CERN School of Computing

Testing methods and tools for large scale distributed systems

Ramon Medrano Llamas
CERN

Inverted CERN School of Computing, 25-26 February 2013

CERN School of Computing

Disclaimer

CERN School of Computing

Crafting (good) software

Life of a distributed system

CERN School of Computing

We were so happy in the 80s…

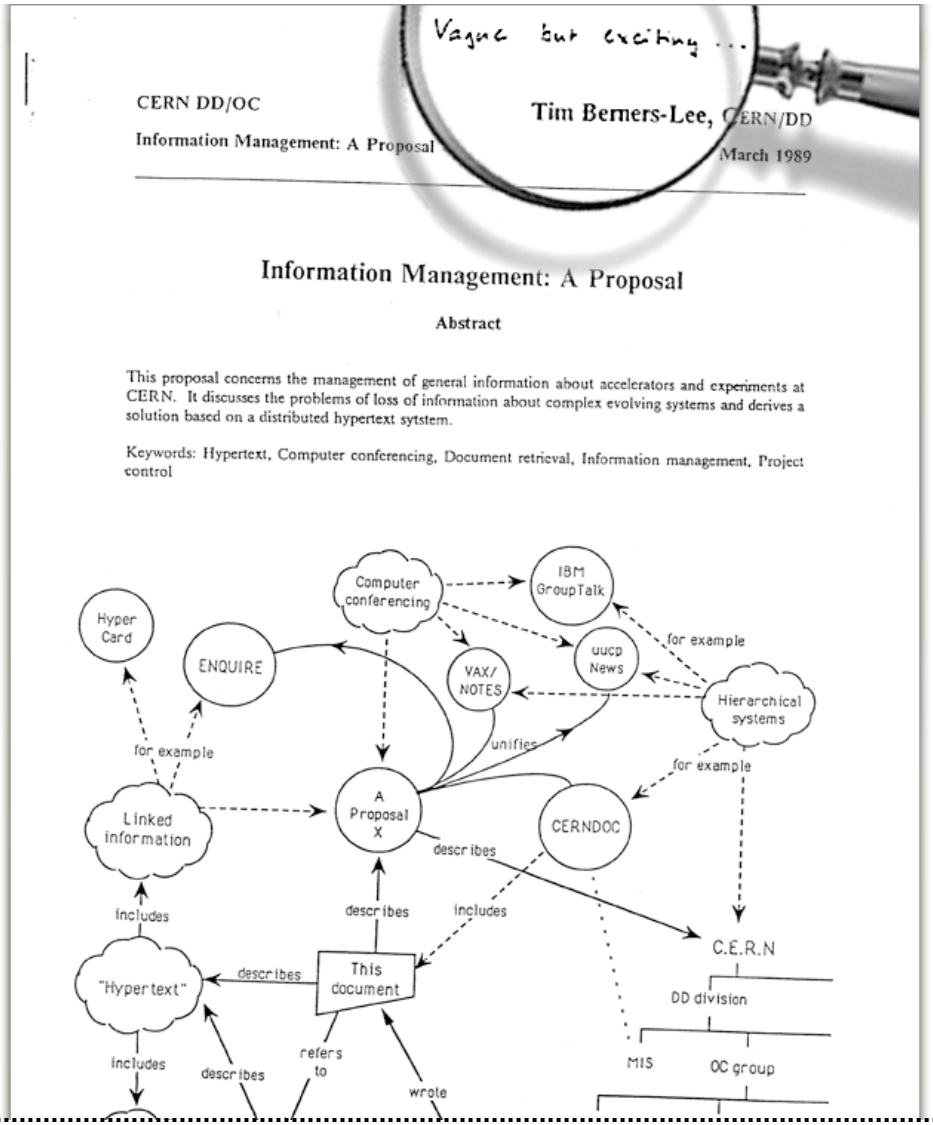
- **One platform.**
- **One codebase.**
- **One viewport.**
- **Release cycles of year(s).**

Cray X-MP 48 (ca. 1988)

CERN School of Computing

And then, some day…

- **2.4 billion users**
- **566% growth YoY**
  - 2000-2012
- **Zillions of devices**
  - 10 bn by 2016
  - |Mobile| > |Desktop|
  - 260 EiB/year
    - 66 bn DVDs


Vague but exciting ...

CERN DD/OC

Information Management: A Proposal

Tim Berners-Lee, CERN/DD

March 1989

Information Management: A Proposal

Abstract

This proposal concerns the management of general information about accelerators and experiments at CERN. It discusses the problems of loss of information about complex evolving systems and derives a solution based on a distributed hypertext sytstem.

Keywords: Hypertext, Computer conferencing, Document retrieval, Information management, Project control

***"Information Management: A Propsal"*, Tim Berners-Lee, March 1989**

Source: CERN, W3C, Cisco

CERN School of Computing

The rise of distributed

- **Computer networks vs. distributed systems.**
- **Latency vs. throughput.**
- **Batch vs. real-time.**
- **Highly vs. loosely coupled.**
- **Committee vs. *de facto* standard.**
- **Over architected vs. simple.**

CERN School of Computing

Sadly, we…

- **As programmers:**
  - We are not smart enough…
  - We are lazy…
  - We tend to not think globally…
  - We don't speak with others…
  - We don't like to learn new stuff…
  - We love politics so damn much…

  - Thus, we cannot exploit all the computing resources we have.
  - Neither we can make software run reliably

CERN School of Computing

Wait a minute…

- **If we are too bad:**
  - How the LHC can generate aprox. 15 PiB/year?
  - How Gmail can have 425 million users?
  - How Facebook can have 1.01 billion users?
  - How BOINC could averaged 7.28 PFLOPS in 2012?

  - Obviously, we can do nifty stuff.
  - But we are far, by a long shot, from being efficient.
  - Also, quality is a huge concern.

Source: CERN, Google, Facebook

CERN School of Computing

Introduction to software testing

- **A bug can be proof, but not the absence of it.**
- **…**
- **Wait…**
- **I believe that I studied this at the university…**
- **<u>So, why you don't test your stuff?</u>**

CERN School of Computing

Quality

- **What the f**k is quality?**
  - "Quality can have two meanings:
    a) The characteristics of a product or service that bear on its ability to satisfy stated or implied needs
    b) A product or service free of deficiencies."

American Society for Quality

- **Quality ≠ Test**
  - "Get it right from the beginning or you've created a permanent mess."

James Whittaker

- **Measurement**
  - "A science is as mature as its measurement tools."

Louis Pasteur

CERN School of Computing

Quality management

- **Quality management must target:**
  - Reliability.
  - Efficiency.
  - Security.
  - Maintainability.
- **Quality must be measured:**
  - Make something subjective objective.
  - If you cannot measure, you cannot optimize.
- **Some standard methods:**
  - ISO/IEC 9000 → ISO/IEC 25000:2005
  - ITIL
  - QFD, 6σ, ERD…

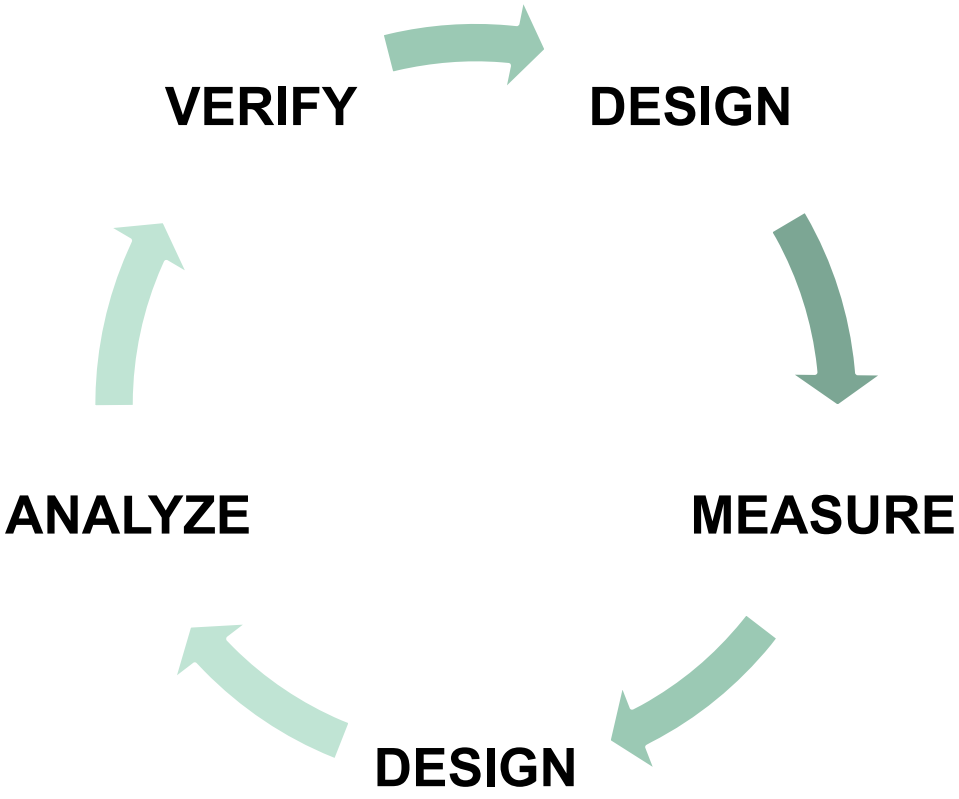
CERN School of Computing

SQuaRE

- **ISO25000: Software QUAlity Requirements and Evaluation**
- **2501n: Quality model:**
  - What is quality?
  - External: client's perception of the product.
  - Internal: business process improvements.
- **2502n: Quality measurement:**
  - What to measure?
  - Mathematical definition of quality.
- **2504n: Quality evaluation:**
  - How to measure a software product?

QFD / 6σ / ERD

- **Iterative process improvement:**
  - Statistical, predictive models → minimize variability
  - Introduce quality from the beginning.
  - Release early, release often™



CERN School of Computing

ITIL

- **Running a service is complex:**
  - How to coordinate suppliers and clients?
  - How to define expected service levels?
  - How to react to change?
- **ITIL is yet another standard for this:**
  - Service Operation.
  - Service Levels.
  - Change management.

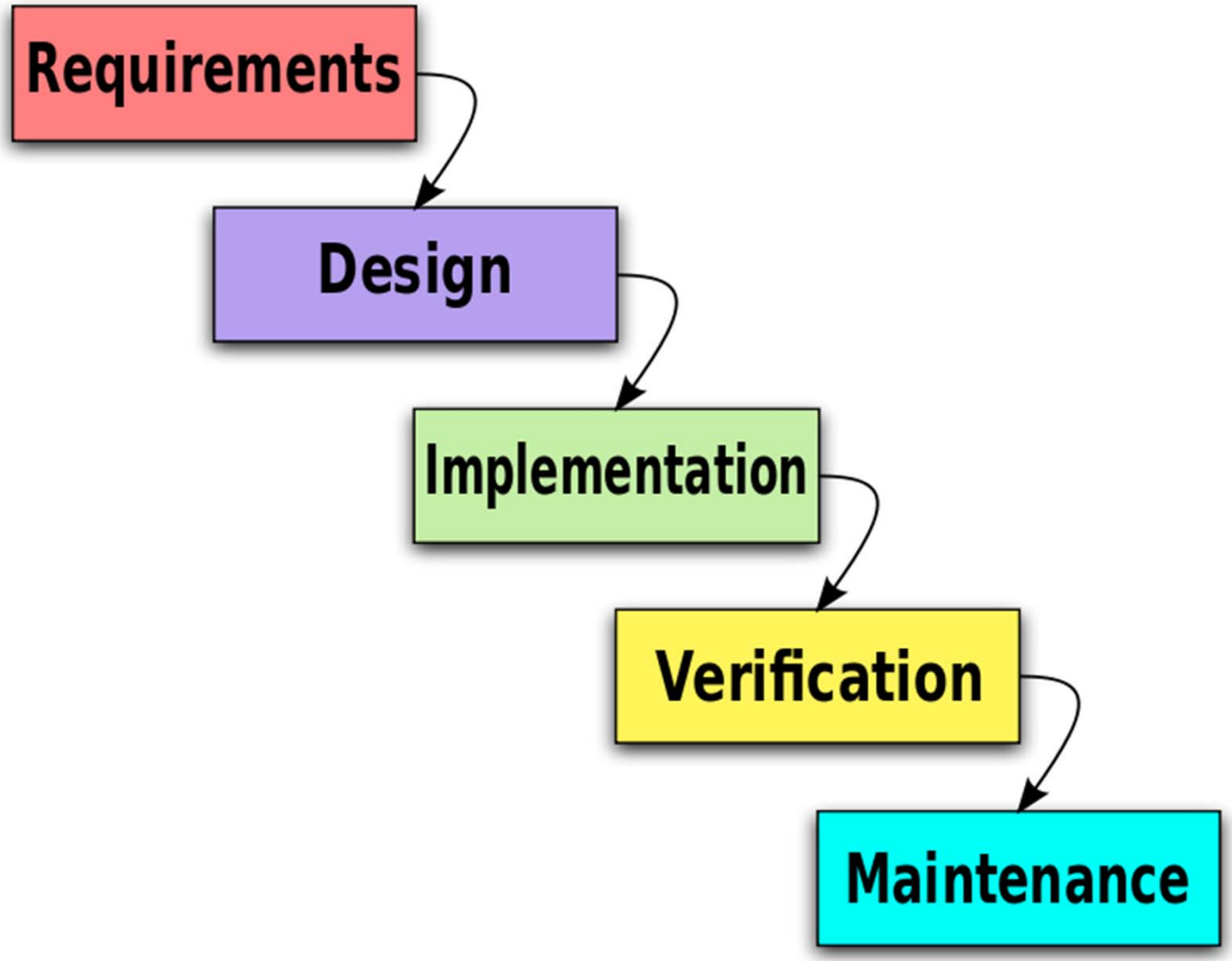
CERN School of Computing

Methodologies. Wat?

Life of a bug

CERN School of Computing

A good old friend



Source: Wikipedia

CERN School of Computing

A new method

Let engineers be engineers

- **No bureaucracy.**
- **Focus on the user**
  - And the rest will follow.
- **Good is never enough.**

Get Shit Done™

- **We love to build stuff.**
- **Do one thing**
  - And do it well.
- **And to ship it.**

1. **Build a perfect team.**
2. **Build stuff**
   1. Plan.
   2. Build.
   3. Go to 1.1.

CERN School of Computing

Test Driven Development

- **Sounds harder than it is:**
  - Just make tests first…
  - And you get the best contracts for the software.
  - Less coupling and nicer designs.
  - Requires testing automation.

1. **Choose a component.**
2. **Write a test.**
3. **Make sure that it fails.**
4. **Fix the stuff.**
5. **Eliminate redundancies.**

CERN School of Computing

The perfect team

- **Feature development:**
  - Owned by software engineers.
- **Unit testing:**
  - Owned by software engineers. Yes.
- **Testing infrastructure and testability:**
  - Software engineers dedicated to this task.
  - Roughly 1 or 2 per team.
- **Test management, analysis and planning:**
  - Test manager (this guy is a software engineer as well).
  - Coordinates all the larger scale testing.
  - Might be the previous role.

CERN School of Computing

The perfect team

- **Quality comes from solid engineering**
  - Stop talking and go build things.
  - No meetings.
- **Don't hire too many testers**
  - Testing is owned by the entire team.
  - Is a culture, not a process.
  - Testers are software engineers. Yes.
- **There is not place to mediocrity**
  - Hiring good people is the base.
  - And keeping them challenged.

CERN School of Computing

The Agile wave

- **It is just a formalization of some old principles:**
  - We are humans.
  - Software that works.
  - Client matters.
  - Change happens.
- **Look at:**
  - SCRUM,
  - Kanban,
  - Lean manufacturing.
- **Also**
  - Code and fix.

CERN School of Computing

SCRUM

- **Incremental development:**
  - Backlogs.
  - Scrum Master vs. Product Owner.
  - Sprints:
    - Produce something usable.

- **Testing in this scenario:**
  - Can be interleaved in each sprint.
  - Integration tests should be built incrementally.
  - Regression tests are fundamental.

CERN School of Computing

Tools for sprinting

- **Post-it + whiteboard:**
  - Very simple.
  - More powerful than one might expect.
- **JIRA + Greenhopper:**
  - CERN's choice.
  - Integrated with issue collection and SCM.
  - Custom workflows allow the integration of test and review.
  - Integration with Bamboo → Automatic deployments.
- **Microsoft Project:**
  - There is a plugin for SCRUM.

CERN School of Computing

How to nail testing?

- **Attribute, Component, Capability.**
- **This is a method to create:**
  - The design document.
  - Test plan.
  - Risk analysis.
- **In one process of 30 minutes:**
  - Should be done in a quick meeting.
  - Ideally, integrated in the backlog of the product.
  - You just need a spreadsheet for this.

CERN School of Computing

About the Design Document

- **It is the encyclopedia of your software:**
  - Involve testing and testers from the beginning.
  - Just do this document.
  - Avoid prose, this is not a novel:
    - Just bulleted lists and tables.
  - Make it worth to keep it updated.

Attributes, Components, Capabilities

- **An attribute:**
  - Sales people and managers have them.
  - They are… attributes.

  - e.g. A batch system:
    - Reliable.
    - Easy.
    - Generic.
    - Scalable.

Attributes, Components, Capabilities

- **A component:**
  - Engineers have them.
  - They are nouns.

  - e.g. A batch system:
    - Scheduler.
    - Worker node.
    - Job.
    - Queue.

CERN School of Computing

Attributes, Components, Capabilities

- **Capabilities:**
  - A subset of the A×C product.
  - They are verbs.
  - Looks like a nice description of requirements.

  - e.g. A batch system:
    - {Generic, Worker node}: Enables different types of jobs in each WN.
    - {Easy, Job}: Users are abstracted of the infrastructure.
    - {Reliable, Scheduler}: Supports n failures on the infrastructure.
    - {Scalable, Queue}: Allows O(x) users in parallel.
    - …

Attributes, Components, Capabilities

- **Risk analysis:**
  - You will test capabilities.
  - But not everything at once.
  - Add:
    - Impact ∈ {Minimal, Some, Considerable, Fatal}
    - Frequency ∈ {Rarely, Seldom, Occasionally, Often}
    - And you have a risk assessment.

$$\boldsymbol{Risk}_{(a,\,c)} = \sum_{C} \boldsymbol{Impact}_{(a,\,c,\,C)} \cdot \boldsymbol{Frequency}_{(a,\,c,\,C)}$$

CERN School of Computing

Attributes, Components, Capabilities

a × c = C	Scheduler	Worker node	Job	Queue
Reliable	19	6	9	15
Easy	2	3	15	6
Generic	9	15	10	6
Scalable	18	2	2	5

CERN School of Computing

Case study: AliEn mocking

- **Implements the full submit queue:**
  - Every changeset triggers a build
  - And a test pass.
- **The interesting thing at this poing is in the mocking:**
  - The systems sets up a entire grid in a node for testing:
    - A Storage Element
    - A Computing Element
    - Even central services.

CERN School of Computing

Legacy management

- **Legacy:**
  - Has its value.
  - Cost is rising quickly.
  - People don't know how it works.
- **It is not always easy:**
  - Try to move things up.
  - Virtualization can help…
    - Don't stack shit if possible.
  - Pay the technical debt:
    - Integrate on test strategies.
    - Integrate on deployment systems.

CERN School of Computing

Test certification

- **How do you progress on testing:**
  - Set some milestones in the form of levels.
- **Level 1:**
  - Continuous integration in place.
- **Level 2:**
  - Pre-commit smoke testing.
- **Level 3:**
  - All features covered by integration tests.
- **Level 4:**
  - No-nondeterministic testing.

CERN School of Computing

Test automation

Life of a changeset

CERN School of Computing

Test automation

- **A testing infrastructure must:**
  - Allow developers to get a unit test results immediately.
  - Allow developer to run all unit tests in one go.
  - Allow running tests for only the changed components.
  - Allow code coverage calculations.
  - Allow running unit tests for the changesets submitted.
  - Show dashboards of testing evolution.

CERN School of Computing

Test types

- **Unit test:**
  - Executes in less than 100 ms.
  - Test just a module.
- **Integration tests:**
  - Executes in less than 1 minute.
  - Test interaction between few modules.
- **System tests:**
  - Execute as quickly as possible.
  - You can test a functionality with mock data.

CERN School of Computing

Developing code

1. **Build the feature in a set of files that compile.**
2. **Build it as library target.**
3. **Write unit tests for that.**
4. **Automate the unit testing**
   1. A make rule…
   2. A CI profile…
5. **Run static analysis tools.**
6. **Now you can define a binary target and run the thing.**
7. **Send the changeset for review.**

CERN School of Computing

Pre-commit

- **SCM is not optional:**
  - It is the base of any test automation.
  - Subversion vs. Git.
    - They are both good.
    - No flames, please.
- **The pre-commit checks:**
  - A subset of the unit tests (“smoke tests”).
  - Never allow a commit without smoke compliance.

CERN School of Computing

The Code Review

- **The code review is well established in large companies:**
  - Other's view on your work.
  - Maximize readability.
  - Keeps code reusable and self-contained.

CERN School of Computing

Code review tools

- **Rietveld:**
  - A version of Mondrian.
  - Couples with Subversion.
- **Gerrit:**
  - Written in Java.
  - Couples with Git.
- **GitHub's pull requests:**
  - A distributed model based on Git.
- **More:**
  - Review Board, Mavelich

CERN School of Computing

Submit queue

- **The submit queue runs all the tests in each commit:**
  - Starts on a clean working copy.
  - Applies the changeset.
  - Runs the tests.
  - All of this in parallel with other change submissions.
- **If everything green:**
  - Deploy.

CERN School of Computing

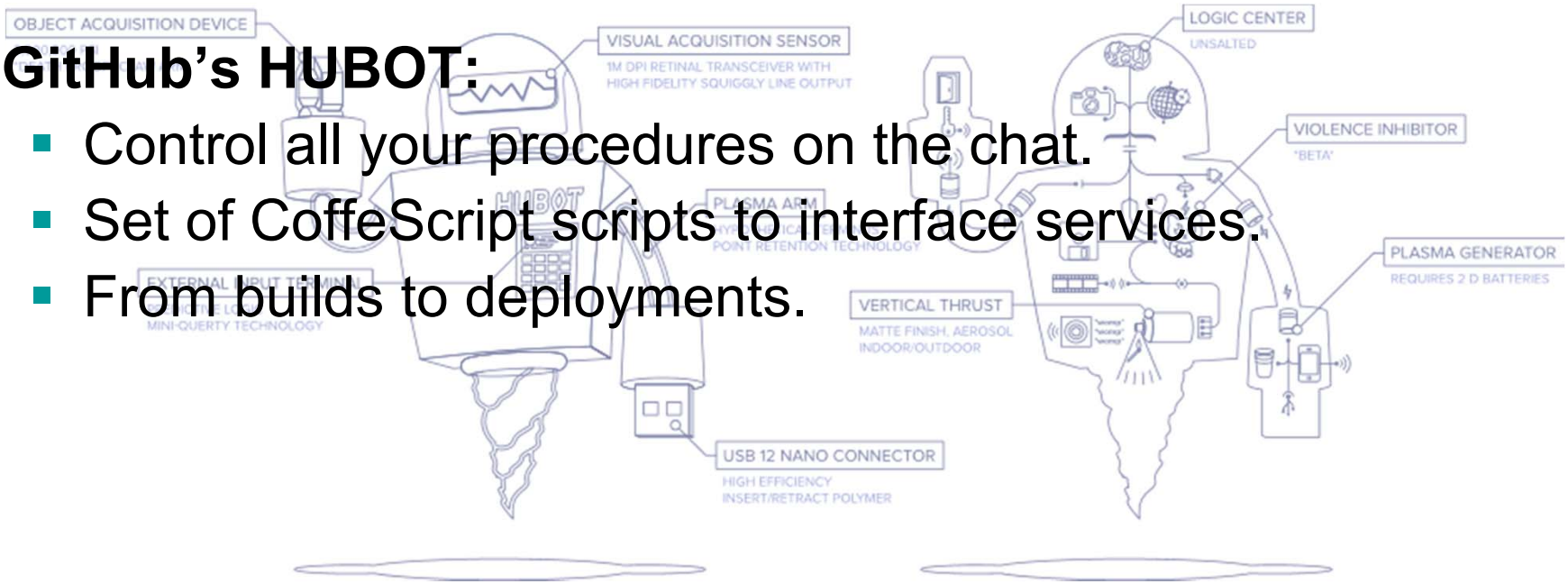
Release

- **Use different release channels:**
  - Canary
    - Nightly builds, for engineers and testers.
  - Alpha and Beta
    - For engaged users.
    - Make feedback submission easy for them!
  - Stable
    - Release for production.
- **This pipeline has to be autonomous.**

CERN School of Computing

Continuous Integration

- **A CI system helps implementing this:**
  - Jenkins
  - Travis
  - Bamboo
    - Integrated with JIRA & Co.
    - Interesting for CERN's case.
- **GitHub's HUBOT:**
  - Control all your procedures on the chat.
  - Set of CoffeScript scripts to interface services.
  - From builds to deployments.



CERN School of Computing

Case study: LHCbDirac

- **Using Jenkins for each build**
  - Automated build with dependency detection
- **Passes tests automatically**
  - After build succeeds
- **Static analysis through Coverity**
  - Automatic test coverage analysis
  - And static analysis checks

CERN School of Computing

Test analysis

- **Who to blame in case of bug:**
  - The entire team has failed.
- **Statistics:**
  - Detect background bugs.
  - Code coverage analysis.
- **Provide dashboards:**
  - Needed to control the automation.

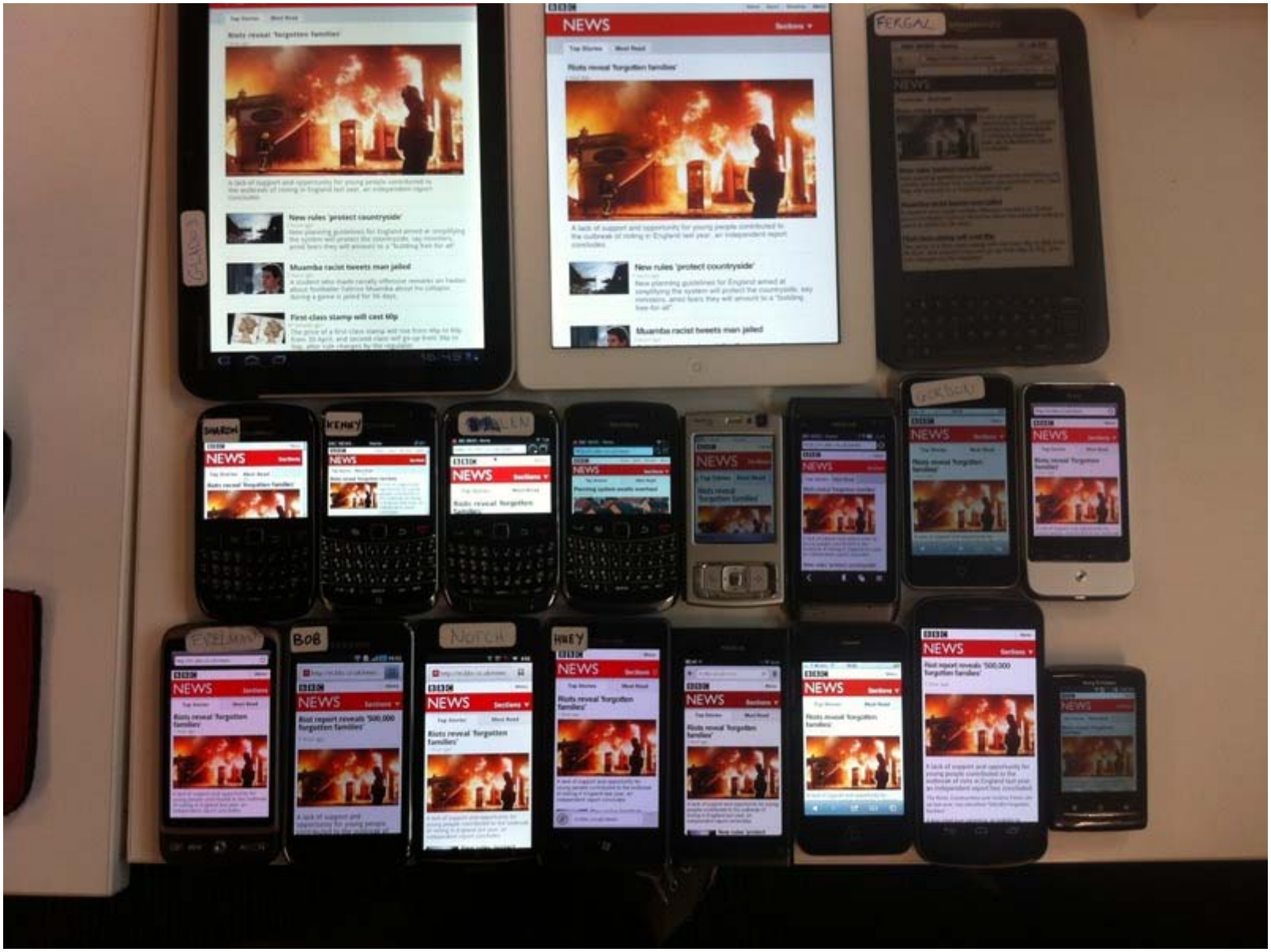
CERN School of Computing

Case study: CORAL/COOL

- **Functional testing:**
  - Automatic unit testing
  - On production platforms
    - GNU/Linux + OS X
- **Non-functional testing:**
  - Performance probes against the Oracle DB
  - Code coverage measured with Coverity

CERN School of Computing

Compatibility labs



CERN School of Computing

UX testing automation

- **Should be automated:**
  - In order to be regressed.
- **Selenium:**
  - JS testing on the browser.
- **WebDriver:**
  - A proposal of a API to automate testing.
- **Bots:**
  - Google's approach for validation of Chrome.

CERN School of Computing

Crowd sourcing

- **Release a beta version:**
  - People love them.
  - Make easy to send feedback.
  - Instantly, free testing:
    - Real environments,
    - real use cases,
    - more difficult to repeat.
  - Use the proper channels.
- **Amazon's Mechanical Turk**
  - Used by Twitter for search quality.

CERN School of Computing

Autonomic Computing

Life of an issue

CERN School of Computing

Autonomic systems

- **If every time things break the same way:**
  - Just make the system auto recover.
  - If you run on an IaaS, you have much already done.
- **Autonomic Computing:**
  - A vision from IBM Research.
  - 2003!
- **Systems:**
  - Self-configure.
  - Self-heal.
  - Self-optimize.
  - Self-protect.

CERN School of Computing

Self-configure

- **Automatic application of configurations.**
- **Automatic configuration of software.**
- **Automatic integration in network environments.**

- **Just set some policies and the rest follows.**

CERN School of Computing

Self-heal

- **Automatic recovery of failures.**
- **Automatic fail-over on upgrades.**
- **Automatic diagnose.**

- **Systems react to problems automatically.**

CERN School of Computing

Self-optimize

- **Automatic performance tuning.**
- **Automatic clean up.**
- **Automatic update.**

- **Learning and monitoring for machines, not humans.**

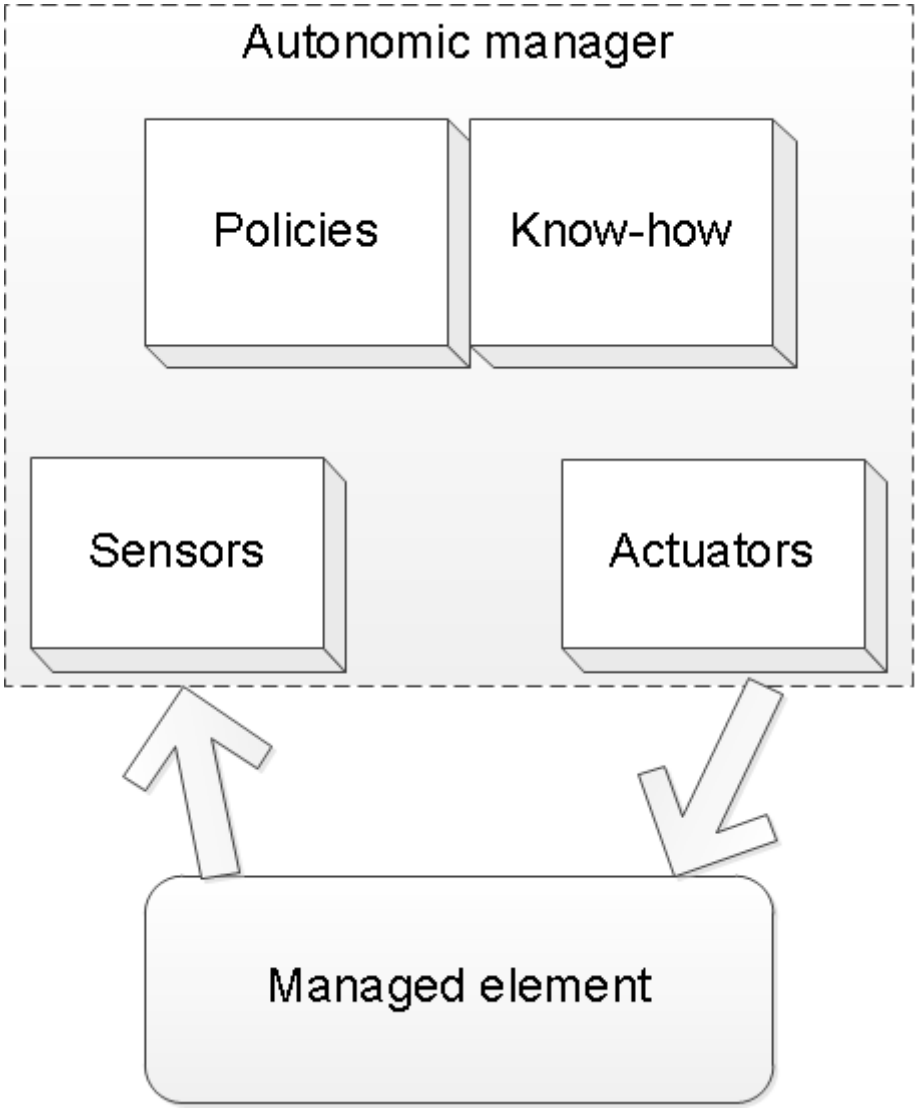
CERN School of Computing

Self-protect

- **Automatic protection against large-scale attacks.**
- **Anticipation of problems.**

- **Not only security issues, but failures of components…**

The orchestrator



Case study: The Agile Infrastructure

- **Renovation of tools at CERN:**
  - Go with the industry…
  - If they manage O(1,000,000)* machines, why not us?
- **A case of study for operations and development.**
- **A step closer to an autonomic system.**
- **Automation of operations via:**
  - Self-configuration.
  - Self-optimization.
- **In theatres this spring.**

* The Big O notation is clearly wrongly used here, but you get the idea.

CERN School of Computing

The DevOps way

- **Usually, there was a problem:**
  - Developers and operations were two like water and oil.
- **DevOps shifts responsibilities:**
  - Built quality into product first.
  - The team is responsible of project success, not some areas.
  - Break down barriers between departments.
  - Remember the Test-enabled team?
- **Requirements: CAMS**
  - Culture
  - Automation
  - Measurement
  - Sharing

CERN School of Computing

Implications

- **Reduced changes, more often.**
- **Tighter collaboration between stakeholders.**
- **Less risk on each deployment.**
  - Ideally, there are no deployments.
  - Makes the Autonomic Process closer.
- **Developers are in control. And operators.**

CERN School of Computing

Tools for Culture Change

CERN School of Computing

Tools for Self-configuration

- **Puppet:**
  - Very high momentum.
- **Chef:**
  - Very similar to Puppet.
- **The Foreman:**
  - A frontend for Puppet.
  - Can provision bare metal and cloud resources.
- **Marionette Collective:**
  - Orchestrator tool for Puppet.

CERN School of Computing

OpenStack

- **Is a cloud engine (IaaS).**
- **Started by RackSpace:**
  - Managing 79,000 machines as of 2011.
- **Offers:**
  - Compute: nova.
  - Object storage: swift, cinder.
  - Virtual networking: quantum.
  - Many more modules.
- **CERN's choice.**
  - And NASA's, HP's, Wikimedia's, Canonical's, Intel's…
  - There are other options: CloudStack, OpenNebula…

CERN School of Computing

Tools for measurement

- **Puppet reports.**
- **Splunk, New Relic, Logstash…**
- **Graphite:**
  - Integrate monitoring data from different sources.
- **Old friends:**
  - Nagios, Ganglia.
- **But #monitoringsucks.**
  - Clunky interfaces
  - Host centric
  - Tied hands

CERN School of Computing

Case study: perfsonar

- **While accessing data:**
  - Collect metrics of network performance.
  - Deploy point-to-point monitoring.
    - iperf
  - Detect slowness
  - Allows the introduction of Software Defined Network
    - Self-optimization!

CERN School of Computing

Live testing

Life of a distributed system (2)

CERN School of Computing

Live testing

- **Testing does not end on release:**
  - These systems need to be monitored,
  - and checked for availability.
  - The only way to do it is with active testing.
  - And it is a requirement of self-healing.
  - And can play a big role in self-optimization.
- **Approximations:**
  - Profiling, probing.
  - Monitoring.
  - Either case: be carful! You are playing in production.

CERN School of Computing

System wide profiling

- **Profile everything on production:**
  - There is an overhead of profiling.
  - But it is worth.
- **Procedure:**
  - Instrument the software to emit performance metrics.
  - Collect them and start gathering statistics.
  - Apply machine learning techniques to predict.

CERN School of Computing

Probing

- **Simulate the end user:**
  - Send real jobs and look
  - This is a kind of system testing,
    - But on real infrastructure
  - Collect data as on SWP.
  - Apply the same techniques for data mining.

CERN School of Computing

#monitoringsucks

- **Monitoring is so old-fashioned:**
  - You have to look at stuff.
  - Let the system work for you.
- **The true power of SWP comes:**
  - When the machines are able to auto tune.
  - When, based on load, the infrastructure changes:
    - To cope with it,
    - To save power,

CERN School of Computing

Case study: DDM autoexclusion

- **Excludes storage sites based on:**
  - Metrics of free space available: SRM spacecollector.
  - Scheduled downtimes from AGIS.
  - SAM testing (Nagios).
- **With this, it produces exclusions automatically:**
  - No operators needed.
  - Self-configuration!

CERN School of Computing

Case study: HammerCloud

- **It can be submitted to something?**
  - Then it can be tested with HammerCloud
  - Mainly batch systems and IaaS.
- **Stress testing:**
  - Measure the resources
  - Analyse,
  - Tune
  - (Looks like QFD…)
- **Functional testing**
  - The live testing.

CERN School of Computing

HC's Functional testing

- **Monitors:**
  - Availability
  - Functional quality
  - User-seen performance.
- **HC is always submitting probes everywhere.**
  - And collects data.
  - 50,000,000 probes/year
  - Offers monitoring
  - And actions.

CERN School of Computing

HC's Infrastructure probing

- **HC can test anything with an API.**
- **For instance, cloud resources:**
  - VM life cycle duty.
  - Site performance:
    - Network,
    - CPU overhead.
- **Tested resources on several clouds:**
  - T-Systems, CloudSigma, Atos, RackSpace, Google…
  - More than 40,000 CPU hours.

CERN School of Computing

Testing distributed systems

Ramon Medrano Llamas
CERN

Inverted CERN School of Computing, 25-26 February 2013

CERN School of Computing

References

- **The Art of Software Testing**
  - Glenn Myers
- **Testing Computer Software**
  - Cem Kaner
- **Test-Driven Development by Example**
  - Kent Beck
- **How Google Tests Software**
  - James Whittaker, Jason Arbon and Jeff Carollo

CERN School of Computing

Acknowlegments

- **José García Fanjul,**
  - Professor and researcher on testing
  - University of Oviedo
- **All the people at IT-ES for the input**
- **James Whittaker for awesome books**
- **Teams at Google for releasing awesome tools**
- **Teams at Heroku and GitHub for Getting Shit Done™**

Case study: Android's submit queue