Programming Massively Parallel Multiprocessors and Heterogeneous Systems (Understanding and programming the devices powering AI)

Lecture 0: Class overview and Introductions

Jonathan Appavoo email: jappavoo @ bu.edu office: CDS 706

~~Programming Massively Parallel Multiprocessors and Heterogeneous Systems (Understanding and programming the devices powering AI)~~

CUDA Programming on GPU’s

Lecture 0: Class overview and Introductions

Jonathan Appavoo email: jappavoo @ b u . e d u office: CDS 706

CS391

Course Synopsis
(See Syllabus on Piazza for details)

Course Prerequisites and Structure

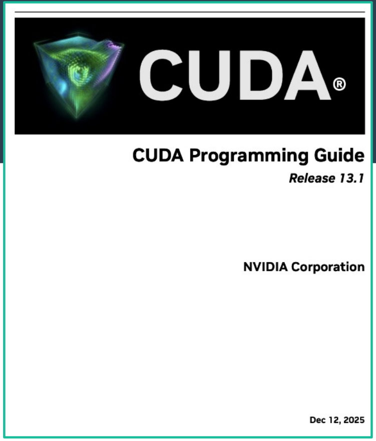
- **Prerequisites**
  - Basic understanding of the C programming language (especially its use of pointers)
  - Undergrad level knowledge of computer architecture
- **Structure**
  - Lectures twice a week for ~7-8 weeks
  - Seminars and Guest Lectures remaining weeks
  - Discussions once a week as needed
  - Office hours

Course Components

- **Lectures 12 -16**
- **Programming Assignments: 5**
- **Seminars: student led paper discussion**
- **Guest Lectures: 5-6 : NVIDIA, IBM, Red Hat, Meta, BU**
- **Midterm: Lecture Material**
- **Final: Predominately based on assignments and programming**
- ***<u>Attendance and Participation in lectures and seminars</u>***

Course Resources

https://docs.nvidia.com/cuda/#programming-guides


CUDA®

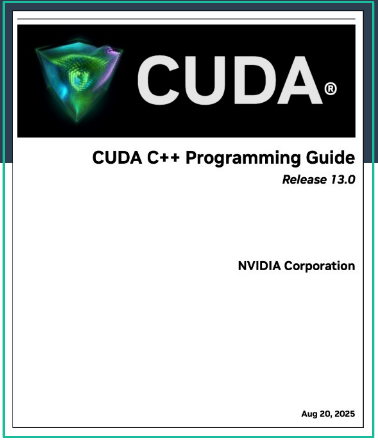
CUDA Programming Guide

Release 13.1

NVIDIA Corporation

Dec 12, 2025

13.1


CUDA®

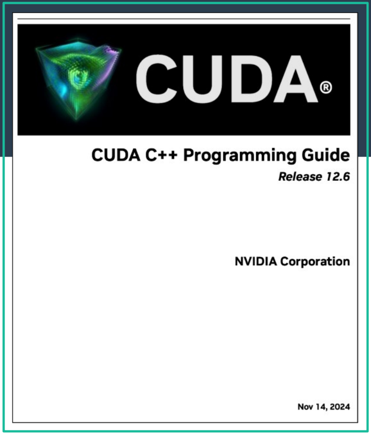
CUDA C++ Programming Guide

Release 13.0

NVIDIA Corporation

Aug 20, 2025

13.0


CUDA®

CUDA C++ Programming Guide

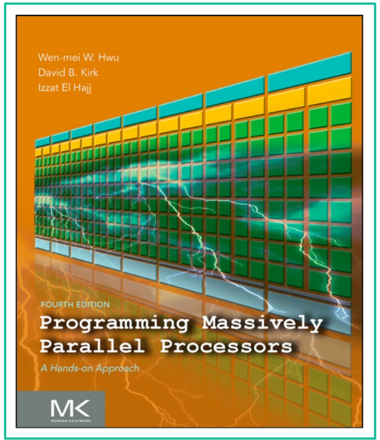
Release 12.6

NVIDIA Corporation

Nov 14, 2024

12.6

- **Primary source of information (besides slides): NVIDIA Inc, "CUDA C++ Programming Guide" (and friends: best practices, API references, white papers, etc)**
  - 13.1 vs 13.0 vs 12.6
- **Textbook: none**
  - but if you need one Kirk and Hwu: "Programming Massively Parallel Processors: A Hands-on Approach (4th edition)" is reasonable.
- **Piazza**
- **Github Classroom**
- **Gradescope**
- **MOC/NERC/Red Hat Open AI**
  - GPUS: V100, A100 and H100
  - CUDA: 12.6.3
- **DGX Sparks**
  - GB10's
  - CUDA: 13.1


Wen-mei W. Hwu
David B. Kirk
Izzat El Hajj

FOURTH EDITION

Programming Massively Parallel Processors

A Hands-on Approach

MK

https://bu.bncollege.com/c/Programming-Massively-Parallel-Processors/p/MBS_6919078_used?currentCampus=8529&rental=true

Grade Beakdown

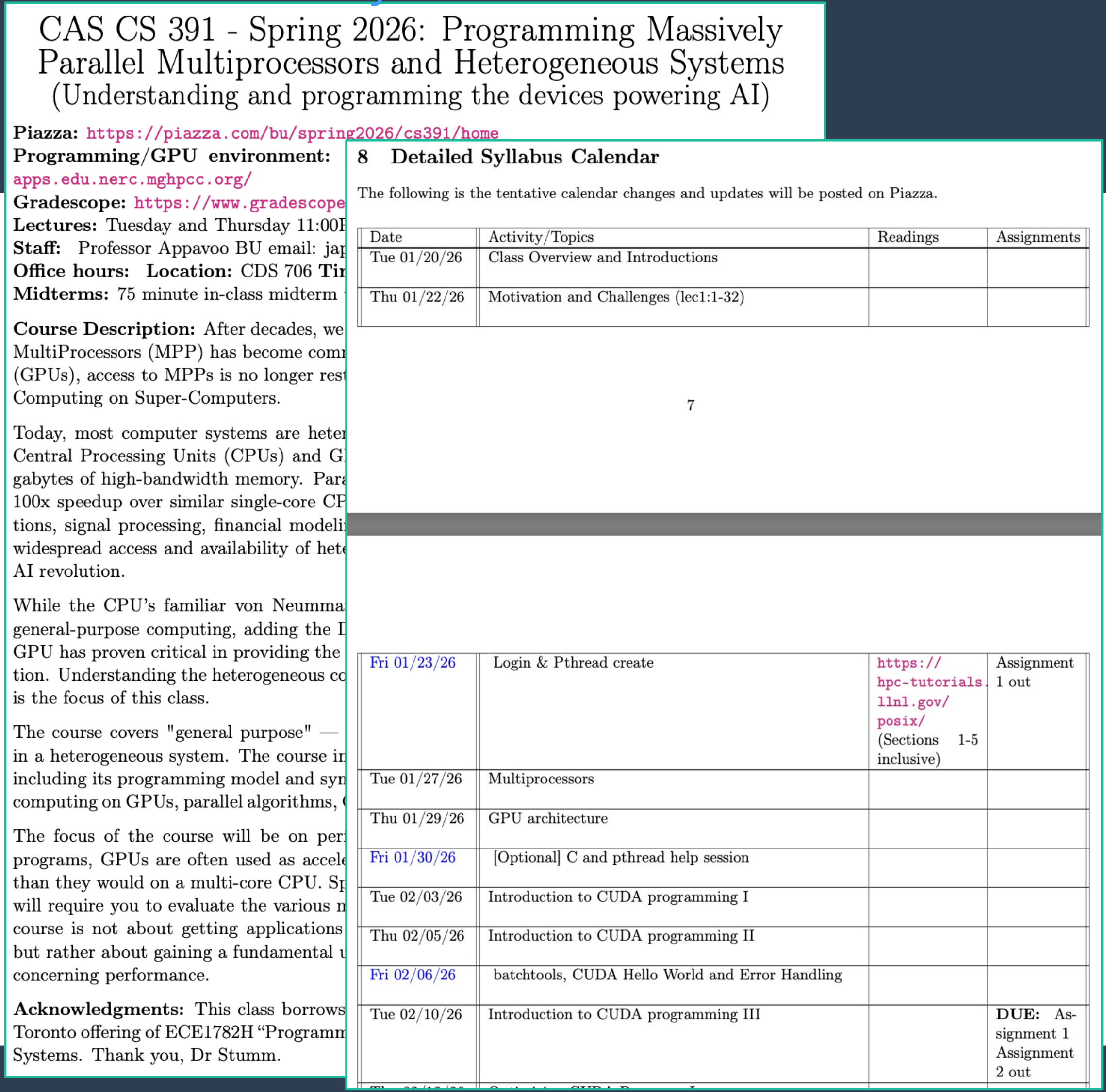
- **Participation, Seminars & Attendance**
  - 30%
- **Programming Assignments:**
  - 40%
- **Midterm:**
  - March 19th: 15%
- **Final:**
  - 15%
-

Syllabus

The details, including a tentative weekly calendar

Please read and ask any questions you have on Piazza

syllabus



CAS CS 391 - Spring 2026: Programming Massively Parallel Multiprocessors and Heterogeneous Systems
(Understanding and programming the devices powering AI)

Piazza: https://piazza.com/bu/spring2026/cs391/home
Programming/GPU environment:
apps.edu.nerc.mghpcc.org/
Gradescope: https://www.gradescope
Lectures: Tuesday and Thursday 11:00F
Staff: Professor Appavoo BU email: jap
Office hours: **Location:** CDS 706 **Tir**
Midterms: 75 minute in-class midterm

Course Description: After decades, we
MultiProcessors (MPP) has become com
(GPUs), access to MPPs is no longer rest
Computing on Super-Computers.

Today, most computer systems are hete
Central Processing Units (CPUs) and G
gabytes of high-bandwidth memory. Para
100x speedup over similar single-core CP
tions, signal processing, financial modeli
widespread access and availability of hete
AI revolution.

While the CPU's familiar von Neumma
general-purpose computing, adding the I
GPU has proven critical in providing the
tion. Understanding the heterogeneous co
is the focus of this class.

The course covers "general purpose" —
in a heterogeneous system. The course in
including its programming model and syn
computing on GPUs, parallel algorithms,

The focus of the course will be on per
programs, GPUs are often used as accele
than they would on a multi-core CPU. Sp
will require you to evaluate the various n
course is not about getting applications
but rather about gaining a fundamental u
concerning performance.

Acknowledgments: This class borrows
Toronto offering of ECE1782H "Programm
Systems. Thank you, Dr Stumm.

8 Detailed Syllabus Calendar

The following is the tentative calendar changes and updates will be posted on Piazza.

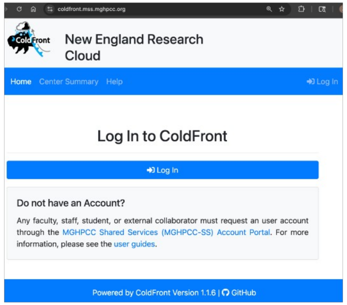
Date	Activity/Topics	Readings	Assignments
Tue 01/20/26	Class Overview and Introductions		
Thu 01/22/26	Motivation and Challenges (lec1:1-32)		

Date	Activity/Topics	Readings	Assignments
Fri 01/23/26	Login & Pthread create	https://hpc-tutorials.llnl.gov/posix/ (Sections 1-5 inclusive)	Assignment 1 out
Tue 01/27/26	Multiprocessors		
Thu 01/29/26	GPU architecture		
Fri 01/30/26	[Optional] C and pthread help session		
Tue 02/03/26	Introduction to CUDA programming I		
Thu 02/05/26	Introduction to CUDA programming II		
Fri 02/06/26	batchtools, CUDA Hello World and Error Handling		
Tue 02/10/26	Introduction to CUDA programming III		**DUE:** Assignment 1 Assignment 2 out

GPU Lab Infrastructure

Containerized CUDA + Batch GPUs

- Getting Started
  - ColdFront
  - OpenShift and Red Hat Open AI
- Dev Container
  - RHEL 9 + CUDA 12.6.3
  - Browser Jupyter Lab Access
  - Terminal Remote Shell Access
  - Persistent home directories
  - Idle culler (but please shutdown)
- Batch Queues
  - bqstat, bjobs, brun,


coldfront.mss.mghpcc.org

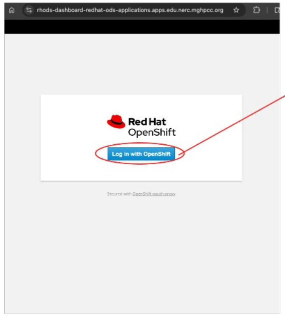
New England Research Cloud

Log In to ColdFront

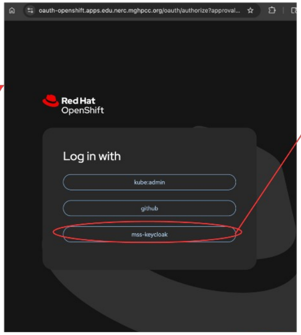
Do not have an Account?

Any faculty, staff, student, or external collaborator must request an user account through the MGHPCC Shared Services (MGHPCC-SS) Account Portal. For more information, please see the user guides.

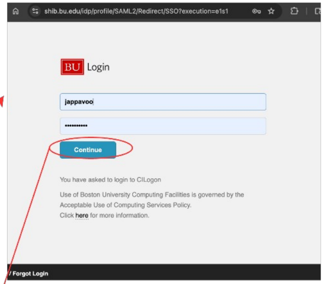
Powered by ColdFront Version 1.1.6 | GitHub


rhods-dashboard-redhat-ods-applications.apps.edu.nerc.mghpcc.org

Secured with OpenShift oauth-proxy


oauth-openshift.apps.edu.nerc.mghpcc.org/oauth/authorize?approval...

Log in with


shib.bu.edu/idp/profile/SAML2/Redirect/SSO?execution=e1s1

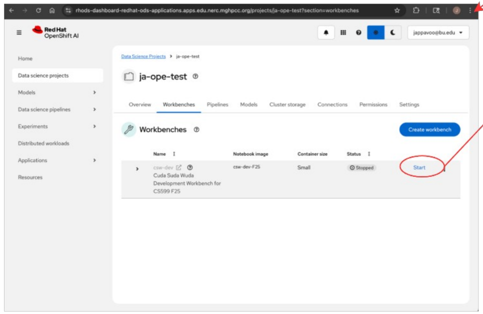
Login

jappavoo

••••••••••

You have asked to login to CILogon

Use of Boston University Computing Facilities is governed by the Acceptable Use of Computing Services Policy.
Click here for more information.

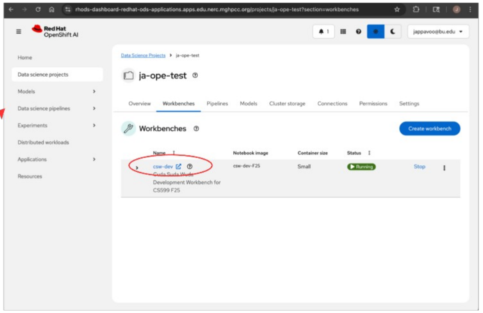

rhods-dashboard-redhat-ods-applications.apps.edu.nerc.mghpcc.org/projects/ja-ope-test?section=workbenches

Data Science Projects > ja-ope-test

ja-ope-test

Workbenches

Name	Notebook image	Container size	Status	
csw-dev Cuda Suda Wuda Development Workbench for CS599 F25	csw-dev-F25	Small	Stopped	Start

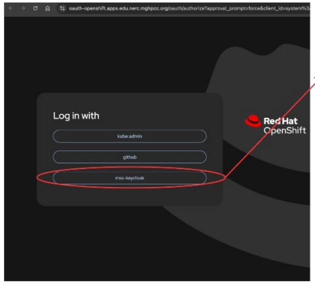

rhods-dashboard-redhat-ods-applications.apps.edu.nerc.mghpcc.org/projects/ja-ope-test?section=workbenches

Data Science Projects > ja-ope-test

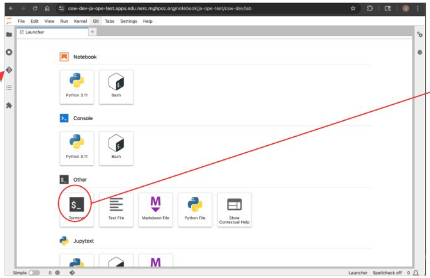
ja-ope-test

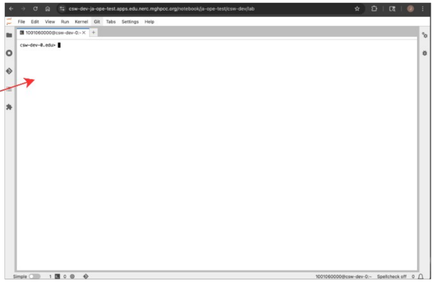
Workbenches

Name	Notebook image	Container size	Status	
csw-dev Cuda Suda Wuda Development Workbench for CS599 F25	csw-dev-F25	Small	Running	Stop


oauth-openshift.apps.edu.nerc.mghpcc.org/oauth/authorize?approval_prompt=force&client_id=system%3

Log in with

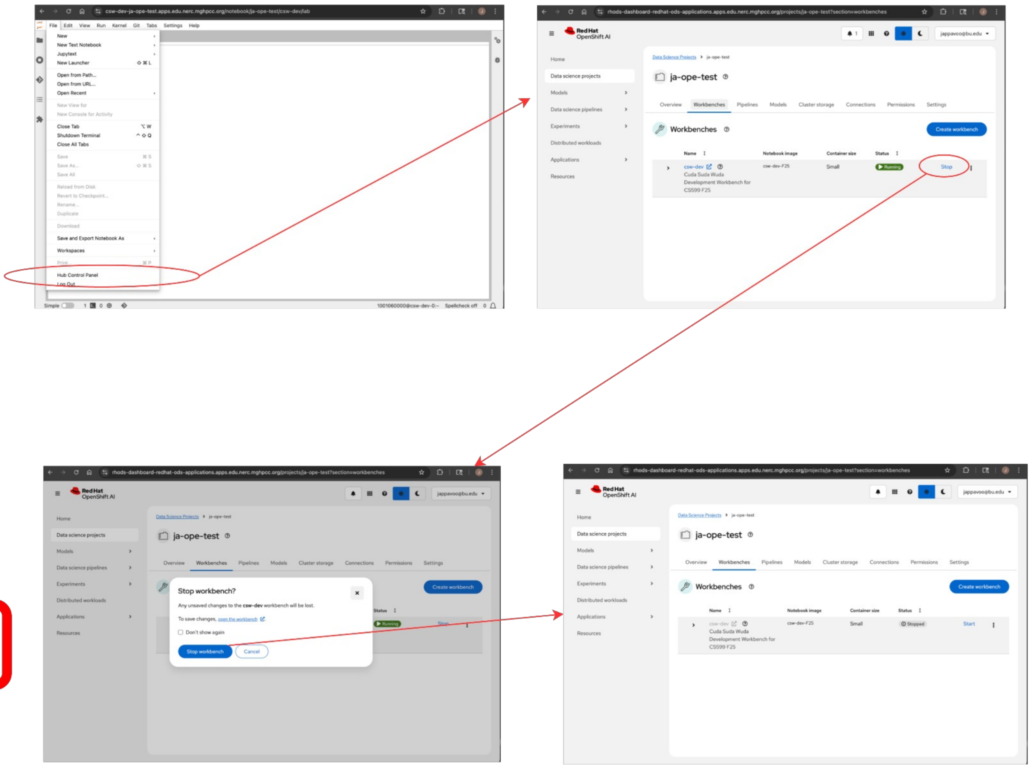

csw-dev-ja-ope-test.apps.edu.nerc.mghpcc.org/notebook/ja-ope-test/csw-dev/lab


csw-dev-ja-ope-test.apps.edu.nerc.mghpcc.org/notebook/ja-ope-test/csw-dev/lab

```
csw-dev-0.edu>
```

Containerized CUDA + Batch GPUs

- Getting Started
  - ColdFront
  - OpenShift and Red Hat Open AI
- Dev Container
  - RHEL 9 + CUDA 12.6.3
  - Browser Jupyter Lab Access
  - Terminal Remote Shell Access
  - Persistent home directories
  - Idle culler (but please shutdown)
- Batch Queues
  - bqstat, bjobs, brun,



Stop workbench?

Any unsaved changes to the **csw-dev** workbench will be lost.

To save changes, open the workbench.

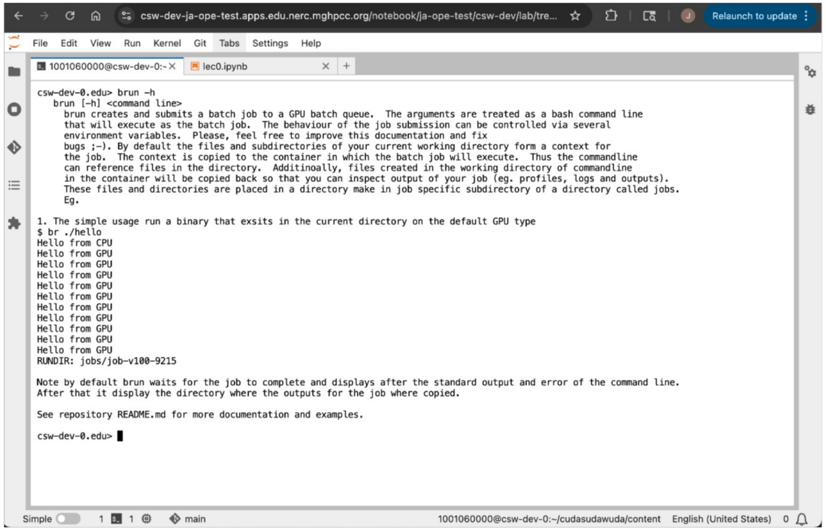
□ Don't show again

Batch Queues

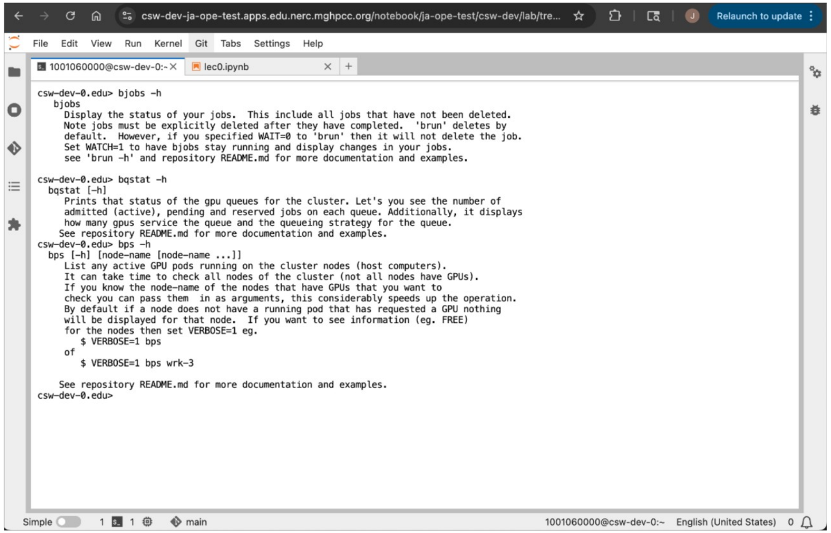
https://github.com/jappavoo/batchtools

- **`brun`**: run a binary on a GPU "node"
- **`./jobs`**: outputs from run/job
- **`bjobs`**: current jobs
- **`bqstat`**: status of queues
- **`bps`**: list activity on GPU nodes (broken)
- misc: **`blog`**, **`bpods`**, **`bwait`**

Please help me fix bugs


csw-dev-ja-ope-test.apps.edu.nerc.mghpcc.org/notebook/ja-ope-test/csw-dev/lab/tre...
Relaunch to update
File
Edit
View
Run
Kernel
Git
Tabs
Settings
Help
1001060000@csw-dev-0:~
lec0.ipynb
Simple
1
1
main
1001060000@csw-dev-0:~/cudasudawuda/content
English (United States)
0

```
csw-dev-0.edu> brun -h
   brun [-h] <command line>
     brun creates and submits a batch job to a GPU batch queue.  The arguments are treated as a bash command line
     that will execute as the batch job.  The behaviour of the job submission can be controlled via several
     environment variables.  Please, feel free to improve this documentation and fix
     bugs ;-). By default the files and subdirectories of your current working directory form a context for
     the job.  The context is copied to the container in which the batch job will execute.  Thus the commandline
     can reference files in the directory.  Additinoally, files created in the working directory of commandline
     in the container will be copied back so that you can inspect output of your job (eg. profiles, logs and outputs).
     These files and directories are placed in a directory make in job specific subdirectory of a directory called jobs.
     Eg.

1. The simple usage run a binary that exsits in the current directory on the default GPU type
$ br ./hello
Hello from CPU
Hello from GPU
Hello from GPU
Hello from GPU
Hello from GPU
Hello from GPU
Hello from GPU
Hello from GPU
Hello from GPU
Hello from GPU
Hello from GPU
RUNDIR: jobs/job-v100-9215

Note by default brun waits for the job to complete and displays after the standard output and error of the command line.
After that it display the directory where the outputs for the job where copied.

See repository README.md for more documentation and examples.

csw-dev-0.edu> 
```



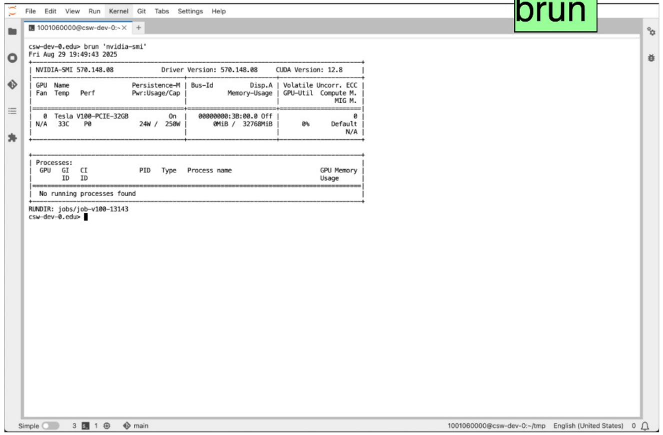
```
csw-dev-0.edu> bjobs -h
   bjobs
     Display the status of your jobs.  This include all jobs that have not been deleted.
     Note jobs must be explicitly deleted after they have completed.  'brun' deletes by
     default.  However, if you specified WAIT=0 to 'brun' then it will not delete the job.
     Set WATCH=1 to have bjobs stay running and display changes in your jobs.
     see 'brun -h' and repository README.md for more documentation and examples.

csw-dev-0.edu> bqstat -h
  bqstat [-h]
     Prints that status of the gpu queues for the cluster. Let's you see the number of
     admitted (active), pending and reserved jobs on each queue. Additionally, it displays
     how many gpus service the queue and the queueing strategy for the queue.
    See repository README.md for more documentation and examples.
csw-dev-0.edu> bps -h
  bps [-h] [node-name [node-name ...]]
     List any active GPU pods running on the cluster nodes (host computers).
     It can take time to check all nodes of the cluster (not all nodes have GPUs).
     If you know the node-name of the nodes that have GPUs that you want to
     check you can pass them  in as arguments, this considerably speeds up the operation.
     By default if a node does not have a running pod that has requested a GPU nothing
     will be displayed for that node.  If you want to see information (eg. FREE)
     for the nodes then set VERBOSE=1 eg.
        $ VERBOSE=1 bps
     of
        $ VERBOSE=1 bps wrk-3

    See repository README.md for more documentation and examples.
csw-dev-0.edu>
```

Please help me fix bugs

Batch Queues

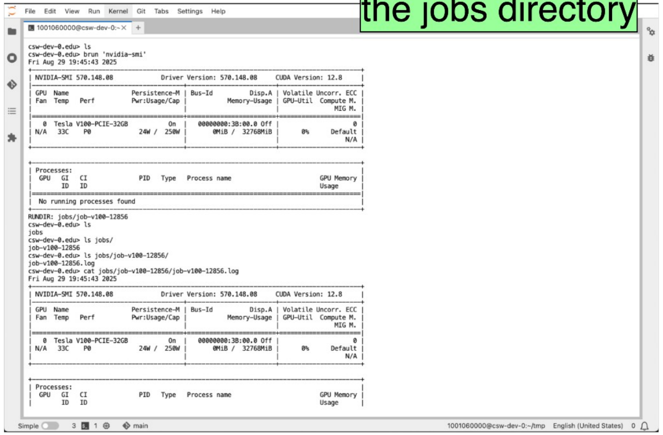
https://github.com/jappavoo/batchtools

brun



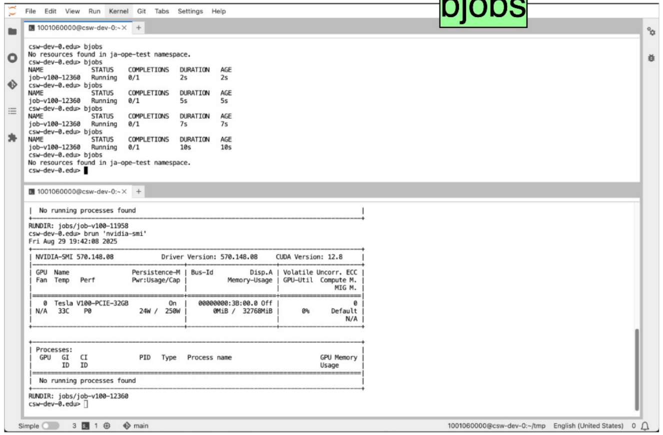
```
csw-dev-0.edu> brun 'nvidia-smi'
Fri Aug 29 19:49:43 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   33C    P0             24W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-13143
csw-dev-0.edu> 
```

the jobs directory



```
csw-dev-0.edu> ls
csw-dev-0.edu> brun 'nvidia-smi'
Fri Aug 29 19:45:43 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   33C    P0             24W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-12856
csw-dev-0.edu> ls
jobs
csw-dev-0.edu> ls jobs/
job-v100-12856
csw-dev-0.edu> ls jobs/job-v100-12856/
job-v100-12856.log
csw-dev-0.edu> cat jobs/job-v100-12856/job-v100-12856.log
Fri Aug 29 19:45:43 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   33C    P0             24W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
```

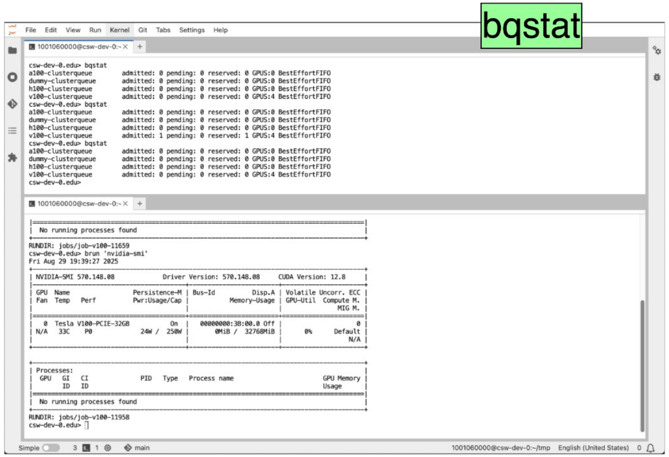
bjobs



```
csw-dev-0.edu> bjobs
No resources found in ja-ope-test namespace.
csw-dev-0.edu> bjobs
NAME             STATUS    COMPLETIONS   DURATION   AGE
job-v100-12360   Running   0/1           2s         2s
csw-dev-0.edu> bjobs
NAME             STATUS    COMPLETIONS   DURATION   AGE
job-v100-12360   Running   0/1           5s         5s
csw-dev-0.edu> bjobs
NAME             STATUS    COMPLETIONS   DURATION   AGE
job-v100-12360   Running   0/1           7s         7s
csw-dev-0.edu> bjobs
NAME             STATUS    COMPLETIONS   DURATION   AGE
job-v100-12360   Running   0/1           10s        10s
csw-dev-0.edu> bjobs
No resources found in ja-ope-test namespace.
csw-dev-0.edu> 
```

```
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-11958
csw-dev-0.edu> brun 'nvidia-smi'
Fri Aug 29 19:42:08 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   33C    P0             24W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-12360
csw-dev-0.edu> 
```

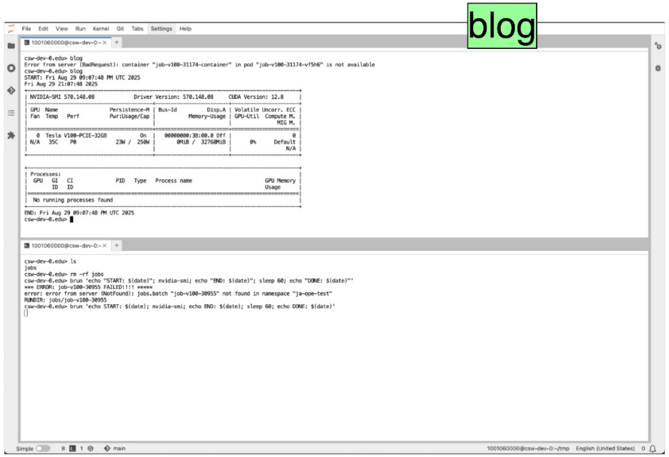
bqstat



```
csw-dev-0.edu> bqstat
a100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
dummy-clusterqueue       admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
h100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
v100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:4 BestEffortFIFO
csw-dev-0.edu> bqstat
a100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
dummy-clusterqueue       admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
h100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
v100-clusterqueue        admitted: 1 pending: 0 reserved: 1 GPUS:4 BestEffortFIFO
csw-dev-0.edu> bqstat
a100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
dummy-clusterqueue       admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
h100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
v100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:4 BestEffortFIFO
csw-dev-0.edu>
```

```
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-11659
csw-dev-0.edu> brun 'nvidia-smi'
Fri Aug 29 19:39:27 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   33C    P0             24W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-11958
csw-dev-0.edu> 
```

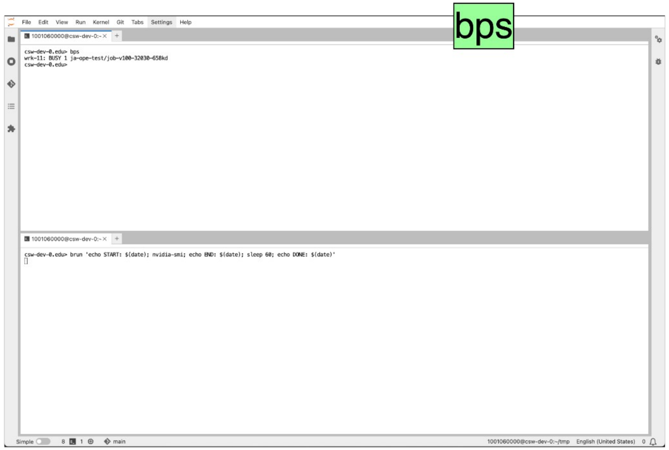
blog



```
csw-dev-0.edu> blog
Error from server (BadRequest): container "job-v100-31174-container" in pod "job-v100-31174-vf5h6" is not available
csw-dev-0.edu> blog
START: Fri Aug 29 09:07:48 PM UTC 2025
Fri Aug 29 21:07:48 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   35C    P0             23W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
END: Fri Aug 29 09:07:48 PM UTC 2025
csw-dev-0.edu> 
```

```
csw-dev-0.edu> ls
jobs
csw-dev-0.edu> rm -rf jobs
csw-dev-0.edu> brun 'echo "START: $(date)"; nvidia-smi; echo "END: $(date)"; sleep 60; echo "DONE: $(date)"'
*** ERROR: job-v100-30955 FAILED!!!! *****
error: error from server (NotFound): jobs.batch "job-v100-30955" not found in namespace "ja-ope-test"
RUNDIR: jobs/job-v100-30955
csw-dev-0.edu> brun 'echo START: $(date); nvidia-smi; echo END: $(date); sleep 60; echo DONE: $(date)'
```

bps



```
csw-dev-0.edu> bps
wrk-11: BUSY 1 ja-ope-test/job-v100-32030-658kd
csw-dev-0.edu>
```

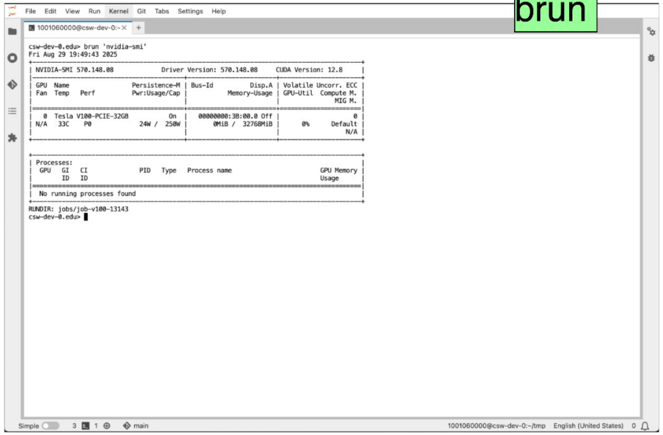
```
csw-dev-0.edu> brun 'echo START: $(date); nvidia-smi; echo END: $(date); sleep 60; echo DONE: $(date)'
```

Please help me fix bugs

Batch Queues

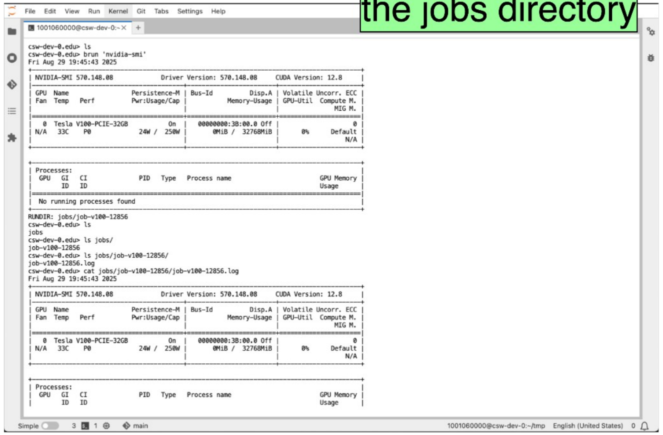
https://github.com/jappavoo/batchtools

brun


File Edit View Run Kernel Git Tabs Settings Help
1001060000@csw-dev-0:~
Simple 3 1 main
1001060000@csw-dev-0:~/tmp English (United States) 0

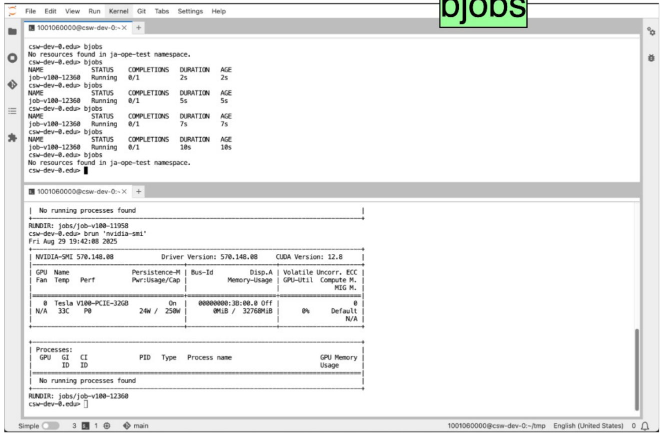
```
csw-dev-0.edu> brun 'nvidia-smi'
Fri Aug 29 19:49:43 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   33C    P0             24W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-13143
csw-dev-0.edu> 
```

the jobs directory


File Edit View Run Kernel Git Tabs Settings Help
1001060000@csw-dev-0:~
Simple 3 1 main
1001060000@csw-dev-0:~/tmp English (United States) 0

```
csw-dev-0.edu> ls
csw-dev-0.edu> brun 'nvidia-smi'
Fri Aug 29 19:45:43 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   33C    P0             24W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-12856
csw-dev-0.edu> ls
jobs
csw-dev-0.edu> ls jobs/
job-v100-12856
csw-dev-0.edu> ls jobs/job-v100-12856/
job-v100-12856.log
csw-dev-0.edu> cat jobs/job-v100-12856/job-v100-12856.log
Fri Aug 29 19:45:43 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   33C    P0             24W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
```

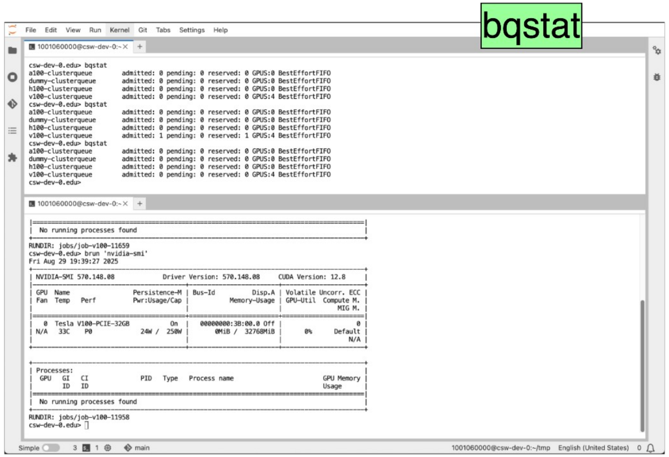
bjobs


File Edit View Run Kernel Git Tabs Settings Help
1001060000@csw-dev-0:~
1001060000@csw-dev-0:~
Simple 3 1 main
1001060000@csw-dev-0:~/tmp English (United States) 0

```
csw-dev-0.edu> bjobs
No resources found in ja-ope-test namespace.
csw-dev-0.edu> bjobs
NAME             STATUS    COMPLETIONS   DURATION   AGE
job-v100-12360   Running   0/1           2s         2s
csw-dev-0.edu> bjobs
NAME             STATUS    COMPLETIONS   DURATION   AGE
job-v100-12360   Running   0/1           5s         5s
csw-dev-0.edu> bjobs
NAME             STATUS    COMPLETIONS   DURATION   AGE
job-v100-12360   Running   0/1           7s         7s
csw-dev-0.edu> bjobs
NAME             STATUS    COMPLETIONS   DURATION   AGE
job-v100-12360   Running   0/1           10s        10s
csw-dev-0.edu> bjobs
No resources found in ja-ope-test namespace.
csw-dev-0.edu> 
```

```
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-11958
csw-dev-0.edu> brun 'nvidia-smi'
Fri Aug 29 19:42:08 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   33C    P0             24W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-12360
csw-dev-0.edu> 
```

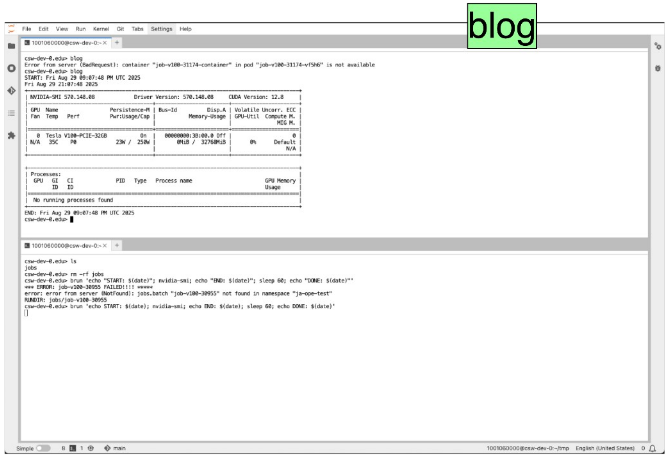
bqstat


File Edit View Run Kernel Git Tabs Settings Help
1001060000@csw-dev-0:~
1001060000@csw-dev-0:~
Simple 3 1 main
1001060000@csw-dev-0:~/tmp English (United States) 0

```
csw-dev-0.edu> bqstat
a100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
dummy-clusterqueue       admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
h100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
v100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:4 BestEffortFIFO
csw-dev-0.edu> bqstat
a100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
dummy-clusterqueue       admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
h100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
v100-clusterqueue        admitted: 1 pending: 0 reserved: 1 GPUS:4 BestEffortFIFO
csw-dev-0.edu> bqstat
a100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
dummy-clusterqueue       admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
h100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:0 BestEffortFIFO
v100-clusterqueue        admitted: 0 pending: 0 reserved: 0 GPUS:4 BestEffortFIFO
csw-dev-0.edu>
```

```
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-11659
csw-dev-0.edu> brun 'nvidia-smi'
Fri Aug 29 19:39:27 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   33C    P0             24W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
RUNDIR: jobs/job-v100-11958
csw-dev-0.edu> 
```

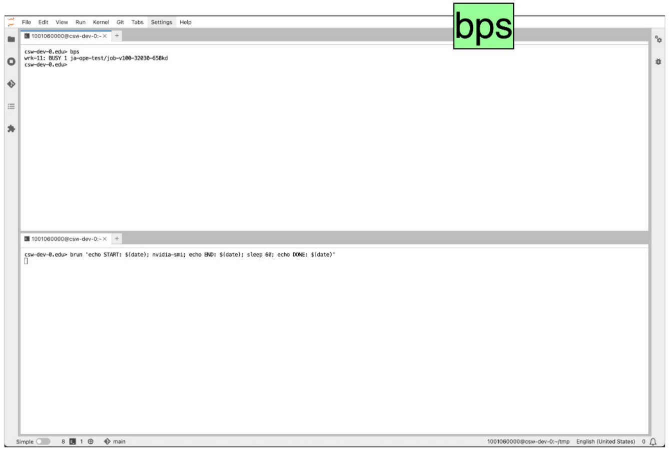
blog


File Edit View Run Kernel Git Tabs Settings Help
1001060000@csw-dev-0:~
1001060000@csw-dev-0:~
Simple 8 1 main
1001060000@csw-dev-0:~/tmp English (United States) 0

```
csw-dev-0.edu> blog
Error from server (BadRequest): container "job-v100-31174-container" in pod "job-v100-31174-vf5h6" is not available
csw-dev-0.edu> blog
START: Fri Aug 29 09:07:48 PM UTC 2025
Fri Aug 29 21:07:48 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 570.148.08             Driver Version: 570.148.08     CUDA Version: 12.8     |
|-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  Tesla V100-PCIE-32GB           On  |   00000000:3B:00.0 Off |                    0 |
| N/A   35C    P0             23W /  250W |       0MiB /  32768MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|  No running processes found                                                             |
+-----------------------------------------------------------------------------------------+
END: Fri Aug 29 09:07:48 PM UTC 2025
csw-dev-0.edu> 
```

```
csw-dev-0.edu> ls
jobs
csw-dev-0.edu> rm -rf jobs
csw-dev-0.edu> brun 'echo "START: $(date)"; nvidia-smi; echo "END: $(date)"; sleep 60; echo "DONE: $(date)"'
*** ERROR: job-v100-30955 FAILED!!!! *****
error: error from server (NotFound): jobs.batch "job-v100-30955" not found in namespace "ja-ope-test"
RUNDIR: jobs/job-v100-30955
csw-dev-0.edu> brun 'echo START: $(date); nvidia-smi; echo END: $(date); sleep 60; echo DONE: $(date)'
```

bps


File Edit View Run Kernel Git Tabs Settings Help
1001060000@csw-dev-0:~
1001060000@csw-dev-0:~
Simple 8 1 main
1001060000@csw-dev-0:~/tmp English (United States) 0

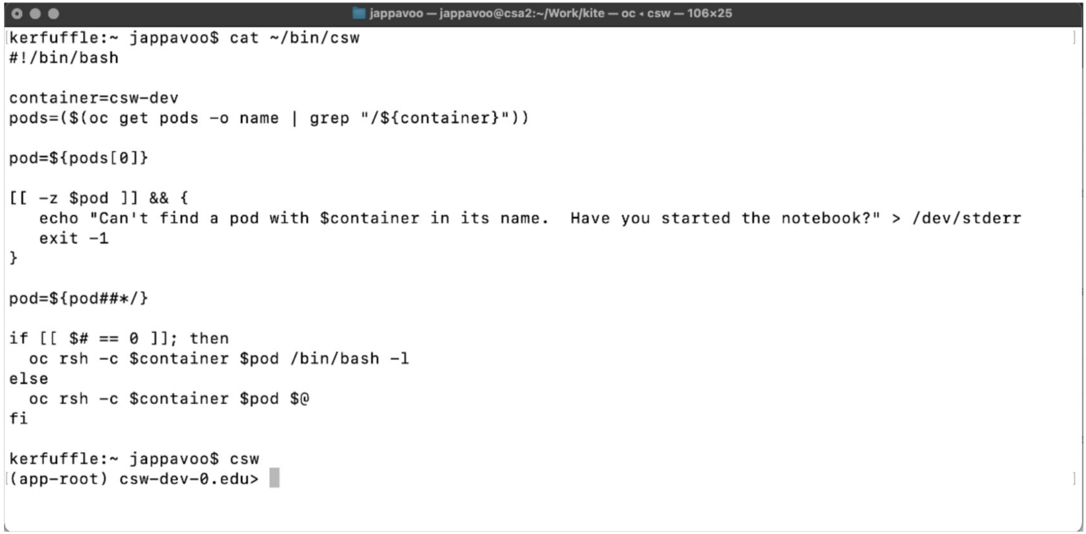
```
csw-dev-0.edu> bps
wrk-11: BUSY 1 ja-ope-test/job-v100-32030-658kd
csw-dev-0.edu>
```

```
csw-dev-0.edu> brun 'echo START: $(date); nvidia-smi; echo END: $(date); sleep 60; echo DONE: $(date)'
```

Terminal Interface

Alternative to using browser

- Install OpenShift CLI client (oc)
  - https://console.apps.edu.nerc.mghpcc.org/command-line-tools
- Get and execute login command
  - https://oauth-openshift.apps.edu.nerc.mghpcc.org/oauth/token/display
- Start csw-dev workbench via Red Hat OpenShift AI
- Use 'oc rsh' and friends
  - see my csw script for an example of how I start shells sessions



```
kerfuffle:~ jappavoo$ cat ~/bin/csw
#!/bin/bash

container=csw-dev
pods=($(oc get pods -o name | grep "/${container}"))

pod=${pods[0]}

[[ -z $pod ]] && {
   echo "Can't find a pod with $container in its name.  Have you started the notebook?" > /dev/stderr
   exit -1
}

pod=${pod##*/}

if [[ $# == 0 ]]; then
  oc rsh -c $container $pod /bin/bash -l
else
  oc rsh -c $container $pod $@
fi

kerfuffle:~ jappavoo$ csw
(app-root) csw-dev-0.edu> 
```

Concurrency, parallelism, scalability, me and you

Our backgrounds, our understanding and why we are here

Some Ice Breakers

Well for geeks anyway

- What does "Parallel Computing" make you think/feel?
- How many cores does your laptop have?
- What is the largest number of cores that a system you have worked on has had?
- What is the largest number of threads you have explicitly created in a program?
- Have you written a pthreaded application? How long did you debug it?
- What are your CS interests?
- Why brings you to this class?