# Grid Compute Resources and Job Management

Open Science Grid

# How do we access the grid ?

- Command line with tools that you'll use
- Specialised applications
  - Ex: Write a program to process images that sends data to run on the grid as an inbuilt feature.
- Web portals
  - I2U2
  - SIDGrid

# Grid Middleware glues the grid together

- *A short, intuitive definition:*

  the software that glues together different clusters into a grid, taking into consideration the socio-political side of things (such as common policies on who can use what, how much, and what for)

# Grid middleware

- Offers services that couple users with remote resources through resource brokers
- Remote process management
- Co-allocation of resources
- Storage access
- Information
- Security
- QoS

# Globus Toolkit

- the *de facto* standard for grid middleware.
- Developed at ANL & UChicago (Globus Alliance)
- Open source
- Adopted by different scientific communities and industries
- Conceived as an open set of architectures, services and software libraries that support grids and grid applications
- Provides services in major areas of distributed systems:
  - Core services
  - Data management
  - Security

# GRAM
## Globus Resource Allocation Manager

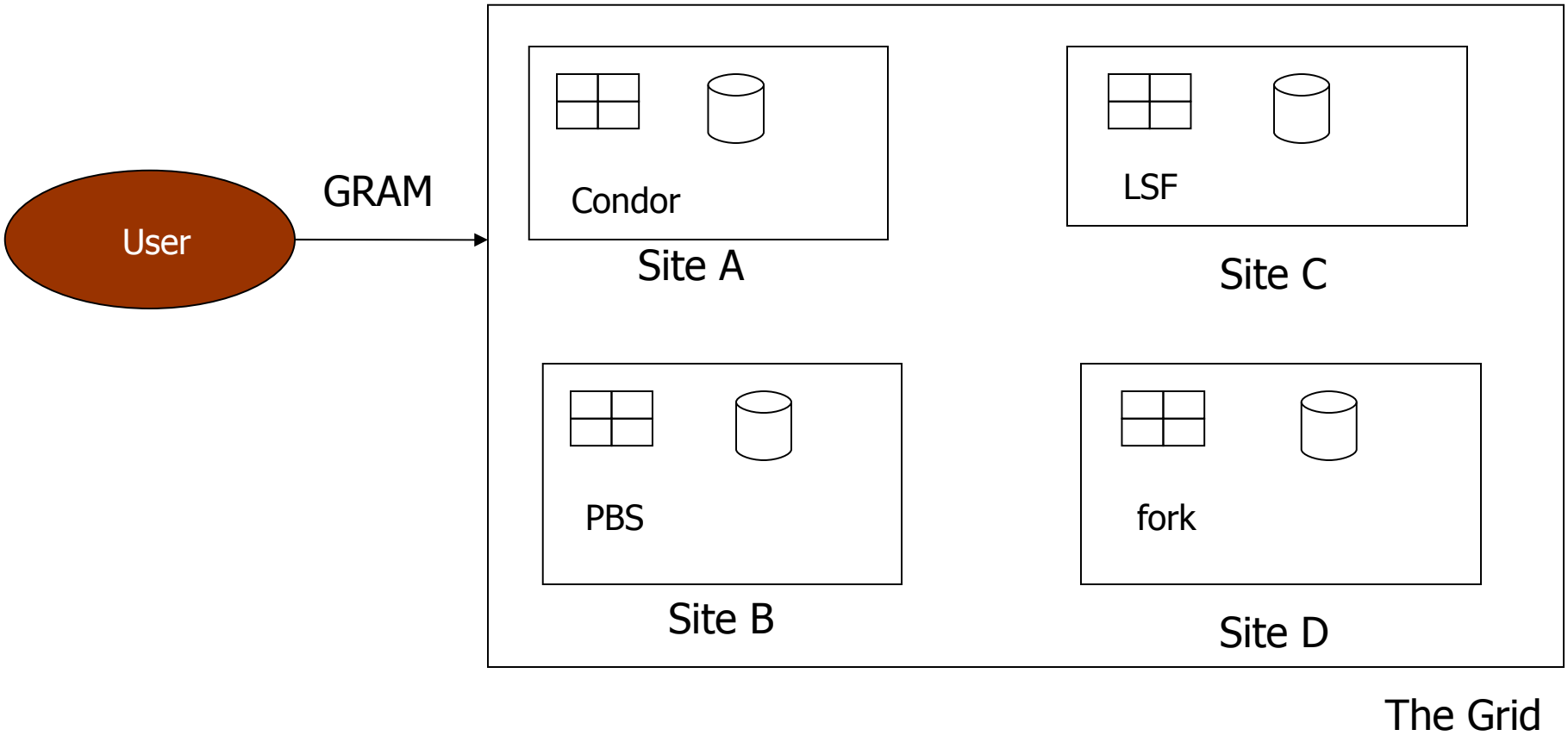
- **GRAM** = provides a standardised interface to submit jobs to LRMs.
- Clients submit a job request to GRAM
- GRAM translates into something a(ny) LRM can understand

  …. Same job request can be used for many different kinds of LRM

# Local Resource Managers (LRM)

- Compute resources have a **local resource manager** (LRM) that controls:
  - Who is allowed to run jobs
  - How jobs run on a specific resource
- *Example policy:*
  - Each cluster node can run one job.
  - If there are more jobs, then they must wait in a queue
- LRMs allow nodes in a cluster can be **reserved** for a specific person
- *Examples:* PBS, LSF, Condor

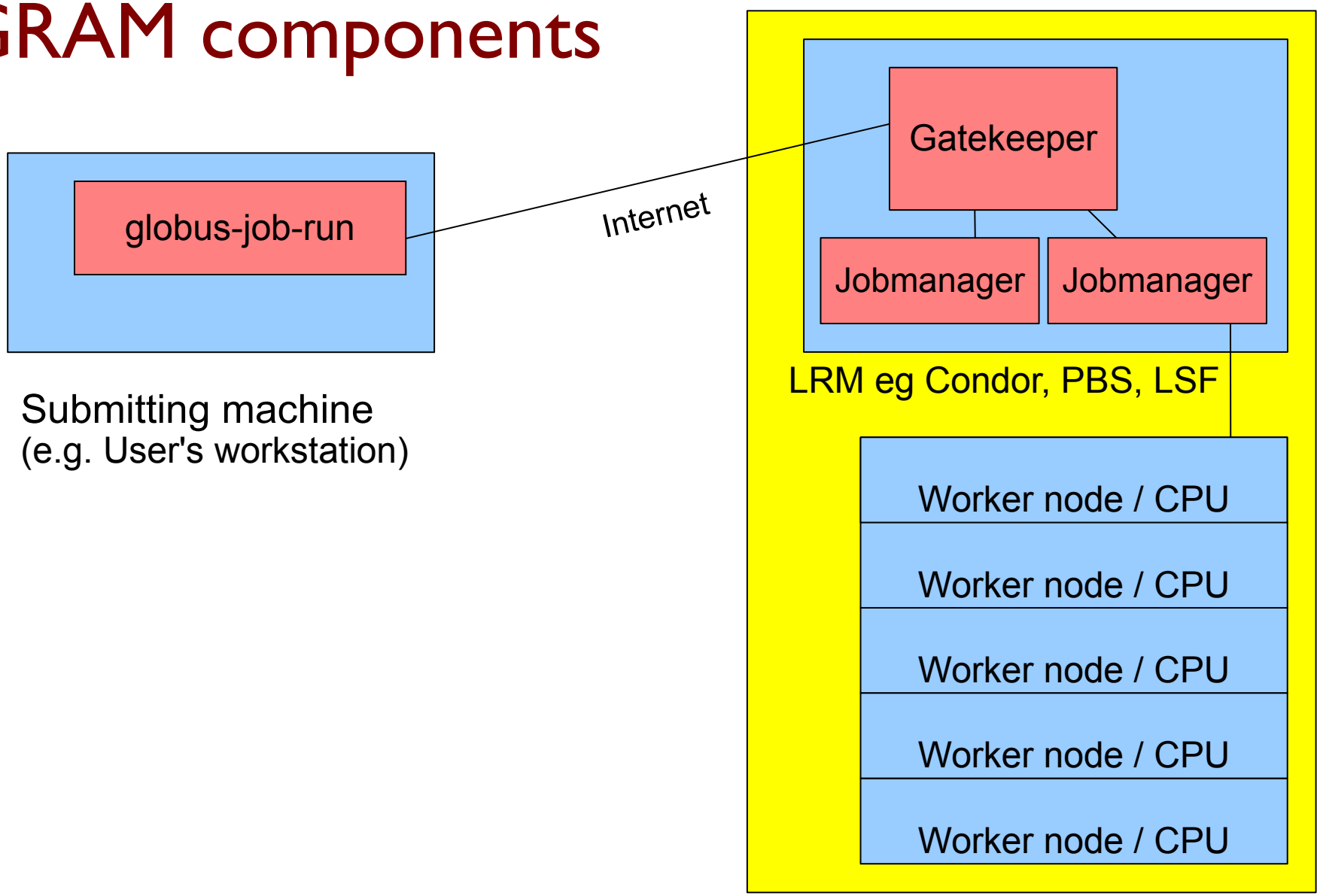
# Job Management on a Grid



# GRAM

- Given a job specification:
  - Creates an environment for the job
  - Stages files to and from the environment
  - Submits a job to a local resource manager
  - Monitors a job
  - Sends notifications of the job state change
  - Streams a job's stdout/err during execution

# GRAM components




Submitting machine
(e.g. User's workstation)

# Condor

- is a software system that creates an HTC environment
  - Created at UW-Madison
- Condor is a specialized workload management system for compute-intensive jobs.
  - Detects machine availability
  - Harnesses available resources
  - Uses remote system calls to send R/W operations over the network
  - Provides powerful resource management by ***matching*** resource owners with consumers (broker)

# How Condor works

**Condor provides:**

- a job queueing mechanism
- scheduling policy
- priority scheme
- resource monitoring, and
- resource management.

Users **submit** their serial or parallel jobs to Condor,
Condor places them into a **queue**,
… chooses **when** and **where** to run the jobs based upon a policy,

… carefully **monitors** their progress, and
… ultimately **informs** the user upon completion.

# Condor - features

- Checkpoint & migration
- Remote system calls
  - Able to transfer data files and executables across machines
- Job ordering
- *Job requirements and preferences can be specified via powerful expressions*

# Condor lets you manage a large number of jobs.

- Specify the jobs in a file and submit them to Condor
- Condor runs them and keeps you notified on their progress
  - Mechanisms to help you manage huge numbers of jobs (1000's), all the data, etc.
  - Handles inter-job dependencies (DAGMan)
- Users can set Condor's job priorities
- Condor administrators can set user priorities
- Can do this as:
  - Local resource manager (LRM) on a compute resource
  - Grid client submitting to GRAM (as Condor-G)

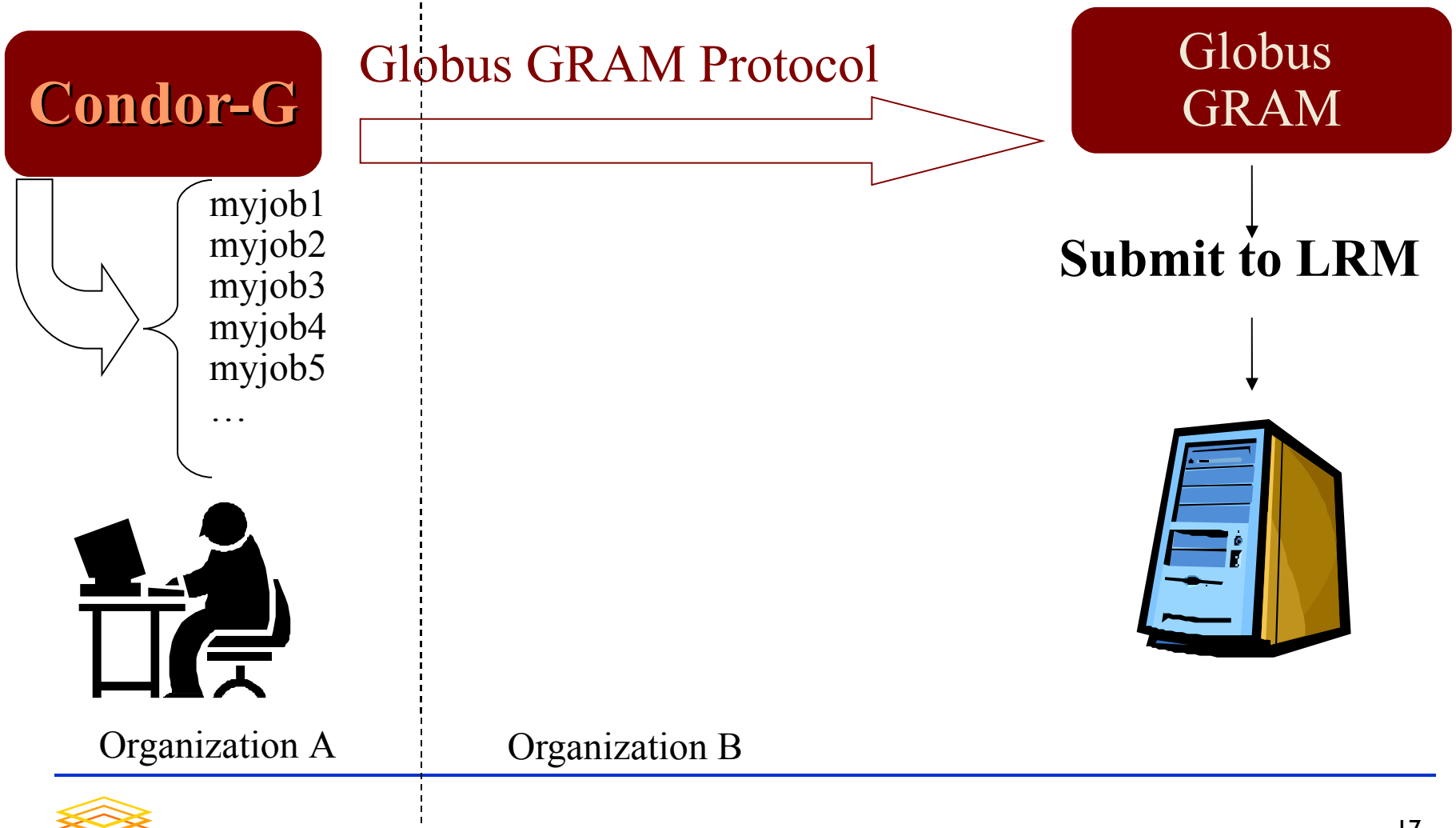
# Condor-G

- is the grid job management part of Condor.
- *Use* Condor-G to submit to resources accessible through a Globus interface.

# Condor-G …

- does whatever it takes to run your jobs, even if …
  - The gatekeeper is temporarily unavailable
  - The job manager crashes
  - Your local machine crashes
  - The network goes down

# Remote Resource Access: Condor-G + Globus + Condor



# Condor-G: Access non-Condor Grid resources


- middleware deployed across entire Grid
- remote access to computational resources
- dependable, robust data transfer


- job scheduling across multiple resources
- strong fault tolerance with checkpointing and migration
- layered over Globus as "personal batch system" for the Grid

# Four Steps to Run a Job with Condor

- These choices tell Condor
  - **how**
  - **when**
  - **where** to run the job,
  - and describe exactly **what** you want to run.

- Make your job batch-ready
- Create a *submit description* file
- Run *condor_submit*

# 1. Make your job batch-ready

- Must be able to run in the background:
  - no interactive input, windows, GUI, etc.
- Condor is designed to run jobs as a batch system, with pre-defined inputs for jobs
- Can still use `STDIN`, `STDOUT`, and `STDERR` (the keyboard and the screen), but files are used for these instead of the actual devices
- Organize data files

# 2. Create a Submit Description File

- A plain ASCII text file
- Condor does not care about file extensions

- Tells Condor about your job:
  - Which executable to run and where to find it
  - Which universe
  - Location of input, output and error files
  - Command-line arguments, if any
  - Environment variables
  - Any special requirements or preferences

# Simple Submit Description File

```
# myjob.submit file
Universe   = grid
grid_resource = gt2 osgce.cs.clemson.edu/jobmanager-fork
Executable = /bin/hostname
Arguments  = -f
Log        = /tmp/benc-grid.log
Output     = grid.out
Error      = grid.error
should_transfer_files   = YES
when_to_transfer_output = ON_EXIT
Queue
```

# 4. Run condor_submit

- You give *condor_submit* the name of the submit file you have created:

```
condor_submit my_job.submit
```

- *condor_submit* parses the submit file

# Details

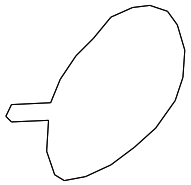
- Lots of options available in the submit file
- Commands to
  - watch the queue,
  - the state of your pool,
  - and lots more
- You'll see much of this in the hands-on exercises.

# Other Condor commands

- condor_q – show status of job queue

- condor_status – show status of compute nodes
- condor_rm – remove a job
- condor_hold – hold a job temporarily
- condor_release – release a job from hold

# Submitting more complex jobs



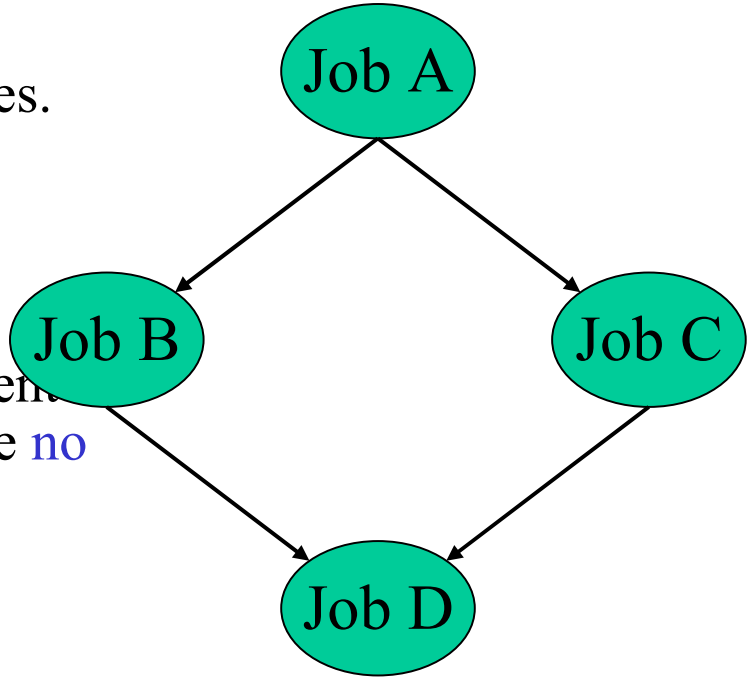
- express dependencies between jobs
  ⇒ WORKFLOWS
- We would like the workflow to be managed even in the face of failures

# DAGMan

- **Directed Acyclic Graph Manager**
- DAGMan allows you to specify the *dependencies* between your Condor jobs, so it can *manage* them automatically for you.
- (e.g., “Don’t run job “B” until job “A” has completed successfully.”)

# What is a DAG?

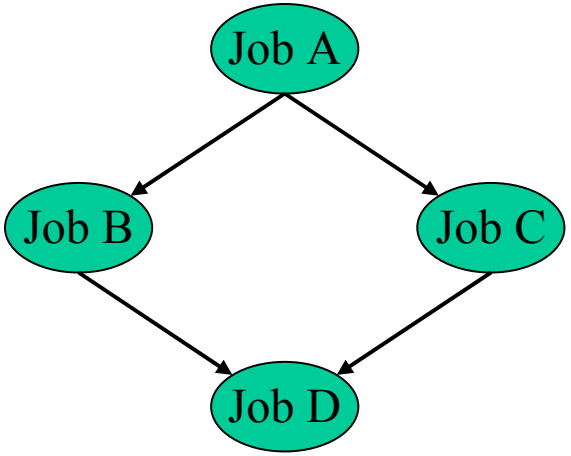
- A DAG is the data structure used by DAGMan to represent these dependencies.
- Each job is a "node" in the DAG.
- Each node can have any number of "parent" or "children" nodes – as long as there are no loops!



# Defining a DAG

- A DAG is defined by a *.dag file*, listing each of its nodes and their dependencies:

```
# diamond.dag
Job A a.sub
Job B b.sub
Job C c.sub
Job D d.sub
Parent A Child B C
Parent B C Child D
```




- each node will run the Condor job specified by its accompanying Condor submit file

# Submitting a DAG

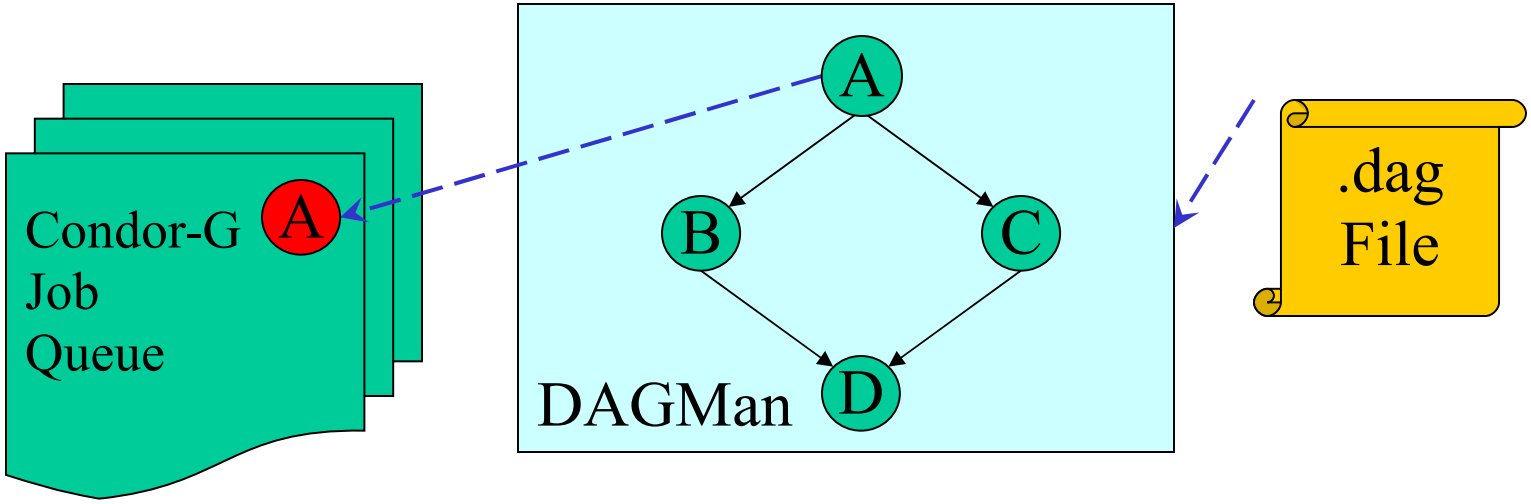
- To start your DAG, just run ***condor_submit_dag*** with your .dag file, and Condor will start a personal DAGMan daemon which to begin running your jobs:

```
% condor_submit_dag diamond.dag
```

- condor_submit_dag submits a Scheduler Universe Job with DAGMan as the executable.
- Thus the DAGMan daemon itself runs as a Condor job, so you don't have to baby-sit it.

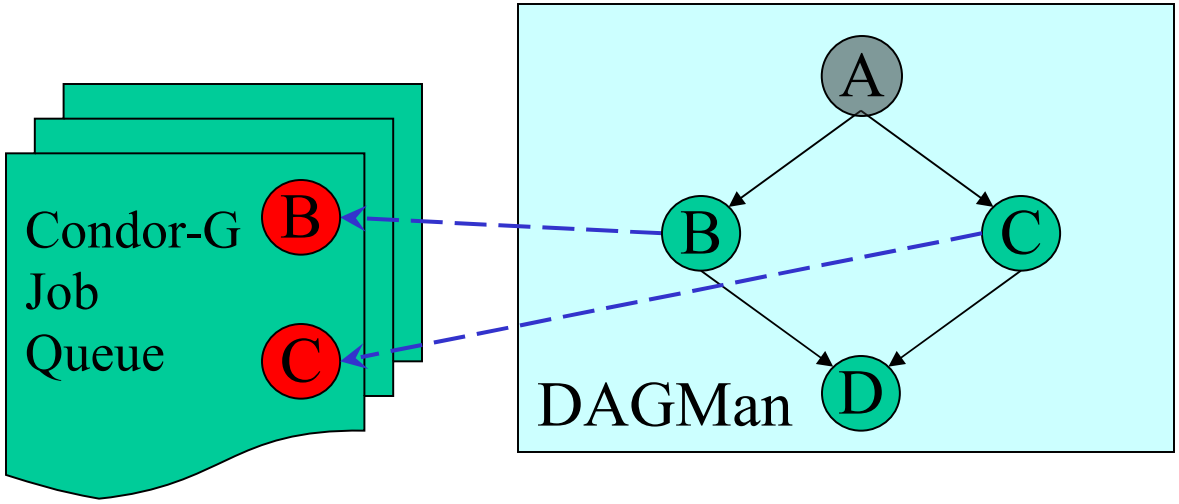
# Running a DAG

- DAGMan acts as a “meta-scheduler”, managing the submission of your jobs to Condor-G based on the DAG dependencies.



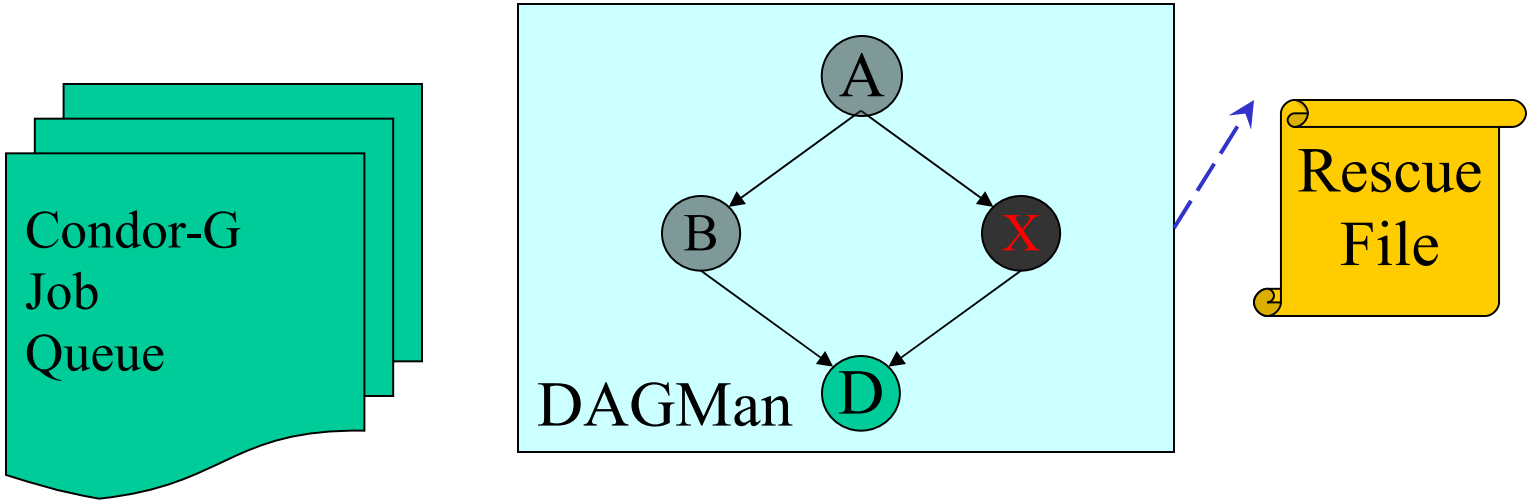
# Running a DAG (cont'd)

- DAGMan holds & submits jobs to the Condor-G queue at the appropriate times.



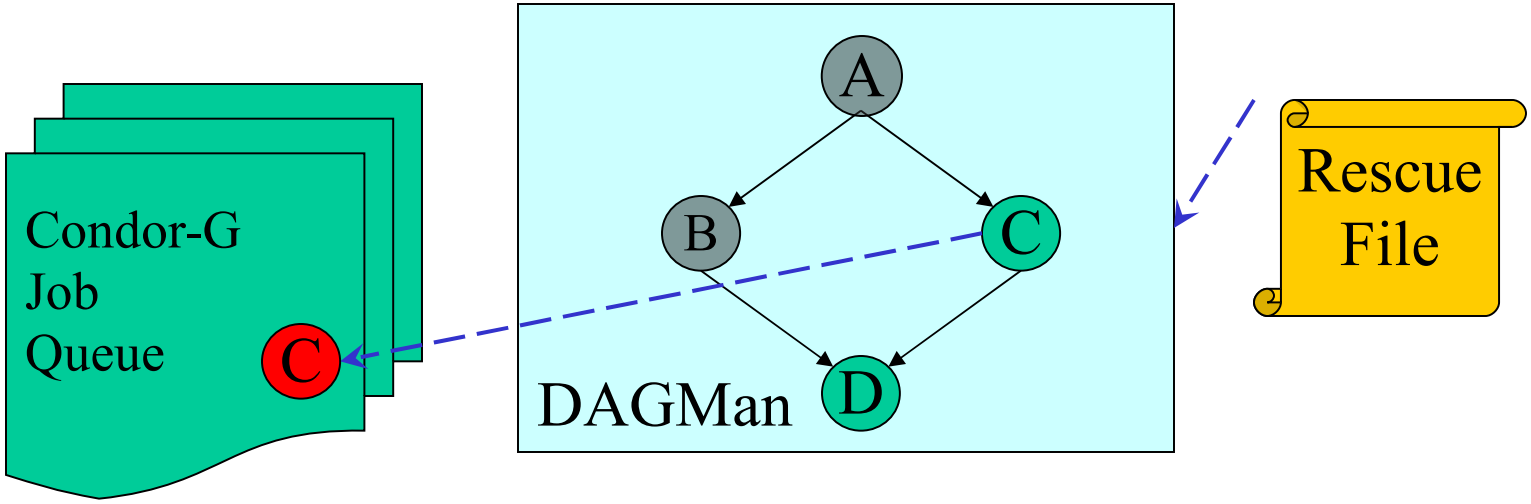
# Running a DAG (cont'd)

- In case of a job failure, DAGMan continues until it can no longer make progress, and then creates a *"rescue" file* with the current state of the DAG.



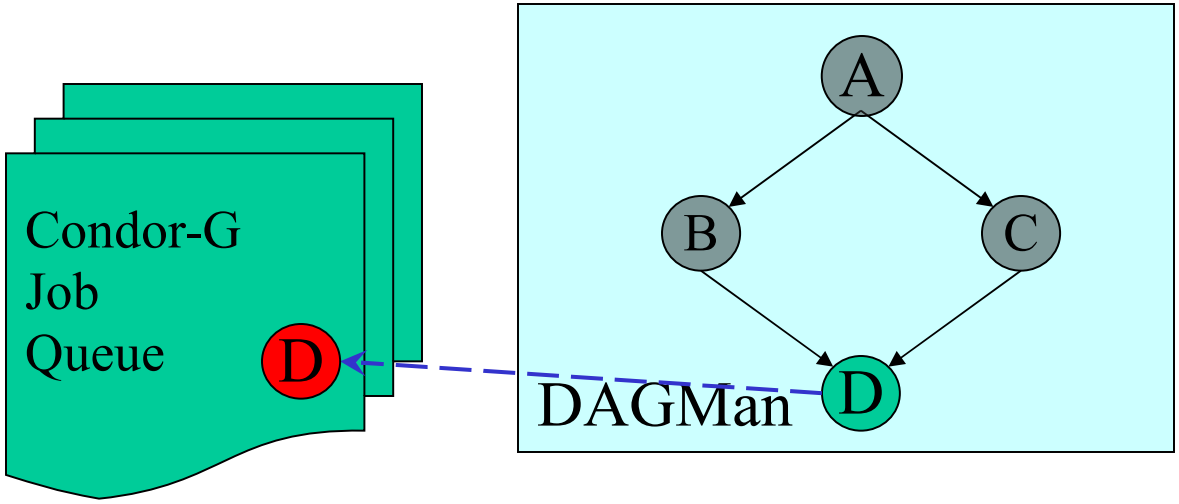
# Recovering a DAG -- fault tolerance

- Once the failed job is ready to be re-run, the rescue file can be used to restore the prior state of the DAG.



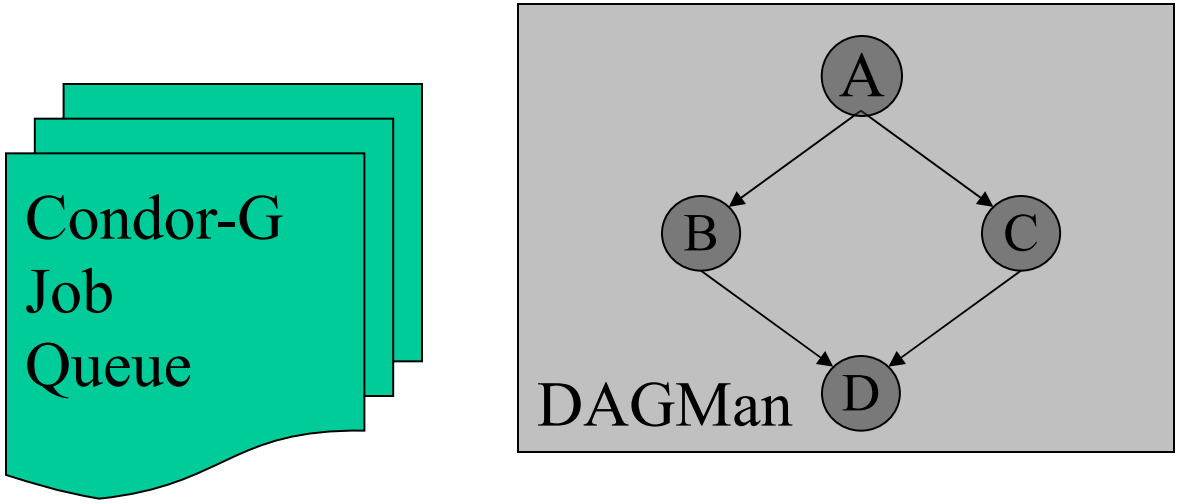
# Recovering a DAG (cont'd)

- Once that job completes, DAGMan will continue the DAG as if the failure never happened.



# Finishing a DAG

- Once the DAG is complete, the DAGMan job itself is finished, and exits.



# We have seen how Condor:

… monitors submitted jobs and reports progress

… implements your policy on the execution order of the jobs

… keeps a log of your job activities

# OSG & job submissions

- OSG sites present interfaces allowing remotely submitted jobs to be accepted, queued and executed locally.
- OSG supports the Condor-G job submission client which interfaces to the Globus GRAM interface at the executing site.
- Job managers at the backend of the GRAM gatekeeper support job execution by local Condor, LSF, PBS, or SGE batch systems.