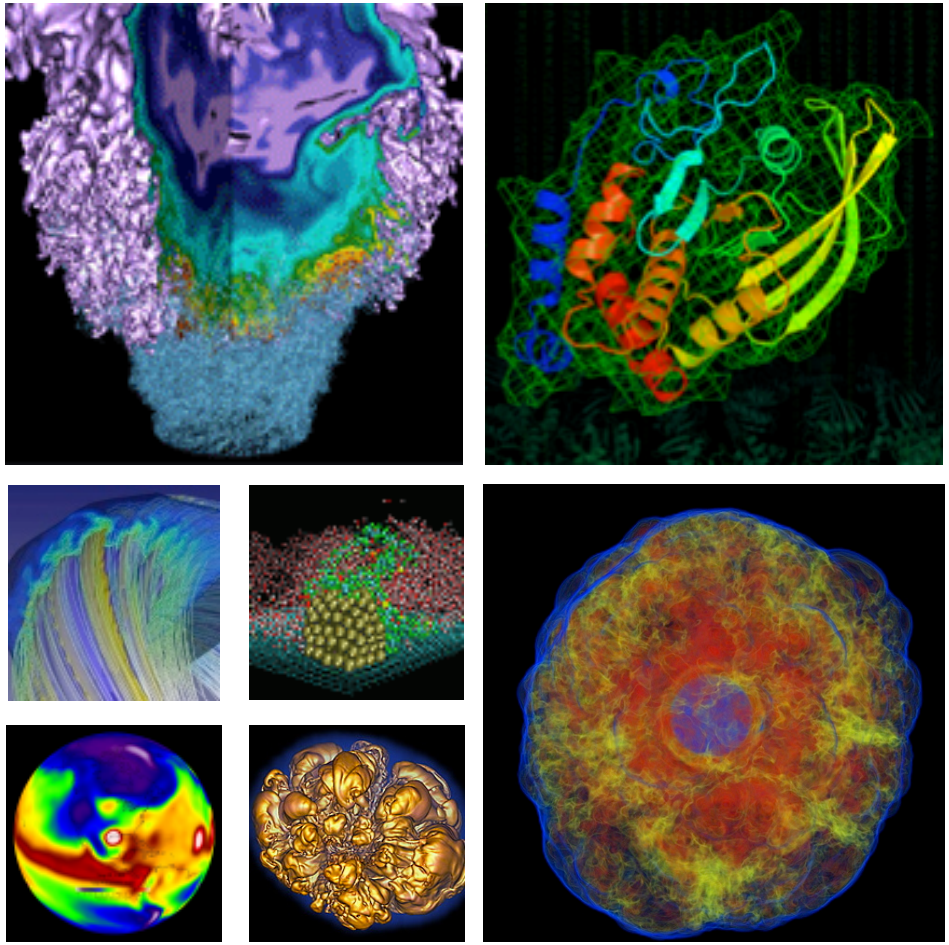
Intro to Shifter



Shane Canon

SC17 - Tutorial

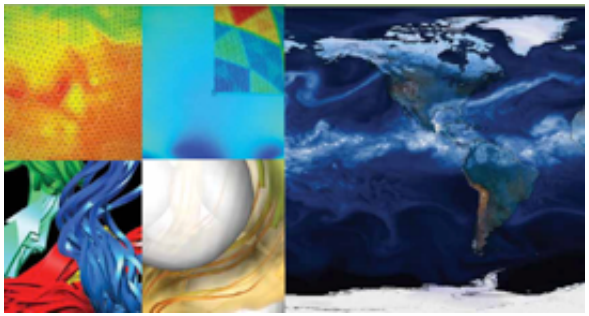
November 13, 2017

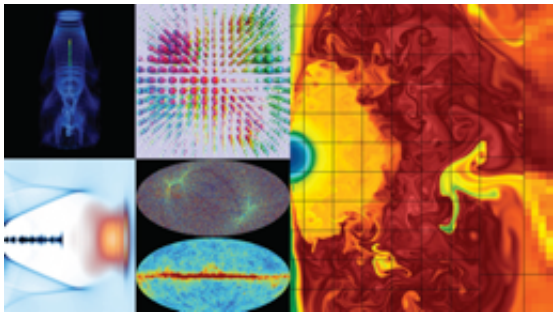
Topics

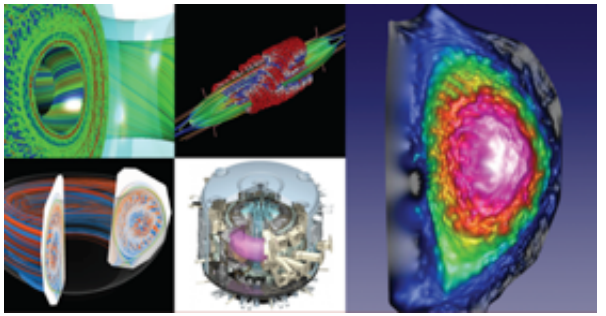
- Motivation
- Shifter Architecture and Design
- Shifter in Action
- Related Work and Discussion
- Installing Shifter

NERSC is the mission HPC computing center for the DOE Office of Science

- NERSC deploys advanced HPC and data systems for the broad Office of Science community
- NERSC staff provide advanced application and system performance expertise to users
- Approximately 6000 users and 750 projects
- Over 2000 publication resulting in NERSC resources per year
- New Data Initiative: *Pioneer new capabilities to enable scientists to make large-scale data-intensive science discoveries.*







Why not just run Docker

- **Security: Docker currently uses an all or nothing security model. Users would effectively have system privileges**

```
> docker run -it -v /:/mnt --rm busybox
```

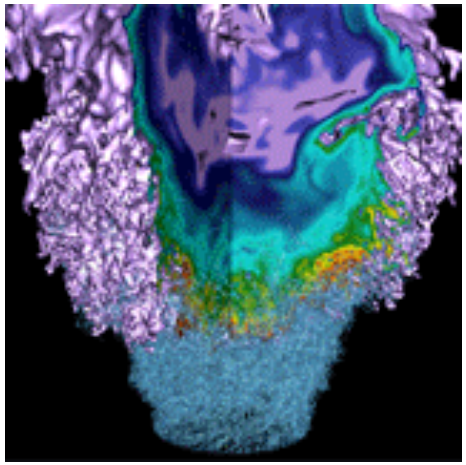
- **System Architecture: Docker assumes local disk**
- **Integration: Docker doesn't play nice with batch systems.**
- **System Requirements: Docker typically requires very modern kernel**

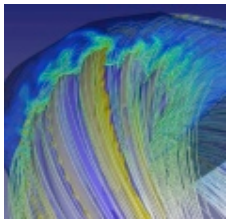
- **Complexity: Running real Docker would add new layers of complexity**
- **Scale: Stock Docker would create a several scaling issues.**

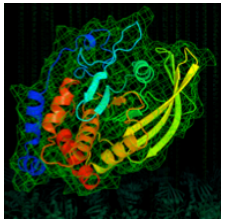
Solution: Shifter

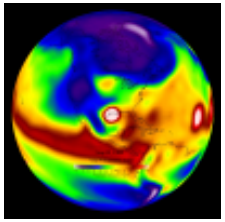
- **Design Goals:**
  - User independence: Require no administrator assistance to launch an application inside an image
  - Shared resource availability (e.g., file systems and network interfaces)
  - Leverage Docker image ecosystem (i.e. DockerHub)
  - Seamless user experience
  - Robust and secure implementation
  - Run at scale
- **Hosted at GitHub:**
  - https://github.com/nersc/shifter

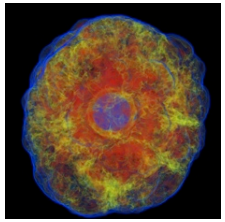
Implementation

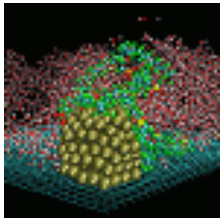












Basic Idea

Once for each image

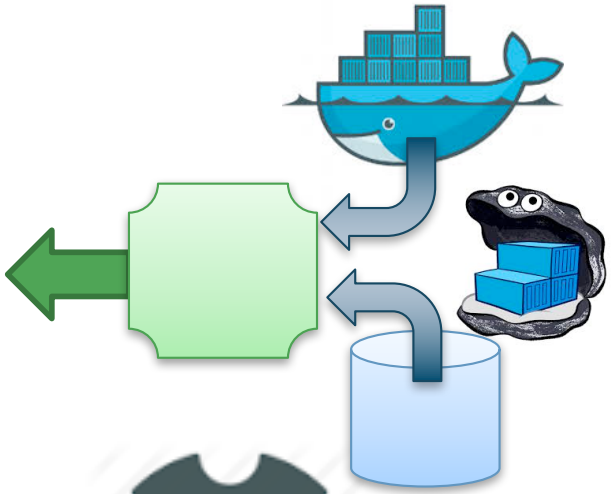
1. **Download the contents of an image**
2. **Unpack the contents**
3. **“Flatten” the image into a squashfs file**
4. **Copy that squash file to a global/cluster file system**

At Runtime

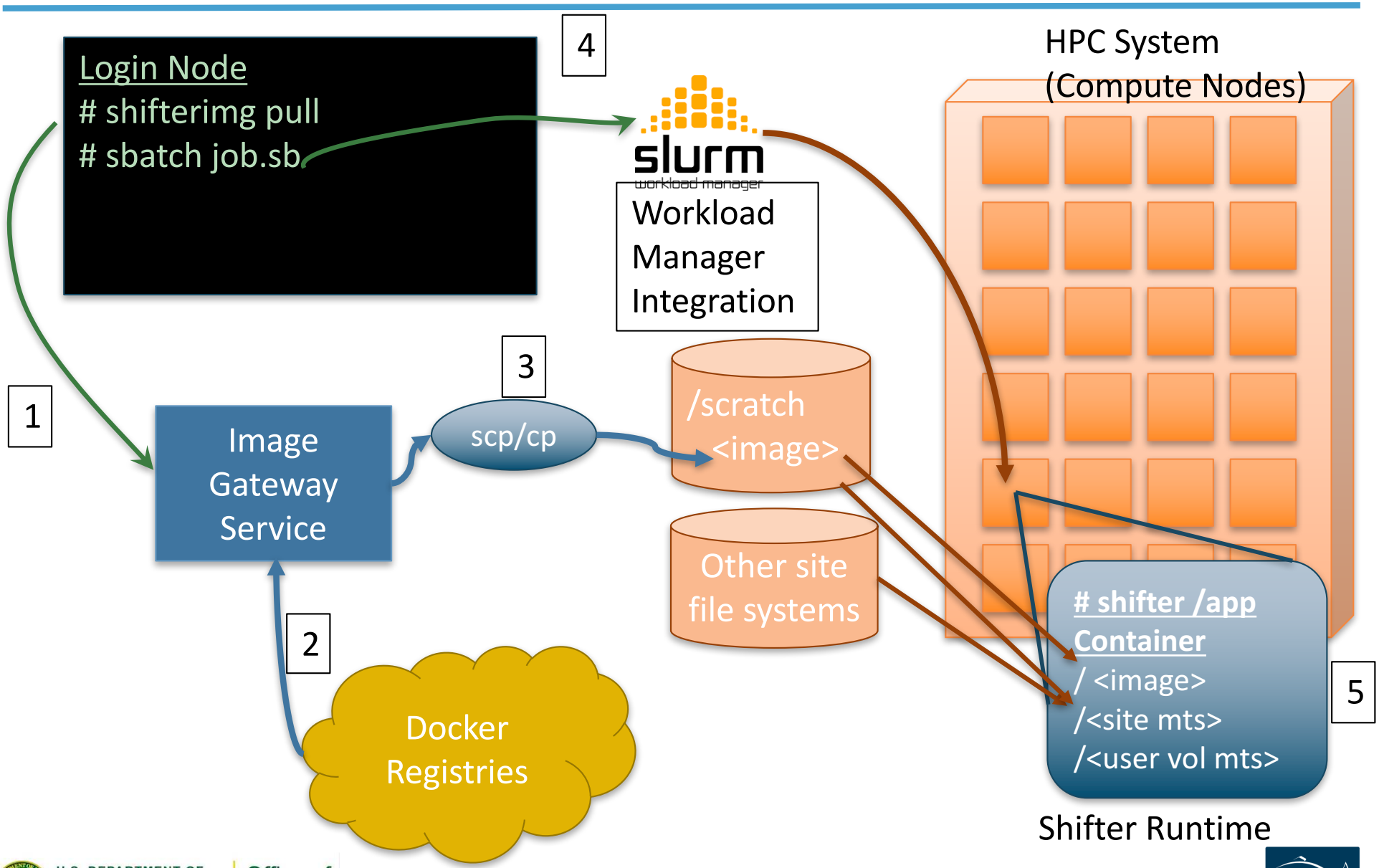
1. **Mount the image with a loop back mount at run-time**

Shifter Components

- **Shifter Image Gateway**
  - Imports and converts images from DockerHub and Private Registries
- **Shifter Runtime**
  - Instantiates images securely on compute resources
- **Work Load Manager Integration**
  - Integrates Shifter with WLM



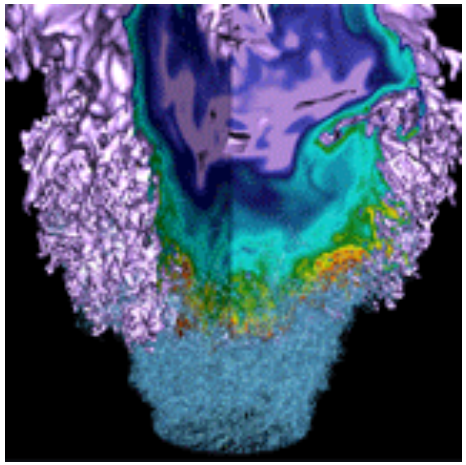
Shifter Architecture and Flow

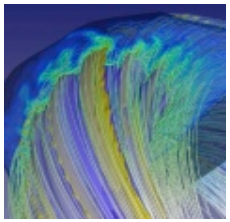


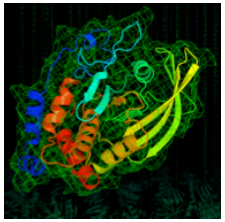
Workload Integration - Slurm

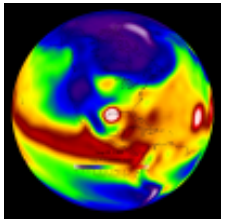
- Custom Plugin using the SLURM plugin architecture
- Allows users to specify images, volumes and other options directly in the batch submission.
- Extensions pre-create a common Shifter area (optimal for MPI applications).
- Support for Integration with other batch systems exist (Torque/MOAB, UGE)

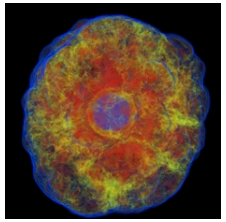
Shifter in Action

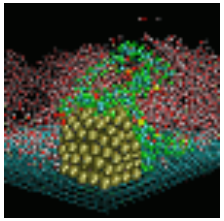












Basic Usage

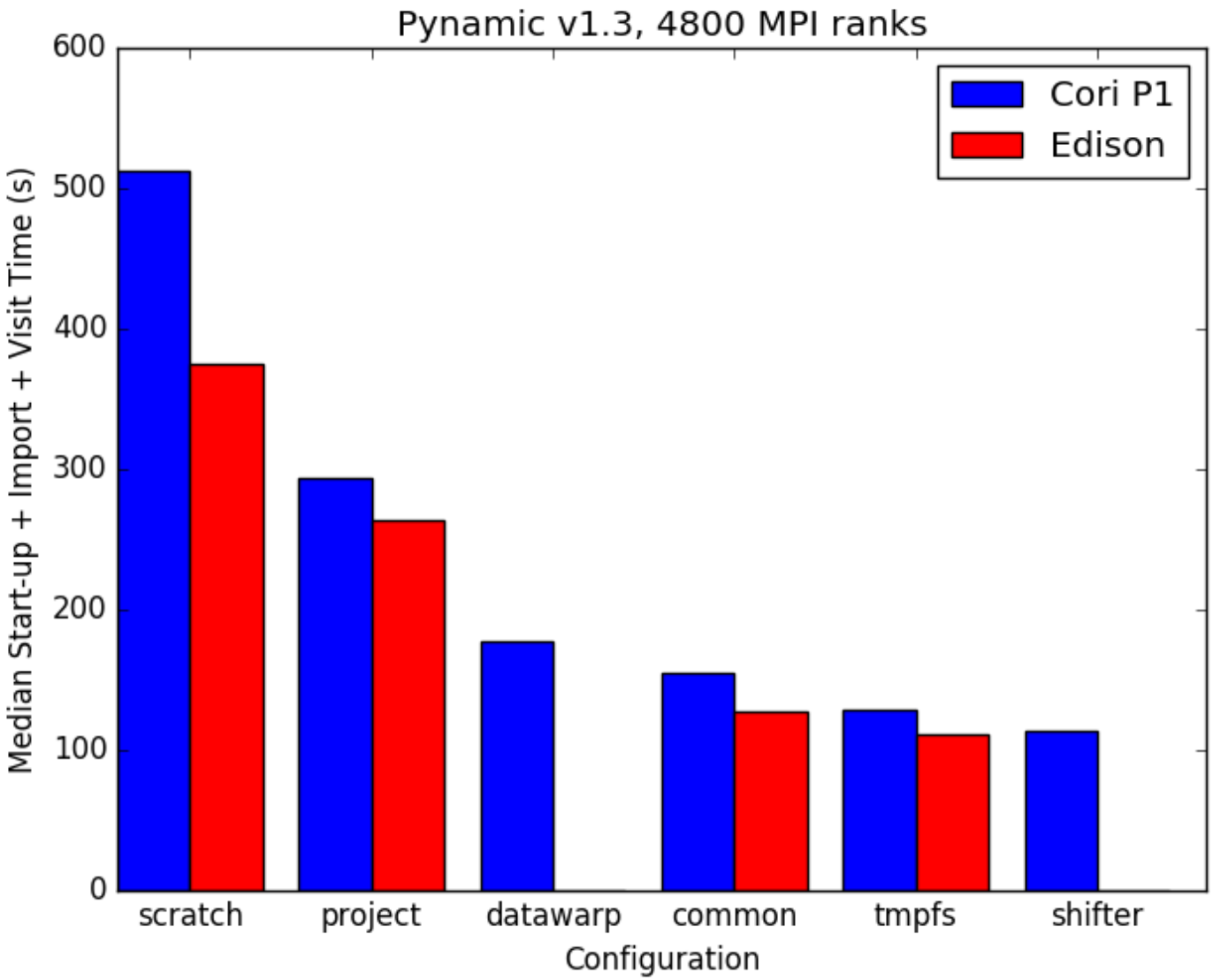
- **Pull image with shifterimg**

```
> shifterimg pull scanon/myapp:1.1
```

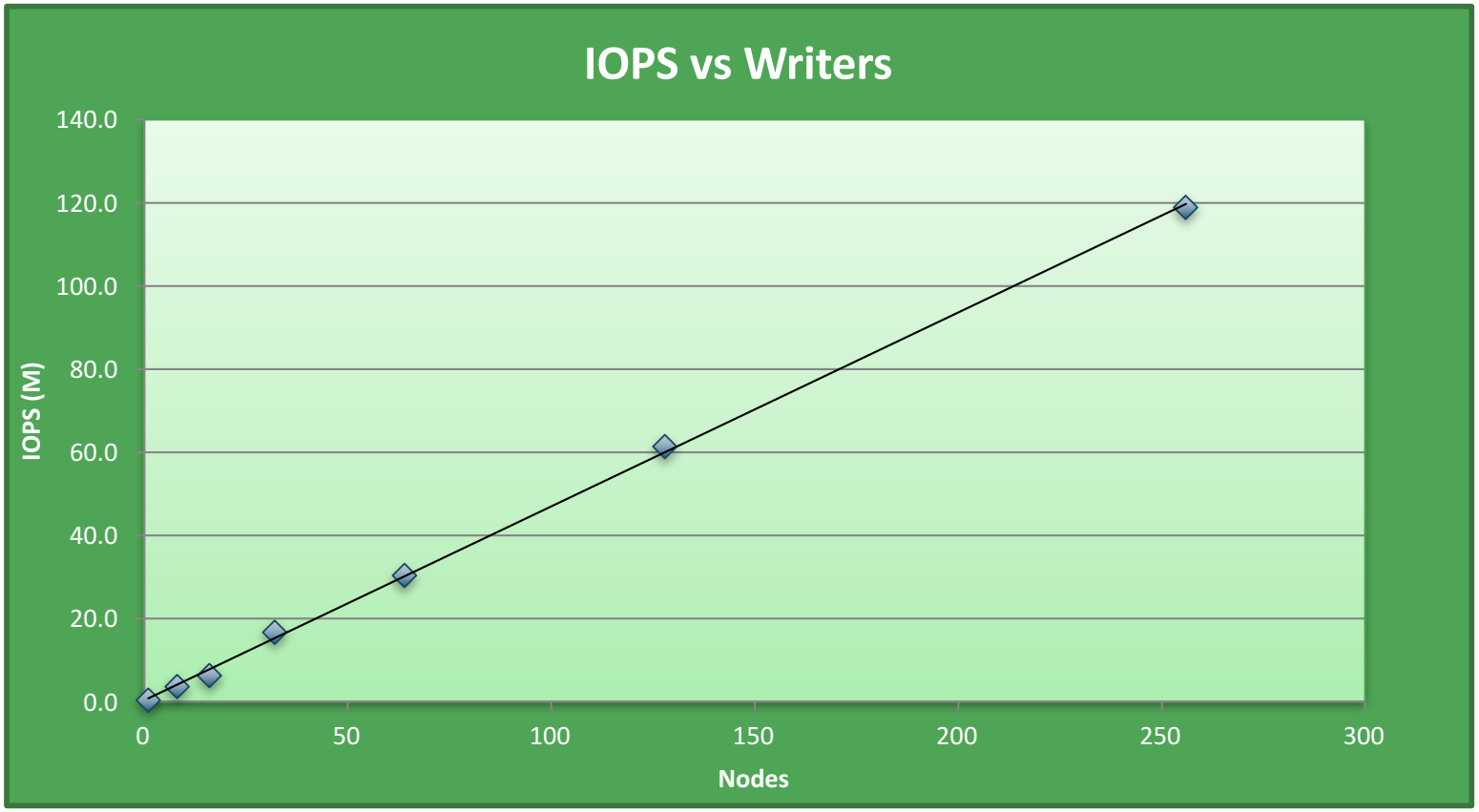
- **Use shifter to use the image**

```
> salloc –N 1 –C haswell –image=scanon/myapp:1.1
# shifter /myapp/app
```

Shifter accelerates Python Apps



Per-Node Write Cache (IOPS)



Results of an IOR File per-process, 2 tasks per node, 512B transfer size, 2GB write. 100x faster than Lustre at the same scale.

Shifter and MPI

- **In Image**
  - Add required libraries directly into image.
  - Users would have to maintain libraries and rebuild images after an upgrade.
- **Managed Base Image (Golden Images)**
  - User builds off of a managed image that has required libraries.
  - Images are built or provided as part of a system upgrade.
  - Constrained OS choices and a rebuild is still required.
- **Volume Mounting**
  - Applications built using ABI compatibility.
  - Appropriate libraries are volume mounted at run time.
  - No rebuild required, but may not work for all cases.

Volume Mount Approach

```
FROM nersc/mpi-ubuntu:14.04

ADD . /app
RUN cd /app && \
    mpicc -o hello helloworld.c
```

Dockerfile

```
> docker build –t scanon/hello-vm:latest .
> docker push scanon/hello-vm:latest
```

Use the Image with Shifter

Submit script

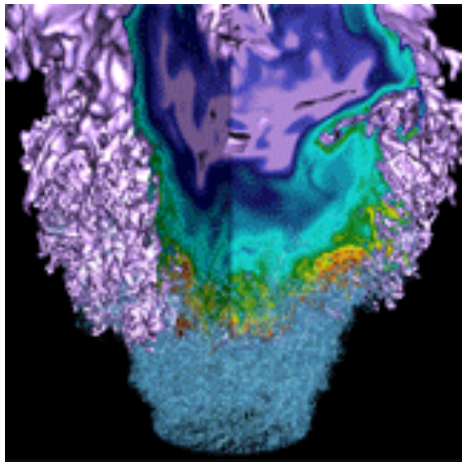
```
#!/bin/bash
#SBATCH -N 16 -t 20
#SBATCH --image=scanon/myapp:1.1

srun -n 16 shifter /myapp/app
```

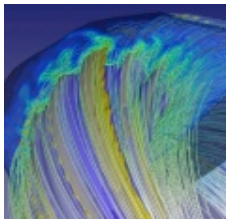
```
> shifterimg pull scanon/myapp:1.1
> sbatch ./job.sl
```

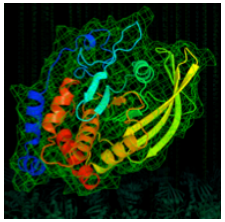
Use the Image with Shifter

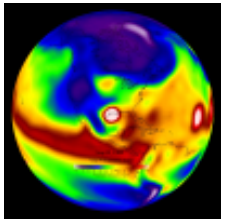
```
> shifterimg pull scanon/myapp:1.1
> salloc –N 1 –C haswell
salloc: Pending job allocation 8345797
salloc: job 8345797 queued and waiting for resources
salloc: job 8345797 has been allocated resources
salloc: Granted job allocation 8345797
salloc: Waiting for resource configuration
salloc: Nodes nid00443 are ready for job
nid00443:~> shifter –image=scanon/myapp:1.1
$
```

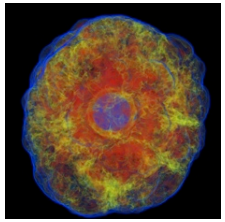
Related Work and Discussion

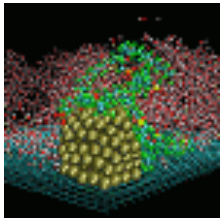












Other HPC Container Solutions

- **Singularity**
  - Very popular
  - Easy Installation
  - Runtime similar to Shifter
  - Native Image format in addition to Docker
- **CharlieCloud**
  - Very light-weight
  - No special privileges required
  - Separate tools to unpack Docker images

Why Users will like Shifter

Enables regular users to take advantage of Docker on HPC systems at scale.

This enables users to:

- Develop an application on the desktop or laptop and easily run it on a cluster or Supercomputer
- Solve their dependency problems themselves
- Run the (Linux) OS of their choice and the software versions they need

And…

- Improves application performance in many cases
- Improves reproducibility
- Improves sharing (through sites like Dockerhub)

Roadmap

- **17.11 Release (Pending)**
  - ACL support (private and authenticated images)
  - Improved GPU and MPI support
  - Image expiry and removal
  - Basic Image usage statistics and metrics
  - Integrated Image Import Support
  - Simplified Installation
- **Future**
  - Support for other image formats
  - OverlayFS support (write-able images)

Future Work

- Expand support for other image types and batch systems (with outside help)
- Continue to promote Docker and Shifter within the HPC community to increase access
- Explore other ways to integrate with Docker (e.g. Moby Project)

How does Shifter differ from Docker?

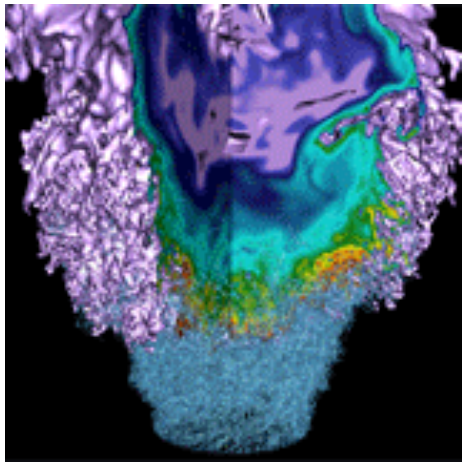
Most Noticeable

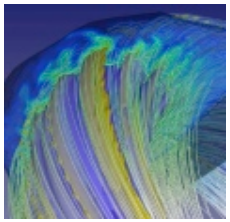
- Image read-only on the Computational Platform
- User runs as the user in the container – not root
- Image modified at container construction time (e.g. additional mounts)

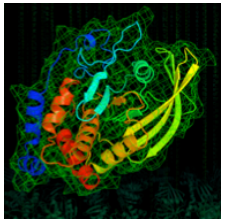
Less Noticeable:

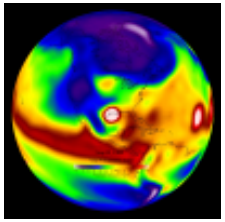
- Shifter only uses mount namespaces, not network or process namespaces
- Shifter does not use cgroups directly (integrated with the Workload Manager)
- Shifter uses individual compressed filesystem files to store images, not the Docker graph (slows down iterative updates)
- Shifter starts some additional services (e.g. sshd in container space)

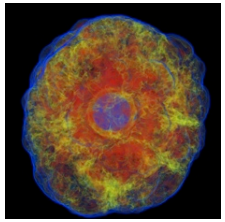
Installing Shifter

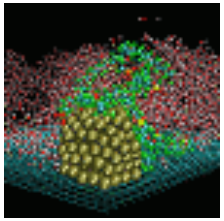












Testing with Shifter-in-a-box

- **Shifter-in-a-box is a complete Shifter install running in a docker container**
- For Docker4Mac install squashfs module first

```
docker run -it --rm --privileged scanon/squashfs
```

- Start shifter-in-a-box

```
> docker run -it --rm --privileged -v shifter:/data \
   scanon/shifterbox
# /src/start.sh
# su - auser
auser# shifterimg pull busybox
```

Quick Installation (CentOS7)

- Install EPEL
- Install Mongo and Munge
- Initialize and start Mongo and Munge

```
yum -y install epel-release
yum -y install mongodb-server mongodb wget munge
#
mkdir -p /data/db
mongod --smallfiles --fork \
    --logpath=/var/log/mongodb/mongo.log \
    --pidfilepath /mongo.pid
#
dd if=/dev/urandom of=/etc/munge/munge.key count=1
chown munge /etc/munge/munge.key
chmod 600 /etc/munge/munge.key
runuser -u munge -- /usr/sbin/munged  --force -F &
```

Quick Installation (CentOS 7)

- **Install Shifter RPMs**

```
R=http://portal.nersc.gov/project/bigdata/shifter/
T=17.11.b1-1.nersc.el7.centos
yum install $R/shifter{,-imagegw,-runtime}-$T.x86_64.rpm
```

- **Create config files**

```
cp /etc/shifter/imagemanager.json{.example,}
cp /etc/shifter/udiRoot.conf{.example,}
sed -i 's|etcPath=|etcPath=/etc/shifter/shifter_etc_files|' \
  /etc/shifter/udiRoot.conf
sed -i 's|imagegwapi|localhost|' /etc/shifter/udiRoot.conf
mkdir -p /images/cache
```

- **Start Services**

```
L=/var/log/shifter_imagegw
/usr/bin/gunicorn -D -b 0.0.0.0:5000 \
  --access-logfile$L/access.log --log-file$L/error.log \
  shifter_imagegw.api:app
```

Quick Installation (CentOS7)

- **Add user and test**
- **Create config files**
- **Start Services**

```
> useradd -m auser
> getent passwd > /etc/shifter/shifter_etc_files/passwd
> su auser
auser> shifterimg images
auser> shifterimg pull alpine
auser> shifter –image alpine
```

Summary

- Shifter enables HPC systems to easily and securely run Containers even at large scale
- Shifter provides the flexibility of Docker without sacrificing security, scalability or performance.
- Shifter opens the door to the many benefits of Docker including easy sharing of images, reproducibility, etc.

Acknowledgements

Cray

NERSC – Benchmarks and Use Cases

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Others – Contributors and Use Cases

CSCS, Vakho Tsulaia, Ted Kisner

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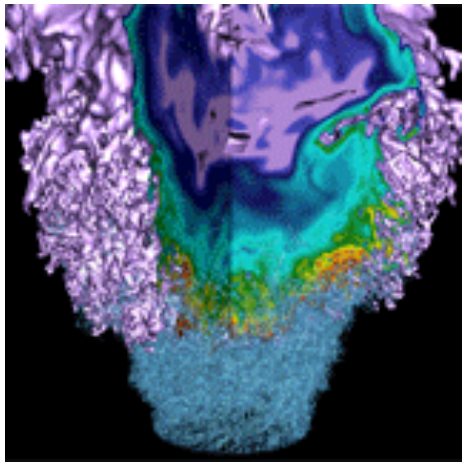
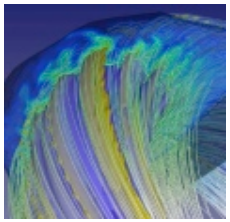
Questions?

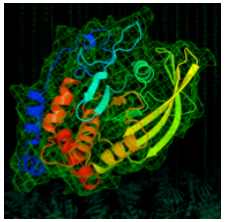
Why?

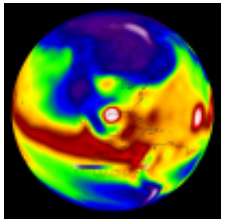
- Python must walk through the python libraries to construct the namespace
- Python must load up any dynamic libraries that are required
- The loader must traverse the LD_LIBRARY_PATH to find the libraries to load

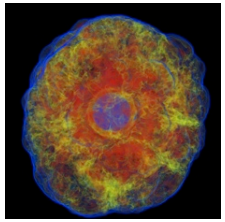
Advanced Installation Info











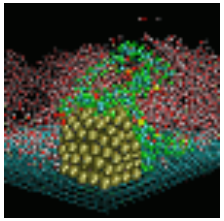
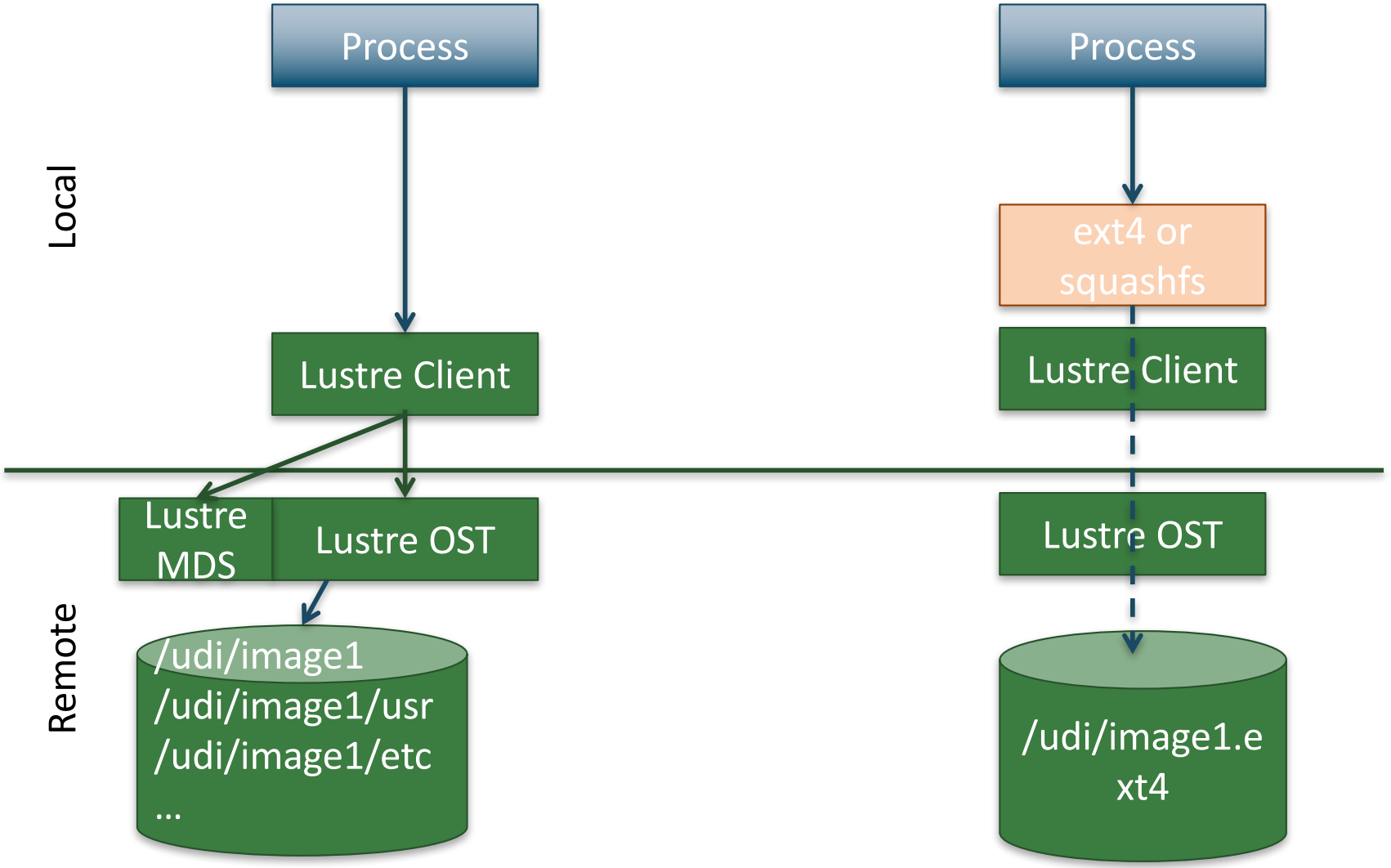


Image Gateway Options and Considerations

- Image Gateway can write image directly (local) or copy images via SCP
- Image Gateway can support multiple systems
- Image Gateway should have access to any external registries (e.g. DockerHub)
- Image Gateway should have sufficient local disk or ramdisk for caching layers and unpacking images

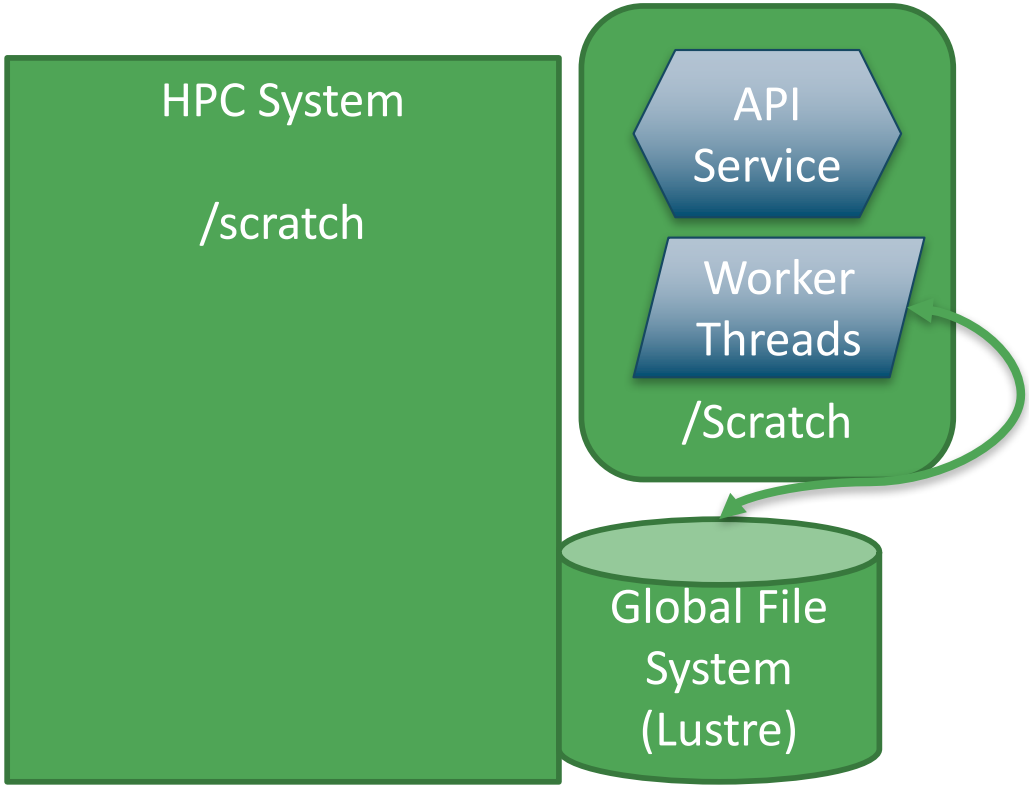
File System flow – Traditional vs Shifter



Deployment Options

1. Gateway service runs on a system with direct access to the cluster file system
2. Gateway service runs on a remote system with ssh access to cluster file system

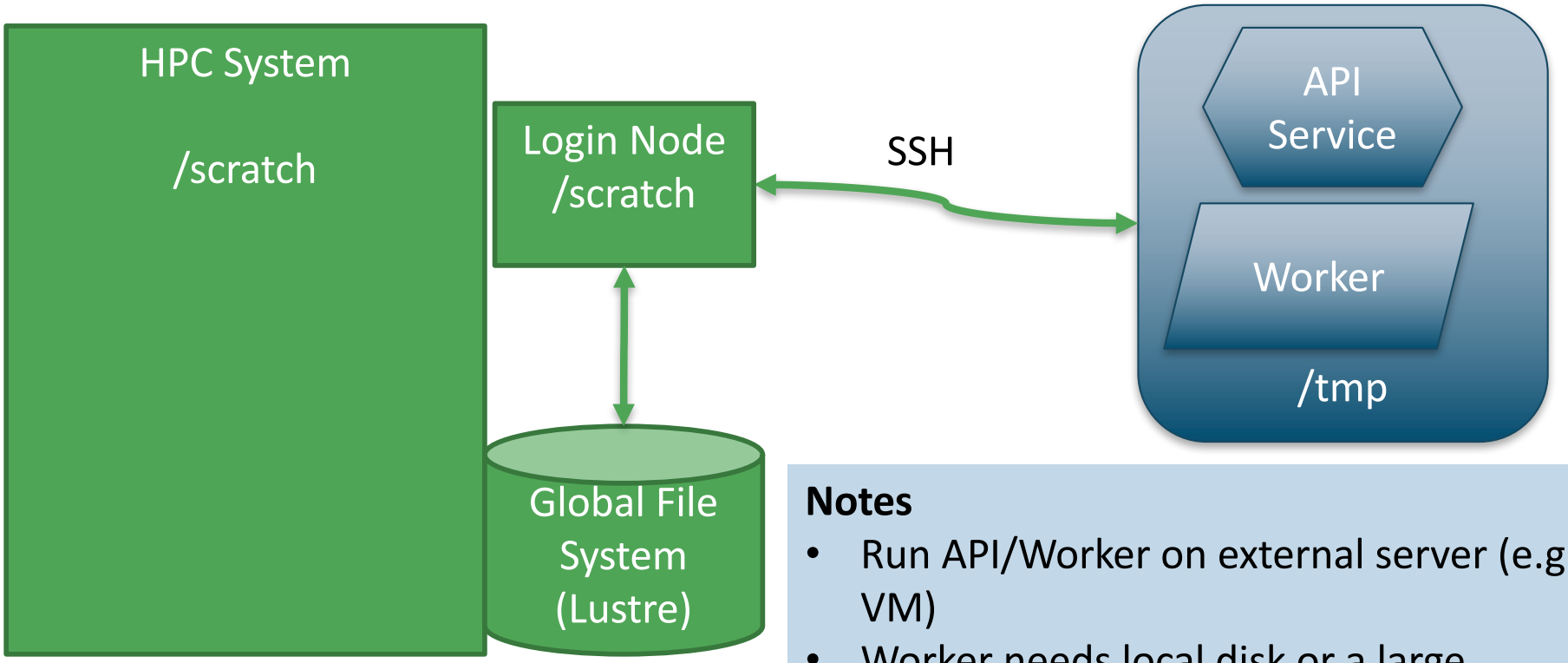
Co-located/Local



Notes

- Typically run on a login-class node
- Worker needs local disk or a large ramdisk space
- This is the easiest model and recommended for most cases

Co-located/Remote



Notes

- Run API/Worker on external server (e.g. VM)
- Worker needs local disk or a large ramdisk space
- Worker needs ssh keys configured to copy image to a node that has the file system mounted.

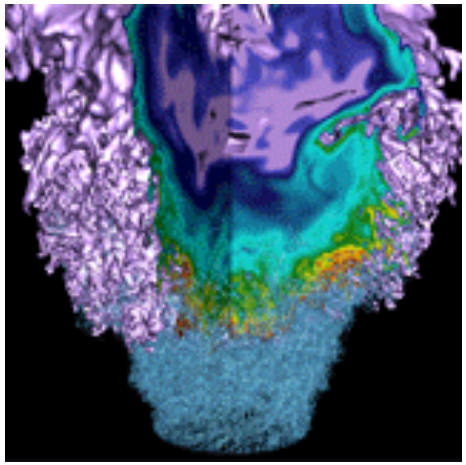
Registries

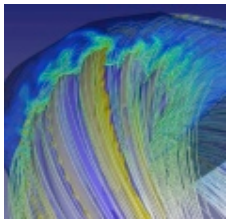
- Adding registries is done in the image manager
- This can be used to add both private and public registries
- Configured in the Locations seciton of the imagemanager.json config file

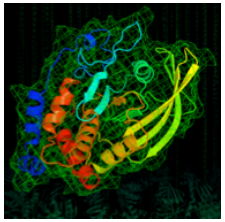
Registries

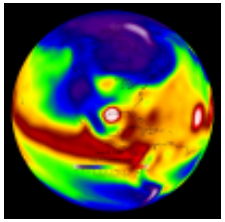
```
…
"Locations": {
        "index.docker.io": {
            "remotetype": "dockerv2",
            "authentication": "http”
        },
"local": {
            "remotetype": "dockerv2",
            "url": "https://localhost:5000",
            "authentication": "http”,
            “sslcacert”: “local.crt”
        }
    },
…
```

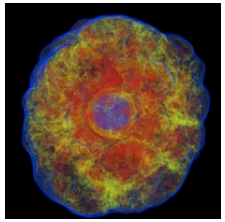
Success Stories

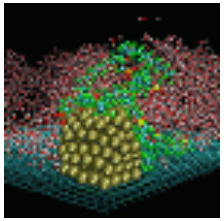










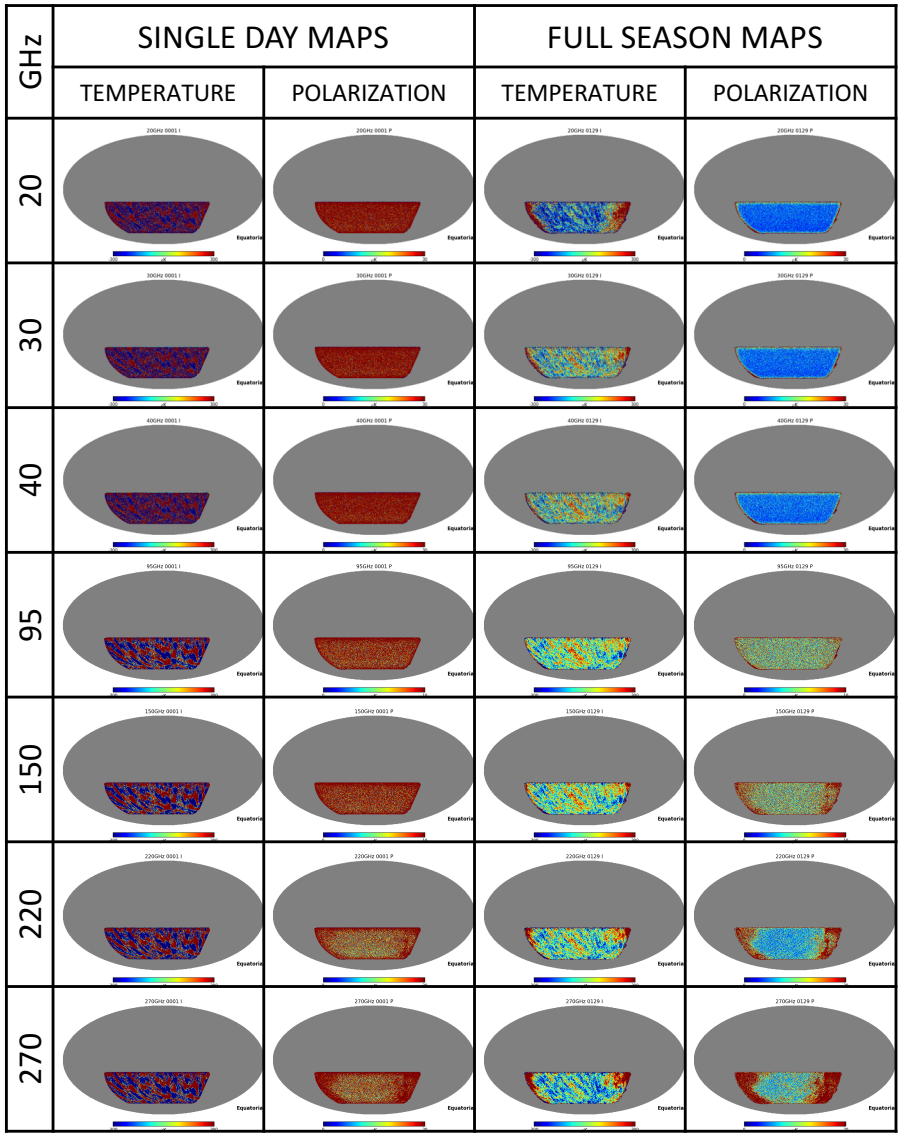


Spark

- "Big Data" high productivity analytics Framework
- Designed around commodity clusters (Ethernet network and local disk)
- Shifter image: lgerhardt/spark-1.6.0
- Uses per-Node write cache for spills and other temporary per-node file caches.
- Tested up to full scale of Cori Phase 1 (1600 nodes) with multiple Spark applications.

CMB Simulation At Scale With TOAST (& Shifter)

- **Simulate & map 50,000 detectors gathering 30X Planck mission data**
- **Using all of NERSC's Cori-2 supercomputer**
  - KNL optimization including Cray/Intel "dungeon session"
  - **Docker/Shifter to distribute python-wrapped code to 600,000 cores.**
- **Including realistic atmosphere simulation, instrument noise & sky signal.**
- **Re-using the expensive simulation in situ to allow multiple reduction pipelines.**
- **Meets Y1 stretch goals for LBNL LDRD project: Simulation & Analysis of CMB-S4 on Xeon Phi Systems.**
- **Animations at http://crd.lbl.gov/cmb-sims**



J. Borrill, R. Keskitalo & T. Kisner

Per-Node Write Cache (New Feature)

Per-Node Write Cache provides local disk like functionality but is backed by the Parallel File System.

Nodes/Writers per node	Lustre (MB/s) per writer	Shifter (MB/s) per writer	Real Local Disk (MB/s) per writer
1/1	83	594	416
10/10	87	625	416*
10/20	67	616	165*
10/40	55	589	53*
20/40	71	627	165*
20/80	55	588	53*

Results of a simple "dd" test to simulate writing ~5GB of small transaction I/O (**`dd if=/dev/zero of=$TARGET bs=512 count=10M`**)

* Extrapolated from a single node test