Scheduling Diverse High Performance Computing Systems with the Goal of Maximizing Utilization

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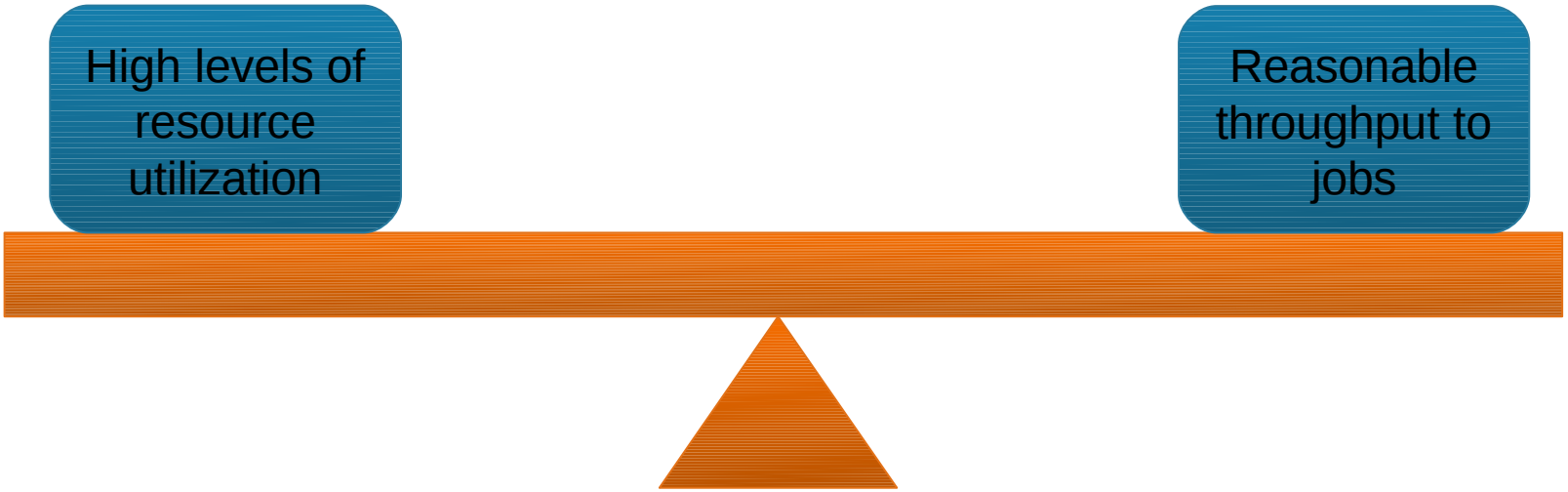
University of Tennessee & ORNL partnership

- **NICS is a NSF HPC center**
  - **Operated by UT, located at ORNL**
  - **XSEDE (formerly Teragrid) Service Provider**
- **Current Systems**
  - **Kraken (Cray XT5, 112,984 cores)**
  - **Nautilus (SGI UV, 1,024 cores)**
  - **Keeneland initial delivery system (HP GPU cluster, 1,440 cores + 360 GPUs) in conjunction with Georgia Tech**

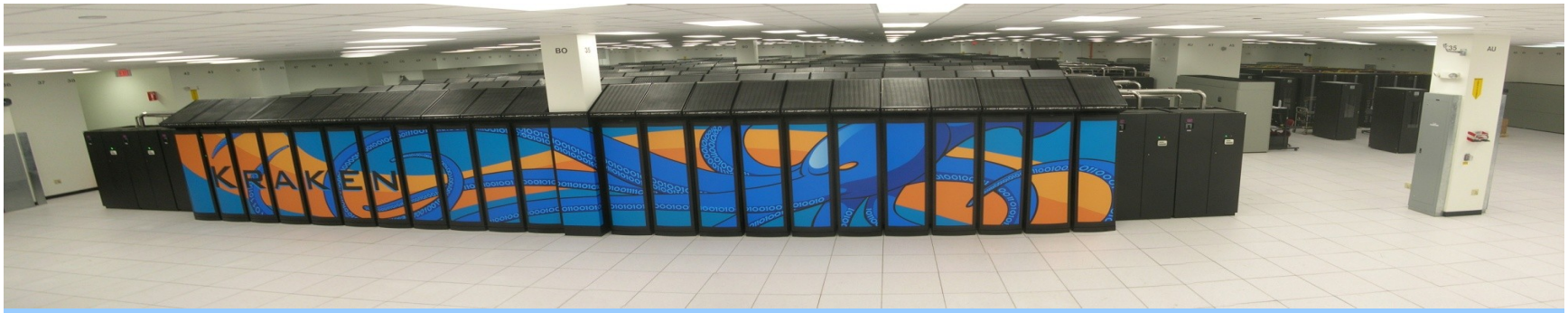
Overview

- **Introduction to NICS**
- **Scheduling on Kraken**
  - **Scheduling Overview**
  - **Need for bimodal scheduling**
  - **Capability Scheduling using Fence Reservations**
  - **Capability Scheduling using Triggers**
- **Scheduling on Keeneland**
  - **Scheduling Overview**
- **Future Work**

Goal of a HPC Service Provider

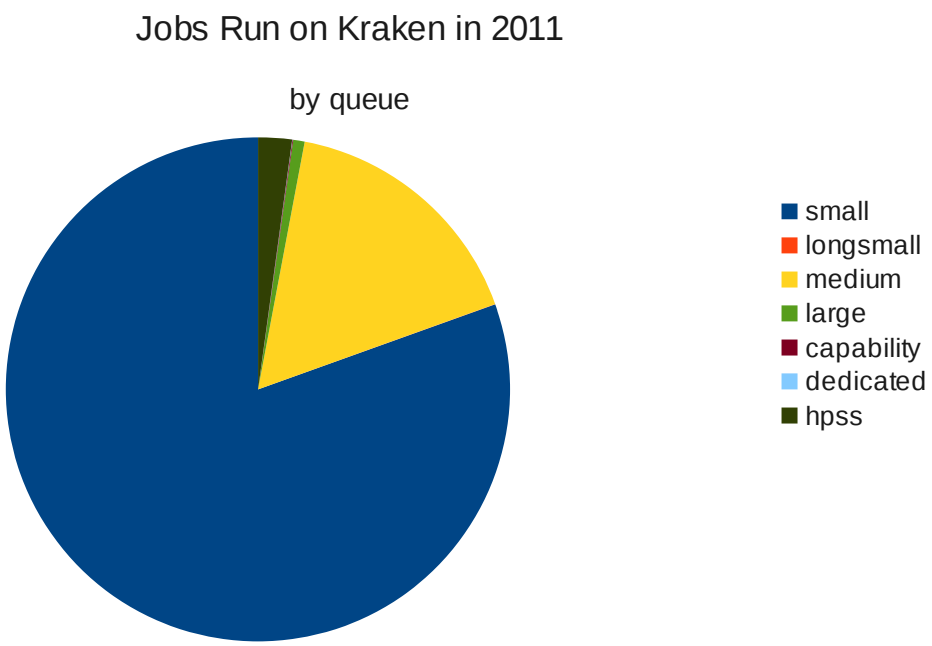


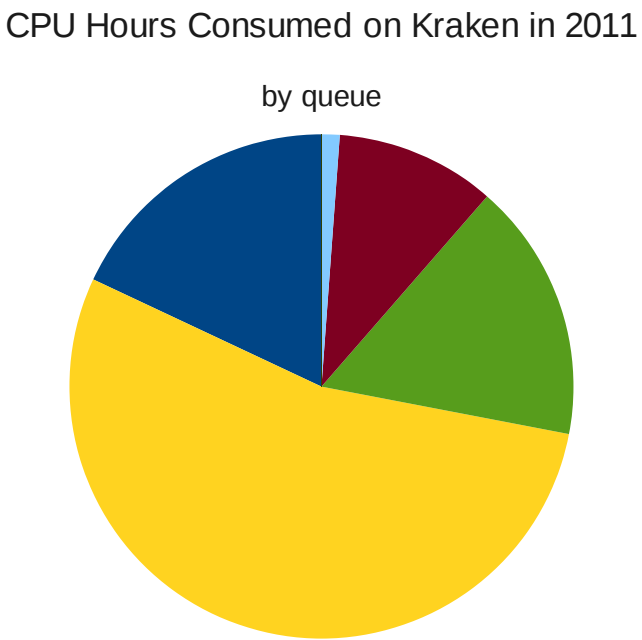
Kraken XT5 Specifications



Compute processor type	AMD 2.6 GHz Istanbul-6
Compute cores	112,896
Compute sockets	18,816 six-core
Compute nodes	9,408
Memory per node	16 GB
Total memory	147 TB
Peak system performance	1.17 PF
Interconnect topology	22 x 16 x 24 Torus/Seastar2+
Parallel file system space	3.3 PB (raw) 2.4 PB (usable)
Parallel file system peak performance	30 GB/s

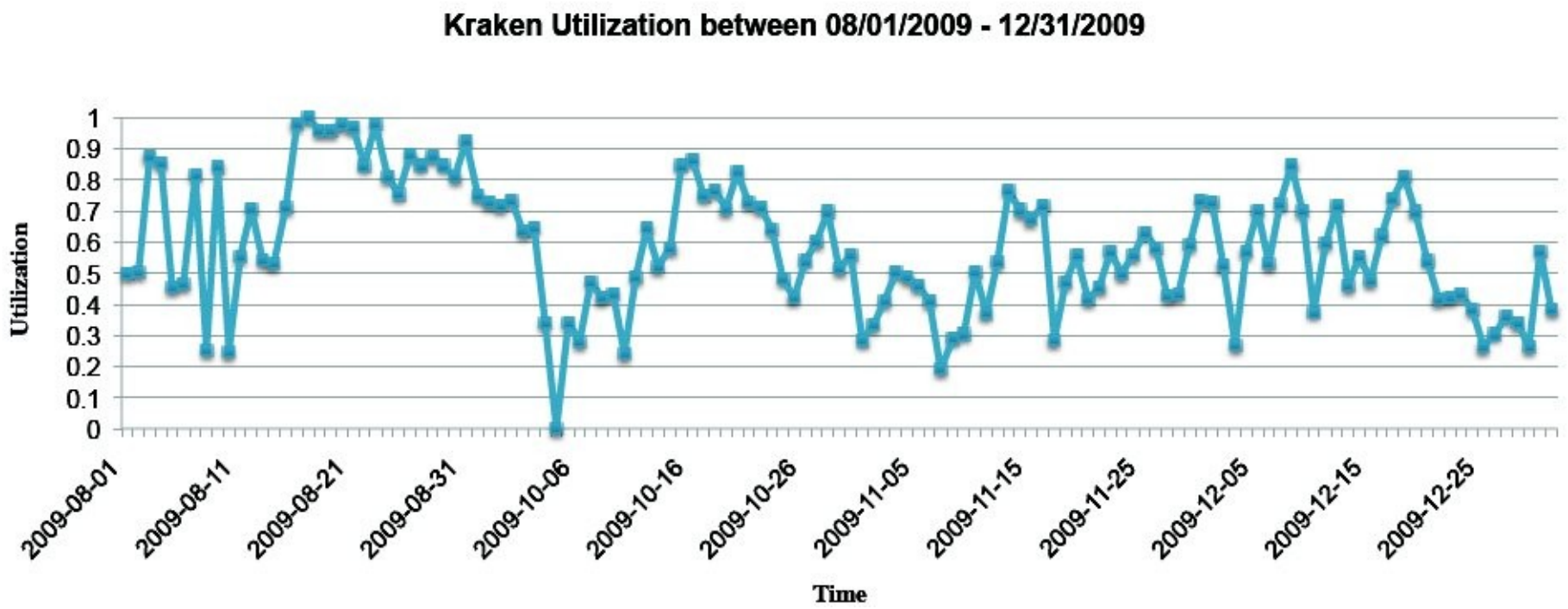
Job Mix on Kraken During 2011





Need for Bimodal Scheduling

- **Prior to January 2010 scheduling was on a strictly priority basis**
- **Peak and valley problem in utilization**



Need for Bimodal Scheduling

- **Capability users had to wait a long time before their jobs could run**
- **Capability jobs often did not manage I/O properly, leading to frequent Lustre problems**
- **This led to a need for a stable and more predictable scheduling system**

Initial attempt at Bimodal Scheduling

- **Friendly user period after Istanbul upgrade on Kraken**
  - **Largely manual scheduling – inspecting the queued jobs and adjusting priorities or running jobs manually**
  - **Resulted in ~20% increase in utilization**
- **Efforts to reduce the amount of manual intervention required**
- **Removal of expansion factor priority component**
  - **Caused priorities to change in ways that were difficult to explain to users**
  - **Remaining priority components were number of cores request and queue wait time**

Problems Running Dedicated jobs

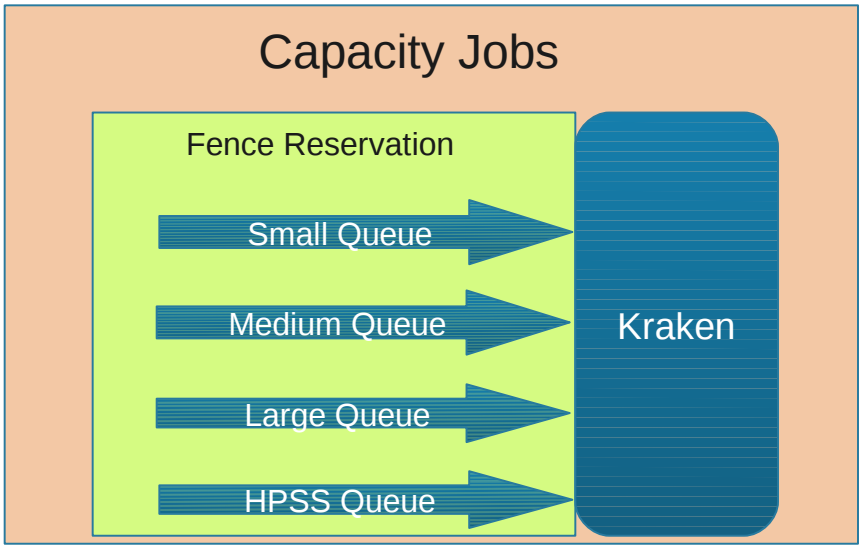
- **Initially run manually with scheduling paused**
- **Disadvantage of this approach:**
  - **On call sys admin had to start next dedicated job (Runs usually lasted 24 – 48 hours)**
  - **Every person involved with job had to stay up to monitor progress**
  - **Backfill jobs had to be run manually as well**

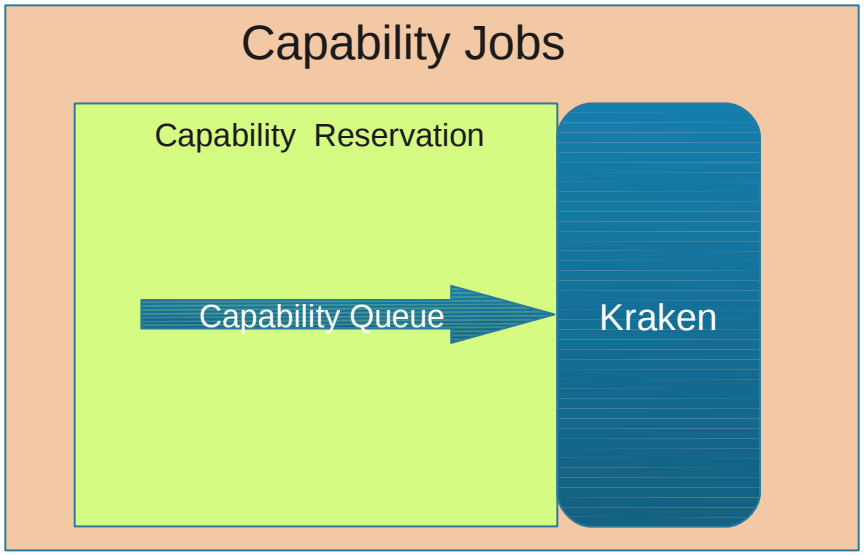
The Moab/ALPS disconnect

- **Moab/ALPS disconnect**
  - **ALPS node health checker runs after every job**
  - **Moab assumed nodes were ready as soon as job was ended, ignoring ALPS health checker**
  - **ALPS reported the nodes were not available immediately**
  - **Jobs would be requeued after failing to acquire nodes until health checker completed**
  - **In some cases, this led to non-capability jobs running while there were capability jobs left in queue**
- **Human errors also led to premature termination of capability jobs**
- **By end of 2010, through trial and error, an acceptable level of reliability was achieved but process was still heavily manual**

Capability Scheduling Using Fence Reservations

- **Fence reservations: Standing reservations set up on Kraken with a granularity of 1 day**
- **Reservation controlled by an ACL which specified which queues could run on the machine**



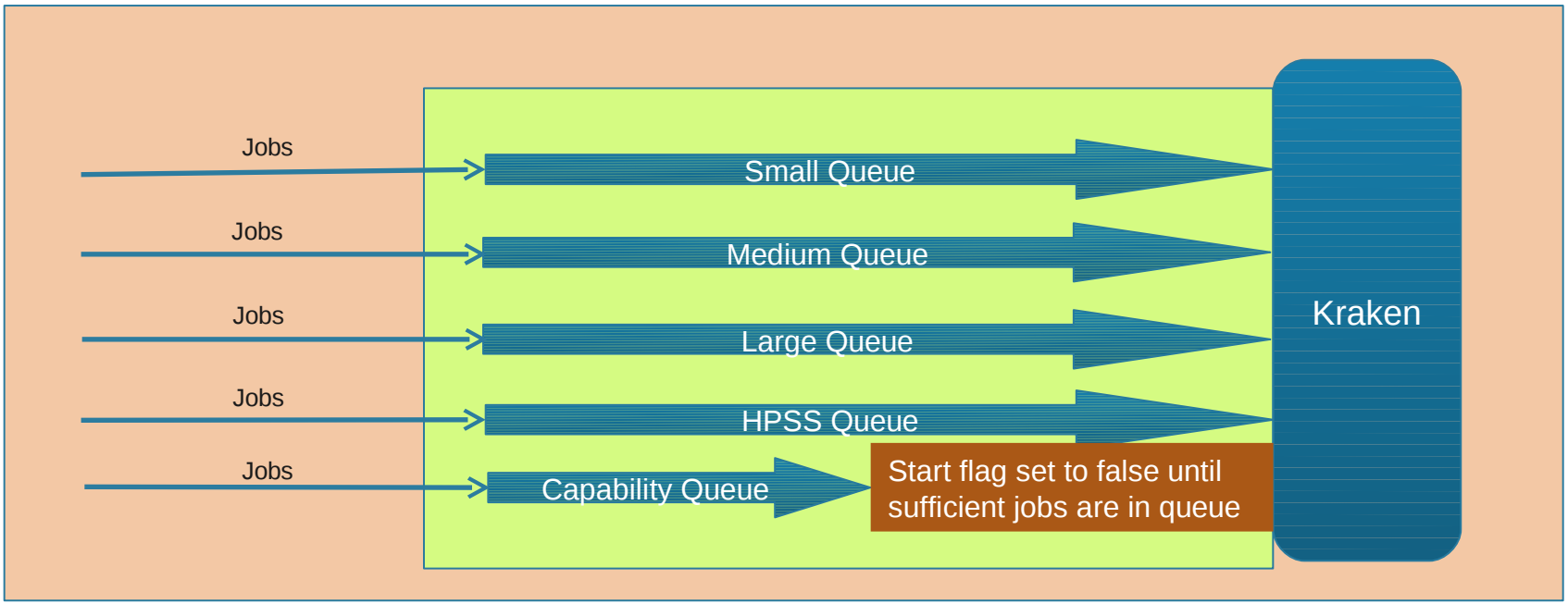


Drawbacks of Capability Scheduling Using Fence Reservations

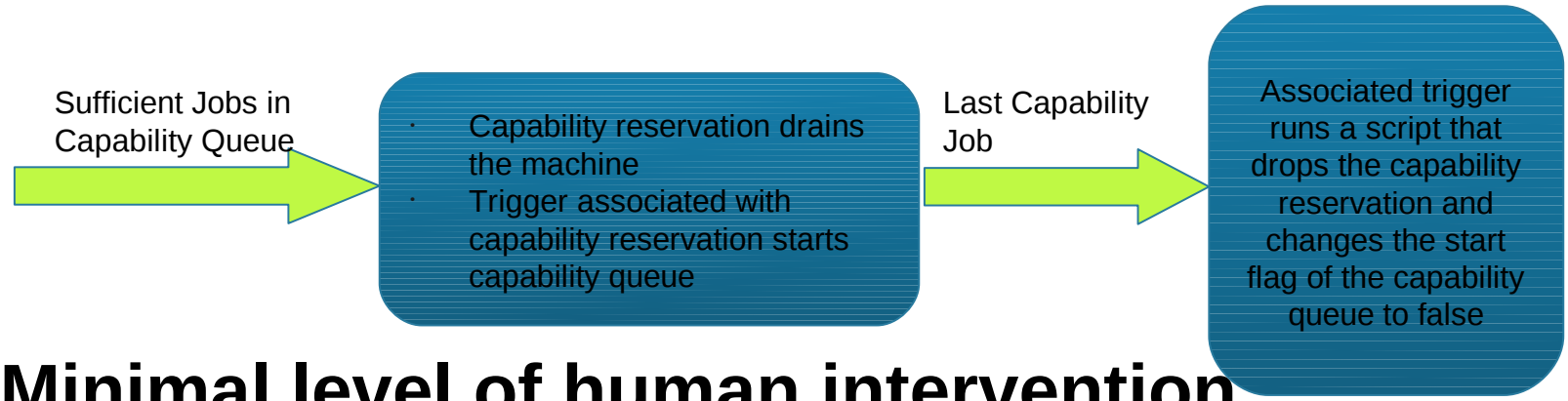
- **Fence reservation had to replace capability reservation as soon as last capability job was done, else machine would idle**
- **Too many reservations in flight**

Capability Scheduling Using Triggers

- **Moab version 5.4 changed the way reservations were handled**
- **From version 5.2, Moab could launch triggers**
- **Triggers enable actions when certain events, offset or threshold criteria are satisfied**



Running Capability Jobs Using Triggers

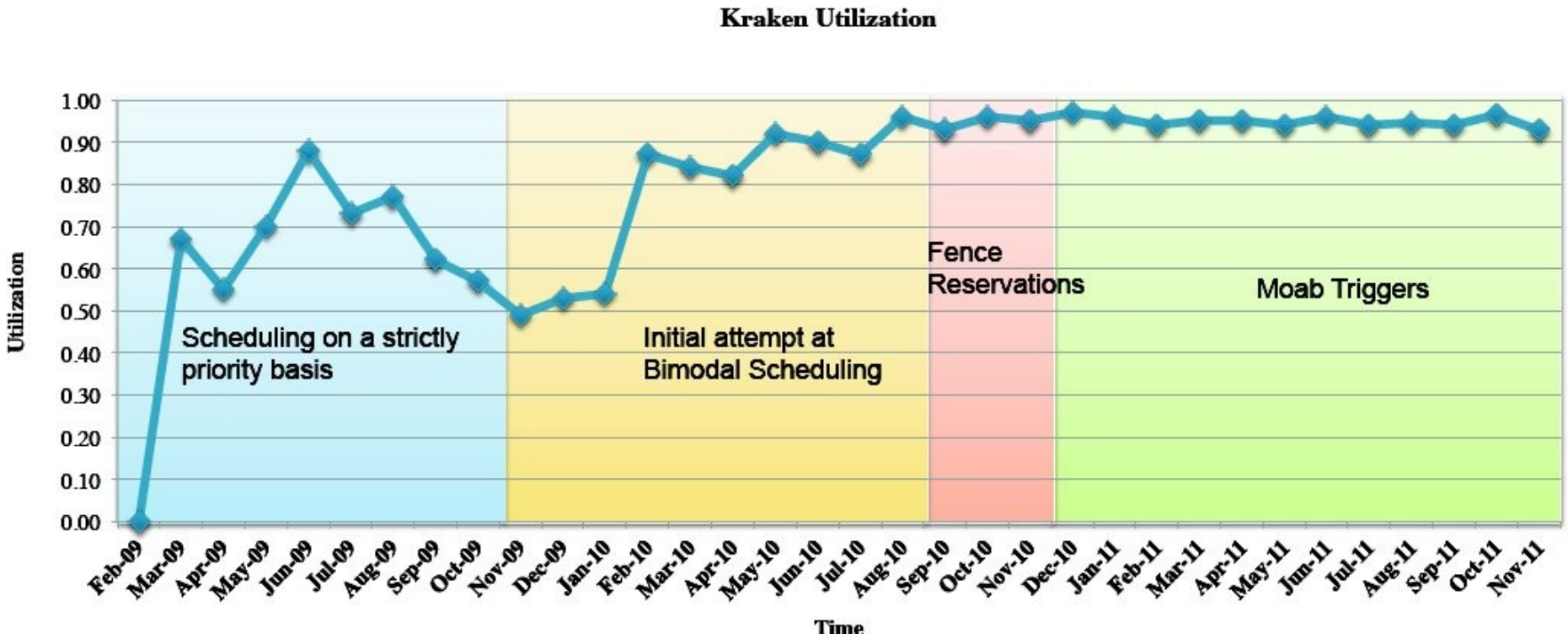


- **Minimal level of human intervention**
  - **Reservation profile used to simplify reservation creation**
  - **Capability queue off by default, turned on and off by triggers**
- **Allows capability users to debug and resubmit jobs within the capability window**
- **Turnaround time for capacity users unaffected**

Current Scheduling on Kraken

- **Capacity Jobs – use <= 49,536 cores**
  - **Run most of the time**
- **Capability Jobs – use between 49,537-98,352 cores**
  - **Run after maintenance windows or crashes**
- **Dedicated Jobs – use > 98,352 cores**
  - **Extremely I/O intensive**
  - **Scheduled roughly once every quarter**
  - **Dedicated jobs with wallclock requests <= 1 hour may run just after a PM or crash**

Overall Utilization on Kraken



Scheduling on Keeneland

Keeneland - Initial Delivery (KID)

CPU	2 x Intel Xeon X5660 2.80 Ghz (Westmere)
GPU	3 x Nvidia Tesla M2070 6GB (Fermi)
Interconnect	Infiniband QDR (single rail)
# Compute Nodes	120
Total CPU cores	1,440
Total GPUs / cores	360 / 161,280
# Login Nodes	4
# Management Nodes	2

Scheduling on Keeneland

- **Keeneland is currently a development system open to friendly users**
- **Fairshare Policy:**
  - **Each project have a default fairshare target of 10%**
  - **To prevent users from “hogging” the machine:**
    - **Maximum eligible jobs per user (at a time): 5**
    - **Maximum eligible jobs per project (at a time): 10**
- **Capability reservations using triggers similar to what's done on Kraken**
  - **Bug in Moab 6.1.x where reservations created using a profile don't get the profile's CLASSLIST ACL – have to add by hand**
  - **This problem now affects Kraken as well after CLE 3.1 upgrade**

Future Work

- **On Kraken, no way currently to distinguish between jobs submitted to capability queue at the start of the reservation and jobs submitted after the reservation was open**
  - **Problem of determining last job to attach trigger to**
  - **Attach higher priority to jobs submitted before capability queue was open**
  - **Alternatively, hold capability jobs by default and release eligible jobs at the start of the capability window**
- **Freeing up cores as capability run progresses**

Questions

Appendix A: Anatomy of a Fence Reservation

```
SRCFG[fence] COMMENT='fence in capability jobs to
run only on certain days'

SRCFG[fence] PARTITION=xt5 TASKCOUNT=8256

SRCFG[fence] PERIOD=DAY DEPTH=7
DAYS=Mon,Tue,Thu,Fri,Sat,Sun

SRCFG[fence] STARTTIME=00:00:01 ENDTIME=23:59:59

SRCFG[fence]
CLASSLIST=small,longsmall,medium,large,dmover,hpss

SRCFG[fence] FLAGS=SPACEFLEX
```

Appendix B: Anatomy of a Trigger-Based Capability Reservation

```
RSVPROFILE[capability]
TRIGGER=AType=exec,EType=start,Action="/var/control_capability
start $OID"

RSVPROFILE[capability]
TRIGGER=AType=exec,EType=end,Action="/var/control_capability
end $OID"

RSVPROFILE[capability]
TRIGGER=AType=exec,EType=cancel,Action="/var/control_capability
cancel $OID"

RSVPROFILE[capability] CLASSLIST=capability,dedicated

RSVPROFILE[capability] FLAGS=DEDICATEDRESOURCE
```