Introduction to Makeflow and Work Queue

Nate Kremer-Herman

Blue Waters Webinar

March 22nd, 2017

The Cooperative Computing Lab

- We *collaborate with people* who have large scale computing problems in science, engineering, and other fields.
- We *operate computer systems* on the O(10,000) cores: clusters, clouds, grids.
- We *conduct computer science* research in the context of real people and problems.
- We *develop open source software* for large scale distributed computing.

Our Philosophy:

- Harness all the resources that are available: desktops, clusters, clouds, and grids.
- Make it easy to scale up from one desktop to national scale infrastructure.
- Provide familiar interfaces that make it easy to connect existing apps together.
- Allow portability across operating systems, storage systems, middleware…
- Make simple things easy, and complex things possible.
- ***No special privileges required.***

A Quick Tour of the CCTools

- Open source, GNU General Public License.
- Compiles in 1-2 minutes, installs in $HOME.
- Runs on Linux, Solaris, MacOS, FreeBSD, …
- Interoperates with many distributed computing systems.
  - Condor, SGE, SLURM, TORQUE, Globus, iRODS, Hadoop…
- Components:
  - **Makeflow** – A portable workflow manager.
  - **Work Queue** – A lightweight distributed execution system.
  - All-Pairs / Wavefront / SAND – Specialized execution engines.
  - Parrot – A personal user-level virtual filesystem.
  - Chirp – A user-level distributed filesystem.

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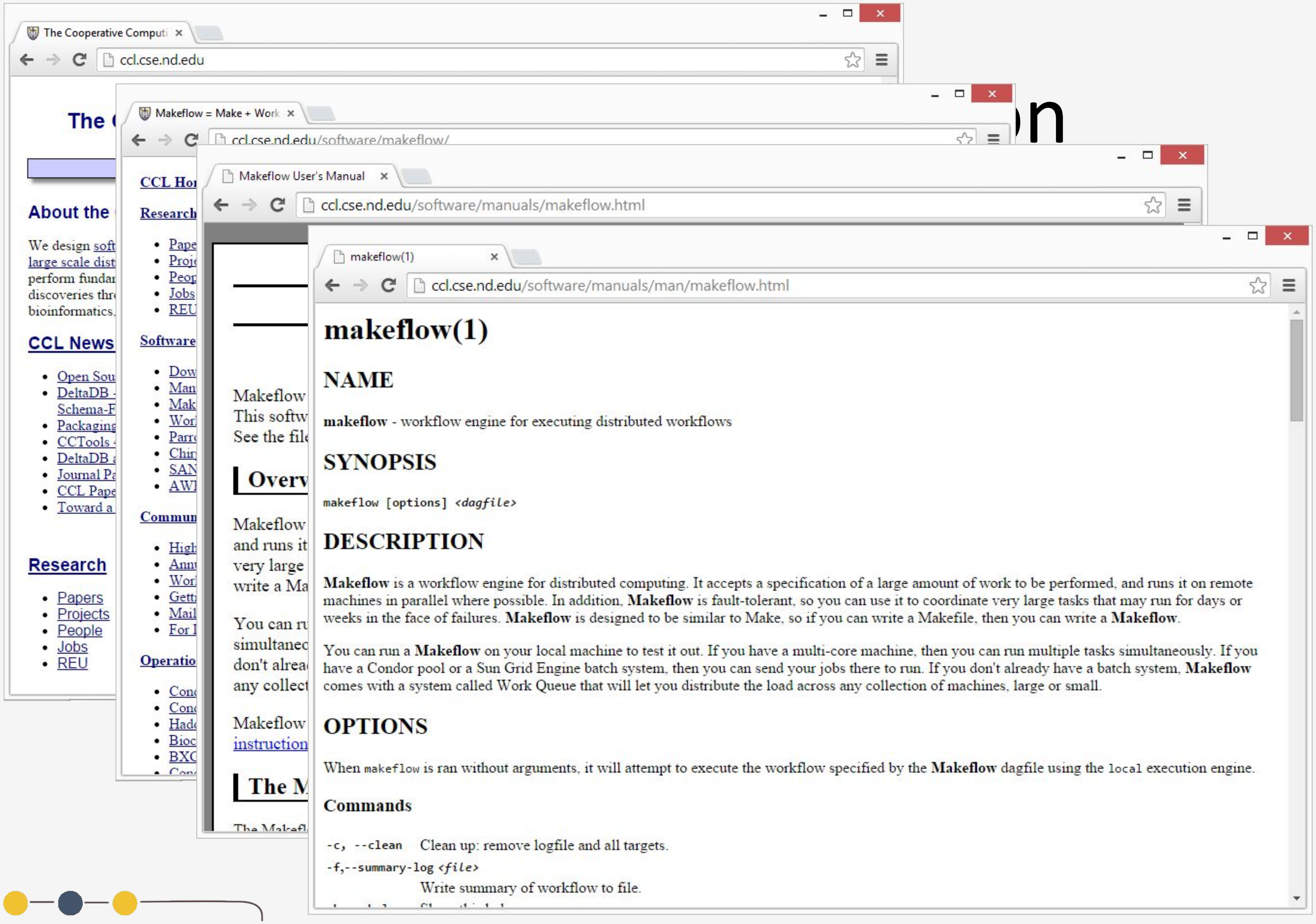

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About the

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Makeflow = Make + Work
ccl.cse.nd.edu/software/makeflow/

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Makeflow User's Manual
ccl.cse.nd.edu/software/manuals/makeflow.html

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makeflow(1)
ccl.cse.nd.edu/software/manuals/man/makeflow.html

makeflow(1)

NAME

makeflow - workflow engine for executing distributed workflows

SYNOPSIS

`makeflow [options] <dagfile>`

DESCRIPTION

Makeflow is a workflow engine for distributed computing. It accepts a specification of a large amount of work to be performed, and runs it on remote machines in parallel where possible. In addition, **Makeflow** is fault-tolerant, so you can use it to coordinate very large tasks that may run for days or weeks in the face of failures. **Makeflow** is designed to be similar to Make, so if you can write a Makefile, then you can write a **Makeflow**.

You can run a **Makeflow** on your local machine to test it out. If you have a multi-core machine, then you can run multiple tasks simultaneously. If you have a Condor pool or a Sun Grid Engine batch system, then you can send your jobs there to run. If you don't already have a batch system, **Makeflow** comes with a system called Work Queue that will let you distribute the load across any collection of machines, large or small.

OPTIONS

When `makeflow` is ran without arguments, it will attempt to execute the workflow specified by the **Makeflow** dagfile using the `local` execution engine.

Commands

`-c, --clean` Clean up: remove logfile and all targets.

`-f,--summary-log <file>`
Write summary of workflow to file.

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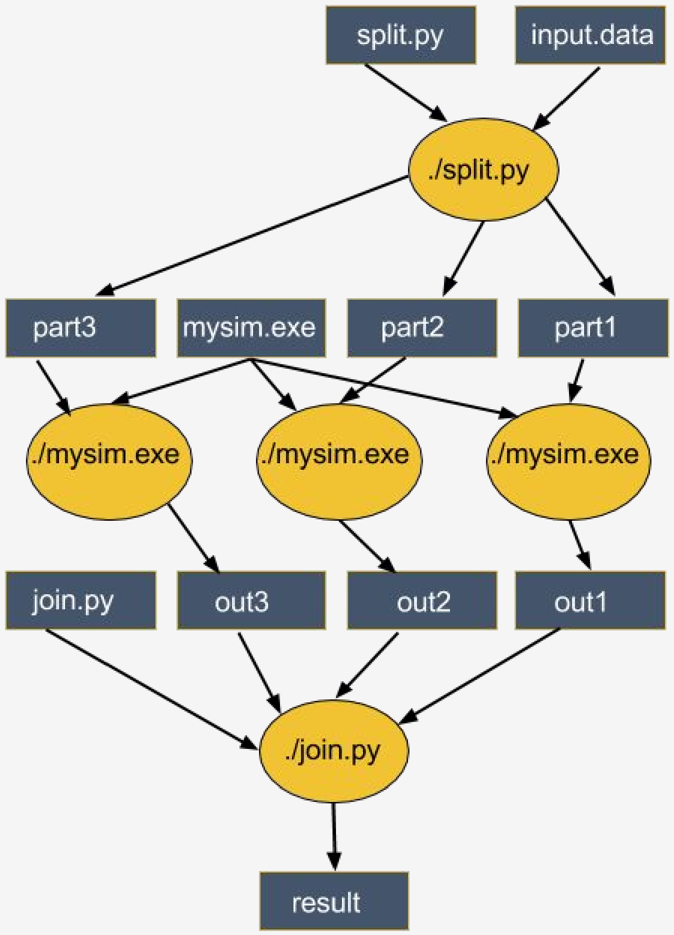
Recap from Last Workflow Webinar

- What is a workflow?
  - A collection of things to do (tasks) to reach a final result.
- What are the parts of a task?
  - The thing we want to do (application to run), input to give that application, output we expect to get from that application.
- How can a workflow management system help me do my research?
  - Add automation, resource provisioning, task scheduling, data management, etc.

bluewaters.ncsa.illinois.edu/webinars/workflows/overview-of-scientific-workflows

Makeflow:
A Portable Workflow System

An Old Idea: Makefiles



```
part1 part2 part3: input.data split.py
     ./split.py input.data

out1: part1 mysim.exe
    ./mysim.exe part1 >out1

out2: part2 mysim.exe
    ./mysim.exe part2 >out2

out3: part3 mysim.exe
    ./mysim.exe part3 >out3

result: out1 out2 out3 join.py
    ./join.py out1 out2 out3 > result
```

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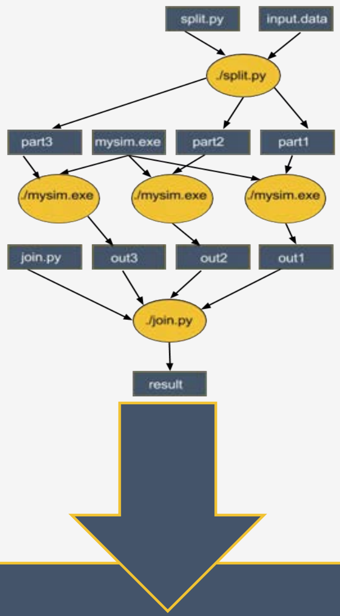
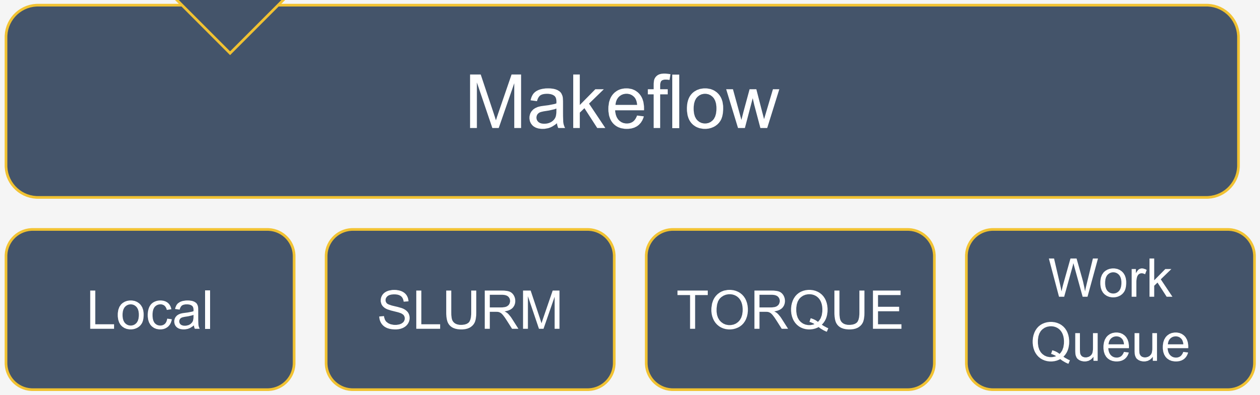
Makeflow = Make + Workflow



- Provides portability across batch systems.
- Enable parallelism (but not too much!).
- Trickle out work to batch system.
- Fault tolerance at multiple scales.
- Data and resource management.



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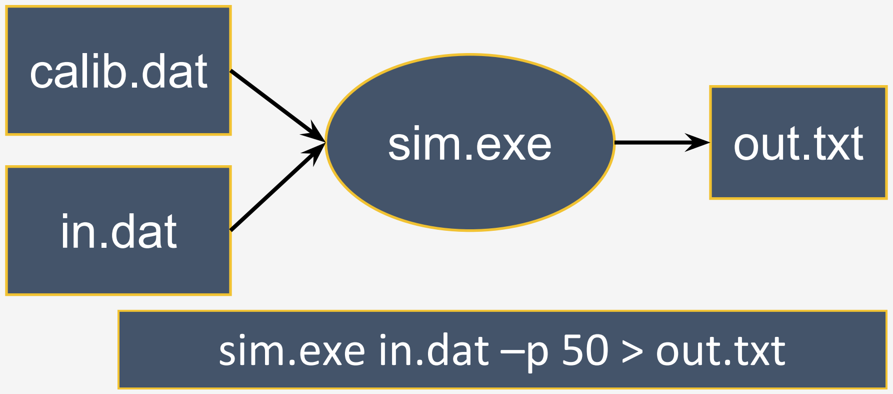
Makeflow Syntax

[output files] : [input files]
[command to run]

One rule



```
out.txt : in.dat calib.dat sim.exe
    sim.exe –p 50 in.data > out.txt
```

You must state all the files needed by the command.

example.makeflow

```
out.10 : in.dat calib.dat sim.exe
        sim.exe –p 10 in.data > out.10

out.20 : in.dat calib.dat sim.exe
        sim.exe –p 20 in.data > out.20

out.30 : in.dat calib.dat sim.exe
        sim.exe –p 30 in.data > out.30
```

Sync Point - Questions?

- Several additional features to Makeflow which we do not have time to cover today (please take a look at our documentation).
- Categories and resource specification.
- Shared filesystems support.
- Container support (Docker and Singularity).

ccl.cse.nd.edu/software/manuals/makeflow.html

Let’s work through a brief tutorial:

ccl.cse.nd.edu/software/tutorials/ncsatut17/makeflow-tutorial.php

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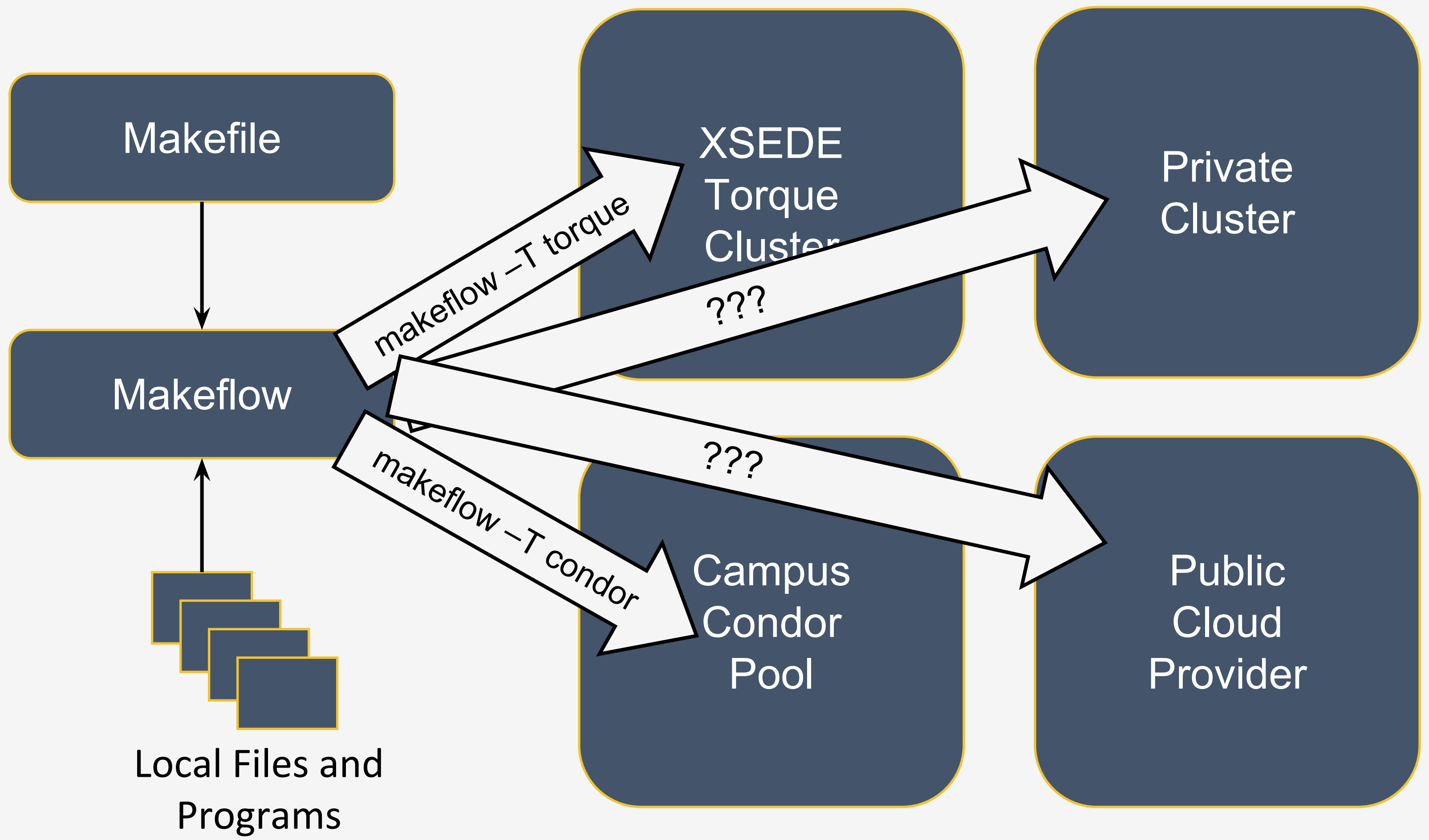
Makeflow + Work Queue

Makeflow + Batch System



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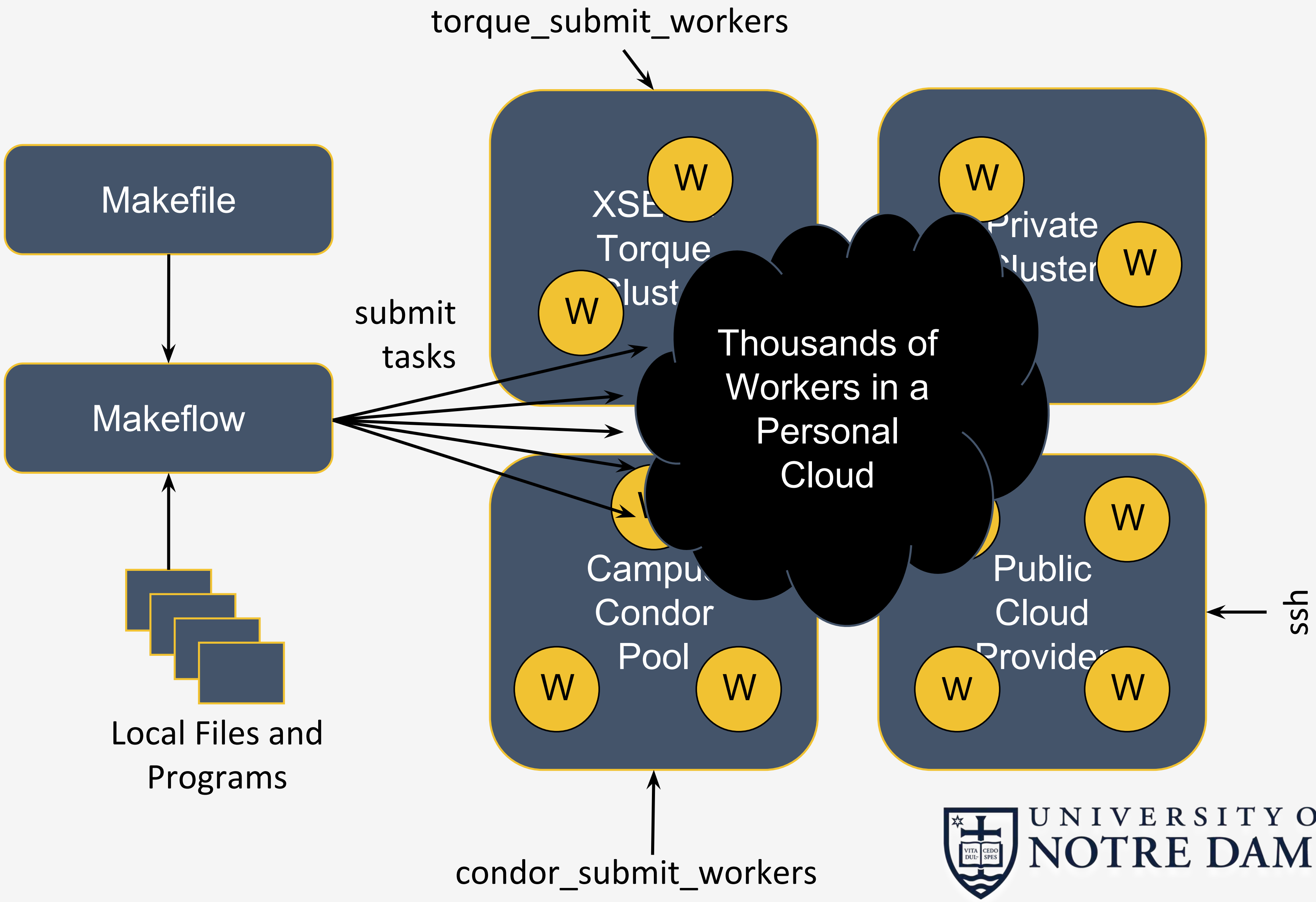
Makeflow + Work Queue



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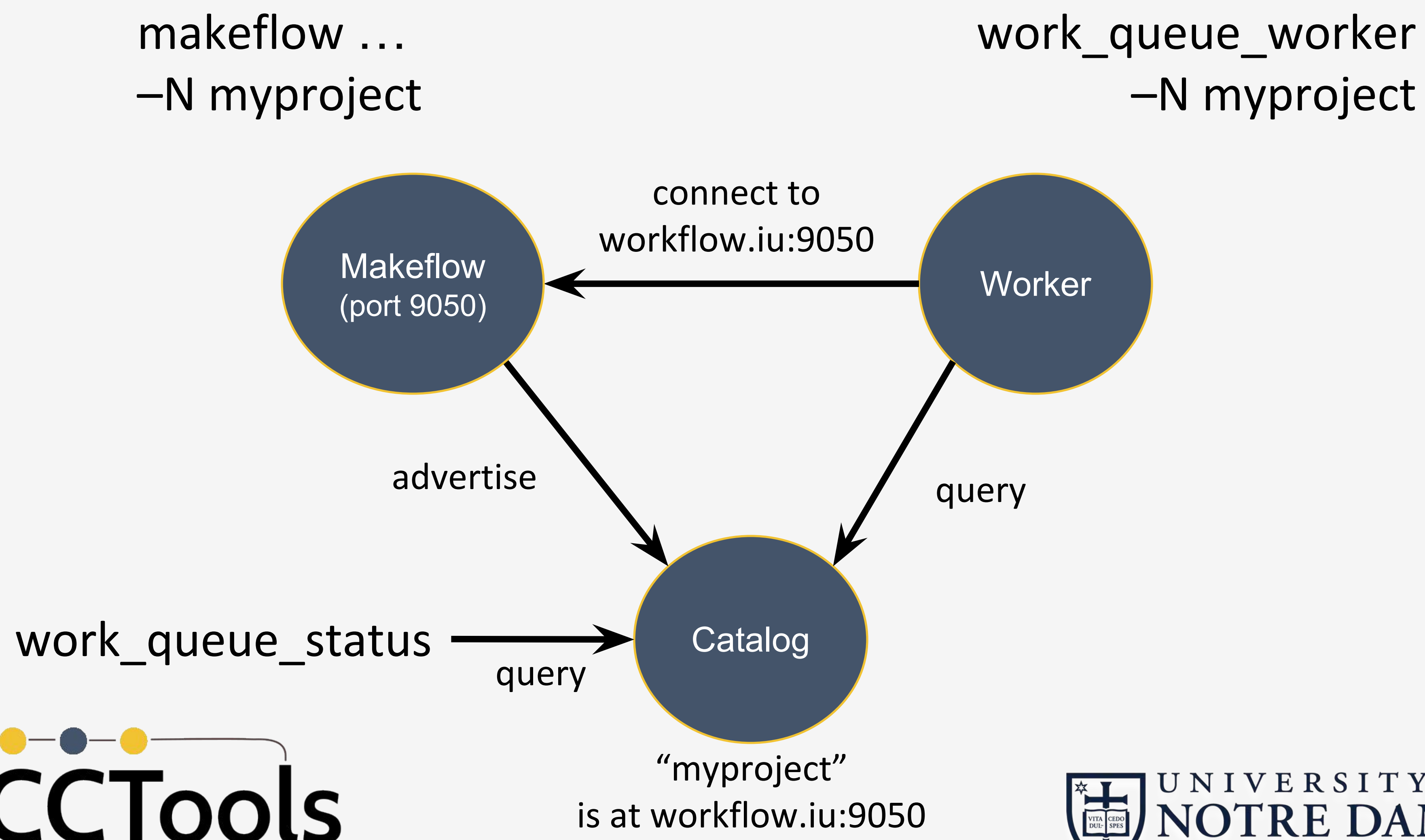
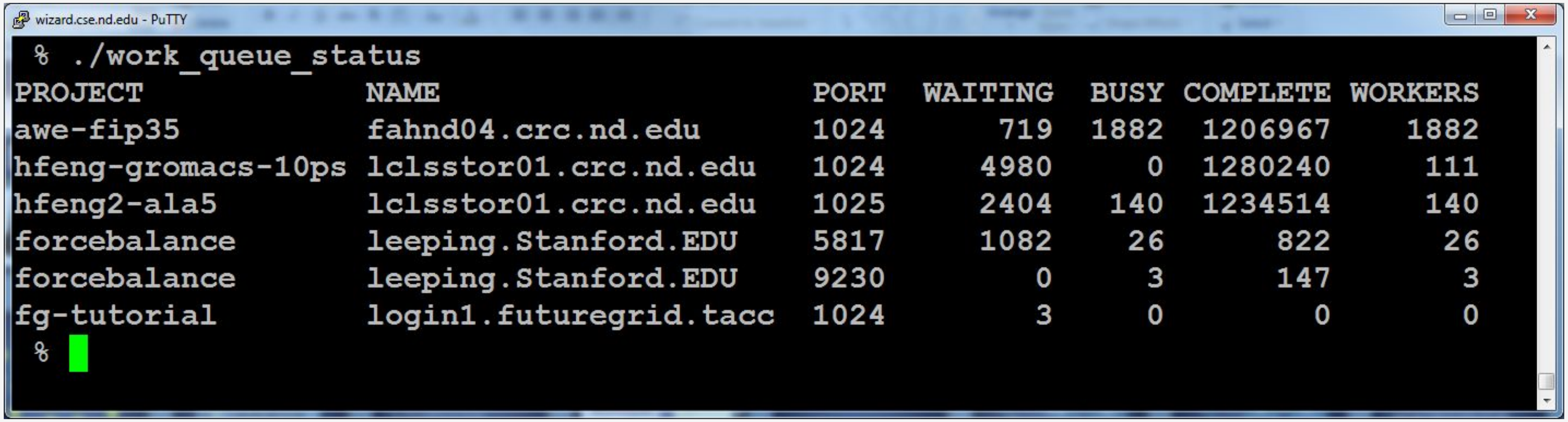
Advantages of Work Queue

- Harness multiple resources simultaneously.
- Hold on to cluster nodes to execute multiple tasks rapidly. (ms/task instead of min/task)
- Scale resources up and down as needed.
- Better management of data, with local caching for data intensive tasks.
- Matching of tasks to nodes with data.

Project Names



work_queue_status


wizard.cse.nd.edu - PuTTY

```
 % ./work_queue_status
PROJECT            NAME                    PORT  WAITING  BUSY  COMPLETE  WORKERS
awe-fip35          fahnd04.crc.nd.edu      1024      719  1882   1206967     1882
hfeng-gromacs-10ps lclsstor01.crc.nd.edu   1024     4980     0   1280240      111
hfeng2-ala5        lclsstor01.crc.nd.edu   1025     2404   140   1234514      140
forcebalance       leeping.Stanford.EDU    5817     1082    26       822       26
forcebalance       leeping.Stanford.EDU    9230        0     3       147        3
fg-tutorial        login1.futuregrid.tacc  1024        3     0         0        0
 %
```

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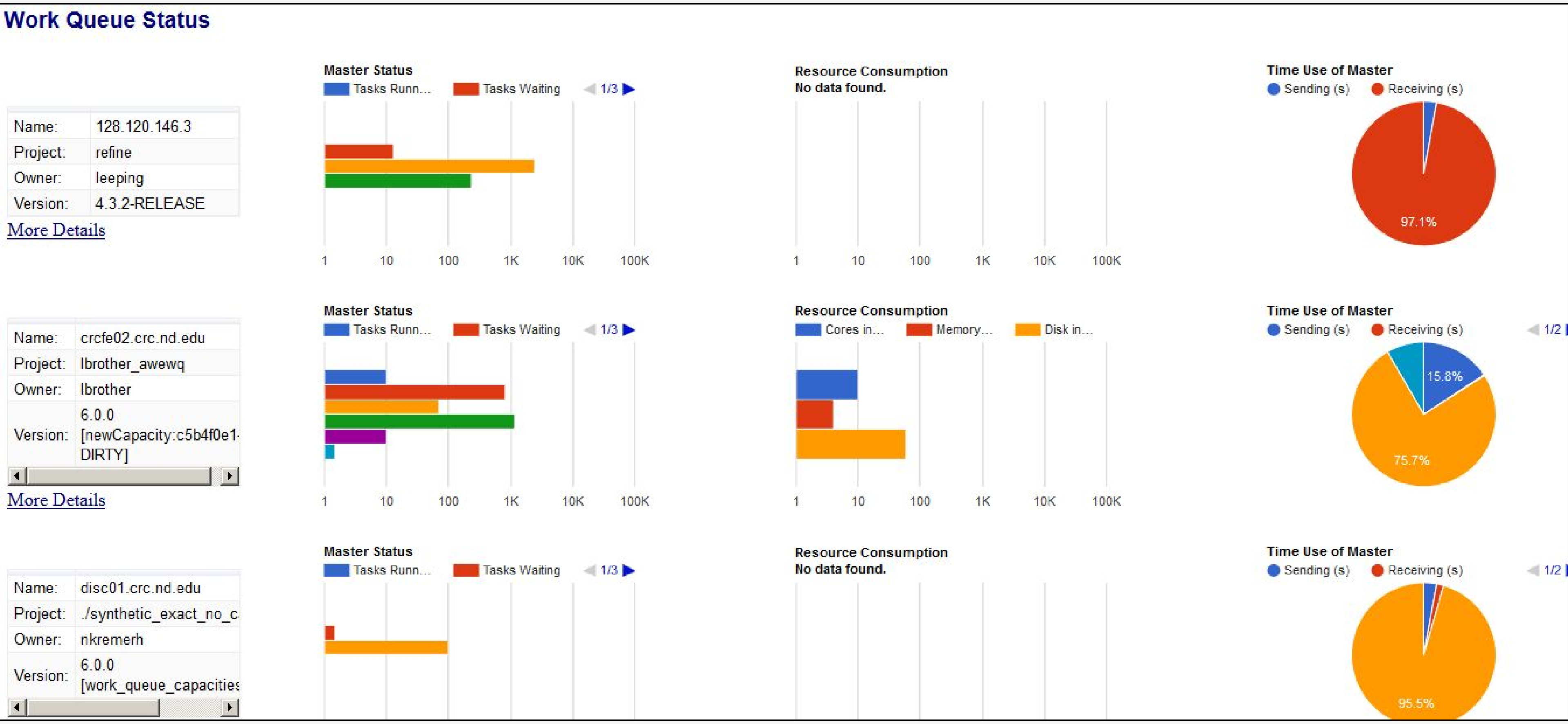
Work Queue Visualization Dashboard



Work Queue Status

Name:	128.120.146.3
Project:	refine
Owner:	leeping
Version:	4.3.2-RELEASE

More Details

Name:	crcfe02.crc.nd.edu
Project:	lbrother_awewq
Owner:	lbrother
Version:	6.0.0 [newCapacity:c5b4f0e1- DIRTY]

More Details

Name:	disc01.crc.nd.edu
Project:	./synthetic_exact_no_c
Owner:	nkremerh
Version:	6.0.0 [work_queue_capacities

ccl.cse.nd.edu/software/workqueue/status

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Resilience and Fault Tolerance

- MF +WQ is fault tolerant in many different ways:
  - If Makeflow crashes (or is killed) at any point, it will recover by reading the transaction log and continue where it left off.
  - Makeflow keeps statistics on both network and task performance, so that excessively bad workers are avoided.
  - If a worker crashes, the master will detect the failure and restart the task elsewhere.
  - Workers can be added and removed at any time during the execution of the workflow.
  - Multiple masters with the same project name can be added and removed while the workers remain.
  - If the worker sits idle for too long (default 15m) it will exit, so it does not hold resources while idle.

Let's return to the tutorial:

ccl.cse.nd.edu/software/tutorials/ncsatut17/makeflow-tutorial.php

Visit our website: ccl.cse.nd.edu

Follow us on Twitter: @ProfThain

Check out our blog: cclnd.blogspot.com

Makeflow examples:
github.com/cooperative-computing-lab
/makeflow-examples