Portable Resource Management for Data Intensive Workflows

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The Cooperative Computing Lab

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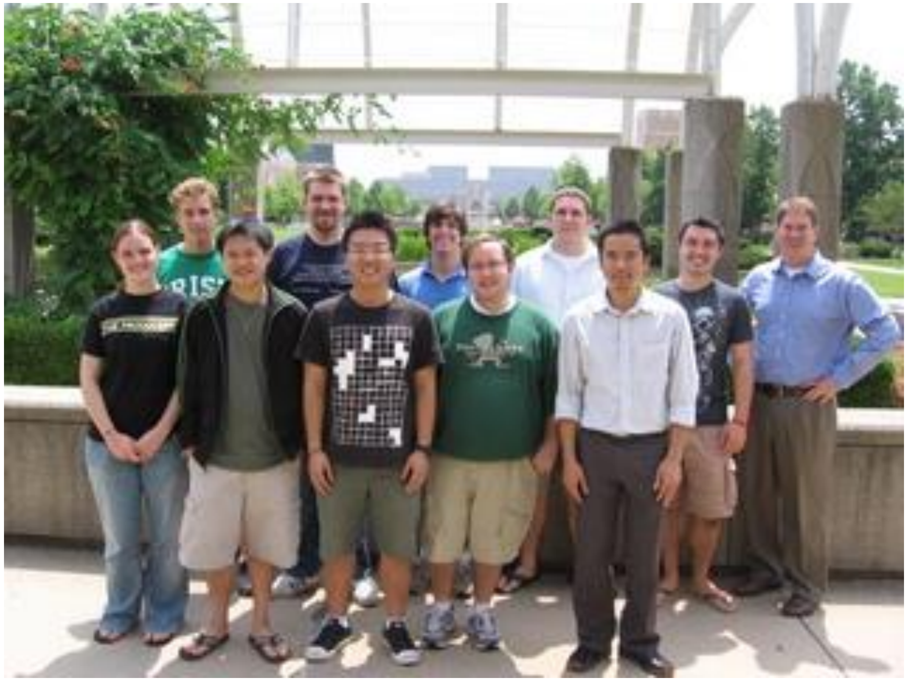

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Makeflow

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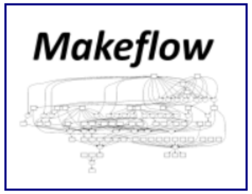

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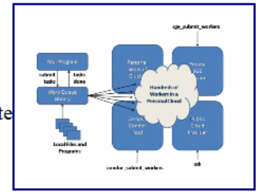

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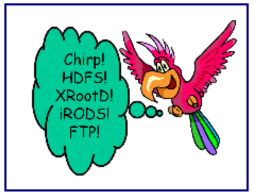

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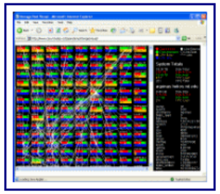

The Cooperative Computing Lab

- 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 *release open source software* for large scale distributed computing.

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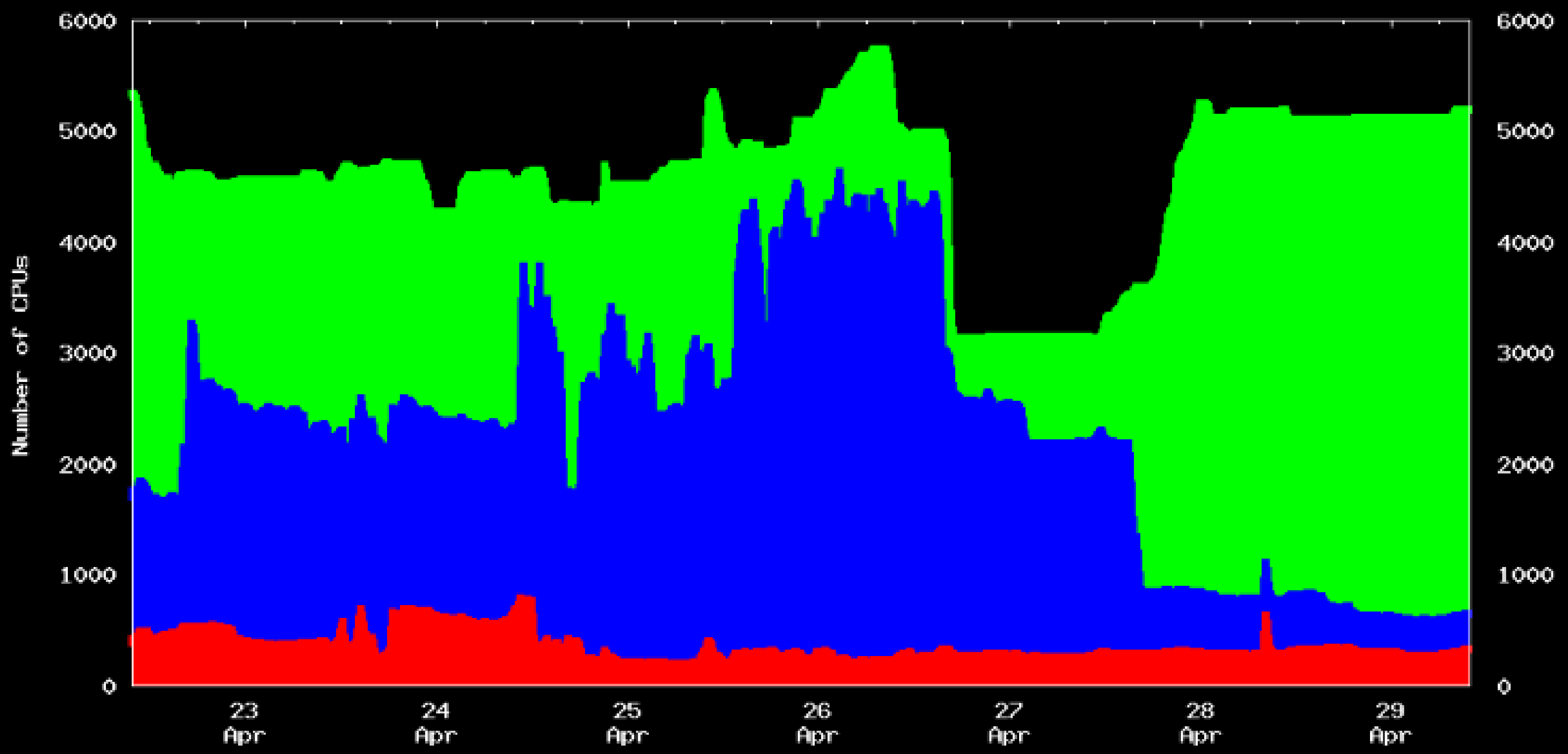
CPU Utilization for the Last Week



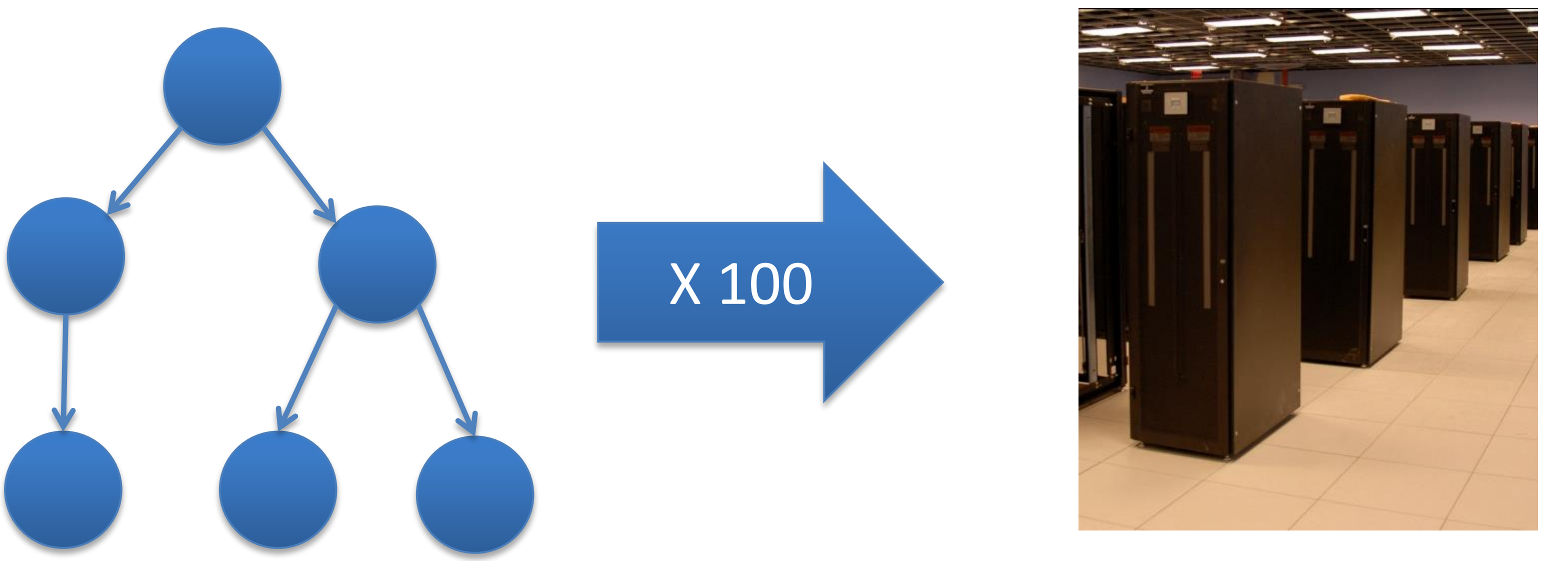
404855 (51%) CPU-Hours Unused

328960 (41%) CPU-Hours Used by Condor

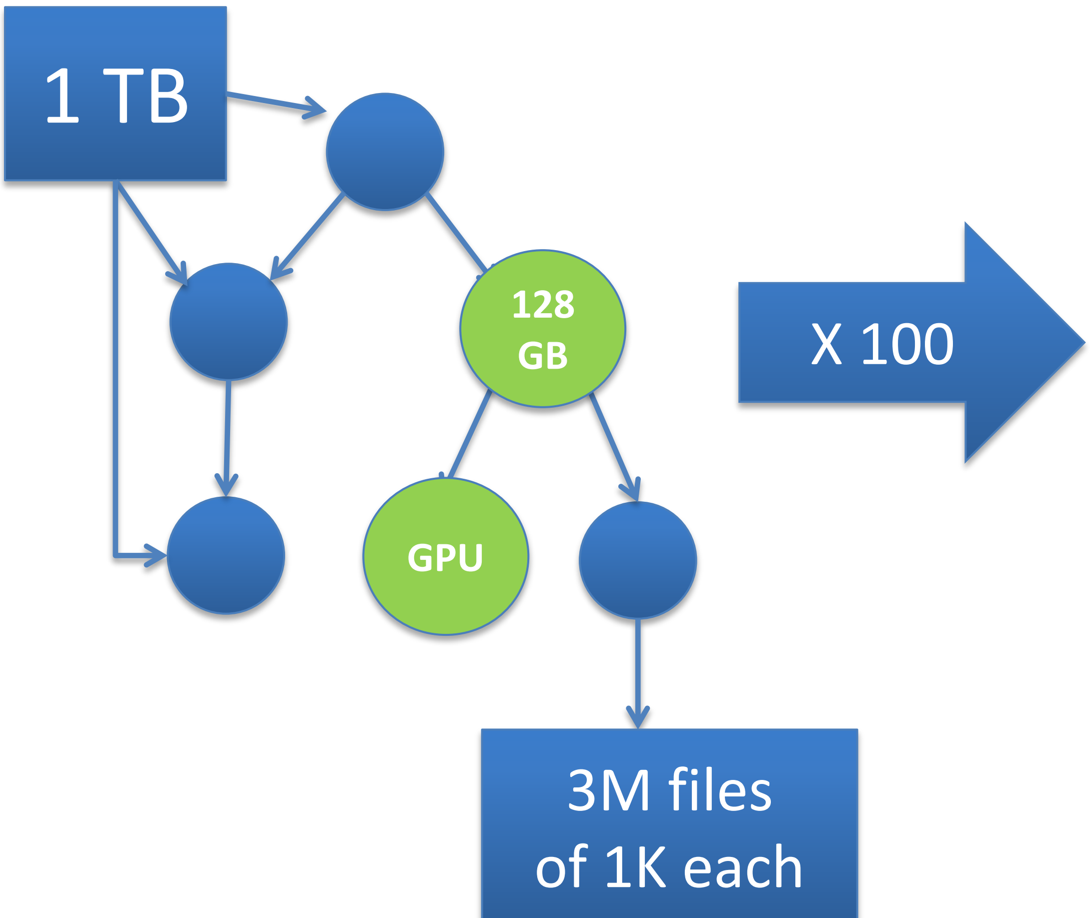
58935 (7%) CPU-Hours Used by Owner

792750 (100%) CPU-Hours Total

A Familiar Problem



What actually happens:



Some reasonable questions:

- Will this workload **at all** on machine X?
- How many workloads can I run simultaneously without running out of storage space?
- Did this workload actually behave as expected when run on a new machine?
- How is run X different from run Y?
- If my workload wasn’t able to run on this machine, where can I run it?

End users have **no idea** what resources their applications actually need.

and…

Computer systems are **terrible** at describing their capabilities and limits.

and…

They don’t know when to say **NO**.

dV/dt : **Accelerating the Rate of Progress Towards Extreme Scale Collaborative Science**

Miron Livny (UW), Ewa Deelman (USC/ISI), Douglas Thain (ND), Frank Wuerthwein (UCSD), Bill Allcock (ANL)

… make it easier for scientists to conduct large-scale computational tasks that use the power of computing resources they do not own to process data they did not collect with applications they did not develop …

dV/dt Project Approach

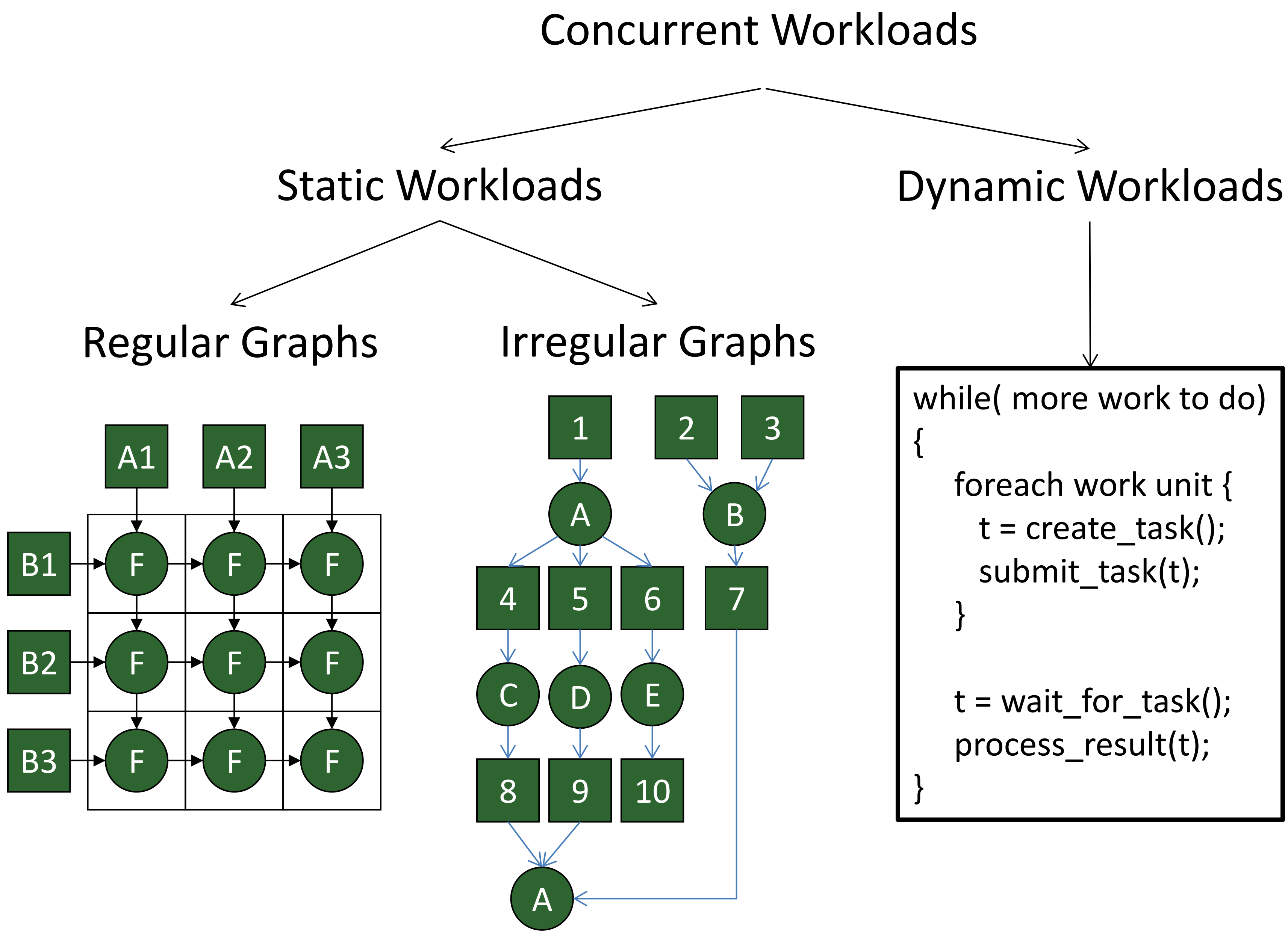
- Identify challenging applications.
- Develop a framework that allows to characterize the application needs, the resource availability, and plan for their use.
- Threads of Research:
  - High level planning algorithms.
  - Measurement, representation, analysis.
  - Resource allocation and enforcement.
  - Resources: Storage, networks, memory, cores…?
  - Evaluate on major DOE resources: OSG and ALCF.

Stages of Resource Management

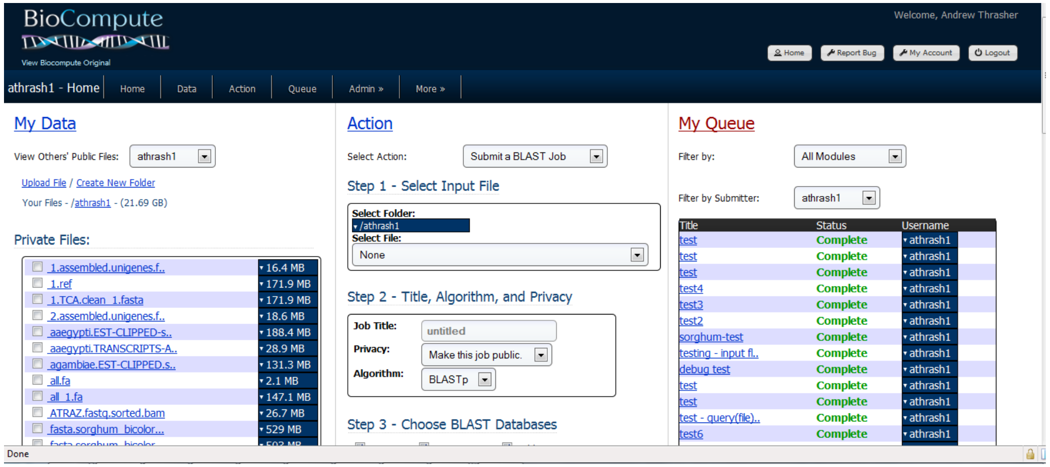
- **Estimate** the application resource needs
- **Find** the appropriate computing resources
- **Acquire** those resources
- **Deploy** applications and data on the resources
- **Manage** applications and resources during run.

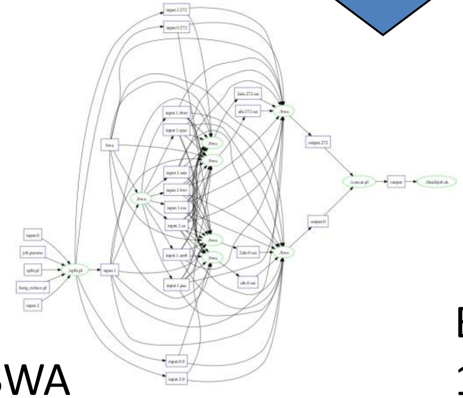
- Can we do it for **one task**?
- How about an app composed of **many tasks**?

Categories of Applications

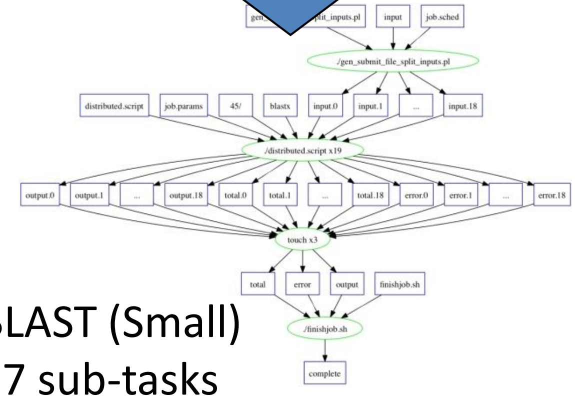


Bioinformatics Portal Generates Workflows for Makeflow



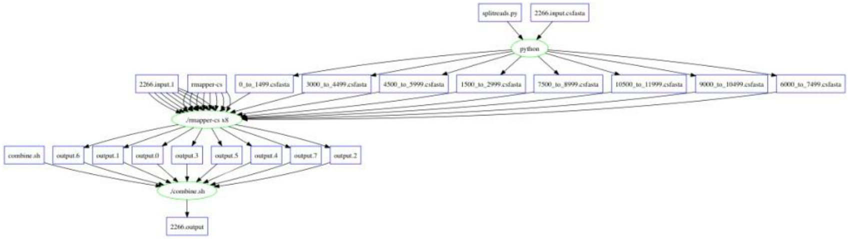


BWA
825 sub-tasks
~27m on 100 nodes

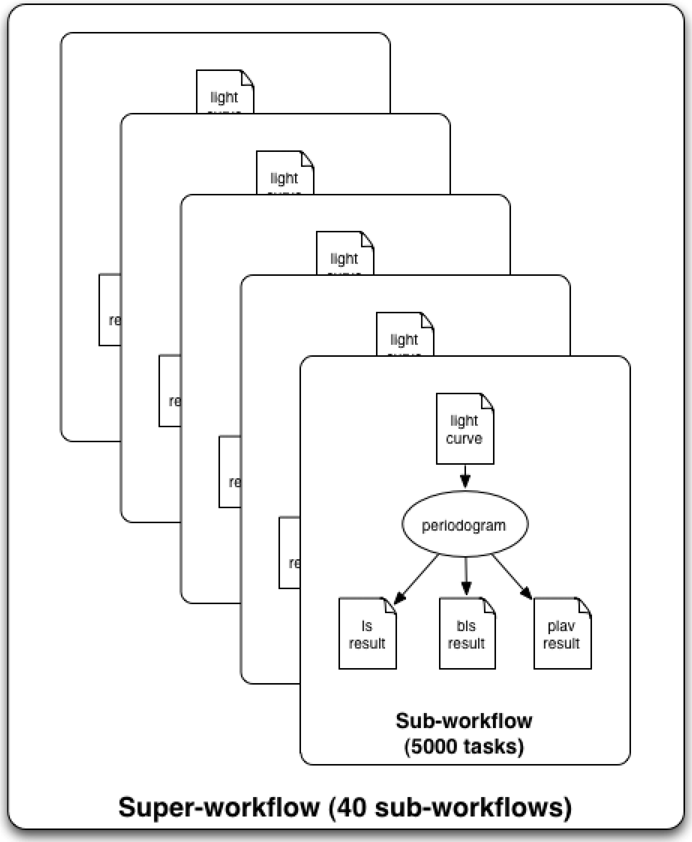


BLAST (Small)
17 sub-tasks
~4h on 17 nodes

SHRIMP
5080 sub-tasks
~3h on 200 nodes



Periodograms: generate an atlas of extra-solar planets

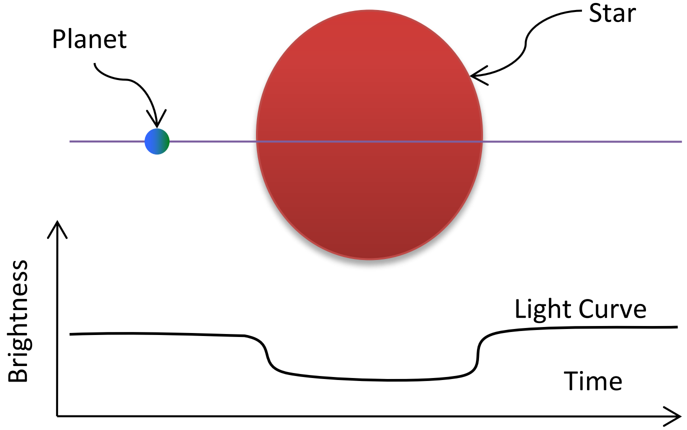


- Find extra-solar planets by
  - Wobbles in radial velocity of star, or
  - Dips in star's intensity

210k light-curves released in July 2010

Apply 3 algorithms to each curve

3 different parameter sets

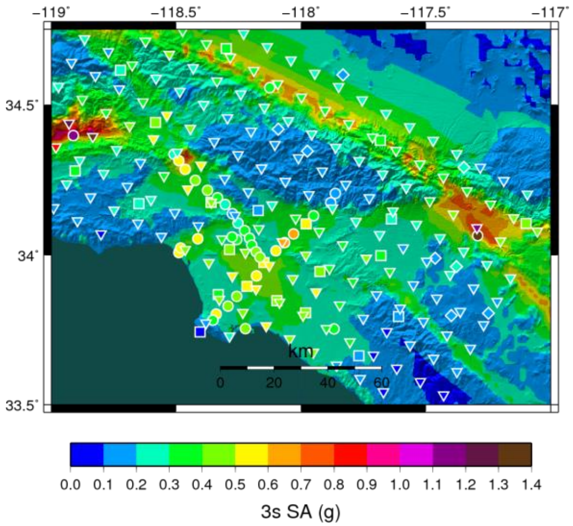


- 210K input, 630K output files
- 1 super-workflow
- 40 sub-workflows
- ~5,000 tasks per sub-workflow
- 210K tasks total

Pegasus managed workflows

Southern California Earthquake Center

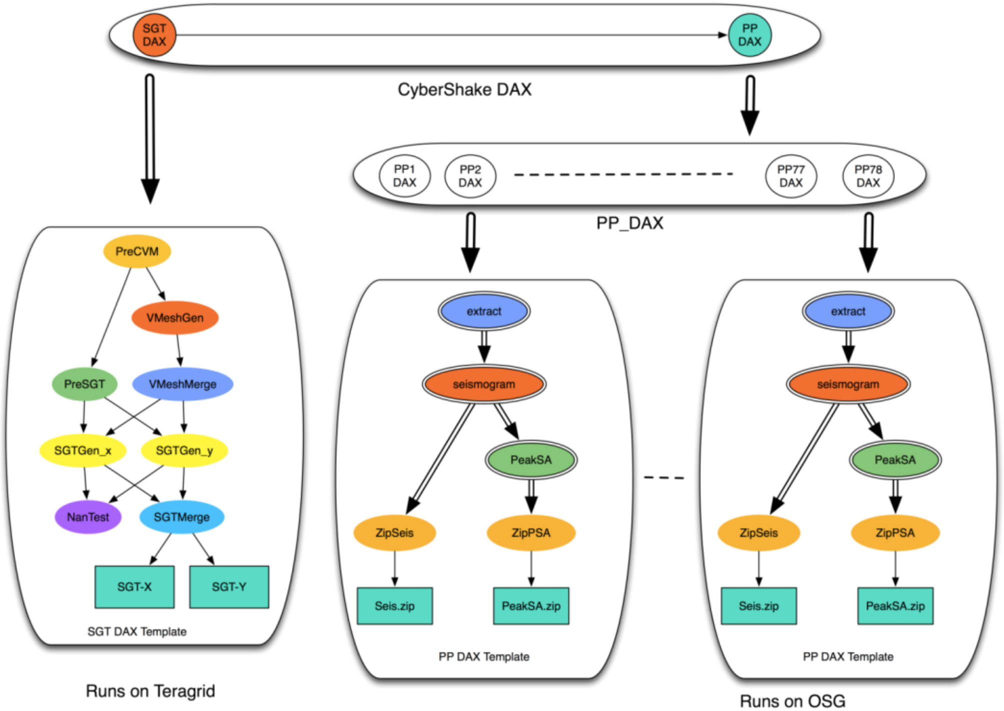
CyberShake PSHA Workflow



❖ **Description**

✧ Builders ask seismologists: "What will the peak ground motion be at my new building in the next 50 years?"

✧ Seismologists answer this question using Probabilistic Seismic Hazard Analysis (PSHA)



239 Workflows

- Each site in the input map corresponds to one workflow
- Each workflow has:

✧ **820,000 tasks**

MPI codes ~ 12,000 CPU hours,
Post Processing 2,000 CPU hours
Data footprint ~ 800GB

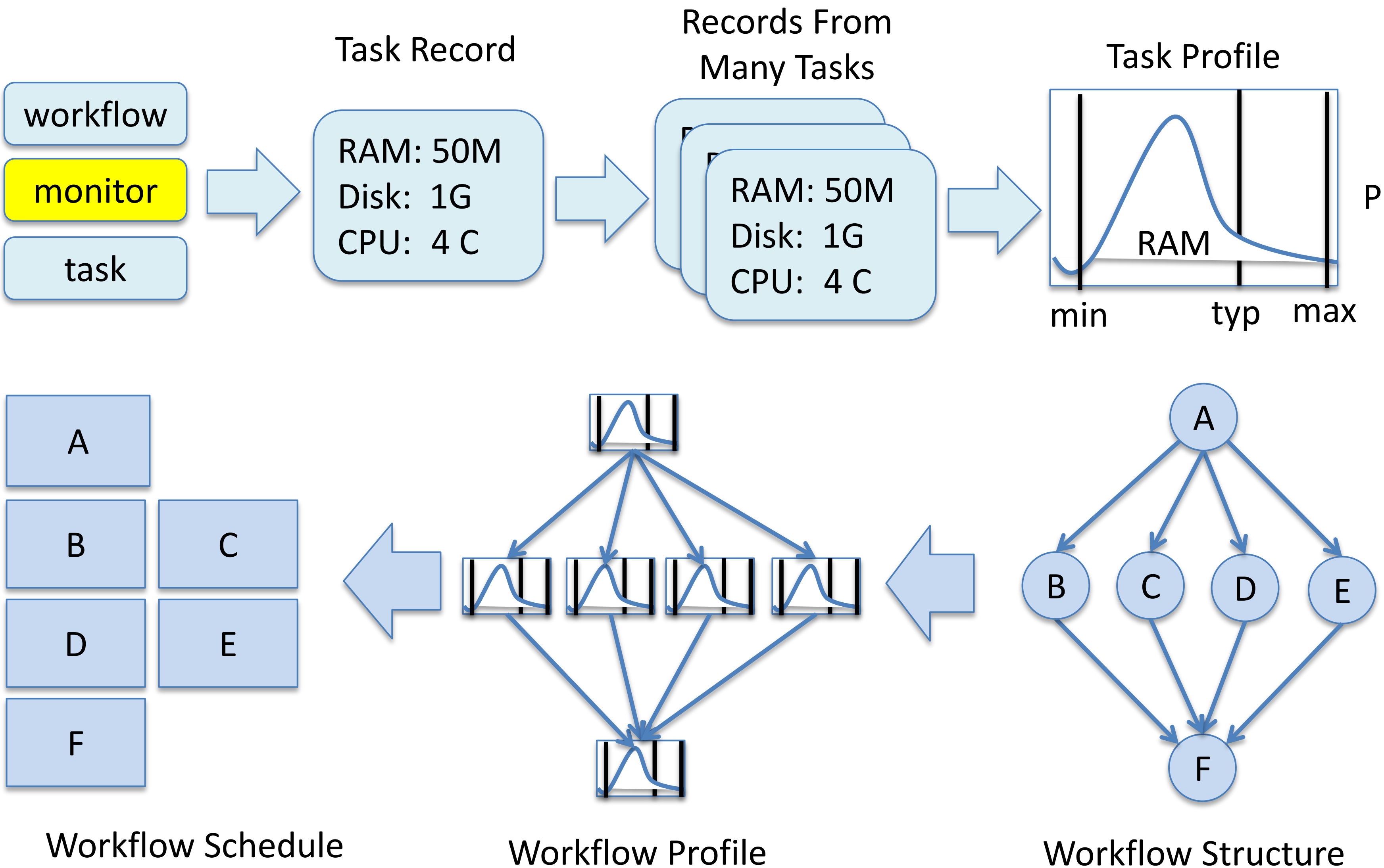
Pegasus managed workflows

Workflow Ensembles

Task Characterization/Execution

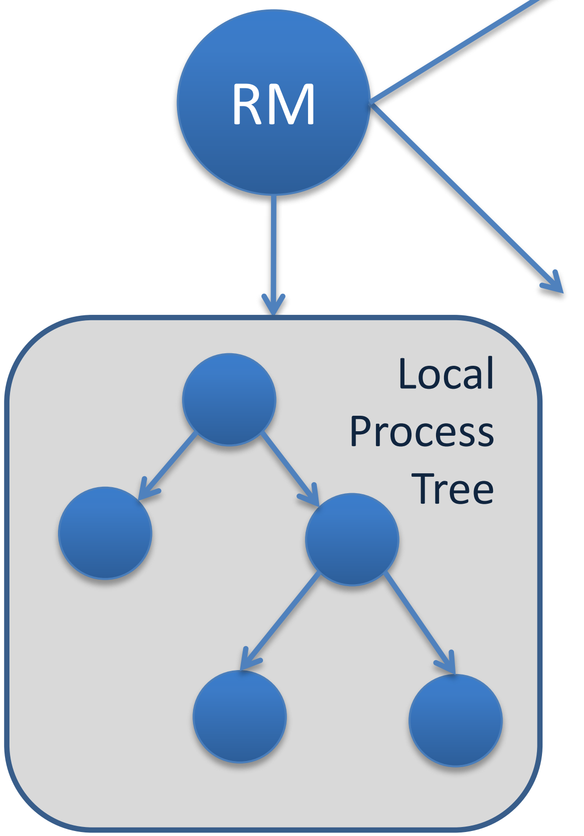
- Understand the resource needs of a task
- Establish expected values and limits for task resource consumption
- Launch tasks on the correct resources
- Monitor task execution and resource consumption, interrupt tasks that reach limits
- Possibly re-launch task on different resources

Data Collection and Modeling



Resource Monitor

% resource_monitor mysim.exe



Log File:

#wall_clock(useconds) concurrent_processes cpu_time(useconds
virtual_memory(kB) resident_memory(kB) swap_memory(kB)
bytes_read bytes_written

1	1	0	8700	376	0	385024	0
2	5	20000	326368	6100	0	27381007	1474560
3	6	20000	394412	7468	0	29735839	1503232
4	8	60000	531468	14092	0	36917793	1503232
5	8	100000	532612	16256	0	39285593	1503232

Summary File

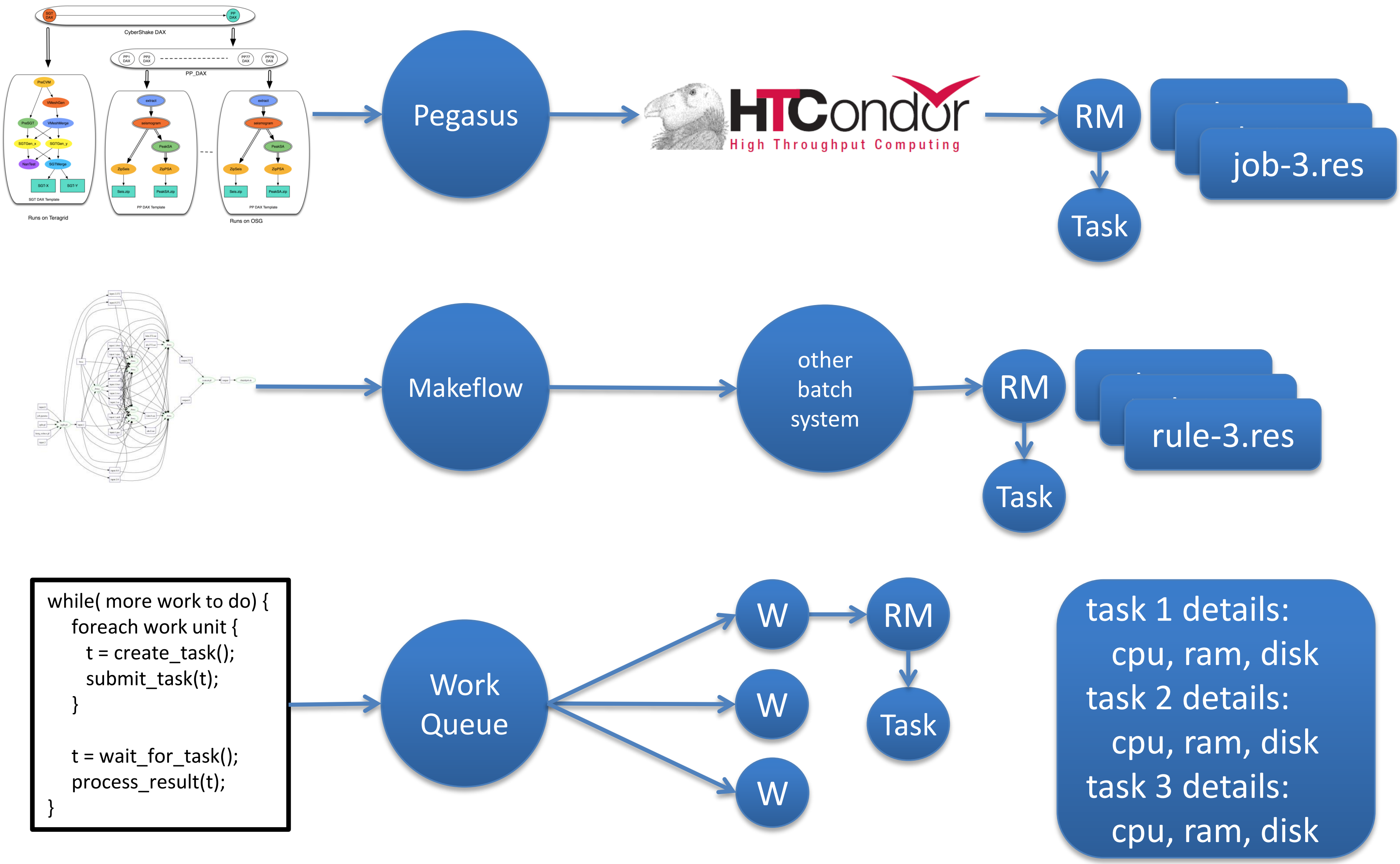
start:	1367424802.676755
end:	1367424881.236612
exit_type:	normal
exit_status:	0
max_concurrent_processes:	16
wall_time:	78.559857
cpu_time:	54.181762
virtual_memory:	1051160
resident_memory:	117604
swap_memory:	0
bytes_read:	4847233552
bytes_written:	256950272

Monitoring Strategies

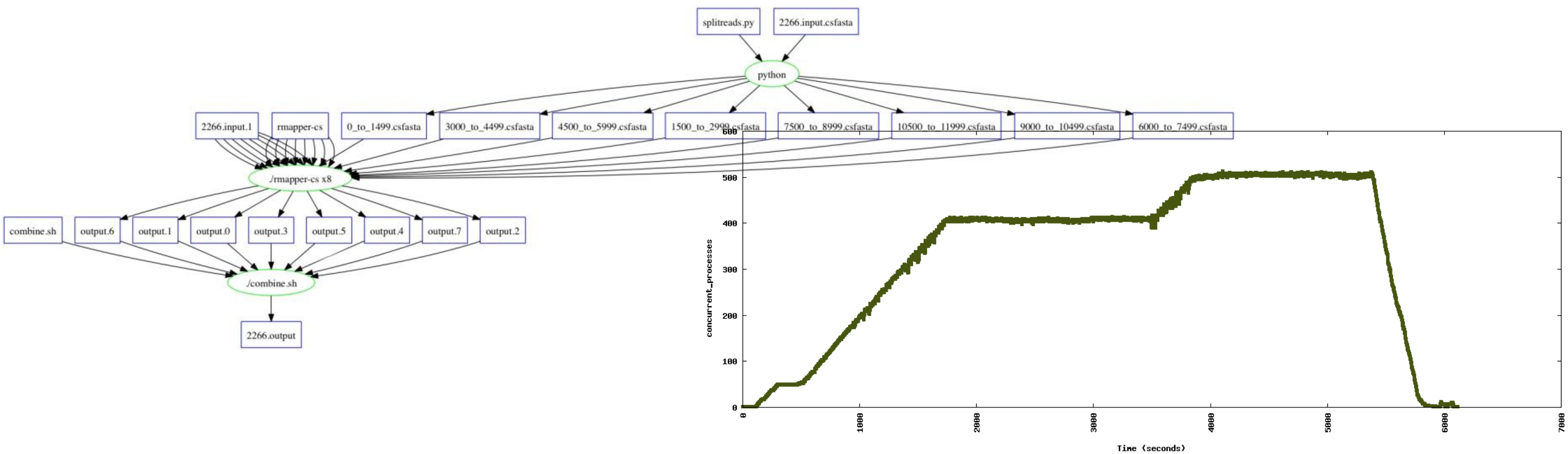
Indirect	Direct
Monitor how the world changes while the process tree is alive.	Monitor what functions, and with which arguments the process tree is calling.

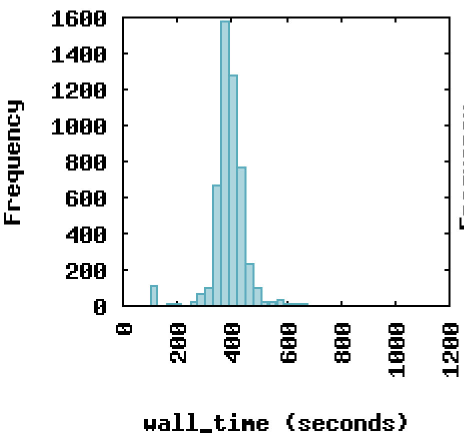
Summaries	Snapshot	Events
getrusage and times	Reading /proc and measuring disk at given intervals.	Linker wrapper to libc
Available only at the end of a process.	Blind while waiting for next interval.	Fragile to modifications of the environment, no statically linked processes.

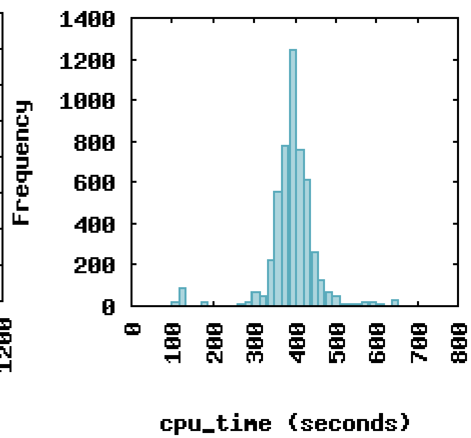
Portable Resource Management

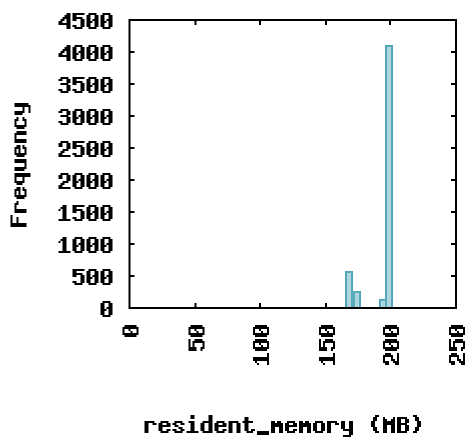


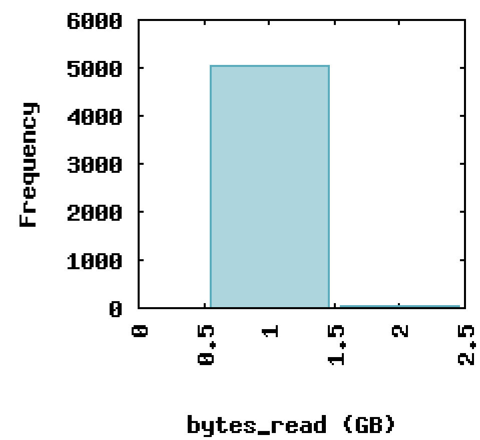
Resource Visualization of SHRiMP



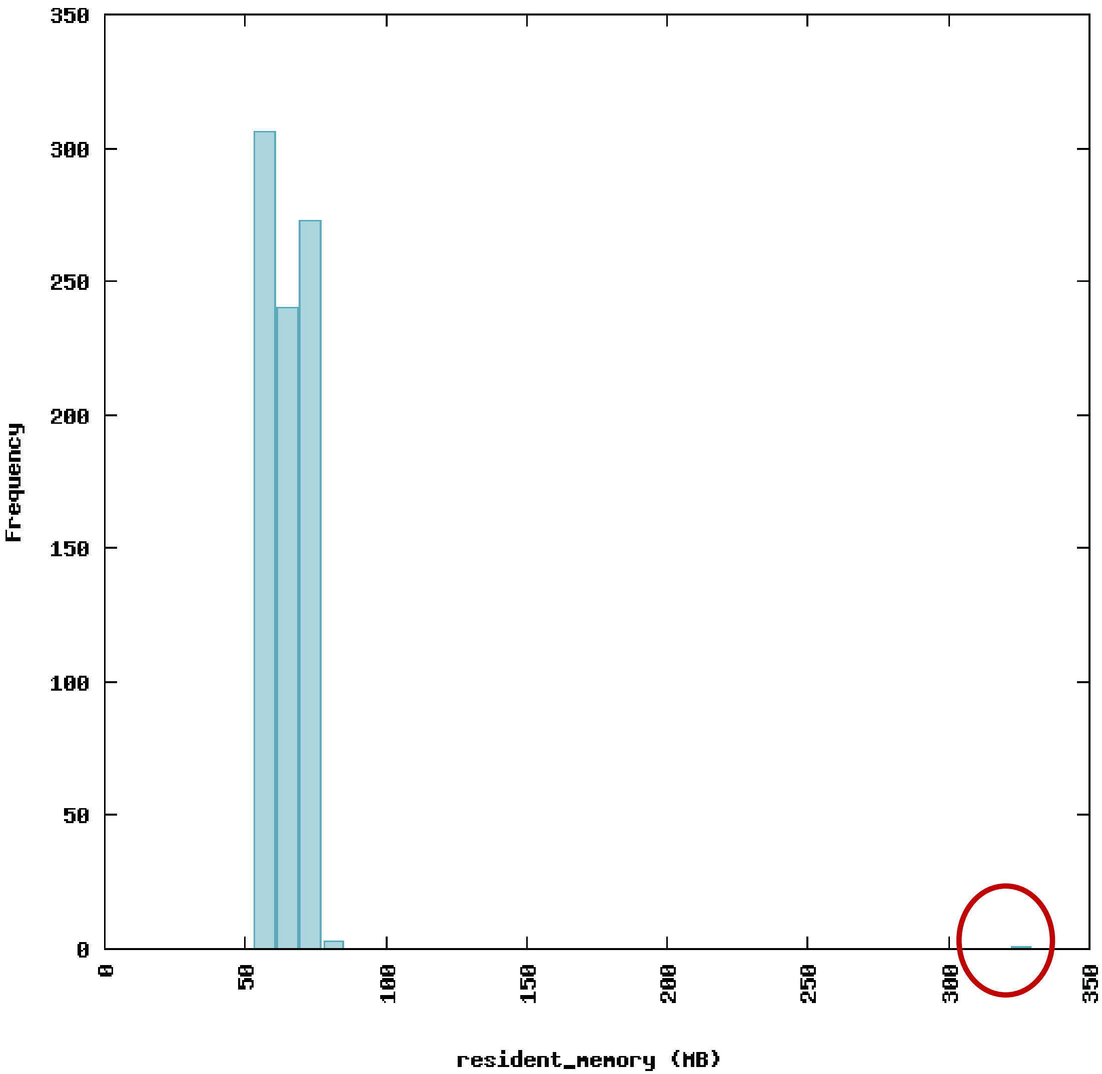


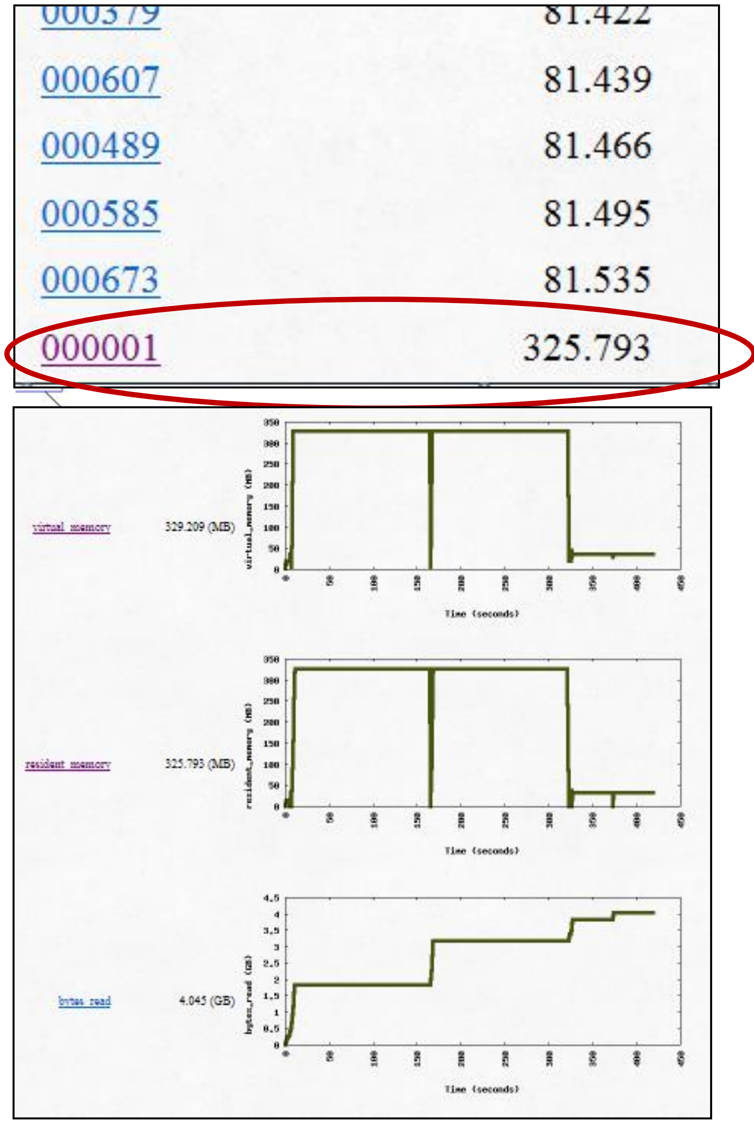




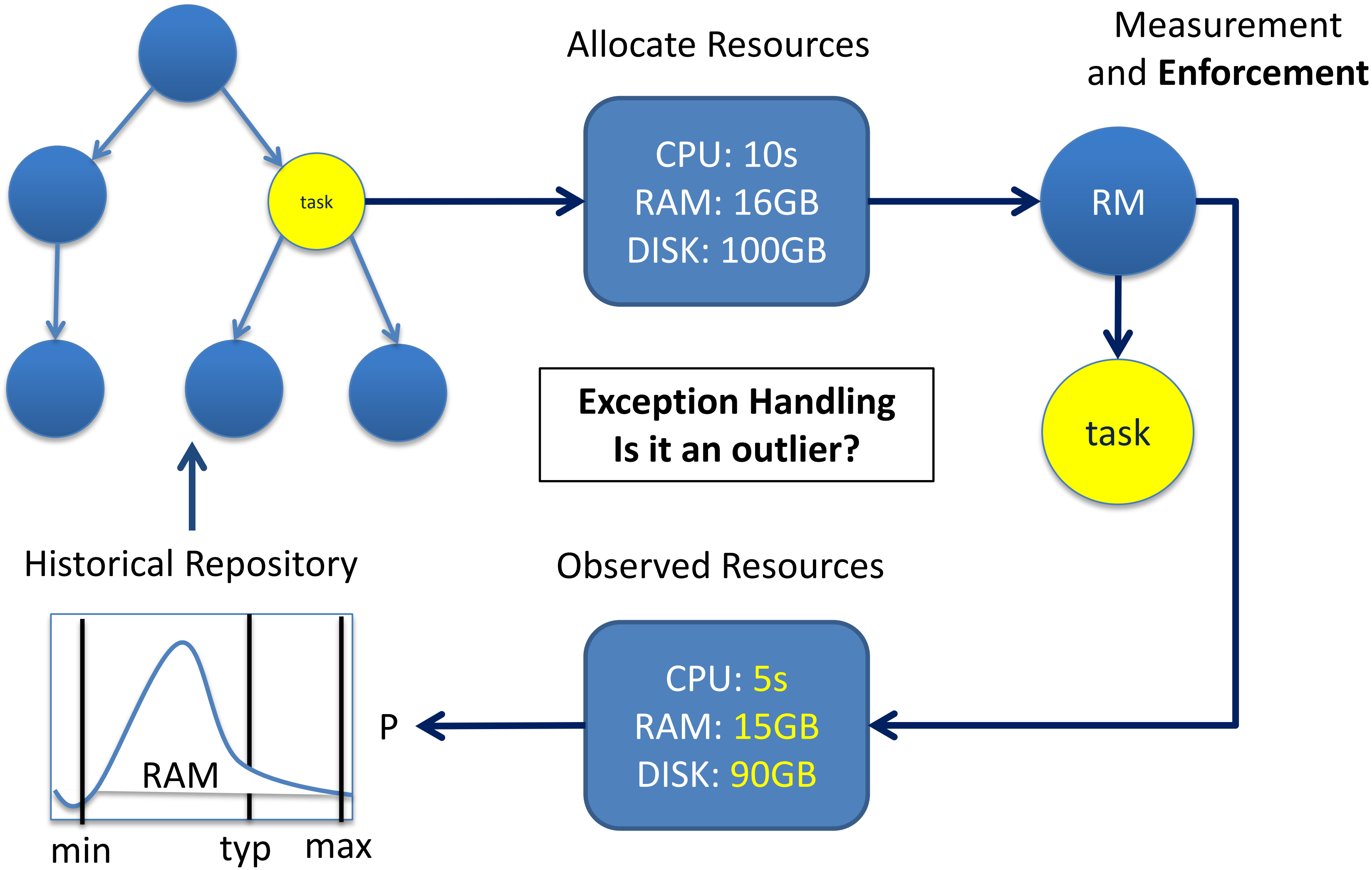


Outliers Happen: BWA Example

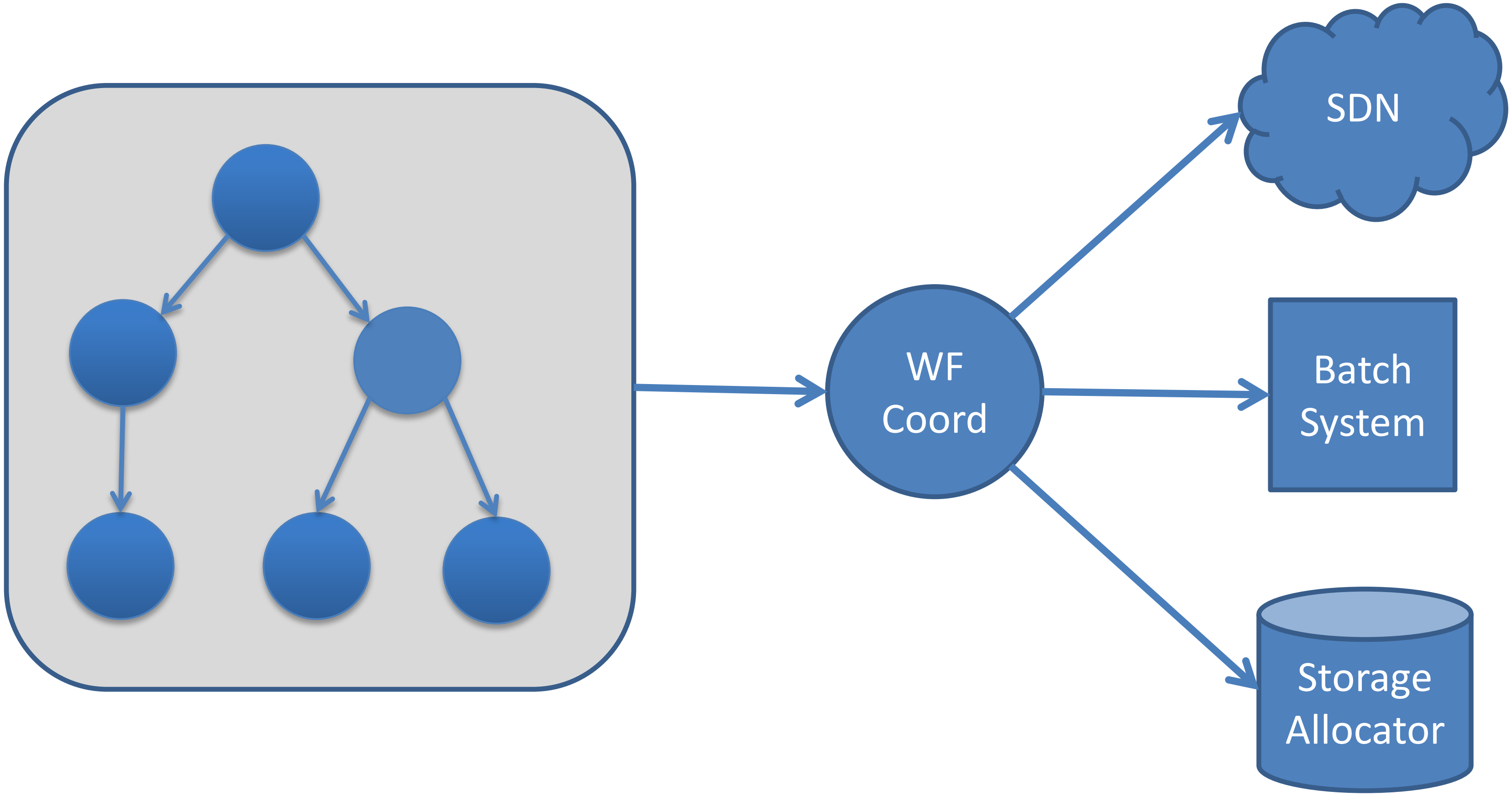




Completing the Cycle



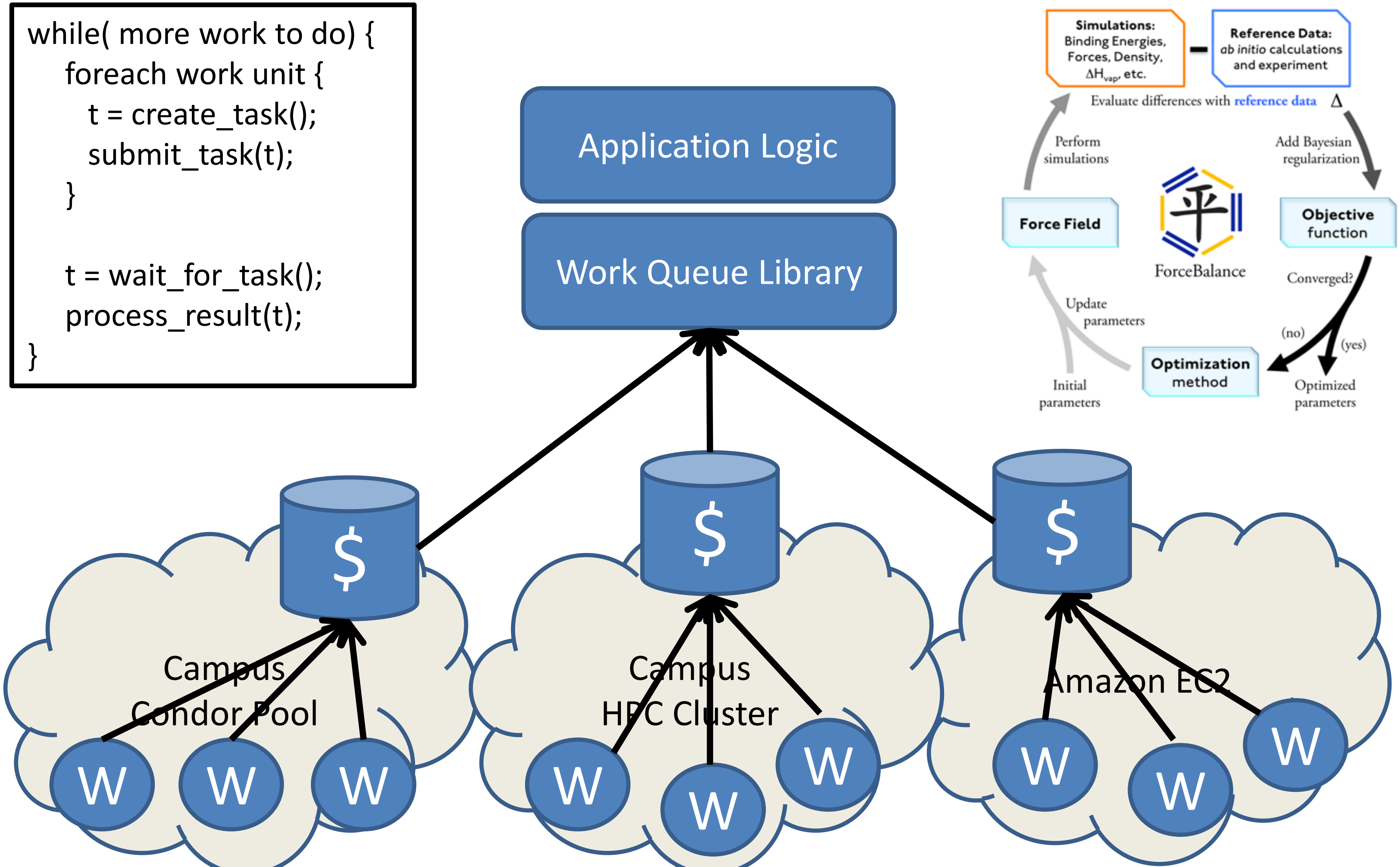
Multi-Party Resource Management



Application to Work Queue

```
while( more work to do) {
    foreach work unit {
      t = create_task();
      submit_task(t);
    }

    t = wait_for_task();
    process_result(t);
}
```



Coming up soon in CCTools…

- Makeflow
  - Integration with resource management.
  - Built-in linker pulls in deps to make a portable package.
- Work Queue
  - Hierarchy, multi-slot workers, cluster caching.
  - Automatic scaling of workers with network capacity.
- Parrot
  - Integration with CVMFS for CMS and (almost?) ATLAS.
  - Continuous improvement of syscall support.
- Chirp
  - Support for HDFS as a storage backend.
  - Neat feature: search() system call.

Acknowledgements

dV/dT Project PIs

- Bill Allcock (ALCF)
- Ewa Deelman (USC)
- Miron Livny (UW)
- Frank Weurthwein (UCSD)

CCL Staff

- **Ben Tovar**

CCL Graduate Students:

- Michael Albrecht
- Patrick Donnelly
- Dinesh Rajan
- **Casey Robinson**
- Peter Sempolinski
- Li Yu

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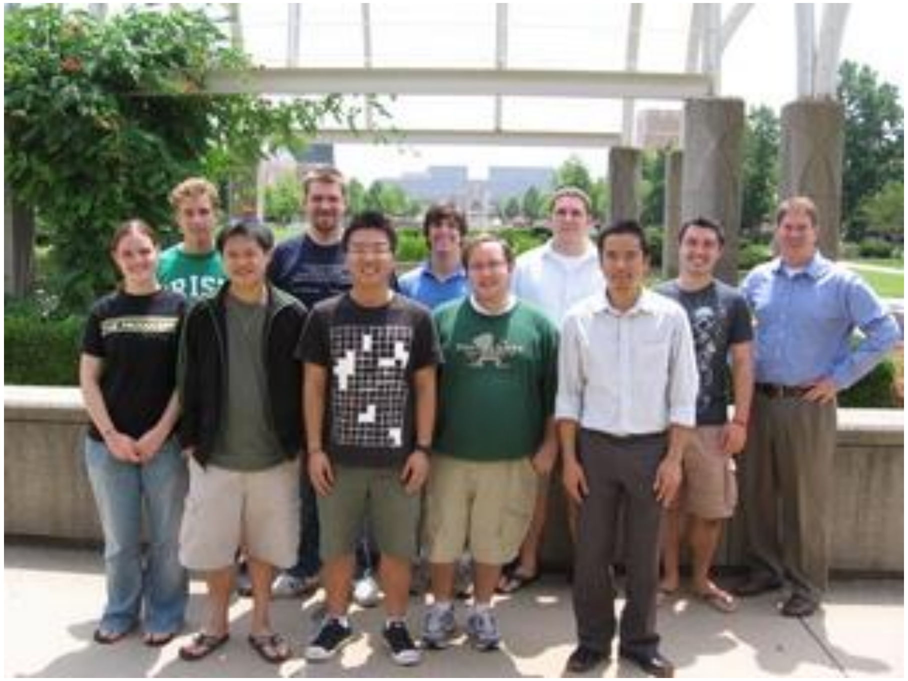

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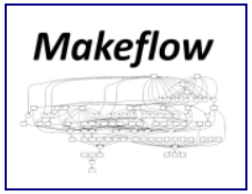

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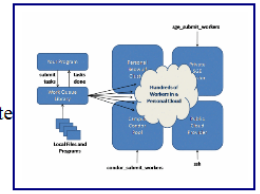

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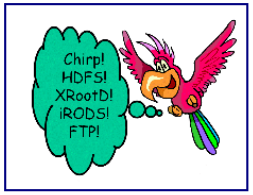

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