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.



- 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

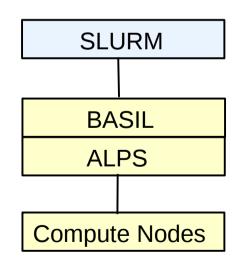
ALPS and BASIL

ALPS – Application Level Placement Scheduler

- 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 Batch Application Scheduler Interface Layer
 - XML interface to ALPS

SLURM Architecture for Cray

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



SLURM and ALPS Functionality

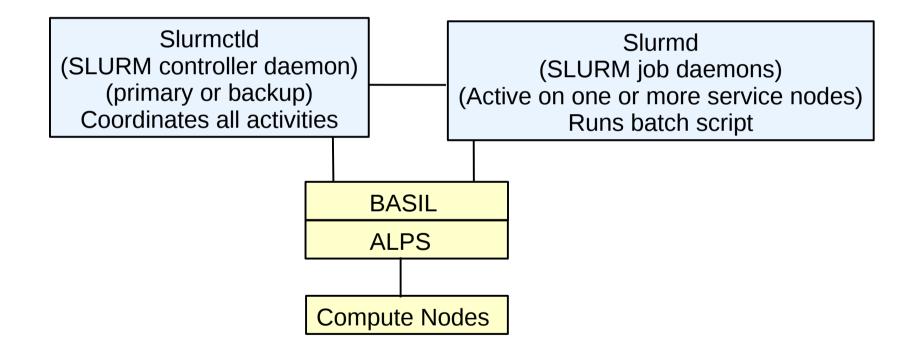
• SLURM

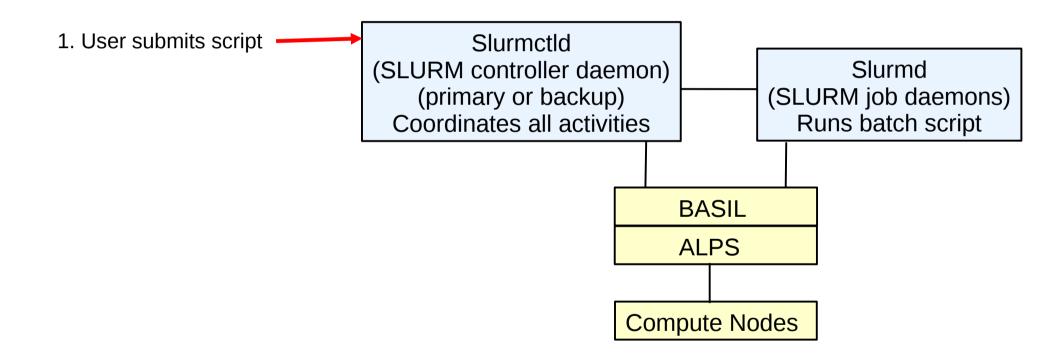
- Prioritizes queue(s) of work and enforces limits
- Decides when and where to start jobs
- Terminates job when appropriate
- Accounts for jobs

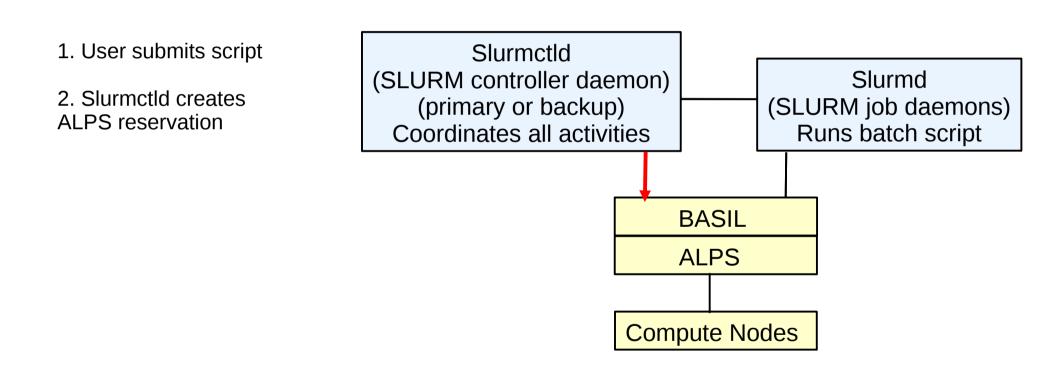
• ALPS

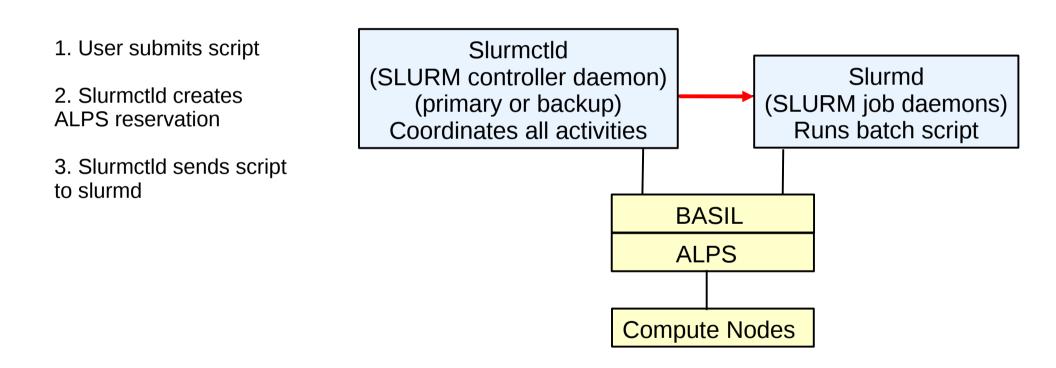
- Allocates and releases resources for jobs
- Launches tasks
- Monitors node health

SLURM Architecture for Cray (Detailed)

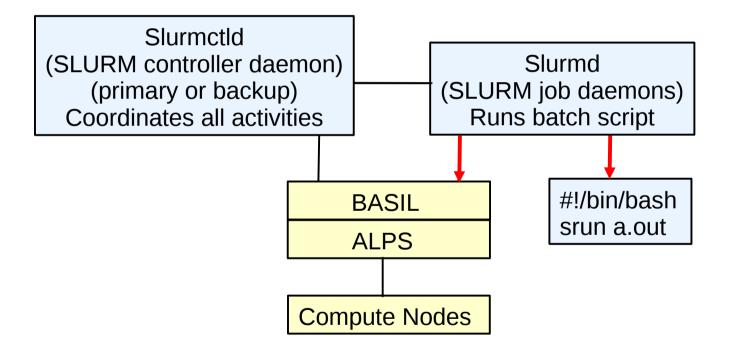




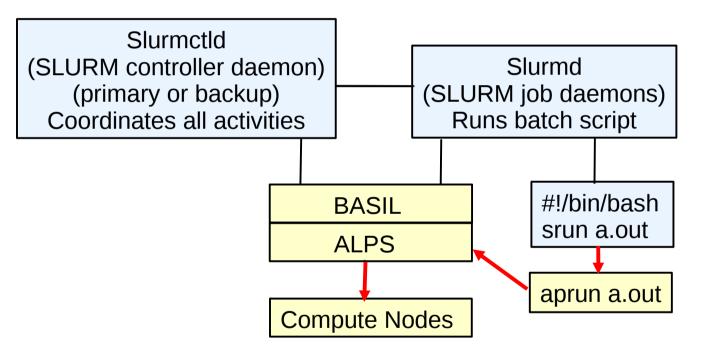




- 1. User submits script
- 2. Slurmctld creates ALPS reservation
- 3. Slurmctld sends script to slurmd
- 4. Slurmd claims reservation for specific session ID and launches interpreter for script

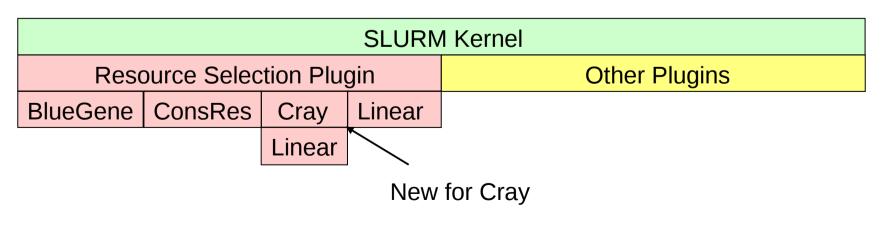


- 1. User submits script
- 2. Slurmctld creates ALPS reservation
- 3. Slurmctld sends script to slurmd
- 4. Slurmd claims reservation for specific session ID and launches interpreter for script
- 5. aprun (optionally using the srun wrapper) launches tasks on compute nodes

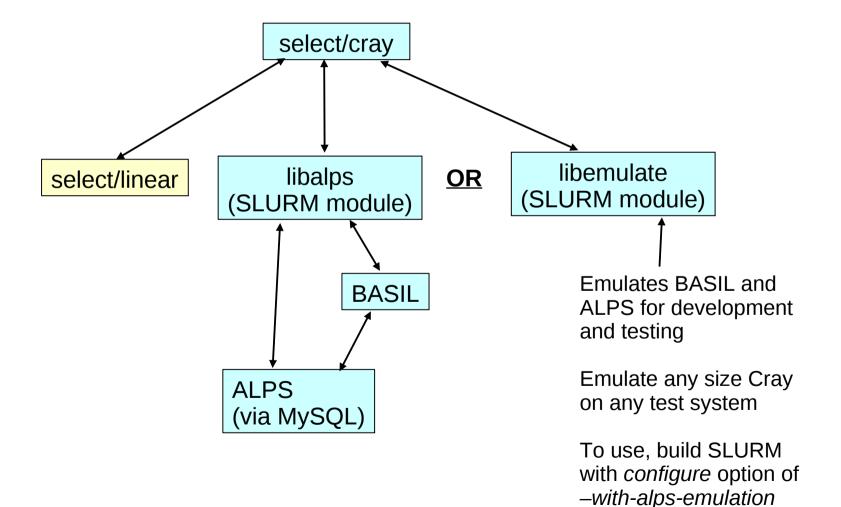


SLURM Architecture for Cray

- 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's select/cray plugin

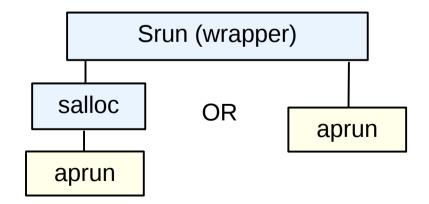


SLURM Configuration

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

	Nmm Node/Addr Node/Addr State CPU Count Cares Sockets Turends Path 11000001 070 c5-0c97n1 Idfe 4 0 4 4 1 20004 11000002 160 c5-0c97n1 Idfe 4 0 4 4 1 20004 11000002 150 c5-0c97n1 Idfe 4 0 4 4 1 20004 11000002 170 c5-0c96n2 Idfe 4 0 4 4 1 20004 11000005 181. c5-0c96n2 Idfe 4 0 4 4 1 20004 11000006 073 c5-0c96n2 Idfe 4 0 4 4 1 20004 11000007 073 c5-0c96n3 Idfe 4 0 4 4 1 20004 11000011 172 c5-0c96n3 Idfe 4 0 4 <td< th=""><th></th><th>lobs = Partitions</th><th>📕 Reservations 🗮</th><th>Nodes 📒 Visible Tabs 👙</th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></td<>		lobs = Partitions	📕 Reservations 🗮	Nodes 📒 Visible Tabs 👙							
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nidoon14 063 c5-0c9h1 ide ide 4 6 0 4 6 4 6 1 2000M nidoon15 052 c5-0c9h0 ide 4 6 0 4 6 1 2000M nidoon17 053 c5-0c9h0 ide 4 0 0 4 6 1 1 2000M inidoon17 053 c5-0c9h1 ide 4 0 0 4 6 1 1 2000M inidoon20 142 c5-0c9h1 ide 4 0 0 4 6 4 1 1 2000M inidoon20 142 c5-0c9h1 ide 4 0 0 4 4 6 1 1 2000M inidoon20 143 c5-0c9h1 ide 4 0 0 4 4 6 1 1 2000M inidoon20 143 c5-0c9h1 ide 4 0 0 4 4 6 1 1 2000M inidoon20 143 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 152 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 153 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 152 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 152 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 152 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 152 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 152 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 151 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 151 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 151 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 14 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 14 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 14 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 150 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 150 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon20 150 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon30 50 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 4 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 1 4 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 1 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 1 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 1 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 0 4 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 0 1 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 0 1 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 0 1 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 0 1 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 0 1 4 1 1 2000M inidoon30 150 c5-0c9h1 ide 4 0 0 0 1 4 1 1 2000M inido	nid00014 063 c5-0c54nl ide 4 o p nid00015 062 c5-0c54nl ide 4 o p o p o p o p o p o p o p o p o p o		nid00013	163	c5-0c0s4n2	idle	4	0	4	4	1	2000M
nid00015 062 c5-0c54n0 ide 4 0 4 4 4 4 0 4 4 4 4 4 6 1 0 1 0 <p< td=""><td>nido0015062c5-0Cdsn0idle404412000Mnid00016052c5-0Cdsn3idle404412000Mnid00017053c5-0Cdsn3idle404412000Mnid00018043c5-0Cdsn1idle404412000Mnid00019042c5-0Cdsn1idle404412000Mnid00020142c5-0Cdsn3idle404412000Mnid00021143c5-0Cdsn3idle404412000Mnid00023152c5-0Cdsn3idle404412000Mnid00024151c5-0Cdsn3idle404412000Mnid00025051c5-0Cdsn3idle404412000Mnid00026051c5-0Cdsn3idle404412000Mnid00027141c5-0Cdsn3idle404412000Mnid00028050c5-0Cdsn3idle404412000Mnid00027141c5-0Cdsn3idle404412000Mnid00028160c5-0Cdsn3idle404412000Mnid00029050c5-0Cd</td><td></td><td>nid00014</td><td>063</td><td>c5-0c0s4n1</td><td>idle</td><td>4</td><td>0</td><td>4</td><td>4</td><td>1</td><td>2000M</td></p<>	nido0015062c5-0Cdsn0idle404412000Mnid00016052c5-0Cdsn3idle404412000Mnid00017053c5-0Cdsn3idle404412000Mnid00018043c5-0Cdsn1idle404412000Mnid00019042c5-0Cdsn1idle404412000Mnid00020142c5-0Cdsn3idle404412000Mnid00021143c5-0Cdsn3idle404412000Mnid00023152c5-0Cdsn3idle404412000Mnid00024151c5-0Cdsn3idle404412000Mnid00025051c5-0Cdsn3idle404412000Mnid00026051c5-0Cdsn3idle404412000Mnid00027141c5-0Cdsn3idle404412000Mnid00028050c5-0Cdsn3idle404412000Mnid00027141c5-0Cdsn3idle404412000Mnid00028160c5-0Cdsn3idle404412000Mnid00029050c5-0Cd		nid00014	063	c5-0c0s4n1	idle	4	0	4	4	1	2000M
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niddoo18043c5-0c0sn1ide404412000Mniddoo20142c5-0c0sn2ide404412000Mniddoo21143c5-0c0sn2ide404412000Mniddoo22153c5-0c0sn2ide404412000Mniddoo23152c5-0c0sn2ide404412000Mniddoo24151c5-0c0sn2ide404412000Mniddoo25051c5-0c0sn2ide404412000Mniddoo2601c5-0c0sn2ide404412000Mniddoo2701c5-0c0sn2ide404412000Mniddoo28051c5-0c0sn2ide404412000Mniddoo29051c5-0c0sn2ide404412000Mniddoo29050c5-0c0sn3ide404412000Mniddoo29040c5-0c0sn3ide40441200Mniddoo29050c5-0c0sn3ide40441200Mniddoo29050c5-0c0sn3ide40441200Mniddoo31150c5-0c0sn3ide	nid00018043c5-0c053n1idle404412000Mnid00019042c5-0c052n3idle404412000Mnid00021142c5-0c052n3idle404412000Mnid00022153c5-0c052n1idle404412000Mnid00023152c5-0c052n1idle404412000Mnid00024151c5-0c05n0idle404412000Mnid00025051c5-0c05n0idle404412000Mnid00026051c5-0c05n0idle404412000Mnid00027141c5-0c05n1idle404412000Mnid00028140c5-0c05n1idle404412000Mnid00029040c5-0c05n1idle404412000Mnid00029040c5-0c05n1idle404412000Mnid00021150c5-0c5n1idle404412000Mnid00025050c5-0c5n1idle404412000Mnid00026040c5-0c5n1idle404412000Mnid00027150c5-0		nid00017	053	c5-0c0s3n2	idle	4	0	4	4	1	2000M
nido001904205-0c93n01dle404412000Mnido02014205-0c92n31dle404412000Mnido02114305-0c92n31dle404412000Mnido02213305-0c92n11dle404412000Mnido02315205-0c92n31dle404412000Mnido02415105-0c93n31dle404412000Mnido02505105-0c91n31dle40441200Mnido02714105-0c91n31dle40441200Mnido02814005-0c91n31dle40441200Mnido02714105-0c91n31dle40441200Mnido02814005-0c91n31dle40441200Mnido02904005-0c90n31dle40441200Mnido02910005005-0c90n31dle40441200Mnido02713105-0c90n31dle40441200Mnido02814005-0c90n31dle40441200Mnido03335004-0c27n2	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 c5-0c0s2n3 idle 4 0 4 4 1 2000M nid00023 152 c5-0c0s2n3 idle 4 0 4 4 1 2000M nid00025 051 c5-0c0s1n2 idle 4 0 4 4 1 2000M nid00027 141 c5-0c0s1n3 idle 4 0 4 4 1 2000M nid00028 040 c5-0c0s0n2 idle 4 0 4 4 1 2000M nid00028 140 c5-0c0s0n2 idle 4 0 4 <		nid00018	043	c5-0c0s3n1	idle	4	0	4	4	1	2000M
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nid00039 251 c4-0c2s6n0 idle 4 0 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
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smap of Emulated System

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BBBBBBBBCCCCCCCC	B 1994					
	C 1995 D 1996	debug debug				00:00:29 64 nid[00320-00383] 00:00:28 64 nid[00256-00319]
EEEEEEEE	E 1997					
BBBBBBBBBCCCCCCCC BBBBBBBBBBCCCCCCCC						
BBBBBBBBBBCCCCCCCC BBBBBBBBBBCCCCCCCC EEEEEEEE						



- 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



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