AN INTRODUCTION TO USING HTCondor

Christina Koch

Covered In This Tutorial

- What is HTCondor?
- Running a Job with HTCondor
- How HTCondor Matches and Runs Jobs

  - pause for questions -
- Submitting Multiple Jobs with HTCondor
- Testing and Troubleshooting
- Use Cases and HTCondor Features
- Automation

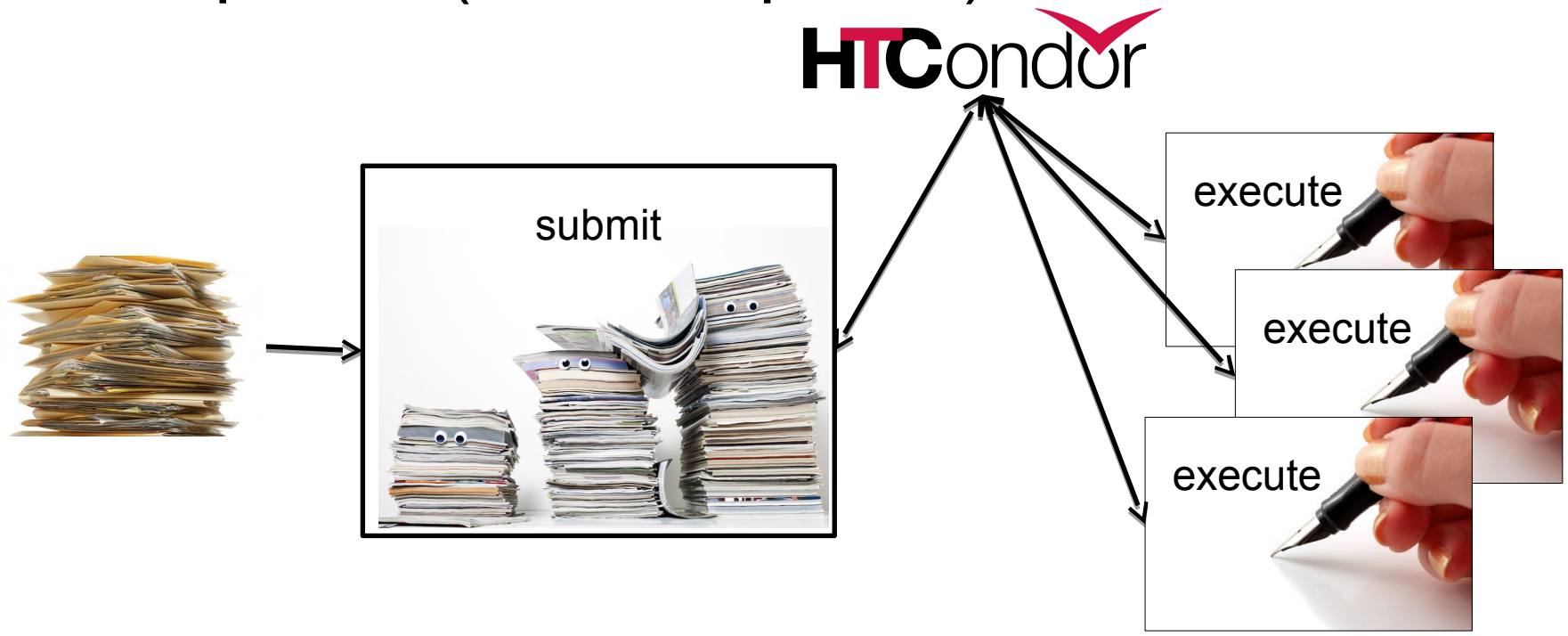
Introduction

What is HTCondor?

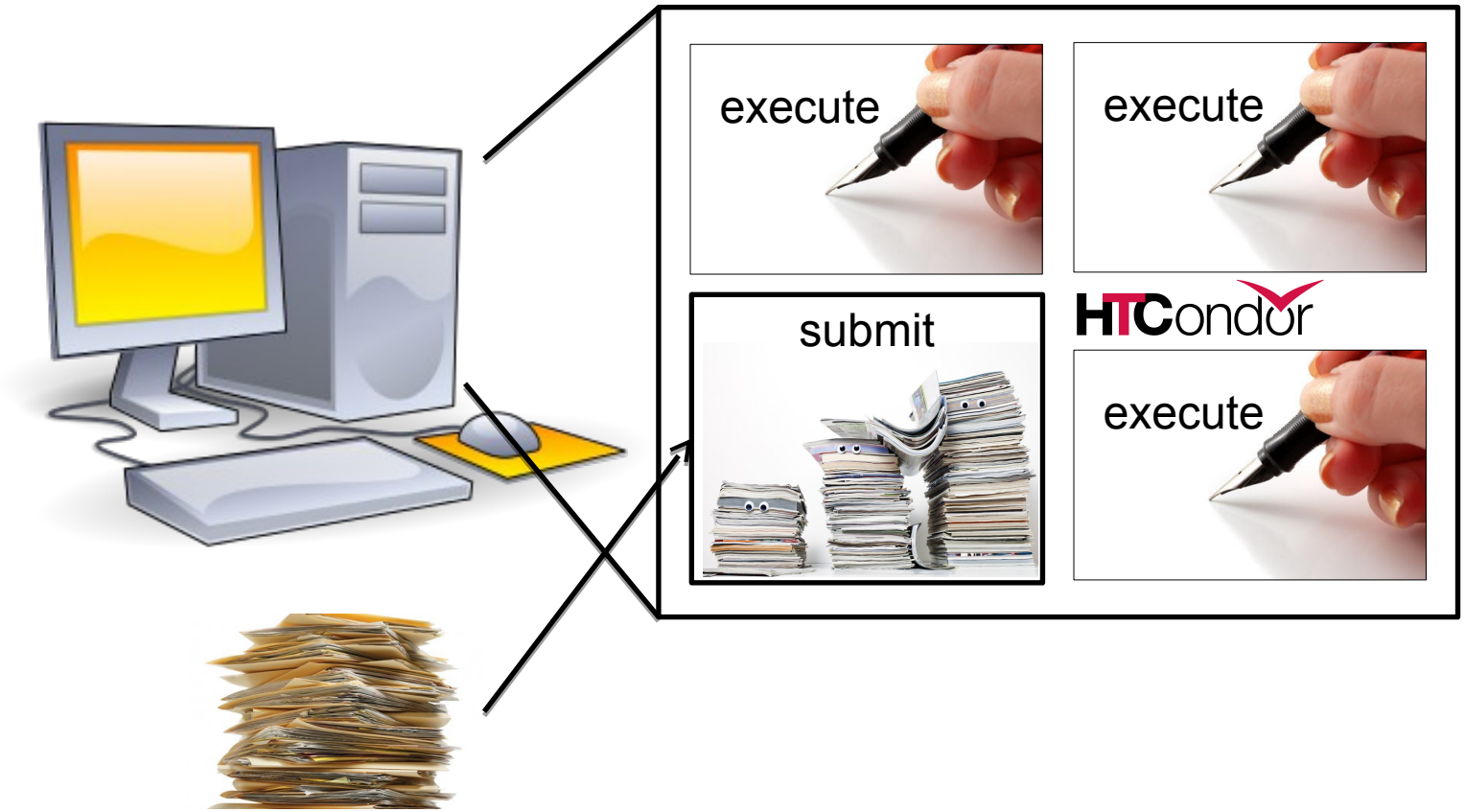
- Software that schedules and runs computing tasks on computers

How It Works

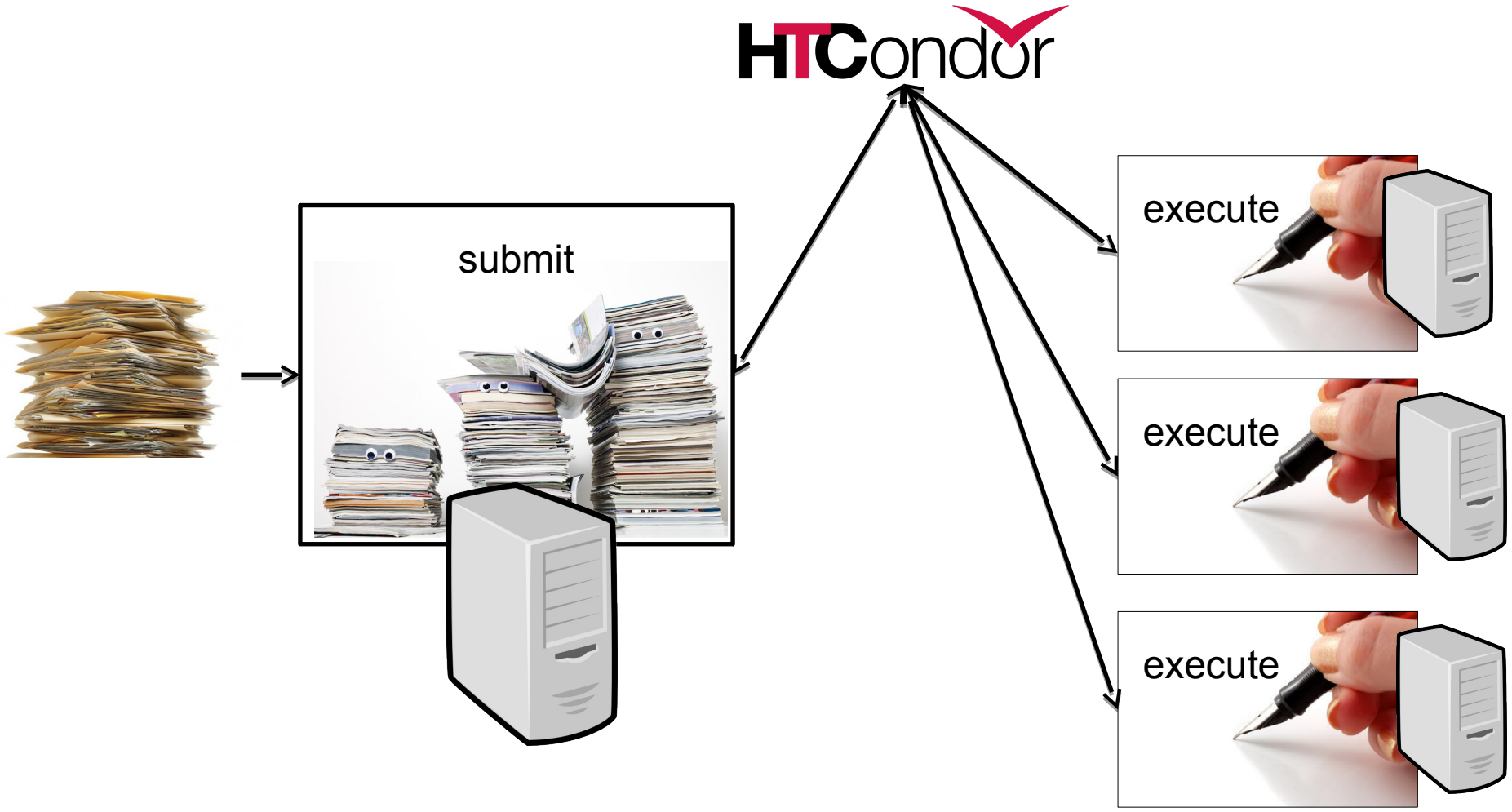
- Submit tasks to a queue (on a submit point)
- HTCondor schedules them to run on computers (execute points)



Single Computer



Multiple 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

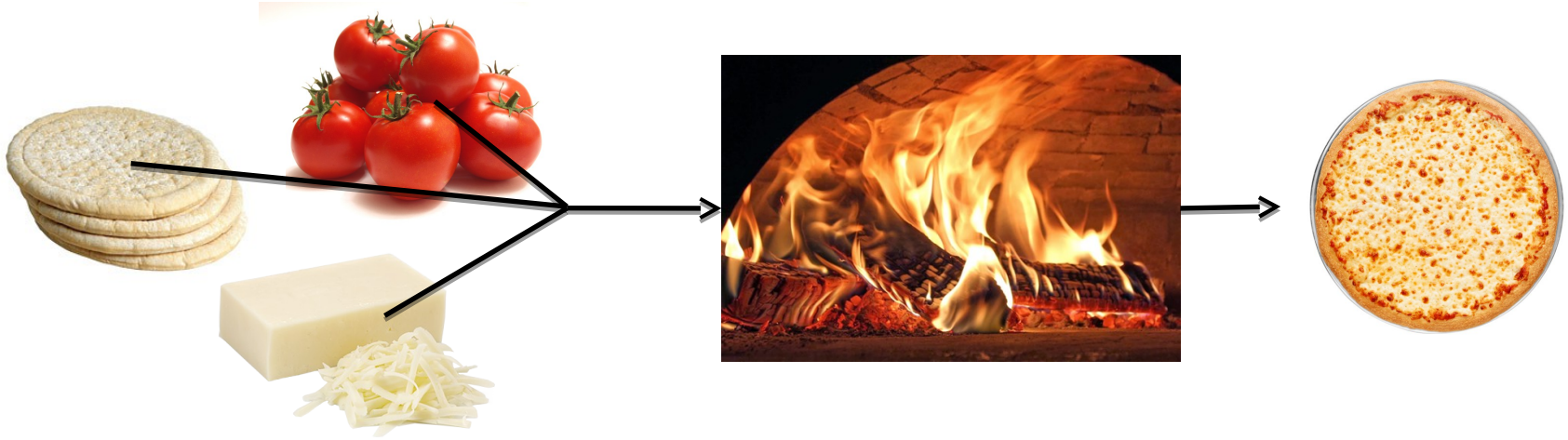
- For the purposes of this tutorial, we are assuming that someone else has set up HTCondor on a computer/computers to create a HTCondor “pool”.
- The focus of this talk is how to run computational work on this system.

Setting up an HTCondor pool will be covered in “Administering HTCondor”, by Greg Thain, at 1:05 today (May 17)

Running a Job with HTCondor

Jobs

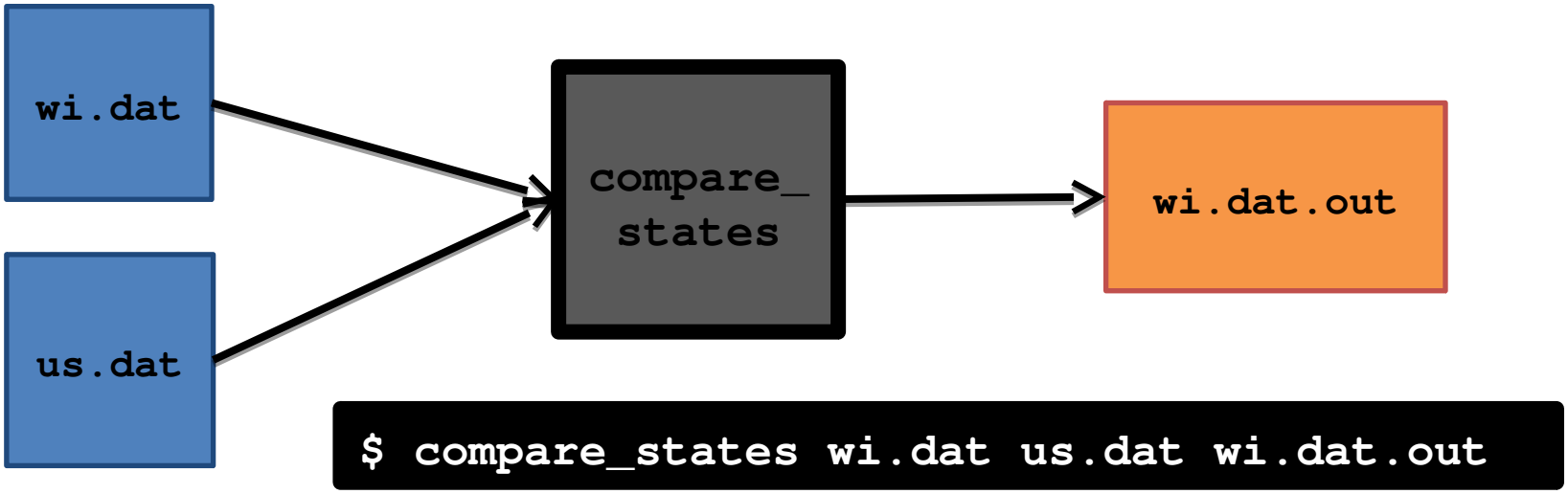
- A single computing task is called a “job”
- Three main pieces of a job are the input, executable (program) and output



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

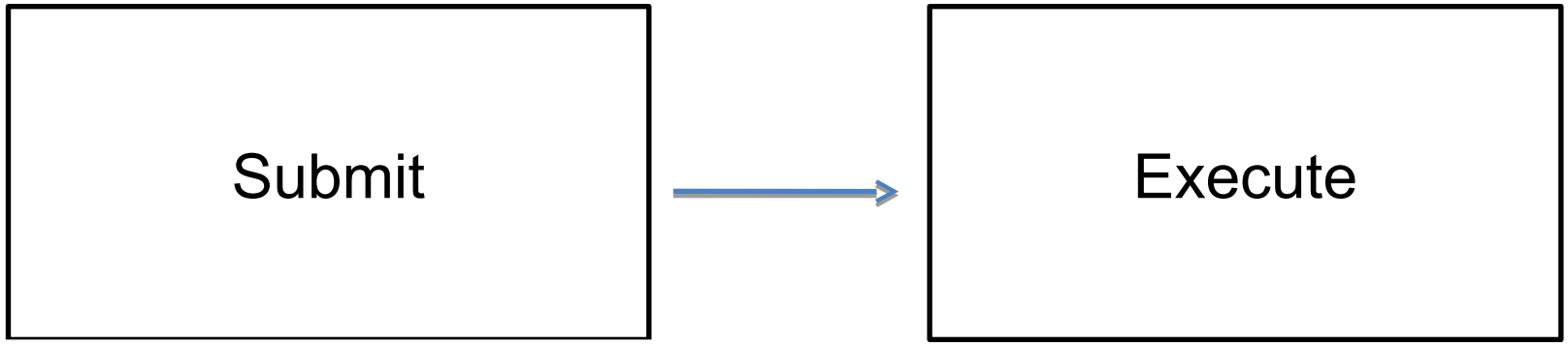
Job Example

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



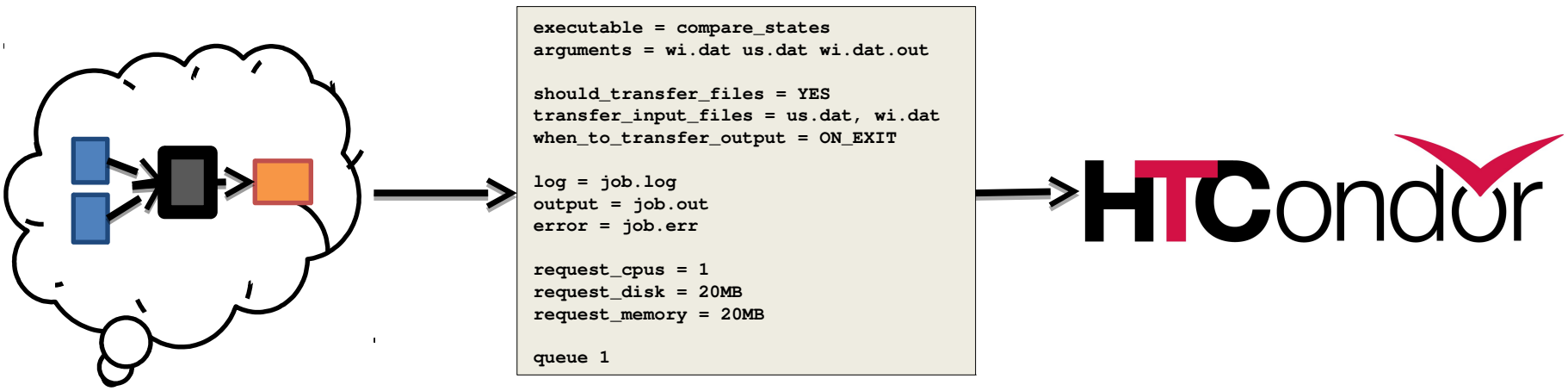
File Transfer

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



Job Translation

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



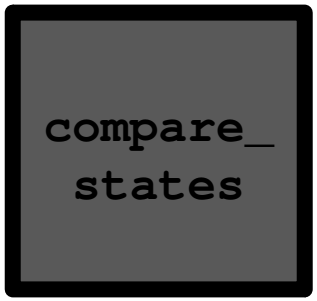
```
executable = compare_states
arguments = wi.dat us.dat wi.dat.out

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_disk = 20MB
request_memory = 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_disk = 20MB
request_memory = 20MB

queue 1
```

- List your executable and any arguments it takes.



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

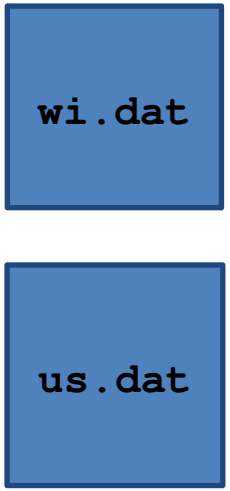
```
$ compare_states wi.dat us.dat wi.dat.out
```

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_disk = 20MB
request_memory = 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_disk = 20MB
request_memory = 20MB

queue 1
```

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

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_disk = 20MB
request_memory = 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_disk = 20MB
request_memory = 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-5.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
```

HTCondor Manual: condor_submit
HTCondor Manual: condor_q

condor_q

```
$ condor_q
-- Schedd: submit-5.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
```

JobId = **ClusterId**.**ProcId**

- By default **condor_q** shows user's job only*
- Constrain with username, **ClusterId** or full **JobId**, which will be denoted **[U/C/J]** in the following slides

* as of version 8.5

Job Idle

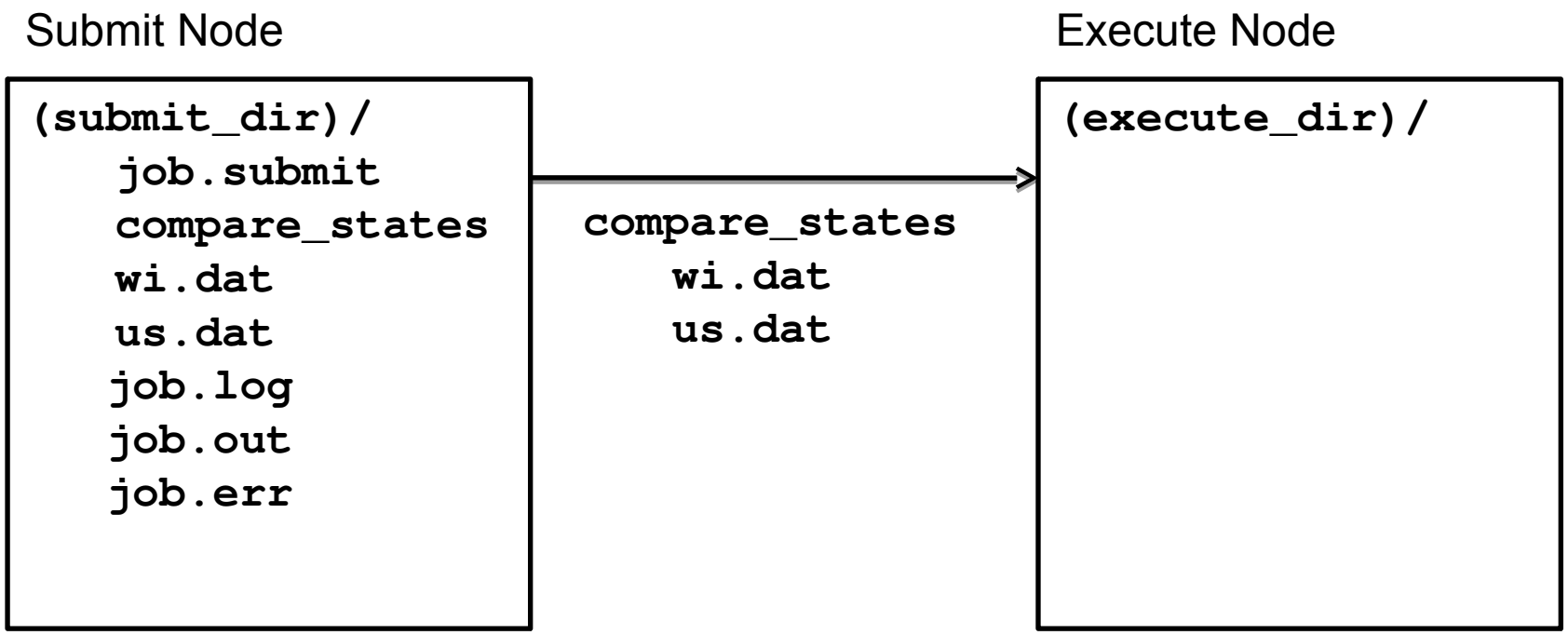
```
$ condor_q
-- Schedd: submit-5.chtc.wisc.edu : <128.104.101.92:9618?...
 ID          OWNER      SUBMITTED     RUN_TIME ST PRI SIZE CMD
128.0        alice      5/9  11:09   0+00:00:00 I  0    0.0 compare_states wi.dat us.dat

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

Submit Node

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

Job Starts

```
$ condor_q
-- Schedd: submit-5.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+00:00:0  <  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

-- Schedd: submit-5.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+00:01:03 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

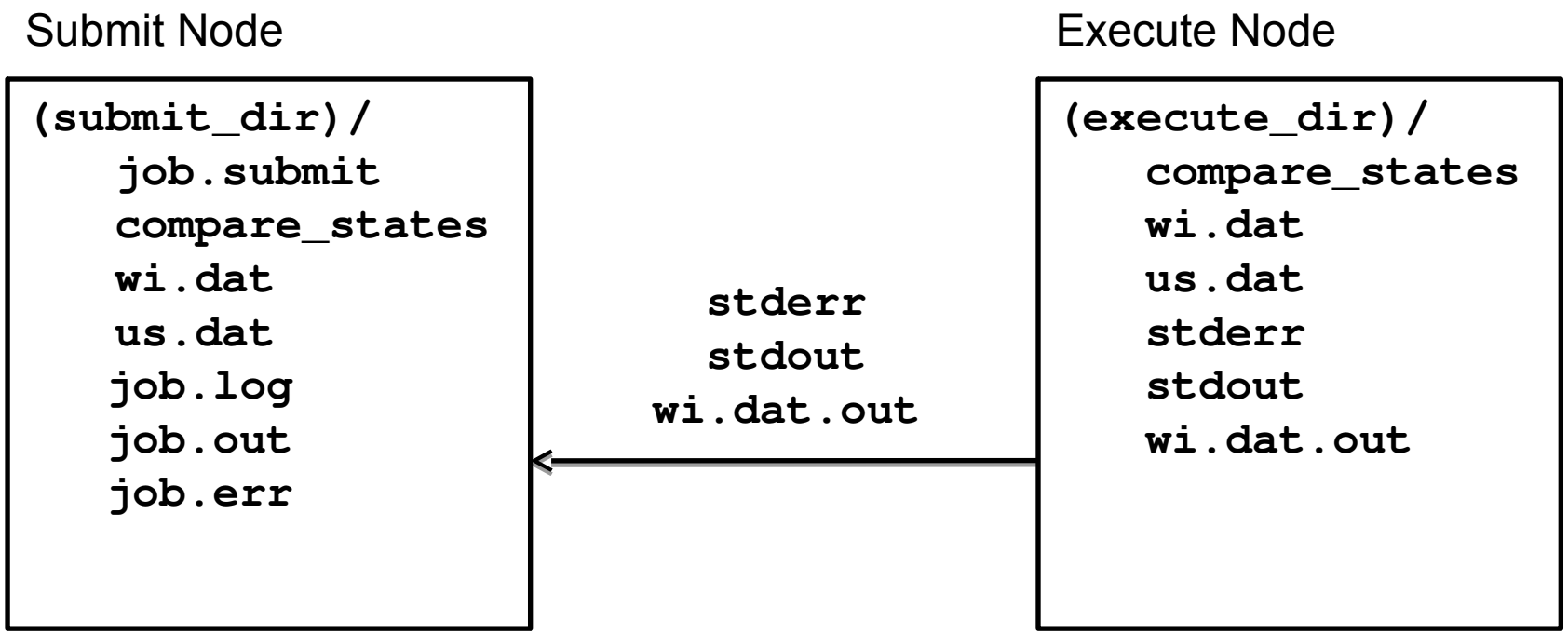
```
(submit_dir)/
    job.submit
    compare_states
    wi.dat
    us.dat
    job.log
    job.out
    job.err
```

Execute Node

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

Job Completes

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

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



Job Completes (cont.)

```
$ condor_q


-- Schedd: submit-5.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
```

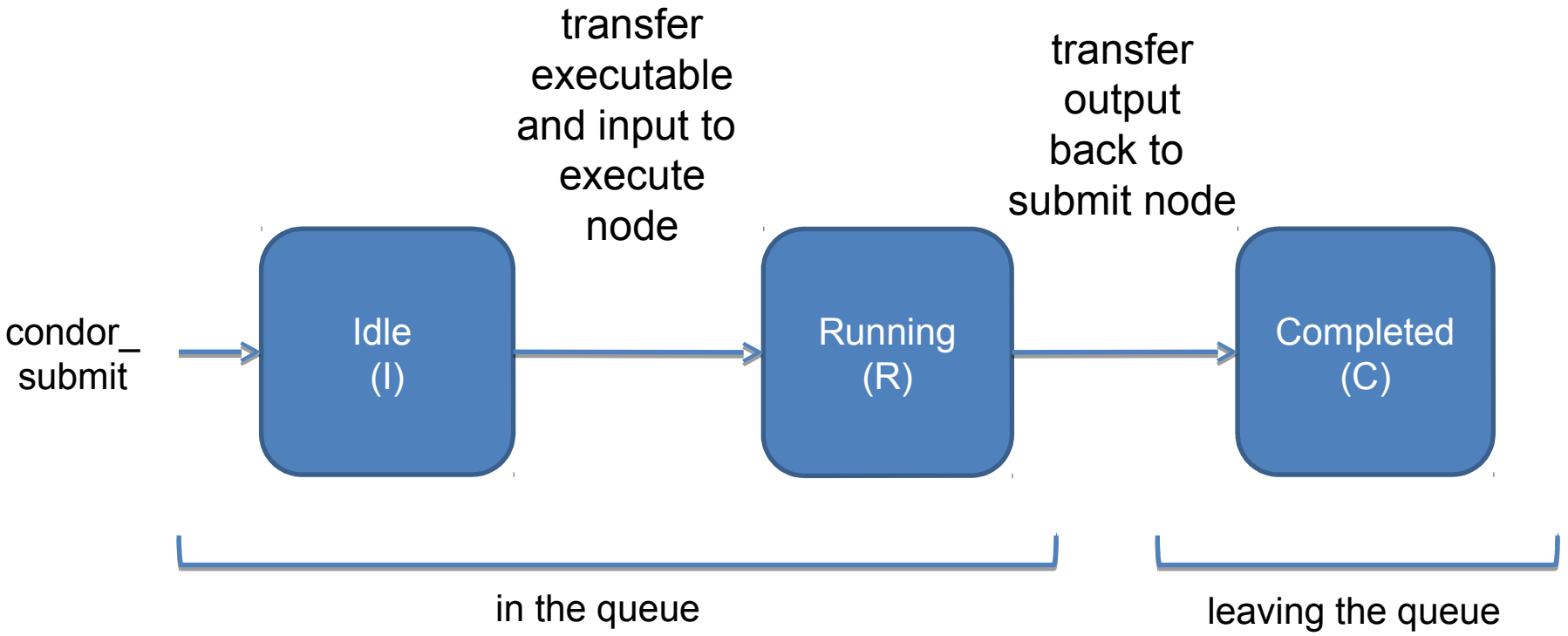
Submit Node

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

Log File

```
000 (128.000.000) 05/09 11:09:08 Job submitted from host:
<128.104.101.92&sock=6423_b881_3>
...
001 (128.000.000) 05/09 11:10:46 Job executing on host:
<128.104.101.128:9618&sock=5053_3126_3>
...
006 (128.000.000) 05/09 11:10:54 Image size of job updated: 220
    1  -  MemoryUsage of job (MB)
    220  -  ResidentSetSize of job (KB)
...
005 (128.000.000) 05/09 11:12:48 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
```

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 + configuration
- For example: file transfer
  - previous example assumed files would need to be transferred between submit/execute

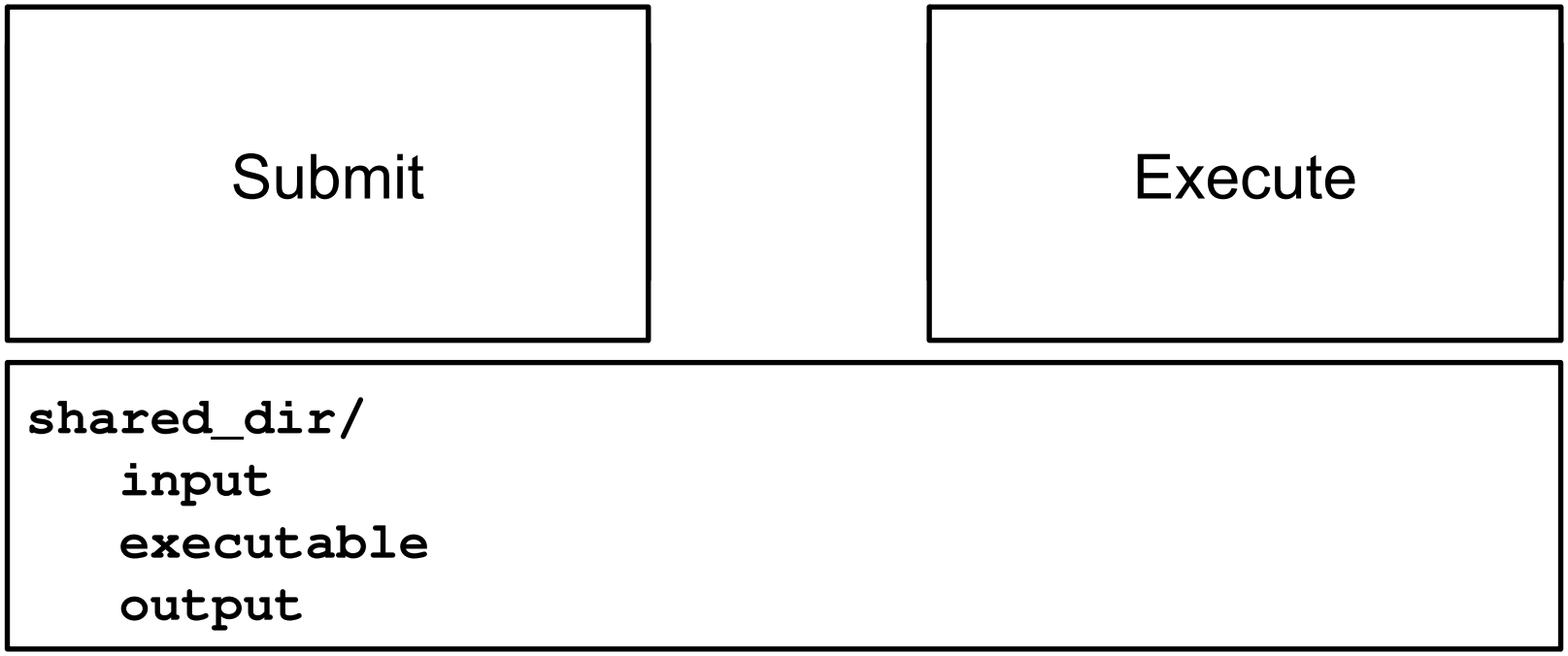
```
should_transfer_files = YES
```

  - 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



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

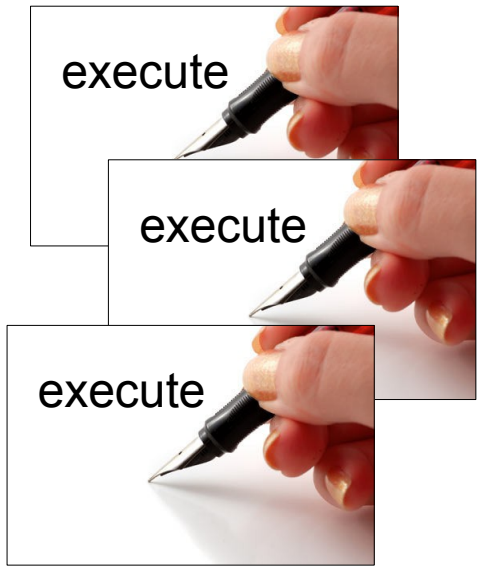
- Even if your system has default CPU, memory and disk requests, these may be too small!
- Important to run test jobs and use the log file to request the right amount of resources:
  - requesting too little: causes problems for your and other jobs; jobs might by held by HTCondor
  - requesting too much: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

Job Matching and Class Ad Attributes

The Central Manager

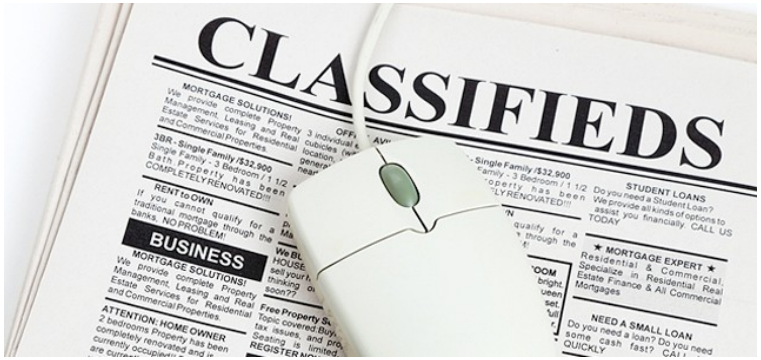
- HTCondor matches jobs with computers via a “central manager”.

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

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
```

+

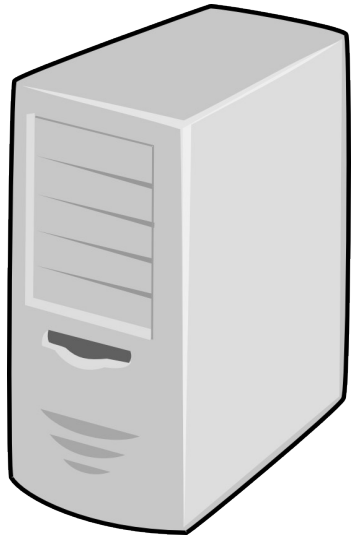
HTCondor configuration*

=

```
RequestCpus = 1
Err = "job.err"
WhenToTransferOutput = "ON_EXIT"
TargetType = "Machine"
Cmd =
"/home/alice/tests/htcondor_week/compar
e_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.lo
g"
RequestMemory = 20
...
```

*Configuring HTCondor will be covered in "Administering HTCondor", by Greg Thain, at 1:05 today (May 17)

Computer “Machine” Class Ad



+

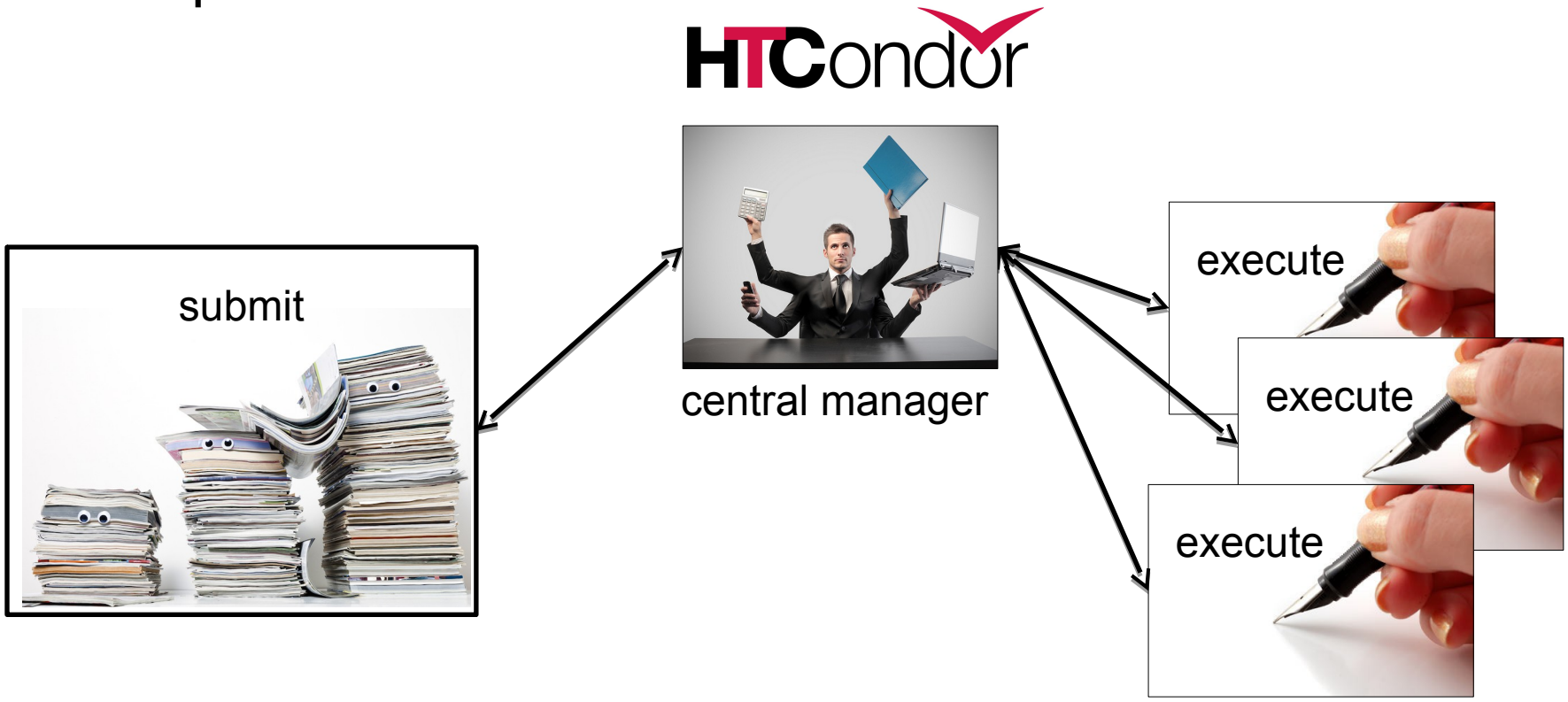
HTCondor configuration

=

```
HasFileTransfer = true
DynamicSlot = true
TotalSlotDisk = 4300218.0
TargetType = "Job"
TotalSlotMemory = 2048
Mips = 17902
Memory = 2048
UtsnameSysname = "Linux"
MAX_PREEMPT = ( 3600 * ( 72 - 68 *
( WantGlidein =?= true ) ) )
Requirements = ( START ) &&
( IsValidCheckpointPlatform ) &&
( WithinResourceLimits )
OpSysMajorVer = 6
TotalMemory = 9889
HasGluster = true
OpSysName = "SL"
HasDocker = true

...
```

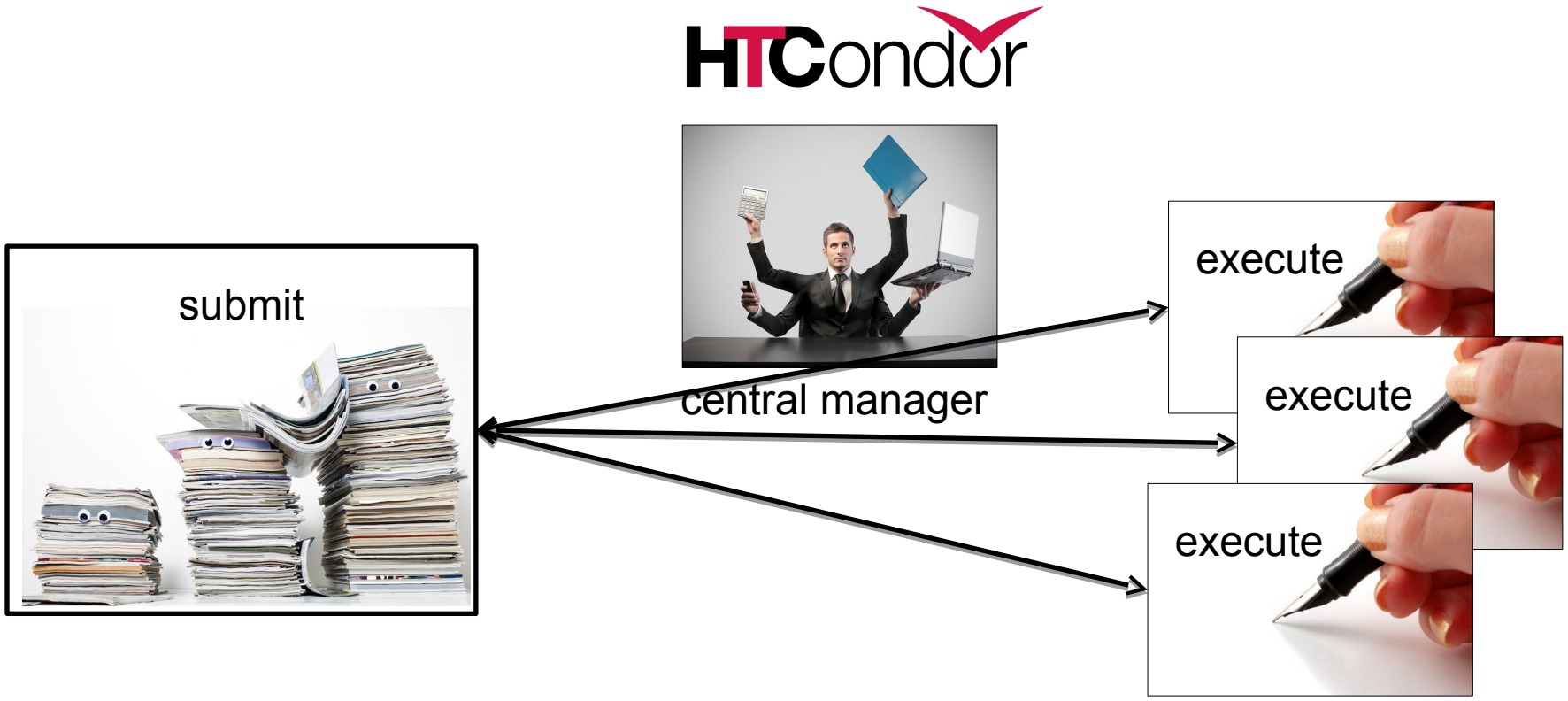
Job Matching

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



Job Execution

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



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
- **`BatchName`**: optional attribute to label job batches
- ...and more

Displaying Job Attributes

- Use the “auto-format” option:

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

```
$ condor_q -af ClusterId ProcId RemoteHost MemoryUsage

17315225 116 slot1_1@e092.chtc.wisc.edu 1709
17315225 118 slot1_2@e093.chtc.wisc.edu 1709
17315225 137 slot1_8@e125.chtc.wisc.edu 1709
17315225 139 slot1_7@e121.chtc.wisc.edu 1709
18050961 0 slot1_5@c025.chtc.wisc.edu 196
18050963 0 slot1_3@atlas10.chtc.wisc.edu 269
18050964 0 slot1_25@e348.chtc.wisc.edu 245
18050965 0 slot1_23@e305.chtc.wisc.edu 196
18050971 0 slot1_6@e176.chtc.wisc.edu 220
```

Other Displays

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

  `condor_q -all`

```
$ condor_q -all

-- Schedd: submit-5.chtc.wisc.edu : <128.104.101.92:9618?...
 ID           OWNER   SUBMITTED     RUN_TIME ST PRI SIZE CMD
233.0         alice   5/3  10:25   2+09:01:27 R  0   3663 wrapper_exec
240.0         alice   5/3  10:35   2+08:52:12 R  0   3663 wrapper_exec
248.0         alice   5/3  13:17   2+08:18:00 R  0   3663 wrapper_exec
631.6         bob     5/4  11:43   0+00:00:00 I  0    0.0 job.sh
631.7         bob     5/4  11:43   0+00:00:00 I  0    0.0 job.sh
631.8         bob     5/4  11:43   0+00:00:00 I  0    0.0 job.sh
631.9         bob     5/4  11:43   0+00:00:00 I  0    0.0 job.sh
631.10        bob     5/4  11:43   0+00:00:00 I  0    0.0 job.sh
631.16        bob     5/4  11:43   0+00:00:00 I  0    0.0 job.sh
```

Other Displays (cont.)

- See the whole queue, grouped in batches

  condor_q -all -batch

```
$ condor_q -all -batch

-- Schedd: submit-5.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_test.sh    5/9  10:55      _      _       _      2      _ 18913029.0 ...
alice    CMD: sb            5/9  10:57      _      2     998      _      _ 18913030.0-999
```

- Batches can be grouped manually using the **BatchName** attribute in a submit file:

```
+JobBatchName = "CoolJobs"
```

- Otherwise HTCondor groups jobs automatically

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
```

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_q -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
```

(60 SECOND) PAUSE

Questions so far?

Submitting Multiple Jobs with HTCondor

Many Jobs, One Submit File

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

Advantages

- 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

Multiple, 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

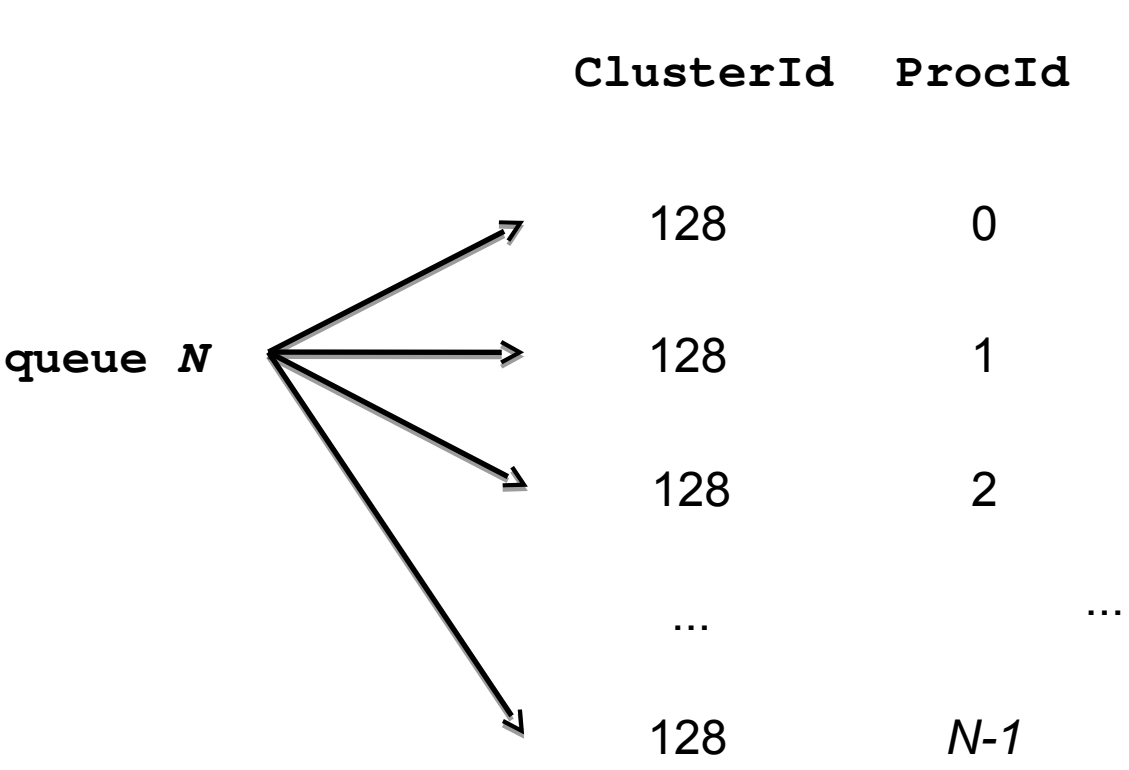
```
executable = analyze.exe
arguments = file0.in file0.out
transfer_input_files = file.in

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



- Each job's **`ClusterId`** and **`ProcId`** numbers are saved as job attributes
- They can be accessed inside the submit file using:
  - $(**`ClusterId`**)
  - $(**`ProcId`**)

Job Variation

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
```

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

Using $(ProcId)

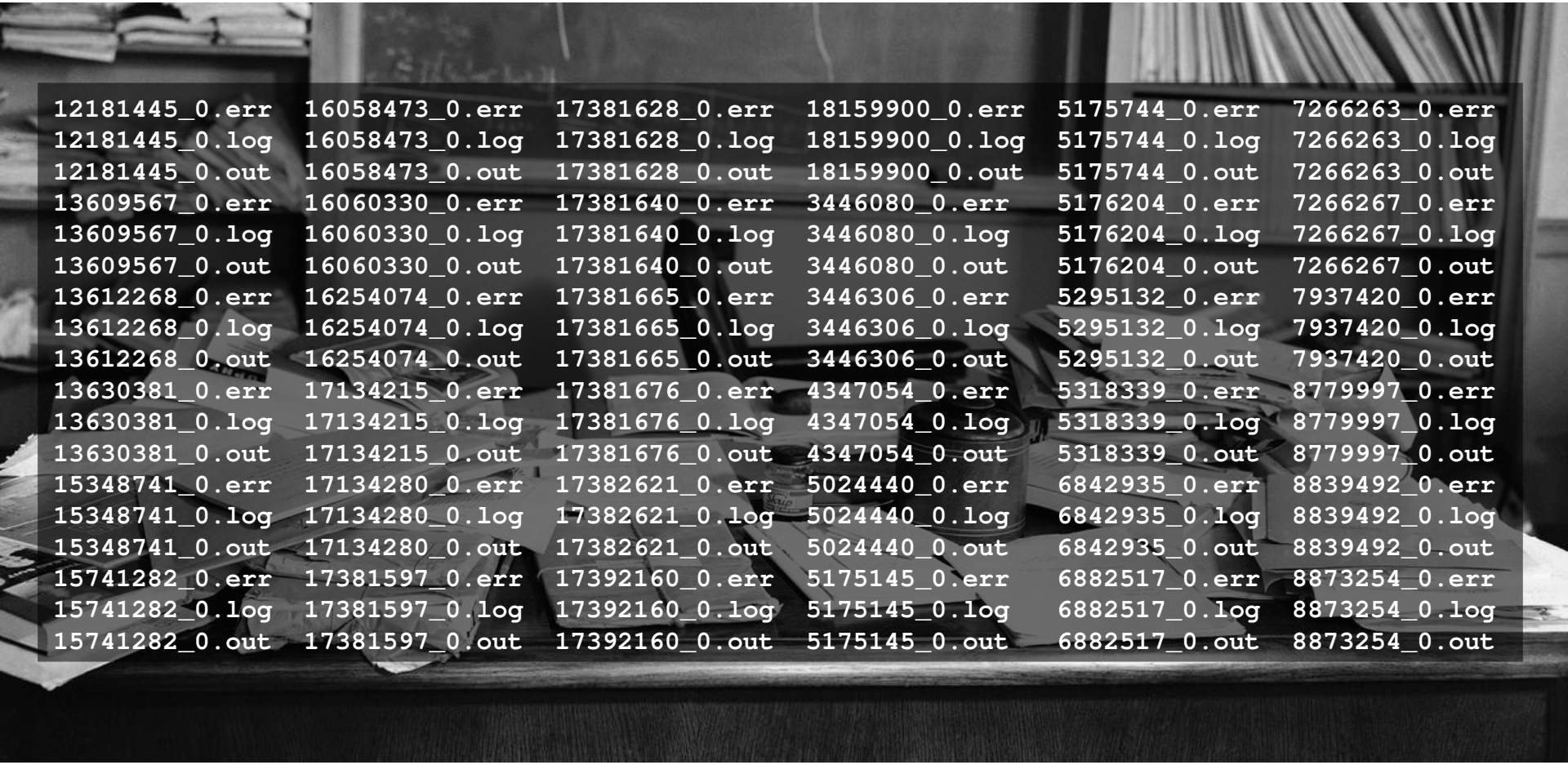
job.submit

```
executable = analyze.exe
arguments = file$(ProcId).in file$(ProcId).out
should_transfer_files = YES
transfer_input_files = file$(ProcId).in
when_to_transfer_output = ON_EXIT

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

queue 3
```

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

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

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
15348741_0.err  17134280_0.err  17382621_0.err  5024440_0.err   6842935_0.err  8839492_0.err
15348741_0.log  17134280_0.log  17382621_0.log  5024440_0.log   6842935_0.log  8839492_0.log
15348741_0.out  17134280_0.out  17382621_0.out  5024440_0.out   6842935_0.out  8839492_0.out
15741282_0.err  17381597_0.err  17392160_0.err  5175145_0.err   6882517_0.err  8873254_0.err
15741282_0.log  17381597_0.log  17392160_0.log  5175145_0.log   6882517_0.log  8873254_0.log
15741282_0.out  17381597_0.out  17392160_0.out  5175145_0.out   6882517_0.out  8873254_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

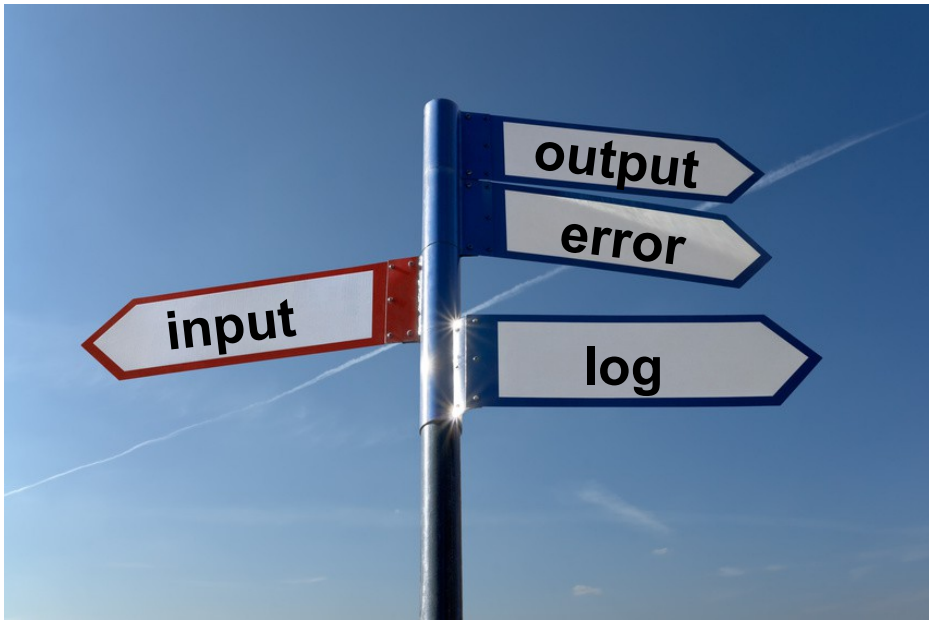
```
transfer_input_files = shared/
```

```
(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

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 only 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
```

- Come to TJ's talk: Advanced Submit at 4:25 today

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	Ecaptured by the operating system

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
```

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.
```

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 a job on hold, it provides a hold reason, which can be viewed with:

  condor_q -hold

```
$ condor_q -hold
128.0 alice  5/2 16:27 Error from slot1_1@wid-003.chtc.wisc.edu: Job
  has gone over memory limit of 2048 megabytes.
174.0 alice  5/5 20:53 Error from slot1_20@e098.chtc.wisc.edu: SHADOW at
  128.104.101.92 failed to send file(s) to <128.104.101.98:35110>: error
  reading from /home/alice/script.py: (errno 2) No such file or directory;
  STARTER failed to receive file(s) from <128.104.101.92:9618>
319.959 alice  5/10 05:23 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
534.2   alice  5/10 09:46 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
```

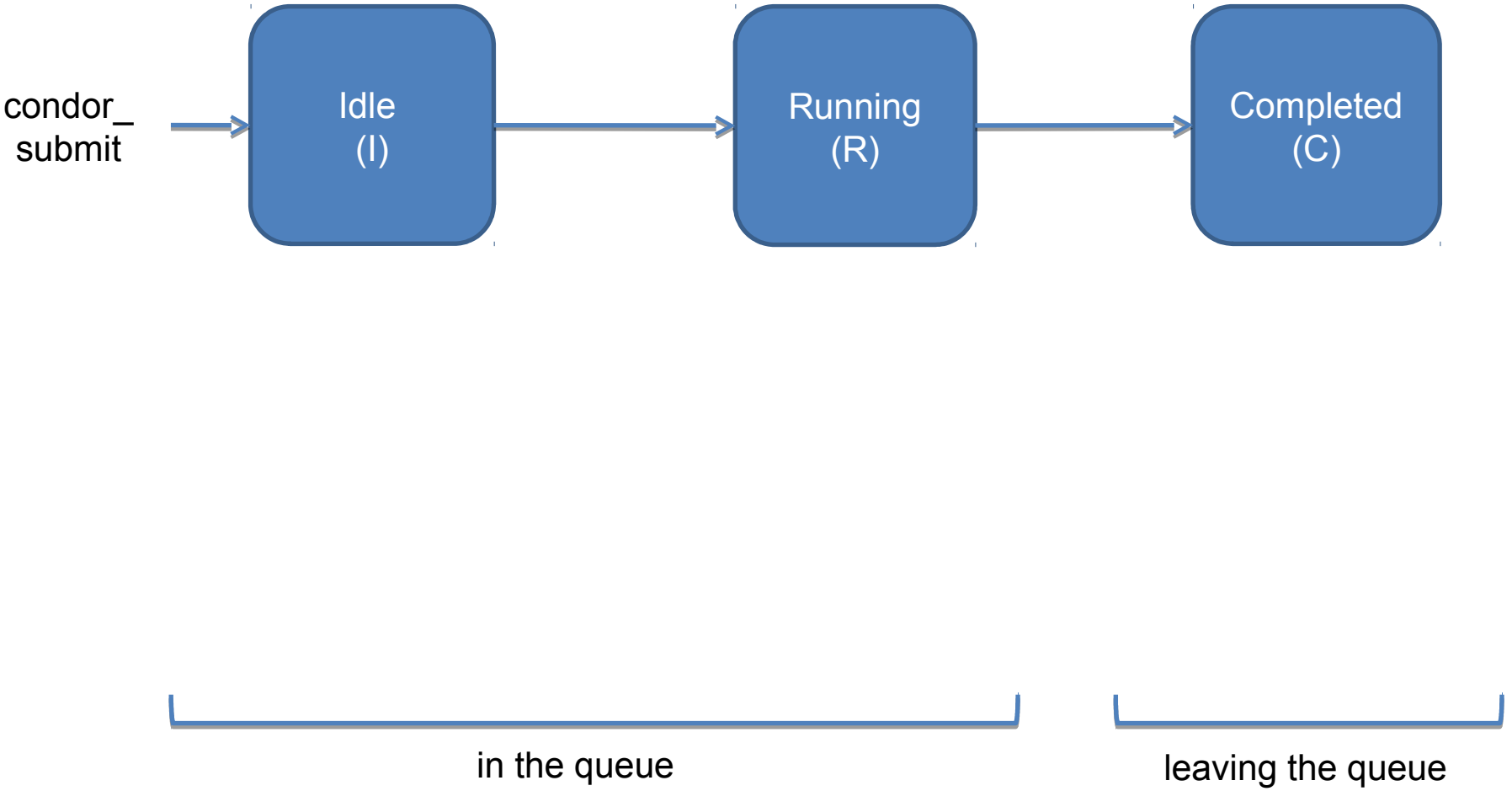
```
$ condor_hold 128
All jobs in cluster 128 have been held
```

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

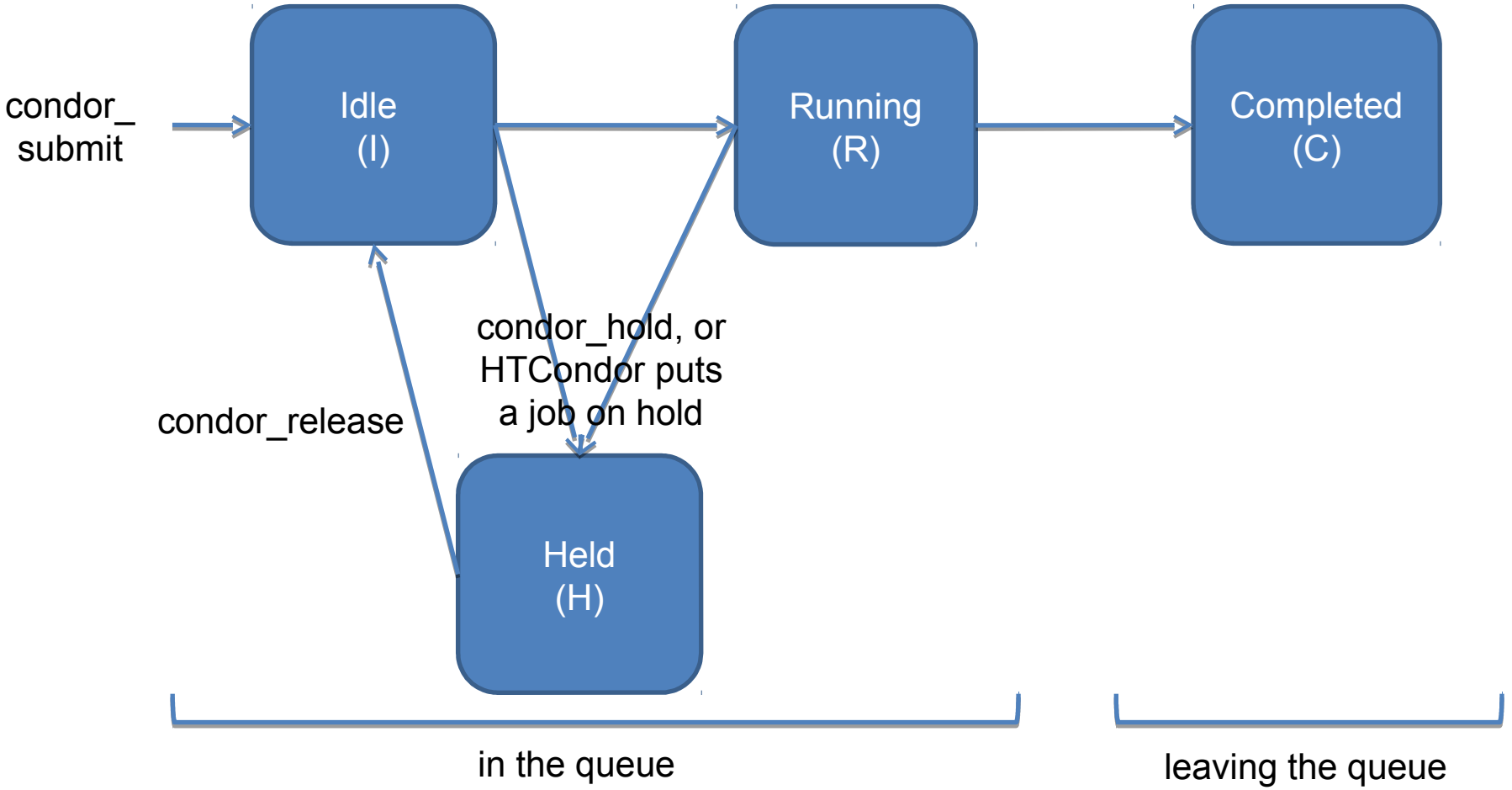
  - Remove it from the queue, using `condor_rm [U/C/J]`

HTCondor Manual: condor_hold
HTCondor Manual: condor_rm

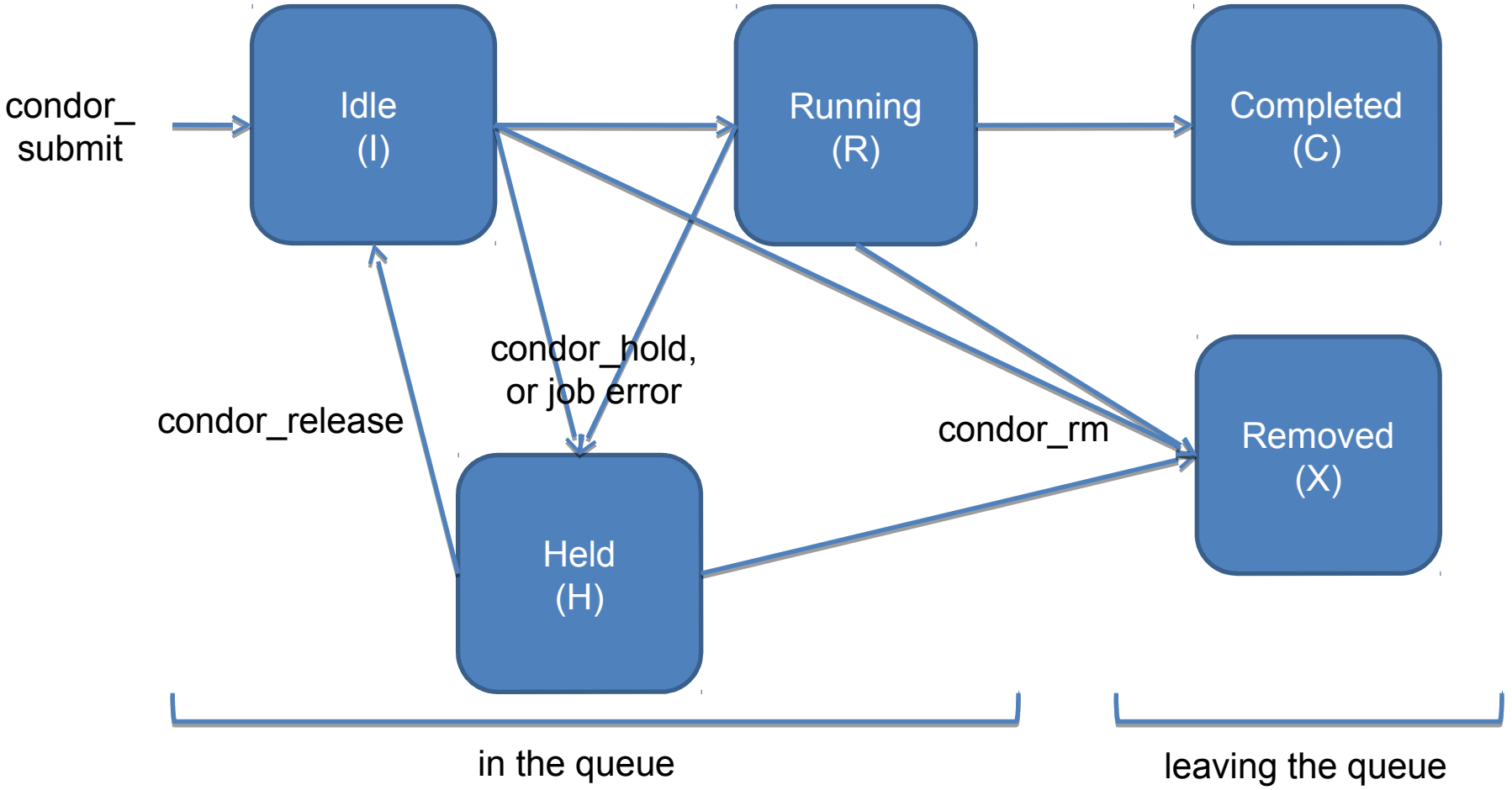
Job States, Revisited



Job States, Revisited



Job States, Revisited*



*not comprehensive

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
```

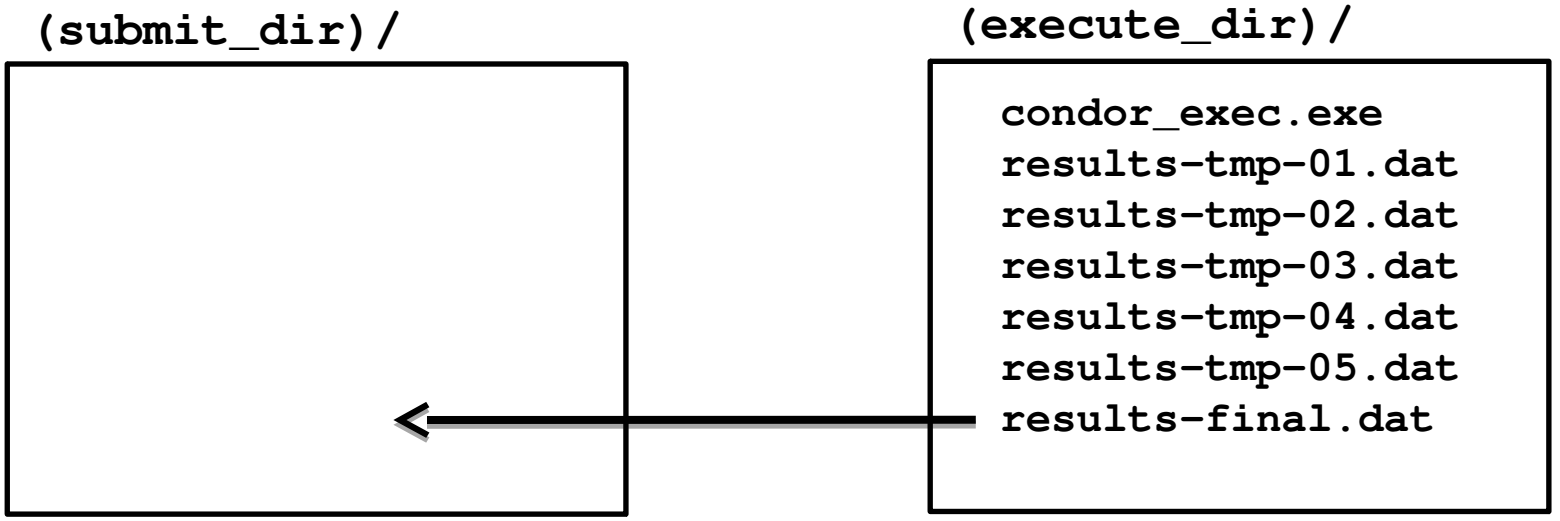
```
$ condor_submit -i interactive.submit
Submitting job(s).
1 job(s) submitted to cluster 18980881.
Waiting for job to start...
Welcome to slot1_9@e184.chtc.wisc.edu!
```

- Useful for testing and troubleshooting

Output Handling

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

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



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

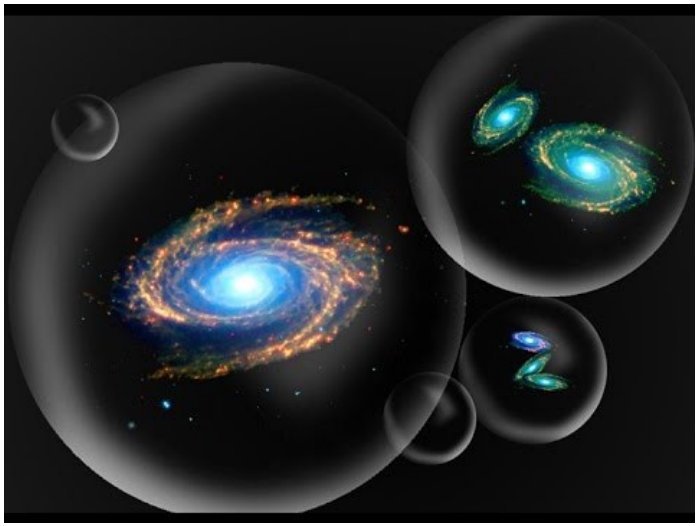
- HTCondor has different “universes” for running specialized job types

  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`**

HTCondor Manual: Standard Universe

- Java
  - Built-in Java support

HTCondor Manual: Java Applications

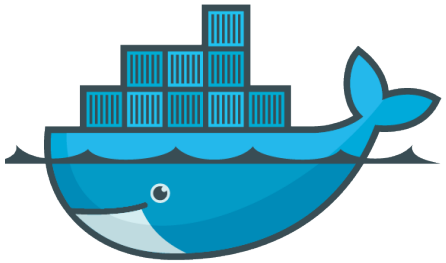
- Local
  - Run jobs on the submit node

HTCondor Manual: Local Universe

Other Universes (cont.)

- Docker
  - Run jobs inside a Docker container

  HTCondor Manual: Docker Universe Applications



- VM
  - Run jobs inside a virtual machine

  HTCondor Manual: Virtual Machine Applications
- Parallel
  - Used for coordinating jobs across multiple servers (e.g. MPI code)
  - Not necessary for single server multi-core jobs

  HTCondor Manual: Parallel Applications

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.

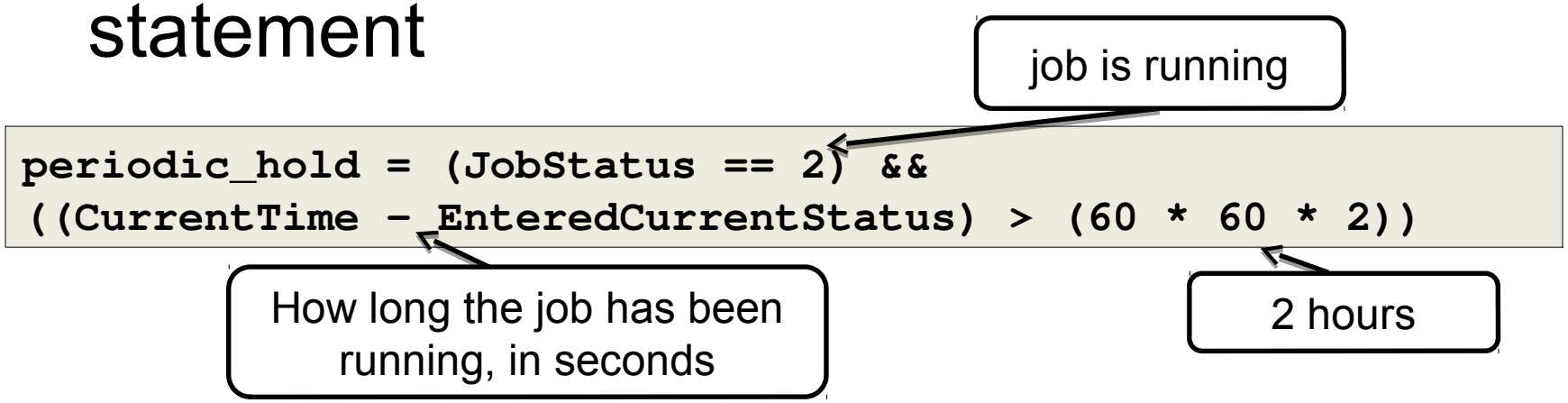
Retries

- Problem: a small number of jobs fail with a known error code; if they run again, they complete successfully.
- Solution: If the job exits with the error code, leave it in the queue to run again

```
on_exit_remove = (ExitBySignal == False) && (ExitCode == 0)
```

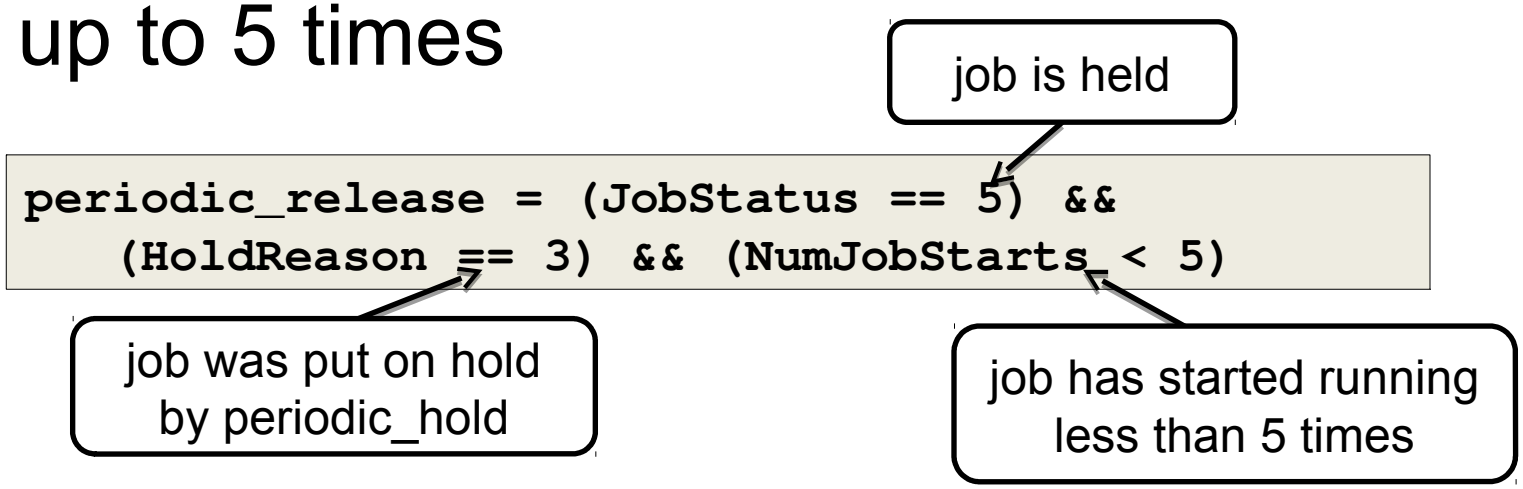
Automatically Hold Jobs

- 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



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



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

Automatic Memory Increase

- Putting all these pieces together, the following lines will:
  - request a default amount of memory (2GB)
  - put the job on hold if it is exceeded
  - release the the job with an increased memory request

```
request_memory = ifthenelse(MemoryUsage =!= undefined,(MemoryUsage *
3/2), 2048)
periodic_hold = (MemoryUsage >= ((RequestMemory) * 5/4 )) &&
(JobStatus = 2)
periodic_release = (JobStatus == 5) && ((CurrentTime -
EnteredCurrentStatus) > 180) && (NumJobStarts < 5) &&
(HoldReasonCode =!= 13) && (HoldReasonCode =!= 34)
```

Relevant Job Attributes

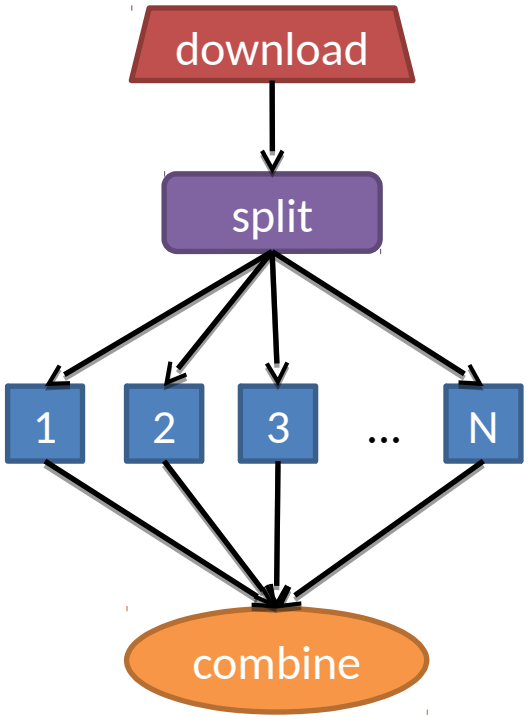
- **`CurrentTime`**: current time
- **`EnteredCurrentStatus`**: time of last status change
- **`ExitCode`**: the exit code from the job
- **`HoldReasonCode`**: number corresponding to a hold reason
- **`NumJobStarts`**: how many times the job has gone from idle to running
- **`JobStatus`**: number indicating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

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, attend the next talk, DAGMan: HTCondor and Workflows by Kent Wenger at 10:45 today (May 17).



FINAL QUESTIONS?