Oak Ridge National Laboratory

Summit Scheduler and Job Launch Introduction

OLCF Summit Training Workshop

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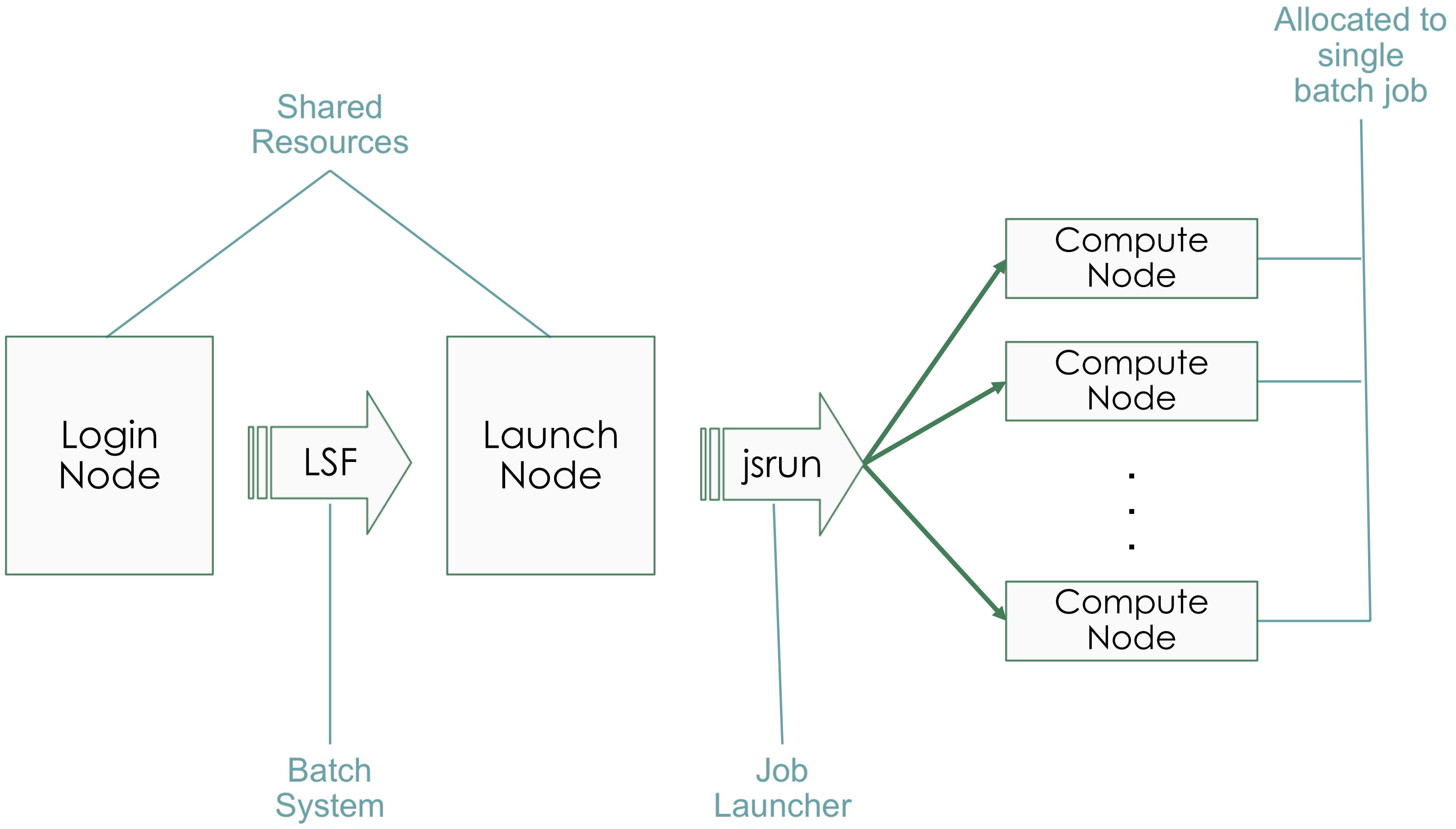
Summit Login, Launch, Compute Nodes



Summit Parallel Job Execution

Batch System

LSF

- Allocates resources
- Batch scheduler
- Similar functionality to PBS/MOAB
- Allocates entire nodes

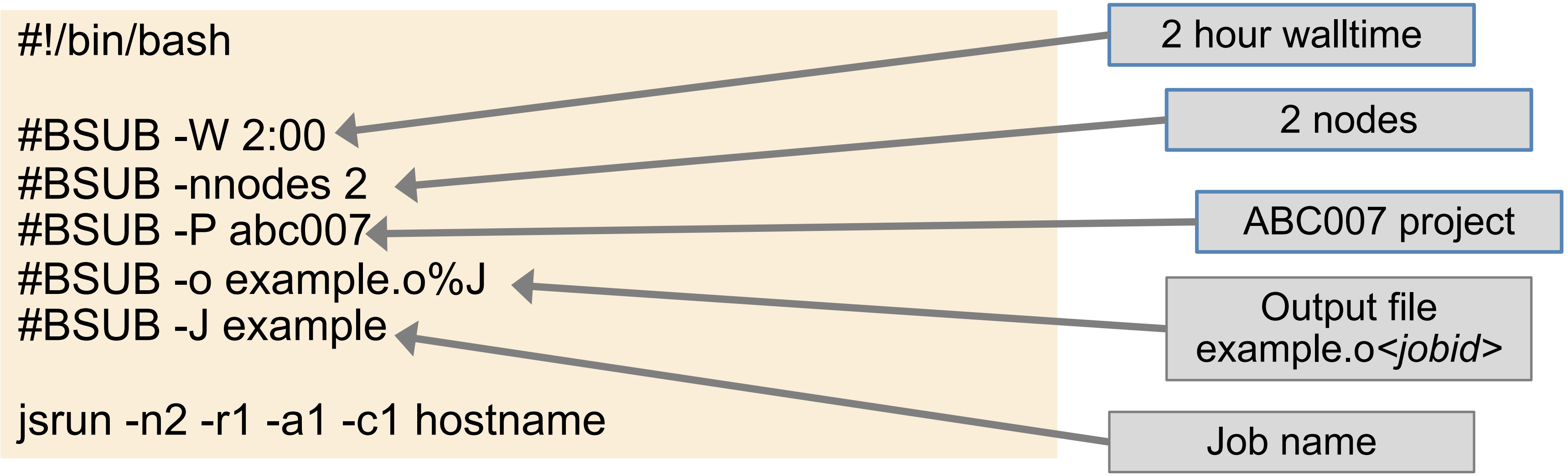
Job Launcher

jsrun

- Developed by IBM for the Oak Ridge and Livermore CORAL systems
- Similar functionality to aprun and mpirun

LSF Example Batch Script

Batch script example



```
#!/bin/bash

#BSUB -W 2:00
#BSUB -nnodes 2
#BSUB -P abc007
#BSUB -o example.o%J
#BSUB -J example

jsrun -n2 -r1 -a1 -c1 hostname
```

Batch submission

```
summit-login1> bsub example.lsf
Job <29209> is submitted to default queue <batch>.
summit-login1>
```

Common bsub Options

Option	Example Usage	Description
-W	#BSUB –W 1:00	Requested Walltime [hours:]minutes
-nnodes	#BSUB –nnodes 1024	Number of nodes (*CORAL systems*)
-P	#BSUB –P *ABC123*	Project to which the job should be charged
-J	#BSUB –J MyJobName	Name of the job. If not specified, will be set to '*Not_Specified*'.
-o	#BSUB –o jobout.%J	File into which job STDOUT should be directed (%J will be replaced with the job ID number) If not specified will be set to '*JobName.%J*'
-e	#BSUB –e joberr.%J	File into which job STDERR should be directed
-w	#BSUB –w ended*(1234)*	Place dependency on previously submitted jobID 1234
-N -B	#BSUB –N #BSUB -B	Send job report via email once job completes (N) or begins (B)
-alloc_flags	#BSUB –alloc_flags gpumps #BSUB –alloc_flags smt1	Used to request GPU Multi-Process Service (MPS) and to set SMT (Simultaneous Multithreading) levels. Setting gpumps enables NVIDIA's Multi-Process Service, which allows multiple MPI ranks to simultaneously access a GPU.

*More details and flags can be found in the bsub manpage

LSF Interactive Batch Job

- Allows access to compute resources interactively
- Through batch system similar to batch script submission, but returns prompt on launch node
- Run multiple jsrun with only one queue wait, very useful for testing and debugging
- Syntax
  - Use –Is and the shell to be started
  - Most other batch flags valid
  - Add batch flags to command line

Presentation examples use the following to allocate resources

```
summit-login1> bsub -Is -P abc007 –nnodes 2 –W 2:00 $SHELL
Job <29507> is submitted to default queue <batch>.
<<Waiting for dispatch ...>>
<<Starting on batch1>>
summit-batch1 307> jsrun -n2 -r1 hostname
a01n01
a01n02
summit-batch1 308>
```

Common LSF Commands

Function	PBS/MOAB	LSF
Submit	qsub	bsub
Monitor Queue	showq/qstat	bjobs
Alter Queued Job	qalter	bmod
Remove Queued Job	qdel	bkill
Hold Queued Job	qhold	bstop
Release Held Job	qrls	bresume

Viewing the Batch Queue with bjobs

- ‘bjobs’
  - Will display *only your jobs by default* if no options given
- ‘bjobs -u all’
  - Will show all queued jobs
- ‘bjobs –l *jobID*’
  - Will show details of given jobID
- As with MOAB, jobs can be organized into three high level categories
  - 1) Running 2) Pending Eligible 3) Pending Ineligible
- ‘bjobs –uall –pei’
  - Will show pending jobs separated into eligible and ineligible

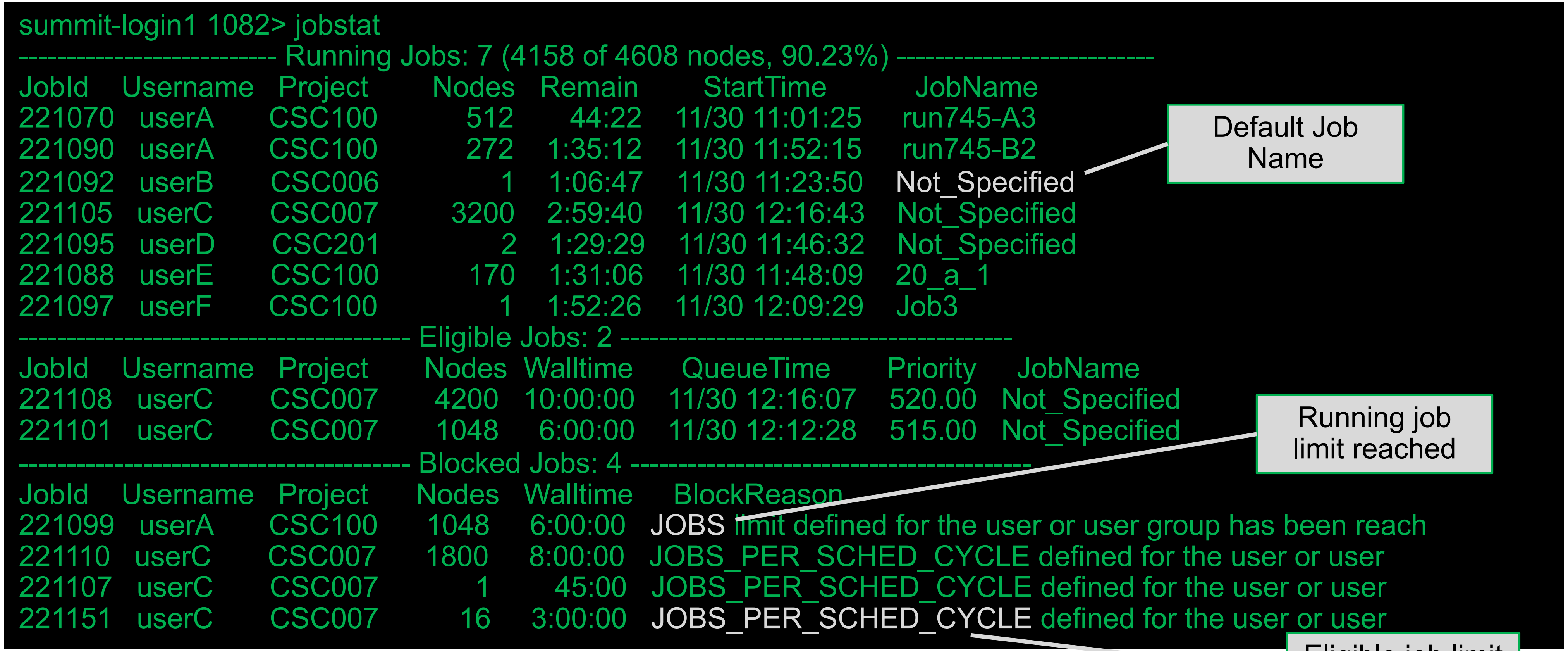
Summit Queue Policy

Bin	Min Nodes	Max Nodes	Max Walltime (hrs)	Aging Boost (days)
1	2,765	4,608	24	15
2	922	2,764	24	10
3	92	921	12	0
4	46	91	6	0
5	1	45	2	0

- Eligible to run limit: 2

Viewing the Batch Queue with *jobstat*

- OLCF developed tool to help view queue



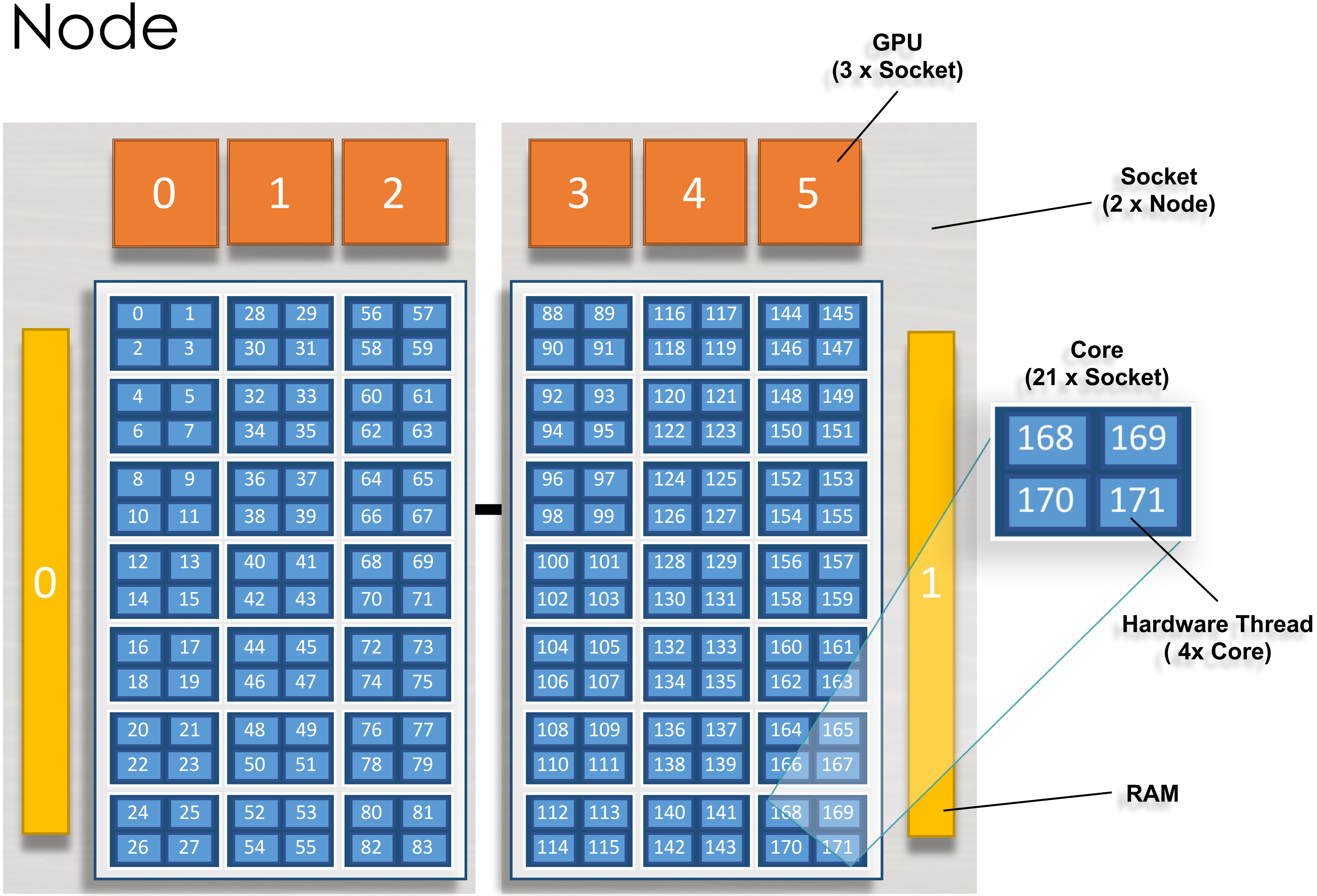
```
summit-login1 1082> jobstat
--------------------------- Running Jobs: 7 (4158 of 4608 nodes, 90.23%) ---------------------------
JobId     Username   Project        Nodes    Remain        StartTime          JobName
221070    userA      CSC100           512      44:22    11/30 11:01:25    run745-A3
221090    userA      CSC100           272    1:35:12    11/30 11:52:15    run745-B2
221092    userB      CSC006             1    1:06:47    11/30 11:23:50    Not_Specified
221105    userC      CSC007          3200    2:59:40    11/30 12:16:43    Not_Specified
221095    userD      CSC201             2    1:29:29    11/30 11:46:32    Not_Specified
221088    userE      CSC100           170    1:31:06    11/30 11:48:09    20_a_1
221097    userF      CSC100             1    1:52:26    11/30 12:09:29    Job3
----------------------------------------- Eligible Jobs: 2 -----------------------------------------
JobId     Username   Project       Nodes   Walltime      QueueTime        Priority    JobName
221108    userC      CSC007         4200   10:00:00    11/30 12:16:07     520.00    Not_Specified
221101    userC      CSC007         1048    6:00:00    11/30 12:12:28     515.00    Not_Specified
----------------------------------------- Blocked Jobs: 4 -----------------------------------------
JobId     Username   Project      Nodes   Walltime      BlockReason
221099    userA      CSC100        1048    6:00:00    JOBS limit defined for the user or user group has been reach
221110    userC      CSC007        1800    8:00:00    JOBS_PER_SCHED_CYCLE defined for the user or user
221107    userC      CSC007           1      45:00    JOBS_PER_SCHED_CYCLE defined for the user or user
221151    userC      CSC007          16    3:00:00    JOBS_PER_SCHED_CYCLE defined for the user or user
```

Default Job Name

Running job limit reached

Eligible job limit reached

Summit Node


GPU
(3 x Socket)

Socket
(2 x Node)

Core
(21 x Socket)

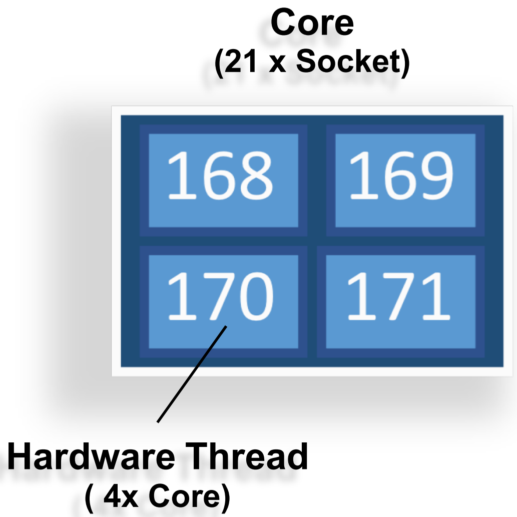
Hardware Thread
(4x Core)

RAM

*Numbering skips due to core isolation

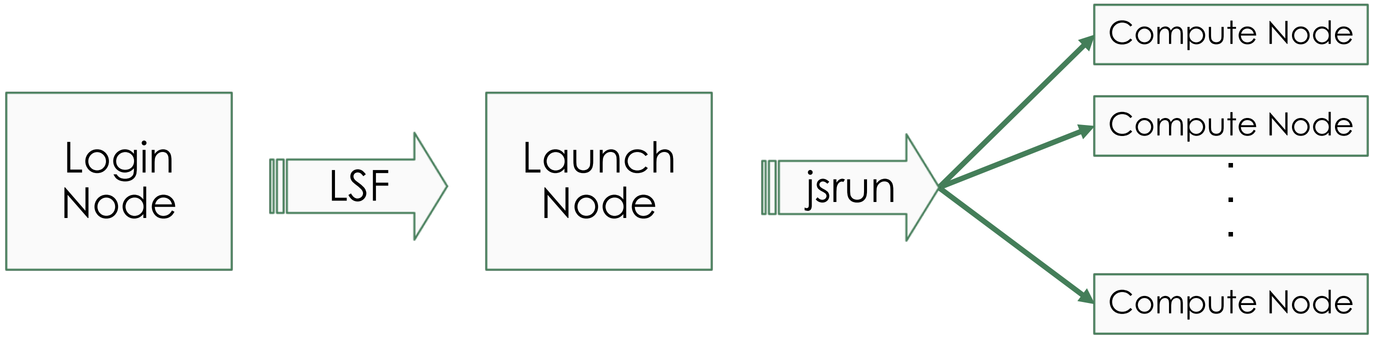
Hardware Thread Levels

- Each physical core contains 4 hardware threads
- Simultaneous Multithreading (SMT)
- Power9 supports 3 levels: 1, 2, or 4 virtual cores
- SMT level set for each batch job
  - #BSUB –alloc_flags smt1
  - #BSUB –alloc_flags smt2
  - #BSUB –alloc_flags smt4 (default)
- jsrun controls task/thread layout



jsrun Introduction

- Launch job on compute resources
- Similar functionality to aprun and mpirun
- Launch nodes
  - Similar to Titan
  - Non-jsrun commands executed on launch node
  - Shared resource
- Multiple jsruns per node



Basic jsrun Examples

Description	jsrun command	Layout notes
64 MPI tasks, no GPUs	***jsrun –n 64 ./a.out***	2 nodes: 42 tasks node1, 22 tasks on node2
12 MPI tasks each with access to 1 GPU	***jsrun –n 12 –a 1 –c 1 –g1 ./a.out***	2 nodes, 3 tasks per socket
12 MPI tasks each with 4 threads and 1 GPU	***jsrun –n 12 –a 1 –c 4 –g1 –bpacked:4 ./a.out***	2 nodes, 3 tasks per socket
24 MPI tasks two tasks per GPU	***jsrun –n 12 –a 2 –c 2 –g1 ./a.out***	2 nodes, 6 tasks per socket
4 MPI tasks each with 3 GPUs	***jsrun -n 4 –a 1 –c 1 –g 3 ./a.out***	2 nodes: 1 task per socket

Resource Set Introduction

- jsrun format:

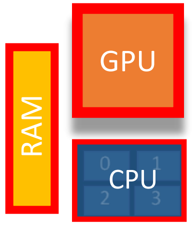
```
jsrun [ -n #Resource Sets ] [tasks, threads, and GPUs w/in each Resource Set] program
```

- Resource set
  - Sub group of resources within a node
    - GPUs, CPUs, RAM
  - cgroups under the covers
  - Building blocks of jsrun
  - Provides the ability to create subsets of nodes
    - Flexibility to add resources based on code’s requirements
  - Limitations
    - Can span sockets; can not span nodes
    - Entire cores; not hyper-thread level

Resource Sets: Subdivide a Node

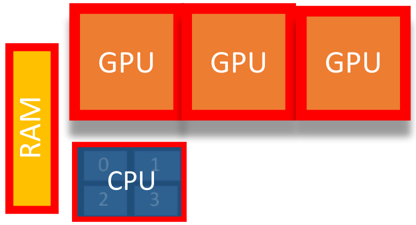
- RS provides the ability to subdivide node’s resources into smaller groups.
- The following examples show how a node could be subdivided and how many RS will fit on a node.

1



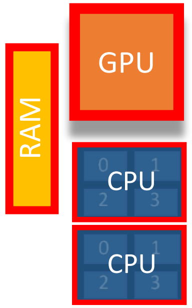
- 1 Task access 1 GPU
- Fit 3 RS per socket, 6 per node

3



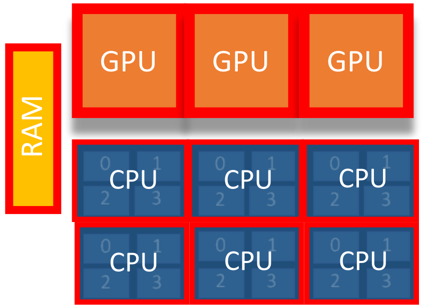
- 1 Task access 3 GPUs
- Fit 1 RS per socket, 2 per node

2



- 2 Tasks access 1 GPU
- Fit 3 RS per socket, 6 per node

4



- 6 Tasks access 3 GPUs
- Fit 1 RS per socket, 2 per node

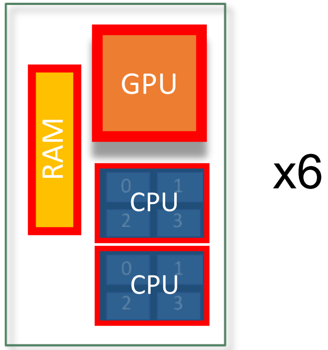
Resource Sets: Multiple Methods

- Create resource sets based on code
- Example: two MPI tasks, single GPU
- 3 example methods
  1. RS containing 2 cores and 1 GPU
     - Cores can only see 1 GPU
  2. RS containing 6 cores and 3 GPUs
     - 6 cores can see 3 GPUs (socket)
  3. RS containing 12 cores and 6 GPUs
     - 12 cores can see 6 GPUs (node)

1) RS Example: 2 Tasks per GPU Resource Set per GPU

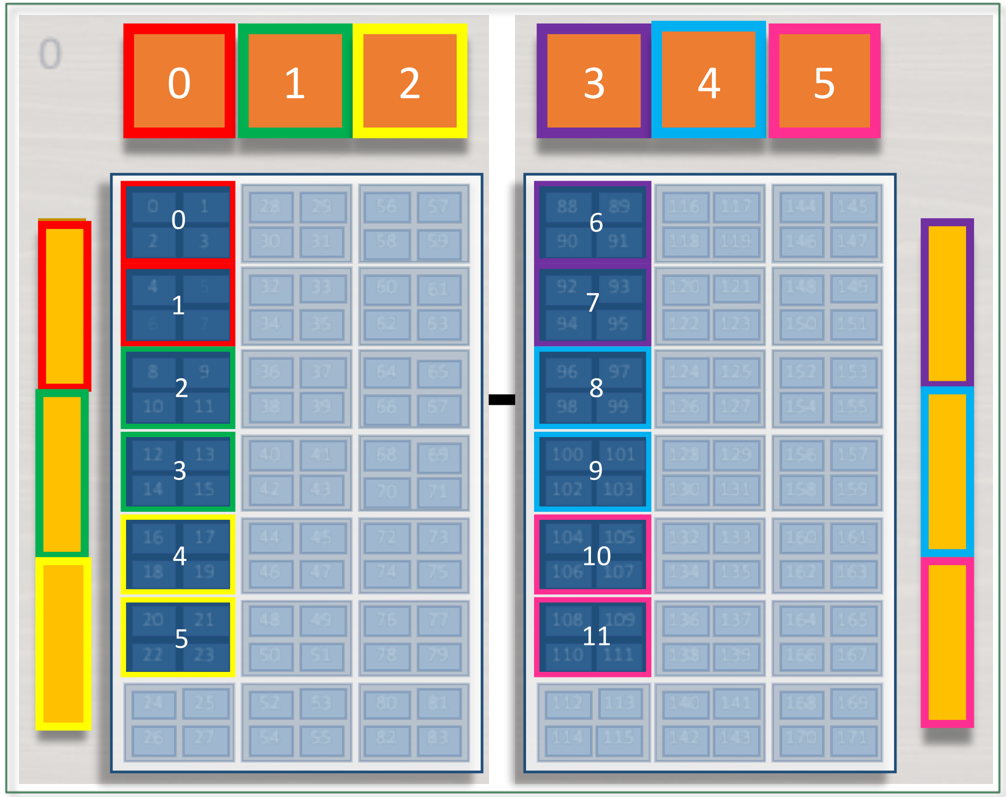
6 resource sets per node: 1 GPU, 2 cores per (Titan)

Individual RS



- CPUs see single assigned GPU

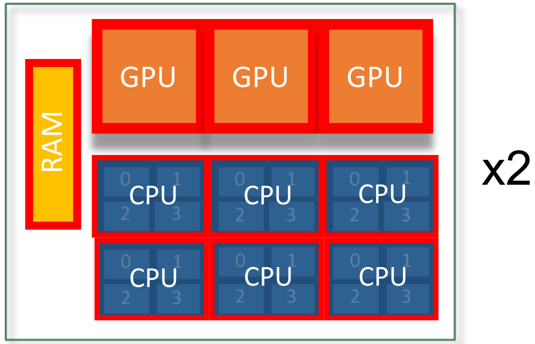
RS Mapped to Node



2) RS Example: 2 Tasks per GPU Resource Set per Socket

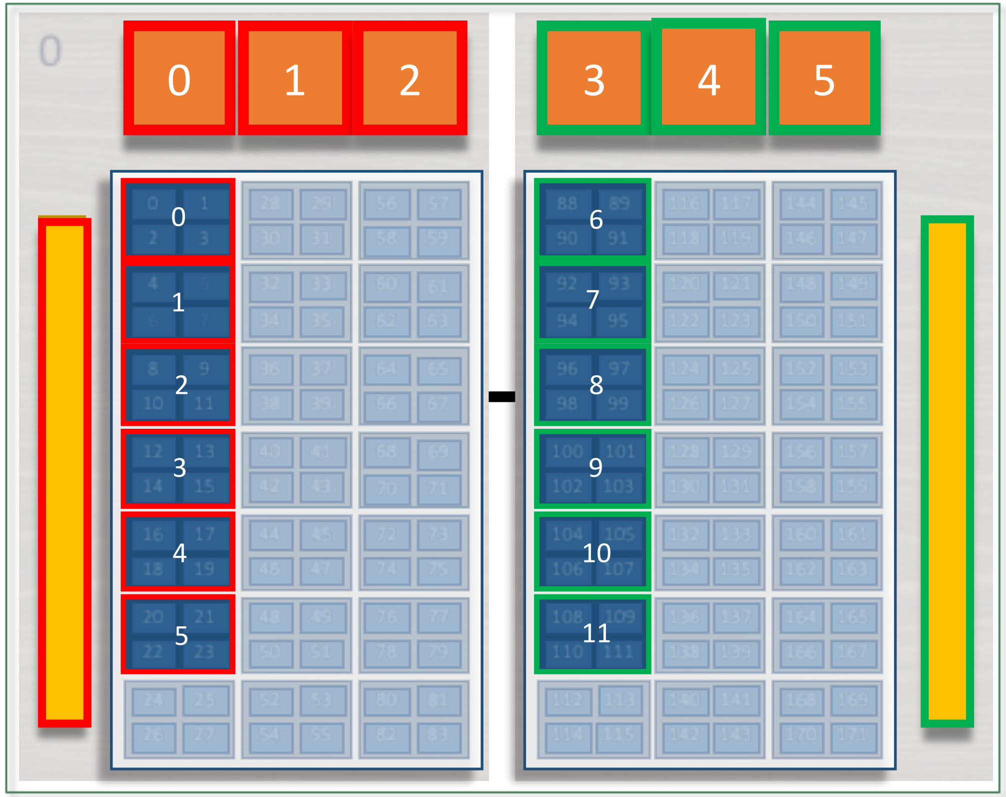
2 resource sets per node: 3 GPUs and 6 cores per socket

Individual RS



- All 6 CPUs can see 3 GPUs. Code must manage CPU -> GPU communication.
- CPUs on socket0 can not access GPUs on socket1.

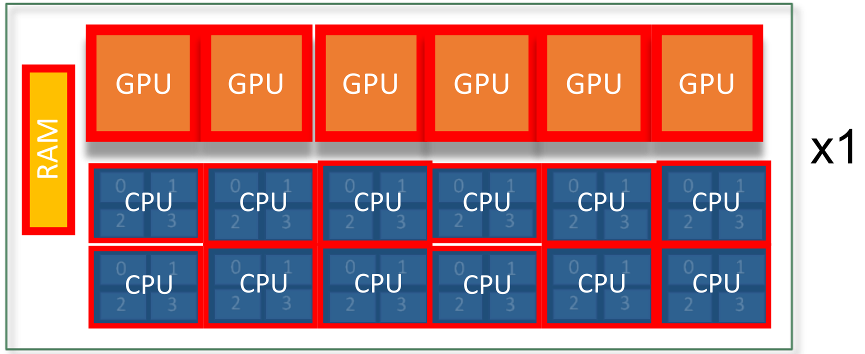
RS Mapped to Node



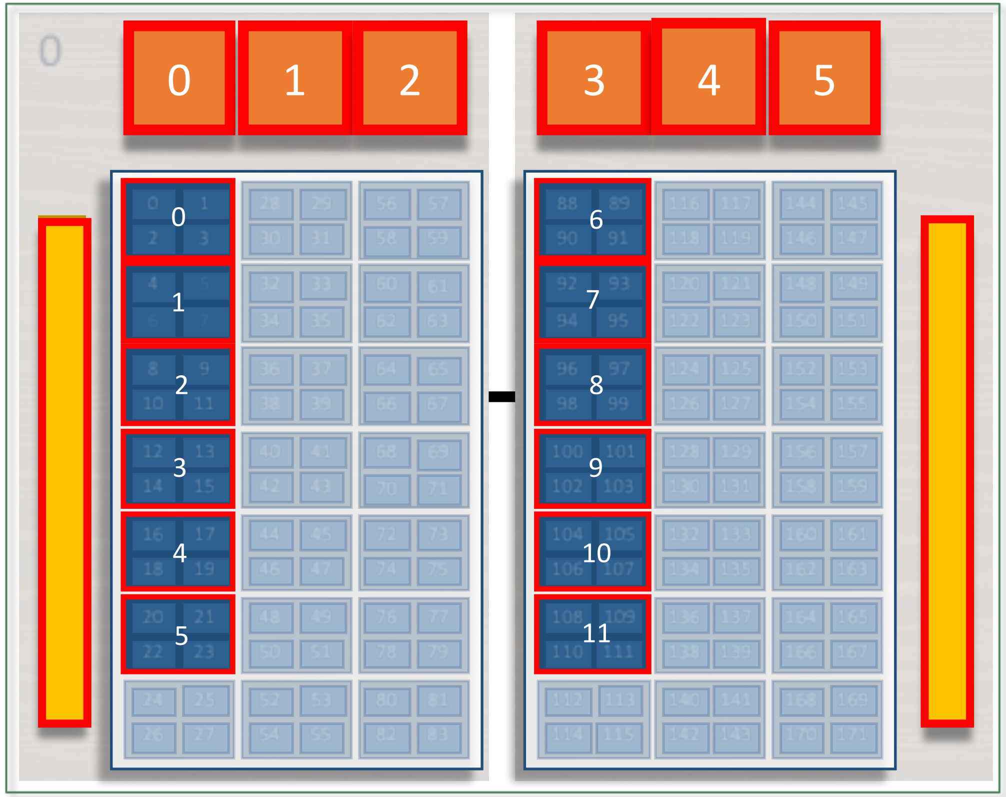
3) RS Example: 2 Tasks per GPU Resource Set per Node

Single resource set per node: 6 GPUs, 12 cores

Individual RS



RS Mapped to Node



- All 12 CPUs can see all node's 6 GPUs. Code must manage CPU to GPU communication.
- CPUs on socket0 can access GPUs on socket1.
- Code must manage cross socket communication.

Choosing a Resource Set

- **Understand how your code expects to interact with the system.**
  - How many tasks/threads per GPU?
  - Does each task expect to see a single GPU? Do multiple tasks expect to share a GPU? Is the code written to internally manage task to GPU workload based on the number of available cores and GPUs?
- **Create resource sets containing the needed GPU to task binding**
  - Based on how your code expects to interact with the system, you can create resource sets containing the needed GPU and core resources.
  - If a code expects to utilize one GPU per task, a resource set would contain one core and one GPU. If a code expects to pass work to a single GPU from two tasks, a resource set would contain two cores and one GPU.
- **Decide on the number of resource sets needed**
  - Once you understand tasks, threads, and GPUs in a resource set, you simply need to decide the number of resource sets needed.

Jsrun Format and Options

jsrun [-n #Resource Sets] [tasks, threads, and GPUs w/in each Resource Set] program

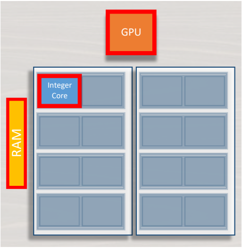
Flags (*long*)	Flags (*short*)	Description
--nrs	**-n**	Number of resource sets
--rs_per_host	-r	Number of resource sets per host (node)
--tasks_per_rs	**-a**	Number of MPI tasks/ranks per resource set
--cpu_per_rs	**-c**	Number of CPUs (cores) per resource set.
--gpu_per_rs	**-g**	Number of GPUs per resource set
--bind	**-b**	Binding of tasks within a resource set. Can be none, rs, or packed:#
--latency priority	-l	Latency Priority. Controls layout priorities. Can currently be cpu-cpu or gpu-cpu. Upper v/s lower case.
--launch_distribution	**-d**	How tasks are distributed between resource sets. Can be cyclic, packed, plane.

**for additional flags see the jsrun man page*

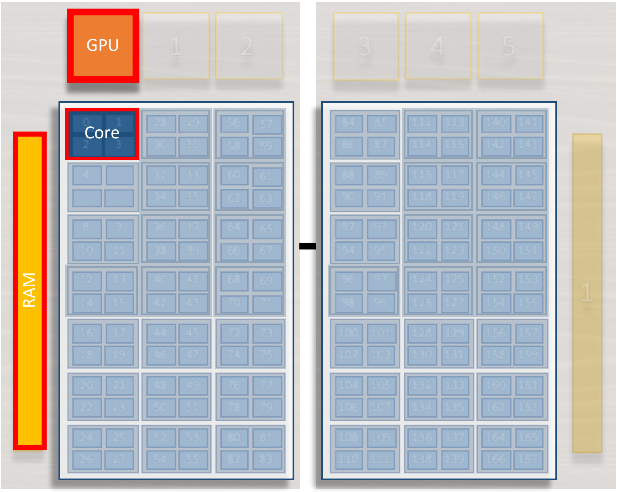
jsrun to aprun Comparisons

- Comparing Titan’s aprun to Summit’s jsrun
- Due to node and launcher differences, no direct equivalent for many use cases
- Table below lists basic single GPU use cases

Titan



Summit



GPUs per Task	MPI Tasks	Threads per Task	aprun	jsrun
1	1	0	aprun –n1	jsrun -n1 -g1 -a1 -c1
1	2	0	aprun –n2	jsrun –n1 -g1 -a2 –c2
1	1	4	aprun –n1 –d4	jsrun -n1 -g1 -a1 -c4 –bpacked:4
1	2	8	aprun –n2 –d8	jsrun -n1 -g1 -a2 –c16 –bpacked:8

Basic jsrun Examples

Description	Jsrun command	Layout notes
64 MPI tasks, no GPUs	***jsrun –n 64 ./a.out***	2 nodes: 42 tasks node1, 22 tasks on node2
12 MPI tasks each with access to 1 GPU	***jsrun –n 12 –a 1 –c 1 –g1 ./a.out***	2 nodes, 3 tasks per socket
12 MPI tasks each with 4 threads and 1 GPU	***jsrun –n 12 –a 1 –c 4 –g1 –bpacked:4 ./a.out***	2 nodes, 3 tasks per socket
24 MPI tasks two tasks per GPU	***jsrun –n 12 –a 2 –c 2 –g1 ./a.out***	2 nodes, 6 tasks per socket
4 MPI tasks each with 3 GPUs	***jsrun -n 4 –a 1 –c 1 –g 3 ./a.out***	2 nodes: 1 task per socket

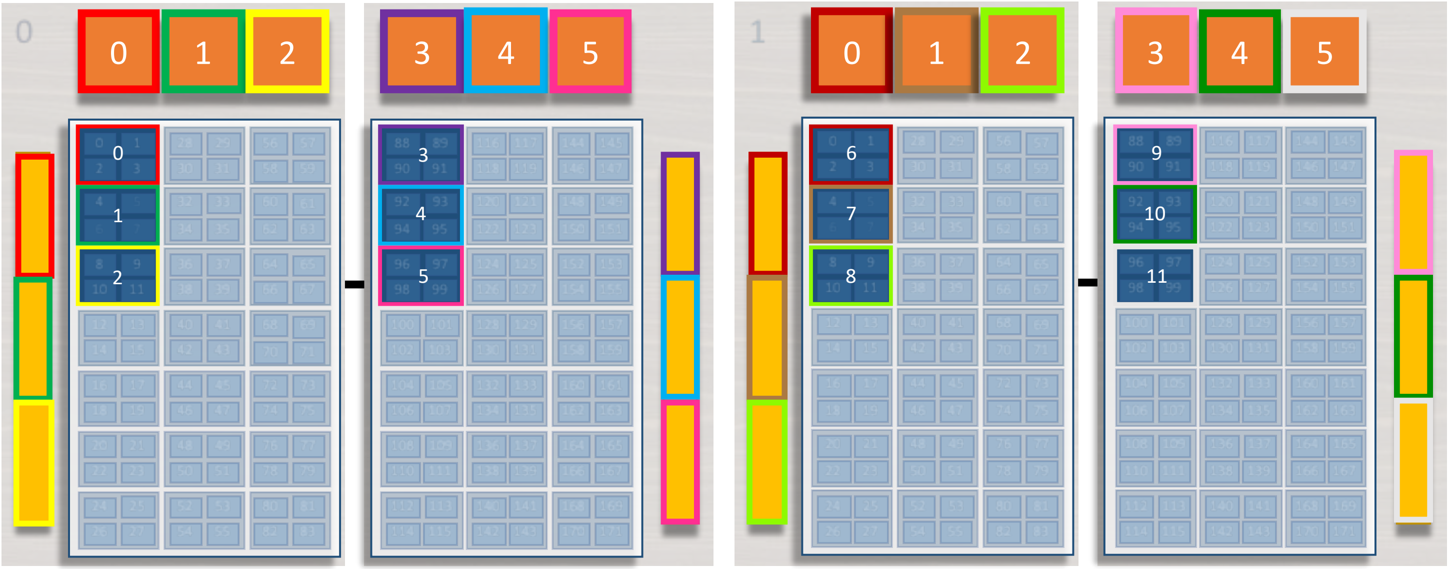
12 MPI tasks each with access to 1 GPU

jsrun –n 12 –a 1 –c 1 –g1 ./a.out

12 resource sets x [1 task | 1 physical core | 1 GPU]

Specify key flags each submission, do not rely on defaults

First RS (red) contains
- task 0
- core 0
- GPU 0



2 Tasks, 1 GPU per RS

jsrun –n 12 –a 2 –c 2 –g1 –d packed ./a.out

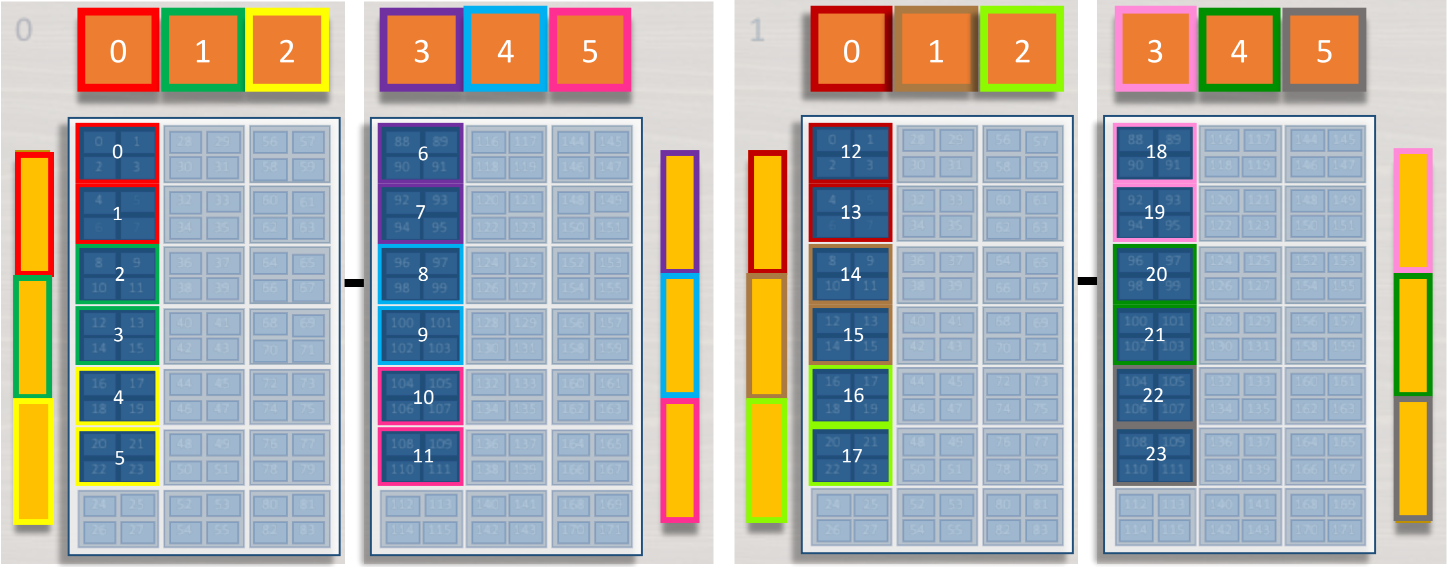
12 resource sets x 2 tasks 2 physical cores 1 GPU

assign tasks sequentially filling RS first

Increase cores in RS as needed to prevent accidental oversubscription

Packed distribution option places tasks sequentially *(not currently default)*

First RS (red) contains
- 2 tasks (0-1)
- 2 cores (0,4)
- 1 GPU (0)



6 MPI Tasks, 3 GPUs per RS

jsrun –n 4 –a 6 –c 6 –g3 -d packed -l GPU-CPU ./a.out

4
resource
sets

x

6
tasks

6
physical
cores

3
GPUs

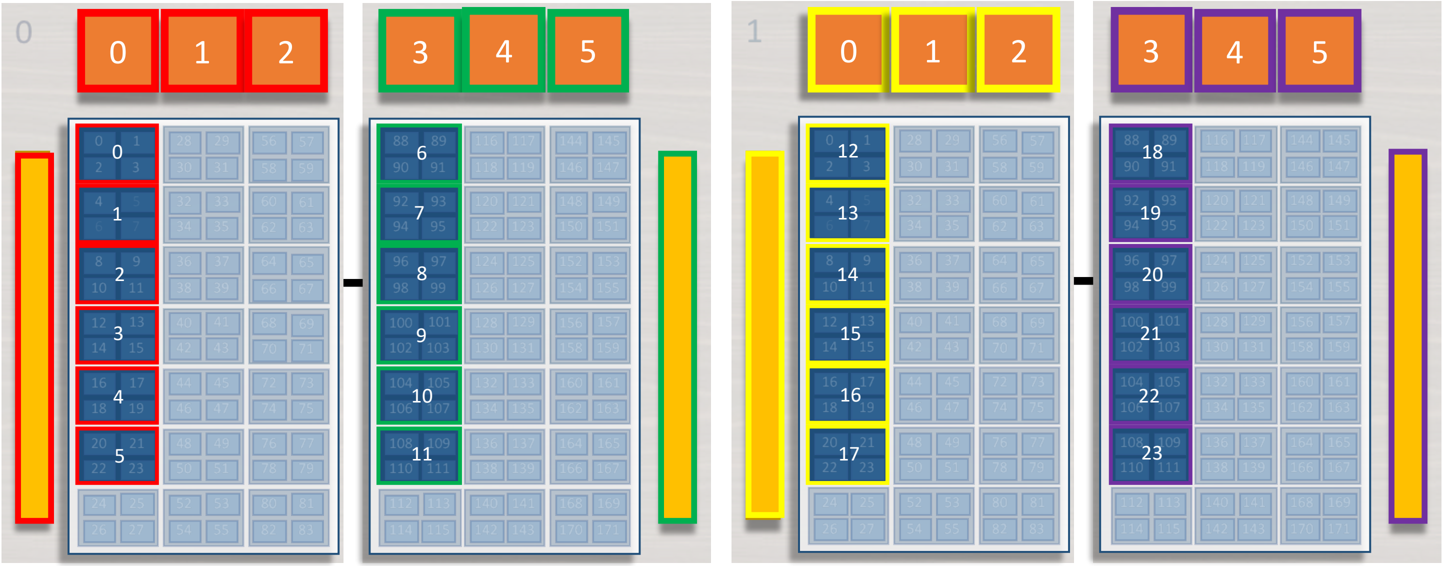
assign tasks
sequentially
filling RS
first

assign tasks
for best CPU
to GPU
transfers

-l latency flag
impacts core
layout

First RS (red)
contains

- 6 tasks (0-5)
- 6 cores(0,4,…20)
- 3 GPUs (0-2)



1 MPI Task, 4 Threads, 1 GPU per RS

```
jsrun   –n 12   –a 1   –c 4   –g 1   –b packed:4   -d packed   ./a.out
```

12 resource sets x 1 task 4 physical cores 1 GPU

bind tasks to 4 cores in resource set

assign tasks sequentially filling RS first

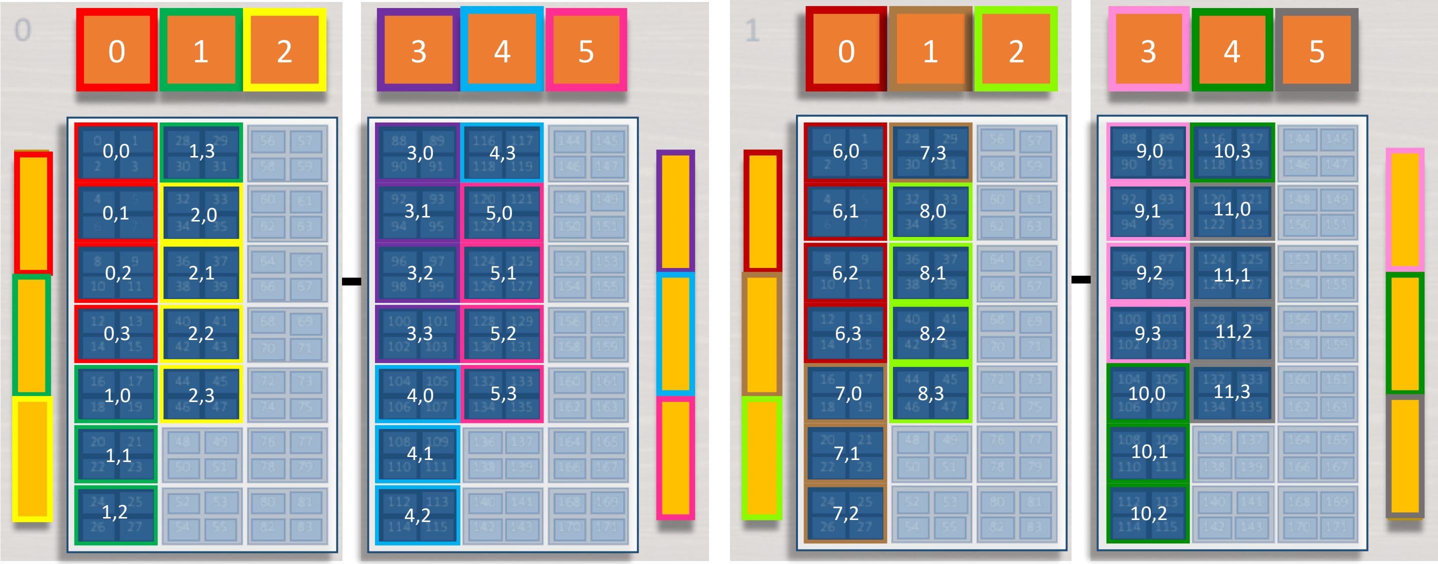
User should set OMP_NUM_THREADS = 4

For rank 0 jsrun will set

OMP_PLACES {0},{4},{8},{12}

First RS (red) contains

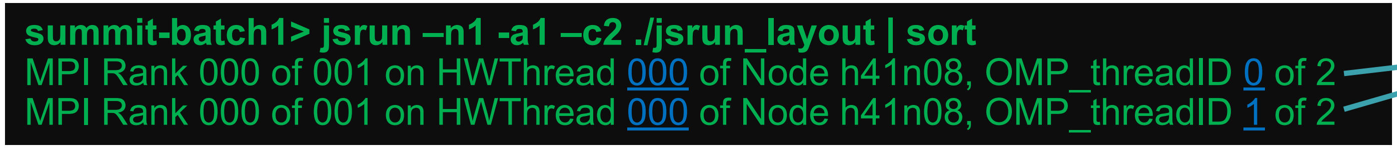
- 1 task (0)
- 4 threads (0-3)
- 4 cores (0,4,…12)
- 1 GPU (0)



jsrun Binding Flag

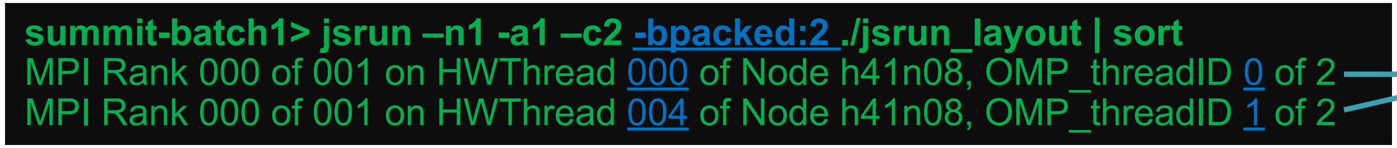
- -b, --bind
- Binding of tasks within a resource set
- OMP_PLACES, affinity
- **Should specify binding to help prevent unwanted oversubscription**

- Options:
  - none
    - No binding
  - rs
    - Bind to cores in resource set
    - ***Not Recommended***
  - packed:#
    - **Default: packed:1**
    - Number of CPUs bound to task
  - packed:smt:#
    - Hardware threads bound to task



```
summit-batch1> jsrun –n1 -a1 –c2 ./jsrun_layout | sort
MPI Rank 000 of 001 on HWThread 000 of Node h41n08, OMP_threadID 0 of 2
MPI Rank 000 of 001 on HWThread 000 of Node h41n08, OMP_threadID 1 of 2
```

Threads placed on same core with default binding.



```
summit-batch1> jsrun –n1 -a1 –c2 -bpacked:2 ./jsrun_layout | sort
MPI Rank 000 of 001 on HWThread 000 of Node h41n08, OMP_threadID 0 of 2
MPI Rank 000 of 001 on HWThread 004 of Node h41n08, OMP_threadID 1 of 2
```

Use ‘–b packed:2’ to bind each rank to 2 cores.

Hardware Threads: Multiple Threads per Core

```
jsrun   –n 12   –a 1   –c 2   –g 1   –b packed:2   –d packed   ./a.out
```

12 resource sets x 1 task, 2 physical cores, 1 GPU

bind tasks to 2 cores in resource set

assign tasks sequentially filling RS first

User should set OMP_NUM_THREADS = 4

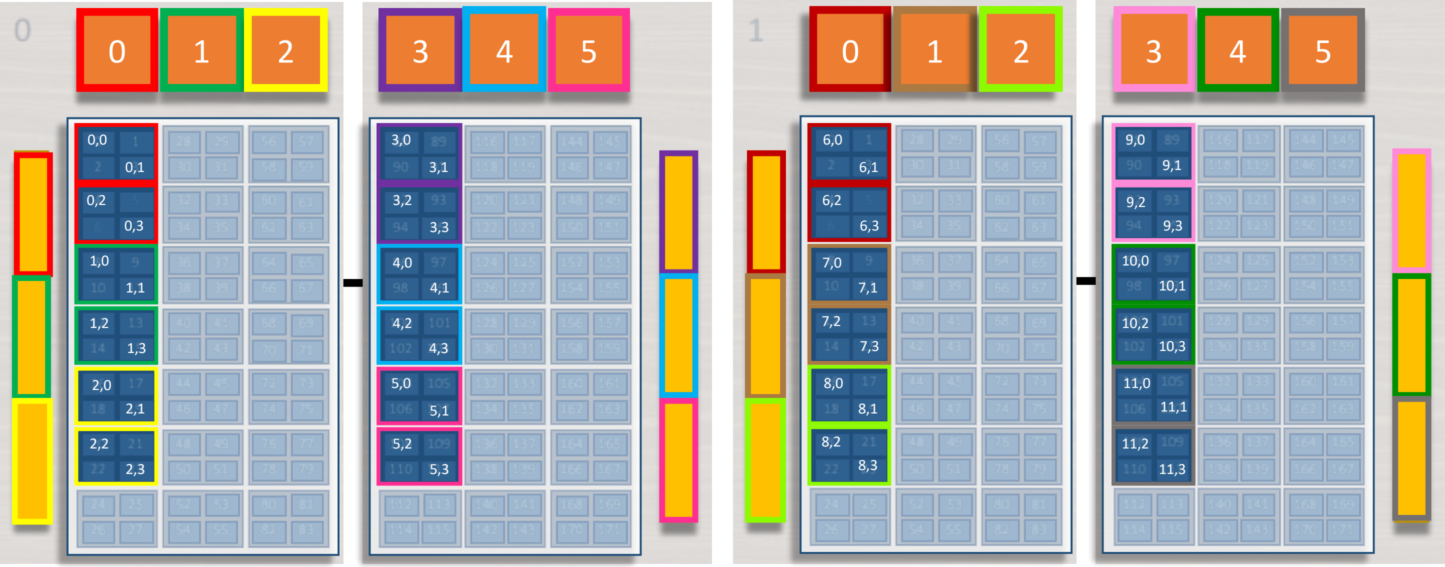
#BSUB –alloc_flags smt2

For rank 0 jsrun will set

OMP_PLACES {0:2},{4:2}

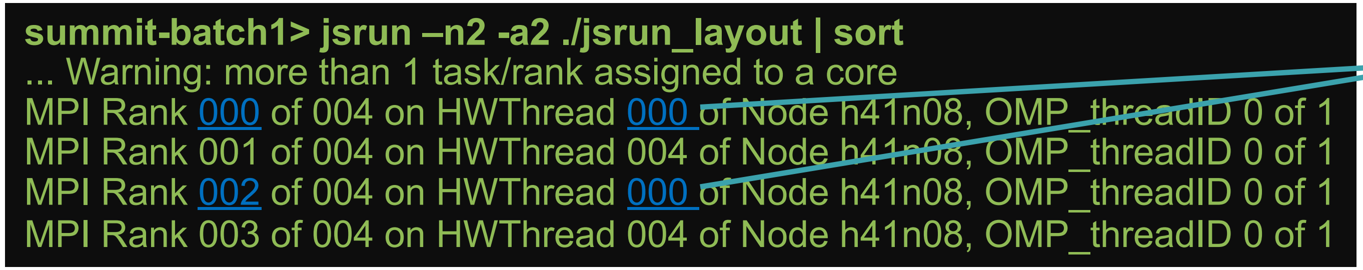
First RS (red) contains

- 1 task (0)
- 4 threads (0-3)
- 2 cores (0,4)
- 1 GPU (0)



Viewing jsrun Layout

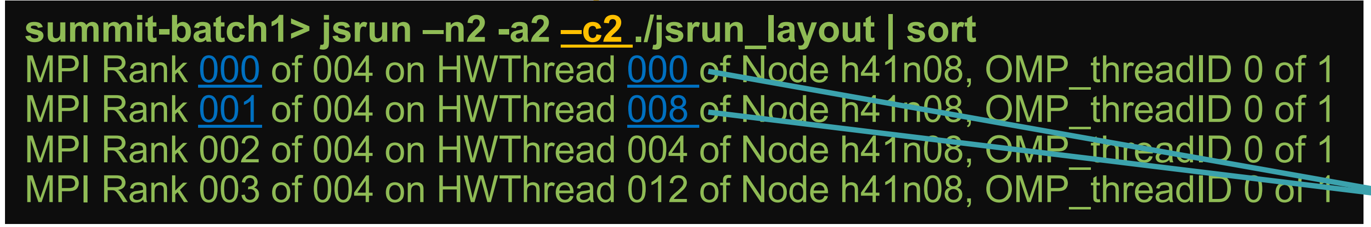
- Execute code within interactive batch job to view jsrun layout
- Lab maintained example code:
  - www.olcf.ornl.gov/for-users/system-user-guides/summit/running-jobs/#hello_jsrun



```
summit-batch1> jsrun –n2 -a2 ./jsrun_layout | sort
... Warning: more than 1 task/rank assigned to a core
MPI Rank 000 of 004 on HWThread 000 of Node h41n08, OMP_threadID 0 of 1
MPI Rank 001 of 004 on HWThread 004 of Node h41n08, OMP_threadID 0 of 1
MPI Rank 002 of 004 on HWThread 000 of Node h41n08, OMP_threadID 0 of 1
MPI Rank 003 of 004 on HWThread 004 of Node h41n08, OMP_threadID 0 of 1
```

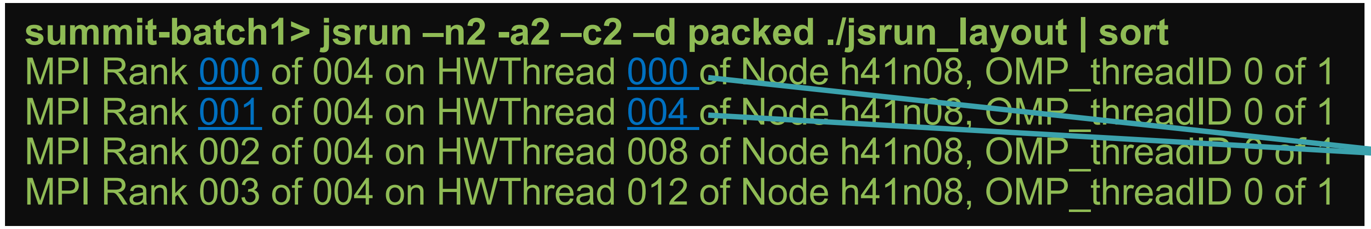
Without –c multiple ranks are placed on single core.

Adding cores to RS provides a core for each rank.



```
summit-batch1> jsrun –n2 -a2 –c2 ./jsrun_layout | sort
MPI Rank 000 of 004 on HWThread 000 of Node h41n08, OMP_threadID 0 of 1
MPI Rank 001 of 004 on HWThread 008 of Node h41n08, OMP_threadID 0 of 1
MPI Rank 002 of 004 on HWThread 004 of Node h41n08, OMP_threadID 0 of 1
MPI Rank 003 of 004 on HWThread 012 of Node h41n08, OMP_threadID 0 of 1
```

Notice default rank placement order cycles between RS.

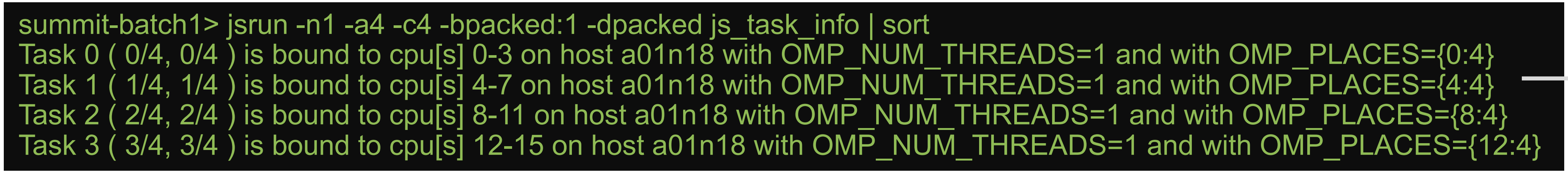


```
summit-batch1> jsrun –n2 -a2 –c2 –d packed ./jsrun_layout | sort
MPI Rank 000 of 004 on HWThread 000 of Node h41n08, OMP_threadID 0 of 1
MPI Rank 001 of 004 on HWThread 004 of Node h41n08, OMP_threadID 0 of 1
MPI Rank 002 of 004 on HWThread 008 of Node h41n08, OMP_threadID 0 of 1
MPI Rank 003 of 004 on HWThread 012 of Node h41n08, OMP_threadID 0 of 1
```

Changing distribution order to packed changes RS rank placement.

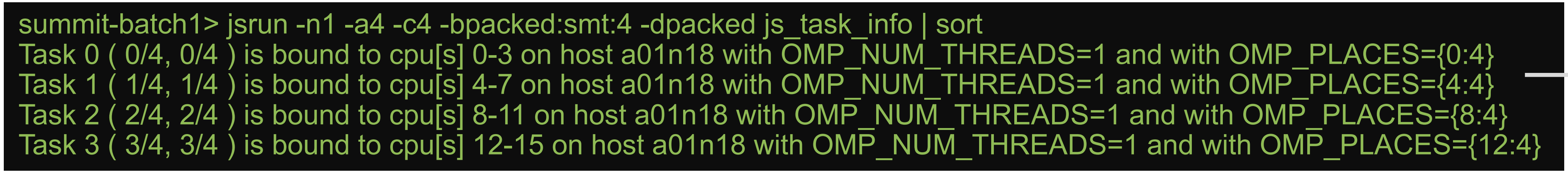
Viewing jsrun Layout

- ***js_task_info*** : binary provided by jsrun developers
- Examples ran with default SMT4



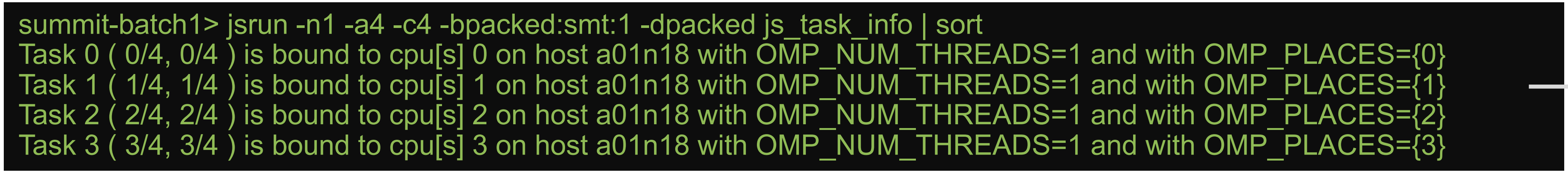
```
summit-batch1> jsrun -n1 -a4 -c4 -bpacked:1 -dpacked js_task_info | sort
Task 0 ( 0/4, 0/4 ) is bound to cpu[s] 0-3 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={0:4}
Task 1 ( 1/4, 1/4 ) is bound to cpu[s] 4-7 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={4:4}
Task 2 ( 2/4, 2/4 ) is bound to cpu[s] 8-11 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={8:4}
Task 3 ( 3/4, 3/4 ) is bound to cpu[s] 12-15 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={12:4}
```

Default binding to one physical core



```
summit-batch1> jsrun -n1 -a4 -c4 -bpacked:smt:4 -dpacked js_task_info | sort
Task 0 ( 0/4, 0/4 ) is bound to cpu[s] 0-3 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={0:4}
Task 1 ( 1/4, 1/4 ) is bound to cpu[s] 4-7 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={4:4}
Task 2 ( 2/4, 2/4 ) is bound to cpu[s] 8-11 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={8:4}
Task 3 ( 3/4, 3/4 ) is bound to cpu[s] 12-15 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={12:4}
```

Binding packed:smt:4



```
summit-batch1> jsrun -n1 -a4 -c4 -bpacked:smt:1 -dpacked js_task_info | sort
Task 0 ( 0/4, 0/4 ) is bound to cpu[s] 0 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={0}
Task 1 ( 1/4, 1/4 ) is bound to cpu[s] 1 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={1}
Task 2 ( 2/4, 2/4 ) is bound to cpu[s] 2 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={2}
Task 3 ( 3/4, 3/4 ) is bound to cpu[s] 3 on host a01n18 with OMP_NUM_THREADS=1 and with OMP_PLACES={3}
```

Binding packed:smt:1

All tasked placed on single physical core

Viewing jsrun Layout

- Execute tools on compute nodes through jsrun

```
summit-batch3> jsrun -n1 -g0 sh -c 'nvidia-smi --query-gpu=gpu_name,gpu_bus_id --format=csv'
No devices were found
```

No visible GPUs

```
summit-batch3> jsrun -n1 -g3 sh -c 'nvidia-smi --query-gpu=gpu_name,gpu_bus_id --format=csv'
name, pci.bus_id
Tesla V100-SXM2-16GB, 00000004:04:00.0
Tesla V100-SXM2-16GB, 00000004:05:00.0
Tesla V100-SXM2-16GB, 00000004:06:00.0
```

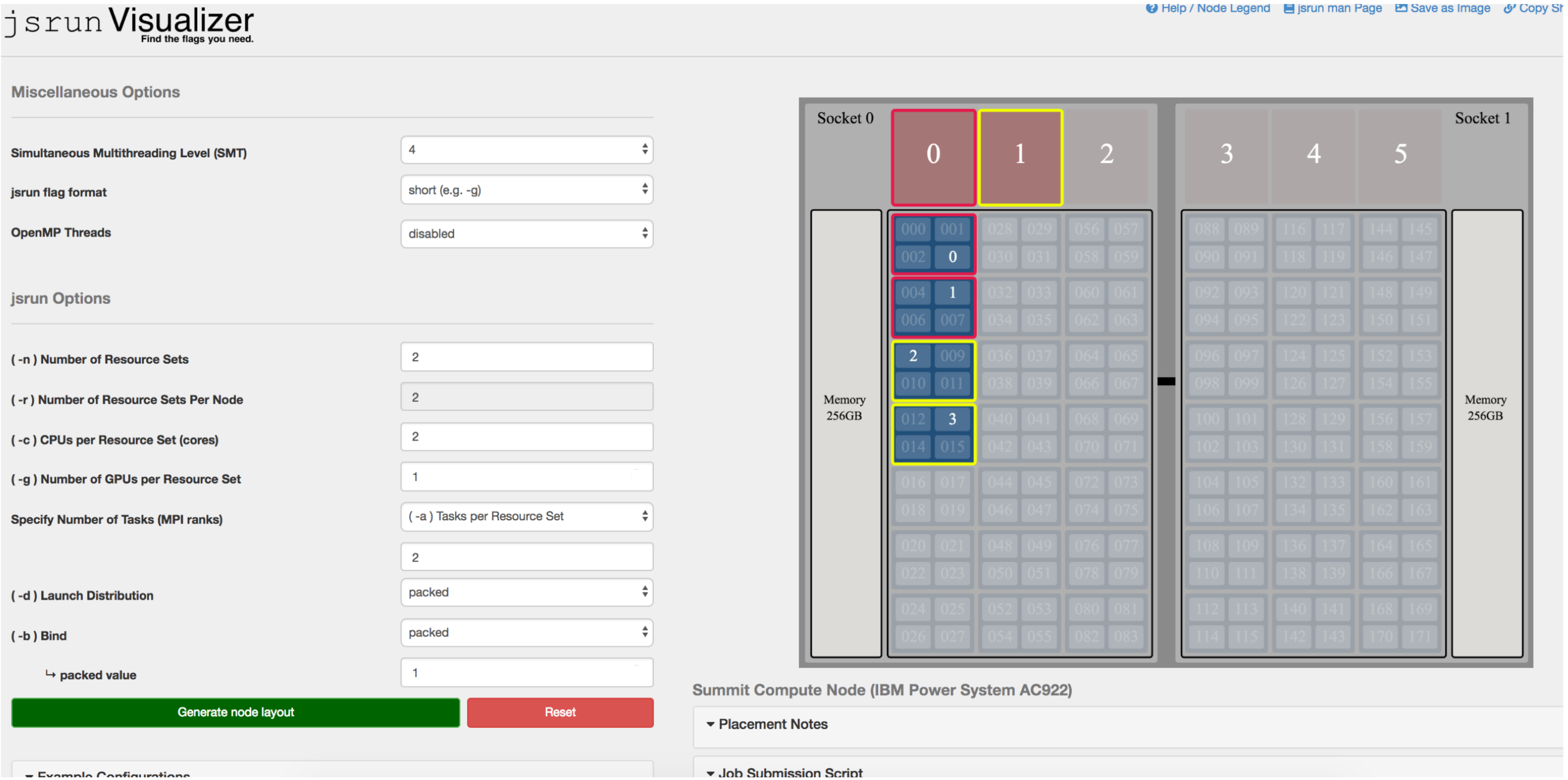
3 visible GPUs

```
summit-batch3> jsrun -n1 -g4 -c42 sh -c 'nvidia-smi --query-gpu=gpu_name,gpu_bus_id --format=csv'
name, pci.bus_id
Tesla V100-SXM2-16GB, 00000004:04:00.0
Tesla V100-SXM2-16GB, 00000004:05:00.0
Tesla V100-SXM2-16GB, 00000035:03:00.0
Tesla V100-SXM2-16GB, 00000035:04:00.0
```

Bus ID shows two GPUs per socket visible

Viewing jsrun Layout (jsrunVisualizer)

- jsrunVisualizer, web based tool to view jsrun layout
- https://jsrunvisualizer.olcf.ornl.gov



Miscellaneous Options

Simultaneous Multithreading Level (SMT): 4

jsrun flag format: short (e.g. -g)

OpenMP Threads: disabled

jsrun Options

(-n) Number of Resource Sets: 2

(-r) Number of Resource Sets Per Node: 2

(-c) CPUs per Resource Set (cores): 2

(-g) Number of GPUs per Resource Set: 1

Specify Number of Tasks (MPI ranks): (-a) Tasks per Resource Set

2

(-d) Launch Distribution: packed

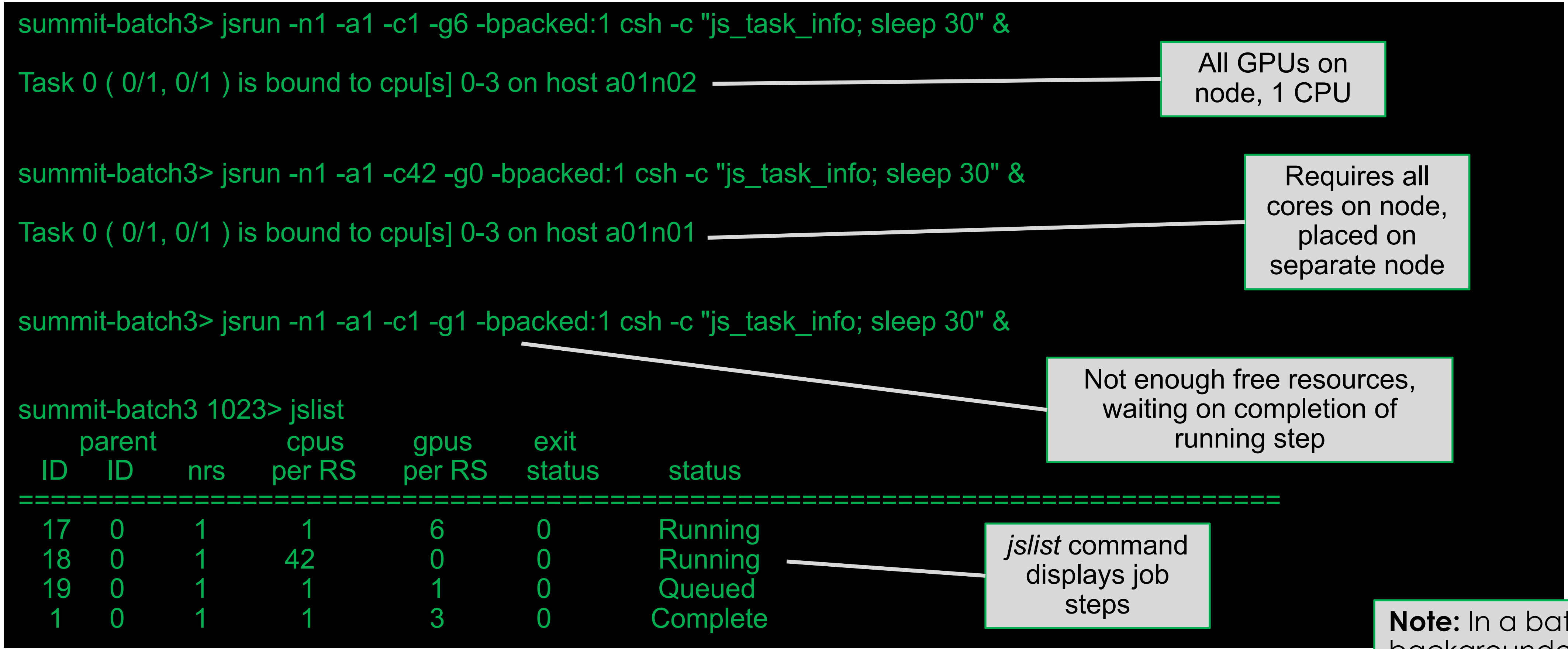
(-b) Bind: packed

↳ packed value: 1

Summit Compute Node (IBM Power System AC922)

Multiple Simultaneous Job Steps

- jsrun placement managed by IBM's CSM (Cluster System Management)
- Aware of all jsrun allocations within LSF job; allows multiple per node, multi node, …
- Following example ran on 2-node allocation



```
summit-batch3> jsrun -n1 -a1 -c1 -g6 -bpacked:1 csh -c "js_task_info; sleep 30" &

Task 0 ( 0/1, 0/1 ) is bound to cpu[s] 0-3 on host a01n02


summit-batch3> jsrun -n1 -a1 -c42 -g0 -bpacked:1 csh -c "js_task_info; sleep 30" &

Task 0 ( 0/1, 0/1 ) is bound to cpu[s] 0-3 on host a01n01


summit-batch3> jsrun -n1 -a1 -c1 -g1 -bpacked:1 csh -c "js_task_info; sleep 30" &


summit-batch3 1023> jslist
      parent           cpus       gpus      exit
  ID    ID     nrs     per RS     per RS    status       status
==============================================================================
  17    0       1        1          6         0         Running
  18    0       1       42          0         0         Running
  19    0       1        1          1         0         Queued
   1    0       1        1          3         0         Complete
```

All GPUs on node, 1 CPU

Requires all cores on node, placed on separate node

Not enough free resources, waiting on completion of running step

jslist command displays job steps

Note: In a batch job, backgrounded tasks require ***wait*** command

Moving Forward

- December 14 software stack update
  - Bug fixes, features
- Documentation
  - www.olcf.ornl.gov/for-users/system-user-guides/summit
  - Man pages
    - jsrun, bsub
- Help/Feedback
  - help@olcf.ornl.gov