Introduction to Job Submission with HTCondor

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Slides adapted from Lauren Michaels, Rachel Lombardi, Andrew Owen

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Objective

By the end of this session, you should be able to:

- Describe how the HTCondor manages workflows
- Translate your computational tasks to “jobs”
- Run, monitor, and review your jobs
- Submit multiple jobs using multiple methods
- Test, tune, and troubleshoot your workflow

History of HTCondor

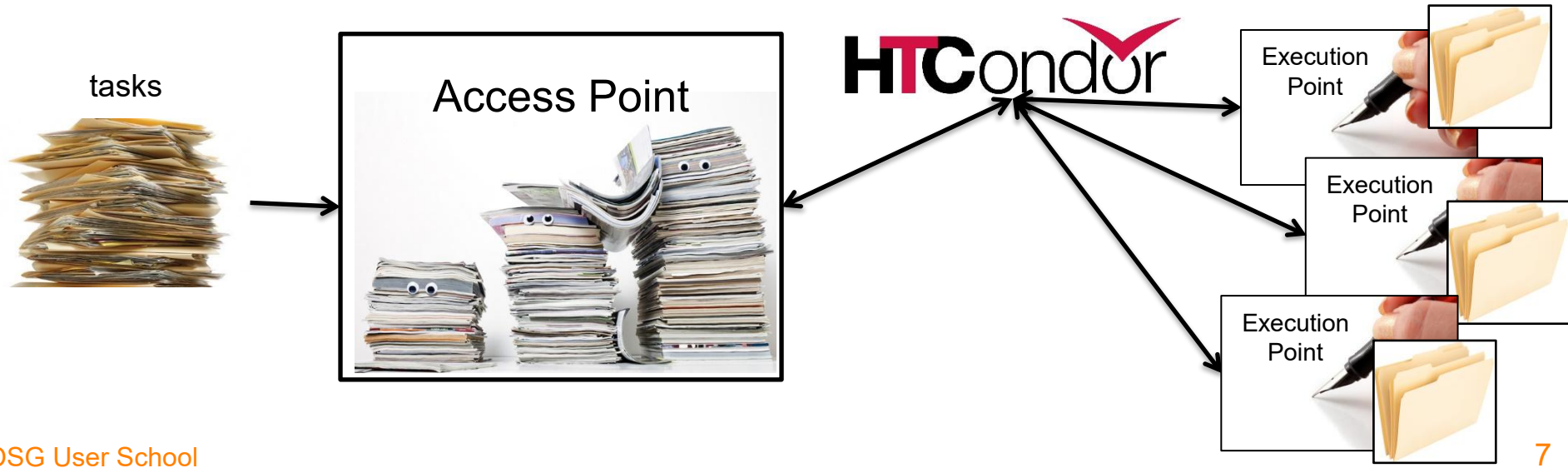
HTCondor History and Status

- Beginnings
  - Started in 1988 as a “cycle scavenger”
- Today
  - Developed at CHTC by professional developers
  - Used all over the world, by:
    - Campuses, national labs, Einstein/Folding@Home
    - Dreamworks, Boeing, SpaceX, investment firms, …
    - **The OSPool!!**
- Miron Livny
  - Professor, UW-Madison Computer Sciences
  - CHTC Director, OSG Technical Director

How does HTCondor work?

HTCondor — How It Works

1. You create and describe your tasks on the **Access Point**.
2. You submit tasks to HTCondor on an **Access Point**.
3. HTCondor schedules your tasks to run on **Execution Points**



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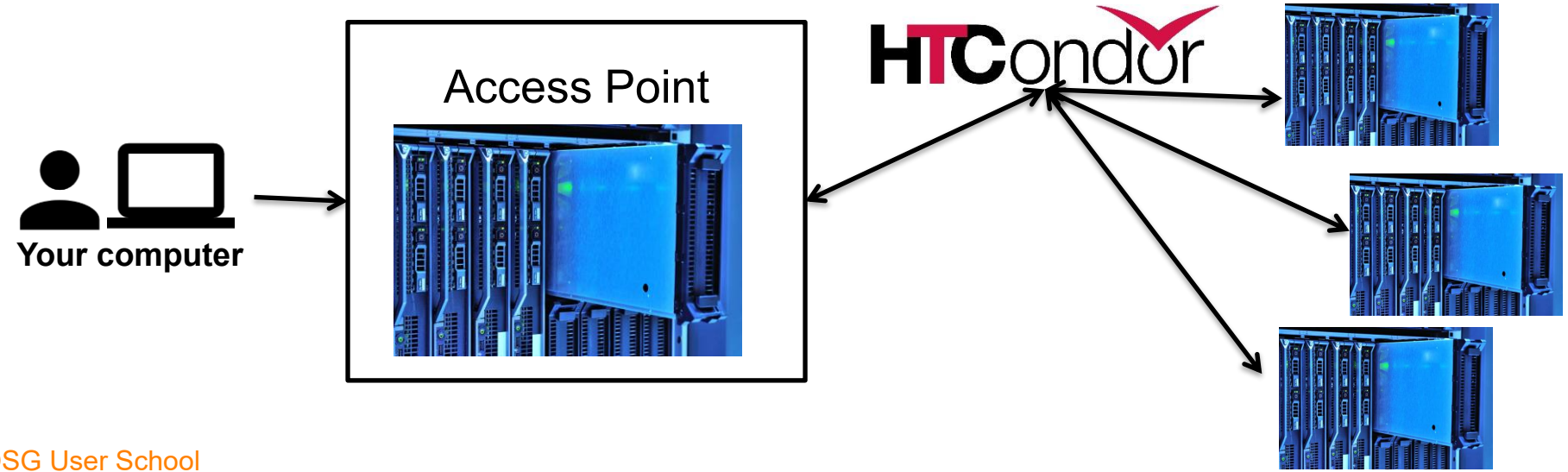


Terminology: *Job*

***Job*: An independently-scheduled unit of computing work**

Three main pieces:

- **Executable:** the script or program to run
- **Input:** any options (arguments) and/or file-based information
- **Output:** files printed by the executable

Note: In order to run *many* jobs, executable must run on the command-line without any graphical input from the user

Terminology: *Machine, Slot*

Machine

- A whole computer (desktop or server)
- Has multiple processors (***CPU cores***), some amount of **memory**, and some amount of file space (**disk**)

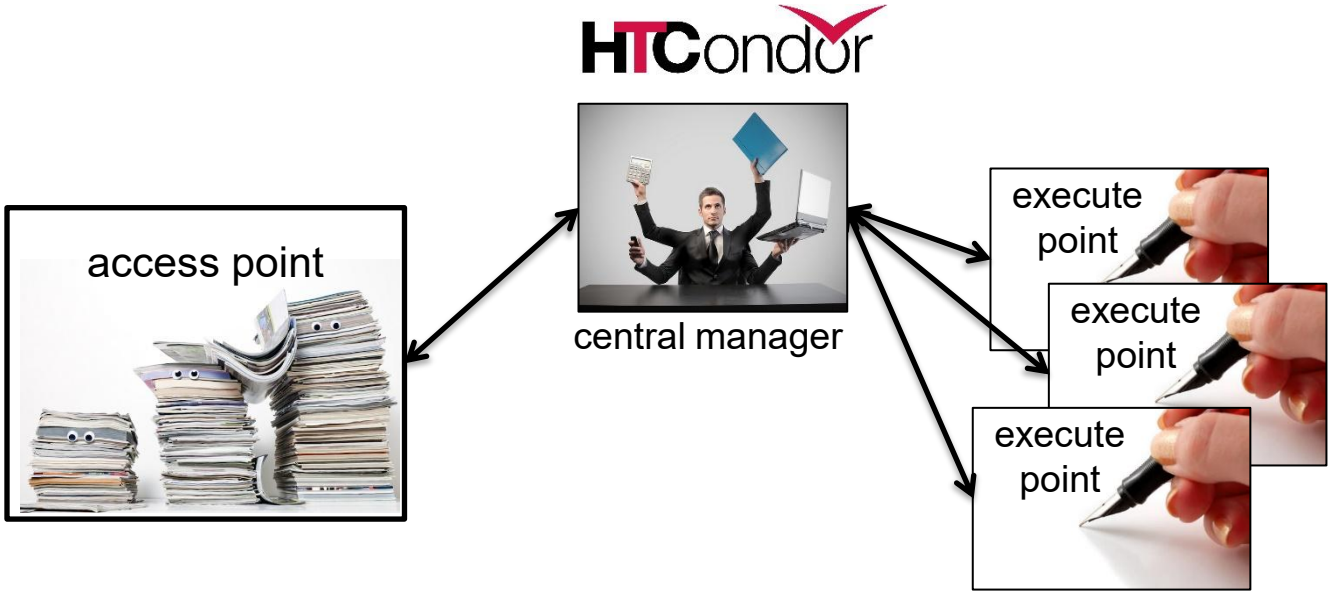
Slot

- **an assignable unit of a machine (i.e. 1 job per slot)**
- may correspond to one core with some memory and disk
- a typical machine will have multiple slots

HTCondor can break up and create new slots, dynamically, as resources become available from completed jobs

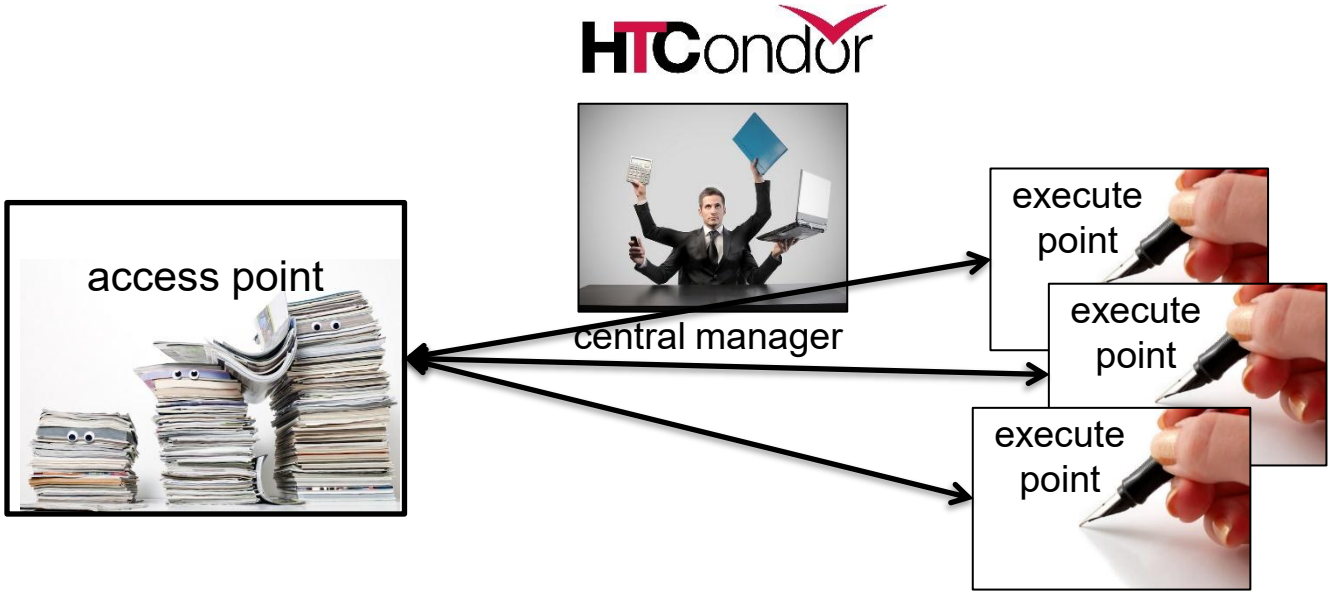
Job Matching

On a regular basis, the ***central manager*** reviews ***Job*** and ***Machine*** attributes and matches jobs to ***Slots***.



Job Execution

Then the Access and Execution points communicate directly.



Basics of submitting jobs

HTCondor — How It Works

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Terminology: *Job*

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Note: In order to run *many* jobs, executable must run on the command-line without any graphical input from the user

Components of a job

Software environment

What software, packages, and libraries do you need?

Executable + arguments

How do you run your computation?

Input files/output files

What input files are needed? What output files are created?

Standard output/error

Where do you save messages printed to the screen?

Requirements

What resources (CPU, GPU, memory, disk) do you need?

Components of a job

Software environment

What software, packages, and libraries do you need?

We will cover Software on Tuesday!

Executable + arguments

How do you run your computation?

Input files/output files

What input files are needed? What output files are created?

Standard output/error

Where do you save messages printed to the screen?

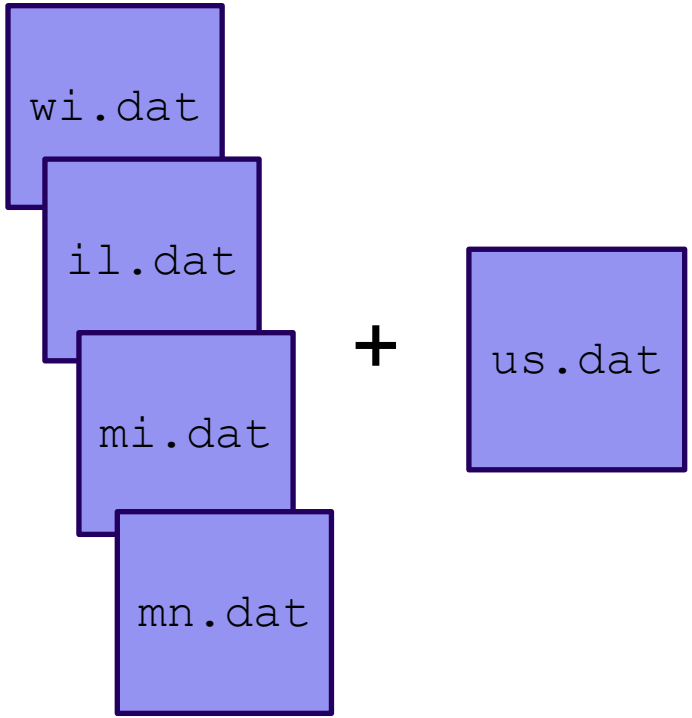
Requirements

What resources (CPU, GPU, memory, disk) do you need?

Job Example

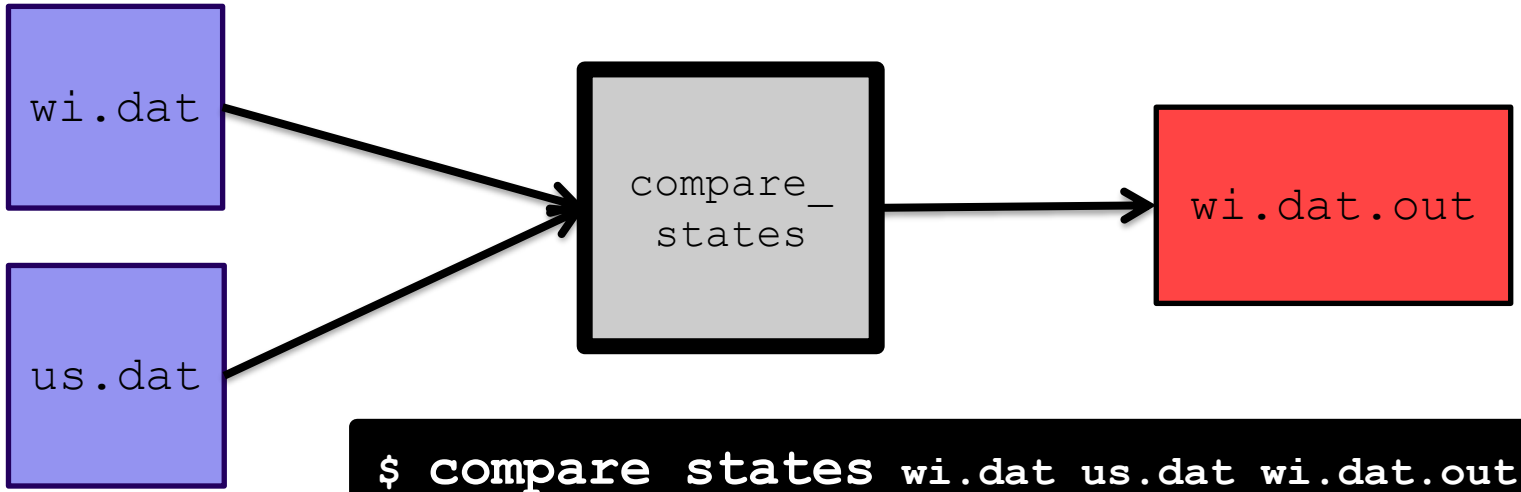
Imagine you are a researcher who needs to compare each state's data to national data.

- One comparison takes a few hours.
- Each comparison is independent.



Command for One Task

Your program called “compare_states” (executable), which compares two data files (input) and produces a single output file.




```
$ compare_states wi.dat us.dat wi.dat.out
```

HTCondor Submit File

```
executable = compare_states
arguments = wi.dat us.dat wi.dat.out

transfer_input_files = us.dat, wi.dat

log = job.log
output = job.out
error = job.err

request_cpus = 1
request_disk = 20MB
request_memory = 20MB

queue 1
```

HTCondor Submit File

```
executable = compare_states
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transfer_input_files = us.dat, wi.dat

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request_cpus = 1
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queue 1
```

List your **`executable`** and any **`arguments`** it takes

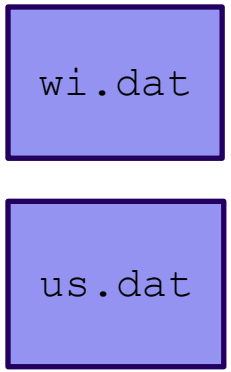
Arguments are any options passed to the executable from the command line

```
$ compare_states wi.dat us.dat wi.dat.out
```

HTCondor Submit File

```
executable = compare_states
arguments = wi.dat us.dat wi.dat.out

transfer_input_files = us.dat, wi.dat

log = job.log
output = job.out
error = job.err

request_cpus = 1
request_disk = 20MB
request_memory = 20MB

queue 1
```

Provide HTCondor a comma-separated list of **input files to transfer** to the slot



The Access Point and the Execution Point are **separate** machines, so we must specify which files to transfer.

HTCondor Submit File

```
executable = compare_states
arguments = wi.dat us.dat wi.dat.out

transfer_input_files = us.dat, wi.dat

log = job.log
output = job.out
error = job.err

request_cpus = 1
request_disk = 20MB
request_memory = 20MB

queue 1
```

HTCondor will transfer back all new and changed files (output) from the job, automatically.

HTCondor Submit File

```
executable = compare_states
arguments = wi.dat us.dat wi.dat.out

transfer_input_files = us.dat, wi.dat

log = job.log
output = job.out
error = job.err

request_cpus = 1
request_disk = 20MB
request_memory = 20MB

queue 1
```

log: file created by HTCondor to track job progress

- *Explored in exercises!*

output/**error**: captures stdout and stderr from your program (what would otherwise be printed to the terminal)

HTCondor Submit File

```
executable = compare_states
arguments = wi.dat us.dat wi.dat.out

transfer_input_files = us.dat, wi.dat

log = job.log
output = job.out
error = job.err

request_cpus = 1
request_disk = 20MB
request_memory = 20MB

queue 1
```

`request_cpus`, `request_disk`, `request_memory`:

the resources your job needs.

HTCondor Submit File

```
executable = compare_states
arguments = wi.dat us.dat wi.dat.out

transfer_input_files = us.dat, wi.dat

log = job.log
output = job.out
error = job.err

request_cpus = 1
request_disk = 20MB
request_memory = 20MB

queue 1
```

Very important to request appropriate resources (***memory***, ***cpus***, ***disk***)

- **requesting too little**: causes problems for your jobs; jobs might by ‘held’ by HTCondor
- **requesting too much:** jobs will match to fewer “slots” than they could, and you’ll block other jobs

HTCondor Submit File

```
executable = compare_states
arguments = wi.dat us.dat wi.dat.out

transfer_input_files = us.dat, wi.dat

log = job.log
output = job.out
error = job.err

request_cpus = 1
request_disk = 20MB
request_memory = 20MB

queue 1
```

queue: keyword indicating the number of jobs to queue

- must be the last line of the submit file

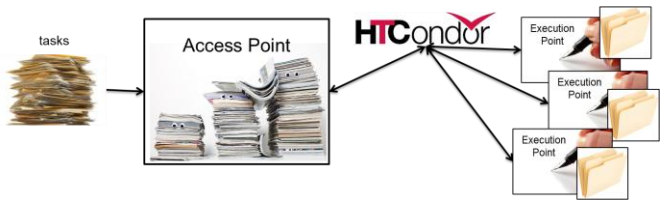
- has different syntax options we will learn later!

Let's pause!

```
executable = compare_states
arguments = wi.dat us.dat wi.dat.out

transfer_input_files = us.dat, wi.dat

log = job.log
output = job.out
error = job.err

request_cpus = 1
request_disk = 20MB
request_memory = 20MB

queue 1
```

What questions do you have about—

- How HTCondor works?
- Components of a job?
- The HTCondor submit file?



Submitting and monitoring HTCondor jobs

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Submitting and Monitoring

- Submit jobs on the Access Point
- To submit jobs: **`condor_submit submit_file`**
- To monitor submitted jobs: **`condor_q`**

```
$ condor_submit job.submit
Submitting job(s).
1 job(s) submitted to cluster 128.

$ condor_q
-- Schedd: ap40.uw.osg-htc.org : <128.105.68.62:9618> @ 08/01/24 10:35:54
OWNER  BATCH_NAME              SUBMITTED   DONE   RUN    IDLE  TOTAL JOB_IDS
alice  ID:128                 8/1  10:05      _      _      1      1 128.0

1 jobs; 0 completed, 0 removed, 1 idle, 0 running, 0 held, 0 suspended
```

HTCondor Manual: condor_submit
HTCondor Manual: condor_q

More about `condor_q`

- By default, **`condor_q`** …
  - Only shows your jobs and not anyone else's
  - Groups jobs that were submitted together ("batch" or "cluster")
  - Only shows active batches

```
$ condor_q
-- Schedd: ap40.uw.osg-htc.org : <128.105.68.62:9618> @ 08/01/24 10:35:54
OWNER  BATCH_NAME              SUBMITTED   DONE   RUN    IDLE  TOTAL JOB_IDS
alice  CMD: compare_states   8/1  10:09      3     4       3     10 129.0-9

10 jobs; 3 completed, 0 removed, 3 idle, 4 running, 0 held, 0 suspended
```

JobId = **ClusterID.ProcID**

- Limit **`condor_q`** by *`username`*, *`ClusterId`* or full *`JobId`*, (denoted `[U/C/J]` in following slides).

More about `condor_q`

- To see individual job details, use:
  `condor_q -nobatch`

```
$ condor_q -nobatch
-- Schedd: ap40.uw.osg-htc.org : <128.105.68.62:9618>
 ID          OWNER      SUBMITTED     RUN_TIME ST PRI SIZE CMD
129.0        alice      8/1  10:09   0+00:00:00 I  0   0.0 compare_states
129.1        alice      8/1  10:09   0+00:00:00 R  0   0.0 compare_states
...

7 jobs; 0 completed, 0 removed, 3 idle, 4 running, 0 held, 0 suspended
```

- We will use the **`-nobatch`** option in the following slides to see extra detail about what is happening with a job

Monitoring Jobs with condor_q

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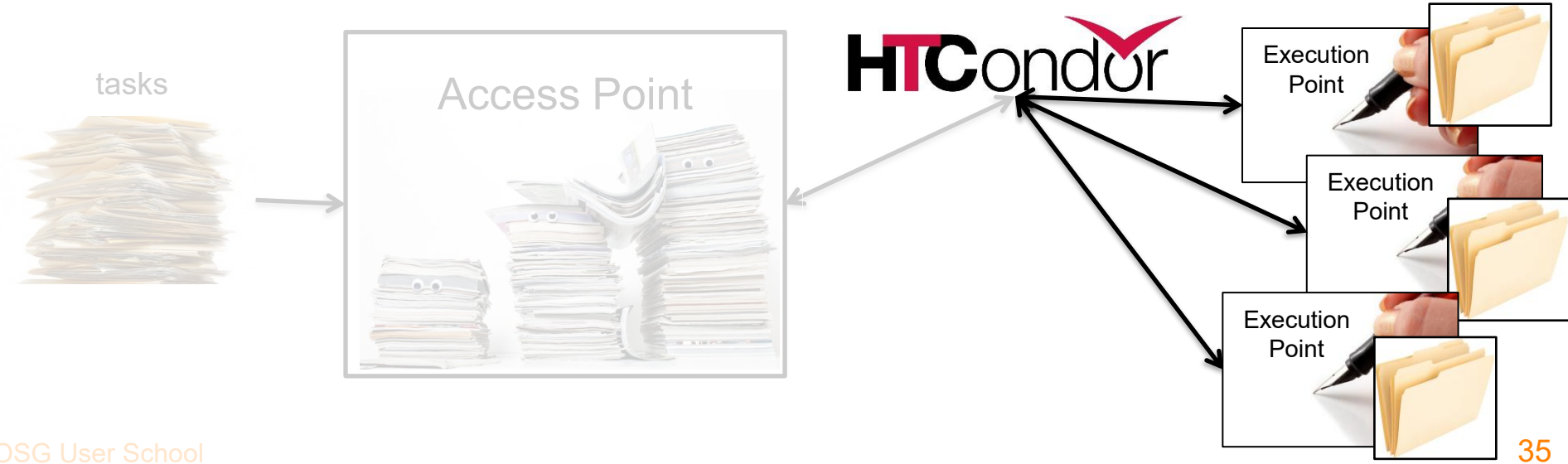


Job Idle

```
$ condor_q -nobatch
-- Schedd: ap40.uw.osg-htc.org : <128.105.68.62:9618>
 ID          OWNER      SUBMITTED     RUN_TIME ST PRI SIZE CMD
128.0        alice      8/1  10:05   0+00:00:00 I  0   0.0 compare_states wi.dat us.dat

Total for query: 1 jobs; 0 completed, 0 removed, 1 idle, 0 running, 0 held, 0 suspended
```

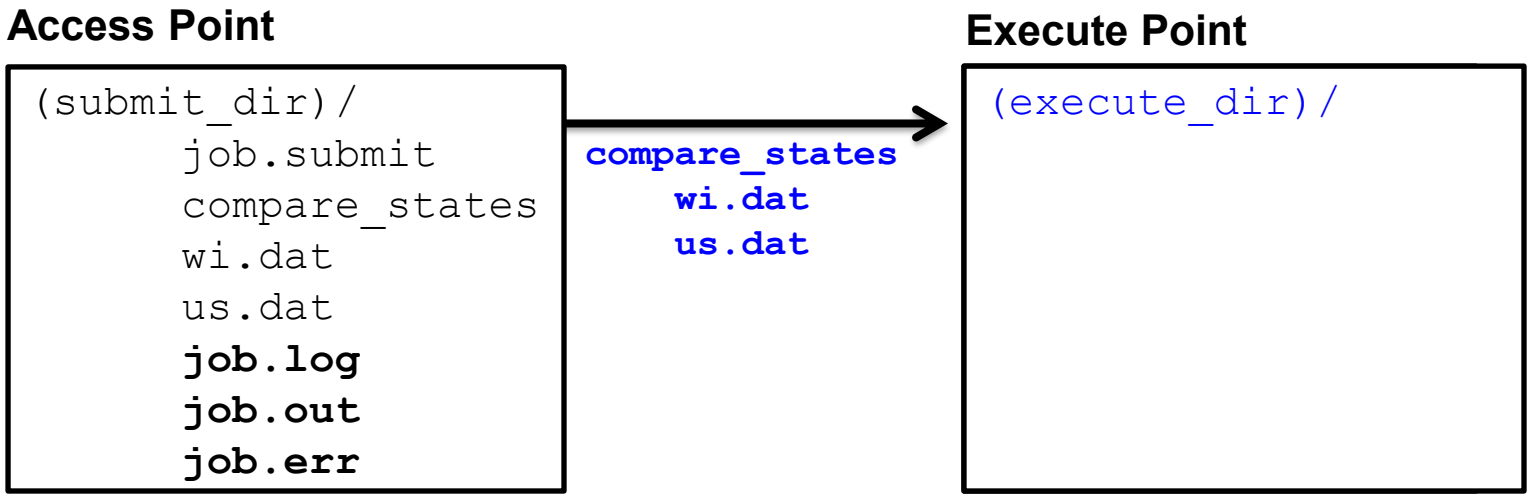
Access Point

```
(submit_dir)/
        job.submit
        compare_states
        wi.dat
        us.dat
        job.log
        job.out
        job.err
```

Job Starts

```
$ condor_q -nobatch
-- Schedd: ap40.uw.osg-htc.org : <128.105.68.62:9618>
 ID          OWNER      SUBMITTED     RUN_TIME ST PRI SIZE CMD
128.0        alice      8/1  10:05   0+00:00:00 <  0   0.0 compare_states wi.dat us.dat

Total for query: 1 jobs; 0 completed, 0 removed, 1 idle, 0 running, 0 held, 0 suspended
```



Job Running

```
$ condor_q -nobatch
-- Schedd: ap40.uw.osg-htc.org : <128.105.68.62:9618>
 ID          OWNER      SUBMITTED     RUN_TIME ST PRI SIZE CMD
128.0        alice      8/1  10:05   0+00:00:00 R  0   0.0 compare_states wi.dat us.dat

Total for query: 1 jobs; 0 completed, 0 removed, 0 idle, 1 running, 0 held, 0 suspended
```

Access Point

```
(submit_dir)/
        job.submit
        compare_states
        wi.dat
        us.dat
        job.log
        job.out
        job.err
```

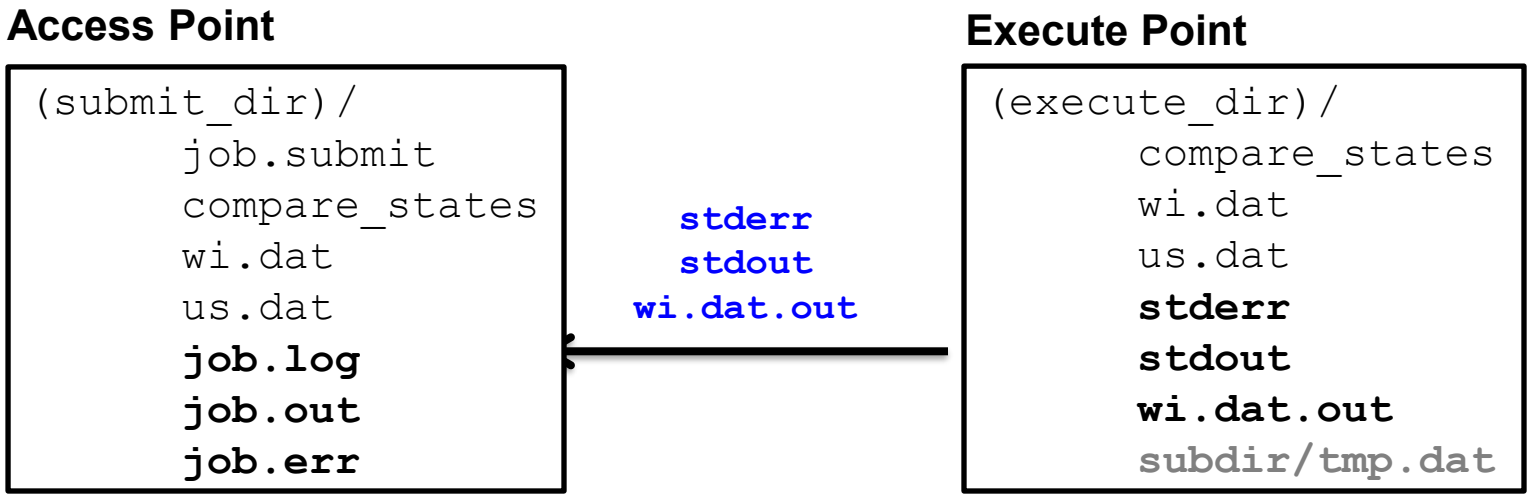
Execute Point

```
(execute_dir)/
        compare_states
        wi.dat
        us.dat
        stderr
        stdout
        wi.dat.out
        subdir/tmp.dat
```

Job Completes

```
$ condor_q -nobatch
-- Schedd: ap40.uw.osg-htc.org : <128.105.68.62:9618>
 ID          OWNER      SUBMITTED     RUN_TIME ST PRI SIZE CMD
128.0        alice      8/1  10:05   0+00:00:00 >  0   0.0 compare_states wi.dat us.dat

Total for query: 1 jobs; 0 completed, 0 removed, 0 idle, 1 running, 0 held, 0 suspended
```



Job Completes (cont.)

```
$ condor_q -nobatch
-- Schedd: ap40.uw.osg-htc.org : <128.105.68.62:9618>
 ID          OWNER      SUBMITTED     RUN_TIME ST PRI SIZE CMD

Total for query: 0 jobs; 0 completed, 0 removed, 0 idle, 0 running, 0 held, 0 suspended
```

Access Point

```
(submit_dir)/
        job.submit
        compare_states
        wi.dat
        us.dat
        job.log
        job.out
        job.err
        wi.dat.out
```

Job completed →
Disappears from **`condor_q`** output!

Reviewing Completed Jobs

Log File

```
000 (128.000.000) 2024-08-01 10:05:08 Job submitted from host: <128.104.101.92>
...
001 (128.000.000) 2024-08-01 10:05:46 Job executing on host: <128.104.101.128:9618>
...
006 (128.000.000) 2024-08-01 10:07:54 Image size of job updated: 220
        1  -  MemoryUsage of job (MB)
        220  -  ResidentSetSize of job (KB)
...
005 (128.000.000) 2024-08-01 10:12:48 Job terminated.
        (1) Normal termination (return value 0)
                Usr 0 00:00:00, Sys 0 00:00:00  -  Run Remote Usage
                Usr 0 00:00:00, Sys 0 00:00:00  -  Run Local Usage
                Usr 0 00:00:00, Sys 0 00:00:00  -  Total Remote Usage
                Usr 0 00:00:00, Sys 0 00:00:00  -  Total Local Usage
        0  -  Run Bytes Sent By Job
        33  -  Run Bytes Received By Job
        0  -  Total Bytes Sent By Job
        33  -  Total Bytes Received By Job
        Partitionable Resources :    Usage  Request Allocated
           Cpus                 :                1         1
           Disk (KB)            :       14    20480  17203728
           Memory (MB)          :        1       20        20
```

Reviewing Jobs

- To review a large group of jobs at once, use **`condor_history`**

As **`condor_q`** is to the present, **`condor_history`** is to the past

```
$ condor_history alice
 ID      OWNER    SUBMITTED   RUN_TIME    ST  COMPLETED   CMD
189.1012 alice    5/11 09:52   0+00:07:37 C   5/11 16:00 /home/alice
189.1002 alice    5/11 09:52   0+00:08:03 C   5/11 16:00 /home/alice
189.1081 alice    5/11 09:52   0+00:03:16 C   5/11 16:00 /home/alice
189.944  alice    5/11 09:52   0+00:11:15 C   5/11 16:00 /home/alice
189.659  alice    5/11 09:52   0+00:26:56 C   5/11 16:00 /home/alice
189.653  alice    5/11 09:52   0+00:27:07 C   5/11 16:00 /home/alice
189.1040 alice    5/11 09:52   0+00:05:15 C   5/11 15:59 /home/alice
189.1003 alice    5/11 09:52   0+00:07:38 C   5/11 15:59 /home/alice
189.962  alice    5/11 09:52   0+00:09:36 C   5/11 15:59 /home/alice
189.961  alice    5/11 09:52   0+00:09:43 C   5/11 15:59 /home/alice
189.898  alice    5/11 09:52   0+00:13:47 C   5/11 15:59 /home/alice
```

Watching Job Progress with condor_watch_q

Watching Progress of Jobs

- To get a live update of the progress of your jobs, use **`condor_watch_q`**

  This command does an initial **`condor_q`** and then tracks the entries of the corresponding .log file(s)

```
$ condor_watch_q
BATCH         IDLE   RUN   DONE   TOTAL   JOB_IDS
ID: 129        10     -      -      10    129.0 ... 129.9 [--------------------]

[------------------------------------------------------------------------------]

Total: 10 jobs; 10 idle

Updated at 2024-08-01 10:10:32
Input ^C to exit
```

Watching Progress of Jobs

- As the work progresses, output updates with changes to the progress bar
  - updates every 2 seconds

```
$ condor_watch_q
BATCH         IDLE   RUN   DONE   TOTAL   JOB_IDS
ID: 129         9     1      -      10    129.0 ... 129.9 [==------------------]

[=======-----------------------------------------------------------------------]

Total: 10 jobs; 9 idle, 1 running

Updated at 2024-08-01 10:10:52
Input ^C to exit
```

Watching Progress of Jobs

- Yellow hyphens (-) = “idle”
- Blue greater than signs (>) = “transferring files”
- Blue equal signs (=) = “running”
- Green number signs (#) = “completed”
- Red exclamation marks (!) = “hold”

```
$ condor_watch_q
BATCH         IDLE   RUN   DONE   TOTAL   JOB_IDS
ID: 129         3     4      3      10    129.0 ... 129.9 [######========------]

[####################==============================----------]

Total: 10 jobs; 3 completed, 4 idle, 3 running

Updated at 2024-08-01 10:11:52
Input ^C to exit
```

Watching Progress of Jobs

- To exit out of the `condor_watch_q` view, use the keyboard shortcut `Ctrl+C`

```
$ condor_watch_q
BATCH         IDLE   RUN   DONE   TOTAL   JOB_IDS
ID: 129         -     -     10      10    129.0 ... 129.9 [####################]

[##########################################################################]

Total: 10 jobs; 3 completed, 4 idle, 3 running

Updated at 2024-08-01 10:11:52
Input ^C to exit
```

Questions?