# Code Inspection and Code Review

# One-Slide Summary

- In a **code review**, another developer examines your proposed change and explanation, offers feedback, and decides whether to accept it. Modern code reviews have significant tool support.
- In a **(formal) code inspection**, a team of developers meets and examines existing code, following a process to understand it and spot issues.
- Both of these static quality assurance approaches have costs and benefits.

# The Story So Far …

- Quality assurance is critical to software engineering.
- Testing is the most common dynamic (“run the program”) approach to QA.
  - We can generate some test inputs and oracles, but testing remains very expensive.

- What about static (“look at the program”) approaches to QA?

# Intuition

"Given enough eyeballs, all bugs are shallow."

– Linus's Law

"Have peers, rather than customers, find defects."

– Karl Wiegers

# Example of Both: Twilight

[ http://reasoningwithvampires.tumblr.com/ ]

The Cullens and the Hales sat at the same table as always, not eating, talking only among themselves. None of them, especially Edward, glanced my way anymore.

One person cannot do nothing more than other people who are also doing nothing.

Example:

*None of them bought an apple, especially Edward.*

I went ~~to go try~~ to watch TV ~~while I waited~~.

Not only did Meyer make the sentence far more complicated than necessary, but she also made the act of watching television complicated.

Our heroine is so insecure that she actually doubts her ability to succeed at watching television by herself.

**Our Bodies, Ourselves:** ***A Mystery***

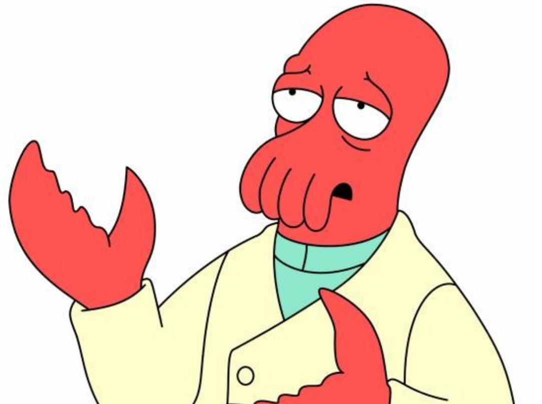
By Isabella M. Swan

Yes, I wanted to say. Anything. But I couldn't find my lips.

I tried to obey, though I couldn't quite locate my lungs.

# Why not simply test?

- Faults can mask other faults at runtime
- Only completed implementations can be tested (esp. for scalability or performance)
- Many quality attributes (e.g., security, compliance, maintainability) are hard to test
- Non-code artifacts (e.g., design documents) cannot be tested



# A Second Pair of Eyes

- Different background, different experience
- No preconceived idea of correctness
- Not biased by “what was intended”
- “Breadth of experience in an individual is essential to creativity and hence to good engineering. … Collective diversity, or diversity of the group - the kind of diversity that people usually talk about - is just as essential to good engineering as individual diversity. … Those differences in experience are the "gene pool" from which creativity springs.”

  – Bill Wulf, Nat. Academy of Engineering President

# What To Examine

- Code Inspection: Examine Whole Program
  - Expensive if the program changes
  - Good if a new concern arises
- Code Review: Examine Each Change
  - Inductive Argument:
    - V(0) is good; V(n) is good → V(n+1) is good
  - Bad if the definition of "good" changes

# Code Inspection Example:
# It's A Bug Hunt!

```
year = ORIGINYEAR; /* = 1980 */
while (days > 365) {
    if (IsLeapYear(year)) {
        if (days > 366) {
            days -= 366;
            year += 1;
        }
    } else {
        days -= 365;
        year += 1;
    }
}
```

# Leap-year glitch freezes Zune MP3 players

**STORY HIGHLIGHTS**
- NEW: Microsoft says proble
- Thousands of older 30GB Z
- Message boards are buzzin
- User: "It seems that every Z

Next Article in Technology »

READ VIDEO

By Brandon Griggs
CNN

DecreaseEnlarge font

**(CNN)** -- A leap-year related glitch caused thousands of Zune MP3 players to simultaneously stop working late Tuesday and early Wednesday, Microsoft said on the product's Web site.


GETTY IMAGES/FILE

Microsoft issued the first Zune portable music player in 2006 to compete with the iPod.

The problem should resolve itself after 7 a.m. ET Thursday, Matt Akers of the Zune Product Team wrote on Zune.net. "A bug in the internal clock driver related to the way the device handles a leap year" is to blame, he said.

The issue was limited to older Zune 30GB models, the Web site said.

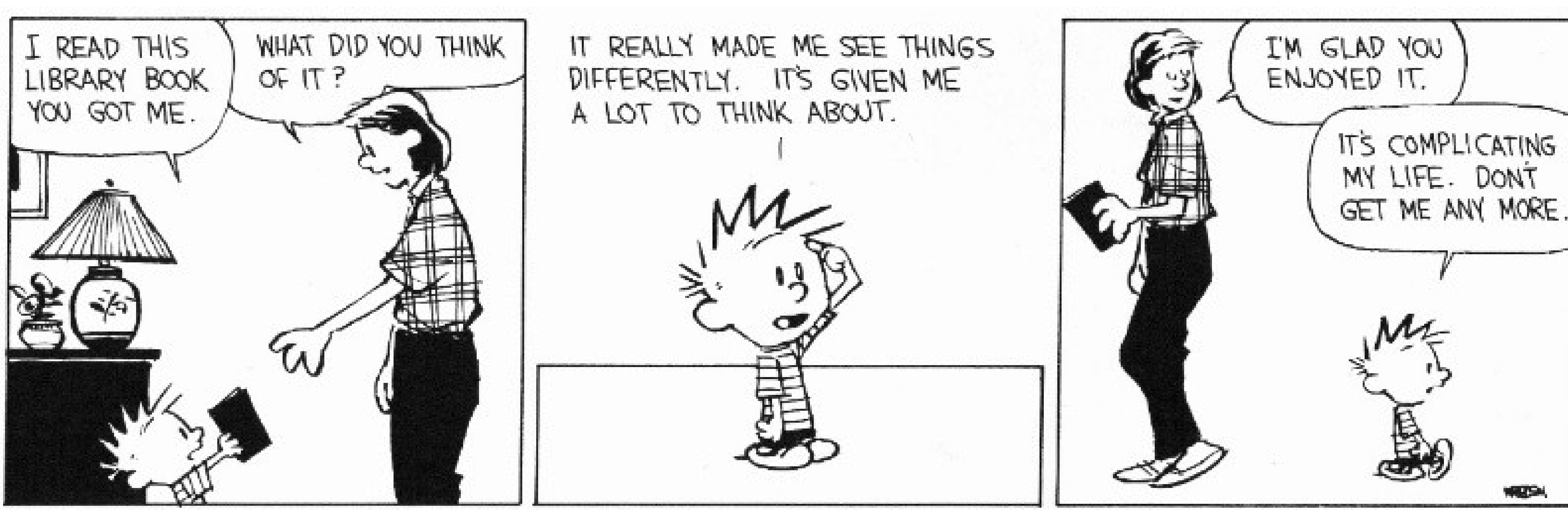
The Zune support page says users should allow the internal battery to fully drain. Then, after noon GMT on January 1, 2009 (7 a.m. ET), users should recharge by connecting the Zune to a computer or AC power.

Internet message boards were flooded with complaints about Zunes freezing, prompting Y2K-like speculation about end-of-year hardware or software problems.

"It seems that every Zune on the planet has just frozen up and will not work," posted a Mountain Home, Idaho, user on CNN's iReport.com. "I have 3 and they all in the same night stopped working."

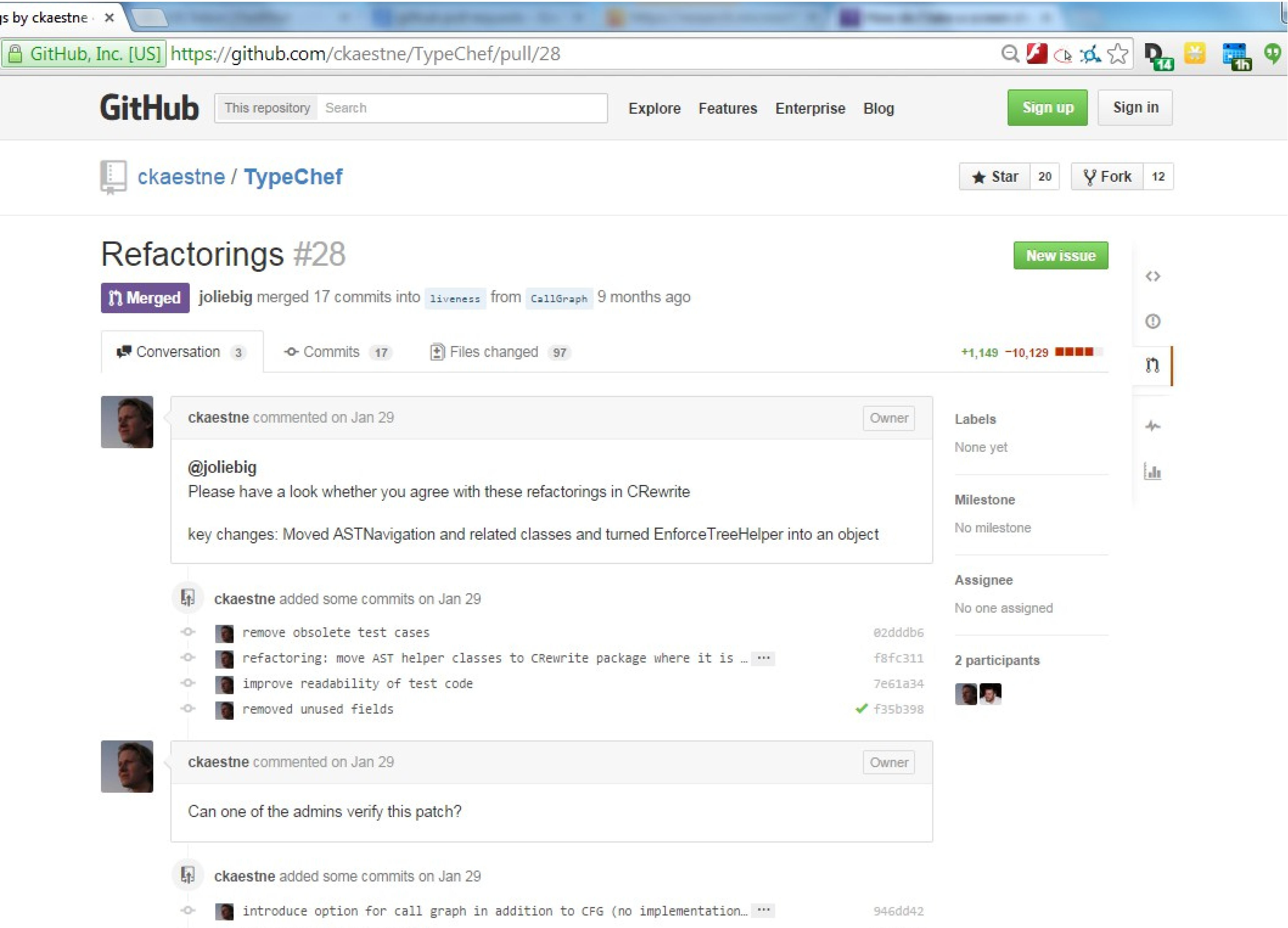
# Code Review

- What is code review?
- What is different between code review and code inspection in practice?



# GitHub

- **Pull requests** let you tell others about changes you've pushed to a [Git] repository. Once a pull request is opened, you can discuss and review the potential changes with collaborators and add follow-up commits before the changes are merged into the repository.
- Other contributors can review your proposed changes, add review comments, contribute to the pull request discussion, and even add commits to the pull request.



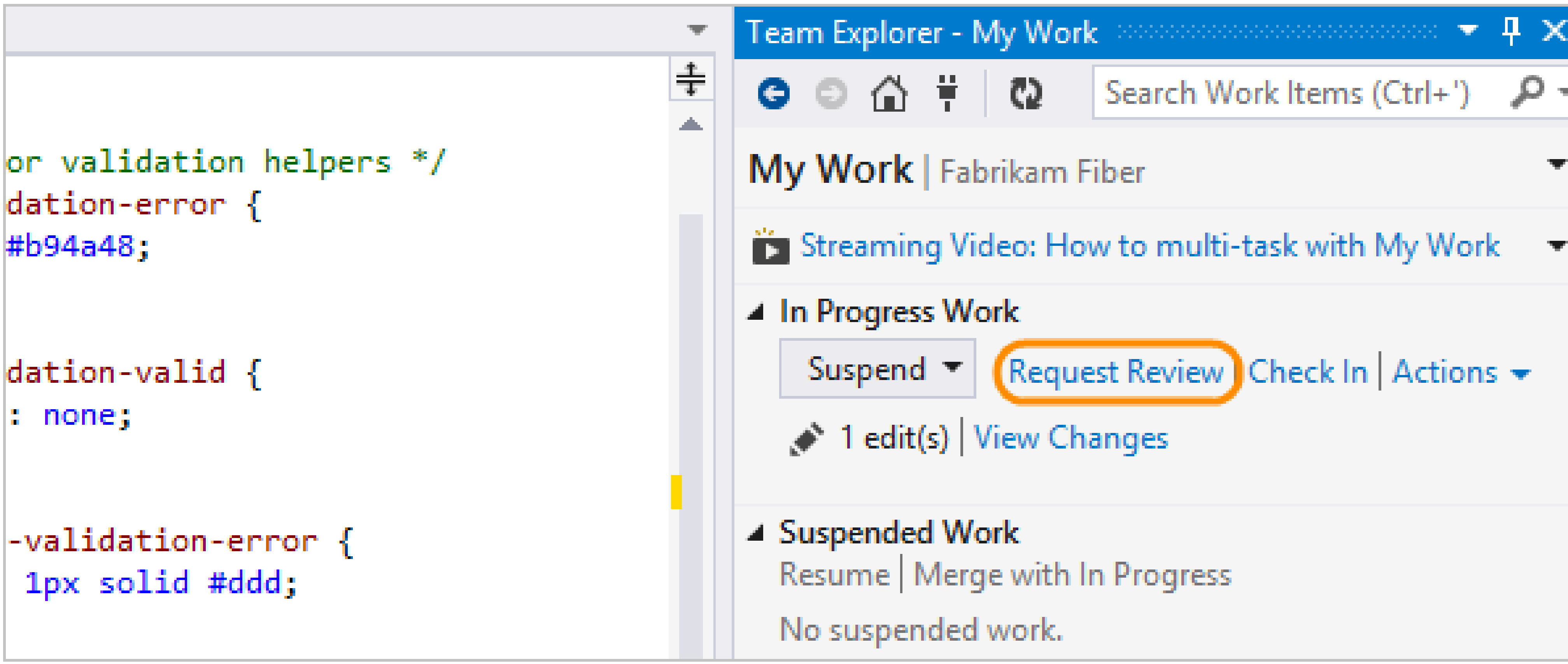
gs by ckaestne
GitHub, Inc. [US] https://github.com/ckaestne/TypeChef/pull/28
GitHub
This repository
Search
Explore
Features
Enterprise
Blog
Sign up
Sign in
ckaestne / TypeChef
Star 20
Fork 12
Refactorings #28
New issue
Merged
joliebig merged 17 commits into liveness from CallGraph 9 months ago
Conversation 3
Commits 17
Files changed 97
+1,149 −10,129
ckaestne commented on Jan 29
Owner
@joliebig
Please have a look whether you agree with these refactorings in CRewrite
key changes: Moved ASTNavigation and related classes and turned EnforceTreeHelper into an object
ckaestne added some commits on Jan 29
remove obsolete test cases 02dddb6
refactoring: move AST helper classes to CRewrite package where it is … f8fc311
improve readability of test code 7e61a34
removed unused fields f35b398
ckaestne commented on Jan 29
Owner
Can one of the admins verify this patch?
ckaestne added some commits on Jan 29
introduce option for call graph in addition to CFG (no implementation… 946dd42
Labels
None yet
Milestone
No milestone
Assignee
No one assigned
2 participants

# Microsoft (Visual Studio, CodeFlow, etc.)

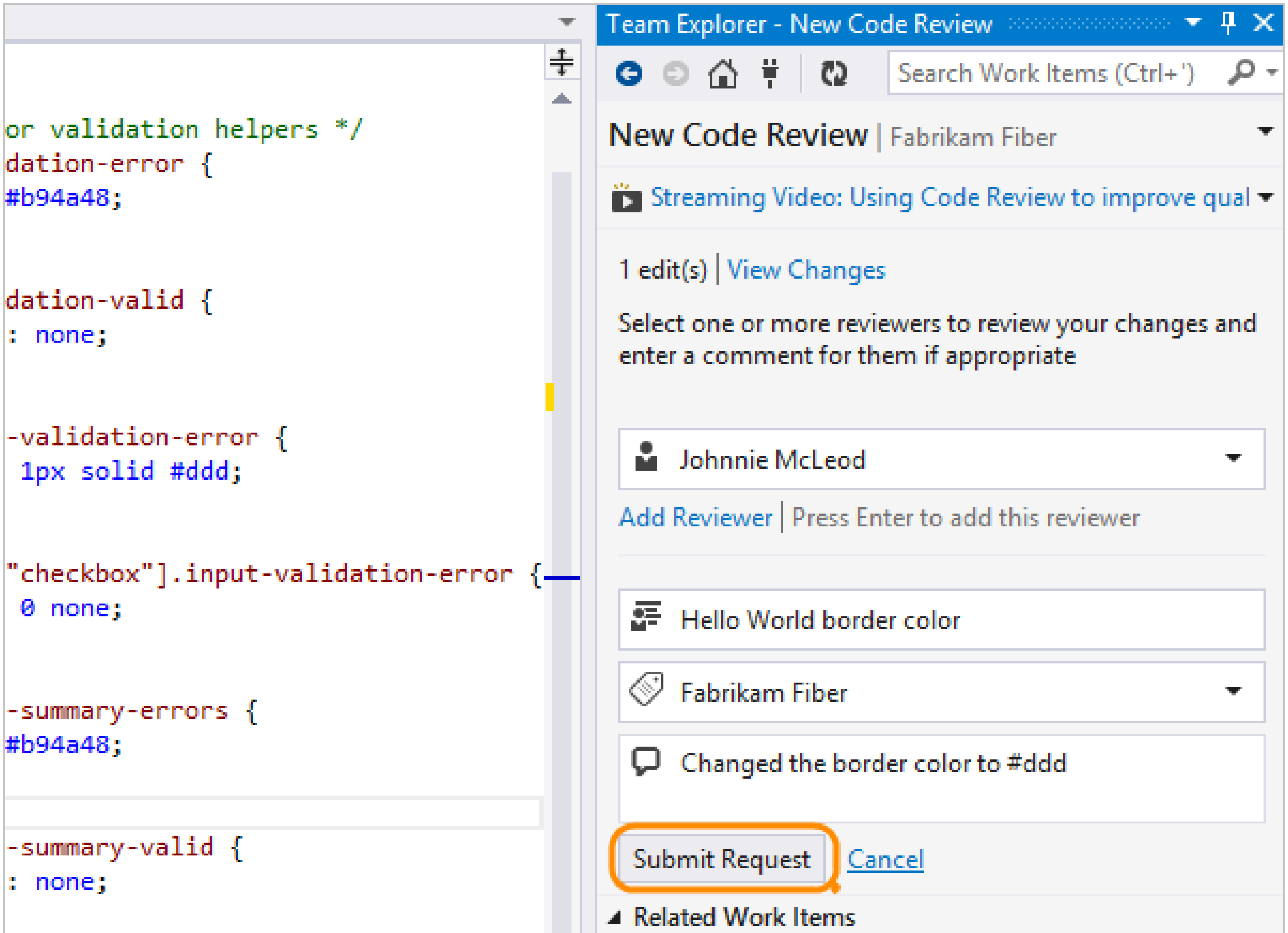
- Before you check in your code, you can use Visual Studio to ask someone else from your team to review it. Your request will show up in the Team Explorer, in the “My Work” page.

- (Are you using Git to share your code? If so, then use a pull request.)

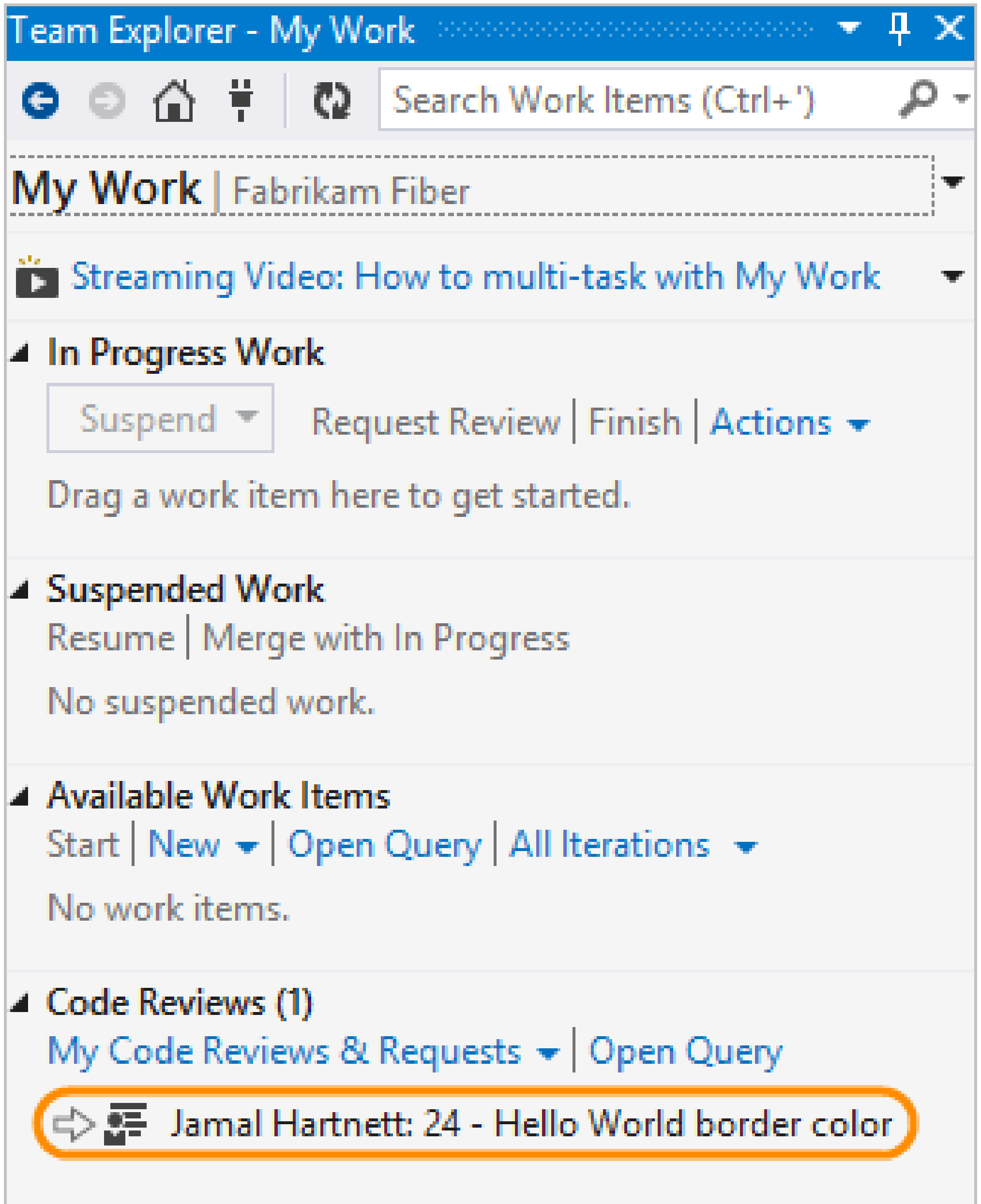
# Dev #1 – Request Review

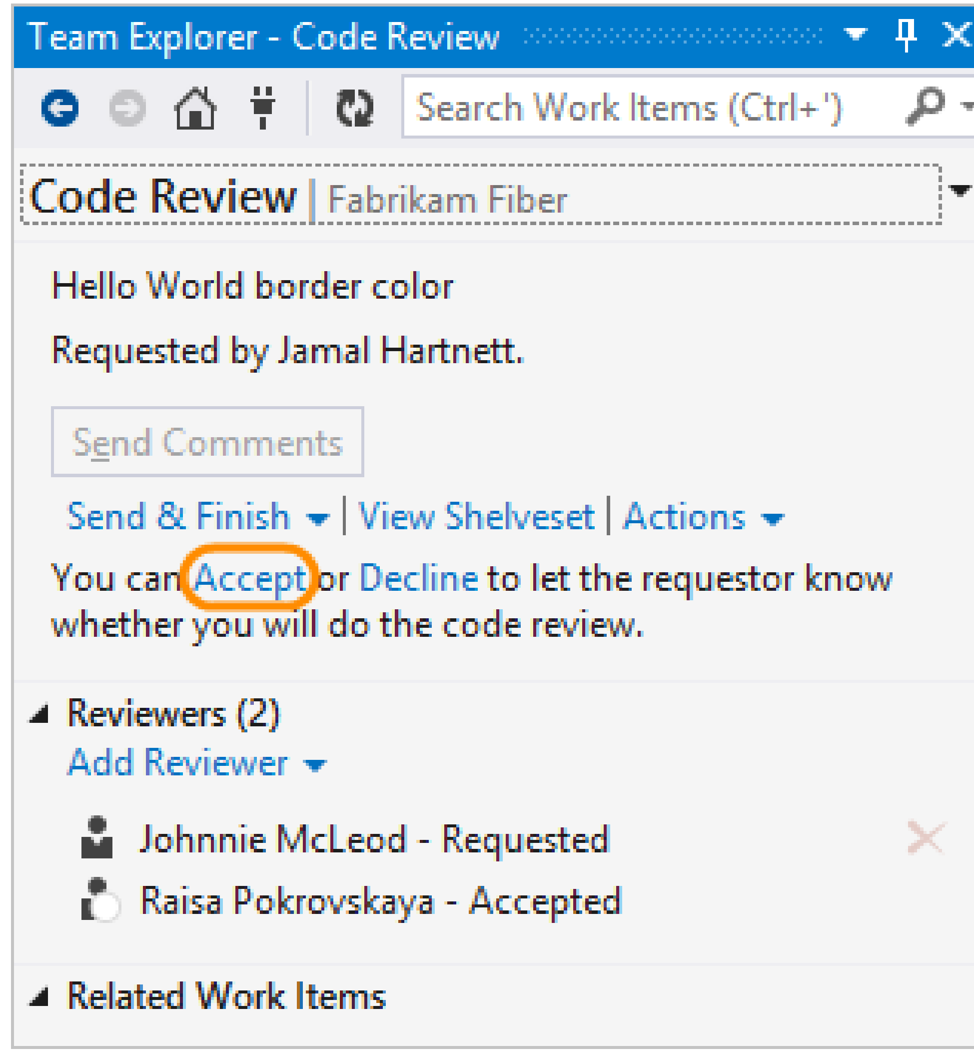


# Dev #1 - Submit Request to Dev #2

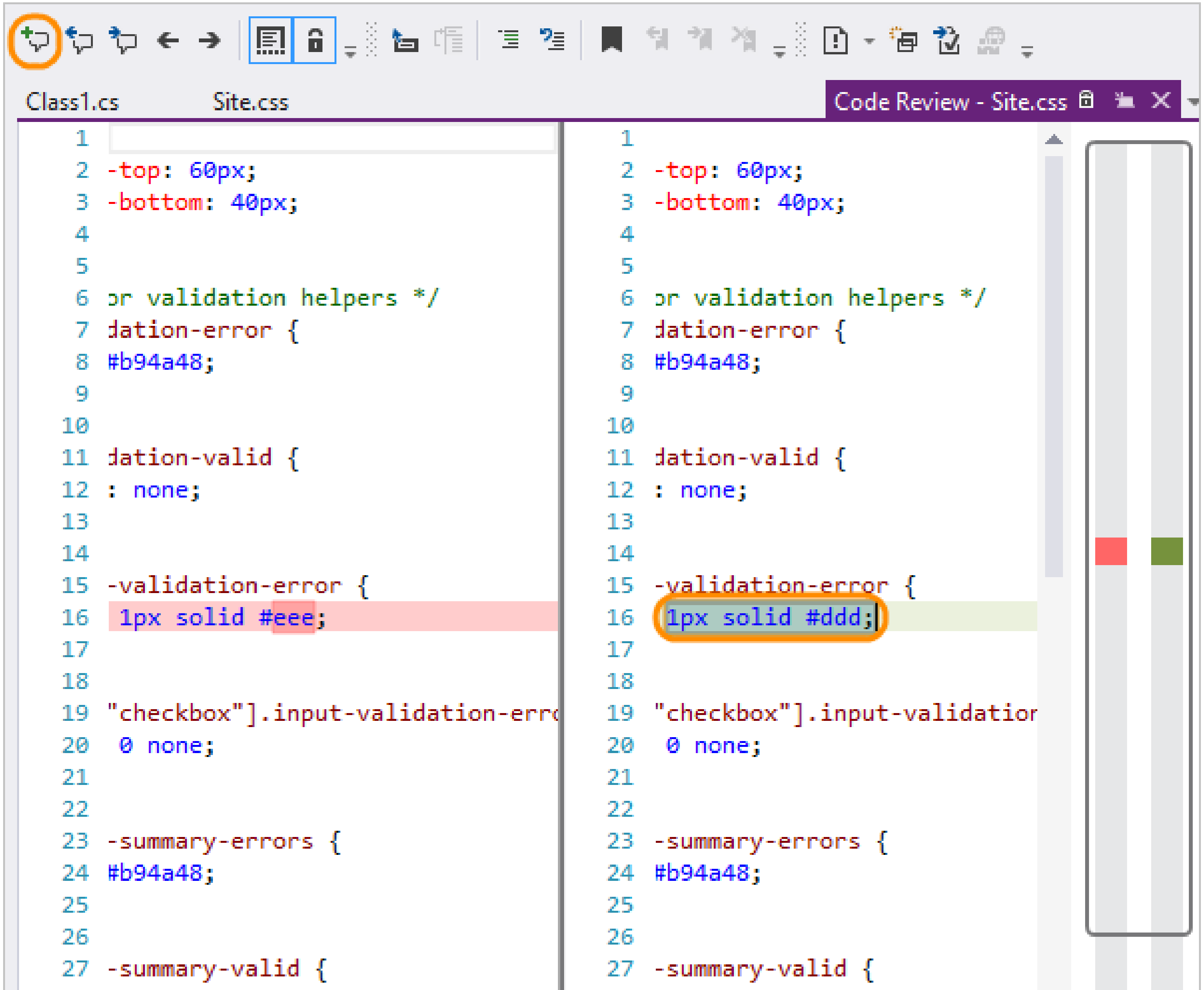


# Dev #2 – See and Accept Request

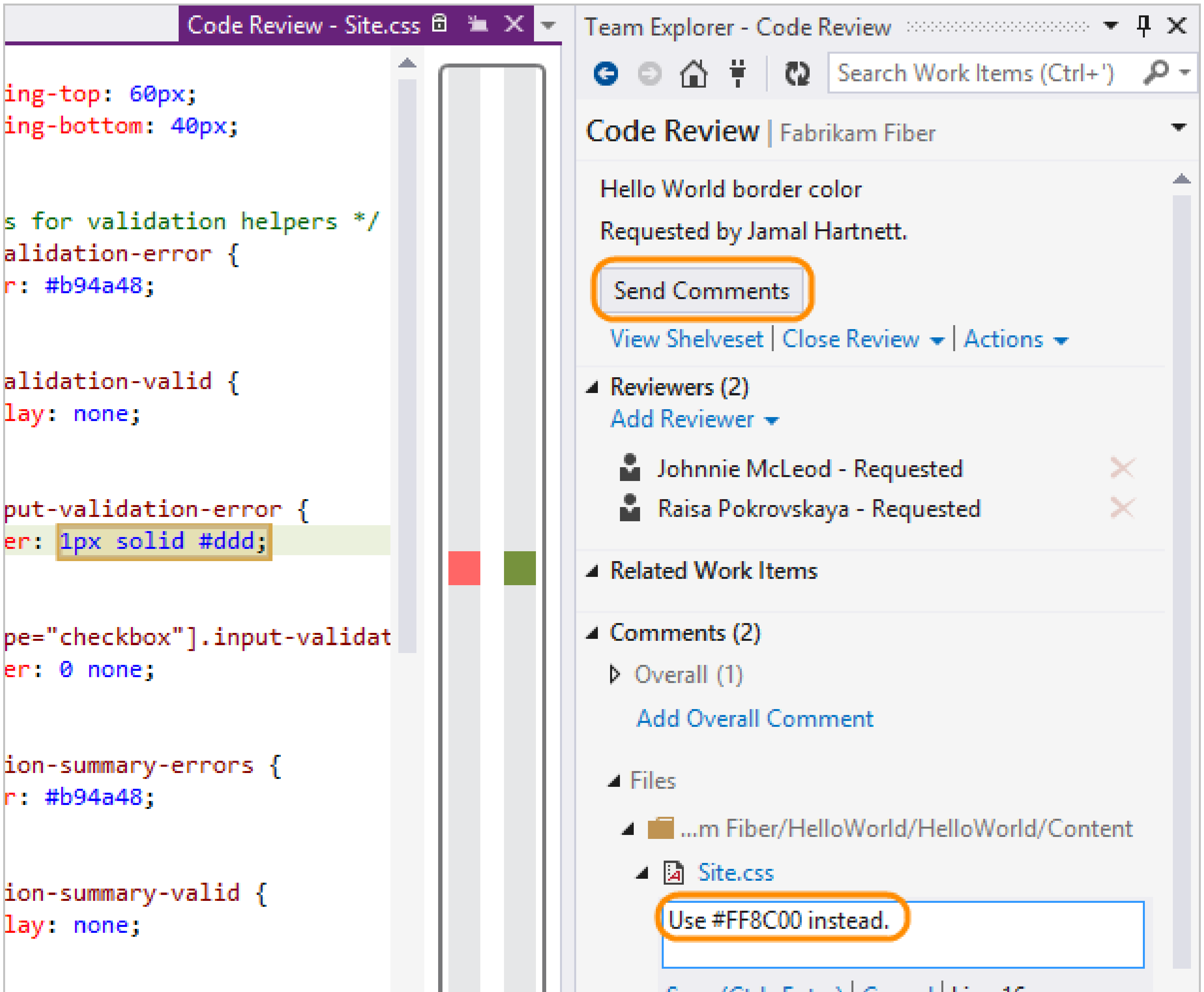


# Dev #2 – View Details



# Dev #2 - Suggest Improvements



# Google's Code Review Policy

- All change lists ("CLs") must be reviewed. Period.
- Any CL can be reviewed by any engineer at Google.
- Each directory has a list of owners. At least one reviewer or the author must be an owner for each file that was touched in the commit. If the author is not in the owners file, the reviewer is expected to pay extra attention to how the code fits in to the overall codebase.
- One can enforce that any CLs to that directory are CC'd to a team mailing list.
- Reviews are conducted either by email, or using a web interface called `Mondrian`.
- In general, the review must have a positive outcome before the change can be submitted (enforced by `perforce` hooks). However, if the author of the changelist meets the readability and owners checks, they can submit the change "To Be Reviewed", and have a post-hoc review. There is a process which will harass reviewers with very annoying emails if they do not promptly review the change.

# Google, Facebook

- “In broad strokes, code review processes in Google and Facebook are similar. In both companies it is practically required that every change to production code is reviewed by at least one team member.

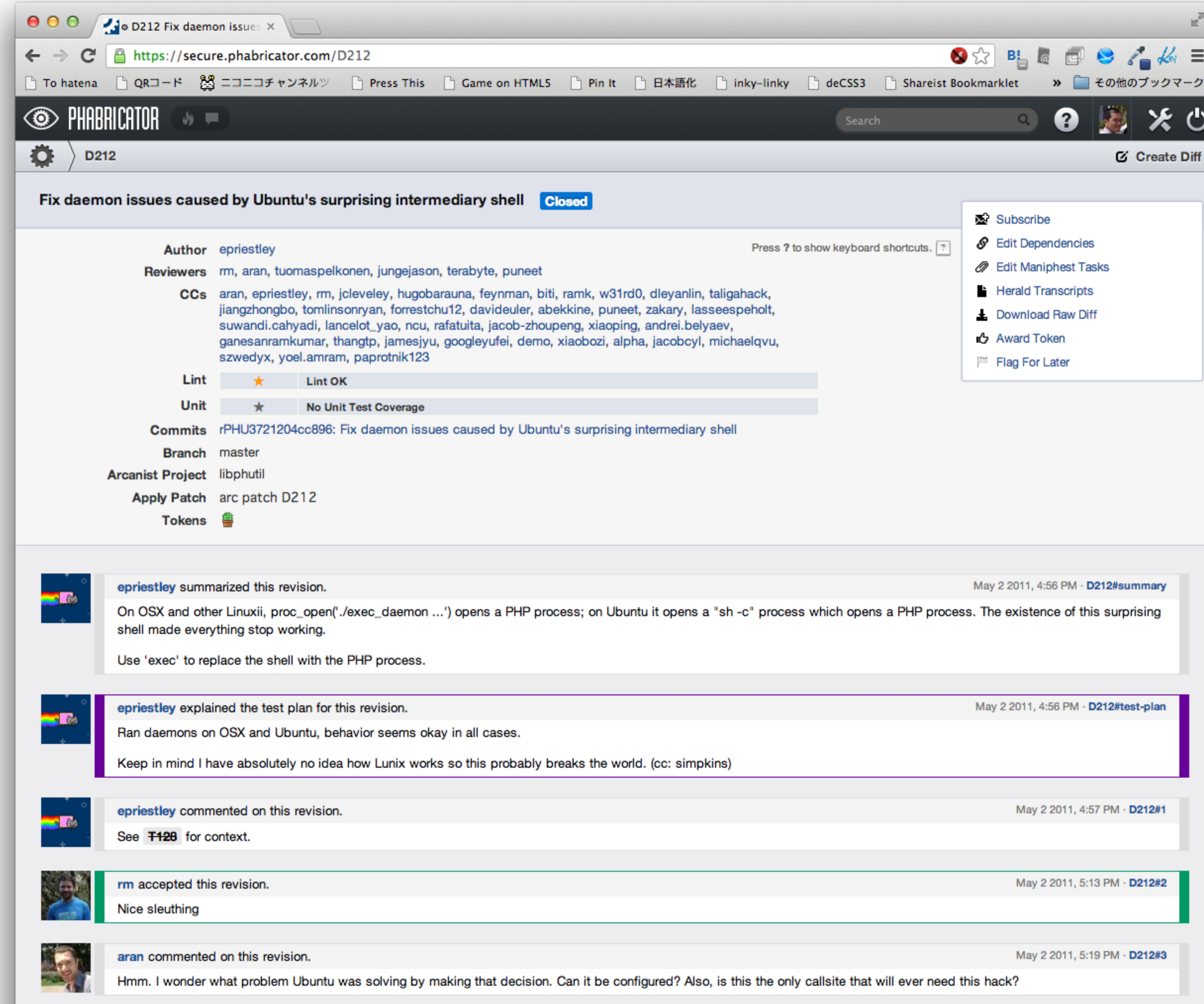
  Google has this readability process where you need to earn a privilege to commit in a given programming language. Readability is literally a badge on your profile that the code review system checks to see if you can commit the code yourself or you need to ask for an extra review for the compliance with company-wide language style guides.”

  - Marcin Wyszynski 2017, worked at both companies

# Tools

- Google uses Mondrian, an in-house tool
  - One of its authors later made https://www.gerritcodereview.com/
  - Reportedly, one of its authors later made https://reviewable.io/
  - Those give a taste of what Mondrian is like
- Facebook uses Phabricator
  - Developed in-house, later open-sourced

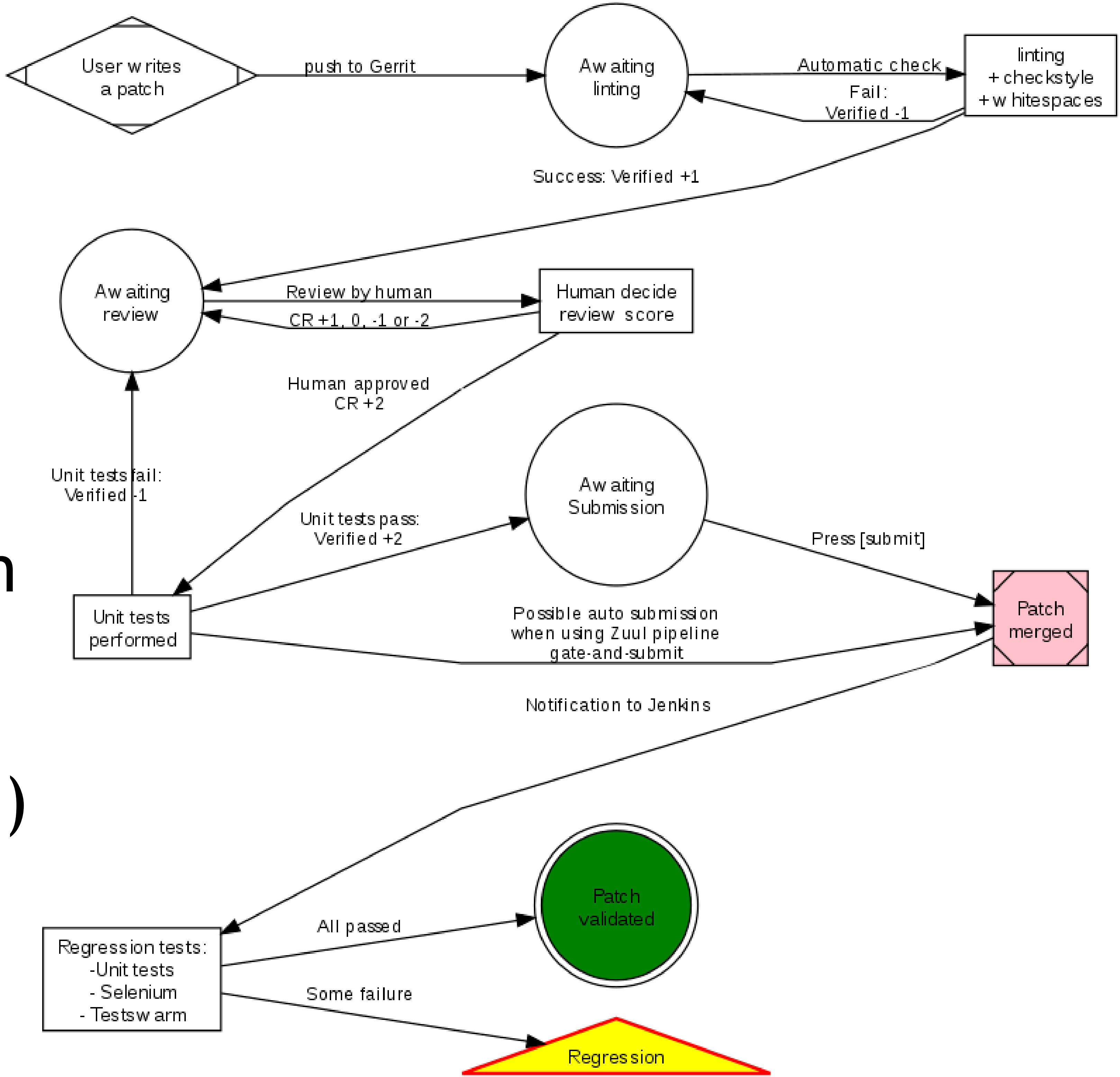
    https://www.phacility.com/



D212 Fix daemon issues
https://secure.phabricator.com/D212
To hatena
QRコード
ニコニコチャンネルツ
Press This
Game on HTML5
Pin It
日本語化
inky-linky
deCSS3
Shareist Bookmarklet
その他のブックマーク
PHABRICATOR
Search
D212
Create Diff
Fix daemon issues caused by Ubuntu's surprising intermediary shell
Closed
Subscribe
Edit Dependencies
Edit Maniphest Tasks
Herald Transcripts
Download Raw Diff
Award Token
Flag For Later
Press ? to show keyboard shortcuts.
Author epriestley
Reviewers rm, aran, tuomaspelkonen, jungejason, terabyte, puneet
CCs aran, epriestley, rm, jcleveley, hugobarauna, feynman, biti, ramk, w31rd0, dleyanlin, taligahack, jiangzhongbo, tomlinsonryan, forrestchu12, davideuler, abekkine, puneet, zakary, lasseespeholt, suwandi.cahyadi, lancelot_yao, ncu, rafatuita, jacob-zhoupeng, xiaoping, andrei.belyaev, ganesanramkumar, thangtp, jamesjyu, googleyufei, demo, xiaobozi, alpha, jacobcyl, michaelqvu, szwedyx, yoel.amram, paprotnik123
Lint Lint OK
Unit No Unit Test Coverage
Commits rPHU3721204cc896: Fix daemon issues caused by Ubuntu's surprising intermediary shell
Branch master
Arcanist Project libphutil
Apply Patch arc patch D212
Tokens
epriestley summarized this revision.
May 2 2011, 4:56 PM · D212#summary
On OSX and other Linuxii, proc_open('./exec_daemon ...') opens a PHP process; on Ubuntu it opens a "sh -c" process which opens a PHP process. The existence of this surprising shell made everything stop working.
Use 'exec' to replace the shell with the PHP process.
epriestley explained the test plan for this revision.
May 2 2011, 4:56 PM · D212#test-plan
Ran daemons on OSX and Ubuntu, behavior seems okay in all cases.
Keep in mind I have absolutely no idea how Lunix works so this probably breaks the world. (cc: simpkins)
epriestley commented on this revision.
May 2 2011, 4:57 PM · D212#1
See ~~T128~~ for context.
rm accepted this revision.
May 2 2011, 5:13 PM · D212#2
Nice sleuthing
aran commented on this revision.
May 2 2011, 5:19 PM · D212#3
Hmm. I wonder what problem Ubuntu was solving by making that decision. Can it be configured? Also, is this the only callsite that will ever need this hack?

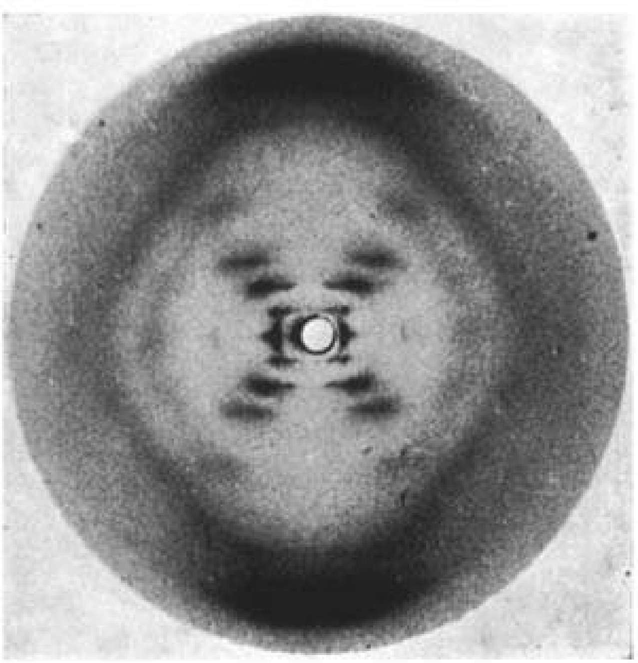
# Code Review Integration Example

# (MediaWiki)



# Trivia: Chemistry, Biology

- This English chemist and X-ray crystallographer used X-ray diffraction images of DNA, leading to the discovery of its double helix structure (see "*Photo 51*" below). After dying at age 37 of cancer, other collaborators on the work were awarded the Nobel prize (controversy: not awarded posthumously).



# Psychology: Group Decision Making

- 156 students read descriptions of three hypothetical candidates for student body president and then met in 4-person groups to elect a winner
  - Each candidate had 16 associated pieces of information (*unambiguously* positive, negative and neutral facts related to the job)
  - Collectively, each 4-person group had *all* the info
  - Individually, each person only had *some* info
  - Candidate A is *objectively twice as good* as B or C
    - Who wins the election?

- Starting individual information distribution breakdown by group condition:

*Number of Items of Information About Each Candidate Received by Group Members Before Discussion*

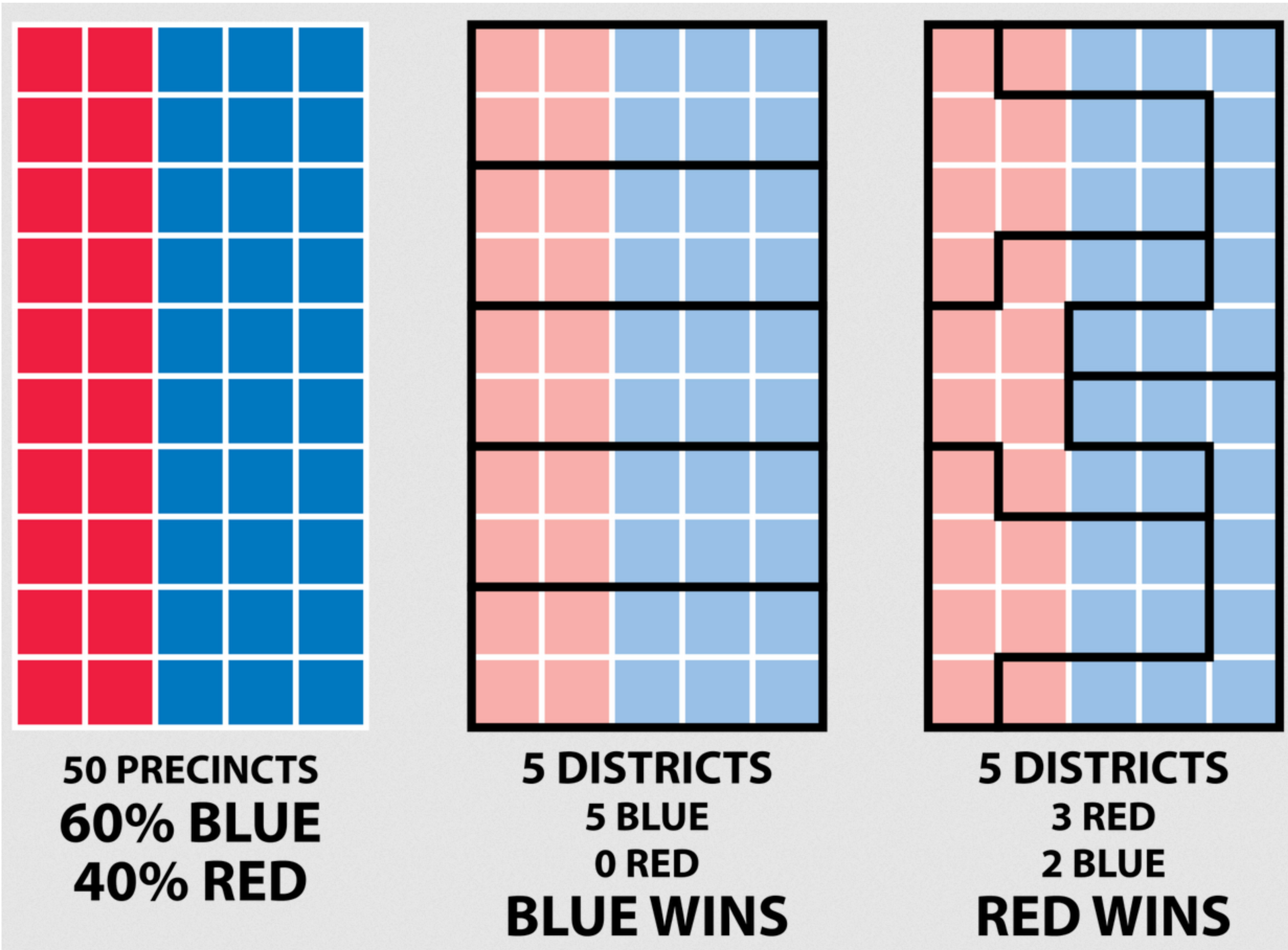
| Condition and information valence | Candidate A | Candidate B | Candidate C |
|---|---|---|---|
| Shared | | | |
| Positive | 8 | 4 | 4 |
| Neutral | 4 | 8 | 8 |
| Negative | 4 | 4 | 4 |
| Unshared/consensus | | | |
| Positive | 2 | 4 | 1 |
| Neutral | 4 | 5 | 8 |
| Negative | 4 | 1 | 1 |
| Unshared/conflict | | | |
| Positive | 2 | 4 [4] | 4 [4] |
| Neutral | 4 | 6 [4] | 4 [6] |
| Negative | 4 | 0 [2] | 2 [0] |

*Note.* In the unshared/conflict condition, 2 members of a 4-person group received configurations of information about Candidates B and C given by the numbers without brackets, whereas the other 2 members received configurations given by the numbers in brackets.

# Group Decision Making

- “Even though groups could have produced unbiased composites of the candidates through discussion, they decided in favor of the candidate initially preferred by a plurality rather than the most favorable candidate. Group members' pre and postdicussion recall of candidate attributes indicated that discussion tended to perpetuate, not correct, members' distorted pictures of the candidates.”

# Analogy: Gerrymandering



# Group Decision Making

[ G. Stasser, W. Titus. *Pooling of Unshared Information in Group Decision Making: Biased Information Sampling During Discussion*. J. of Personality and Social Psychology, 48(6) 1985.]

- Implications for SE: Both “formal code inspection” and “modern multiperson passaround code review” are group decision making tasks. Reviewers/inspectors are unlikely to start with uniformly perfect information and are thus vulnerable to this bias.

# Do Code Reviews Work?

## Expectations, Outcomes, and Challenges Of Modern Code Review

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***Abstract*—Code review is a common software engineering practice employed both in open source and industrial contexts. Review today is less formal and more "lightweight" than the code inspections performed and studied in the 70s and 80s. We empirically explore the motivations, challenges, and outcomes of tool-based code reviews. We observed, interviewed, and surveyed developers and managers and manually classified hundreds of review comments across diverse teams at Microsoft. Our study reveals that while finding defects remains the main motivation for review, reviews are less about defects than expected and instead provide additional benefits such as knowledge transfer, increased team awareness, and creation of alternative solutions to**

when to use code review and how it should fit into their development process. Researchers can focus their attention on practitioners' challenges to make code review more effective.

We present an in-depth study of practices in teams that use modern code review, revealing what practitioners think, do, and achieve when it comes to modern code review.

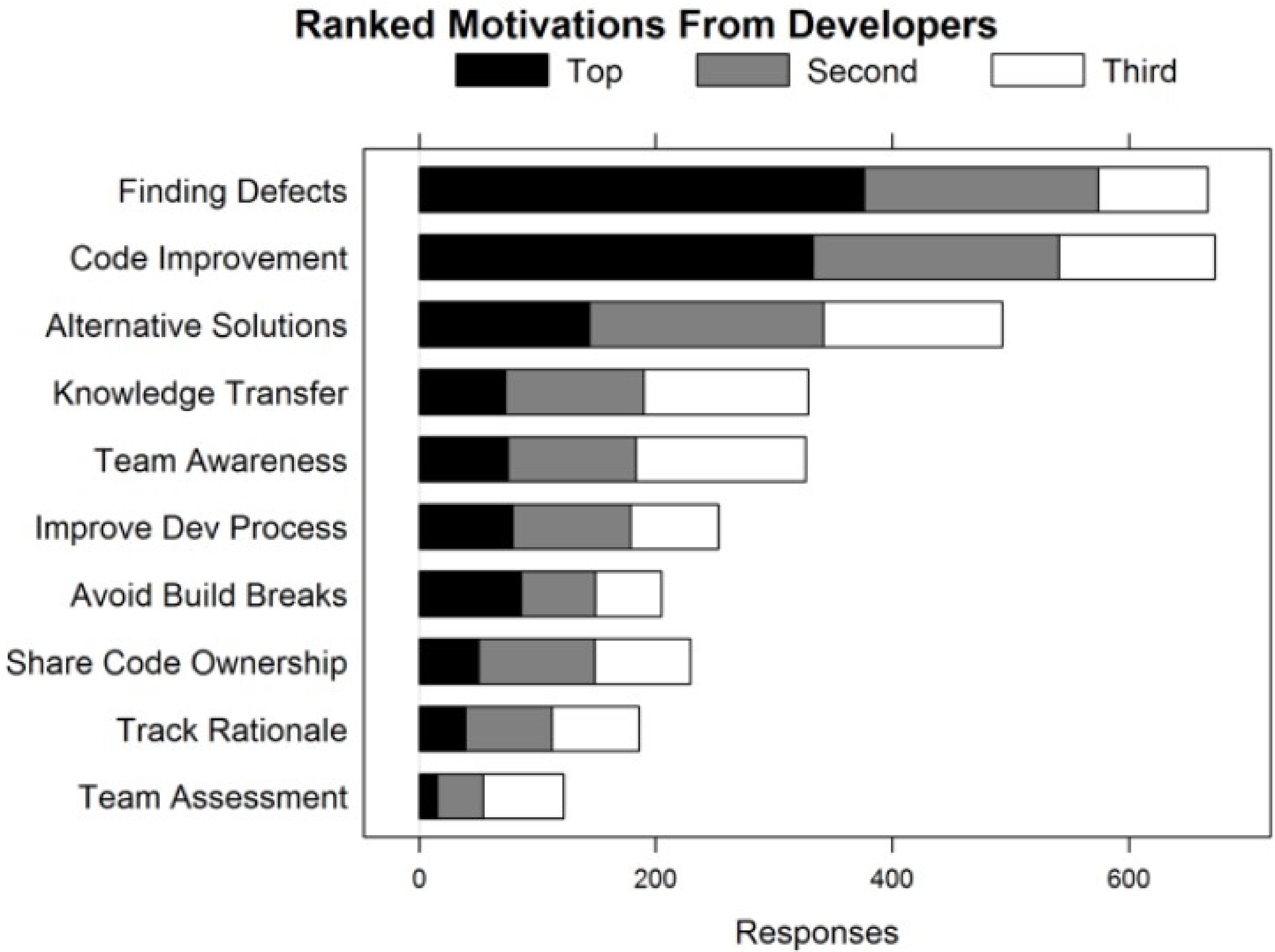
Since Microsoft is made up of many different teams working on very diverse products, it gives the opportunity to study teams performing code review *in situ* and understand their expectations, the benefits they derive from code review, the needs they have, and the problems they face.

# Code Review Goals

- **Finding defects**
  - both low-level and high-level issues (requirements/design/code)
- **Code improvement**
  - readability, formatting, commenting, consistency, dead code removal, naming, coding standards
- Identifying alternative solutions
- Knowledge transfer
  - learn about API usage, available libraries, best practices, team conventions, system design, "tricks", "developer education", especially for junior developers

# Code Review Goals (cont'd)

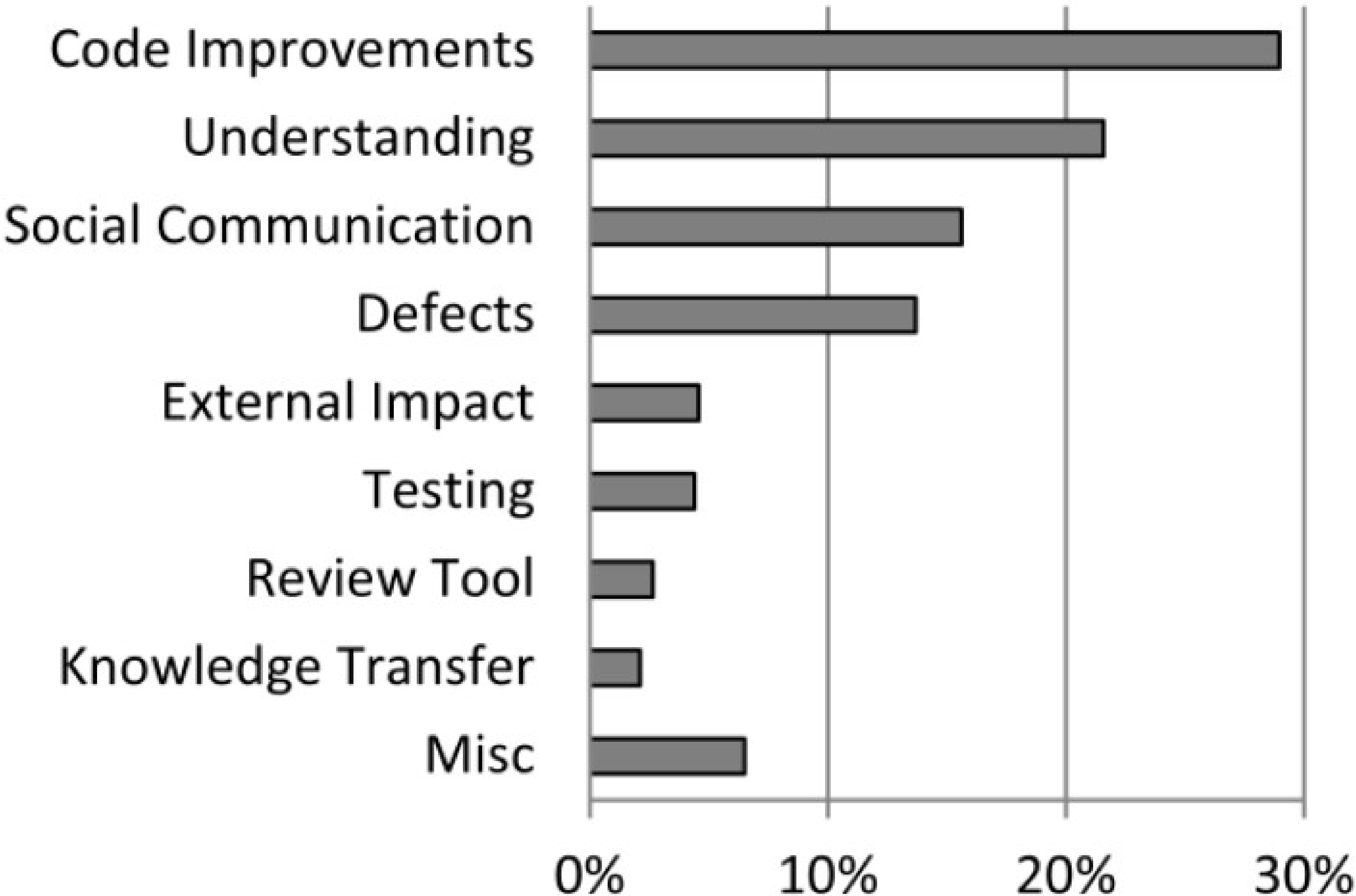
- Team awareness and transparency
  - let others "double check" changes
  - announce changes to specific developers or entire team ("FYI")
- Shared code ownership
  - openness toward critique and changes
  - makes developers "less protective" of their code


Ranked Motivations From Developers
Top
Second
Third
Finding Defects
Code Improvement
Alternative Solutions
Knowledge Transfer
Team Awareness
Improve Dev Process
Avoid Build Breaks
Share Code Ownership
Track Rationale
Team Assessment
0
200
400
600
Responses

# Outcomes
## (200 Microsoft reviews, 570 comments)

- Most frequent: **code improvements** (29%)
  - 58 better coding practices
  - 55 removing unused/dead code
  - 52 improving readability
- Moderate: **defect finding** (14%)
  - 65 logical issues ("uncomplicated logical errors, e.g., corner cases, common configuration values, operator precedence")
  - 6 high-level issues
  - 5 security issues
  - 3 wrong exception handling
- Rare: **knowledge transfer**
  - 12 pointers to internal/external documentation, etc.

# Outcomes


Code Improvements
Understanding
Social Communication
Defects
External Impact
Testing
Review Tool
Knowledge Transfer
Misc
0%
10%
20%
30%

# Aside: Philosophy

- One definition of the source of unhappiness is unrealized desires
  - You are unhappy when you desire reality (or your experience) to have property *X* but it does not
  - Buddhism: “craving is the cause of all suffering”
- You can either change what you want
- … or try to change reality / your experiences
- Both are usually very difficult!

# Expectation/Outcome Mismatch

- Low quality of code reviews
  - Reviewers look for easy errors (formatting issues)
  - Miss serious errors
- **Understanding** is the main challenge
  - Understanding the reason for a change
  - Understanding the code and its context
  - Feedback channels to ask questions often needed
- No quality assurance on the outcome

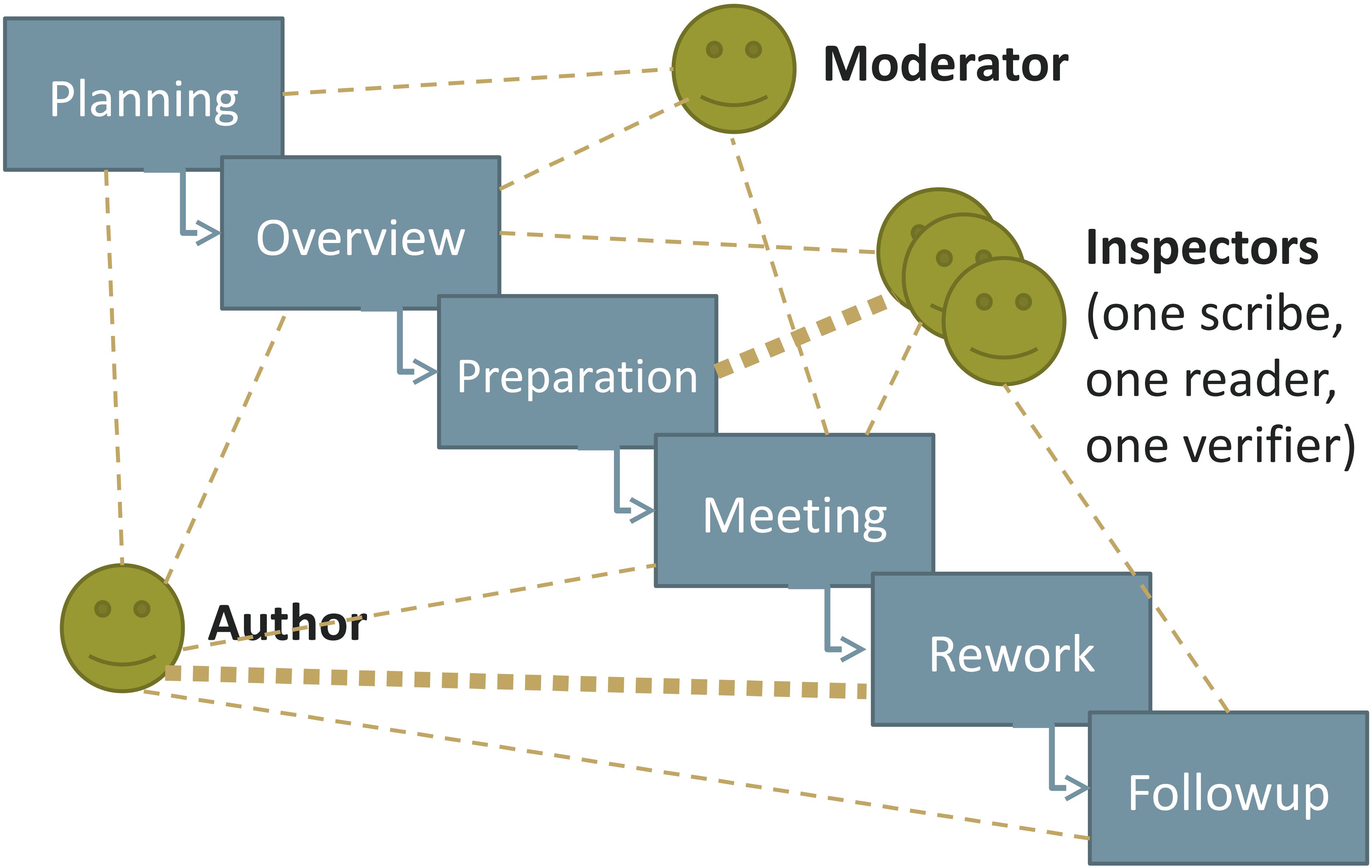
# Formal Code Inspections

- In a **formal code inspection** a group of developers meets to review code or other artifacts
  - Popularized by IBM in the 1970s, broadly adopted in the 1980s, subject of much research
- Viewed as the most effective approach to finding bugs
  - 60-90% of bugs were found with inspections
- Very expensive and labor-intensive

# Inspection Team and Roles

- Typically 4-5 people (at least 3 if “formal”)
  - Author
  - Inspector(s)
    - Find faults and broader issues
  - Reader
    - Presents the code or document at inspection meeting
  - Scribe
    - Records results
  - Moderator
    - Manages process, facilitates, reports

# Inspection Process



# Inspection Steps

- Planning (select Moderator)
- Overview (brief) – Author presents context in meeting
- **Preparation** (1-2h) – Every reviewer inspects the code separately
- **Meeting** (1h)
  - Reader presents the code
  - All reviewers identify issues
  - Meetings only discover issues, do not discuss solution or whether it really is an issue
- Rework
- Followup (Verifier checks changes)

# Inspection Checklists

- Reminder of what to look for
- Include issues detected in the past
- Preferably focus on few important items
- Examples:
  - Are all variables initialized before use? Are all variables used?
  - Is the condition of each if/while statement correct?
  - Does each loop terminate?
  - Do function parameters have the right types and appear in the right order?
  - Are linked lists efficiently traversed?
  - Is dynamically allocated memory released?

# Process Details

- **Authors do not explain or defend** the code – not objective
  - Author != moderator, != scribe, != reader
  - Author observes questions and misunderstandings and clarifies issues if necessary
- Reader (optional) walks through the code line by line, explaining it
  - Reading the code aloud requires deeper understanding
  - Verbalizes interpretations, thus observing differences in interpretation

# Social Issues: Egos in Inspections

- Authors *should* separate self-worth from code
- Identify defects, not alternatives; do not criticize authors
    - “you didn’t initialize variable *x*” → “I don’t see where variable *x* is initialized”
- Avoid defending code. Avoid discussions of solutions or alternatives
- Reviewers should not “show off” as smarter
- Author decides how to resolve defects

# Social Issues: Inspection Incentives

- Meetings should not include management
- Do not use code reviews for HR evaluations!
  - Bad: “finding more than 5 bugs during inspection counts against the author”
  - Leads to avoidance, fragmented submission, not pointing out defects, holding pre-reviews
- Responsibility for quality with authors, not reviewers
  - “why fix this, reviewers will find it”
- cf. lecture on Metrics and Incentives

# Root Cause Analysis

- An overarching goal is look beyond the immediate puzzle
- Identify way to improve the development process to avoid this problem in the future
  - Restructure the development process
  - Introduce new policies
  - Use new development tools, languages, analyses, etc.
- cf. “definition of insanity”

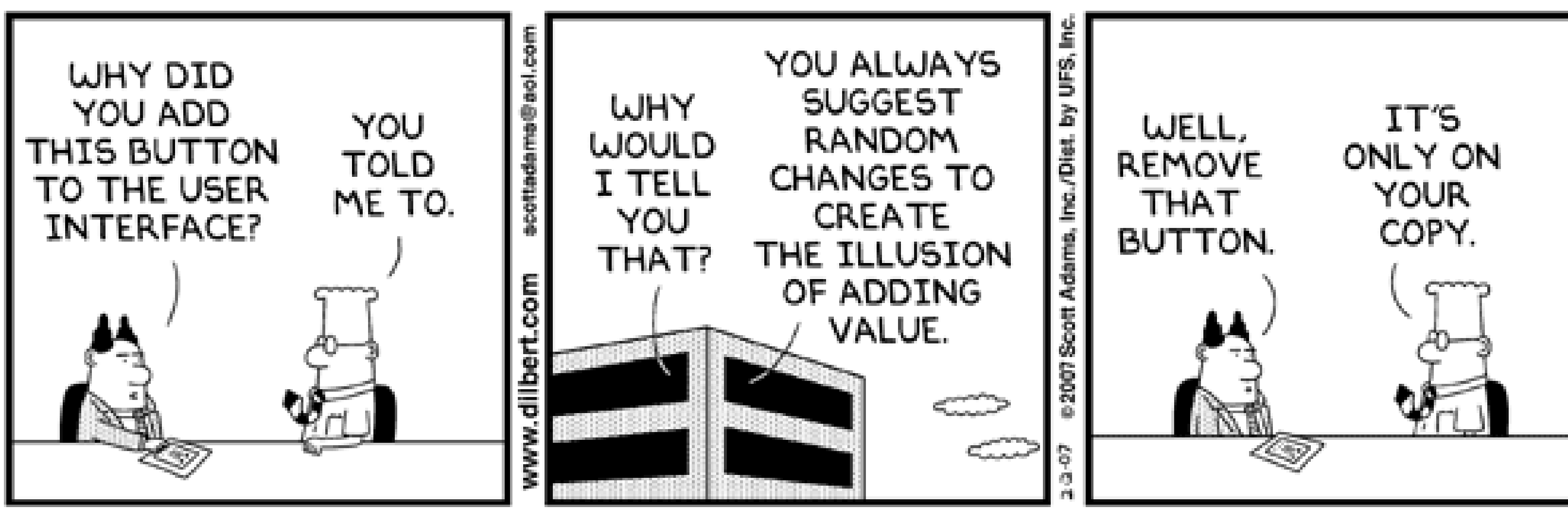
# When to Inspect

- Inspect before milestones
- Incremental inspections during development
  - Earlier often better than later: smaller fragments, chance to influence further development
  - Large code bases can be expensive and frustrating to review
    - Break down, divide and conquer
    - Focus on critical components
    - Identify defect density in first sessions to guide further need of inspections

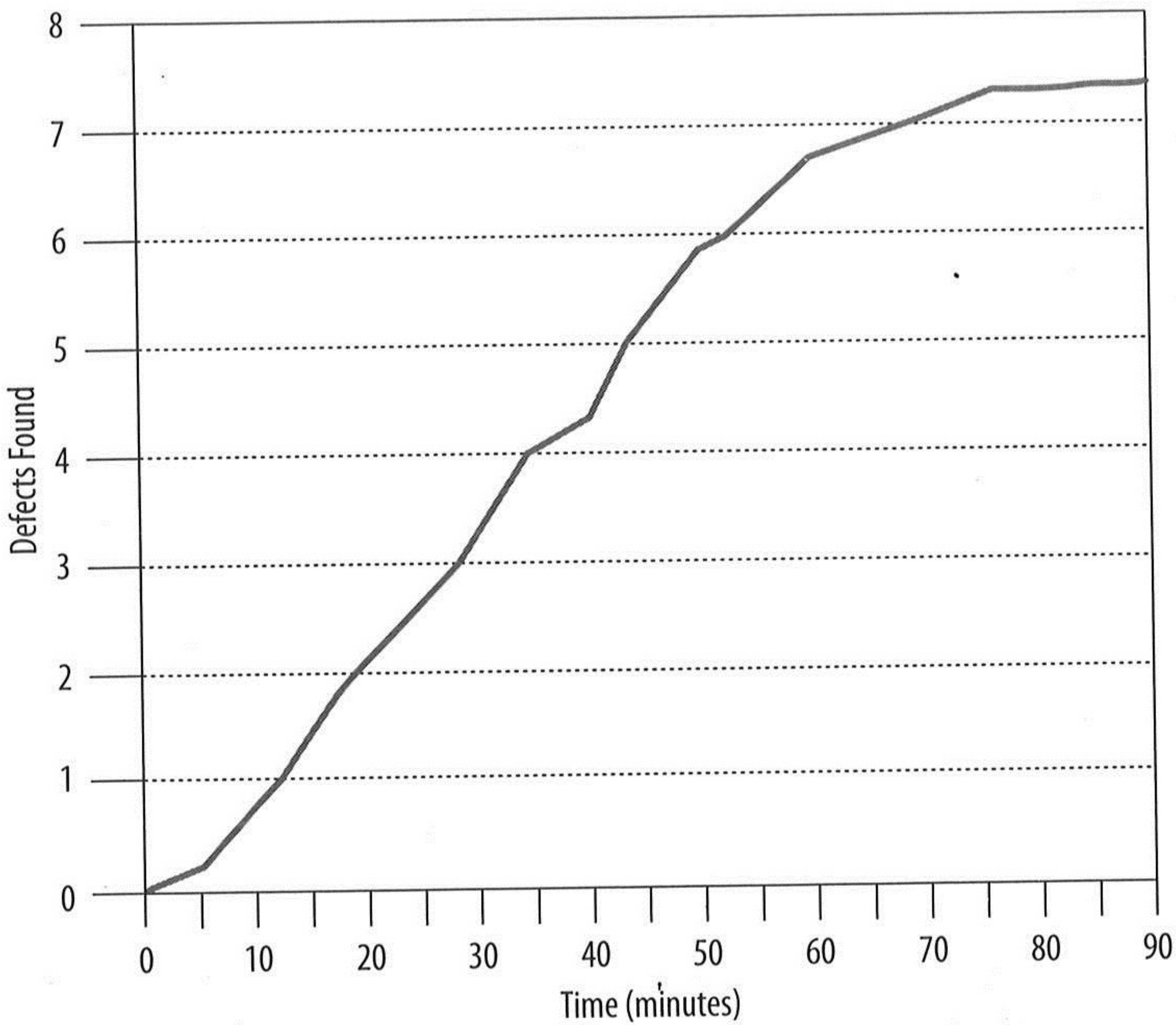
# Guidelines for Inspections

- Collected over many companies in many projects and experiments
- Several metrics are easily measurable
  - Effort, issues found, lines of code inspected, etc.

[ Oram and Wilson (ed.). Making Software. O'Reilly 2010. Chapter 18 and papers reviewed therein. ]

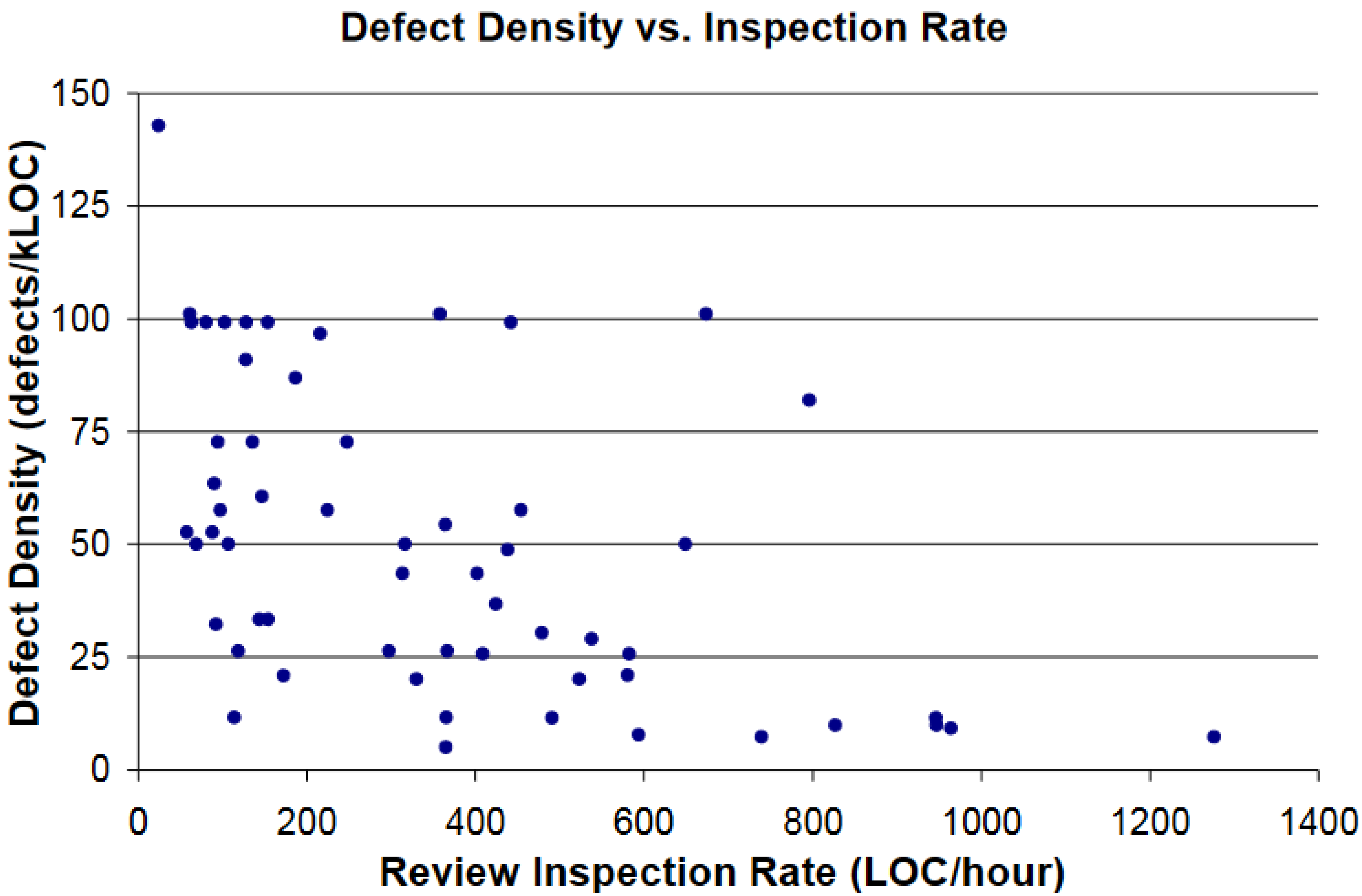


# Focus Fatigue




Recommendation:
Do not exceed
60 minute session

# Inspection Speed

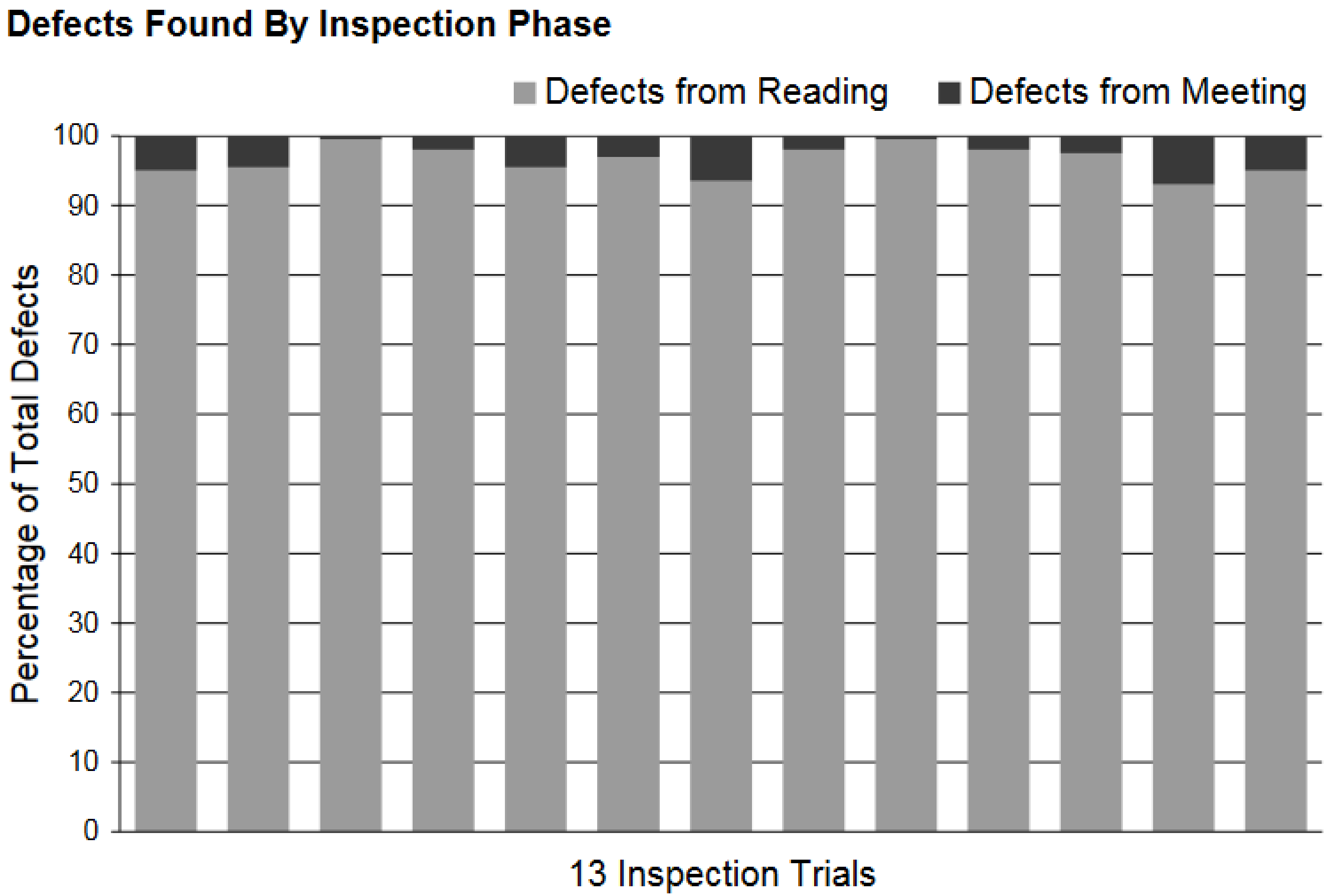



Above 400 LOC/h reviews get shallow

Recommendation: Schedule fewer than 400 LOC for a 1h review session

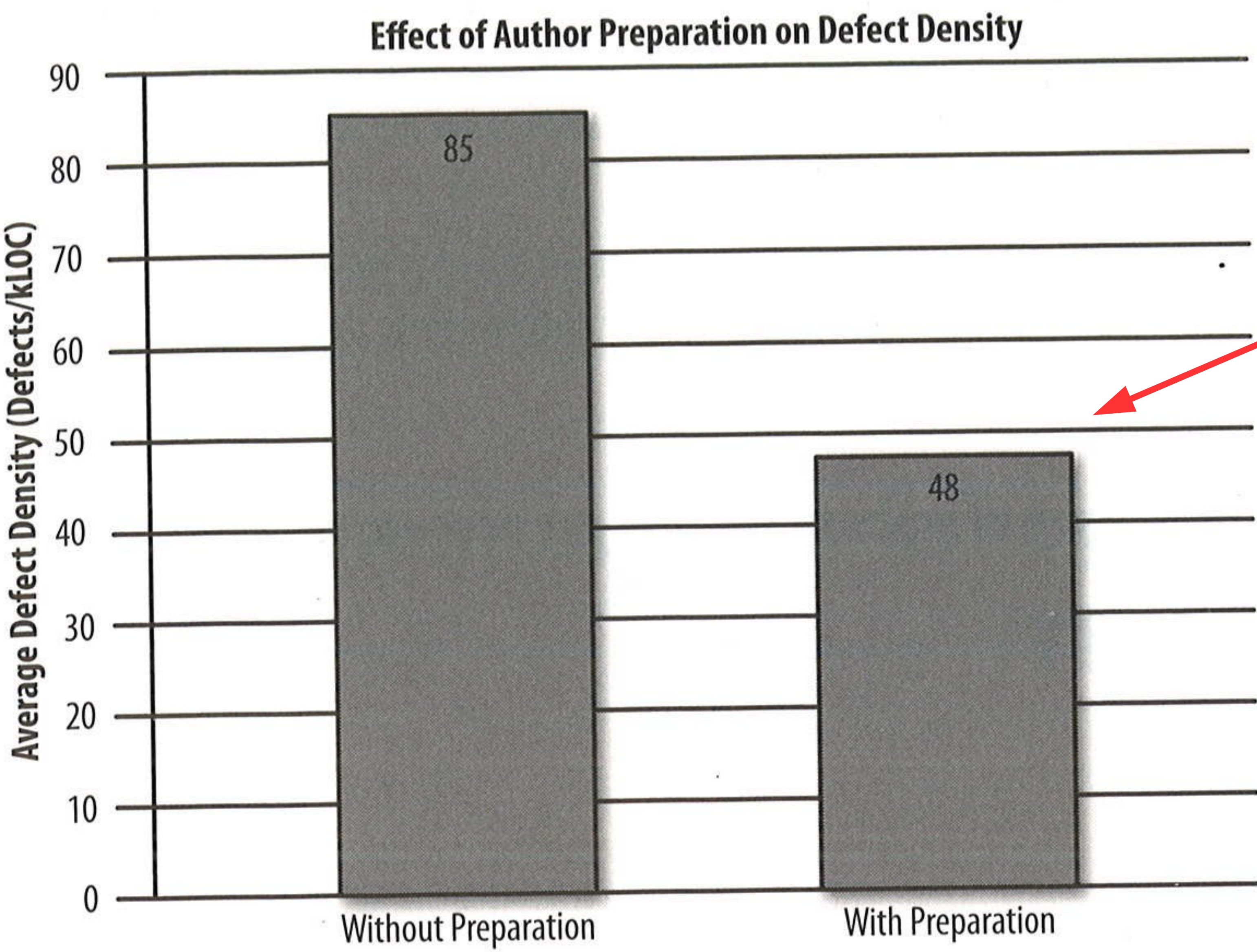
[ Code Review at Cisco Systems. In J A Cohen et al.'s *Best Kept Secrets of Peer Code Review*, 2013. ]

# Inspection Meeting Efficacy




Most issues found during preparation, not in meeting
Suggested synergy seems to have only low impact
Claim: Defects found in meetings often more subtle

# Self-Checks Matter




Authors have self-checked documents before inspection

# Inspection Accuracy

- About 25% of found issues are false positives
  - We'll return to this issue later in the course: it turns out humans are not perfect …
- Avoid discussing during meeting
- Confusion during meeting is an indicator that document could be clearer
  - For maintainability, if someone says “I don't think the code does X”, it does not actually matter if the code does X or not!

private question

8 views

Actions

## Using Tutorial Code for HW1 d

I found a tutorial on how to make chart (different from PieChart) using JFreeChart. I implemented the line chart in a test case and it gave me good enough coverage to pass the autograder.

I am afraid that my code is quite similar to the code provided in the tutorial. Since there's only one way to really make PieCharts, I cannot change it much. Is it okay if I cite the source in my report and submit my code? I haven't submitted it yet, will do once instructors confirm.

private question

## 1C Tests

Can we use tests from the GitHub repo that was linked in the spec for part 1C?

private question

## Use of online code 1c (h

I am curious about our ability to use o

For example, tutorialspoint has a section on jfreechart (https://www.tutorialspoint.com/jfreechart/jfreechart_bar_chart.htm) and I am wondering if submitting one of their files and giving them credit would be acceptable or if we must modify the

question

59 views

## test case submit

When we submit our test cases to the autograder, is including the test cases provided in spec allowed? Or do all of our test cases have to be unique?

## hw1c Using examples online

Can we take (or use as a starting point) lines directly out of the Github project to use as test coverage?

private

## 1b test cases from internet

Are we allowed to use png files that were downloaded from the internet as test coverages or do we need to create one?

# Homework Assignment #1 — Test Coverag

In this assignment yo
spanning three differe
asked to write a short

Two of the key proper
academic coursework
Microsoft as a softwa
in class, the vast majo
codebases (i.e., old co

Thus, there is no parti
assignment. Indeed, t

3. **Question:** Can I really use images or code snippets I found online to help with this assignment?

**Answer:** Yes, provided that you cite them at the end of your report. This class is about "everything except writing code", in some sense, and in the real world people do everything they can to get high-coverage test suites (including paying people to construct them and using special tools). So you can use image files or benchmarks you find on the Internet if you like — but you'll still have to do the work of paring things down to a small number of high-coverage files. Similarly, you can use Java code snippets if you like — but note that the grading server does not support `junit` or graphics, so you may have to manually edit them. You'll likely get the most out of the assignment if you use a combination of white-box testing, black-box testing and searching for resources — but there are many ways to complete it for full credit.

You *may* work with a partner for this assignment. If you do you must use the same partner for all sub-components of this assignment. Only one partner needs to submit the report on Gradescope, but you *do* need to use Gradescope's interface to select your partner. (Here is a video showing Gradescope partner selection.) You *may* use files, benchmarks or resources from the Internet (unlike in many other classes), provided you cite them in your written report.

Feel free to scour the web (e.g., Stack Overflow, etc.) or this webpage (e.g., the example tests shown above) or the tarballs (e.g., yes, you can submit `pngtest.png` or `toucan.png` if you want to) for ideas and example images to use directly as part of your answer (with or without modification) — just cite your sources (or URLs) in the report. However, submissions are limited to 50 test cases (so just finding a big repository of two hundred images may not immediately help you without additional work) totalling 30 megabytes. In addition, you may never submit another student's work (images or test selection) as your own.

# The Goal Is Not To Be "Right" (cf. "save effort/money")

- "A Pyrrhic victory is a victory that inflicts such a devastating toll on the victor that it is tantamount to defeat. Someone who wins a Pyrrhic victory has also taken a heavy toll that negates any true sense of achievement or damages long-term progress."
- Perhaps counter-intuitively, whether you (the code author) are right or not is usually irrelevant
  - "I don't think X has Y" means "Clarify X's use of Y"

# Inspections vs. Reviews: Costs

- Formal inspections and modern code reviews
  - Formal inspections very expensive (about one developer-day per session)
  - Passaround review is distributed, asynchronous
- Code reviews vs. testing
  - Code reviews claimed more cost effective
- Code reviews vs. not finding the bug

# Code Review by Formality

More Formal

- Ad hoc review
- Passaround ("modern code reviews")
- Pair programming
- Walkthrough
- Inspection

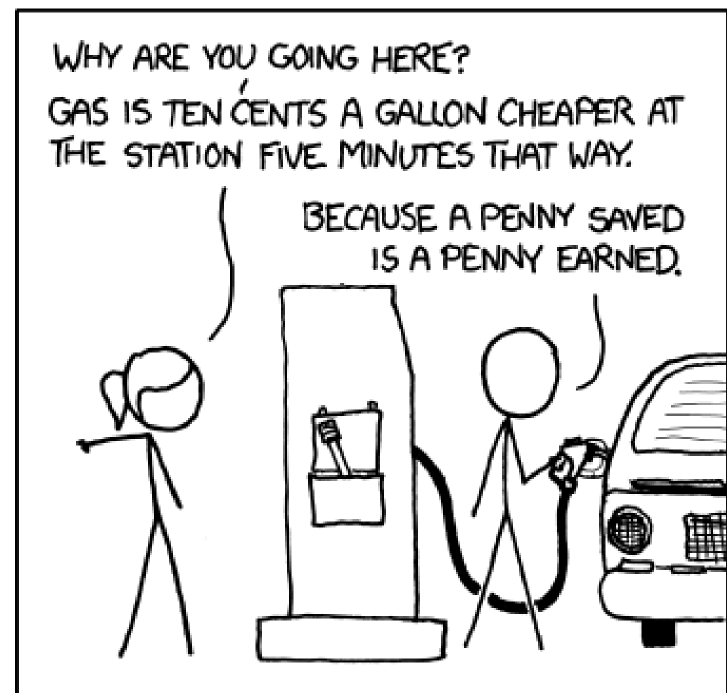
*(When should you use which type?)*

# Review Type and Differences

| Review Type | Planning | Preparation | Meeting | Correction | Verification |
|---|---|---|---|---|---|
| Formal Inspection | Yes | Yes | Yes | Yes | Yes |
| Walkthrough | Yes | Yes | Yes | Yes | No |
| Pair Programming | Yes | No | Continuous | Yes | Yes |
| Passaround (modern code review) | No | Yes | Rarely | Yes | No |
| Ad Hoc Review | No | No | Yes | Yes | No |

# Studies, Claims, Results

- Raytheon review study
  - Reduced "rework" from 41% of costs to 20%
  - Reduced integration effort by 80%
- Paulk et al. – costs to fix a space shuttle software
  - $1 if found in inspection
  - $13 during system test
  - $92 after delivery
- IBM – 1h of inspection saves 20h of testing
- R. Grady – efficiency data from HP
  - System use 0.21 defects/h
  - Black box testing 0.28 defects/h
  - White box testing 0.32 defects/h
  - Reading/inspection 1.06 defects/h




IF YOU SPEND NINE MINUTES OF YOUR TIME TO SAVE A DOLLAR, YOU'RE WORKING FOR LESS THAN MINIMUM WAGE.

# Questions?

- Homework continues …
- You can ask the course staff about homeworks “early” (e.g., how to get started, common pitfalls, etc.)