Comparison of Scheduling Policies and Workloads on the NCCS and NICS XT4 Systems at Oak Ridge National Laboratory

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Introduction

- **Oak Ridge National Laboratory is home to two supercomputing centers:**
  - **National Center for Computational Sciences**
    - **Founded in 1992.**
    - **DoE Leadership Computing Facility**
  - **National Institute for Computational Science**
    - **Joint project between ORNL and University of Tennessee, founded in 2007.**
    - **NSF Petascale Track 2B awardee**
- **Both centers have Cray XT4 systems**
  - **Jaguar (NCCS)**
  - **Kraken (NICS)**
- **Both systems have the goal of running as many big jobs as possible**

System Hardware and Software

Jaguar

- **84 cabinets**
- **7,832 compute nodes (31,328 cores)**
- **Quad-core Opteron @ 2.1 GHz**
- **61.19 TB of RAM**
- **700 TB of disk**
- **CLE 2.0**

Kraken

- **40 cabinets**
- **4,508 compute nodes (18,032 cores)**
- **Quad-core Opterons @ 2.3 GHz**
- **17.61 TB of RAM**
- **450 TB of disk**
- **CLE 2.0**

Batch Environment

- **Both Jaguar and Kraken use TORQUE as their batch system, with Moab as the scheduler.**
- **Moab has a number of advanced features, including a "native resource manager" interface for connecting to e.g. ALPS.**
- **While the software is the same on the two systems, there are significant differences in how it is configured on the two systems.**

Jaguar Queue Structure

- **`dataxfer`**
  - **Size = 0**
  - **Max time = 24 hrs.**
- **`batch`**
  - **Max time = 24 hrs.**
- **`debug`**
  - **Max time = 4 hrs.**
- **Additional walltime limits for smaller jobs (size<1024) imposed by TORQUE submit filter**

Kraken Queue Structure

- **`dataxfer`**
  - **Size = 0**
  - **Max time = 24 hrs.**
- **`small`**
  - **0 >= size >= 512**
  - **Max time = 12 hrs.**
- **`longsmall`**
  - **0 <= size <= 512**
  - **Max time = 60 hrs.**
- **`medium`**
  - **512 < size <= 2048**
  - **Max time = 24 hrs.**
- **`large`**
  - **2048 < size <= 8192**
  - **Max time = 24 hrs.**
- **`capability`**
  - **8192 < size <=18032**
  - **Max time = 48 hrs.**

Job Prioritization

Jaguar

- **Priority thought of in units of "days", equivalent to one day of queue wait time**
- **Components:**
  - **QoS, assigned based mainly on job size**
  - **Queue wait time**
  - **Fair share targets assigned to QoS**

Kraken

- **Priority units are arbitrary**
- **Components:**
  - **Job size**
  - **Queue wait time**
  - **Expansion factor (ratio of queue time plus run time to run time)**

Quality of Service Levels on Jaguar

- **sizezero**
  - size = 0
  - +90 days priority.
  - Max 10 jobs/user.
- **smallmaxrun**
  - 0 < size <= 256
  - 20% fair share target.
  - Max 2 jobs/user.
- **nonldrship**
  - 256 < size <= 6000
  - 20% fair share target.
- **ldrship**
  - 6000 < size <= 17000
  - +8 days priority.
  - 80% fair share target.
- **topprio**
  - size > 17000
  - +10 days priority.
  - 80% fair share target.

Quality of Service Levels on Kraken

- **`sizezero`**
  - **size=0**
  - **Queue time target of 00:00:01.**
  - **Priority grows exponentially after queue time target is passed.**
- **`negbal`**
  - **Applied to jobs from projects with negative balances.**
  - **-100000 priority.**
  - **Additional penalties (e.g. disabling backfill or a small fair share target) have been discussed as well.**

Other Scheduling Policies on Kraken

- **`longsmall` jobs limited to 1,600 cores total.**
- **Only 1 capability is eligible to run at any given time.**

Allocation Processes

Jaguar

- **DoE INCITE**
- **Made annually**
- **Allocations can last multiple years**
- **Applications must be able to use a "significant fraction" of LCF systems at ORNL and/or ANL**

Kraken

- **NSF/Teragrid TRAC**
- **Made quarterly**
- **Allocations last one year (i.e. "use it or lose it")**
- **No major requirement on application scalability**

Workload Analysis

- **TORQUE accounting records parsed and loaded into a database.**
- **Job scripts also captured and stored in DB.**
  - **On Kraken, this happens automatically.**
  - **On Jaguar, the `aprun` parts of scripts are reconstructed using another database.**
- **Period of interest is the 4th quarter of 2008.**
  - **Both XT4 machines in production and allocated.**
  - **XT5 successor systems not yet generally available.**
- **To be able to compare apples to apples, size breakdowns are normalized by the size of each machine.**

Overall Utilization for 4Q2008

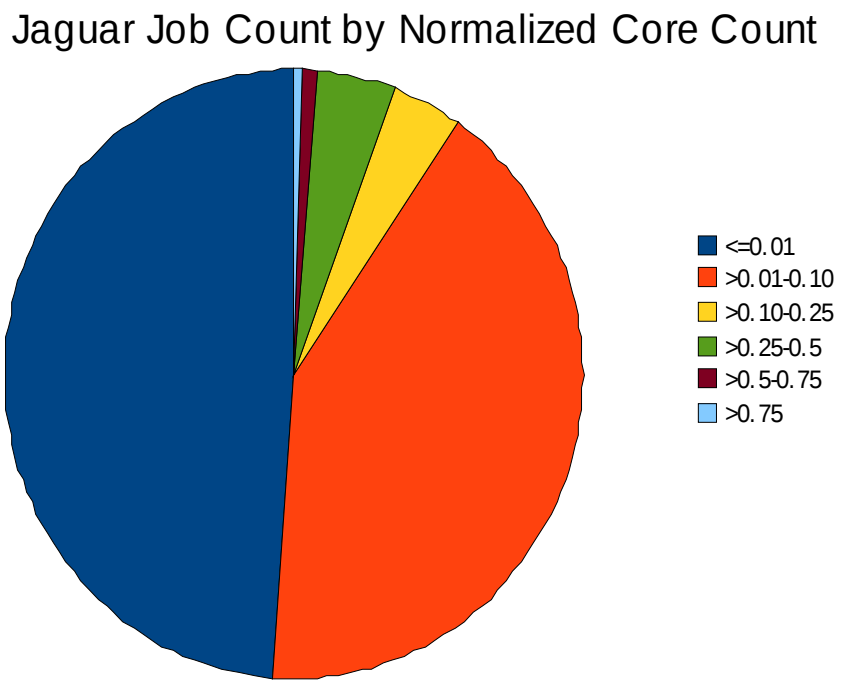
Jaguar

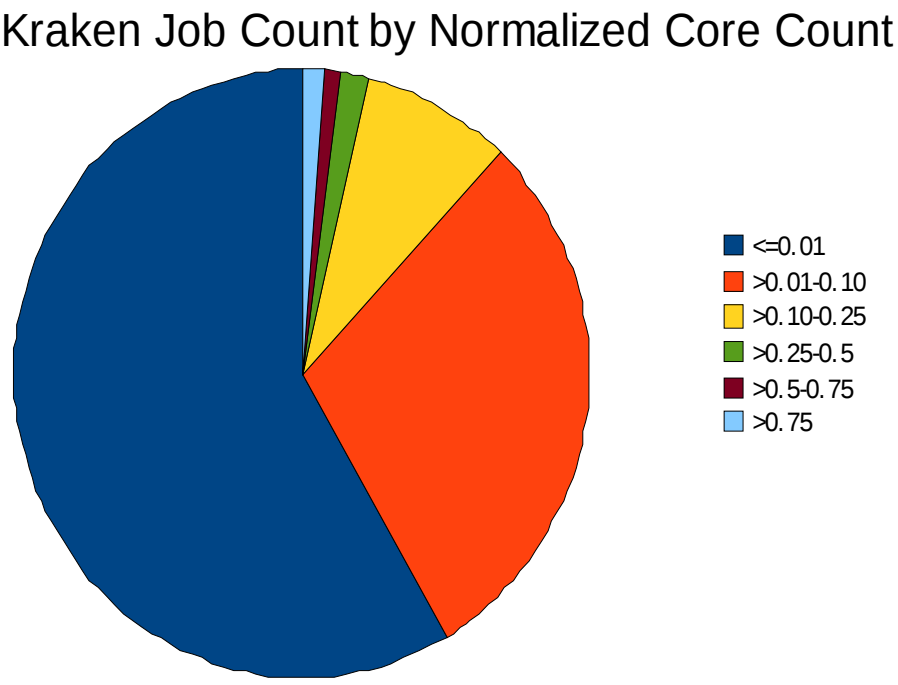
- **46,023 jobs run.**
- **54.46 million CPU-hours consumed.**
- **89.7% average utilization.**
- **300 active users.**
- **142 active projects.**

Kraken

- **15,744 jobs run.**
- **21.00 million CPU-hours consumed.**
- **57.0% average utilization.**
- **116 active users.**
- **40 active projects.**

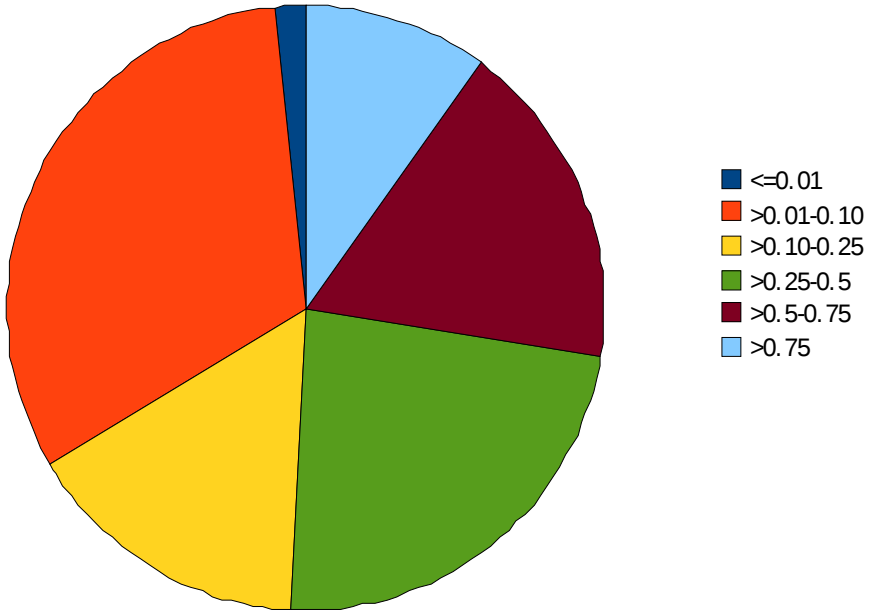
Breakdown by Job Size -- Count



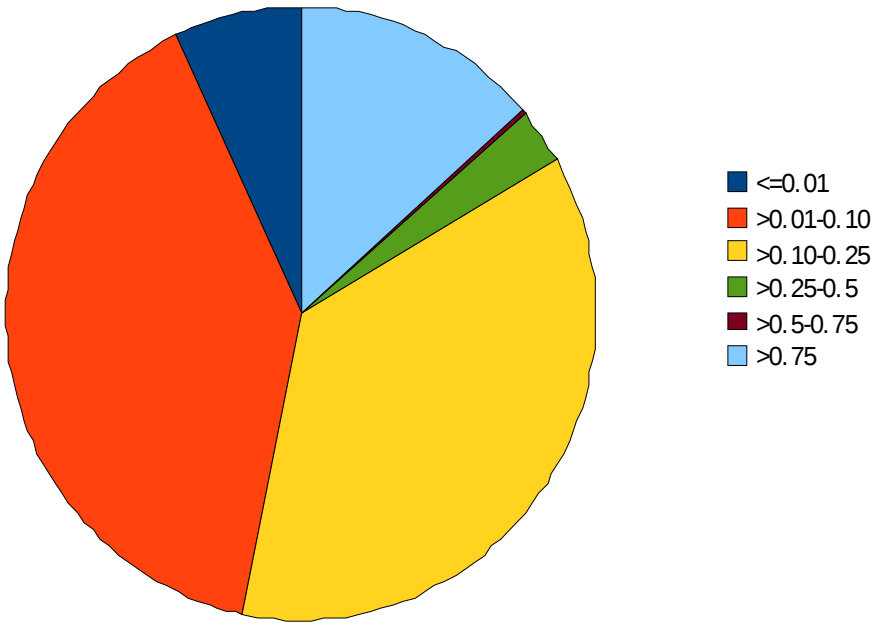


Breakdown by Job Size – CPU Hours

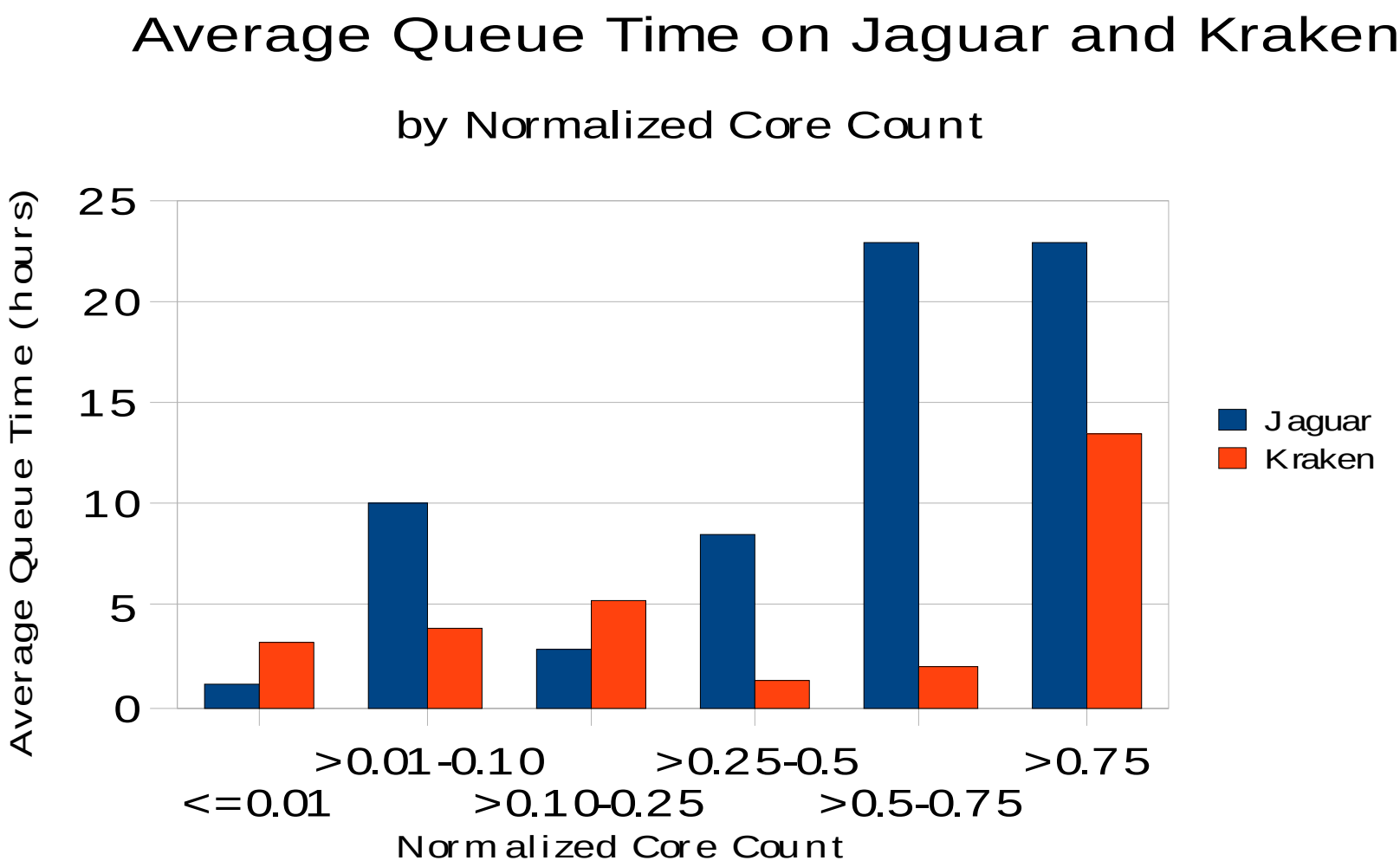
Jaguar CPU Hours by Normalized Core Count



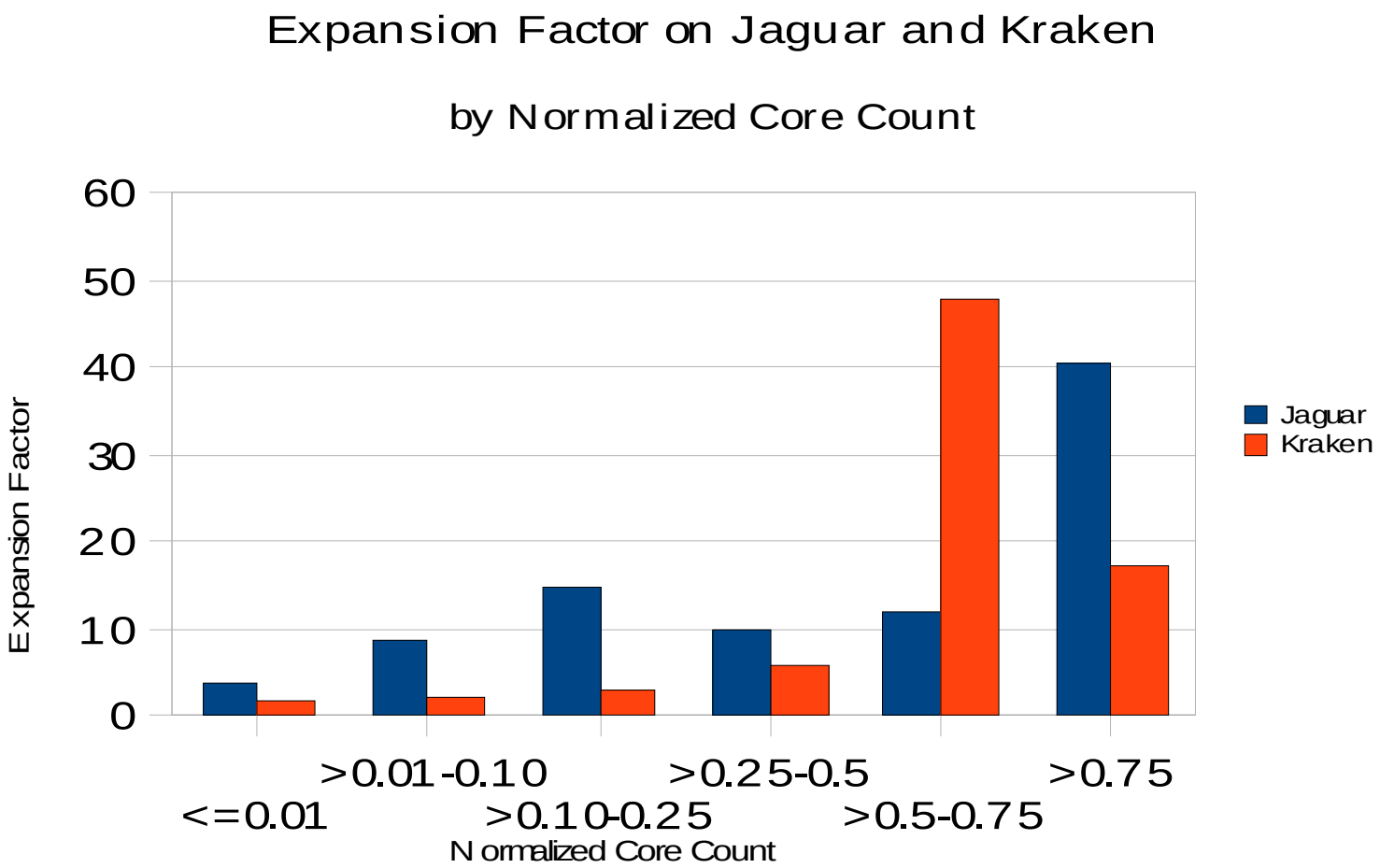
Kraken CPU Hours by Normalized Core Count



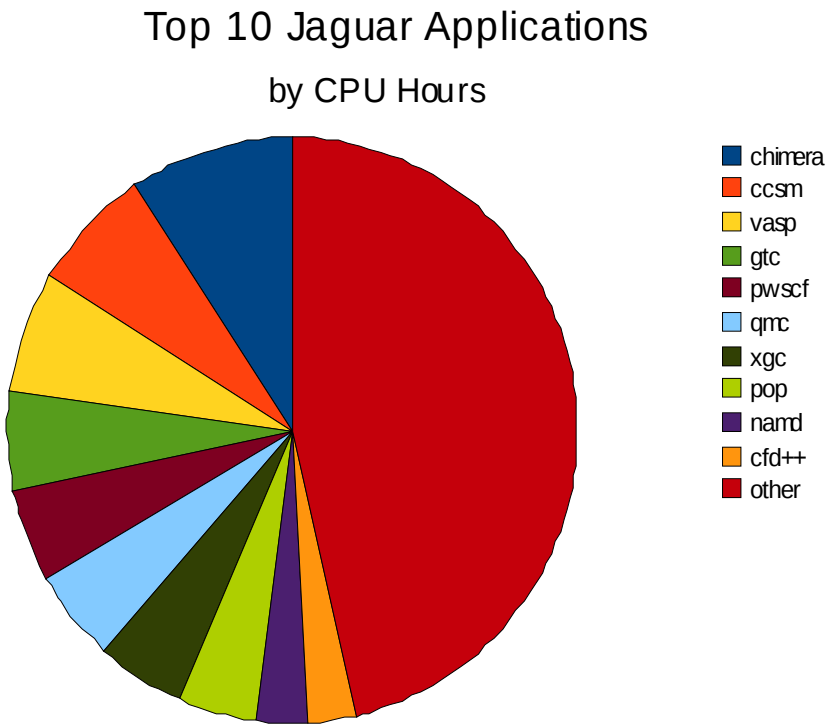
Quantifying User Experience

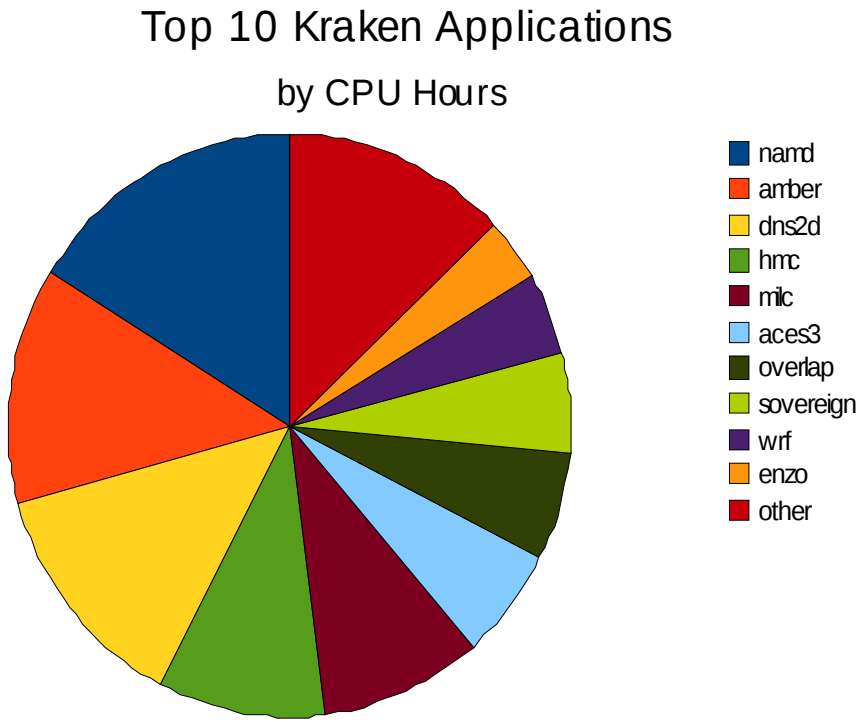


Quantifying User Experience (con't.)



Application Usage





Conclusions

- **Jaguar and Kraken actually do a lot of the same things using different mechanisms**
- **Both systems achieve their goal of running the big jobs**
  - **For Jaguar, this consists mostly of jobs using 10% or more of the system each, with a strong bias toward jobs using 25% or more.**
  - **For Kraken, this is a more bimodal distribution with many small jobs (<25% of the system) and a significant number of whole-system jobs with no much in between.**
  - **Difference is largely due by how the systems are allocated.**

Future Work

Future Work (con't)

- **XT5 systems will require some changes due to sheer scale.**
- **Better understanding of queue time**
  - **Resource availability and policy components.**
  - **Some times these overlap (e.g. standing reservations).**
- **Fair share on Kraken?**
  - **On per-project basis, based on allocation balance.**
- **More complex queue structure on Jaguar?**
  - **Centralize where walltime limits are defined.**
  - **Would simplify TORQUE submit filter.**