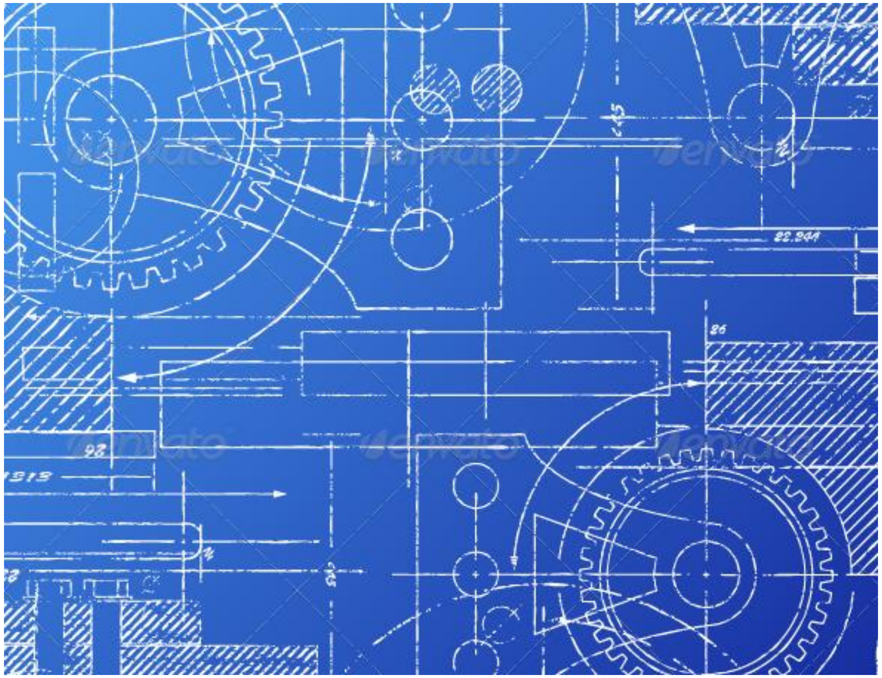
Principles of Software Analysis and Design

What is *Software Design*?

- A plan or pattern (e.g., blueprint) for constructing software

- A model, a simplified illustration of software



https://graphicriver.net/item/blueprint/2849763

Communicating Software Design

- UML is widely used to communicate design
  - Class Diagrams
  - Sequence Diagrams
  - State Charts

- *Design Patterns* have emerged from a search for higher-level abstractions, best practices in design

When to Communicate Design?

- Prior to implementation during the formative design process
  - To communicate and test design proposals ("We could do this…")
  - To critique their limitations and/or failures ("THAT won't work!")

- Following the design's implementation
  - To teach future developers how the design works
  - To teach future developers why some choices were avoided

What type of properties do we want from design?

What We Want from Design: Sufficiency

- The design needs to satisfy the product requirements

- But sufficiency is inadequate by itself

What We Want from Design: Understandability

- You must be able to communicate your design

- Your development team will not adopt your design if they cannot understand it…

- …even if you have the best design!

What We Want from Design: Encapsulation

- We seek to conceal the internal operation of a module:
  - …so that we can someday change its implementation without that change rippling through other modules that use it
  - …so that its user need not understand its internal operation

- Example: If I build a List data structure, I wish to protect my implementation from unwanted coupling

What We Want from Design: Flexibility

- Want to be able to add, modify or remove features…
- …as business conditions change

What We Want from Design: Reusability

- Want to leverage reusable components from other designs

- Want to create new components to leverage in future designs

Virtues of Programmers

- Laziness?

Virtues of Programmers
Larry Wall, Inventor of Perl

- Laziness?

"It makes you write labor-saving programs that other people will find useful, and document what you wrote so you don't have to answer so many questions about it."

What We Want from Design: Modularity

What We Want from Design: Modularity

- Need to divide a large system into smaller modules, each to be implemented independently of the others

- This enables us to apply dozens, hundreds, even thousands of developers to large problems

- …an approach to achieving understandability

What We Want from Design: Cohesion and Coupling

- Modularity must be achieved with attention to *cohesion* and *coupling*

The Object-Oriented Paradigm: Cohesion

- *Cohesion* is good!

- Cohesion refers to the degree of interaction within a module

- OOP can achieve cohesion by encapsulating
  - related methods and
  - state variables
  - NB: But Java doesn’t force you to do that — it’s up to you to ensure the members are related!

The Object-Oriented Paradigm: Cohesion

- Each object should have a single responsibility

- Instance variables model the state of an object. Instance variables should be:
  - orthogonal
    - captures “independence” between different dimensions
      - do not store redundant data, or data that can be derived from existing data (e.g., DOB vs. age)
  - related and
  - necessary to model the object’s responsibility

The Object-Oriented Paradigm: Cohesion

- Methods model the behaviors of that object. Each method should reference:
  - an instance variable, or
  - at least another method in the same object

The Object-Oriented Paradigm:

Coupling

The Object-Oriented Paradigm: Coupling

- *Coupling* refers to the degree of interaction between modules

- Coupling often arises in
  - a dependency,
  - a local variable or
  - parameter referencing an object of a different data type

The Object-Oriented Paradigm: Coupling

- *Coupling* is undesirable

The Object-Oriented Paradigm: Coupling

- *Coupling* is undesirable but always necessary

- Approaches for minimizing coupling:
  - Use built-in data types for parameters
  - Use interfaces
  - Use getters/setters

What We Want from Design: Cohesion and Coupling

- Modularity must be achieved with attention to *cohesion* and *coupling*
  - *Cohesion* refers to interactions within a module
  - *Coupling* refers to interactions between modules

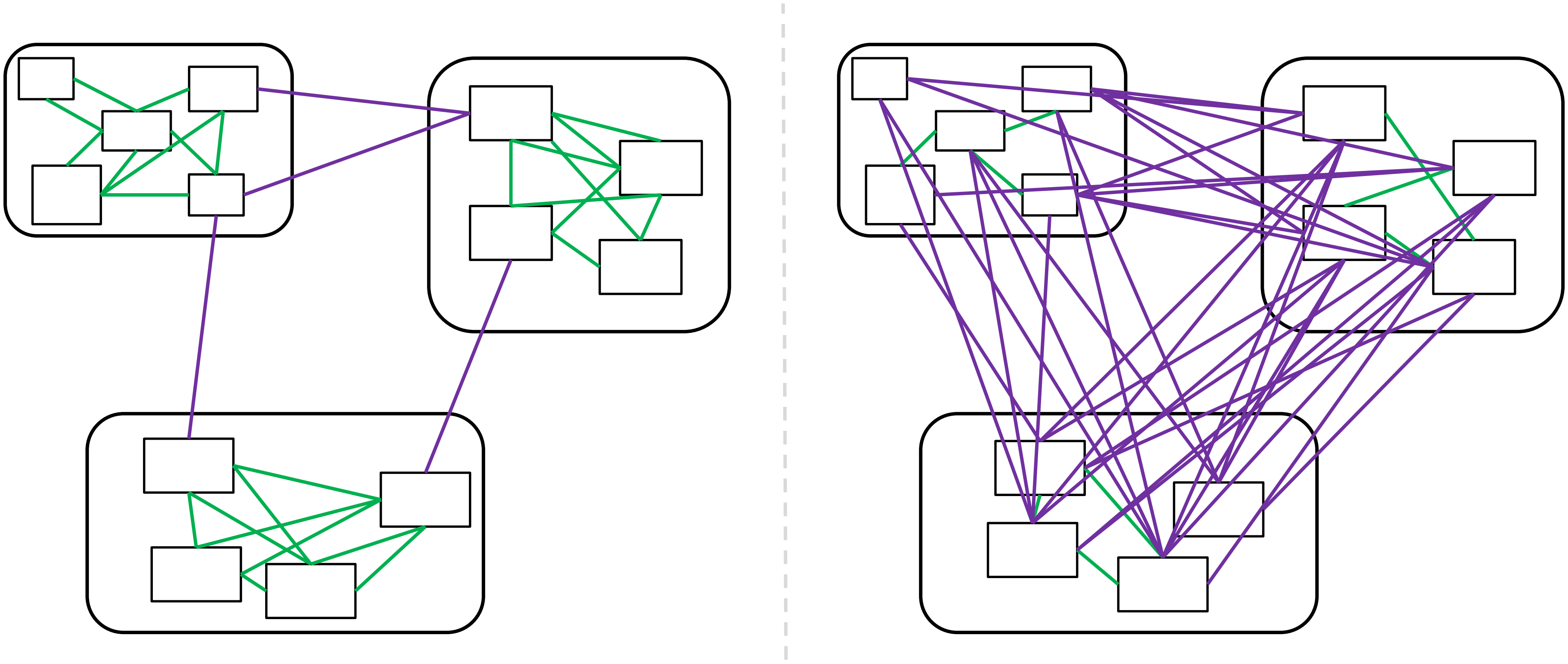
What We Want from Design: Cohesion and Coupling

- Modularity must be achieved with attention to *cohesion* and *coupling*
  - *Cohesion* refers to interactions within a module
  - *Coupling* refers to interactions between modules

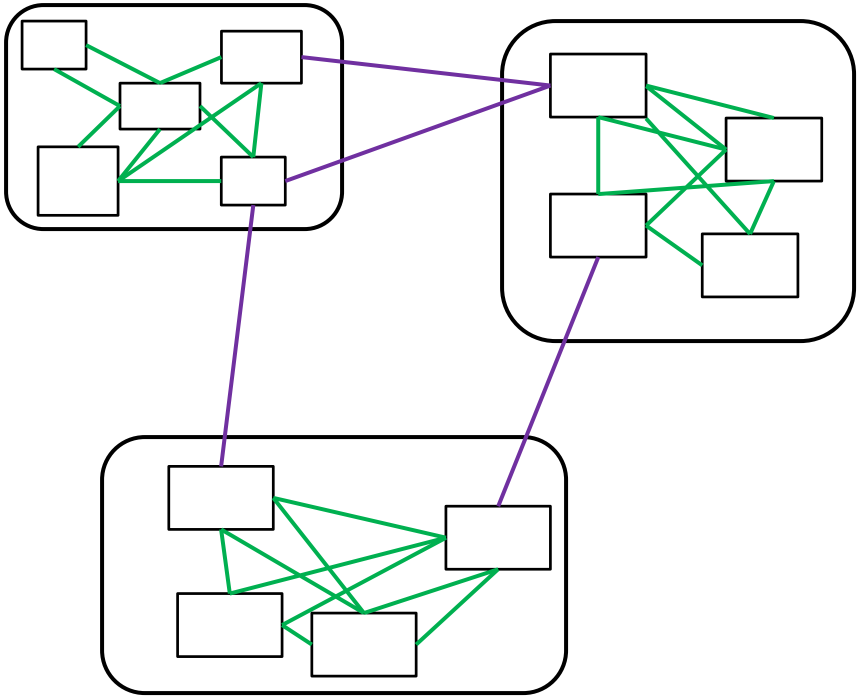
- Maximize *cohesion* by grouping like-minded parts in a module

- Minimize *coupling* (dependencies) between modules

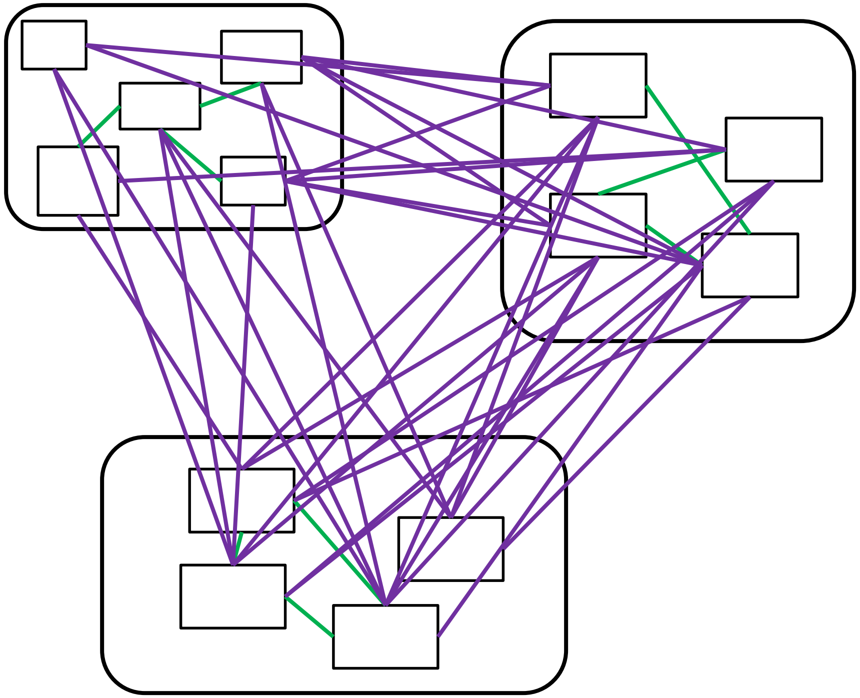
Which Design is "Better"?



Which Design is “Better”?

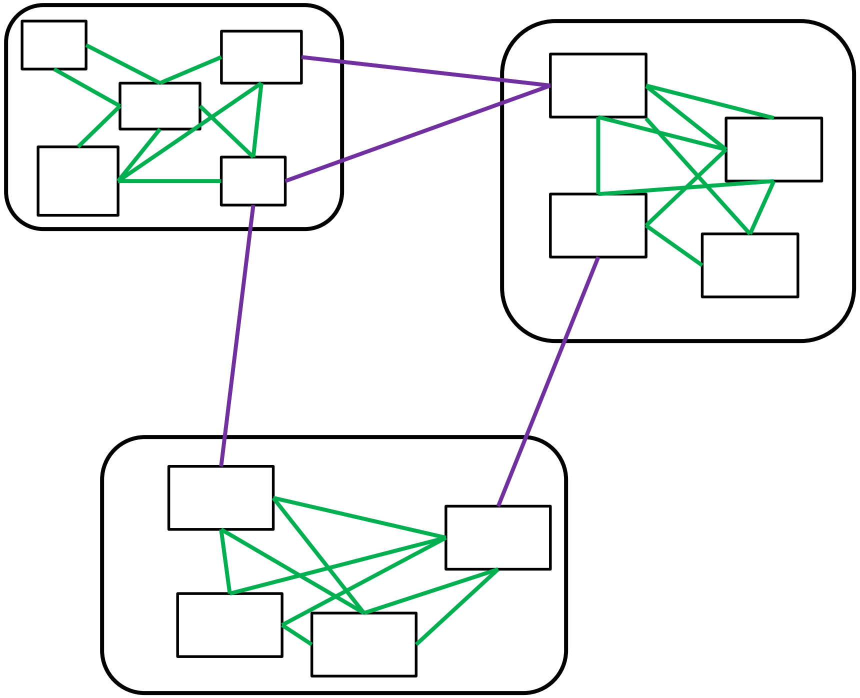


High Cohesion
Low Coupling



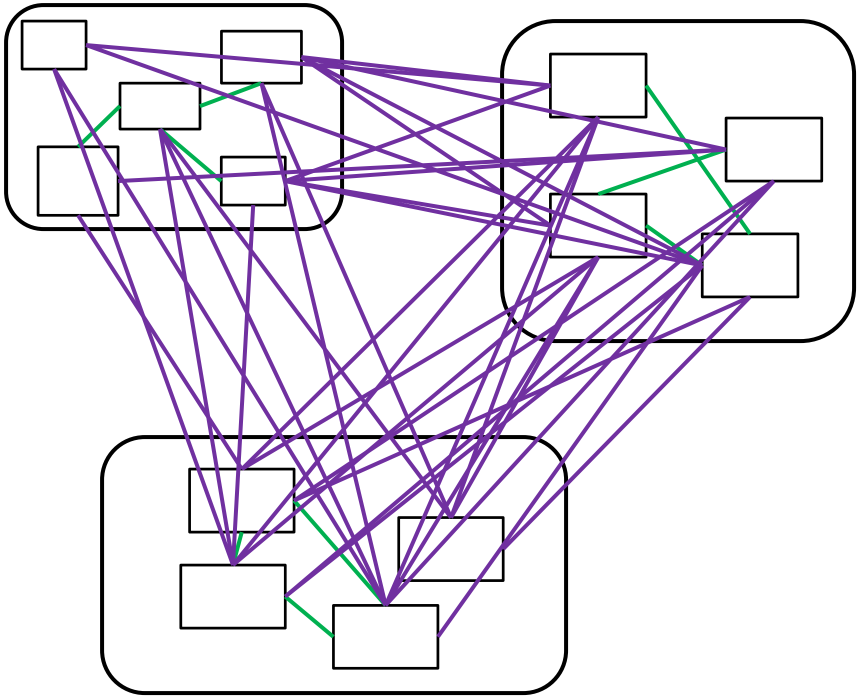
Low Cohesion
High Coupling

Which Design is "Better"?



High Cohesion
Low Coupling

👍



Low Cohesion
High Coupling

👎

Software Metrics

Software Metrics

- A *metric* is a system of measurement

- A *software metric* is a measurement of a software project
  - Allows the software to be quantified

Really Basic Scrum Metrics

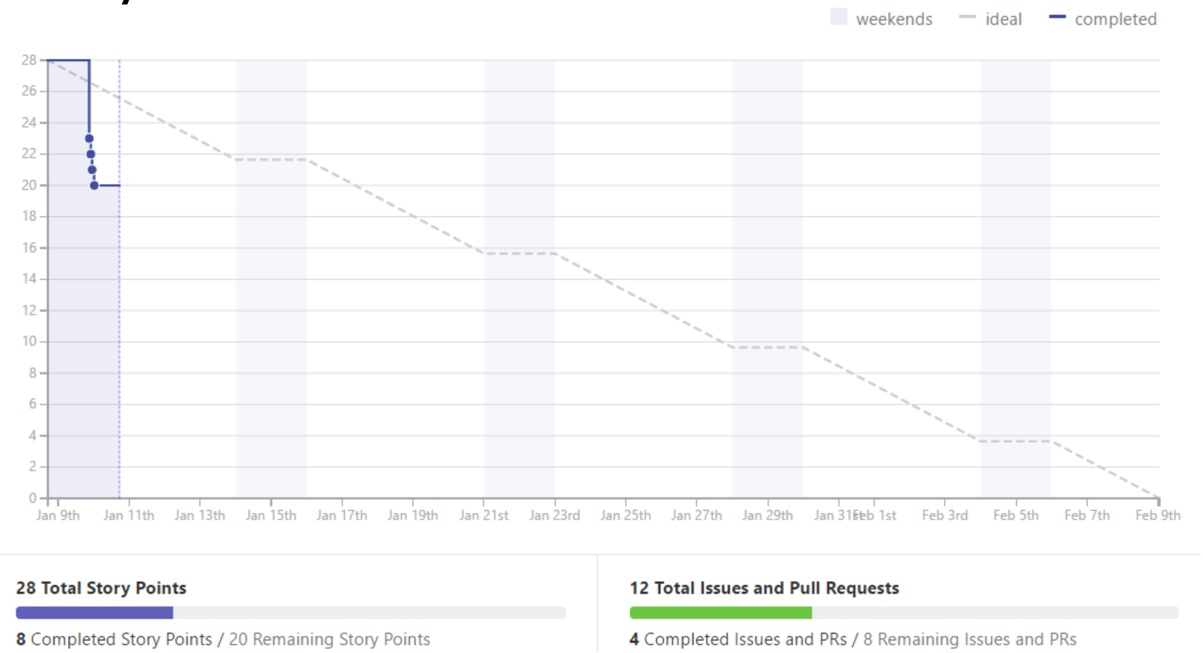
- Velocity (e.g., Story Points per Sprint)
  - Useful for …

- Work Remaining in Sprint (e.g., Story Points)
  - Applicability …

Really Basic Scrum Metrics

- Velocity (e.g., Story Points per Sprint)
  - Useful for planning

- Work Remaining in Sprint (e.g., Story Points)
  - Applicability: burndown chart



28 Total Story Points

8 Completed Story Points / 20 Remaining Story Points

12 Total Issues and Pull Requests

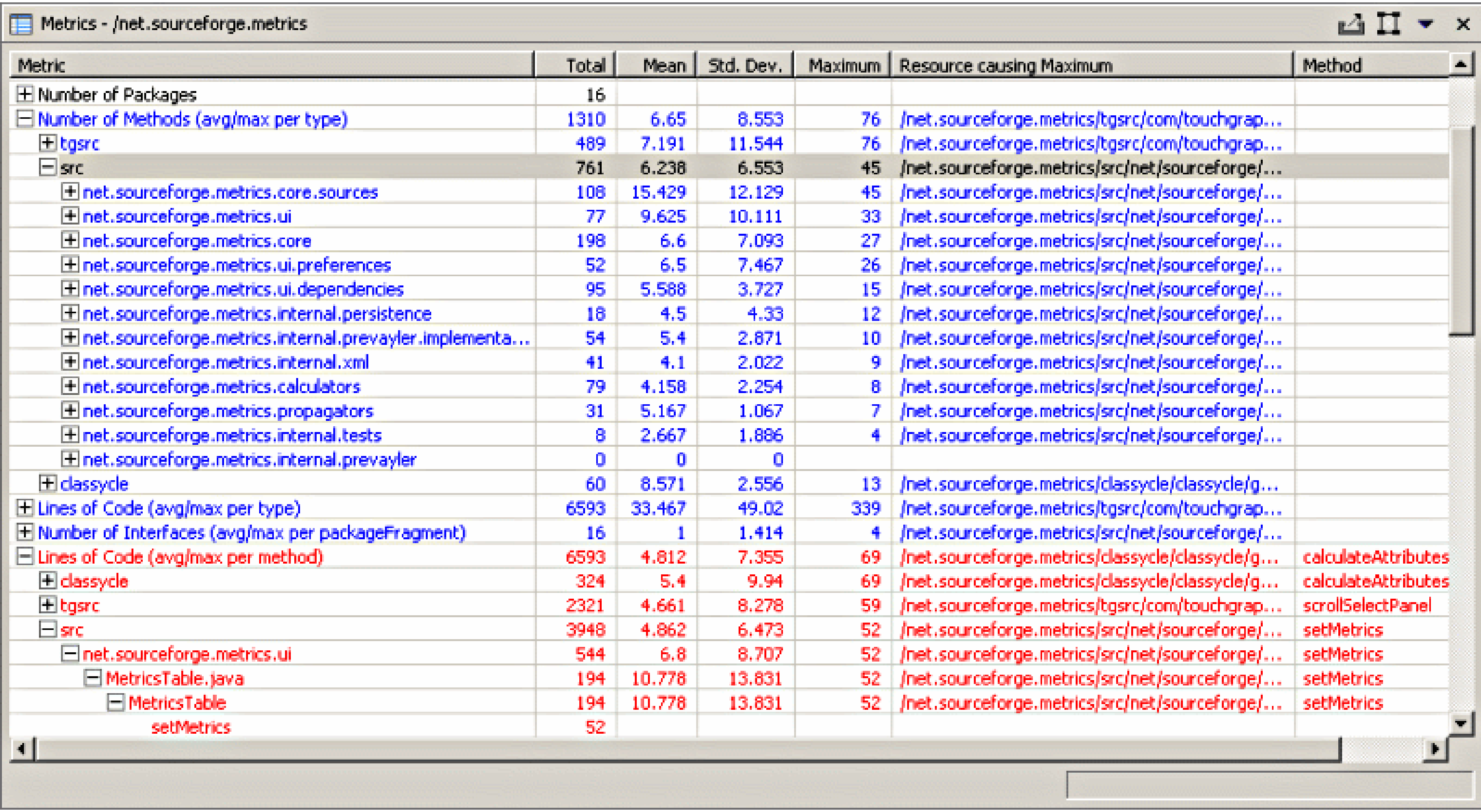
4 Completed Issues and PRs / 8 Remaining Issues and PRs

Software Metrics: Examples

- Code complexity:
    - Lines-of-Product-Code
    - Fan-in/fan-out
        - Number of “incoming” / ”outgoing” dependencies
    - Cyclomatic Complexity
        - “counts” the number of conditions in a program

- Productivity:
    - Lines-of-Product-Code per engineer-day

Example metrics: http://metrics.sourceforge.net/



Metrics - /net.sourceforge.metrics

Metric	Total	Mean	Std. Dev.	Maximum	Resource causing Maximum	Method
⊞ Number of Packages	16					
⊟ Number of Methods (avg/max per type)	1310	6.65	8.553	76	/net.sourceforge.metrics/tgsrc/com/touchgrap…	
⊞ tgsrc	489	7.191	11.544	76	/net.sourceforge.metrics/tgsrc/com/touchgrap…	
⊟ src	761	6.238	6.553	45	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.core.sources	108	15.429	12.129	45	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.ui	77	9.625	10.111	33	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.core	198	6.6	7.093	27	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.ui.preferences	52	6.5	7.467	26	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.ui.dependencies	95	5.588	3.727	15	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.internal.persistence	18	4.5	4.33	12	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.internal.prevayler.implementa…	54	5.4	2.871	10	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.internal.xml	41	4.1	2.022	9	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.calculators	79	4.158	2.254	8	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.propagators	31	5.167	1.067	7	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.internal.tests	8	2.667	1.886	4	/net.sourceforge.metrics/src/net/sourceforge/…	
⊞ net.sourceforge.metrics.internal.prevayler	0	0	0			
⊞ classycle	60	8.571	2.556	13	/net.sourceforge.metrics/classycle/classycle/g…	
⊞ Lines of Code (avg/max per type)	6593	33.467	49.02	339	/net.sourceforge.metrics/tgsrc/com/touchgrap…	
⊞ Number of Interfaces (avg/max per packageFragment)	16	1	1.414	4	/net.sourceforge.metrics/src/net/sourceforge/…	
⊟ Lines of Code (avg/max per method)	6593	4.812	7.355	69	/net.sourceforge.metrics/classycle/classycle/g…	calculateAttributes
⊞ classycle	324	5.4	9.94	69	/net.sourceforge.metrics/classycle/classycle/g…	calculateAttributes
⊞ tgsrc	2321	4.661	8.278	59	/net.sourceforge.metrics/tgsrc/com/touchgrap…	scrollSelectPanel
⊟ src	3948	4.862	6.473	52	/net.sourceforge.metrics/src/net/sourceforge/…	setMetrics
⊟ net.sourceforge.metrics.ui	544	6.8	8.707	52	/net.sourceforge.metrics/src/net/sourceforge/…	setMetrics
⊟ MetricsTable.java	194	10.778	13.831	52	/net.sourceforge.metrics/src/net/sourceforge/…	setMetrics
⊟ MetricsTable	194	10.778	13.831	52	/net.sourceforge.metrics/src/net/sourceforge/…	setMetrics
setMetrics	52					

Software Metrics: Examples

- Object-Oriented Metrics:
  - Depth of Inherence
  - Method fan-in/fan-out
  - Number of overriding operations
  - Coupling between Object Classes (COB)
  - Lack of Cohesion in Methods (LCOM)

Software Metrics: Examples

- Quality:
  - Defect Density
  - Number of errors found per person hour
  - Availability

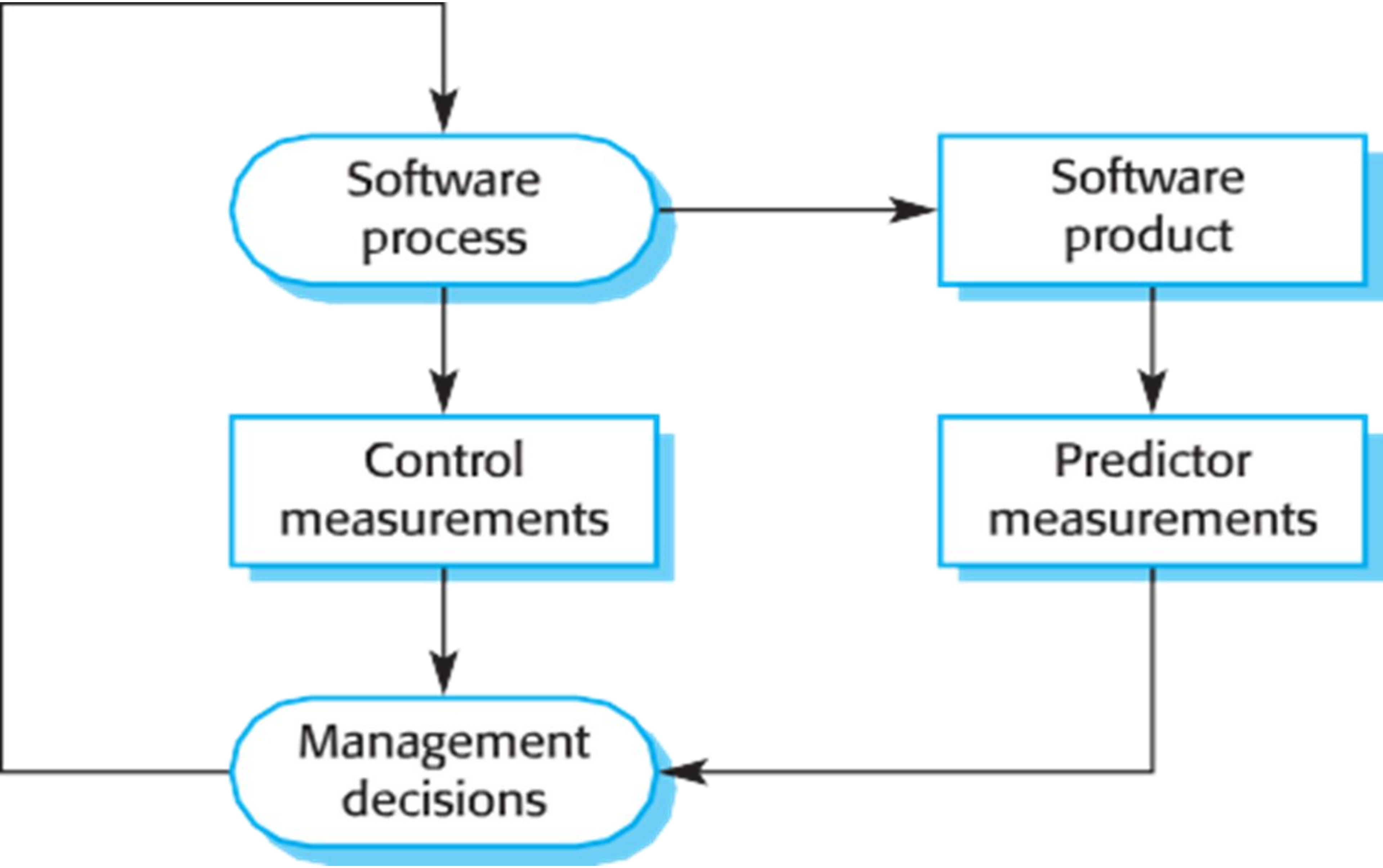
- Test Suite Effectiveness:
  - Lines-of-Test-Code / Lines-of-Product-Code
  - Defect Removal Efficiency (Effectiveness)
  - Test (AKA Code) Coverage
  - Killed-Mutant Fraction

Example Industry Data

- Product Size: 207 KLOC
- Productivity: 24 LinesOfProductCode/EngineerDay
- Delivered Quality: 5 Defects/KLOC
- Test Coverage: 55%
- System-Level Defects Removed/EngineerWeek: 4.3

Software Metrics Applicability

Software Metrics Applicability



Software Metrics Applicability

- predict product attributes/artifacts
  - e.g., we will be able to release by …

- control the software process
  - Improve the code quality

- Note: There are no standardized and universally applicable software metrics

Mylyn

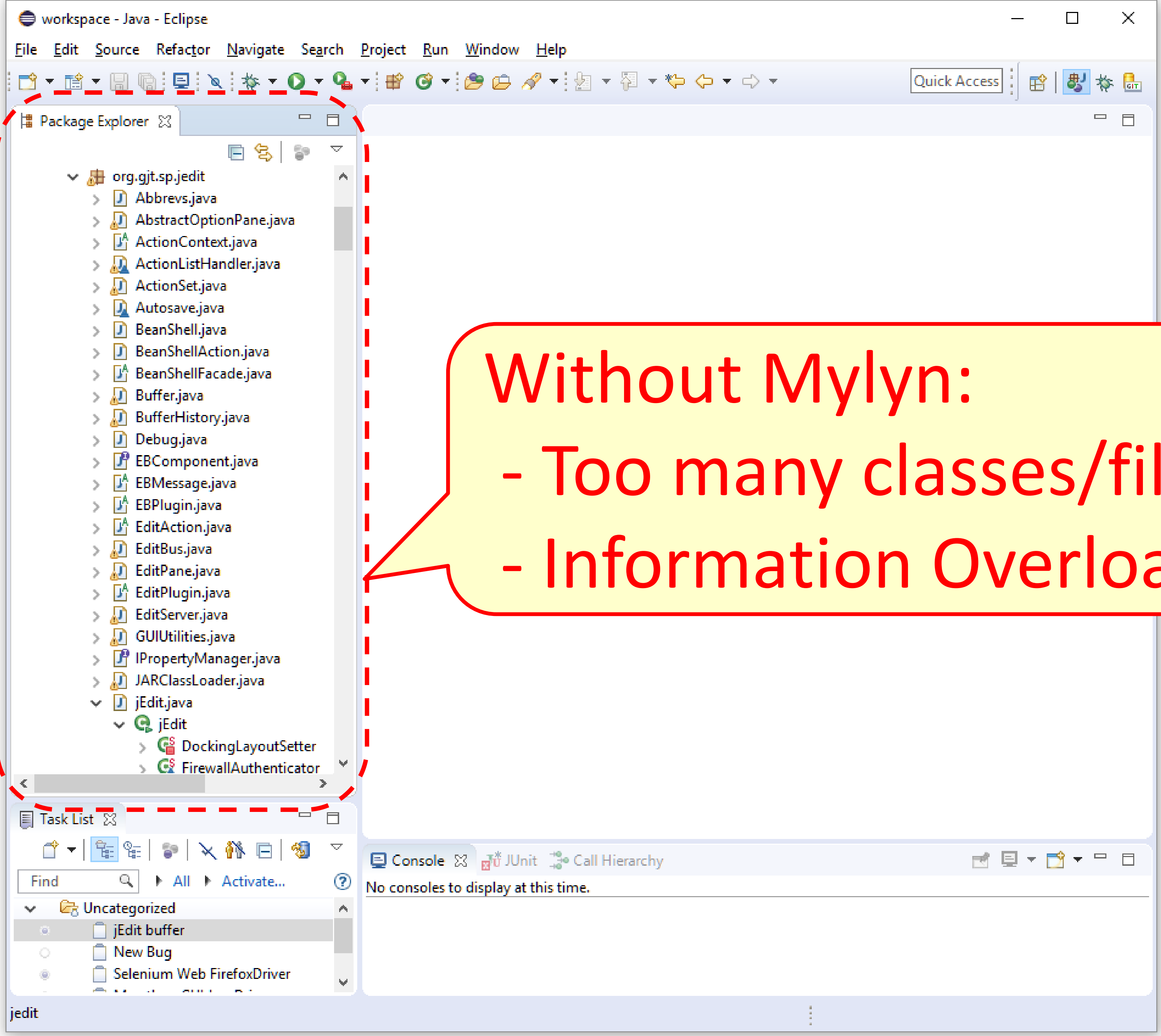
Mylyn

- Eclipse Plugin (http://www.eclipse.org/mylyn/)
  - Already installed on Eclipse distributions

- Associate a *context* (i.e., set of software artifacts related to a task) with a maintenance issue

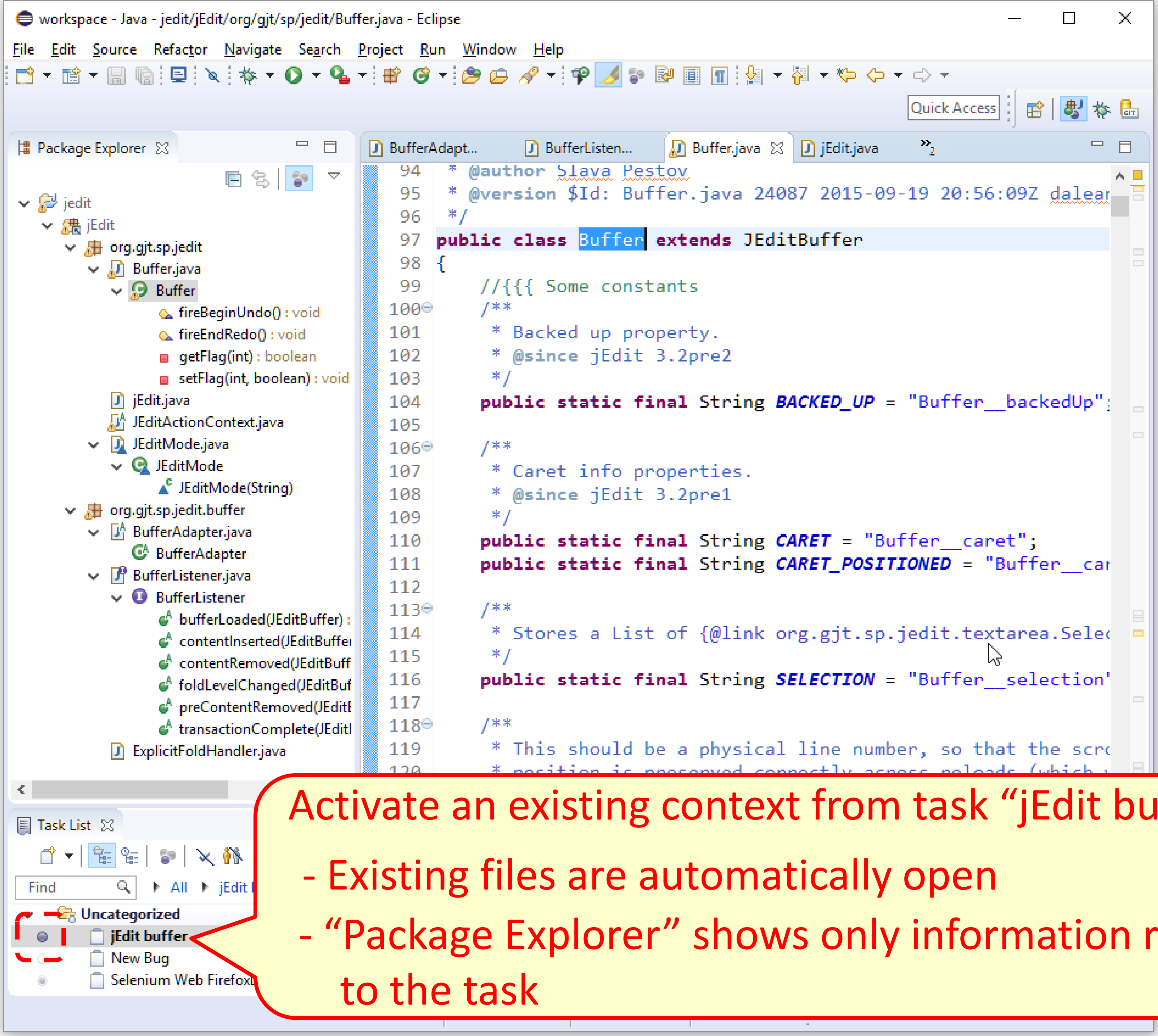
- Helps reduce information overload

- Allows to easily switch context, i.e.,
  - set of files opened for a maintenance task
  - methods/classes already visited



Without Mylyn:

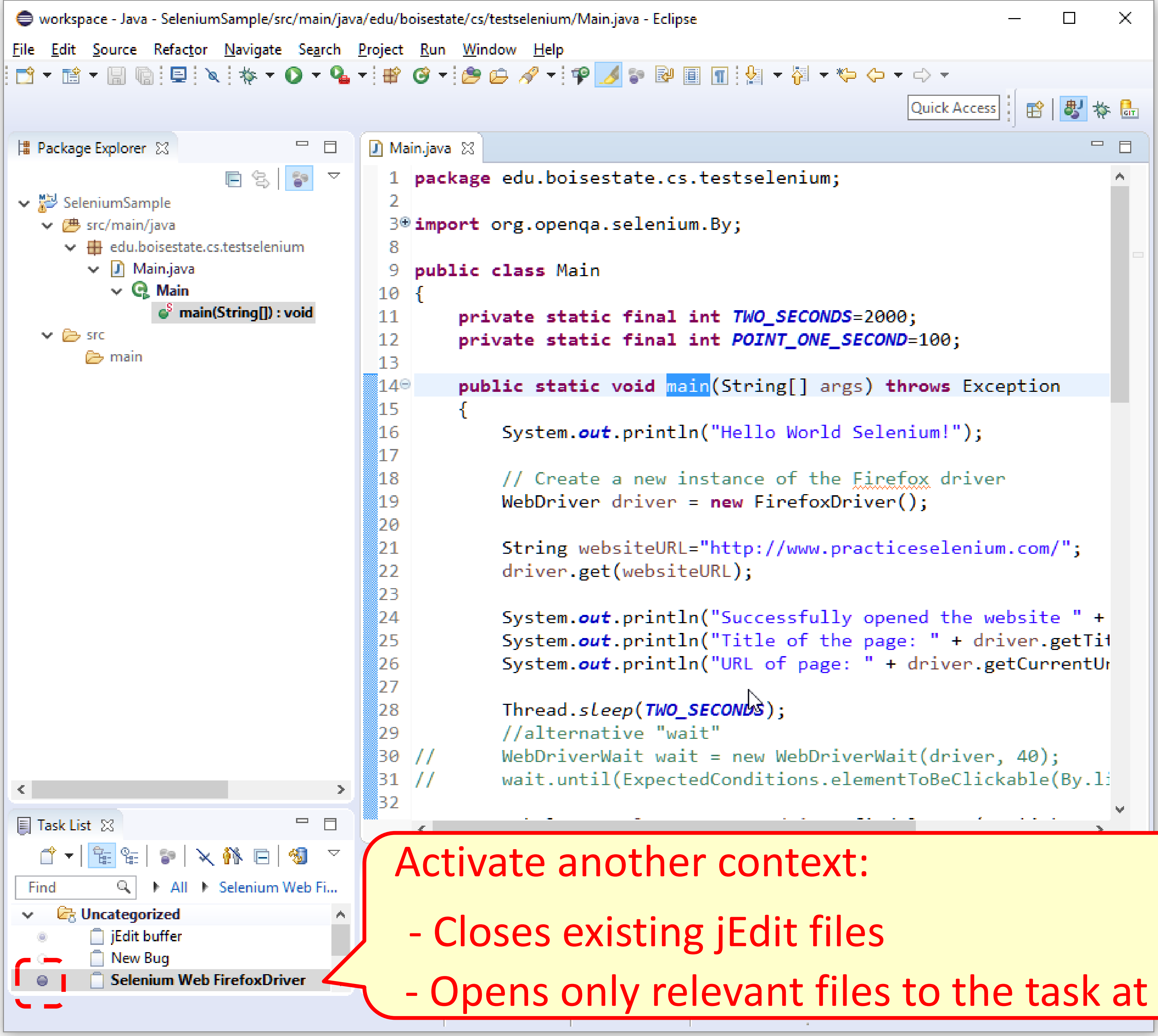
- Too many classes/files
- Information Overload



```
 * @author Slava Pestov
 * @version $Id: Buffer.java 24087 2015-09-19 20:56:09Z dalear
 */
public class Buffer extends JEditBuffer
{
	//{{{ Some constants
	/**
	 * Backed up property.
	 * @since jEdit 3.2pre2
	 */
	public static final String BACKED_UP = "Buffer__backedUp";

	/**
	 * Caret info properties.
	 * @since jEdit 3.2pre1
	 */
	public static final String CARET = "Buffer__caret";
	public static final String CARET_POSITIONED = "Buffer__car

	/**
	 * Stores a List of {@link org.gjt.sp.jedit.textarea.Selec
	 */
	public static final String SELECTION = "Buffer__selection'

	/**
	 * This should be a physical line number, so that the scro
	 * position is preserved correctly across reloads (which
```

Activate an existing context from task “jEdit buffer” :

- Existing files are automatically open
- “Package Explorer” shows only information relevant to the task



```java
package edu.boisestate.cs.testselenium;

import org.openqa.selenium.By;

public class Main
{
    private static final int TWO_SECONDS=2000;
    private static final int POINT_ONE_SECOND=100;

    public static void main(String[] args) throws Exception
    {
        System.out.println("Hello World Selenium!");

        // Create a new instance of the Firefox driver
        WebDriver driver = new FirefoxDriver();

        String websiteURL="http://www.practiceselenium.com/";
        driver.get(websiteURL);

        System.out.println("Successfully opened the website " +
        System.out.println("Title of the page: " + driver.getTit
        System.out.println("URL of page: " + driver.getCurrentUr

        Thread.sleep(TWO_SECONDS);
        //alternative "wait"
//      WebDriverWait wait = new WebDriverWait(driver, 40);
//      wait.until(ExpectedConditions.elementToBeClickable(By.li

```

Activate another context:

- Closes existing jEdit files
- Opens only relevant files to the task at hand

Time-travel debugging (TTD)

Time-Travel Debugging for JavaScript/Node.js (Demo), *Earl T. Barr, Mark Marron, Ed Maurer, Dan Moseley, and Gaurav Seth – FSE'16,* https://github.com/nodejs/node-chakracore/tree/debugging-ttd-preview

Time-travel debugging (TTD) for JavaScript/Node.js

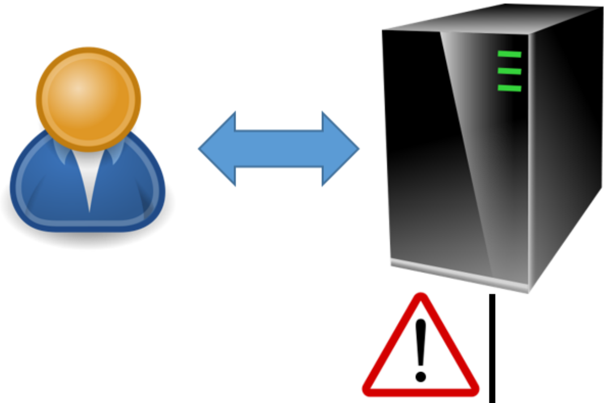
- record and playback principle:
  - the record mode creates a trace file during execution
  - file can be played back allowing developers to deeply inspect the code as it was during the original execution
- look at the faulting code within the full fidelity of the debugger
- all the runtime context preserved

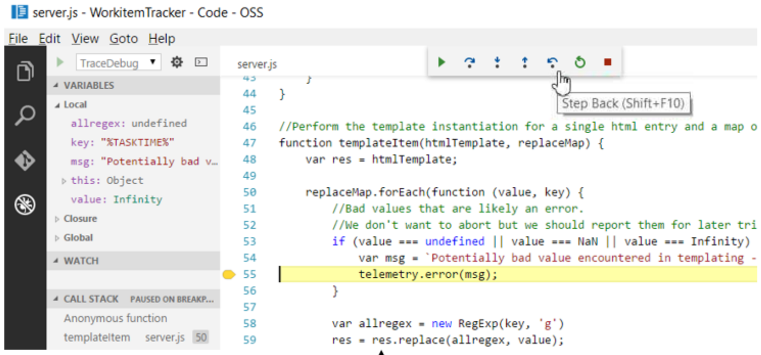
Time-Travel Debugging for JavaScript/Node.js (Demo), *Earl T. Barr, Mark Marron, Ed Maurer, Dan Moseley, and Gaurav Seth – FSE'16,* https://github.com/nodejs/node-chakracore/tree/debugging-ttd-preview

TTD Architecture

```
>node -TTRecord:\\remote\ttlog app.js
```

```
>TTDebugHost \\remote\ttlog
```





VARIABLES

Local

allregex: undefined

key: "%TASKTIME%"

msg: "Potentially bad v…

this: Object

value: Infinity

Closure

Global

WATCH

CALL STACK PAUSED ON BREAKP...

Anonymous function

templateItem server.js 50

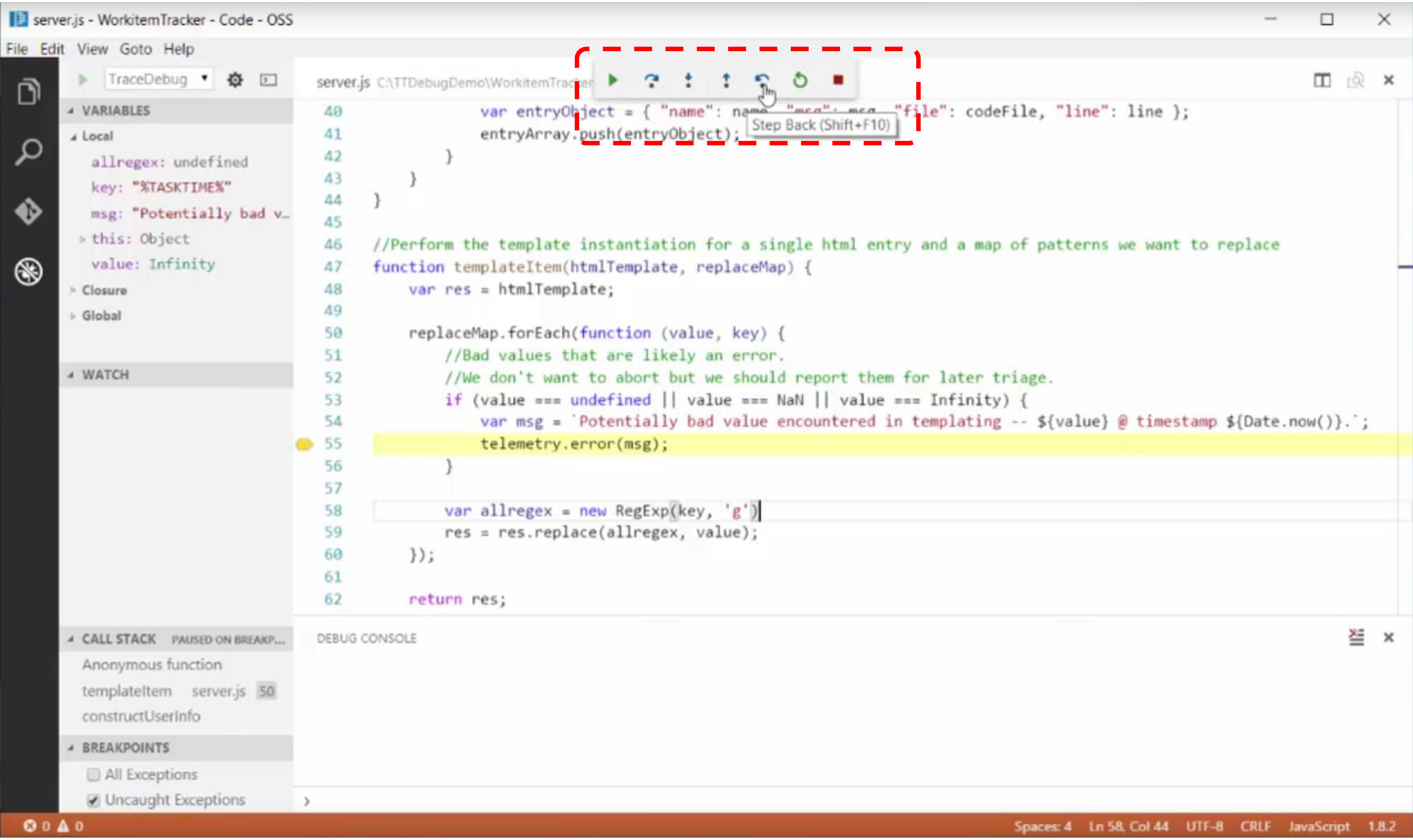
```
    }
}

//Perform the template instantiation for a single html entry and a map o
function templateItem(htmlTemplate, replaceMap) {
    var res = htmlTemplate;

    replaceMap.forEach(function (value, key) {
        //Bad values that are likely an error.
        //We don't want to abort but we should report them for later tri
        if (value === undefined || value === NaN || value === Infinity)
            var msg = `Potentially bad value encountered in templating -
            telemetry.error(msg);
        }

        var allregex = new RegExp(key, 'g')
        res = res.replace(allregex, value);
```

Remote Server/Cloud Storage

Serialize & Transmit Log

Load & Debug on Local Machine

TTD Demo



```
VARIABLES
Local
  allregex: undefined
  key: "%TASKTIME%"
  msg: "Potentially bad v…
  this: Object
  value: Infinity
Closure
Global

WATCH

CALL STACK   PAUSED ON BREAKP...
  Anonymous function
  templateItem   server.js   50
  constructUserInfo

BREAKPOINTS
  □ All Exceptions
  ☑ Uncaught Exceptions
```

```javascript
            var entryObject = { "name": name, "msg": msg, "file": codeFile, "line": line };
            entryArray.push(entryObject);
        }
    }
}

//Perform the template instantiation for a single html entry and a map of patterns we want to replace
function templateItem(htmlTemplate, replaceMap) {
    var res = htmlTemplate;

    replaceMap.forEach(function (value, key) {
        //Bad values that are likely an error.
        //We don't want to abort but we should report them for later triage.
        if (value === undefined || value === NaN || value === Infinity) {
            var msg = `Potentially bad value encountered in templating -- ${value} @ timestamp ${Date.now()}.`;
            telemetry.error(msg);
        }

        var allregex = new RegExp(key, 'g')
        res = res.replace(allregex, value);
    });

    return res;
```

https://www.youtube.com/watch?v=EJqo3j9we0A

Continuous Integration (CI) vs. Continuous Delivery (CD)

Continuous Integration (CI) vs. Continuous Delivery (CD)

- CI = the practice of merging all developer code to a shared branch as often as possible (daily)

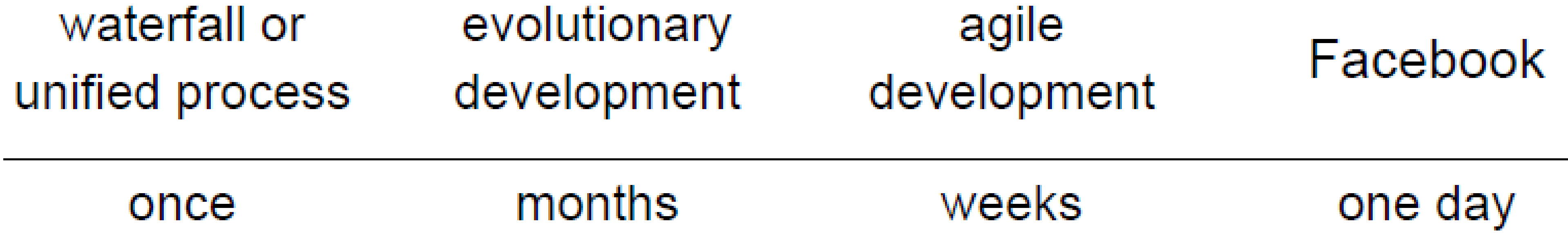
- CD = the practice of ensuring that the software from the main branch is always in a deployable state
  - the deployment process should be very fast
  - CD is an extension of CI

Engineering Activities at Facebook

- 1 billion users / month

- 2.5 billion content items / day

Frequency of Deployments



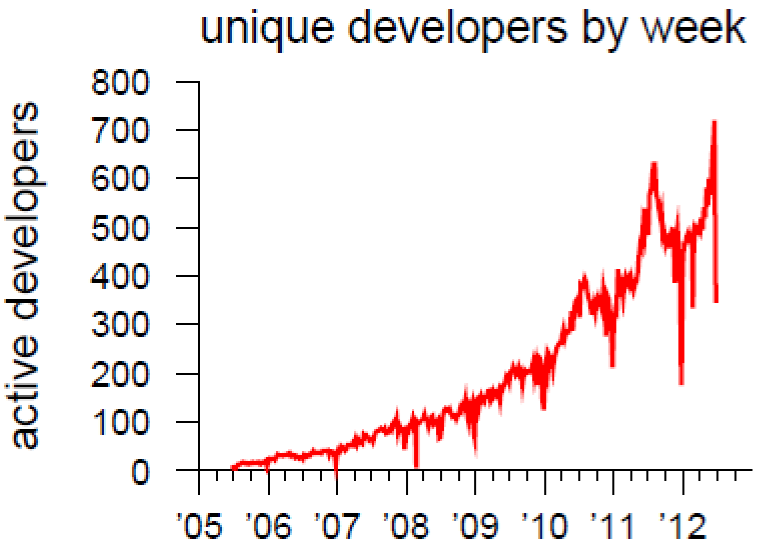
waterfall or unified process	evolutionary development	agile development	Facebook
once	months	weeks	one day

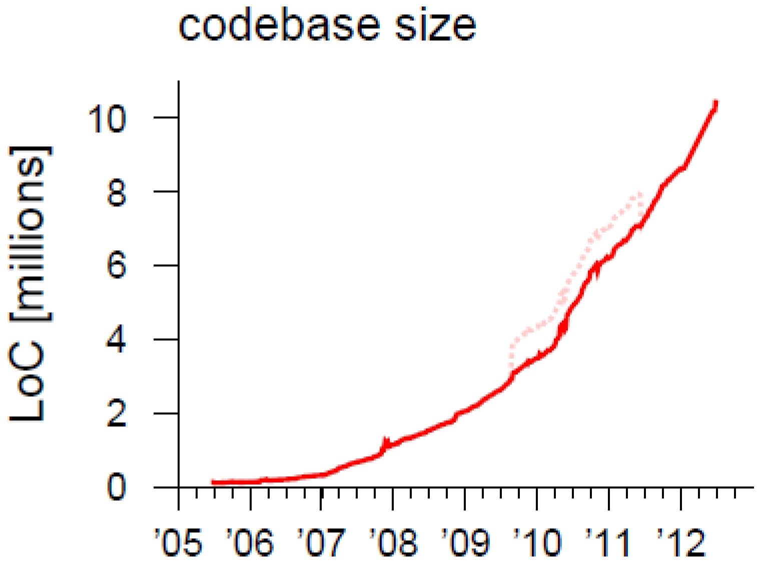
Why Continuous Deployment?

- Frequent deployment imply that each deployment introduces only a limited amount of new code
  - Reduces the risk that something will go wrong
  - Easily identify the source of and solution to problems while they are fresh in engineers minds
- All commits are individually tested for regression
- Deploying code quickly in small increments and without fear enables rapid innovation

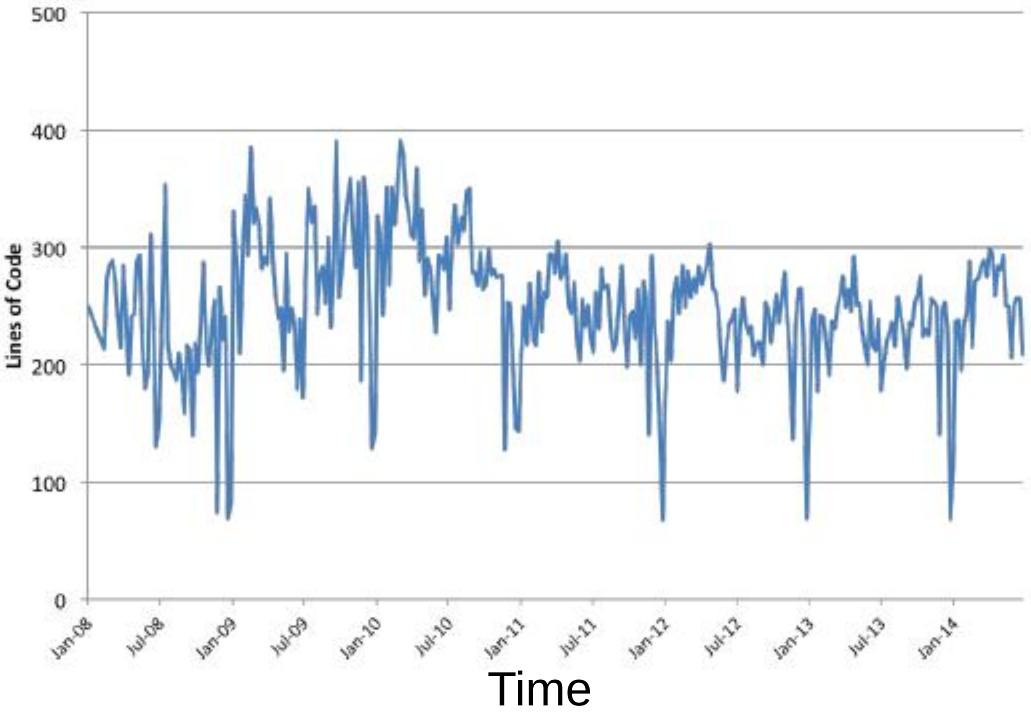
Web Frontend: 10.5 MillionsLOC (MLOC)

- 8.5 MLOC PHP + Python





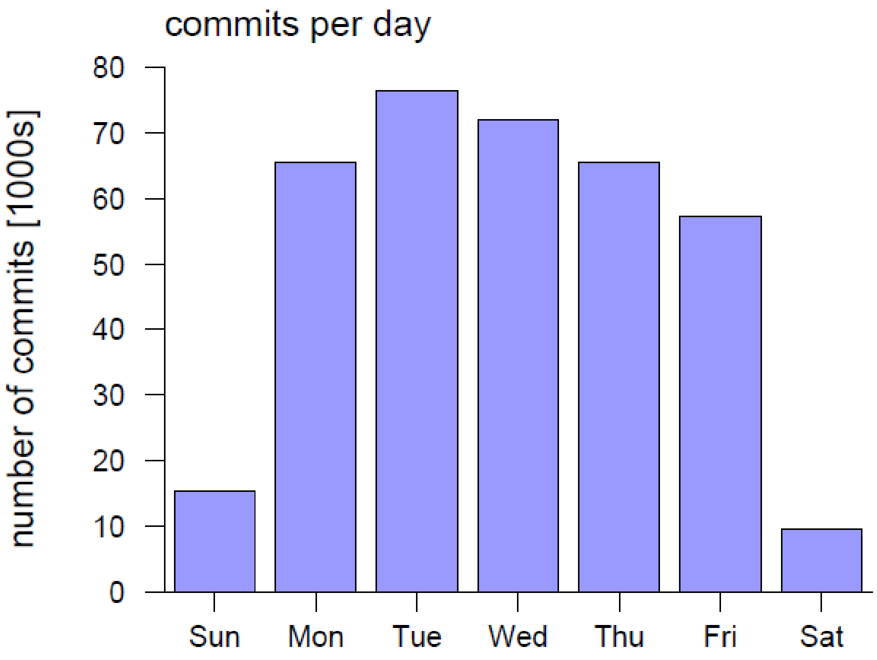
Developer Productivity

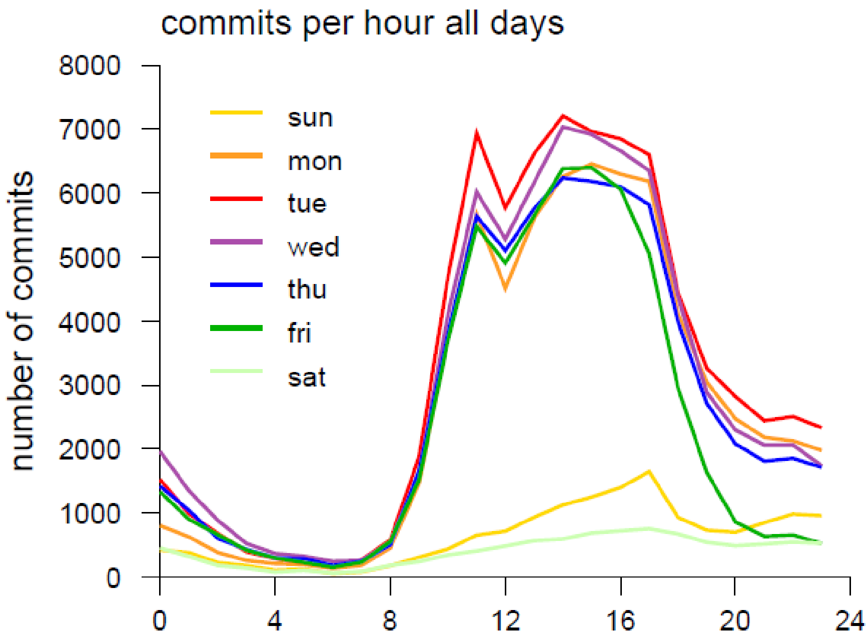


Codebase increased 50x

- Each developer releases 3.5 updates to production per week
  - Average: 92 LOC / update
  - Median: 33 LOC / update

Sustainable Work Practices





- Developer are free to join/switch teams

Perpetual Development

- Mindset: “system will continue to be developed indefinitely”

- Engineers are also users
  - first-hand knowledge of what the system does and what services it provides

- Live experimentation using A/B testing
  - Finding what users want, rather than trying to elicit requirements in advance and writing specifications
- In-house usability tests with user focus groups

What is the ratio of developers to testers at Facebook?

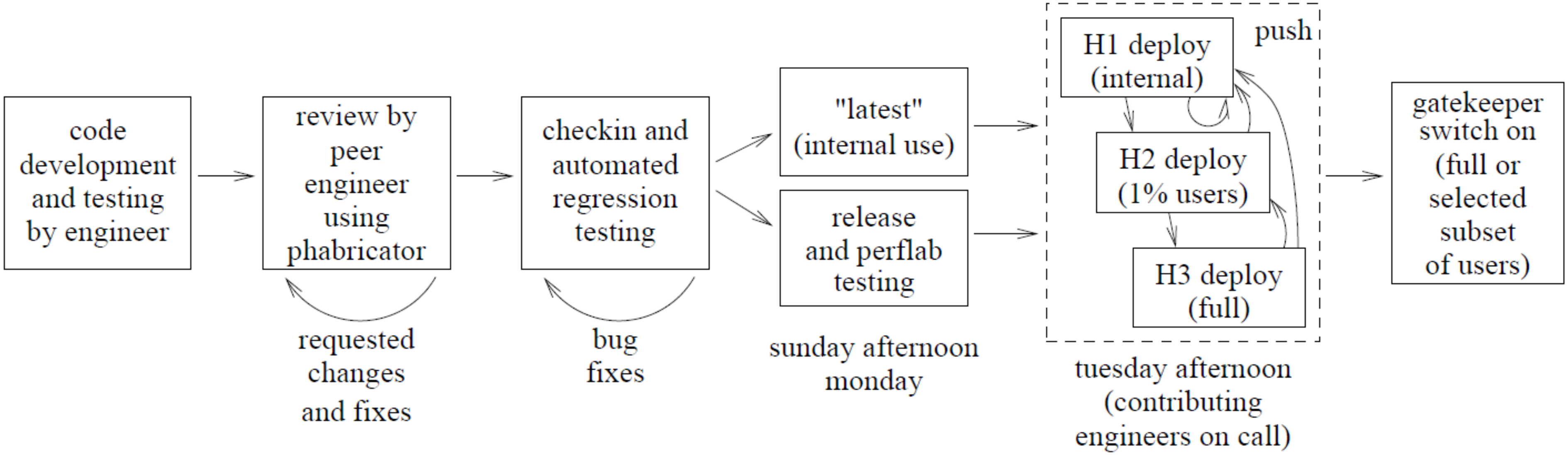
Personal Responsibility

- 1,000 development engineers responsible for
  - Writing code
  - Writing test cases
  - Fixing bugs for their code discovered during regression testing or after deployment

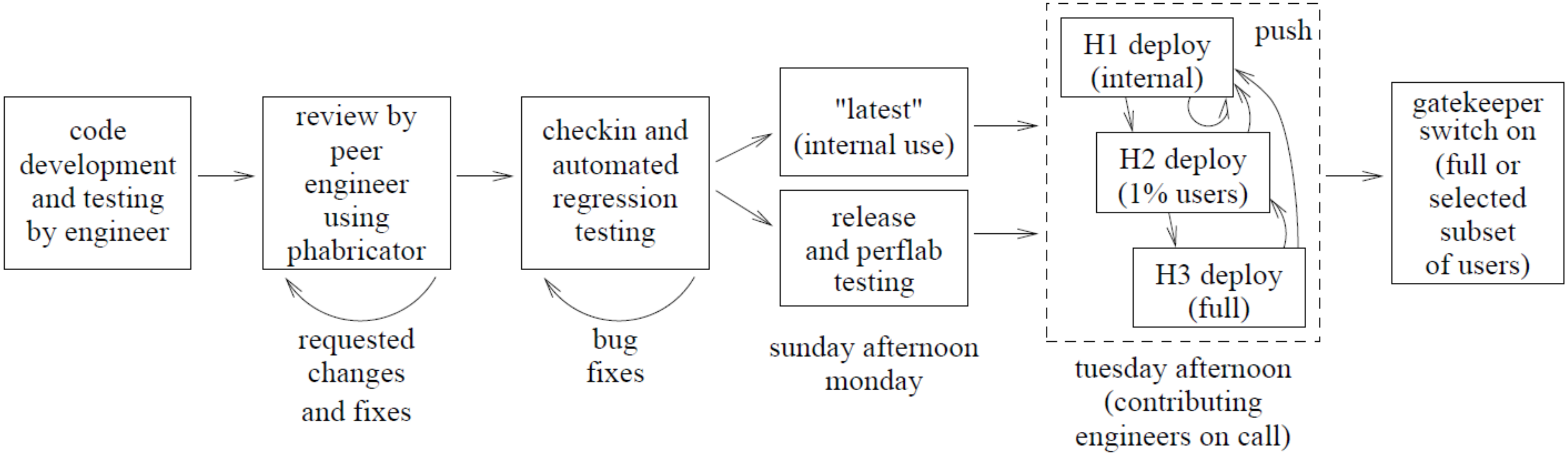
- 3 release engineers

- No separate QA/Testing team

Facebook’s Deployment Pipeline

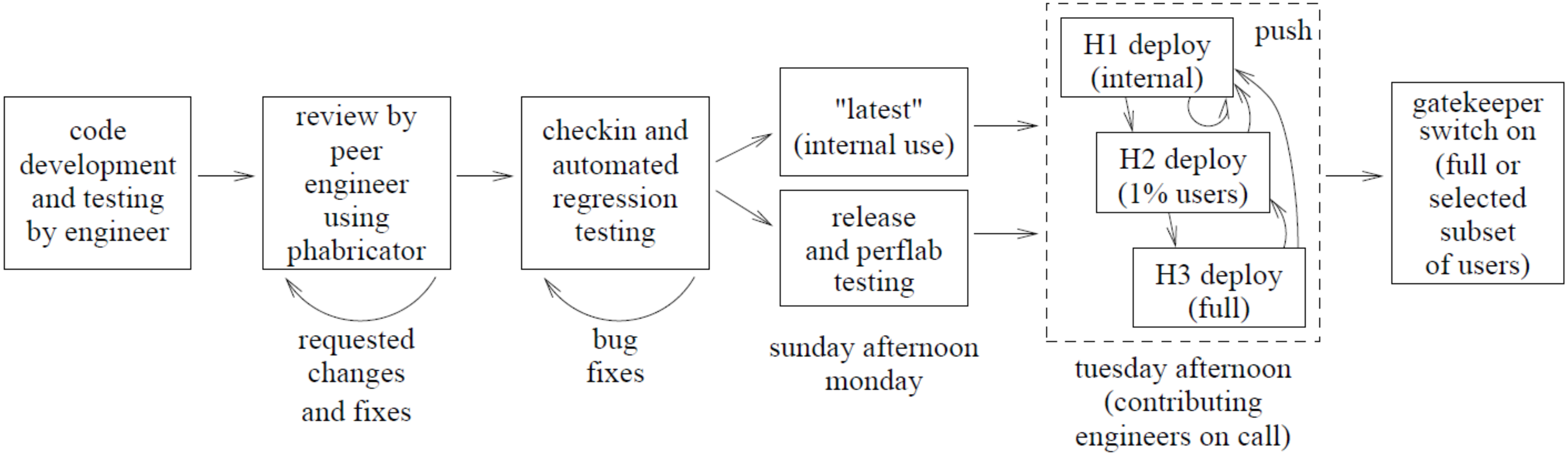

code development and testing by engineer
review by peer engineer using phabricator
requested changes and fixes
checkin and automated regression testing
bug fixes
"latest" (internal use)
release and perflab testing
sunday afternoon monday
push
H1 deploy (internal)
H2 deploy (1% users)
H3 deploy (full)
tuesday afternoon (contributing engineers on call)
gatekeeper switch on (full or selected subset of users)

Facebook's Deployment Pipeline


code development and testing by engineer
review by peer engineer using phabricator
requested changes and fixes
checkin and automated regression testing
bug fixes
"latest" (internal use)
release and perflab testing
sunday afternoon monday
H1 deploy (internal)
H2 deploy (1% users)
H3 deploy (full)
push
tuesday afternoon (contributing engineers on call)
gatekeeper switch on (full or selected subset of users)

- Gatekeeper
  - Server side feature control
  - Gradually release code (specific regions, users, platforms)
  - Rollback

Facebook’s Deployment Pipeline


code development and testing by engineer
review by peer engineer using phabricator
requested changes and fixes
checkin and automated regression testing
bug fixes
"latest" (internal use)
release and perflab testing
sunday afternoon monday
push
H1 deploy (internal)
H2 deploy (1% users)
H3 deploy (full)
tuesday afternoon (contributing engineers on call)
gatekeeper switch on (full or selected subset of users)

- Gatekeeper
  - Server side feature control
  - Gradually release code (specific regions, users, platforms)
  - Rollback
- Automation
- Monitoring ⇒ Metrics

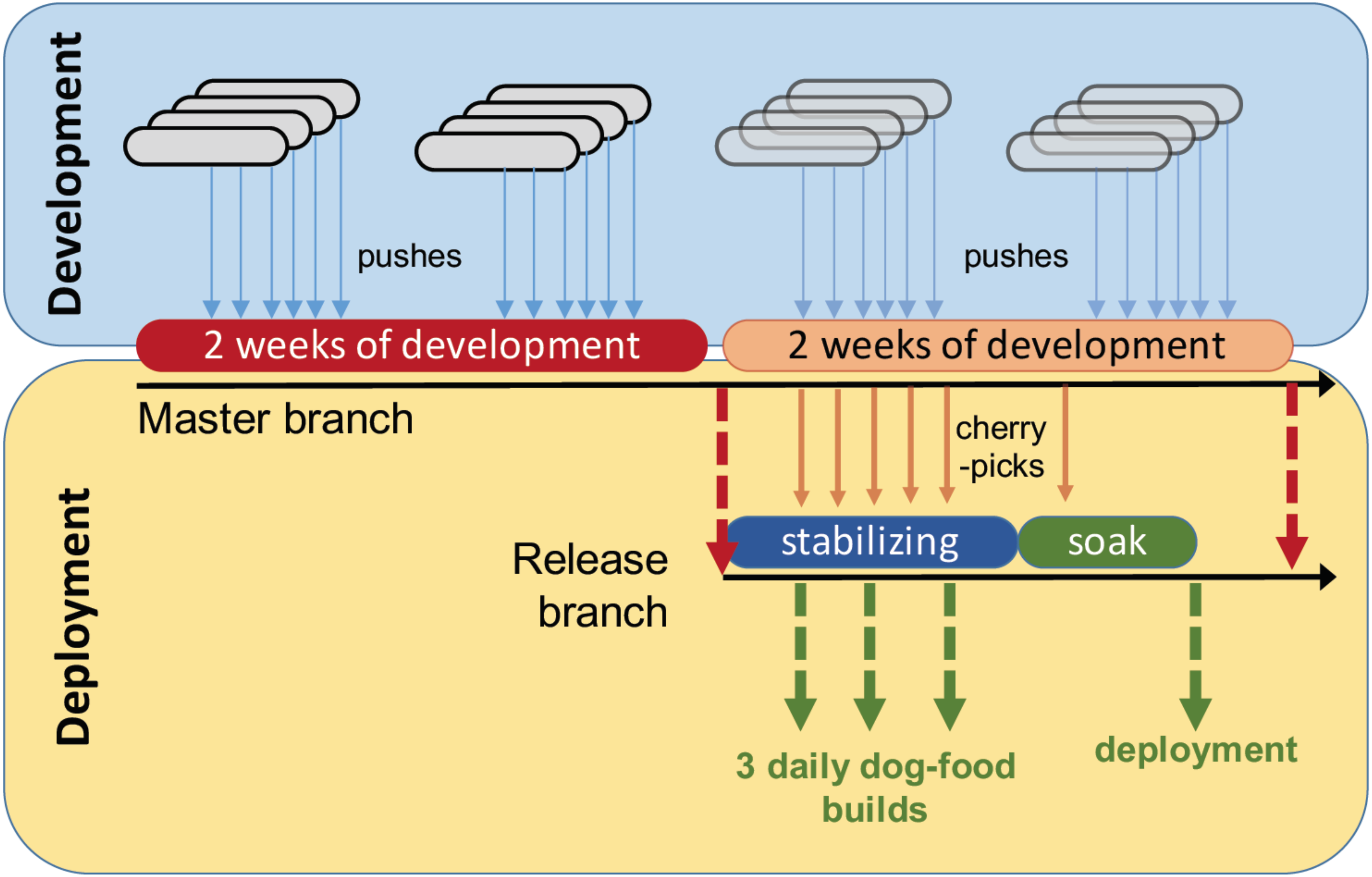
Automation

- 5% of engineers at Facebook develop in-house automation tools:
  - Testing
  - Deploying
  - Monitoring

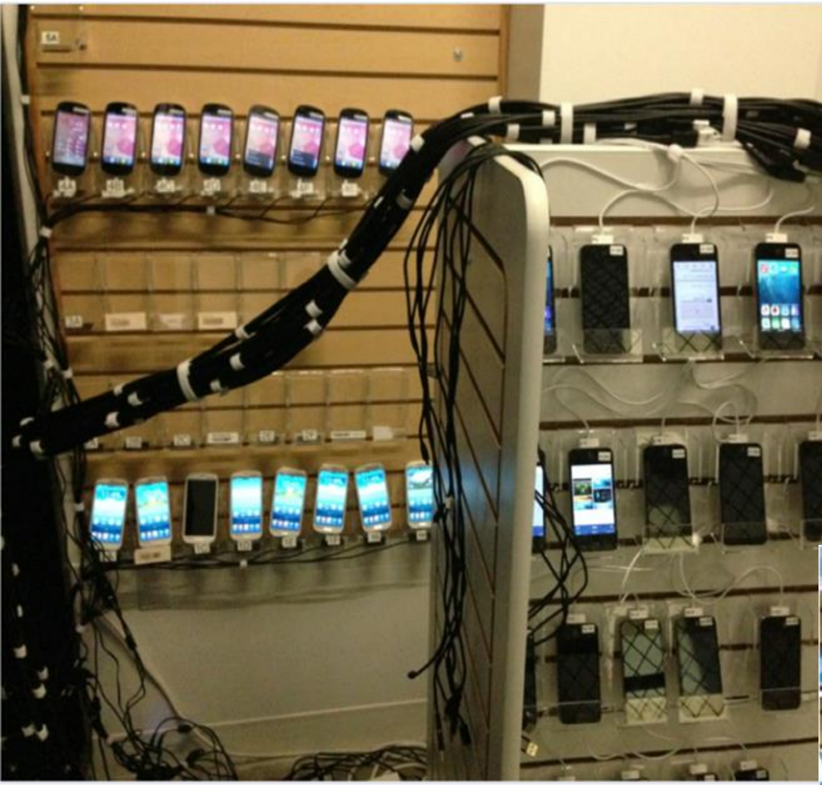
Code Base

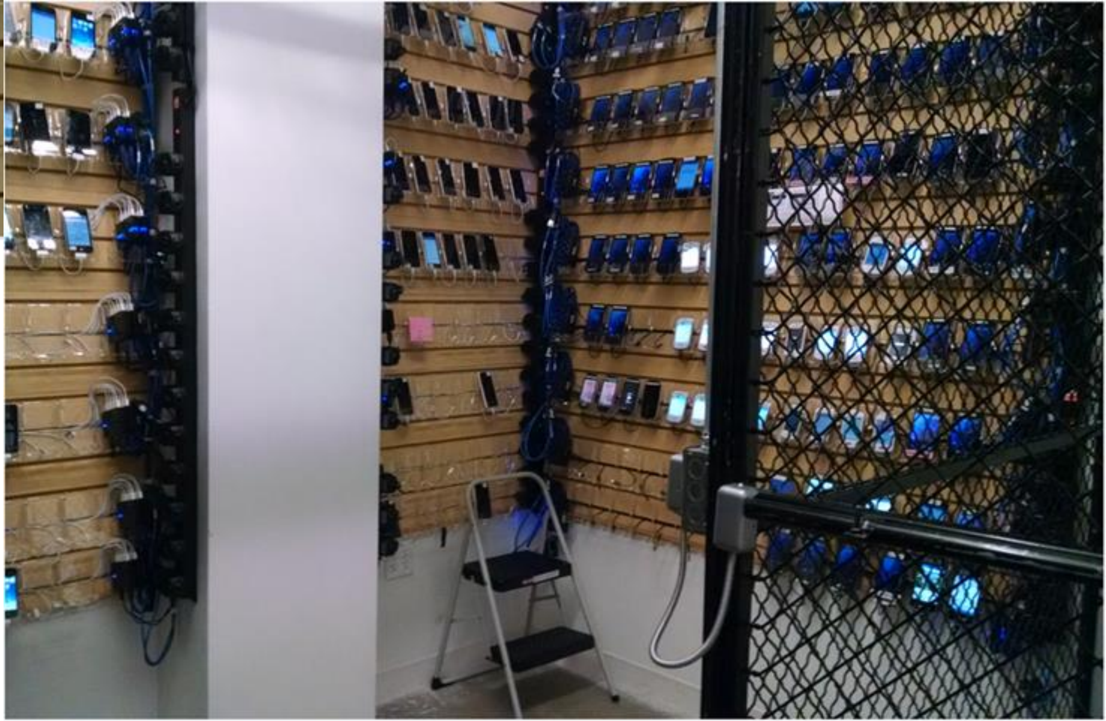
System	# of commits 2008 – 2014	LOC added/modified
Web	705K	76 Million LOC
Android	68K	10 Million LOC
iOS	146K	12 Million LOC
Backend	238K	30 Million LOC

Release cycle for Facebook iOS Mobile App



Testing on Real Hardware (2000+ phones)





- Battery consumption
- Scroll performance
- Start times

https://code.facebook.com/posts/300815046928882/the-mobile-device-lab-at-the-prineville-data-center

Bibliography (available in Piazza)

- Dror Feitelson, Eitan Frachtenberg, Kent Beck, “Development and Deployment at Facebook”, IEEE Internet Computing 17(4), 2013 https://research.fb.com/publications/development-and-deployment-at-facebook/

- Chuck Rossi, Elisa Shibley, Shi Su, Kent Beck, Tony Savor, Michael Stumm, "Continuous Deployment of Mobile Software at Facebook (Showcase)", ACM SIGSOFT: International Symposium on the Foundations of Software Engineering (FSE), 2016 https://research.fb.com/publications/continuous-deployment-of-mobile-software-at-facebook-showcase/

- Tony Savor, Mitchell Douglas, Michael Gentili, Laurie Williams, Kent Beck, Michael Stumm, "Continuous Deployment at Facebook and OANDA", 38th IEEE International Conference on Software Engineering (ICSE), 2016 https://research.fb.com/publications/continuous-deployment-at-facebook-and-oanda/

Fun Facts about Google

- How many repositories does Google have?

- How many LOC are in those repositories?

Fun Facts about Google

(data was "a few months old" when it was presented during the FSE'16 conference in November'16)

- Monolithic repository
  - 2 billion LOC
  - 1 billion files
  - 9 million unique source files
  - most development at head, very few branches

- Lots of commits
  - 35 million commits
  - 40K commits per workday
  - 24K commits by automated systems each day

Fun Facts about Google

(data was "a few months old" when it was presented during the FSE'16 conference in November'16)

- No binaries in repository ⇒ compile everything from sources
- Identical work environments for each developer
- Code ⇒ Build ⇒ Test ⇒ Analyze ⇒ Review ⇒ Release ⇒ Monitor

Bibliography

- Conference presentation of the following showcase:

Caitlin Sadowski, "Developer workflow at Google (showcase)", ACM SIGSOFT: International Symposium on the Foundations of Software Engineering (FSE), 2016, https://dl.acm.org/citation.cfm?id=2994156

Building high quality software is a marathon…

…not a hackathon

“Hacking”

“Hacking”

⇓

“Hacking”

⇓

⇒

Final Exam

- **Open-note, take-home exam via Blackboard**

- Format is very similar to previous midterms

- The exam is **time limited** (~ 2 hours)

- Assigned ~ Friday (April 27)
- Due next Friday (May 4)

Final Exam

- Material covered in the final:
  - All the lecture materials and class discussions from the beginning of the semester

- Resources:
  - Have a calculator ready
  - CS471_S18_Sprint2_TemplateQualityPlanAndDefectRemovalModel.xlsx
    - For computing defect removal

Final Exam

- Only provide answers you are confident are correct

- Submitting incorrect answers will result in deducted points

Final Exam

- Only provide answers you are confident are correct
- Submitting incorrect answers will result in deducted points

Answer	Partial Credit
Correct answer 1	33%
Correct answer 2	33%
Correct answer 3	33%
Incorrect answer 4	-50%
Incorrect answer 5	-50%

Availability

- https://bdit.youcanbook.me/

- All assignments/exams will be graded by Monday, May 7

- Grades submitted to registrar Tuesday, May 8