Continuous Integration at Google Scale

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Developer Infrastructure

Google Speed and Scale

- >10,000 developers in 40+ offices
- 5000+ projects under active development
- 17k submissions per day (1 every 5 seconds)
- Single monolithic code tree with mixed language code
- Development on one branch - submissions at head
- All builds from source
- 20+ sustained code changes per minute with 60+ peaks
- 50% of code changes monthly
- 100+ million test cases run per day

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Google Overview

1. Continuous Integration Goals
2. Continuous Integration at Google
3. Practical Matters

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Google Continuous Integration

- Provide real-time information to build monitors
  - Identify failures fast
  - Identify culprit Changes
  - Handle flaky tests
- Provide frequent green builds for cutting releases
  - Identify recent green builds
  - Show results of all testing together
  - Allow release tooling to choose a green build
  - Handle flaky tests

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Google Continuous Integration (cont)

- Develop Safely
  - Sync to last green changelist
  - Identify whether change will break the build before submit
  - Submit with confidence
  - Handle flaky tests

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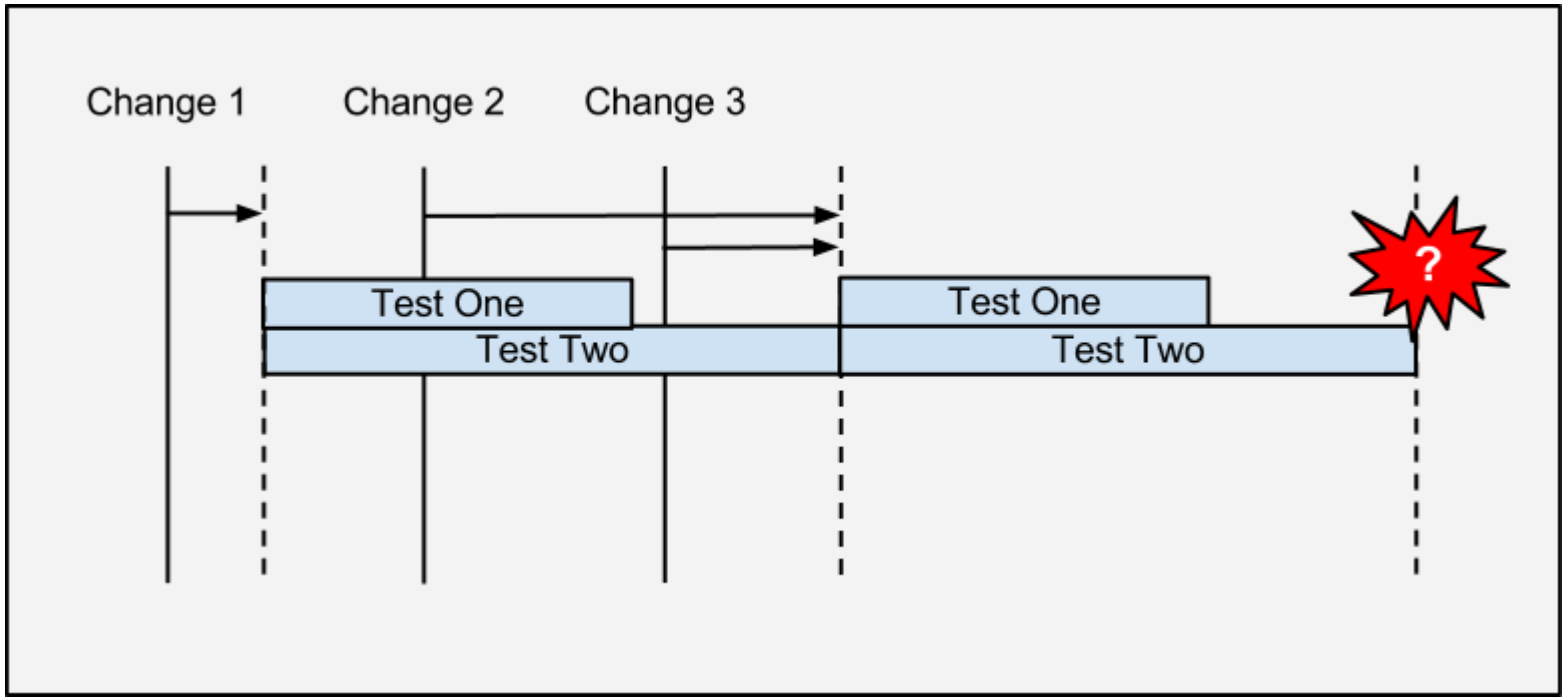
Google Standard Continuous Build System

- Triggers builds in continuous cycle
- Cycle time = longest build + test cycle
- Tests many changes together
- Which change broke the build?



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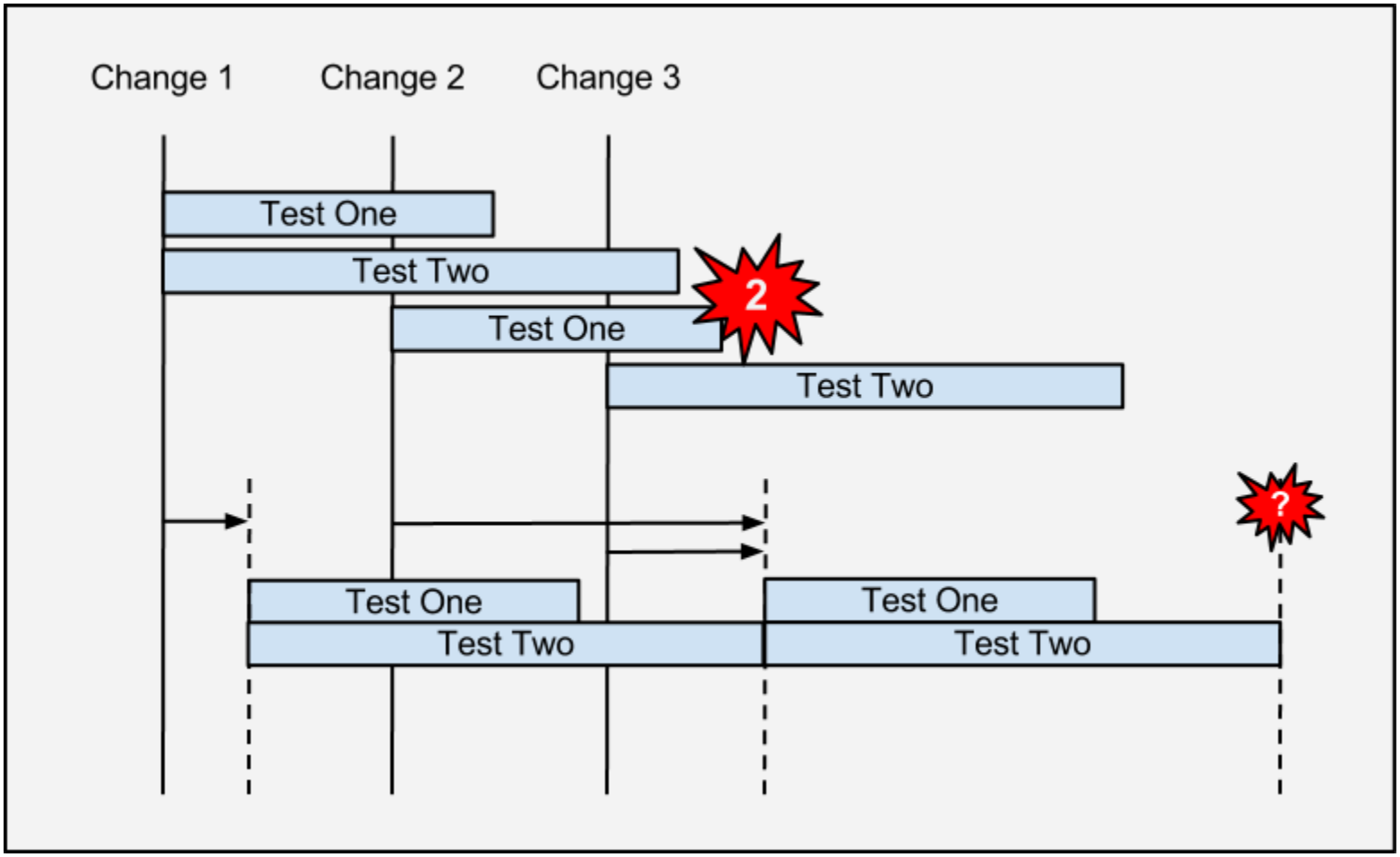
Google Continuous Build System

- Triggers tests on every change
- Uses fine-grained dependencies
- Change 2 broke test 1



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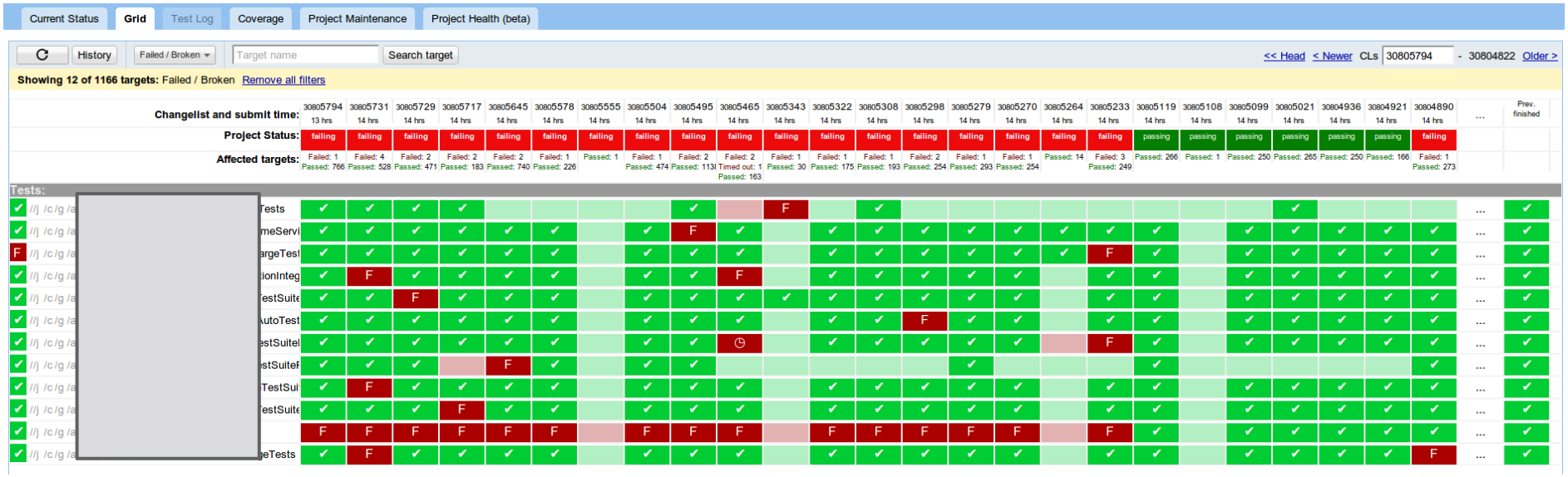
Google Continuous Integration Display



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Google Benefits

- Identifies failures sooner
- Identifies culprit change precisely
  - Avoids divide-and-conquer and tribal knowledge
- Lowers compute costs using fine grained dependencies
- Keeps the build green by reducing time to fix breaks
- Accepted enthusiastically by product teams
- Enables teams to ship with fast iteration times
  - Supports submit-to-production times of less than 36 hours for some projects

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Google Costs

- Requires enormous investment in compute resources (it helps to be at Google) grows in proportion to:
  - Submission rate
  - Average build + test time
  - Variants (debug, opt, valgrind, etc.)
  - Increasing dependencies on core libraries
  - Branches
- Requires updating dependencies on each change
  - Takes time to update - delays start of testing

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Developing Safely - presubmit

- Makes testing available before submit
- Uses fine-grained dependencies
  - Recalculate any dependency changes
- Uses same pool of compute resources at high priority
- Avoids breaking the build
- Captures contents of a change and tests in isolation
  - Tests against head
  - Identifies problems with missing files
- Integrates with
  - submission tool - submit iff testing is green
  - Code Review Tool - results are posted to the review thread

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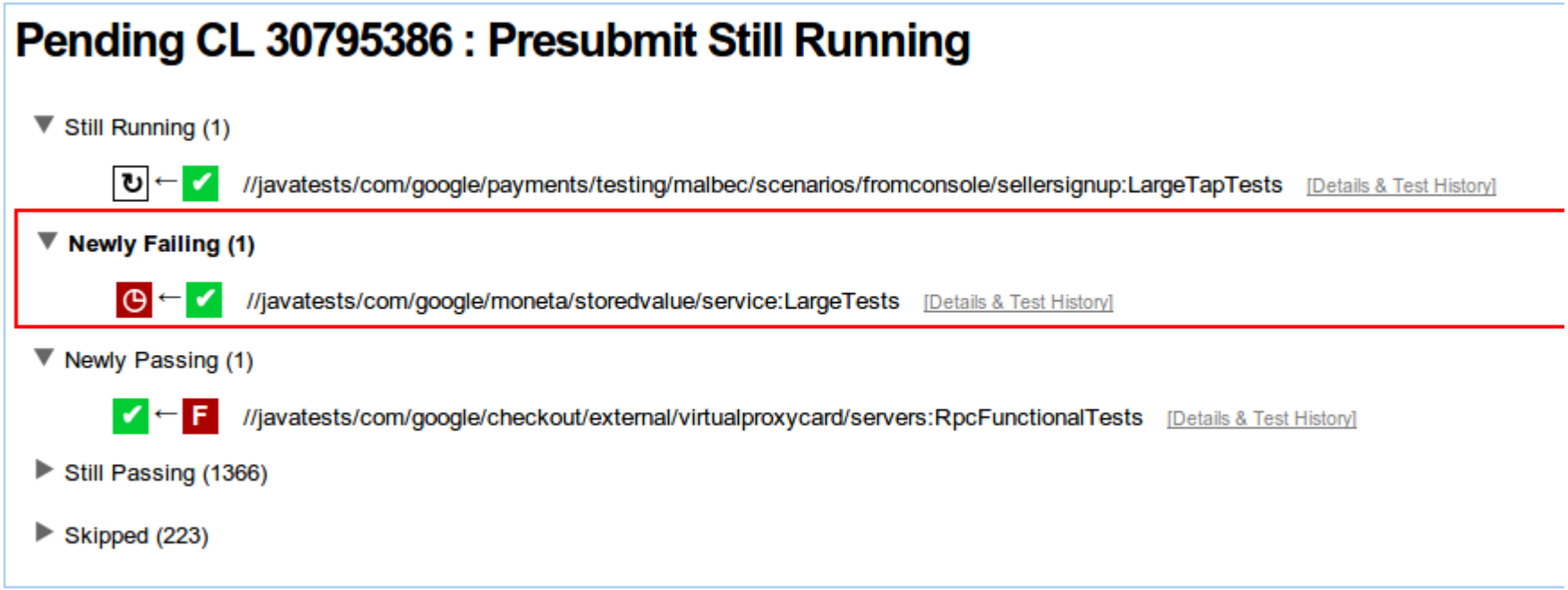
Example Presubmit Display



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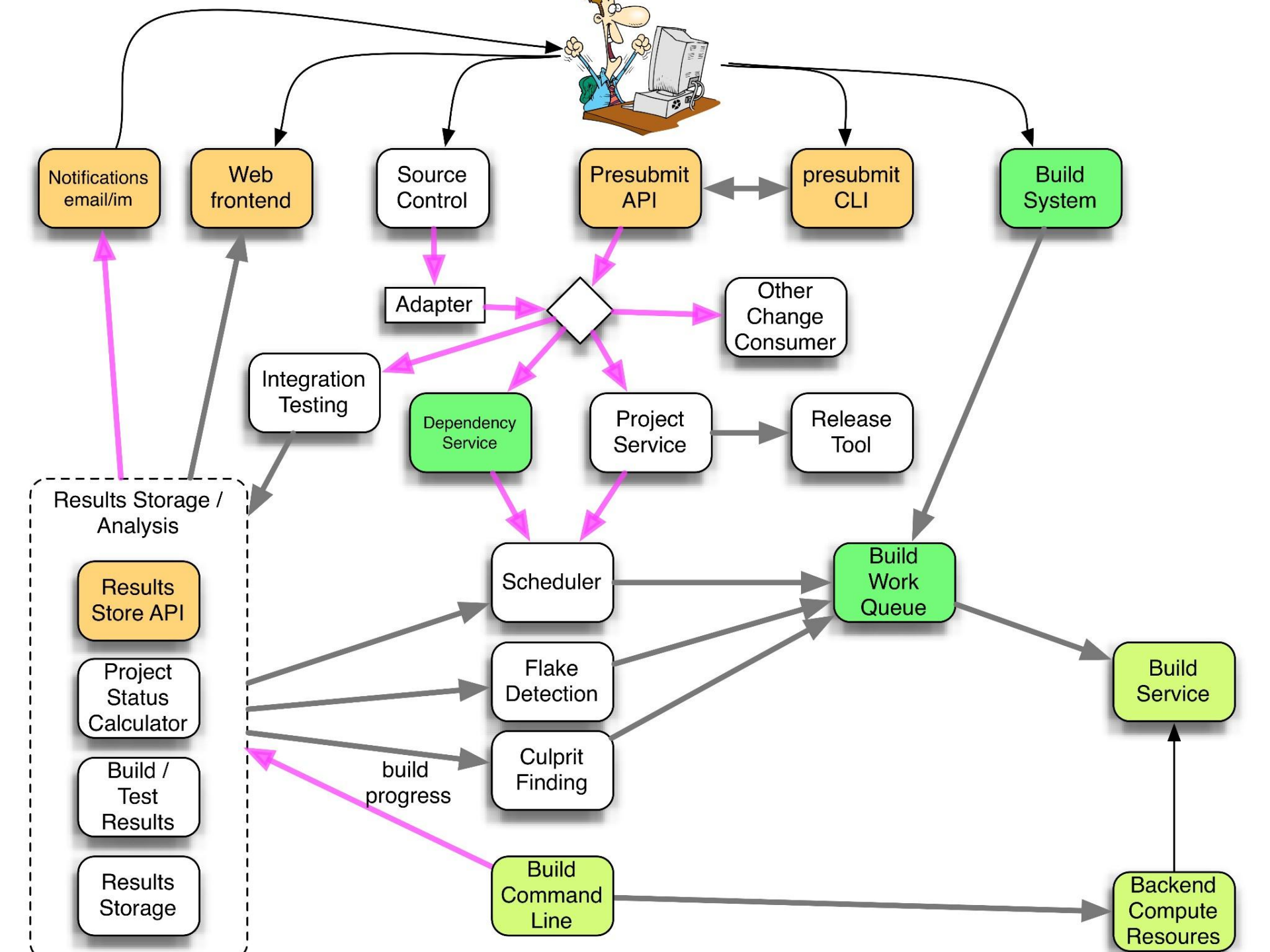
Notifications email/im
Web frontend
Source Control
Presubmit API
presubmit CLI
Build System
Adapter
Other Change Consumer
Integration Testing
Dependency Service
Project Service
Release Tool
Results Storage / Analysis
Results Store API
Project Status Calculator
Build / Test Results
Results Storage
Scheduler
Build Work Queue
Flake Detection
Culprit Finding
build progress
Build Service
Build Command Line
Backend Compute Resoures

Practical Matters - Flaky Tests

- System assumes tests pass or fail reliably given code
  - Tests that don't have this property are "flaky"
- Sources of test flakiness:
  - Infrastructure
    - machine failure
    - environment / setup problems
    - leakage - one test impacting another
    - Overloading resources
  - Tests
    - race conditions
    - external dependencies
    - timeouts
  - Code-under-test
    - memory problems
    - order dependence (e.g. hash tables)

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Flaky Tests (cont)

- Causes
  - Inability to find changes breaking the build - false positives
  - Inability to identify green builds for releases
  - Wasted work for build monitors
  - Wasted compute resources
  - Inappropriately failing presubmits - wasting developer time
- Solutions (Google does all of these):
  - Fix them!!!
    - Difficult - requires developer time
  - Hide them
    - Retry causing delays
    - Identify infrastructure flakes
    - Use metrics to ignore
  - Track them
    - Provide metrics to prioritize fix / hide

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Practical Matters - Test Growth

- Sources of growth in test execution time
  - More developers = increased submission rate
  - More tests
  - Longer running tests
  - Tests consuming more resources (threading)

- Examine the growth trends
  - Predict compute needs
  - Look for any build system features required

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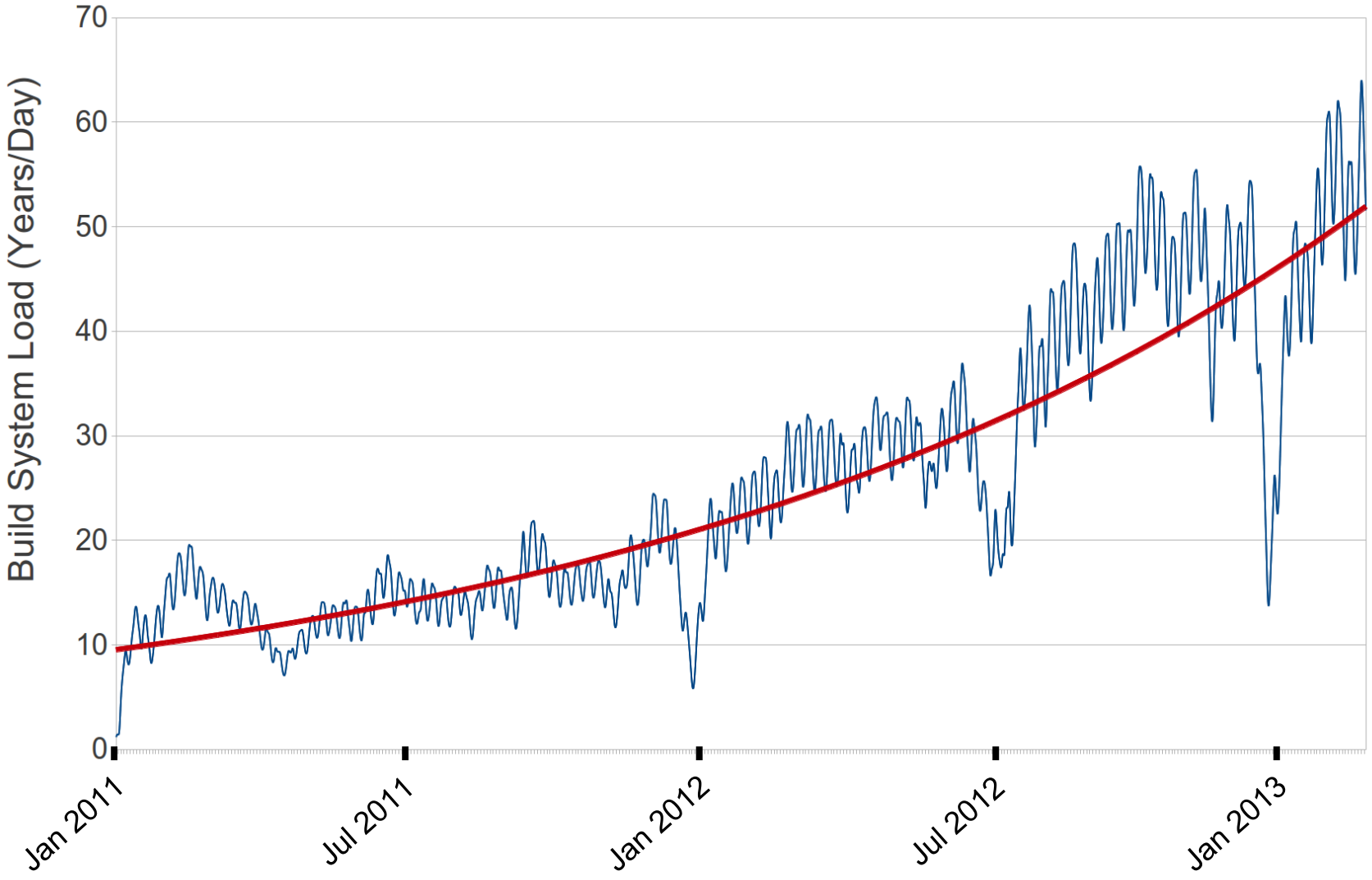
Build / Test Compute Resources



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Test Growth

- Problems
  - Quadratic execution time growth
  - Ultimately cannot run every affected test @ every change
  - Low latency results still top requirement

- Solution: Just in time scheduling (JIT)

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Google TAP

Continuous Integration:

- Run every test affected at ~~every changelist.~~ JIT as often as possible

In Production:

- Build and run tests concurrently on Google's distributed build and test backend.

JIT Scheduling

Schedule tests to run only when system has capacity.

Produce project-wide results at periodic changelists.

Same User Experience; Lower Cost

Culprit finding

- Failures / breaks between changes may be more difficult to localize to the offending change.
- **Short-term:** Command-line tool to find culprits
- **Longer Term**: Integrated automatic culprit finding

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Same User Experience; Lower Cost

Flaky Tests

- Tests which only pass some of the time could cause fewer green statuses for projects.
- **Short Term**: Optionally retry failed tests
- **Longer Term**: Tightly integrated flake mitigation and automatic / manual re-running of suspected flakes

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Q & A

For more information:

- http://google-engtools.blogspot.com/2011/06/testing-at-speed-and-scale-of-google.html
- http://www.youtube.com/watch?v=b52aXZ2yi08
- http://www.infoq.com/presentations/Development-at-Google
- http://google-engtools.blogspot.com/
- http://misko.hevery.com/2008/11/11/clean-code-talks-dependency-injection/
- https://www.youtube.com/watch?v=KH2_sB1A6lA&feature=youtube_gdata_player

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