MONTEREY
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Monitoring and Controlling a Scientific Computing Infrastructure

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Overview

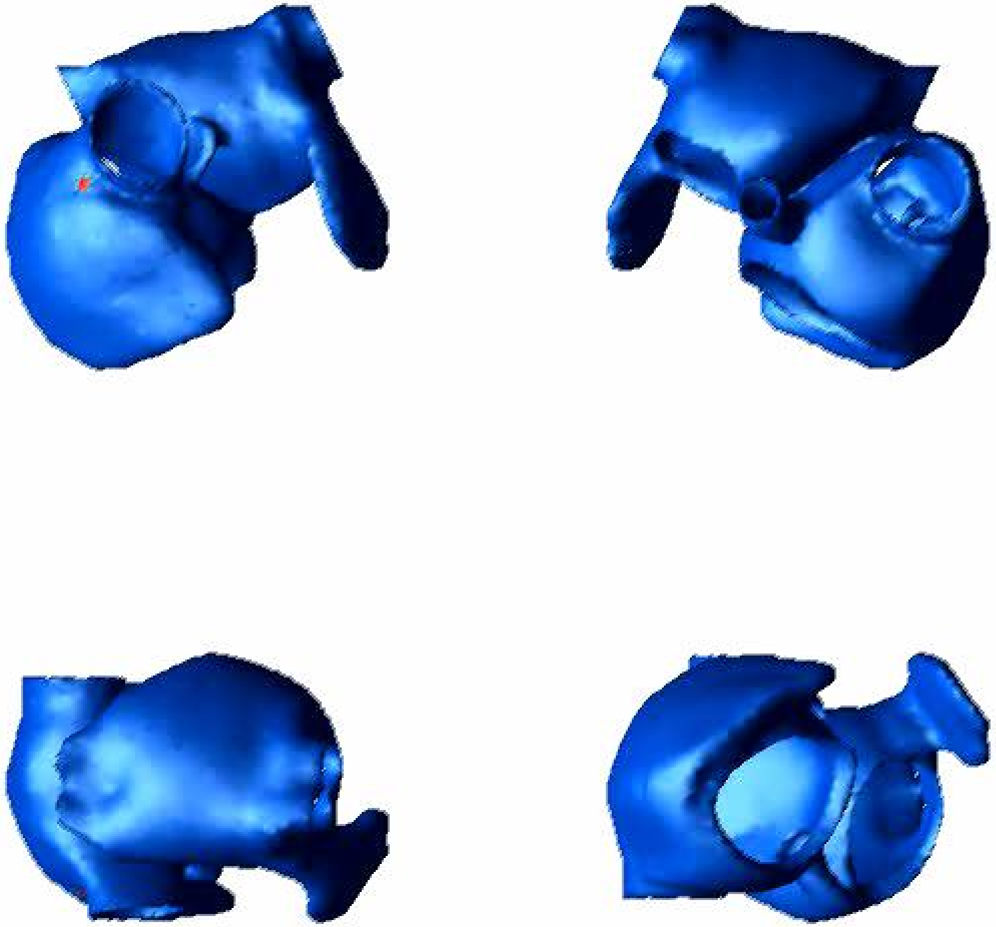
- Overview of operations
  - Scientific research
  - Computational infrastructure
- Building a monitoring framework with IT Monitor and PI
- Conserving power used by compute clusters
- Future challenges

Scientific Research

- Develop, integrate and maintain computational and other technological resources to support…
  - Dept. of Physiology and Biophysics
  - Institute for Computational Biomedicine
  - Computational Genomics Core Facility

…at the Weill Medical College of Cornell University

- Research, educational, and clinical mission
- Roughly 75 people to support



Christini Lab, Weill Cornell Medical College

High Performance Computing

- Simulations of biological systems
  - Molecules, tissues, cells, organs
- Analysis of large datasets
  - Genomes, other -omes
  - High-throughput experiments
  - Corpus of biological literature
- Imaging & Viz (MRI, confocal microscopy, ...)
  - Clinical and basic science
  - Immersive visualization (CAVE Q4’07)
- Other services
  - Desktop, print, videoconference

Desktop Environment

- Not possible or desirable to standardize
- Operating System Distribution
  - 60% Windows XP
  - 35% Mac OS X*
  - 5% Linux (RedHat, Debian)
- Need to support all of them

Compute Resources

- 750+ processors; 2+ Tflop/sec
  - 208 node/416 processor Linux cluster
  - 90 node/186 processor Linux cluster*
  - 24 processor IBM pSeries (48G memory)
  - 16 processor SGI Altix
- Fairly heterogeneous environment
  - Primarily Dell/Intel (~95%); some IBM, SGI
  - Primarily Linux (Red Hat); some AIX, IRIX

Storage Resources

- Mainline storage and cluster storage
  - 40+ TB raw spinning disk
  - 14 RAID arrays
    - Apple FibreChannel (Brocade and QLogic switches)
    - Dell SCSI direct attach
    - Some SGI
- Server Backup is LTO3 tape based
  - Two libraries (robots)
  - Four drives
- Desktop backup is disk based
  - Retrospect

Application Resources

- Scientific Software Library
  - 100+ programs/versions
  - Open Source and Commercial
- LAMP+ stack
  - Redundant Apache servers
  - Web app server (Tomcat/Java)
  - Oracle 10g Enterprise

Physical Plant

- Three Server Rooms
  - Cornell University Ithaca Campus
    - 208 node cluster was too power/HVAC intensive to house on NYC campus
    - Fully equipped for remote management
    - Lights out facility, one visit last year
  - NYC Campus
    - 125 kVA server room (10 cabinets) [12.5 kW/cabinet]
    - 300 kVA server room (12 cabinets) [25 kW/cabinet!!!]
- At full load, we can draw over 1 MW to run and cool!

Managing the Infrastructure

- All of the above built and maintained by a group of three people.
  - Automation required
  - Don’t want to standardize too much, so we need to be very flexible

Why IT Monitor and PI?

- IT Monitor / PI selected to be the central repository for health and performance monitoring (and control).
  - Able to talk to a diverse set of devices
    - Printers, servers, desktops
    - Network switches
    - Building management systems
    - …pretty much anything we care about
  - Pick and choose the parts you want to use, you build the solution
    - Ping, SNMP, HTMP interfaces, ODBC
  - Very strong, proven analytics
- Vendor specific solutions are (expensive) islands

Project 1: The Big Board

Overall Systems Health

- Want a quick, holistic view of our key resources
  - Core infrastructure
    - File servers, web servers, app servers
    - Backup servers
  - Cluster utilization
    - Node statuses and summary
  - Physical plant
    - Temperature monitoring

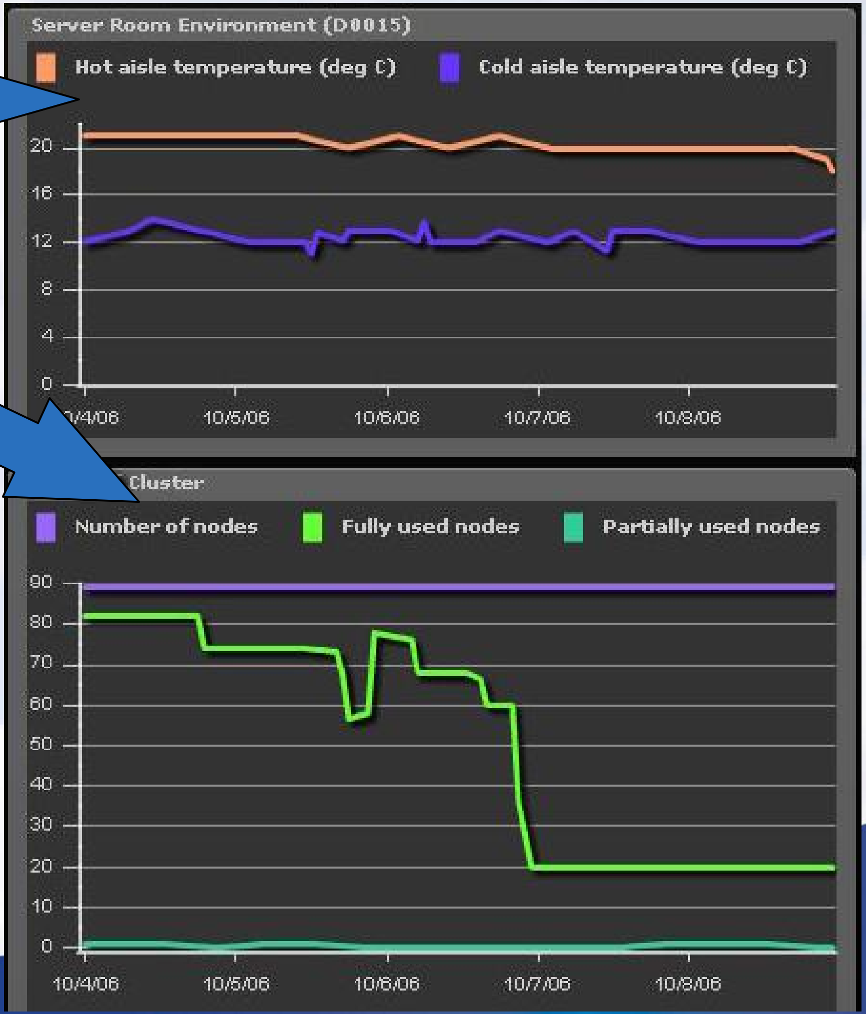
Data is Available to Everyone

- Adobe Flash/Flex used for display

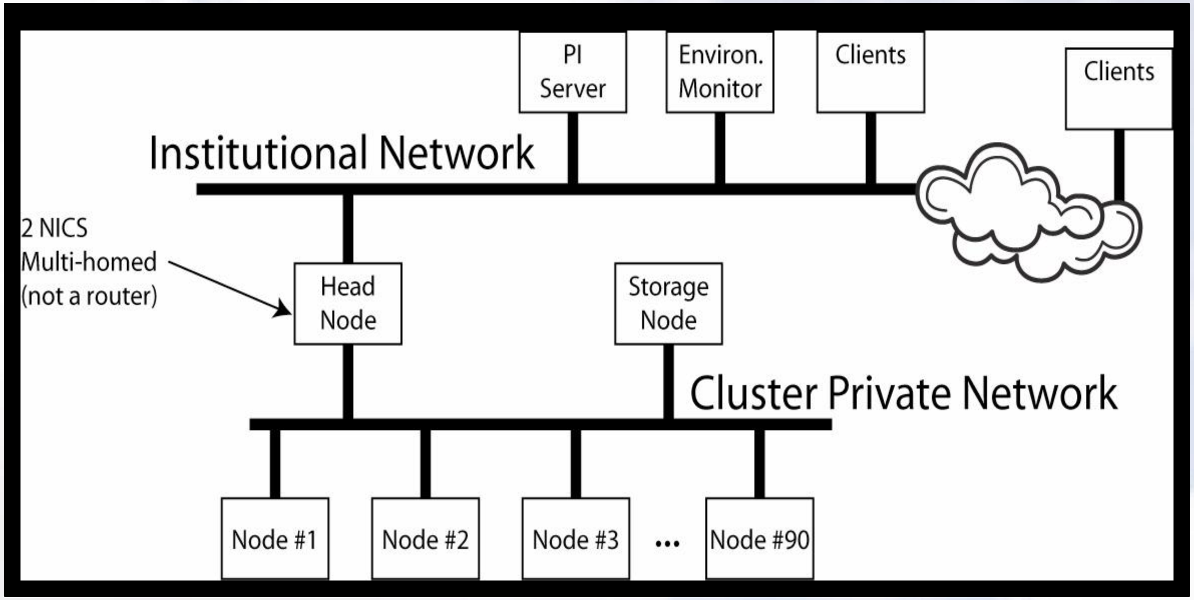
Why IT Monitor / PI? (revisited)

Is this affected by that?

- This can only be answered if all your data is in the same place.

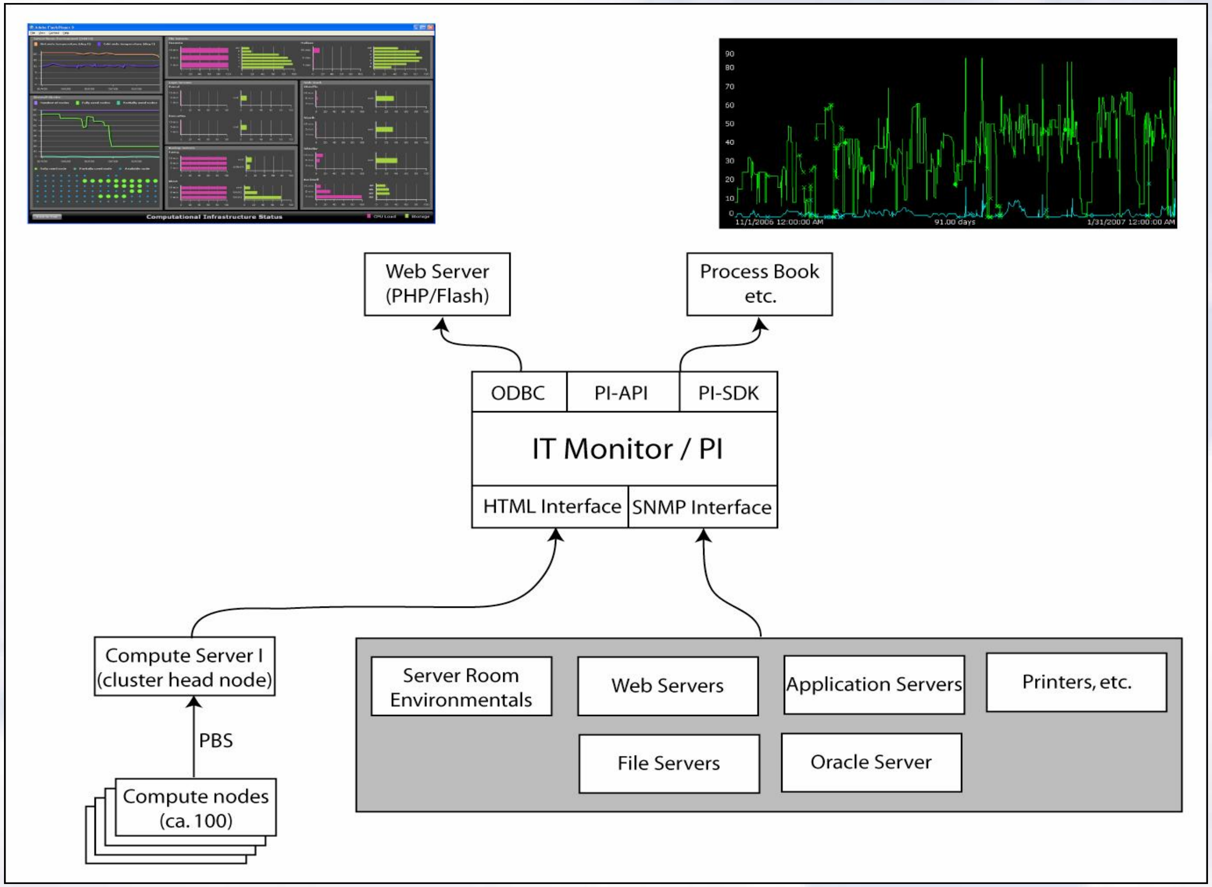


Network Layout



- PI Server can only see head node
  - OK; head node knows what's going on anyway
- How does PI Server read the data we are interested in?
  - Node statuses and summary statistics

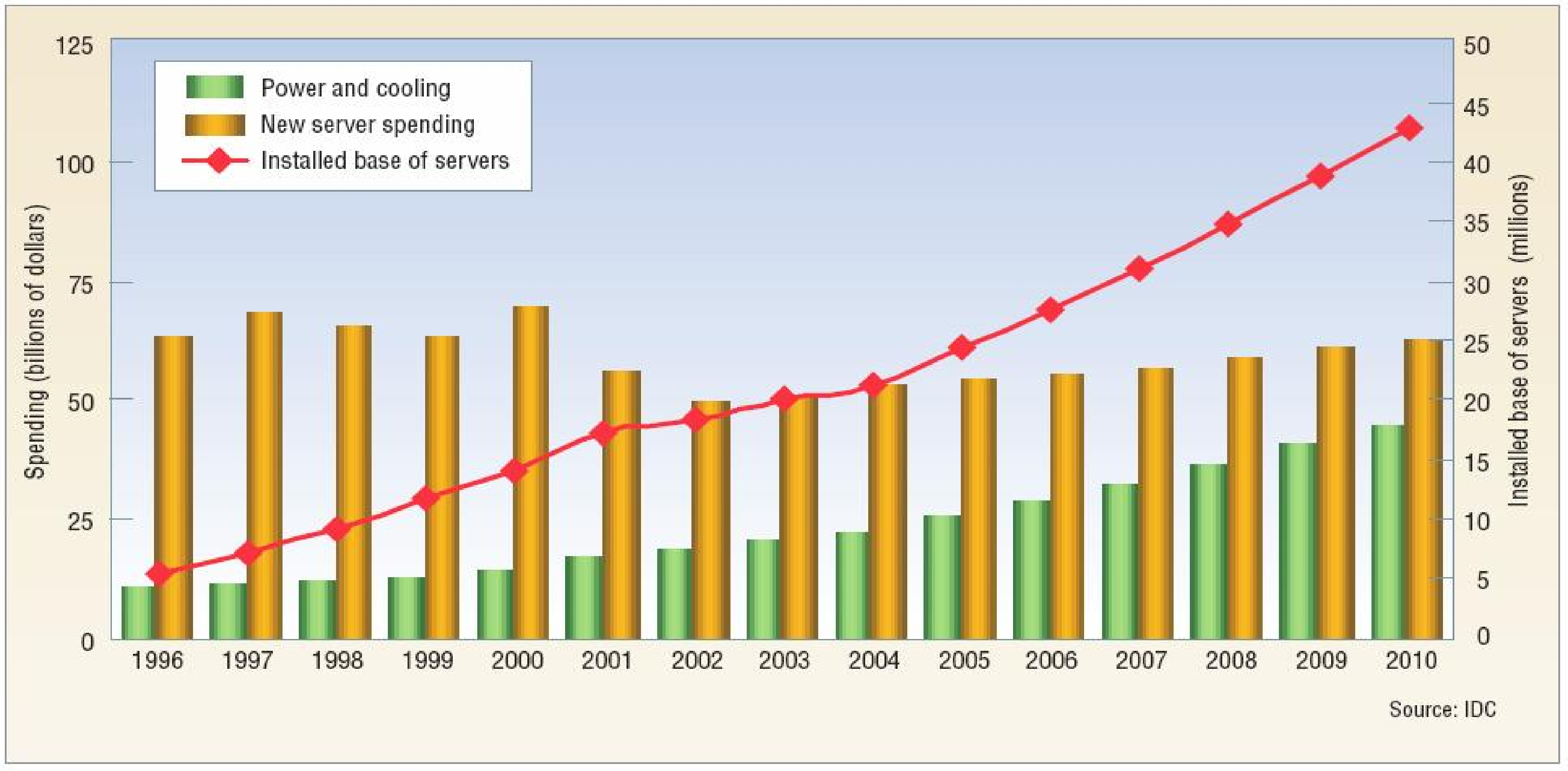
Data Collection and Dissemination Architecture



Project 2: Cluster Power Management

- Green computing…
  - Save power (and $$$) by shutting down nodes that are not in use.
- …but minimize impact on performance
  - Maintain a target number of stand-by nodes ready to run new jobs immediately.
  - Reduce latency perceived by end-users

The Cost of Power and Cooling

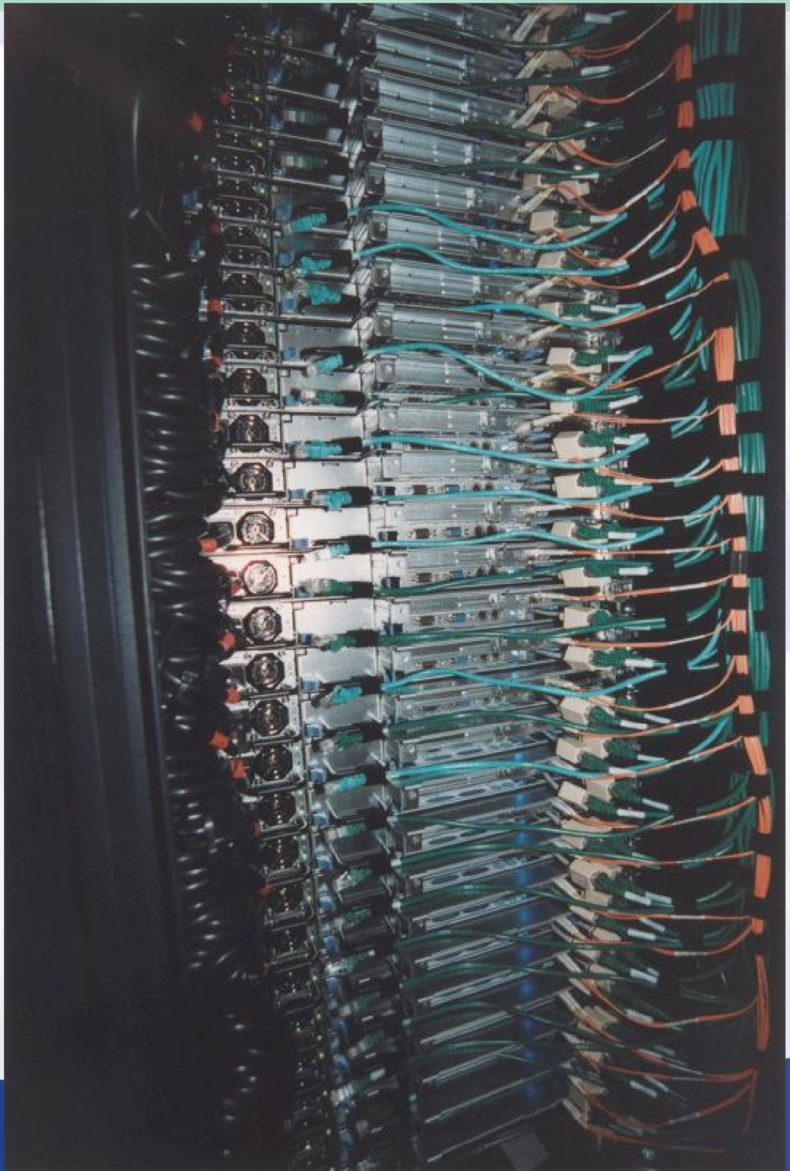


Lawton, *IEEE Computer*, Feb 2007

Powering HPC

- Density is increasing
  - 20+ kW per cabinet (standard designs were 2-4 kW only a few years ago)
  - Localized heat removal is a problem
  - HVAC failures leave very little time for response
- Load is highly variable
  - Harder to control

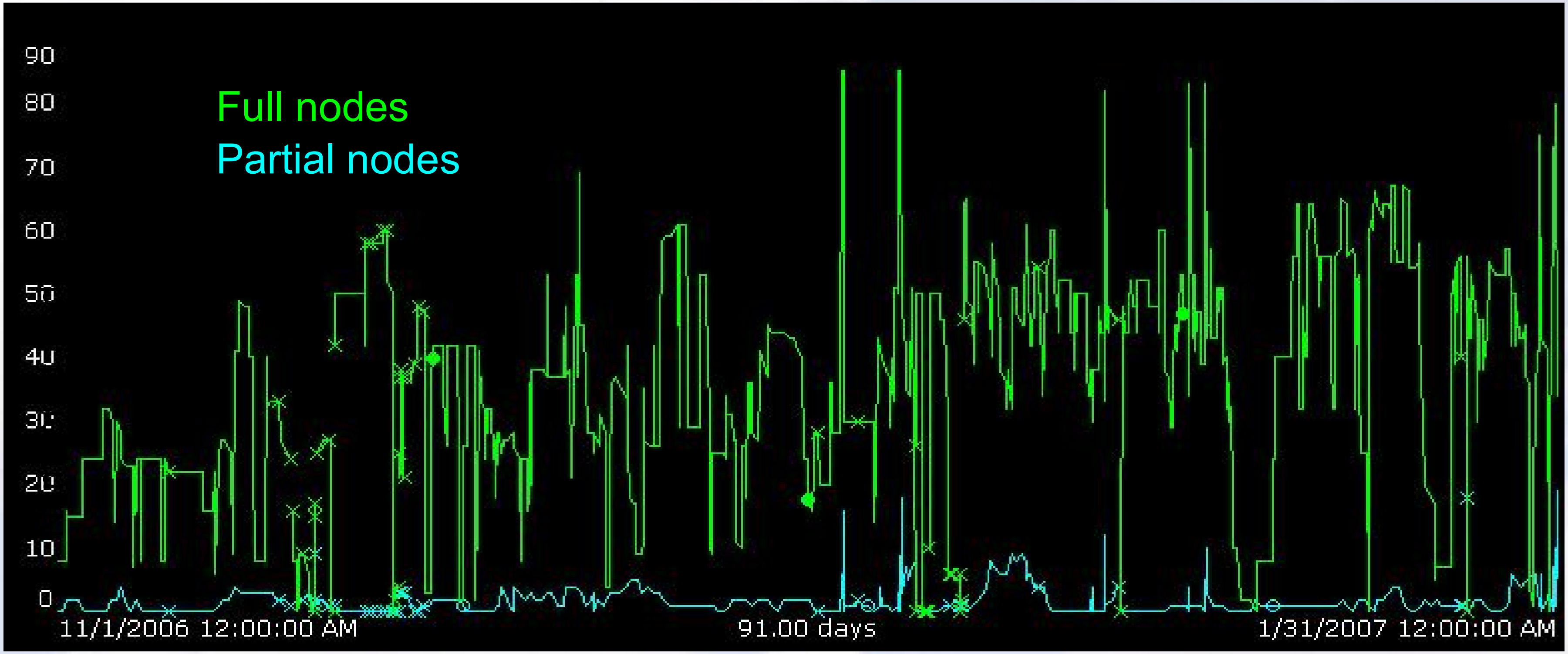
Dense Computing



Our Cluster

- 90 compute nodes
  - 3 ‘fat’ nodes; 2 ‘debug’ node
  - 85 nodes under CPM
- Power used:
  - In Use node: 250 W
  - Stand-by node: 125 W
  - Power Save nodes: 0 W
- With 50% usage and no standby nodes: power savings is 32%
- With 66% usage and 16 standby nodes: power savings is 11%

Historical Cluster Usage



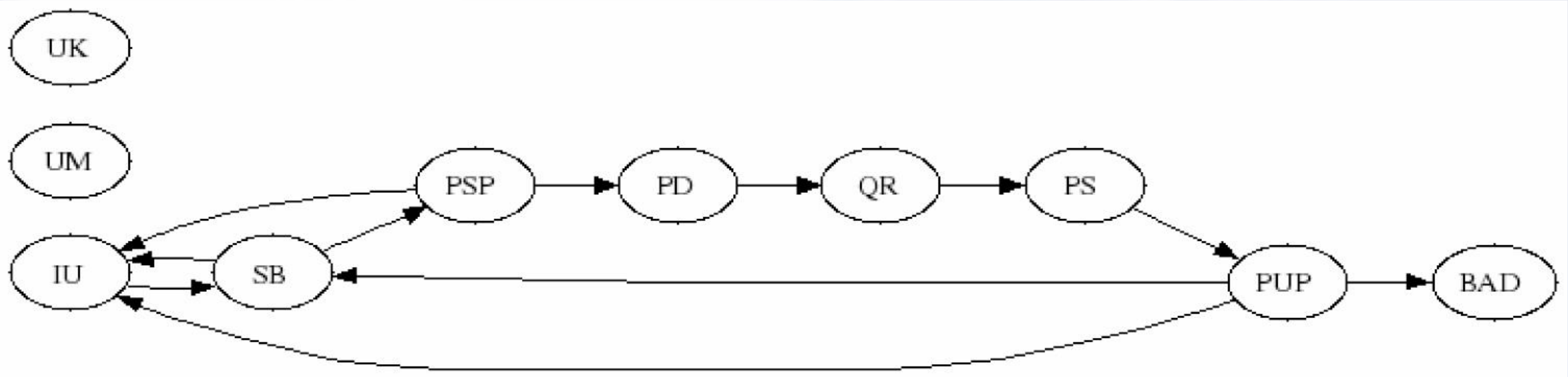
Hardware Requirements

- Hardware Requirements
  - Chassis Power Status
  - Remote Power Up
  - PXE is a plus for any large system
- Dell Servers do all of this standard (and much more!)
  - Baseboard Management Controller
  - Dell Remote Access Card

IPMI + IT Monitor = Data + Control

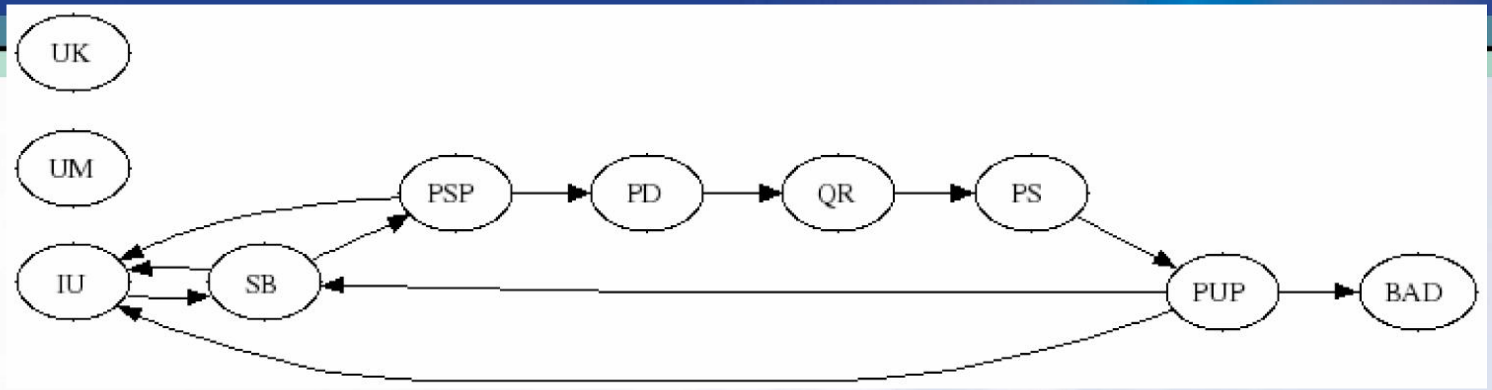
```
[root@cluster clusterfi]# ipmitool -I lan -H 10.1.12.190 -U root -f
   passfile sensor list
Temp             | 21.000   | degrees C | ok | 120.0 | 125.0 | na
Temp             | 20.000   | degrees C | ok | 120.0 | 125.0 | na
Temp             | 23.000   | degrees C | ok | 120.0 | 125.0 | na
Temp             | 23.000   | degrees C | ok | 120.0 | 125.0 | na
Temp             | 40.000   | degrees C | ok | na    | na    | na
Temp             | 61.000   | degrees C | ok | na    | na    | na
Ambient Temp     | 16.000   | degrees C | ok | 5.000 | 10.0  | 49.0 | 54.0
Planar Temp      | 20.000   | degrees C | ok | 5.000 | 10.0  | 69.0 | 74.0
CMOS Battery     | 3.019    | Volts     | ok | 2.245 | na    | na   | na
```

Lifecycle of a Compute Node



- CPM uses a finite state machine model
- Tunable parameters
  - Target number of standby nodes
  - Global time delay for shutdowns
    - Prevent churn of nodes

Lifecycle of a Compute Node

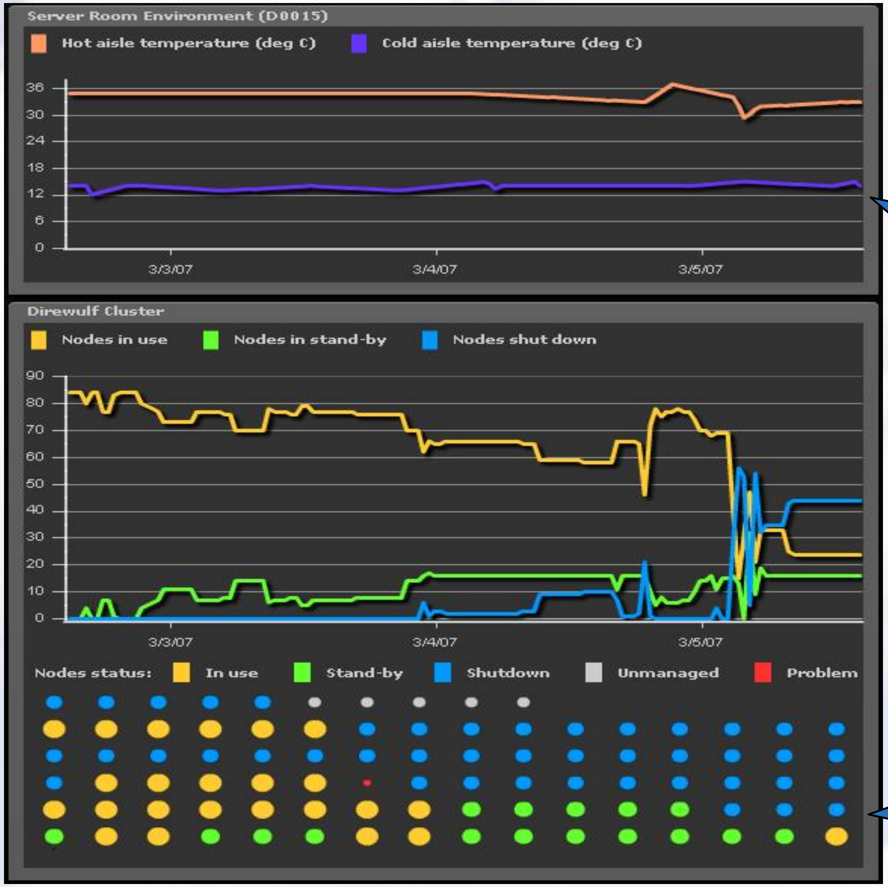


- IU: In Use
- SB: Standing by
- PSP, PD, QR: Shutting down
- <u>PS: Power Save</u>
- PUP: Powering Up
- BAD: Problems
- UK: Unknown
- UM: Unmanaged

	1	2	3	4	5	6	7	8	9	10
Nodes 081-090	PS	PS	PS	PS	PS	UM	UM	UM	UM	UM
Nodes 071-080	QR	QR	QR	PS	PS	PS	PS	PS	PS	PS
Nodes 061-070	PS	PS	PS	PS	IU	IU	IU	IU	IU	IU
Nodes 051-060	PS	PS	PS	PS	PS	PS	PS	PS	PS	PS
Nodes 041-050	SB	SB	SB	SB	PS	PS	PS	PS	PS	PS
Nodes 031-040	SB	SB	IU	IU	IU	IU	IU	IU	Bad	SB
Nodes 021-030	IU	IU	IU	IU	SB	SB	SB	SB	SB	SB
Nodes 011-020	IU	IU	IU	IU	IU	IU	IU	IU	IU	IU
Nodes 001-010	SB	IU	IU	SB	SB	IU	IU	IU	IU	IU

BAD	1
IU	33
PD	0
PS	32
PSP	0
PUP	0
QR	3
SB	16
UK	0
UM	5

Cluster Power Management In Action



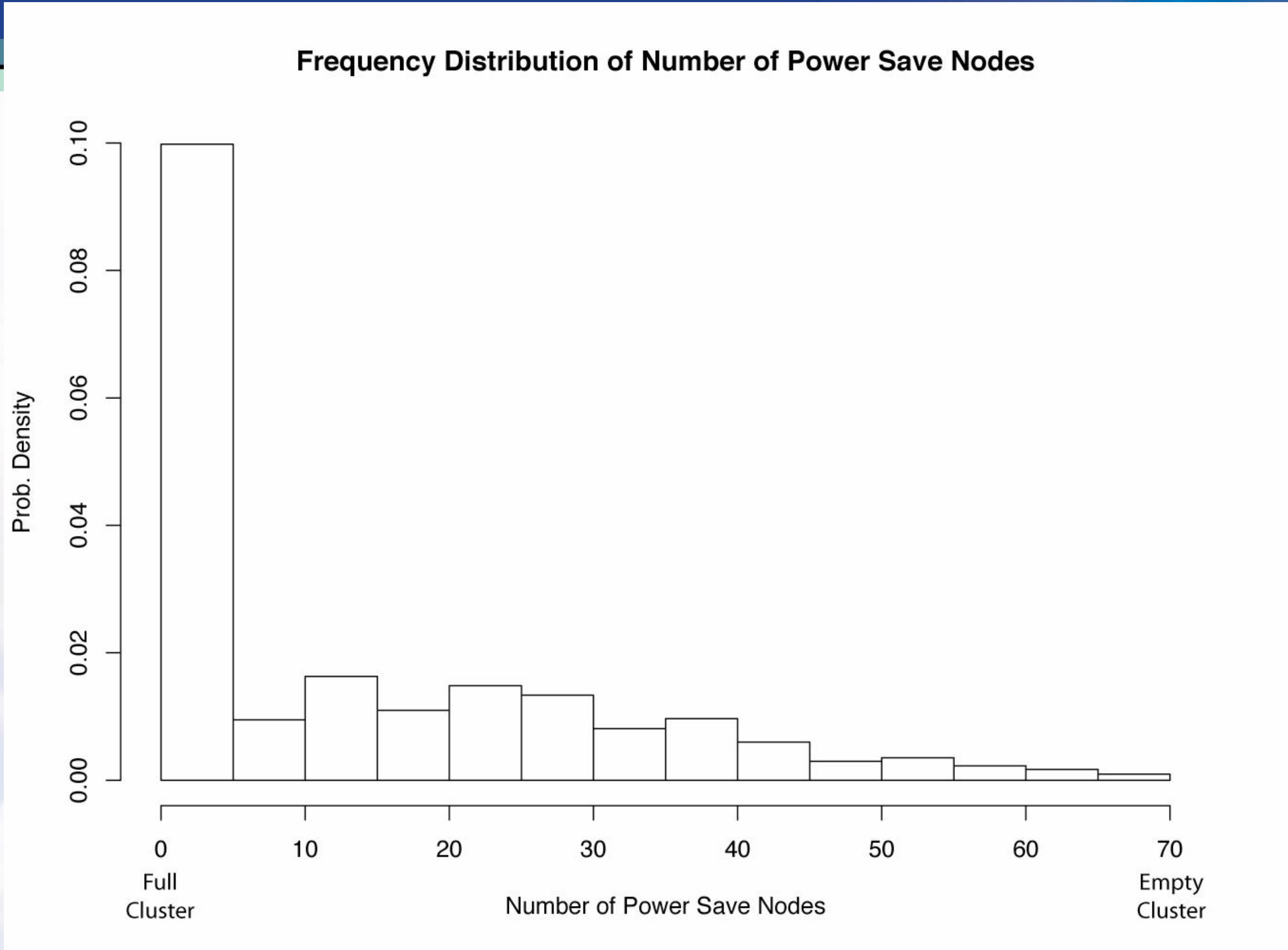
Note correlation between temperature and cluster usage

Powered down

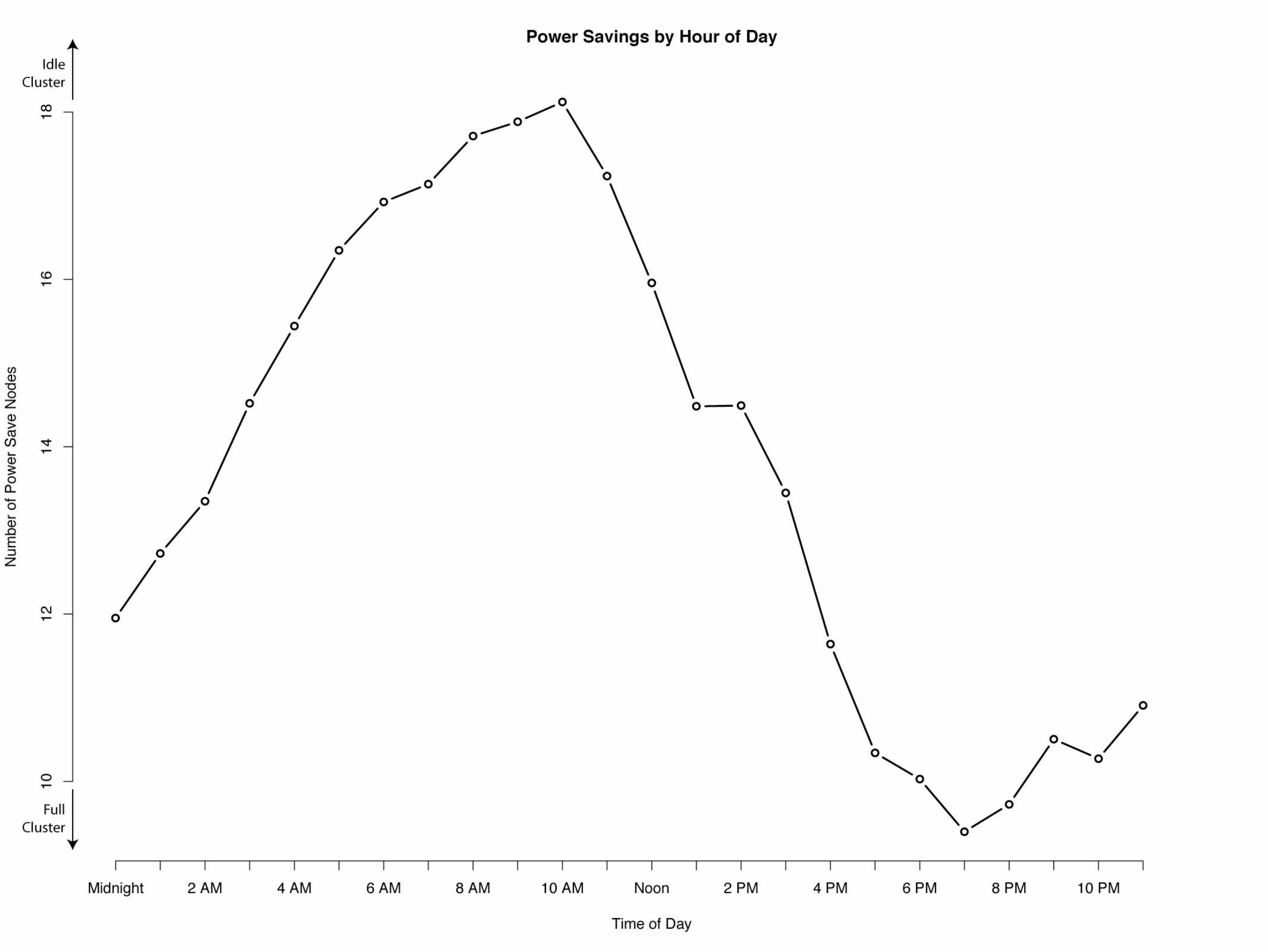
Results: Six Months of CPM

- Six Month Average:
  - 13.6 nodes shut down for power savings.
  - 16% of managed nodes
  - 8% power savings
- 15.06 MW*h annual savings
- $3,000 annual power savings ($0.20/kW*h)
- Probably double when considering HVAC
- Equipment life

Results: Six months of CPM



Results: Six Months of CPM



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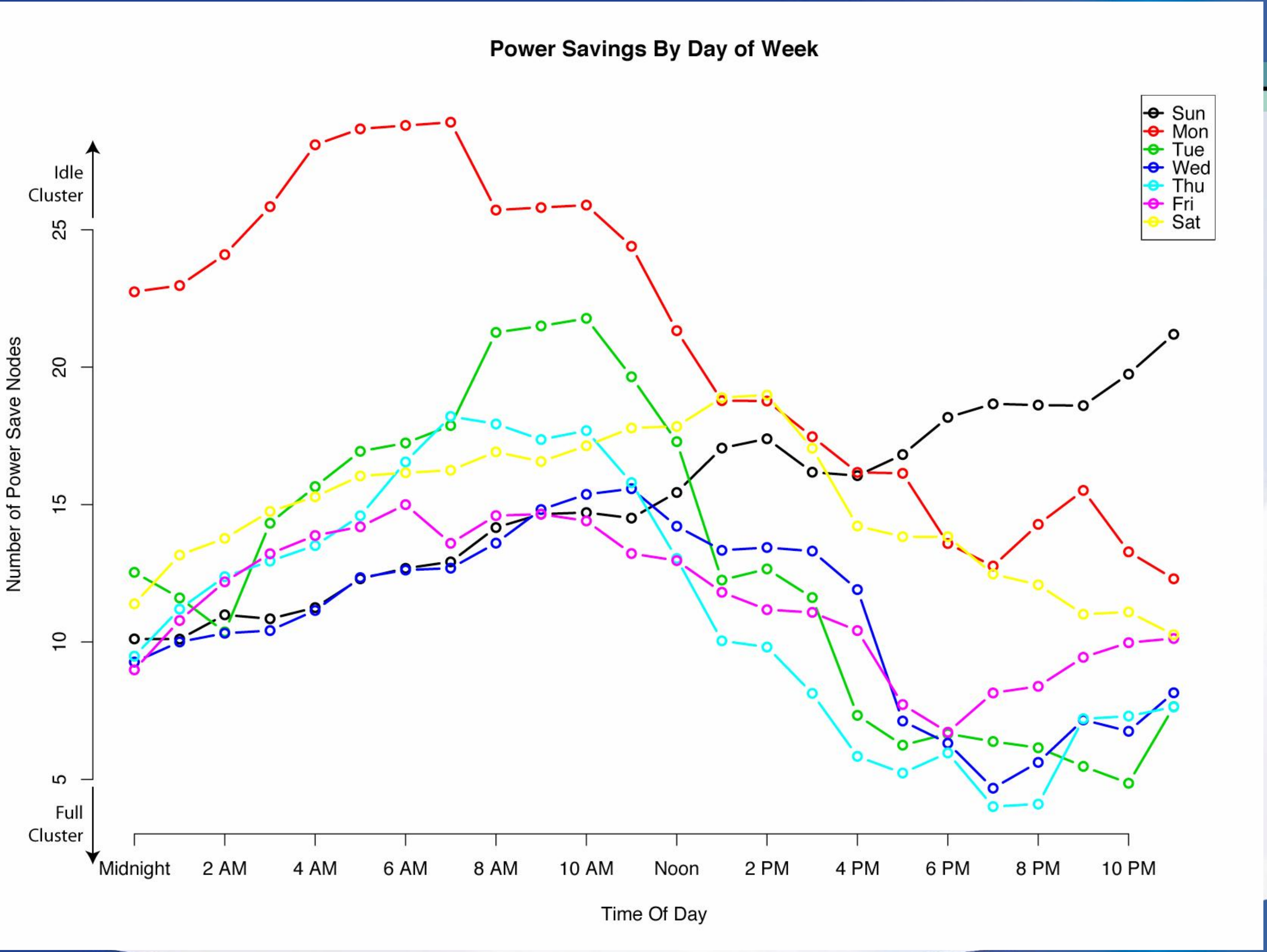
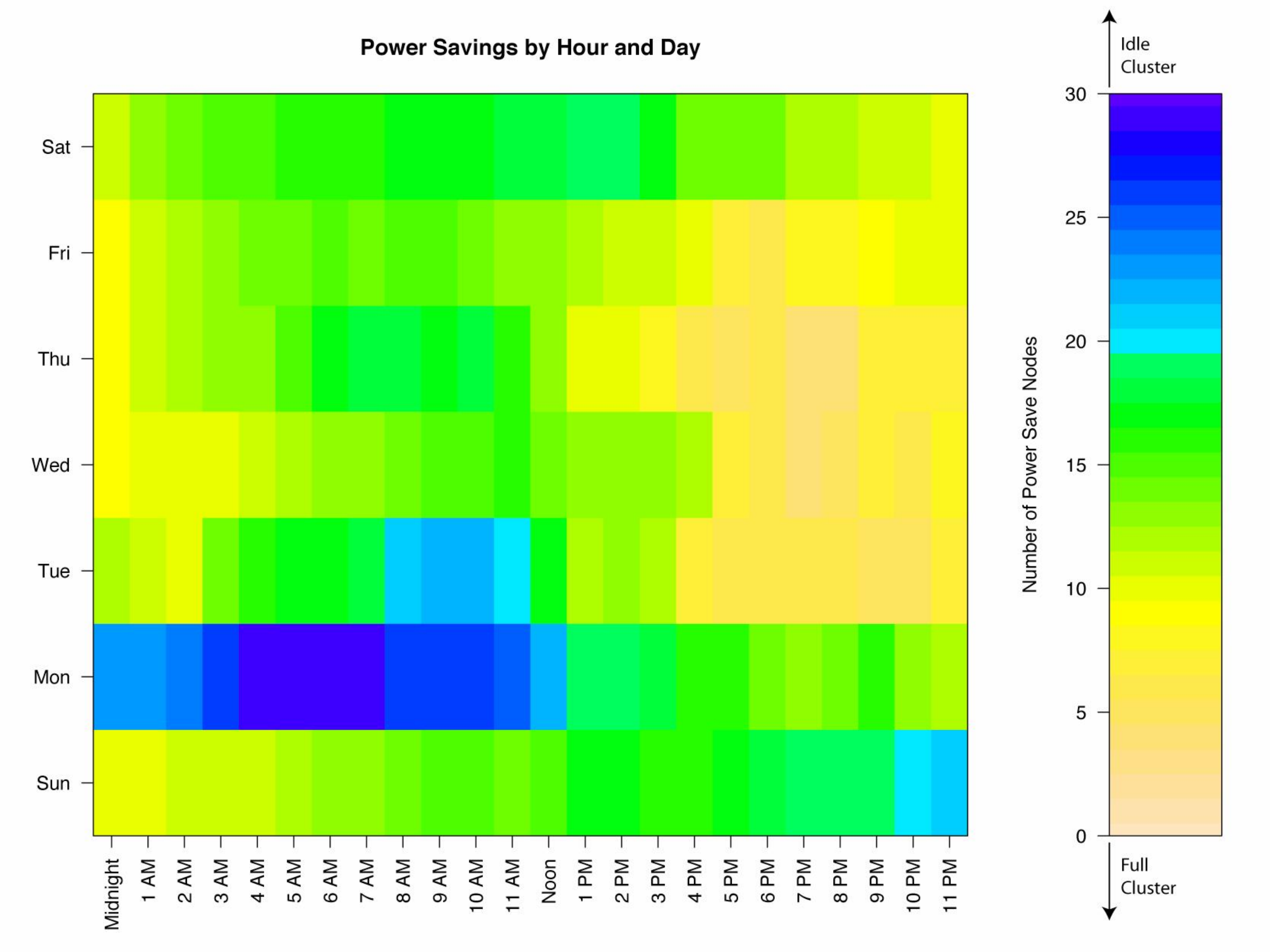


Results: Six Months of CPM



Future Ideas/Challenges

- Tunable parameters
  - Function of time of day, day of week?
  - Based on past observations?
- Balance runtime of nodes
- Balance heat distribution in data center
  - Synchronize with HVAC rotation schedule and failures

Physical Plant

Future Ideas/Challenges

- Integration with building systems
  - Detecting nascent problems is critical
  - Very fast temperature rises
- Integration with power companies
  - IT is being targeted as an ‘easy’ load to manage in an emergency
  - Variable power costs (over time, across locations)

Thank You

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Q & A

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