



# Cluster management at Google

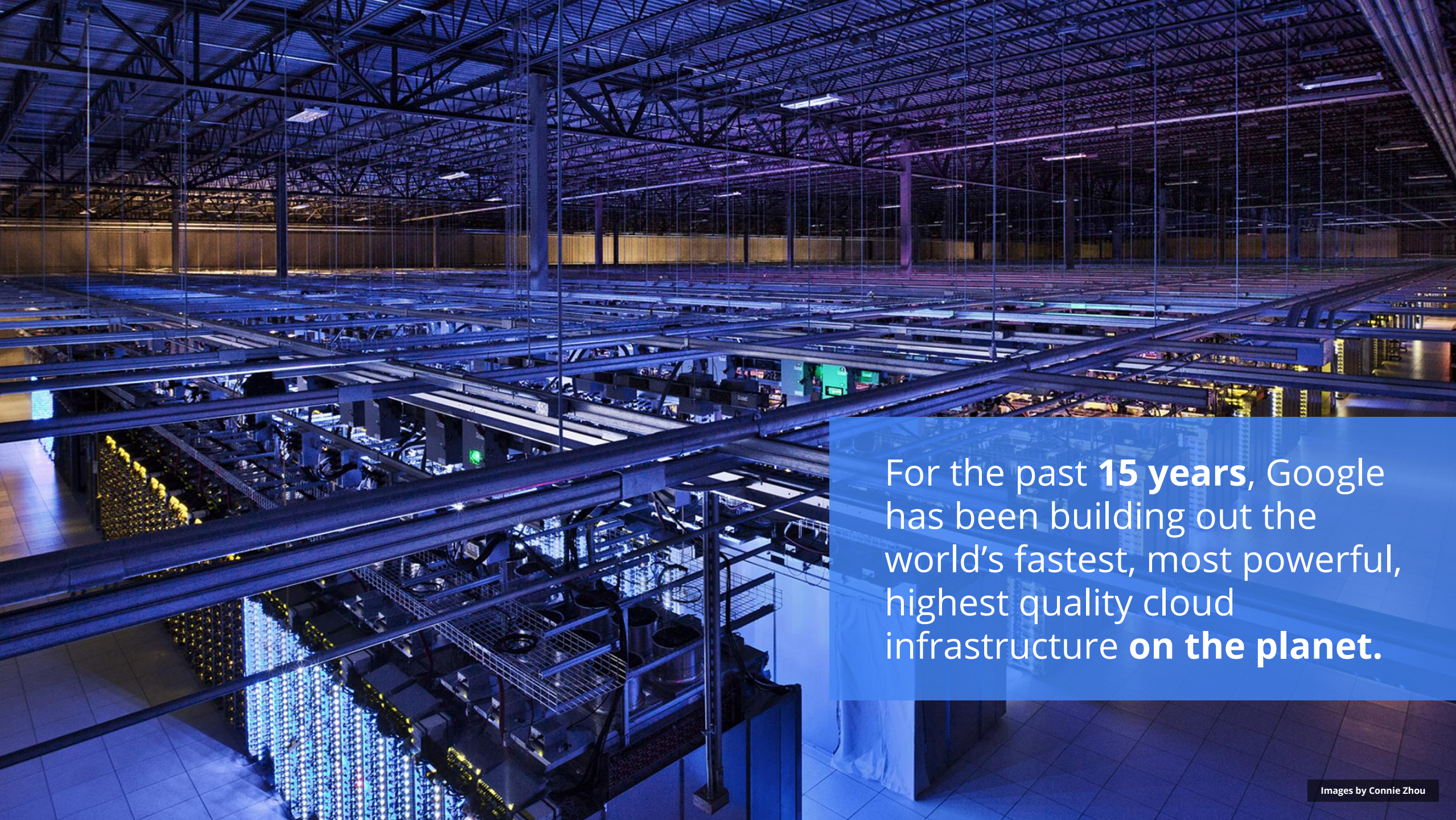
2015-02

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Principal Software Engineer



Google Cloud Platform





For the past **15 years**, Google has been building out the world's fastest, most powerful, highest quality cloud infrastructure **on the planet.**



# Hello World

```
job hello_world = {  
  runtime = { cell = 'ic' }           // What cluster should we run in?  
  binary = '../hello_world_webserver' // What program are we to run?  
  args = { port = '%port%' }         // Command line parameters  
  requirements = {                   // Resource requirements  
    ram = 100M  
    disk = 100M  
    cpu = 0.1  
  }  
  replicas = 10000 // Number of tasks  
}
```

# Hello World

```
> borgcfg .../hello_world_webserver.borg up
```

```
...
```

```
About to affect 10000 tasks and 1 packages on cell IC.
```

```
Do you wish to continue (yes/no) [no]? yes
```

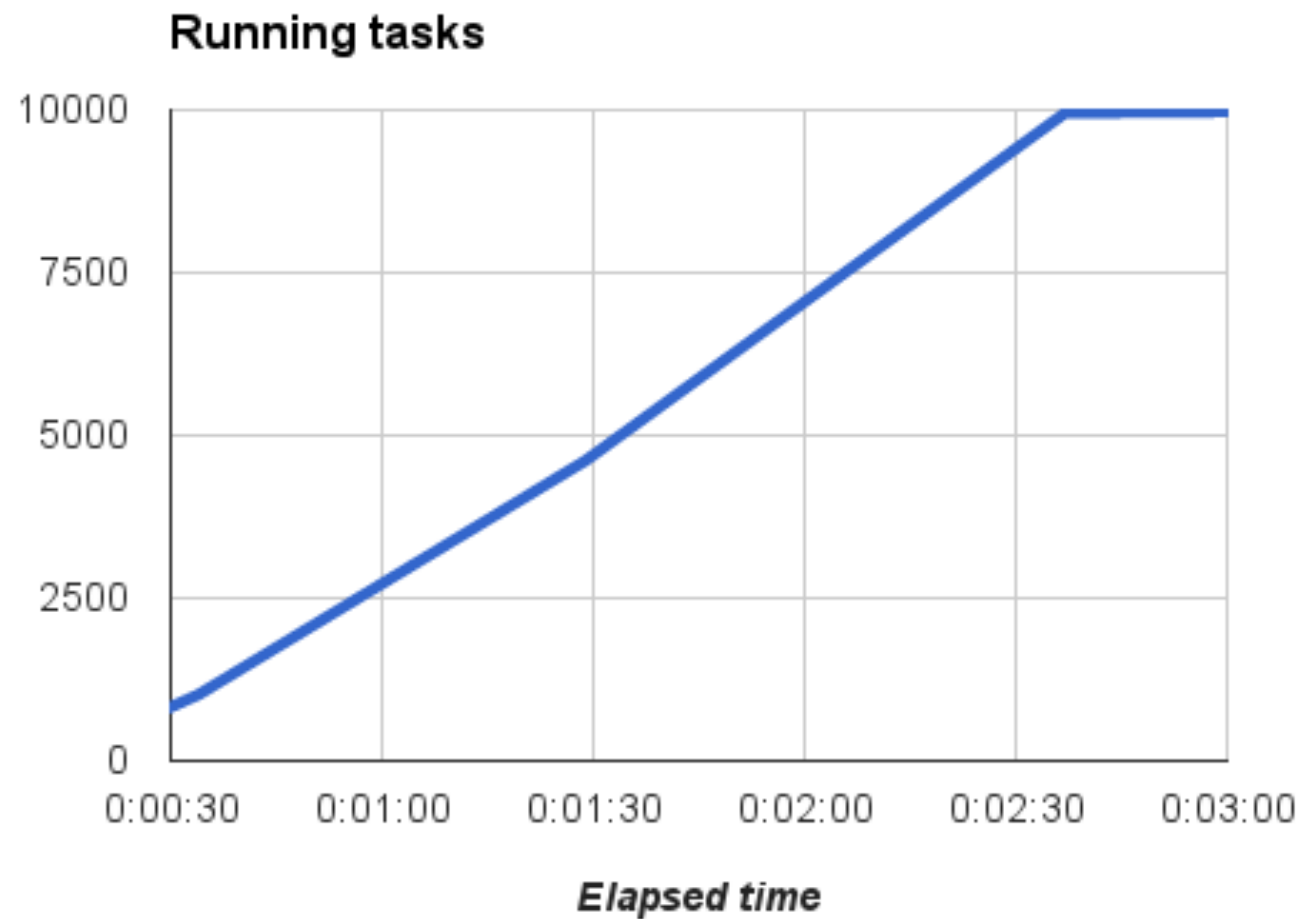
```
==== Staging package hello_world_webserver.63ce1b965155c75e/johnwilkes on ic... SUCCESS
```

```
==== Making package hello_world_webserver.63ce1b965155c75e/johnwilkes on ic... SUCCESS
```

```
==== Starting job hello_world on ic... SUCCESS
```

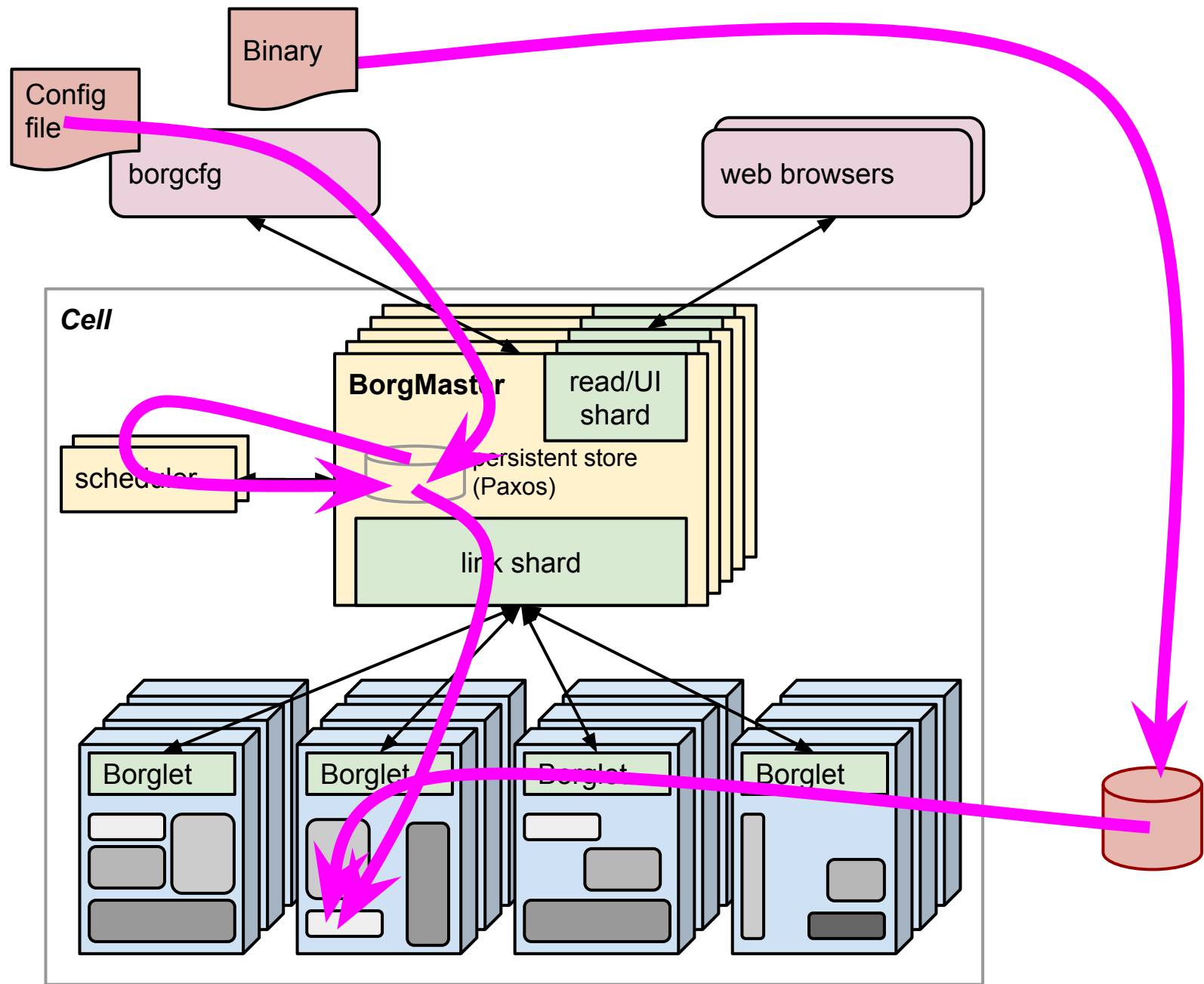


# Hello World



# Hello World

What just happened?



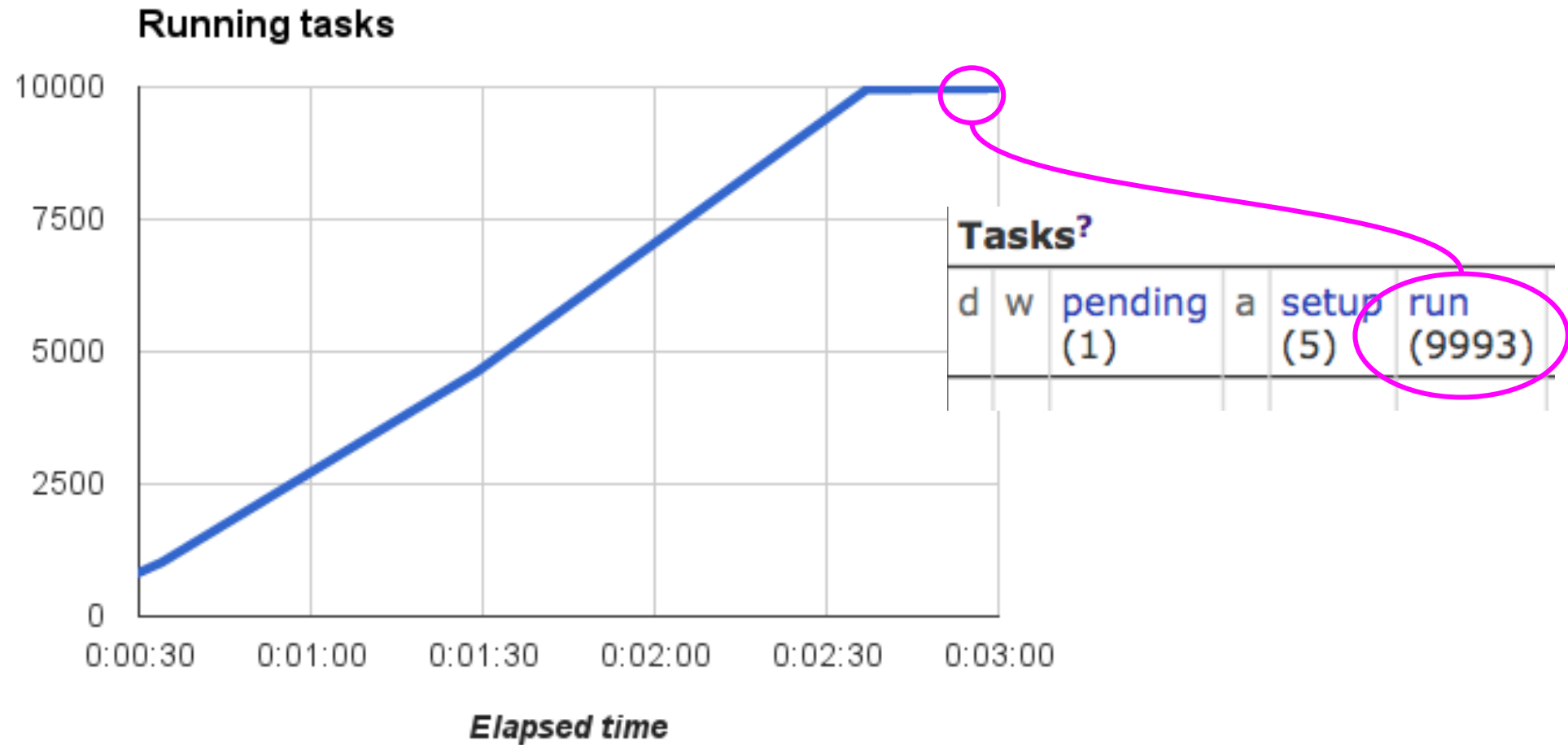


# Hello World

A wide-angle photograph of a large, modern server room. The room is filled with rows of server racks, some of which are illuminated with blue light. The ceiling is high and features a complex network of metal beams and pipes. The floor is made of light-colored tiles. The overall atmosphere is one of a high-tech, industrial environment.



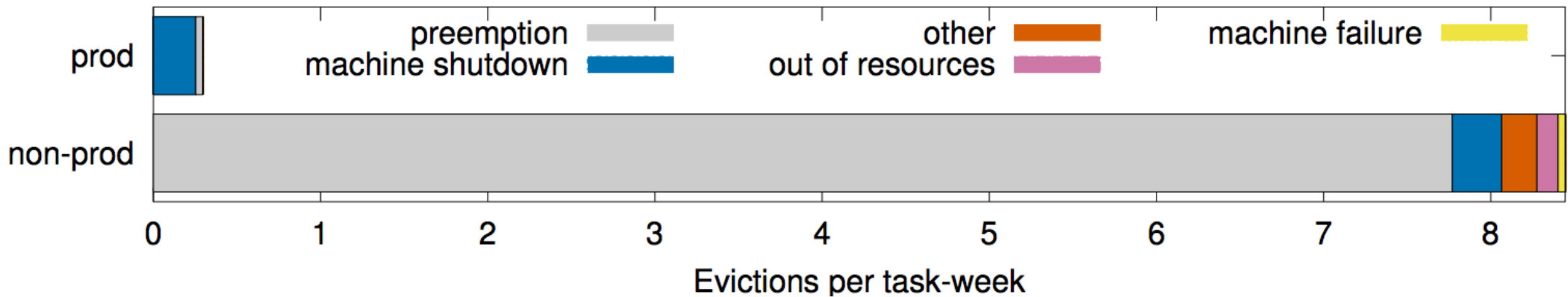
# Hello World



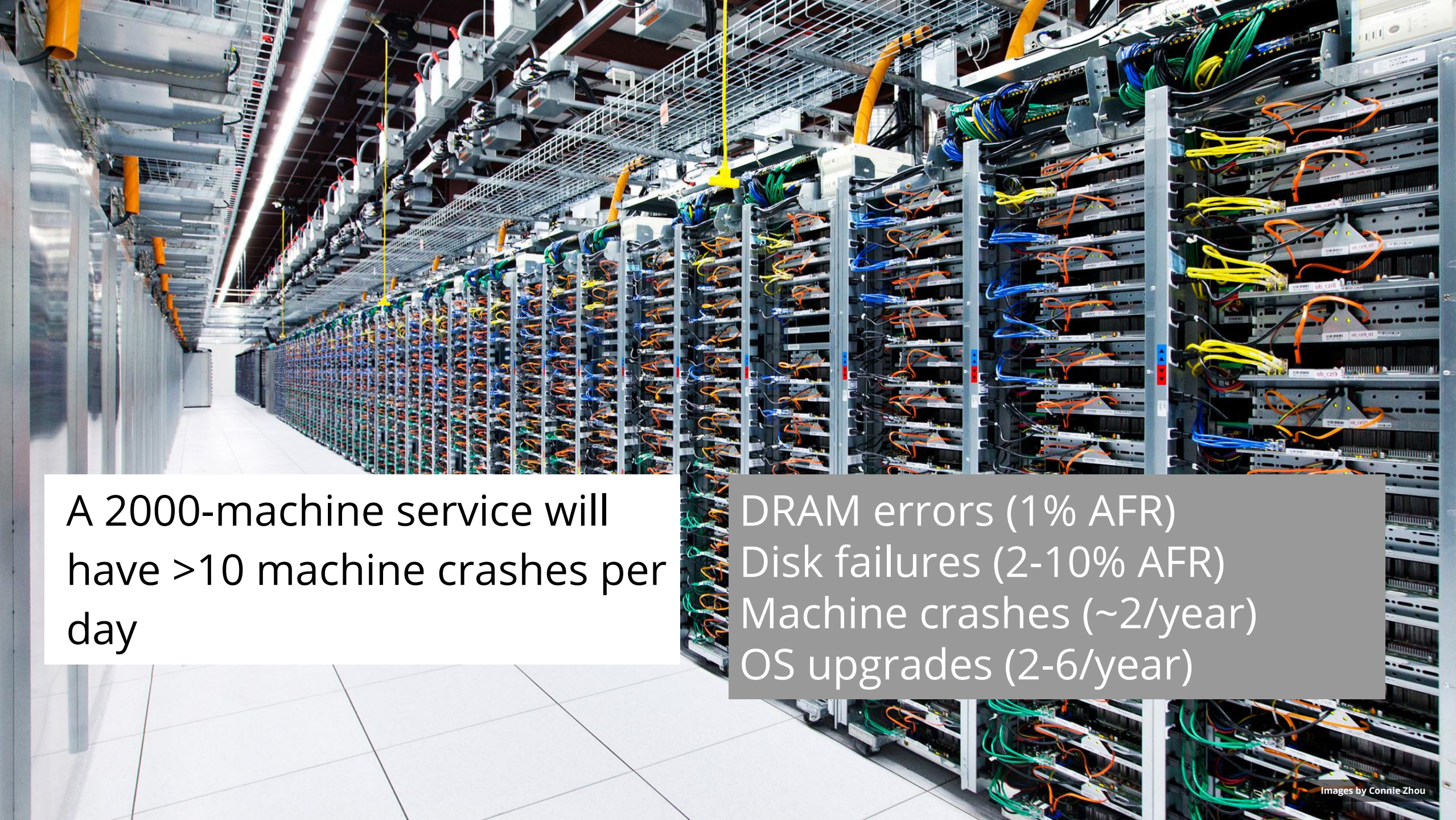


# Failures

task-eviction rates  
and causes



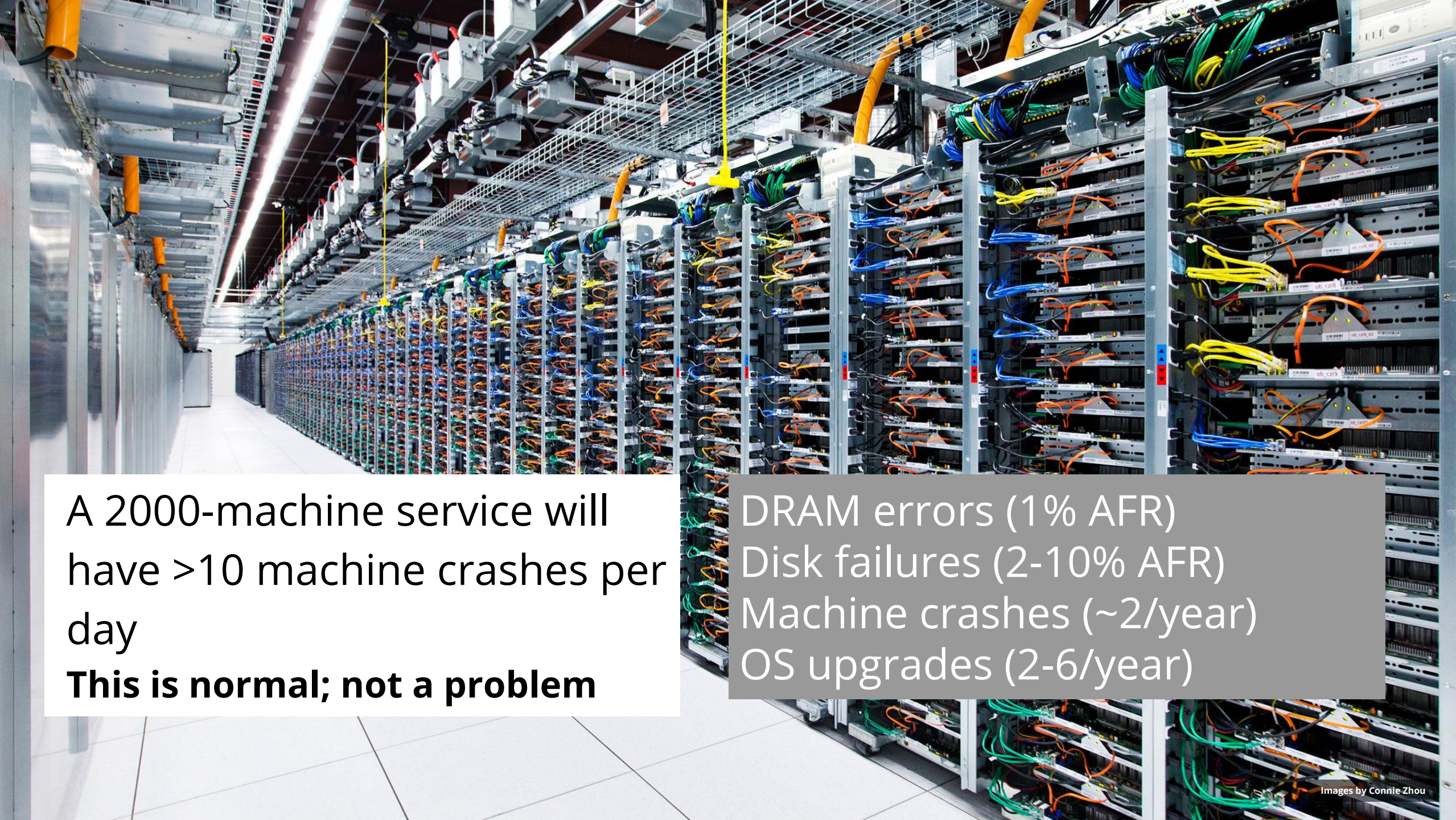




A 2000-machine service will  
have >10 machine crashes per  
day

DRAM errors (1% AFR)  
Disk failures (2-10% AFR)  
Machine crashes (~2/year)  
OS upgrades (2-6/year)





A 2000-machine service will  
have >10 machine crashes per  
day  
**This is normal; not a problem**

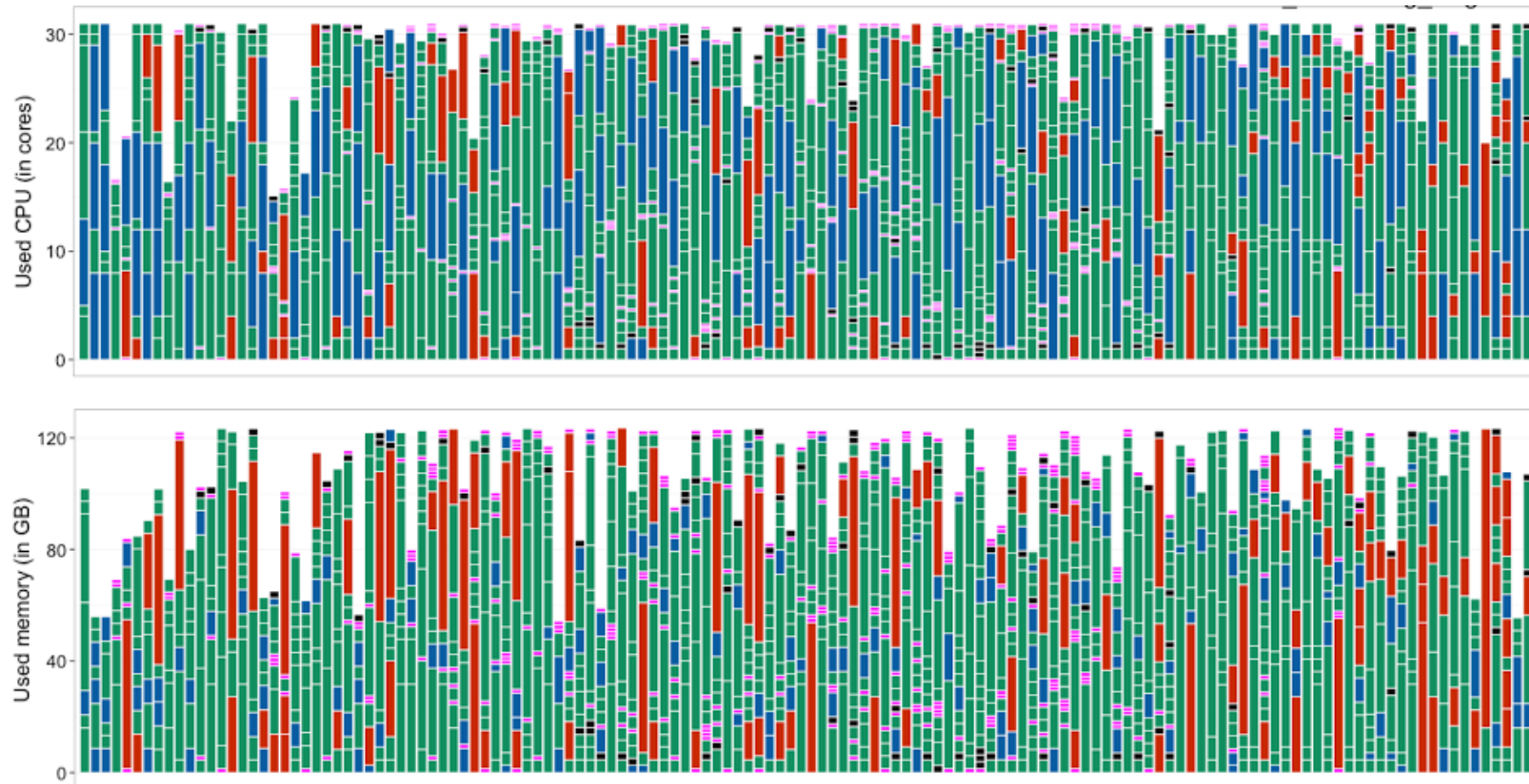
DRAM errors (1% AFR)  
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Machine crashes (~2/year)  
OS upgrades (2-6/year)



# Efficiency

## Advanced bin-packing algorithms

Experimental placement of production VM workload, July 2014

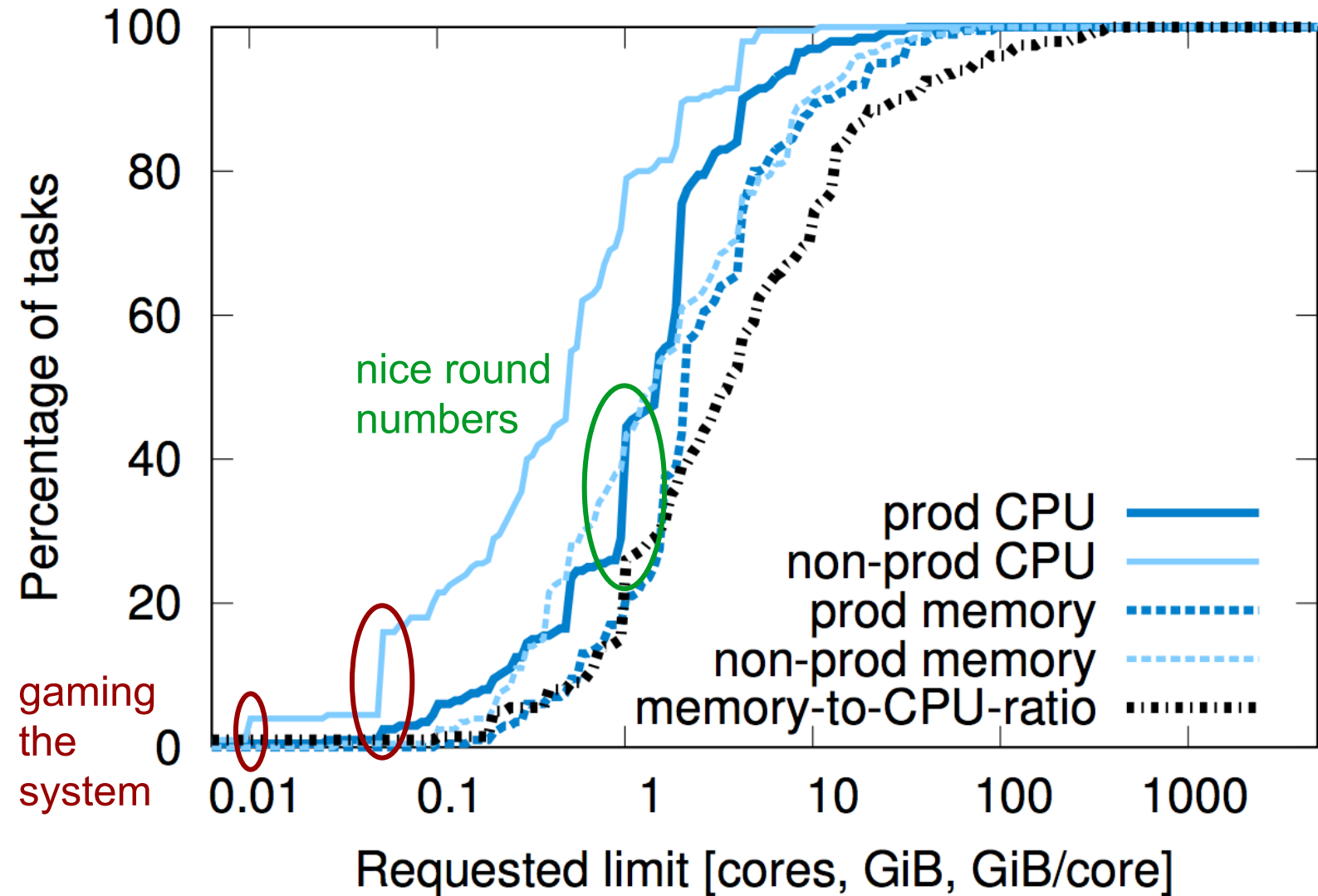




# Efficiency

## Advanced bin-packing algorithms

There are no obvious bucket sizes (cf. cloud VMs)

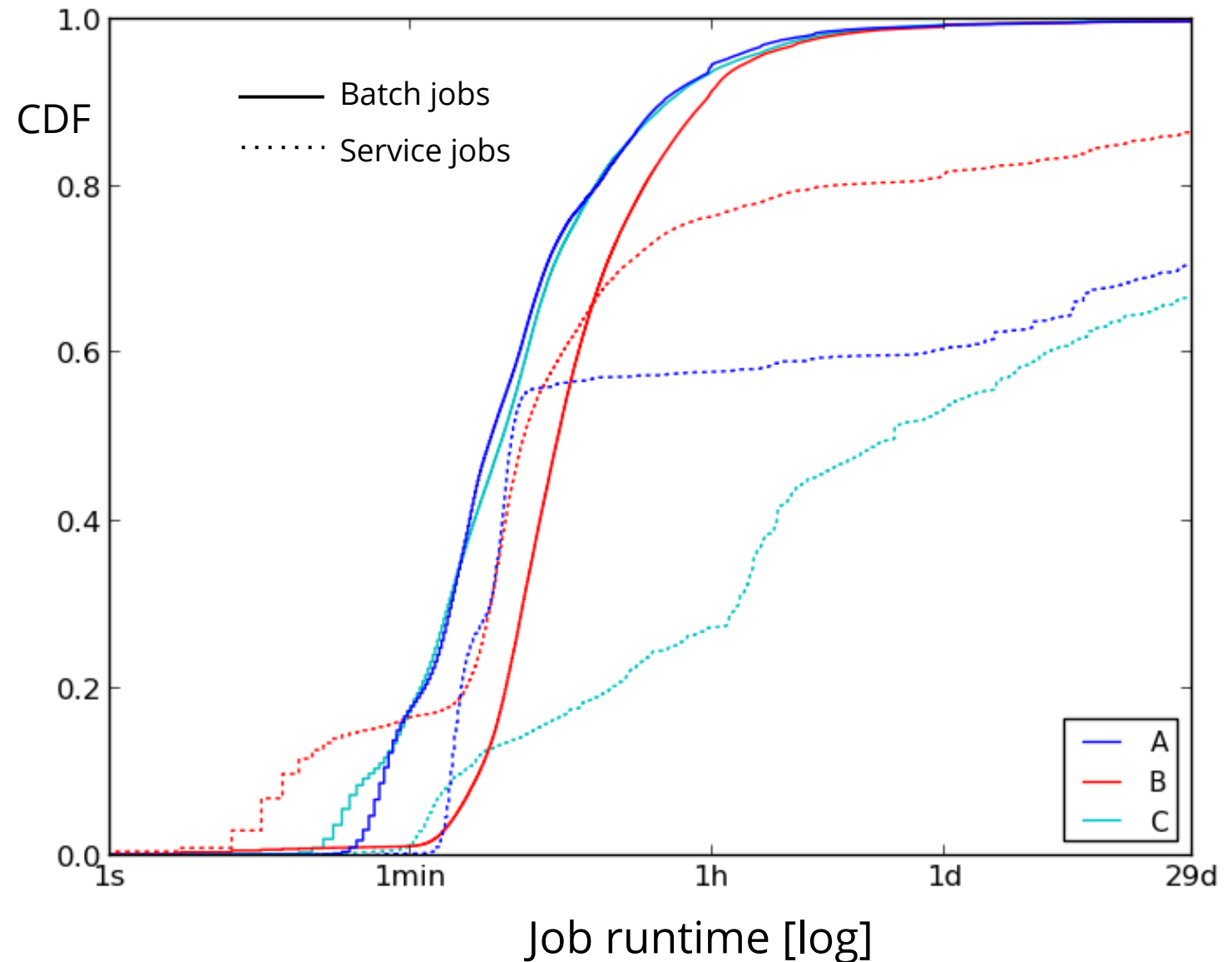


# Efficiency

## Advanced bin-packing algorithms

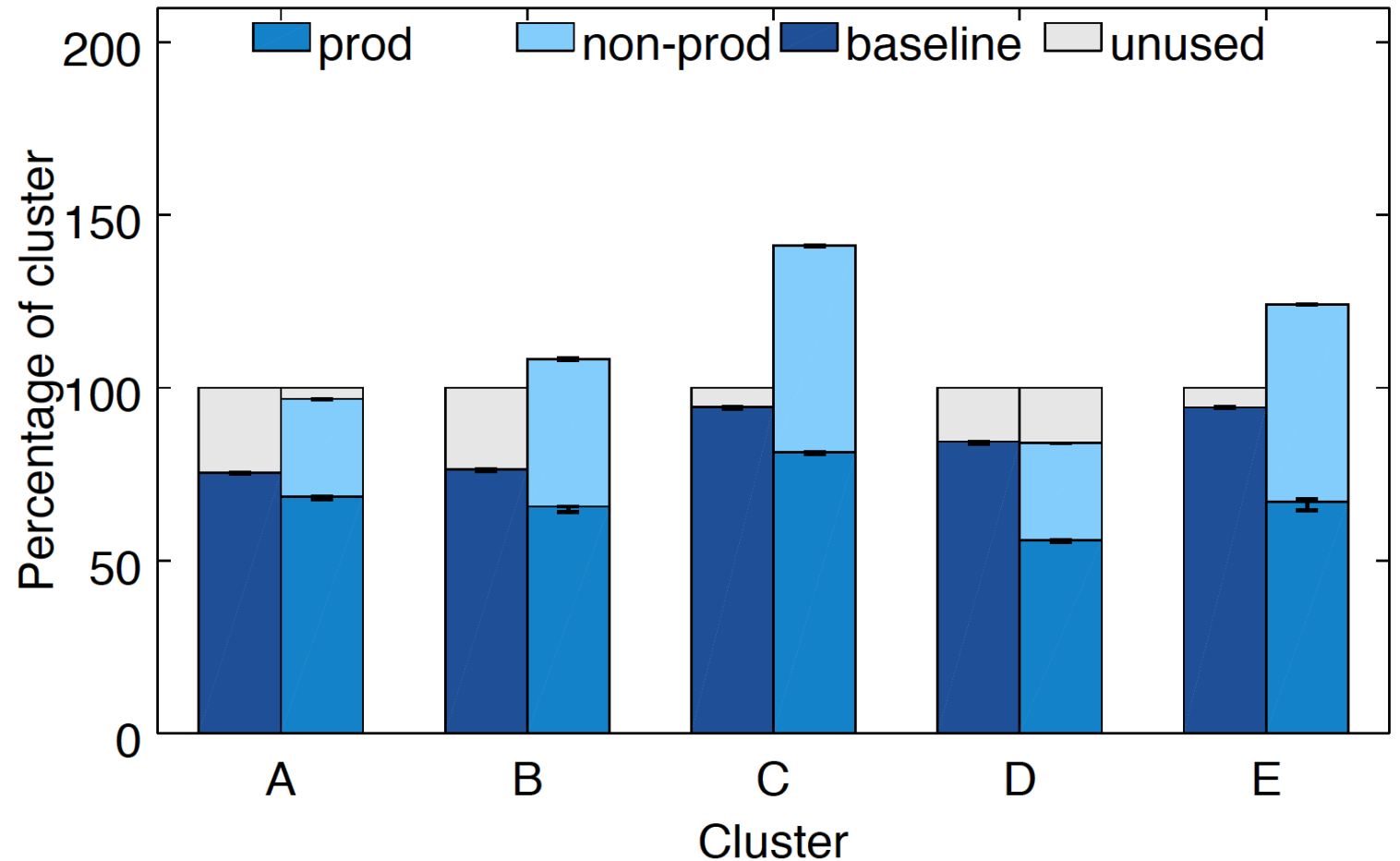
Heterogeneous workloads, May 2011

*Omega* paper,  
EuroSys 2013



# Efficiency

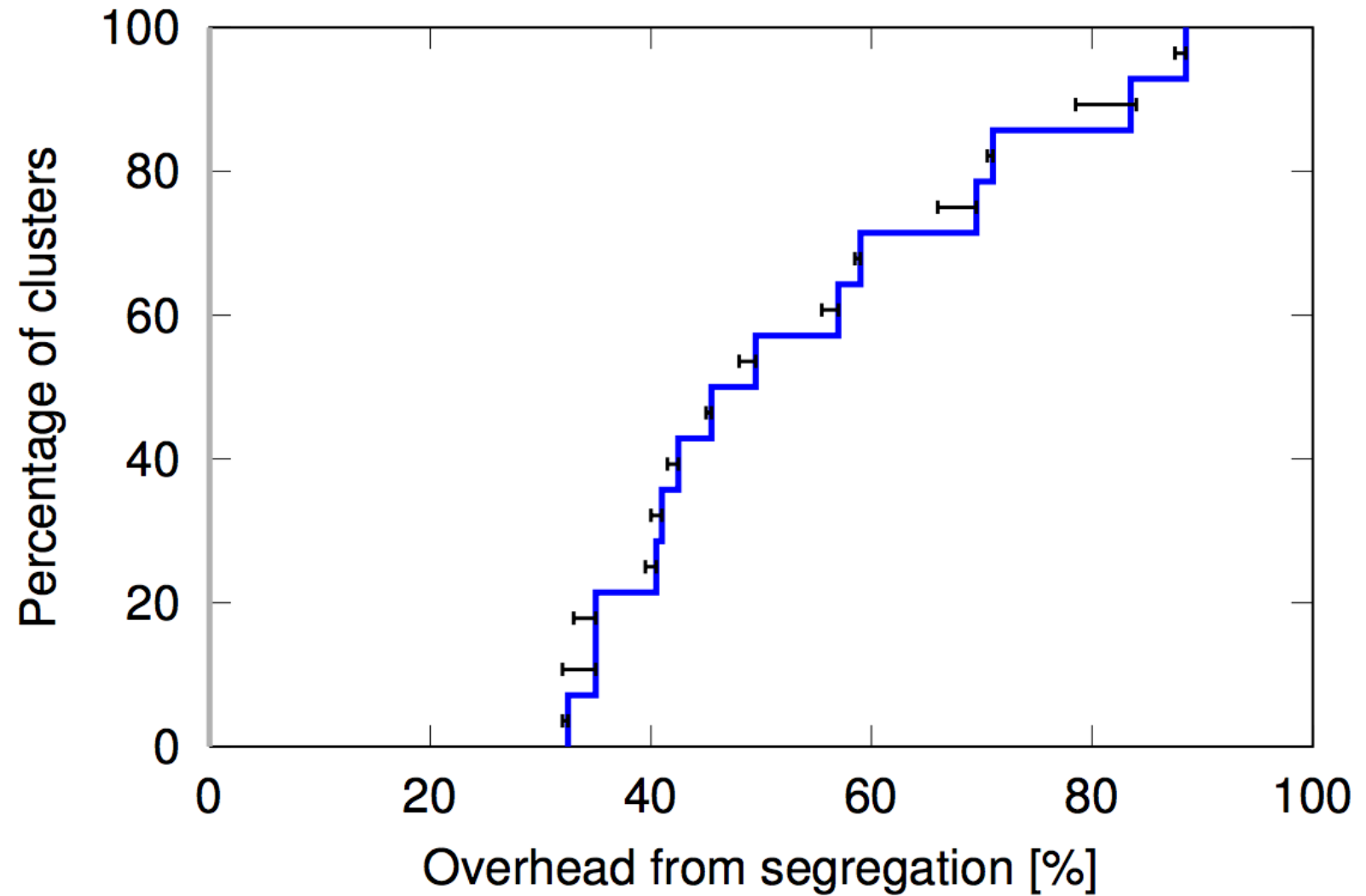
**Utilization:**  
sharing clusters  
between  
prod/batch helps





# Efficiency

**Utilization:**  
sharing clusters  
between  
prod/batch helps

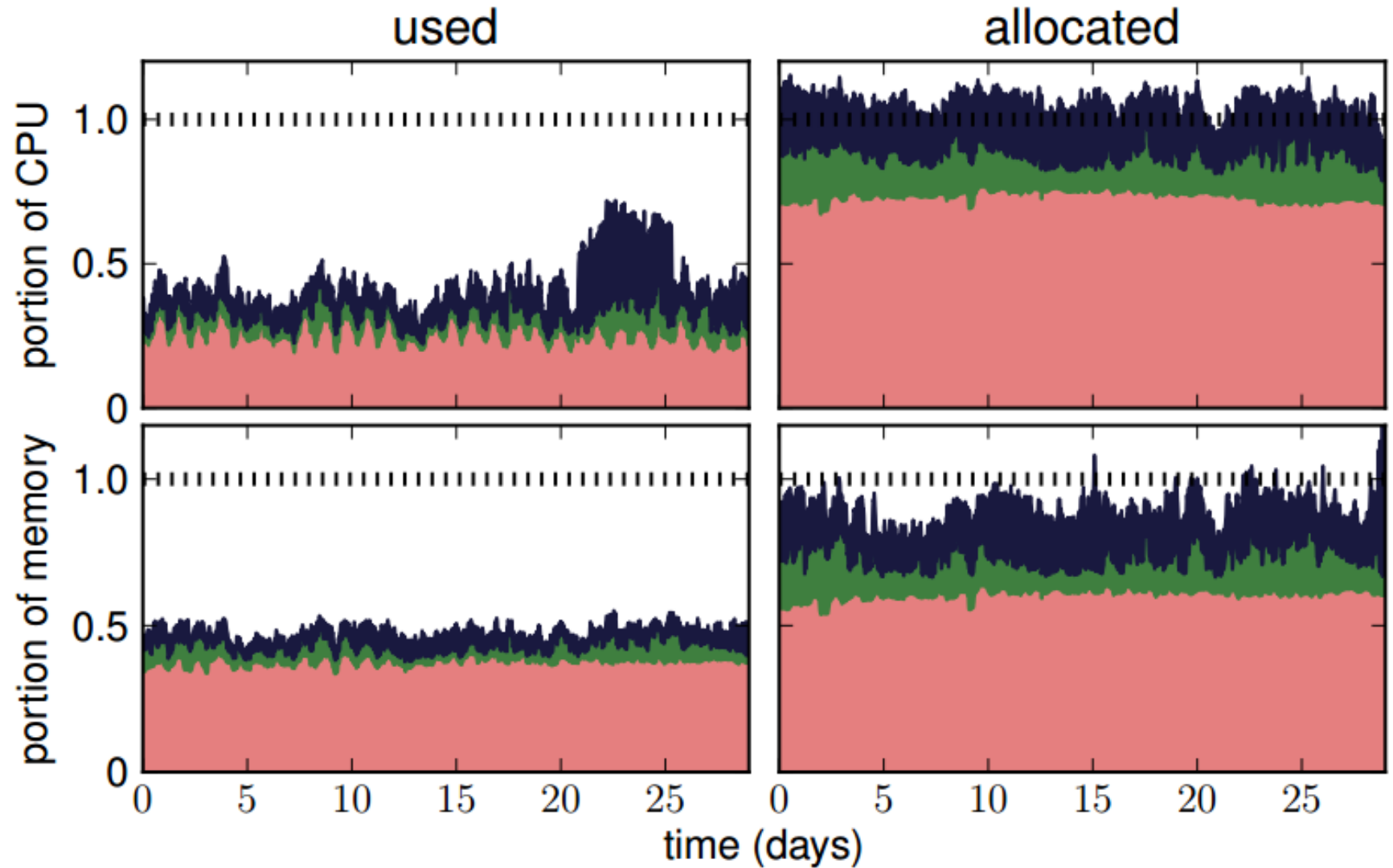


# Efficiency

## Advanced bin-packing algorithms

Data from a cluster with 12k machines, May 2011

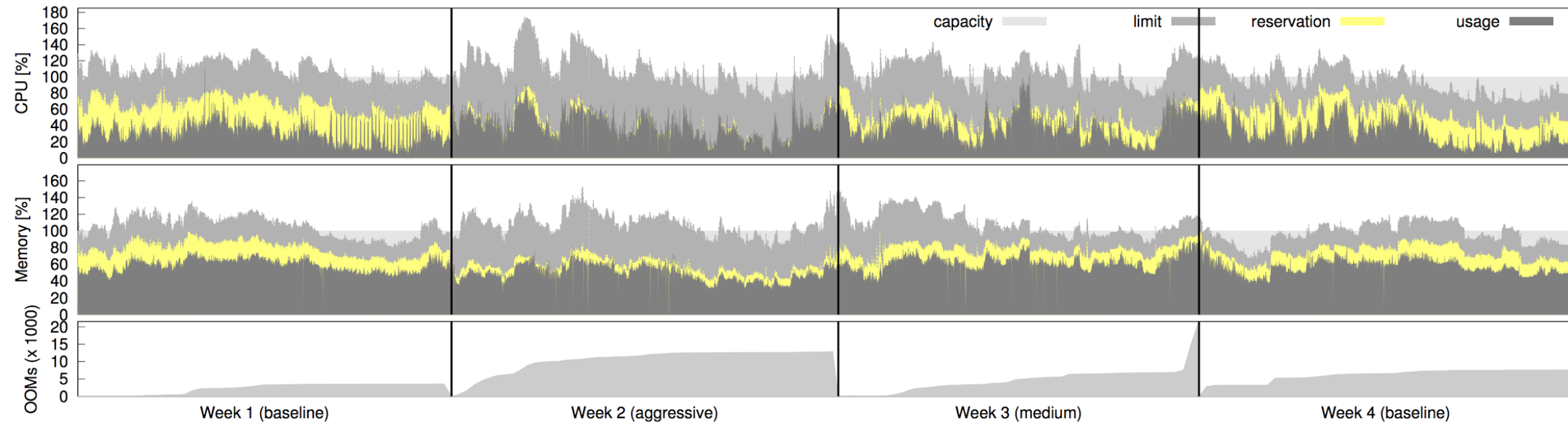
Trace is publicly available





# Efficiency

Resource reclamation could be more aggressive

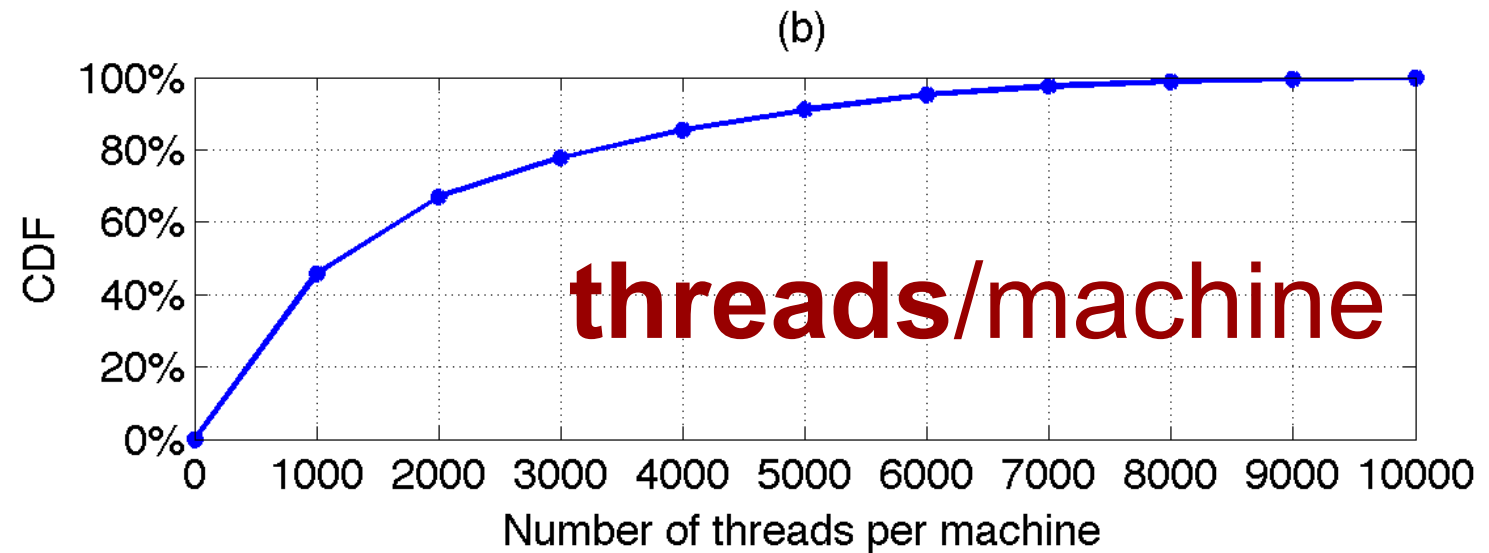
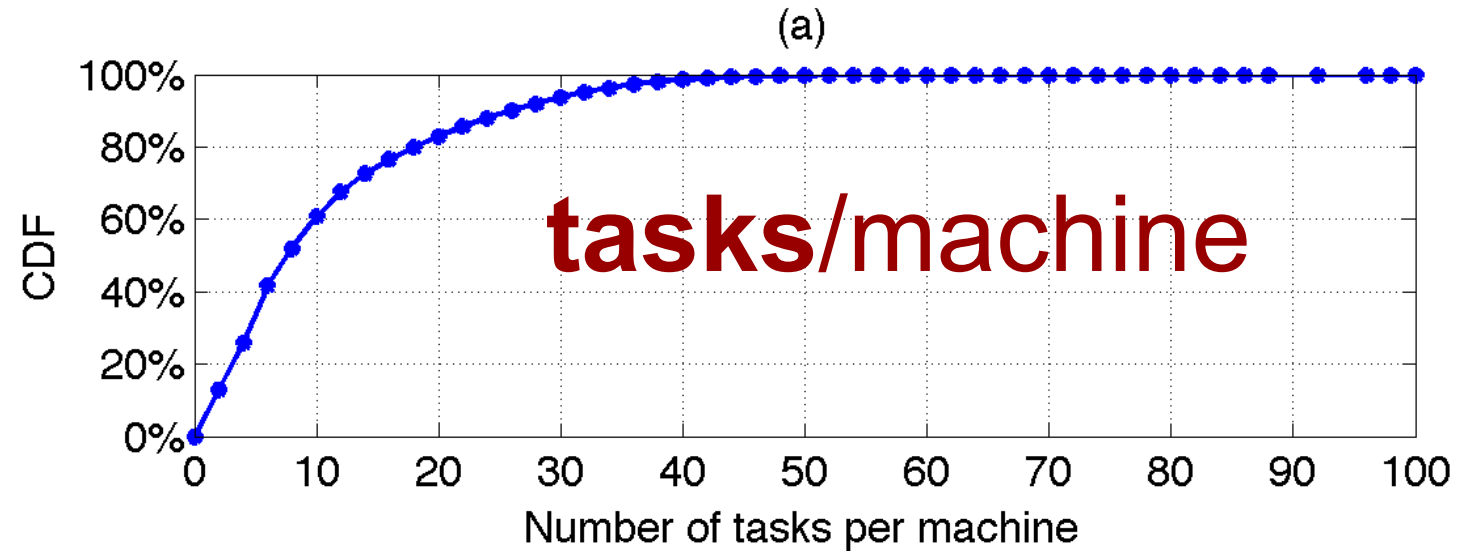


Nov/Dec 2013

# Efficiency

Multiple applications per machine

*CPI*<sup>2</sup> paper,  
EuroSys 2013



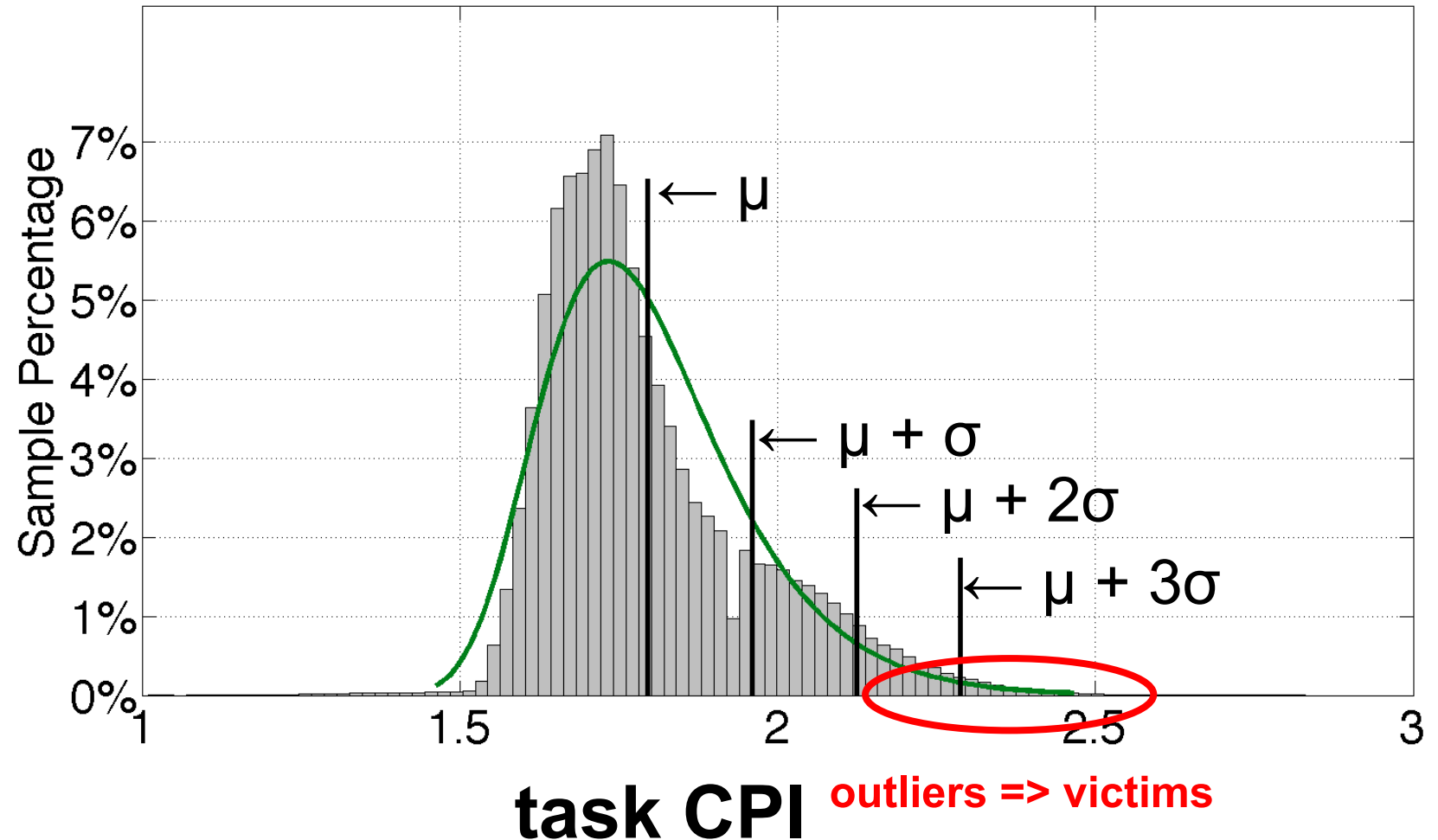


# Efficiency

## Multiple applications per machine

*CPI^2* paper,  
EuroSys 2013

1. Gather CPI for all the tasks in a job
2. Find outliers
3. Take action



# Achieving desired behavior

Exposing mechanisms is fragile

Better: **declarative intents**



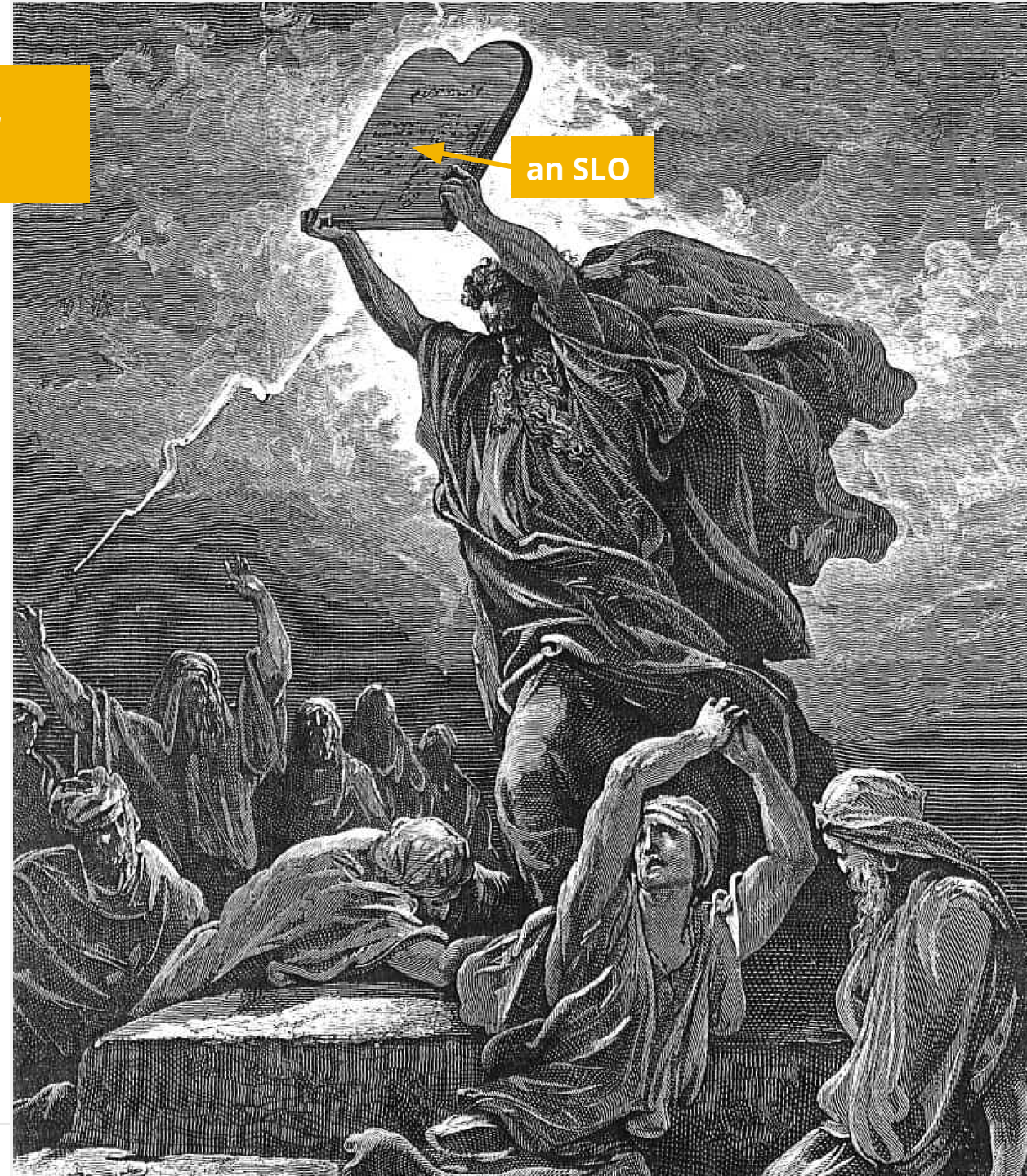


# Achieving desired behavior

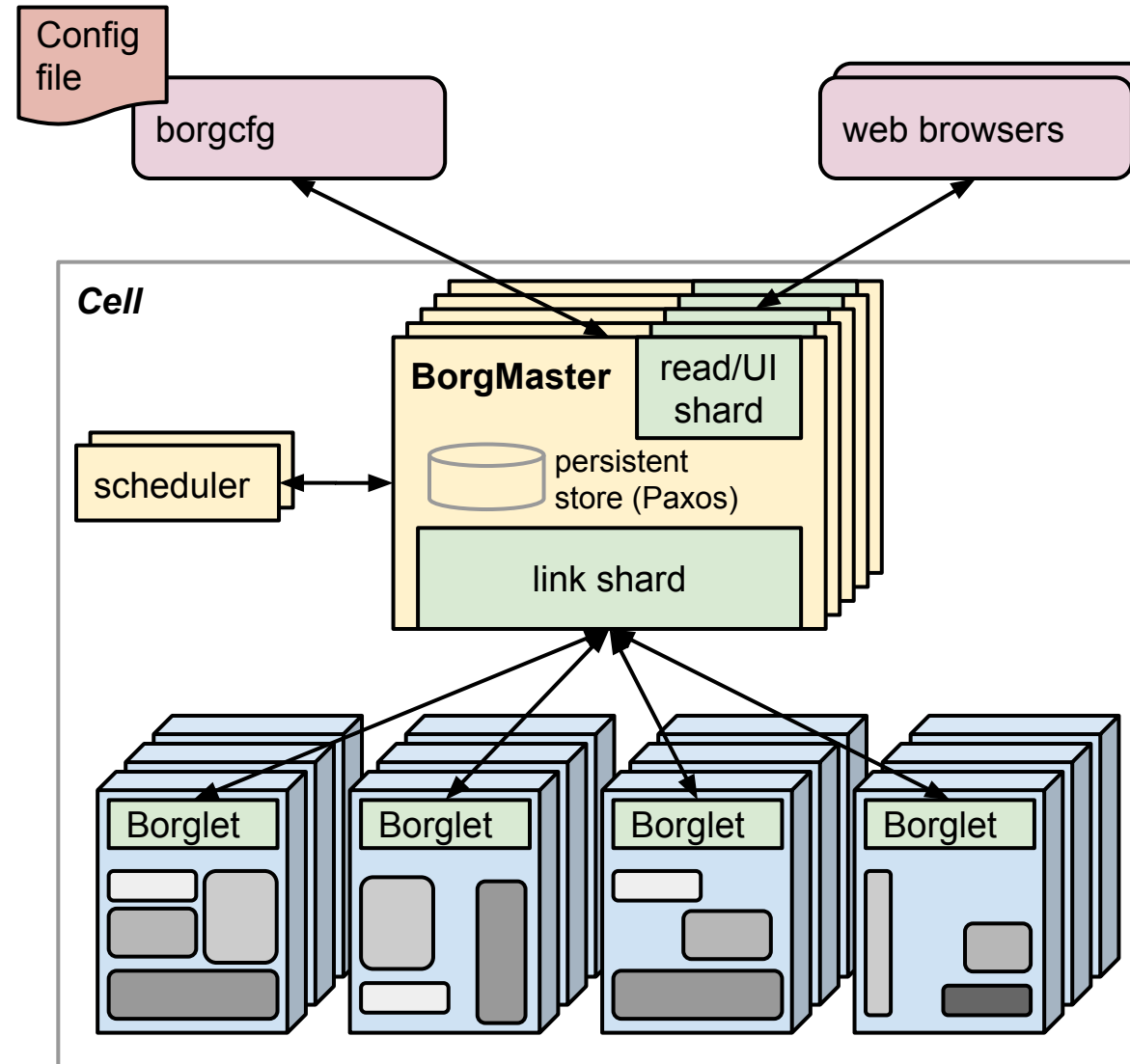
## Service level objective (SLO)

Examples:

- availability
- obtainability
- reliability
- velocity
- freshness?
- accuracy?
- security?



# A few other moving parts

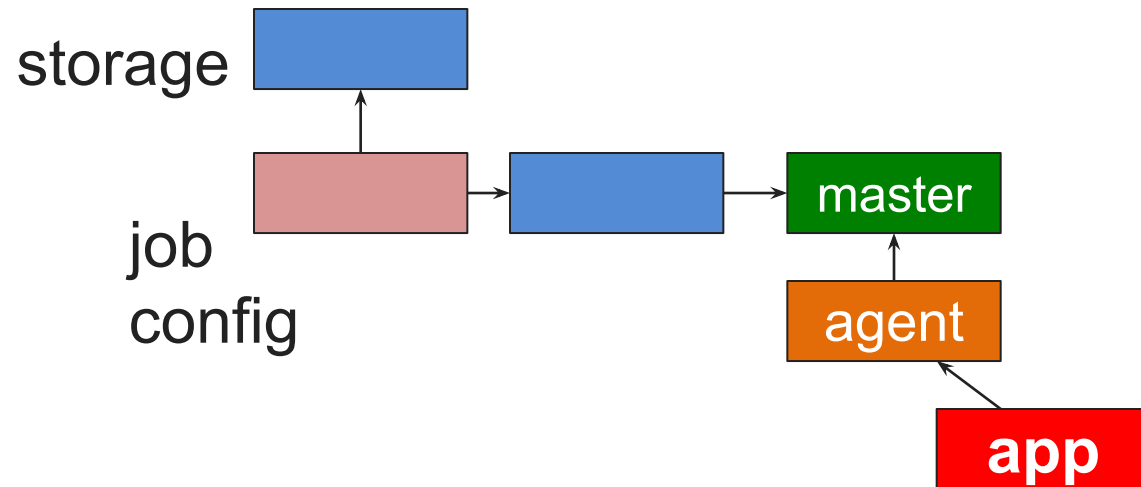




# A few other moving parts

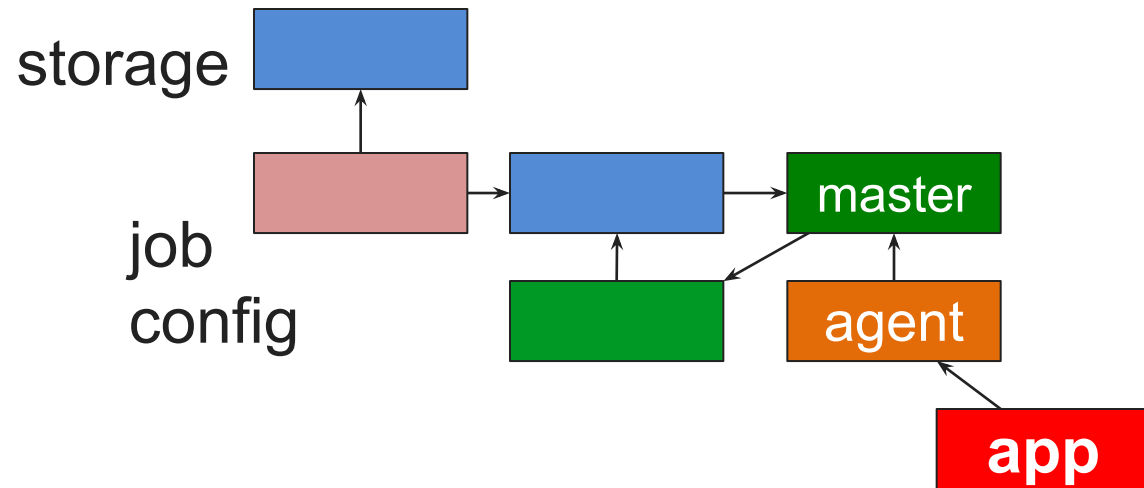


# A few other moving parts

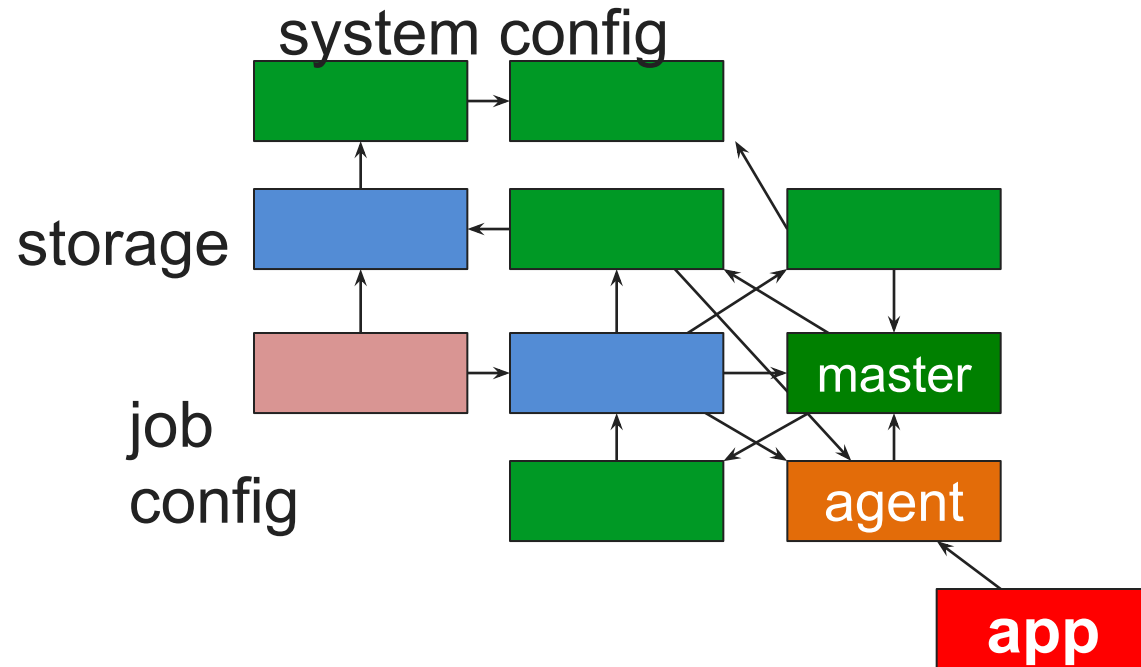




# A few other moving parts

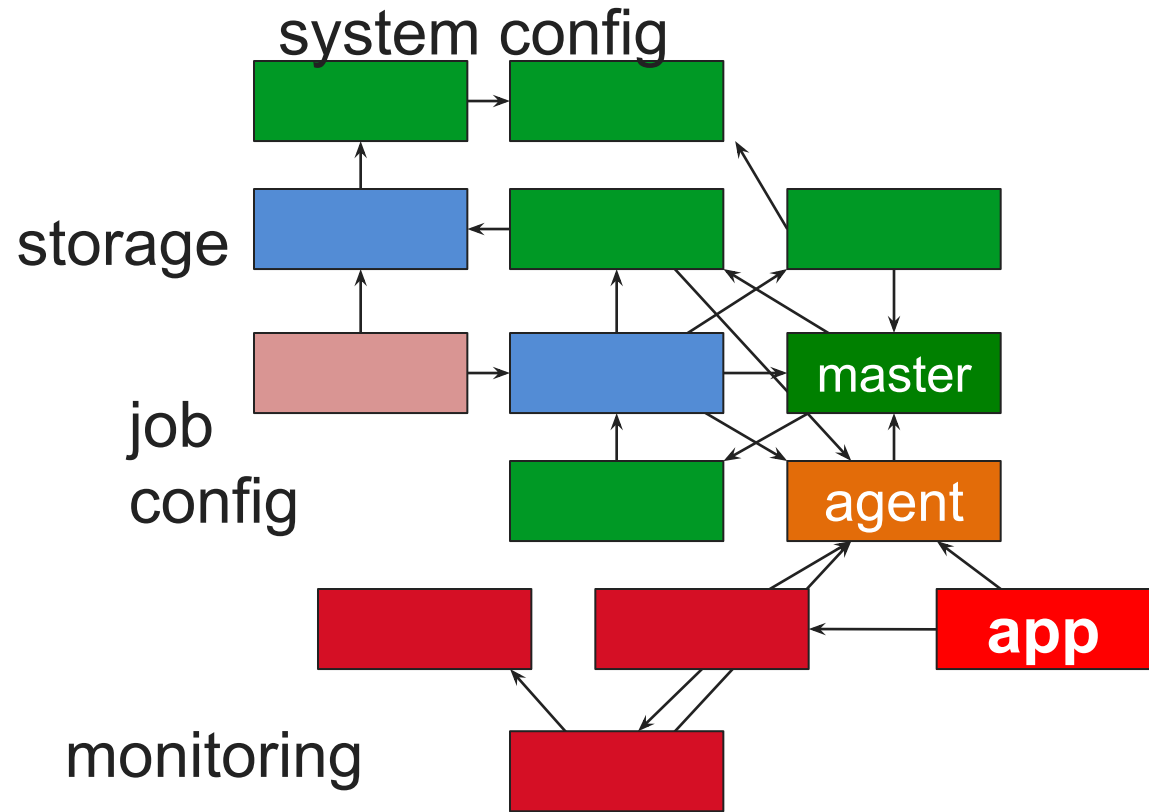


# A few other moving parts

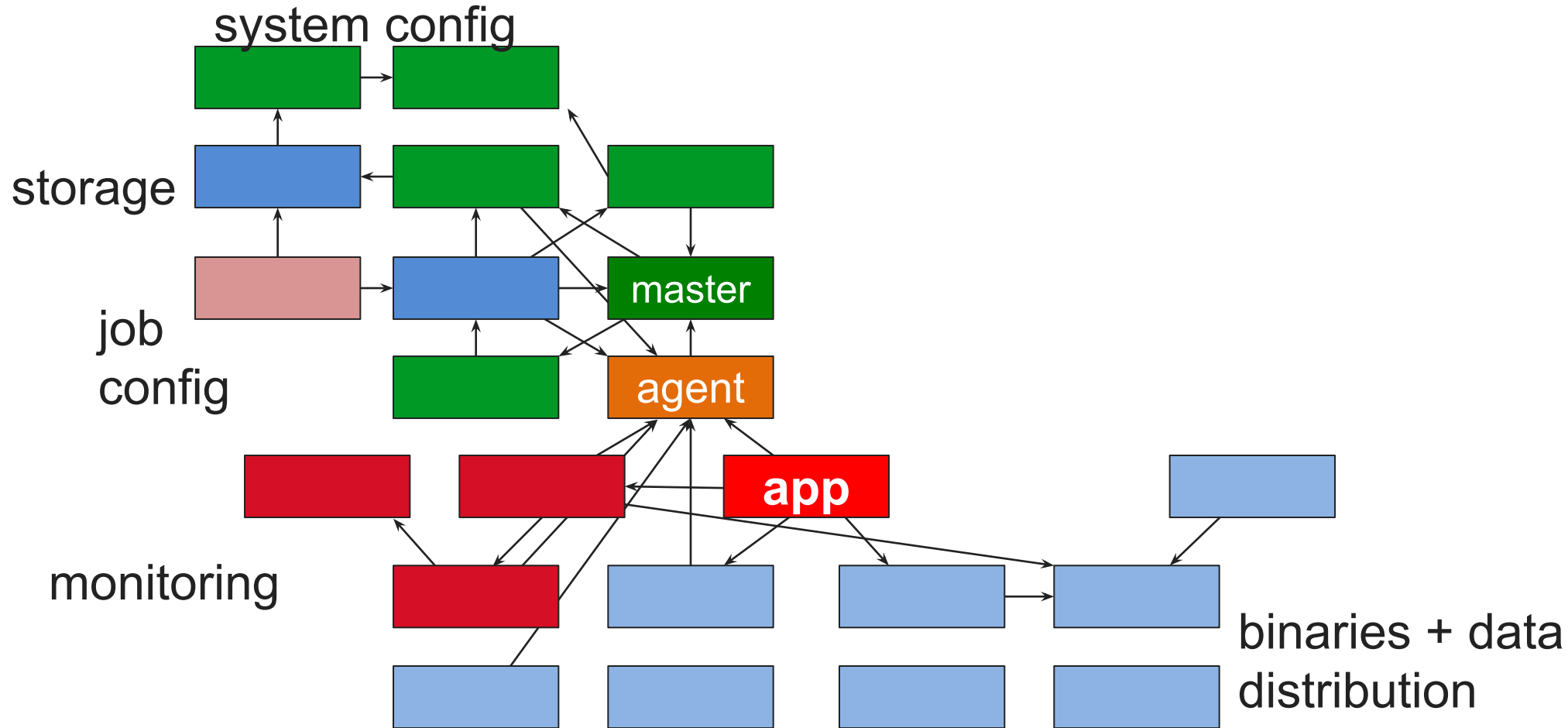




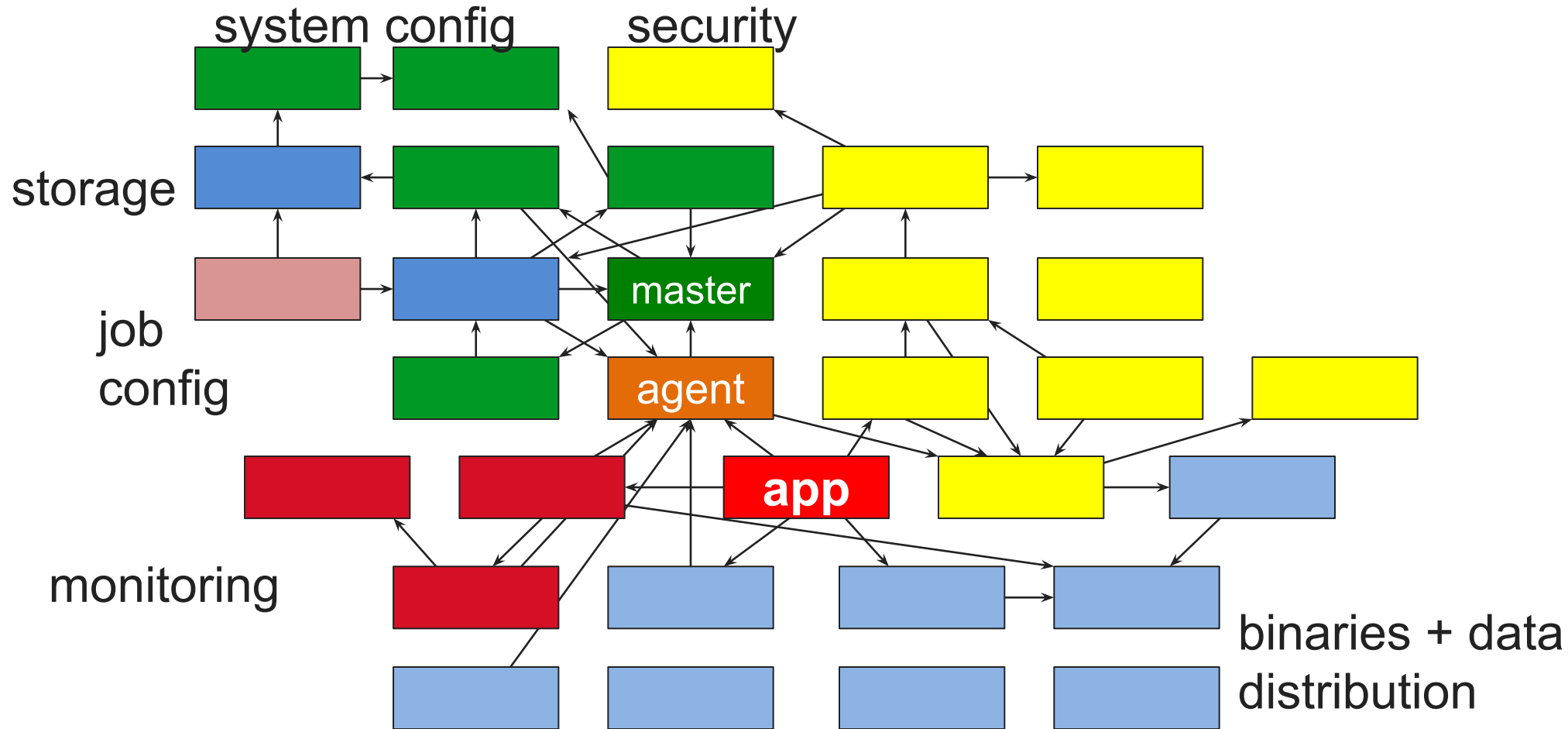
# A few other moving parts



# A few other moving parts

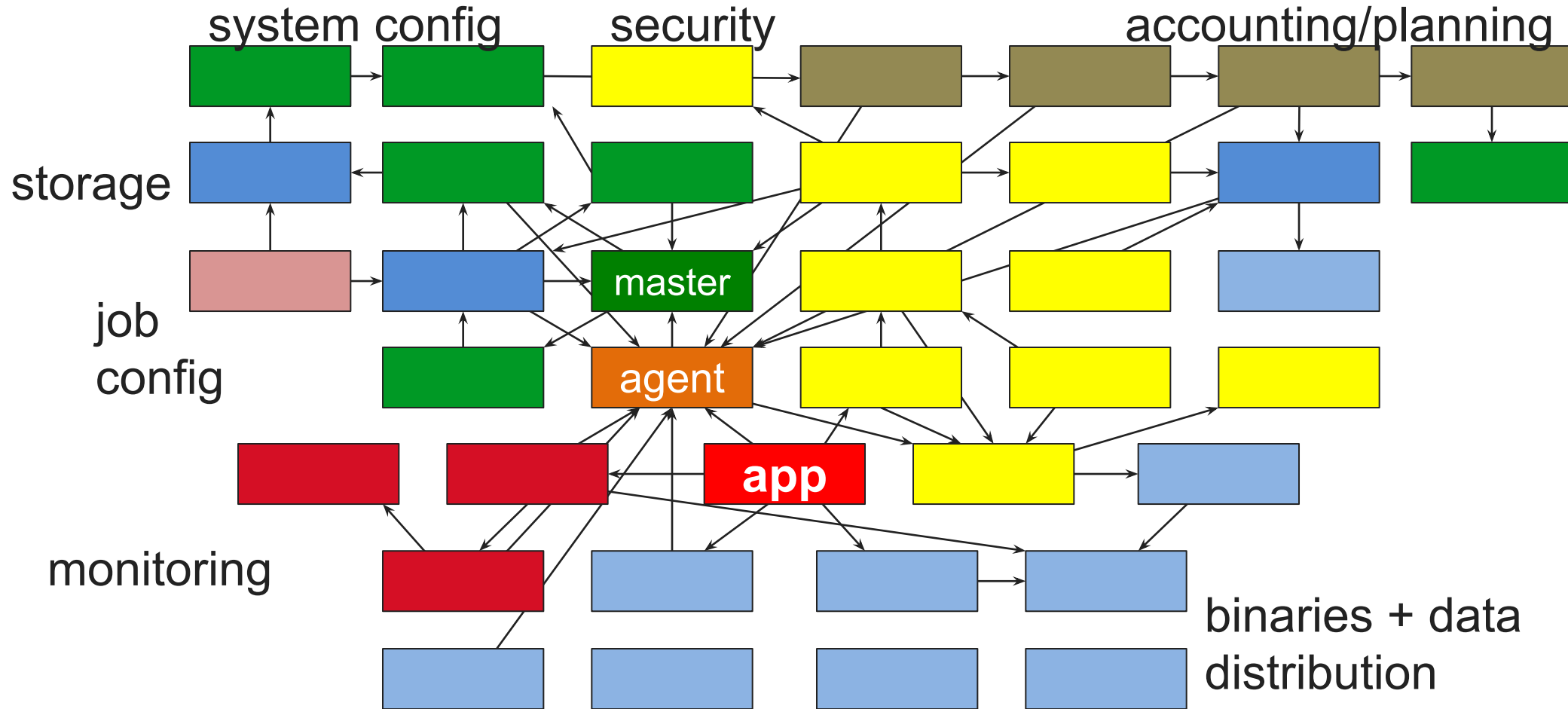


# A few other moving parts

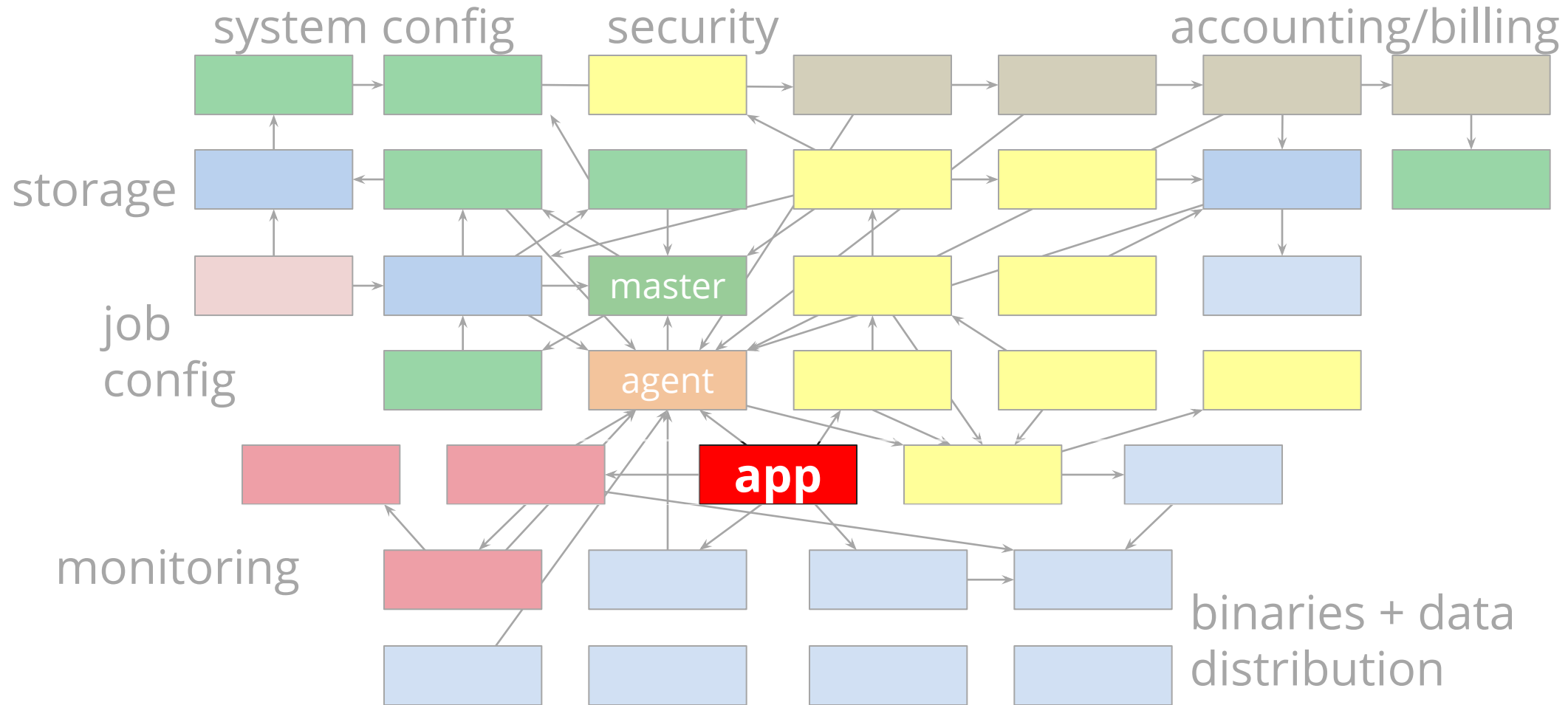




# A few other moving parts



# A few other moving parts



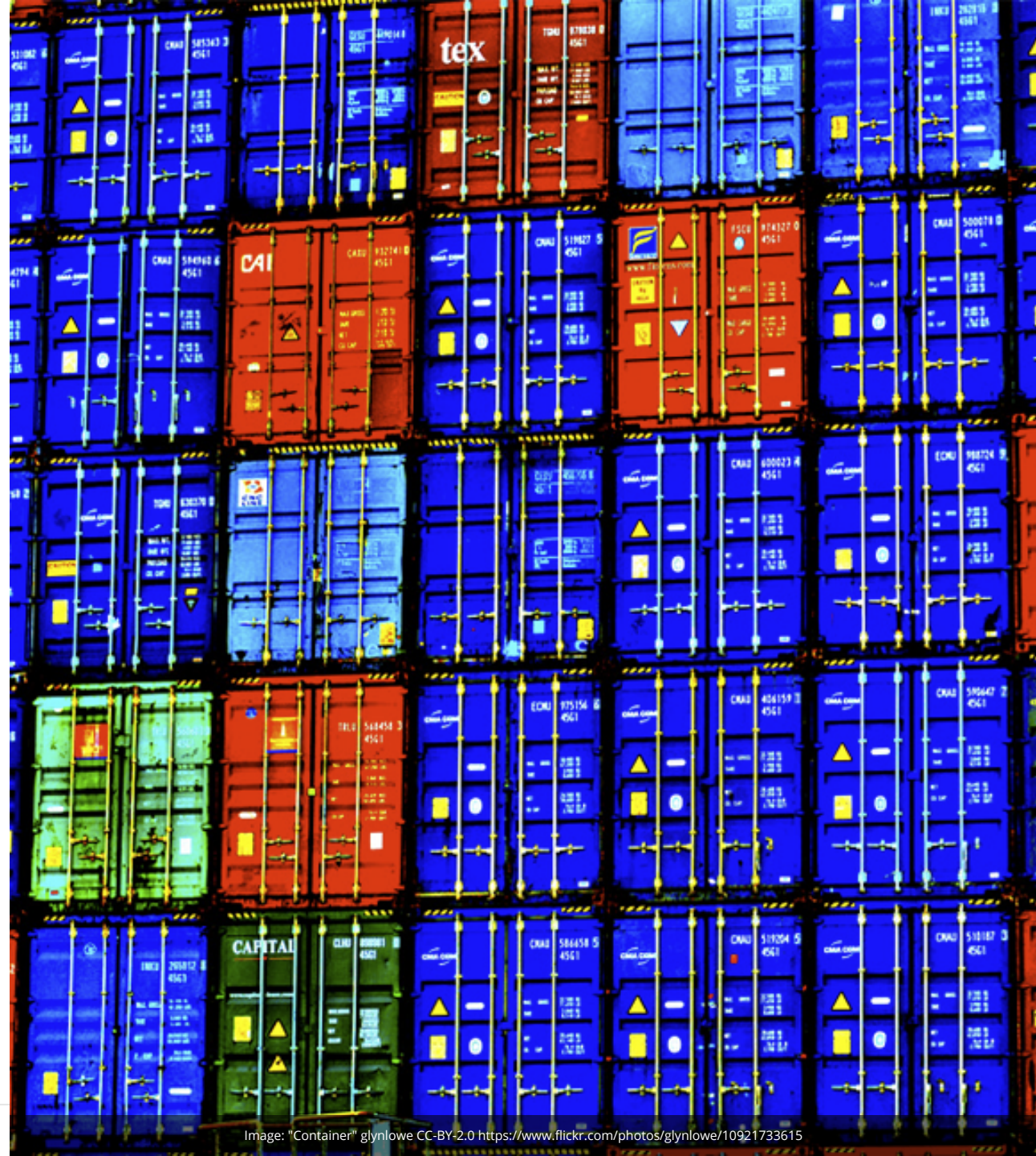
# Containers

**Everything** at Google runs in a container -- including our VMs

Containers give us:

- resource isolation
- execution isolation
- CPU QoS

We start over 2 billion containers per week.







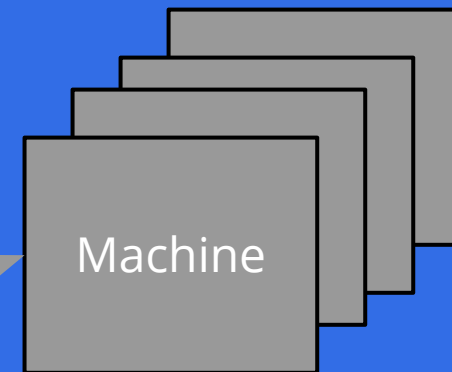
# Kubernetes

κυβερνήτης:  
*Greek for “pilot” or  
“helmsman of a ship”*

The open source  
cluster manager from  
Google.



kubernetes by Google



Manage a cluster of Linux containers as a single  
system to accelerate Dev and simplify Ops.

[View on GitHub](#)

[Try Kubernetes](#)

# Kubernetes

Web server

Log roller

Container  
Agent

Machine  
Host

Container  
Agent

Machine  
Host

Container  
Agent

Machine  
Host

Container  
Agent

Machine  
Host

Container  
Agent

Machine  
Host

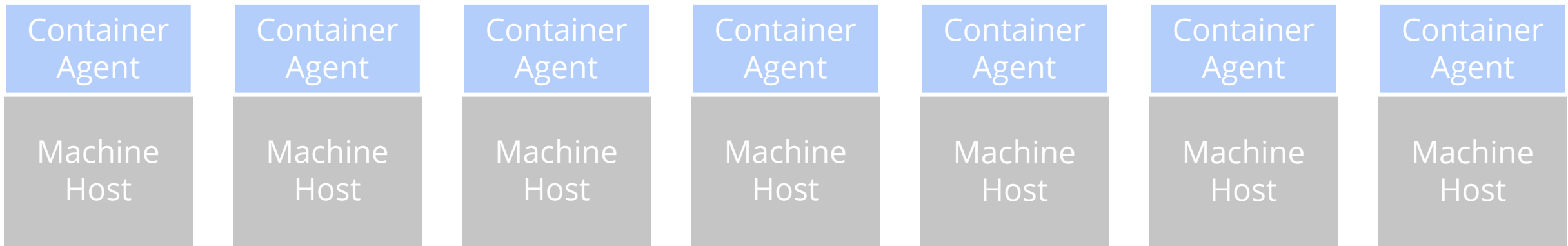
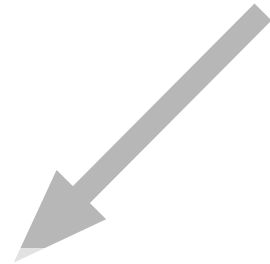
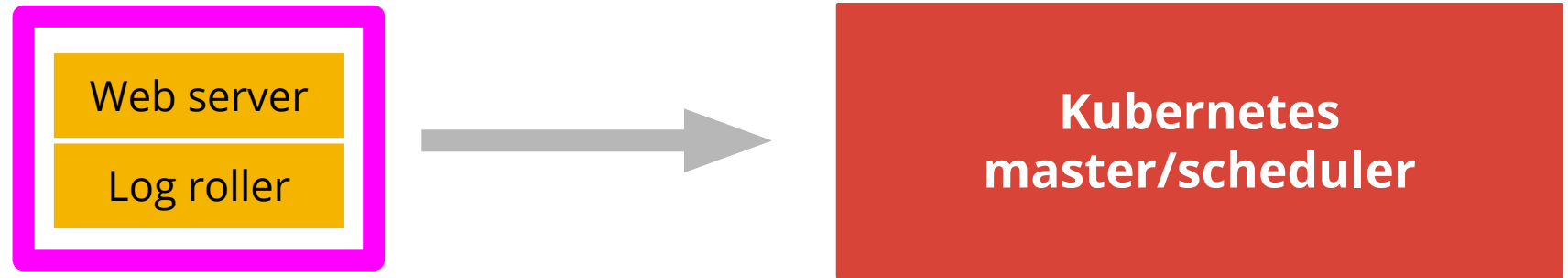
Container  
Agent

Machine  
Host

Container  
Agent

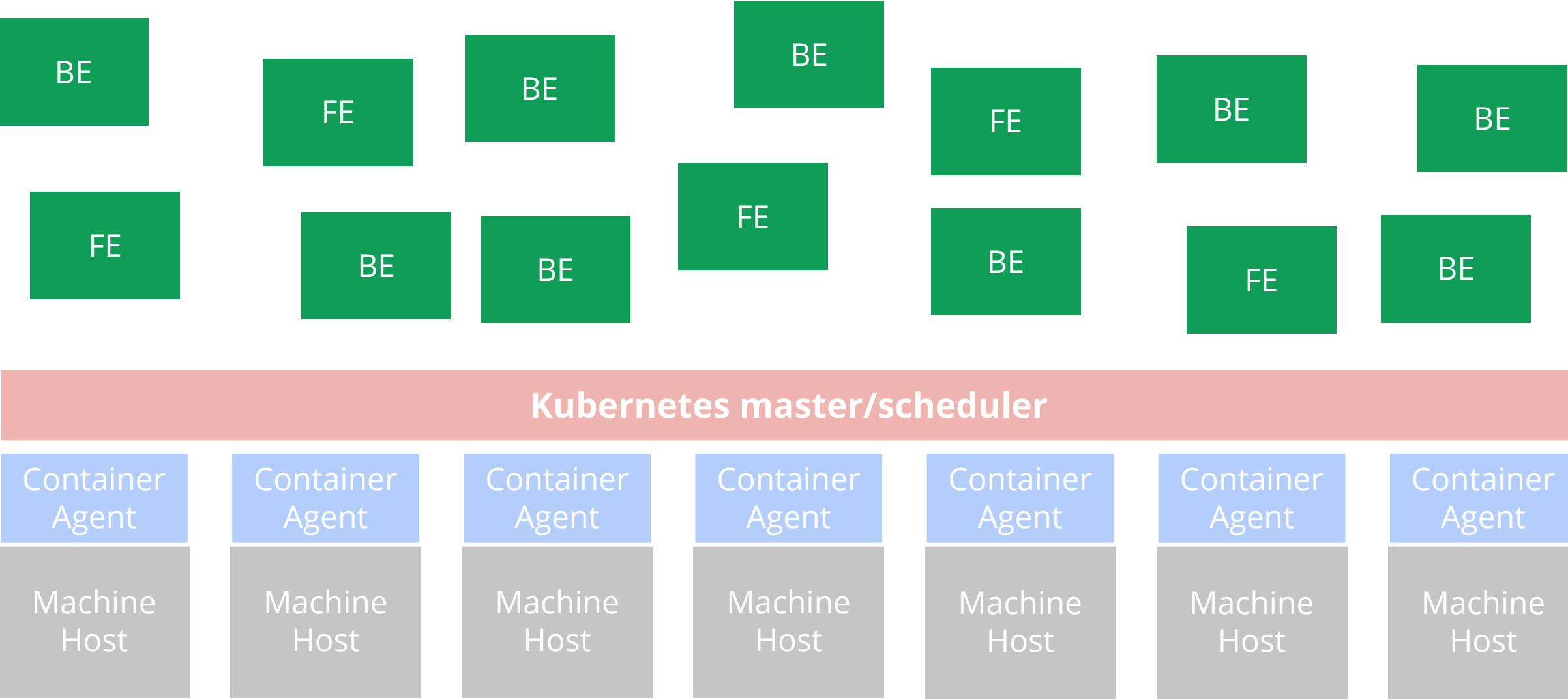
Machine  
Host

# Pods



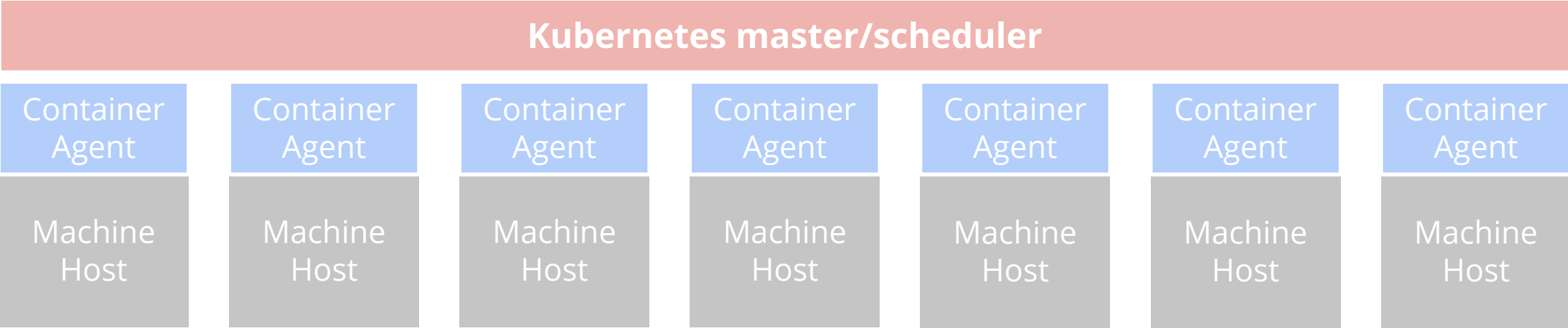
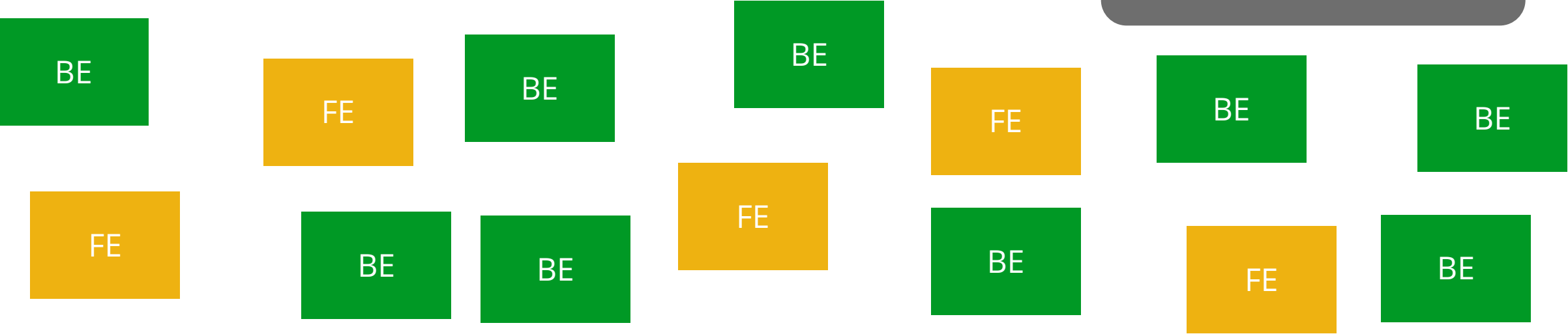


# Labels

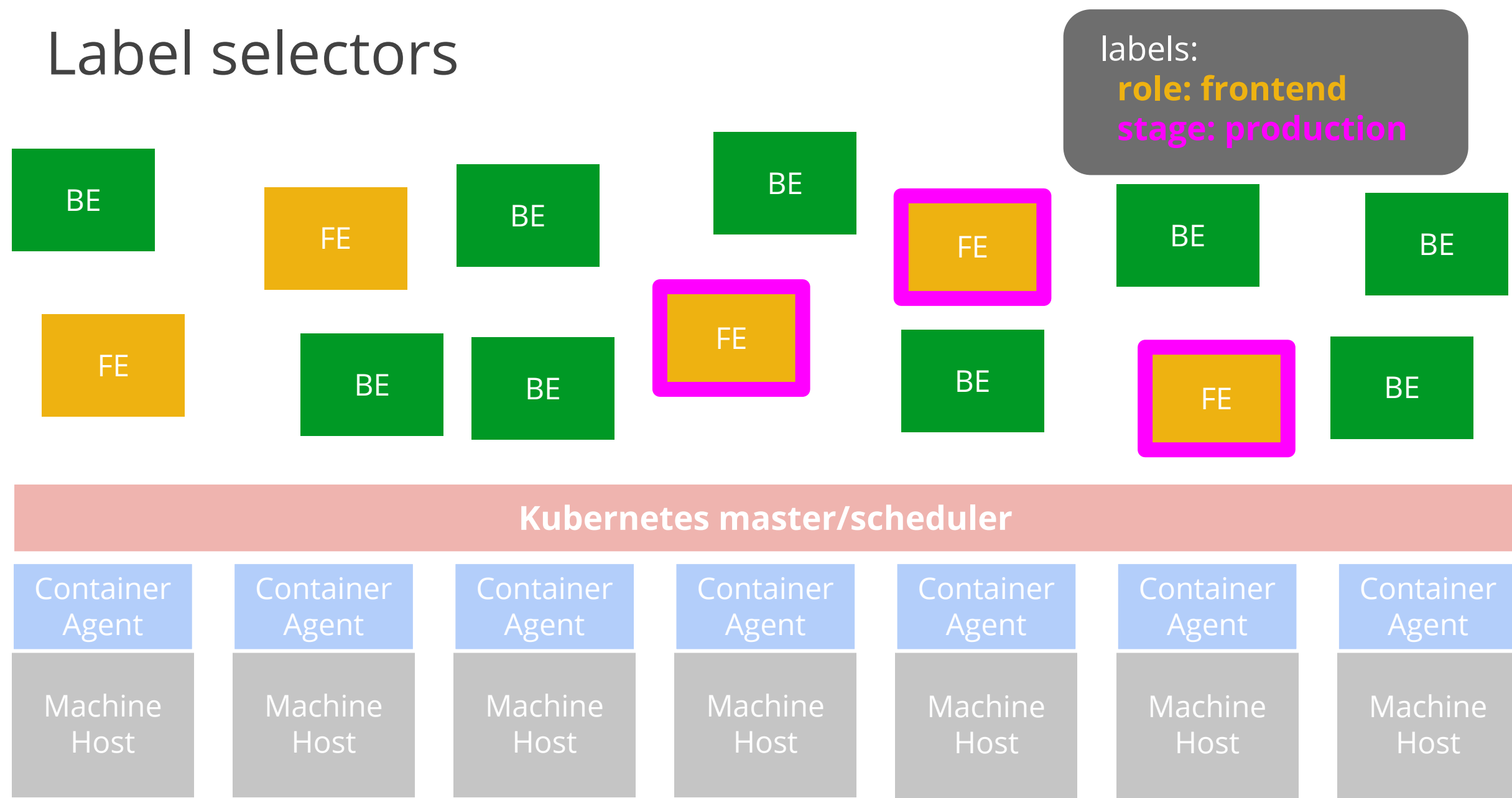


# Label selectors

labels:  
**role: frontend**



# Label selectors





# Replica controller



**replicas: 3**

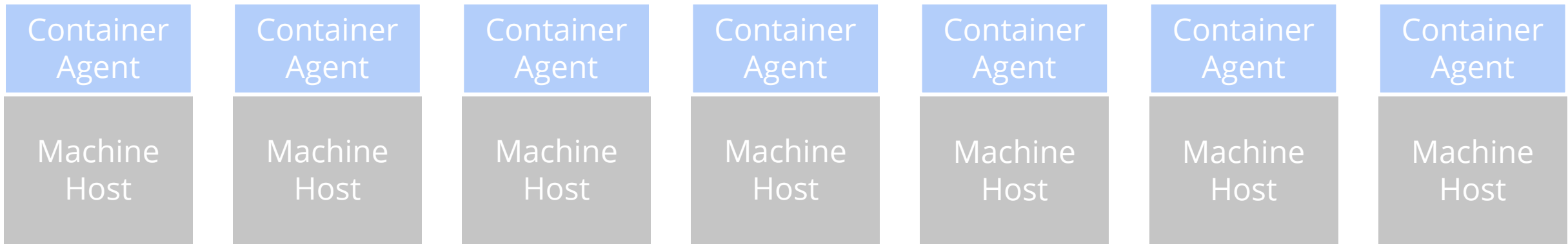
template:

...

labels:

role: frontend

## Kubernetes - Master/Scheduler



# Replica controller

**replicas: 4**

template:

...

labels:

role: frontend

FE

FE

FE

FE

## Kubernetes - Master/Scheduler

Container  
Agent

Container  
Agent

Container  
Agent

Container  
Agent

Container  
Agent

Container  
Agent

Container  
Agent

Machine  
Host

Machine  
Host

Machine  
Host

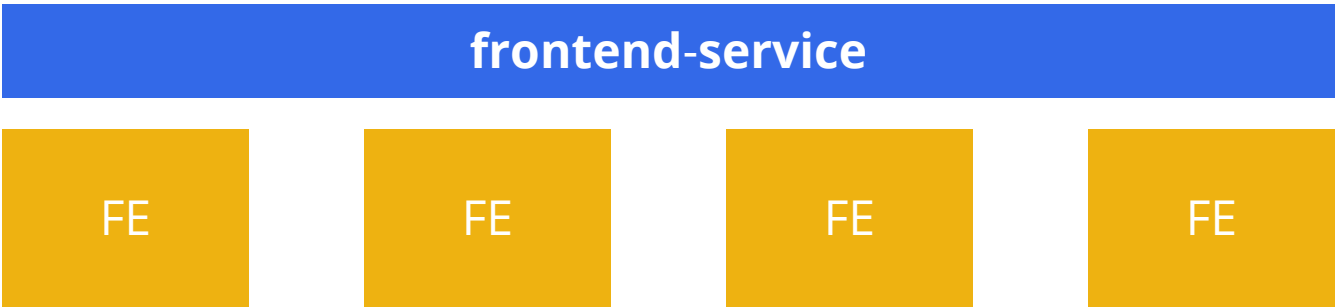
Machine  
Host

Machine  
Host

Machine  
Host

Machine  
Host

# Service



id: **frontend-service**  
port: 9000  
labels:  
    role: **frontend**

## Kubernetes - Master/Scheduler





# Kubernetes

The open source cluster manager from Google.

- Pods: groups of containers
- Labels
- Replica controller
- Services

<http://kubernetes.io>

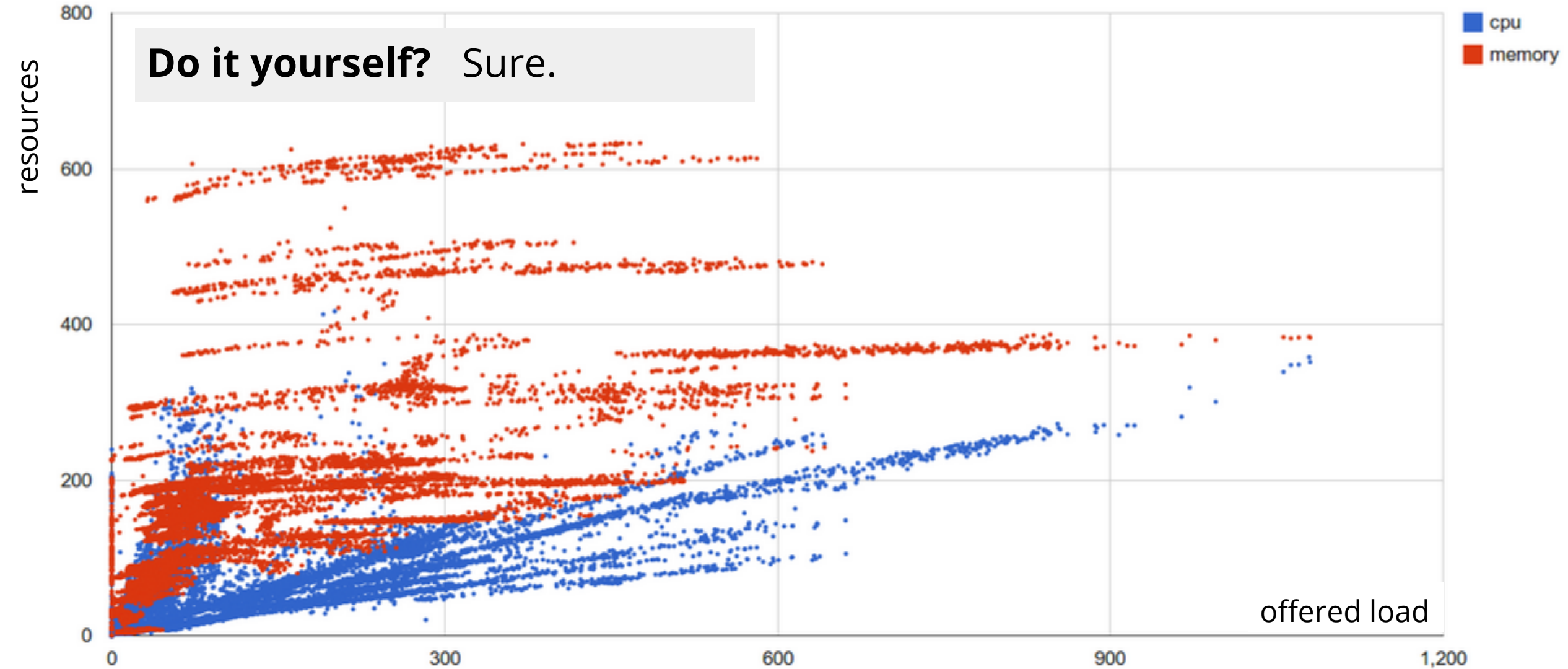


**kubernetes** by Google

Manage a cluster of Linux containers as a single system to accelerate Dev and simplify Ops.

# Pulling it all together

**Do it yourself?** Sure.





# Google Cloud Platform

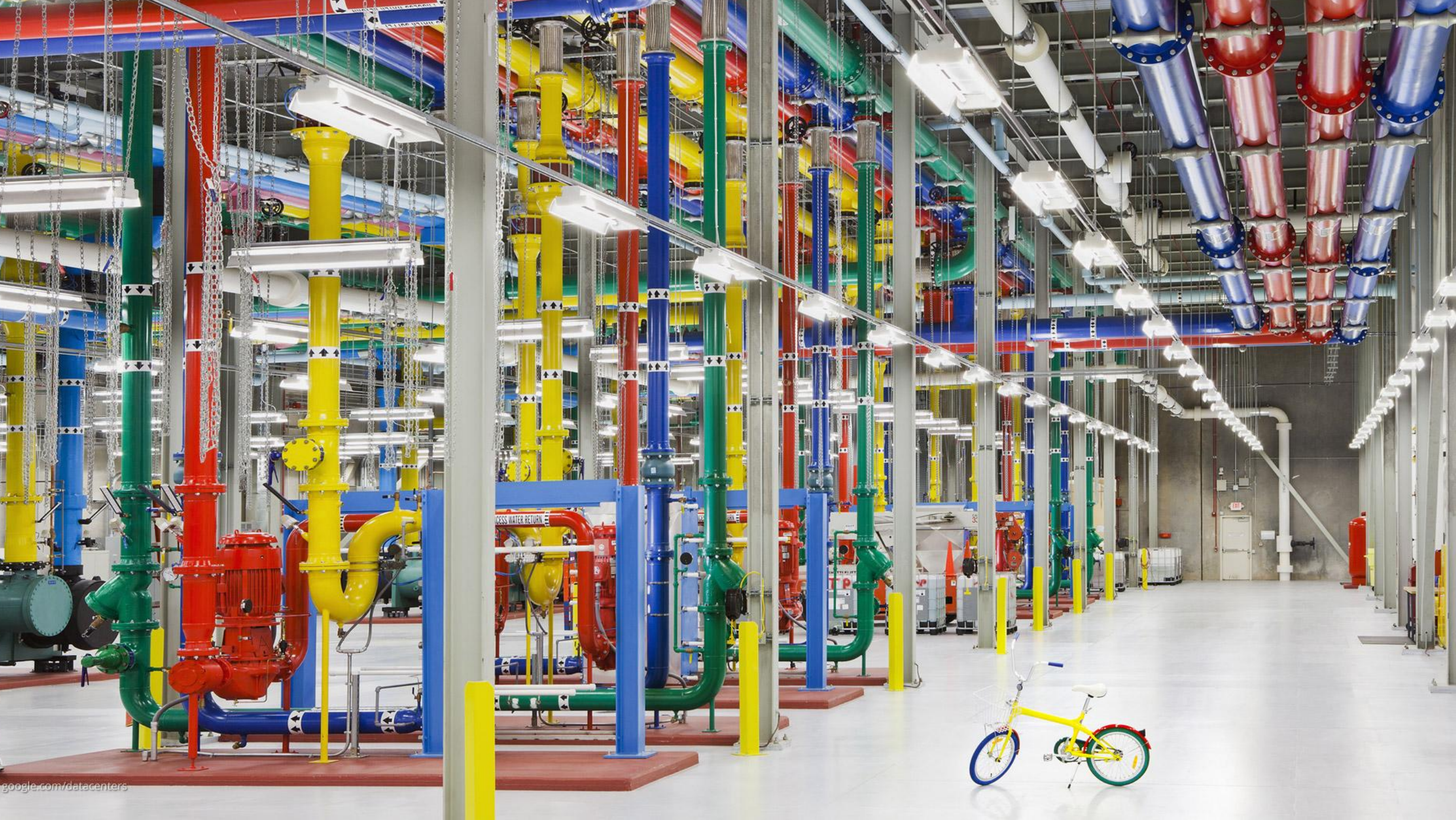


## Google Container Engine (Alpha)

Run Docker containers on Google Cloud Platform, powered by Kubernetes. Container Engine takes care of provisioning and maintaining the underlying virtual machine cluster, scaling your application, and operational logistics like logging, monitoring, and health management.

[Start your free trial](#)





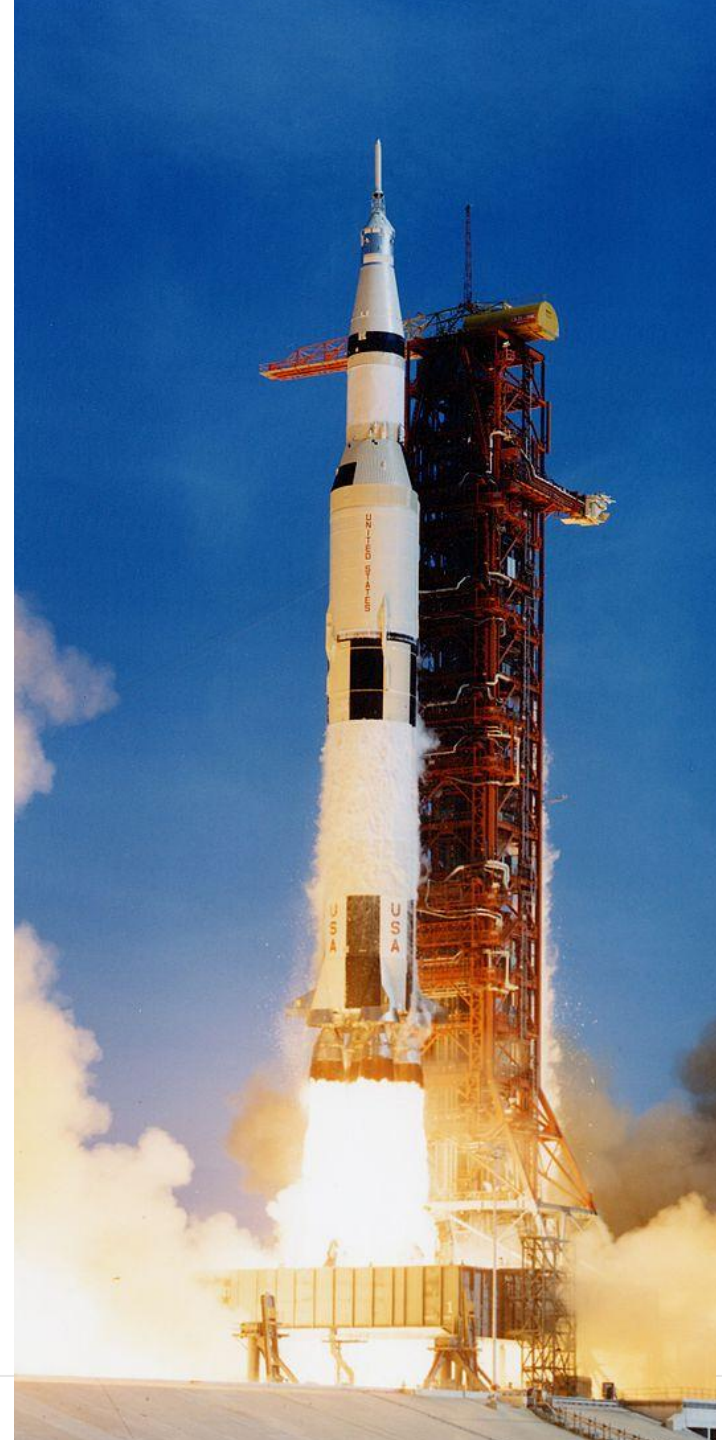


# Pulling it all together

*We choose to go to the roof not because it is glamorous, but because it is right there!*

... the bulk of our success is the result of the methodical, relentless, persistent pursuit of 1.3-2x opportunities -- what I have come to call "**roofshots**".

-- Luiz Barroso





# Pulling it all together

Data: Volkswagen, 2014-07-31  
Image: john wilkes

Porsche doesn't **make** cars:  
it designs and assembles them

1H2014:

- **1.7%** (89k) of VW group's vehicles
- **23% (€1.4b) of its profits**



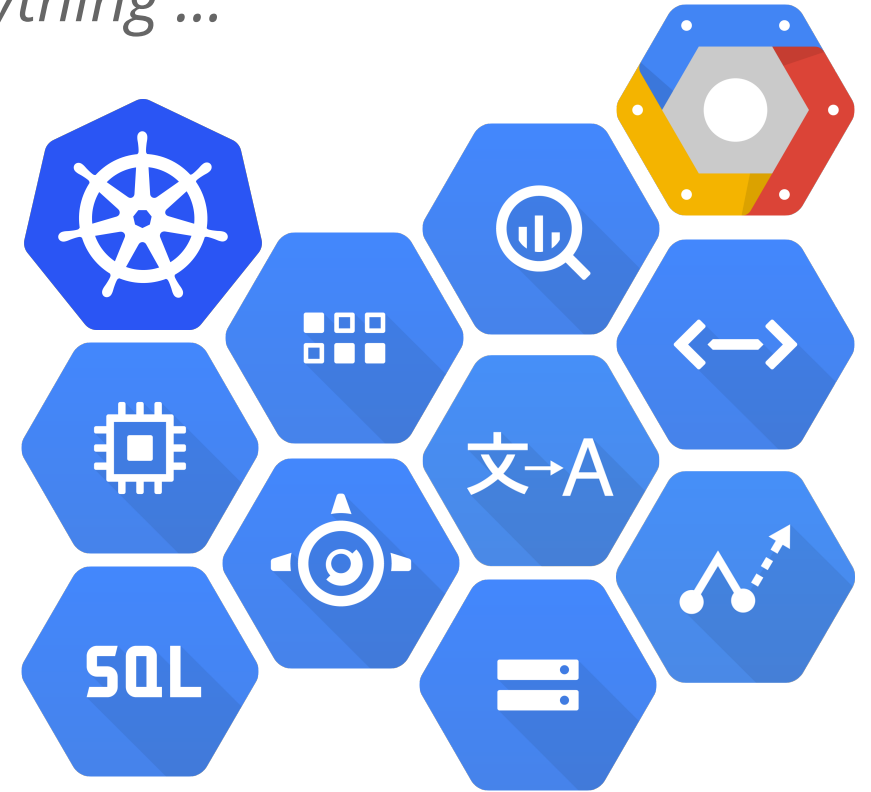


# Pulling it all together

Cloud system providers are getting better at *everything* ...

- capacity management
- monitoring
- storage + networking
- reliability
- software development tooling
- ...

Wouldn't you like to stand on others' shoulders?



## Three rules of thumb:

1. *Resiliency* is more important than performance.
2. Relax. Let go. *Build on* what others have done.
3. Do more *monitoring*.

[johnwilkes@google.com](mailto:johnwilkes@google.com)

<http://kubernetes.io>





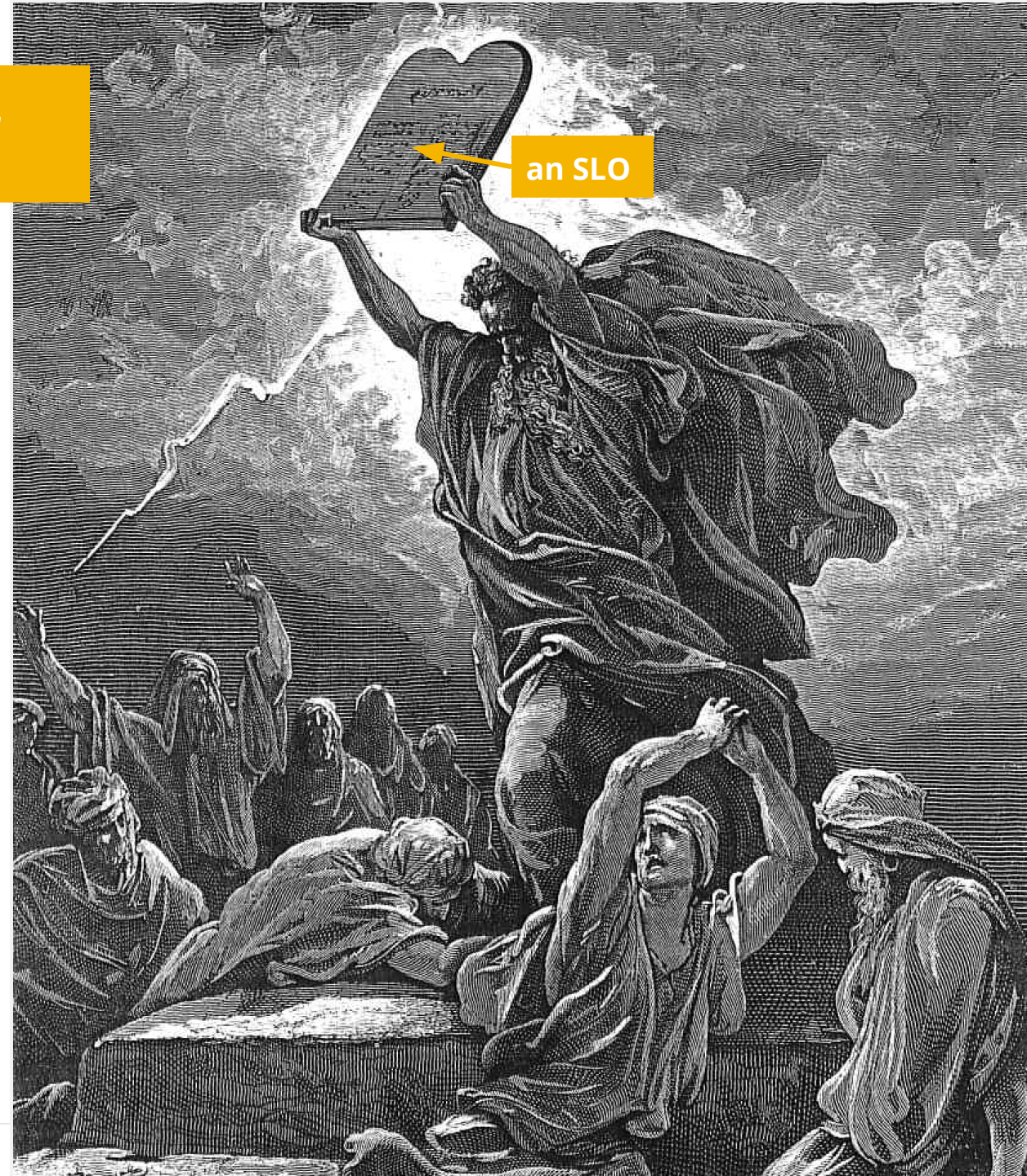
# Achieving desired behavior

## Service level agreement (SLA)

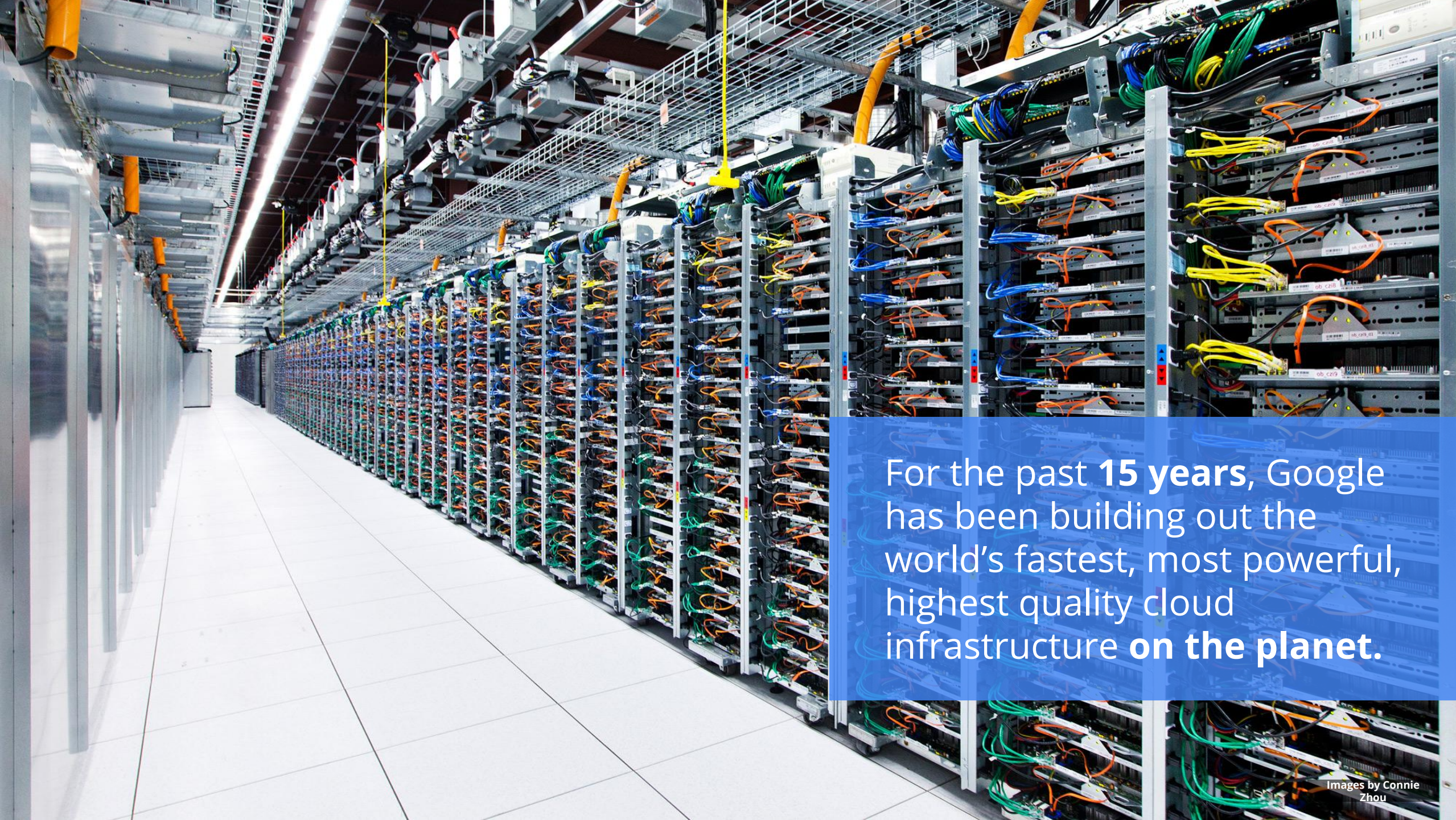
SLA = SLOs + consequences of achieving or missing them

Example:

- if *availability* > 99.95% (SLO)  
user pays £xx/CPU-week
- else gets a 30% refund







For the past **15 years**, Google has been building out the world's fastest, most powerful, highest quality cloud infrastructure **on the planet.**