Summary of Mesos investigations

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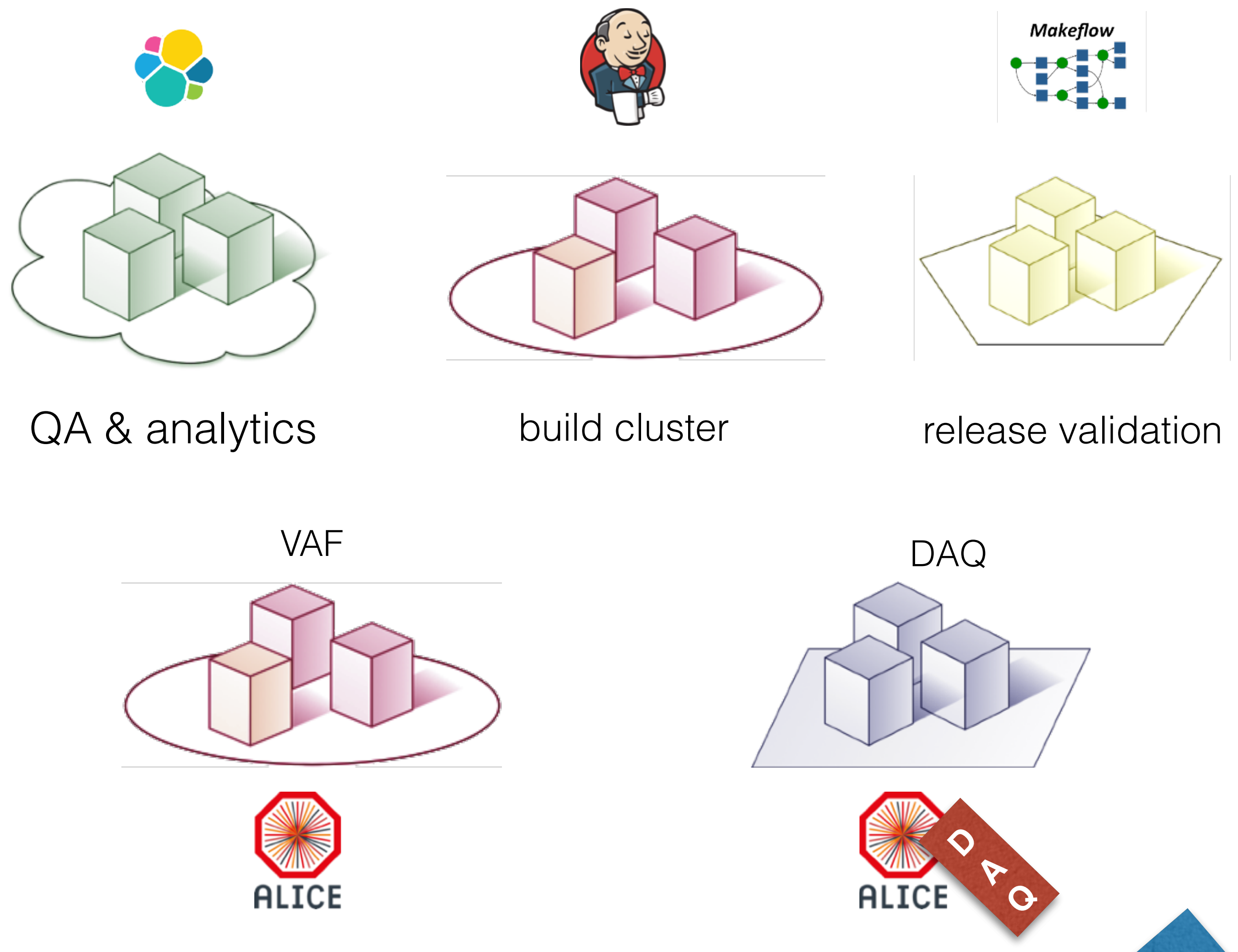
See also:

This is a summarised version of the **O2 CWG10 talk** I gave in the (Configuration and Control) context: http://cern.ch/go/hT6Q

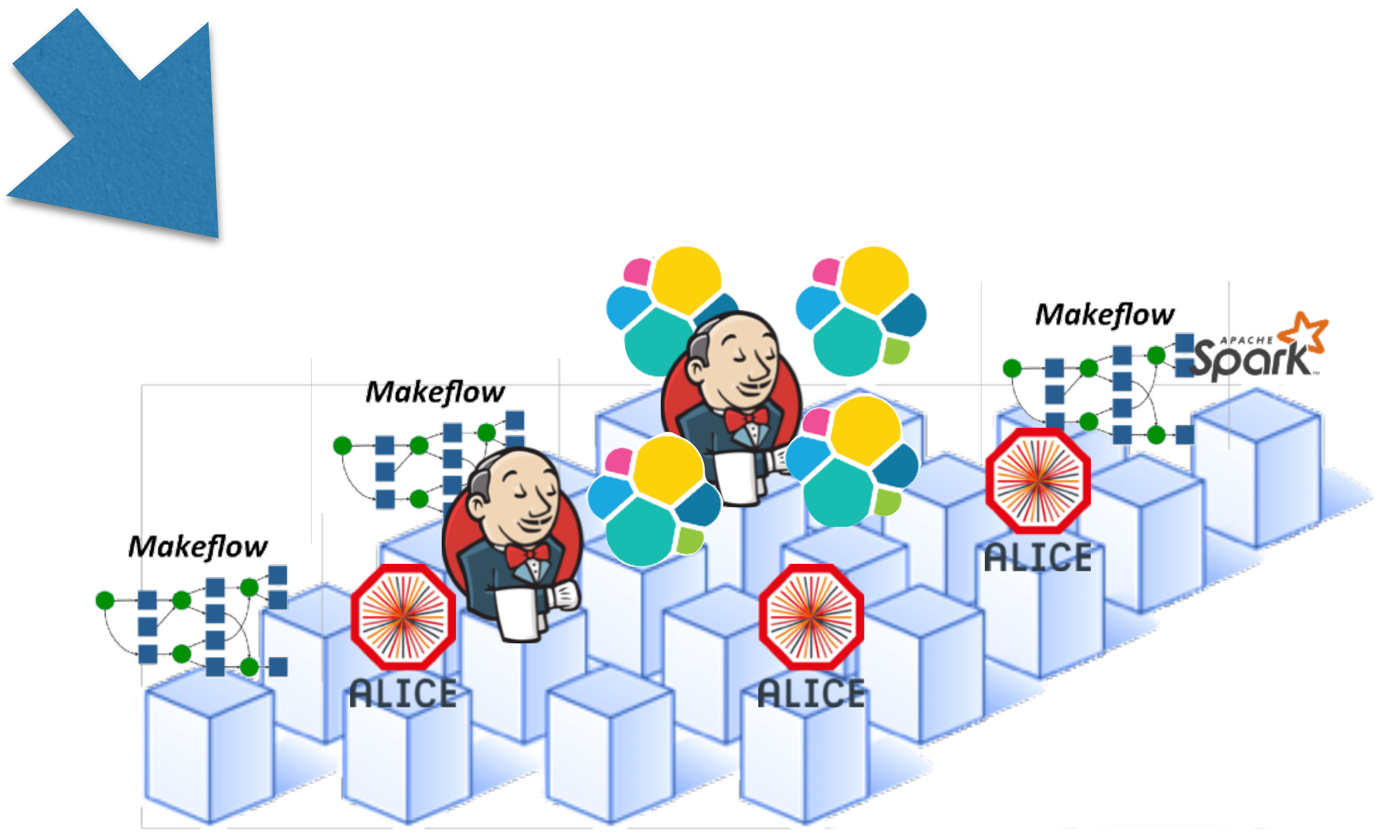
CHEP2016 presentation by Dario: http://cern.ch/go/X9bC

Our investigations so far

- ☑ Run the build infrastructure on top of Mesos
    - ☑ Understand how to install it
    - ☑ Understand how to operate it
- ☑ Understand how to extend Mesos to fit our custom use-cases:
    - ☑ Prototype of a Mesos DDS plugin
    - ☑ mesos-workqueue
- ☑ Understand how much we can rely on pre-existing solutions on top of Mesos:
    - ☑ Evaluate Mesosphere DC/OS
    - ☑ Evaluate Cisco Mantl



Architectual shift from statically partitioned silos...



*...to an **undifferentiated** set of resources which can be **reassigned dynamically** depending on load (**horizontal scalability**) and failures (**high availability**).*

What is Mesos?

"Program against your datacenter like it’s a single pool of resources"

A data-center kernel
Mesos is to the datacenter what the kernel is to the desktop: resource management and scheduler at large.

Apache Foundation project
Initially developed by AMPLab at UC Berkley [1], now under the Apache Foundation umbrella since a few years. Shares commonalities (and authors) with Google's known architecture papers [2].

Used in production by big players
Twitter, Apple, Netflix, AirBnB, Uber, NASA JPL and many others use Mesos in production [3]. Claimed to scale linearly to 10'000s of machines.

Large ecosystem
Thanks to the efforts of companies like Mesosphere, Cisco, Rancher, and many others a large ecosystem of pre-packaged solutions are available for most common "big data" tools (e.g. Spark, Elasticsearch).

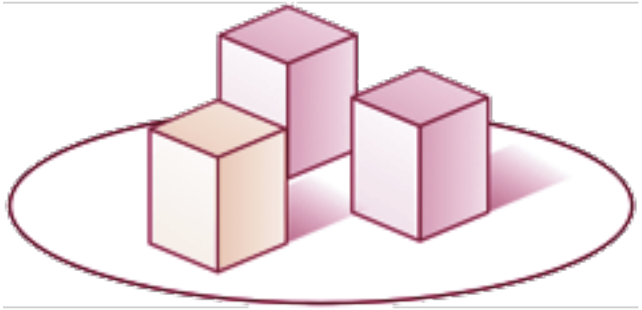
Mesos Components

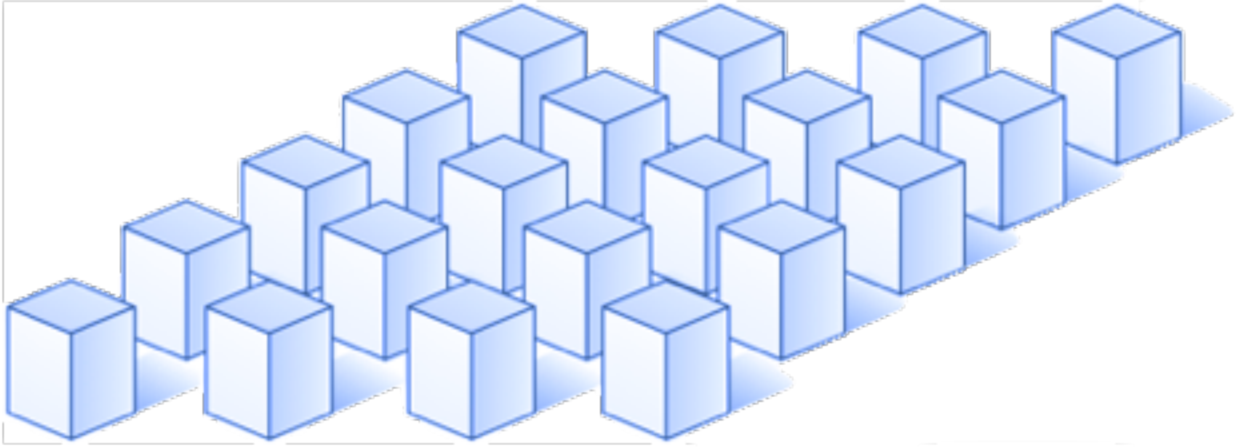
Masters

- Track application state
- Distribute resource offers
- Provide High Availability
- Accounting and authorisation
- Service discovery
- Monitoring / Debugging GUI

Agents

- "Cattle" like.
- Provide computational / storage resources
- Run (optionally containerised) applications
- Provide isolation





Frontends

- Routing
- Authentication

Mesos Features

High Availability
Zookeeper based ensemble which allows you to lose (N-1)/2 Masters before scheduler goes down. Agents can be restarted (or die) and can reconciliate and adopt orphaned tasks.

Resource Management
Allocate CPU, memory, GPU, disk space to given tasks.

Resource Isolation
First class isolation support for CPU, memory, disk, ports, GPU, and modules for custom resource isolation.

APIs
Native C++ or HTTP REST based API for scheduling, operating the clusters (e.g. scheduled downtimes), monitoring.

Fine grained authentication and authorisation
E.g. only operators can delete volumes, only application X can access certain resources, application X has at least Y resources associated to it.

Containers
(Optional) native support for running containers. Can run Docker or AppC (without the need for their runtime).

How do I use Mesos?

Mesos by itself only fulfils the "resource manager" needs and provides a very raw monitoring / debugging GUI. In order to have a full blown solution one has three ways:

Generic OpenSource PaaS: *Using one of the several opensource "Platform as a Service" (PaaS) already available, e.g. Mesosphere's **Marathon** or Twitter's **Aurora**. We use Marathon at large in or build cluster and we started looking into Aurora.*

Write a custom application (Framework): this is what we did for the release validation, in order to integrate with the existing Workqueue code.

- C++ / Python / Java API (requires linking / JNI against libmesos.so and Protobuf)
- HTTP REST API (preferred choice nowadays, no direct dependency)

Ad hoc PaaS: *e.g. Apple J.A.R.V.I.S., or "**mesos-dds**" plug-in for DDS (https://github.com/alisw/mesos-dds kudos to Kevin).*

By design you are not forced to select one single solution. Mesos is based on the assumption that different problems require different solutions and makes sure **those solutions can coexist**.

Running builds on top of Mesos

In production since over 1 year, it gave us:

Platform abstraction
We keep doing production builds on slc5, while managing an slc7 / ubuntu infrastructure (thanks to docker support).

High availability
Builders are really "cattle" by now, we do not care if they get lost by CERN Openstack, migrated from one Hypervisor to another in 10 hours, or if Costin updates to the latest Ubuntu. ;-)

Resource sharing
Release validation and builds (and a few other services) happily coexists on the same set of machines.

Installing Mesos

By now I think I can deploy a Mesos cluster in less than a day, starting from 0...

Deploy with different tools:

- ***Custom script:*** *it is really a bunch of scp and ssh.*
- ***Puppet:*** *it is really needed for all the parts which need to integrate with CERN/IT services (e.g. SSO, DNS Load balancing, secrets storage).*
- ***Ansible:*** *It is IMHO the best of the tools. Given the Mesos configuration is actually small, even ansible "client mode" can deploy few hundreds of machines quickly.*
- ***docker-compose:*** *it is very good for play-testing on your laptop, see https://github.com/alisw/ali-bot/blob/master/docker-compose.yml*.

Docker very valuable to deploy on resources we do not control.

Future investigation: deploy via CVMFS? You would still need to customise the configuration on a per-machine basis, but in principle it could be done.

Operating Mesos

Operate as a Service
The idea is really that a Mesos cluster is provided to you as a service, like Condor or SWAN would. You can run your own Mesos setup on your laptop, but it's clearly not the way it's intended to be used.

Pick a pre-existing solution
Mesos by itself only provides primitives to write your own distributed architecture. Unless you have a specific use-cases, best option is to pick one or more of the already available "frameworks" (e.g. Mesosphere Marathon, the Mesos Jenkins plugin) and start building on top of it.

High availability
Everything in Mesos is thought with redundancy in mind and once you get used to it, anything which is not annoys you. A lot.

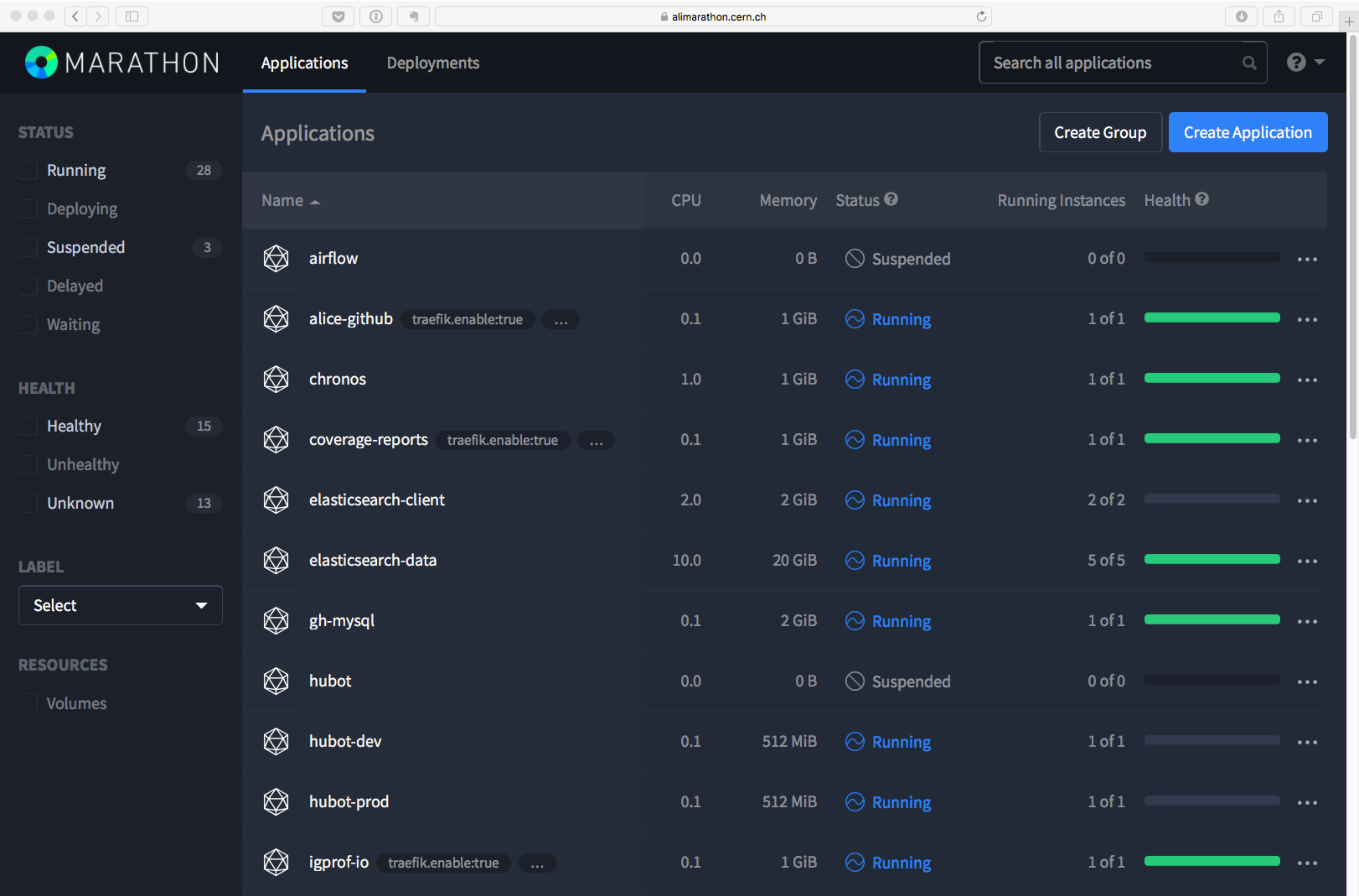
Rolling upgrades
Most / all changes can be done in a rolling upgrade mode. One can even update and restart the Mesos agent, without having to lose the actual job / service.

Operating Mesos: using Marathon

An off the shelf solution for long running jobs
Marathon is an "init.d for your cluster" by Mesosphere, a commercial company focused on providing a Mesos based solution for the datacenter (a.k.a. DC/OS).

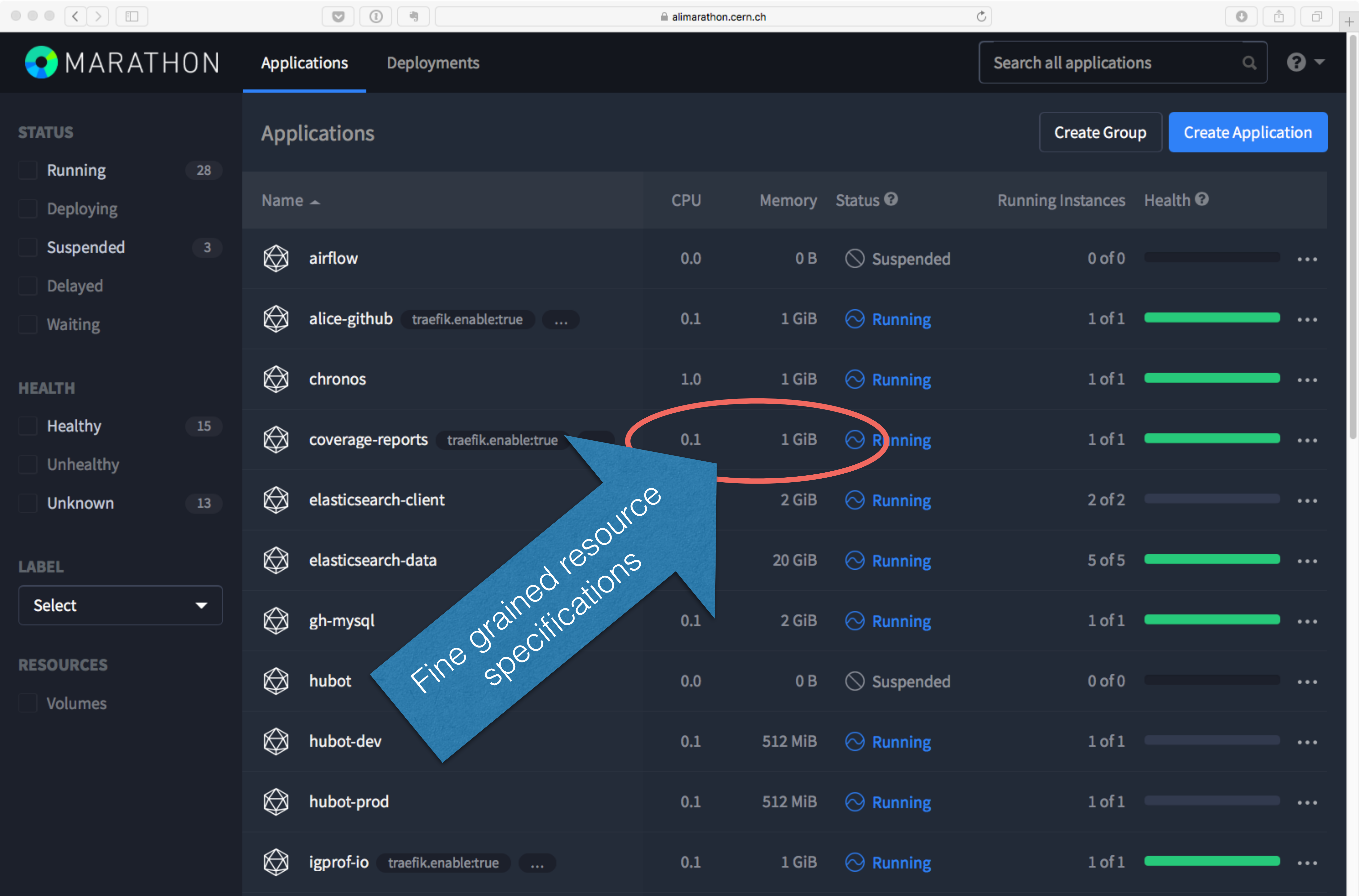
- Especially thought for long running jobs (hence the name).
- Easy to use GUI + complete REST based API + command line client.
- Provides High Availability, support for stateful applications (e.g. MySQL databases), flexible constrains, service discovery, health checks, metrics, (optional) Docker support.
- Used in the Offline Build and QA cluster (250 cores, 20 machines)

Marathon: Top level view



Name	CPU	Memory	Status	Running Instances	Health
airflow	0.0	0 B	Suspended	0 of 0	▭
alice-github traefik.enable:true ...	0.1	1 GiB	Running	1 of 1	🟩
chronos	1.0	1 GiB	Running	1 of 1	🟩
coverage-reports traefik.enable:true ...	0.1	1 GiB	Running	1 of 1	🟩
elasticsearch-client	2.0	2 GiB	Running	2 of 2	▭
elasticsearch-data	10.0	20 GiB	Running	5 of 5	🟩
gh-mysql	0.1	2 GiB	Running	1 of 1	🟩
hubot	0.0	0 B	Suspended	0 of 0	▭
hubot-dev	0.1	512 MiB	Running	1 of 1	▭
hubot-prod	0.1	512 MiB	Running	1 of 1	▭
igprof-io traefik.enable:true ...	0.1	1 GiB	Running	1 of 1	🟩

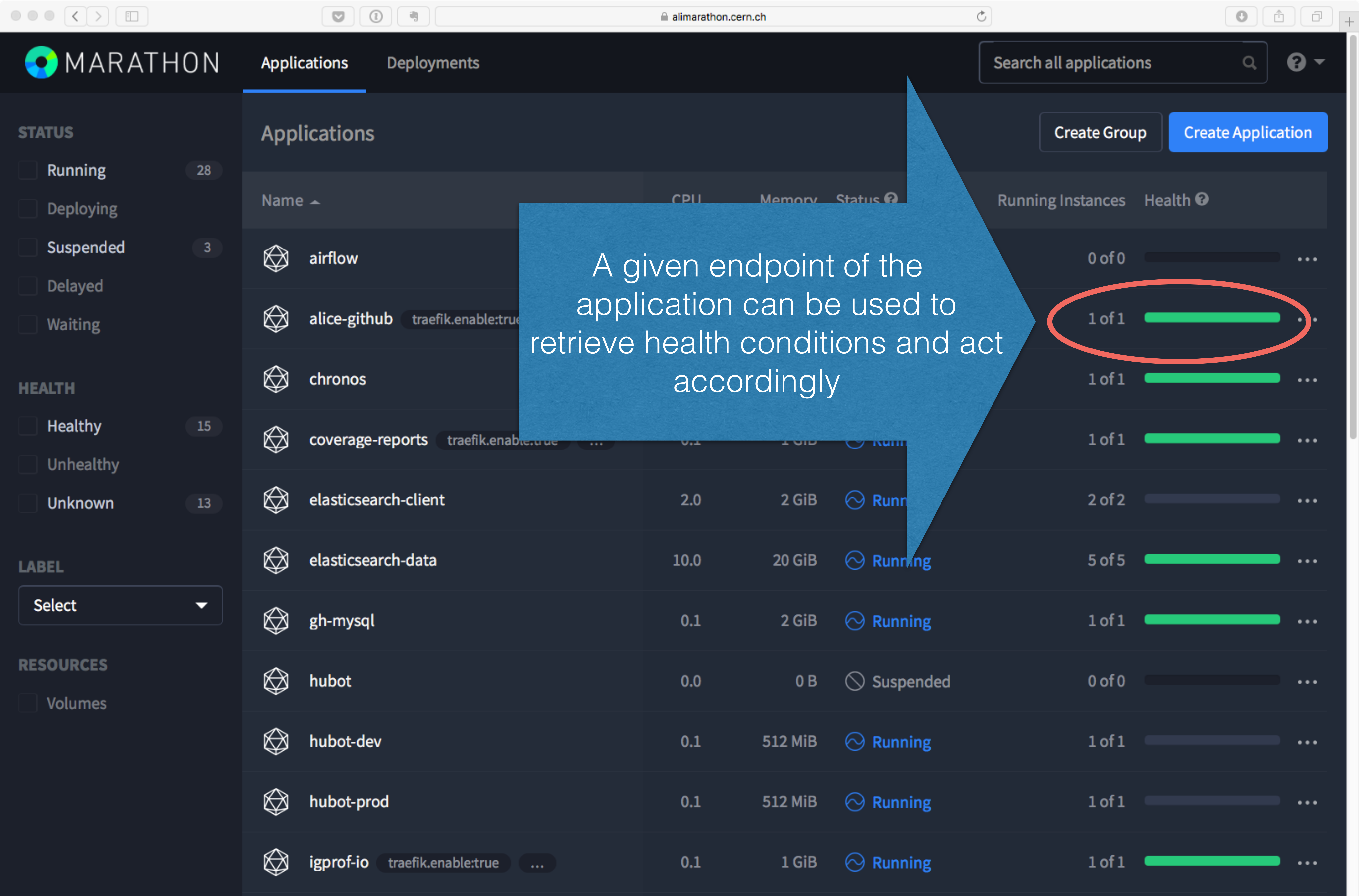
Marathon: fine grained resources



Name	CPU	Memory	Status	Running Instances	Health
airflow	0.0	0 B	Suspended	0 of 0	
alice-github traefik.enable:true ...	0.1	1 GiB	Running	1 of 1	
chronos	1.0	1 GiB	Running	1 of 1	
coverage-reports traefik.enable:true	0.1	1 GiB	Running	1 of 1	
elasticsearch-client		2 GiB	Running	2 of 2	
elasticsearch-data		20 GiB	Running	5 of 5	
gh-mysql	0.1	2 GiB	Running	1 of 1	
hubot	0.0	0 B	Suspended	0 of 0	
hubot-dev	0.1	512 MiB	Running	1 of 1	
hubot-prod	0.1	512 MiB	Running	1 of 1	
igprof-io traefik.enable:true ...	0.1	1 GiB	Running	1 of 1	

Fine grained resource specifications

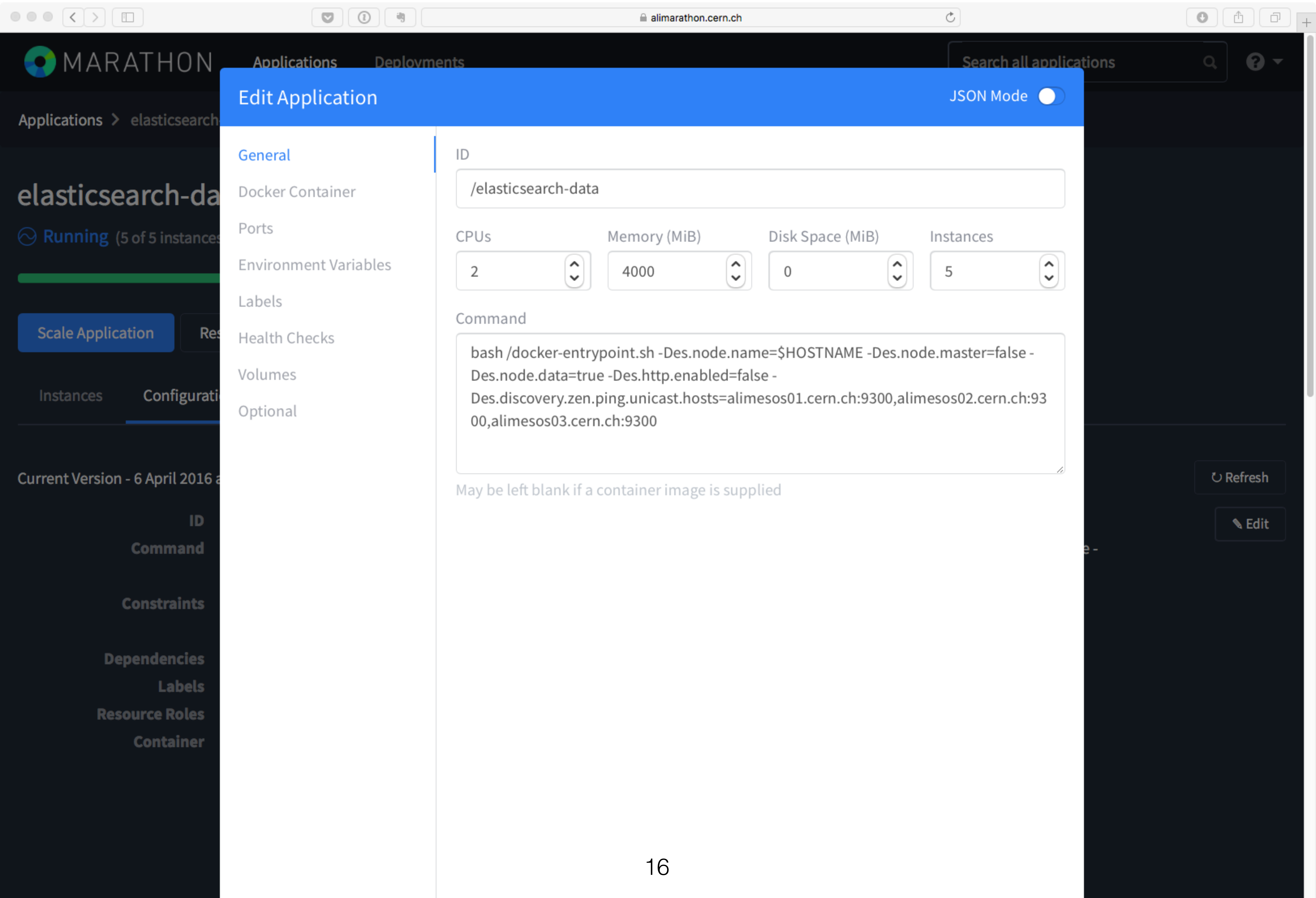
Marathon: health checks



Name	CPU	Memory	Status	Running Instances	Health
airflow				0 of 0	
alice-github traefik.enable:true				1 of 1	🟩
chronos				1 of 1	🟩
coverage-reports traefik.enable:true ...	0.1	1 GiB	Runn	1 of 1	🟩
elasticsearch-client	2.0	2 GiB	Runn	2 of 2	
elasticsearch-data	10.0	20 GiB	Running	5 of 5	🟩
gh-mysql	0.1	2 GiB	Running	1 of 1	🟩
hubot	0.0	0 B	Suspended	0 of 0	
hubot-dev	0.1	512 MiB	Running	1 of 1	
hubot-prod	0.1	512 MiB	Running	1 of 1	
igprof-io traefik.enable:true ...	0.1	1 GiB	Running	1 of 1	🟩

A given endpoint of the application can be used to retrieve health conditions and act accordingly

Marathon: configuring application through the GUI



ID: /elasticsearch-data

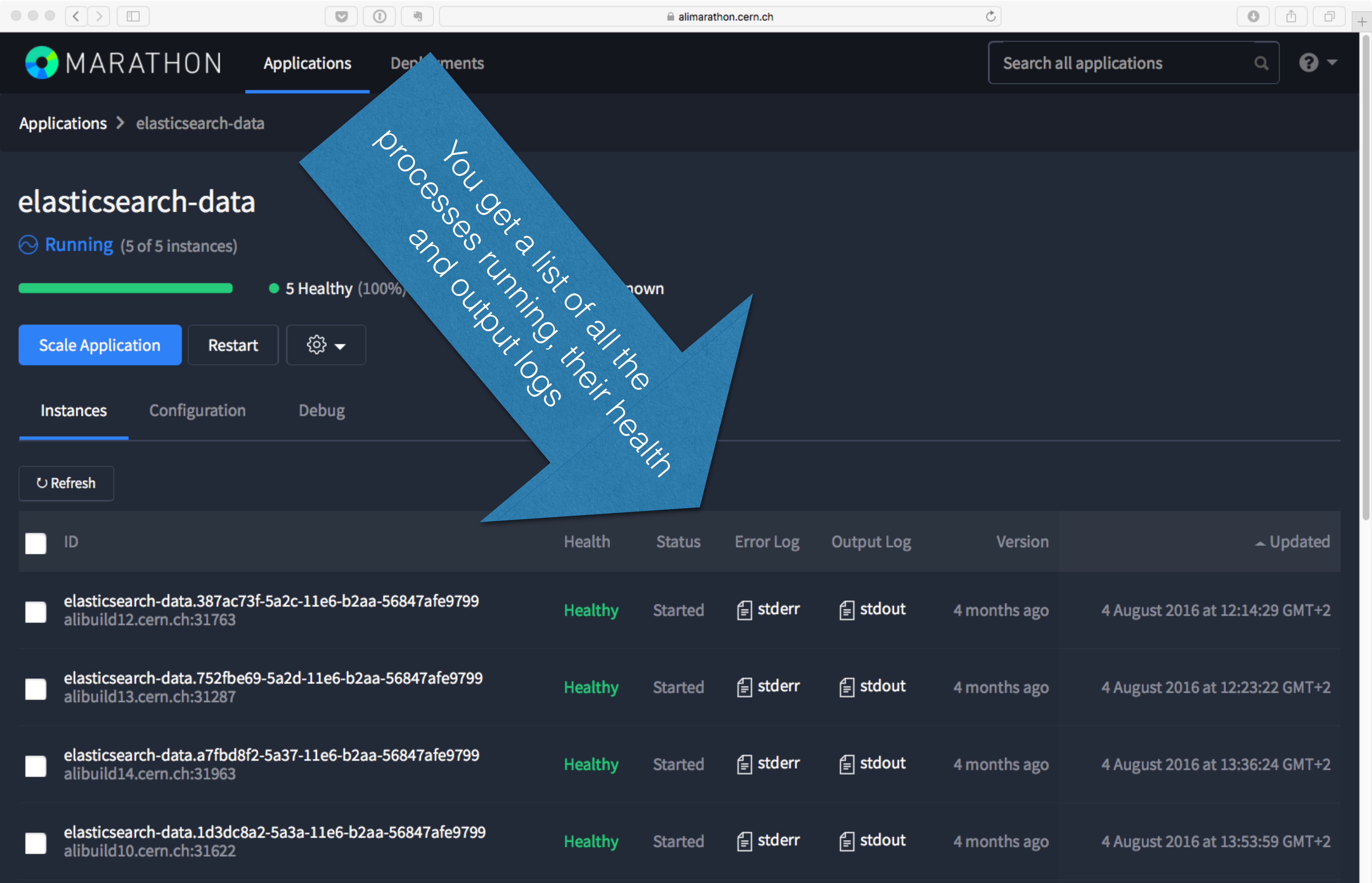
CPUs	Memory (MiB)	Disk Space (MiB)	Instances
2	4000	0	5

Command

```
bash /docker-entrypoint.sh -Des.node.name=$HOSTNAME -Des.node.master=false -Des.node.data=true -Des.http.enabled=false -Des.discovery.zen.ping.unicast.hosts=alimesos01.cern.ch:9300,alimesos02.cern.ch:9300,alimesos03.cern.ch:9300
```

May be left blank if a container image is supplied

Marathon: fine grained task details



You get a list of all the processes running, their health and output logs

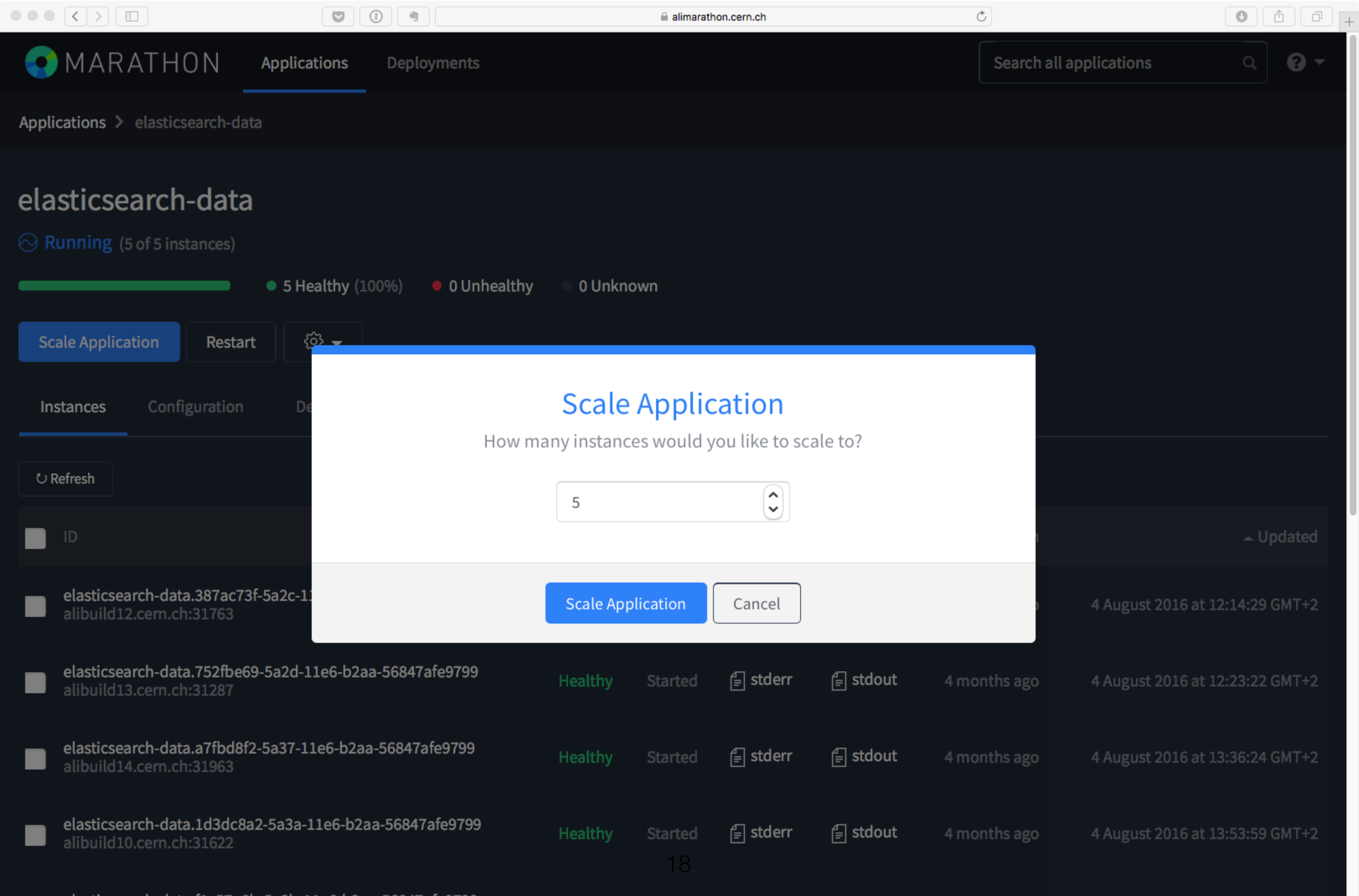
elasticsearch-data

Running (5 of 5 instances)

● 5 Healthy (100%) … own

ID	Health	Status	Error Log	Output Log	Version	Updated
elasticsearch-data.387ac73f-5a2c-11e6-b2aa-56847afe9799 alibuild12.cern.ch:31763	Healthy	Started	stderr	stdout	4 months ago	4 August 2016 at 12:14:29 GMT+2
elasticsearch-data.752fbe69-5a2d-11e6-b2aa-56847afe9799 alibuild13.cern.ch:31287	Healthy	Started	stderr	stdout	4 months ago	4 August 2016 at 12:23:22 GMT+2
elasticsearch-data.a7fbd8f2-5a37-11e6-b2aa-56847afe9799 alibuild14.cern.ch:31963	Healthy	Started	stderr	stdout	4 months ago	4 August 2016 at 13:36:24 GMT+2
elasticsearch-data.1d3dc8a2-5a3a-11e6-b2aa-56847afe9799 alibuild10.cern.ch:31622	Healthy	Started	stderr	stdout	4 months ago	4 August 2016 at 13:53:59 GMT+2

Marathon: scaling applications with a click



elasticsearch-data

Running (5 of 5 instances)

● 5 Healthy (100%) ● 0 Unhealthy ● 0 Unknown

Scale Application

How many instances would you like to scale to?

5

ID						Updated
elasticsearch-data.387ac73f-5a2c-11 alibuild12.cern.ch:31763						4 August 2016 at 12:14:29 GMT+2
elasticsearch-data.752fbe69-5a2d-11e6-b2aa-56847afe9799 alibuild13.cern.ch:31287	Healthy	Started	stderr	stdout	4 months ago	4 August 2016 at 12:23:22 GMT+2
elasticsearch-data.a7fbd8f2-5a37-11e6-b2aa-56847afe9799 alibuild14.cern.ch:31963	Healthy	Started	stderr	stdout	4 months ago	4 August 2016 at 13:36:24 GMT+2
elasticsearch-data.1d3dc8a2-5a3a-11e6-b2aa-56847afe9799 alibuild10.cern.ch:31622	Healthy	Started	stderr	stdout	4 months ago	4 August 2016 at 13:53:59 GMT+2

Apache Aurora

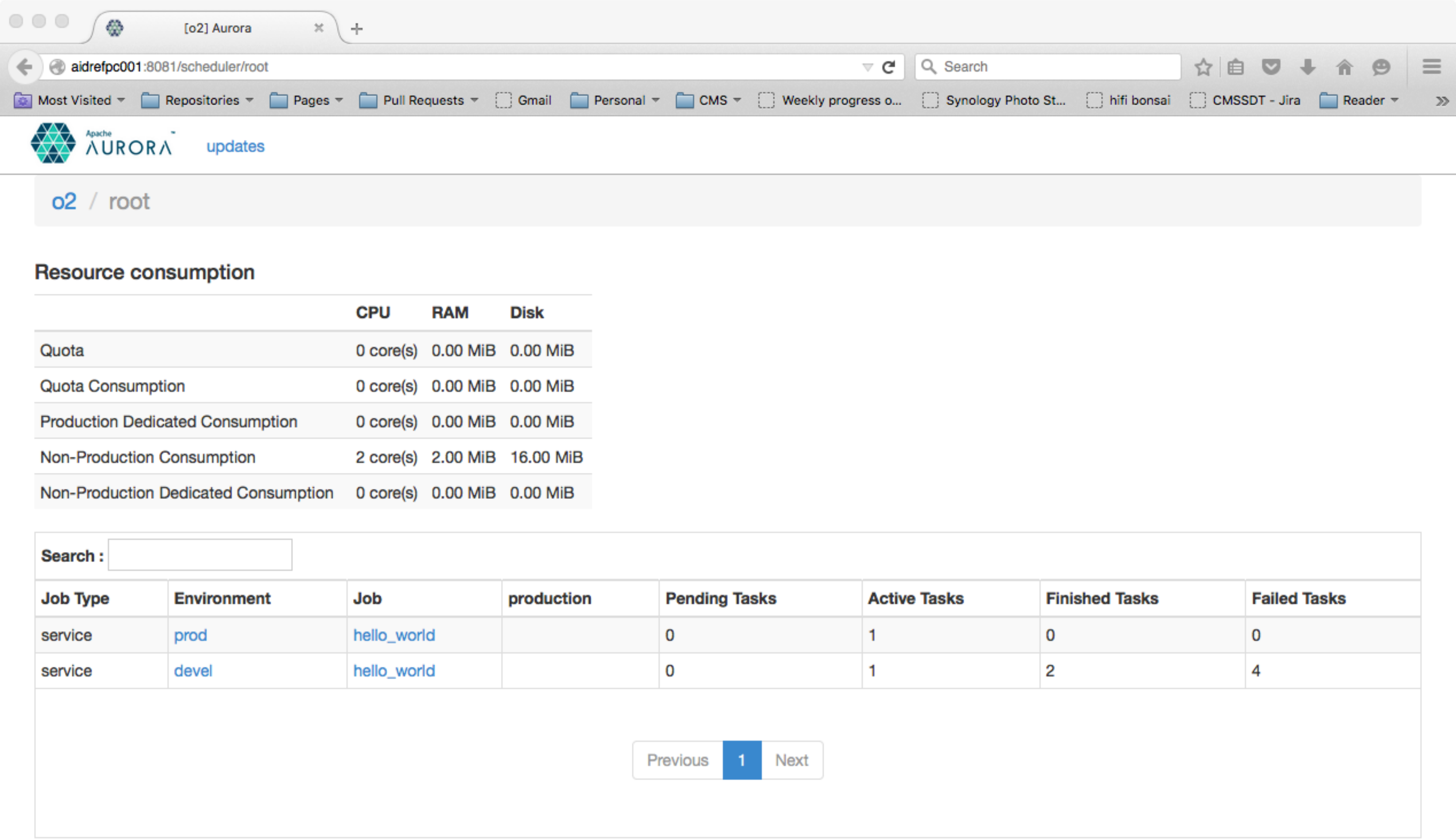
What Twitter runs

Aurora is the PaaS developed at Twitter (now Open Source) to run all of their workloads. Oldest Mesos based project to my knowledge. They disclosed it scales for their 250,000 containers running on 30,000 nodes.*

- *Both for **long-running** and **cron jobs***
- *Tasks described in a Python based DSL. Command-line based interaction. Monitoring GUI.*
- ***Multi role / environment support**, with associated quotas and preemption. E.g. online / offline role, development / production environment.*
- *Supports multiple deployment updates strategies (e.g. canary)*

*: https://youtu.be/FU7wrqsRj3o?t=21m11s

Apache Aurora: toplevel view



o2 / root

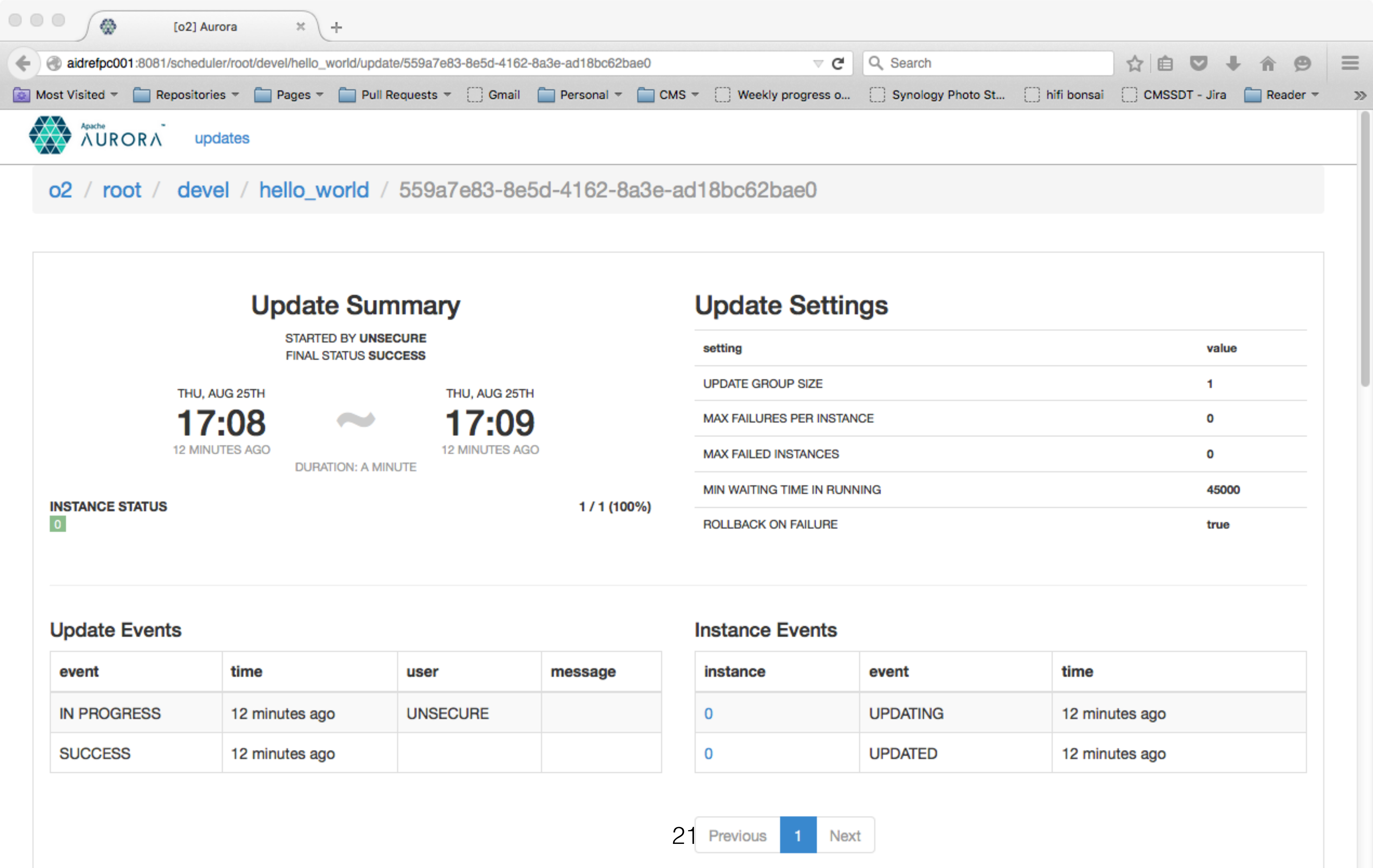
Resource consumption

	CPU	RAM	Disk
Quota	0 core(s)	0.00 MiB	0.00 MiB
Quota Consumption	0 core(s)	0.00 MiB	0.00 MiB
Production Dedicated Consumption	0 core(s)	0.00 MiB	0.00 MiB
Non-Production Consumption	2 core(s)	2.00 MiB	16.00 MiB
Non-Production Dedicated Consumption	0 core(s)	0.00 MiB	0.00 MiB

Search :

Job Type	Environment	Job	production	Pending Tasks	Active Tasks	Finished Tasks	Failed Tasks
service	prod	hello_world		0	1	0	0
service	devel	hello_world		0	1	2	4

Apache Aurora: task updates view



o2 / root / devel / hello_world / 559a7e83-8e5d-4162-8a3e-ad18bc62bae0

Update Summary

STARTED BY **UNSECURE**
FINAL STATUS **SUCCESS**

THU, AUG 25TH
17:08
12 MINUTES AGO

~

THU, AUG 25TH
17:09
12 MINUTES AGO

DURATION: A MINUTE

INSTANCE STATUS **1 / 1 (100%)**

0

Update Settings

setting	value
UPDATE GROUP SIZE	1
MAX FAILURES PER INSTANCE	0
MAX FAILED INSTANCES	0
MIN WAITING TIME IN RUNNING	45000
ROLLBACK ON FAILURE	true

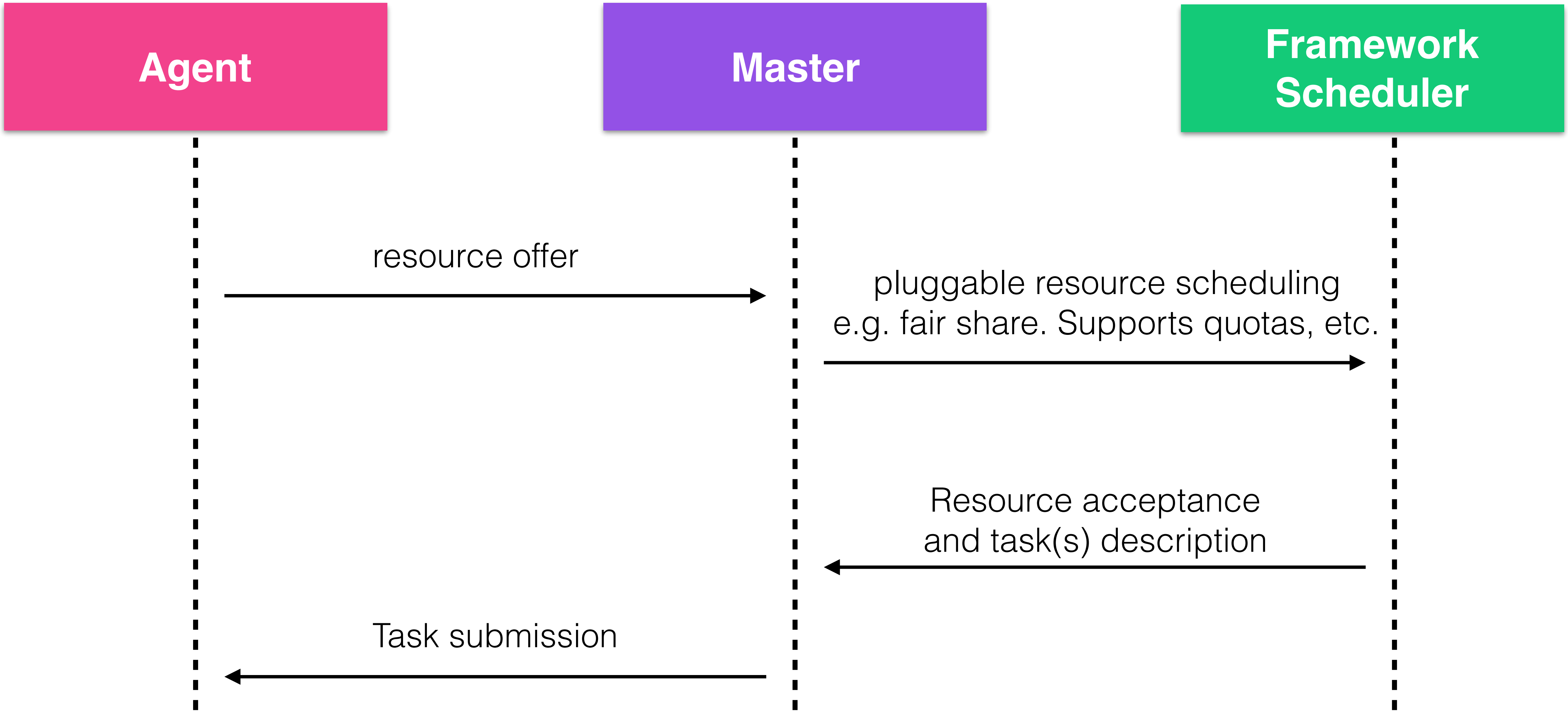
Update Events

event	time	user	message
IN PROGRESS	12 minutes ago	UNSECURE	
SUCCESS	12 minutes ago		

Instance Events

instance	event	time
0	UPDATING	12 minutes ago
0	UPDATED	12 minutes ago

Mesos difference: application aware


Agent
Master
Framework Scheduler
resource offer
pluggable resource scheduling e.g. fair share. Supports quotas, etc.
Resource acceptance and task(s) description
Task submission

*Mesos is a **two level scheduler**. The first level being some generic resource scheduling done by the master, the second level being the application (Framework) itself taking finer grained, **application-aware**, decisions.*

http://mesos.berkeley.edu/mesos_tech_report.pdf

Adapting Mesos to our specific needs

Why writing your own framework?

Don't: Think twice before writing your own framework, *writing a Mesos framework is easy. Writing a good Mesos framework is hard and one should have a pretty good reason for doing so.*

Automatic scaling: *your applications needs to scale up and down quickly as response to its own internal state.*

Dynamic resource management: *your applications has the need to allocate / deallocate resources (e.g. storage) as part of its life-cycle.*

Complex task placement: *e.g. your application needs to run only once on every node of the cluster every day, but only when the machine is idle.*

Interface with your own scheduler: *you already have a working scheduler and you want to share resources with others, but you do not want to give up ownership of the scheduling to a third party.*

Mesos Workqueue

Integrate legacy system into new one
Old release validation used workqueue, so we decided to keep things unchanged and plug workqueue on top of Mesos.

https://github.com/alisw/mesos-workqueue
Total work to do it, roughly 1 week, 362 C++ SLOC. Nothing particularly smart, but it works and runs in production.

Scales dynamically
Depending on the needs of the release validation it can dynamically scale workers.

Missing features
Task reconciliation (if the master dies, all the workers do), high availability.

DDS Mesos

DDS plugin to use Mesos as a RMS
By design DDS does not do any resource management, but it delegates it to external Resource Management Systems. Mesos is a perfect fit there.

https://github.com/alisw/mesos-dds
Work done by Kevin Napoli (University of Malta) for his master thesis.

Client - Server architecture
By separating the part which talks to mesos to a separate server-side component, allows multiple DDS to share the same Mesos cluster.

Future developments
Resource constrains, e.g. run task on a node which has a GPU (was discussed in the last DDS workshop). Integrate with Aurora to get all the nice multi-user / multi-tier features?

End-to-End Mesos solutions

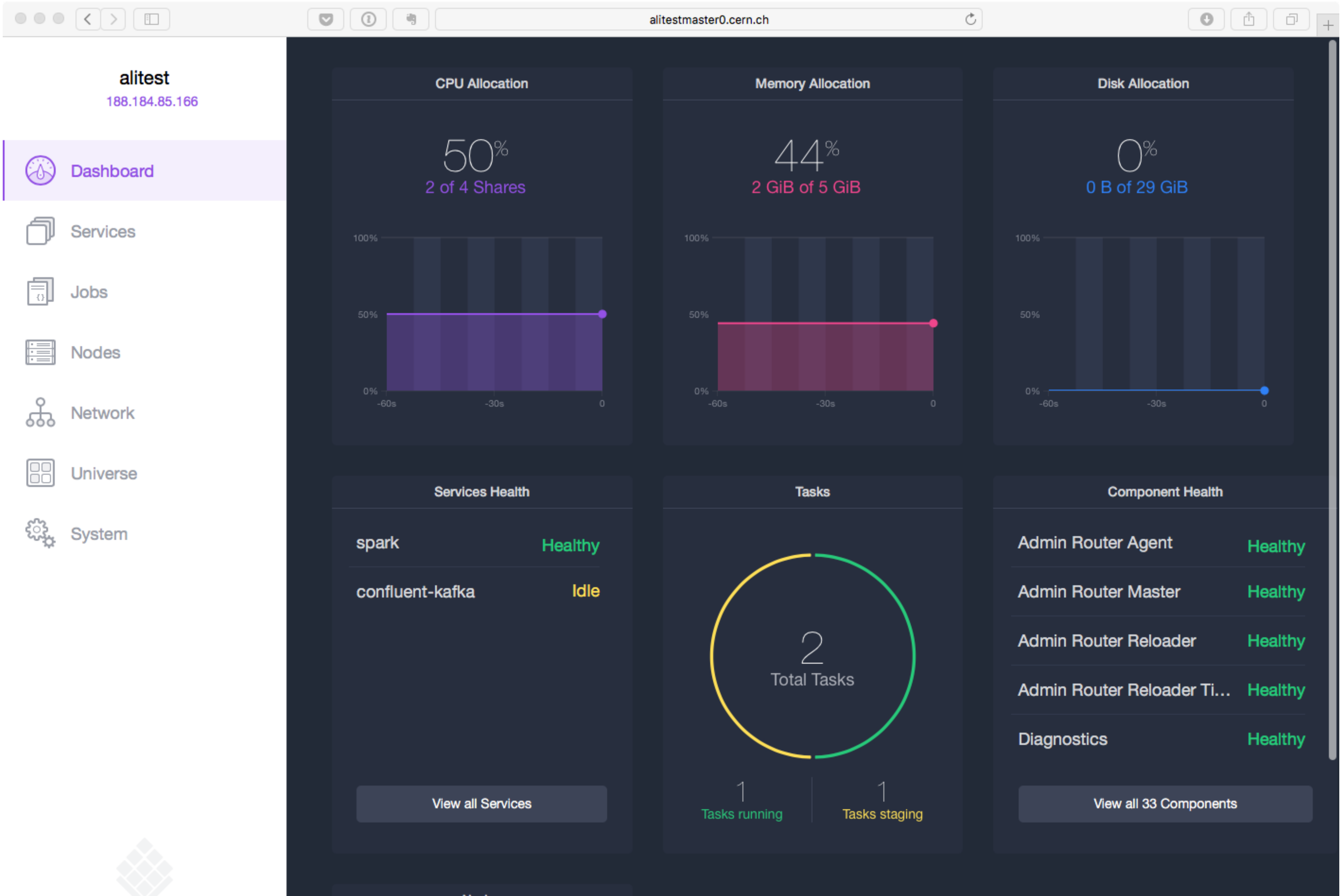
Mesosphere DC/OS

A Mesos Distribution
End to end solution for Mesos. If Mesos is the kernel and a Framework is an application, DC/OS is a Linux distribution. Developed by Mesosphere, recently OpenSourced (Apache Licensed).

Brainless Mesos Setup
Provides easy installation, user management, prepackaged applications, nicer monitoring GUI, CLI and fully integrated GUI. Built around Marathon.

Too brainless?
DC/OS is extremely nice to quickly deploy and operate well known tools like Hadoop, Spark, Storm. Not clear what is the added value w.r.t. Marathon / Aurora, if you do not need those, and you need to package your own tools.

Mesosphere DC/OS: dashboard



CPU Allocation

50%

2 of 4 Shares

Memory Allocation

44%

2 GiB of 5 GiB

Disk Allocation

0%

0 B of 29 GiB

Services Health

spark	Healthy
confluent-kafka	Idle

Tasks

2 Total Tasks

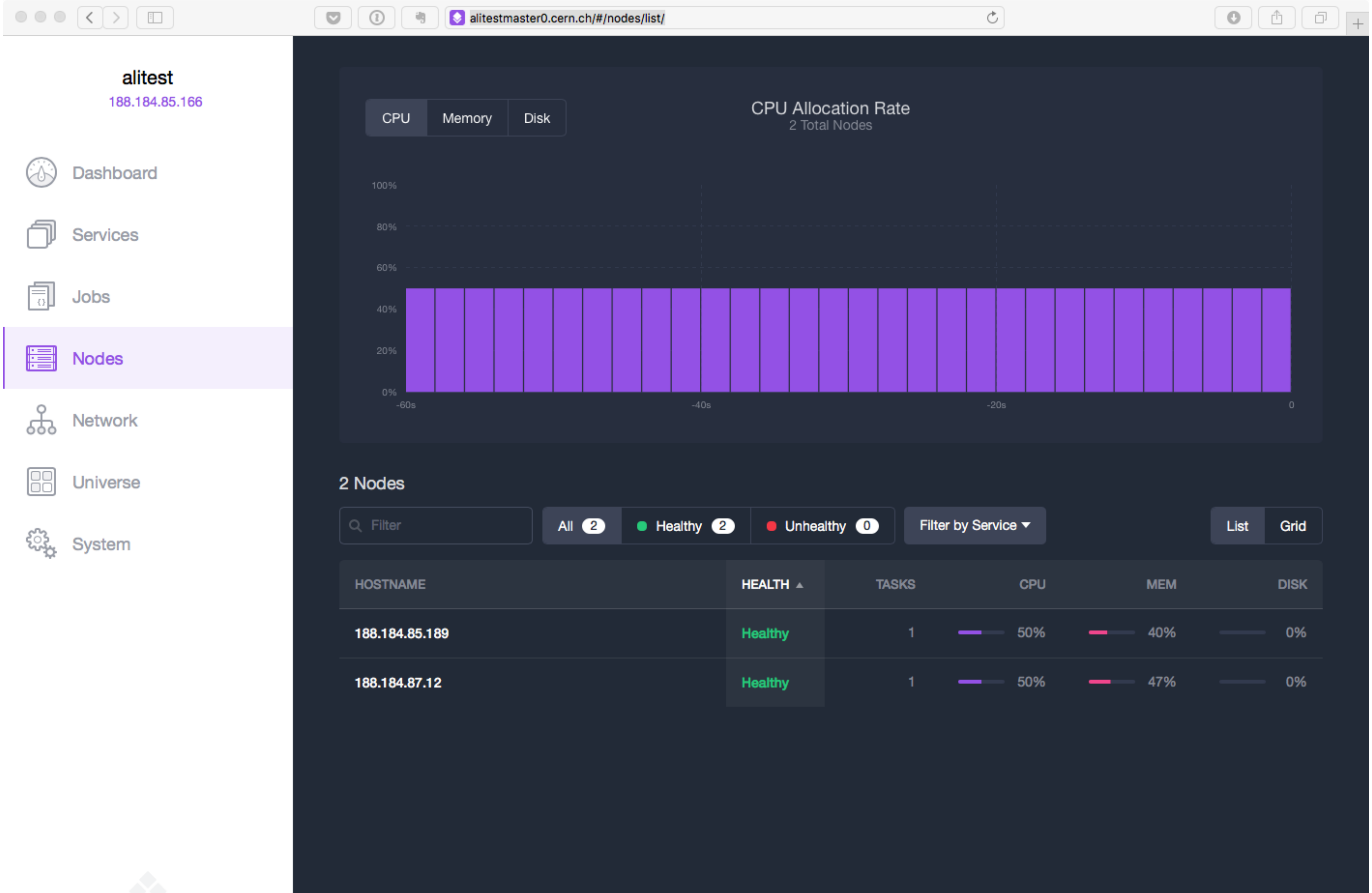
1 Tasks running

1 Tasks staging

Component Health

Admin Router Agent	Healthy
Admin Router Master	Healthy
Admin Router Reloader	Healthy
Admin Router Reloader Ti...	Healthy
Diagnostics	Healthy

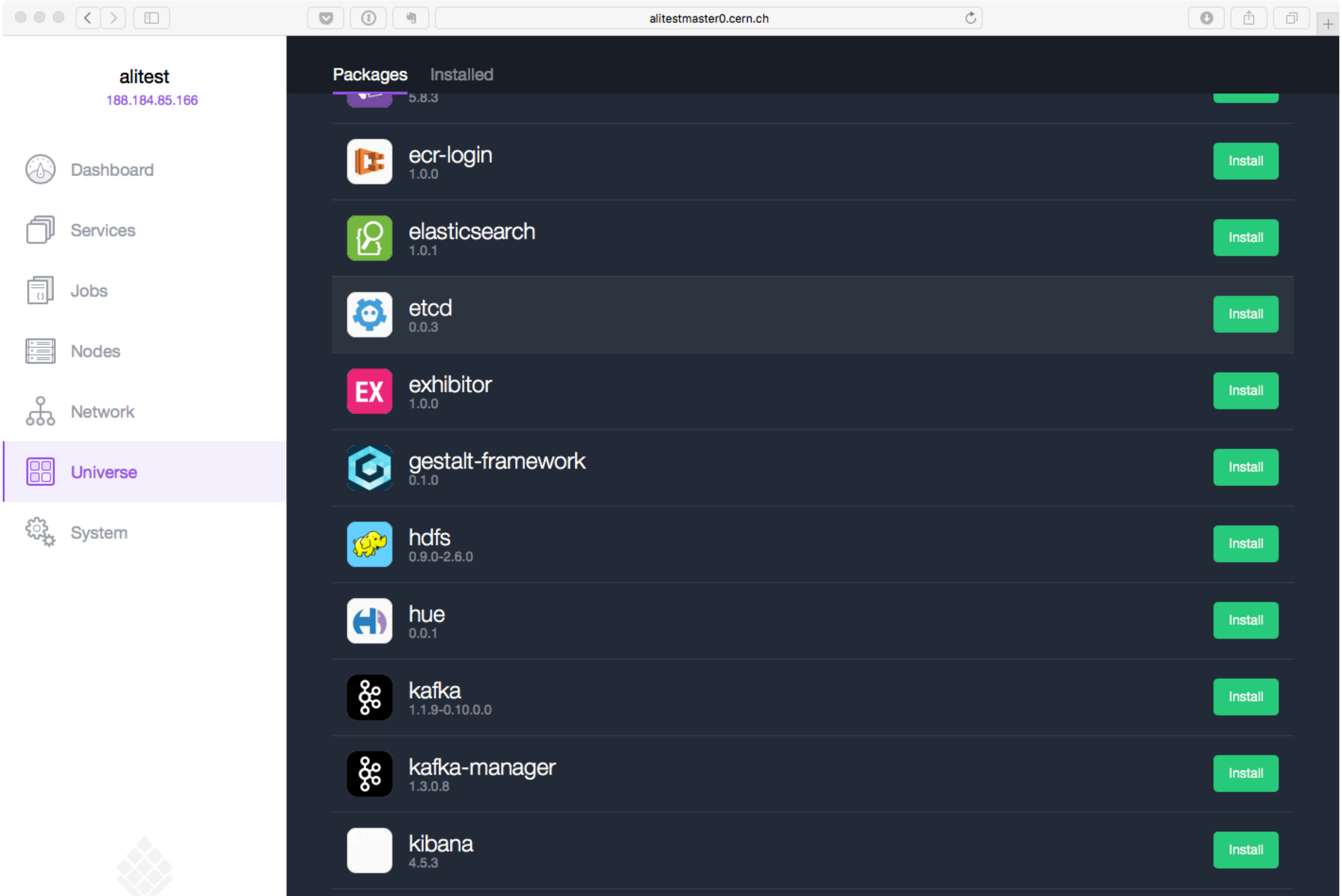
Mesosphere DC/OS: cluster monitoring



alitestmaster0.cern.ch/#/nodes/list/

HOSTNAME	HEALTH ▲	TASKS	CPU	MEM	DISK
188.184.85.189	Healthy	1	50%	40%	0%
188.184.87.12	Healthy	1	50%	47%	0%

Mesosphere DC/OS: GUI based installation



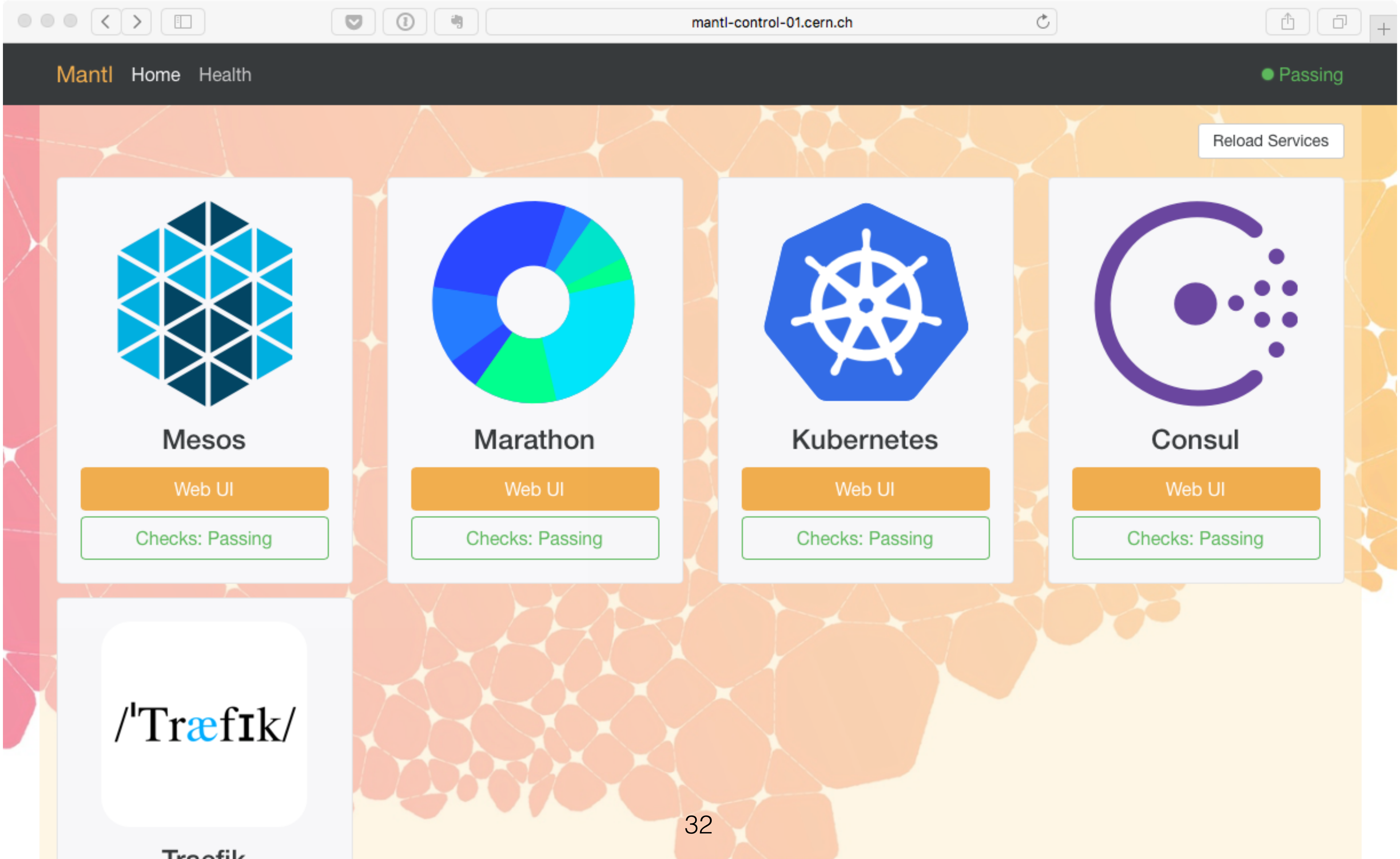
5.8.3

ecr-login	1.0.0	Install
elasticsearch	1.0.1	Install
etcd	0.0.3	Install
exhibitor	1.0.0	Install
gestalt-framework	0.1.0	Install
hdfs	0.9.0-2.6.0	Install
hue	0.0.1	Install
kafka	1.1.9-0.10.0.0	Install
kafka-manager	1.3.0.8	Install
kibana	4.5.3	Install

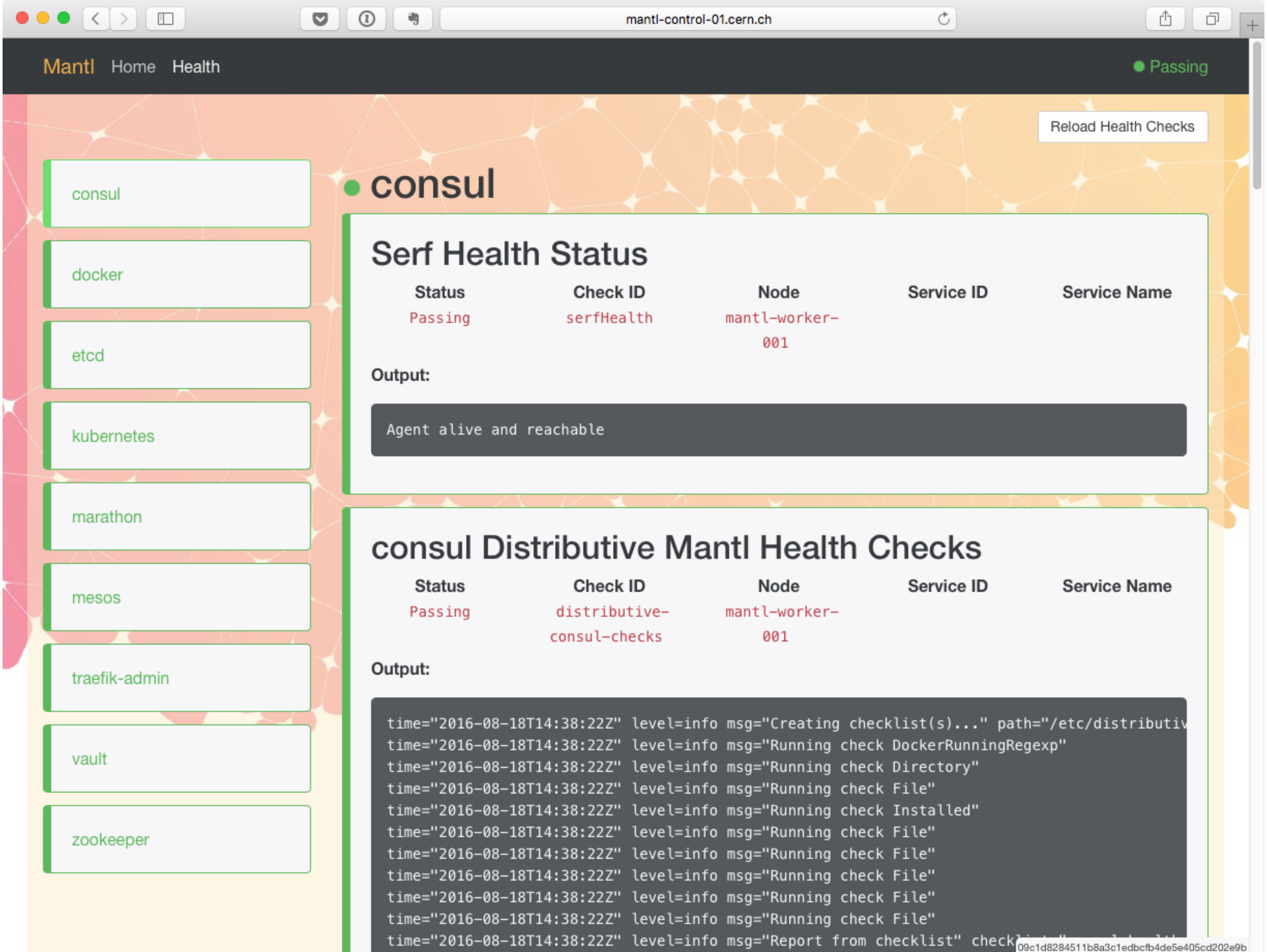
CISCO mantl.io

- Similar concept as DC/OS: a "curated" Mesos distribution.
- Works with Centos / Ubuntu
- Can provision servers to OpenStack (albeit CERN/IT setup is a cumbersome), using Hashicorp Terraform [4].
- Deploys configuration via RedHat Ansible [5].
- Tested by Kevin Napoli during his Summer Studentship, not particularly impressed, compared to DC/OS.

mantl.io



mantl-control-01.cern.ch
Mantl
Home
Health
Passing
Reload Services
Mesos
Web UI
Checks: Passing
Marathon
Web UI
Checks: Passing
Kubernetes
Web UI
Checks: Passing
Consul
Web UI
Checks: Passing
/ˈTræfɪk/
Traefik



● consul

Serf Health Status

Status	Check ID	Node	Service ID	Service Name
Passing	serfHealth	mantl-worker-001		

Output:

```
Agent alive and reachable
```

consul Distributive Mantl Health Checks

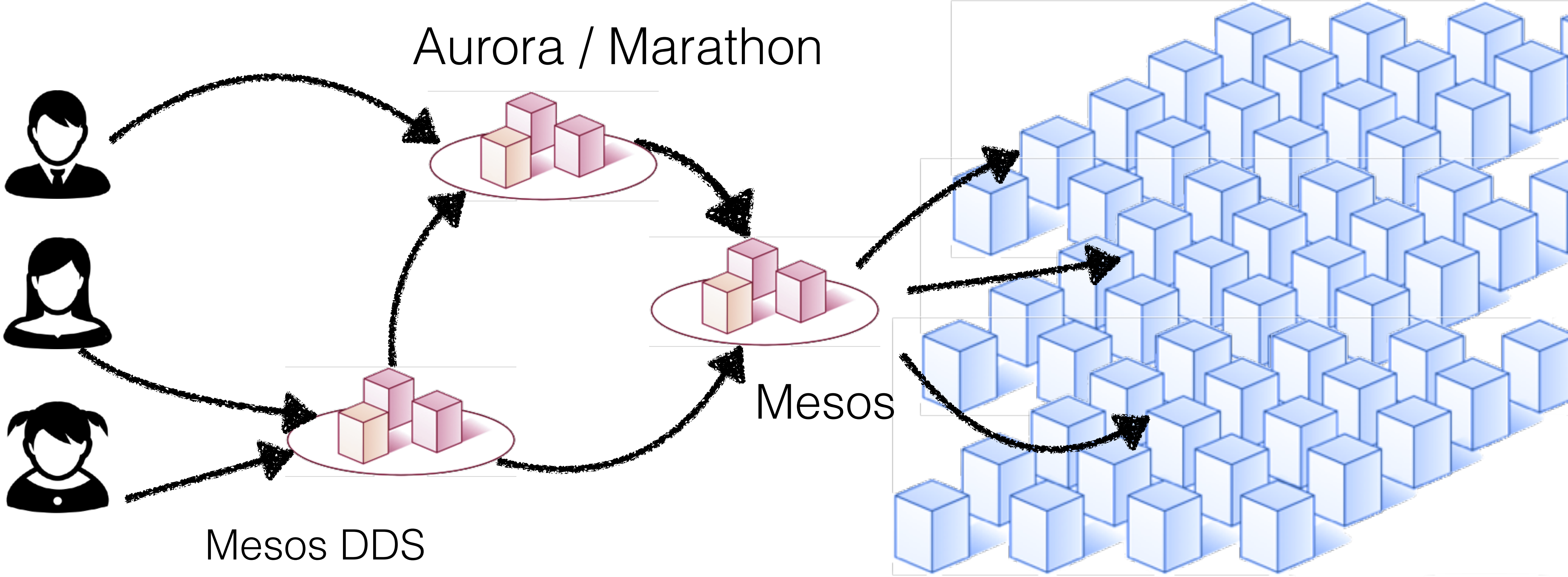
Status	Check ID	Node	Service ID	Service Name
Passing	distributive-consul-checks	mantl-worker-001		

Output:

```
time="2016-08-18T14:38:22Z" level=info msg="Creating checklist(s)..." path="/etc/distributiv
time="2016-08-18T14:38:22Z" level=info msg="Running check DockerRunningRegexp"
time="2016-08-18T14:38:22Z" level=info msg="Running check Directory"
time="2016-08-18T14:38:22Z" level=info msg="Running check File"
time="2016-08-18T14:38:22Z" level=info msg="Running check Installed"
time="2016-08-18T14:38:22Z" level=info msg="Running check File"
time="2016-08-18T14:38:22Z" level=info msg="Running check File"
time="2016-08-18T14:38:22Z" level=info msg="Running check File"
time="2016-08-18T14:38:22Z" level=info msg="Running check File"
time="2016-08-18T14:38:22Z" level=info msg="Running check File"
time="2016-08-18T14:38:22Z" level=info msg="Report from checklist" check
```

What's next?

Provide a demonstrator for a **multi-user**, **multi-tier**, cluster which can be used to deploy tasks via DDS (e.g. O2 Devices) or Aurora / Marathon (e.g. cronjobs, non O2 services).



References

- [1]: Mesos: https://people.eecs.berkeley.edu/~alig/papers/mesos.pdf

- [2]: Omega: flexible, scalable schedulers for large compute clusters http://research.google.com/pubs/pub41684.html

- [3] Powered by Mesos: http://mesos.apache.org/documentation/latest/powered-by-mesos/

- [4]: Terraform: https://www.terraform.io

- [5]: Ansible: https://www.ansible.com