Principles of Software Construction: Objects, Design, and Concurrency

DevOps

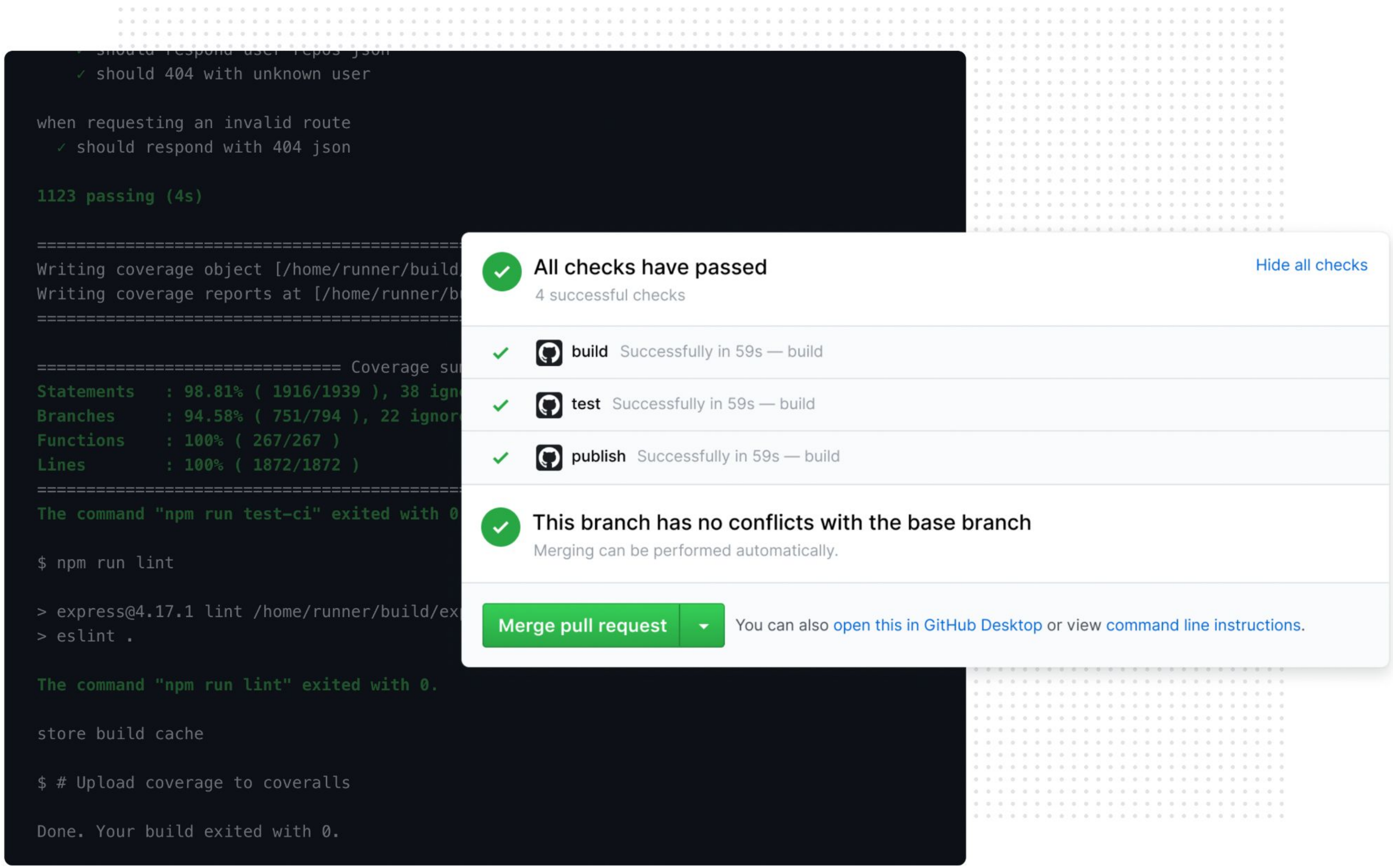
Claire Le Goues **Bogdan Vasilescu**

Reading Quiz: Modules (on Canvas)

Where we are

	Small scale: One/few objects	*Mid scale:* Many objects	*Large scale:* Subsystems
Design for understanding change/ext. reuse robustness ...	Subtype Polymorphism ✓ Information Hiding, Contracts ✓ Immutability ✓ Types ✓ Static Analysis ✓ Unit Testing ✓	Domain Analysis ✓ Inheritance & Del. ✓ Responsibility Assignment, Design Patterns, Antipattern ✓ Promises/ Reactive P. ✓ Static Analysis ✓	GUI vs Core ✓ Frameworks and Libraries ✓, APIs ✓ Distributed systems, microservices ✓ Testing for Robustness ✓ CI ✓, **DevOps**, Teams

Recall: Continuous Integration



```
    ✓ should respond user repos json
    ✓ should 404 with unknown user

  when requesting an invalid route
    ✓ should respond with 404 json

  1123 passing (4s)

  ===============================================
  Writing coverage object [/home/runner/build/
  Writing coverage reports at [/home/runner/bu
  ===============================================

  =============================== Coverage su
  Statements   : 98.81% ( 1916/1939 ), 38 ign
  Branches     : 94.58% ( 751/794 ), 22 ignor
  Functions    : 100% ( 267/267 )
  Lines        : 100% ( 1872/1872 )
  ===============================================
  The command "npm run test-ci" exited with 0

  $ npm run lint

  > express@4.17.1 lint /home/runner/build/ex
  > eslint .

  The command "npm run lint" exited with 0.

  store build cache

  $ # Upload coverage to coveralls

  Done. Your build exited with 0.
```

All checks have passed

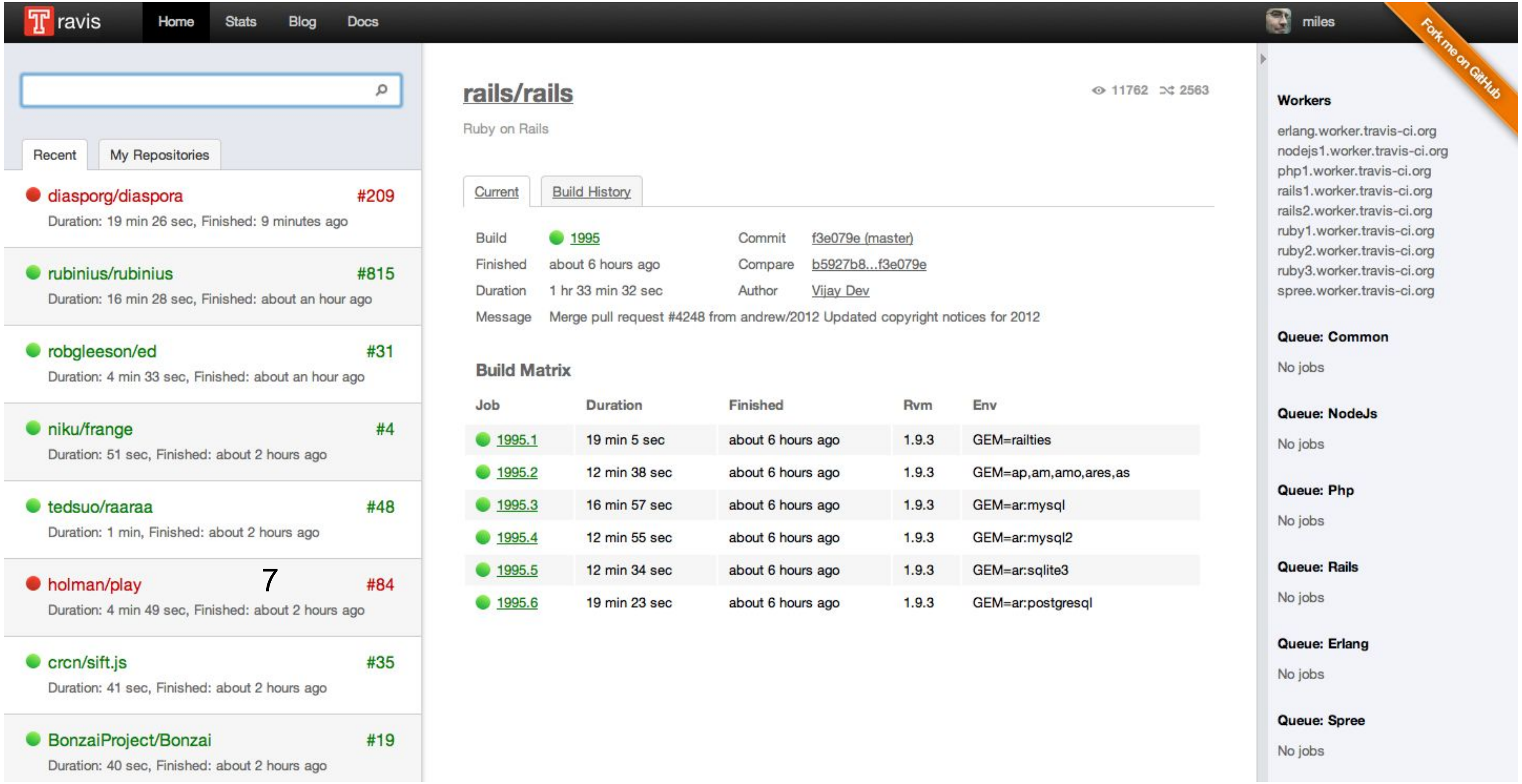
4 successful checks

✓	build	Successfully in 59s — build
✓	test	Successfully in 59s — build
✓	publish	Successfully in 59s — build

This branch has no conflicts with the base branch

Merging can be performed automatically.

You can also open this in GitHub Desktop or view command line instructions.



● diasporg/diaspora #209
Duration: 19 min 26 sec, Finished: 9 minutes ago

● rubinius/rubinius #815
Duration: 16 min 28 sec, Finished: about an hour ago

● robgleeson/ed #31
Duration: 4 min 33 sec, Finished: about an hour ago

● niku/frange #4
Duration: 51 sec, Finished: about 2 hours ago

● tedsuo/raaraa #48
Duration: 1 min, Finished: about 2 hours ago

● holman/play #84
Duration: 4 min 49 sec, Finished: about 2 hours ago

● crcn/sift.js #35
Duration: 41 sec, Finished: about 2 hours ago

● BonzaiProject/Bonzai #19
Duration: 40 sec, Finished: about 2 hours ago

rails/rails 11762 2563

Ruby on Rails

Build	● 1995	Commit	f3e079e (master)
Finished	about 6 hours ago	Compare	b5927b8...f3e079e
Duration	1 hr 33 min 32 sec	Author	Vijay Dev
Message	Merge pull request #4248 from andrew/2012 Updated copyright notices for 2012		

Build Matrix

Job	Duration	Finished	Rvm	Env
● 1995.1	19 min 5 sec	about 6 hours ago	1.9.3	GEM=railties
● 1995.2	12 min 38 sec	about 6 hours ago	1.9.3	GEM=ap,am,amo,ares,as
● 1995.3	16 min 57 sec	about 6 hours ago	1.9.3	GEM=ar:mysql
● 1995.4	12 min 55 sec	about 6 hours ago	1.9.3	GEM=ar:mysql2
● 1995.5	12 min 34 sec	about 6 hours ago	1.9.3	GEM=ar:sqlite3
● 1995.6	19 min 23 sec	about 6 hours ago	1.9.3	GEM=ar:postgresql

Workers

erlang.worker.travis-ci.org
nodejs1.worker.travis-ci.org
php1.worker.travis-ci.org
rails1.worker.travis-ci.org
rails2.worker.travis-ci.org
ruby1.worker.travis-ci.org
ruby2.worker.travis-ci.org
ruby3.worker.travis-ci.org
spree.worker.travis-ci.org

Queue: Common
No jobs

Queue: NodeJs
No jobs

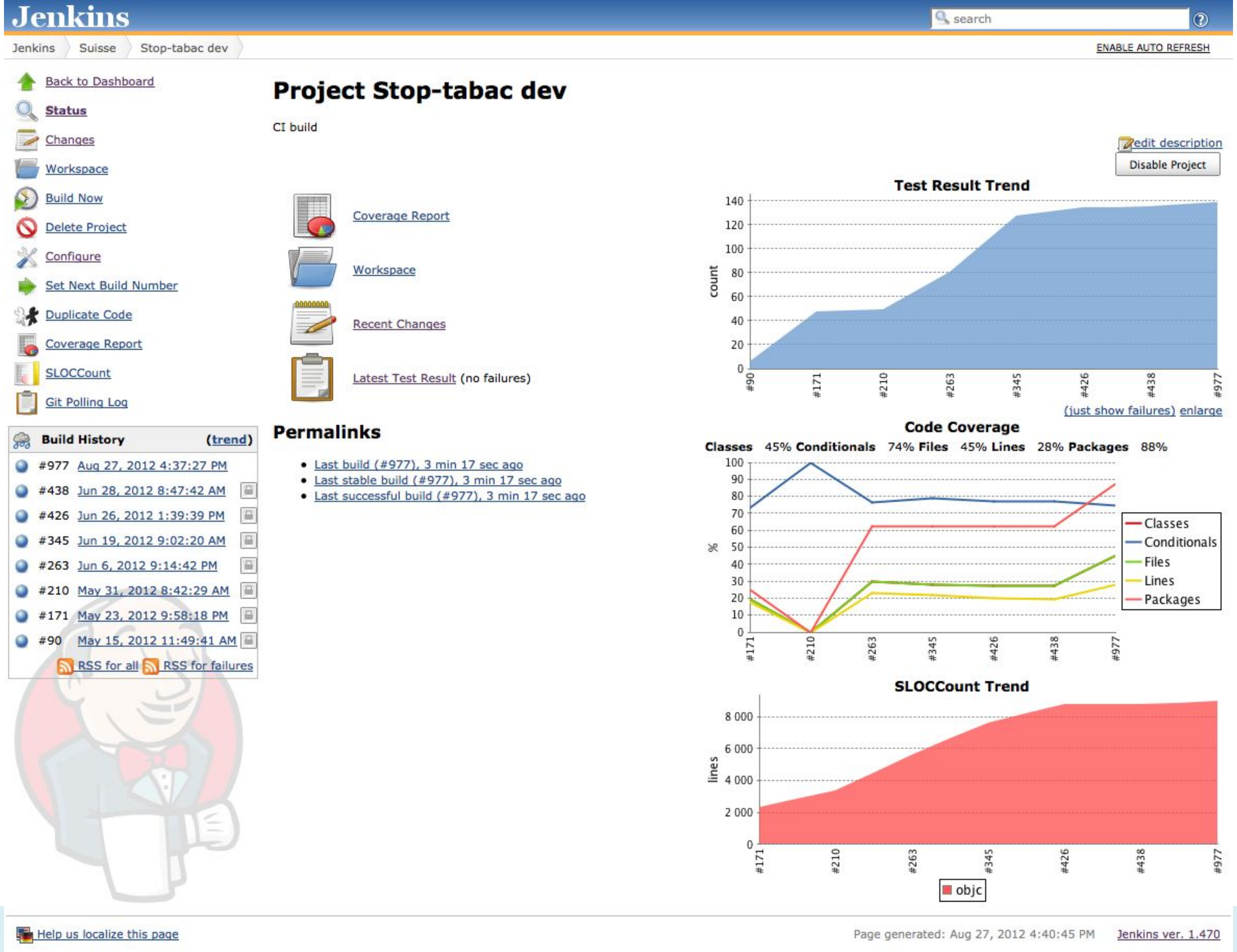
Queue: Php
No jobs

Queue: Rails
No jobs

Queue: Erlang
No jobs

Queue: Spree
No jobs

7



Jenkins › Suisse › Stop-tabac dev

ENABLE AUTO REFRESH

- Back to Dashboard
- Status
- Changes
- Workspace
- Build Now
- Delete Project
- Configure
- Set Next Build Number
- Duplicate Code
- Coverage Report
- SLOCCount
- Git Polling Log

Build History (trend)

#977	Aug 27, 2012 4:37:27 PM
#438	Jun 28, 2012 8:47:42 AM
#426	Jun 26, 2012 1:39:39 PM
#345	Jun 19, 2012 9:02:20 AM
#263	Jun 6, 2012 9:14:42 PM
#210	May 31, 2012 8:42:29 AM
#171	May 23, 2012 9:58:18 PM
#90	May 15, 2012 11:49:41 AM

RSS for all RSS for failures

Project Stop-tabac dev

CI build

edit description

Disable Project

- Coverage Report
- Workspace
- Recent Changes
- Latest Test Result (no failures)

Permalinks

- Last build (#977), 3 min 17 sec ago
- Last stable build (#977), 3 min 17 sec ago
- Last successful build (#977), 3 min 17 sec ago

(just show failures) enlarge

Classes 45% Conditionals 74% Files 45% Lines 28% Packages 88%

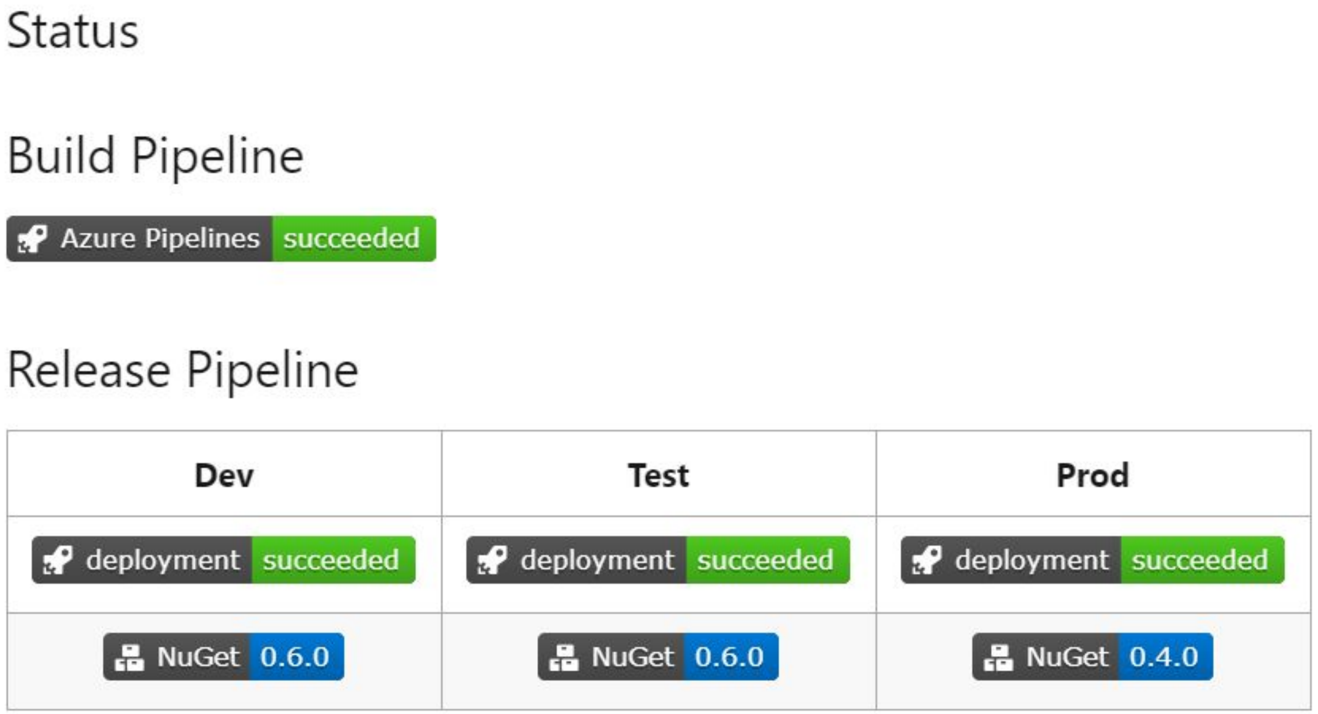
Help us localize this page

Page generated: Aug 27, 2012 4:40:45 PM Jenkins ver. 1.470

Continuous Integration

- Automation
- Ensures absence of obvious build issues and configuration issues (e.g., dependencies all checked in)
- Ensures tests are executed
- May encourage more tests
- Can run checks on different platforms

Aside: The role of signaling



Status

Build Pipeline

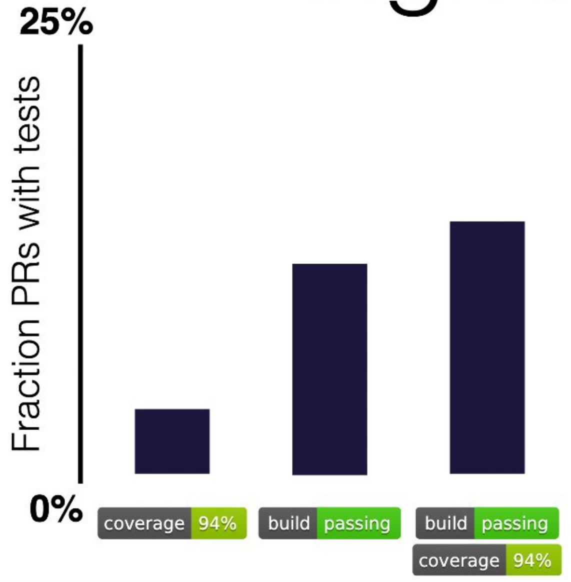
Azure Pipelines | succeeded

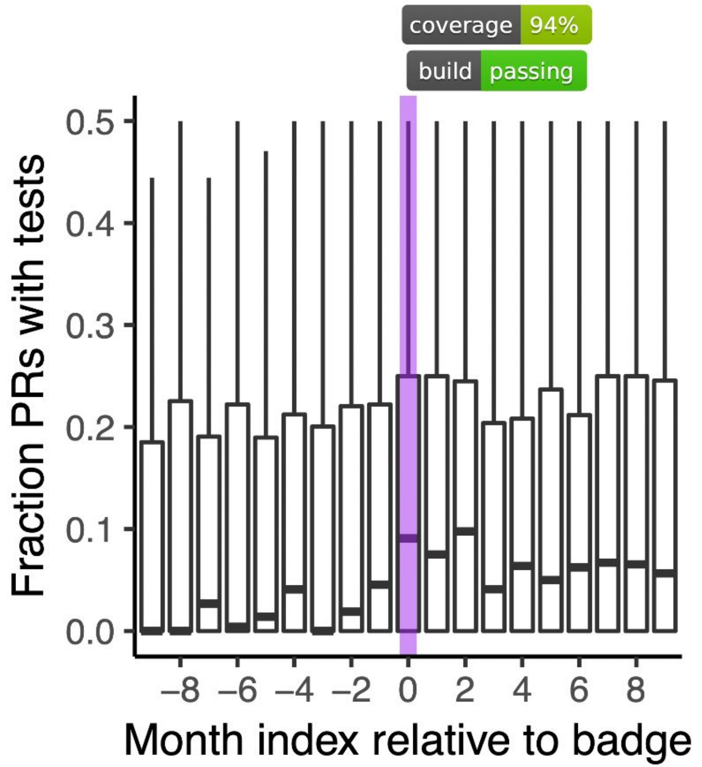
Release Pipeline

Dev	Test	Prod
deployment succeeded	deployment succeeded	deployment succeeded
NuGet 0.6.0	NuGet 0.6.0	NuGet 0.4.0

https://blog.devops4me.com/status-badges-in-azure-devops-pipelines/

Signals of PR quality





Result: Build status+code coverage badges indicate *more tests in PRs*

STRUDEL
Carnegie Mellon University

Continuous Integration

- Automation
- Ensures absence of obvious build issues and configuration issues (e.g., dependencies all checked in)
- Ensures tests are executed
- May encourage more tests
- Can run checks on different platforms

- What can all be automated?

Any repetitive QA work remaining?

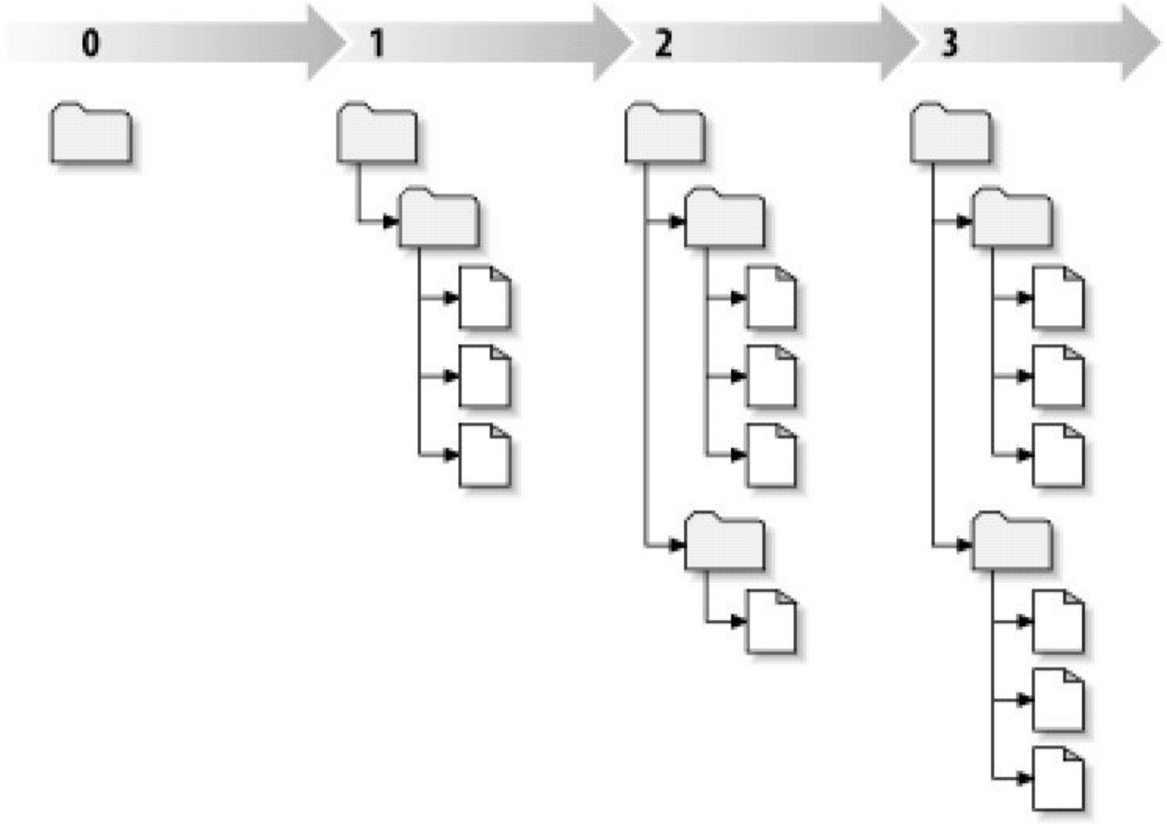
Releasing Software

Semantic Versioning for Releases

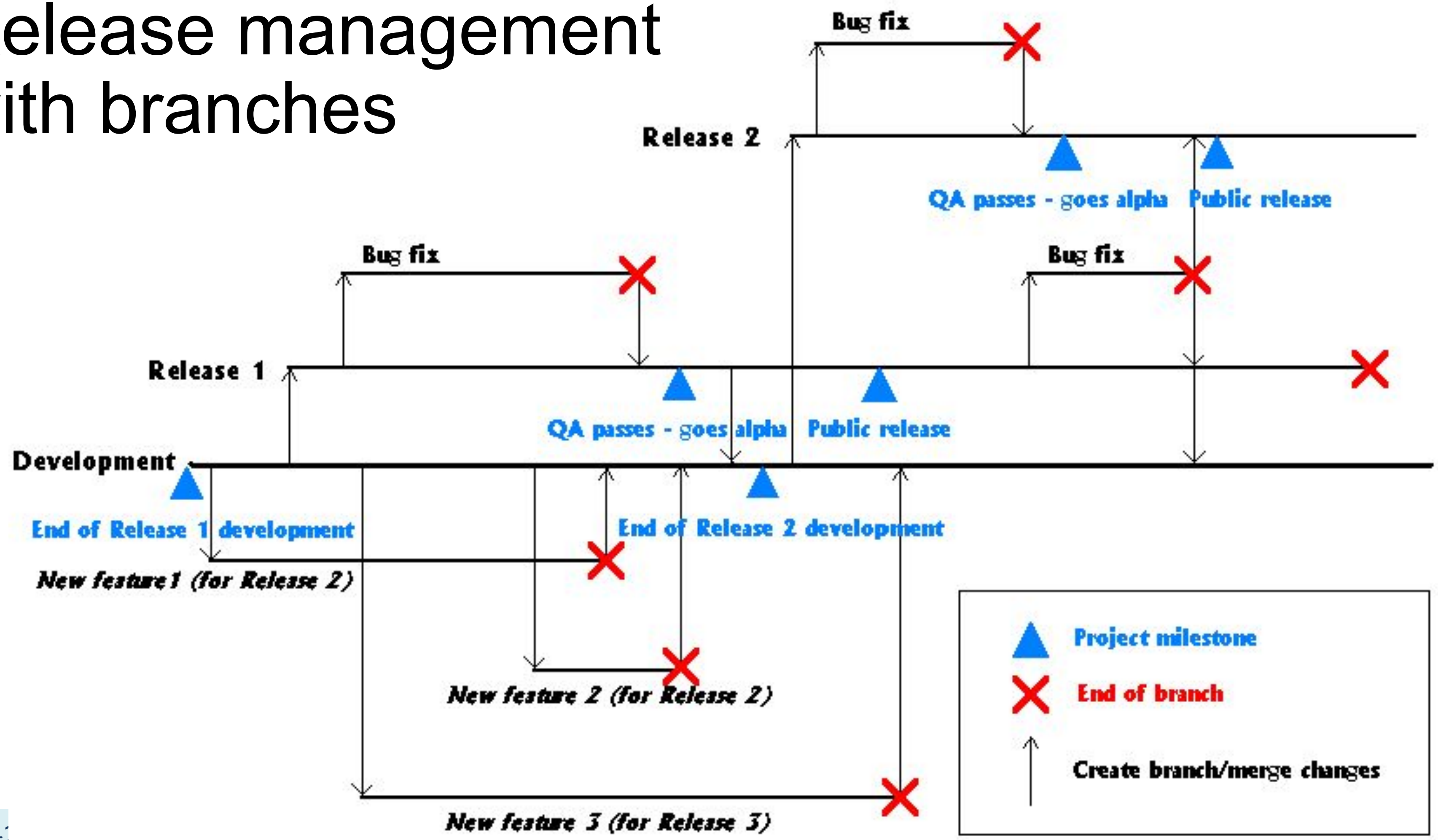
- Given a version number MAJOR.MINOR.PATCH, increment the:
  - MAJOR version when you make incompatible API changes,
  - MINOR version when you add functionality in a backwards-compatible manner, and
  - PATCH version when you make backwards-compatible bug fixes.
- Additional labels for pre-release and build metadata are available as extensions to the MAJOR.MINOR.PATCH format.

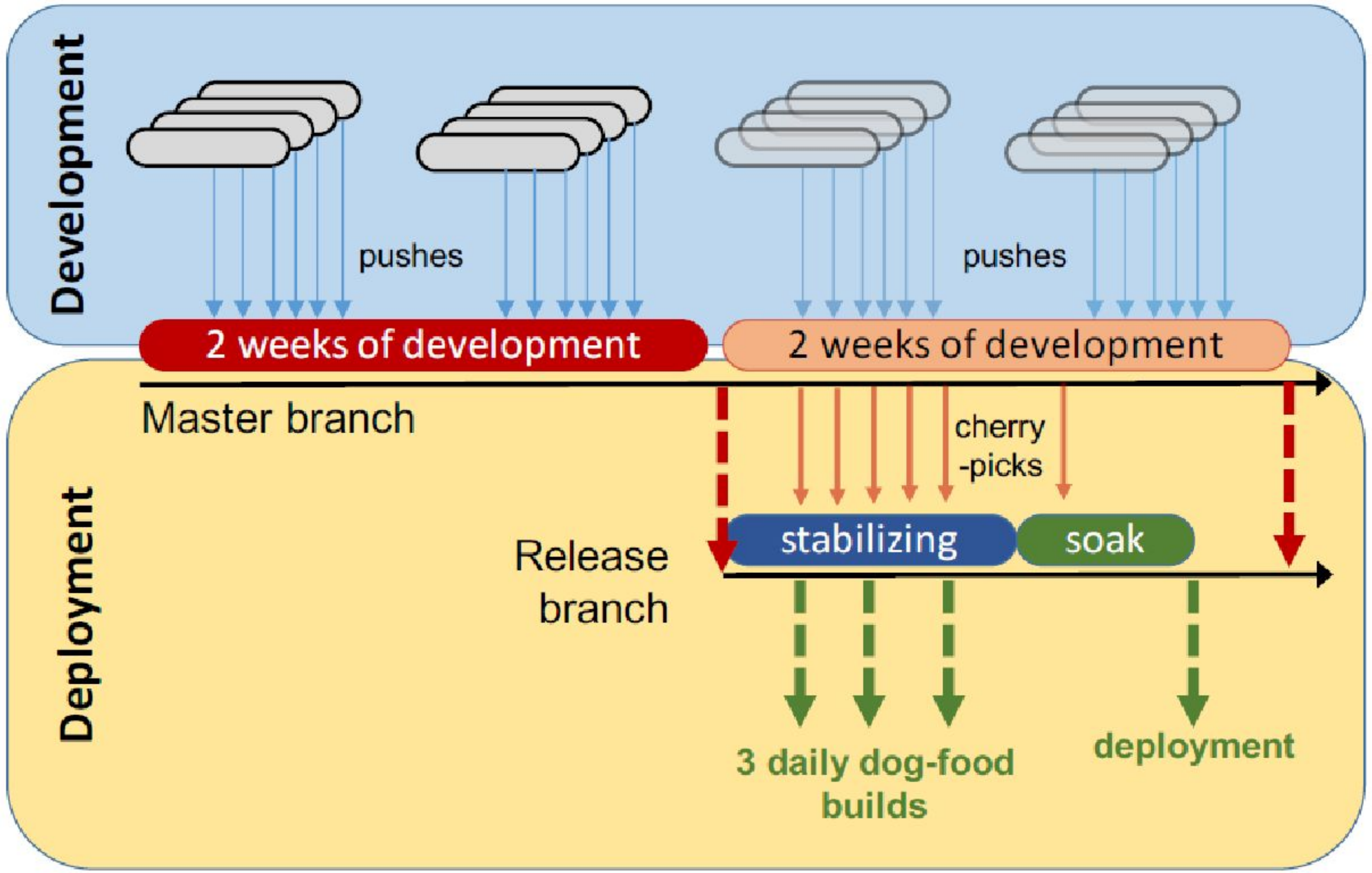
http://semver.org/

Versioning entire projects



Release management with branches


Bug fix
Release 2
QA passes - goes alpha
Public release
Bug fix
Bug fix
Release 1
QA passes - goes alpha
Public release
Development
End of Release 1 development
End of Release 2 development
New feature 1 (for Release 2)
New feature 2 (for Release 2)
New feature 3 (for Release 3)
Project milestone
End of branch
Create branch/merge changes



Release cycle of Facebook's apps

Facebook Tests for Mobile Apps

Unit tests (white box)

Static analysis (null pointer warnings, memory leaks, ...)

Build tests (compilation succeeds)

Snapshot tests (screenshot comparison, pixel by pixel)

Integration tests (black box, in simulators)

Performance tests (resource usage)

Capacity and conformance tests (custom)

Further readings: Rossi, Chuck, Elisa Shibley, Shi Su, Kent Beck, Tony Savor, and Michael Stumm. Continuous deployment of mobile software at facebook (showcase). In Proceedings of the 2016 24th ACM SIGSOFT International Symposium on Foundations of Software Engineering, pp. 12-23. ACM, 2016.

Release Challenges for Mobile Apps

Large downloads

Download time at user discretion

Different versions in production

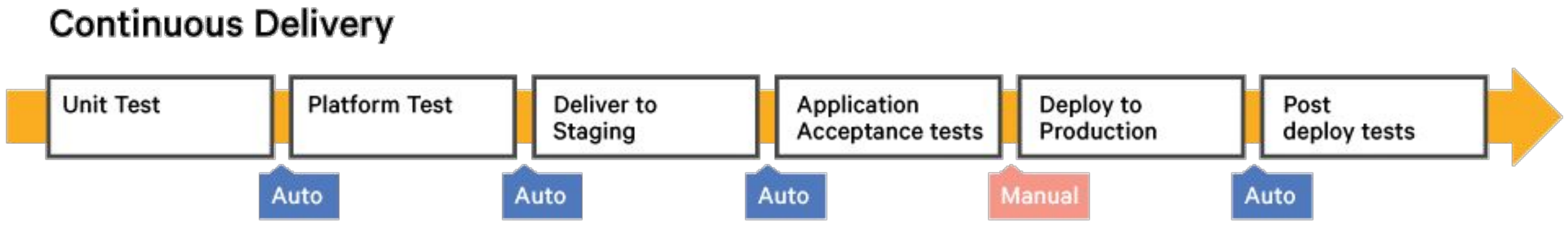
Pull support for old releases?

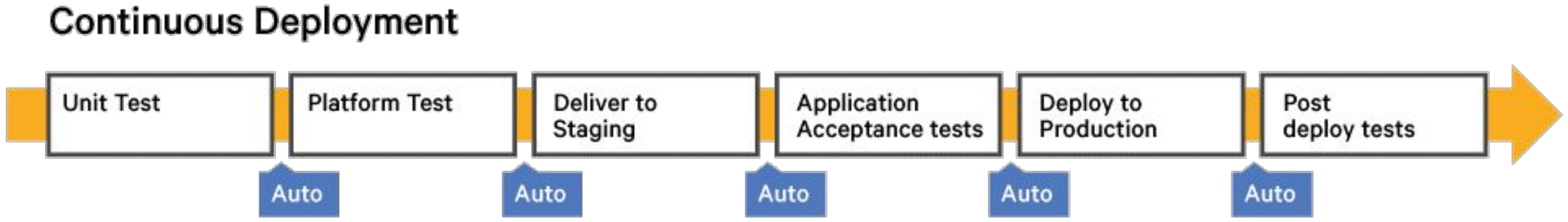
Server side releases silent and quick, consistent

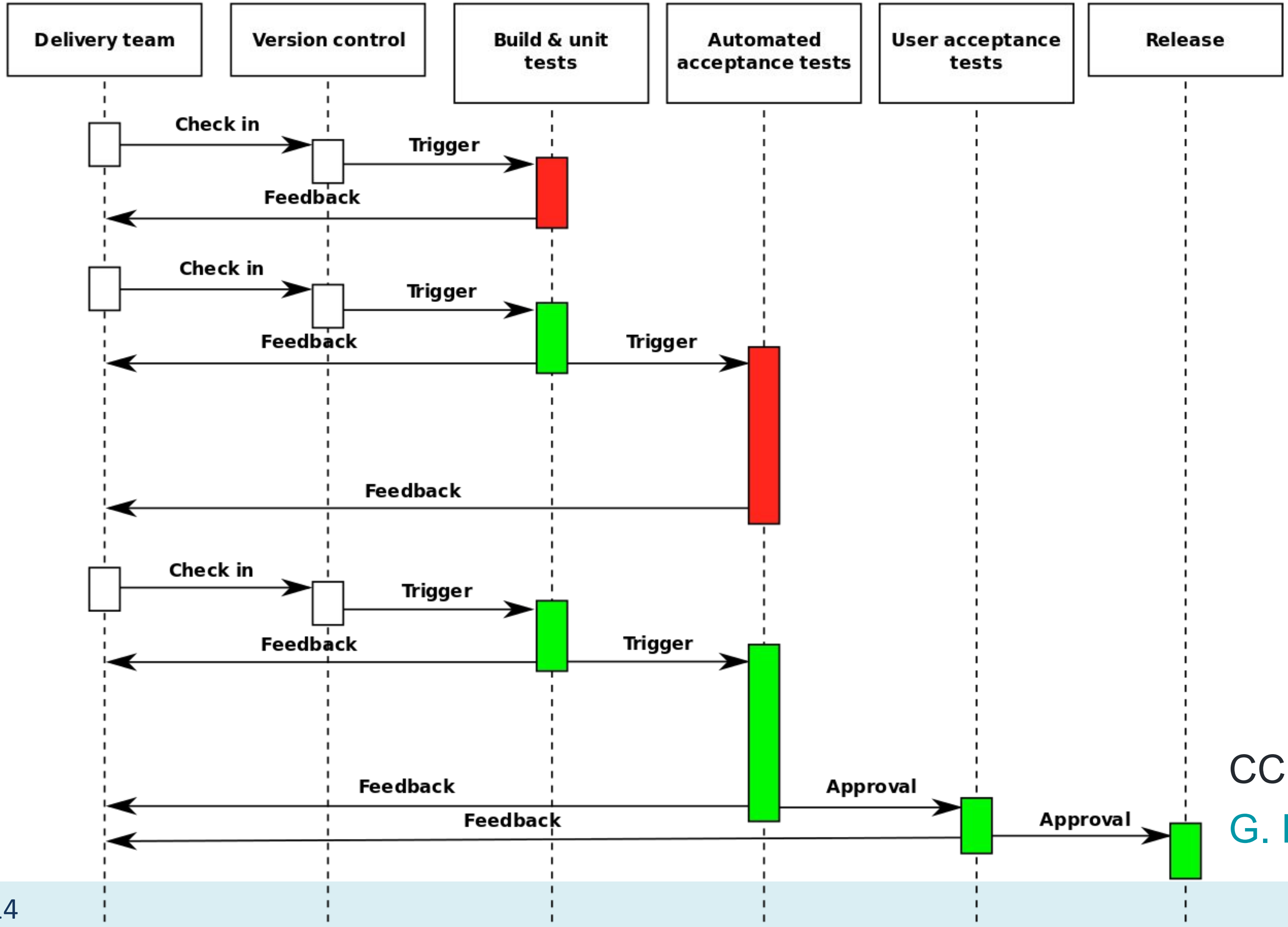
→ App as container, most content + layout from server

From Release Date to Continuous Release

- Traditional View: Boxed Software
  - Working toward fixed release date, QA heavy before release
  - Release and move on
  - Fix post-release defects in next release or through expensive patches
- Frequent releases
  - Incremental updates delivered frequently (weeks, days, …), e.g. Browsers
  - Automated updates (“patch culture”; “updater done? ship it”)
- Hosted software
  - Frequent incremental releases, hot patches, different versions for different customers, customer may not even notice update


Continuous Delivery
Unit Test
Platform Test
Deliver to Staging
Application Acceptance tests
Deploy to Production
Post deploy tests
Auto
Auto
Auto
Manual
Auto


Continuous Deployment
Unit Test
Platform Test
Deliver to Staging
Application Acceptance tests
Deploy to Production
Post deploy tests
Auto
Auto
Auto
Auto
Auto


Delivery team
Version control
Build & unit tests
Automated acceptance tests
User acceptance tests
Release
Check in
Trigger
Feedback
Check in
Trigger
Feedback
Trigger
Feedback
Check in
Trigger
Feedback
Trigger
Feedback
Approval
Feedback
Approval

The Shifting Development-Operations Barrier

WORKED FINE IN DEV
OPS PROBLEM NOW
memegenerator.net

Common Release Problems?

Common Release Problems (Examples)

- Missing dependencies
- Different compiler versions or library versions
- Different local utilities (e.g. unix grep vs mac grep)
- Database problems
- OS differences
- Too slow in real settings
- Difficult to roll back changes
- Source from many different repositories
- Obscure hardware? Cloud? Enough memory?

The Dev – Ops Divide

- Coding
- Testing, static analysis, reviews
- Continuous integration
- Bug tracking
- Running local tests and scalability experiments
- …

- Allocating hardware resources
- Managing OS updates
- Monitoring performance
- Monitoring crashes
- Managing load spikes, …
- Tuning database performance
- Running distributed at scale
- Rolling back releases
- …

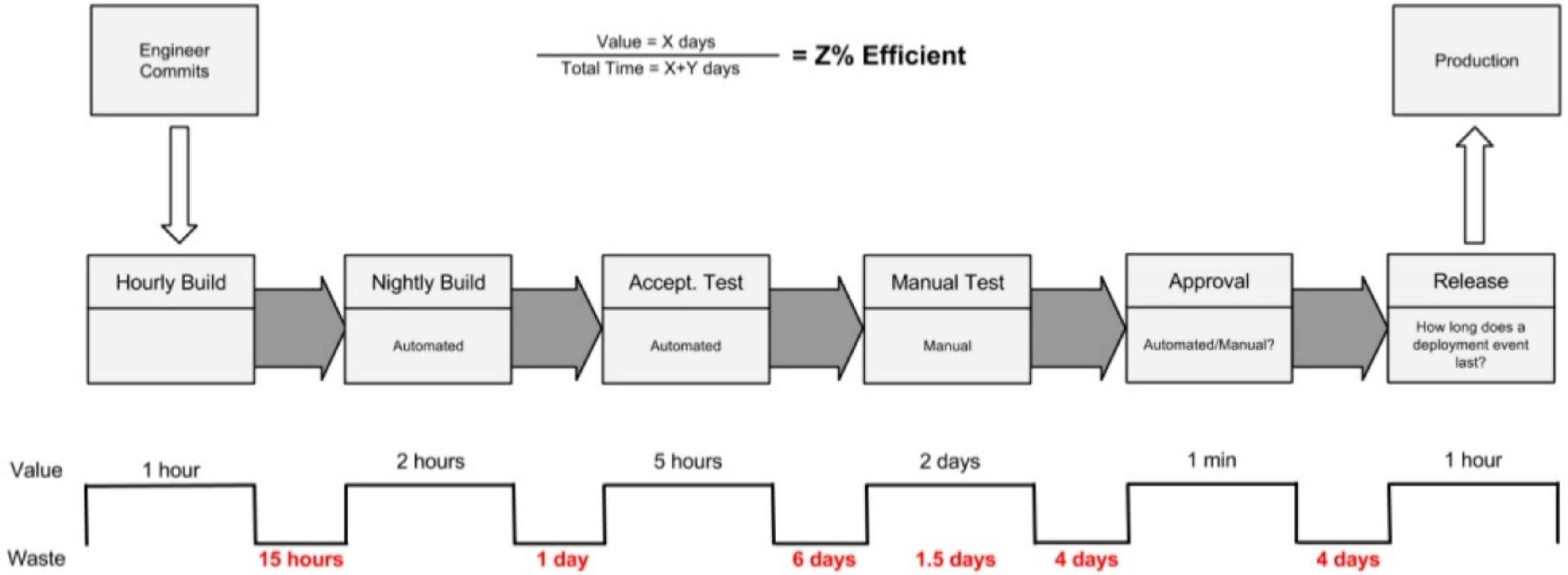
QA responsibilities in both roles

QA Does not Stop in Dev

QA Does not Stop in Dev

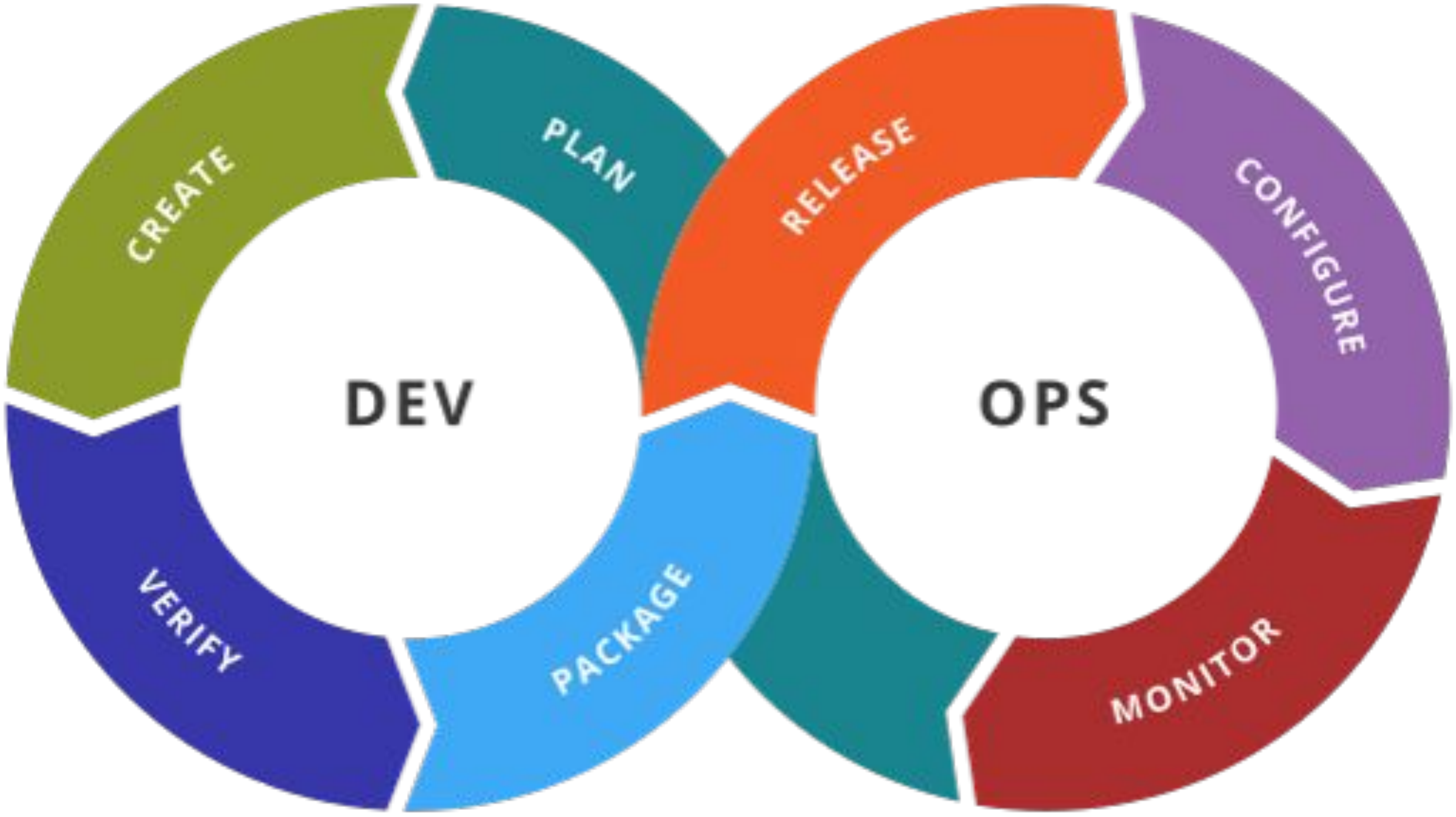
- Ensuring product builds correctly (e.g., reproducible builds)
- Ensuring scalability under real-world loads
- Supporting environment constraints from real systems (hardware, software, OS)
- Efficiency with given infrastructure
- Monitoring (server, database, Dr. Watson, etc)
- Bottlenecks, crash-prone components, … (possibly thousands of crash reports per day/minute)

Efficiency of release pipeline



https://www.slideshare.net/jmcgarr/continuous-delivery-at-netflix-and-beyond

DevOps


CREATE
PLAN
RELEASE
CONFIGURE
DEV
OPS
VERIFY
PACKAGE
MONITOR

Key Ideas and Principles

Better coordinate between developers and operations (collaborative)

Key goal: Reduce friction bringing changes from development into production

Considering the entire tool chain into production (holistic)

Documentation and versioning of all dependencies and configurations ("configuration as code")

Heavy automation, e.g., continuous delivery, monitoring

Small iterations, incremental and continuous releases

Buzz word!

Common Practices

All configurations in version control

Test and deploy in containers

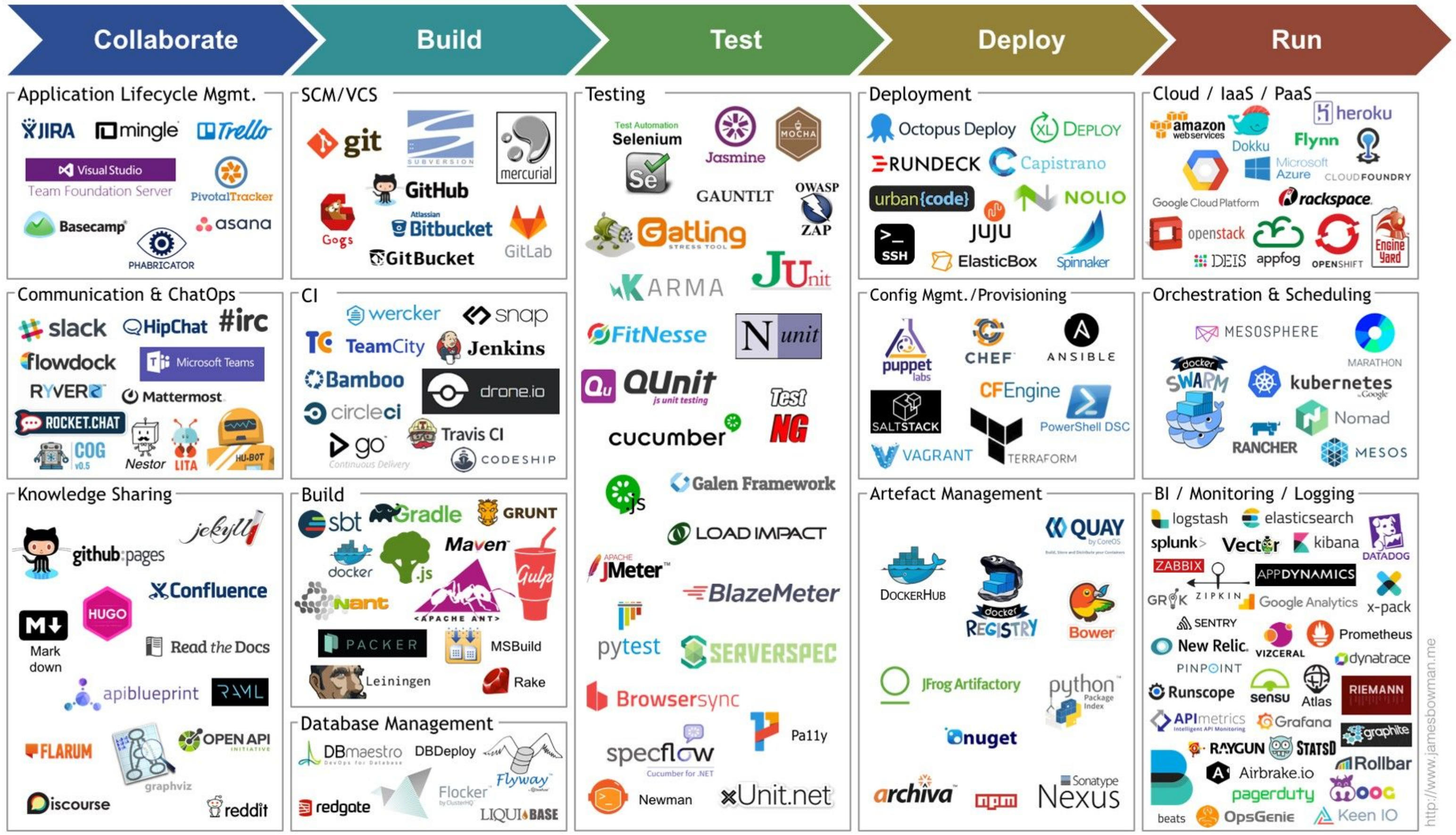
Automated testing, testing, testing, ...

Monitoring, orchestration, and automated actions in practice

Microservice architectures

Release frequently

Heavy Tooling and Automation



Heavy tooling and automation -- Examples

Infrastructure as code — Ansible, Terraform, Puppet, Chef

CI/CD — Jenkins, TeamCity, GitLab, Shippable, Bamboo, Azure DevOps

Test automation — Selenium, Cucumber, Apache JMeter

Containerization — Docker, Rocket, Unik

Orchestration — Kubernetes, Swarm, Mesos

Software deployment — Elastic Beanstalk, Octopus, Vamp

Measurement — Datadog, DynaTrace, Kibana, NewRelic, ServiceNow

DevOps: Tooling Overview

DevOps Tools

- Containers and virtual machines (Docker, …)
- Orchestration and configuration (ansible, Puppet, Chef, Kubernetes, …)
- Sophisticated (custom) pipelines

docker

- Lightweight virtualization
- Sub-second boot time
- Shareable virtual images with full setup incl. configuration settings
- Used in development and deployment
- Separate docker images for separate services (web server, business logic, database, …)

Configuration management, Infrastructure as Code

- Scripts to change system configurations (configuration files, install packages, versions, ...); declarative vs imperative
- Usually put under version control

(ansible)

```
- hosts: all
  sudo: yes
  tasks:
  - apt: name={{ item }}
    with_items:
      - ldap-auth-client
      - nscd
  - shell: auth-client-config -t nss -p lac_ldap
  - copy: src=ldap/my_mkhomedir dest=/…
  - copy: src=ldap/ldap.conf dest=/etc/ldap.conf
  - shell: pam-auth-update --package
  - shell: /etc/init.d/nscd restart
```

(Puppet)

```
$nameservers = ['10.0.2.3']
file { '/etc/resolv.conf':
     ensure => file,
     owner => 'root',
     group => 'root',
     mode => '0644',
     content => template('resolver/r.conf'),
}
```

Container Orchestration with Kubernetes

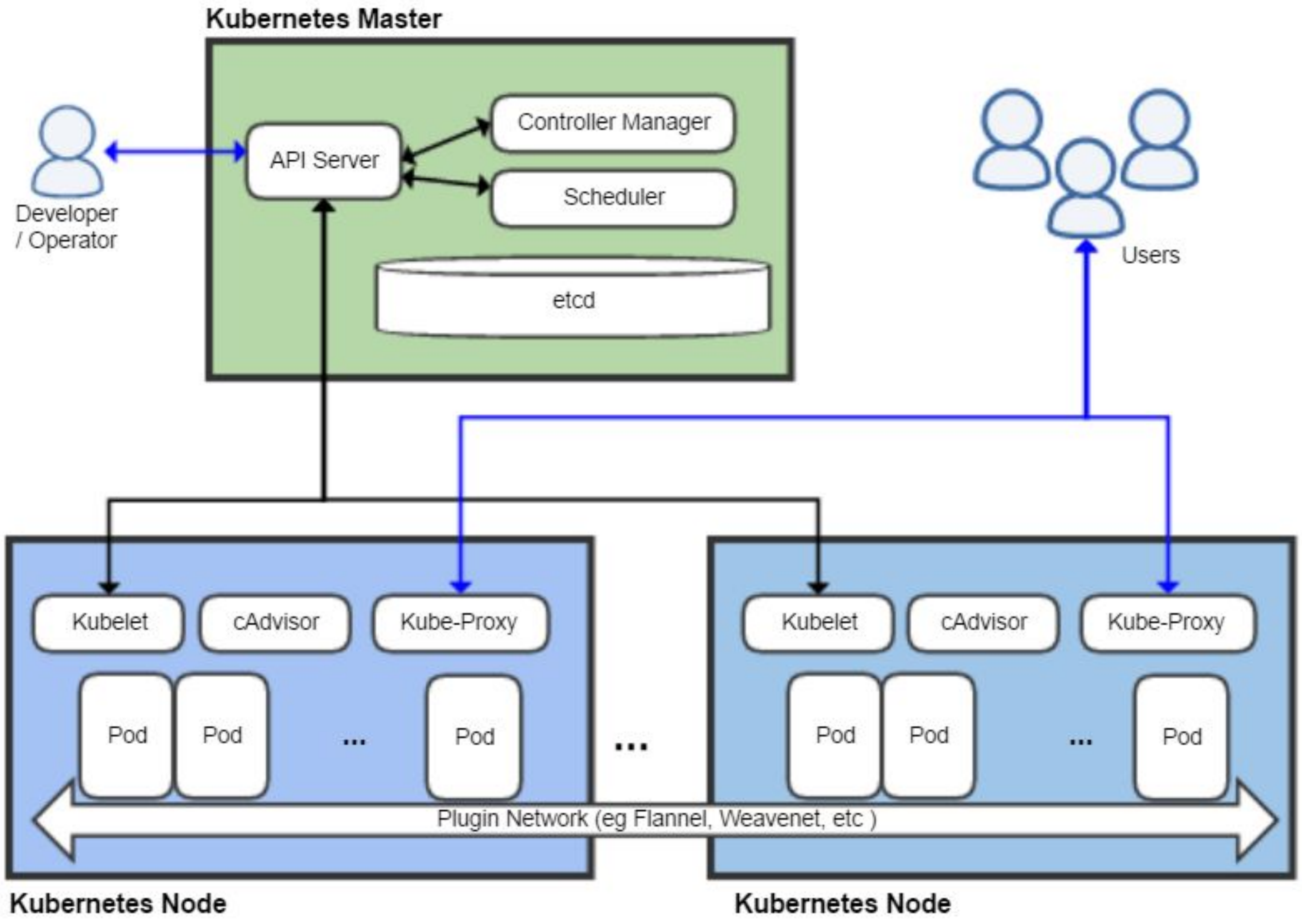
Manages which container to deploy to which machine

Launches and kills containers depending on load

Manage updates and routing

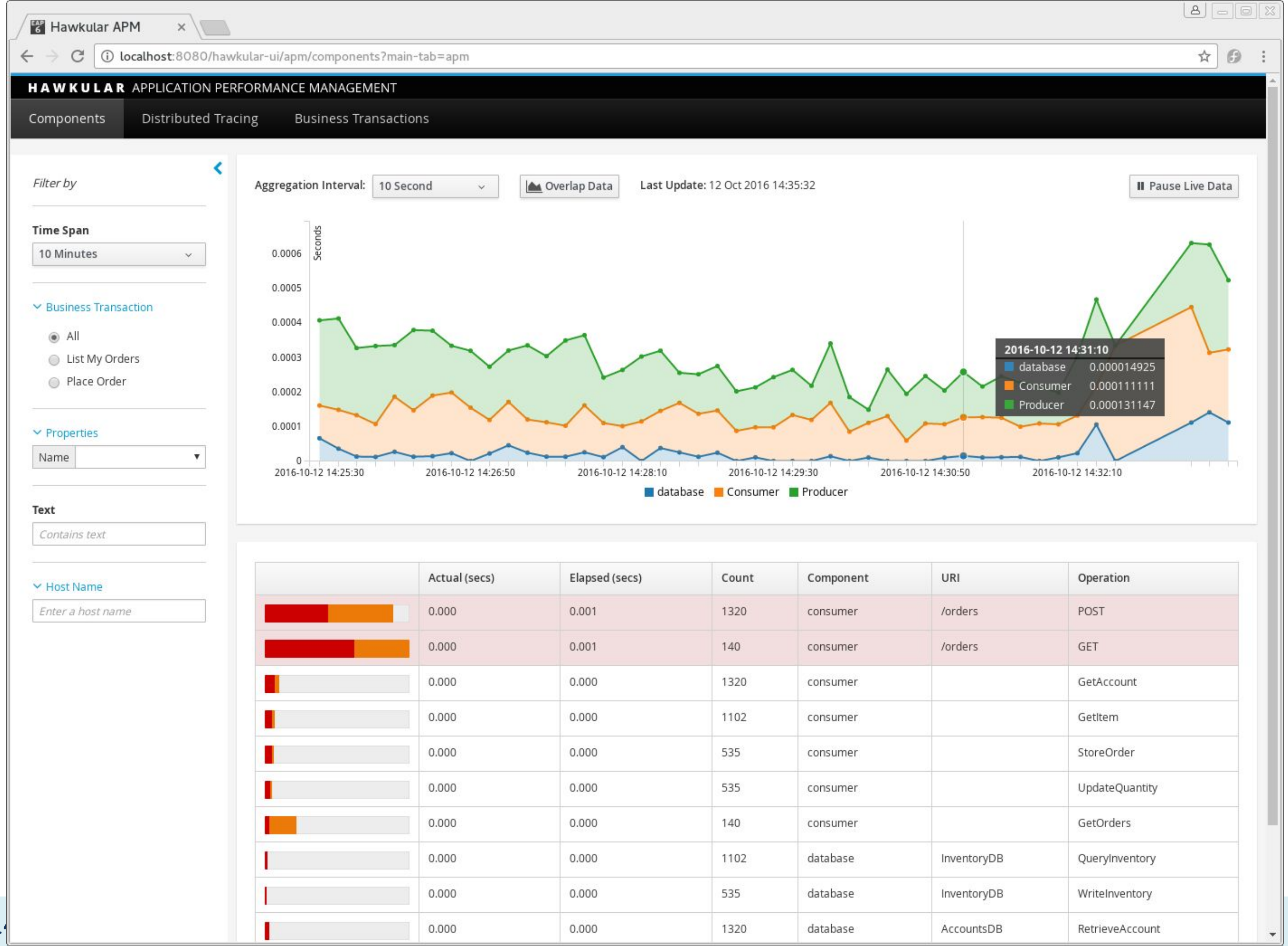
Automated restart, replacement, replication, scaling

Kubernetes master controls many nodes


Kubernetes Master
Developer / Operator
API Server
Controller Manager
Scheduler
etcd
Users
Kubelet
cAdvisor
Kube-Proxy
Pod
Pod
...
Pod
...
Kubelet
cAdvisor
Kube-Proxy
Pod
Pod
...
Pod
Plugin Network (eg Flannel, Weavenet, etc)
Kubernetes Node
Kubernetes Node

Monitoring

- Monitor server health
- Monitor service health
- Collect and analyze measures or log files
- Dashboards and triggering automated decisions
    - Many tools, e.g., Grafana as dashboard, Prometheus for metrics, Loki + ElasticSearch for logs
    - Push and pull models



Hawkular APM

localhost:8080/hawkular-ui/apm/components?main-tab=apm

HAWKULAR APPLICATION PERFORMANCE MANAGEMENT

Components | Distributed Tracing | Business Transactions

Filter by

Time Span
10 Minutes

Business Transaction
- [✓ All]
- List My Orders
- Place Order

Properties
Name

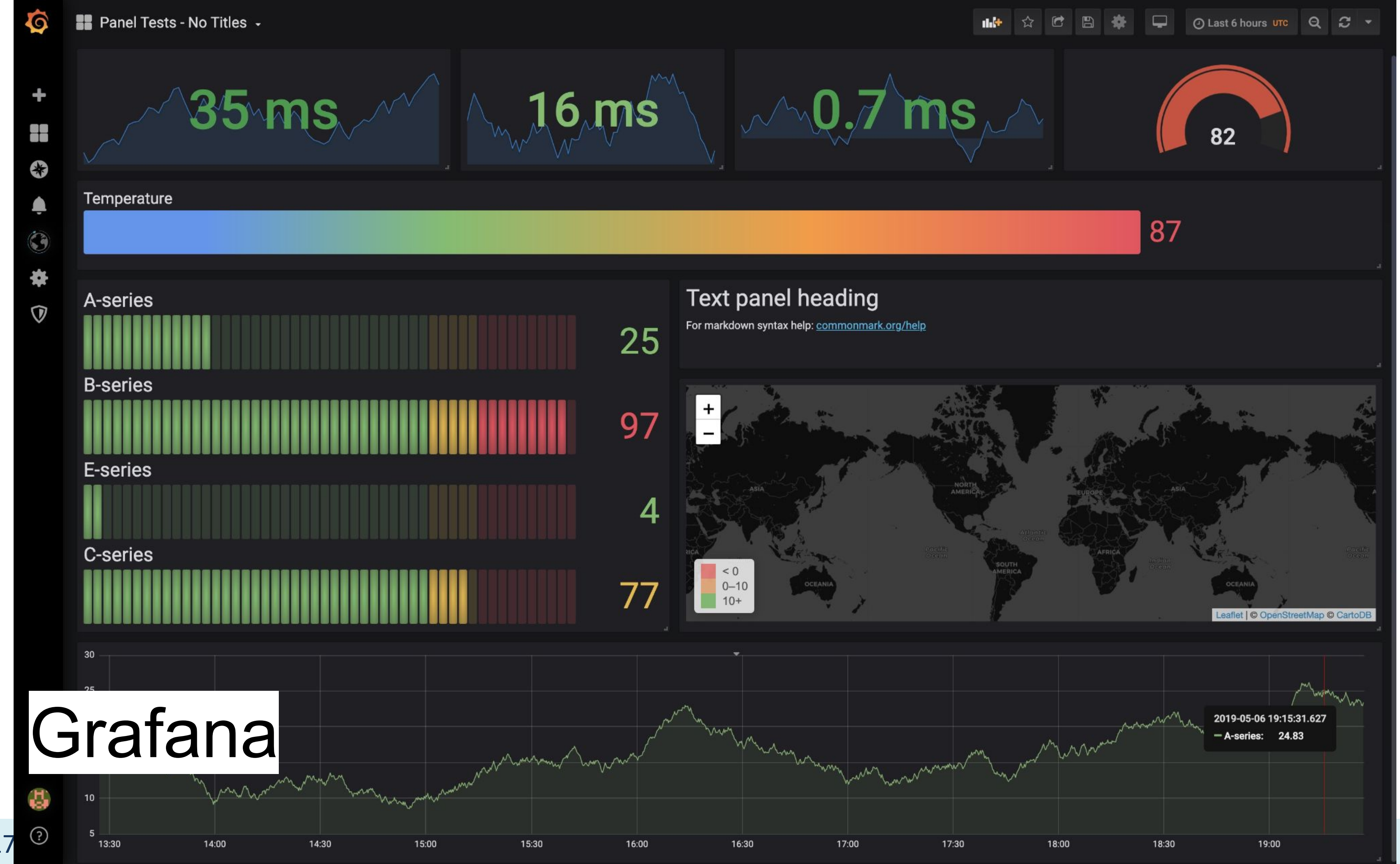
Text
Contains text

Host Name
Enter a host name

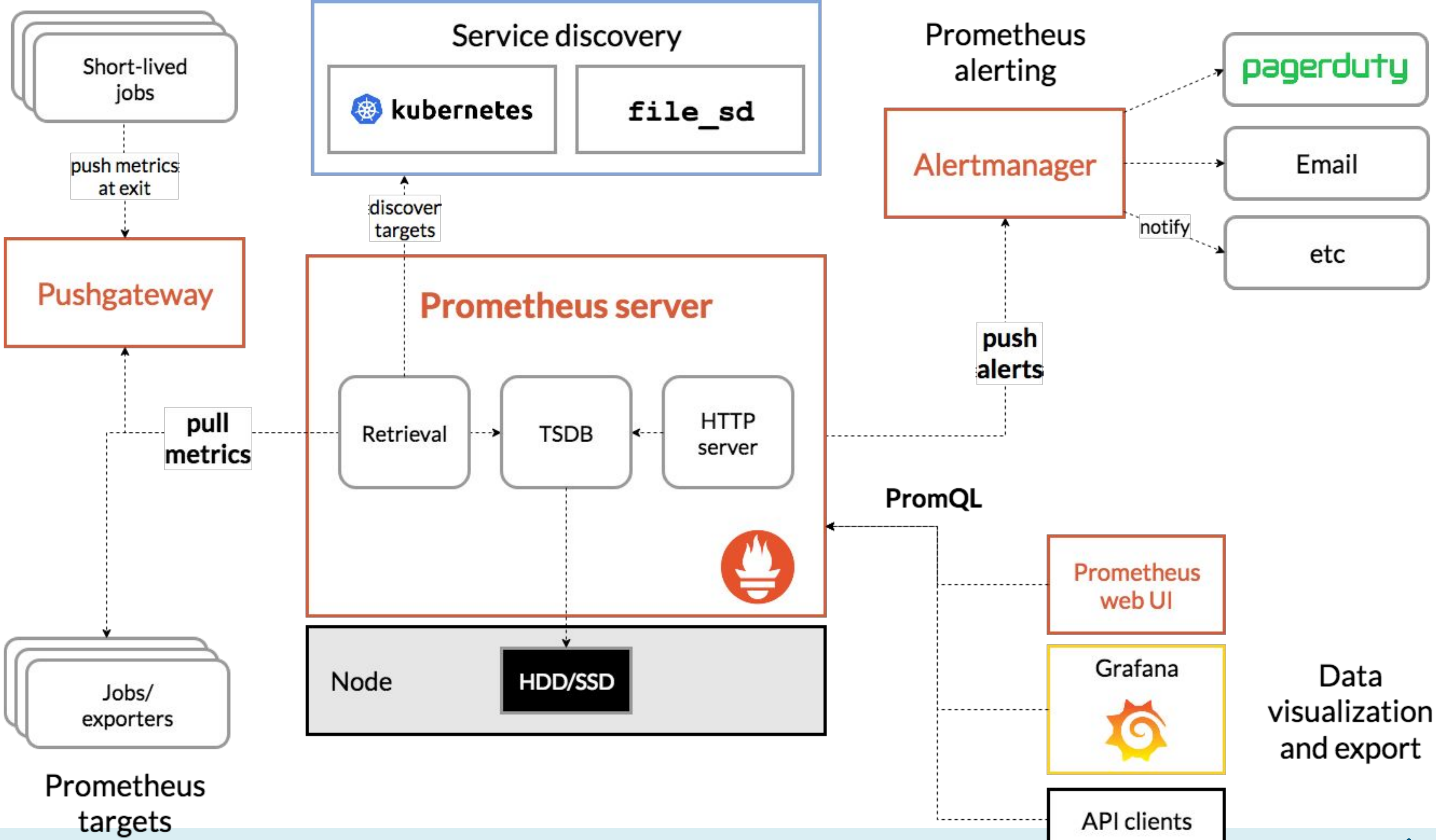
Aggregation Interval: 10 Second | Overlap Data | **Last Update:** 12 Oct 2016 14:35:32 | Pause Live Data

2016-10-12 14:31:10	
database	0.000014925
Consumer	0.000111111
Producer	0.000131147

	Actual (secs)	Elapsed (secs)	Count	Component	URI	Operation
	0.000	0.001	1320	consumer	/orders	POST
	0.000	0.001	140	consumer	/orders	GET
	0.000	0.000	1320	consumer		GetAccount
	0.000	0.000	1102	consumer		GetItem
	0.000	0.000	535	consumer		StoreOrder
	0.000	0.000	535	consumer		UpdateQuantity
	0.000	0.000	140	consumer		GetOrders
	0.000	0.000	1102	database	InventoryDB	QueryInventory
	0.000	0.000	535	database	InventoryDB	WriteInventory
	0.000	0.000	1320	database	AccountsDB	RetrieveAccount

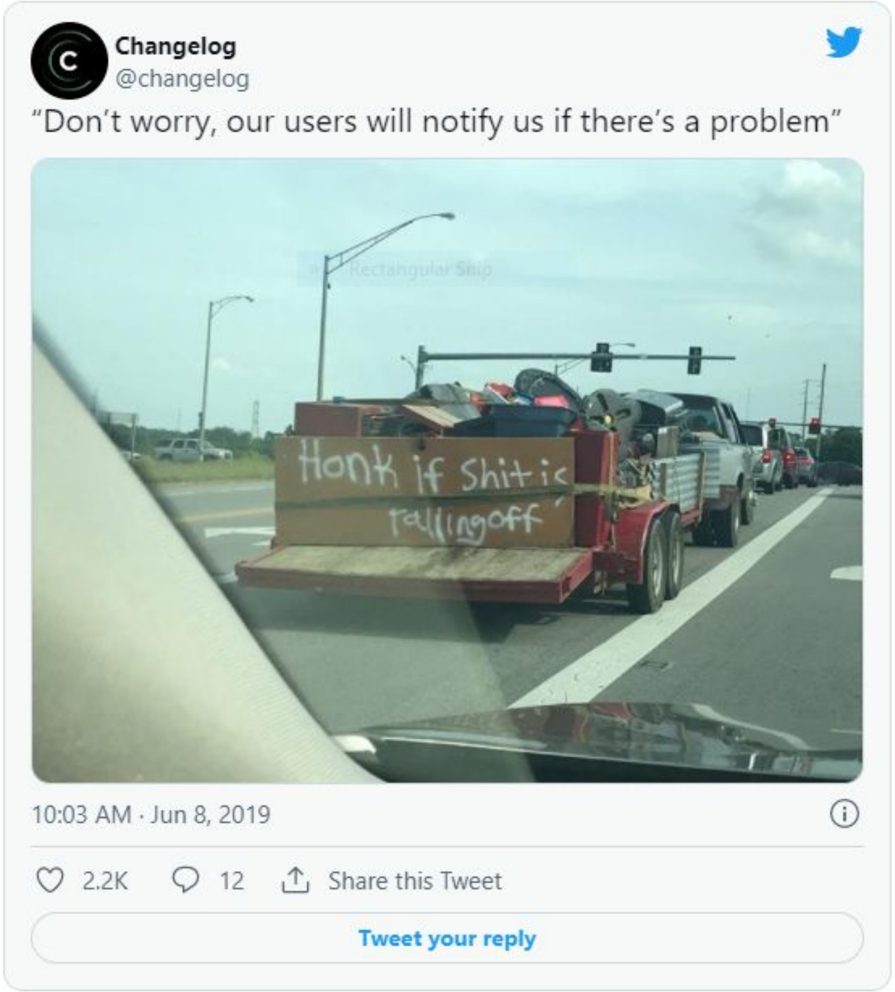

Panel Tests - No Titles
Last 6 hours UTC
35 ms
16 ms
0.7 ms
82
Temperature
87
A-series
25
B-series
97
E-series
4
C-series
77
Text panel heading
For markdown syntax help: commonmark.org/help
< 0
0–10
10+
Leaflet | © OpenStreetMap © CartoDB
2019-05-06 19:15:31.627
A-series: 24.83

Grafana


Short-lived jobs
push metrics at exit
Pushgateway
Service discovery
kubernetes
file_sd
discover targets
Prometheus alerting
Alertmanager
pagerduty
Email
etc
notify
push alerts
Prometheus server
Retrieval
TSDB
HTTP server
pull metrics
PromQL
Node
HDD/SSD
Prometheus web UI
Grafana
API clients
Jobs/ exporters
Prometheus targets
Data visualization and export

Testing in Production

Testing in Production

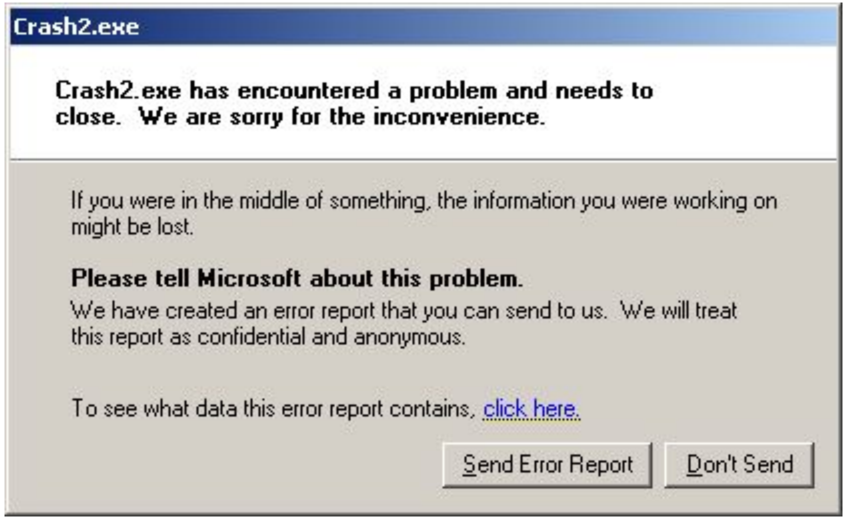

Changelog
@changelog
"Don't worry, our users will notify us if there's a problem"

10:03 AM · Jun 8, 2019

Chaos Experiments

Microsoft
Windows 95
Final Beta Release

Crash Telemetry


Crash2.exe

Crash2.exe has encountered a problem and needs to close. We are sorry for the inconvenience.

If you were in the middle of something, the information you were working on might be lost.

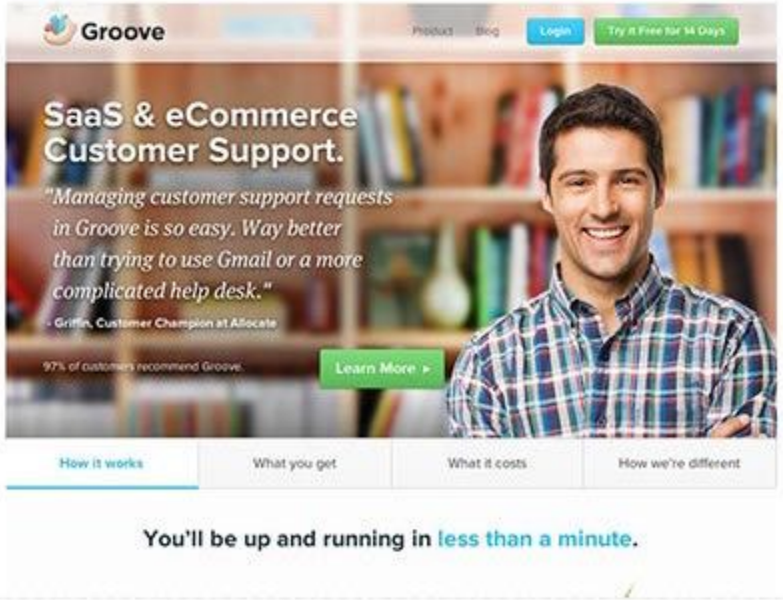
Please tell Microsoft about this problem.

We have created an error report that you can send to us. We will treat this report as confidential and anonymous.

To see what data this error report contains, click here.

A/B Testing

Original: 2.3%



Groove

Product Blog Login Try it Free for 14 Days

SaaS & eCommerce Customer Support.

"Managing customer support requests in Groove is so easy. Way better than trying to use Gmail or a more complicated help desk."

- Griffin, Customer Champion at Allocate

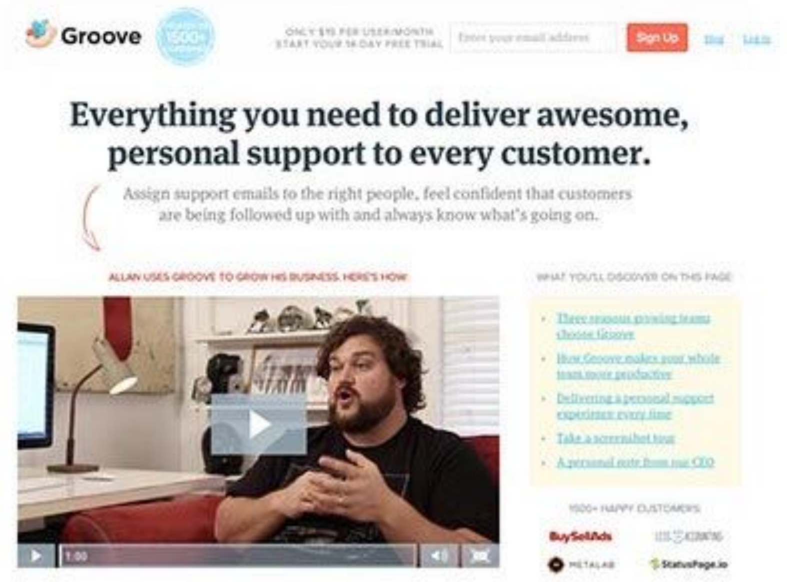
97% of customers recommend Groove.

Learn More ▸

How it works	What you get	What it costs	How we're different

You'll be up and running in less than a minute.

Long Form: 4.3%



Groove

ONLY $15 PER USER/MONTH
START YOUR 14-DAY FREE TRIAL

Enter your email address

Sign Up Blog Log in

Everything you need to deliver awesome, personal support to every customer.

Assign support emails to the right people, feel confident that customers are being followed up with and always know what's going on.

ALLAN USES GROOVE TO GROW HIS BUSINESS. HERE'S HOW

WHAT YOU'LL DISCOVER ON THIS PAGE

- Three reasons growing teams choose Groove
- How Groove makes your whole team more productive
- Delivering a personal support experience every time
- Take a screenshot tour
- A personal note from our CEO

1500+ HAPPY CUSTOMERS

BuySellAds METALAB StatusPage.io

WHAT IF...?

... we hand plenty of subjects for experiments

... we could randomly assign subjects to treatment and control group without them knowing

... we could analyze small individual changes and keep everything else constant

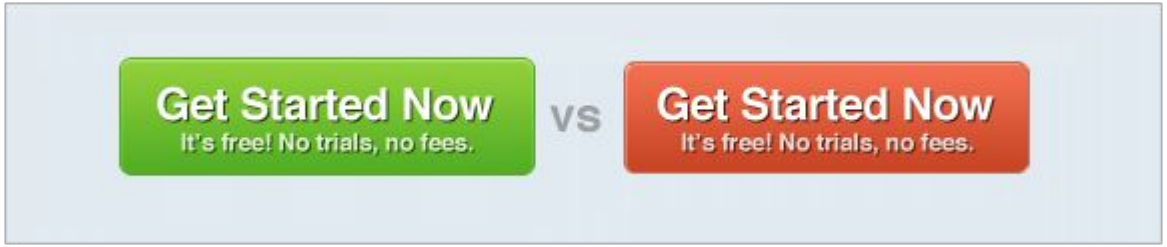
- ▶ Ideal conditions for controlled experiments

Experiment Size

With enough subjects (users), we can run many many experiments

Even very small experiments become feasible

Toward causal inference


Get Started Now
It's free! No trials, no fees.
vs
Get Started Now
It's free! No trials, no fees.

IMPLEMENTING A/B TESTING

Implement alternative versions of the system

- using feature flags (decisions in implementation)
- separate deployments (decision in router/load balancer)

Map users to treatment group

- Randomly from distribution
- Static user - group mapping
- Online service (e.g., launchdarkly, split)

Monitor outcomes per group

- Telemetry, sales, time on site, server load, crash rate

FEATURE FLAGS

Boolean options

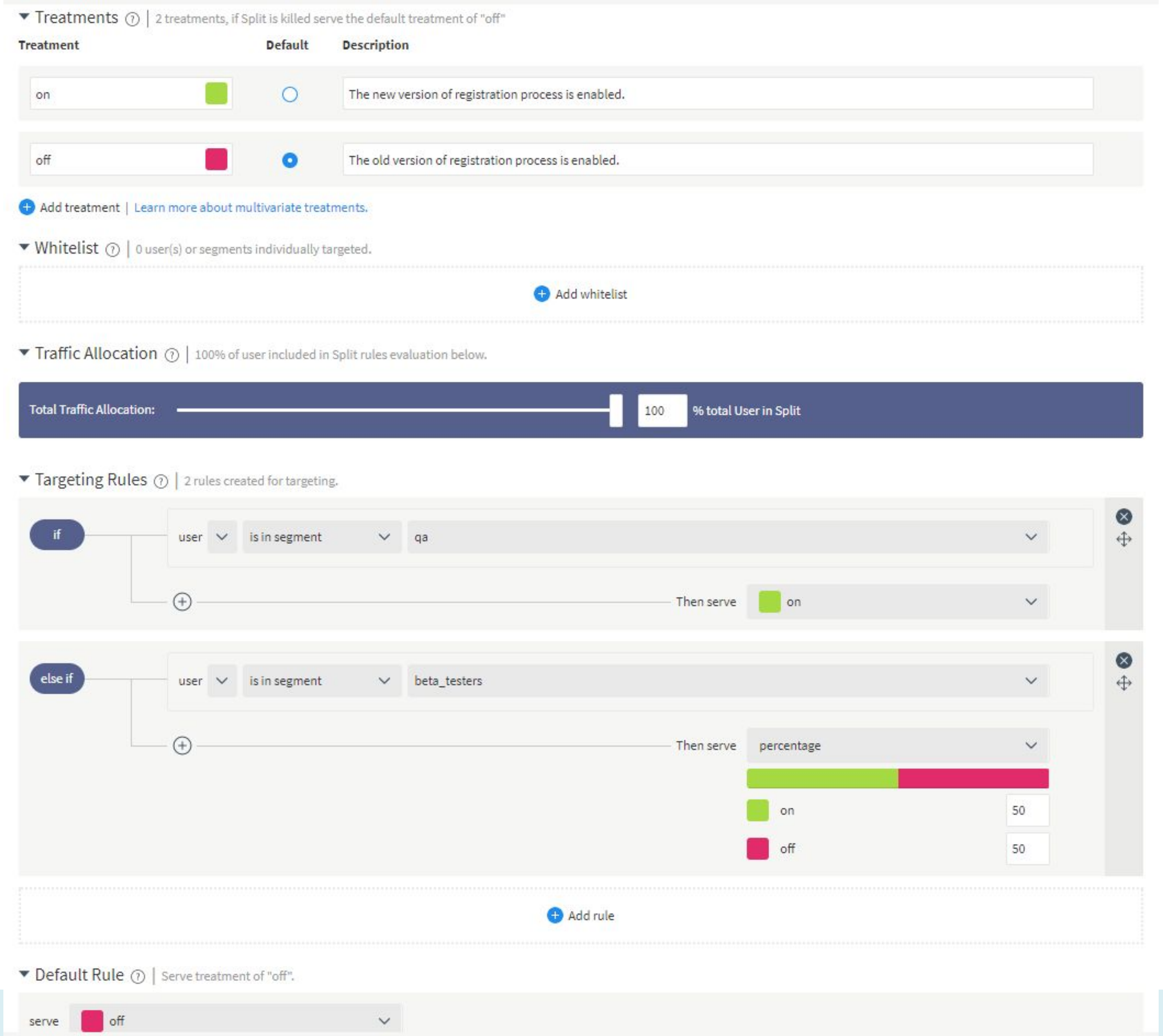
Good practices: tracked explicitly, documented, keep them localized and independent

External mapping of flags to customers

- who should see what configuration
- e.g., 1% of users sees one_click_checkout, but always the same users; or 50% of beta-users and 90% of developers and 0.1% of all users

```
if (features.enabled(userId, "one_click_checkout")) {
     // new one click checkout function
} else {
     // old checkout functionality
}
```

```
def isEnabled(user): Boolean = (hash(user.id) % 100) < 10
```



Treatments | 2 treatments, if Split is killed serve the default treatment of "off"

Treatment	Default	Description
on 🟩	○	The new version of registration process is enabled.
off 🟥	●	The old version of registration process is enabled.

Add treatment | Learn more about multivariate treatments.

Whitelist | 0 user(s) or segments individually targeted.

Add whitelist

Traffic Allocation | 100% of user included in Split rules evaluation below.

Total Traffic Allocation: 100 % total User in Split

Targeting Rules | 2 rules created for targeting.

if user is in segment qa
Then serve 🟩 on

else if user is in segment beta_testers
Then serve percentage

🟩 on	50
🟥 off	50

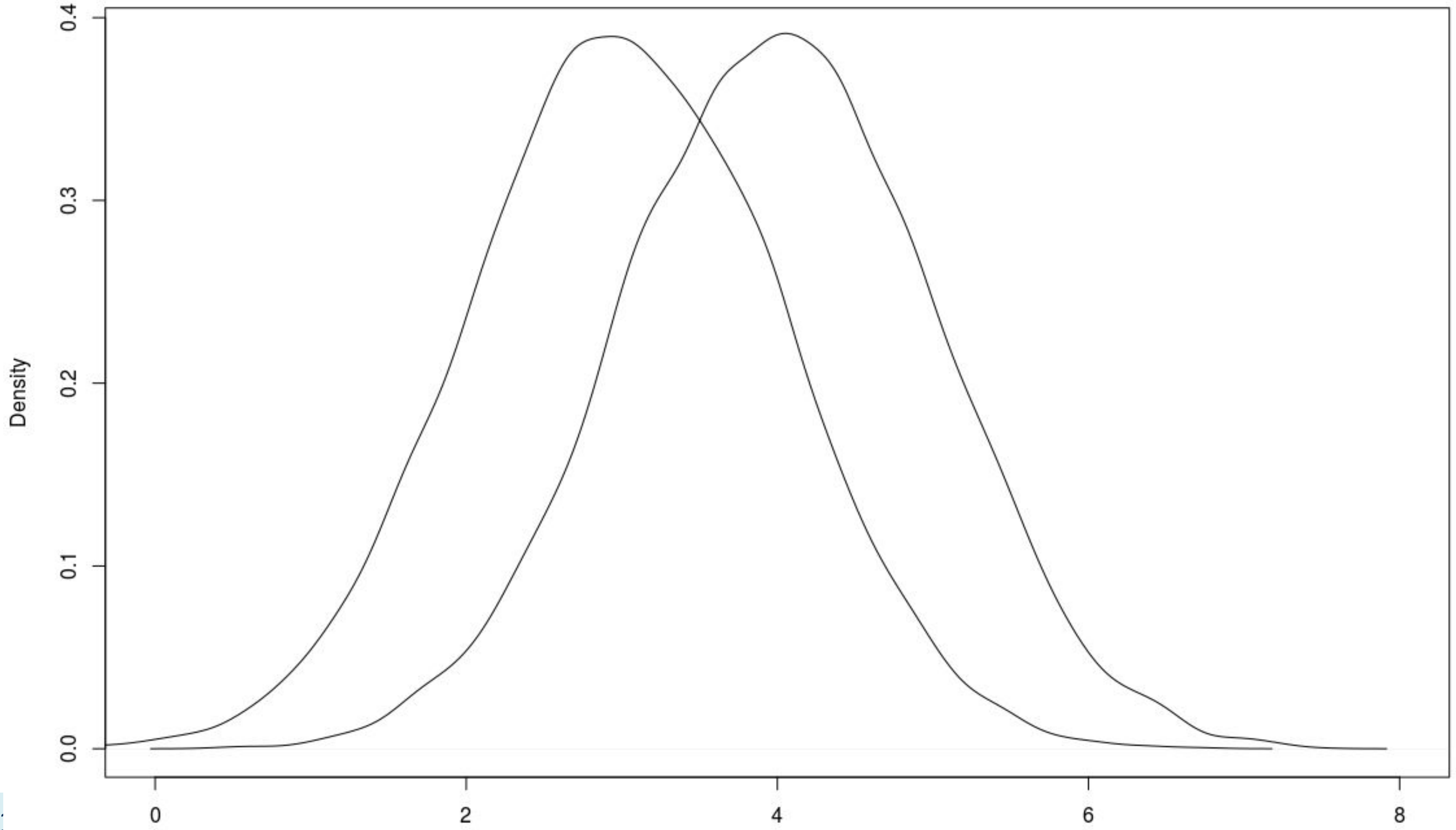
Add rule

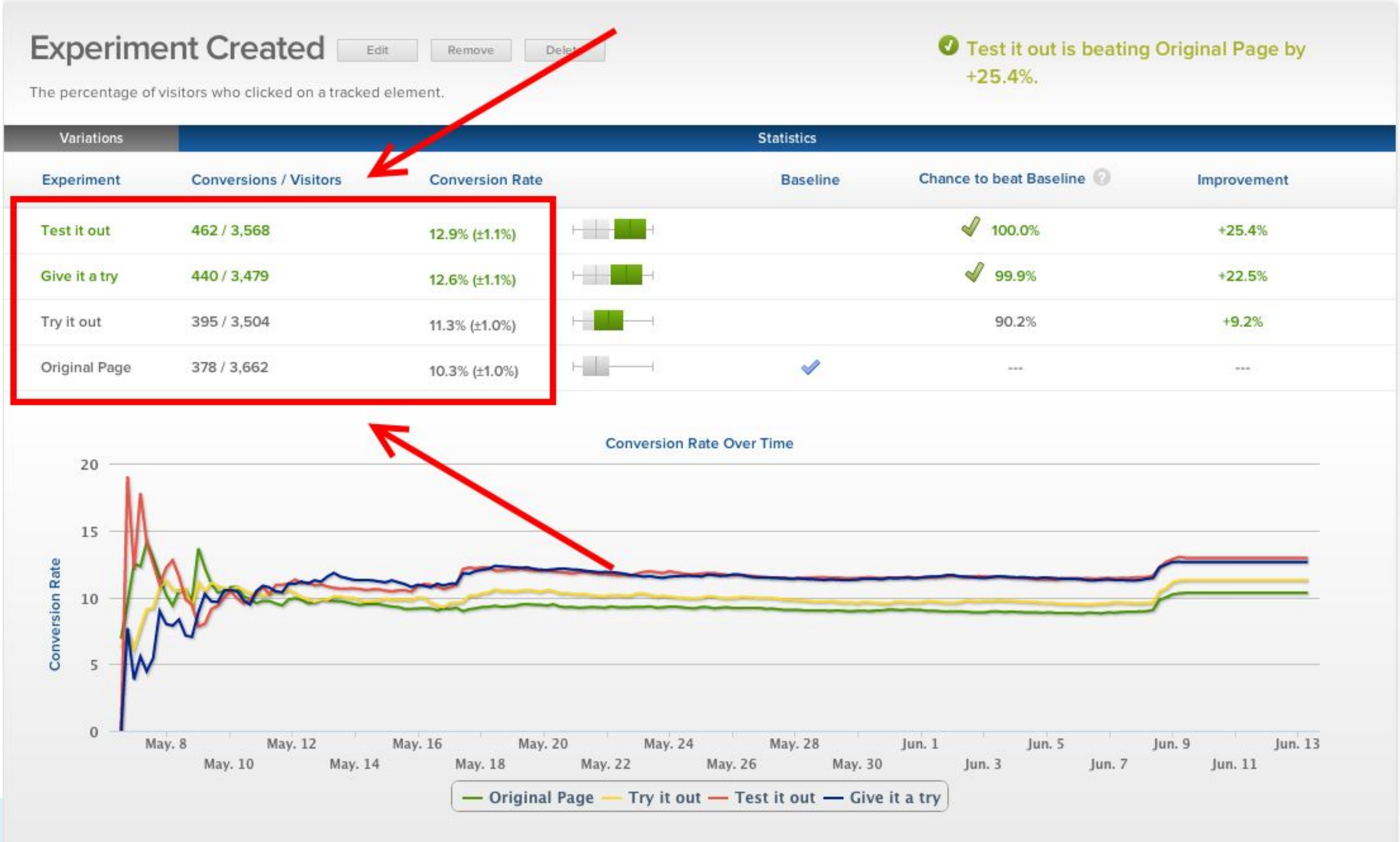
Default Rule | Serve treatment of "off".

serve 🟥 off

Comparing Outcomes

Group A	Group B
base game	game with extra god cards
2158 Users	10 Users
average 18:13 min time on site	average 20:24 min time on site


Density
0.0
0.1
0.2
0.3
0.4
0
2
4
6
8



Experiment Created

The percentage of visitors who clicked on a tracked element.

Test it out is beating Original Page by +25.4%.

Experiment	Conversions / Visitors	Conversion Rate	Baseline	Chance to beat Baseline	Improvement
Test it out	462 / 3,568	12.9% (±1.1%)		✓ 100.0%	+25.4%
Give it a try	440 / 3,479	12.6% (±1.1%)		✓ 99.9%	+22.5%
Try it out	395 / 3,504	11.3% (±1.0%)		90.2%	+9.2%
Original Page	378 / 3,662	10.3% (±1.0%)	✓	---	---

The Morality Of A/B Testing

Josh Constine @joshconstine / 11:50 PM EDT • June 29, 2014 Comment

We don't use the "real" Facebook. Or Twitter. Or Google, Yahoo, or LinkedIn. We are almost all part of experiments they quietly run to see if different versions with little changes make us use more, visit more, click more, or buy more. By signing up for these services, we technically give consent to be treated like guinea pigs.

But this weekend, Facebook stirred up controversy because one of its data science researchers published the results of an experiment on 689,003 users to see if showing them more positive or negative sentiment posts in the News Feed would affect their happiness levels as deduced by what they posted. The impact of this experiment on manipulating emotions was tiny, but it

Canary Releases

Canary Releases

Testing releases in production

Incrementally deploy a new release to users, not all at once

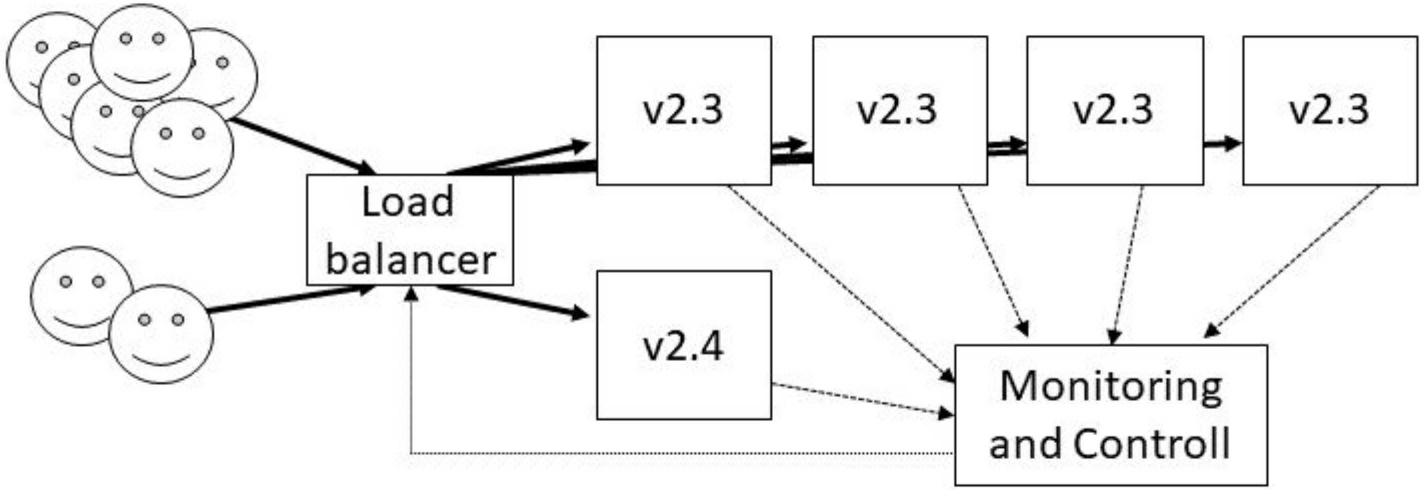
Monitor difference in outcomes (e.g., crash rates, performance, user engagement)

Automatically roll back bad releases

Technically similar to A/B testing

Telemetry essential

Canary Releases



Canary Releases at Facebook

Phase 0: Automated unit tests

Phase 1: Release to Facebook employees

Phase 2: Release to subset of production machines

Phase 3: Release to full cluster

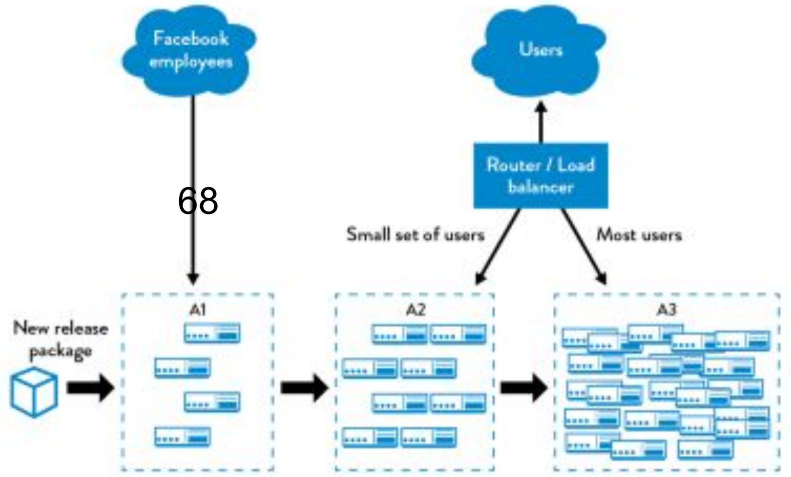
Phase 4: Commit to master, rollout everywhere

Monitored metrics: server load, crashes, click-through rate

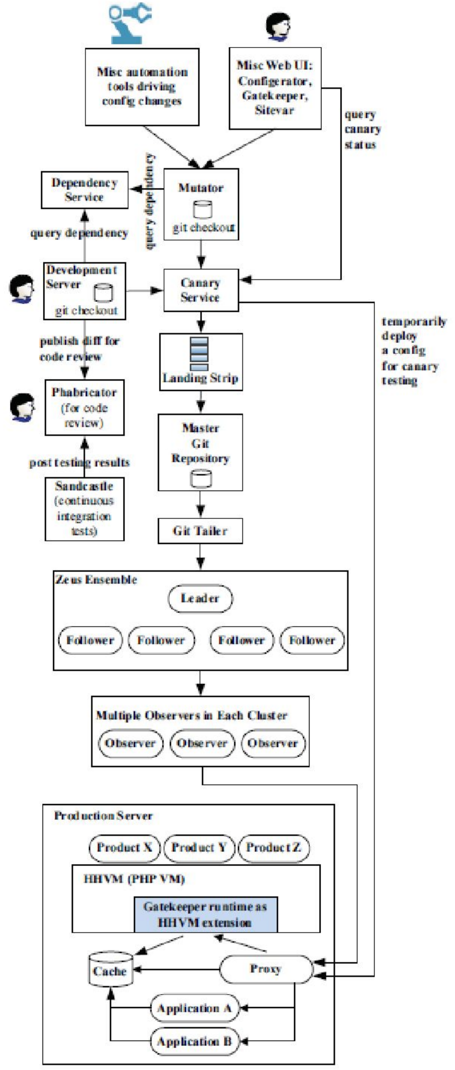
Further readings: Tang, Chunqiang, Thawan Kooburat, Pradeep Venkatachalam, Akshay Chander, Zhe Wen, Aravind Narayanan, Patrick Dowell, and Robert Karl. Holistic configuration management at Facebook. In Proceedings of the 25th Symposium on Operating Systems Principles, pp. 328-343. ACM, 2015. *and* Rossi, Chuck, Elisa Shibley, Shi Su, Kent Beck, Tony Savor, and Michael Stumm. Continuous deployment of mobile software at facebook (showcase). In Proceedings of the 2016 24th ACM SIGSOFT International Symposium on Foundations of Software Engineering, pp. 12-23. ACM, 2016.

Real DevOps Pipelines are Complex

- Incremental rollout, reconfiguring routers
- Canary testing
- Automatic rolling back changes



Chunqiang Tang, Thawan Kooburat, Pradeep Venkatachalam, Akshay Chander, Zhe Wen, Aravind Narayanan, Patrick Dowell, and Robert Karl. [Holistic Configuration Management at Facebook](). Proc. of SOSP: 328--343 (2015).



Chaos Experiments

Summary

Increasing automation of tests and deployments

Containers and configuration management tools help with automation, deployment, and rollbacks

Monitoring becomes important

Many new opportunities for testing in production (feature flags are common)