Lobster: Scaling Opportunistic CMS Workflows to 10k cores

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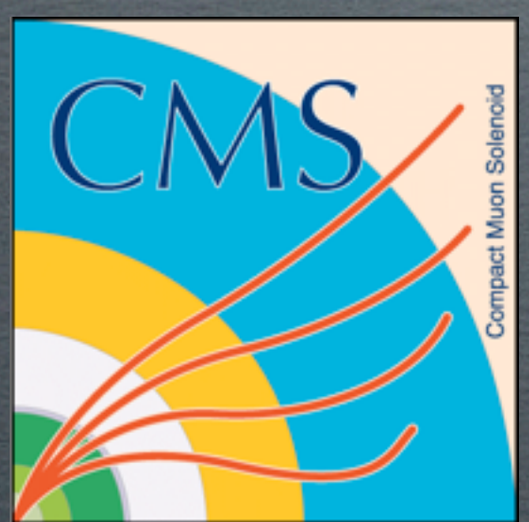
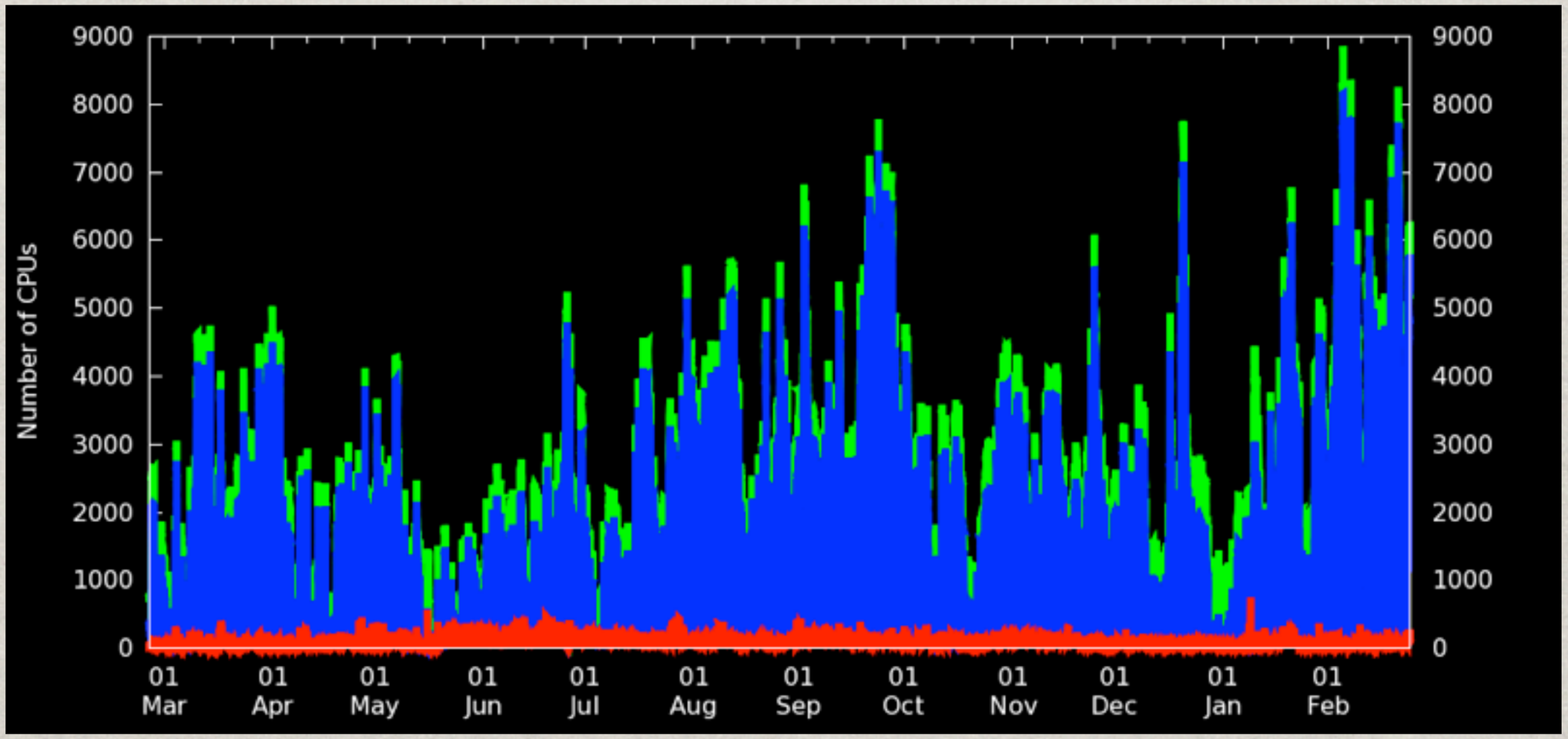


What is Lobster?

- **L**arge-scale **O**pportunistic **B**atch **S**ubmission **T**oolkit for **E**xploiting **R**esources
- Workflow submission and management tool written from scratch by two ND grad students (Matthias Wolf and Anna Woodard)
- Borrows ideas from CRAB2/3 and grid-control
- Based on CCTools suite (WorkQueue, Parrot, Chirp) from ND team led by Doug Thain
- Primary goal: Get access to ND's opportunistic computing resources

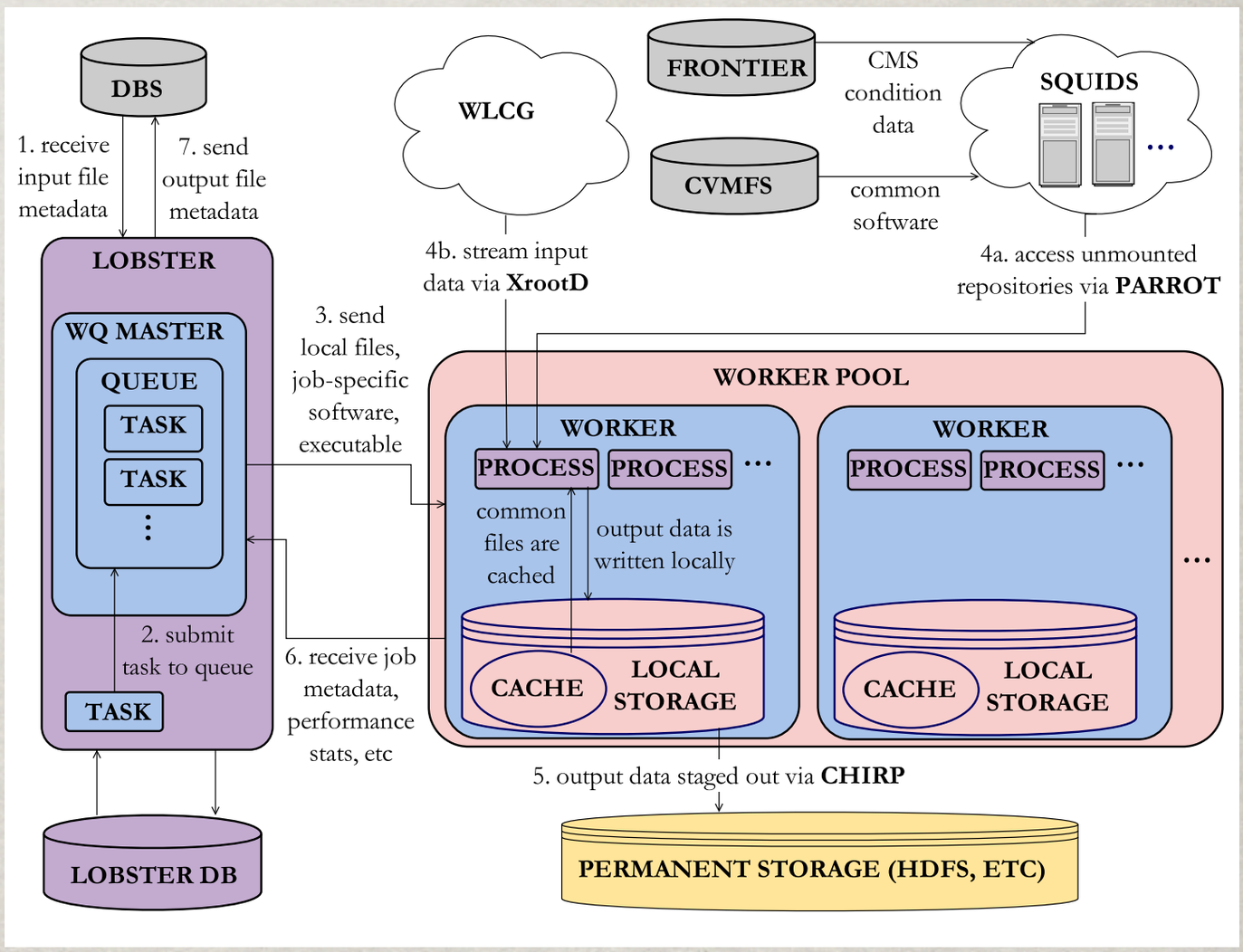
ND CRC Resources

- ND Center for Research Computing houses ~21k CPU cores and 2.5 PB of storage
  - Most resources belong to individual PIs
  - Available for opportunistic usage when idle (evicted when owners reclaim resources)



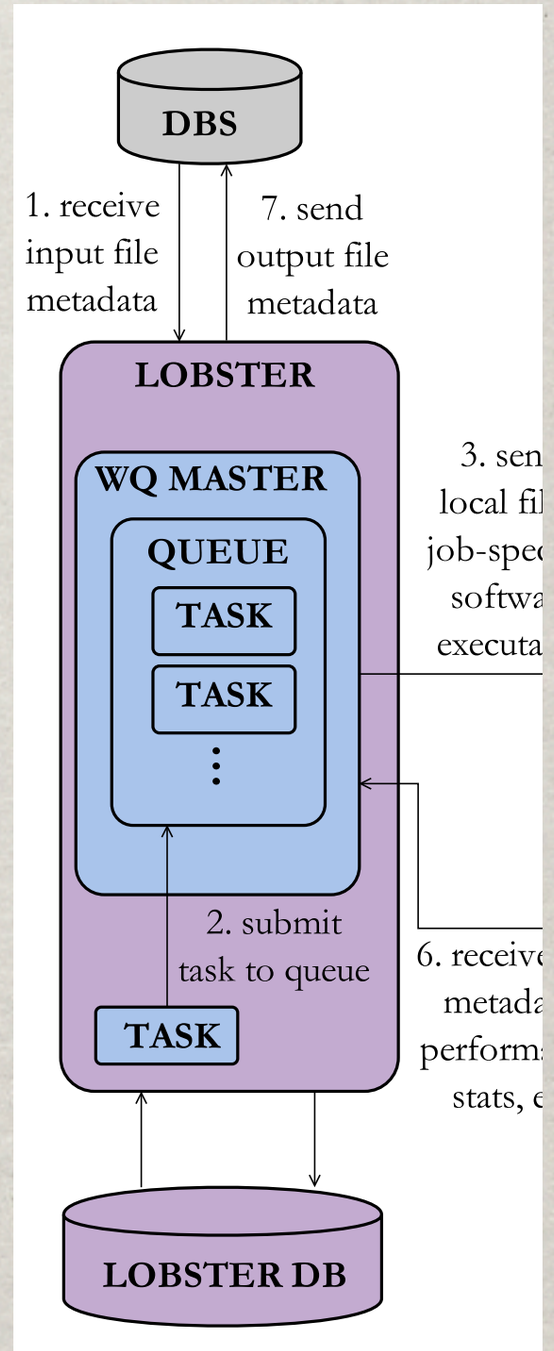
Lobster Architecture

- Main components
  - Scheduling: schedules and dispatches jobs
  - Data: managing input/output data and software
  - Execution: runs tasks on opportunistic resources
- Master-worker architecture

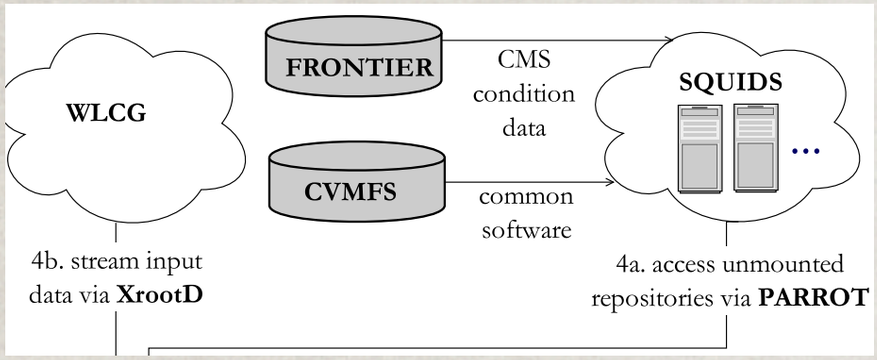


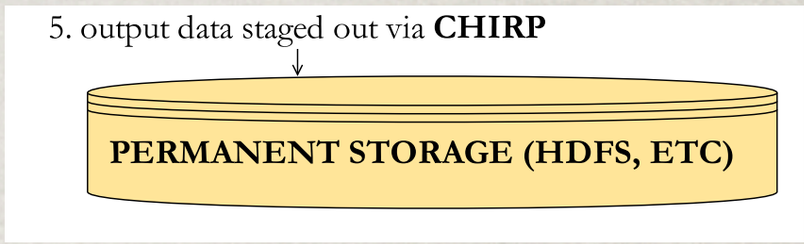
Scheduling

- Lobster master uses DBS to build database of work to be done
  - Work broken down into smallest sensible quantum: jobit
  - Lobster master schedules assigns jobits to tasks and schedules in Work Queue (WQ)
- WQ master handles distributing tasks to workers and tracks task progress
  - Optionally, system may include "foremen" to mediate between WQ master and workers
- Lobster communicates with WQ master to track jobit completion



Data

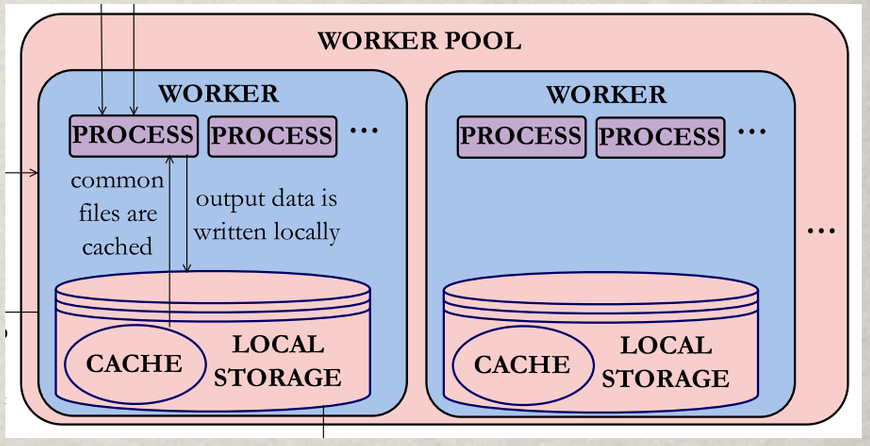




- Leverage wide variety of tools (CVMFS, Parrot, Chirp, XrootD, WQ) to distribute data to jobs
  - CMSSW distributed to workers via CVMFS+Parrot (squid cache, worker cache)
  - Job scripts and sandbox transferred via WQ (worker cache)
  - Conditions via Frontier (squid cache)
  - Input data delivered via AAA (XrootD) or ND T3 storage (XrootD or Chirp)
  - Outputs transferred via Chirp

Execution: Workers

- Can be submitted via whatever batch system is available (HTCondor, SGE, PBS, etc.)
  - CCTools includes tools for managing worker pools
- Responsible for configuring resource to accept CMS tasks (setup CMSSW, etc.)
- Holds resources and runs tasks for master until work is finished or worker is evicted
- Multicore workers will run multiple tasks in parallel, sharing local cache for CVMFS and WQ files



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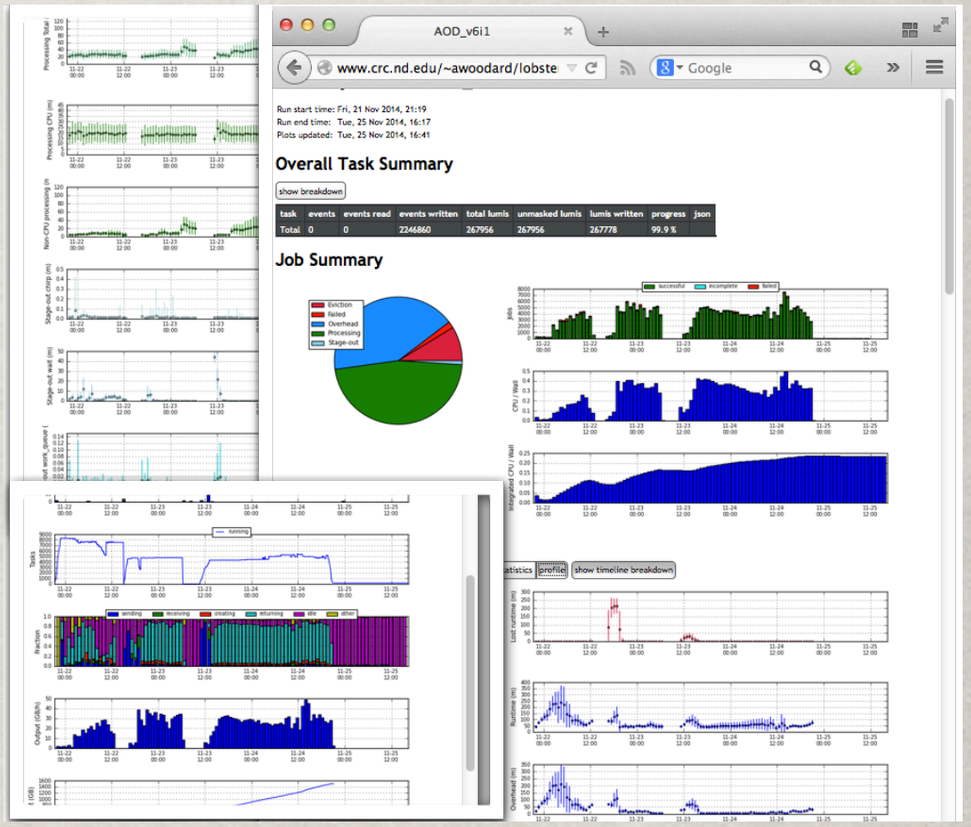
Monitoring

- Opportunistic resources change dynamically (chaotically)
  - Resources come and go depending on owner activity
  - Heterogeneous quality
  - Can fail randomly
- Monitoring critical to Lobster success
  - Lobster tracks time stamps of every phase of task setup and execution
  - Collects information in plots and tables on webpage
  - Gives comprehensive picture of system components so that bottlenecks and failures can be diagnosed and overcome

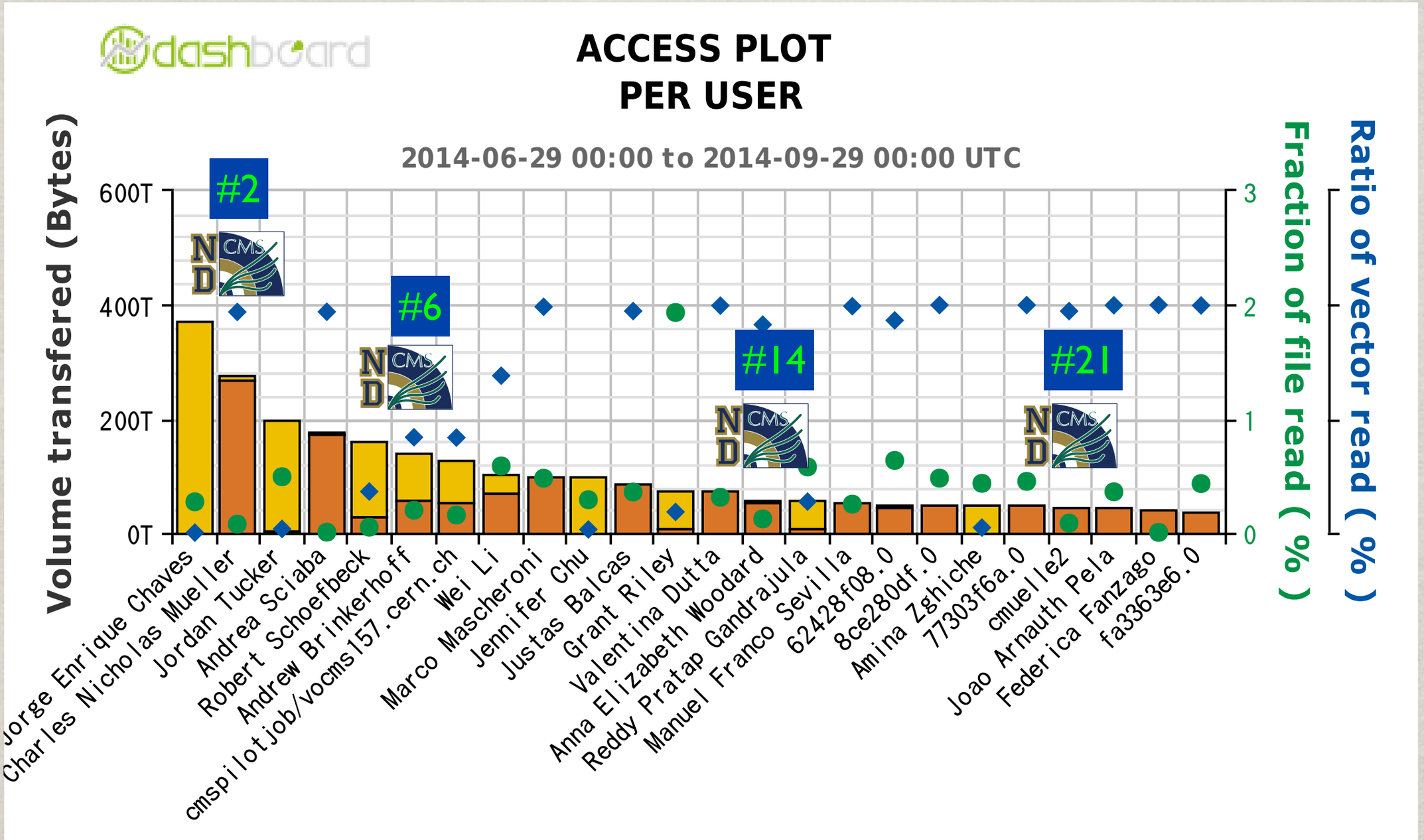


Design Motivations

- Maximize opportunistic spirit!
- CCTools suite operates completely in user space: no admin intervention required to use opportunistic resources
- Eviction requires agility: Decouple job size from output size and user task management
  - Lobster works in jobits, tracks splitting, handles resubmission without user intervention
    - Often leads to really small output files--merged automatically
    - When processing multiple datasets, jobit execution randomized to level load on AAA
  - Persistence pays off
    - Workers try very hard to get tasks started: Use local CVMFS if present, switch to Parrot if not, etc.
    - Lobster retries failed tasks until you stop it: needs to be resilient against transient failure in opportunistic system
    - Work Queue Pool: if workers die/lost, resubmit more

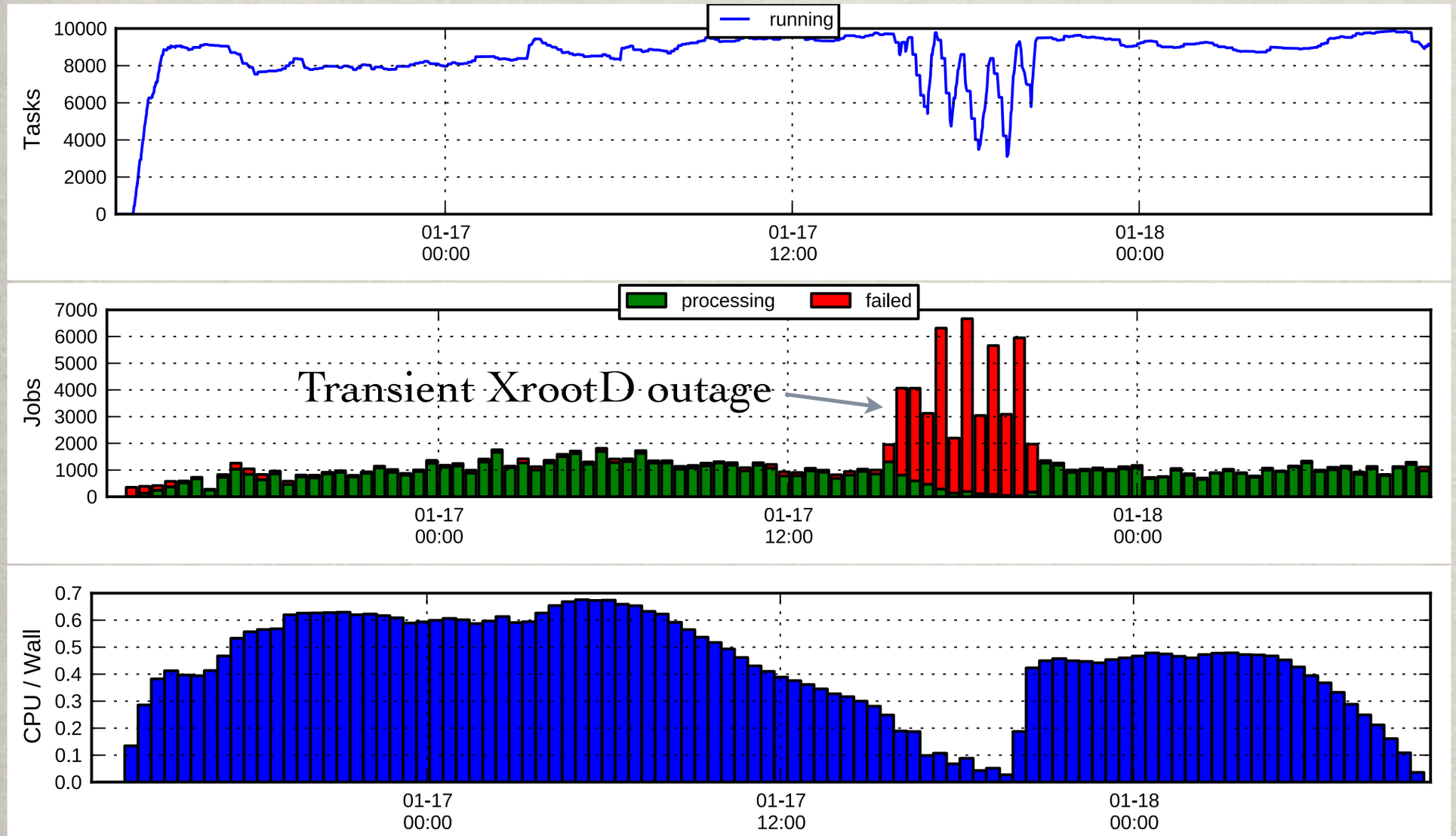
Processing Lots of Data

- ND users running only on ND resources competitive with CSA14 activity



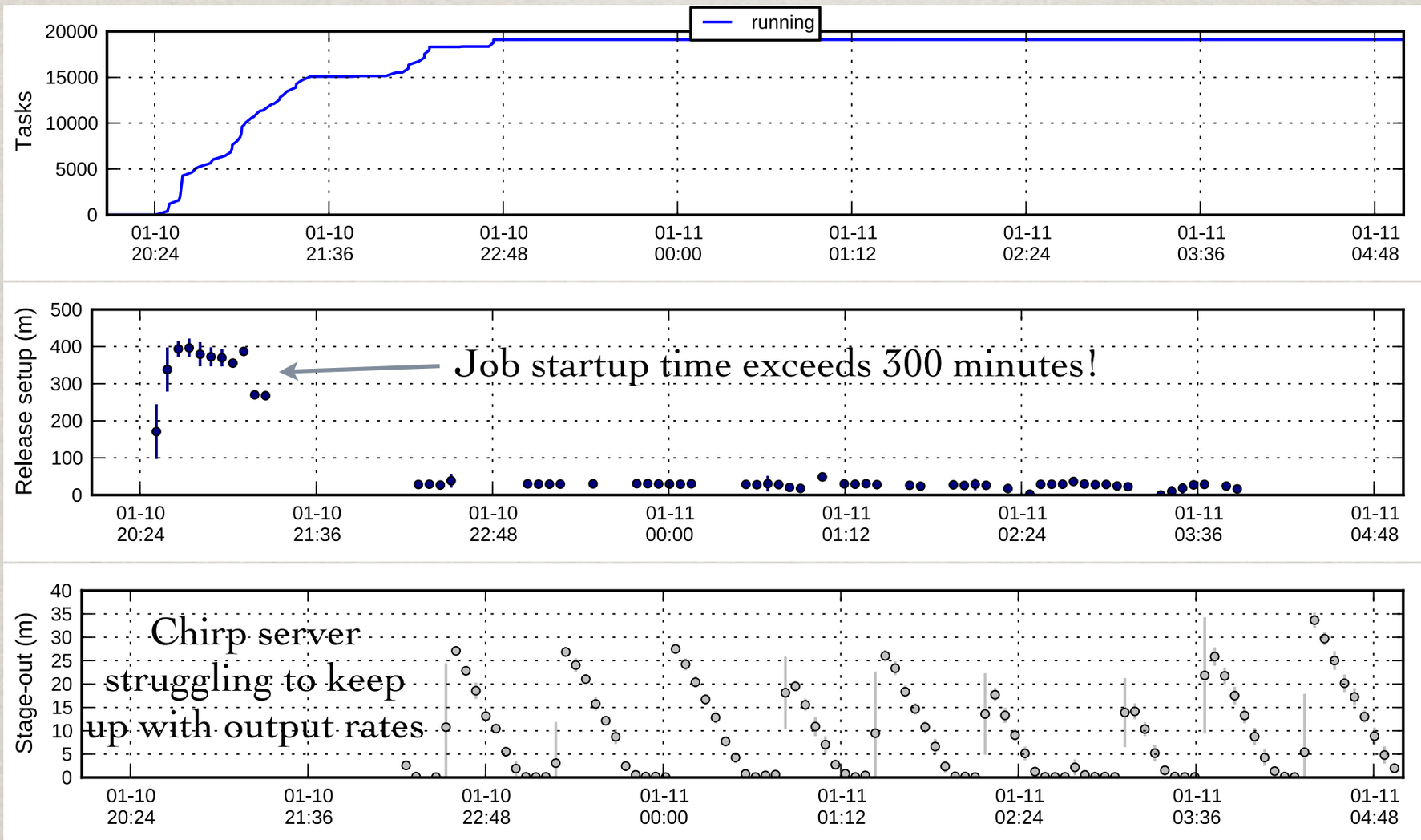
Reaching ~10k running jobs

- This is ~10% of size of CMS global pool
- Comparable to scale of one US CMS T2 site
- More than total of all US CMS dedicated T3 resources



Challenges

- Bottlenecks when running at large scales
  - Job overhead time increases non-linearly: bottleneck in squid cache?
  - Output Chirp server can get overloaded and fail



Near Term Future

- Resolve bottlenecks preventing scaling to 20k cores
  - Also important for decreasing overhead to minimize eviction losses
- Explore possibilities for Lobster to dynamically adapt to running conditions
  - E.g. Automatically adjust jobits/task to optimize for current running conditions (eviction)
- Improvements in reliability and robustness
  - E.g. Run Chirp server as service instead of user process to keep users from overwhelming login node with Chirp processes

Conclusions

- Lobster has enabled ND team to exploit opportunistic campus resources to 10k core scale
- Successful collaboration between physics and CS teams
  - Learned a number of useful things
  - Motivated improvements to CCTools suite
- Potential for lessons learned and innovations to be translated more widely to CMS
  - Anna and Matthias now working as CRAB3 developers
  - See Brian's talk for longer term vison