CS 4530 Software Engineering

Module 13: Continuous Development Processes

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Learning objectives for this lesson

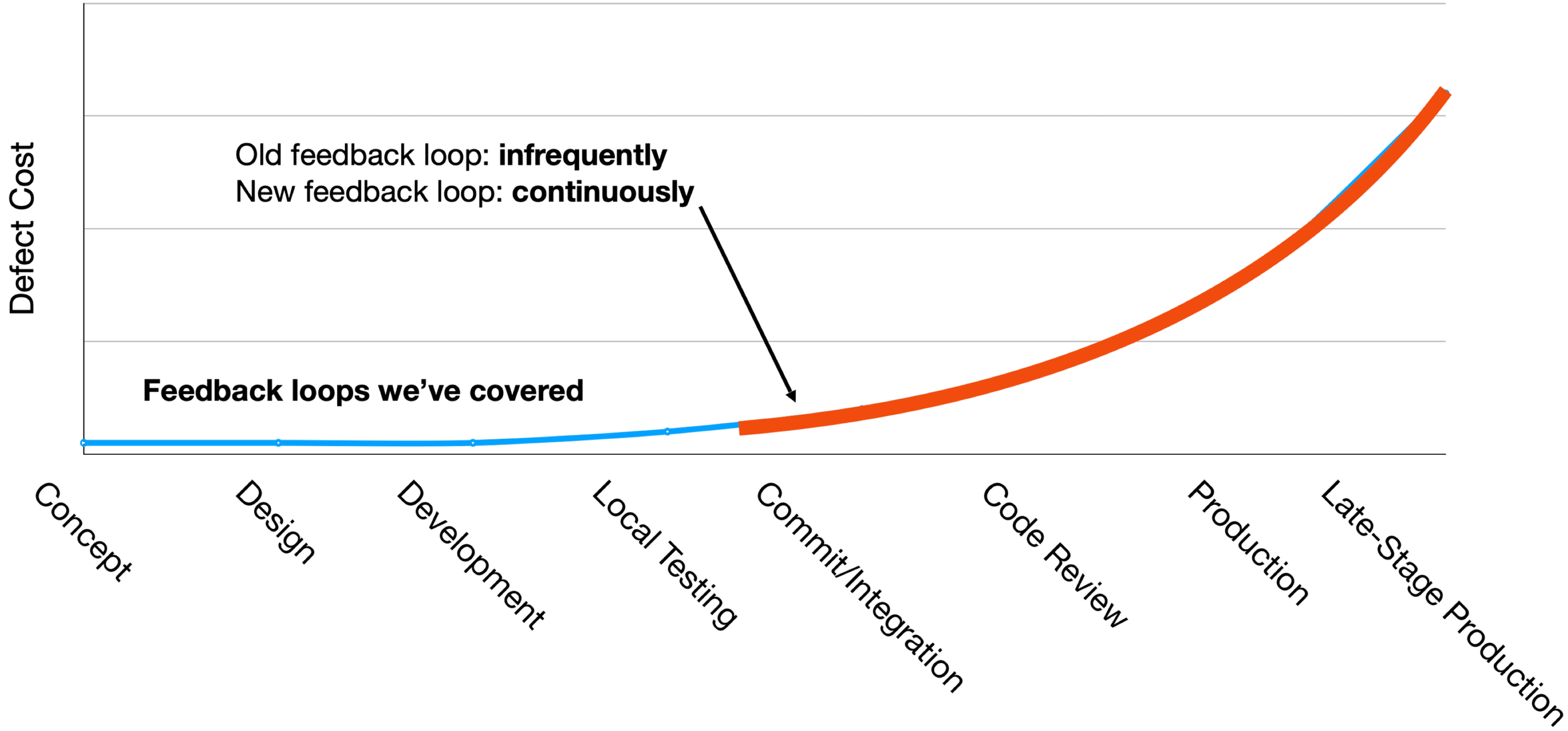
- By the end of this lesson, you should be able to…
  - Describe how continuous development helps to catch errors sooner in the software lifecycle
  - Describe strategies for performing quality-assurance on software as and after it is delivered
  - Compare and contrast continuous delivery with test driven development as a quality assurance strategy

Review: The Agile Model Reduces Risk by Embracing Change (~2000)

- The Waterfall philosophy:
  - "The project is too large and complex, and it will take months (or years!) to plan, so once we come up with the plan, that plan can not change"
  - Reduce risk by proceeding in stages
- The Agile philosophy:
  - The project is too large and complex, it is unlikely that we will know exactly what we need right now, and to some extent, we are inventing something new. We think that as we make it, we will figure it out as we go”
  - Reduce risk by limiting time on any one stage; then reassess. (“time-boxing”)
  - Reduce risk through automated testing

Agile values fast quality feedback loops

Faster feedback = lower cost to fix bugs



Agile requires a quality assurance process

- Multiple processes have to work together to ensure quality:
  - unit testing/TDD
  - mix of unit tests & integration tests (we'll see more of this)
  - code review
  - continuous integration (also: watch for canaries
  - continuous deployment (A/B, canaries, etc.)
  - quality includes non-functional requirements (resource consumption, response time) or generally speaking extensibility, maintainability, etc.
- Quality is everyone’s responsibility

Example: Some bugs slip through testing, even in highly-regulated industries

Aviation

After Alaska Airlines planes bump runway while taking off from Seattle, a scramble to ‘pull the plug’

By Dominic Gates, The Seattle Times
Updated: February 20, 2023
Published: February 20, 2023

“That morning, a software bug in an update to the DynamicSource tool caused it to provide seriously undervalued weights for the airplanes.

The Alaska 737 captain said the data was on the order of 20,000 to 30,000 pounds light. With the total weight of those jets at 150,000 to 170,000 pounds, the error was enough to skew the engine thrust and speed settings.

Both planes headed down the runway with less power and at lower speed than they should have. And with the jets judged lighter than they actually were, the pilots rotated too early

Both the Max 9 and 737-900ER have long passenger cabins, which makes them more vulnerable to a tail strike when the nose comes up too soon.” …

Photo: saiters_photography (IG, different plane/airpot)

… “A quick interim fix proved easy: When operations staff turned off the automatic uplink of the data to the aircraft and switched to manual requests “we didn’t have the bug anymore.”

Peyton said his team also checked the integrity of the calculation itself before lifting the stoppage. All that was accomplished in 20 minutes.

The software code was permanently repaired about five hours later.

Peyton added that even though the update to the DynamicSource software had been tested over an extended period, the bug was missed because it only presented when many aircraft at the same time were using the system.

Subsequently, a test of the software under high demand was developed.”

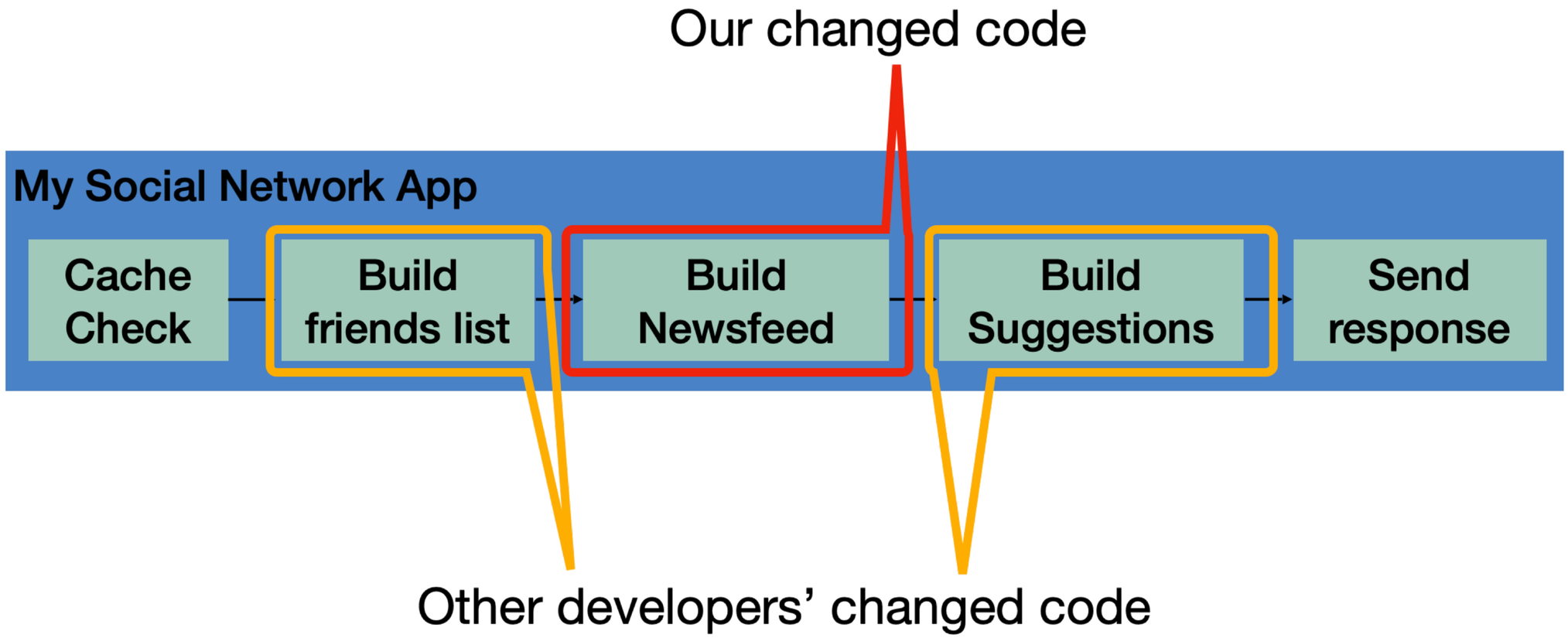
https://www.adn.com/alaska-news/aviation/2023/02/20/after-alaska-airlines-planes-bump-runway-a-scramble-to-pull-the-plug/

Continuous development practices improve code quality and dev velocity

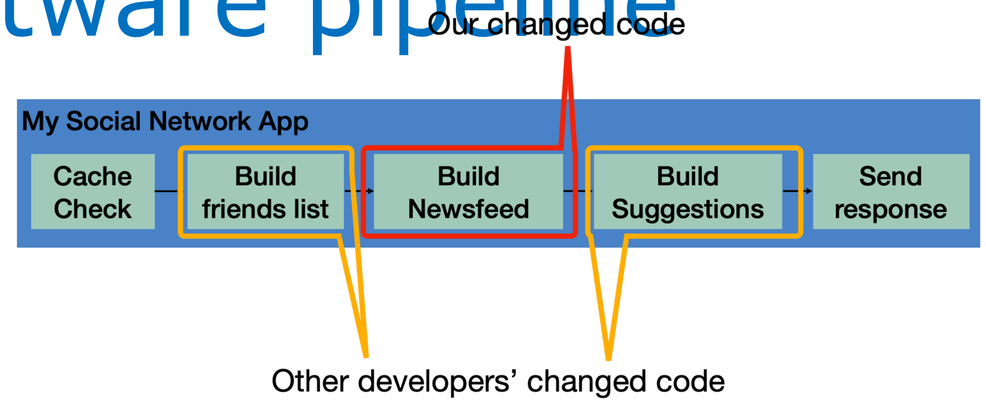
- Continuous integration: Perform frequent integrations with entire codebase, running integration-scale tests
- Continuous delivery: Deploy frequently and monitor

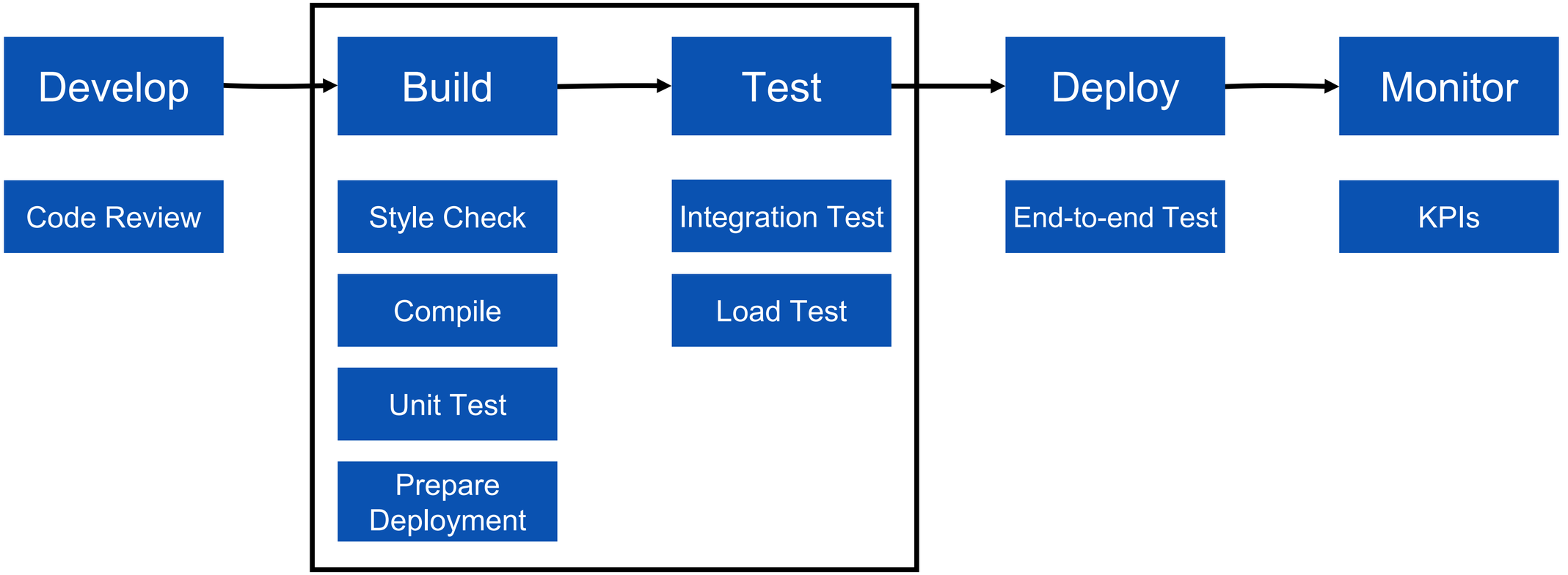
Continuous Integration (CI) provides global feedback on local changes

- Given: Our systems involve many components, some of which might even be in different version control repositories
- Consider: How does a developer get feedback on their (local) change?



A CI process is a software pipeline

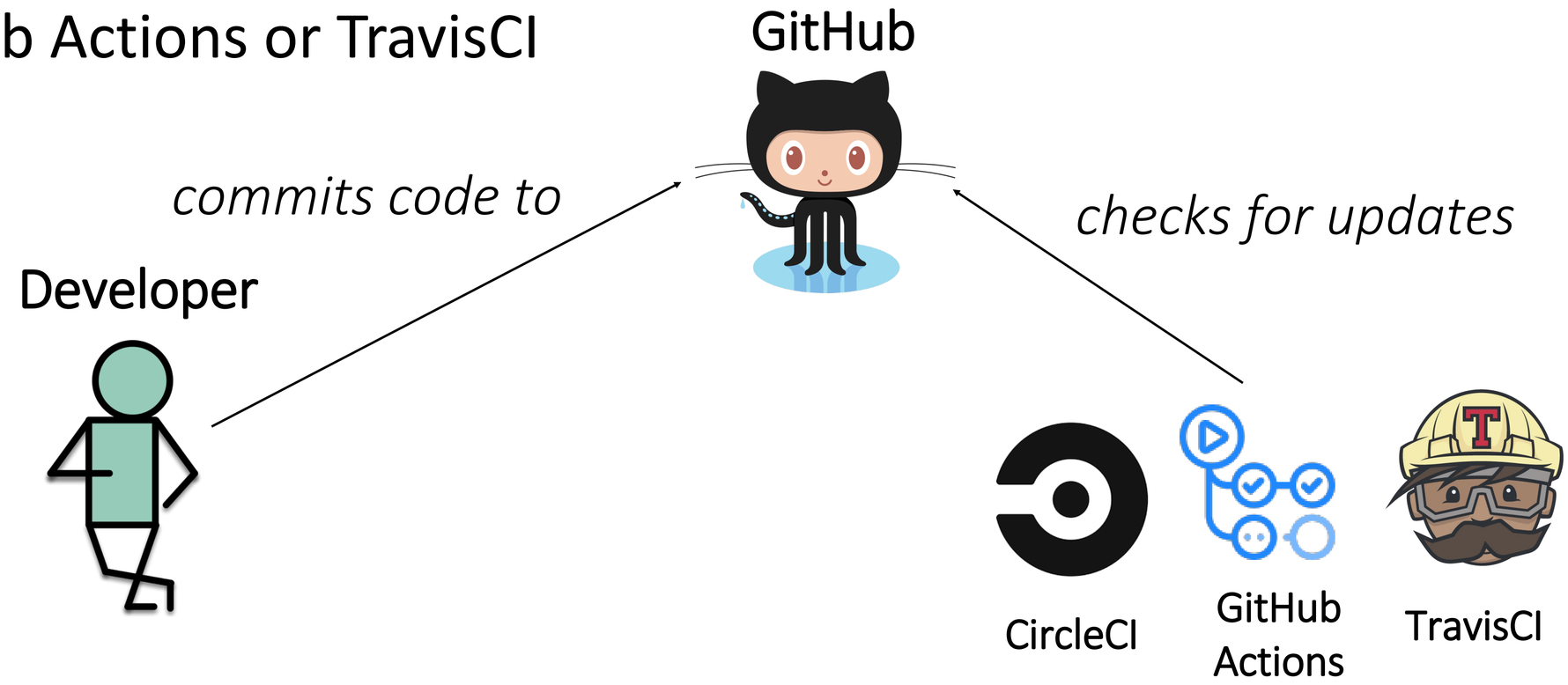




Automate this centrally, provide a central record of results

CI is triggered by commits, pull requests, and other actions

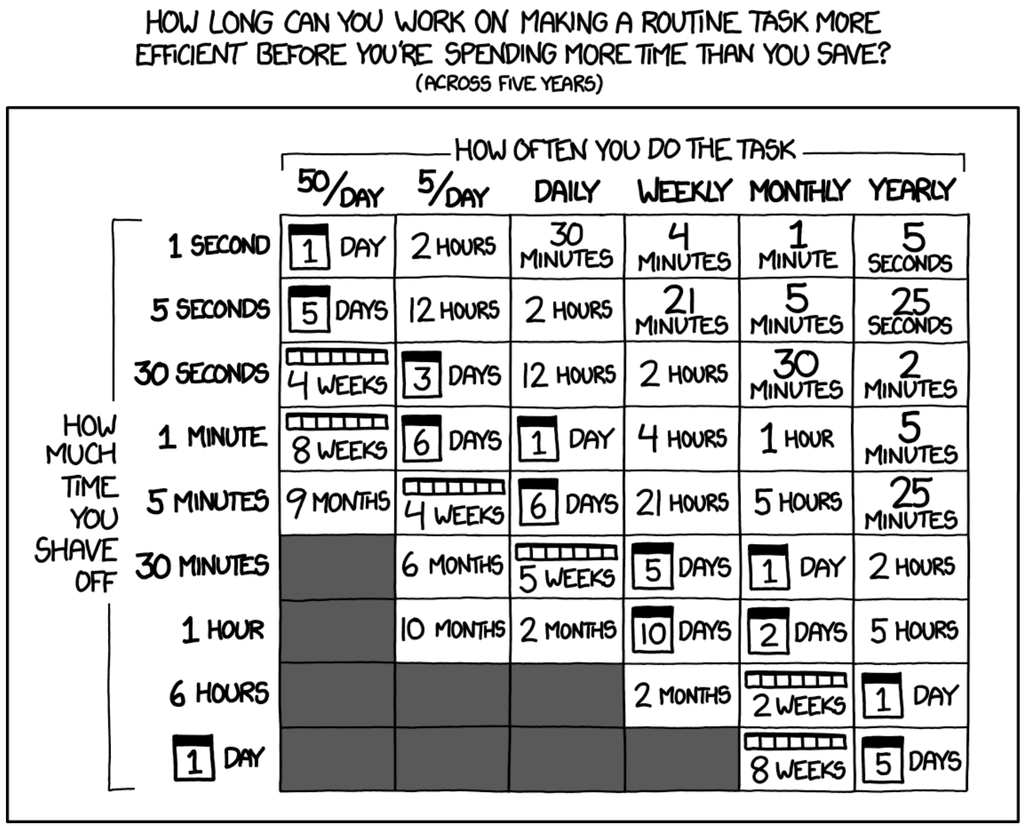
Example: Small scale CI, with a service like CircleCI, GitHub Actions or TravisCI



Runs build for each commit

Automating Feedback Loops is Powerful

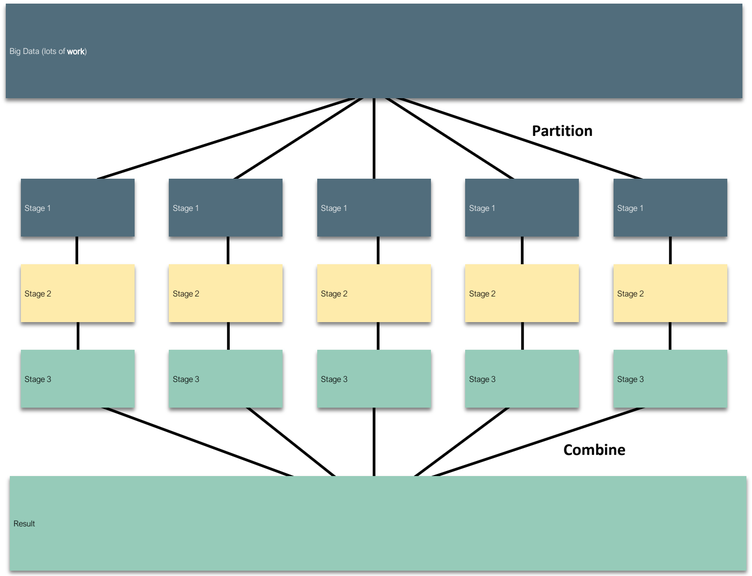
Consider tasks that are done by *dozens* of developers (e.g. testing/deployment)



https://xkcd.com/1205/

Typical CI pipeline

- Set up testing environment
- Set up tests
- Set up multiple input
- Run all tests against all inputs
  - (preferably in parallel)
- Record results and performance in central db

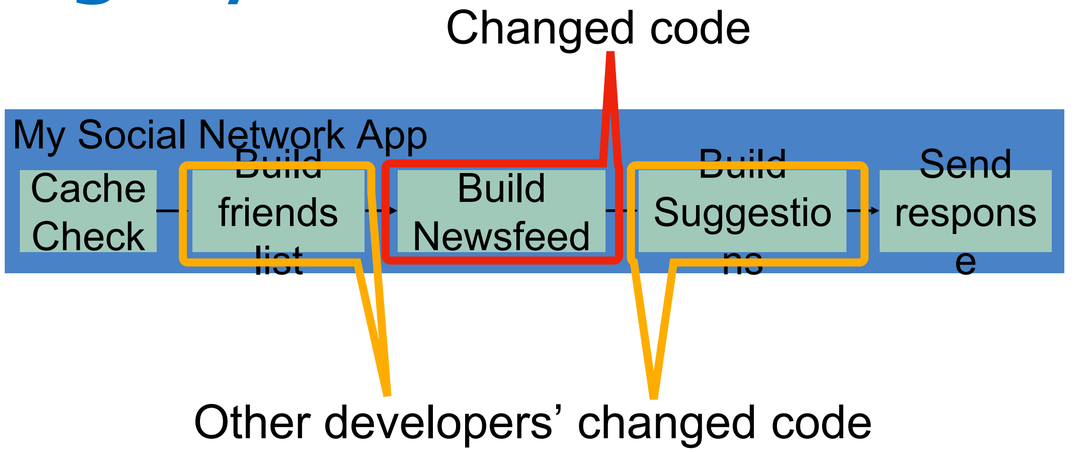


You could set up multiple CI processes

- Run a short test daily
  - or oftener
  - maybe on every commit?
- More comprehensive test less often
  - provides more accurate performance data
- Either way, you know that your integration is working!

Continuous Integration is Highly Configurable

- Determining *how* to apply CI can be non-trivial for a larger project, all with a cost vs quality tradeoff: what is the cost of automation vs the value of developer time?
- Do we integrate changes immediately, or do a pre-commit test?
- Which tests do we run when we integrate?
- When do we integrate code review?
- How do we compose the system under test at each point?

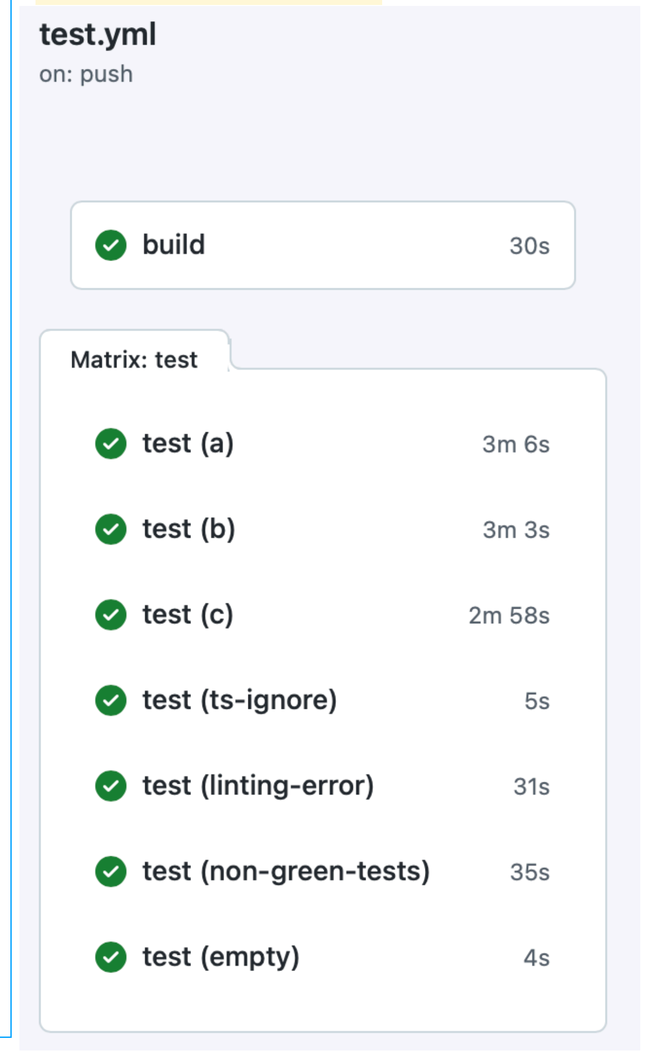


CI In Practice: Autograder

test.yml (CI workflow file)

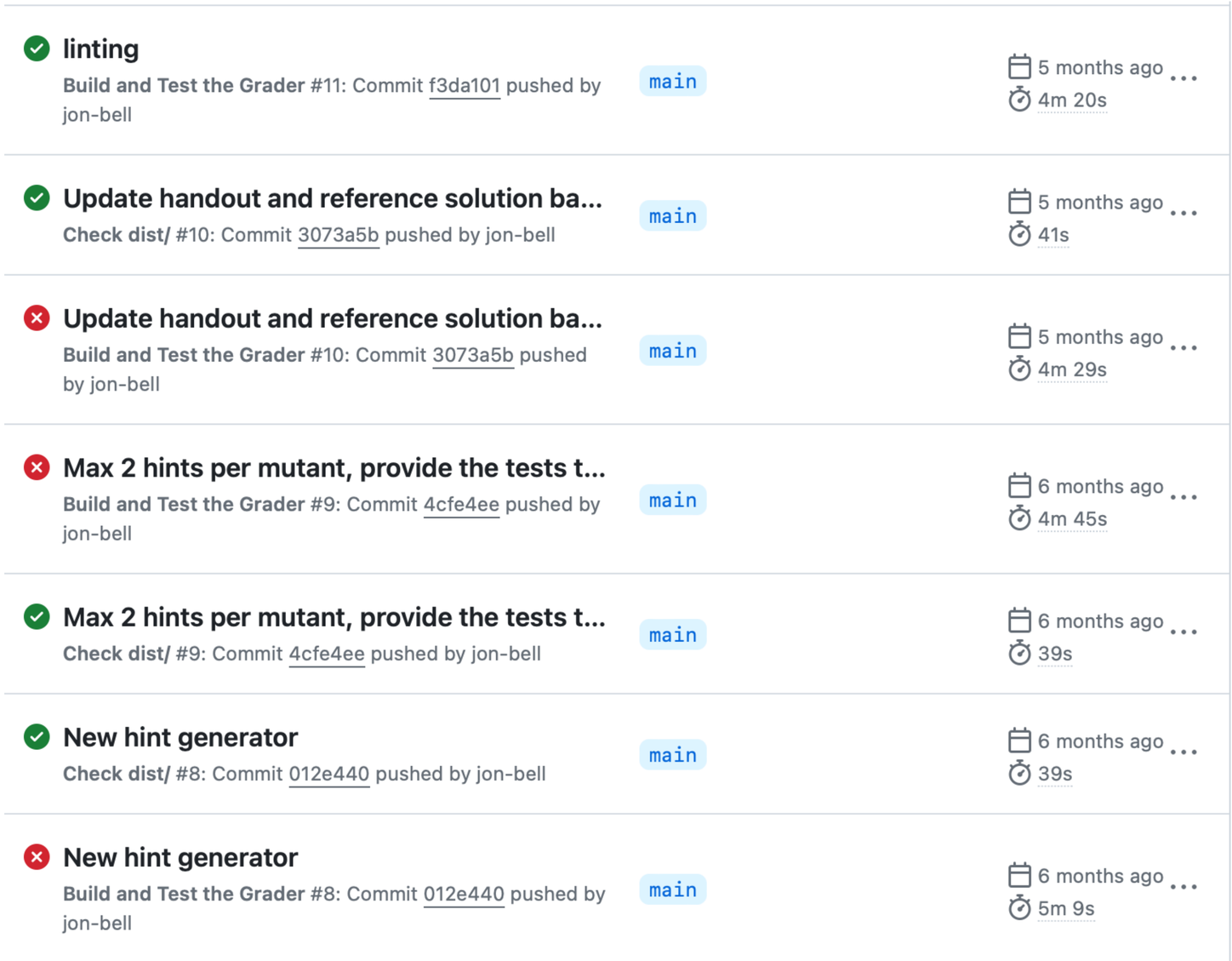
```yaml
name: 'Build and Test the Grader'
on: # rebuild any PRs and main branch changes
  pull_request:
  push:
    branches:
      - main
      - 'releases/*'
jobs:
  build:
    runs-on: self-hosted
    steps:
      - uses: actions/checkout@v2
      - uses: actions/setup-node@v2
        with:
          node-version: '16'
      - run: |
          npm install
  test:
    runs-on: self-hosted
    strategy:
      matrix:
        submission: [a, b, c, ts-ignore, linting-error, non-green-tests, empty]
    steps:
      - uses: actions/checkout@v2
      - uses: actions/setup-node@v2
        with:
          node-version: '16'
      - uses: ./
        with:
          submission-directory: solutions/${{ matrix.submission }}
```

GitHub Actions Results



Example CI Pipeline - Autograder

At a glance, see history of build

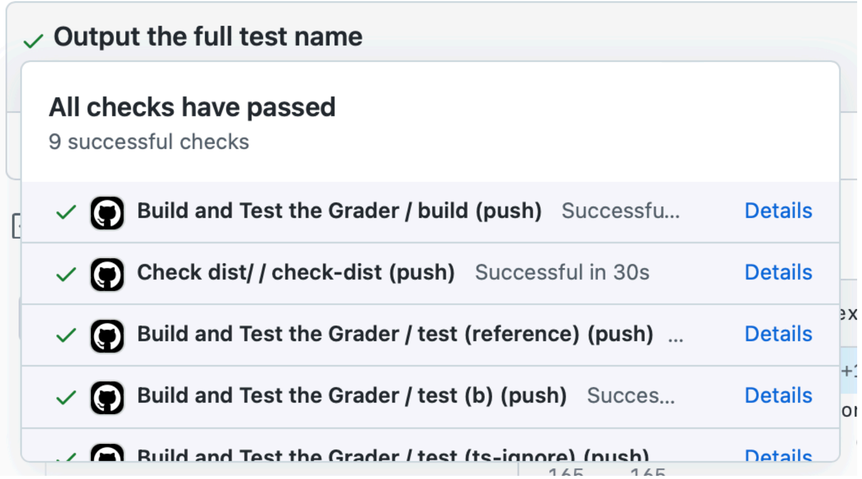


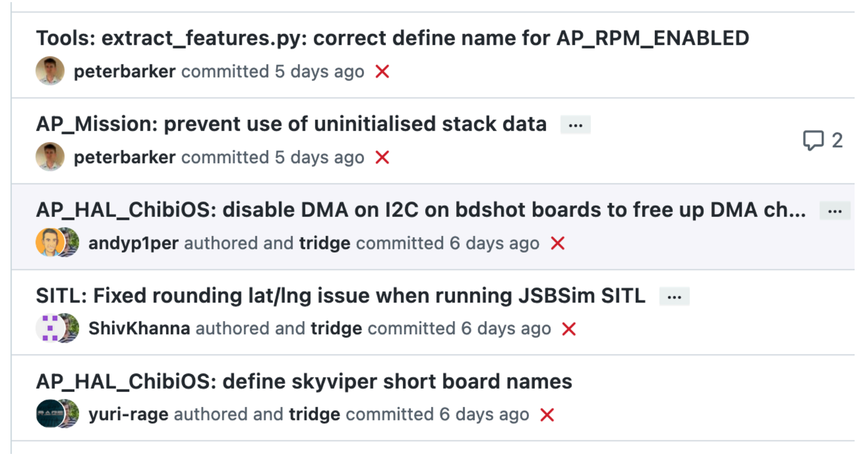
Attributes and challenges for designing an effective CI process

- Attributes of effective CI processes
- Challenges for effective CI processes

Attributes of effective CI processes

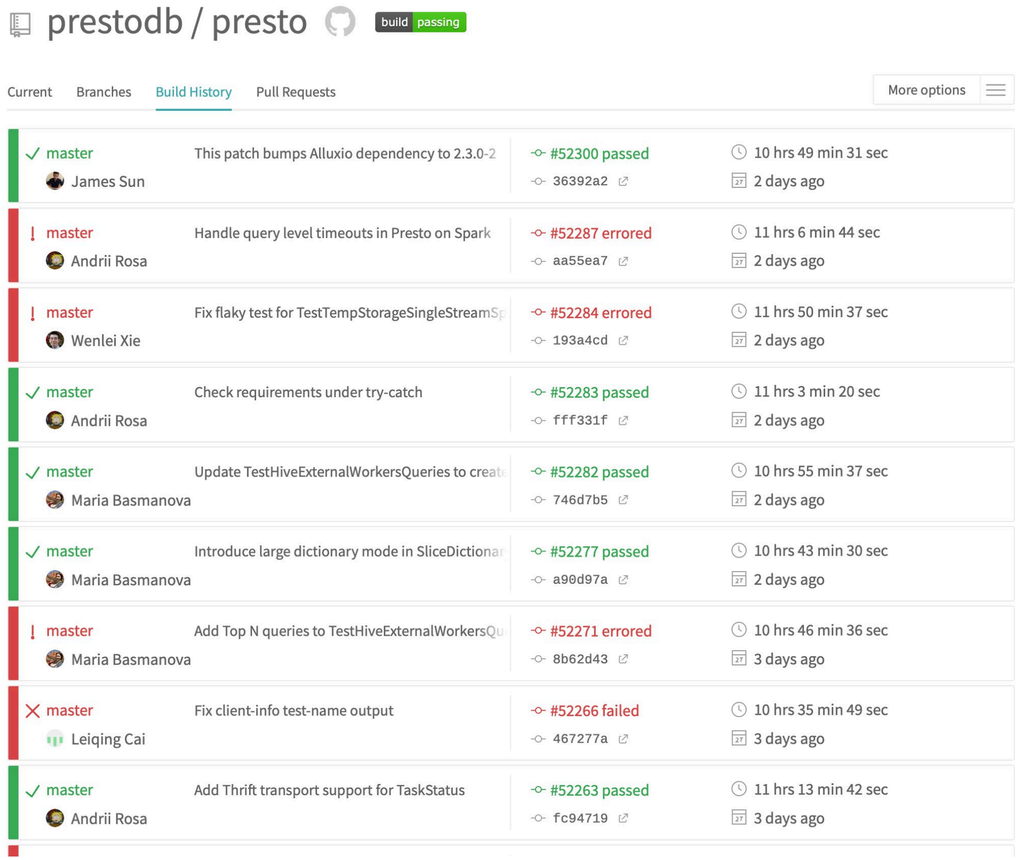
- Policies:
  - Do not allow builds to remain broken for a long time
  - CI should run for every change
  - CI should not completely replace pre-commit testing
- Infrastructure:
  - CI should be fast, providing feedback within minutes or hours
  - CI should be repeatable (deterministic)





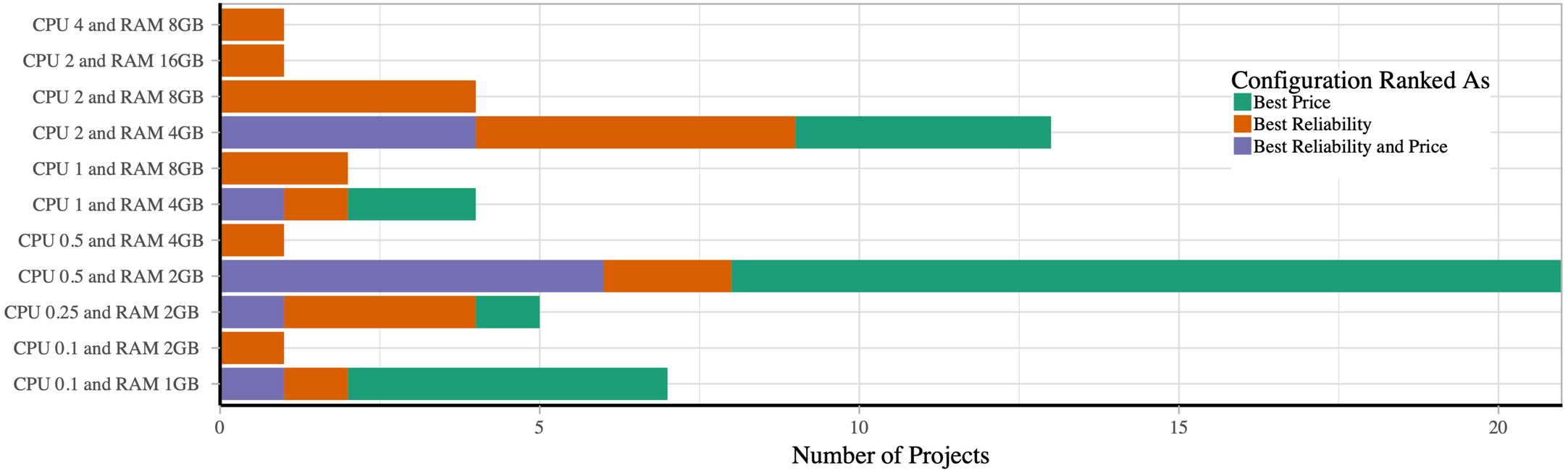
Effective CI processes are run often enough to reduce debugging effort

- Failed CI runs indicate a bug was introduced, and caught in that run
- More changes per-CI run require more manual debugging effort to assign blame
- A single change per-CI run pinpoints the culprit



Effective CI processes allocate enough resources to mitigate flaky tests

- *Flaky* tests might be dependent on timing (failing due to timeouts)
- Running tests without enough CPU/RAM can result in increased flaky failure rates and unreliable builds



"The Effects of Computational Resources on Flaky Tests", Silva et al

Build Systems Orchestrate Software Engineering Tasks

- “Orchestrate” -> Execute in the right order, ideally with concurrency, example tasks:
  - Installing dependencies
  - Compiling the code
  - Running static analysis
  - Generating documentation
  - Running tests
  - Creating artifacts for customers
  - Deploying Code
- Example build systems: xMake, ant, maven, gradle, npm…

Challenges and Solutions for Repeatable Builds

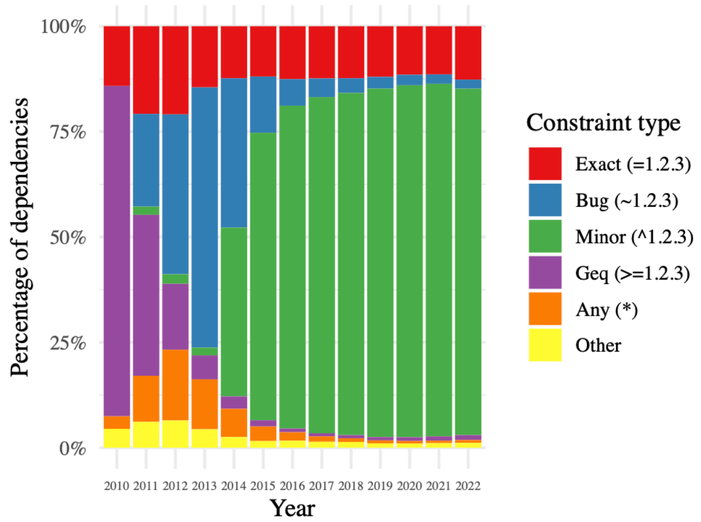
- Which commands to run to produce an executable? (build systems)
- How to link third-party libraries? (dependency managers)
- How to specify system-level software requirements? (containers)
- How to specify infrastructure requirements? (Infrastructure as code)

Dependency Managers Organize External Dependencies

- Addresses this problem: “Before you compile this code, install commons-lang from the Apache website”
- Declare a dependency using coordinates (unique ID of a package plus version)
- Packages are archived in common repositories; fetched/linked by dependency manager
- Dependency managers handle transitive dependencies 
- Examples: Maven, NPM, pip, cargo, apt

Specify and Depend on Package Versions with Care

- Semantic Versioning is often expected:
  - Library maintainers expected to indicate breaking changes with version numbers
  - Dependency consumers can specify constraints on versions (e.g. accept 2.0.x)



2.0.0 2.0.0-rc.2 2.0.0-rc.1 1.0.0 1.0.0-beta

Semantic Versioning 2.0.0

Summary

Given a version number MAJOR.MINOR.PATCH, increment the:

1. MAJOR version when you make incompatible API changes
2. MINOR version when you add functionality in a backwards compatible manner
3. PATCH version when you make backwards compatible bug fixes

Additional labels for pre-release and build metadata are available as extensions to the MAJOR.MINOR.PATCH format.

Distribution of dependencies of all packages in NPM over time (2023, Pinckney et al)

Continuous Integration Service Models

- Self-hosted/managed on-premises or in cloud
  - Jenkins
- Fully cloud managed
  - GitHub Actions, CircleCI, Travis, many more…
  - Billing model: pay per-build-minute running on SaaS infrastructure
  - “Self-hosted runners” run builds on your own infrastructure, usually “free”

Continuous Delivery

- “Faster is safer”: Key values of continuous delivery
  - Release frequently, in small batches
  - Maintain key performance indicators to evaluate the impact of updates
  - Phase roll-outs
  - Evaluate business impact of new features

Continuous Delivery is about deciding which new features to deliver, and when

- You have a large system with many engineers working on new features (and bug fixes ☺)
- When a new feature or fix is ready, how do you roll it out to your users?

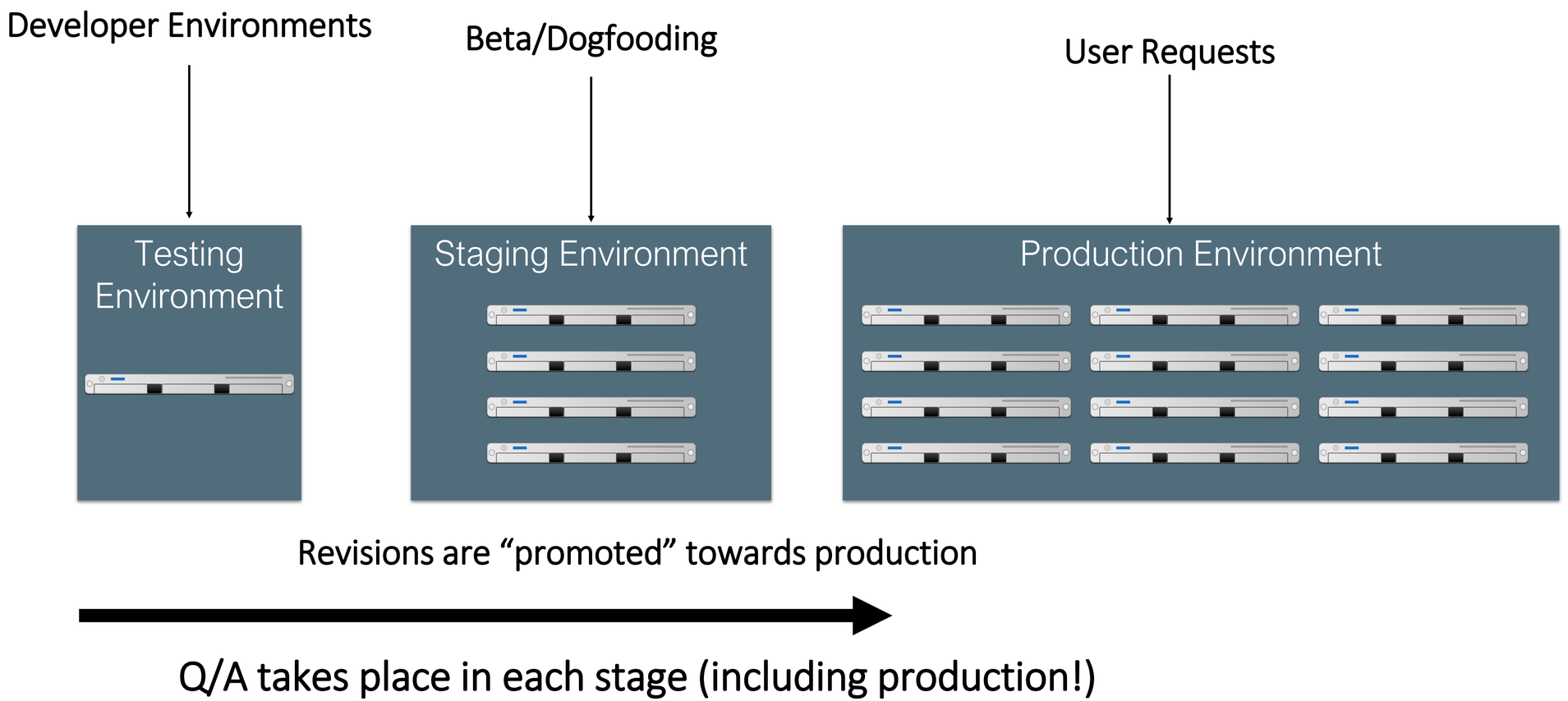
Continuous Delivery != Immediate Delivery

- Even if you are deploying every day ("continuously"), you still have some latency
- A new feature I develop today won't be released today
- But, a new feature I develop today can begin the **release pipeline** today (minimizes risk)
- **Release Engineer**: gatekeeper who decides when something is ready to go out, oversees the actual deployment process

Ways to mitigate deployment risks

- Use a realistic staging environment
- Use post-deployment monitoring
- Use split deployments
- Use tools to automate deployment tasks

Build a staging environment to qualify features for delivery

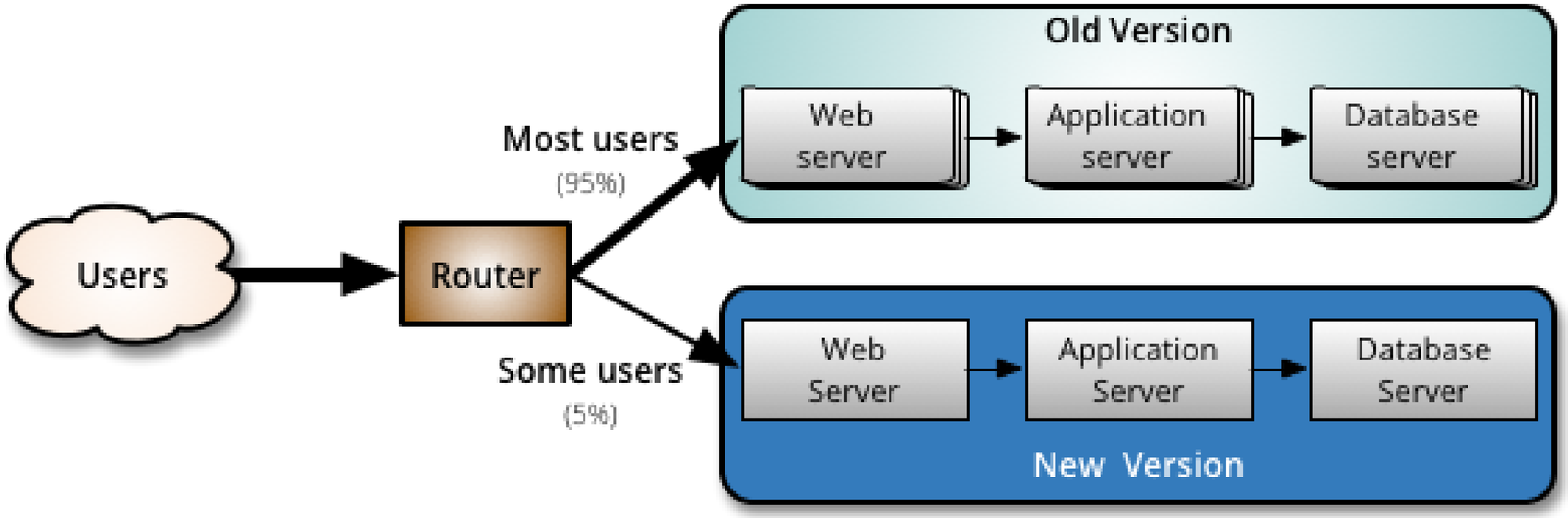


Post-delivery monitoring mitigates risk

- Consider both direct (e.g. business) metrics, and indirect (e.g. system) metrics
- Hardware
  - Voltages, temperatures, fan speeds, component health
- OS
  - Memory usage, swap usage, disk space, CPU load
- Middleware
  - Memory, thread/db connection pools, connections, response time
- Applications
  - Business transactions, conversion rate, status of 3rd party components

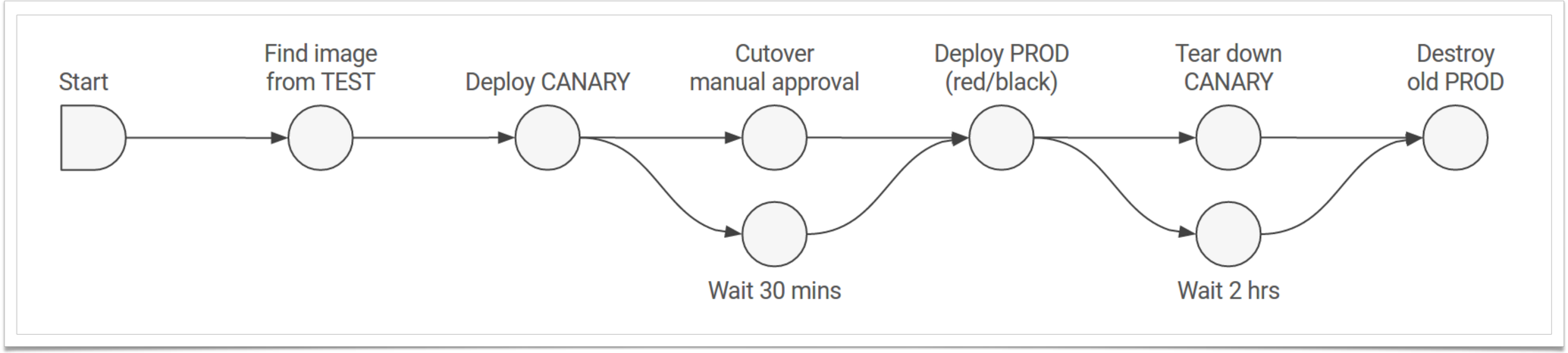
Split Deployments Mitigate Risk

- Idea: Deploy to a complete production-like environment, but don't have users use it, collect preliminary feedback
- Lower risk if a problem occurs in staging than in production
- Examples:
  - “Eat your own dogfood”
  - Beta/Alpha testers



Continuous Delivery Tools

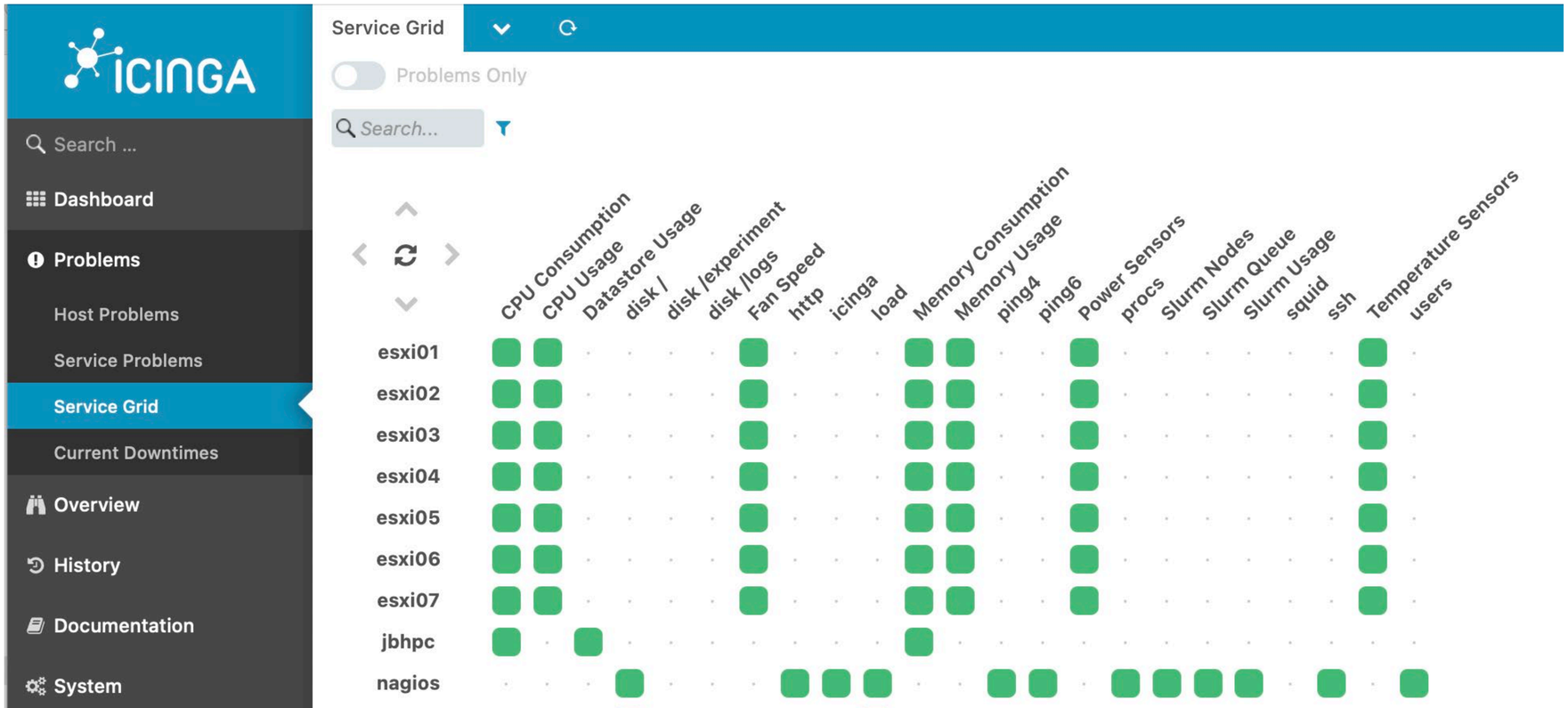
- Simplest tools deploy from a branch to a service (e.g. Render.com, Heroku)
- More complex tools:
  - Auto-deploys from version control to a staging environment + promotes through release pipeline
  - Monitors key performance indicators to automatically take corrective actions
  - Example: “Spinnaker” (Open-Sourced by Netflix, c 2015)



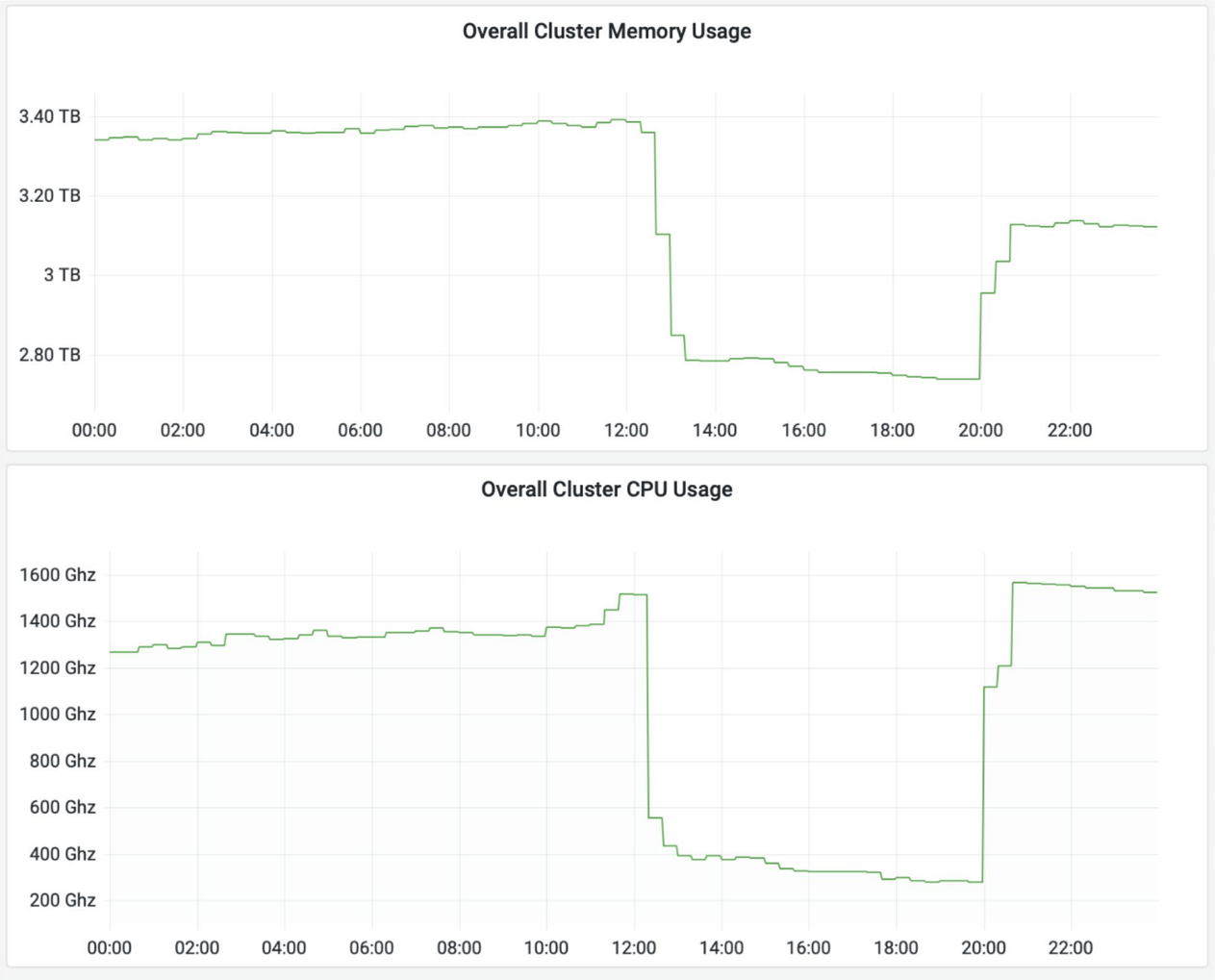
Example CD pipeline from Spinnaker’s documentation: https://spinnaker.io/docs/concepts/#application-deployment

Tools for Monitoring Deployments

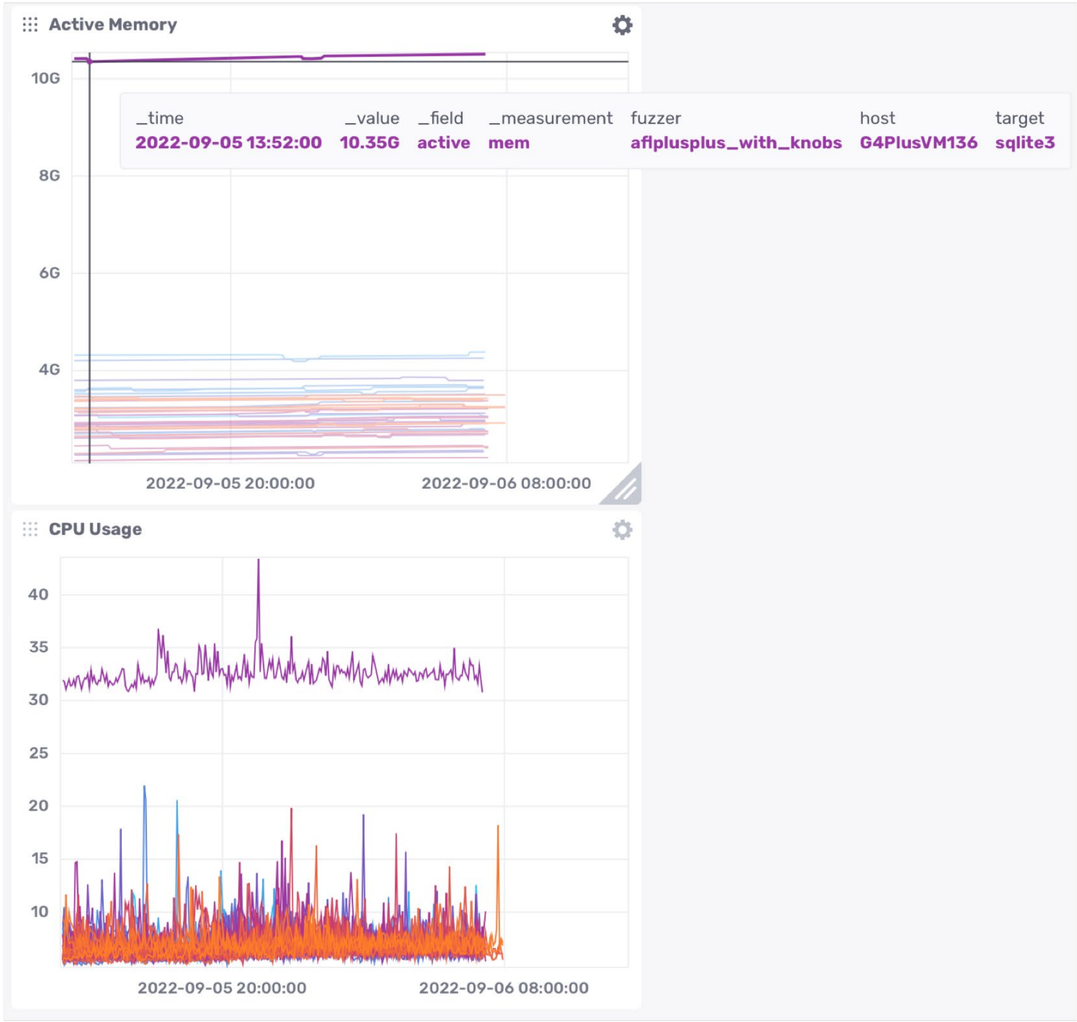
- Nagios (c 2002): Agent-based architecture (install agent on each monitored host), extensible plugins for executing “checks” on hosts
- Track system-level metrics, app-level metrics, user-level KPIs



Monitoring can help identify operational issues



Grafana (AGPL, c 2014)



InfluxDB (MIT license, c 2013)

Continuous Delivery Tools Take Automated Actions

- Example: Automated roll-back of updates at Netflix based on SPS

https://www.youtube.com/watch?v=qyzymLlj9ag

What not to do: Failed Deployment at Knight Capital

Knightmare: A DevOps Cautionary Tale

D7 DevOps April 17, 2014 6 Minutes

I was speaking at a conference last year on the topics of DevOps, Configuration as Code, and Continuous Delivery and used the following story to demonstrate the importance making deployments fully automated and repeatable as part of a DevOps/Continuous Delivery initiative. Since that conference I have been asked by several people to share the story through my blog. This story is true – this really happened. This is my telling of the story based on what I have read (I was not involved in this).

This is the story of how a company with nearly $400 million in assets went ba
minutes because of a failed deployment.

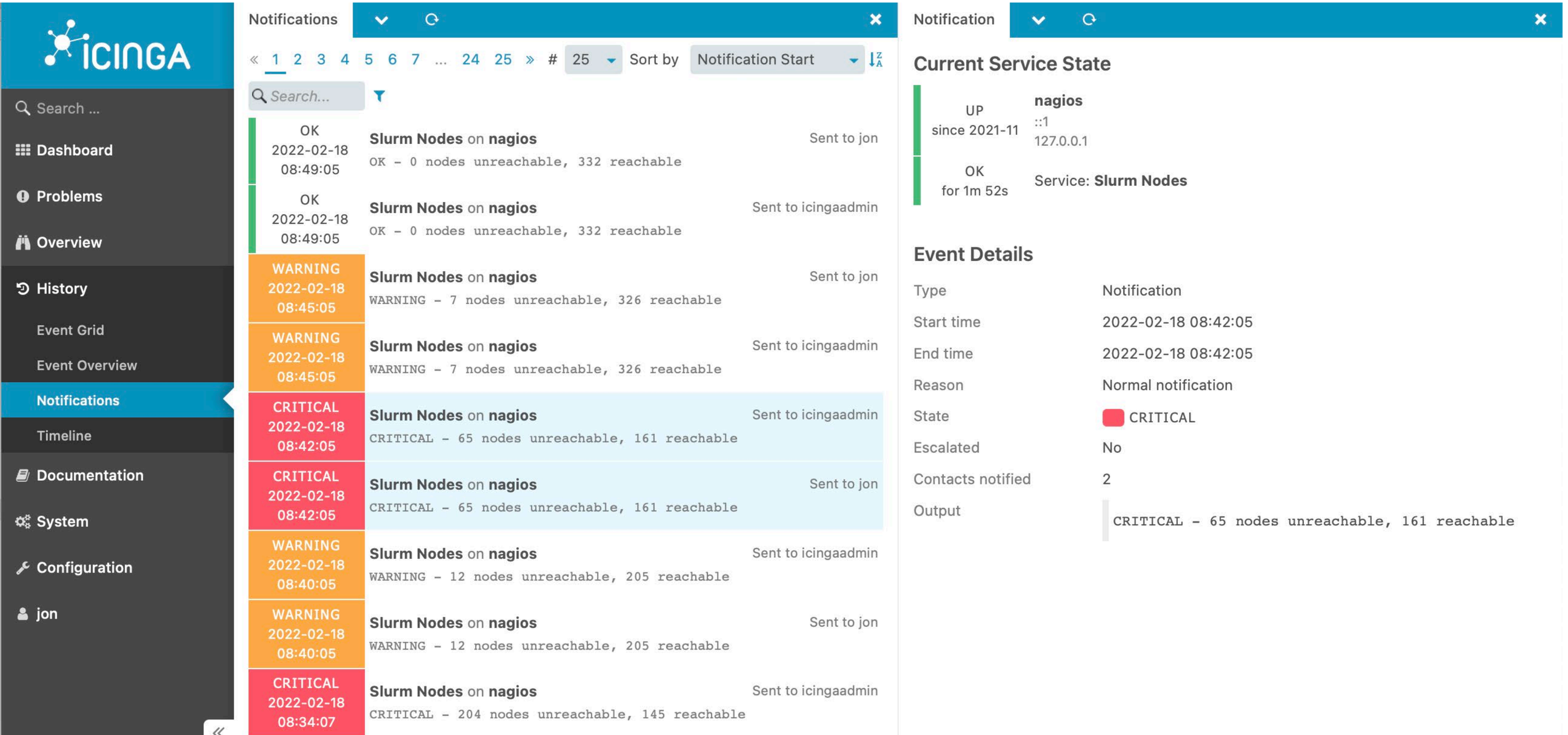
"In the week before go-live, a Knight engineer manually deployed the new RLP code in SMARS to its 8 servers. However, he made a mistake and did not copy the new code to one of the servers. Knight did not have a second engineer review the deployment, and neither was there an automated system to alert anyone to the discrepancy. "

https://www.henricodolfing.com/2019/06/project-failure-case-study-knight-capital.html

What could Knight capital have done better?

- Use capture/replay testing instead of driving market conditions in a test
- Avoid including “test” code in production deployments
- Automate deployments
- Define and monitor risk-based KPIs
- Create checklists for responding to incidents

Monitoring Services Take Automated Actions



Beware of Metrics

McNamara Fallacy

- Measure whatever can be easily measured
- Disregard that which cannot be measured easily
- Presume that which cannot be measured easily is not important
- Presume that which cannot be measured easily does not exist

How should we allocate our testing resources?

- How much unit testing should be required?
- When should we do code reviews?
- How often should we do integration tests?
- Different organizations may make different choices

Compare Continuous Delivery and TDD

- Test driven development
  - Write and maintain tests per-feature
  - Unit tests help locate bugs (at unit level)
  - Integration/system tests also needed to locate interaction-related faults
- Continuous delivery
  - Write and maintain high-level observability metrics
  - Deploy features one-at-a-time, look for canaries in metrics
  - Write fewer integration/system tests

CI in practice at Google

- Large scale example: Google TAP
  - 50,000 unique changes per-day, 4 billion test cases per-day
  - Pre-submit optimization: run fast tests for each individual change (before code review).
    Block merge if they fail.
  - Then: run all affected tests; “build cop” monitors and acts immediately to roll-back or fix
  - Build cop monitors integration test runs
  - Average wait time to submit a change: 11 minutes

“Software Engineering at Google: Lessons Learned from Programming Over Time,” Wright, Winters and Manshreck, 2020 (O’Reilly)

Facebook: "Move fast and break things"

- They de-prioritize unit tests
- Emphasis on getting features to users quickly

Facebook used to have an elaborate system of branches

- dev branches get merged into master,
- then once a week all changes from the past week are pulled into a release branch.
- For 3 days they “stabilize” the release branch – find changes that are causing very bad behavior and back them out.
- Then for the last 4 days of the week, every change that survived that stabilization gets individually pushed to production batched so that this happens 3x/day.
- Important to do small deploys so that you can isolate bad changes)

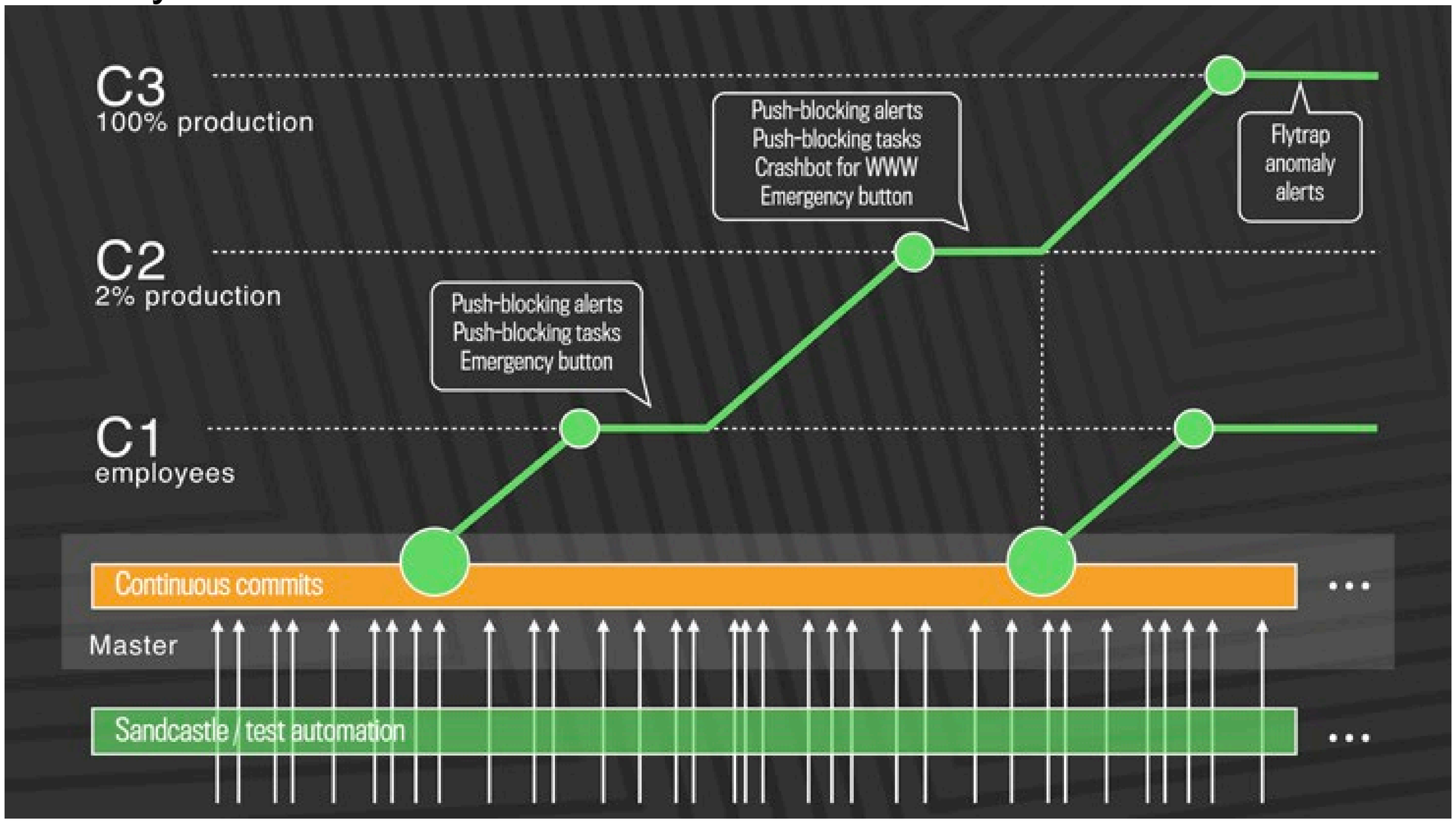
Post-2016: Truly Continuous Releases from Master Branch (excerpts from blog post)

1. First, diffs that have passed a series of automated internal tests and land in master are pushed out to Facebook employees.
2. In this stage, get push-blocking alerts if we've introduced a regression, and an emergency stop button lets us keep the release from going any further.
3. If everything is OK, push the changes to 2 percent of production, where again we collect signal and monitor alerts, especially for edge cases that our testing or employee dogfooding may not have picked up.
4. Finally, roll out to 100 percent of production, where our Flytrap tool aggregates user reports and alerts us to any anomalies.
5. Many of the changes are initially kept behind feature flags, which allows to roll out mobile and web code releases independently from new features, helping to lower the risk of any particular update causing a problem.
6. If we do find a problem, simply switch the feature off rather than revert back to a previous version or fix forward.

https://engineering.fb.com/2017/08/31/web/rapid-release-at-massive-scale/

Deployment Example

Post-2016: Truly continuous releases from master branch



https://engineering.fb.com/2017/08/31/web/rapid-release-at-massive-scale/

Review

- By now, you should be able to…
  - Describe how continuous development helps to catch errors sooner in the software lifecycle
  - Describe strategies for performing quality-assurance on software as and after it is delivered
  - Compare and contrast continuous delivery with test driven development as a quality assurance strategy