An Introduction to Using HTCondor 2013

The Team - 2012

Established in 1985,

to do research and development of distributed high-throughput computing

HTCondor does High-Throughput Computing

- Allows for many computational tasks to be completed over a long period of time
- Useful for researchers and other users who are more concerned with the number of computations they can do over long spans of time than they are with short-burst computations

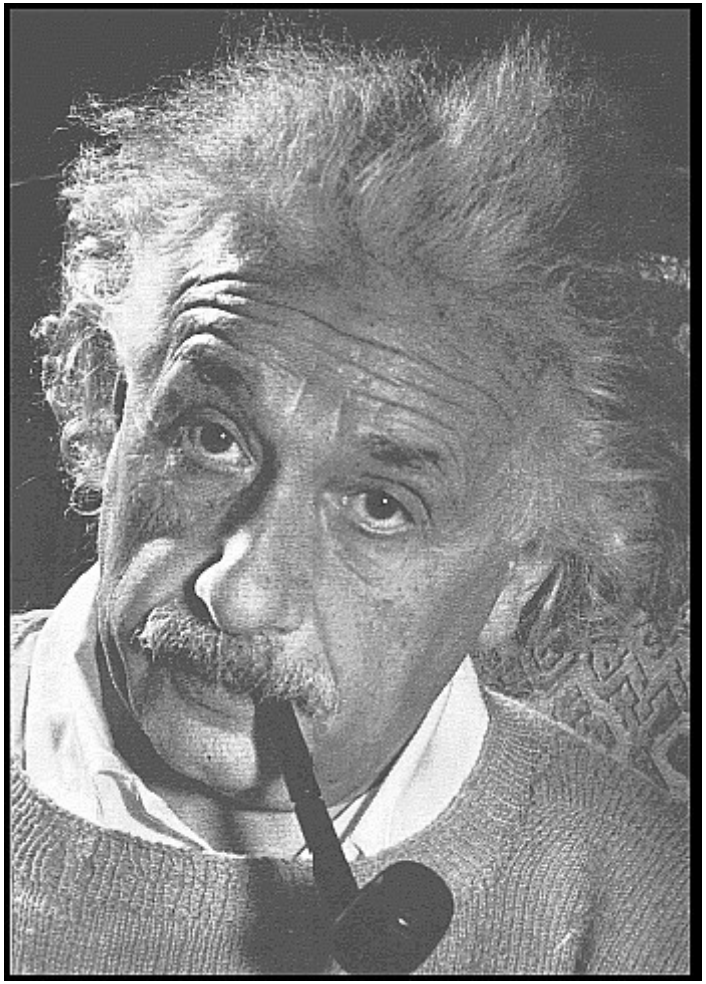
HTCondor's strengths

- Cycle scavenging works!
- High-throughput computing
- Very configurable, adaptable
- Supports strong security methods
- Interoperates with many types of computing grids
- Has features to manage both dedicated CPUs (clusters) and non-dedicated resources (desktops)
- Fault-tolerant: can survive crashes, network outages, any single point of failure

HTCondor will ...

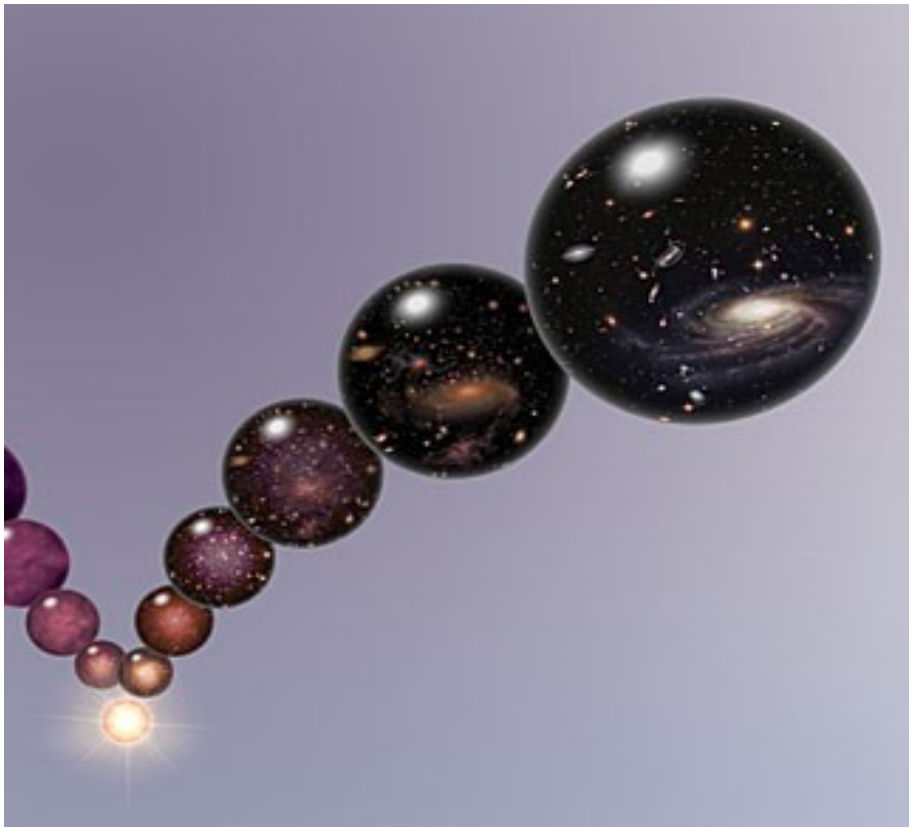
- Keep an eye on your jobs and keep you posted on their progress
- Implement your policy on the execution order of your jobs
- Log your job's activities
- Add fault tolerance to your jobs
- Implement your policy as to when the jobs can run on your desktop

Our esteemed scientist*, has plenty of simulations to do.



* and Karen's cousin

Einstein's Simulation



Simulate the evolution of the cosmos, assuming various properties.

Simulation Overview

Varying values for each of:

- G (the gravitational constant): 100 values
- $R_{\mu\nu}$ (the cosmological constant): 100 values
- c (the speed of light): 100 values

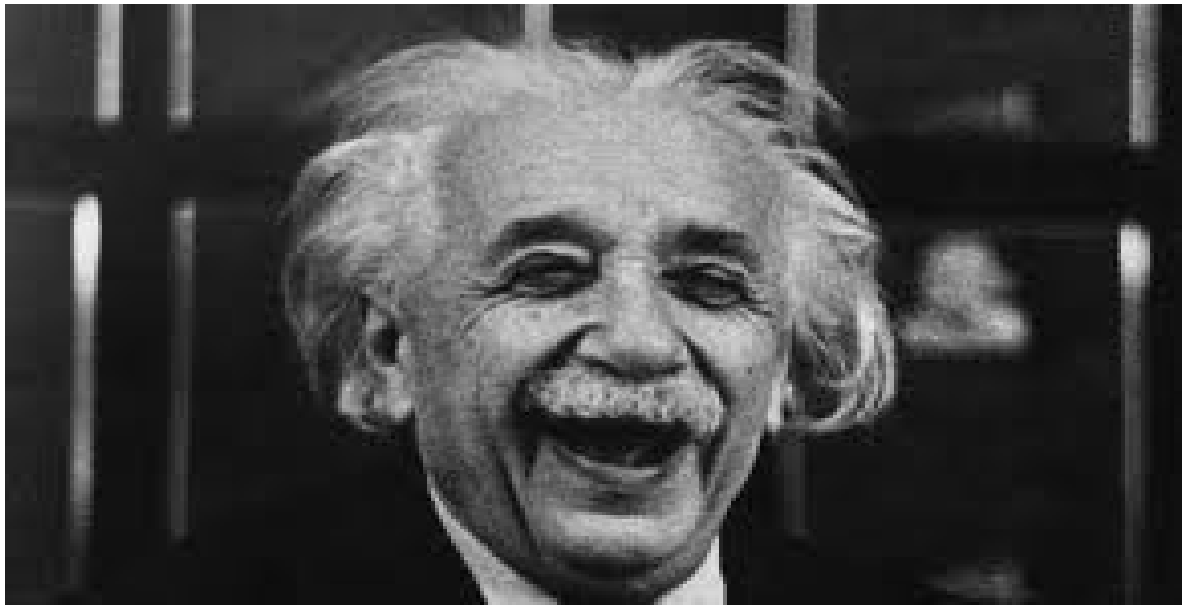
100 × 100 × 100 = 1,000,000 jobs

Each *job* within the simulation:

- Requires up to 4 GBytes of RAM
- Requires 20 MBytes of input
- Requires 2 – 500 hours of computing time
- Produces up to 10 GBytes of output

Estimated total:

- 15,000,000 CPU hours or 1,700 compute YEARS
- 10 *Petabytes* of output



Albert will be happy, since HTCondor will make the completion of the entire simulation easy.

Definitions

Job

- the HTCondor representation of a piece of work
- Like a Unix process
- Can be an element of a workflow

ClassAd

- HTCondor's internal data representation

Machine or Resource

- computers that can do the processing

More Definitions

Match Making

- Associating a job with a machine resource

Central Manager

- Central repository for the whole pool
- Does match making

Submit Host

- The computer from which jobs are submitted to HTCondor

Execute Host

- The computer that runs a job

Jobs state their needs and preferences:

- Requirements (needs):
  - I **require** a Linux x86-64 platform
- Rank (preferences):
  - I **prefer** the machine with the most memory
  - I **prefer** a machine in the botany department

Machines specify needs and preferences:

- Requirements (needs):
  - **Require** that jobs run only when there is no keyboard activity
  - **Never** run jobs belonging to Dr. Heisenberg
- Rank (preferences):
  - I **prefer** to run Albert's jobs

ClassAds

the language that Condor uses to represent information – about jobs (job ClassAd), machines (machine ClassAd), and programs that implement Condor's functionality (called daemons)

ClassAd Structure

semi-structured

user-extensible

schema-free

AttributeName = Value

or

AttributeName = Expression

Part of a Job ClassAd

```
MyType          = "Job"
TargetType      = "Machine"
ClusterId       = 1
ProcId          = 0
IsPhysics       = True
Owner           = "einstein"
Cmd             = "cosmos"
Requirements    = (Arch == "INTEL")
.
.
.
```

String

Integer

Boolean

Boolean Expression

The Magic of Matchmaking

The match maker matches job ClassAds with machine ClassAds, taking into account:

- Requirements of both the machine *and* the job
- Rank of both the job *and* the machine
- Priorities, such as those of users and groups

Getting Started

1. Choose a universe for the job
2. Make the job batch-ready, which includes making the input data available and accessible
3. Create a submit description file
4. Run **`condor_submit`** to put the job(s) in the queue

1. Choose the Universe

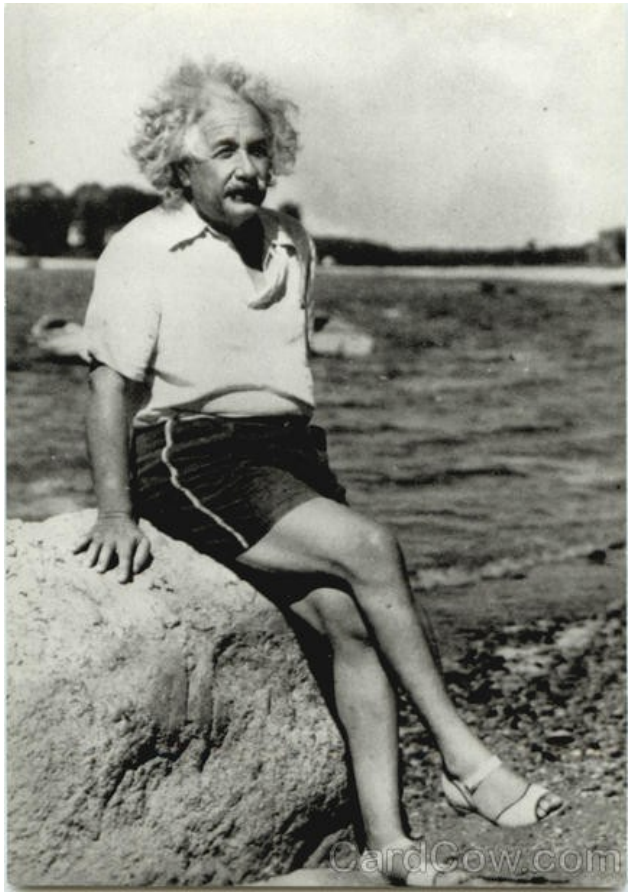
- controls how HTCondor handles jobs
- the many universes include:
  - vanilla
  - standard
  - grid
  - java
  - parallel
  - vm

Using the vanilla Universe

- Allows running almost any “serial” job
- Provides automatic file transfer for input and output files
- Like vanilla ice cream, can be used in just about any situation

2. Make the job batch-ready

- Must be able to run in the background
- No interactive input
- No GUI/window clicks



Batch-Ready: Standard Input & Output

- Job can still use **`stdin`**, **`stdout`** (the keyboard and the screen) , and **`stderr`** , but files are used instead of the actual devices
- Similar to Unix shell:

```
$ ./myprogram <input.txt >output.txt
```

Make the Data Available

- HTCondor will
  - Transfer data files *to* the location where the job runs
  - Transfer result files *back from* the location where the job runs
- Place the job's data files in a place where HTCondor can access them

3. Create a Submit Description File

- A plain ASCII text file
- File name extensions are irrelevant, although many use **`.sub`** or **`.submit`** as suffixes
- Tells HTCondor about the job
- Can describe many jobs at once (a cluster), each with different input, output, command line arguments, etc.

Simple Submit Description File

```
# file name is cosmos.sub
# (Lines beginning with # are comments)
# NOTE: the commands on the left are not
#   case sensitive, but file names
#   (on the right) are!

Universe   = vanilla
Executable = cosmos
Input      = cosmos.in
Output     = cosmos.out
Log        = cosmos.log
Queue
```

Put 1 instance of the job in the queue

Input, Output, and Error Files

`Input = in_file`

Read job's standard input from **`in_file`**

Like shell command: **`$ program < in_file`**

`Output = out_file`

Write job's standard output to **`out_file`**

Like shell command: **`$ program > out_file`**

`Error = error_file`

Write job's standard error to **`error_file`**

Like shell command: **`$ program 2> error_file`**

Logging the Job's Activities

- In the submit description file:

```
log = cosmos.log
```

- Creates a log of job events, which shows all events that occur as the job executes
- Good advice: *always* have a log file

Sample Portion of Job Log

```
000 (0101.000.000) 05/25 19:10:03 Job submitted from host:
<128.105.146.14:1816>
...
001 (0101.000.000) 05/25 19:12:17 Job executing on host:
<128.105.146.14:1026>
...
005 (0101.000.000) 05/25 19:13:06 Job terminated.
    (1) Normal termination (return value 0)
...
```

000, 001, and 005 are examples of event numbers.

4. Submit the Job

Run **`condor_submit`**, providing the name of the submit description file:

```
$ condor_submit cosmos.sub
Submitting job(s).
1 job(s) submitted to cluster 100.
```

`condor_submit` then

- parses the submit description file, checking for errors
- creates a ClassAd that describes the job(s)
- places the job(s) in the queue, which is an atomic operation, with a two-phase commit

Observe Jobs in the Queue

```
$ condor_q
-- Submitter: submit.chtc.wisc.edu : <128.104.55.9:51883> :
   submit.chtc.wisc.edu
ID      OWNER          SUBMITTED     RUN_TIME ST PRI SIZE CMD
2.0      heisenberg   1/13 13:59    0+00:00:00 R  0   0.0  env
3.0      hawking      1/15 19:18    0+04:29:33 H  0   0.0  script.sh
4.0      hawking      1/15 19:33    0+00:00:00 H  0   0.0  script.sh
5.0      hawking      1/15 19:33    0+00:00:00 H  0   0.0  script.sh
6.0      hawking      1/15 19:34    0+00:00:00 H  0   0.0  script.sh
...
96.0     bohr         4/5  13:46    0+00:00:00 I  0   0.0  atoms H
97.0     bohr         4/5  13:46    0+00:00:00 I  0   0.0  atoms H
98.0     bohr         4/5  13:52    0+00:00:00 I  0   0.0  atoms H
99.0     bohr         4/5  13:52    0+00:00:00 I  0   0.0  atoms H
100.0    einstein     4/5  13:55    0+00:00:00 I  0   0.0  cosmos

100 jobs; 1 completed, 0 removed, 20 idle, 1 running, 77 held,
   0 suspended
```

File Transfer

`Transfer_Input_Files` specifies a list of files to transfer from the submit machine to the execute machine

`Transfer_Output_Files` specifies a list of files to transfer back from the execute machine to the submit machine If `Transfer_Output_Files` is *not* specified, HTCondor will transfer back all *new* files in the execute directory

More on File Transfer

Files need to get from the submit machine to the execute machine. 2 possibilities:

1. both machines have access to a shared file system
2. machines have separate file systems

`Should_Transfer_Files`

- = `YES`: Transfer files to execution machine
- = `NO`: Rely on shared file system
- = `IF_NEEDED`: Automatically transfer the files, if the submit and execute machine are not in the same `FileSystemDomain` (translation: use shared file system if available)

`When_To_Transfer_Output`

- = `ON_EXIT`: Transfer output files only when job completes
- = `ON_EXIT_OR_EVICT`: Transfer output files when job completes or is evicted

File Transfer Example

```
# new cosmos.sub file
Universe                        = vanilla
Executable                       = cosmos
Log                             = cosmos.log
Transfer_Input_Files             = cosmos.dat
Transfer_Output_Files           = results.dat
Should_Transfer_Files           = IF_NEEDED
When_To_Transfer_Output         = ON_EXIT
Queue
```

Command Line Arguments

```
# Example with command line arguments
Universe   = vanilla
Executable = cosmos
Arguments  = -c 299792458 –G 6.67300e-112

. . .
Queue
```

- Invokes executable with `cosmos –c 299792458 –G 6.673e-112`

Look at the `condor_submit` man page to see syntax for `Arguments`. This example has argc = 5.

More Feedback

- HTCondor sends email about job events to the submitting user
- Specify *one* of these in the submit description file:

```
Notification = complete
Notification = never
Notification = error
Notification = always
```

Default in 7.8

Default in 7.9

ClusterId.ProcID is Job ID

- If the submit description file describes multiple jobs, the set is called a cluster
- Each cluster has a cluster number, where the cluster number is unique to the job queue on a machine
- Each individual job within a cluster is called a process, and process numbers always start at zero
- A Job ID is the cluster number, a period, and the process number. Examples:

  Job ID = 20.0 **Cluster 20, process 0**

  Job IDs: 21.0, 21.1, 21.2 **Cluster 21, processes 0, 1, 2**

1 Cluster

```
Universe   = vanilla
Executable = cosmos

log        = cosmos_0.log
Input      = cosmos_0.in
Output     = cosmos_0.out

Queue
```

Job 102.0 (cluster 102, process 0)

File Organization

A logistical nightmare places all input, output, and log files in one directory

3 files × 1,000,000 jobs = 3,000,000 files

 The submit description file is 4,000,000+ lines

The directory will be difficult (at best) to even look at

Better Organization

- Create subdirectories for each job, intentionally named

  `run_0`, **`run_1`**, … **`run_999999`**
- Implement the creation of directories with a Python or Perl program
- Create or place input files in each of these

  `run_0/cosmos.in`

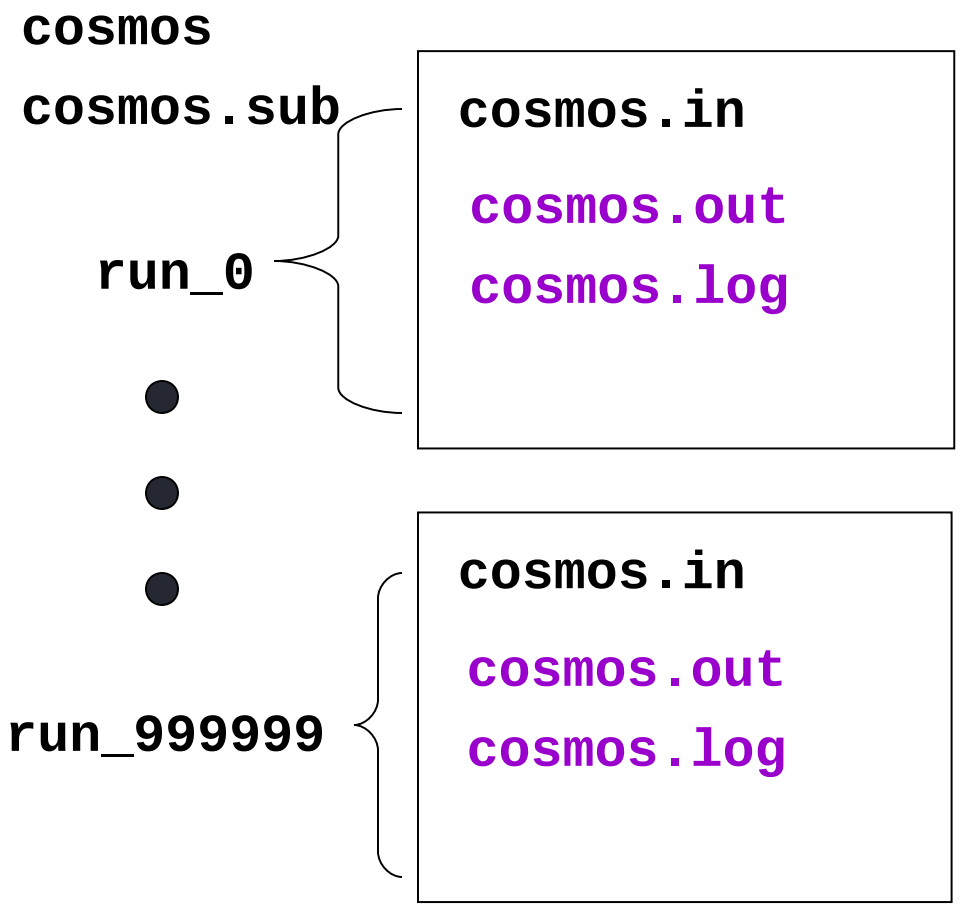
  `run_1/cosmos.in`

  …

  `run_999999/cosmos.in`

- The output and log files for each job will be created by the job, when the job runs

Einstein's simulation directory



Submitter or script creates black-font files

HTCondor creates purple-font files

Better Submit Description File

```
# Cluster of 1,000,000 jobs

Universe                = vanilla
Executable              = cosmos
Log                     = cosmos.log
Output                  = cosmos.out
Input                   = cosmos.in

...

InitialDir = run_0
Queue
InitialDir = run_1
Queue
```

Job 103.0 (Cluster 103, Process 0)

Job 103.1 (Cluster 103, Process 1)

This file contains 999,998 more instances of `InitialDir` and `Queue`.

Submit Description File Macros

- Queue all 1,000,000 processes with the single command:

  `Queue 1000000`

- Within the submit description file, HTCondor permits named macros

  `$(Process)` will be expanded to the process number for each job in the cluster

  Values 0 – 999999 for the 1,000,000 jobs

Using $(Process)

- The initial directory for each job can be specified
  InitialDir = run_$(Process)
  HTCondor expands these to directories
  run_0, **run_1**, … **run_999999**
- Similarly, command-line arguments could use a macro to pass a unique identifier to each job instance

  Arguments = -n $(Process)

  HTCondor expands arguments to:

  -n 0
  -n 1
  …
  -n 999999

(Best) Submit Description File

```
# Example: a cluster of 1000000 jobs

Universe   = vanilla
Executable = cosmos
Log        = cosmos.log
Input      = cosmos.in
Output     = cosmos.out
InitialDir = run_$(Process)
Queue 1000000
```

Albert submits the cosmos simulation. Patience required, it will take a while…

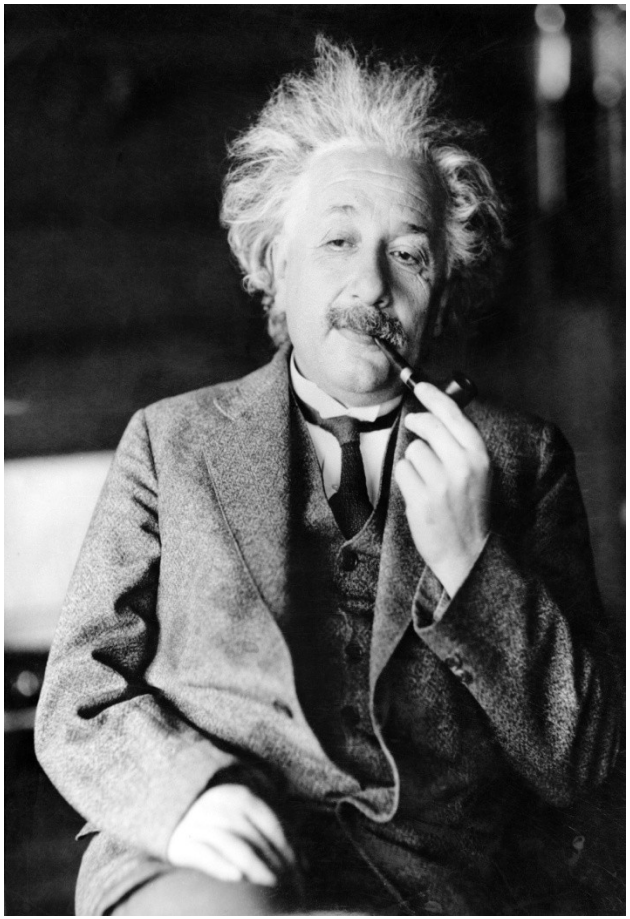
```
$ condor_submit cosmos.sub
Submitting
   job(s) ..........................................
   ..........................................
   ..........................................
   ..........................
Logging submit
   event(s) ..........................................
   ..........................................
   ..........................................
   ..........................
1000000 job(s) submitted to cluster 104.
```

the Job Queue

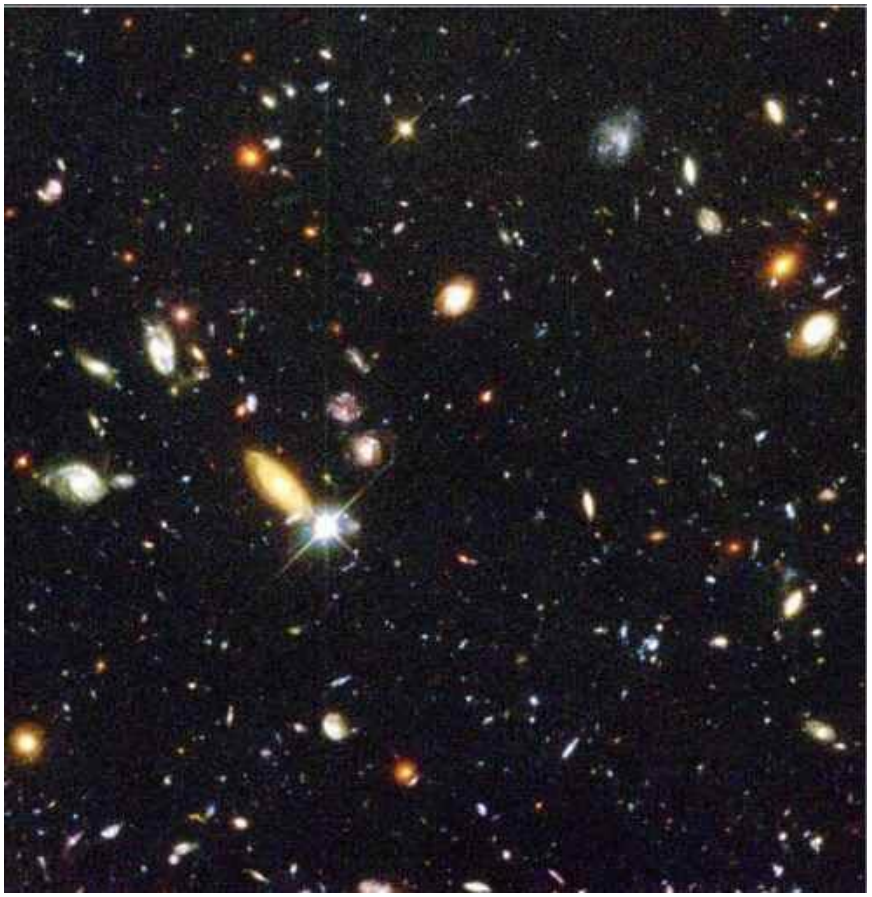
```
$ condor_q
-- Submitter: submit.chtc.wisc.edu :
   <128.104.55.9:51883> : submit.chtc.wisc.edu
ID        OWNER   SUBMITTED   RUN_TIME  ST PRI SIZE CMD
104.0       einstein 4/20 12:08 0+00:00:05 R 0 9.8 cosmos
104.1       einstein 4/20 12:08 0+00:00:03 I 0 9.8 cosmos
104.2       einstein 4/20 12:08 0+00:00:01 I 0 9.8 cosmos
104.3       einstein 4/20 12:08 0+00:00:00 I 0 9.8 cosmos
...
104.999998 einstein 4/20 12:08 0+00:00:00 I 0 9.8 cosmos
104.999999 einstein 4/20 12:08 0+00:00:00 I 0 9.8 cosmos

999999 jobs; 999998 idle, 1 running, 0 held
```

Albert Relaxes

- HTCondor watches over the jobs, and will restart them if required, etc.
- Time for a cold one!



More That You Do With HTCondor



Remove Jobs with `condor_rm`

- You can only remove jobs that you own
- Privileged user can remove any jobs
  - *root* on Linux
  - *administrator* on Windows

`condor_rm 4`	Removes all cluster 4 jobs
`condor_rm 4.2`	Removes only the job with job ID 4.2
`condor_rm -a`	Removes all of your jobs. *Careful !*

Specify Job Requirements

- A boolean expression (syntax similar to C or Java)
- Evaluated with respect to attributes from machine ClassAd(s)
- **Must** evaluate to True for a match to be made

```
Universe     = vanilla
Executable     = mathematica

...

Requirements = (   \
   HasMathematicaInstalled =?= True )
Queue 20
```

Specify Needed Resources

Items appended to job **`Requirements`**

`request_memory` – the amount of memory (in Mbytes) that the job needs to avoid excessive swapping

`request_disk` – the amount of disk space (in Kbytes) that the job needs. Will be sum of space for executable, input files, output files and temporary files. Default is size of initial sandbox (executable plus input files).

`request_cpus` – the number of CPUs (cores) that the job needs. Defaults to 1.

Specify Job Rank

- All matches which meet the requirements can be sorted by preference with a **Rank** expression
  - Numerical
  - Higher rank values match first
- Like **Requirements**, is evaluated against attributes from machine ClassAds

```
Universe     = vanilla
Executable     = cosmos

. . .

Rank           = (KFLOPS*10000) + Memory
Queue 1000000
```

Job Policy Expressions

- Do not remove if exits with a signal:

```
on_exit_remove = ExitBySignal == False
```

- Place on hold if exits with nonzero status or ran for less than an hour:

```
on_exit_hold =
 ( (ExitBySignal==False) && (ExitSignal != 0) ) ||
 ( (ServerStartTime - JobStartDate) < 3600)
```

- Place on hold if job has spent more than 50% of its time suspended:

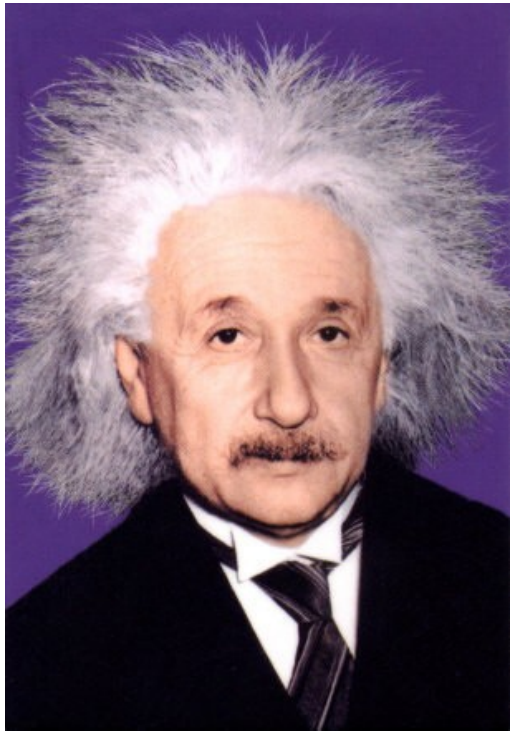
```
periodic_hold =
 ( CumulativeSuspensionTime >
   (RemoteWallClockTime / 2.0) )
```

Lots of Short-Running Jobs

Know that starting a job is somewhat expensive, in terms of time.
3 items that might help:

1. Batch short jobs together
   - Write a wrapper script that will run a set of the jobs in series
   - Submit the wrapper script as the job
1. Explore HTCondor's parallel universe
2. There are some configuration variables that may be able to help
   - Contact a staff person for more info

Common Problems with Jobs



Jobs Are Idle

Our scientist runs **condor_q** and finds all his jobs are idle

```
$ condor_q
-- Submitter: x.cs.wisc.edu : <128.105.121.53:510>
   :x.cs.wisc.edu
ID  OWNER     SUBMITTED     RUN_TIME  ST PRI SIZE CMD
5.0 einstein  4/20 12:23  0+00:00:00  I 0   9.8  cosmos
5.1 einstein  4/20 12:23  0+00:00:00  I 0   9.8  cosmos
5.2 einstein  4/20 12:23  0+00:00:00  I 0   9.8  cosmos
5.3 einstein  4/20 12:23  0+00:00:00  I 0   9.8  cosmos
5.4 einstein  4/20 12:23  0+00:00:00  I 0   9.8  cosmos
5.5 einstein  4/20 12:23  0+00:00:00  I 0   9.8  cosmos
5.6 einstein  4/20 12:23  0+00:00:00  I 0   9.8  cosmos
5.7 einstein  4/20 12:23  0+00:00:00  I 0   9.8  cosmos
8 jobs; 8 idle, 0 running, 0 held
```

Exercise a little patience

- On a busy pool, it can take a while to match jobs to machines, and then start the jobs
- Wait at least a negotiation cycle or two, typically a few minutes

Look in the Job Log

The log will likely contain clues:

```
$ cat cosmos.log
000 (031.000.000) 04/20 14:47:31 Job submitted from
   host: <128.105.121.53:48740>
...
007 (031.000.000) 04/20 15:02:00 Shadow exception!
         Error from starter on gig06.stat.wisc.edu:
   Failed to open
   '/scratch.1/einstein/workspace/v78/condor-
   test/test3/run_0/cosmos.in' as standard input: No
   such file or directory (errno 2)
         0  -  Run Bytes Sent By Job
         0  -  Run Bytes Received By Job
...
```

Check Machines' Status

```
$ condor_status
Name                OpSys      Arch   State     Activity LoadAv Mem   ActvtyTime
slot1@c002.chtc.wi LINUX      X86_64 Claimed   Busy     1.000  4599  0+00:10:13
slot2@c002.chtc.wi LINUX      X86_64 Claimed   Busy     1.000  1024  1+19:10:36
slot3@c002.chtc.wi LINUX      X86_64 Claimed   Busy     0.990  1024  1+22:42:20
slot4@c002.chtc.wi LINUX      X86_64 Claimed   Busy     1.000  1024  0+03:22:10
slot5@c002.chtc.wi LINUX      X86_64 Claimed   Busy     1.000  1024  0+03:17:00
slot6@c002.chtc.wi LINUX      X86_64 Claimed   Busy     1.000  1024  0+03:09:14
slot7@c002.chtc.wi LINUX      X86_64 Claimed   Busy     1.000  1024  0+19:13:49
...
slot7@exec-2.chtc. WINDOWS    INTEL  Owner     Idle     0.000   511  0+00:24:17
slot8@exec-2.chtc. WINDOWS    INTEL  Owner     Idle     0.030   511  0+00:45:01

                     Total Owner Claimed Unclaimed Matched Preempting Backfill

        INTEL/WINDOWS   104    78      16        10       0          0        0
         X86_64/LINUX   759   170     587         0       0          1        0

                Total   863   248     603        10       0          1        0
```

Try: condor_q -analyze

```
> condor_q -analyze 107.5
-- Submitter: crane.cs.wisc.edu :
   <128.105.136.32:61610> : crane.cs.wisc.edu
   User priority for max@crane.cs.wisc.edu is not
   available, attempting to analyze without it.
---
107.005: Run analysis summary. Of 4 machines,
  0 are rejected by your job's requirements
  0 reject your job because of their own requirements
  4 match and are already running your jobs
  0 match but are serving other users
  0 are available to run your job
```

improved in 7.9

condor_q -analyze 102.1

```
-- Submitter: crane.cs.wisc.edu :
   <128.105.136.32:61610> : crane.cs.wisc.edu
   User priority for max@crane.cs.wisc.edu is not
   available, attempting to analyze without it.
---
107.005: Run analysis summary. Of 3184 machines,
 3184 are rejected by your job's requirements
    0 reject your job because of their own requirements
    0 match and are already running your jobs
    0 match but are serving other users
    0 are available to run your job

WARNING: Be advised:
   No resources matched request's constraints
```

(continued)

```
The Requirements expression for your job is:

( TARGET.Arch == "X86_64" ) &&
( TARGET.OpSys == "WINDOWS" ) &&
( TARGET.Disk >= RequestDisk ) &&
( TARGET.Memory >= RequestMemory ) &&
( TARGET.HasFileTransfer )

Suggestions:
   Condition                Machines Matched    Suggestion
   ---------                ----------------    ----------
   1 ( TARGET.OpSys == "WINDOWS" ) 0   MODIFY TO "LINUX"

   2 ( TARGET.Arch == "X86_64" )   3137
   3 ( TARGET.Disk >= 1 )          3184
   4 ( TARGET.Memory >= ifthenelse(MemoryUsage isnt
   undefined,MemoryUsage,1) )      3184
   5 ( TARGET.HasFileTransfer )    3184
```

Learn about available resources

```
$ condor_status –const 'Memory > 8192'
(no output means no matches)

$ condor_status -const 'Memory > 4096'
Name               OpSys   Arch   State     Activ LoadAv Mem   ActvtyTime
slot1@c001.ch LINUX   X86_64 Unclaimed Idle  0.000  5980  1+05:35:05
slot2@c001.ch LINUX   X86_64 Unclaimed Idle  0.000  5980 13+05:37:03
slot3@c001.ch LINUX   X86_64 Unclaimed Idle  0.000  7988  1+06:00:05
slot1@c002.ch LINUX   X86_64 Unclaimed Idle  0.000  7988 13+06:03:47

                     Total Owner Claimed Unclaimed Matched Preempting
        X86_64/LINUX     4     0       0         4       0          0
               Total     4     0       0         4       0          0
```

Interact With A Job

- Perhaps a job is running for much longer than expected.
  - Is it stuck accessing a file?
  - Is it in an infinite loop?
- Try **`condor_ssh_to_job`**
  - Interactive debugging in Unix
  - Use *ps*, *top*, *gdb*, *strace*, *lsof*, …
  - Forward ports, X, transfer files, etc.
  - Currently not available on Windows

Interactive Debug Example

```
$ condor_q
-- Submitter: cosmos.phy.wisc.edu : <128.105.165.34:1027>

ID    OWNER    SUBMITTED  RUN_TIME  ST PRI SIZE CMD

1.0  einstein 4/15 06:52 1+12:10:05 R 0   10.0 cosmos

1 jobs; 0 idle, 1 running, 0 held

$ condor_ssh_to_job 1.0

Welcome to slot4@c025.chtc.wisc.edu!
Your condor job is running with pid(s) 15603.

$ gdb –p 15603
. . .
```

HTCondor is extremely flexible. Here are overviews of some of the many features that you may want to learn more about.

After this tutorial, here are some places you might find help:

1. HTCondor manual
2. htcondor-users mailing list. See

`https://lists.cs.wisc.edu/mailman/listinfo/htcondor-users`

3. Wiki

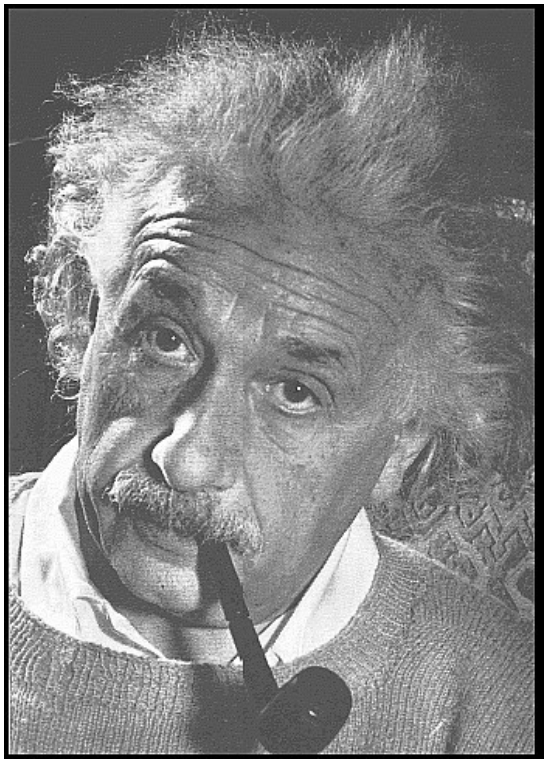
   `https://htcondor-wiki.cs.wisc.edu/index.cgi/wiki`

4. Developers

The more time a job takes to run, the higher the risk of

- being preempted by a higher priority user or job
- getting kicked off a machine (vacated), because the machine has something else it prefers to do

- HTCondor's standard universe may provide a solution.

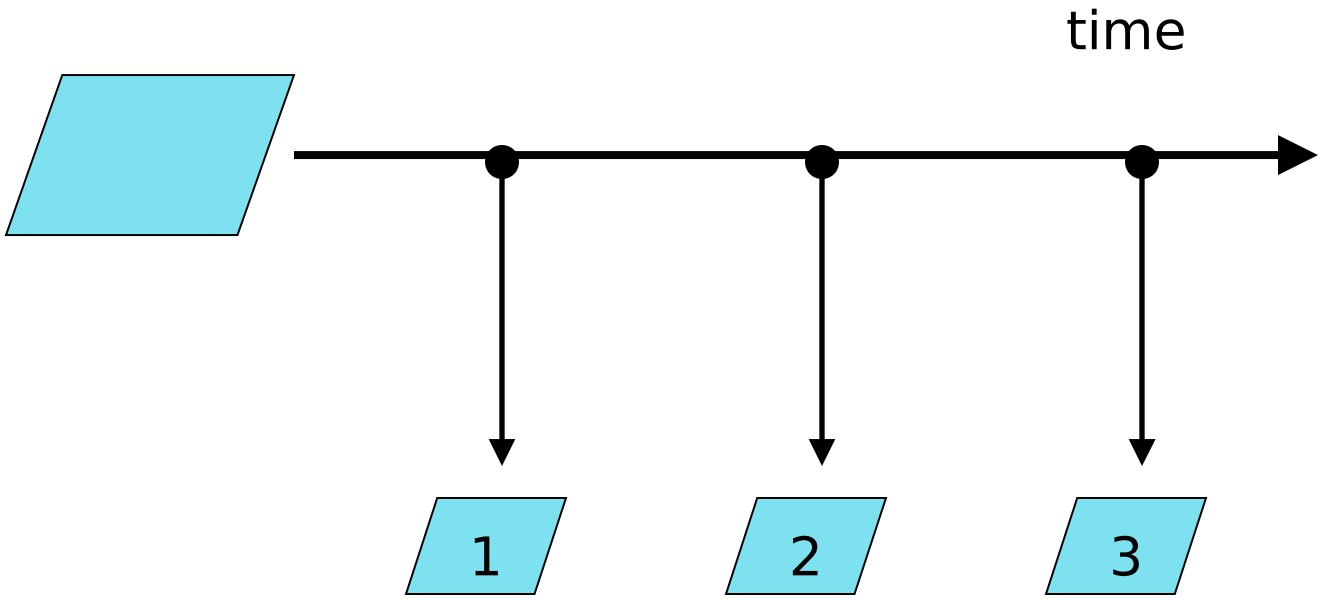


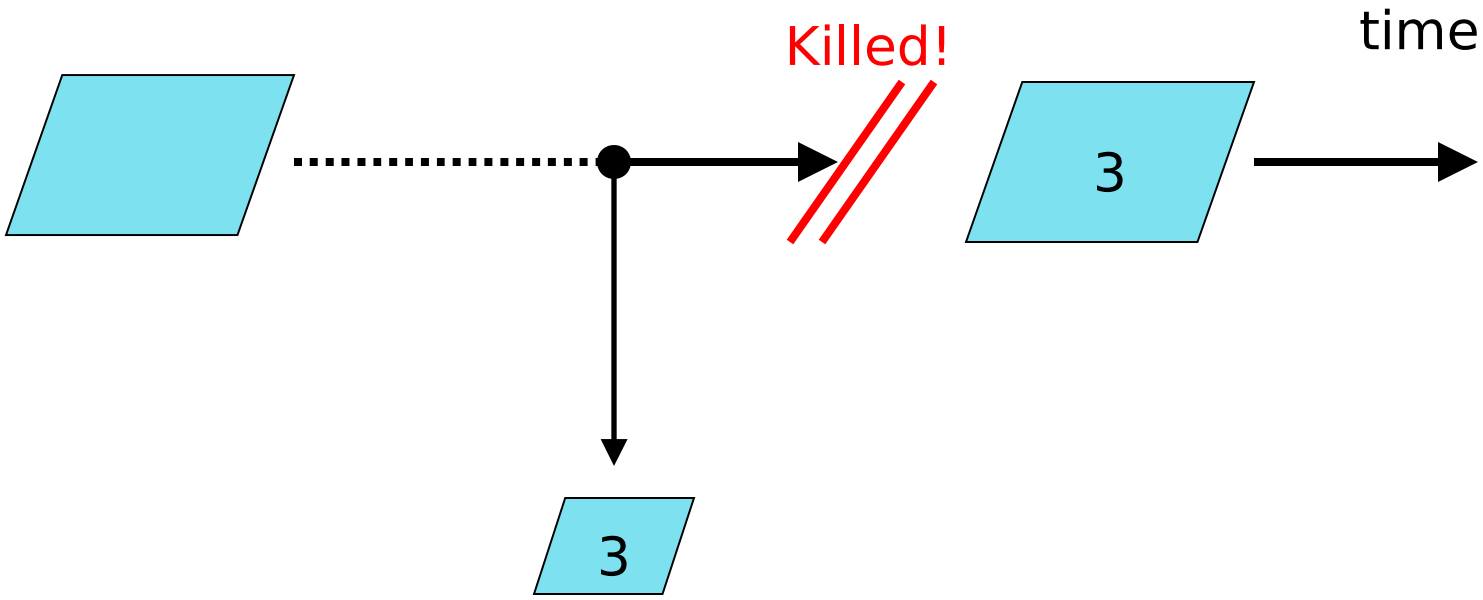
Standard Universe

- Regularly while the job runs, or when the job is to be kicked off the machine, HTCondor takes a checkpoint -- the complete state of the job.
- With a checkpoint, the job can be matched to another machine, and *continue on*.

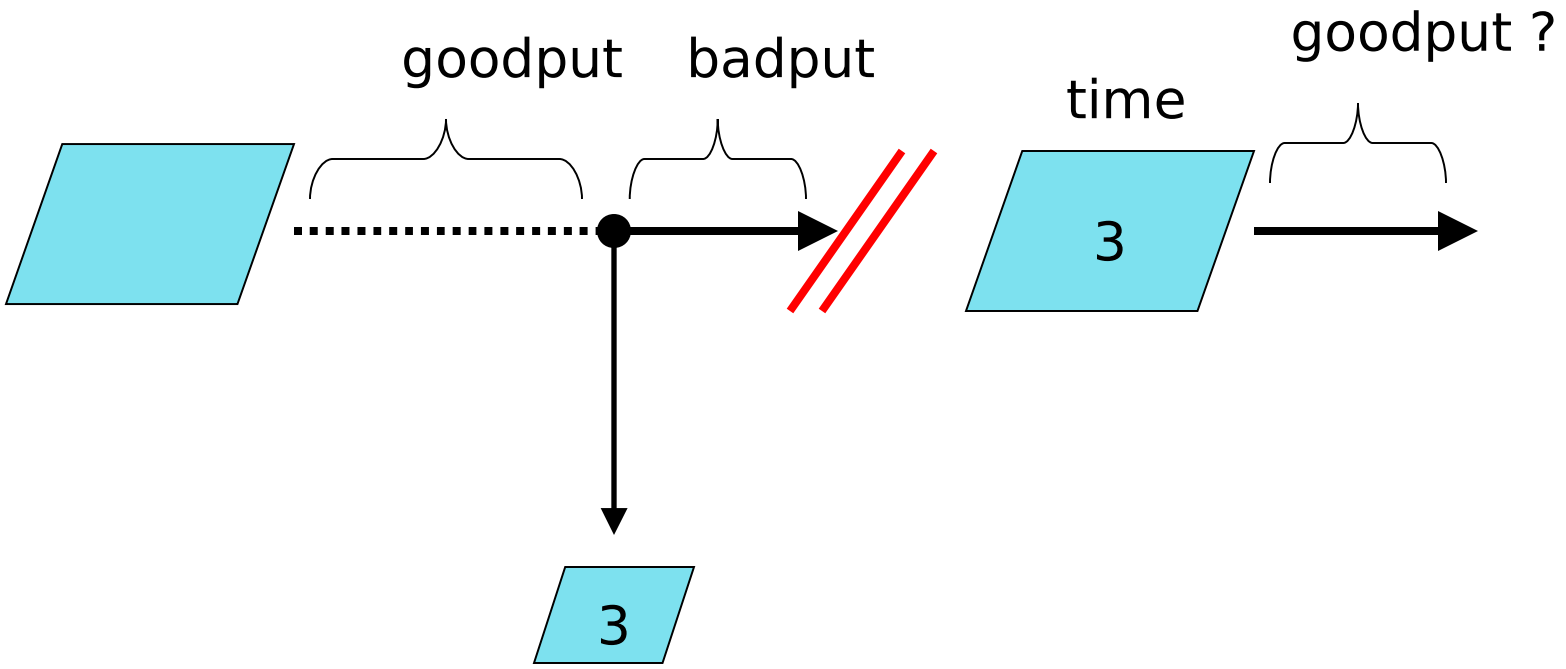
checkpoint: the entire state of a program saved in a file, such as CPU registers, memory image, I/O, etc.

3 Checkpoints




Killed!
time
3
3

Goodput and Badput



Standard Universe Features

- Remote system calls (remote I/O)

  The job can read or write files as if they were local
- Programming language independent
- No source code changes are typically required, but relinking the executable with HTCondor's standard universe support library is required.

How to Relink

Place **condor_compile** in front of the command used to link the job:

```
$ condor_compile gcc -o myjob myjob.c
```

- OR -

```
$ condor_compile f77 -o myjob filea.f fileb.f
```

- OR -

```
$ condor_compile make –f MyMakefile
```

Limitations

- HTCondor's checkpoint mechanism is not at the kernel level. Therefore, a standard universe job may *not* :
  - `fork()`
  - Use kernel threads
  - Use some forms of IPC, such as pipes and shared memory
- Must have access to object code in order to relink
- Only available on some Linux platforms

Parallel Universe

- *When multiple processes of a single job must be running at the same time on different machines.*
- Provides a mechanism for controlling parallel algorithms
  - Fault tolerant
  - Allows for resources to come and go
  - Ideal for Computational Grid environments
- Especially for MPI

MPI Job Submit Description File

```
# MPI job submit description file
universe = parallel
executable = mp1script
arguments = my_mpich_linked_exe arg1 arg2
machine_count = 4
should_transfer_files = YES
when_to_transfer_output = ON_EXIT
transfer_input_files = my_mpich_linked_exe
queue
```

MPI jobs

Note: HTCondor will probably not schedule all of the jobs on the same machine, so consider using whole machine slots

See the HTCondor Wiki:
Under *How To Admin Recipes,*
"How to allow some jobs to claim the whole machine instead of one slot"

VM Universe

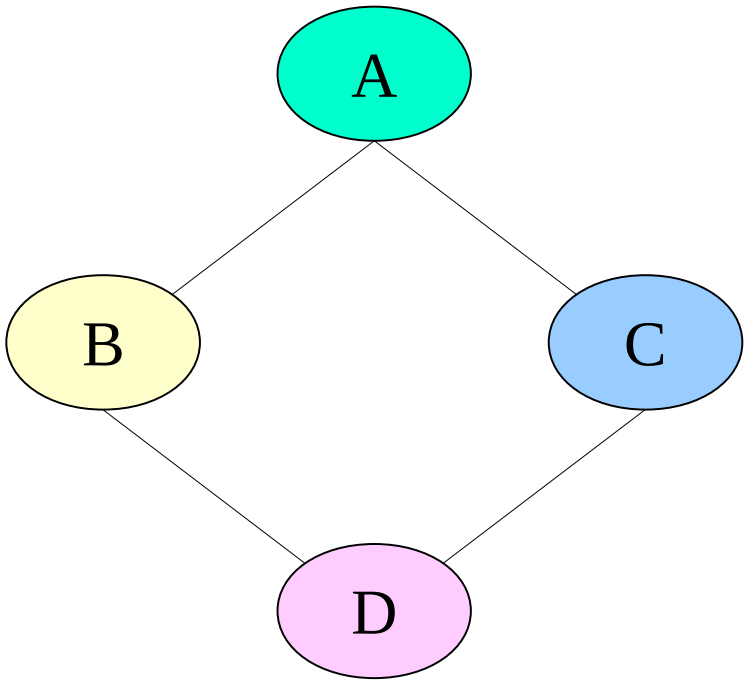
- A virtual machine instance is the HTCondor job
- The vm universe offers
  - Job sandboxing
  - Checkpoint and migration
  - Safe elevation of privileges
  - Cross-platform submission
- HTCondor supports VMware, Xen, and KVM
- Input files can be imported as CD-ROM image
- When the VM shuts down, the modified disk image is returned as job output

Machine Resources are Numerous: The Grid

Given access (authorization) to grid resources , as well as certificates (for authentication) and access to Globus or other resources at remote institutions, HTCondor's grid universe does the trick !

Grid Universe

- All specification is in the submit description file
- Supports many “back end” types:
  - Globus: GT2, GT5
  - NorduGrid
  - UNICORE
  - HTCondor
  - PBS
  - LSF
  - SGE
  - EC2
  - Deltacloud
  - Cream



Some sets of jobs have dependencies.

HTCondor handles them with DAGMan.

› Interested? Stay for Kent's tutorial, later this morning.

the Java Universe

More than

```
$  java mysimulator
```

- Knows which machines have a JVM installed
- Knows the location, version, and performance of JVM on each machine
- Knows about jar files, etc.
- Provides more information about Java job completion than just a JVM exit code
  - Program runs in a Java wrapper, allowing HTCondor to report Java exceptions, etc.

Java Universe Example

```
# sample java universe submit
# description file
Universe   = java
Executable = Main.class
jar_files  = MyLibrary.jar
Input      = infile
Output     = outfile
Arguments  = Main 1 2 3
Queue
```

In Review

With HTCondor's help, both you and Albert can:

- Submit jobs
- Manage jobs
- Organize data files
- Identify aspects of universe choice

Thank you!

Check us out on the web:

http://www.research.wisc.edu/htcondor

Email:

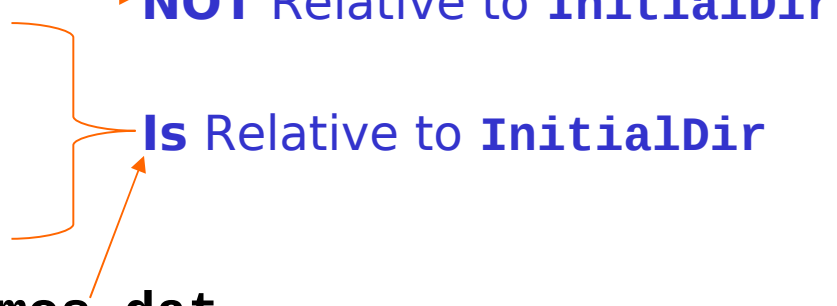
htcondor-admin@cs.wisc.edu

Extra Slides with More Information You Might Want to Reference

InitialDir

- Identifies a directory for file input and output.
- Also provides a directory (on the **submit** machine) for the user log, when a full path is not specified.
- **Note: Executable** is **not** relative to **InitialDir**

```
# Example with InitialDir
Universe   = vanilla
InitialDir = /home/einstein/cosmos/run
Executable = cosmos
Log        = cosmos.log
Input      = cosmos.in
Output     = cosmos.out
Error      = cosmos.err

Transfer_Input_Files=cosmos.dat
Arguments  = -f cosmos.dat
Queue
```



Substitution Macro

$$(<attribute>) will be replaced by the value of the specified attribute from the Machine ClassAd

Example:

Machine ClassAd has:

```
CosmosData = "/local/cosmos/data"
```

Submit description file has

```
Executable   = cosmos
Requirements = (CosmosData =!= UNDEFINED)
Arguments    = -d $$(CosmosData)
```

Results in the job invocation:

```
cosmos –d /local/cosmos/data
```

Getting HTCondor

- Available as a free download from
  http://research.cs.wisc.edu/htcondor
- Download HTCondor for your operating system
  - Available for many modern Unix platforms (including Linux and Apple's OS/X)
  - Also for Windows, many versions
- Repositories
  - YUM: RHEL 4, 5, and 6
    - **`$ yum install condor`**
  - APT: Debian 5 and 6
    - **`$ apt-get install condor`**

HTCondor Releases

- Stable and Developer Releases
  - Version numbering scheme similar to that of the (pre 2.6) Linux kernels …
- Major.minor.release
  - If minor is even (a.b.c): Stable series
    - Very stable, mostly bug fixes
    - Current: 7.8
  - If minor is odd (a.b.c): Developer series
    - New features, may have some bugs
    - Current: 7.9

General User Commands

condor_status	View Pool Status
condor_q	View Job Queue
condor_submit	Submit new Jobs
condor_rm	Remove Jobs
condor_prio	Change a User Priority
condor_history	Completed Job Info
condor_submit_dag	Submit new DAG
condor_checkpoint	Force a checkpoint
condor_compile	Link Condor library with job