

Start Tomcat, run test

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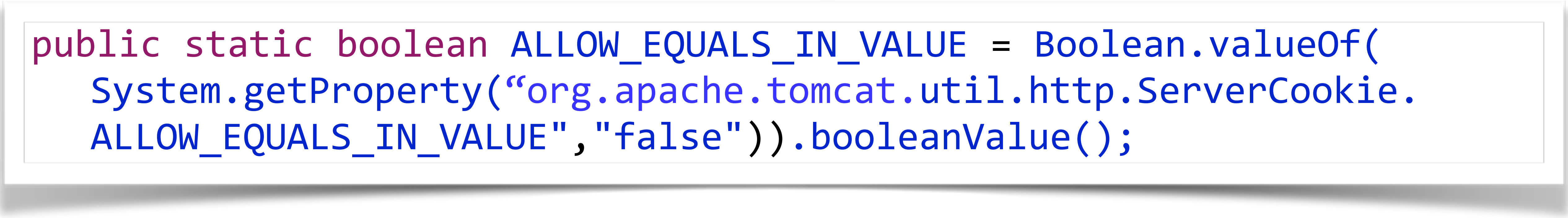

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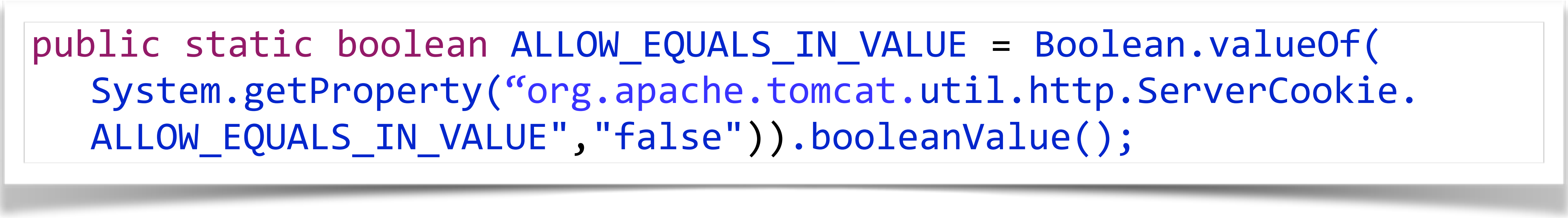

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Sets environmental variable to `true`

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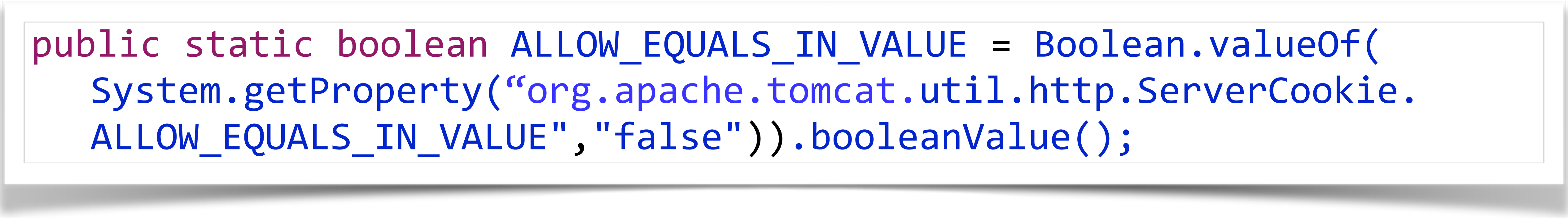
TestDontAllowEqualsInValue

Sets environmental variable to `false`

Start Tomcat, run test

But our static field is stuck!

A Tale of Two Tests



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Start Tomcat, run test

TestDontAllowEqualsInValue

Sets environmental variable to `false`

Start Tomcat, run test

Our Approach

Unit Test Virtualization: Allow tests to leave side-effects.
But efficiently contain them.

How do Tests Leak Data?

Java is **memory-managed**, and **object oriented**

We think in terms of *object graphs*

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Test Runner Instance

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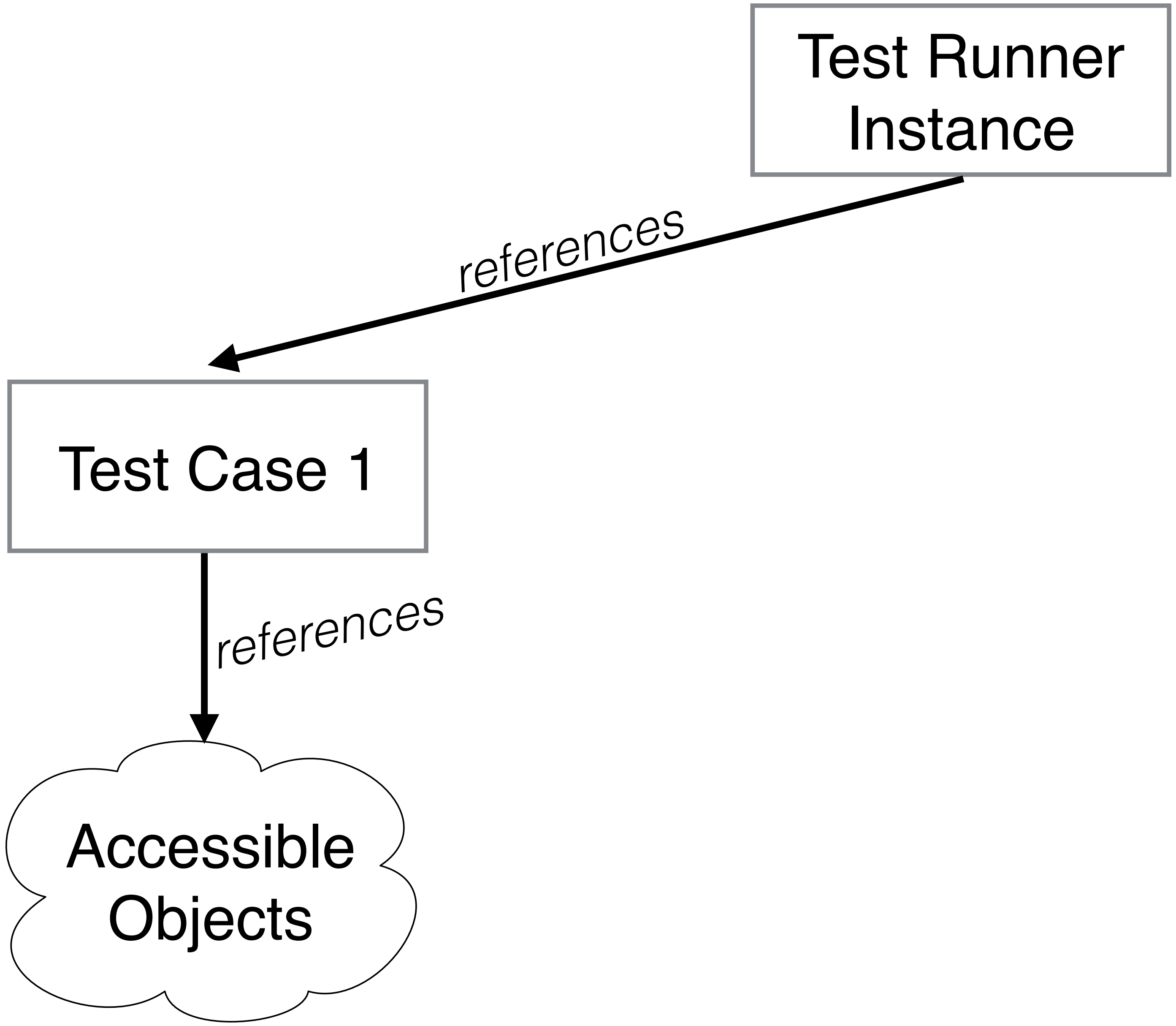

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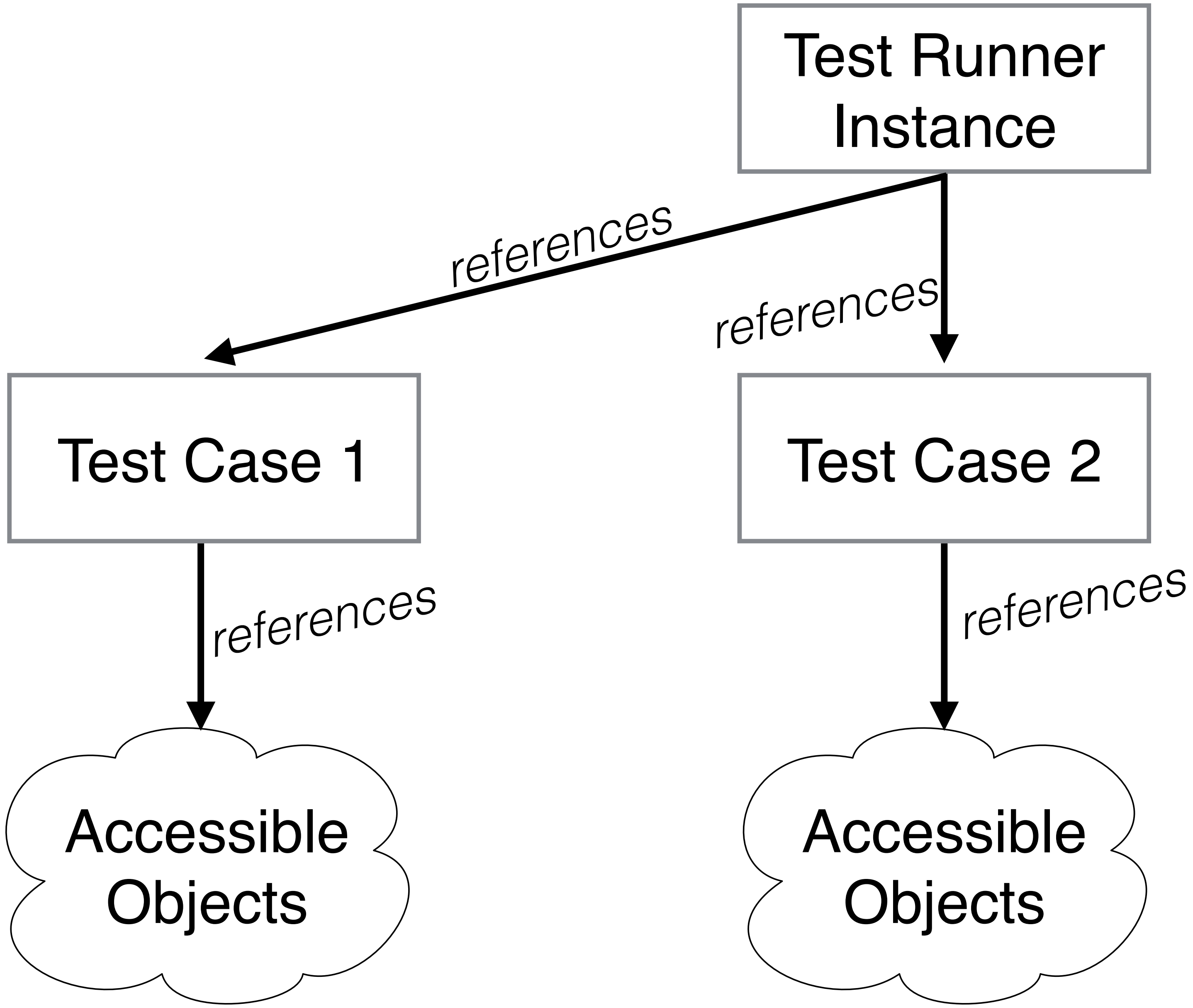

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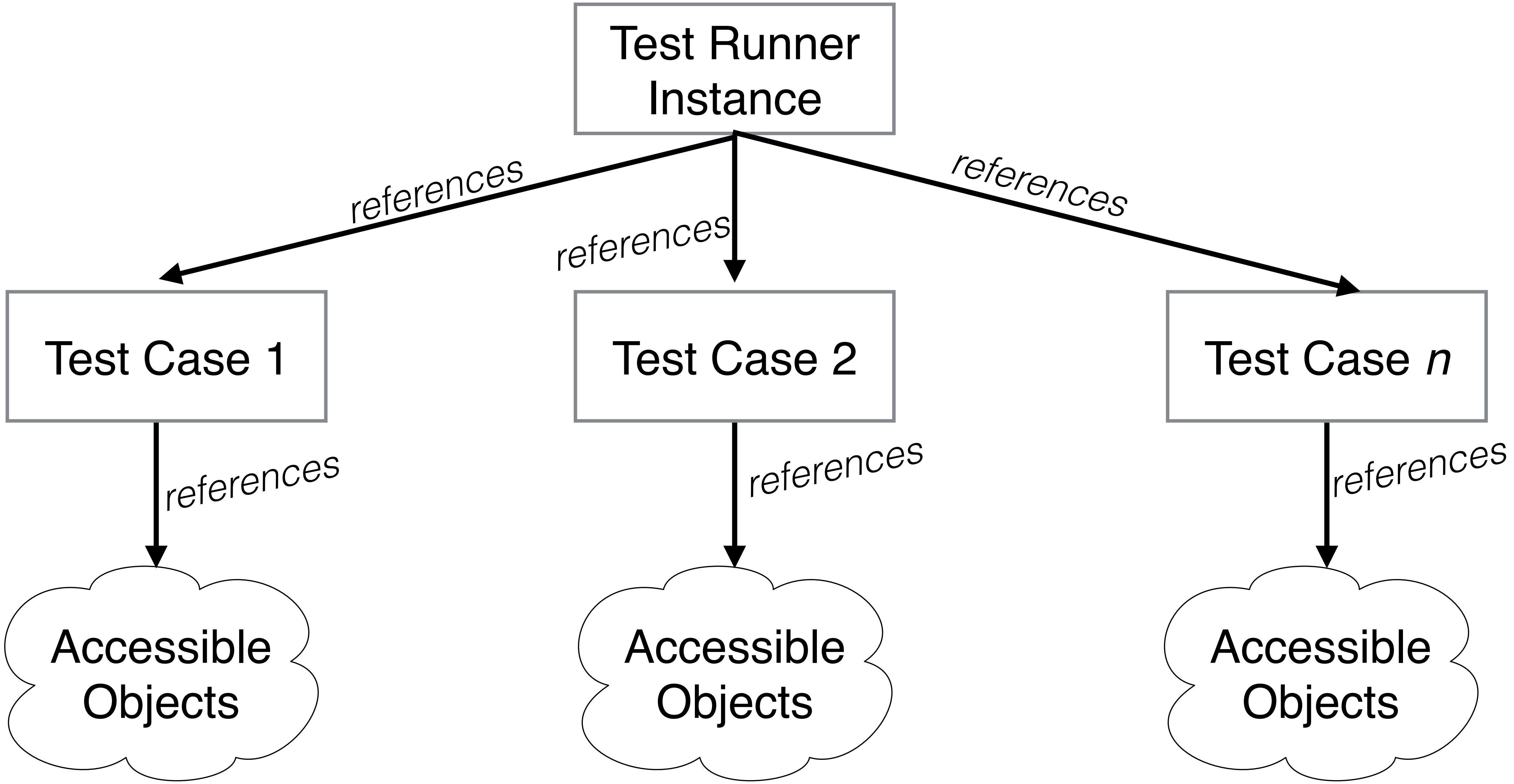

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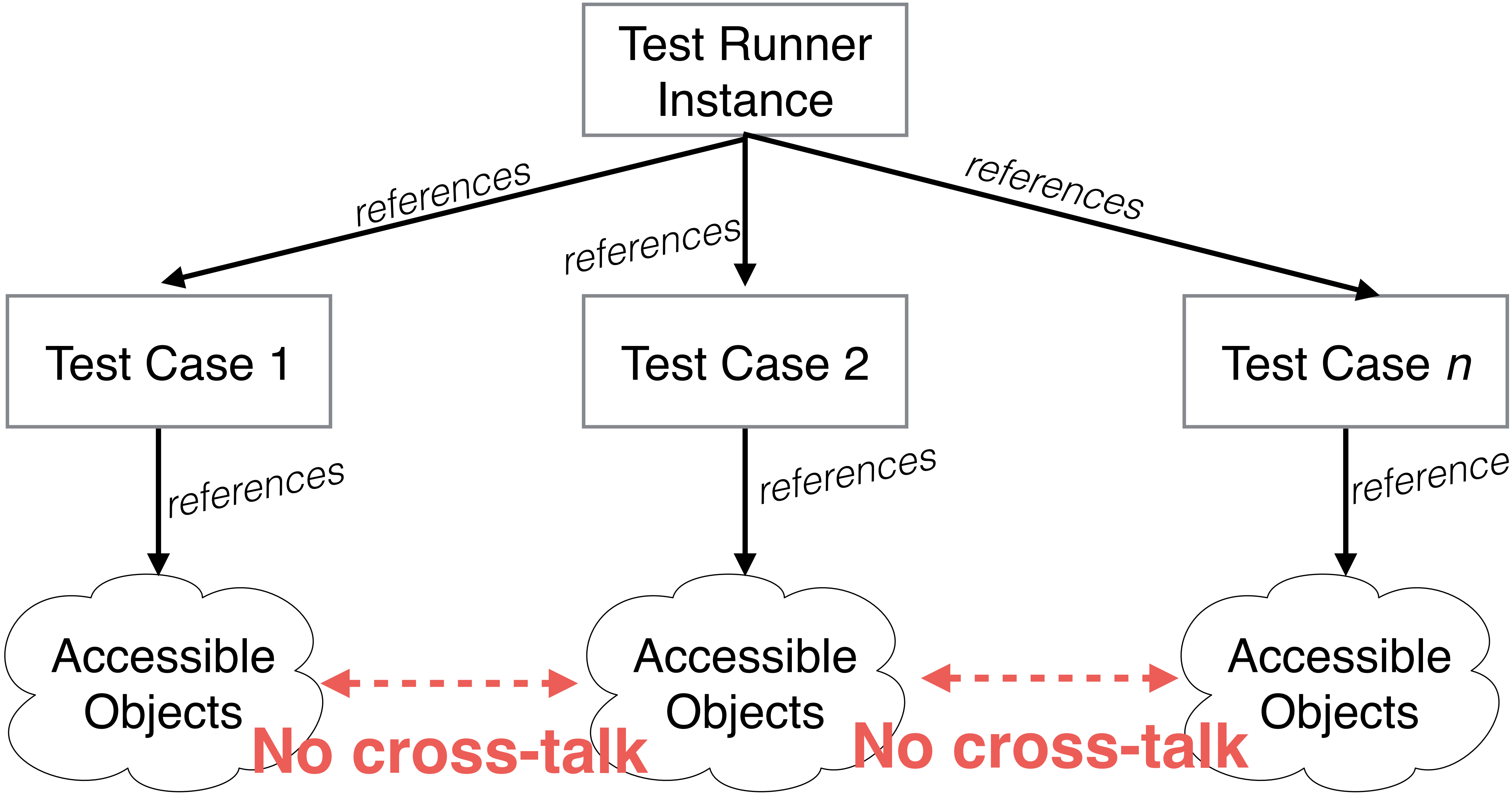

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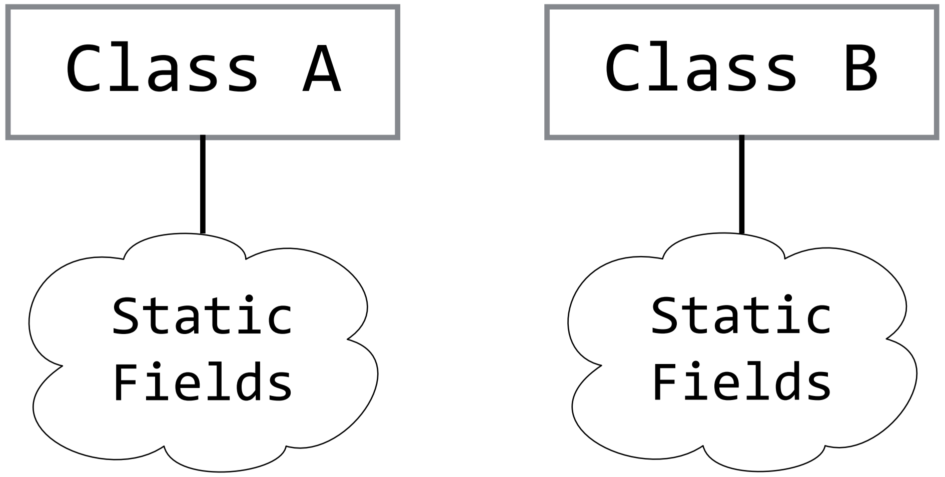
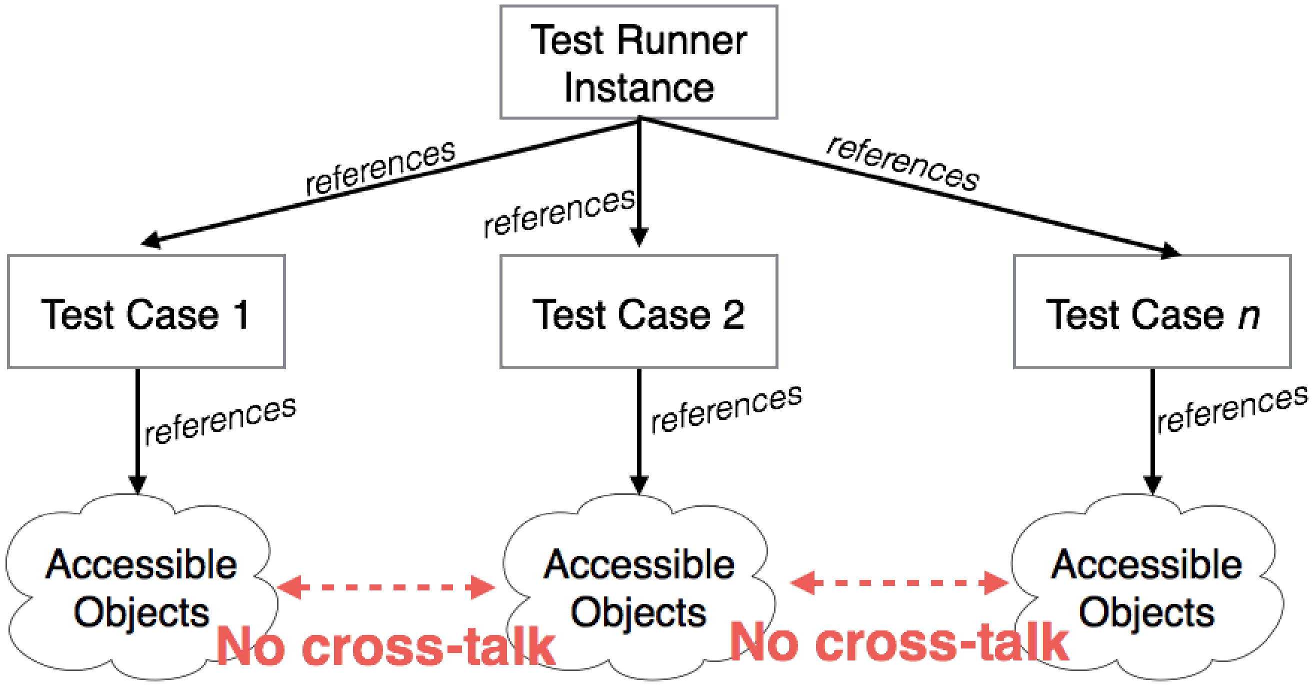


Static fields: owned by a class, NOT by an instance



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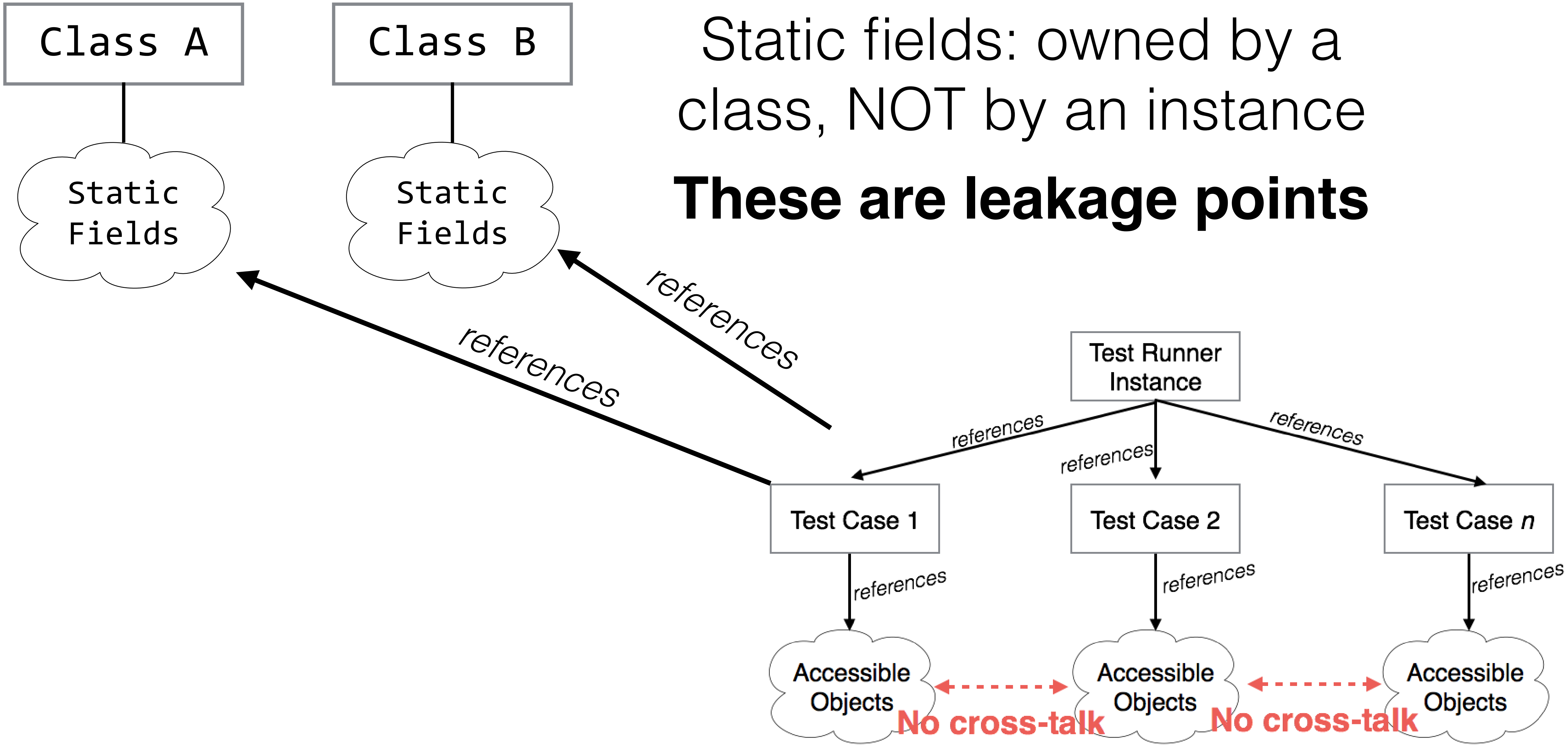
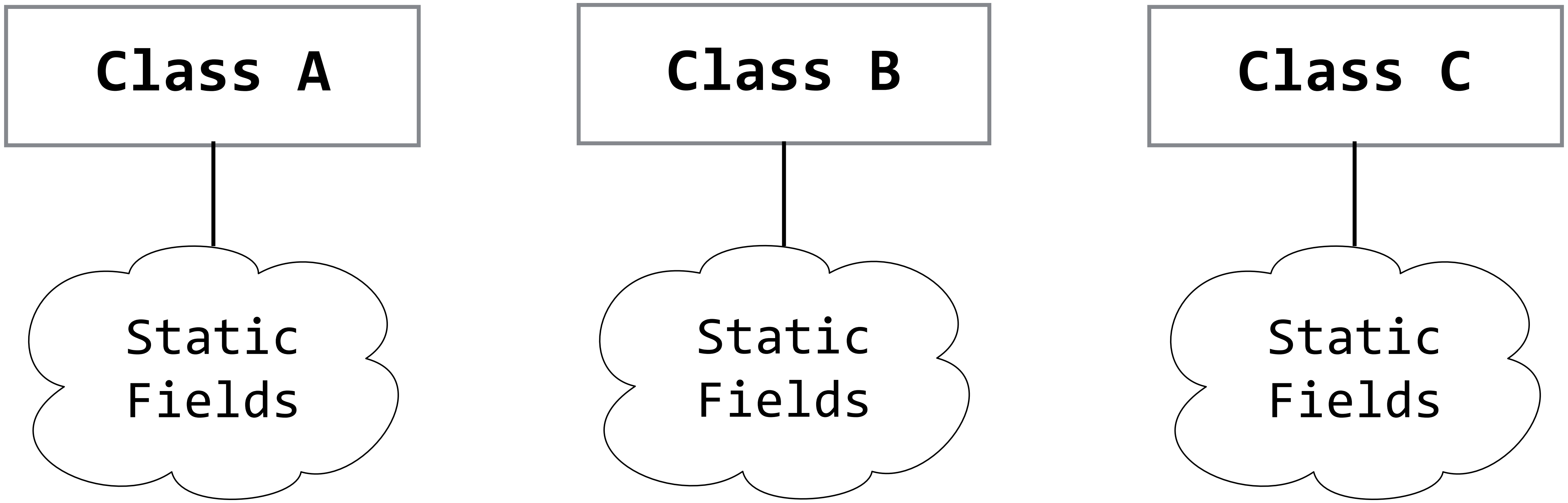
These are leakage points



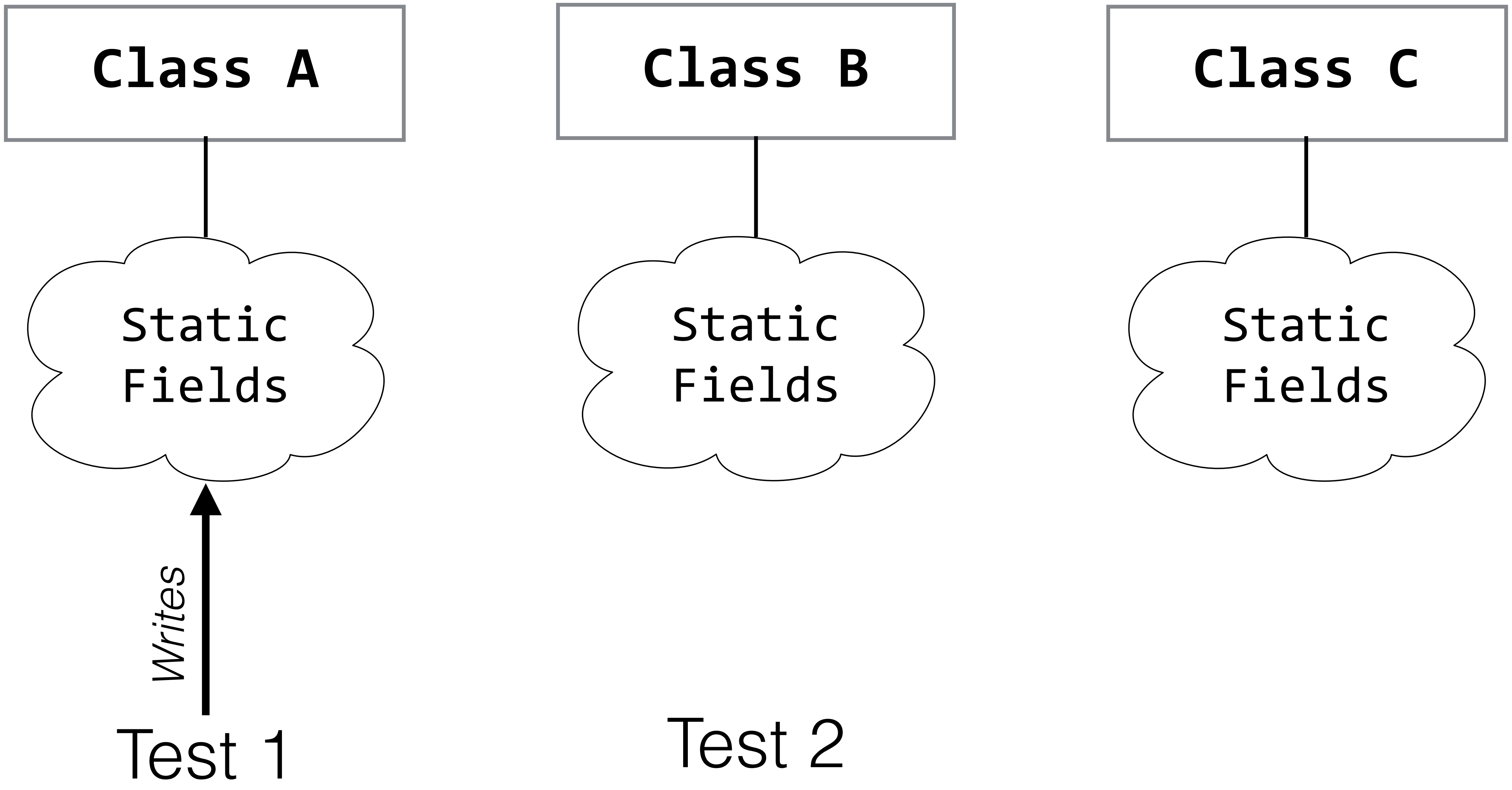
Isolating Side Effects



Test 1

Test 2

Isolating Side Effects



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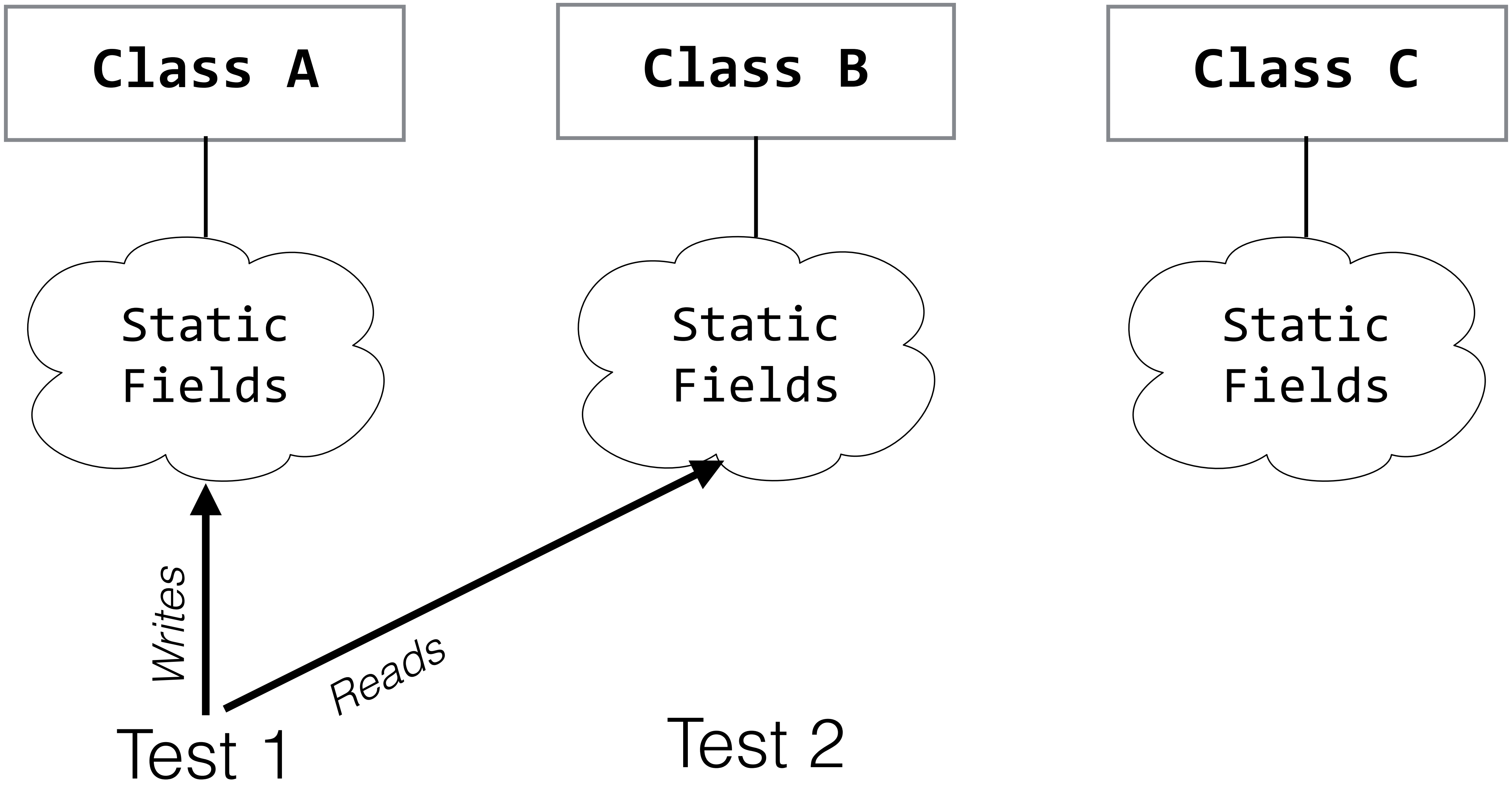

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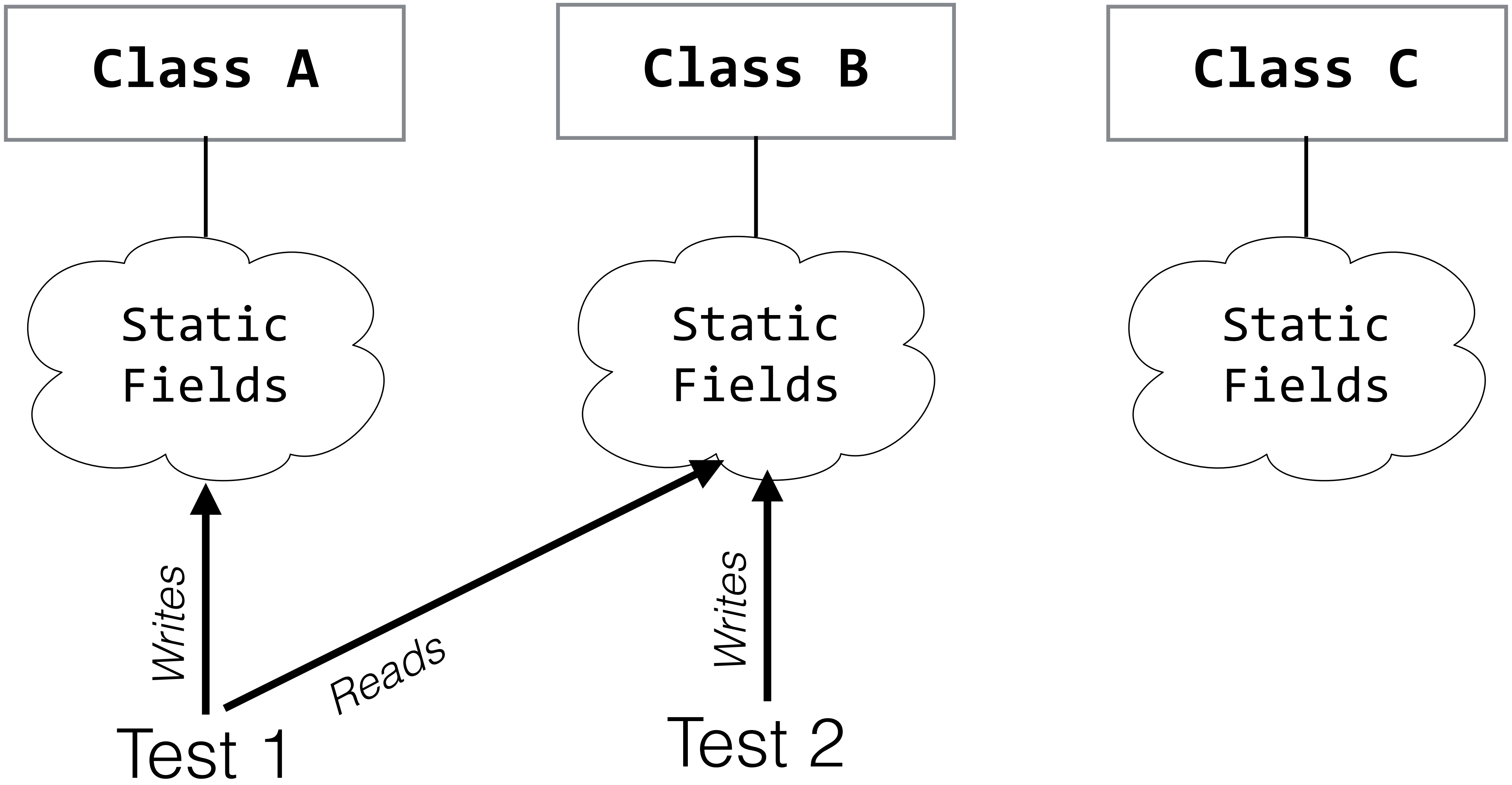

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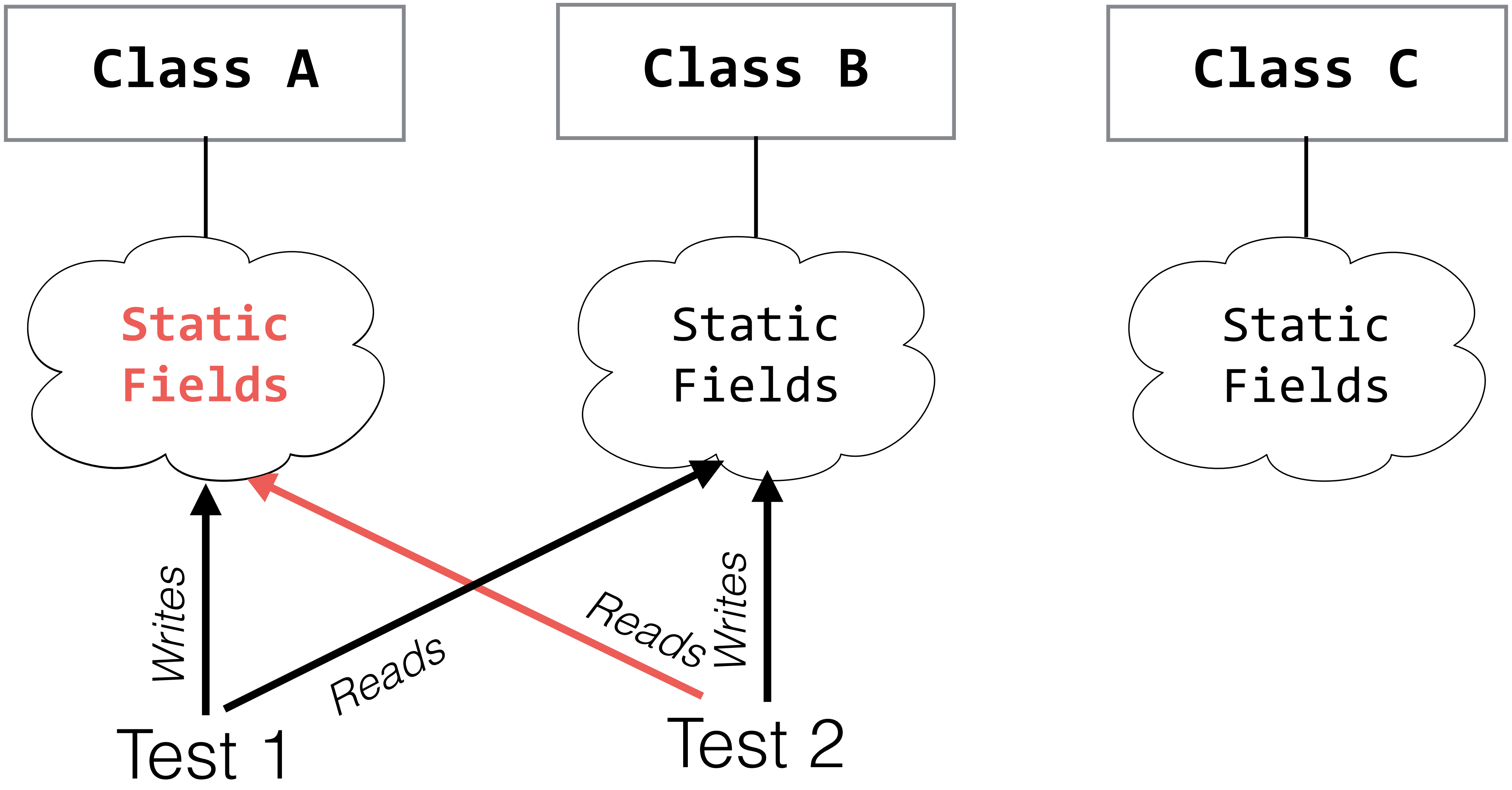

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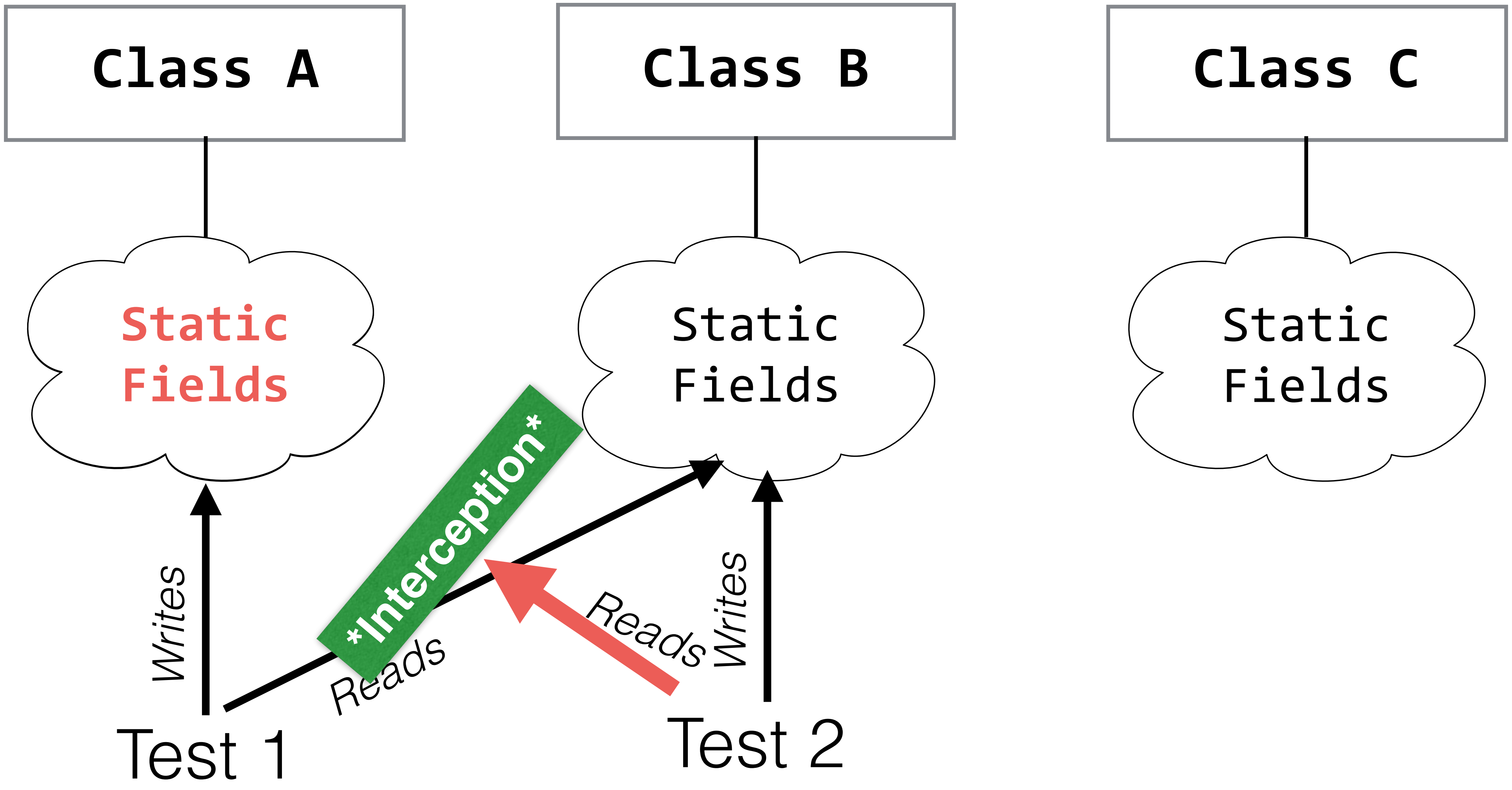

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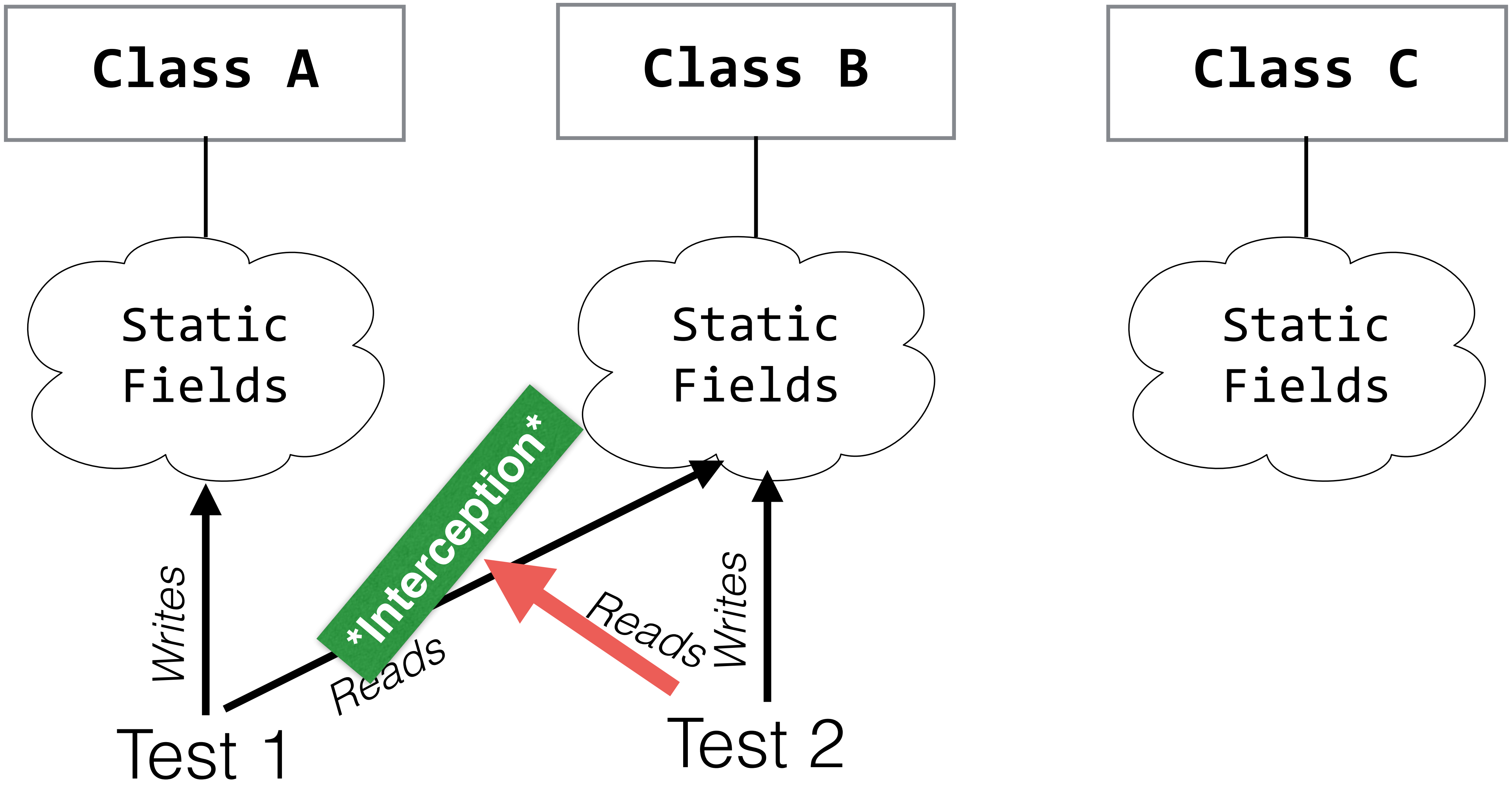

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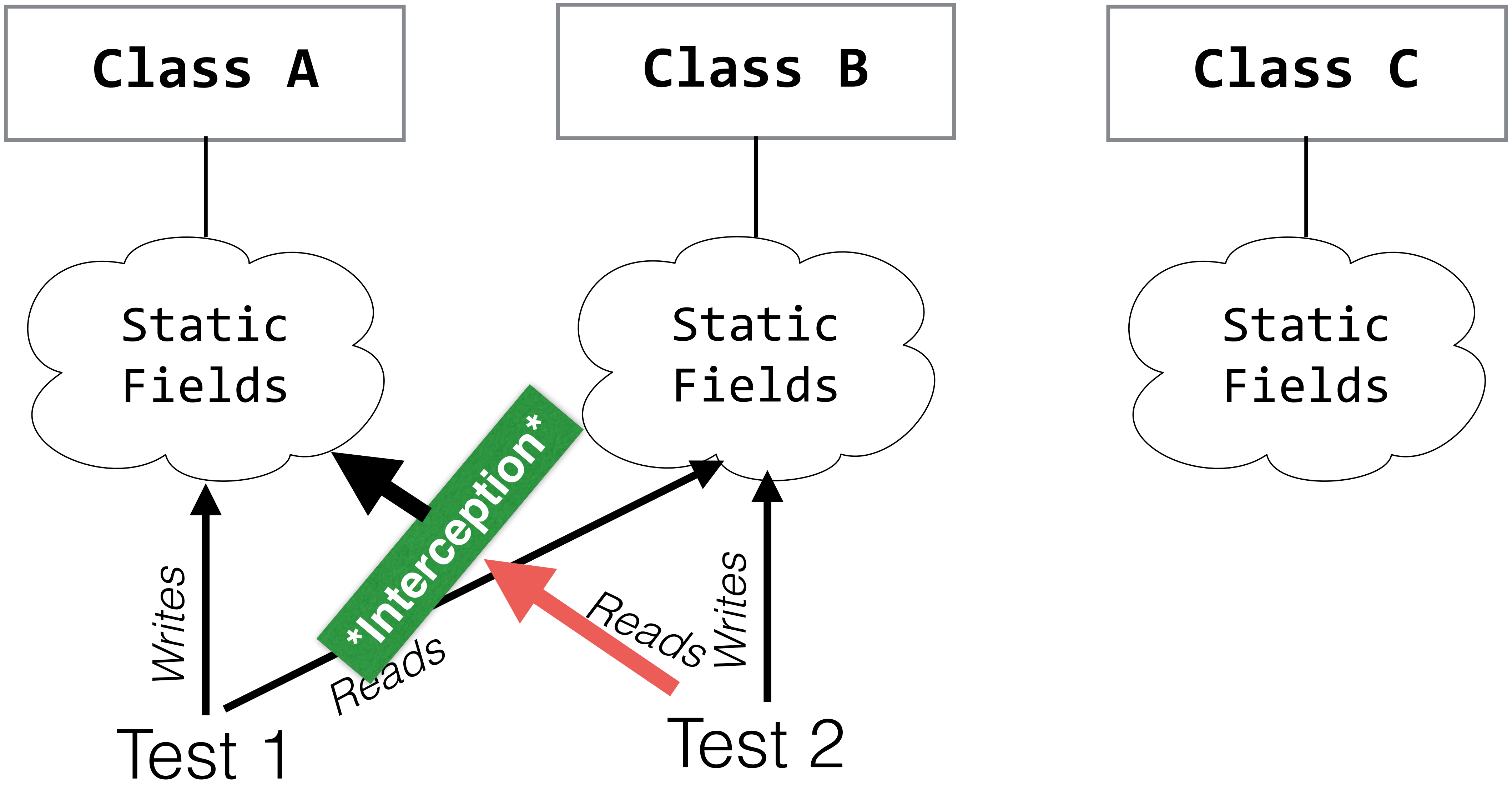


Class A

Class B

Class C

Static Fields

Static Fields

Static Fields

Writes

Reads

Interception

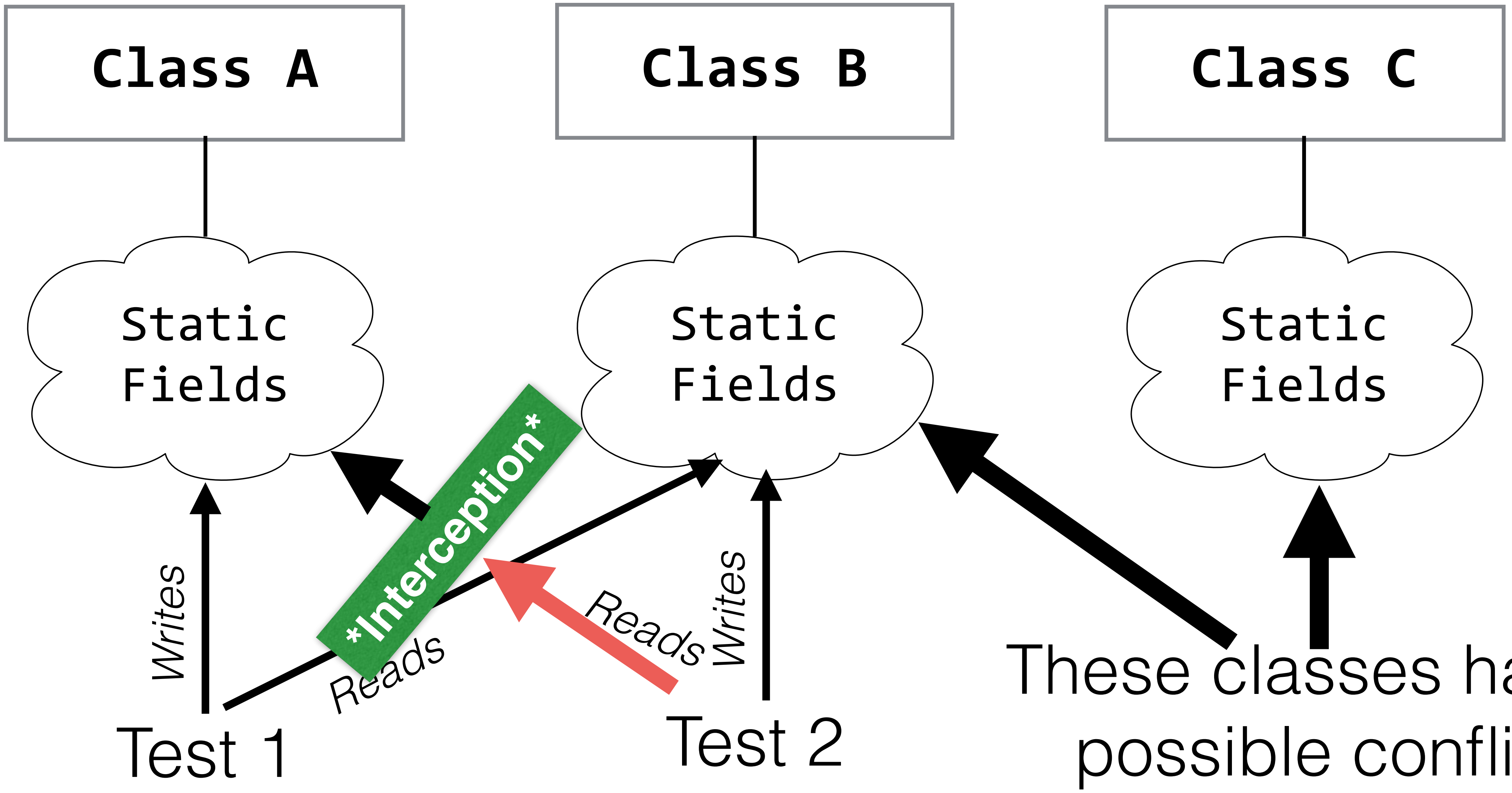
Reads

Writes

Test 1

Test 2

Isolating Side Effects

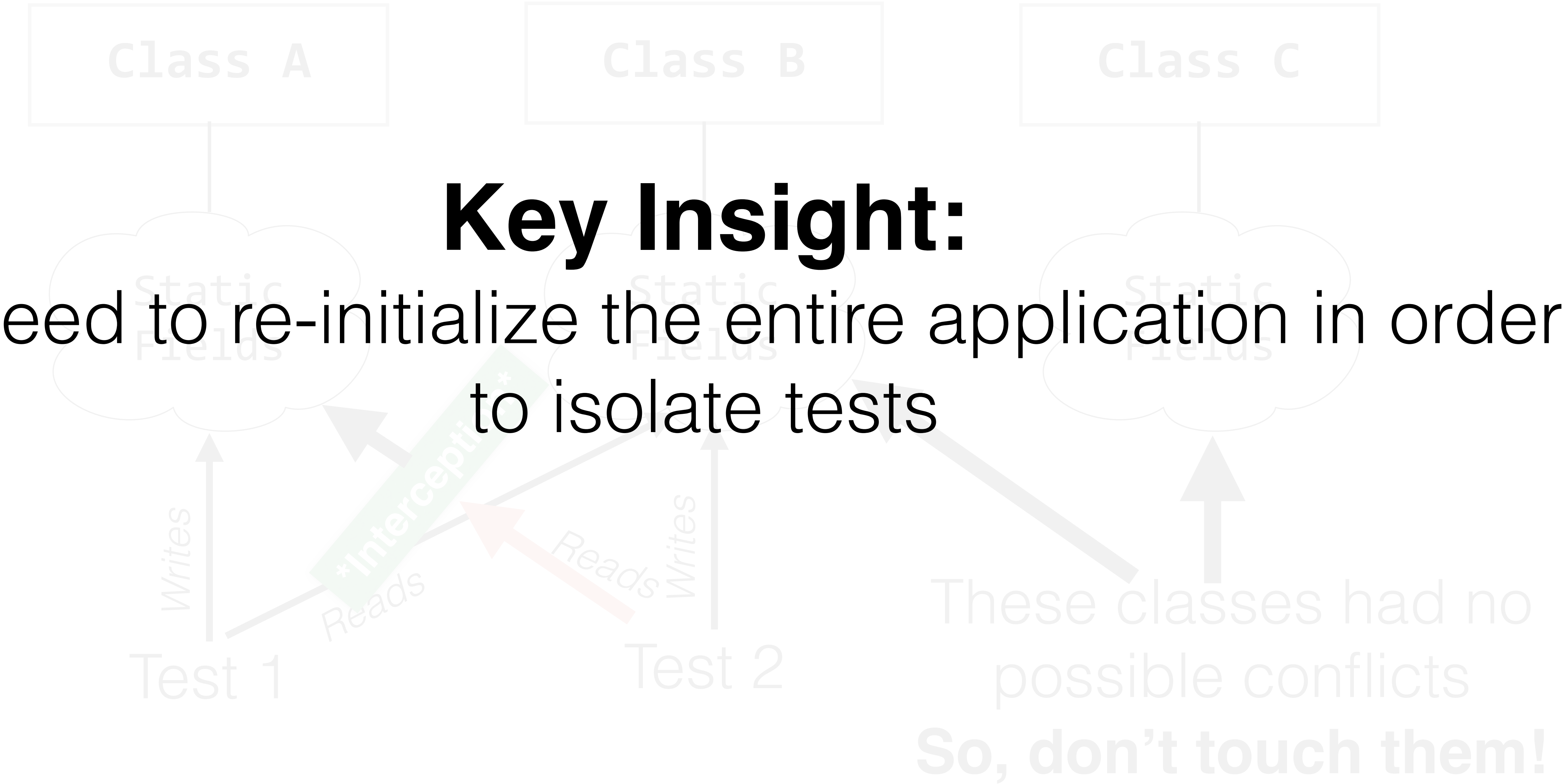


These classes had no possible conflicts
So, don't touch them!

Isolating Side Effects

Key Insight:

No need to re-initialize the entire application in order to isolate tests



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- Isolates in-memory side effects, just like restarting JVM
- Integrates easily with ant, maven, junit
- Implemented completely with application byte code instrumentation
- No changes to JVM, no access to source code required

Efficient Reinitialization

Emulate *exactly* what happens when a class is initialized the first time

Efficient Reinitialization

Emulate *exactly* what happens when a class is initialized the first time

First new instance or static reference of *T*

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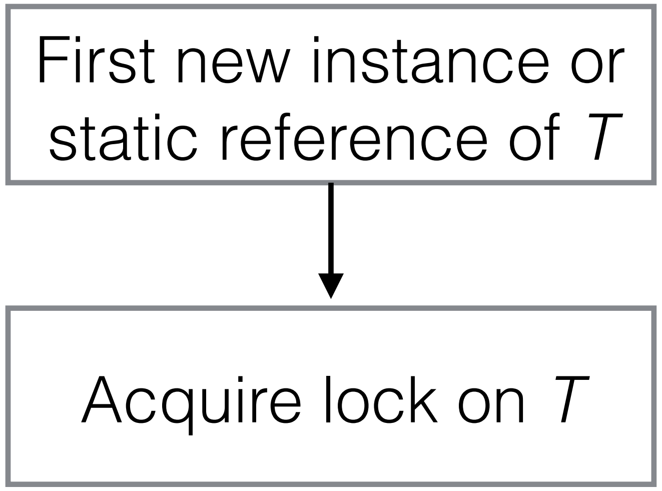

First new instance or static reference of *T*

Acquire lock on *T*

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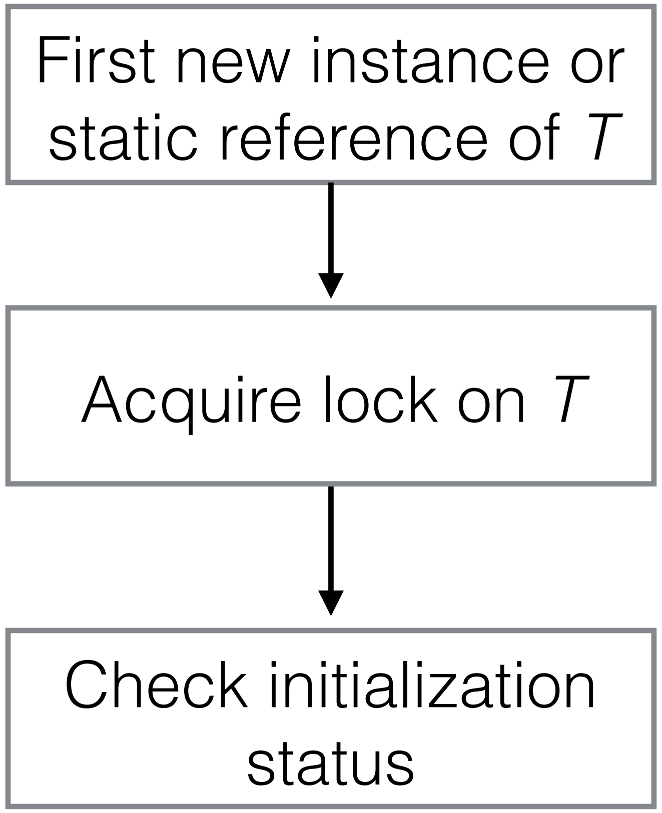
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Check initialization status

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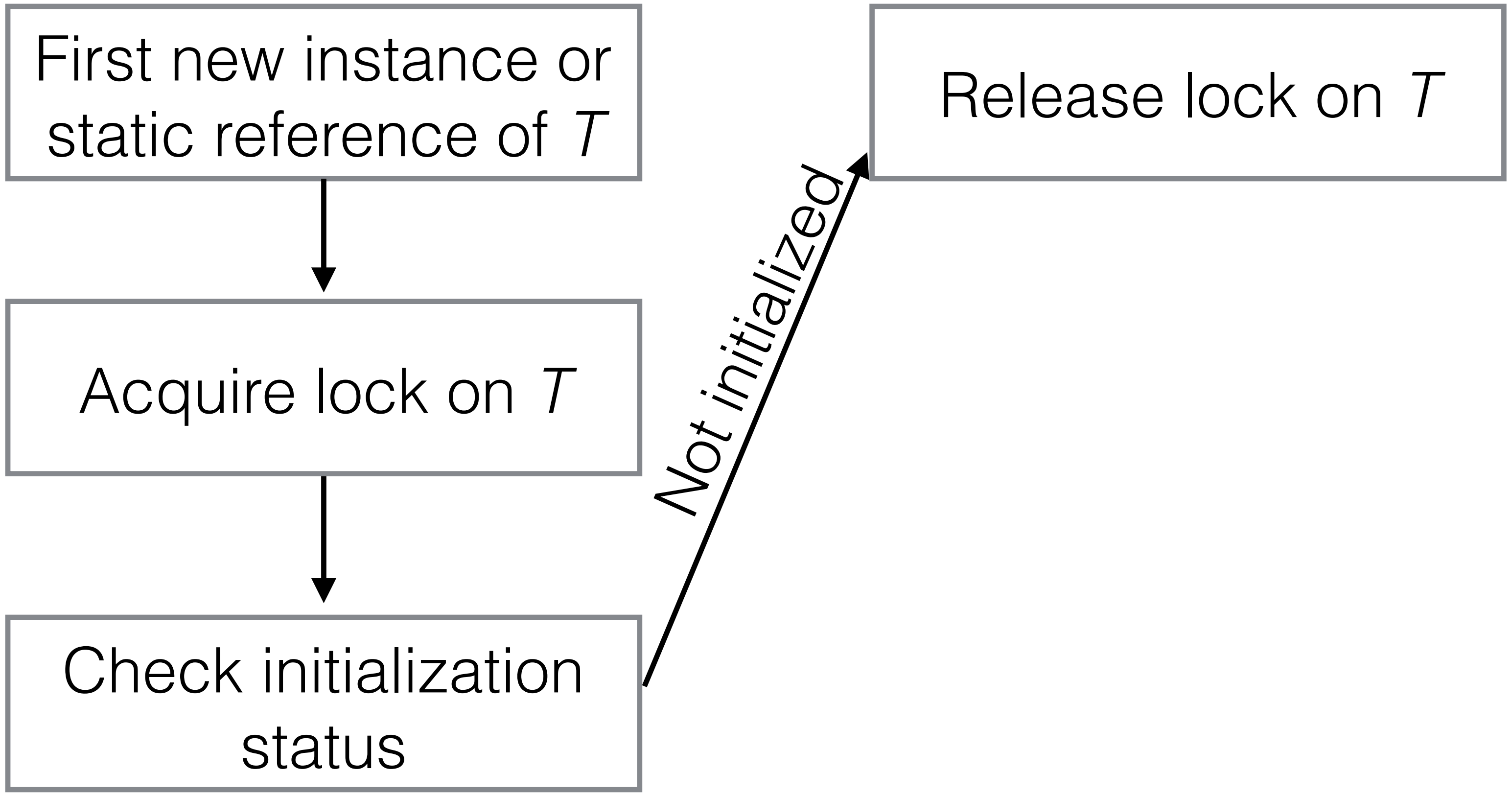

First new instance or static reference of *T*

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Check initialization status

Not initialized

Release lock on *T*

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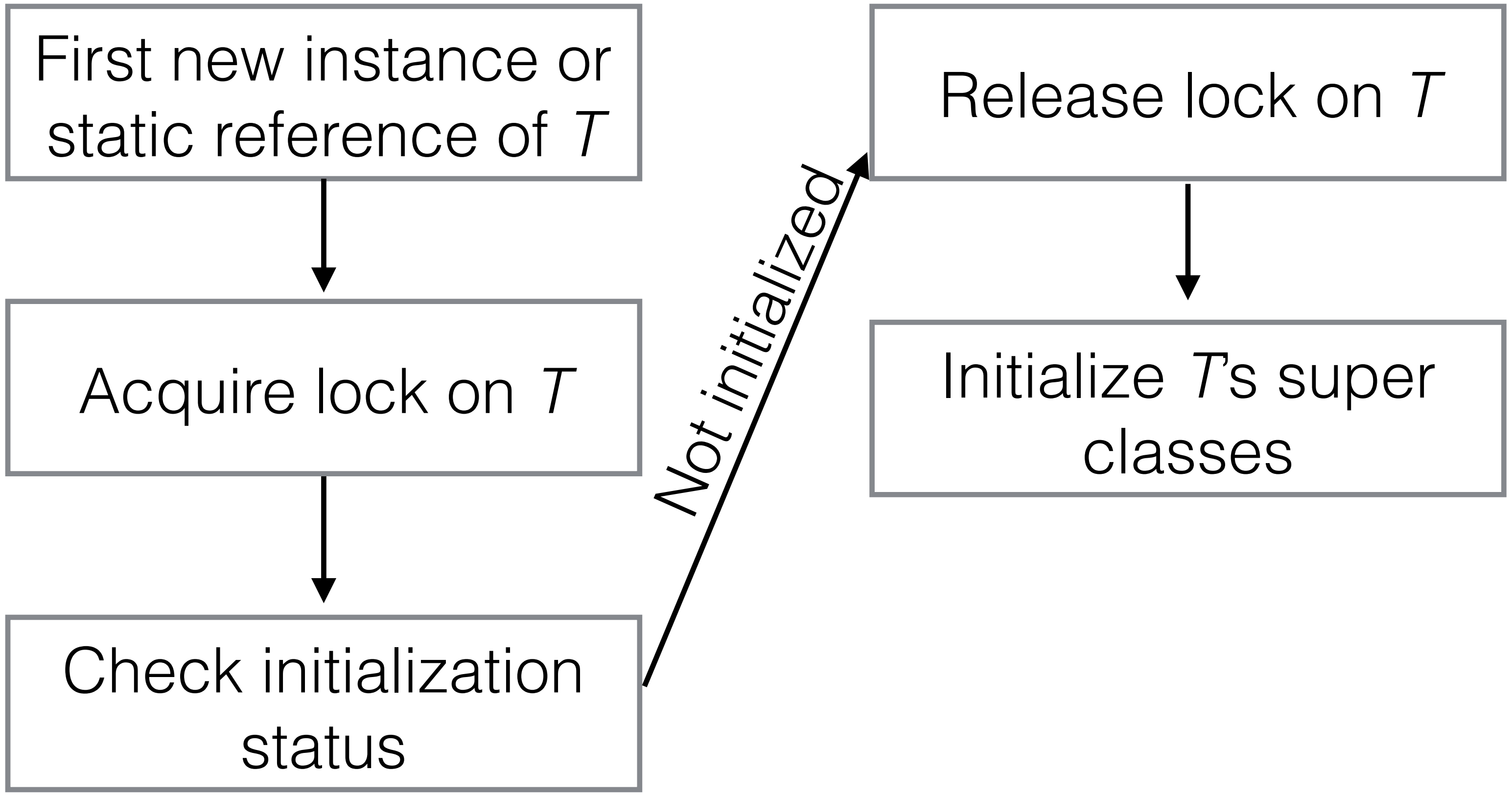

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Check initialization status

Not initialized

Release lock on *T*

Initialize *T*'s super classes

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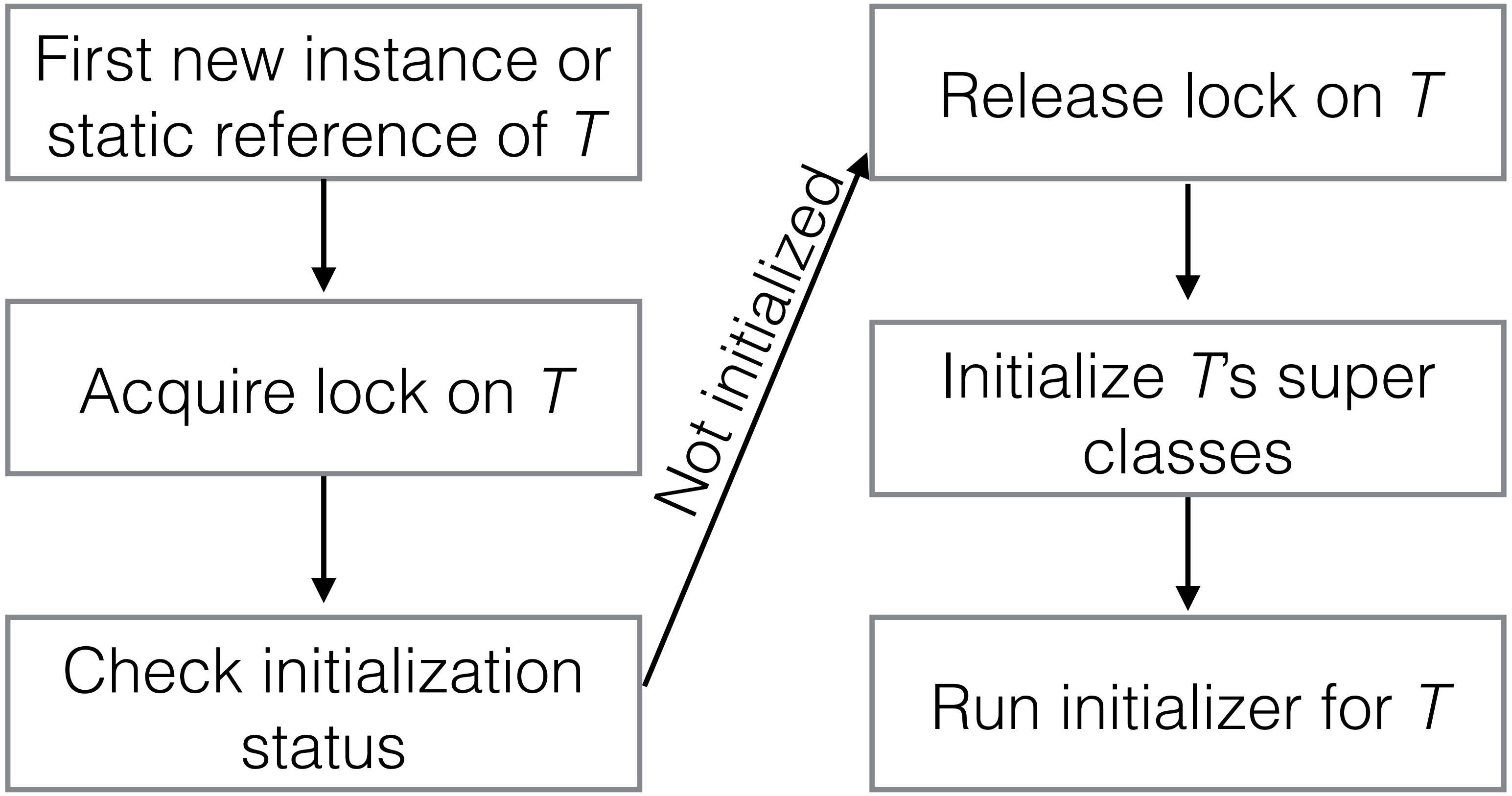
First new instance or static reference of *T*
Acquire lock on *T*
Check initialization status
Not initialized
Release lock on *T*
Initialize *T*'s super classes
Run initializer for *T*

Efficient Reinitialization

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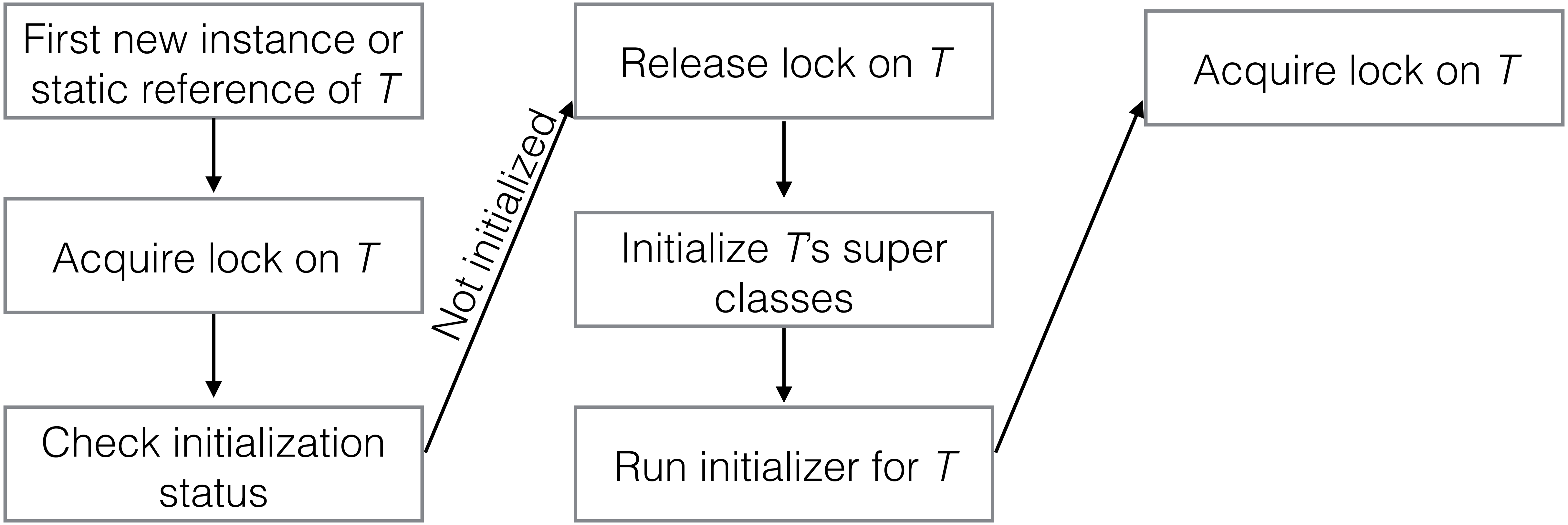

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Acquire lock on *T*

Check initialization status

Not initialized

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Run initializer for *T*

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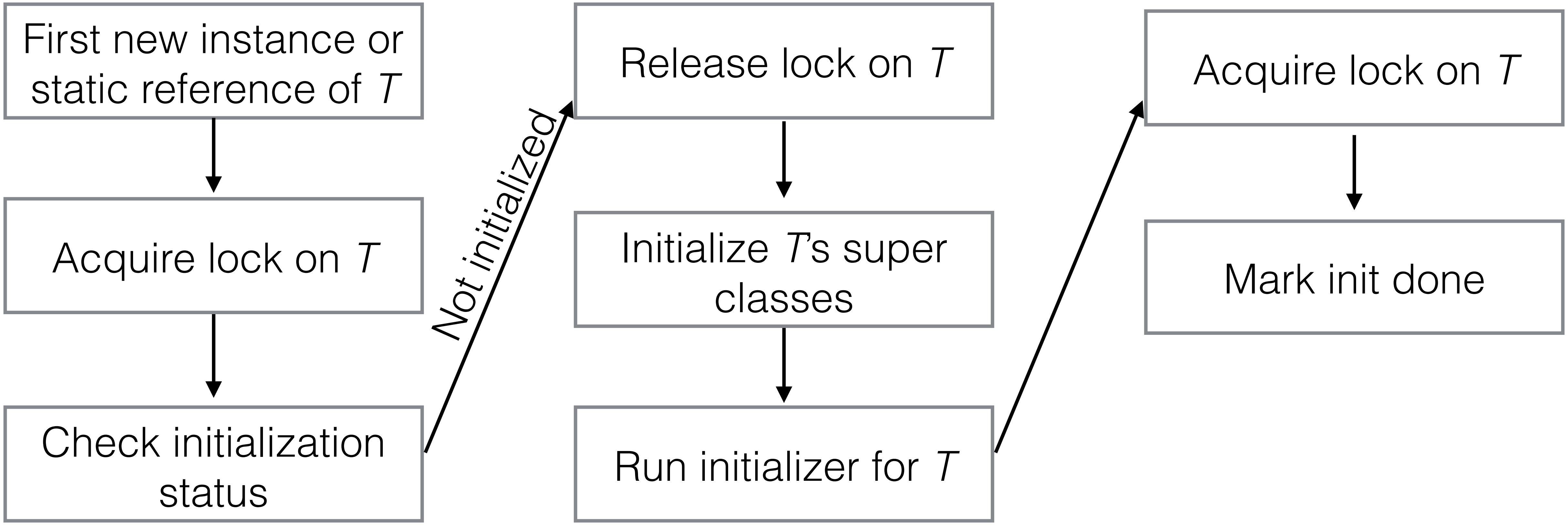

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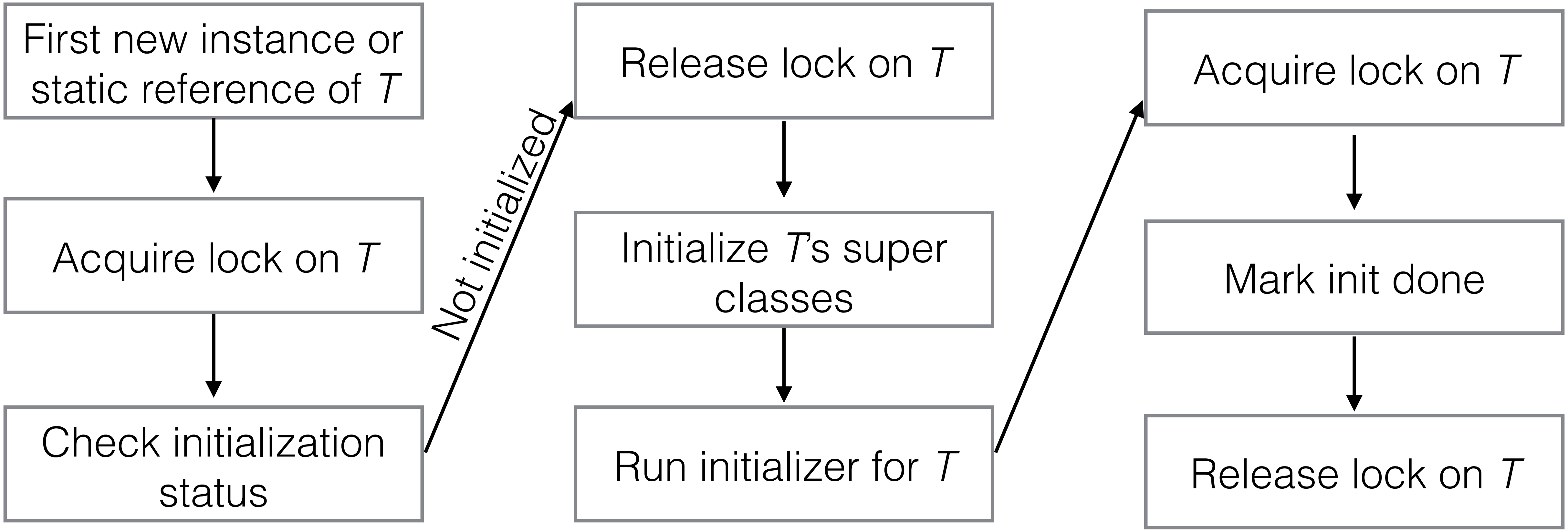

First new instance or static reference of *T*

Acquire lock on *T*

Check initialization status

Release lock on *T*

Initialize *T*'s super classes

Run initializer for *T*

Acquire lock on *T*

Mark init done

Release lock on *T*

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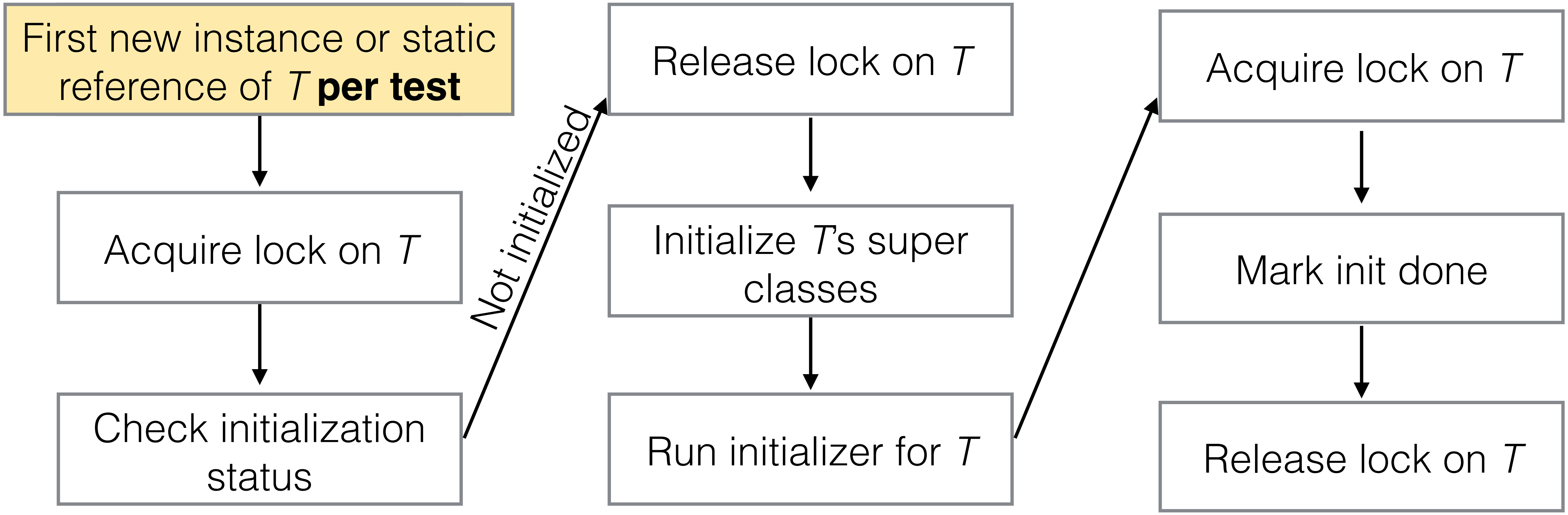


First new instance or static reference of *T* **per test**

Acquire lock on *T*

Check initialization status

Release lock on *T*

Initialize *T*'s super classes

Run initializer for *T*

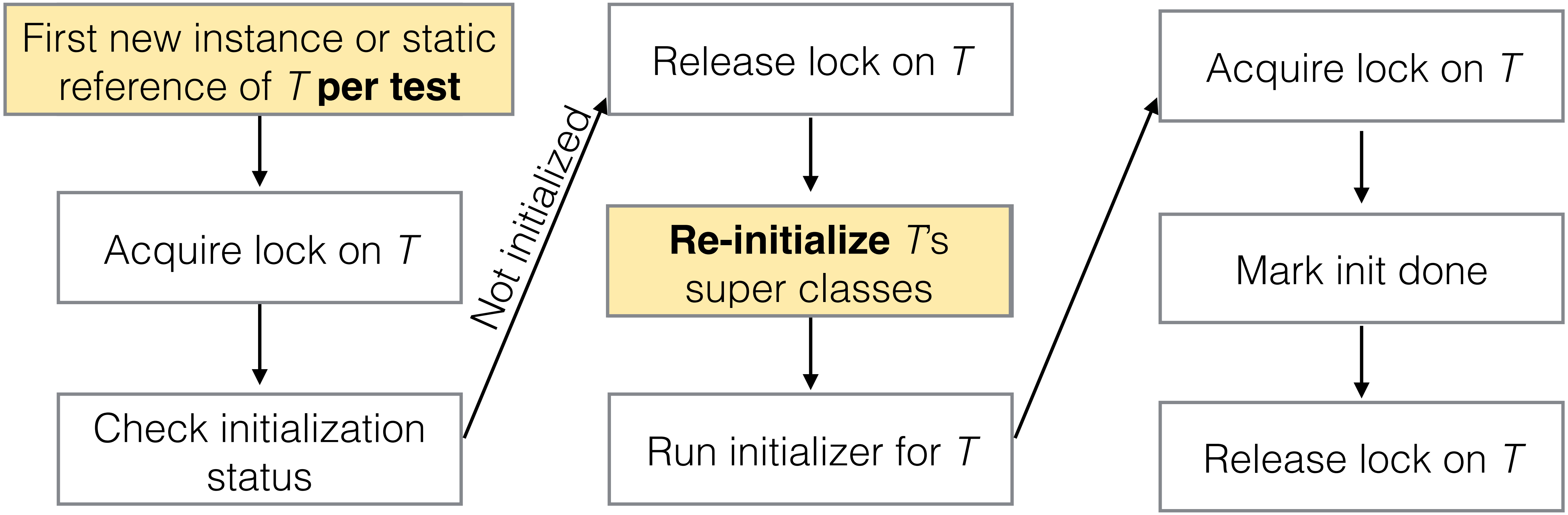
Acquire lock on *T*

Mark init done

Release lock on *T*

Efficient Reinitialization

Emulate *exactly* what happens when a class is initialized the first time



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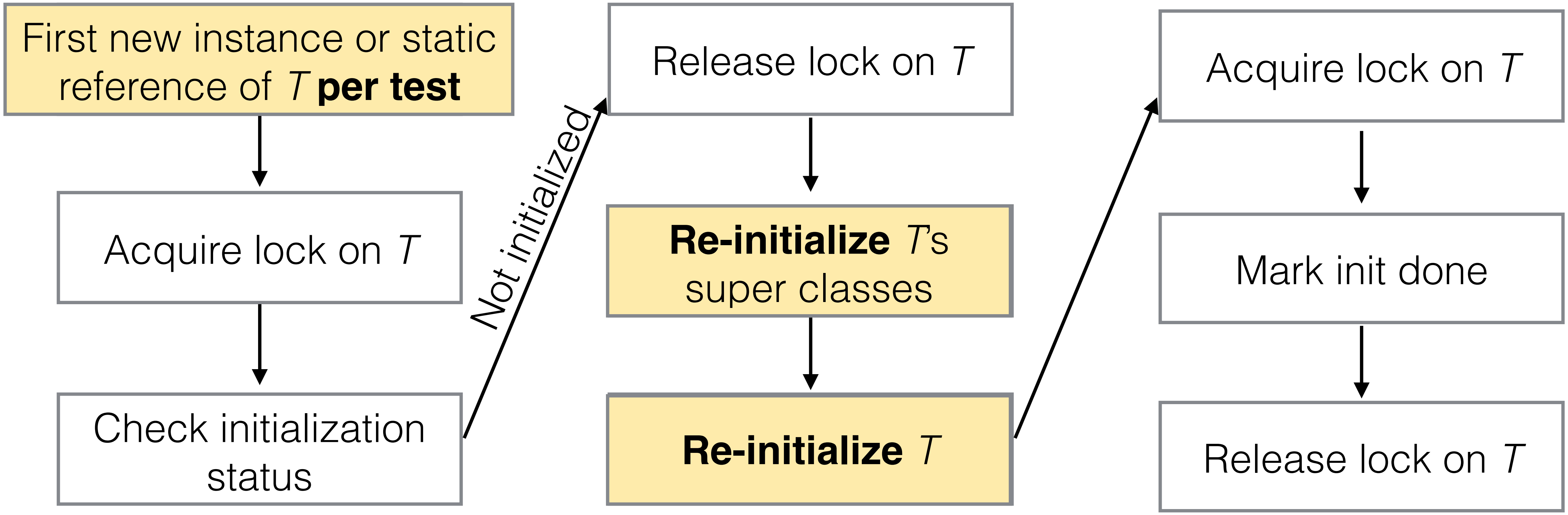

First new instance or static reference of *T* **per test**

Acquire lock on *T*

Check initialization status

Not initialized

Release lock on *T*

Re-initialize *T*'s super classes

Re-initialize *T*

Acquire lock on *T*

Mark init done

Release lock on *T*

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- Register a hook with test runner to tell us when a new test starts

Experiments

- RQ1: How does VMVM compare to Test Suite Minimization?

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- RQ2: What are the performance gains of VMVM?

- RQ3: Does VMVM impact fault finding ability?

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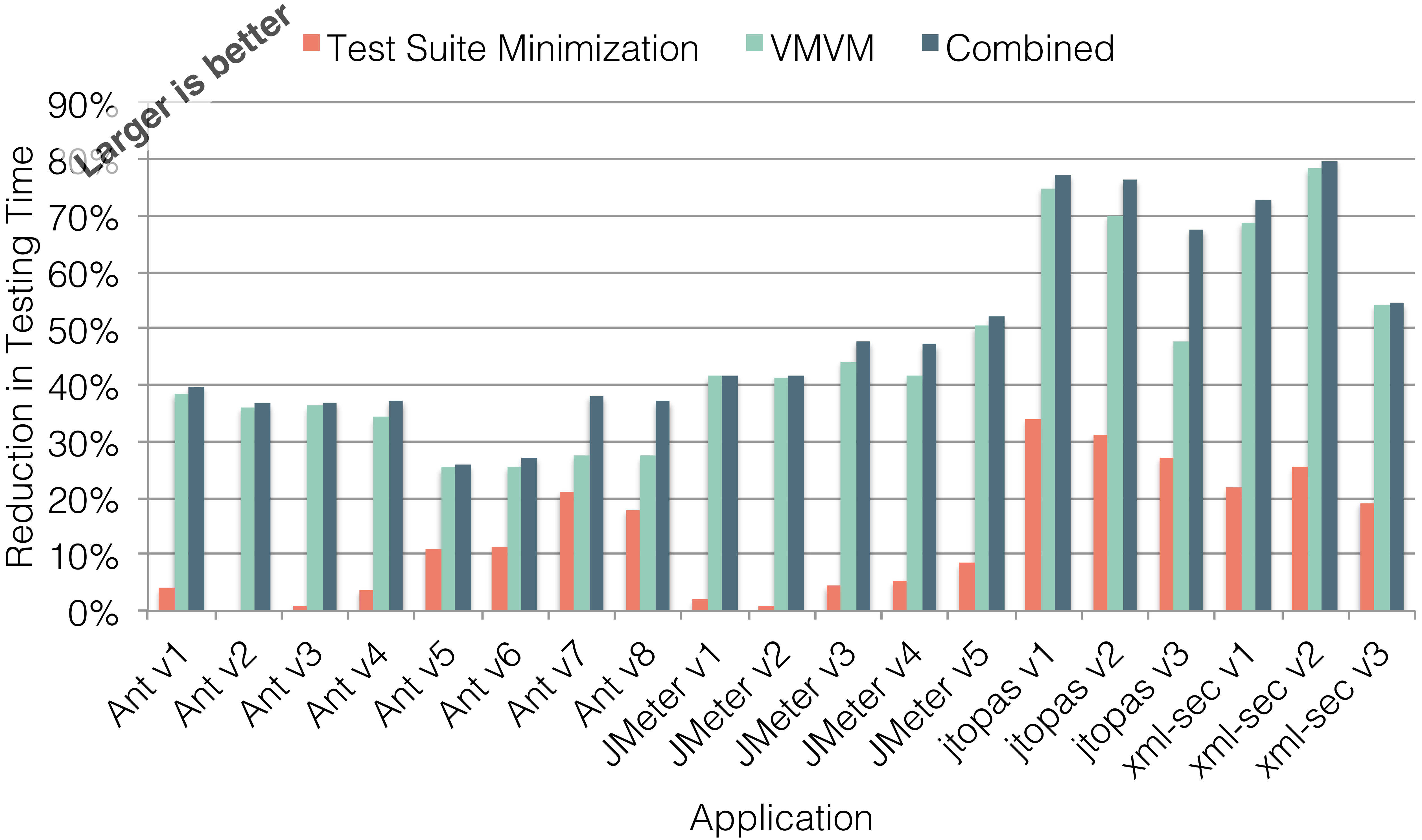
- Compare to the minimization technique with least impact on fault finding ability, Harrold [TOSEM ‘93]'s technique
- Study performed on the popular Software Infrastructure Repository dataset

RQ1: VMVM vs Test Minimization



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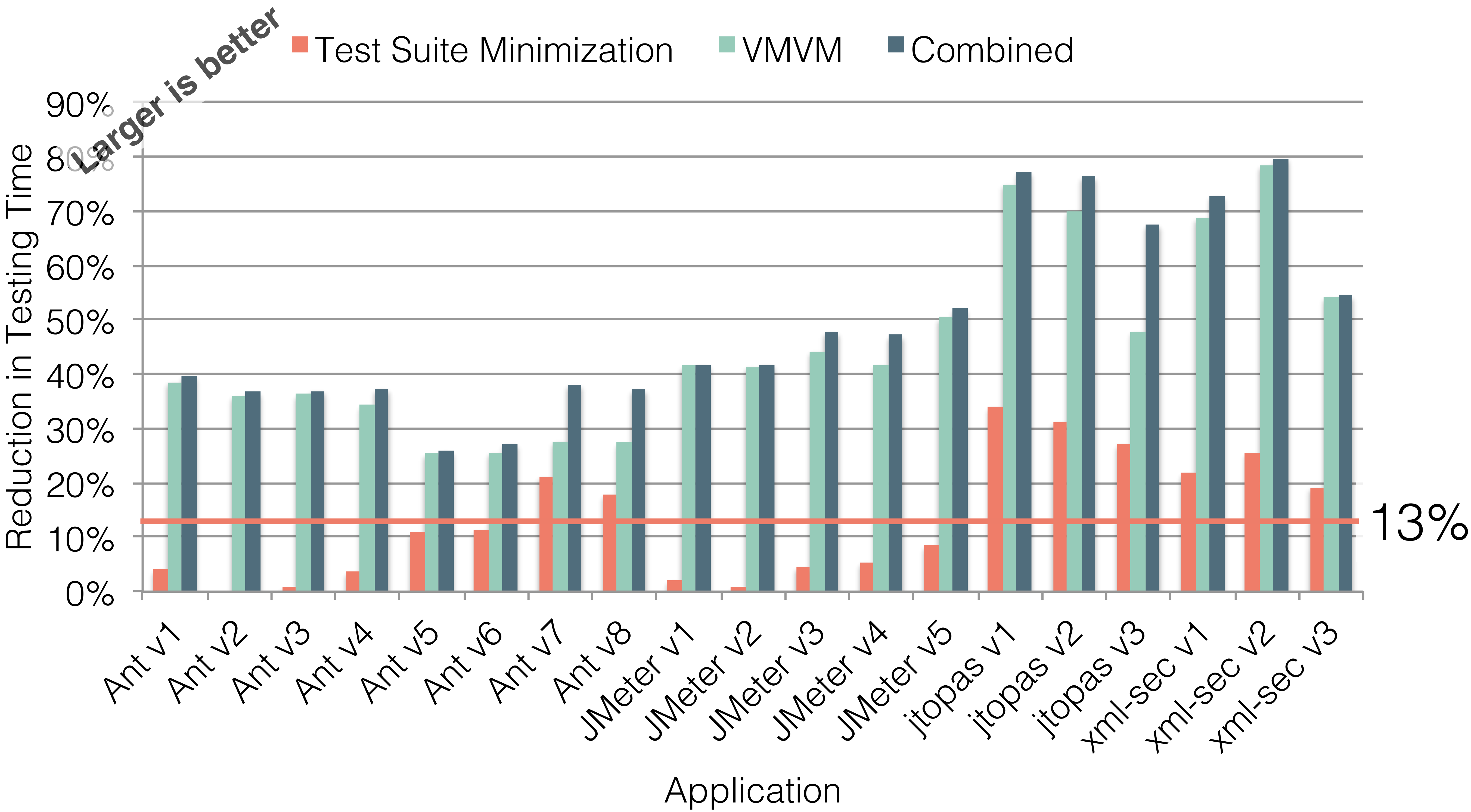

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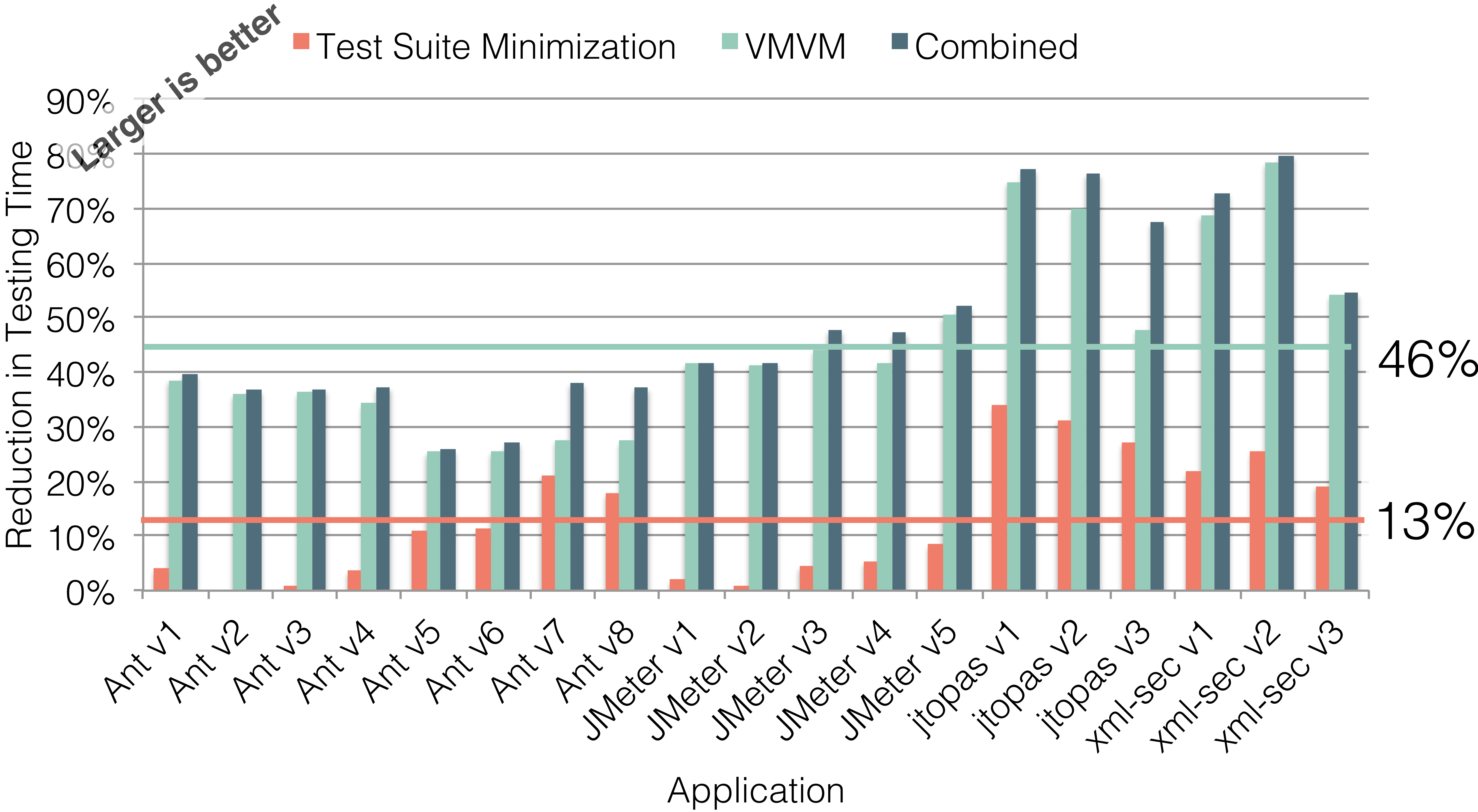

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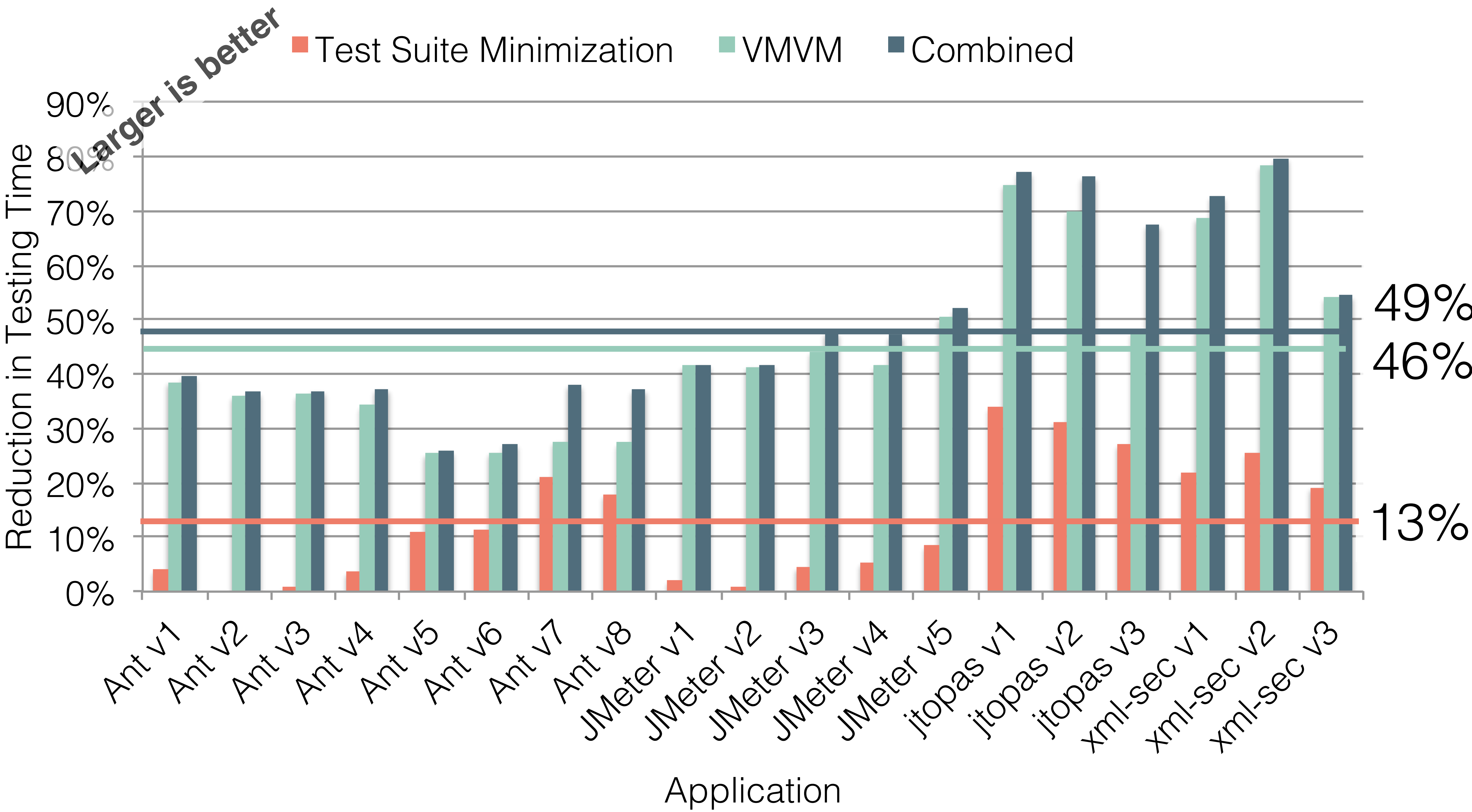

RQ2: Broader Evaluation

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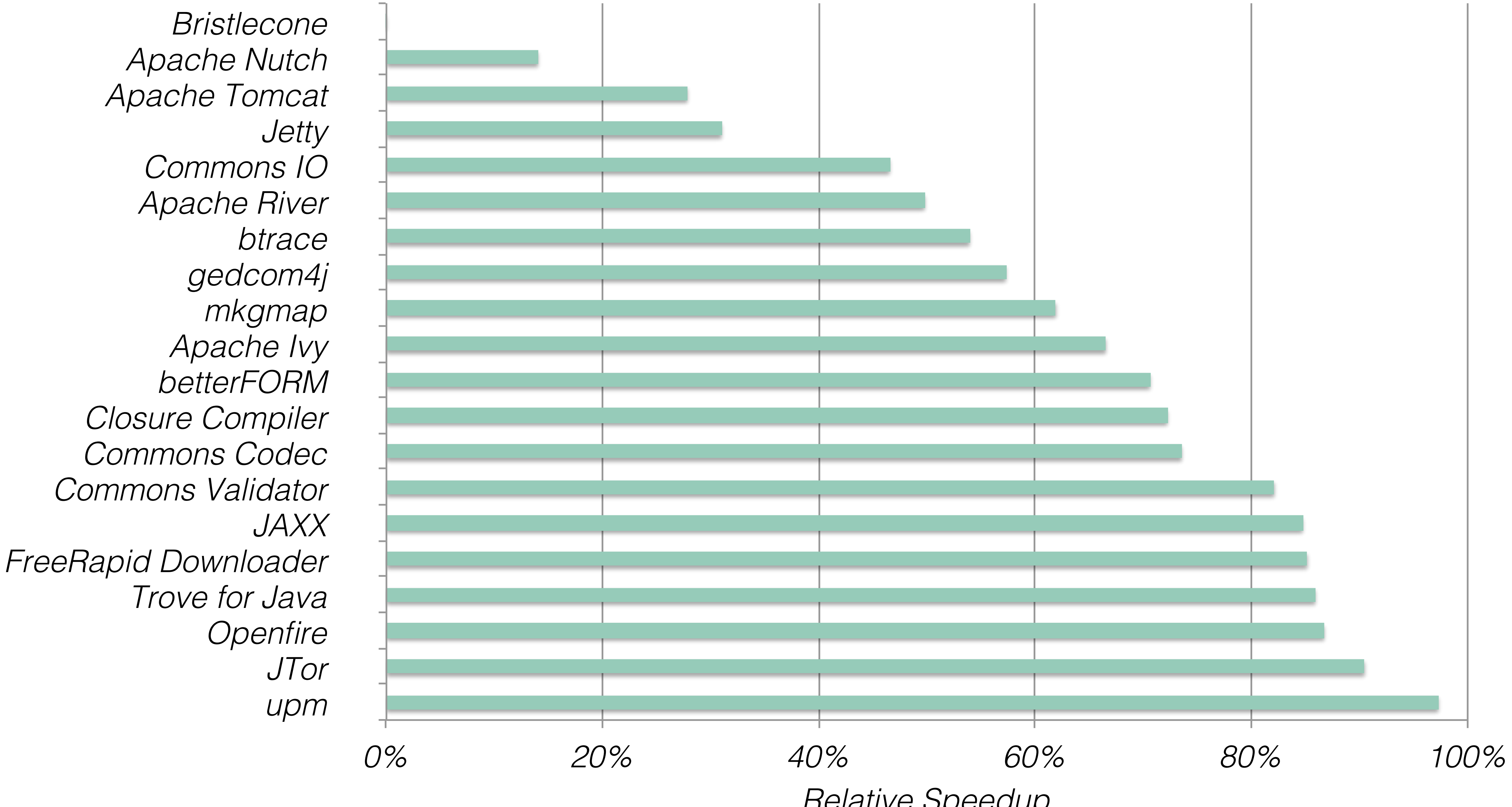
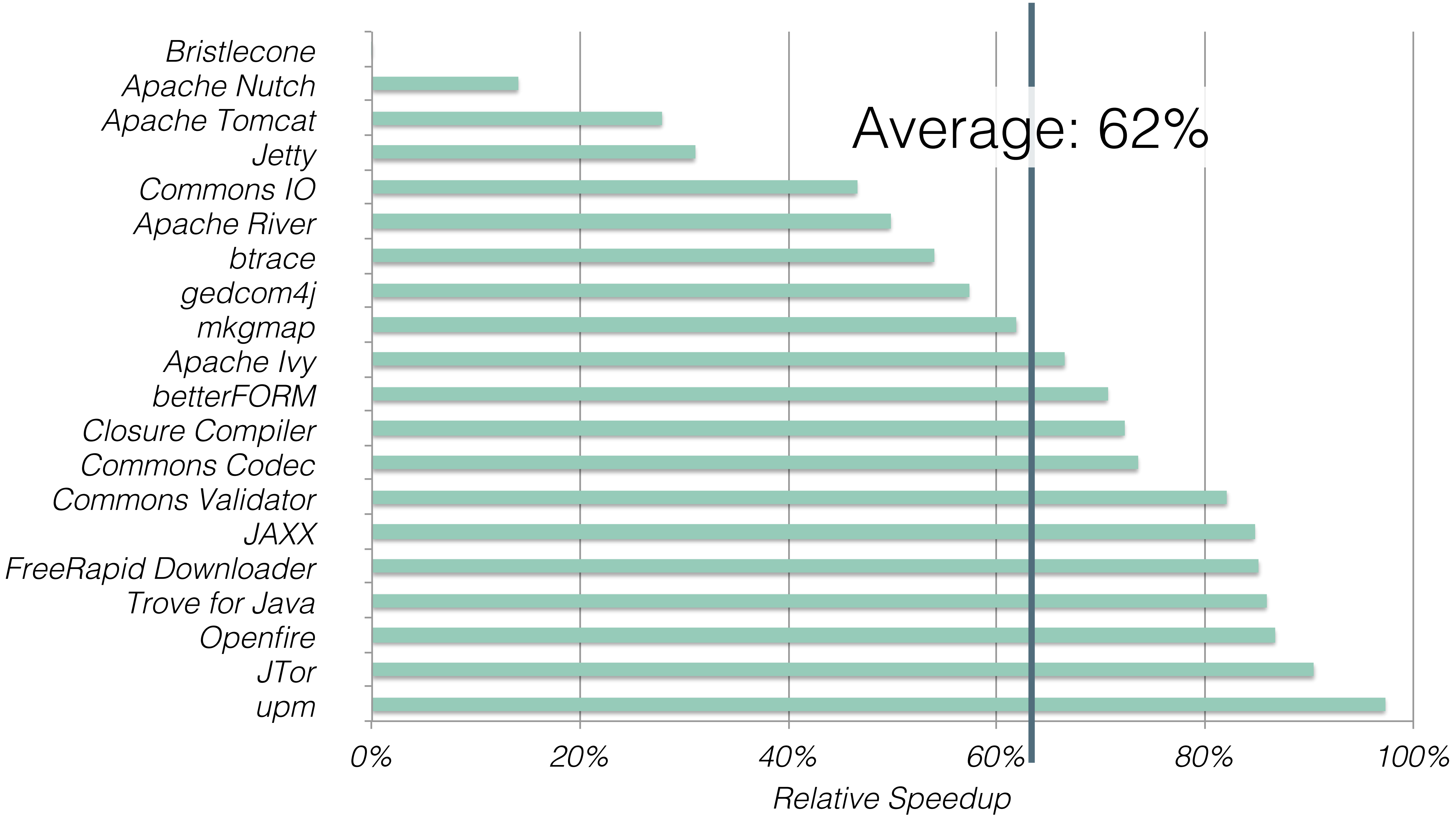
- This study: manually collected repository of 20 projects, average 475,000 LoC and 56 test classes
  - Range from 5,000 LoC - 5,692,450 LoC; 3 - 292 test classes; 3.5-15 years in age

RQ2: Broader Evaluation



Larger is better

RQ2: Broader Evaluation



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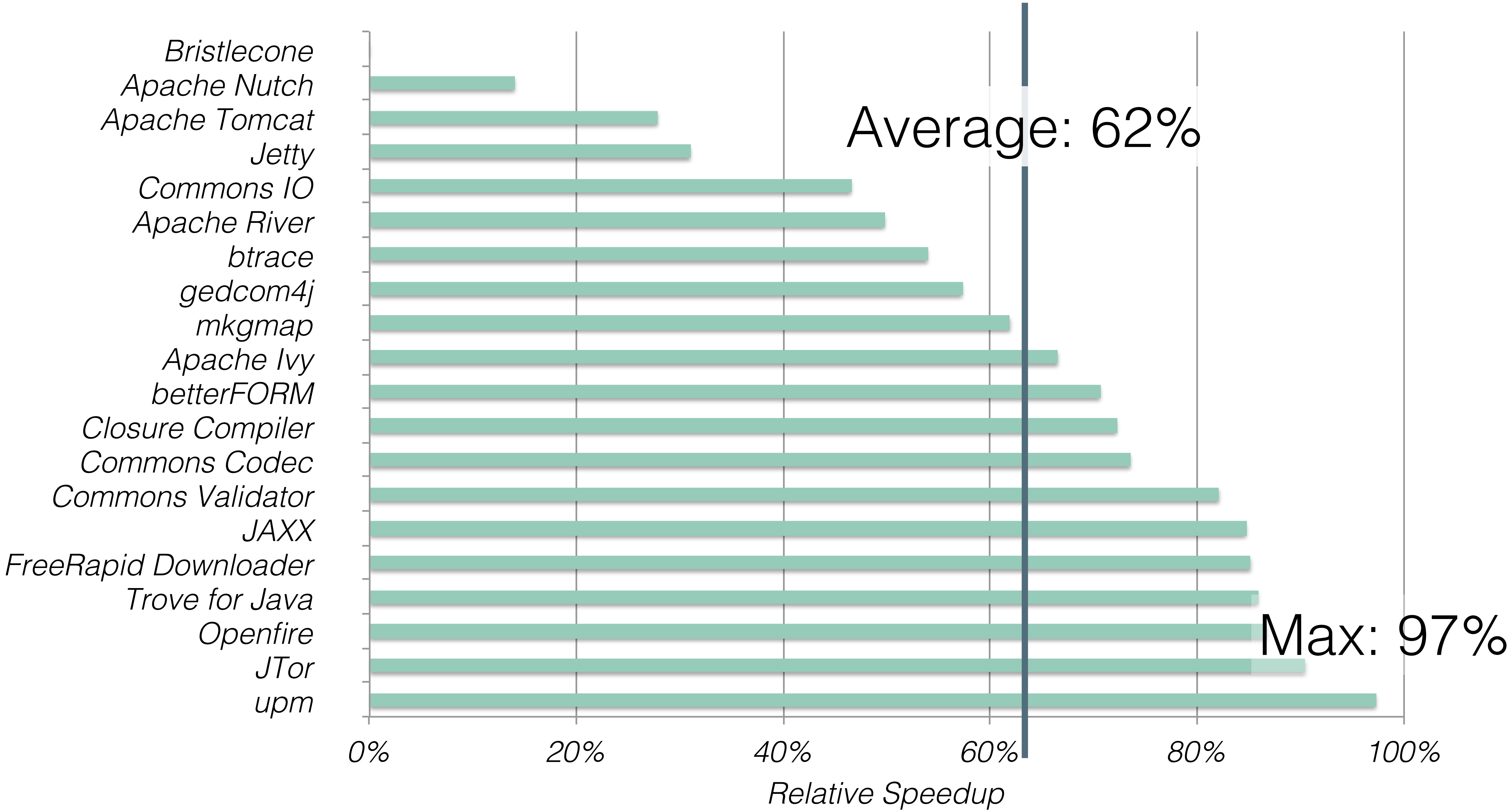

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- Looked for relationships between number of tests, lines of code, age of project, total testing time, time per test, and VMVM's speedup

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- Result: Only average time per test is correlated with VMVM's speedup (in fact, quite strongly; $p < 0.0001$)

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RQ3: Impact on Fault Finding

- **No impact on fault finding** from seeded faults (SIR)
- Does VMVM correctly isolate tests though?
- Compared false positives and negatives between un-isolated execution, traditionally isolated execution, and VMVM-isolated execution for these 20 complex applications
- Result: **False positives occur when not isolated. VMVM shows no false positives or false negatives.**

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- VMVM provides up to a 97% reduction in testing time through more efficient isolation (average 62%)
- VMVM does not risk a reduction in fault finding

Fork me on Github

Unit Test Virtualization with VMVM

Jonathan Bell and Gail Kaiser
Columbia University

https://github.com/Programming-Systems-Lab/vmvm

See a demo of VMVM at 2:30 today! Room MR G1-3

ICSE 2014 @_jon_bell_ June 5, 2014