Singularity in CMS

“Over a million containers served”

Introduction

- The topic of containers is *broad* - and this is a 15 minute talk!
    - I'm filtering out a lot of relevant details, particularly **why** we are using Singularity and e.g., not Docker.
    - *Feel free to grab me after this session for in-depth details*.
- I'm also taking the **CMS-centric view**, even though work was done by many organizations.

What problems are we solving?

- Simple **isolation**: Protect pilot from payloads and payloads from each other. Specifically:
    - *File isolation*: pilot determines what files the payloads can read and write.
    - *Process isolation*: payload can only interact with (see, signal, trace) its own processes.
    - There are other kinds of isolation (e.g., resource management, kernel isolation, network isolation) that are useful *but not required*.
- **glexec replacement**: Retire our particularly problematic current solution to isolation.
- **Homogeneous / portable OS environments**: Make user OS environment as minimal and identical as possible

What is Singularity?

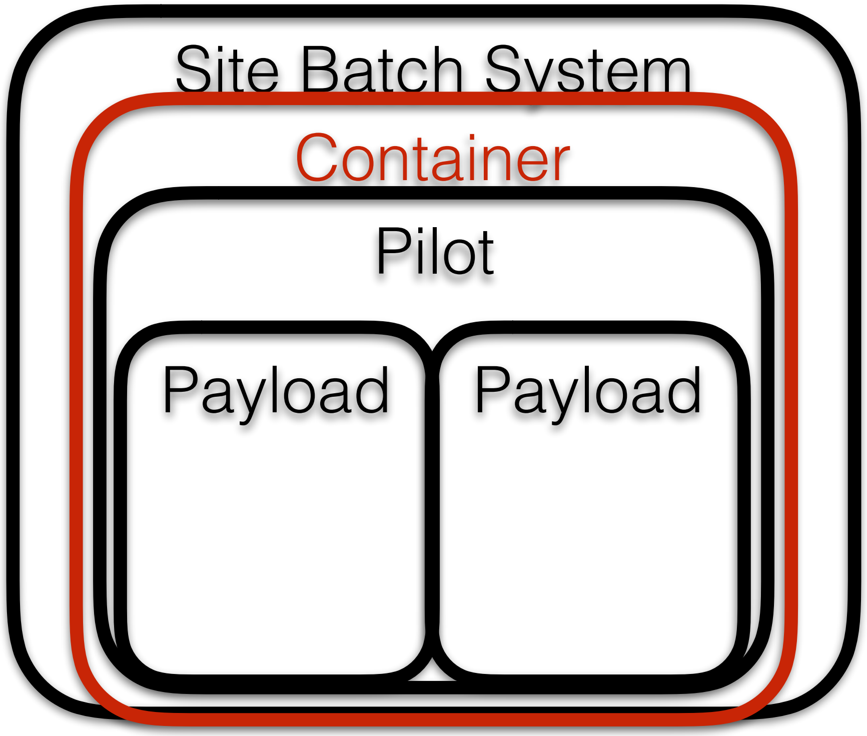
- Singularity is a container solution tailored for the HPC use case.
  - It allows for a portable of OS runtime environments.
  - It can provide isolation needed by CMS.
- Simple isolation: Singularity does not do resource management (i.e., limiting memory use), leaving that to the batch system.
- Operations: No daemons, no UID switching; **no edits to config file needed**. "Install RPM and done."
- Goal: User has no additional privileges by being inside container. E.g., disables all `setuid` binaries inside the container.

http://singularity.lbl.gov

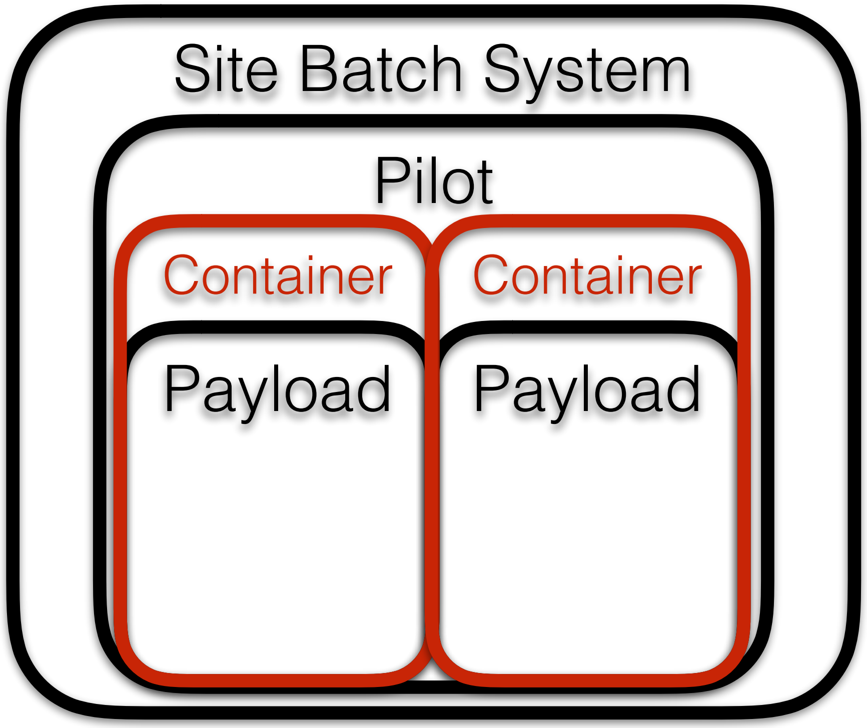
Who is in a container?

- Three options when using containers:
  - A: Batch system starts pilot inside a container.
  - B: Pilot starts each payload inside its own container.
  - C: Combine A and B.
- Option A does not meet our isolation goals. **Option B does**.
- It is important to allow sites to do their container work: ***must* keep option C viable**!

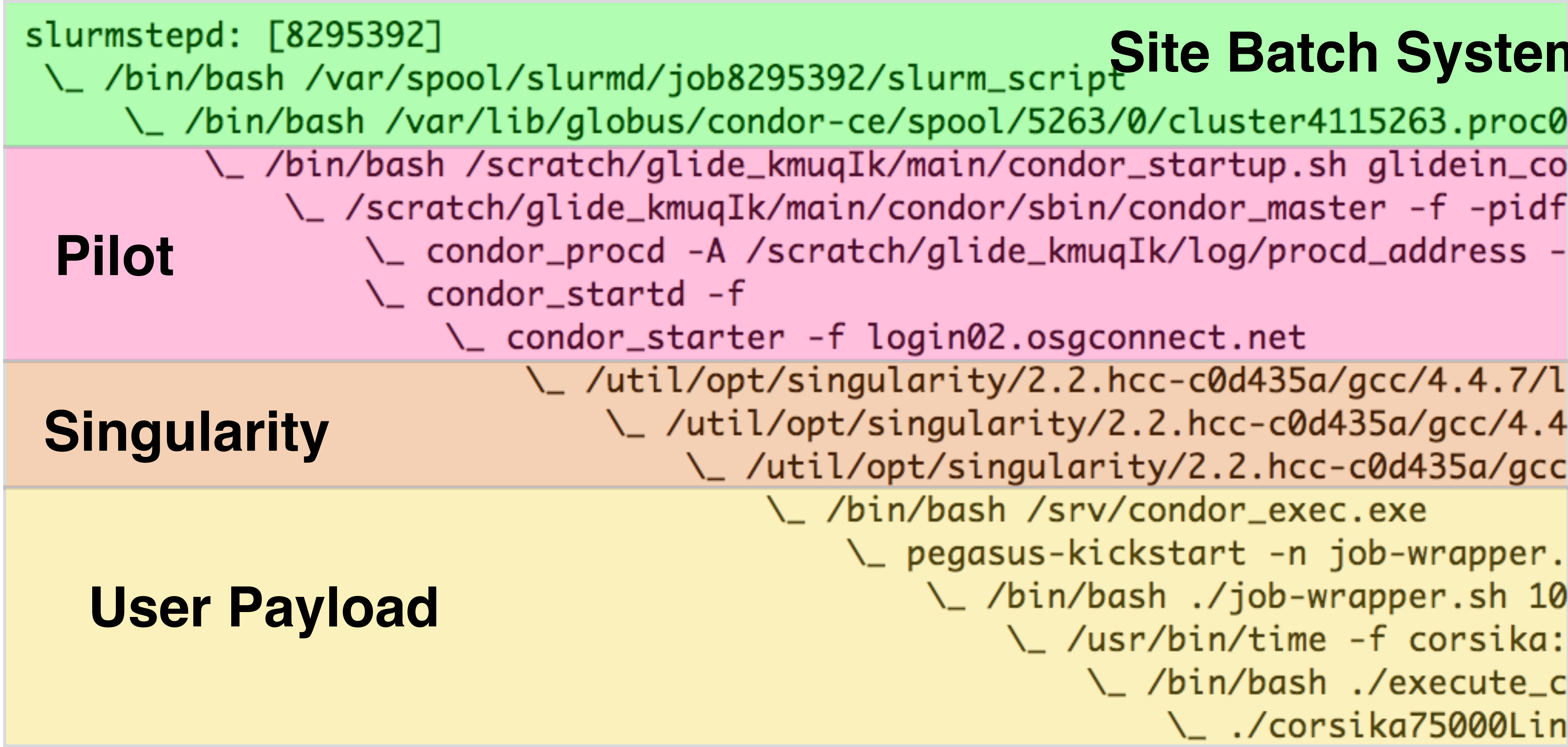
Option A:



Option B:



View From the Worker Node



```
slurmstepd: [8295392]
 \_ /bin/bash /var/spool/slurmd/job8295392/slurm_script
     \_ /bin/bash /var/lib/globus/condor-ce/spool/5263/0/cluster4115263.proc0
         \_ /bin/bash /scratch/glide_kmuqIk/main/condor_startup.sh glidein_co
             \_ /scratch/glide_kmuqIk/main/condor/sbin/condor_master -f -pidf
                 \_ condor_procd -A /scratch/glide_kmuqIk/log/procd_address -
                 \_ condor_startd -f
                     \_ condor_starter -f login02.osgconnect.net
                         \_ /util/opt/singularity/2.2.hcc-c0d435a/gcc/4.4.7/l
                             \_ /util/opt/singularity/2.2.hcc-c0d435a/gcc/4.4
                                 \_ /util/opt/singularity/2.2.hcc-c0d435a/gcc
                                     \_ /bin/bash /srv/condor_exec.exe
                                         \_ pegasus-kickstart -n job-wrapper.
                                             \_ /bin/bash ./job-wrapper.sh 10
                                                 \_ /usr/bin/time -f corsika:
                                                     \_ /bin/bash ./execute_c
                                                         \_ ./corsika75000Lin
```

Singularity and CMS

- **Singularity meets the CMS needs** for isolation! WLCG Isolation and Traceability Task Force adopted it as the replacement technology for glexec.

- It also solves a sticky problem for CMS: provides a portable OS environment.

  - CMS *cannot* run its RHEL6 binaries inside a RHEL7 environment. Hence, **CMS *cannot* transition to RHEL7** using our traditional techniques.

  - Using container technologies means the *payload* can run in an arbitrary OS environment, different from the pilot. In fact, the **pilot could start 8 payloads inside 8 different Linux distributions** if it wanted.

- **CMS policy**, starting April 1: **Sites may provide a RHEL7 environment to the pilot *only if* they also provide `singularity`**. Otherwise, CMS may be unable to utilize the site.

- Alternate - decide on OS environment at pilot launch - is not desirable as it partitions the pool.

Singularity Integration

- To use Singularity, we need a few things.
- Available at sites:
    - Given it is popular at many HPC centers, **several OSG sites already had it** installed.
    - Available from EPEL, but EPEL version is too old for our use.
    - In ~ November, got permission from OSG Security to ship it in OSG Upcoming repository. Done as of January 2017.
    - **Long-term goal remains to utilize version from EPEL**.
- Integrate with pilot infrastructure:
    - HTCondor can invoke Singularity directly or Singularity can be integrated into the wrapper script.
    - Since there is no separate daemon or UID switching, no code needs to be changed besides job startup! For OSG & CMS, this was about 400 lines of bash.

Example Invocation

```
singularity exec --home $PWD:/srv \
                 --bind $PWD:/srv \
                 --bind /cvmfs \
                 --pwd /srv \
                 --scratch /var/tmp \
                 --scratch /tmp \
                 --containall \
                 /cvmfs/singularity.opensciencegrid.org/bbockelm/cms:rhel6 \
                 /srv/.osgvo-user-job-wrapper.sh $CMD
```

From:
https://github.com/jamesletts/CMSglideinWMSValidation/blob/master/singularity_wrapper.sh

Portable OS environment

- How do we deliver an OS environment to CMS pilots?
  - Singularity has its own image creation utilities *or* **can convert Docker images**.
    - Given the immense ecosystem of Docker images and tooling, we have chosen the latter approach.
  - Traditionally, Singularity images are a single file. These get large: simple LIGO image might be about 4GB. Singularity can also just read from a directory.
  - What tool would CMS use to distribute a directory of software across the global infrastructure? CVMFS
  - CVMFS also provides per-file caching and file-level de-duplication. To launch python only requires downloading 3MB of data from a 3GB image. CVMFS also **provides efficient cache management**.

Inside the CMS container

- Inside the container, we have:
  - User payload processes, running (real UID) as the pilot user.
  - A full copy of the base RHEL6 (or 7!) OS, served from CVMFS. By default, everything is *read-only*.
  - Generate basic `passwd`, `group`, and `resolv.conf` so user environment is relatively sane.
  - User working directory is bind-mounted to `/srv`. `$HOME` is set to `/srv`.
    - CVMFS and any POSIX storage elements are also a bind-mount inside the container.
    - User environment is updated to correct any changed file paths.
  - Pilot can select other files to copy or bind-mount inside container.

BYOC

- For CMS, we currently post the image to Docker Hub.
- OSG maintains a list of images to synchronize (https://github.com/opensciencegrid/cvmfs-singularity-sync/blob/master/docker_images.txt).
    - Users can send in PRs and get their image approved.
- Once approved, a `docker push` to update the container should be reflected in CVMFS in **about an hour**.
    - Look in `/cvmfs/singularity.opensciencegrid.org`.
- Not a CMS-specific: any OSG user can request a new image. Currently, only 2 of 36 images are from CMS.

Status on OSG

- Currently, about 15 OSG sites provide Singularity in their runtime environment. **Wider US deploy than glexec**.
  - Worldwide, there are more - including a testbed at CERN.
- OSG and CMS VOs have integrated Singularity support into their glideinWMS setup.
  - CMS is in testing; OSG is in production.
  - Much of the activity has occurred in the last few weeks. In early February, about 5% of the OSG pool supported Singularity. Currently, consistently 40-60% of the OSG pool.
- Learn more from the user support pages: http://bit.ly/2mqt0DS

Conclusions

- Singularity meets an important CMS need; CMS testing is fairly advanced.
- Sites may be able to decommission `glexec` as soon as April 1.
- Delivers a compelling feature set beyond LHC. Both isolation and portable user environments.
  - **Over 2 million OSG VO jobs have been run in containers!**
  - Young rollout: up to **350k containers / day**. Started at 1k containers / day in early February.
- Many miles yet to run, but appears to be a productive path.