AN INTRODUCTION TO USING HTCondor

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Covered In This Tutorial

- What is HTCondor?
- Running a Job with HTCondor
- Submitting Multiple Jobs with HTCondor

  - pause for questions -

- How HTCondor Matches and Runs Jobs
- Testing and Troubleshooting
- Use Cases and HTCondor Features
- Automation

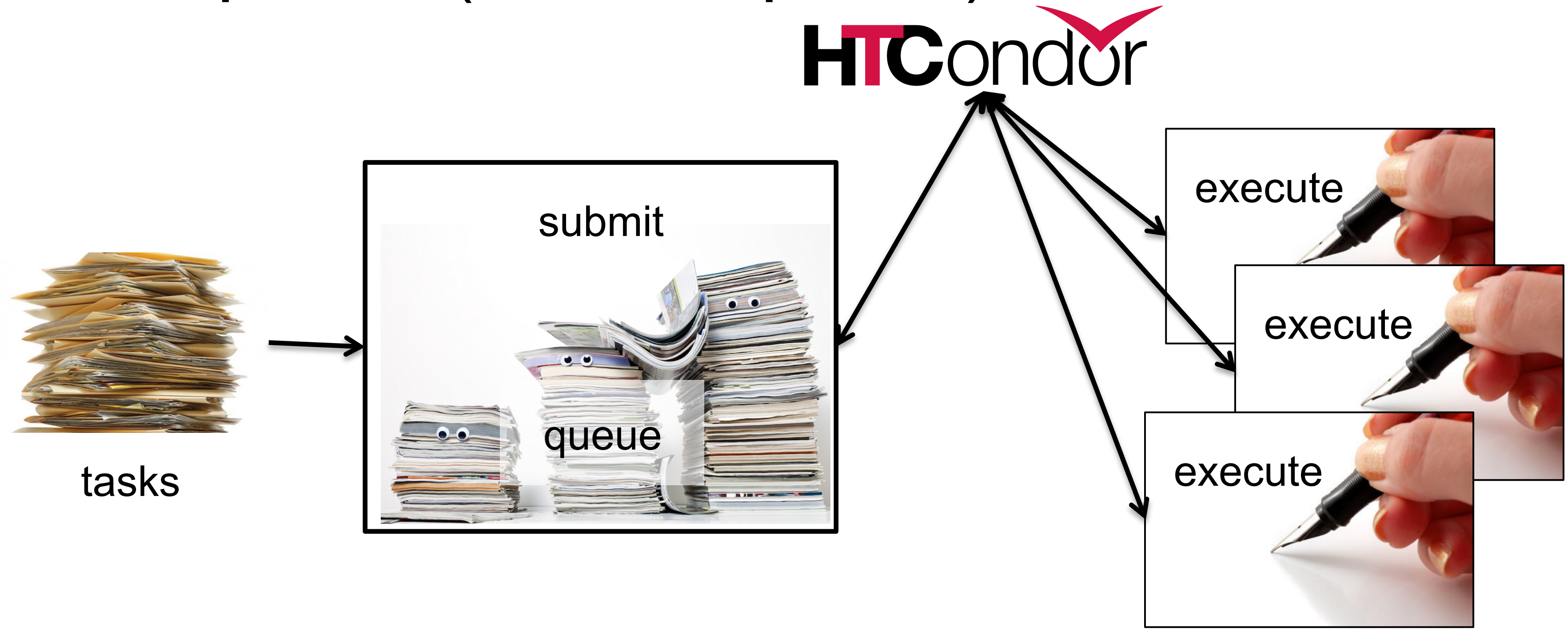
Introduction

What is HTCondor?

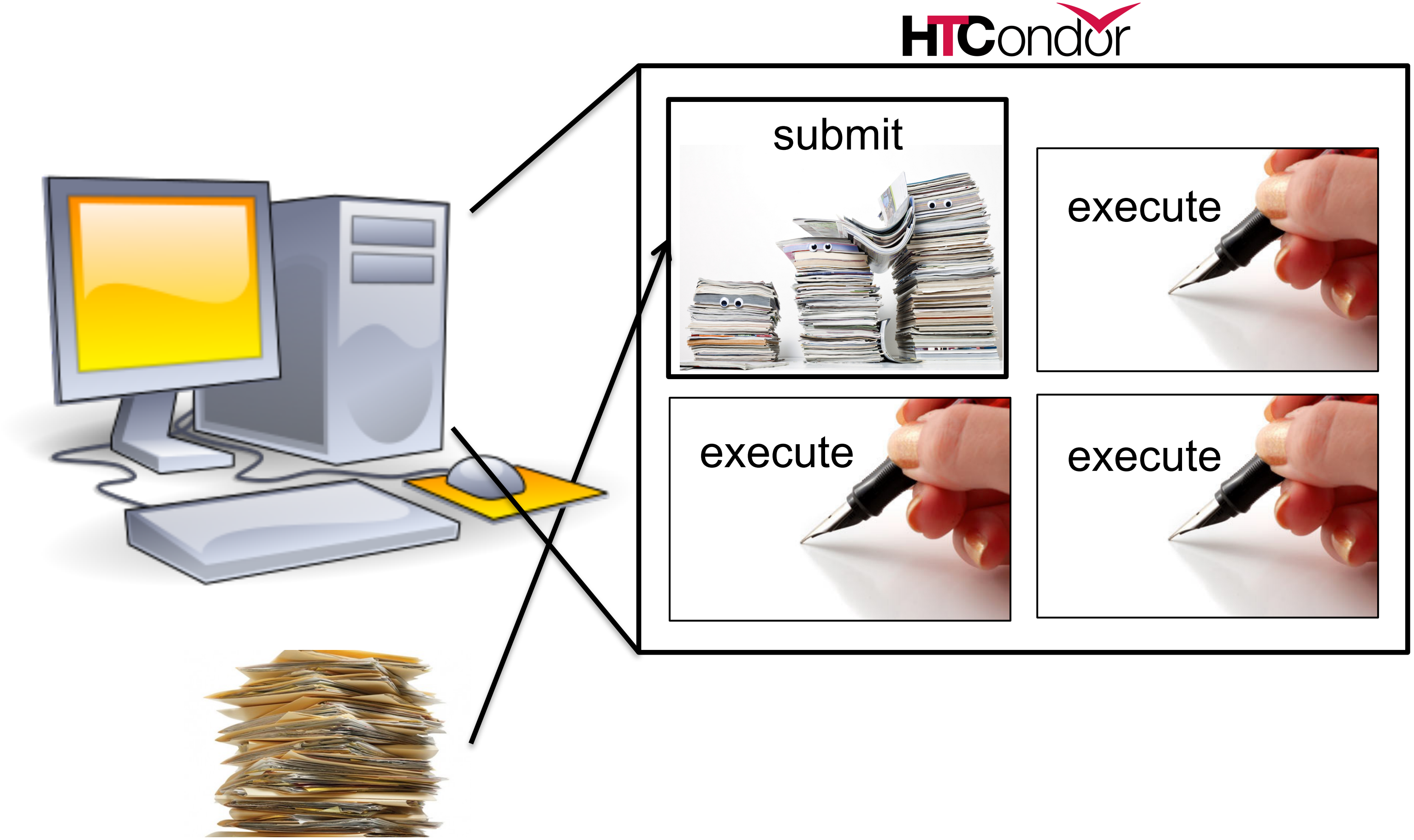
- Software that schedules and runs computing tasks on computers

How It Works

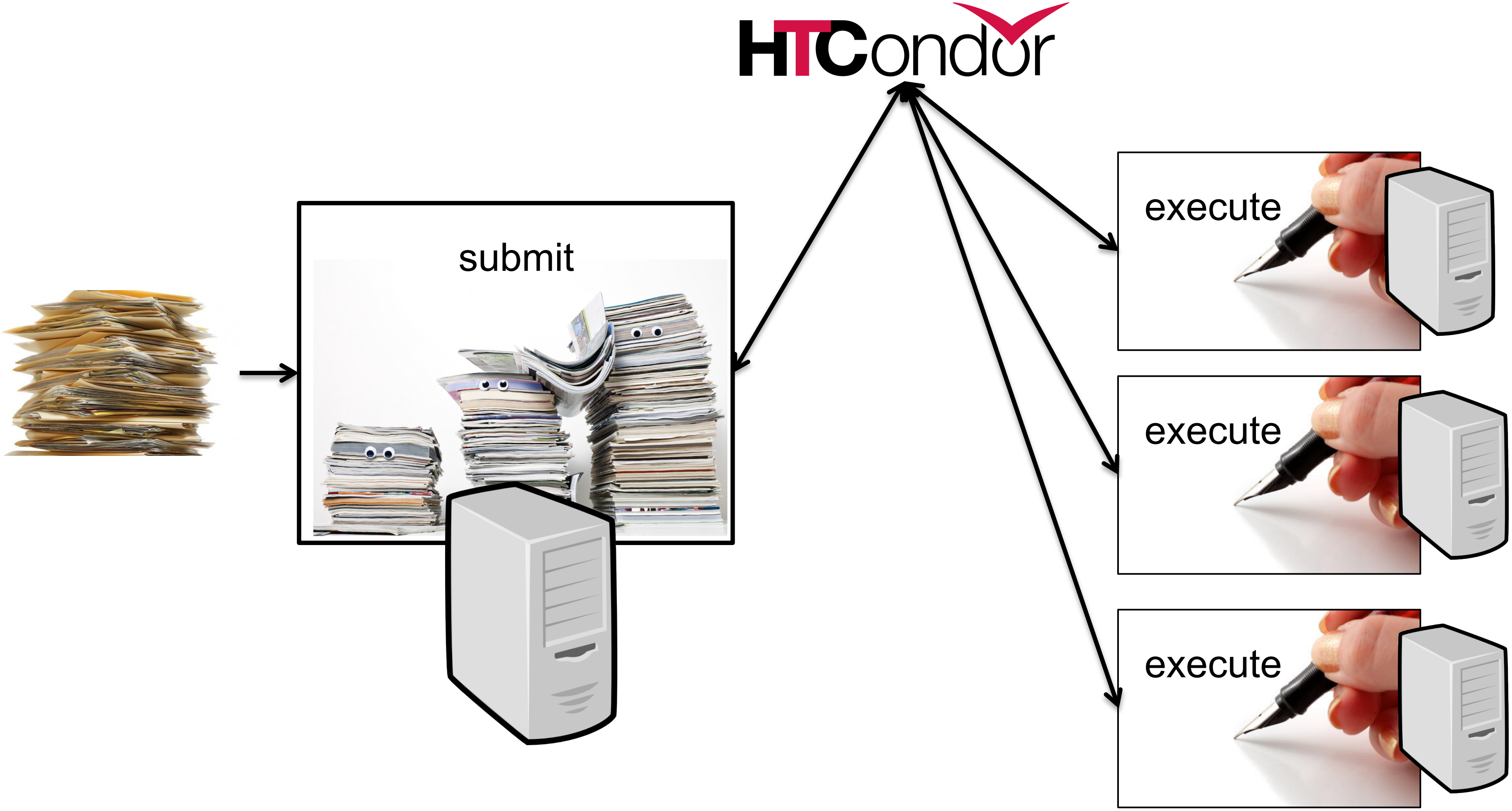
- Submit tasks to a queue (on a submit point)
- HTCondor schedules them to run on computers (execute points)



HTCondor on One Computer



HTCondor on Many Computers



Why HTCondor?

- HTCondor manages and runs work on your behalf
- Schedule tasks on a single computer to not overwhelm the computer
- Schedule tasks on a group* of computers (which may/may not be directly accessible to the user)
- Schedule tasks submitted by multiple users on one or more computers

*in HTCondor-speak, a “pool”

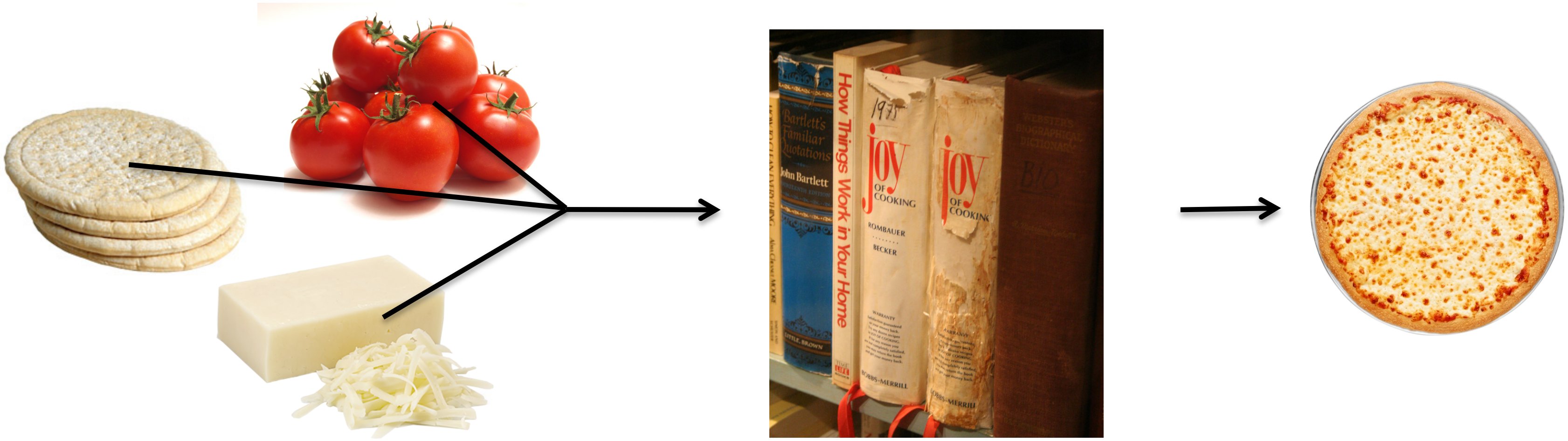
User-Focused Tutorial

- For the purposes of this tutorial, we are assuming that someone else has set up HTCondor on a computer/computers to create a HTCondor “pool”.
- The focus of this talk is how to run computational work on this system.

Running a Job with HTCondor

Jobs

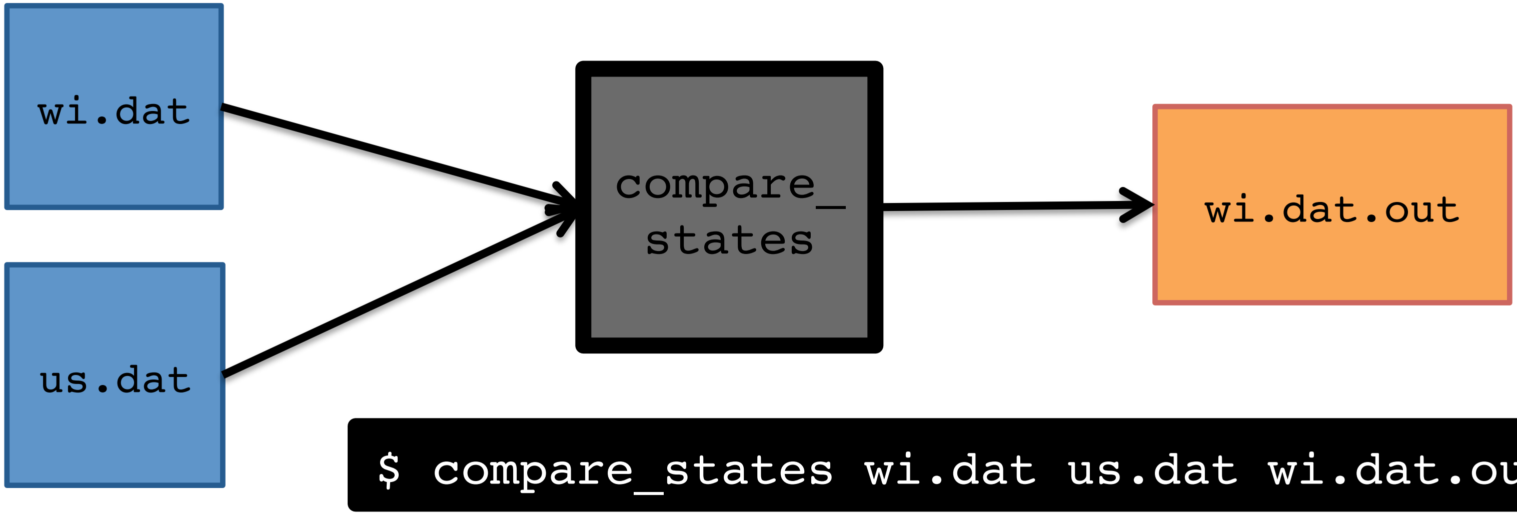
- A single computing task is called a “job”
- Three main pieces of a job are the input, executable (program) and output



- Executable must be runnable from the command line without any interactive input

Job Example

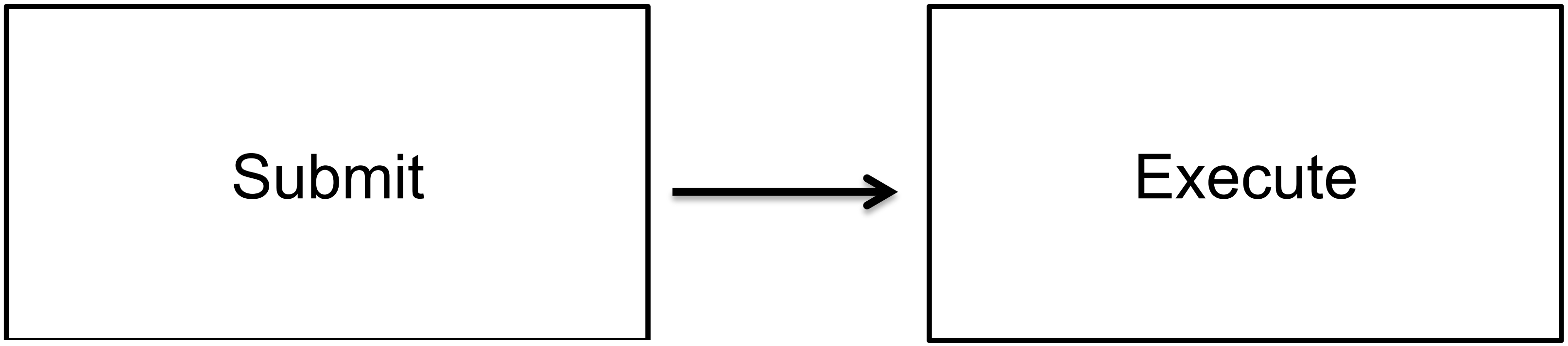
- For our example, we will be using an imaginary program called “compare_states”, which compares two data files and produces a single output file.



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

File Transfer

- Our example will use HTCondor’s file transfer option:



Submit

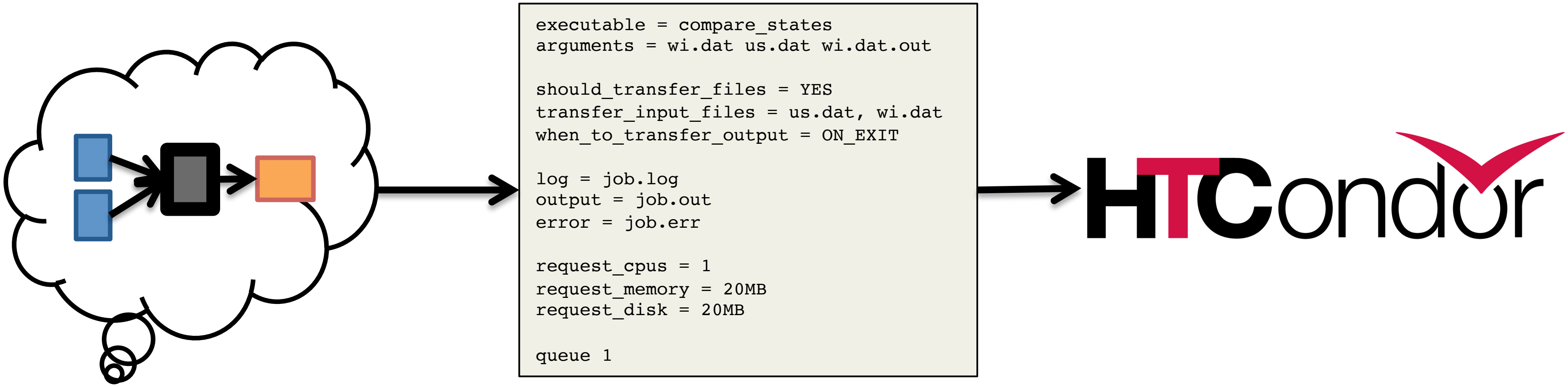
Execute

```
(submit_dir)/
  input files
  executable
```

```
(execute_dir)/
  output files
```

Job Translation

- Submit file: communicates everything about your job(s) to HTCondor



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

should_transfer_files = YES
transfer_input_files = us.dat, wi.dat
when_to_transfer_output = ON_EXIT

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

request_cpus = 1
request_memory = 20MB
request_disk = 20MB

queue 1
```

Submit File

job.submit

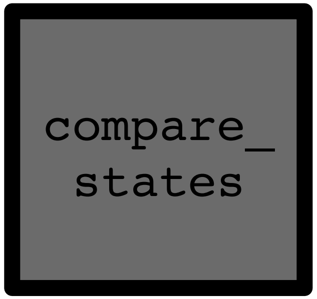
```
executable = compare_states
arguments = wi.dat us.dat wi.dat.out

should_transfer_files = YES
transfer_input_files = us.dat, wi.dat
when_to_transfer_output = ON_EXIT

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

request_cpus = 1
request_memory = 20MB
request_disk = 20MB

queue 1
```

Submit File

job.submit

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

should_transfer_files = YES
transfer_input_files = us.dat, wi.dat
when_to_transfer_output = ON_EXIT

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

request_cpus = 1
request_memory = 20MB
request_disk = 20MB

queue 1
```

- List your executable and any arguments it takes.



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

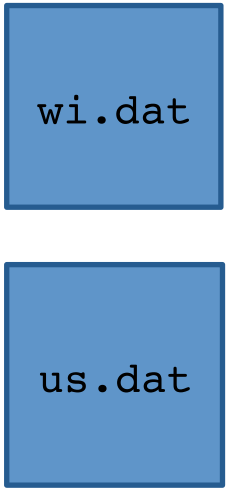
```
$ compare_states wi.dat us.dat wi.dat.out
```

Submit File

job.submit

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

should_transfer_files = YES
transfer_input_files = us.dat, wi.dat
when_to_transfer_output = ON_EXIT

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

request_cpus = 1
request_memory = 20MB
request_disk = 20MB

queue 1
```

- Indicate your input files.



Submit File

job.submit

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

should_transfer_files = YES
transfer_input_files = us.dat, wi.dat
when_to_transfer_output = ON_EXIT

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

request_cpus = 1
request_memory = 20MB
request_disk = 20MB

queue 1
```

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

wi.dat.out

Submit File

job.submit

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

should_transfer_files = YES
transfer_input_files = us.dat, wi.dat
when_to_transfer_output = ON_EXIT

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

request_cpus = 1
request_memory = 20MB
request_disk = 20MB

queue 1
```

- `log`: file created by HTCondor to track job progress
- `output`/`error`: captures stdout and stderr

Submit File

job.submit

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

should_transfer_files = YES
transfer_input_files = us.dat, wi.dat
when_to_transfer_output = ON_EXIT

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

request_cpus = 1
request_memory = 20MB
request_disk = 20MB

queue 1
```

- Request the appropriate resources for your job to run.
- `queue`: keyword indicating “create a job.”

Submitting and Monitoring

- To submit a job/jobs:

  condor_submit *submit_file_name*

- To monitor submitted jobs, use:

  condor_q

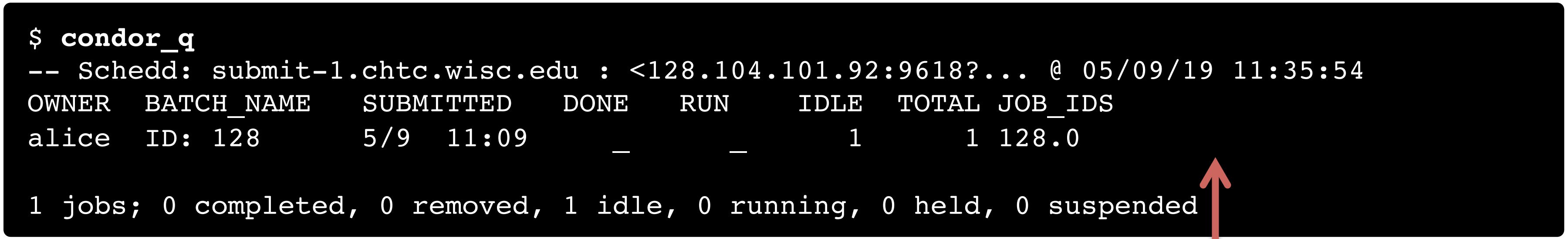
```
$ condor_submit job.submit
Submitting job(s).
1 job(s) submitted to cluster 128.
```

```
$ condor_q
-- Schedd: submit-1.chtc.wisc.edu : <128.104.101.92:9618?... @ 05/01/19 10:35:54
OWNER  BATCH_NAME    SUBMITTED   DONE   RUN    IDLE  TOTAL JOB_IDS
alice  ID: 128       5/9  11:09     _      _      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** shows:
  - user's job(s) only (as of 8.6)
  - jobs summarized in "batches" (as of 8.6)
- Constrain with username, `ClusterId` or full `JobId`, which will be denoted `[U/C/J]` in the following slides



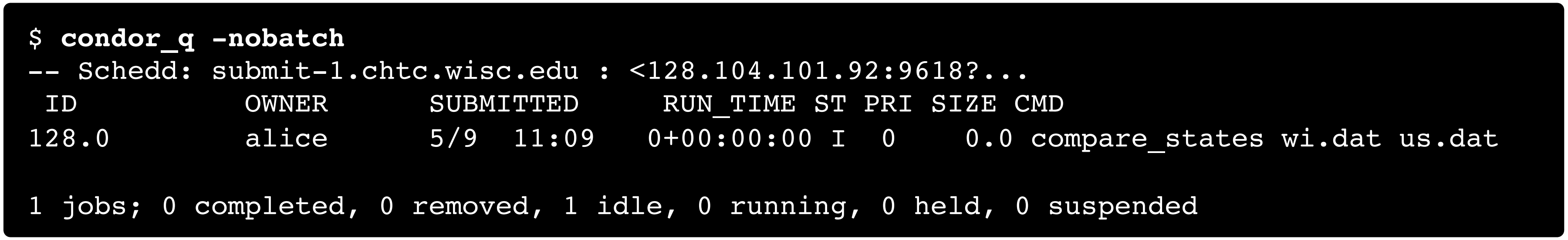
```
$ condor_q
-- Schedd: submit-1.chtc.wisc.edu : <128.104.101.92:9618?... @ 05/09/19 11:35:54
OWNER  BATCH_NAME   SUBMITTED   DONE   RUN    IDLE  TOTAL JOB_IDS
alice  ID: 128      5/9  11:09     _      _      1      1 128.0

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

`JobId` = `ClusterId`.`ProcId`

More about condor_q

- To see individual job information, use:

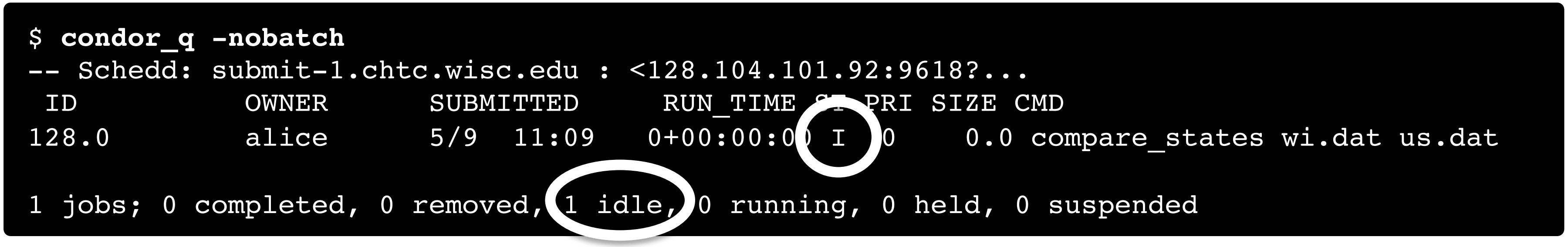
  condor_q -nobatch



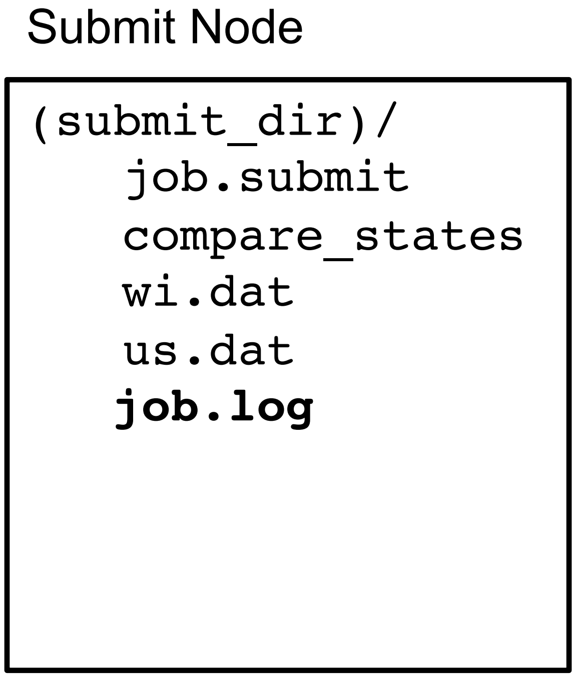
```
$ condor_q -nobatch
-- Schedd: submit-1.chtc.wisc.edu : <128.104.101.92:9618?...
 ID          OWNER      SUBMITTED     RUN_TIME ST PRI SIZE CMD
128.0        alice      5/9  11:09   0+00:00:00 I  0    0.0 compare_states wi.dat us.dat

1 jobs; 0 completed, 0 removed, 1 idle, 0 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

Job Idle

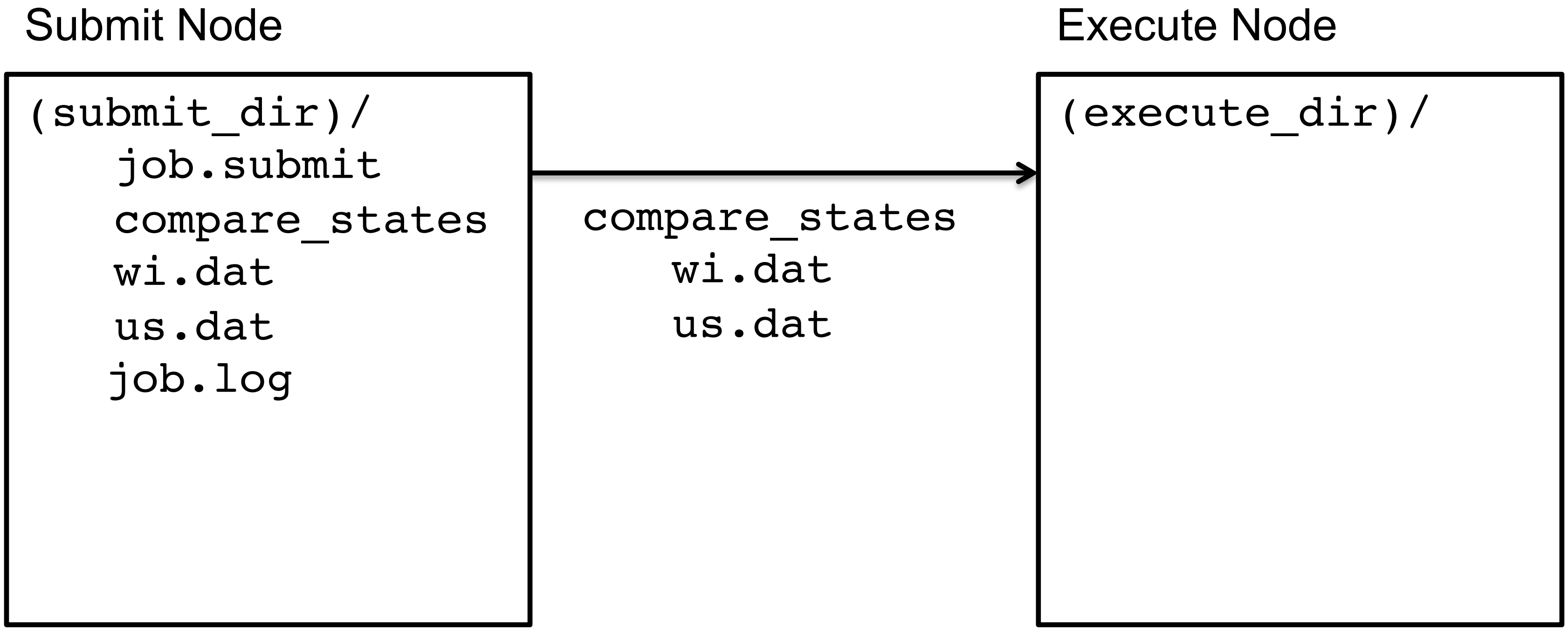


```
$ condor_q -nobatch
-- Schedd: submit-1.chtc.wisc.edu : <128.104.101.92:9618?...
 ID          OWNER      SUBMITTED     RUN_TIME ST PRI SIZE CMD
128.0        alice      5/9  11:09   0+00:00:00 I  0    0.0 compare_states wi.dat us.dat

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

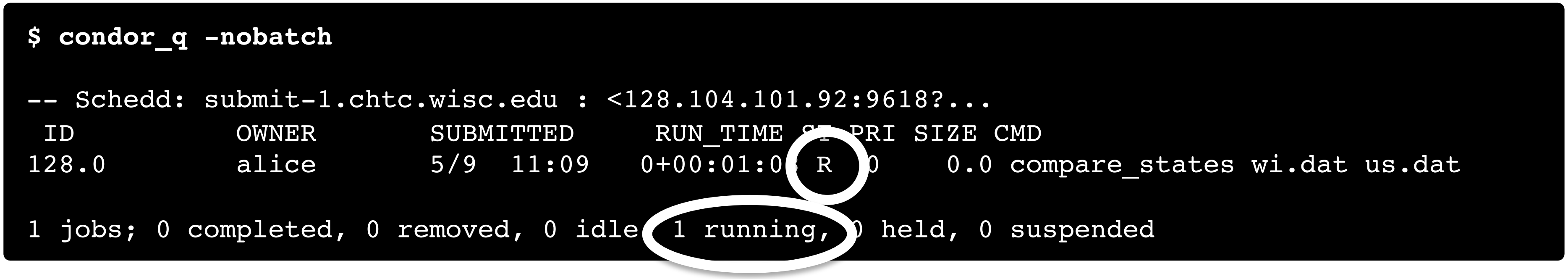


Job Starts

```
$ condor_q -nobatch
-- Schedd: submit-1.chtc.wisc.edu : <128.104.101.92:9618?...
 ID          OWNER       SUBMITTED     RUN_TIME ST PRI SIZE CMD
128.0        alice       5/9  11:09   0+00:00:00 <  0    0.0 compare_states wi.dat us.dat w

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



Job Running



```
$ condor_q -nobatch

-- Schedd: submit-1.chtc.wisc.edu : <128.104.101.92:9618?...
 ID          OWNER        SUBMITTED     RUN_TIME ST PRI SIZE CMD
128.0        alice        5/9  11:09   0+00:01:08 R  0    0.0 compare_states wi.dat us.dat

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

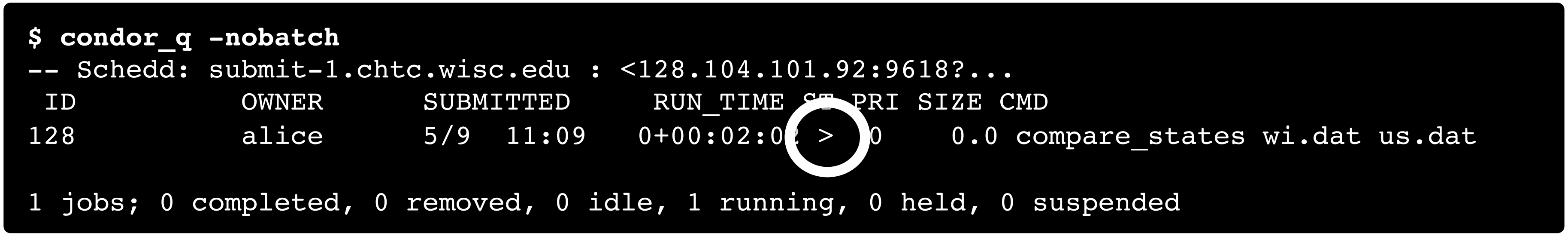
Submit Node

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

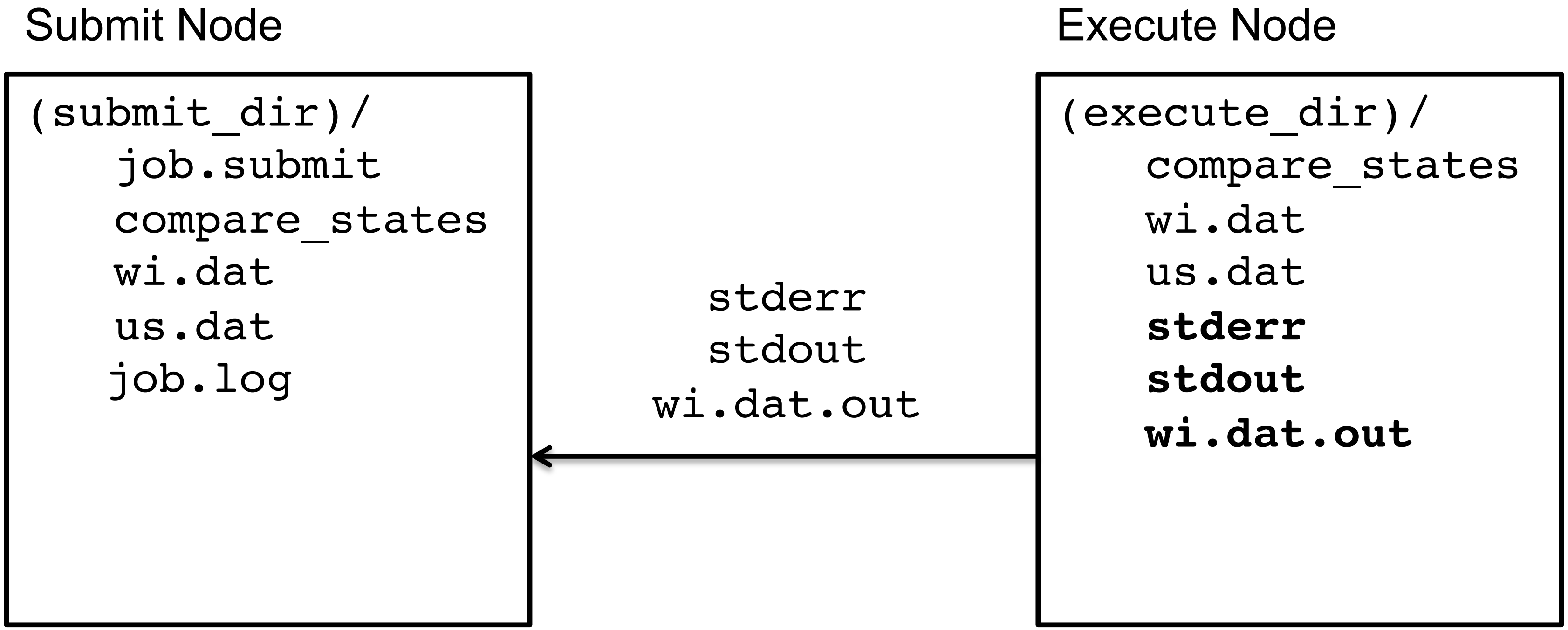
Execute Node

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

Job Completes



```
$ condor_q -nobatch
-- Schedd: submit-1.chtc.wisc.edu : <128.104.101.92:9618?...
 ID          OWNER      SUBMITTED     RUN_TIME ST PRI SIZE CMD
128          alice      5/9  11:09   0+00:02:02 >  0    0.0 compare_states wi.dat us.dat

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



Submit Node

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

Execute Node

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

```
stderr
stdout
wi.dat.out
```

Job Completes (cont.)

```
$ condor_q -nobatch


-- Schedd: submit-1.chtc.wisc.edu : <128.104.101.92:9618?...
 ID      OWNER            SUBMITTED     RUN_TIME ST PRI SIZE CMD

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

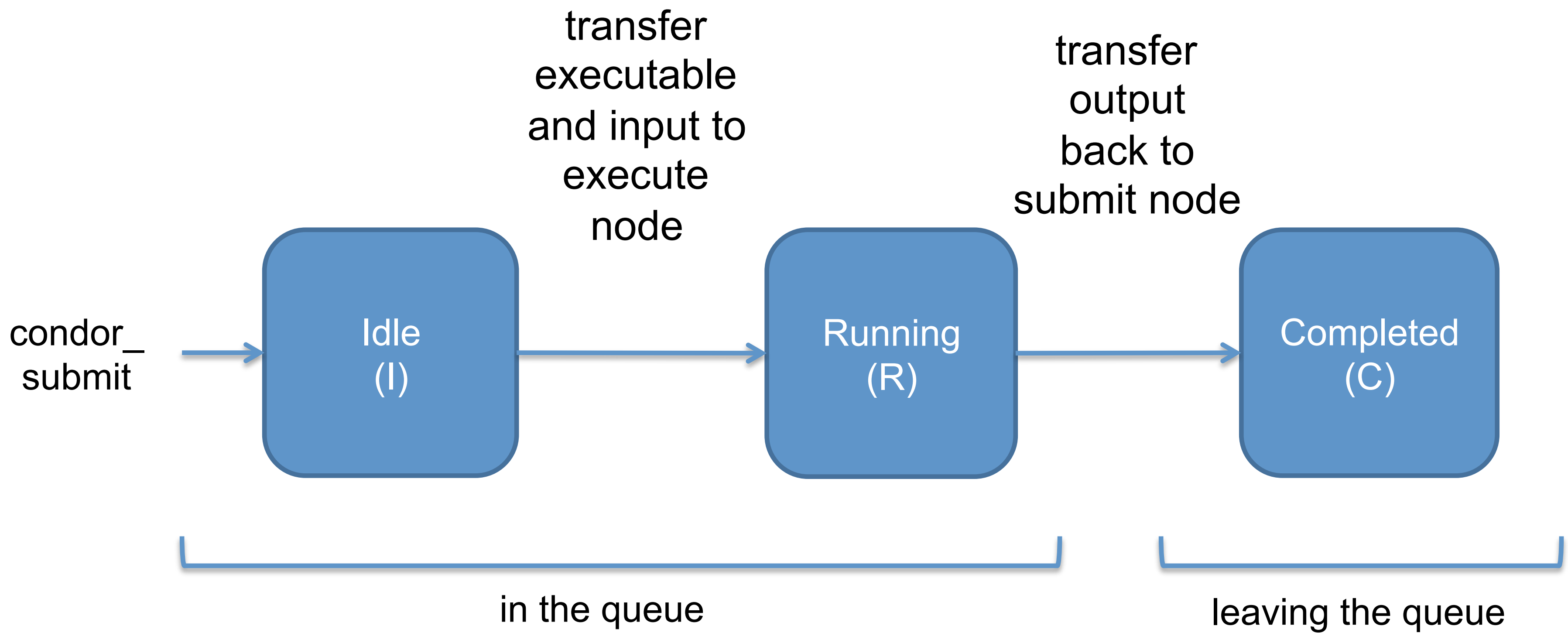
Submit Node

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

Log File

```
000 (7195807.000.000) 05/19 14:30:18 Job submitted from host:
<128.105.244.191:9618 ...>
......
040 (7195807.000.000) 05/19 14:31:55 Started transferring input files
        Transferring to host: <128.105.245.85:9618 ...>
...
040 (7195807.000.000) 05/19 14:31:55 Finished transferring input files
...
001 (7195807.000.000) 05/19 14:31:56 Job executing on host:
<128.105.245.85:9618? ...>
...
005 (7195807.000.000) 05/19 14:35:56 Job terminated.
        (1) Normal termination (return value 0)

        ...

        Partitionable Resources :    Usage  Request Allocated
           Cpus                 :        0        1         1
           Disk (KB)            :       26     1024    995252
          Memory (MB)          :        1     1024      1024
```

Job States


transfer executable and input to execute node
transfer output back to submit node
condor_ submit
Idle (I)
Running (R)
Completed (C)
in the queue
leaving the queue

Assumptions

- Aspects of your submit file may be dictated by infrastructure and configuration
- For example: file transfer
  - previous example assumed files would need to be transferred between submit/execute

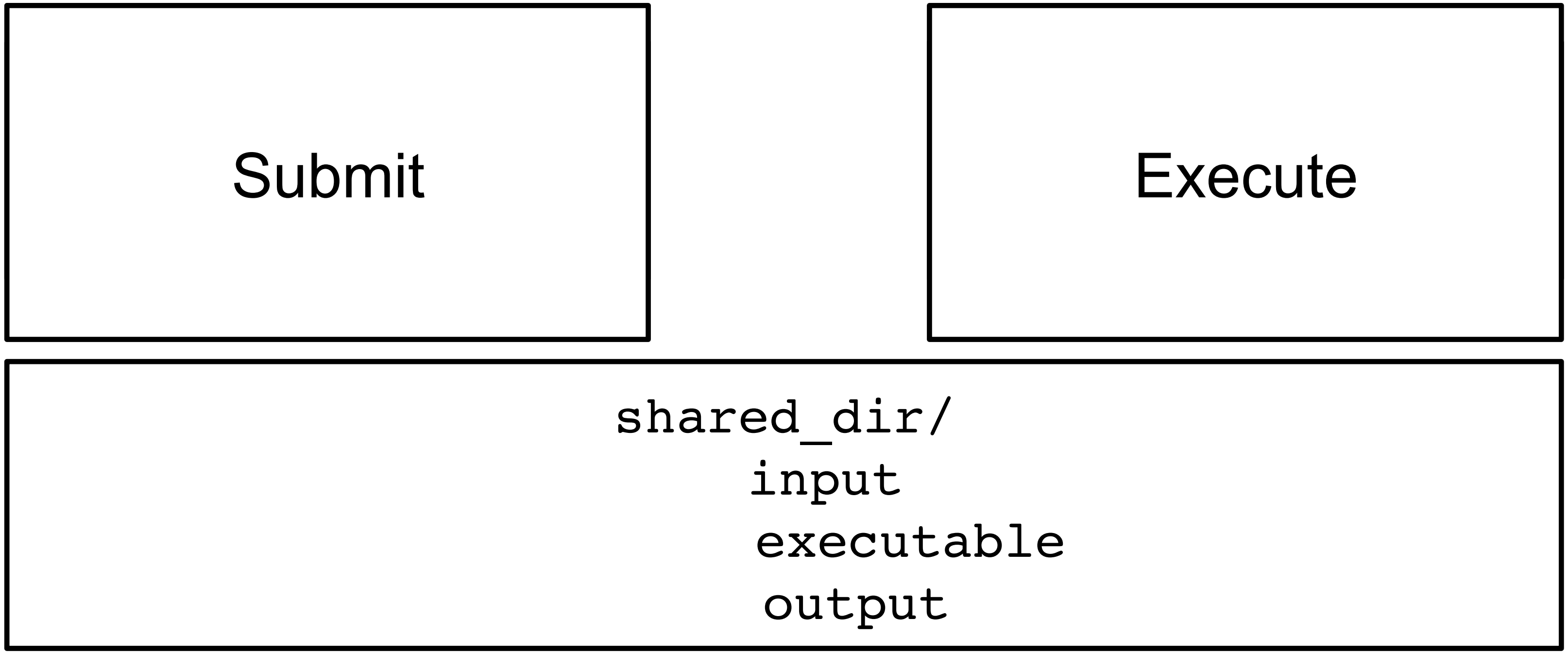
    ```
    should_transfer_files = YES
    ```

  - not the case with a shared filesystem

    ```
    should_transfer_files = NO
    ```

Shared Filesystem

- If a system has a shared filesystem, where file transfer is not enabled, the submit directory and execute directory are the same.



Submit

Execute

```
shared_dir/
    input
    executable
    output
```

Shared Filesystem

job.submit

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

should_transfer_files = NO

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

request_cpus = 1
request_memory = 20MB
request_disk = 20MB

queue 1
```

Resource Request

- Jobs are nearly always using a part of a computer, not the whole thing
- Very important to request appropriate resources (memory, cpus, disk) for a job

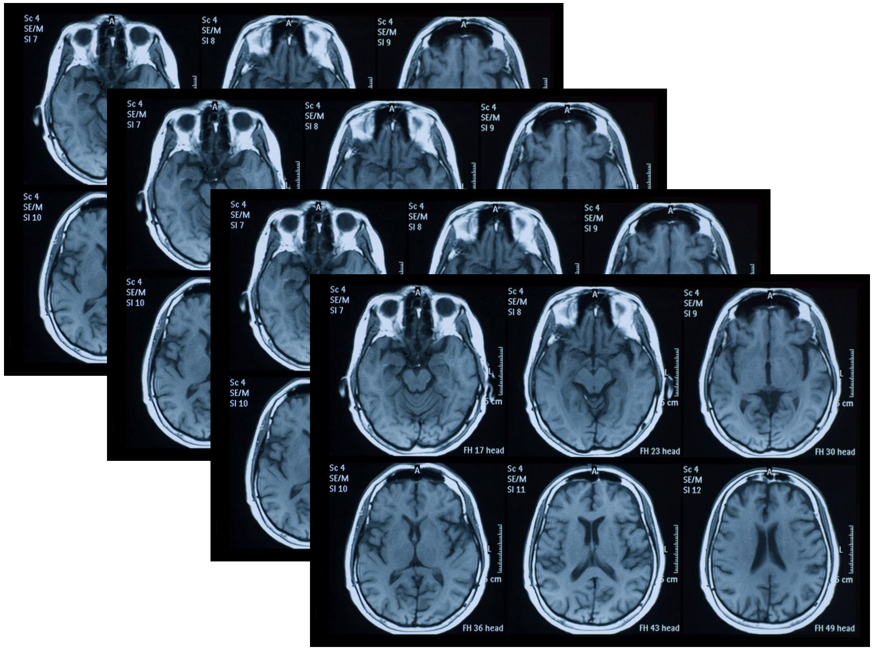
Resource Assumptions

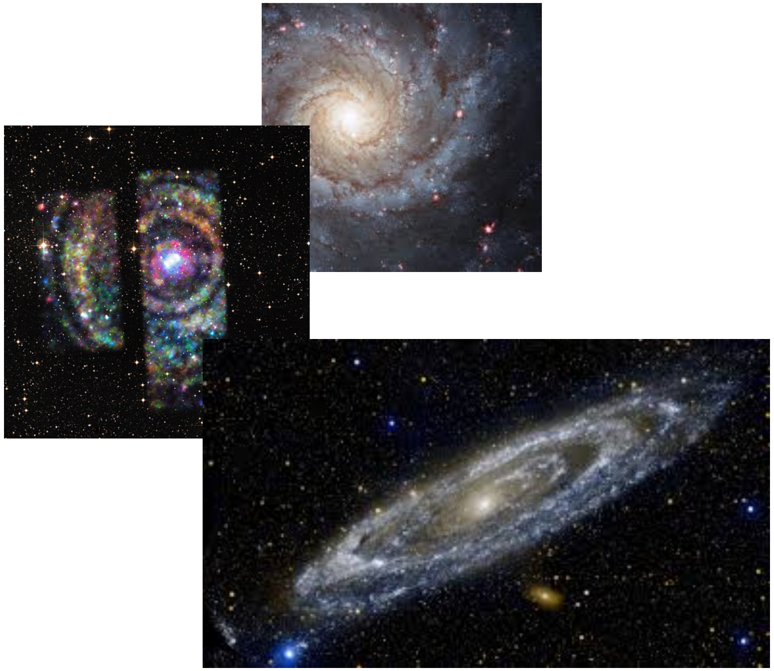
- Even if your system has default CPU, memory and disk requests, these may be too small!
- Important to run test jobs and use the log file to request the right amount of resources:
  - requesting too little: causes problems for your and other jobs; jobs might by held by HTCondor
  - requesting too much: jobs will match to fewer “slots”

Submitting Multiple Jobs with HTCondor

Why do we care?

- Run many independent jobs...
  - – analyze multiple data files
  - – test parameter or input combinations





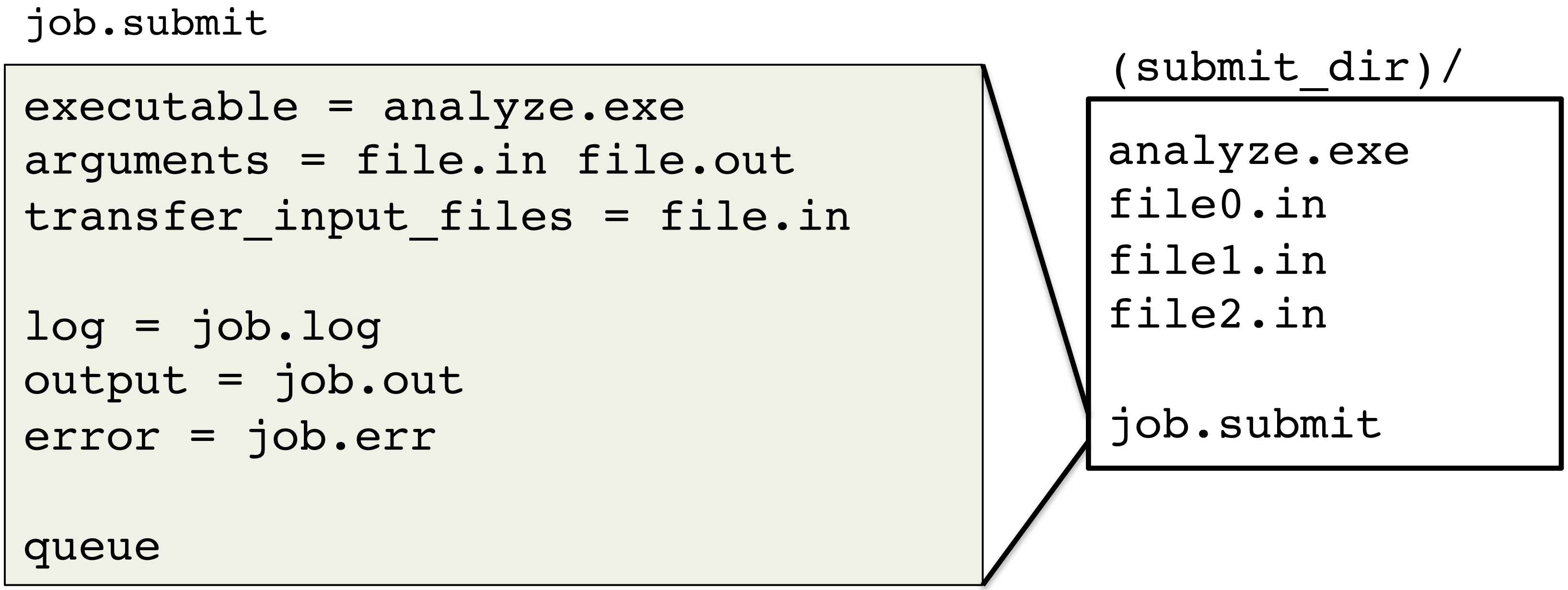
Why do we care?

- Run many independent jobs...
  - – analyze multiple data files
  - – test parameter or input combinations
  - – and more!
- ...without having to:
  - – start each job individually
  - – create separate submit files for each job

Many Jobs, One Submit File

- HTCondor has built-in ways to submit multiple independent jobs with one submit file

Numbered Input Files



job.submit

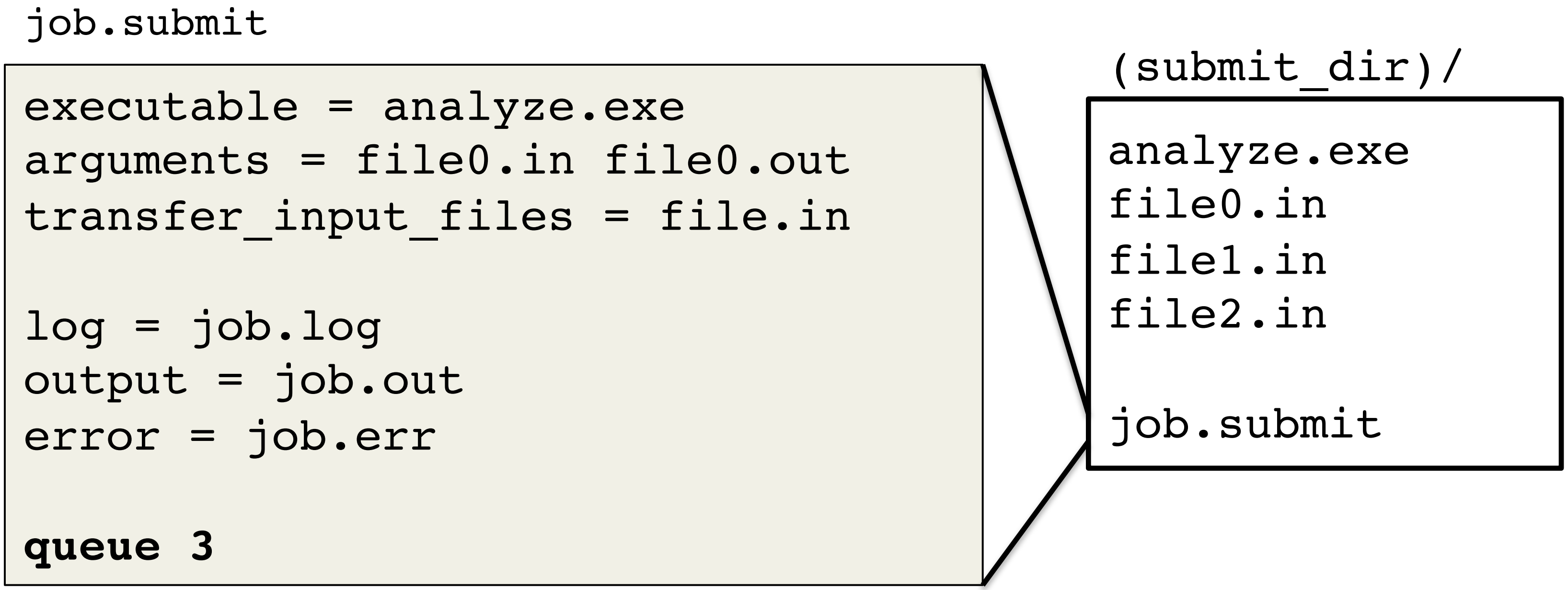
```
executable = analyze.exe
arguments = file.in file.out
transfer_input_files = file.in

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

queue
```

(submit_dir)/

```
analyze.exe
file0.in
file1.in
file2.in

job.submit
```

- Goal: create 3 jobs that each analyze a different input file.

Multiple Jobs, No Variation



job.submit

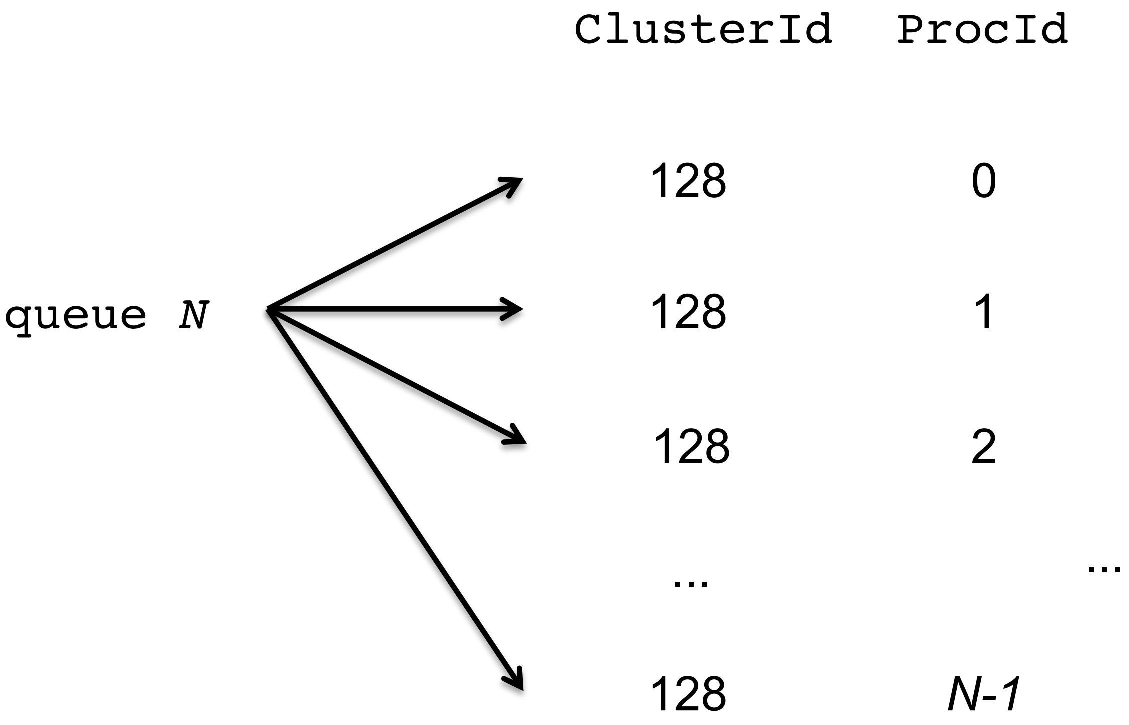
```
executable = analyze.exe
arguments = file0.in file0.out
transfer_input_files = file.in

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

queue 3
```

(submit_dir)/

```
analyze.exe
file0.in
file1.in
file2.in

job.submit
```

- This file generates 3 jobs, but doesn’t use multiple inputs and will overwrite outputs

Automatic Variables



`queue N`

ClusterId	ProcId
128	0
128	1
128	2
...	...
128	*N-1*

- Each job's `ClusterId` and `ProcId` can be accessed inside the submit file using:

  `$(ClusterId)`

  `$(ProcId)`

Job Variation

job.submit

```
executable = analyze.exe
arguments = file0.in file0.out
transfer_input_files = file0.in

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

queue
```

(submit_dir)/

```
analyze.exe
file0.in
file1.in
file2.in

job.submit
```

- How to uniquely identify each job (filenames, log/out/err names)?

Using $(ProcId)

job.submit

```
executable = analyze.exe
arguments = file$(ProcId).in file$(ProcId).out
transfer_input_files = file$(ProcId).in

log = job_$(ClusterId)_$(ProcId).log
output = job_$(ClusterId)_$(ProcId).out
error = job_$(ClusterId)_$(ProcId).err

queue 3
```

(submit_dir)/

```
analyze.exe
file0.in
file1.in
file2.in

job.submit
```

- Use the `$(ClusterId)`, `$(ProcId)` variables to provide unique values to jobs.*

* May also see `$(Cluster)`, `$(Process)` in documentation

Submit and Monitor (review)

`condor_submit` *`submit_file_name`*

`condor_q`

- Jobs in the queue will be grouped in batches (in this case by cluster number)

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

```
$ condor_q
-- Schedd: submit-1.chtc.wisc.edu : <128.104.101.92:9618?... @ 05/09/19 10:35:54
OWNER  BATCH_NAME    SUBMITTED    DONE     RUN     IDLE  TOTAL JOB_IDS
alice  ID: 128       5/9  11:03      _       _       3       3 128.0-2

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

[HTCondor Manual: condor_submit]
[HTCondor Manual: condor_q]

Using Batches

- Alternatively, batches can be grouped manually using the `JobBatchName` attribute in a submit file:

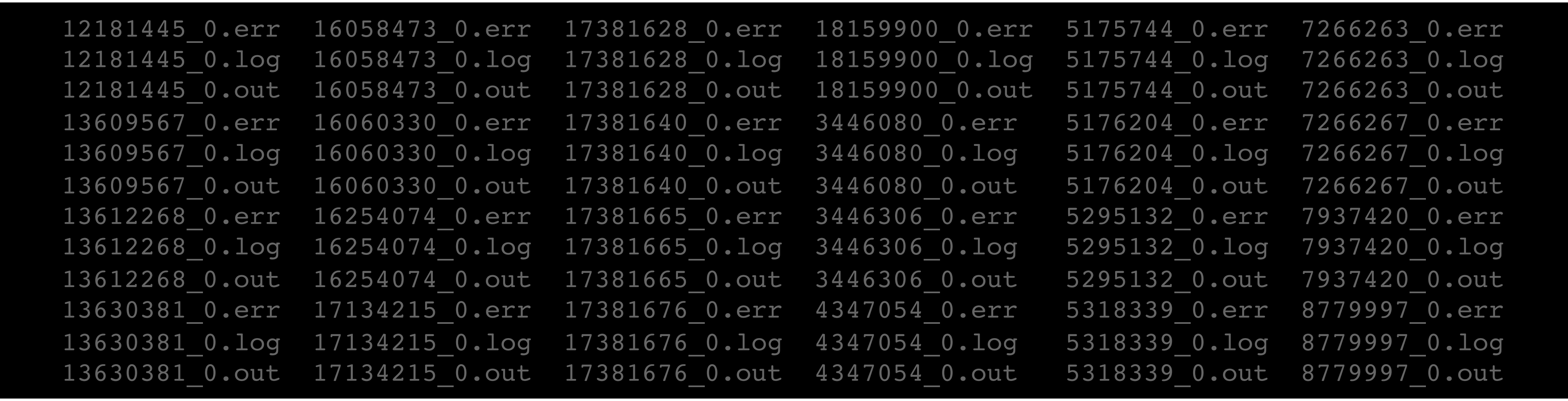
```
+JobBatchName = “CoolJobs”
```

```
$ condor_q
OWNER  BATCH_NAME     SUBMITTED   DONE   RUN    IDLE  TOTAL JOB_IDS
alice  CoolJobs       5/9  11:03     _      _      3      3 128.0-2
```

- To see individual jobs, use:

`condor_q -nobatch`

Organizing Jobs



```
12181445_0.err  16058473_0.err  17381628_0.err  18159900_0.err  5175744_0.err  7266263_0.err
12181445_0.log  16058473_0.log  17381628_0.log  18159900_0.log  5175744_0.log  7266263_0.log
12181445_0.out  16058473_0.out  17381628_0.out  18159900_0.out  5175744_0.out  7266263_0.out
13609567_0.err  16060330_0.err  17381640_0.err  3446080_0.err   5176204_0.err  7266267_0.err
13609567_0.log  16060330_0.log  17381640_0.log  3446080_0.log   5176204_0.log  7266267_0.log
13609567_0.out  16060330_0.out  17381640_0.out  3446080_0.out   5176204_0.out  7266267_0.out
13612268_0.err  16254074_0.err  17381665_0.err  3446306_0.err   5295132_0.err  7937420_0.err
13612268_0.log  16254074_0.log  17381665_0.log  3446306_0.log   5295132_0.log  7937420_0.log
13612268_0.out  16254074_0.out  17381665_0.out  3446306_0.out   5295132_0.out  7937420_0.out
13630381_0.err  17134215_0.err  17381676_0.err  4347054_0.err   5318339_0.err  8779997_0.err
13630381_0.log  17134215_0.log  17381676_0.log  4347054_0.log   5318339_0.log  8779997_0.log
13630381_0.out  17134215_0.out  17381676_0.out  4347054_0.out   5318339_0.out  8779997_0.out
```

Shared Files

- HTCondor can transfer an entire directory or all the contents of a directory
  - – transfer whole directory

```
transfer_input_files = shared
```

  - – transfer contents only

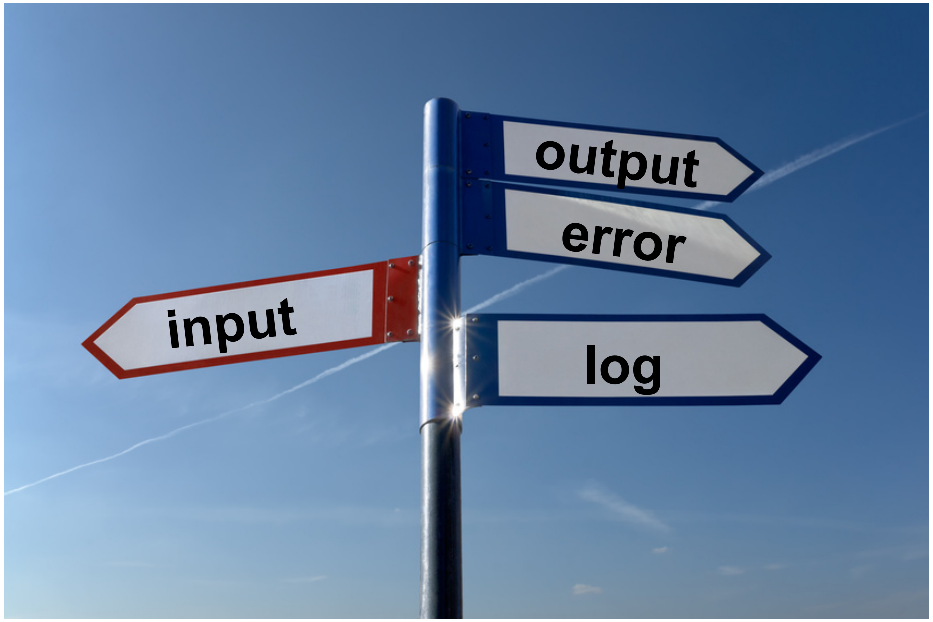
```
transfer_input_files = shared/
```

```
(submit_dir)/
job.submit
shared/
    reference.db
    parse.py
    analyze.py
    cleanup.py
    links.config
```

- Useful for jobs with many shared files; transfer a directory of files instead of listing files individually

Organize Files in Sub-Directories

- Create sub-directories* and use paths in the submit file to separate input, error, log, and output files.



* must be created before the job is submitted

Use Paths for File Type

(submit_dir)/

```
job.submit     file0.out    input/        log/          err/
analyze.exe    file1.out      file0.in      job0.log      job0.err
               file2.out      file1.in      job1.log      job1.err
                              file2.in      job2.log      job2.err
```

job.submit

```
executable = analyze.exe
arguments = file$(Process).in file$(ProcId).out
transfer_input_files = input/file$(ProcId).in

log = log/job$(ProcId).log
error = err/job$(ProcId).err

queue 3
```

InitialDir

- Change the submission directory for each job using `initialdir`
- Allows the user to organize job files into separate directories.
- Use the same name for all input/output files
- Useful for jobs with lots of output files

Separate Jobs with InitialDir

```
(submit_dir)/
```

```
job.submit        job0/          job1/          job2/
analyze.exe         file.in        file.in        file.in
                    job.log        job.log        job.log
                    job.err        job.err        job.err
                    file.out       file.out       file.out
```

job.submit

```
executable = analyze.exe
initialdir = job$(ProcId)
arguments = file.in file.out
transfer_input_files = file.in

log = job.log
error = job.err

queue 3
```

Executable should be in the directory with the submit file, *not* in the individual job directories

(60 SECOND) PAUSE

Questions so far?

Other Submission Methods

- What if your input files/directories aren’t numbered from 0 - (N-1)?
- There are other ways to submit many jobs!

Submitting Multiple Jobs

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

transfer_input_files = us.dat, wi.dat

queue 1
```

Replacing single job inputs

```
executable = compare_states
arguments = $(infile) us.dat $(infile).out

transfer_input_files = us.dat, $(infile)

queue ...
```

with a variable of choice

Possible Queue Statements

multiple "queue" statements	`infile = wi.dat`
	`queue 1`
	`infile = ca.dat`
	`queue 1`
	`infile = ia.dat`
	`queue 1`

matching ... pattern	`queue infile matching *.dat`
in ... list	`queue infile in (wi.dat ca.dat ia.dat)`

from ... file	`queue infile from state_list.txt`
	`wi.dat`
	`ca.dat`
	`ia.dat`
	`state_list.txt`

Possible Queue Statements

multiple "queue" statements	~~`infile = wi.dat`~~ ~~`queue 1`~~ ~~`infile = ca.dat`~~ ~~`queue 1`~~ ~~`infile = ia.dat`~~ ~~`queue 1`~~ Not Recommended
matching ... pattern	`queue infile matching *.dat`
in ... list	`queue infile in (wi.dat ca.dat ia.dat)`

from ... file	`queue infile from state_list.txt`
	`wi.dat`
	`ca.dat`
	`ia.dat`
	`state_list.txt`

Queue Statement Comparison

multiple queue statements	Not recommended. Can be useful when submitting job batches where a single (non-file/argument) characteristic is changing
matching .. pattern	Natural nested looping, minimal programming, use optional “files” and “dirs” keywords to only match files or directories Requires good naming conventions,
in .. list	Supports multiple variables, all information contained in a single file, reproducible Harder to automate submit file creation
from .. file	Supports multiple variables, highly modular (easy to use one submit file for many job batches), reproducible Additional file needed

Using Multiple Variables

- Both the "`from`" and "`in`" syntax support using multiple variables from a list.

job.submit

```
executable = compare_states
arguments = -y $(option) -i $(file)

should_transfer_files = YES
when_to_transfer_output = ON_EXIT
transfer_input_files = $(file)

queue file,option from job_list.txt
```

job_list.txt

```
wi.dat, 2010
wi.dat, 2015
ca.dat, 2010
ca.dat, 2015
ia.dat, 2010
ia.dat, 2015
```

HTCondor Manual: submit file options

Other Features

- Match existing files or directories:

```
queue input matching files *.dat
```

```
queue directory matching dirs job*
```

- Submit multiple jobs with same input data

```
queue 10 input matching files *.dat
```

Use other automatic variables: `$(Step)`

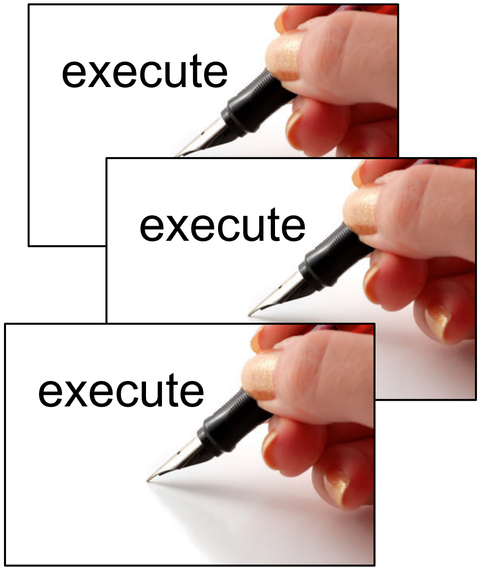
```
arguments = -i $(input) -rep $(Step)
queue 10 input matching files *.dat
```

Job Matching and Class Ad Attributes

The Central Manager

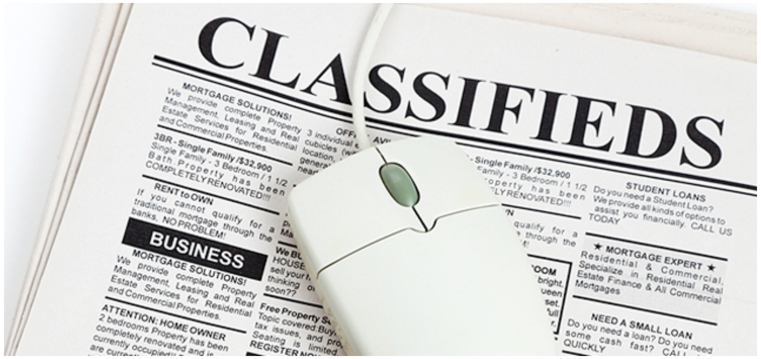
- HTCondor matches jobs with computers via a “central manager”.

central manager



Class Ads

- HTCondor stores a list of information about each job and each computer.
- This information is stored as a “Class Ad”



- Class Ads have the format:

```
AttributeName = value
```

can be a boolean, number, or string

HTCondor Manual: Appendix A: Class Ad Attributes

Job Class Ad

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

should_transfer_files = YES
transfer_input_files = us.dat, wi.dat
when_to_transfer_output = ON_EXIT

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

request_cpus = 1
request_disk = 20MB
request_memory = 20MB

queue 1
```

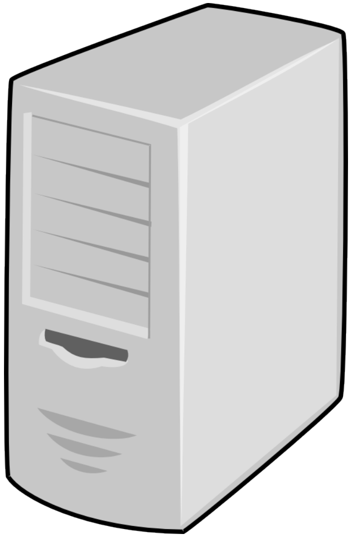
+

HTCondor configuration*

=

```
RequestCpus = 1
Err = "job.err"
WhenToTransferOutput = "ON_EXIT"
TargetType = "Machine"
Cmd = "/home/alice/tests/htcondor_week/
compare_states"
JobUniverse = 5
Iwd = "/home/alice/tests/htcondor_week"
RequestDisk = 20480
NumJobStarts = 0
WantRemoteIO = true
OnExitRemove = true
TransferInput = "us.dat,wi.dat"
MyType = "Job"
Out = "job.out"
UserLog = "/home/alice/tests/
htcondor_week/job.log"
RequestMemory = 20
...
```

Computer "Machine" Class Ad



+

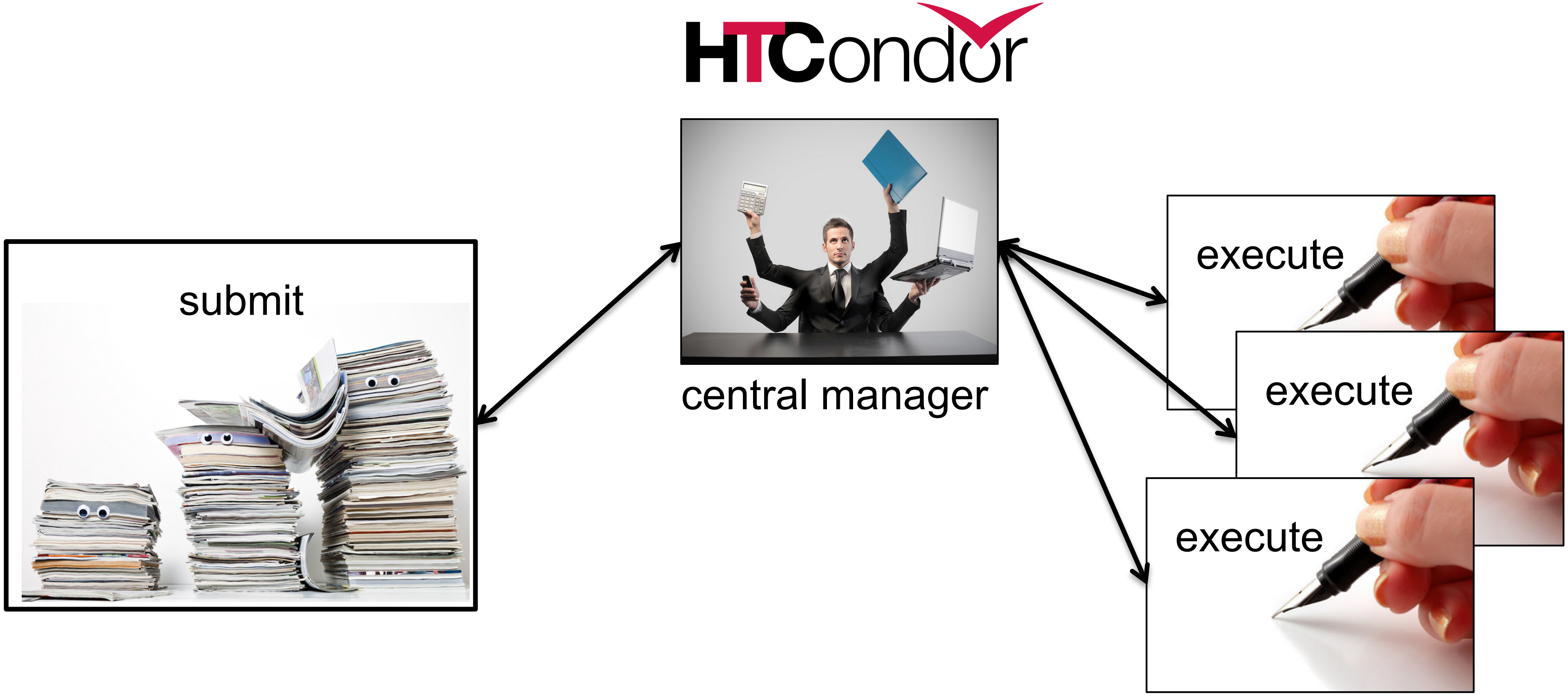
HTCondor configuration

=

```
HasFileTransfer = true
DynamicSlot = true
TotalSlotDisk = 4300218.0
TargetType = "Job"
TotalSlotMemory = 2048
Mips = 17902
Memory = 2048
UtsnameSysname = "Linux"
MAX_PREEMPT = ( 3600 * 72 )
Requirements = ( START ) &&
( IsValidCheckpointPlatform ) &&
( WithinResourceLimits )
OpSysMajorVer = 6
TotalMemory = 9889
HasGluster = true
OpSysName = "SL"
HasDocker = true

...
```

Job Matching

- On a regular basis, the central manager reviews Job and Machine Class Ads and matches jobs to computers.



HTCondor

submit

central manager

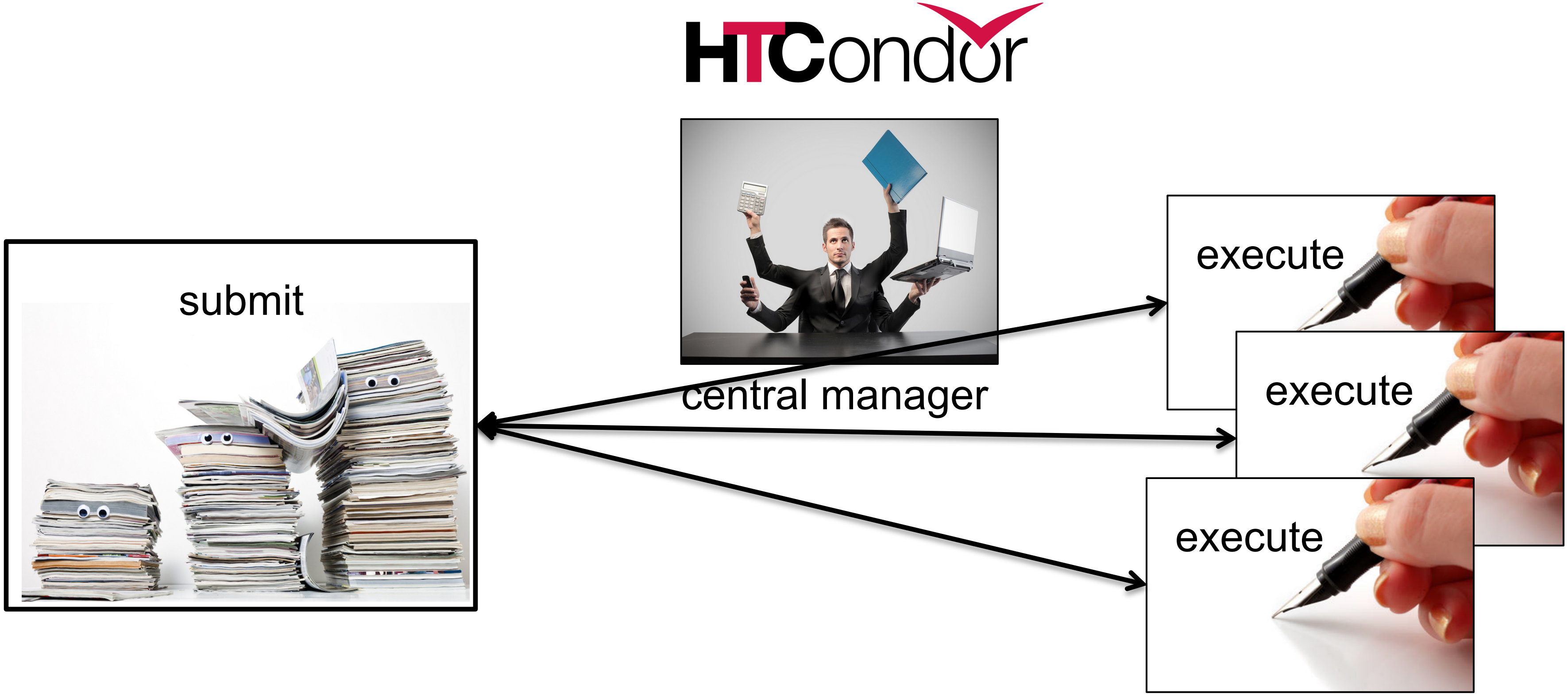
execute

execute

execute

Job Execution

- (Then the submit and execute points communicate directly.)



HTCondor

submit

central manager

execute

execute

execute

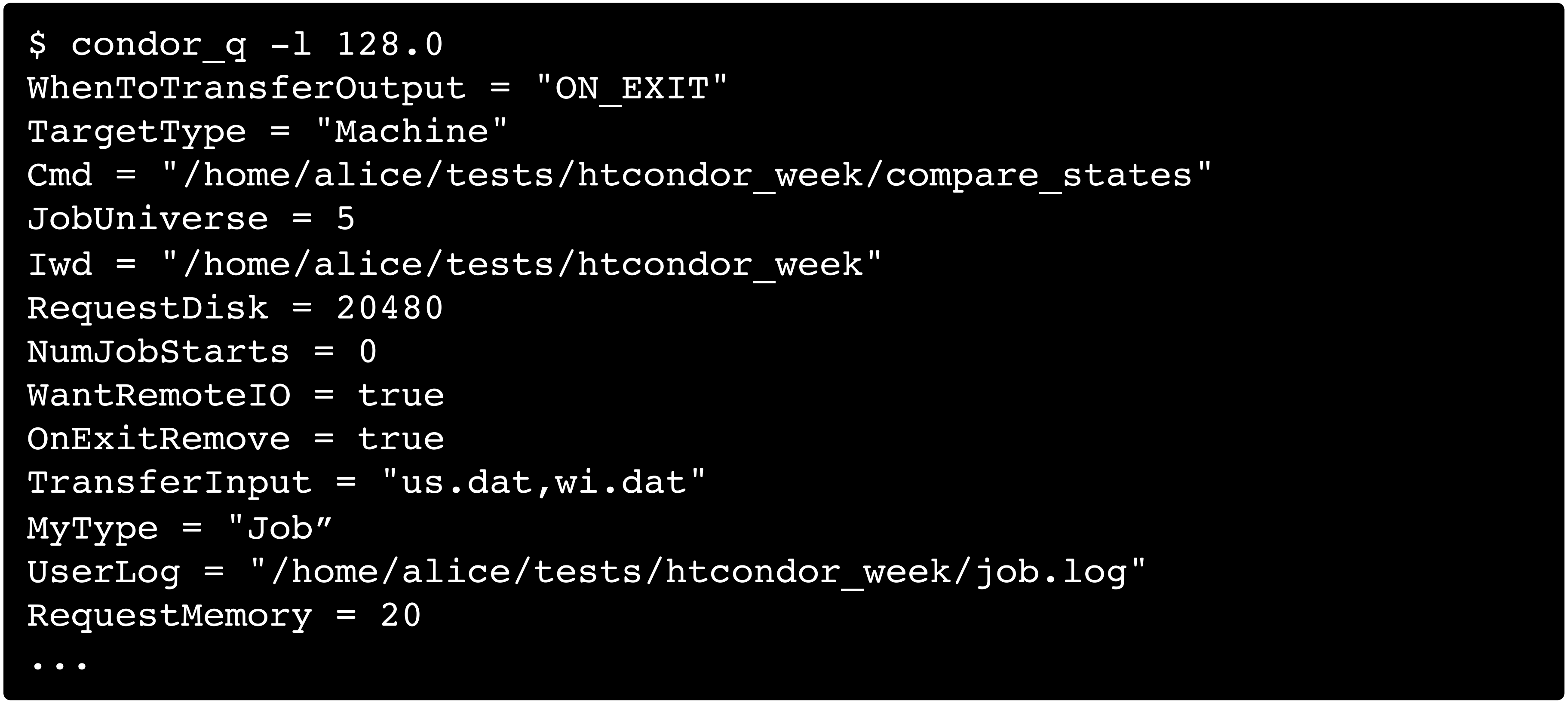
Class Ads for People

- Class Ads also provide lots of useful information about jobs and computers to HTCondor users and administrators

Finding Job Attributes

- Use the “long” option for `condor_q`

  `condor_q -l JobId`



```
$ condor_q -l 128.0
WhenToTransferOutput = "ON_EXIT"
TargetType = "Machine"
Cmd = "/home/alice/tests/htcondor_week/compare_states"
JobUniverse = 5
Iwd = "/home/alice/tests/htcondor_week"
RequestDisk = 20480
NumJobStarts = 0
WantRemoteIO = true
OnExitRemove = true
TransferInput = "us.dat,wi.dat"
MyType = "Job”
UserLog = "/home/alice/tests/htcondor_week/job.log"
RequestMemory = 20
...
```

Useful Job Attributes

- `UserLog`: location of job log
- `Iwd`: Initial Working Directory (i.e. submission directory) on submit node
- `MemoryUsage`: maximum memory the job has used
- `RemoteHost`: where the job is running
- `ClusterId, ProcID, JobBatchName`
- ...and more (see the manual)

Displaying Job Attributes

- Use the “auto-format” option:

condor_q ***[U/C/J] -af Attribute1 Attribute2 ...***

```
$ condor_q -af ClusterId ProcId RemoteHost MemoryUsage

1725 116 slot1_1@e092.chtc.wisc.edu 1709
1725 118 slot1_2@e093.chtc.wisc.edu 1709
1725 137 slot1_8@e125.chtc.wisc.edu 1709
1725 139 slot1_7@e121.chtc.wisc.edu 1709
1861 0 slot1_5@c025.chtc.wisc.edu 196
1863 0 slot1_3@atlas10.chtc.wisc.edu 269
1864 0 slot1_25@e348.chtc.wisc.edu 245
1865 0 slot1_23@e305.chtc.wisc.edu 196
1871 0 slot1_6@e176.chtc.wisc.edu 220
```

Selecting Job Attributes

- Use the “constraint” option, along with an expression for what jobs you want to look at:

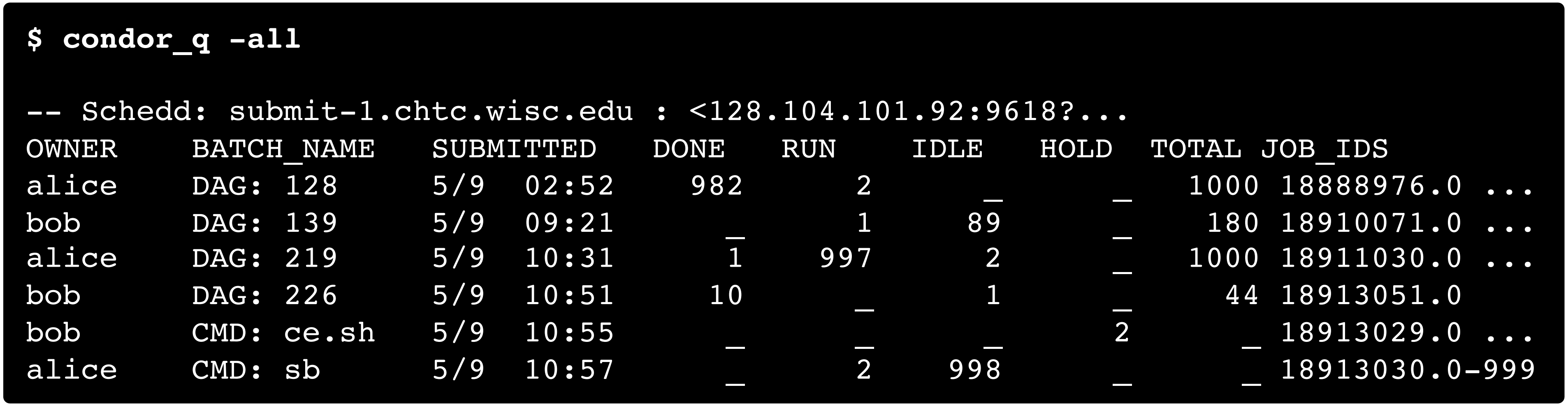
condor_q [U/C/J] -constraint *‘Attribute >/</== value‘*

```
$ condor_q -constraint ‘JobBatchName == “CoolJobs“‘
OWNER  BATCH_NAME     SUBMITTED   DONE   RUN    IDLE  TOTAL JOB_IDS
alice  CoolJobs       5/9  11:03     _      _      3      3 128.0-2
```

Other Displays

- See the whole queue (all users, all jobs)

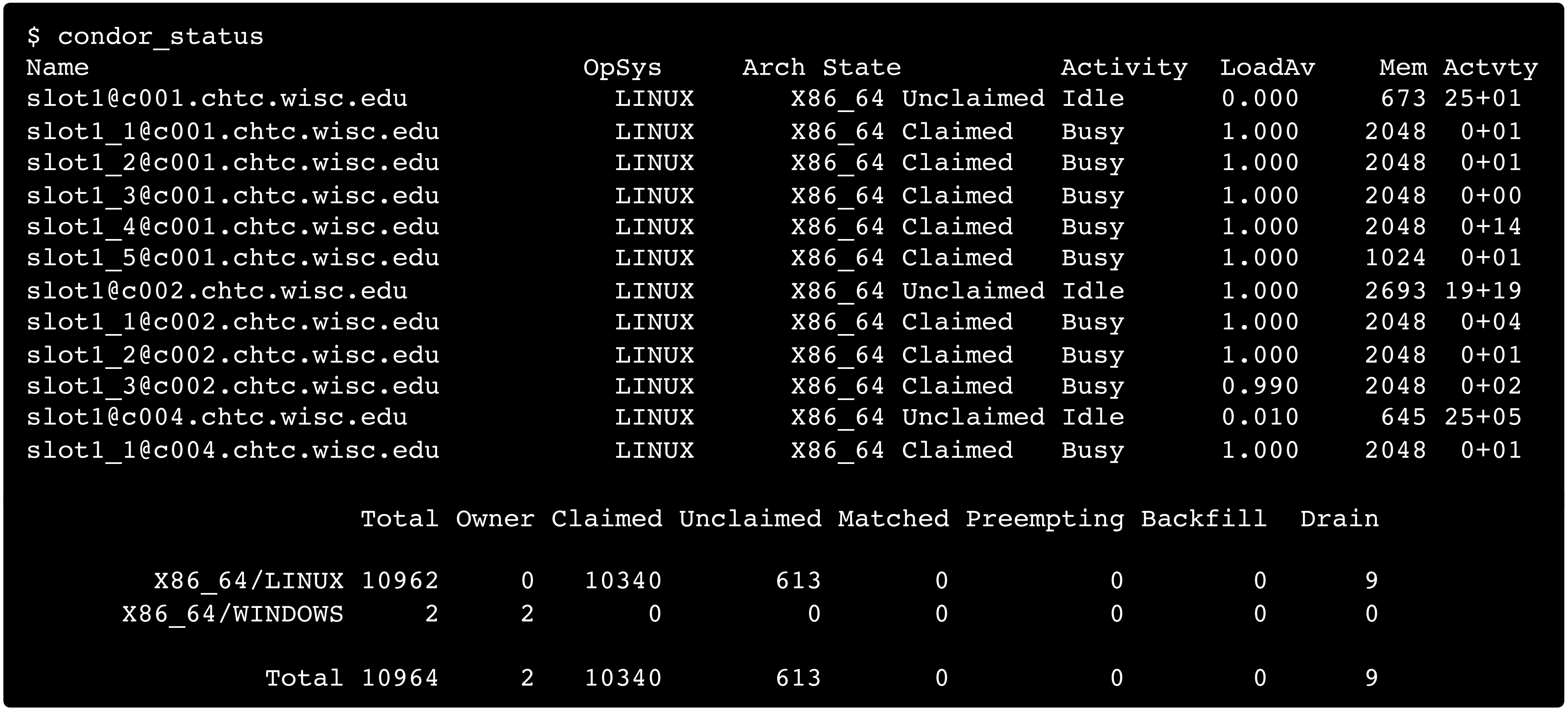
  condor_q -all



```
$ condor_q -all

-- Schedd: submit-1.chtc.wisc.edu : <128.104.101.92:9618?...
OWNER    BATCH_NAME   SUBMITTED   DONE   RUN    IDLE   HOLD  TOTAL JOB_IDS
alice    DAG: 128     5/9  02:52    982      2      _      _   1000 18888976.0 ...
bob      DAG: 139     5/9  09:21      _      1     89      _    180 18910071.0 ...
alice    DAG: 219     5/9  10:31      1    997      2      _   1000 18911030.0 ...
bob      DAG: 226     5/9  10:51     10      _      1      _     44 18913051.0
bob      CMD: ce.sh   5/9  10:55      _      _      _      2      _ 18913029.0 ...
alice    CMD: sb      5/9  10:57      _      2    998      _      _ 18913030.0-999
```

Class Ads for Computers

as **condor_q** is to jobs, **condor_status** is to computers (or "machines")



```
$ condor_status
Name                              OpSys      Arch State     Activity  LoadAv     Mem Actvty
slot1@c001.chtc.wisc.edu            LINUX      X86_64 Unclaimed Idle      0.000     673 25+01
slot1_1@c001.chtc.wisc.edu          LINUX      X86_64 Claimed   Busy      1.000    2048  0+01
slot1_2@c001.chtc.wisc.edu          LINUX      X86_64 Claimed   Busy      1.000    2048  0+01
slot1_3@c001.chtc.wisc.edu          LINUX      X86_64 Claimed   Busy      1.000    2048  0+00
slot1_4@c001.chtc.wisc.edu          LINUX      X86_64 Claimed   Busy      1.000    2048  0+14
slot1_5@c001.chtc.wisc.edu          LINUX      X86_64 Claimed   Busy      1.000    1024  0+01
slot1@c002.chtc.wisc.edu            LINUX      X86_64 Unclaimed Idle      1.000    2693 19+19
slot1_1@c002.chtc.wisc.edu          LINUX      X86_64 Claimed   Busy      1.000    2048  0+04
slot1_2@c002.chtc.wisc.edu          LINUX      X86_64 Claimed   Busy      1.000    2048  0+01
slot1_3@c002.chtc.wisc.edu          LINUX      X86_64 Claimed   Busy      0.990    2048  0+02
slot1@c004.chtc.wisc.edu            LINUX      X86_64 Unclaimed Idle      0.010     645 25+05
slot1_1@c004.chtc.wisc.edu          LINUX      X86_64 Claimed   Busy      1.000    2048  0+01

                     Total Owner Claimed Unclaimed Matched Preempting Backfill  Drain

        X86_64/LINUX 10962     0   10340       613       0          0        0      9
      X86_64/WINDOWS     2     2       0         0       0          0        0      0

               Total 10964     2   10340       613       0          0        0      9
```

HTCondor Manual: condor_status

Machine Attributes

- Use same options as **condor_q**:

condor_status *-l Slot/Machine*

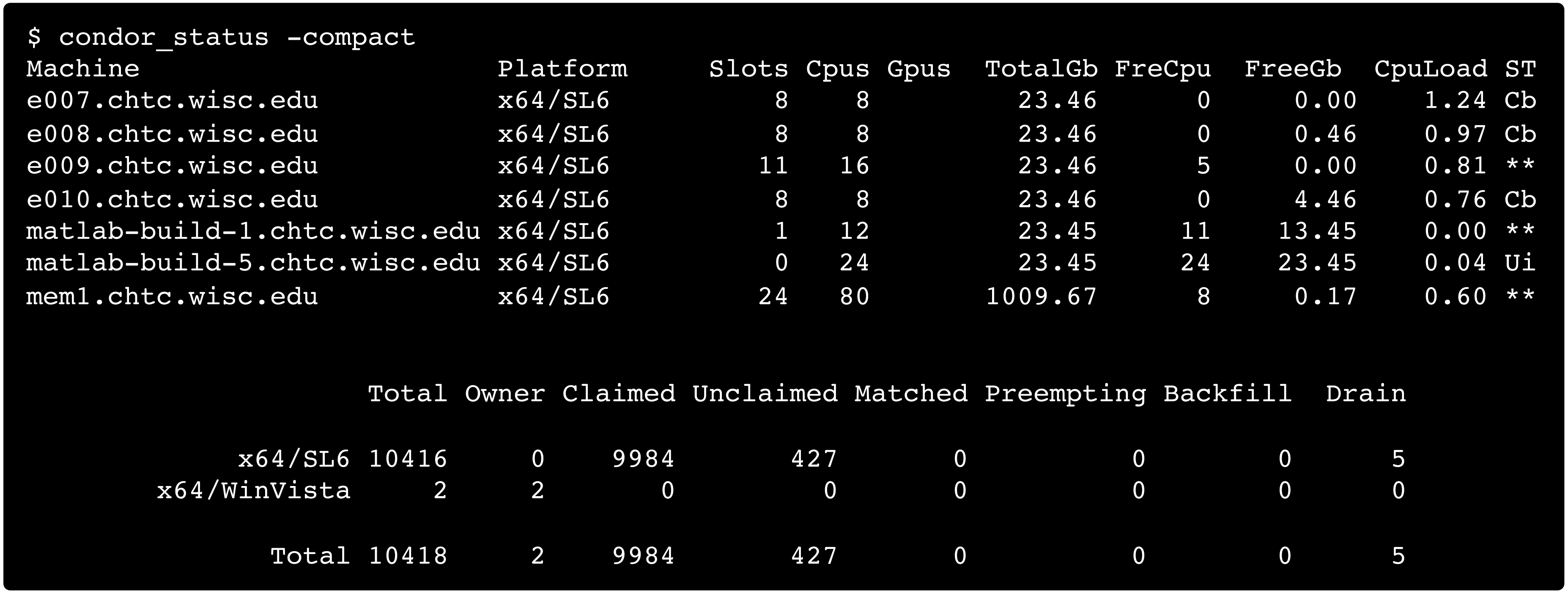
condor_status *[Machine] -af Attribute1 Attribute2 ...*

```
$ condor_status -l slot1_1@c001.chtc.wisc.edu
HasFileTransfer = true
COLLECTOR_HOST_STRING = "cm.chtc.wisc.edu”
TargetType = "Job”
TotalTimeClaimedBusy = 43334c001.chtc.wisc.edu
UtsnameNodename = ""
Mips = 17902
MAX_PREEMPT = ( 3600 * ( 72 - 68 * ( WantGlidein =?= true ) ) )
Requirements = ( START ) && ( IsValidCheckpointPlatform ) &&
( WithinResourceLimits )
State = "Claimed"
OpSysMajorVer = 6
OpSysName = "SL”
...
```

Machine Attributes

- To summarize, use the “-compact” option

`condor_status -compact`



```
$ condor_status -compact
Machine                      Platform     Slots Cpus Gpus  TotalGb FreCpu  FreeGb  CpuLoad ST
e007.chtc.wisc.edu           x64/SL6          8    8         23.46      0     0.00    1.24 Cb
e008.chtc.wisc.edu           x64/SL6          8    8         23.46      0     0.46    0.97 Cb
e009.chtc.wisc.edu           x64/SL6         11   16         23.46      5     0.00    0.81 **
e010.chtc.wisc.edu           x64/SL6          8    8         23.46      0     4.46    0.76 Cb
matlab-build-1.chtc.wisc.edu x64/SL6          1   12         23.45     11    13.45    0.00 **
matlab-build-5.chtc.wisc.edu x64/SL6          0   24         23.45     24    23.45    0.04 Ui
mem1.chtc.wisc.edu           x64/SL6         24   80       1009.67      8     0.17    0.60 **


                     Total Owner Claimed Unclaimed Matched Preempting Backfill  Drain

             x64/SL6 10416     0    9984       427       0          0        0      5
        x64/WinVista     2     2       0         0       0          0        0      0

               Total 10418     2    9984       427       0          0        0      5
```

Testing and Troubleshooting

What Can Go Wrong?

- Jobs can go wrong “internally”:
  - something happens after the executable begins to run
- Jobs can go wrong from HTCondor’s perspective:
  - A job can’t be started at all,
  - Uses too much memory,
  - Has a badly formatted executable,
  - And more...

Reviewing Failed Jobs

- A job’s log, output and error files can provide valuable information for troubleshooting

Log	Output	Error
• When jobs were submitted, started, and stopped • Resources used • Exit status • Where job ran • Interruption reasons	Any “print” or “display” information from your program	Captured by the operating system

Reviewing Recent Jobs

- To review a large group of jobs at once, use **condor_history [U/C/J]**

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
```

HTCondor Manual: condor_history

“Live” Troubleshooting

- To log in to a job where it is running, use:

  condor_ssh_to_job *JobId*

```
$ condor_ssh_to_job 128.0
Welcome to slot1_31@e395.chtc.wisc.edu!
Your condor job is running with pid(s) 3954839.
```

HTCondor Manual: condor_ssh_to_job

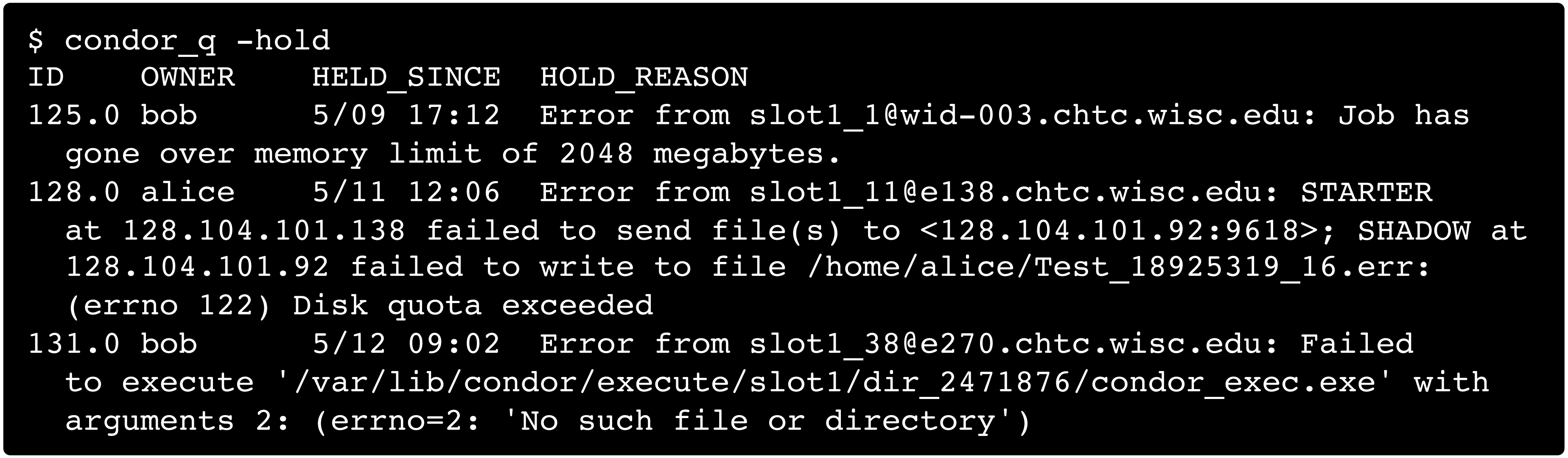
Held Jobs

- HTCondor will put your job on hold if there’s something YOU need to fix.
- A job that goes on hold is interrupted (all progress is lost) and kept from running again, but remains in the queue in the “H” state.

Diagnosing Holds

- If HTCondor puts jobs on hold, it provides a hold reason, which can be viewed with:

  condor_q -hold



```
$ condor_q -hold
ID     OWNER     HELD_SINCE  HOLD_REASON
125.0 bob       5/09 17:12  Error from slot1_1@wid-003.chtc.wisc.edu: Job has
  gone over memory limit of 2048 megabytes.
128.0 alice     5/11 12:06  Error from slot1_11@e138.chtc.wisc.edu: STARTER
  at 128.104.101.138 failed to send file(s) to <128.104.101.92:9618>; SHADOW at
  128.104.101.92 failed to write to file /home/alice/Test_18925319_16.err:
  (errno 122) Disk quota exceeded
131.0 bob       5/12 09:02  Error from slot1_38@e270.chtc.wisc.edu: Failed
  to execute '/var/lib/condor/execute/slot1/dir_2471876/condor_exec.exe' with
  arguments 2: (errno=2: 'No such file or directory')
```

Common Hold Reasons

- Job has used more memory than requested
- Incorrect path to files that need to be transferred
- Badly formatted bash scripts (have Windows instead of Unix line endings)
- Submit directory is over quota
- The admin has put your job on hold

Fixing Holds

- Job attributes can be edited while jobs are in the queue using:

  condor_qedit [U/C/J] Attribute Value

```
$ condor_qedit 128.0 RequestMemory 3072
Set attribute ”RequestMemory".
```

- If a job has been fixed and can run again, release it with:

  condor_release [U/C/J]

```
$ condor_release 128.0
Job 18933774.0 released
```

HTCondor Manual: condor_qedit
HTCondor Manual: condor_release

Holding or Removing Jobs

- If you know your job has a problem and it hasn’t yet completed, you can:
  - Place it on hold yourself, with **condor_hold [U/C/J]**

```
$ condor_hold bob
All jobs of user ”bob" have been held
```

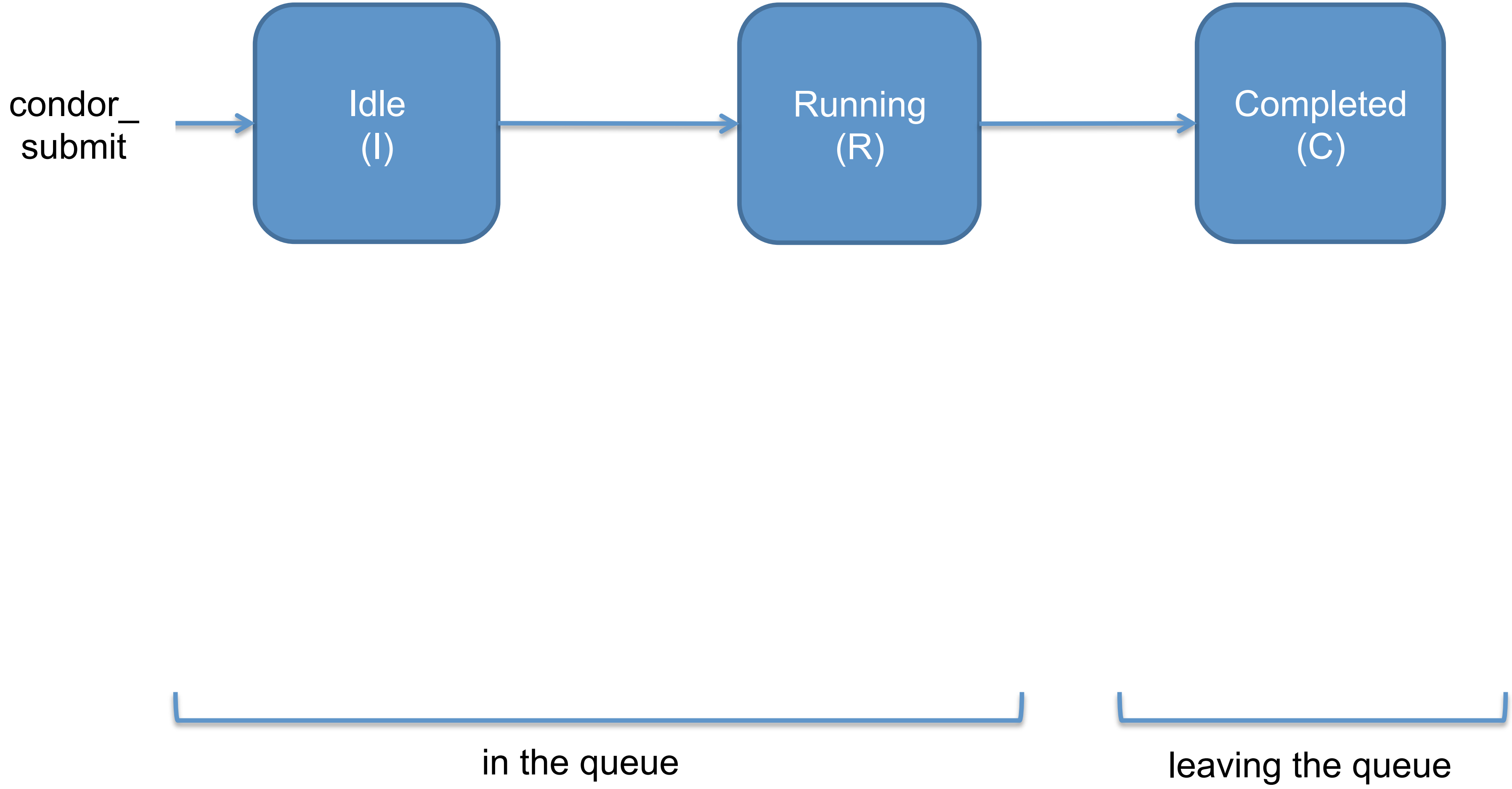
```
$ condor_hold 128
All jobs in cluster 128 have been held
```

```
$ condor_hold 128.0
Job 128.0 held
```

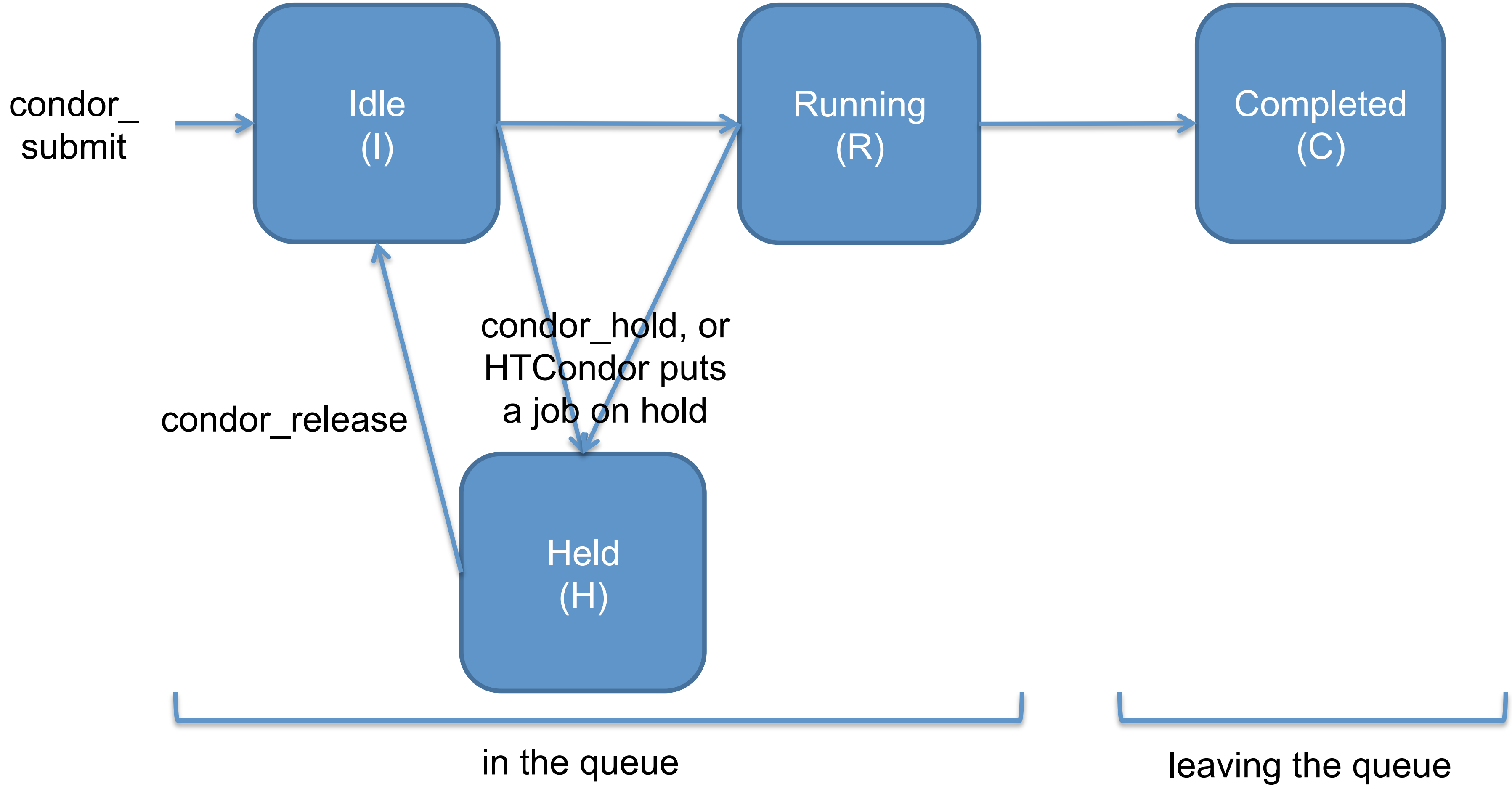
  - Remove it from the queue, using **condor_rm [U/C/J]**

HTCondor Manual: condor_hold
HTCondor Manual: condor_rm

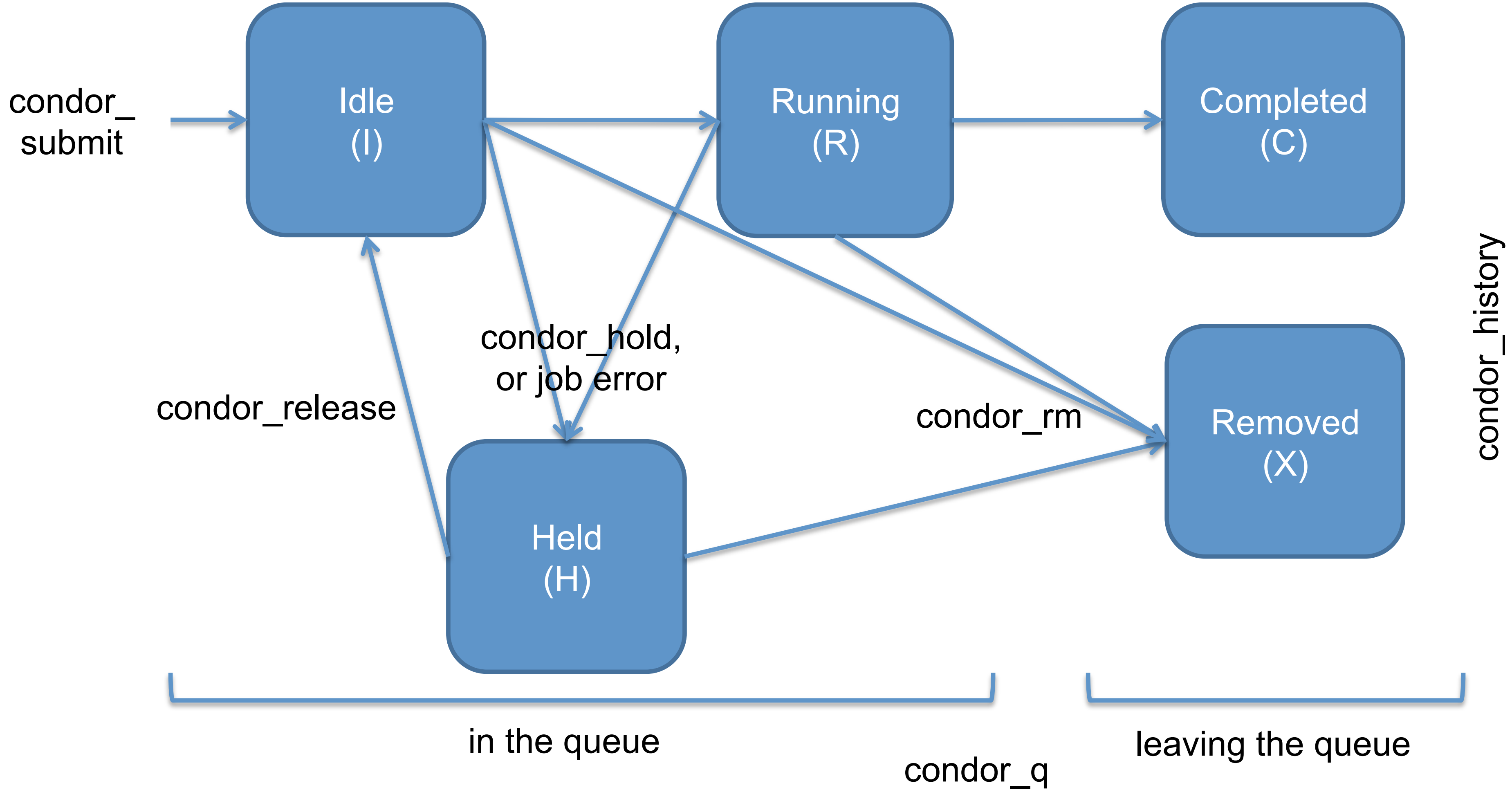
Job States, Revisited



Job States, Revisited



Job States, Revisited*



*not comprehensive

BREAK

Use Cases and HTCondor Features

Interactive Jobs

- An interactive job proceeds like a normal batch job, but opens a bash session into the job's execution directory instead of running an executable.

```
condor_submit -i submit_file
```

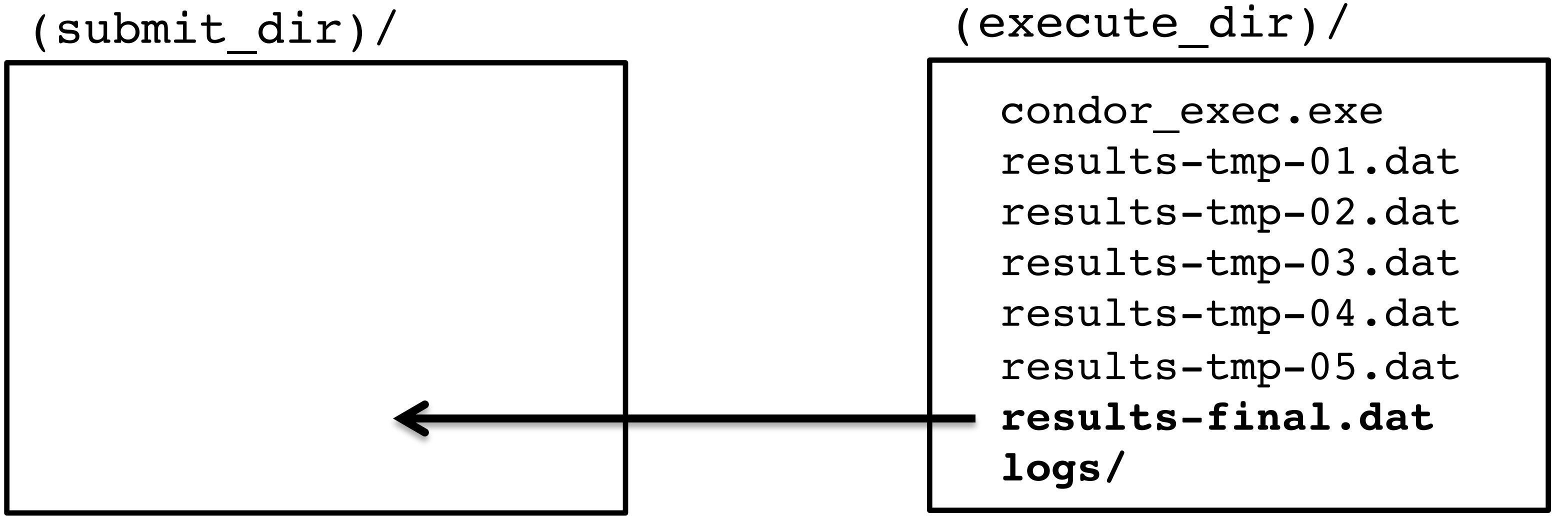
```
$ condor_submit -i interactive.submit
Submitting job(s).
1 job(s) submitted to cluster 18980881.
Waiting for job to start...
Welcome to slot1_9@e184.chtc.wisc.edu!
```

- Useful for testing and troubleshooting

Output Handling

- Only transfer back specific files or directories from the job's execution using `transfer_ouput_files`

```
transfer_output_files = results-final.dat, logs
```



(submit_dir)/

(execute_dir)/

condor_exec.exe
results-tmp-01.dat
results-tmp-02.dat
results-tmp-03.dat
results-tmp-04.dat
results-tmp-05.dat
results-final.dat
logs/

Self-Checkpointing

- By default, a job that is interrupted will start from the beginning if it is restarted.
- It is possible to implement self-checkpointing, which will allow a job to restart from a saved state if interrupted.
- Self-checkpointing is useful for very long jobs, and being able to run on opportunistic resources.

Self-Checkpointing How-To

- Edit executable:
  - Save intermediate states to a checkpoint file
  - Always check for a checkpoint file when starting
- Add HTCondor option that a) saves all intermediate/output files from the interrupted job and b) transfers them to the job when HTCondor runs it again

```
when_to_transfer_output = ON_EXIT_OR_EVICT
```

Job Universes

- HTCondor has different “universes” for running specialized job types

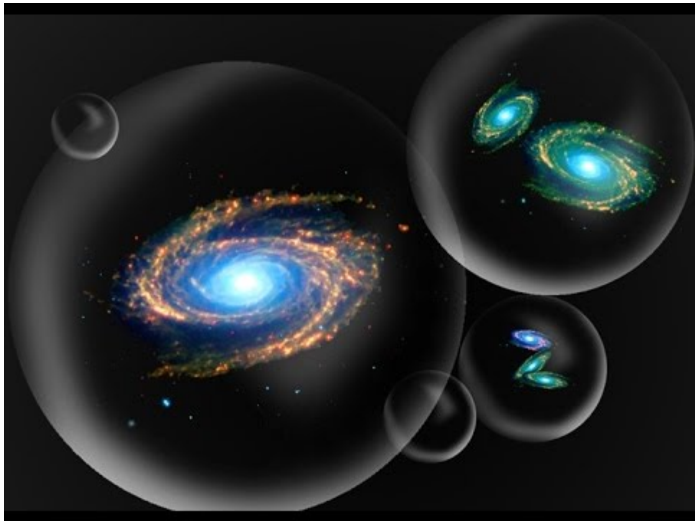
  HTCondor Manual: Choosing an HTCondor Universe

- Vanilla (default)
  - good for most software

  HTCondor Manual: Vanilla Universe

- Set in the submit file using:

```
universe = vanilla
```



Other Universes

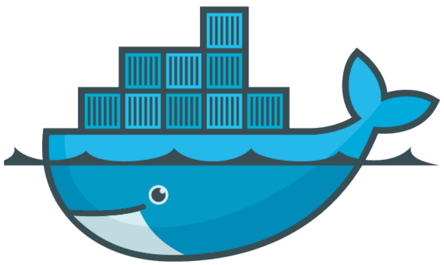
- Standard
  - Built for code (C, fortran) that can be statically compiled with `condor_compile`
- Java
  - Built-in Java support
- Local
  - Run jobs on the submit node
- VM
  - Run jobs inside a virtual machine
- Parallel
  - Used for coordinating jobs across multiple servers (e.g. MPI code)
  - Not necessary for single server multi-core jobs

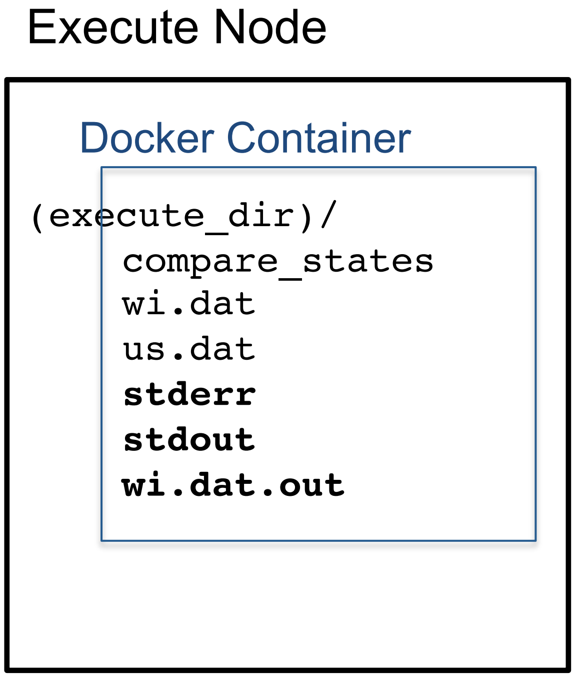
Other Universes (cont.)

- Docker
  - Run jobs inside a Docker container

[HTCondor Manual: Docker Universe Applications]

```
universe = docker
docker_image = ubuntu:trusty
# by default the docker image
# is pulled from DockerHub
```





Execute Node

Docker Container

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

Multi-CPU and GPU Computing

- Jobs that use multiple cores on a single computer can be run in the vanilla universe (parallel universe not needed):

```
request_cpus = 16
```

- If there are computers with GPUs, request them with:

```
request_gpus = 1
```

Automation

Automation

- After job submission, HTCondor manages jobs based on its configuration
- You can use options that will customize job management even further
- These options can automate when jobs are started, stopped, and removed.

Retries

- Problem: a small number of jobs fail; if they run again, they complete successfully.
- Solution: If the job exits with an error, leave it in the queue to run again. This is done via the automatic option `max_retries`.

```
max_retries = 5
```

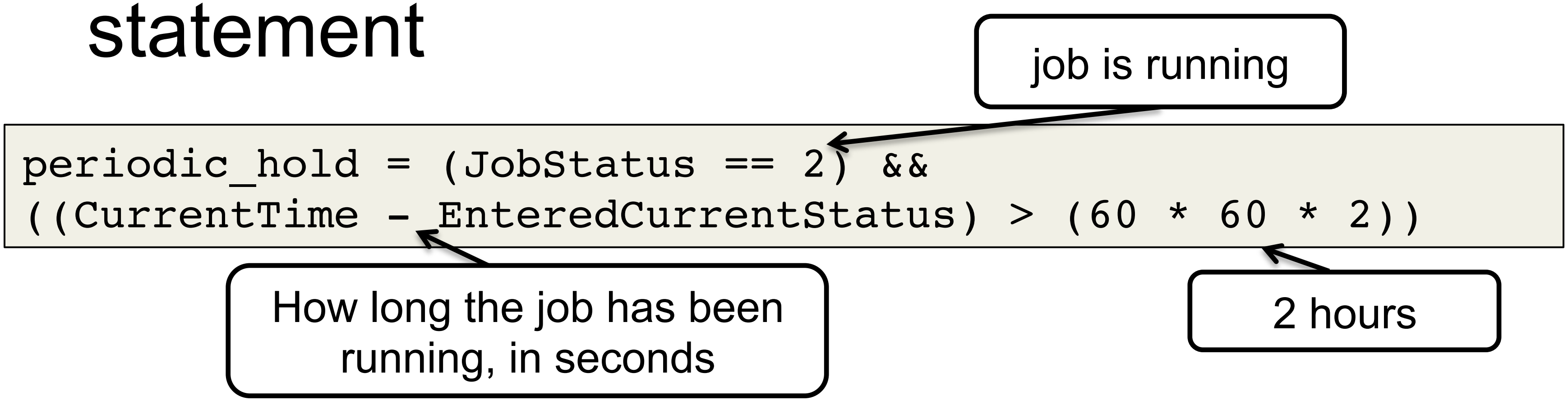
Limiting Jobs

- Problem: Submitting more than a few thousand jobs to the queue at once
- Solution: Use the `max_idle` option. This limits the number of jobs submitted at one time, but allows there to always be idle jobs ready to run.

```
max_idle = 1000
```

Automatically Hold Jobs

- Problem: Your job should run in 2 hours or less, but a few jobs “hang” randomly and run for days
- Solution: Put jobs on hold if they run for over 2 hours, using a `periodic_hold` statement



job is running

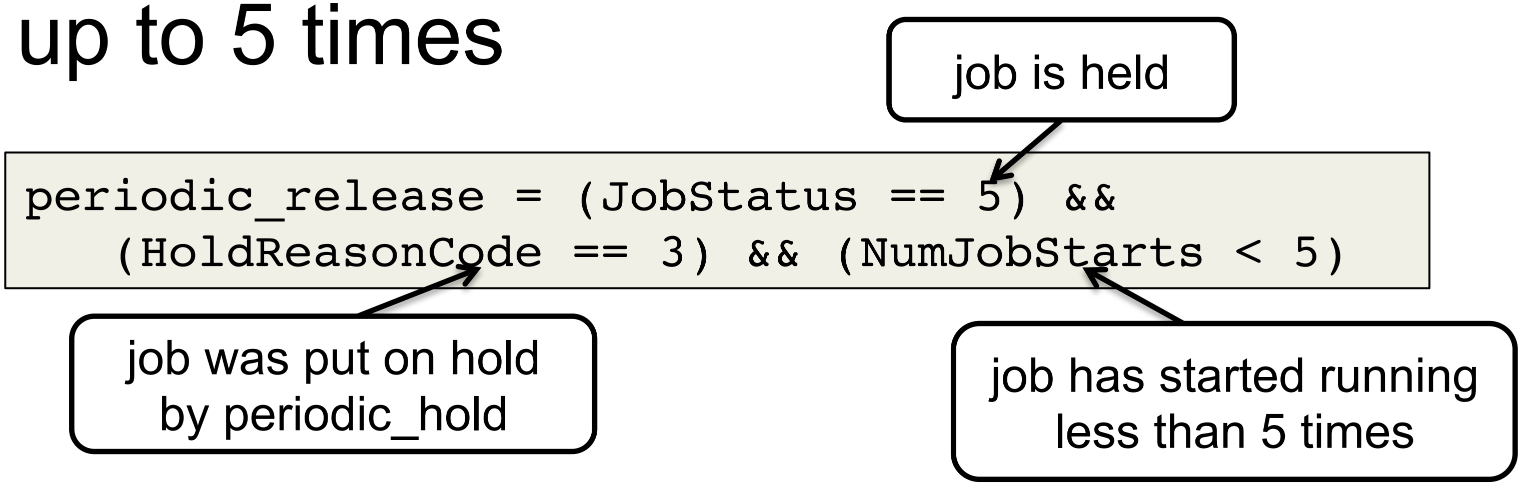
```
periodic_hold = (JobStatus == 2) &&
((CurrentTime - EnteredCurrentStatus) > (60 * 60 * 2))
```

How long the job has been running, in seconds

2 hours

Automatically Release Jobs

- Problem (related to previous): A few jobs are being held for running long; they will complete if they run again.
- Solution: automatically release those held jobs with a `periodic_release` option, up to 5 times



```
periodic_release = (JobStatus == 5) &&
   (HoldReasonCode == 3) && (NumJobStarts < 5)
```

job is held

job was put on hold by periodic_hold

job has started running less than 5 times

Automatically Remove Jobs

- Problem: Jobs are repetitively failing
- Solution: Remove jobs from the queue using a `periodic_remove` statement

```
periodic_remove = (NumJobsStarts > 5)
```

job has started running more than 5 times

Dynamically Request Memory

- Problem: a batch of jobs uses a wide variety of memory; many jobs only need 256MB, but some need up to 2 GB.
- Solution: Use a dynamic memory request.

if the job has run before...

```
request_memory = ifthenelse(MemoryUsage =!= undefined,
MAX({MemoryUsage * 3/2, 256})
256)
```

...request either a multiple of the memory used by a previous run, or the default, whichever is larger.

else, use the default.

Relevant Job Attributes

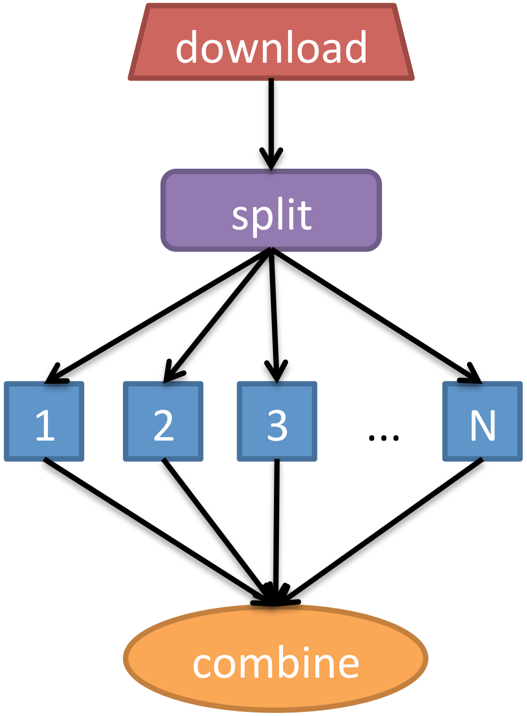
- `CurrentTime`: current time
- `EnteredCurrentStatus`: time of last status change
- `ExitCode`: the exit code from the job
- `HoldReasonCode`: number corresponding to a hold reason
- `NumJobStarts`: how many times the job has gone from idle to running
- `JobStatus`: number indicating idle, running, held, etc.

HTCondor Manual: Appendix A: JobStatus and HoldReason Codes

Workflows

- Problem: Want to submit jobs in a particular order, with dependencies between groups of jobs
- Solution: Write a DAG

- To learn about this, stay for the next talk, [DAGMan: HTCondor and Workflows]() by Lauren Michael.



FINAL QUESTIONS?