Open Science Grid

More HTCondor for HTC

Monday AM, Lecture 2

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Questions so far?

Open Science Grid

Goals for this Session

- Understand HTCondor mechanisms more deeply
- Best ways to submit multiple jobs (what we're here for, right?)
- Testing and troubleshooting
- Automation, additional use cases, and features

How is HTC Optimized?

- System must track jobs, machines, policy, …
- System must recover gracefully from failures
- Try to use all available resources, all the time
- Lots of variety in users, machines, networks, ...
- Sharing is hard (e.g. policy, security)

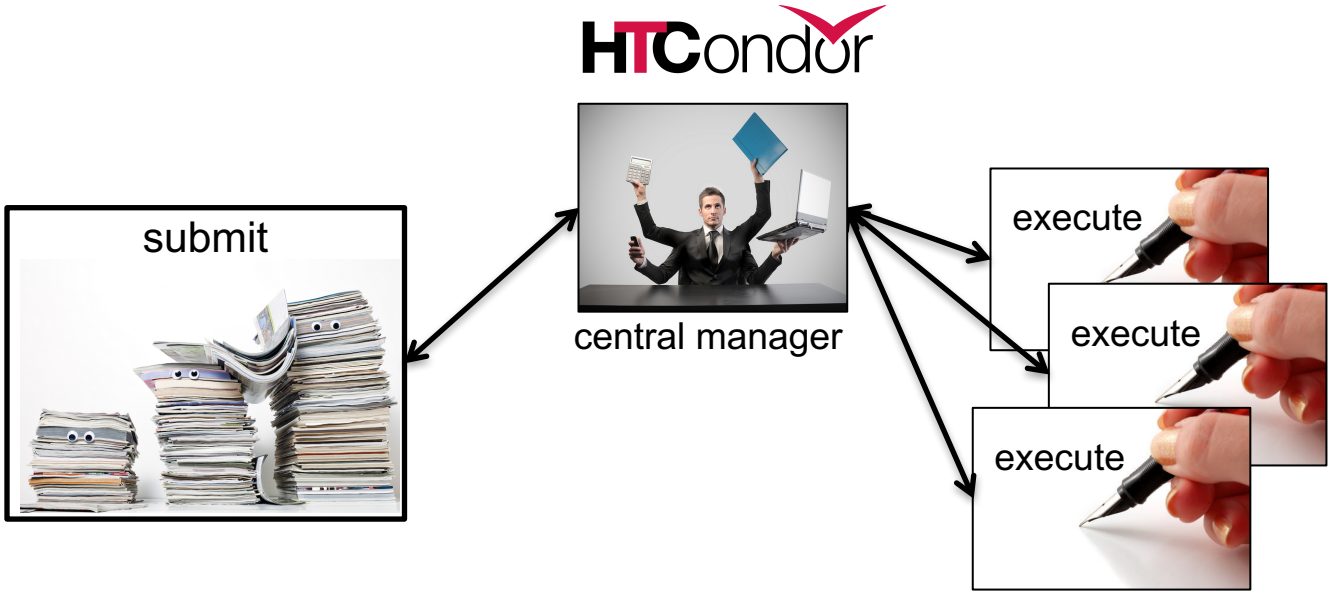
HTCONDOR MATCHMAKING

Roles in an HTCondor System

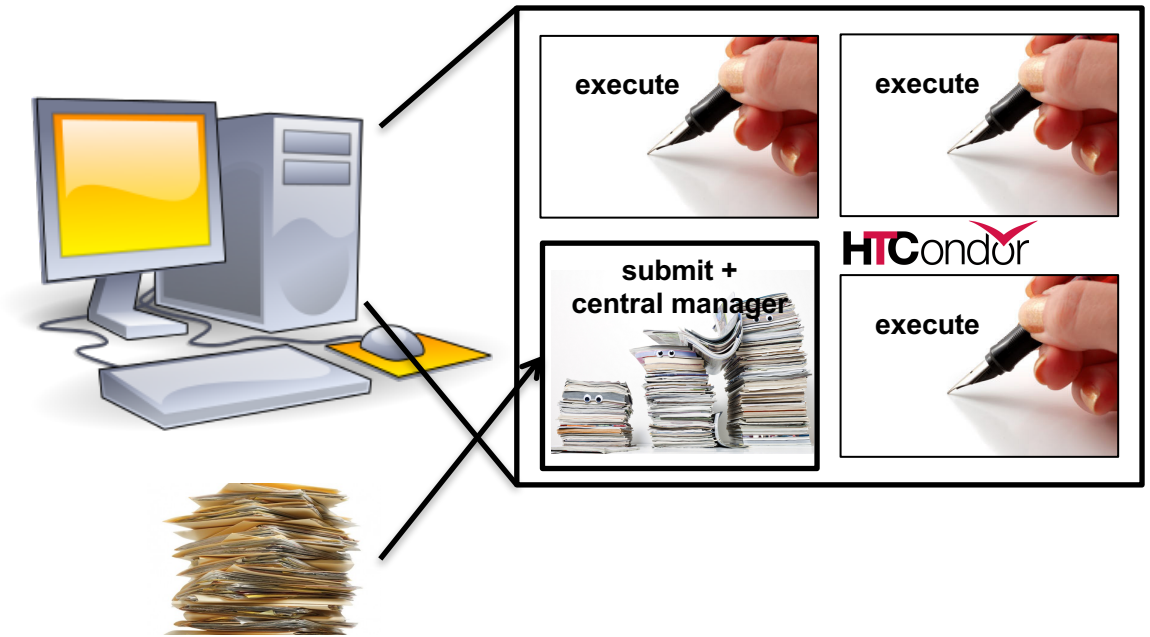
- **Users**
  - Define jobs, their requirements, and preferences
  - Submit and cancel jobs
  - Check on the status of jobs
- **Administrators**
  - Configure and control the HTCondor system
  - Implement policies
  - Check on the status of machines
- **HTCondor Software**
  - Track and manage machines
  - Track and run jobs
  - Match jobs to machines (enforcing all policies)

Job Matching

- On a regular basis, the **central manager** reviews **Job** and **Machine** attributes, and pool policies, and matches jobs to **slots**.



Single Computer



Terminology: Matchmaking

two-way process of finding a slot for a job

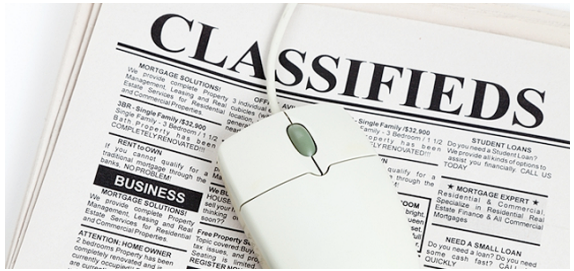
- ***Jobs* have requirements and preferences**
  - e.g.: I need one CPU core, 100 GB of disk space, and 10 GB of memory
- ***Machines* have requirements and preferences**
  - E.g.: I run jobs only from users in the Comp. Sci. dept., and prefer to run ones that ask for a lot of memory
- *Important jobs may run first or replace less important ones*

HTCondor Priorities

- **User priority**
  - Computed based on past usage
  - Determines user's "fair share" percentage of slots
  - Lower number means run sooner (0.5 is minimum)
- **Job priority**
  - Set per job by the user (owner)
  - Relative to that user's other jobs
  - Set in submit file or changed later with `condor_prio`
  - Higher number means run sooner
- **Preemption**
  - Low priority jobs stopped for high priority ones (stopped jobs go back into the regular queue)
  - Governed by fair-share algorithm and pool policy
  - Not enabled on all pools

Class Ads

- HTCondor stores a list of information about **each job** and **each machine** of potential slots.
- This information is stored for each job and each machine as its **"Class Ad"**



- Class Ads have the format:

```
AttributeName = value
```

can be a boolean (T/F), number, or string

HTCondor Manual: Appendix A: Class Ad Attributes

Job ClassAd

Submit file

```
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
```

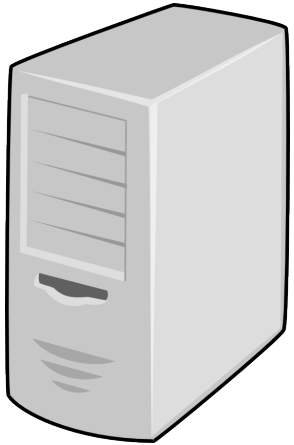
+

Default 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”
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
...
```

Machine ClassAd



+

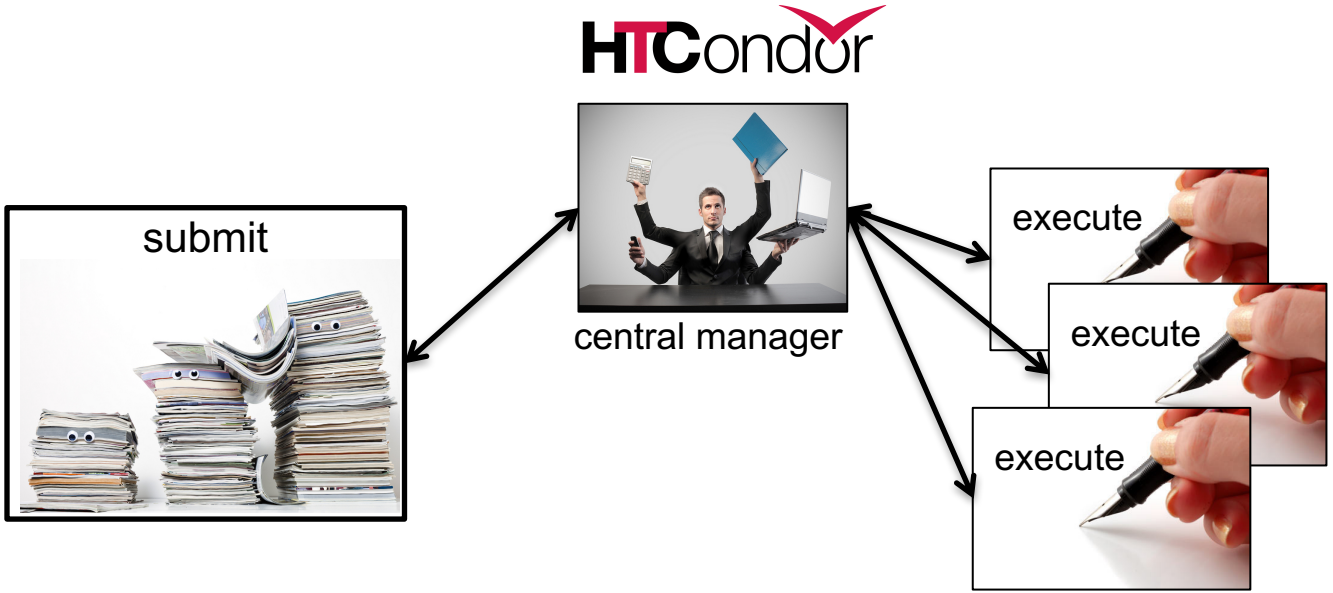
Default HTCondor configuration

=

```
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
...
```

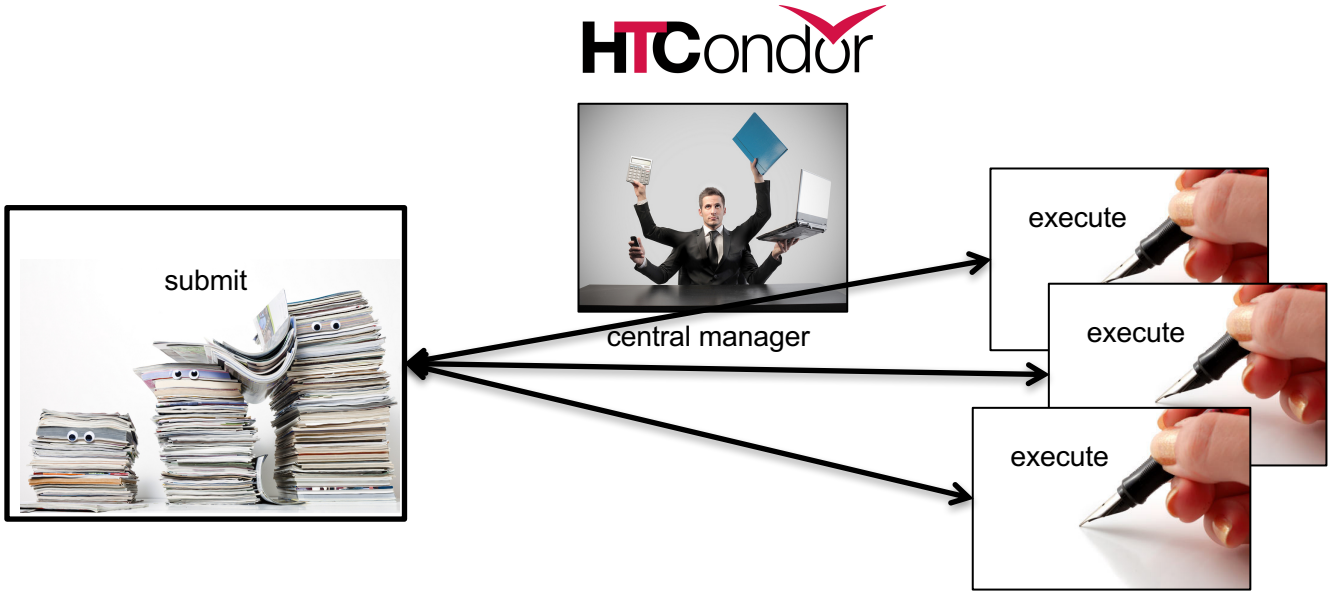
Job Matching

- On a regular basis, the central manager reviews **Job** and **Machine** *ClassAds* and matches jobs to **slots**.



Job Execution

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



USING CLASSADS

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 12008.0
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
- **`JobBatchName`**: user-labeled job batches
- ...and more

Displaying Job Attributes

- View only specific attributes (**`-af`** for ‘autoformat’)

  `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
```

condor_q Reminder

- Default output is batched jobs
  - Batches can be grouped by the user with the **JobBatchName** attribute in a submit file:

```
JobBatchName = CoolJobs
```

  - Otherwise HTCondor groups jobs, automatically, by same executable
- To see individual jobs, use:

condor_q -nobatch

ClassAds for Machines & Slots

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

                     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 ClassAd 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

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

SUBMITTING MULTIPLE JOBS

Many Jobs, One Submit File

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

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Advantages

- Run many independent jobs...
  - analyze multiple data files
  - test parameter or input combinations
  - scale up by breaking up!
  - *we're learning HTC, right?*
- ...without having to:
  - create separate submit files for each job
  - submit and monitor each job, individually

From one job …

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 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 3
```

(submit_dir)/

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

job.submit
```

- Generates 3 jobs, but doesn't change inputs and will overwrite the outputs
- So how can we specify different values to each job?

Manual Approach (Not recommended!)

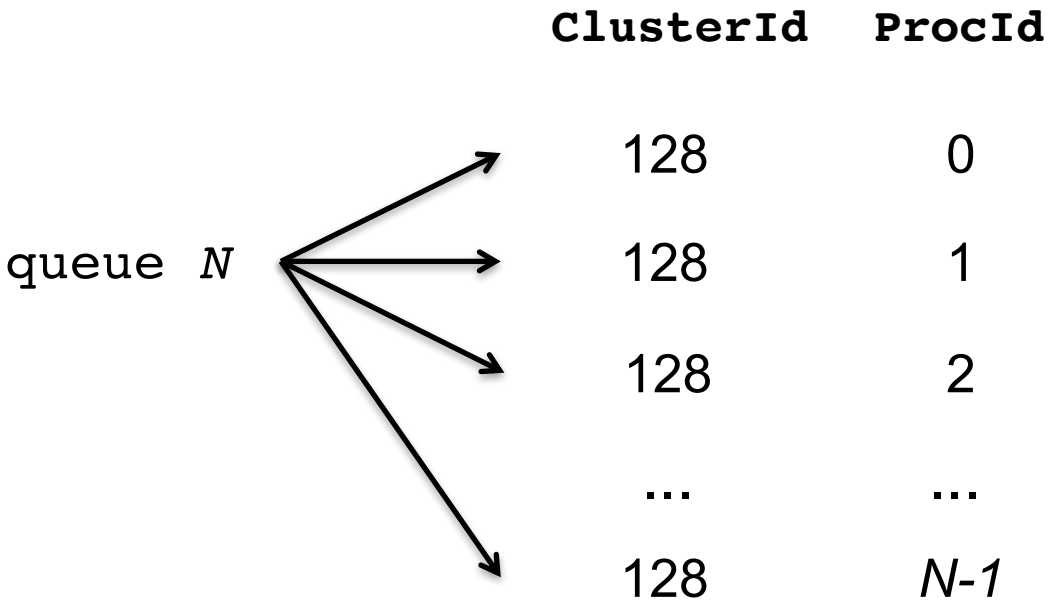
job.submit

```
executable = analyze.exe
log = job.log

arguments = file0.in file0.out
transfer_input_files = file0.in
output = job0.out
error = job0.err
queue 1

arguments = file1.in file1.out
transfer_input_files = file1.in
output = job1.out
error = job1.err
queue 1

...
```

(submit_dir)/

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

job.submit
```

Automatic Variables



Each job's **ClusterId** and **ProcId** numbers are autogenerated and saved as job attributes

They can be referenced inside the submit file using:*

- **$(ClusterId)**
- **$(ProcId)**

* $(Cluster) and $(Process) are also used

Using $(ProcId) for Numbered Files

job.submit

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

log = job_$(Cluster).log
output = job_$(Process).out
error = job_$(Process).err

queue 3
```

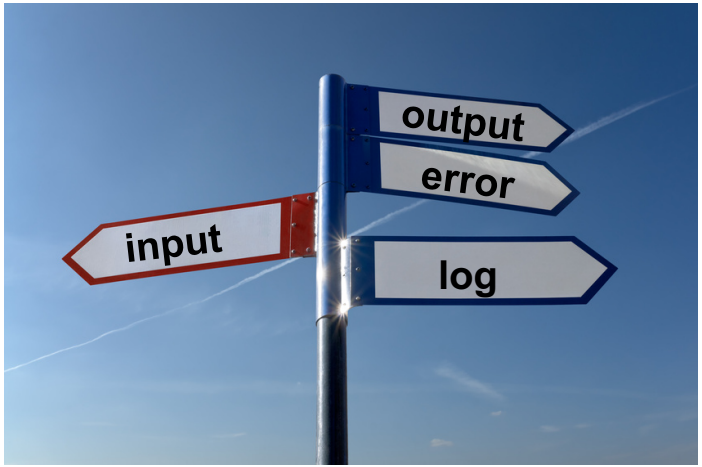
(submit_dir)/

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

job.submit
```

- $(Process) and $(Cluster) allow us to provide unique values to each job and submission!

Organizing Files in Sub-Directories

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



* must be created before the job is submitted

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/
```

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

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

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
```

Separating Files by Job with InitialDir

- **`Initialdir`** sets the initial location for each job's files, allowing each job to "live" in separate directories on the submit server
- Allows same filenames for input/output files across jobs
- Also useful for jobs with lots of output files

Separating jobs with initialdir

(submit_dir)/

```
job.submit
analyze.exe

job0/
   file.in
   job.log
   job.err
   file.out

job1/
   file.in
   job.log
   job.err
   file.out

job2/
   file.in
   job.log
   job.err
   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 must be relative to the submission directory, and *not* in the InitialDir.

Many jobs per submit file

- Back to our compare_states example…
- What if we had data for each state? We could do 50 submit files (or 50 "`queue 1`" statements) ...

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

```
executable = compare_states
arguments = ca.dat us.dat ca.dat.out
…
```

```
executable = compare_states
arguments = mo.dat us.dat mo.dat.out
…
```

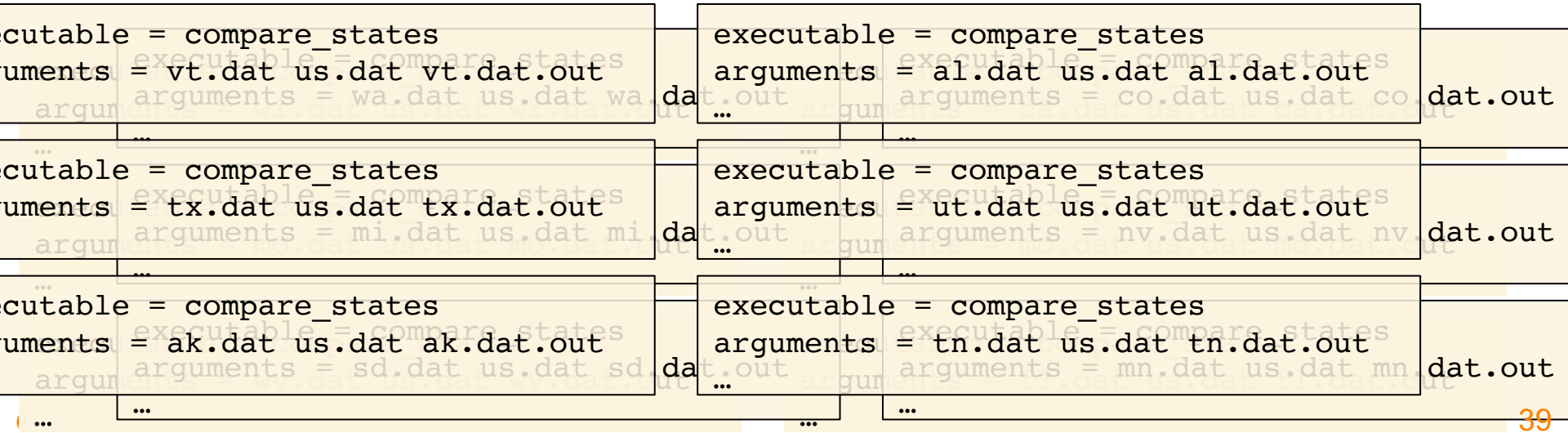
```
executable = compare_states
arguments = md.dat us.dat md.dat.out
…
```

```
executable = compare_states
arguments = wv.dat us.dat wv.dat.out
…
```

```
executable = compare_states
arguments = fl.dat us.dat fl.dat.out
…
```

Many jobs per submit file

- Back to our compare_states example…
- What if we had data for each state? We could do 50 submit files (or 50 "`queue 1`" statements) ...



Many jobs per submit file

- We could rename (map) our data to fit the $(Process) or approach …
- Or we could use HTCondor's powerful **`queue`** language to submit jobs using our own variables!

Submitting Multiple Jobs – Queue Statements

multiple "queue" statements	~~state = wi.dat queue 1 state = ca.dat queue 1 state = mo.dat queue 1~~ Not Recommended
var matching *pattern*	`queue state matching *.dat`
var in (i ii iii …)	`queue state in (wi.dat ca.dat co.dat)`

var1,var2 from *csv_file*	`queue state from state_list.txt`
	state_list.txt:
	`wi.dat`
	`ca.dat`
	`mo.dat`
	`...`

Using Multiple Variables

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

job.submit

```
executable = compare_states
arguments = -y $(year) -i $(infile)

transfer_input_files = $(infile)

queue infile,year from job_list.txt
```

job_list.csv

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

Submitting Multiple Jobs – Queue Statements

multiple "queue" statements	**Not recommended.** Can be useful when submitting job batches where a single non-file/non-argument characteristic is changing
var matching *pattern*	Natural nested looping, minimal programming, can use "files" or "dirs" keywords to narrow possible matches. Requires good naming conventions, less reproducible.
var in (i,ii,iii,…)	All information contained in the submit file: reproducible. Harder to automate submit file creation.
var1,var2 from *csv_file*	Supports multiple variables, highly modular (easy to use one submit file for many job batches that have different *var* lists), reproducible. Additional file needed, but can be automated.

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
```

- Combine with InitialDir:

```
InitialDir = $(directory)
queue directory matching dirs job*
```

TESTING AND TROUBLESHOOTING

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What Can Go Wrong?

- Jobs can go wrong “internally”:
  - the executable experiences an error
- Jobs can go wrong from HTCondor’s perspective:
  - a job can’t be matched
  - a job is missing files
  - 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, held, or stopped • Resources used • Exit status • Where job ran • Interruption reasons	Any "print" or "display" information from your program (may contain errors from the executable).	Errors captured by the operating system while the executable ran, or reported by the executable, itself.

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.
```


HTCondor Manual: condor_ssh_to_job

Held Jobs

- HTCondor will put your job on hold if there's something YOU need to fix.
  - files not found for transfer, over memory, etc.
- 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 until removed, or (fixed and) released.

Diagnosing Holds

- If HTCondor puts a job on hold, it provides a hold reason, which can be viewed in the log file, or with:

`condor_q -hold -af HoldReason`

```
$ condor_q -hold -af HoldReason
Error from slot1_1@wid-003.chtc.wisc.edu: Job has gone over
  memory limit of 2048 megabytes.
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>
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
```

Common Hold Reasons

- Job has used **more memory** than requested.
- **Incorrect path to files** that need to be transferred
- **Badly formatted executable scripts** (have Windows instead of Unix line endings)
- Submit directory is **over quota**.
- **Job has run for too long**. (72 hours allowed in CHTC Pool)
- 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
```

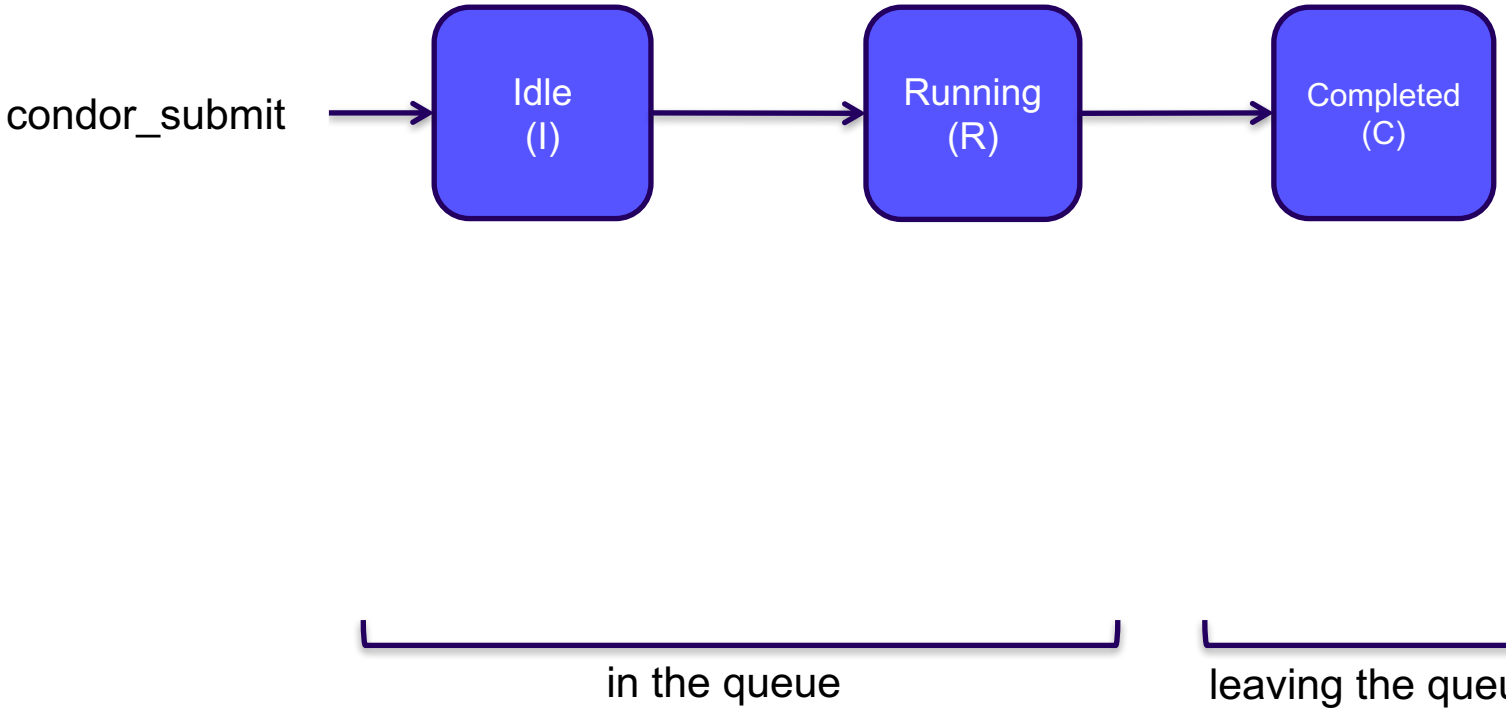
```
$ condor_hold 128
All jobs in cluster 128 have been held
```

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

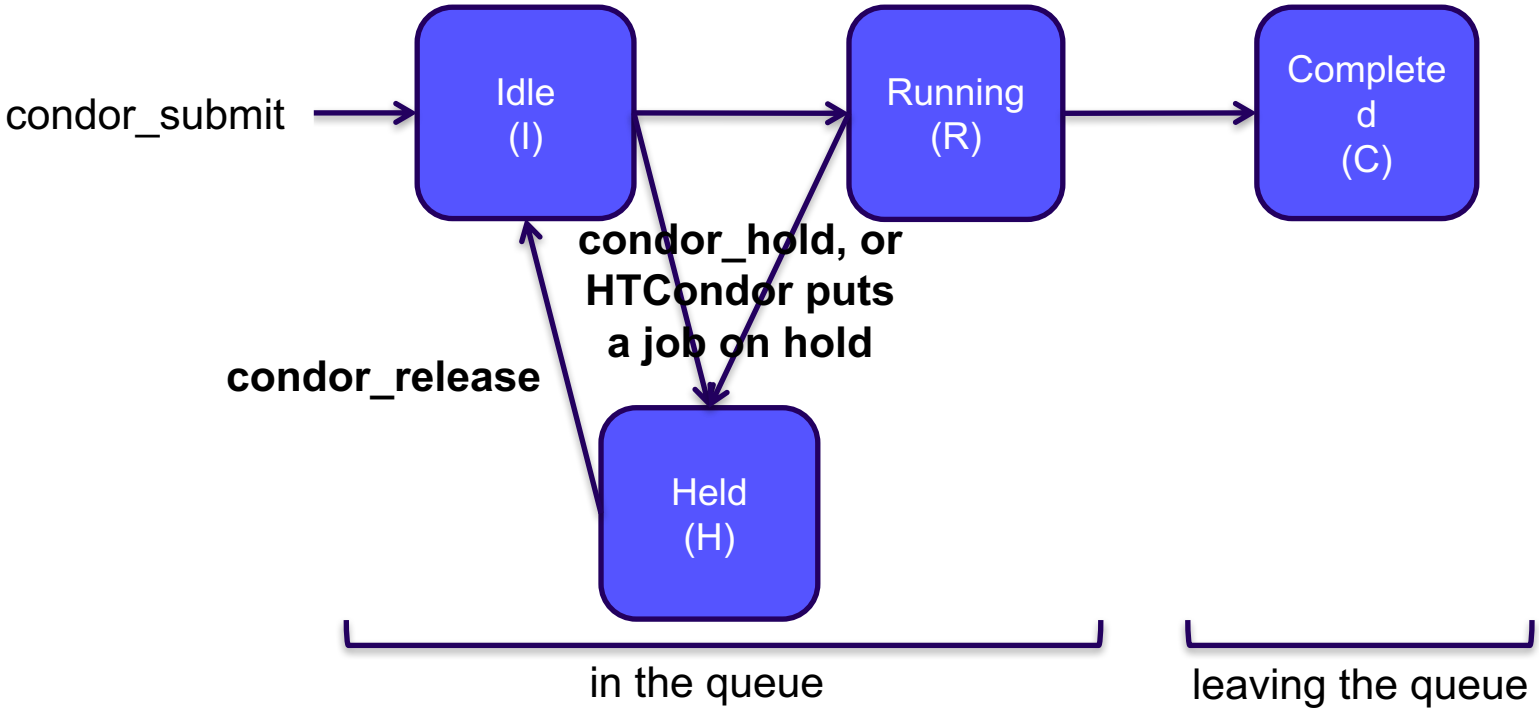
  - Remove it from the queue, using **`condor_rm [U/C/J]`**

HTCondor Manual: condor_hold
HTCondor Manual: condor_rm

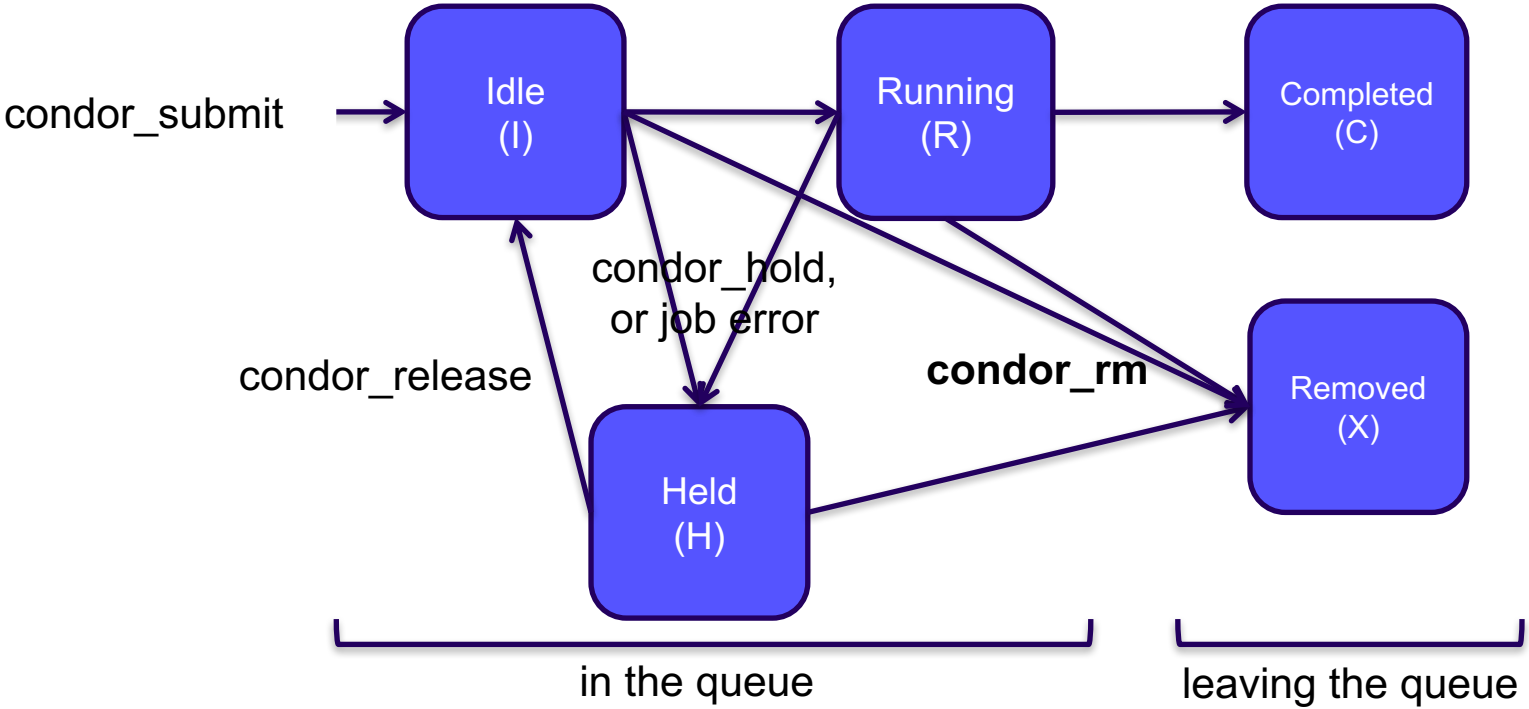
Job States, Revisited



Job States, Revisited



Job States, Revisited*



*not comprehensive

AUTOMATION AND OTHER 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

Open Science Grid

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 an error code, leave it in the queue to run again. This is done via the automatic option `max_retries`.

```
max_retries = 5
```

Open Science Grid

More automation

- Check out the Intro to HTCondor talk from HTCondor Week 2017 for more on:
  - self-checkpointing
  - automatic hold/release (e.g. if job running too long)
  - auto-increasing memory request (e.g. if memory usage varies a lot across jobs)

Job Universes

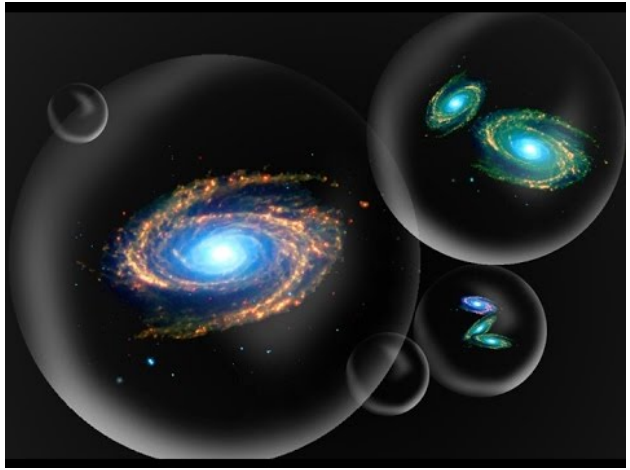
- HTCondor has different “universes” for running specialized job types

  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

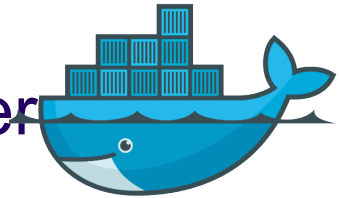
HTCondor Manual: Java Applications

- 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

- Scheduler
  - Runs DAG workflows (next session)

HTCondor Manual: Parallel Applications

Multi-CPU and GPU Computing

- Jobs that use multiple cores on a single computer can use the vanilla universe (parallel universe for multi-server MPI, where supported):

```
request_cpus = 16
```

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

```
request_gpus = 1
```

YOUR TURN!

Exercises!

- Ask questions!
- Lots of instructors around

- Coming up:
  - Now-12:15 Hands-on Exercises
  - 12:15 – 1:15 Lunch
  - 1:15 – 5:00 Afternoon sessions