Slurm Container Support

CNCF Research Users Group

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Adding support for Docker in Slurm

Steps:

1. Slurm needs to be able to:
   a. Run OCI Containers
   b. Schedule jobs with containers
   c. Track containers resources
   d. Enforce all job rules and limits upon containers
2. Docker needs way to interface with Slurm:
   a. Docker uses OCI Runtime to run containers
   b. Slurm needs an OCI Runtime interface
   c. Container images must be reliably sent to and from compute nodes

Slurm OCI Container Support

- Added ‘--container’ (21.08) support to the following:
  - srun
  - salloc
  - sbatch
- Added viewing job container [bundle path] (21.08) and container-id (23.02) to the following:
  - scontrol show jobs
  - scontrol show steps
  - sacct
    - If passed as part of the ‘--format’ argument using “Container”
  - slurmd, slurmstepd, slurmdbd & slurmctld logs (too many places to list)

OCI Container Support (21.08+)

- Slurm cgroups features apply to the OCI containers
  - All processes should be cleaned up even if the container anchor process dies or processes attempt to become daemons and detach from the session
  - Resource usage can be hard limited and monitored
- Slurm is only going to support unprivileged containers in 21.08, 22.05, 23.02
  - Use existing kernel support for containers
  - Users can already call all of these commands directly
  - Containers must be able to function in an existing host network
- Per host configuration via ‘oci.conf’ in /etc/slurm/
    - Environment variables SLURM_CONTAINER and SLURM_CONTAINER_ID (23.02)will always be set with a value (if present).

OCI Container Support (21.08+)

srun example

```
$ srun --container=/tmp/centos grep ^NAME /etc/os-release
NAME="CentOS Linux"
```

salloc example

```
$ salloc --container=/tmp/centos grep ^NAME /etc/os-release
salloc: Granted job allocation 65
NAME="CentOS Linux"
salloc: Relinquishing job allocation 65
```

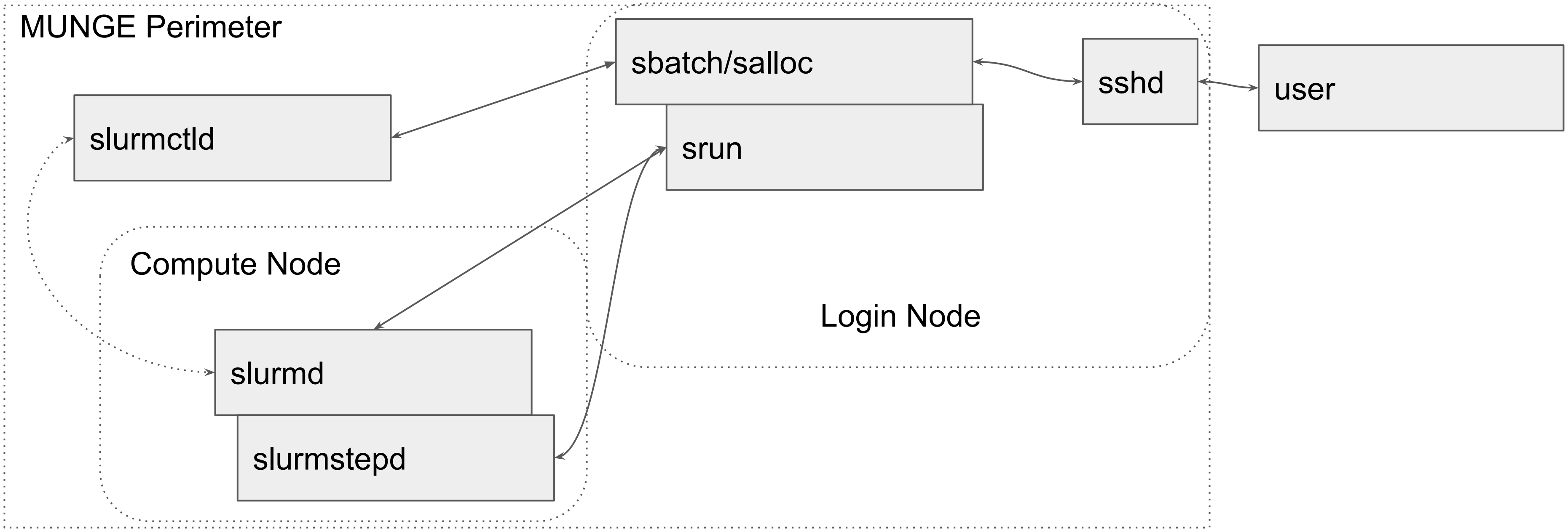
Note: containers have limited permissions and can result in pseudo terminal warnings.

OCI Container Support (21.08+)

sbatch example

```
$ sbatch --container=/tmp/centos --wrap 'grep ^NAME
/etc/os-release'
Submitted batch job 24419
$ cat slurm-24419.out
NAME="CentOS Linux"
```

Batch Job Use Case (23.02)



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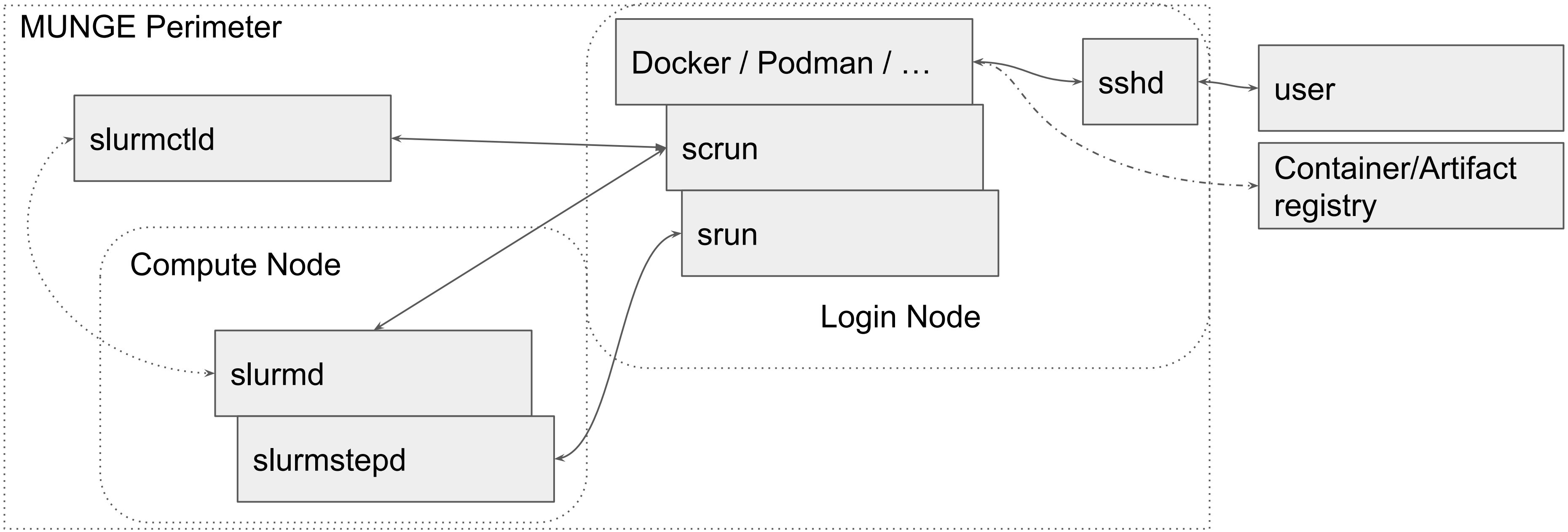
Container Use Case (23.02)



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OCI runtime proxy - scrun (23.02)

- scrun’s goal is to make containers **boring for users**
    - Users have better things to do than learn about the intricacies of containers
    - Site administrators will have to do setup and maintenance on the configuration
- Use Slurm’s existing infrastructure to run containers on compute nodes
- Automatic staging out and in of containers controlled by system administrators
    - End requirement that users manually prepare their images on compute nodes.
- Interface directly with OCI runtime clients (Docker or Podman or …)

OCI runtime proxy - scrun (23.02)

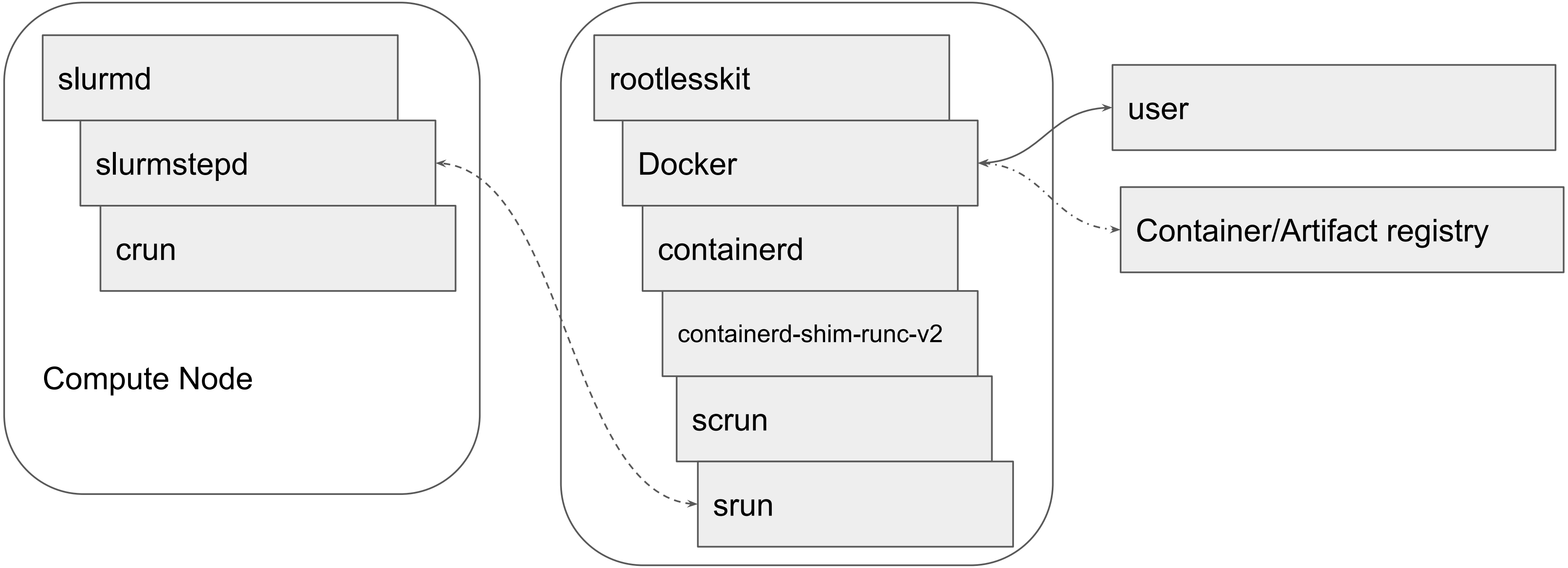
- Allow users to work with the tools they want while running work on the Slurm cluster
- scrun is a new CLI command to join srun, sbatch and salloc, but no user should ever have to call it directly or even really need to be aware of it
- scrun is still very new and we welcome tickets with requests for enhancements and especially bug reports

scrun via rootless Docker (23.02)

example:

```
$ export
DOCKER_HOST=unix://$XDG_RUNTIME_DIR/docker.sock
$ export DOCKER_SECURITY=”--security-opt label:disable
--security-opt seccomp=unconfined  --security-opt
apparmor=unconfined --net=none”
$ docker run $DOCKER_SECURITY -i ubuntu /bin/sh -c 'grep
^NAME /etc/os-release'
NAME="Ubuntu"
$ docker run $DOCKER_SECURITY -i centos /bin/sh -c 'grep
^NAME /etc/os-release'
NAME="CentOS Linux"
```

Rootless Docker Process Trees



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Rootless Docker config (23.02)

~/.config/docker/daemon.json

```
{
  "default-runtime": "slurm",
  "runtimes": {
    "slurm": {
      "path":
"/usr/local/slurm/sbin/scrun"
    }
  },
```

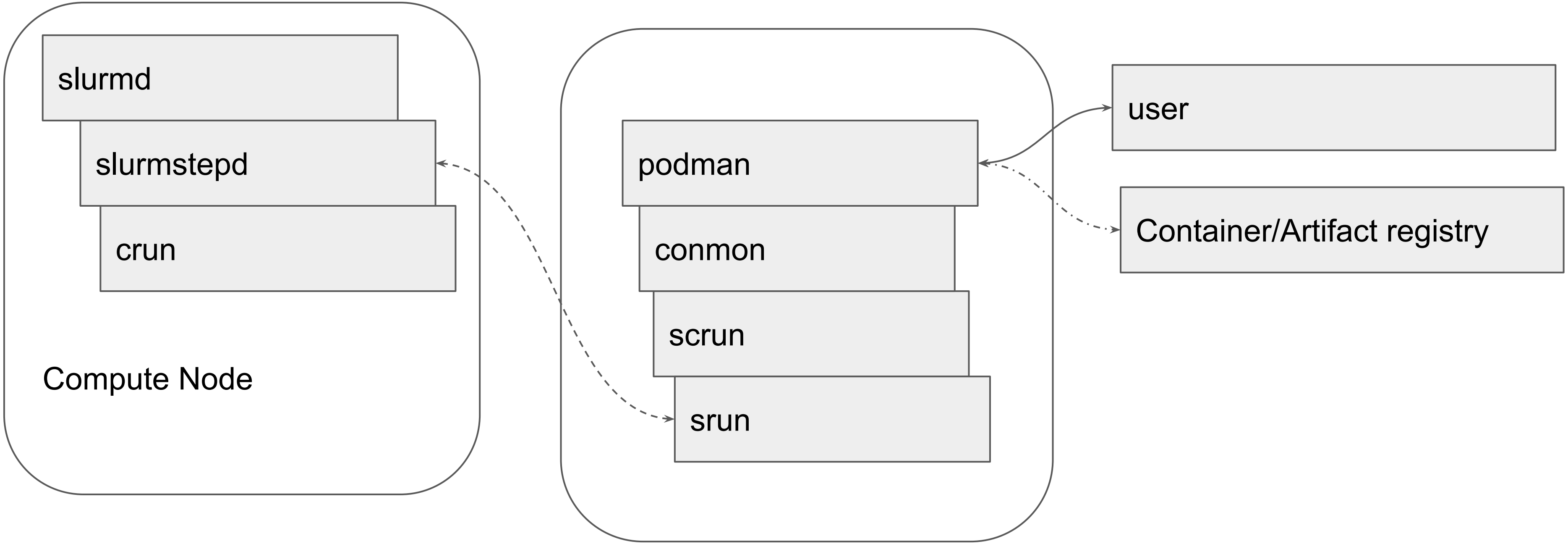
```
  "experimental": true,
  "iptables": false,
  "bridge": "none",
  "no-new-privileges": true,
  "rootless": true,
  "selinux-enabled": false
}
```

scrun via rootless Podman (23.02)

example:

```
$ podman run ubuntu /bin/sh -c 'grep ^NAME /etc/os-release'
NAME="Ubuntu"
$ podman run centos /bin/sh -c 'grep ^NAME /etc/os-release'
NAME="CentOS Linux"
$ podman run centos /bin/sh -c 'printenv SLURM_JOB_ID'
77
$ podman run centos /bin/sh -c 'printenv SLURM_JOB_ID'
78
```

Podman Process Trees



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Podman config for scrun (23.02)

~/.config/containers/containers.conf:

```
[containers]
apparmor_profile = "unconfined"
cgroupns = "host"
cgroups = "enabled"
default_sysctls = []
label = false
netns = "host"
no_hosts = true
pidns = "host"
utsns = "host"
userns = "host"
```

```
[engine]
runtime = "slurm"
runtime_supports_nocgroups = [ "slurm" ]
runtime_supports_json = [ "slurm" ]
remote = false

[engine.runtimes]
slurm = [
"/usr/local/slurm/sbin/scrun"
]
```

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scrun - container staging

- scrun needs to stage out the image to remote host at startup
- scrun needs to stage in the image from remote host at job end
- Flexibility required as every site has a different shared file system configuration and data ingress and egress rules.
    - scrun avoids making as many assumptions about the request host vs the execution host in Slurm itself as possible.
    - Site admins must configure where and how images are staged.

scrun - container staging via Lua

- scrun’s Lua staging plugin allows site to write custom and simple scripts to move the image to and back from the remote storage.
- scrun’s staging lua script is located at:
  - /etc/slurm/staging.lua
- Lua script runs as user avoiding any additional privilege escalation risk
- Lua already has JSON support via libraries
- Sites can write a native Slurm plugin if desired instead of using the Lua plugin.

scrun - Lua container stage in example

Simplified stage in (to compute node) hook:

```
function slurm_stage_in_allocator(id, bundle, spool_path,
config_path)
        os.execute(string.format( "/usr/bin/env rsync --numeric-ids
--delete-after --ignore-errors -a -- %s/ %s/", rootfs, dstfs))

        slurm.set_bundle_path(p)
        slurm.set_root_path(p.."rootfs")

        write_file(jc, json.encode(c))
        return slurm.SUCCESS
end
```

scrun - Lua container stage out example

Simplified stage out (from compute node) hook: (this example only deletes the

```
function slurm_stage_out_allocator(id, bundle, spool_path, config_path)
        os.execute("rm --one-file-system --preserve-root=all -rf "..bundle)
        return slurm.SUCCESS
end
```

See Slurm’s documentation for a full and functional example of the Lua script when slurm-23.02 is officially released.

scrun - limitations (23.02)

- No network namespaces support
  - All containers must run under host network
- No cgroup/apparmor/selinux support via Docker/Podman
  - All the containers are executed remotely making the local system's security systems irrelevant to the container. Podman allows easy configuration disablement while Docker requires command line arguments
- No container annotation support implemented yet
- No automatic resource selections implemented yet
  - Use of Slurm environment variables allow job property control
  - scrun will currently run the default job with default resources requested
- Container failures may require examining slurmd logs and/or syslogs to determine root cause

scrun - limitations (23.02)

- Lua must either be compiled with JSON support or the library must be installed.
  - Slurm may need to be compiled after the JSON library is installed in Lua in order to be able to use it.
- scrun will not currently kill or stop the lua script while it is running.
  - If the Lua staging scripts hang, then the job time limit may be triggered and kill the job.
- scrun has the relevant SPANK and clifilter support.
  - These hooks are not a security device and any user may override them same as srun/sbatch/salloc.
  - scrun uses standard Slurm RPCs and user permissions. Any user may modify or ptrace their own processes. Any security must be applied at the controller.

scrun - limitations (23.02)

- One podman/docker instance per user per host
  - scrun does not provide information for jobs other than its own
    - Jobs will be visible via squeue/sacct/slurmrestd
  - docker / podman will be blind to any externally started containers
- MUNGE Authentication
  - scrun currently only works via MUNGE
  - Job submission host must have Slurm installed and be in MUNGE perimeter
- JWT Authentication
  - Not currently implemented
- Container IDs must be unique per user
  - Docker or Podman will hand the container ID to scrun verbatim.
  - scrun will try to search for the container by ID

    If the local anchor process is dead.

scrun - limitations (23.02)

- All existing limitations for running containers in Slurm still apply:
  - Containers must have a compatible version of Slurm installed to call Slurm commands
  - MUNGE’s socket must be mounted in container to use MUNGE based authentication
  - JWT authentication is possible from container but there are no secrets functionality currently available.
    - Slurm does not support step controls/commands via JWT currently.
- User environment must be explicitly set
  - The environment at time of calling docker/podman will not be inherited by the container unless environment variables are supported by Docker/Podman.

scrun - limitations (23.02)

- scrun will create a local process that must remain alive for the duration of the Job
  - If the local process is killed, then the job will be killed by Slurm. This is the same requirement as any job run via srun
  - scrun can be started from a batch job to avoid submission host uptime requirements
- scrun supports output of Docker JSON formatted log files
  - All output to set to STDOUT instead of being split between STDOUT and STDERR
- Docker current uses an event and poll based system for determining if a container is alive
  - This may result in higher CPU usage on the submission host than only running a container directly via srun

scrun - limitations (23.02)

- scrun requires oci.conf to be fully configured
- I/O restrictions and other limitations from the submission host will affect staging containers in and out
- Slurm (scrun) is run as one of the last steps of starting the container in Docker/Podman
- Slurm has no control over Docker/Podman
  - Docker and podman will need to configured independently of Slurm
  - Only rootless Docker/Podman is supported
    - rootless docker has varying levels of support with older kernels
    - Sites are recommended to run the latest version of their distro and docker to avoid issues
- Not all functionality of Docker/Podman is implemented

scrun - limitations (23.02)

- Online image repositories exist independently of Slurm and may apply bandwidth or usage restrictions
  - These limitations can falsely imply scrun (and Slurm) being slow
  - Sites are suggested to set up local caching proxies if possible
  - scrun does not cache images
- scrun is not a security solution or antivirus or a new security layer
  - It does not scan or reason about the contents of the container images beyond enforcing **basic** OCI image formatting
  - It will push the images to the execution hosts where the configured and the OCI runtime in oci.conf will be executed to start the containers
  - Users are responsible to ensure the container images are following site policies and procedures while being free of malicious code

scrun - limitations (23.02)

- scrun will only run under the POSIX user/group neither adding or removing abilities/capabilities/permissions from the user and therefore the container processes
- Sites must configure the stage in and stage out Lua scripts to clean up cached images
  - Failure to cleanup the images may result in massive wasteful usage of the filesystems.
- Sites must configure docker/podman to cleanup cached images independently of Slurm
  - Dockers build cache can get very large!

Questions?