Experiences running jobs in VMs on Vac

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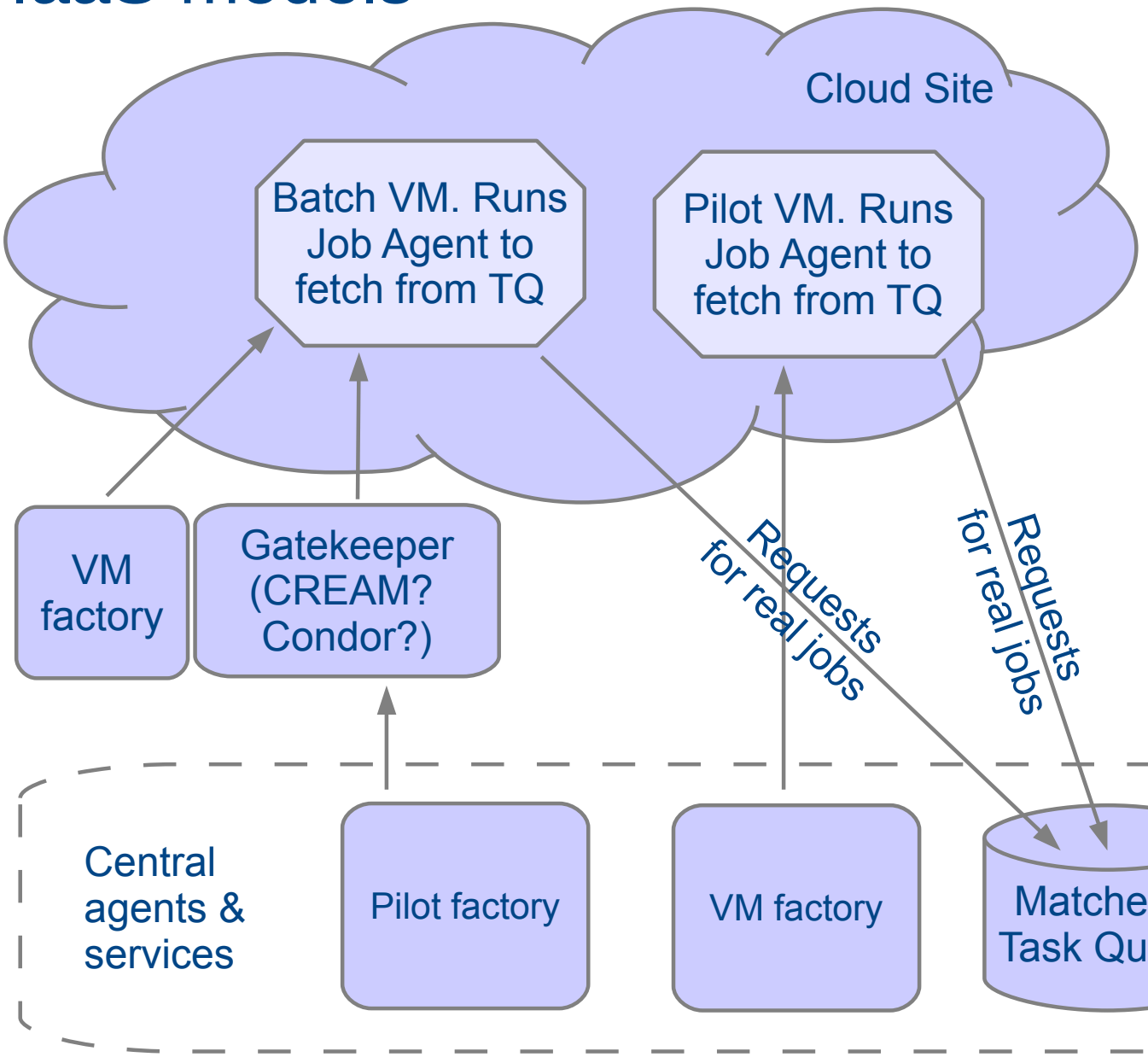
Overview

- Running jobs on IaaS systems
- Vacuum model
- Vac implementation
- Target shares
- Admin-friendly philosophy
- ATLAS and LHCb production jobs
- VM vs Batch efficiency measurements
- Multiprocessor support
- Future plans

IaaS models



Several ways of using IaaS clouds to get pilot clients running

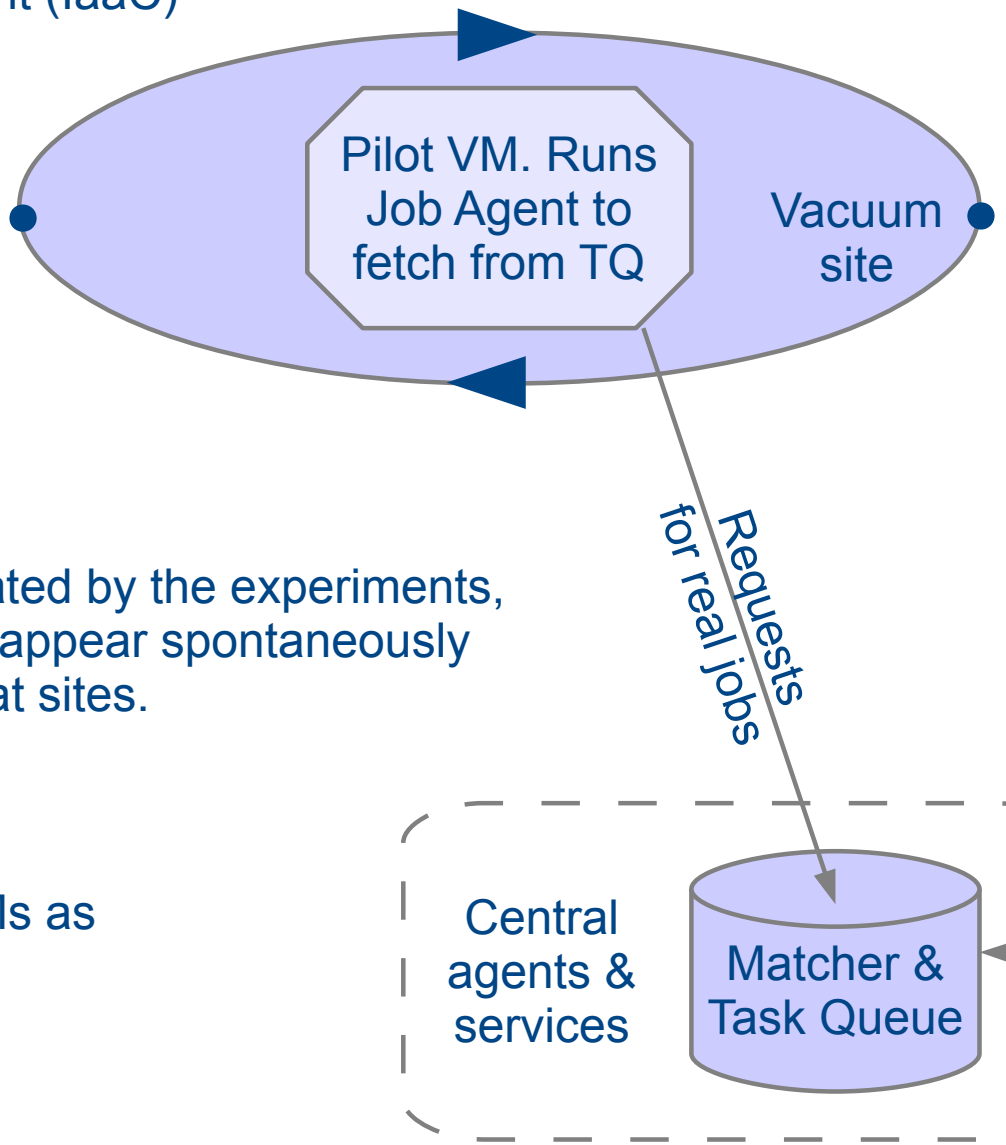
Fetch payload jobs from task queues as we do with Grid+Batch

These give you the benefits of using VMs: custom environment, that's maintained by experiments

But lots of layers and multiple queues (including inside IaaS provisioning)

Vacuum model

Infrastructure-as-a-Client (IaaC)



Since we have the pilot framework, we can do something much simpler.

Strip the system right down and have each physical host at the site create the VMs itself.

Instead of being created by the experiments, the virtual machines appear spontaneously "out of the vacuum" at sites.

Ideally use same VMs as with IaaS clouds

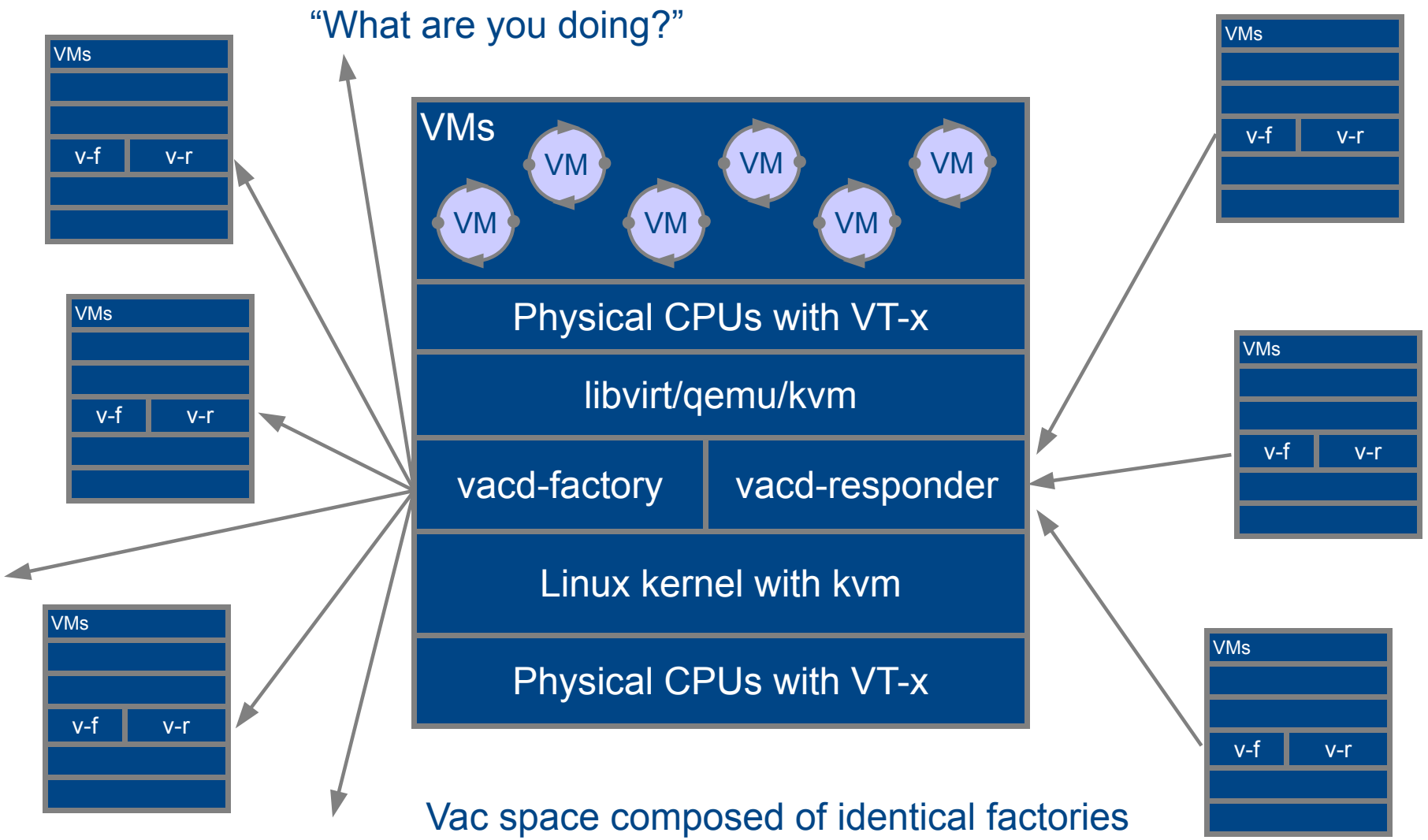
Vacuum model

- For the experiments, VMs appear by “spontaneous production in the vacuum”
  - Like virtual particles in the physical vacuum: they appear, potentially interact, and then disappear
- From the CHEP 2013 paper:
  - *“The Vacuum model can be defined as a scenario in which virtual machines are created and contextualized for experiments by the site itself. The contextualization procedures are supplied in advance by the experiments and launch clients within the virtual machines to obtain work from the experiments' central queue of tasks.”*
- At many sites, 90% of the work is done by 2 or 3 experiments
  - So a simple, reliable way of running their “baseload” of jobs is worthwhile
- cvmfs and pilots mean a small user_data file is all the site needs
  - Experiments can provide a script to create the site's user_data

Vac implementation

- On each physical node, Vac VM factory daemon runs to create and supply contextualization user_data to transient VMs
- Multiple VM flavours (“VM types”) are supported, ~1 per experiment
- Each site or Vac “space” is composed of autonomous factory nodes
  - All using the same /etc/vac.d/*.conf files; supplied by Puppet, Chef, Cfengine, ...
- Factories communicate load info with each other via UDP
- Natively supports CernVM 2 (~SL5) and CernVM 3 (~SL6)
  - Also provides a logical partition to the VM to use as fast workspace
- VMs on a NAT network, with the factory node at 169.254.169.254
- Vac assumes the VM will shut itself down if it has no work
  - Vac can also check a heartbeat file and destroy stalled/idle VMs
  - May add optional check on CPU usage too

Vac factory node and site architecture



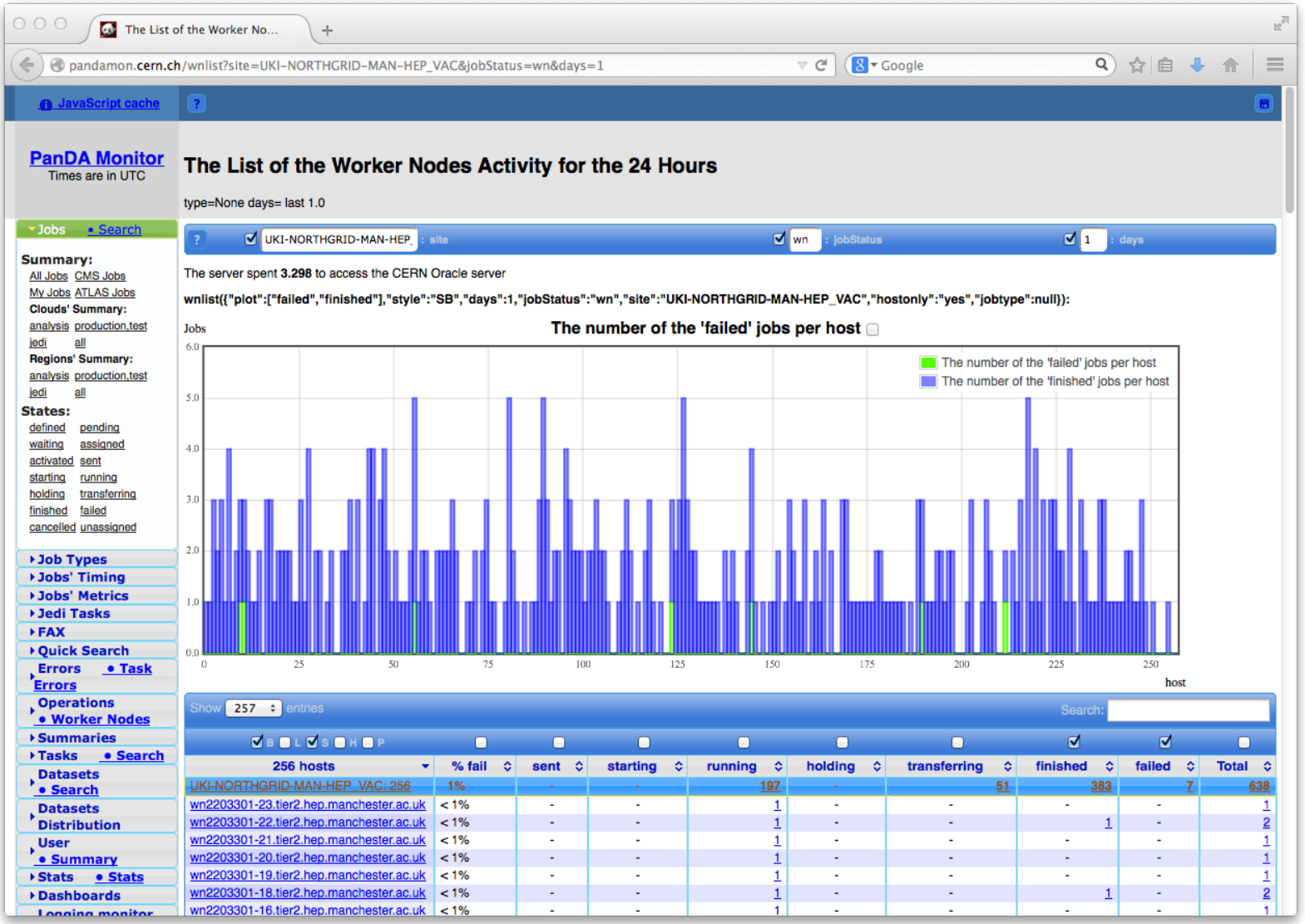
Target shares with Vac

- When a VM slot becomes available, the node decides how to fill it.
- The other Vac nodes are queried via UDP to discover what they are running, in units of HS06
- The node bases decision on its list of target shares for each VM type
  - Uses a site-wide back-off procedure to veto VM types that don't have any work
- This approach is very simple, and means the factory nodes are autonomous
  - Avoids a central management daemon which would be a single point of failure
- The target shares are instantaneous
  - They are fair, in that if all experiments submit lots of jobs, the site shares out the capacity according to the stated shares
  - But quiet periods aren't credited and carried forward, so may need to adjust targetshares to achieve annual shares, say (as many batch sites do...)

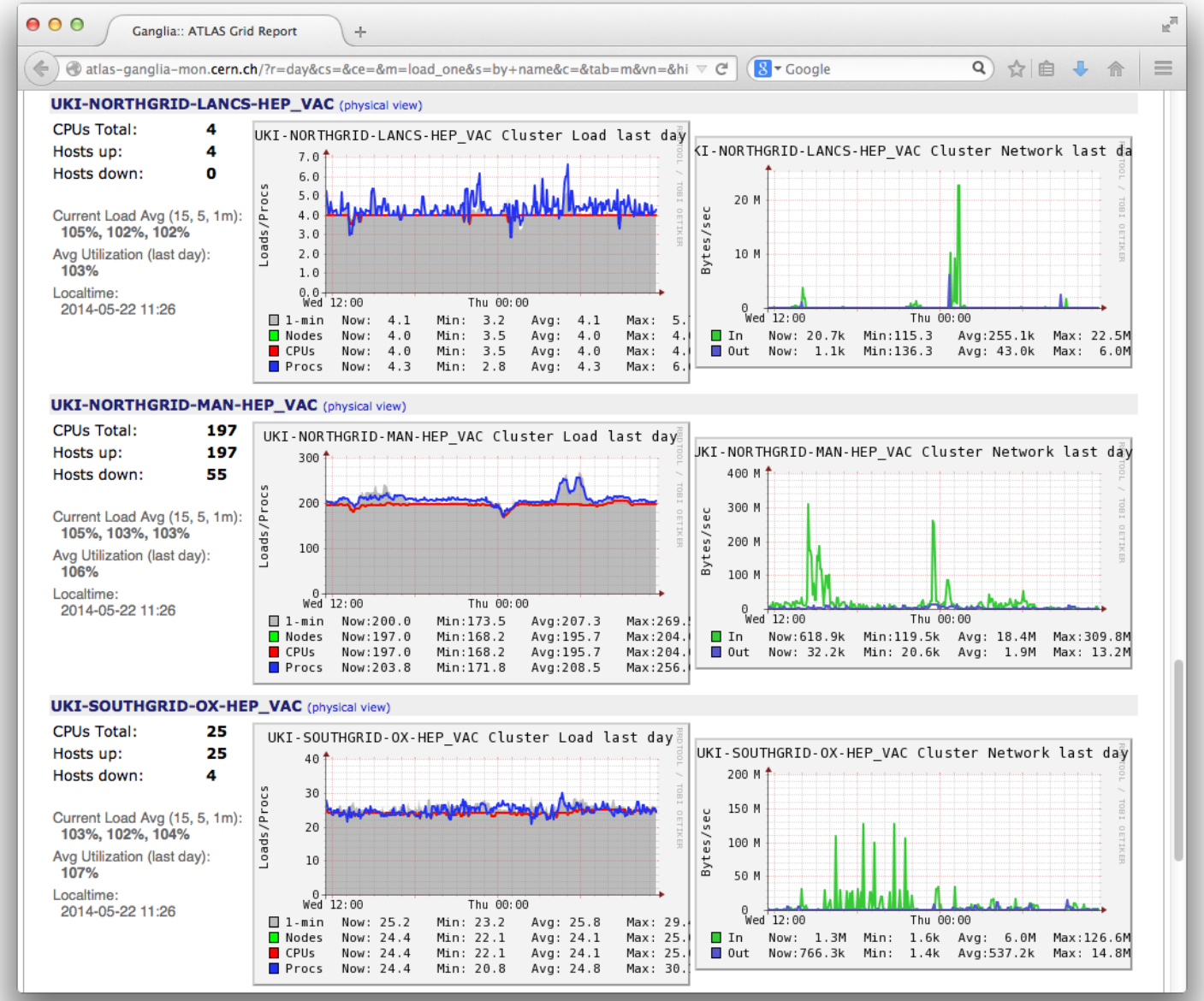
Admin-friendly philosophy

- Vac re-reads configuration and rebuilds its view of what the VMs are doing at the start of each cycle (60secs)
  - Do not need to restart the daemon when changing things (eg via Puppet)
  - Do not need to worry about daemon vs VM inconsistent states
  - We frequently do RPM updates of Vac without disrupting production VMs
- Simple so reliable: boot failure rate is << 1/1000
- Proper man pages for vac command, vacd, vac.conf etc
- Admin Guide with examples and help with “gotchas”
- Sanity checks (eg NAT iptables set up?) and log file warnings
- Nagios monitor provided
- Factory nodes autonomous so can easily take sets of machines down
  - Or deal with losing the power on one rack without this disturbing the others!
- Aim to be as simple to manage as using Apache to serve static files

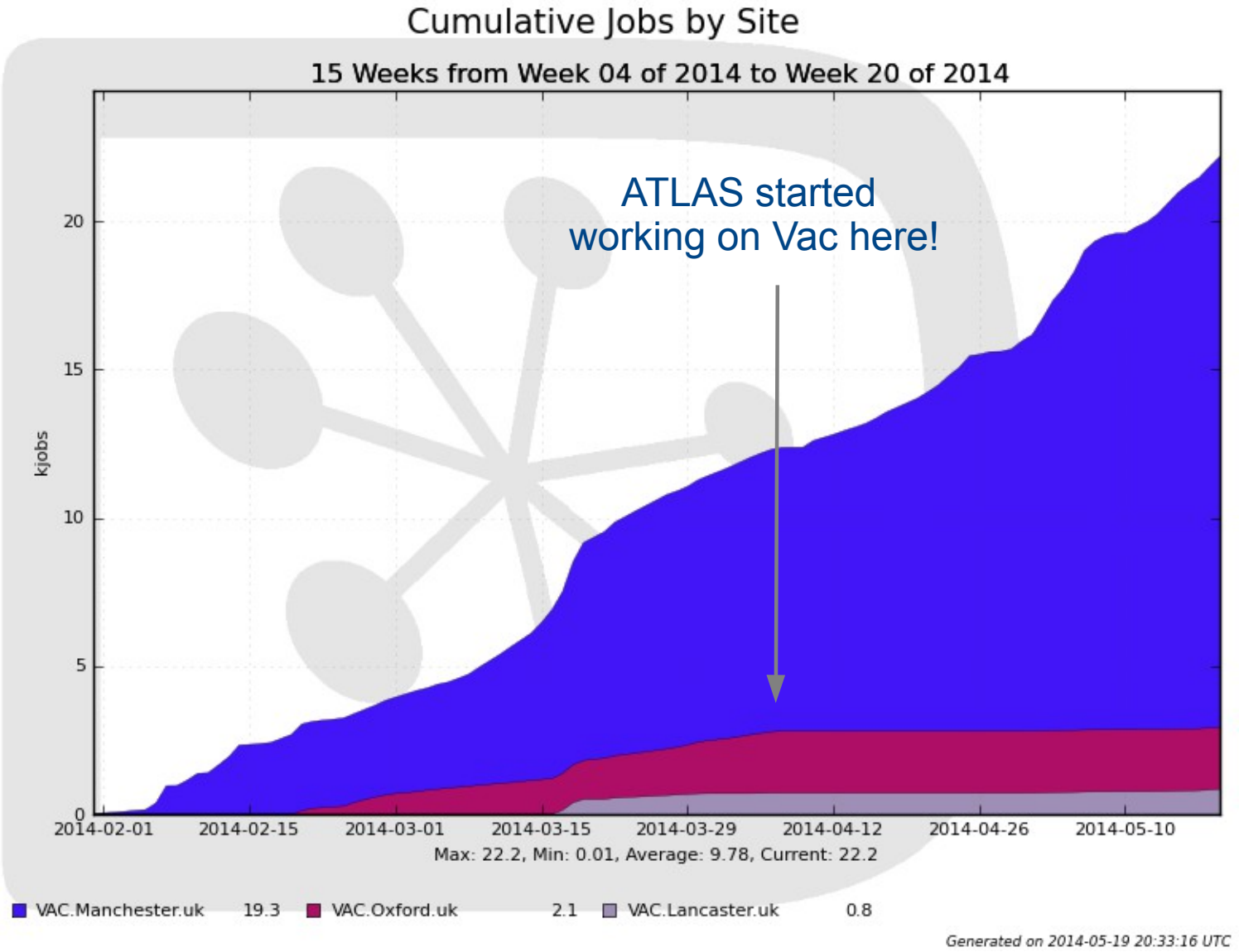
ATLAS Panda jobs running on Vac VMs



Ganglia monitoring of ATLAS Vac sites



LHCb production Monte Carlo



Accounting

- Many sites need to report usage through APEL and EGI Accounting
- Well established for conventional gatekeeper+batch grid sites
  - There is also an EGI Cloud accounting activity
- Vac records data by updating PBS/BLAH format accounting log files on each factory node when each VM finishes
- These are consumed by the normal APEL PBS log file analyzer and published in the same way as gatekeeper+batch resources
  - 56,742 jobs and 300,364 Vac VM CPU hours logged to APEL so far
- In the future, intend to support direct reporting to central APEL service using ssm (as ARC does)
- However, the log file approach does also allow other existing accounting analysis tools to be used

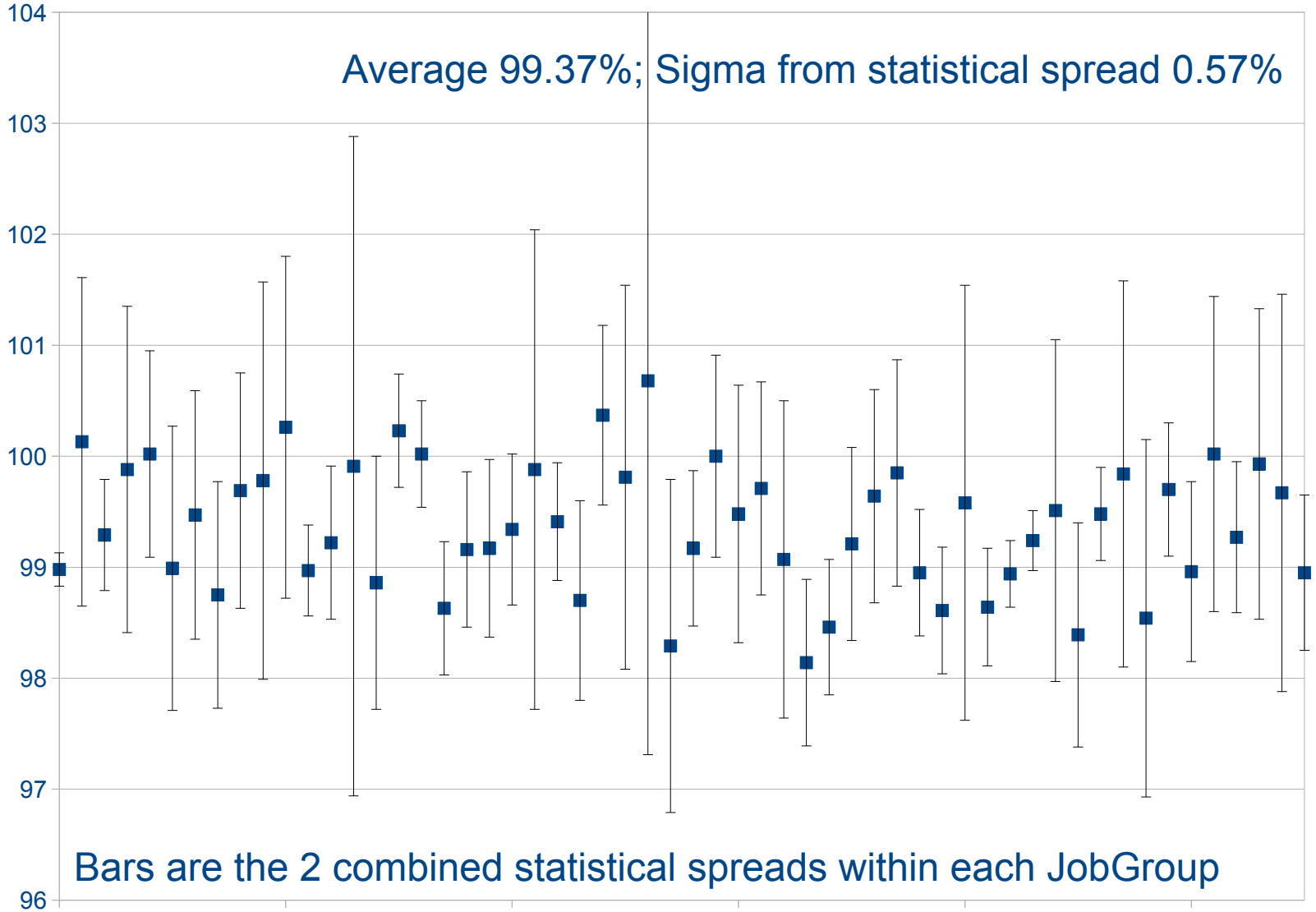
Efficiency measurements on VMs

- What is today's intrinsic cost of using VMs rather than real machines?
  - Lots of hard work done by many people: VT-x, kvm, qemu-kvm, ksm, virtio
- Can get overall cpu/wall efficiency measurements from accounting
- At Manchester, these are comparable for Batch vs VMs
  - So for April/May 2014, the weighted average ATLAS+LHCb efficiencies for batch and Vac VMs were both 92.0%
  - That doesn't distinguish between setup CPU, overhead CPU, and payload CPU
- People have made direct benchmark comparisons or done test runs
  - But can we measure this with routine workloads too?
- We have machines from the same 2010 purchase running both
  - 288 VM slots on Vac; and ~1000 PBS batch job slots
- So can do direct comparison of efficiency of production payload jobs

VM vs Batch efficiency with LHCb MC

- LHCb Monte Carlo production is organised as JobGroups
  - Each job in a JobGroup is part of one production, with the same parameters
  - Expect similar amount of time in event generator, detector physics, reco etc
- We run enough jobs at Manchester that jobs from the same JobGroup will be run on both Batch and VM
  - Sample was 5534 (3216+2318) jobs in 56 JobGroups, 15-22 May 2014
- Using LHCb DIRAC monitoring of payload jobs, can calculate the CPU/Walltime efficiencies for the Batch jobs and for the VM jobs within the same JobGroup separately
- Can then take quotient to give VM/Batch efficiency ratio
  - Also calculate statistical spreads within each group
- The machines we used are dual 6-core Westmere from 2010, with HT enabled, 2GB/slot, and running 24 batch jobs or 24 VMs

VM eff. / Batch eff., per LHCb MC JobGroup



15-22 May 2014

56 LHCb MC JobGroups; 5534 jobs

3216 Batch jobs; 2318 VM jobs

Machines: 12-core Westmere, HT enabled, 2GB/slot, 24 job or VM slots

Multiprocessor VMs

- These are supported by Vac as a parameter in the node's configuration file
- Each factory node has one current value in force
- Can be changed at any time, and new VMs will be created using it
- Vac keeps track of existing VMs' geometry to avoid overcommitting
- VM processor count taken into account by targetshares mechanism
- This system is designed to allow dynamic repartitioning of a Vac space into, say, single processor and 8-processor VM subspaces
  - Just update node's configuration parameter in Puppet etc and wait
- This parallels the dynamic partitioning models being evaluated by the WLCG Multicore Task Force for conventional batch systems
  - Need to worry about the Masonry Problem when allocating processors in blocks

Vac provides machine/job features

- Proposed HEPiX protocol and current WLCG task force
- Allows site/host to communicate details of machine and the job slot to the job or VM
  - HS06, shutdown time for VM/host, CPU and memory limits, ...
- One key file per key/value pair, in one of two directories
- The Vac factory node offers these directories to its VMs via NFS over its internal private network
  - Also provides a writeable NFS directory for log files, shutdown reason, heartbeat files etc
- The basis for several scenarios for telling VMs and payload jobs what resources they have and how long they can run for
  - Want graceful termination of VMs to avoid disrupting payload jobs
  - /etc/machinefeatures/shutdowntime always set using max_wallclock_seconds

Future plans

- Recruit more sites – you?
- See if other experiments' VMs need alternative VM models
- Support Cloud Init contextualization and EC2 metadata
  - Admins can already set this up, as the factory appears at 169.254.169.254
- Direct APEL 3 reporting using ssm
- More VM performance and benchmarking studies
- Reusable Puppet module
- Try with other VM classes: eg PROOF workers

- But avoid “feature creep”, since simplicity is a feature in itself

Summary

- Vac provides a simple way for sites to run VMs
- Demonstrated with ATLAS and LHCb production jobs
  - Measured VM efficiency for MC is very good now
- Admin-friendly philosophy
- Multiprocessor VMs supported
- EGI accounting supported if needed

- We'd like to recruit more sites!
- And experiments that want us to try their VMs
- See http://www.gridpp.ac.uk/vac/ for RPMs, Yum repo, links to GitHub, docs, man pages etc

Extra slides

Vcycle

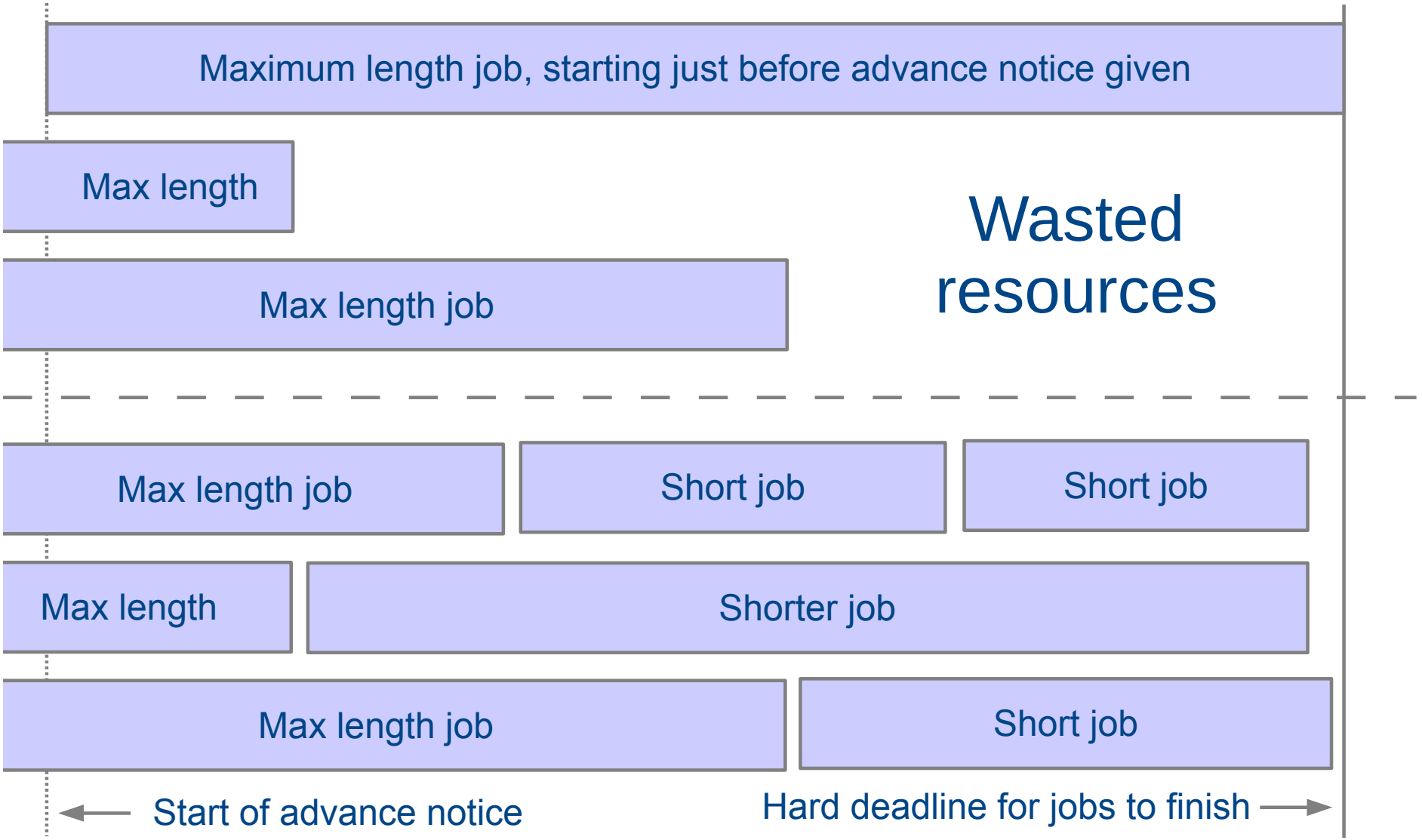
- Applies Vac ideas to OpenStack etc IaaS resources
- Experiment-neutral, and can be run by experiment or site or 3rd party
- Daemon that creates VMs using user_data file
- Watches what they do
- Backs off if they are failing to stay running
  - No work? Fatal errors?
  - Can also use shutdown messages to make better decisions
- Provides machine/job features via HTTP
- Running ~500 concurrent VMs with production jobs for LHCb on CERN central OpenStack
- Also running on GridPP Cloud at Imperial College
- Early days, but the code is in the vacproject GitHub area

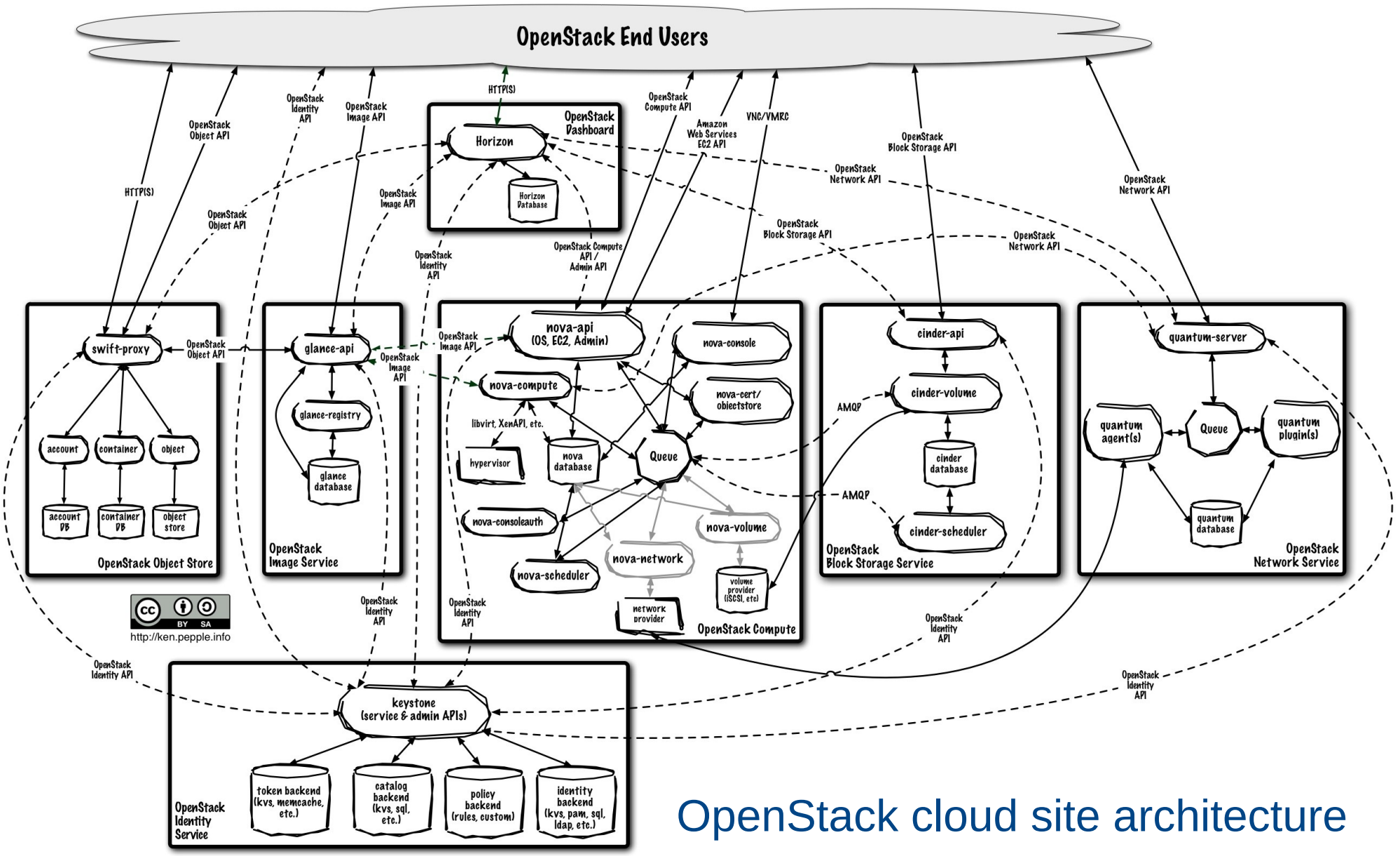
Vac “Back Off” procedure

- To avoid overloading Matcher/TaskQueue, Vac implements “back off”
- If a VM finishes with “no work” / “banned” / “site misconfigured” outcomes then it counts as an abort
  - If no outcome given, then if a VM finishes after less than fizzle_seconds (600sec?) then it counts as an abort
- For a VM type (~experiment), if an abort has happened on **any** factory in the last backoff_seconds (600 sec?), then no more VMs of that type will be started
- After that, if an abort happened in the last backoff_seconds + fizzle_seconds and any new VMs have run for less than fizzle_seconds, then no more VMs of that type will be started
  - ie try to run one or two test VMs to see if ok now
- If backoff_seconds + fizzle_seconds have passed without more aborts, then can start VMs again as fast as slots become available

The Masonry Problem...

The Masonry Problem





OpenStack cloud site architecture