SLURM Operation on Cray XT and XE

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Contributors and Collaborators

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Swiss National Supercomputing Centre performed some of the development and testing.

Cray helped with integration and testing.

Outline

- Cray hardware and software architecture
- SLURM architecture for Cray
- SLURM configuration and use
- Status

Cray Architecture

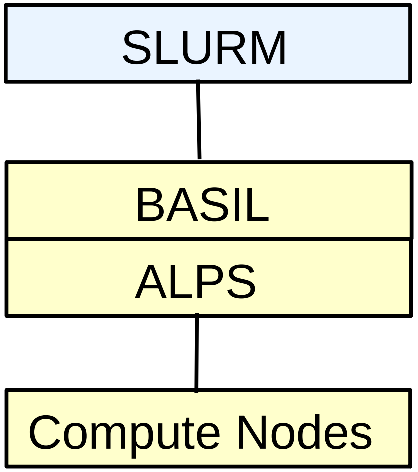
- Many of the most powerful computers built by Cray
- Nodes are diskless
- 2 or 3-dimension torus interconnect
  - Multiple nodes at each coordinate on some systems
- Full Linux on front-end nodes
- Lightweight Linux kernel on compute nodes
- Whole nodes must be allocated to jobs

ALPS and BASIL

- ALPS – **A**pplication **L**evel **P**lacement **S**cheduler
  - Cray's resource manager
  - Six daemons plus variety of tools
    - One daemon runs on each compute node to launch user tasks
    - Other daemons run on service nodes
  - Rudimentary scheduling software
    - Dependent upon external scheduler (e.g. SLURM, etc) for workload management
- BASIL – **B**atch **A**pplication **S**cheduler **I**nterface **L**ayer
  - XML interface to ALPS

SLURM Architecture for Cray

- Many tools dependent upon ALPS
  - Use SLURM as scheduler layer above ALPS and BASIL, not a replacement

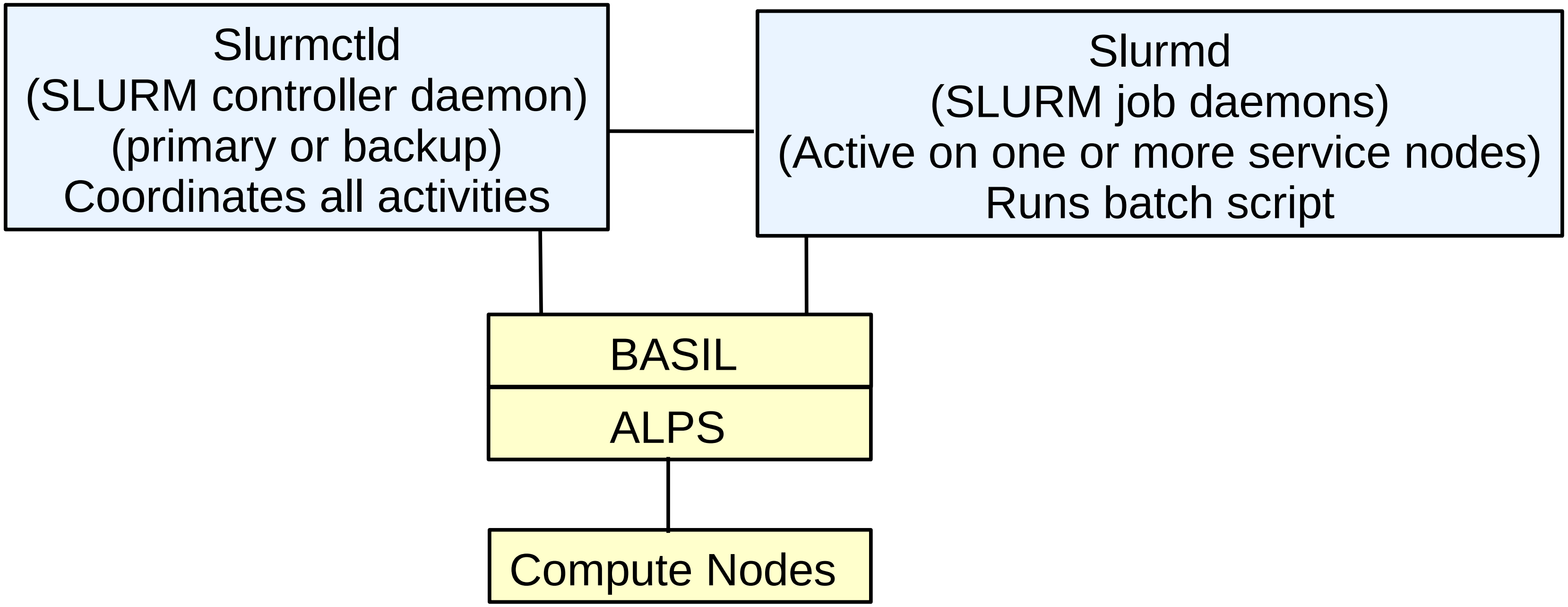


SLURM and ALPS Functionality

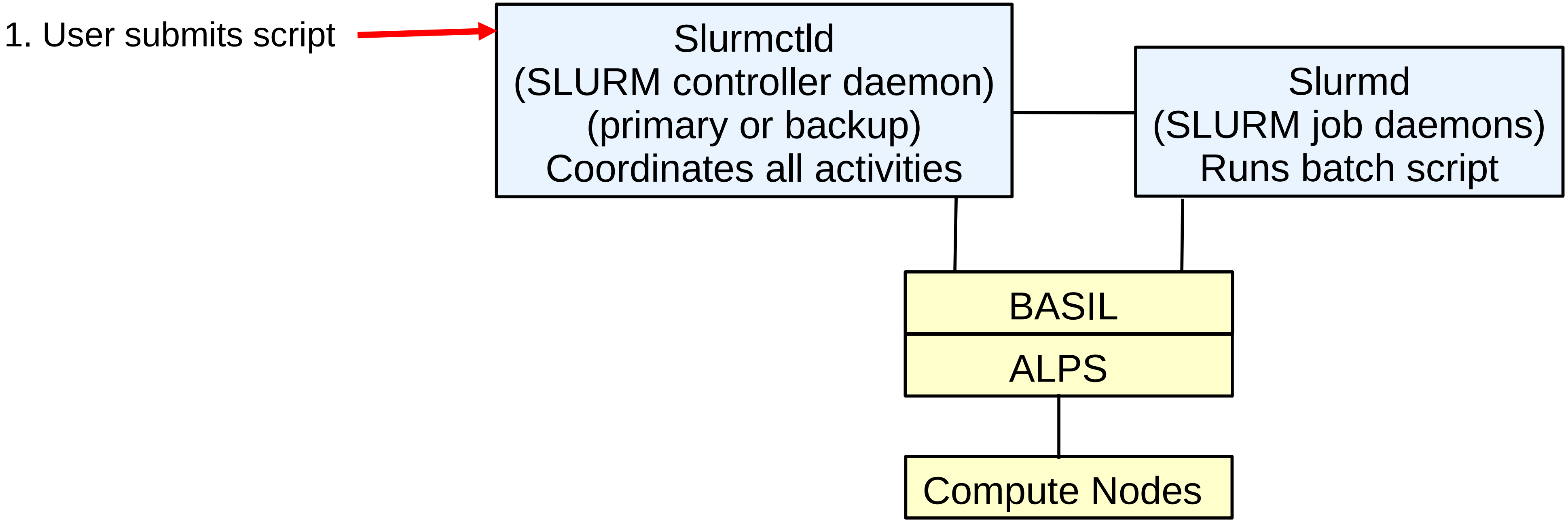
- SLURM
  - Prioritizes queue(s) of work and enforces limits
  - Decides when and where to start jobs
  - Terminates job when appropriate
  - Accounts for jobs

- ALPS
  - Allocates and releases resources for jobs
  - Launches tasks
  - Monitors node health

SLURM Architecture for Cray (Detailed)



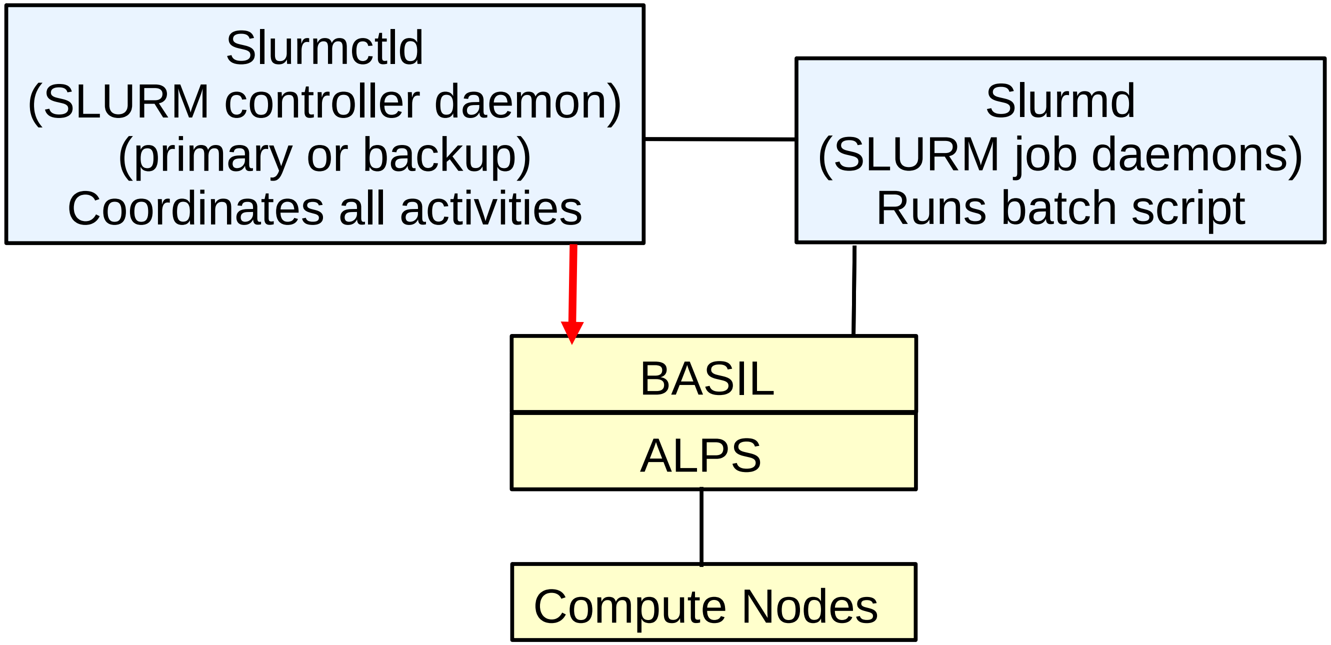
Job Launch Process



Job Launch Process

1. User submits script

2. Slurmctld creates
ALPS reservation



Slurmctld
(SLURM controller daemon)
(primary or backup)
Coordinates all activities

Slurmd
(SLURM job daemons)
Runs batch script

BASIL

ALPS

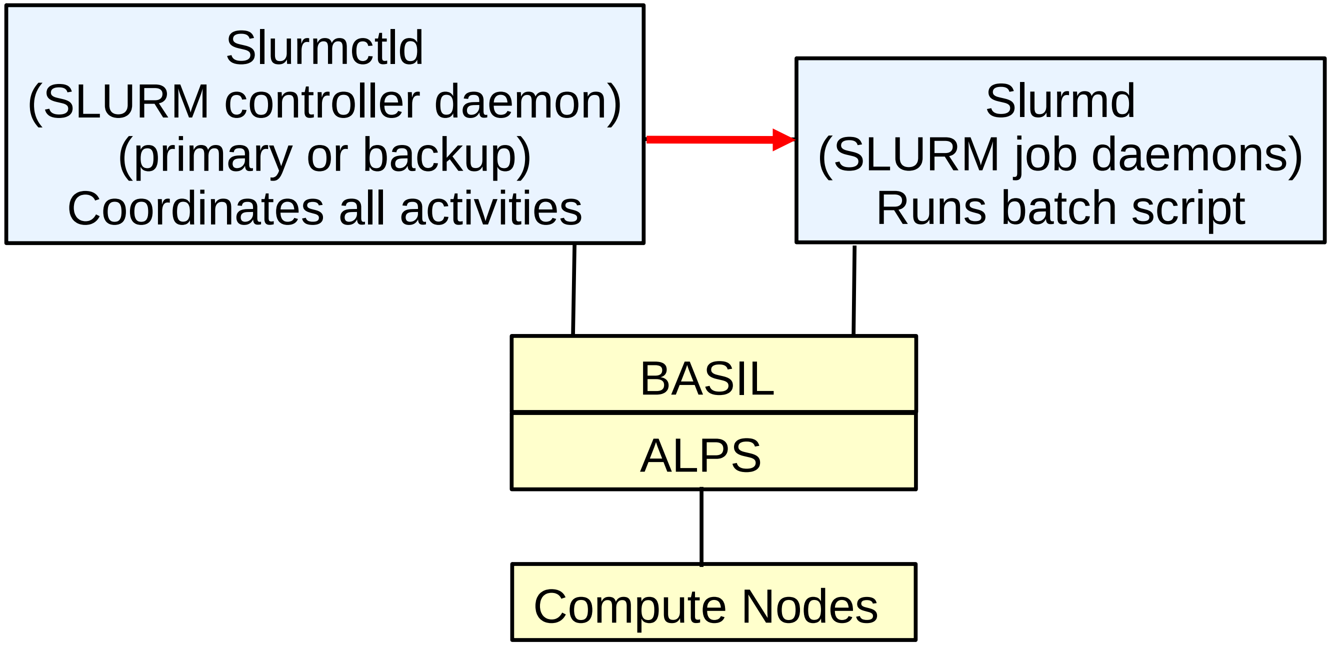
Compute Nodes

Job Launch Process

1. User submits script

2. Slurmctld creates ALPS reservation

3. Slurmctld sends script to slurmd



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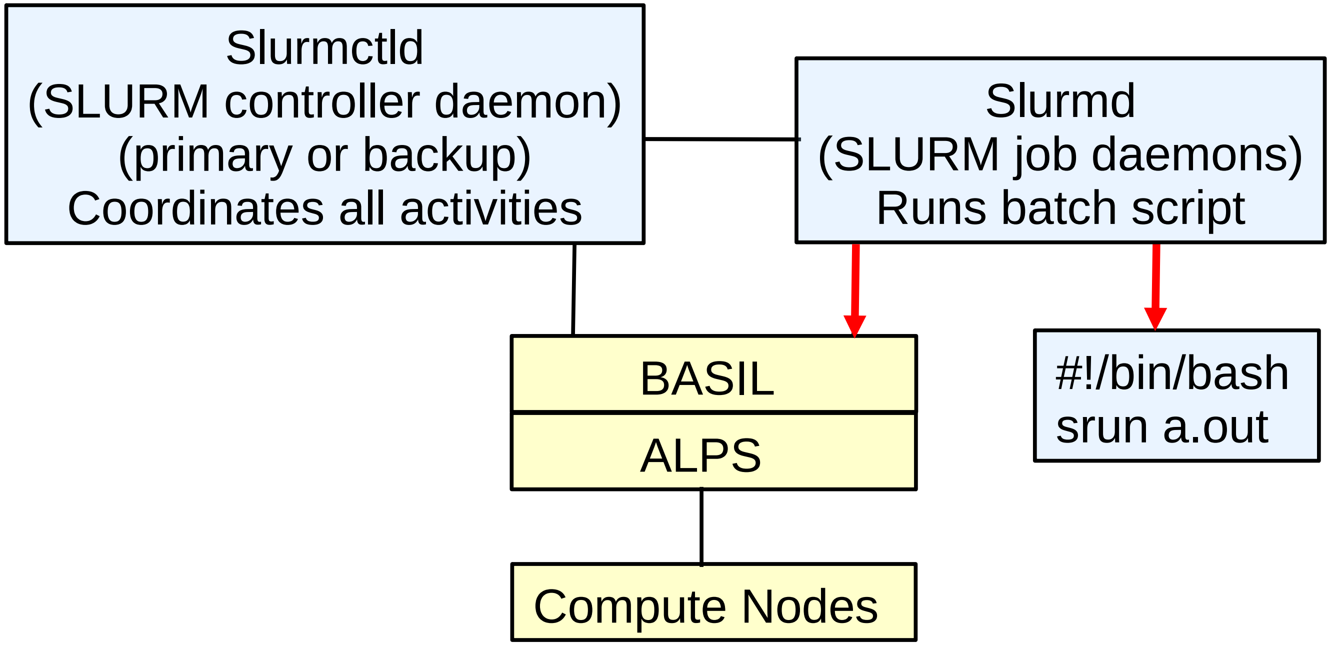
Job Launch Process

1. User submits script

2. Slurmctld creates ALPS reservation

3. Slurmctld sends script to slurmd

4. Slurmd claims reservation for specific session ID and launches interpreter for script



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(SLURM controller daemon)
(primary or backup)
Coordinates all activities

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(SLURM job daemons)
Runs batch script

BASIL

ALPS

Compute Nodes

```
#!/bin/bash
srun a.out
```

Job Launch Process

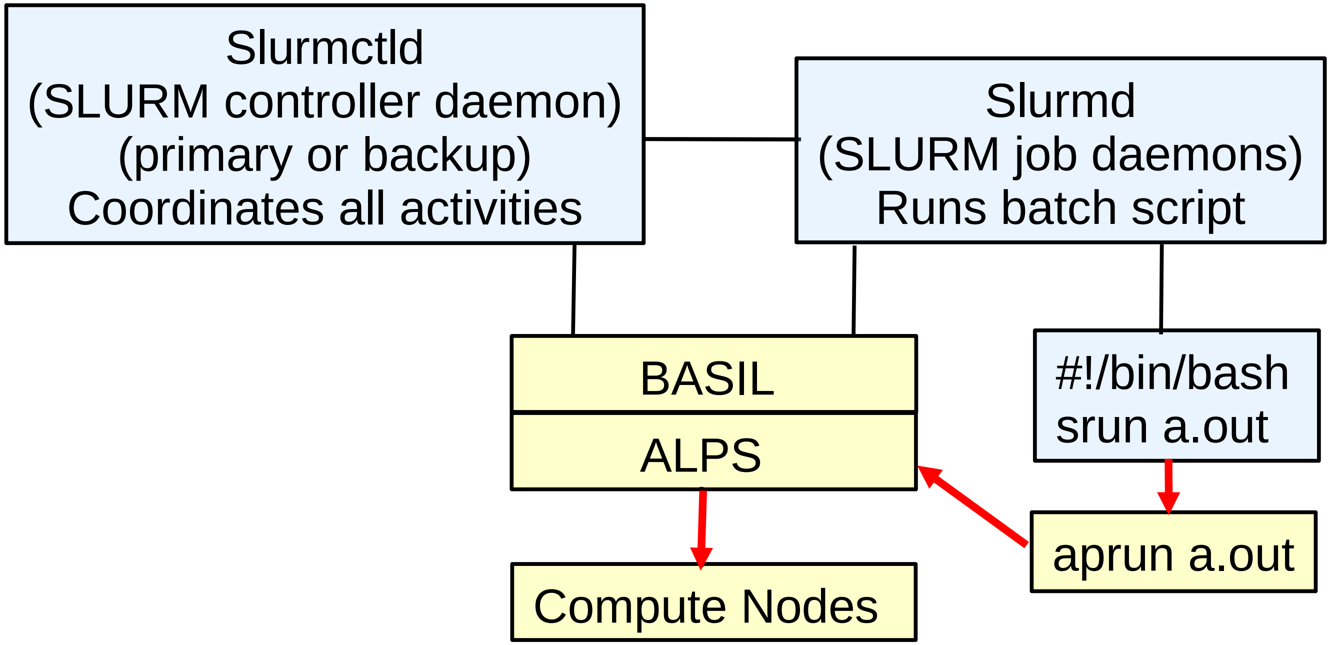
1. User submits script

2. Slurmctld creates ALPS reservation

3. Slurmctld sends script to slurmd

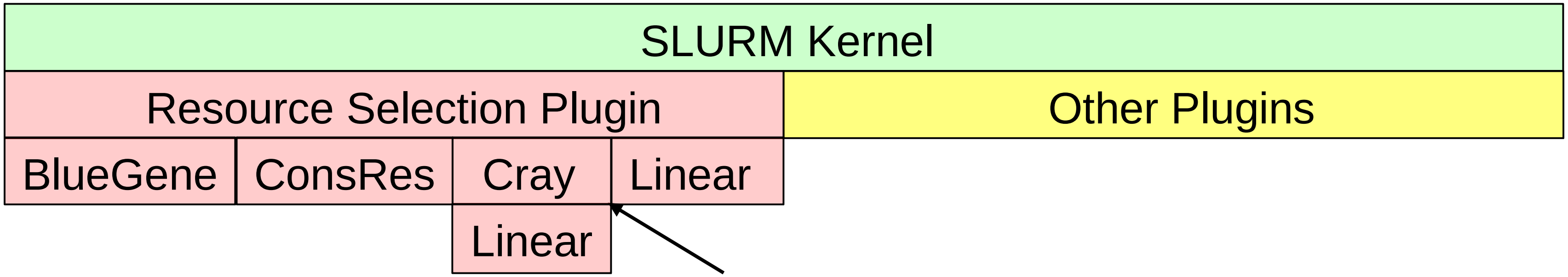
4. Slurmd claims reservation for specific session ID and launches interpreter for script

5. aprun (optionally using the srun wrapper) launches tasks on compute nodes



SLURM Architecture for Cray

- Almost all Cray-specific logic is in a Resource Selection plugin (as SLURM does for IBM BlueGene systems)
- The *select/cray* plugin in-turn calls the *select/linear* plugin to provide full-node resource allocation support including job preemption, memory allocation, optimized topology layout, etc.



SLURM Kernel

Resource Selection Plugin

Other Plugins

BlueGene

ConsRes

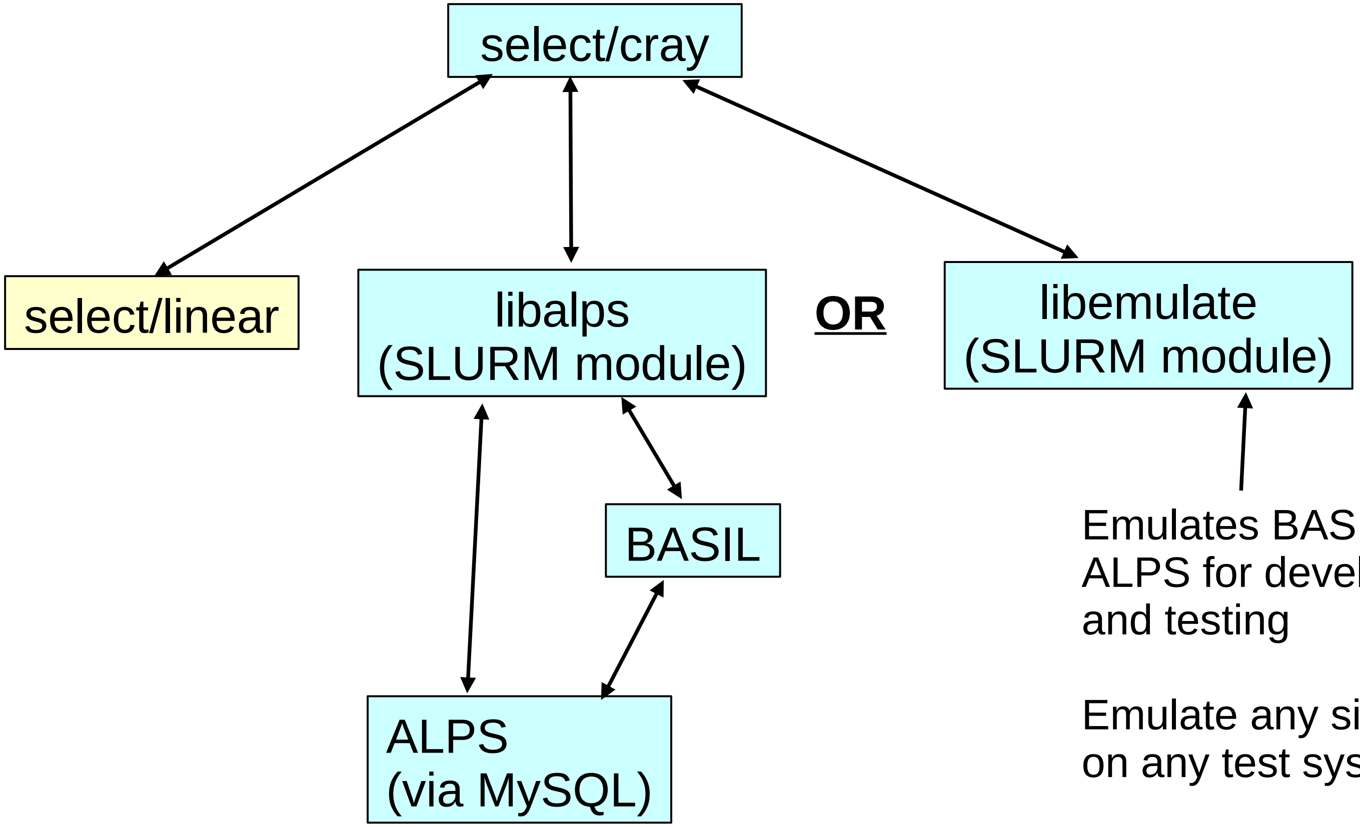
Cray

Linear

Linear

New for Cray

SLURM's *select/cray* plugin



select/cray

select/linear

libalps
(SLURM module)

OR

libemulate
(SLURM module)

BASIL

ALPS
(via MySQL)

Emulates BASIL and
ALPS for development
and testing

Emulate any size Cray
on any test system

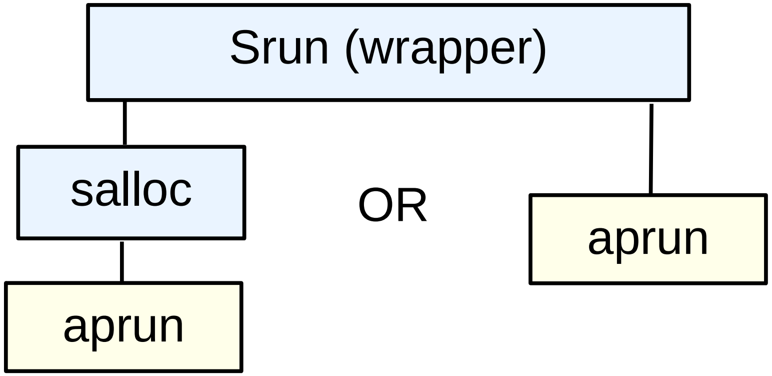
To use, build SLURM
with *configure* option of
–with-alps-emulation

SLURM Configuration

```
#
# Sample slurm.conf file for Cray system
# Selected portions
#
SelectType=select/cray              # Communicates with ALPS
#
FrontEndName=front[00-03]      # Where slurmd daemons run
NodeName=nid[00000-01023]
PartitionName=debug Nodes=nid[00000-00015] MaxTime=30
PartitionName=batch Nodes=nid[00016-01023] MaxTime=24:00:00
```

srun Command

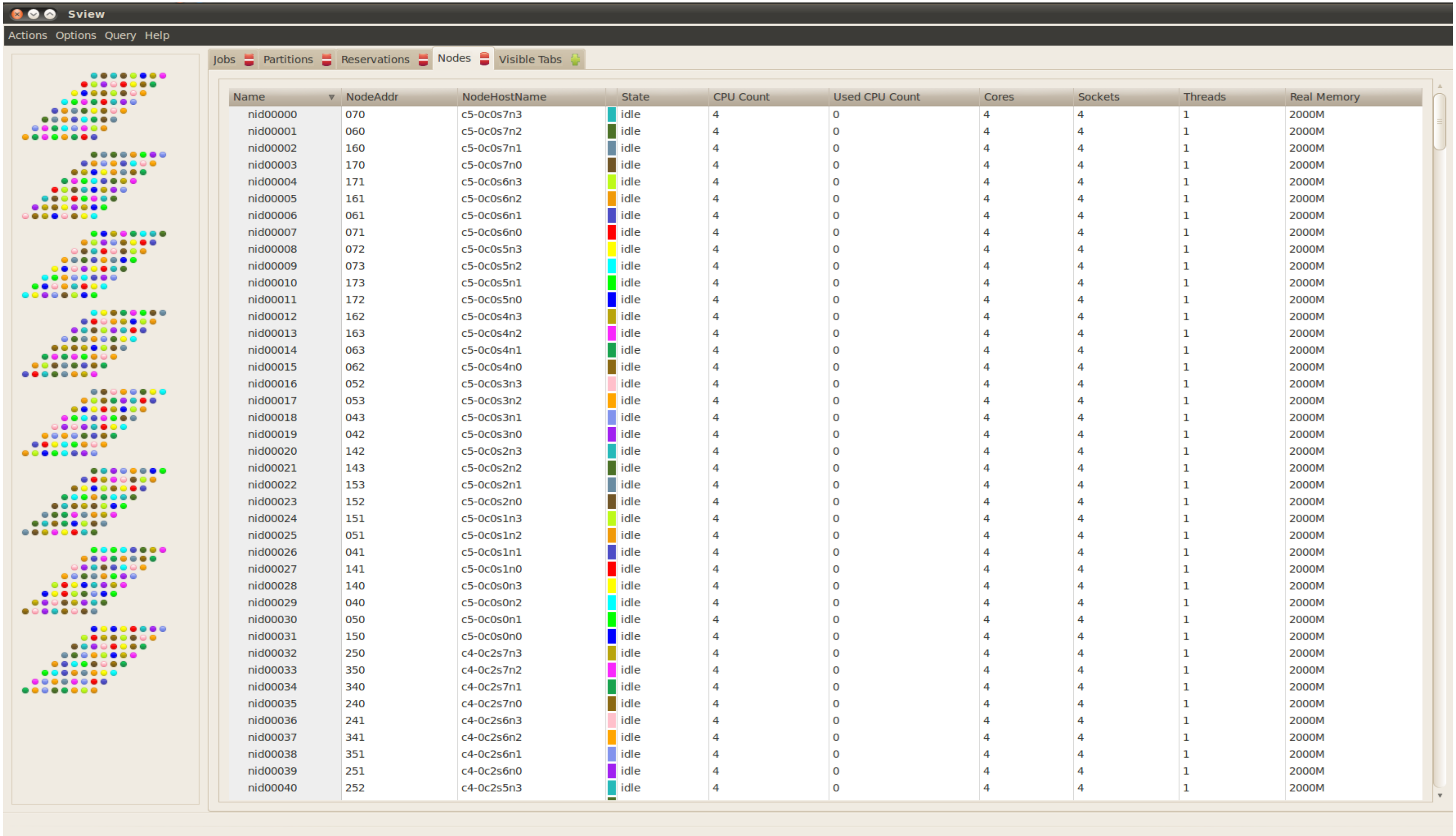
- SLURM has *srun* command for Cray systems that is a wrapper for both *salloc* (to allocate resources as needed) and *aprun* (to launch tasks)
- Options are translated to the extent possible
- Build SLURM with *configure* option *–with-srun2aprun* to build wrapper
  - Otherwise *srun* command advises use of *aprun* and exits



srun Options

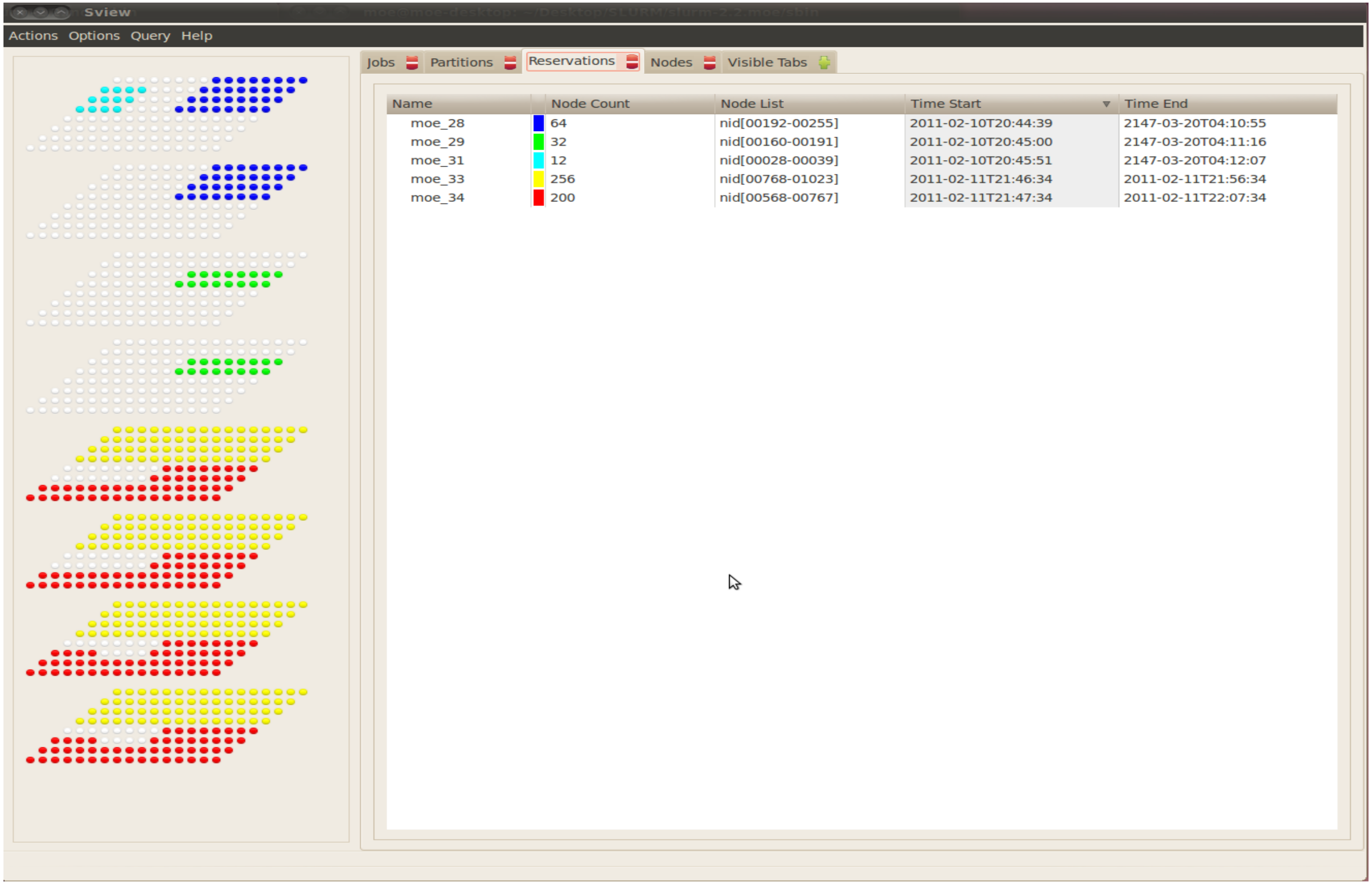
- If no allocation exists, the *srun* options are translated directly to *salloc* options to create a job allocation
  - Many srun option only apply when a job allocation is created
- After an allocation is created
  - Most common options are translated from *srun* to *aprun* (task count, node count, time limit, file names, support for multiple executables, etc.)
  - Some *srun* options lack *aprun* equivalent and vice-versa
  - srun's “–*alps=*” option can pass any other options to *aprun*
- SLURM environment variables are not currently set
- There are fundamental differences in I/O
  - For example, ALPS does not support per-rank I/O streams

sview of Emulated System



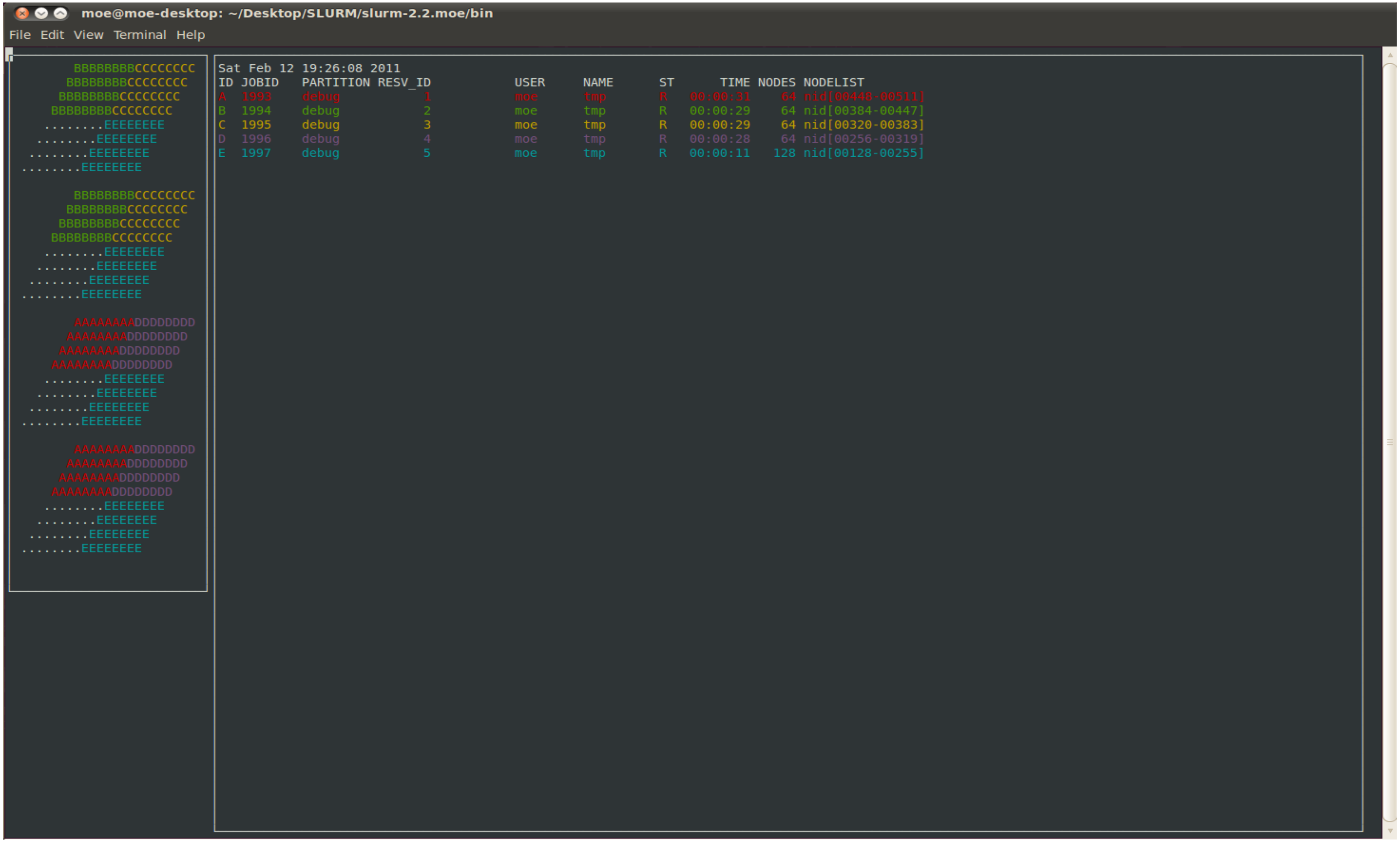
Name	NodeAddr	NodeHostName		State	CPU Count	Used CPU Count	Cores	Sockets	Threads	Real Memory
nid00000	070	c5-0c0s7n3	■	idle	4	0	4	4	1	2000M
nid00001	060	c5-0c0s7n2	■	idle	4	0	4	4	1	2000M
nid00002	160	c5-0c0s7n1	■	idle	4	0	4	4	1	2000M
nid00003	170	c5-0c0s7n0	■	idle	4	0	4	4	1	2000M
nid00004	171	c5-0c0s6n3	■	idle	4	0	4	4	1	2000M
nid00005	161	c5-0c0s6n2	■	idle	4	0	4	4	1	2000M
nid00006	061	c5-0c0s6n1	■	idle	4	0	4	4	1	2000M
nid00007	071	c5-0c0s6n0	■	idle	4	0	4	4	1	2000M
nid00008	072	c5-0c0s5n3	■	idle	4	0	4	4	1	2000M
nid00009	073	c5-0c0s5n2	■	idle	4	0	4	4	1	2000M
nid00010	173	c5-0c0s5n1	■	idle	4	0	4	4	1	2000M
nid00011	172	c5-0c0s5n0	■	idle	4	0	4	4	1	2000M
nid00012	162	c5-0c0s4n3	■	idle	4	0	4	4	1	2000M
nid00013	163	c5-0c0s4n2	■	idle	4	0	4	4	1	2000M
nid00014	063	c5-0c0s4n1	■	idle	4	0	4	4	1	2000M
nid00015	062	c5-0c0s4n0	■	idle	4	0	4	4	1	2000M
nid00016	052	c5-0c0s3n3	■	idle	4	0	4	4	1	2000M
nid00017	053	c5-0c0s3n2	■	idle	4	0	4	4	1	2000M
nid00018	043	c5-0c0s3n1	■	idle	4	0	4	4	1	2000M
nid00019	042	c5-0c0s3n0	■	idle	4	0	4	4	1	2000M
nid00020	142	c5-0c0s2n3	■	idle	4	0	4	4	1	2000M
nid00021	143	c5-0c0s2n2	■	idle	4	0	4	4	1	2000M
nid00022	153	c5-0c0s2n1	■	idle	4	0	4	4	1	2000M
nid00023	152	c5-0c0s2n0	■	idle	4	0	4	4	1	2000M
nid00024	151	c5-0c0s1n3	■	idle	4	0	4	4	1	2000M
nid00025	051	c5-0c0s1n2	■	idle	4	0	4	4	1	2000M
nid00026	041	c5-0c0s1n1	■	idle	4	0	4	4	1	2000M
nid00027	141	c5-0c0s1n0	■	idle	4	0	4	4	1	2000M
nid00028	140	c5-0c0s0n3	■	idle	4	0	4	4	1	2000M
nid00029	040	c5-0c0s0n2	■	idle	4	0	4	4	1	2000M
nid00030	050	c5-0c0s0n1	■	idle	4	0	4	4	1	2000M
nid00031	150	c5-0c0s0n0	■	idle	4	0	4	4	1	2000M
nid00032	250	c4-0c2s7n3	■	idle	4	0	4	4	1	2000M
nid00033	350	c4-0c2s7n2	■	idle	4	0	4	4	1	2000M
nid00034	340	c4-0c2s7n1	■	idle	4	0	4	4	1	2000M
nid00035	240	c4-0c2s7n0	■	idle	4	0	4	4	1	2000M
nid00036	241	c4-0c2s6n3	■	idle	4	0	4	4	1	2000M
nid00037	341	c4-0c2s6n2	■	idle	4	0	4	4	1	2000M
nid00038	351	c4-0c2s6n1	■	idle	4	0	4	4	1	2000M
nid00039	251	c4-0c2s6n0	■	idle	4	0	4	4	1	2000M
nid00040	252	c4-0c2s5n3	■	idle	4	0	4	4	1	2000M

sview of Emulated System



Name	Node Count	Node List	Time Start	Time End
moe_28	🟦 64	nid[00192-00255]	2011-02-10T20:44:39	2147-03-20T04:10:55
moe_29	🟩 32	nid[00160-00191]	2011-02-10T20:45:00	2147-03-20T04:11:16
moe_31	🟦 12	nid[00028-00039]	2011-02-10T20:45:51	2147-03-20T04:12:07
moe_33	🟨 256	nid[00768-01023]	2011-02-11T21:46:34	2011-02-11T21:56:34
moe_34	🟥 200	nid[00568-00767]	2011-02-11T21:47:34	2011-02-11T22:07:34

smap of Emulated System


moe@moe-desktop: ~/Desktop/SLURM/slurm-2.2.moe/bin
File Edit View Terminal Help

```
       BBBBBBBBCCCCCCCC
      BBBBBBBBCCCCCCCC
     BBBBBBBBCCCCCCCC
    BBBBBBBBCCCCCCCC
   ........EEEEEEEE
  ........EEEEEEEE
 ........EEEEEEEE
........EEEEEEEE

       BBBBBBBBCCCCCCCC
      BBBBBBBBCCCCCCCC
     BBBBBBBBCCCCCCCC
    BBBBBBBBCCCCCCCC
   ........EEEEEEEE
  ........EEEEEEEE
 ........EEEEEEEE
........EEEEEEEE

       AAAAAAAADDDDDDDD
      AAAAAAAADDDDDDDD
     AAAAAAAADDDDDDDD
    AAAAAAAADDDDDDDD
   ........EEEEEEEE
  ........EEEEEEEE
 ........EEEEEEEE
........EEEEEEEE

       AAAAAAAADDDDDDDD
      AAAAAAAADDDDDDDD
     AAAAAAAADDDDDDDD
    AAAAAAAADDDDDDDD
   ........EEEEEEEE
  ........EEEEEEEE
 ........EEEEEEEE
........EEEEEEEE
```

```
Sat Feb 12 19:26:08 2011
ID JOBID   PARTITION RESV_ID           USER     NAME      ST       TIME NODES NODELIST
A  1993    debug           1           moe      tmp       R    00:00:31    64 nid[00448-00511]
B  1994    debug           2           moe      tmp       R    00:00:29    64 nid[00384-00447]
C  1995    debug           3           moe      tmp       R    00:00:29    64 nid[00320-00383]
D  1996    debug           4           moe      tmp       R    00:00:28    64 nid[00256-00319]
E  1997    debug           5           moe      tmp       R    00:00:11   128 nid[00128-00255]
```

Caveats

- Some SLURM functionality has no ALPS equivalent
  - Independent I/O by task
  - Output labeled by task ID
- Some ALPS options have no SLURM equivalent
  - *srun* wrapper has –*alps* option to pass arbitrary arguments to *aprun*
- Some options are similar, but impossible to directly translate
  - Task binding syntax
  - Per-task vs. per-CPU limits

Caveats
(continued)

- SLURM environment variables are not set
  - Many need to be set on a per-node or per-task basis, so ALPS must do this
  - Under development by Cray

Caveats
(continued)

- SLURM GUIs (actually the *curses* and GTK libraries they use) have limited scalability
  - Scales to a few thousand nodes
  - Currently each position displayed represents a unique X, Y, Z-coordinate
  - If multiple nodes share an X, Y, Z-coordinate, the information for only one node is displayed
  - We found this better than displaying each node independently and providing confusing topology information, but could change this if desired

Status

- SLURM has been running reliably over ALPS at Swiss National Supercomputer Centre since April 2011
- Validated by Cray in July/August 2011