Highlights of Early Facility Experience at the New High Efficiency NCAR Wyoming Supercomputing Center

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General Facility Information

- 153,000 Gross Sq.Ft.
- 2 - 12,000 Sq.Ft. Data Halls
- 4 – 4MW electrical modules 16MW possible
- 98~99% annual hours Evaporative Water Side Economizer
- Critical Systems are on UPS and Generator Backup
  - Network, Cybersecurity, Storage, Archive
  - HPC Nodes are not on UPS
- 10 ft. Raised Floor System
  - Primary reason was large liquid cooled systems
  - Secondary reason limit copper distances
- Heat Pump System Recover Heat from Computing for Building Use

Facility Highlights

- All about Energy Efficiency
  - Operational cost savings
  - Emissions reduction
- Minimize risk
  - Not increasing inlet temperatures or using outside air
  - Utilize liquid cooling where cost effective
- Efficient use of Capital
  - Efficiency efforts had to show 5 year payback

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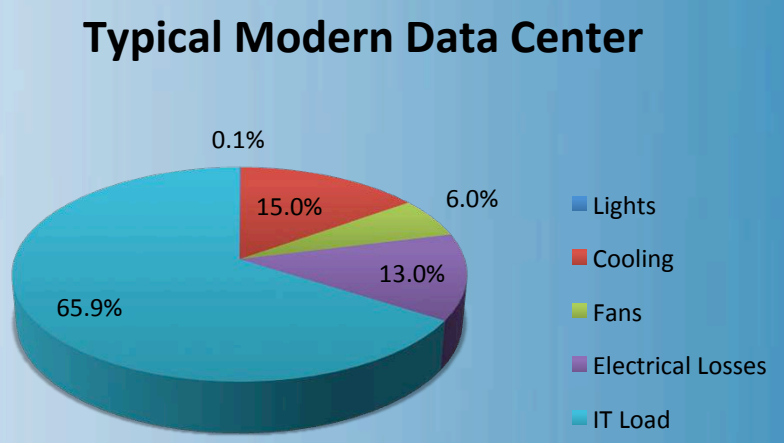
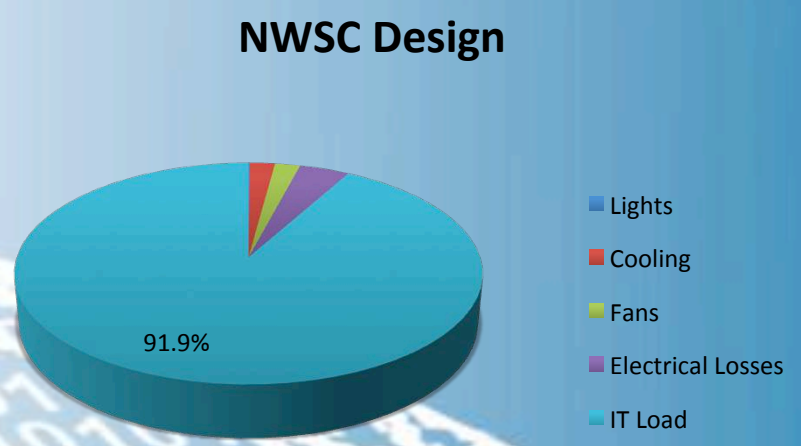
Big Picture Focus On Efficiency

- Utilize the regions cool, dry climate to minimize energy use
  - Very low pressure drop
    - Minimize bends
    - Oversized pipe
  - Elevated chilled water temp
    - 65 degree
- Utilize liquid cooled computer solutions where practical
  - HPC Systems
- Utilize hot aisle containment for commodity equipment
- Focus on the biggest losses
  - Compressor based cooling
  - Transformer losses





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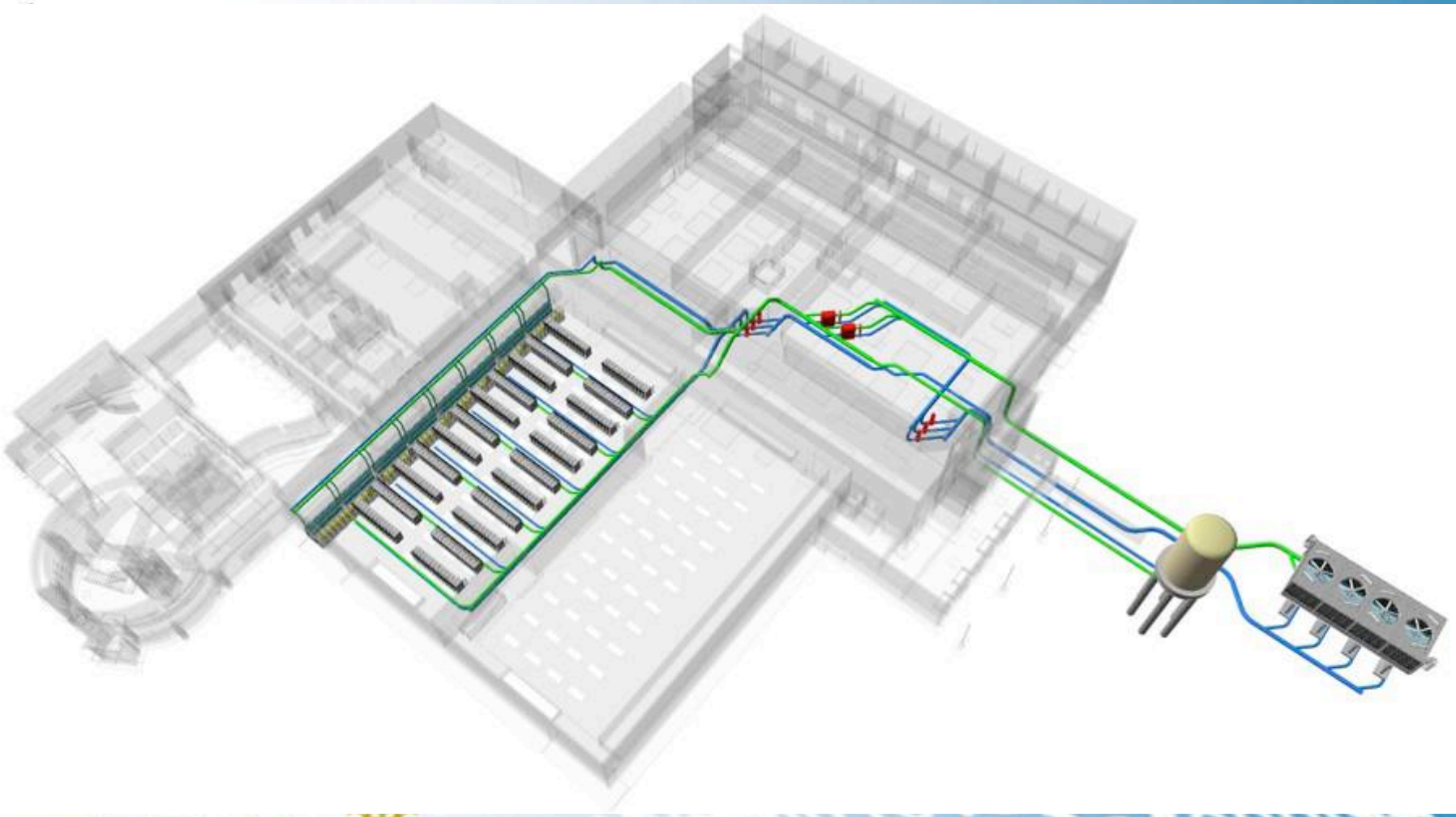
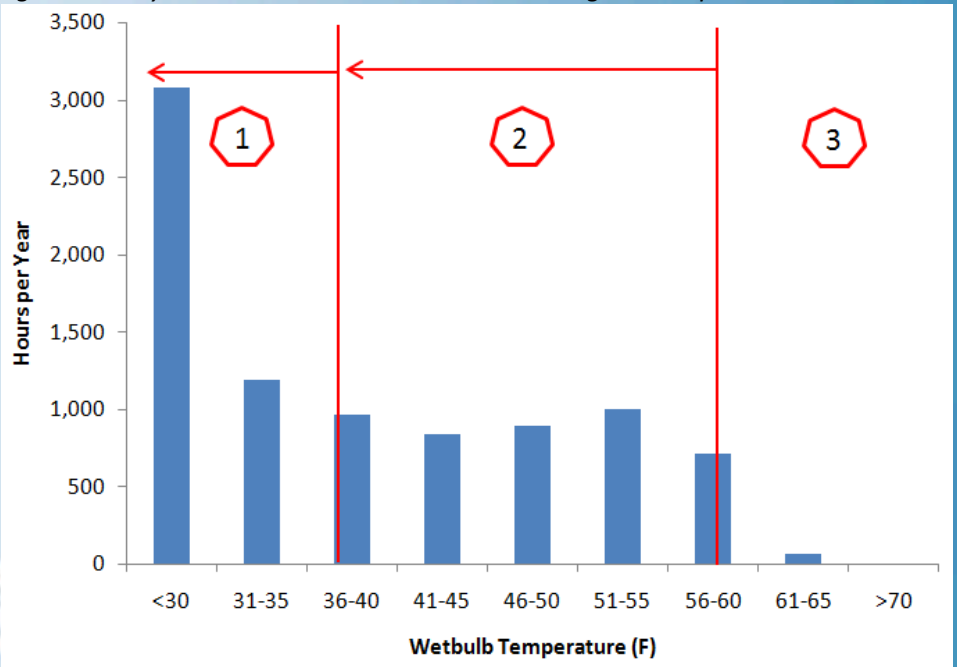
65 F (18.3 C) Degree Chilled Water Evaporative Solution



Cooling Tower

- Very high efficiency tower
- Utilization of outside conditions to optimize performance
  - ***Water use reduction*** by not running the fans all year
  - ***Energy use reduction***

Figure 4: Cheyenne weather conditions and cooling tower operation



Region 1: Cooling tower without fans, 46% of the year
Region 2: Cooling tower with fans, 48% of the year
Region 3: Chiller operates, 7% of the year

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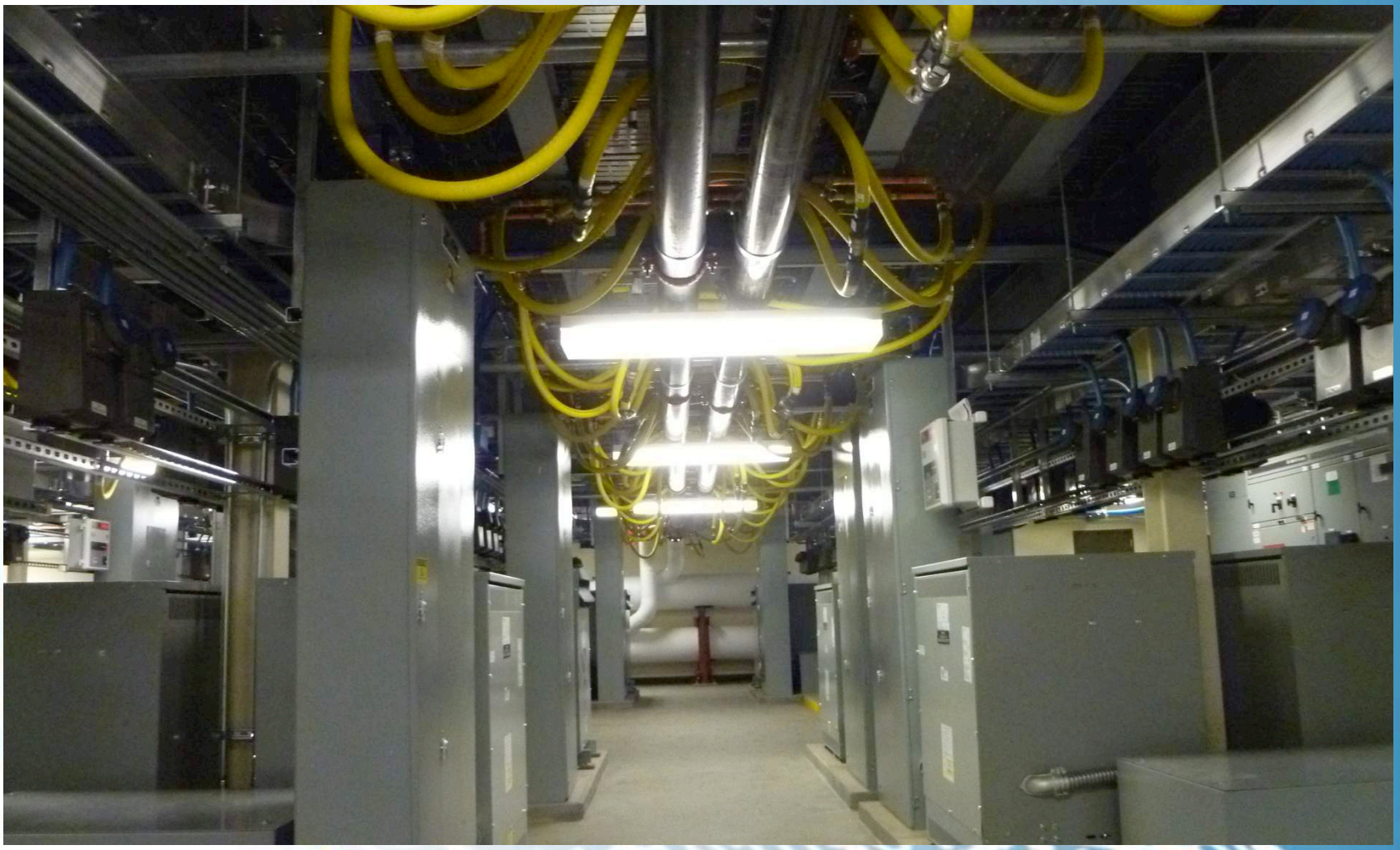
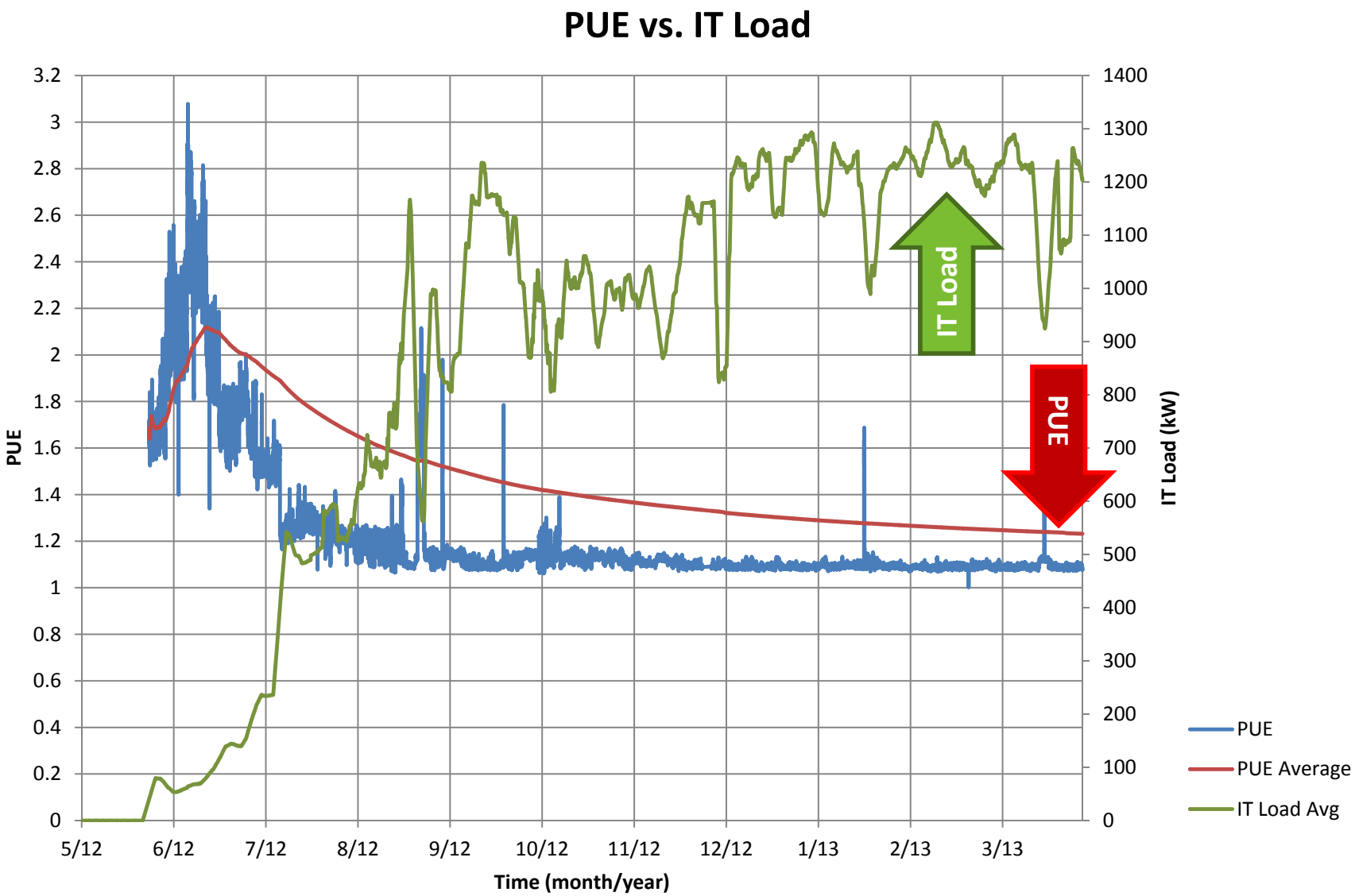
Hot Aisle Containment

Fan Wall and 10 ft. (3 m.) Raised Floor

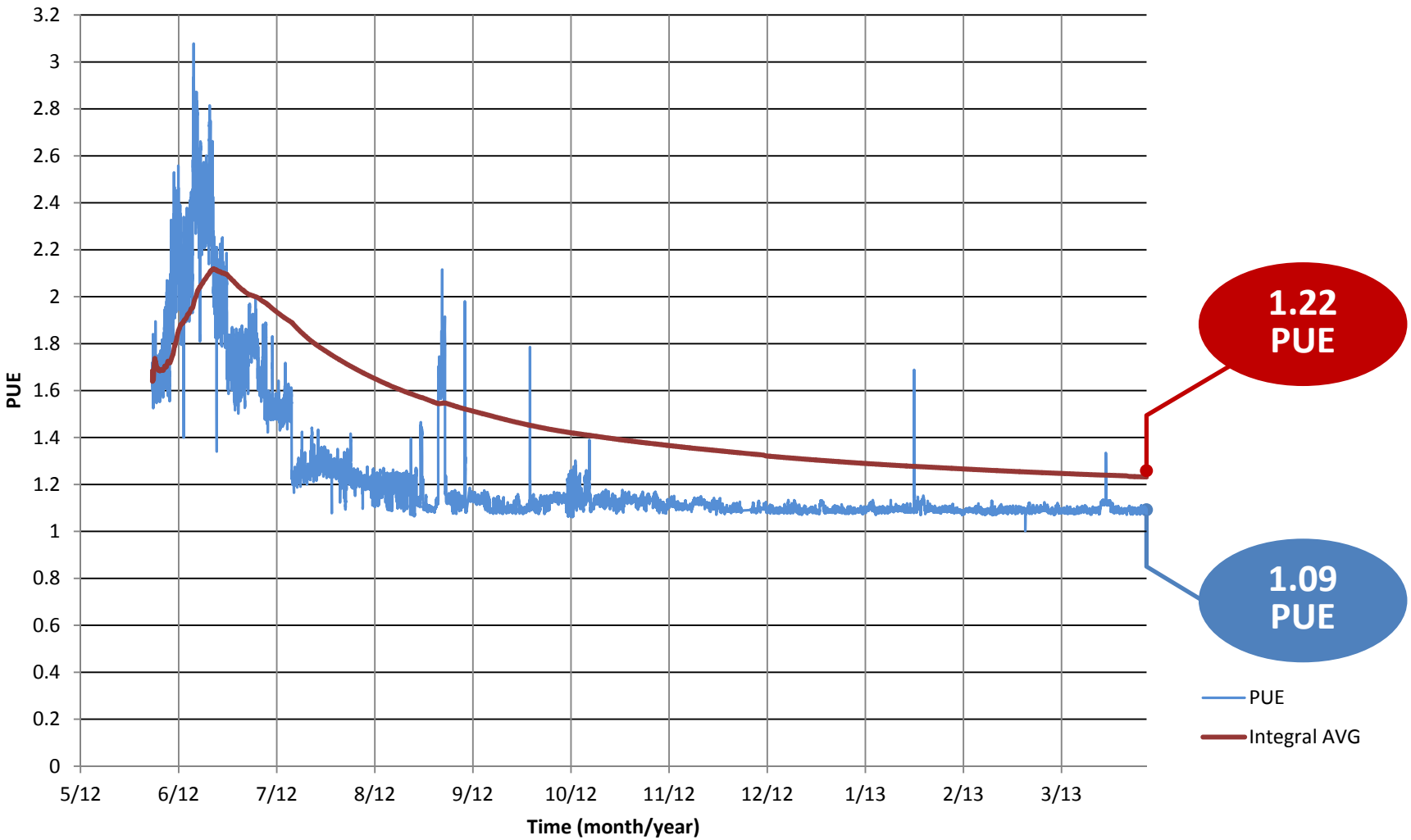
Yellowstone Water Cooling



IT Load and Facility Tuning



Actual Annual PUE
Trending Toward Design PUE



Two Main Sources of Variability

- Computer Load Variability
  - Power saving computer system at scale
  - Peak Demand ~1700W
  - Typical ~700kW – 1500kW
  - Idle ~300kW
- Weather Variability
  - Heating Load increase in winter months affects PUE
  - Real cost savings in part dependent on natural gas prices

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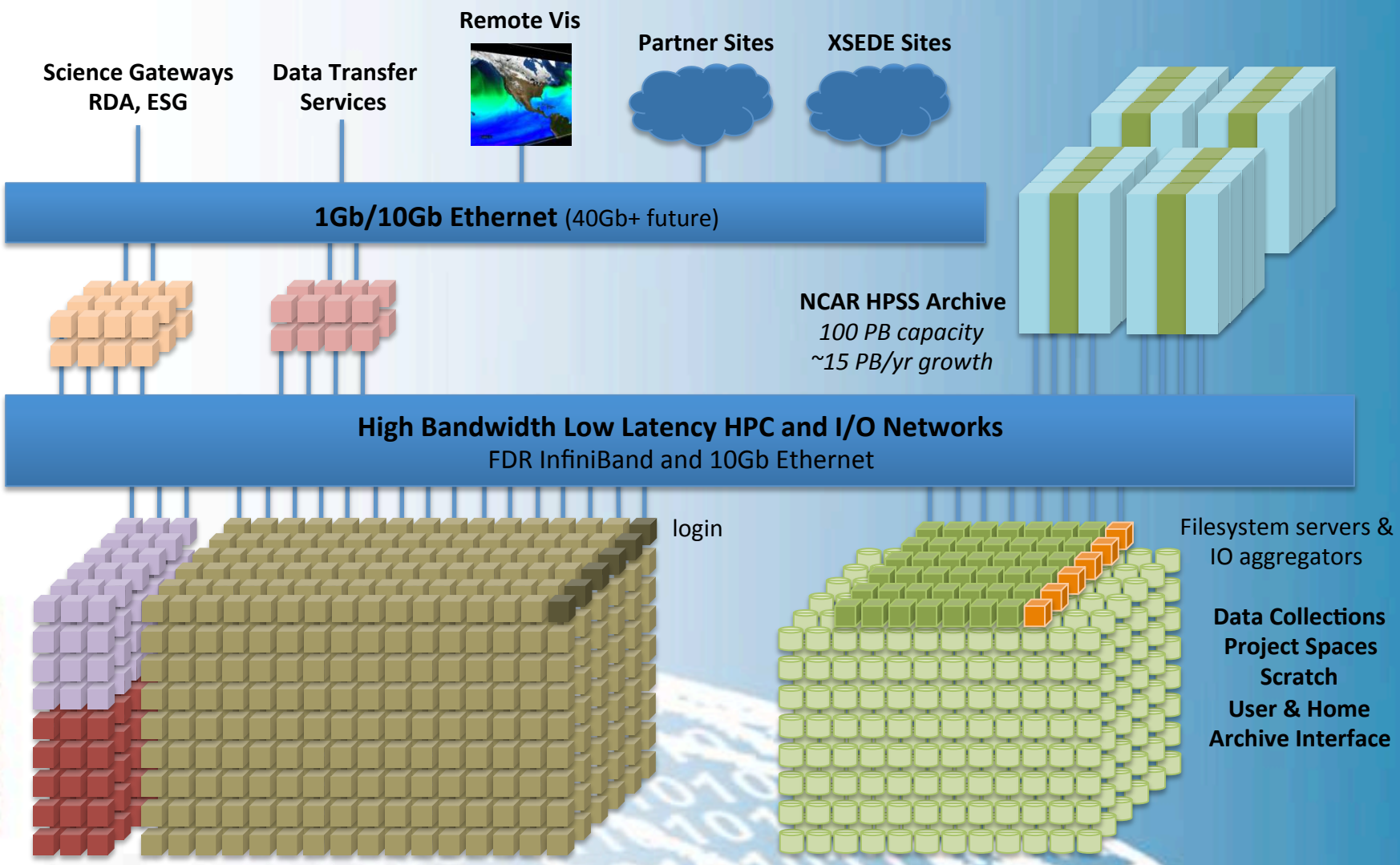
NCAR Data-Centric Architecture



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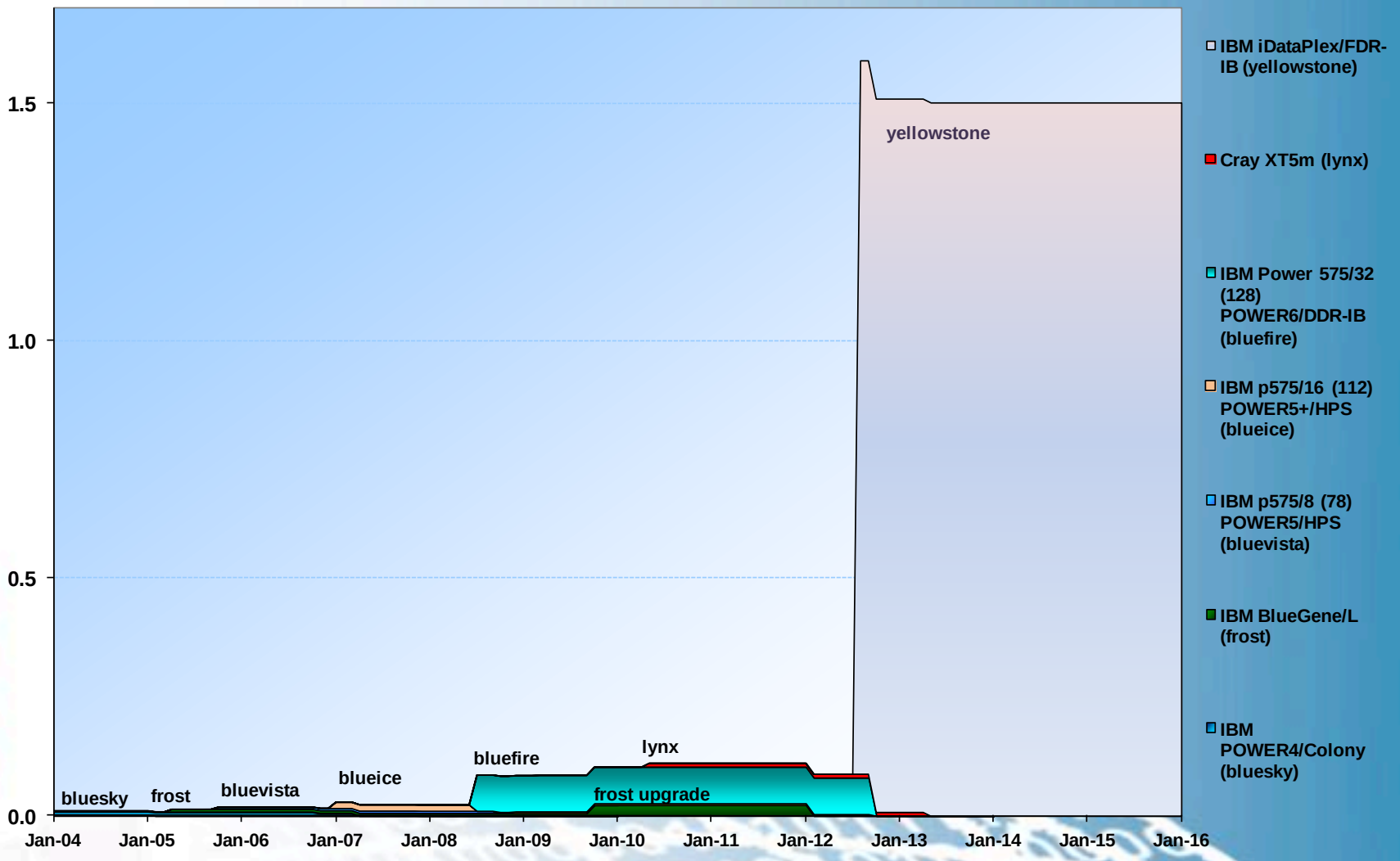
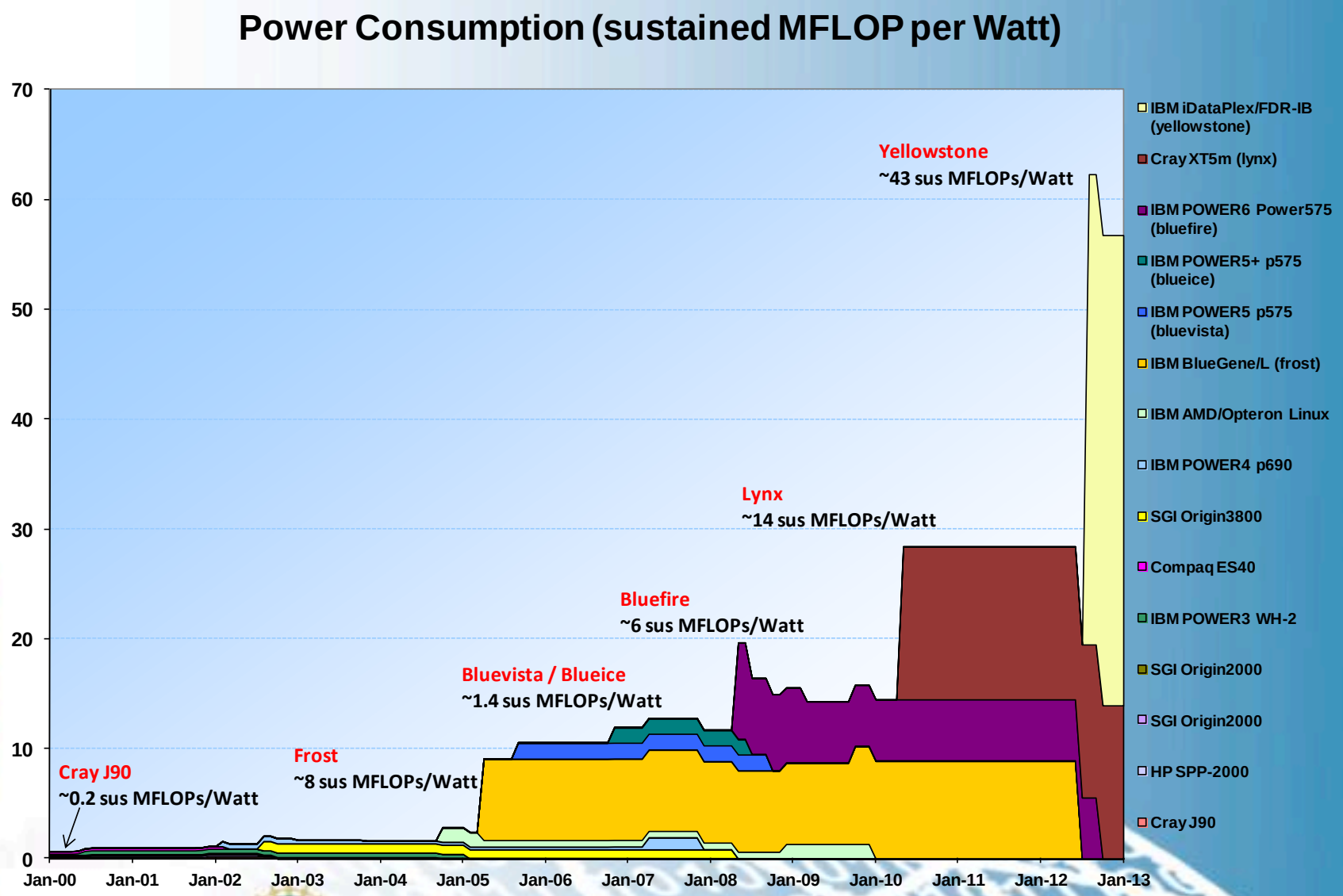
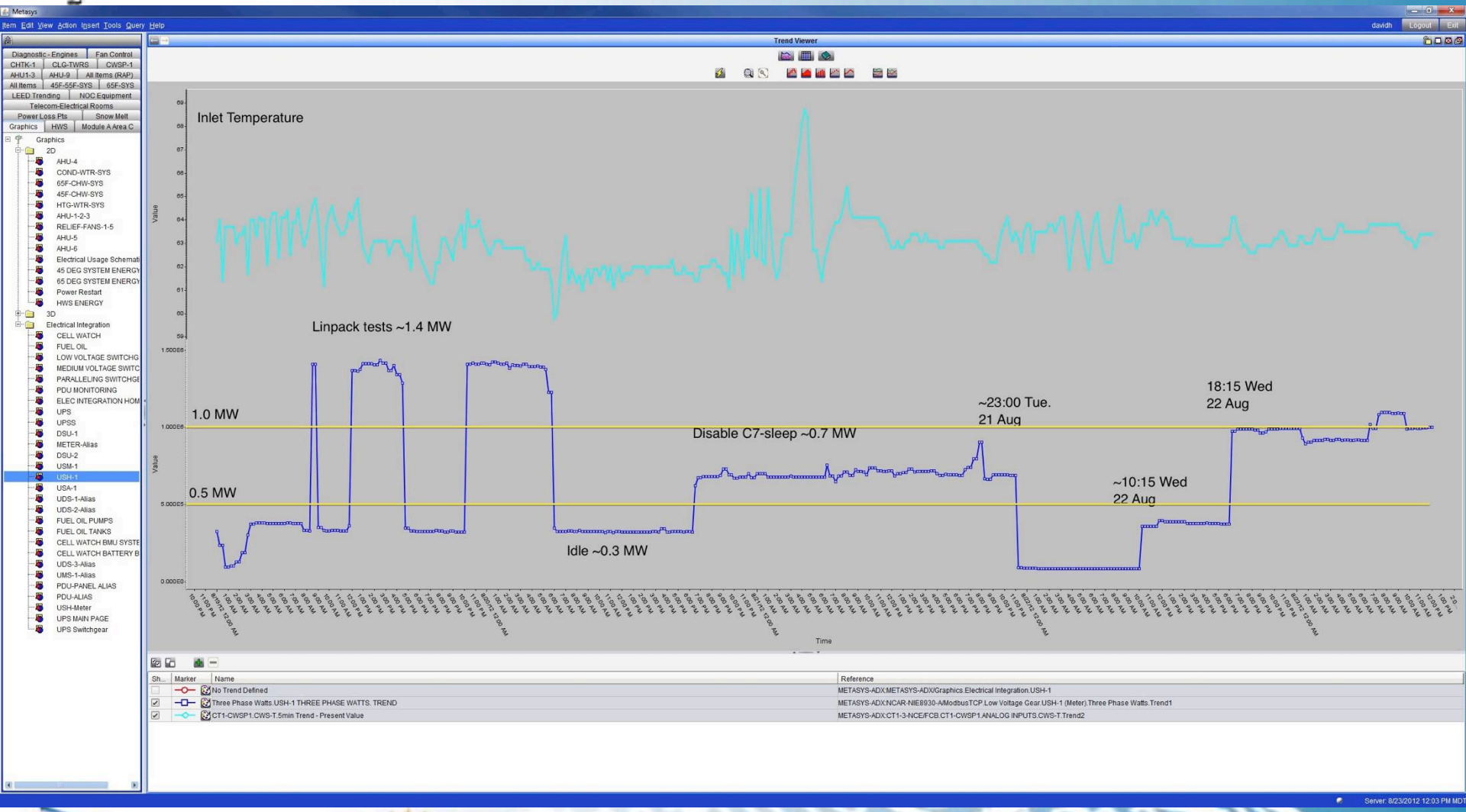
NCAR HPC Profile



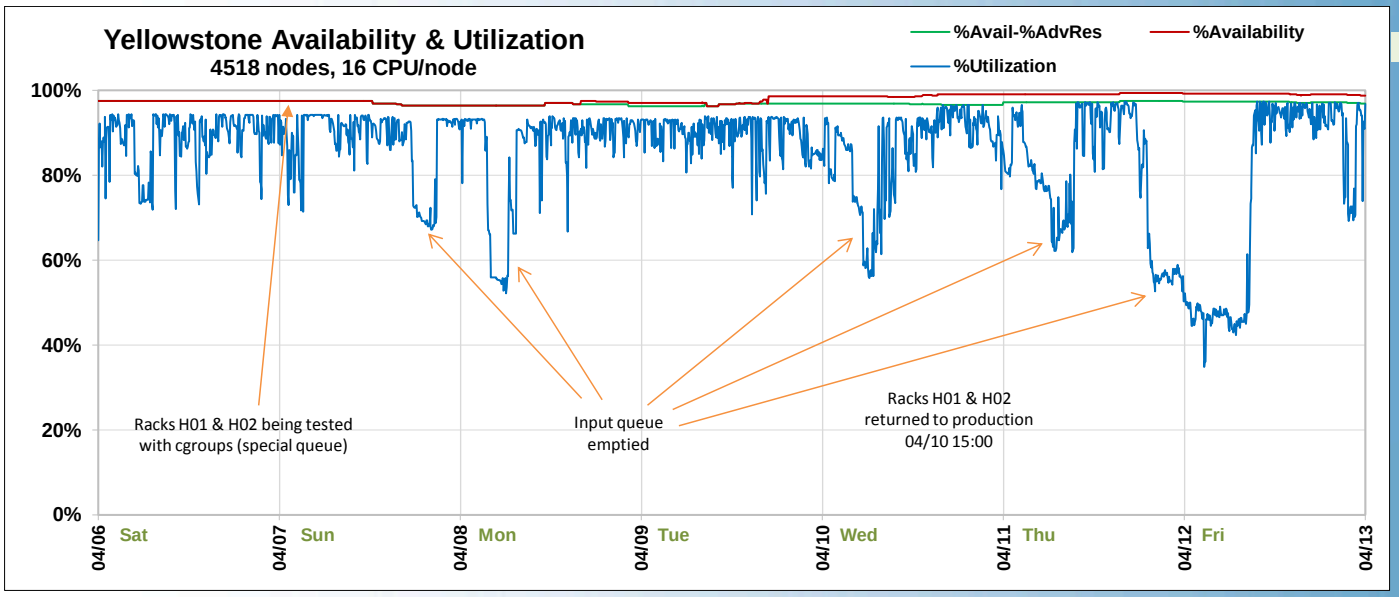
Historical Power Efficiency on NCAR Workload



Beyond PUE
Highly Dynamic Compute System Loads



System Utilization

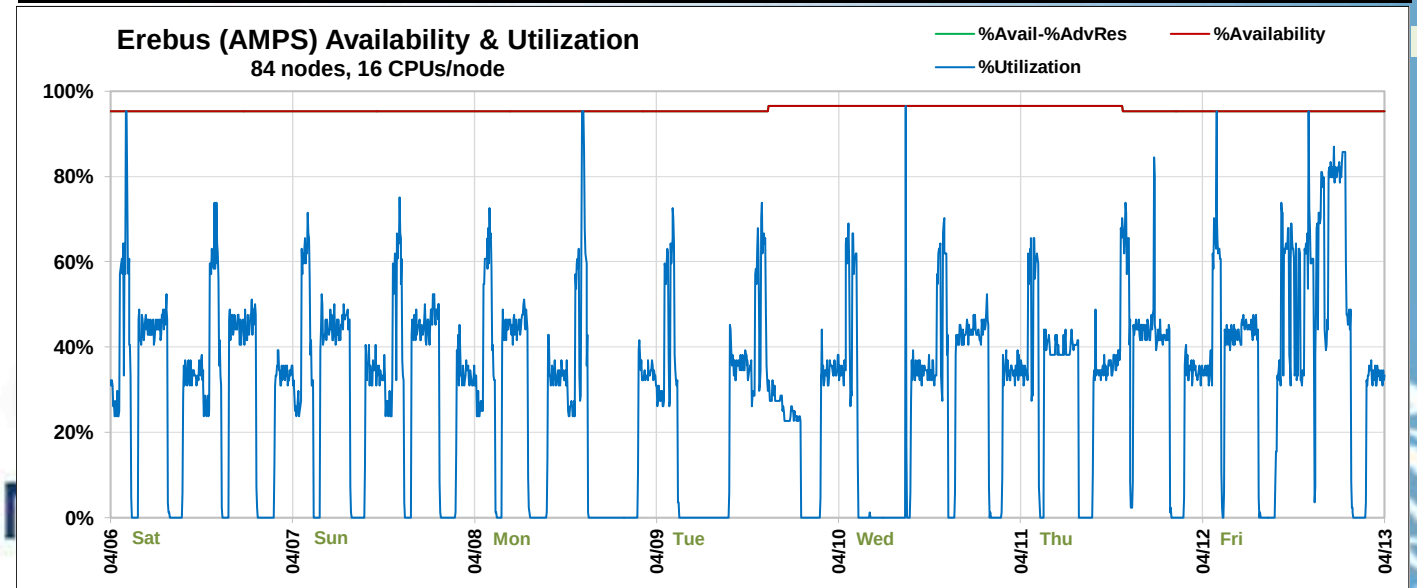


Yellowstone

Avg Availability
98.02%

Avg Utilization
84.82%

Avg AdvRes
0.97%



Erebus

Avg Availability
95.57%

Avg Utilization
29.67%

Avg AdvRes
0.00%

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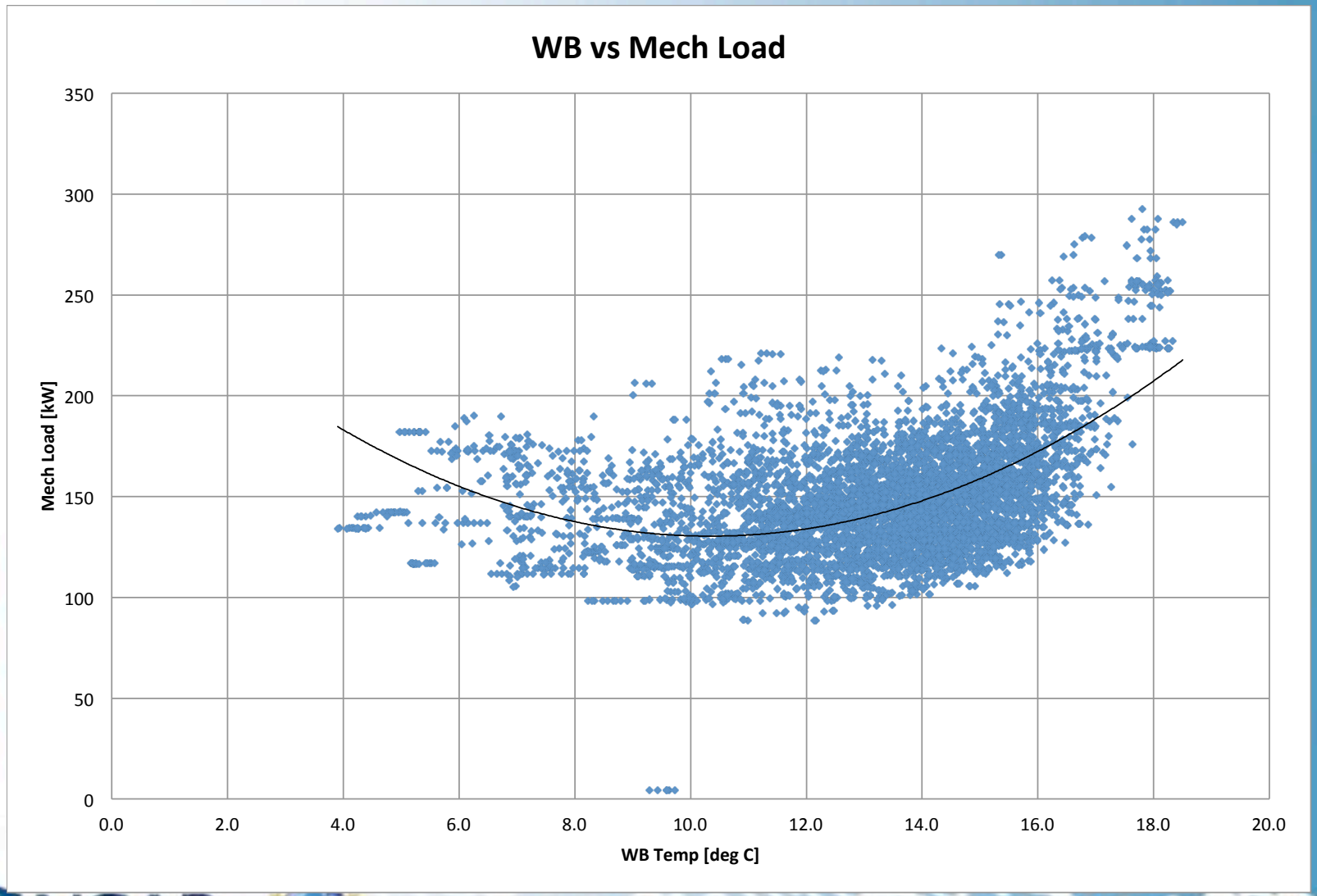
Summer Mechanical Trend



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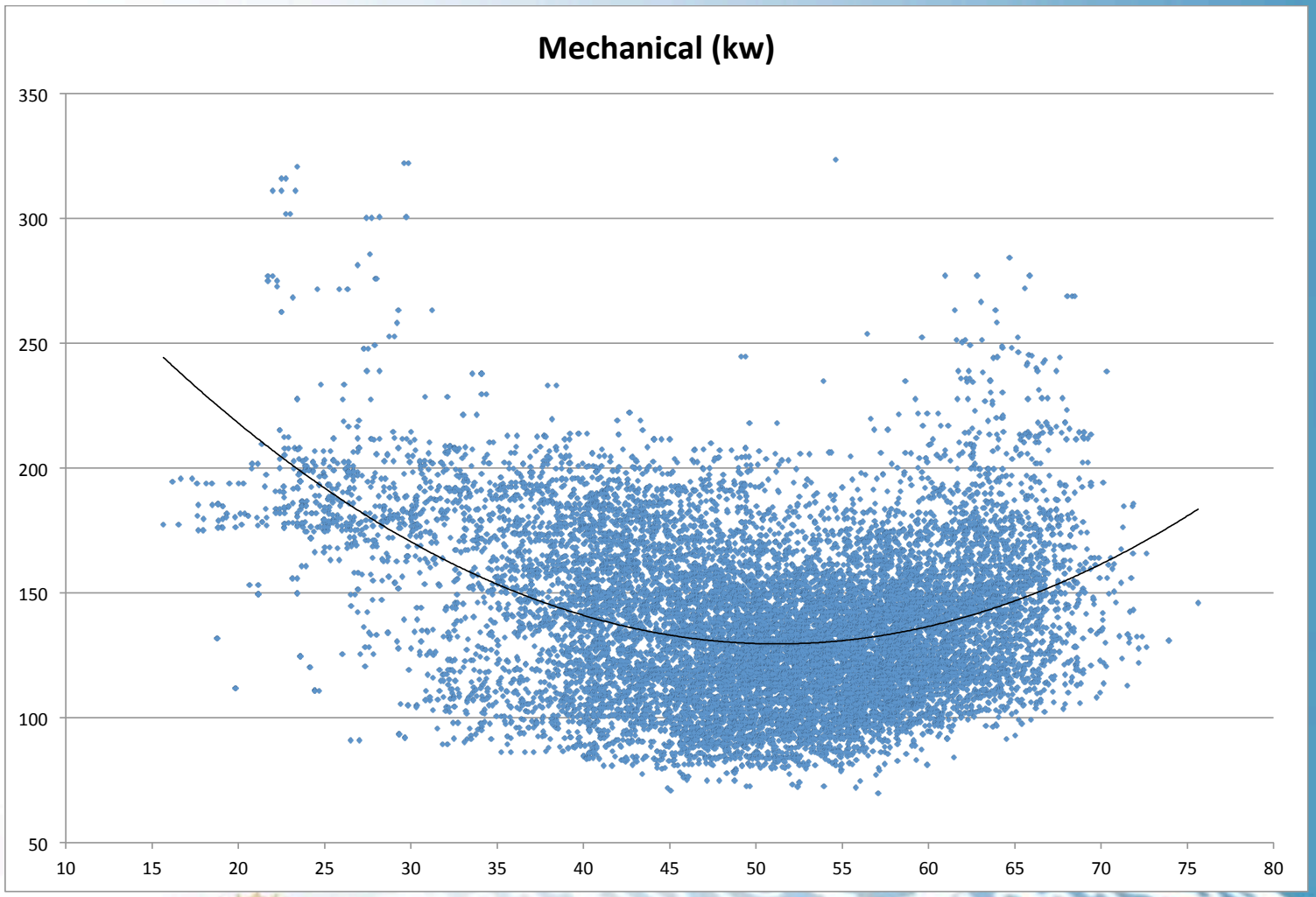
An Initial Fall Surprise
(Mechanical Load (kw) vs. WetBulb (F)



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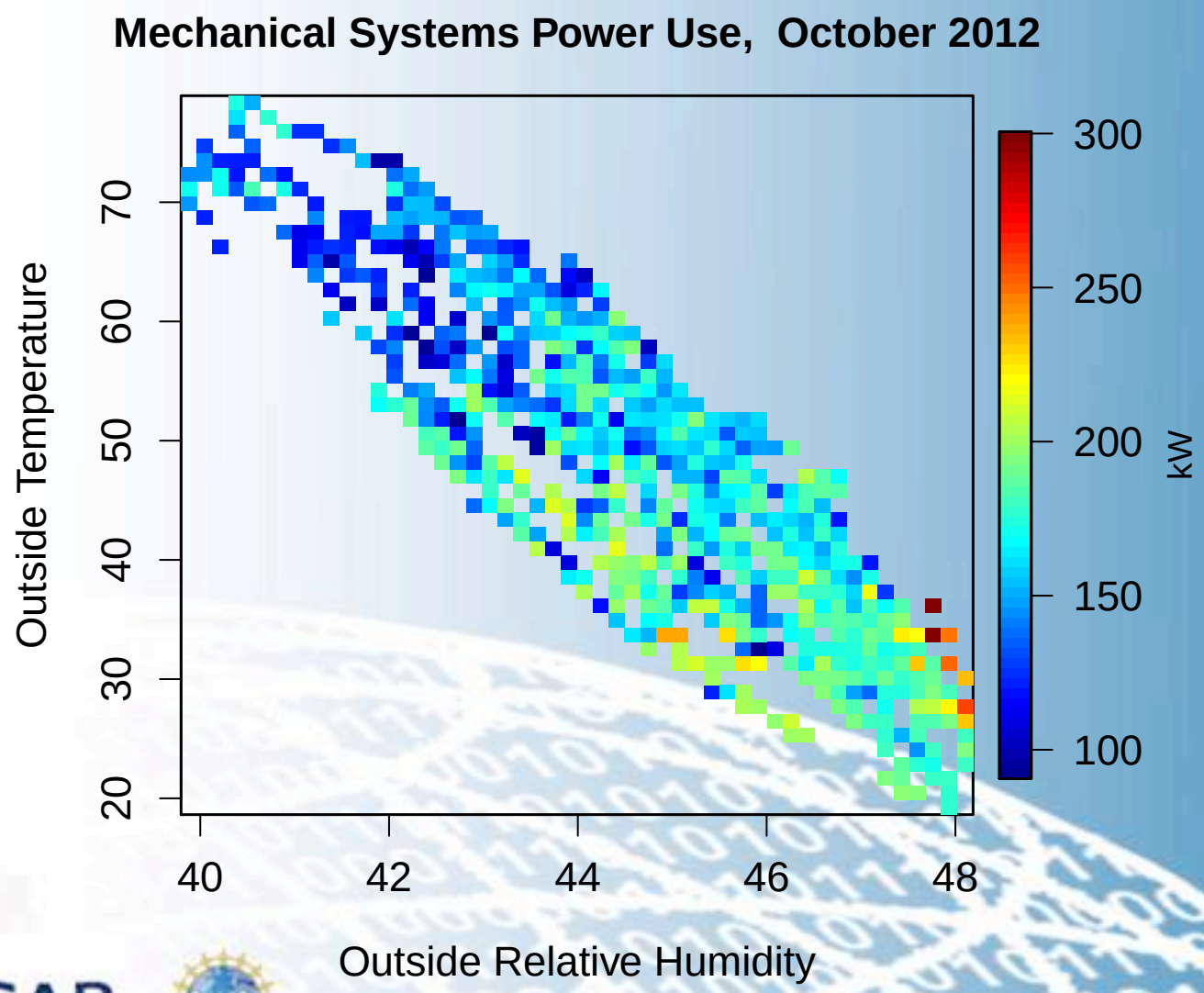
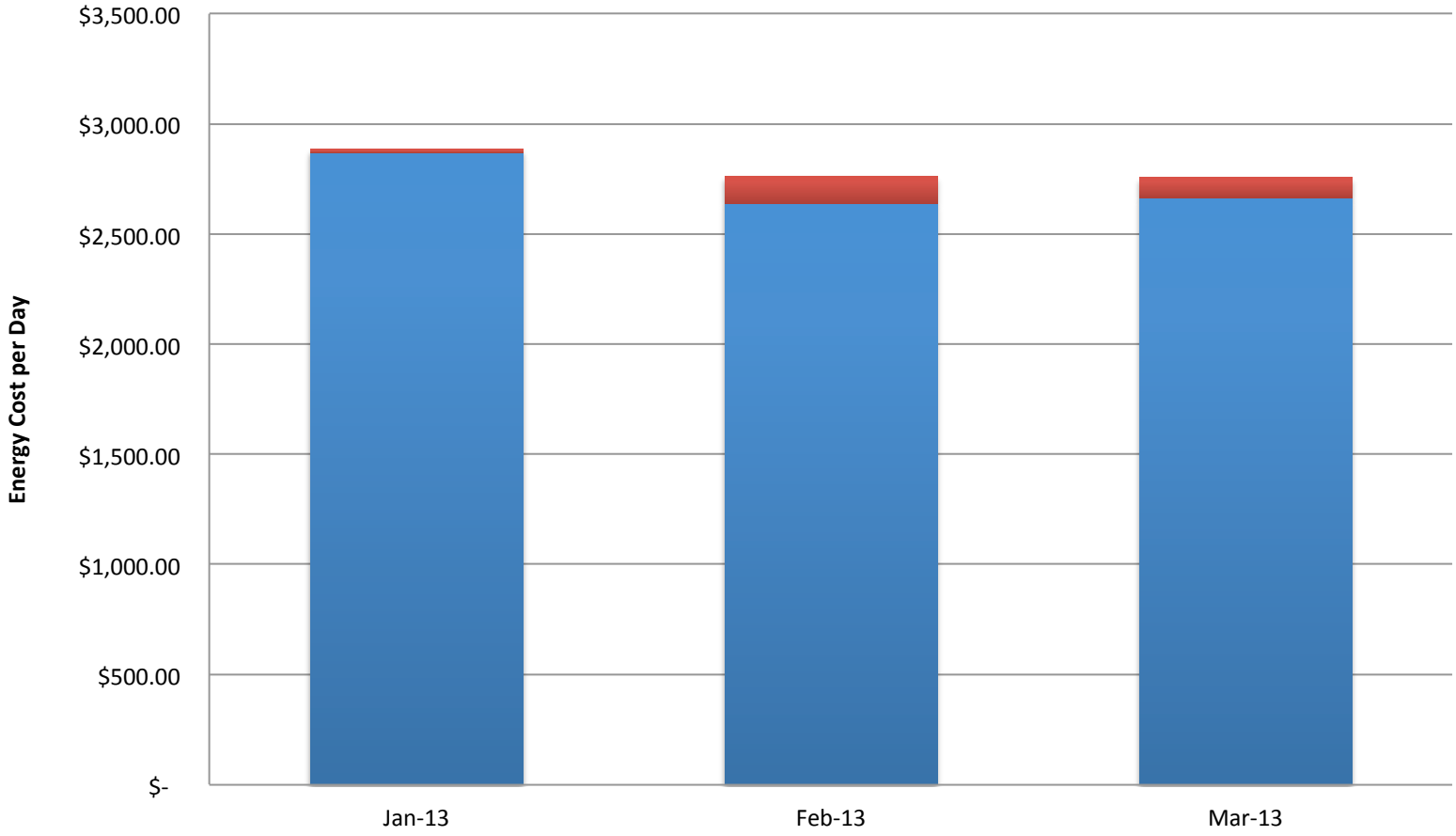
Looking Closer at October Data



Comparison of Daily Cost Heat Pumps vs. Boiler



	Jan-13	13-Feb	13-Mar
Cost Per Day Gas	$14.14	$122.95	$90.76
Cost Per Day Elec	$2,870.19	$2,638.93	$2,665.76

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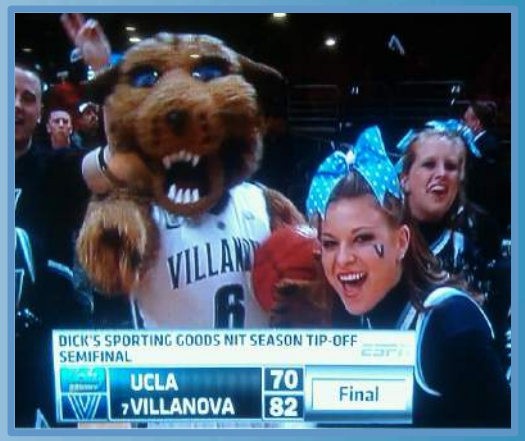
NWSC as a Teaching Laboratory

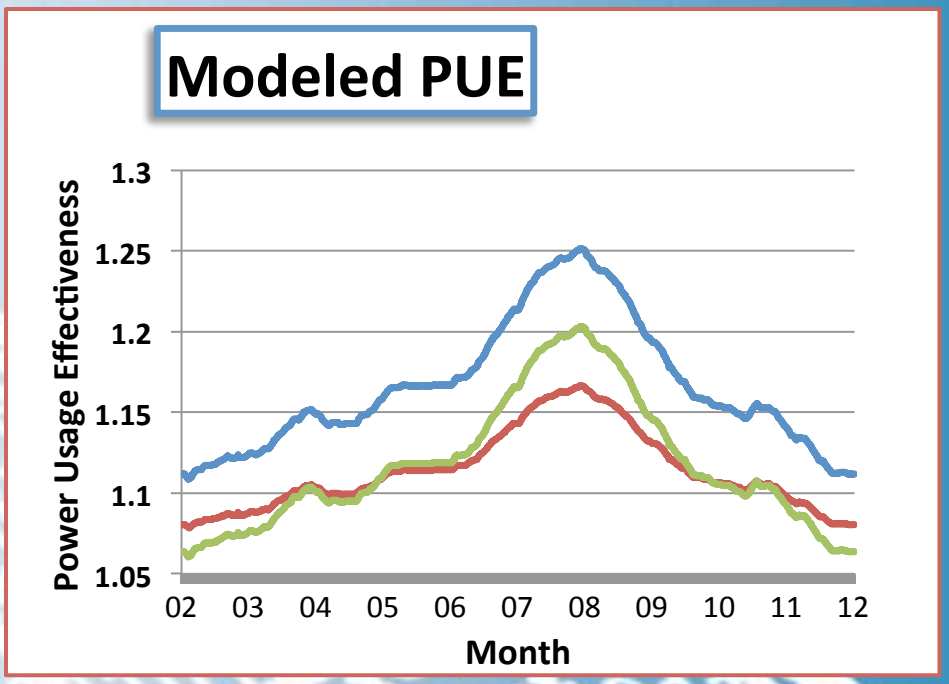
Emerson Hannon

Villanova

Electrical Engineering



- Energy Efficiency
- Modeling of NWSC during construction
- Developed energy model NWSC based on outside conditions



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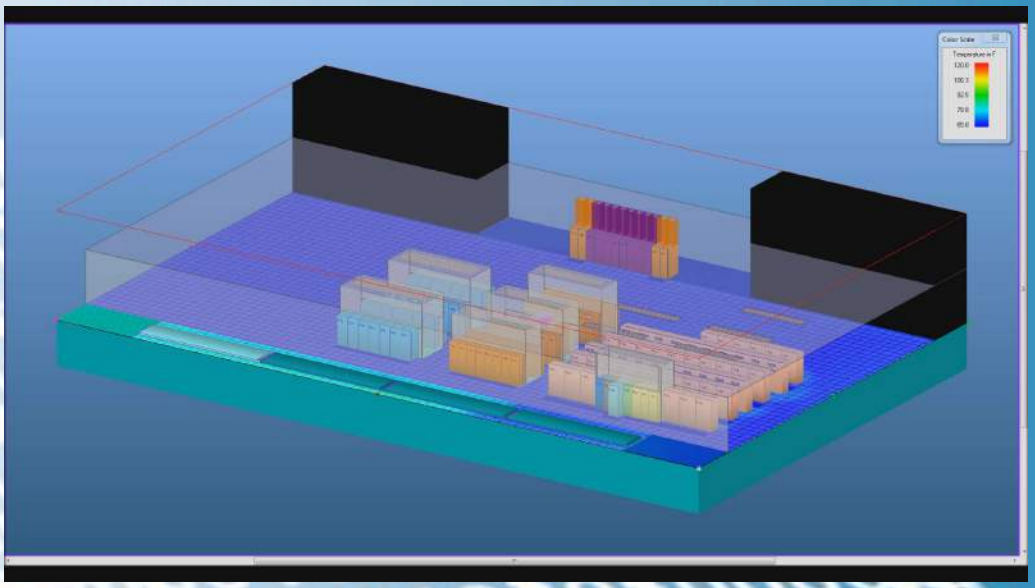
Jared Baker

University of Wyoming
Mechanical Engineering

- Computational Fluid Dynamics
- Validated TileFlow During Construction
- Simulated multiple computer vendor configurations during procurement selection process



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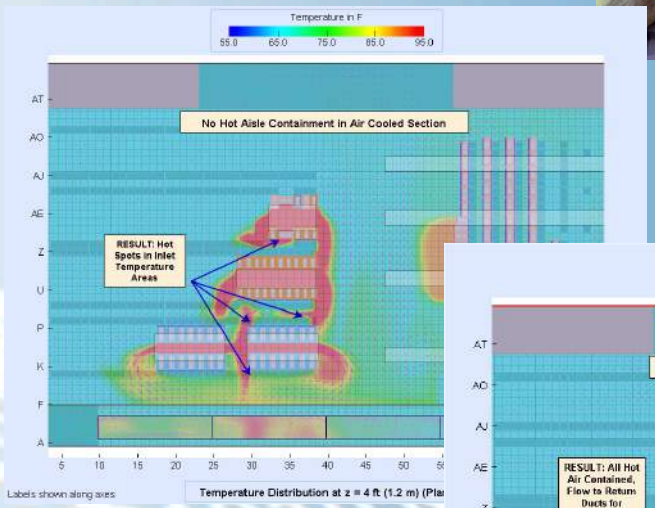
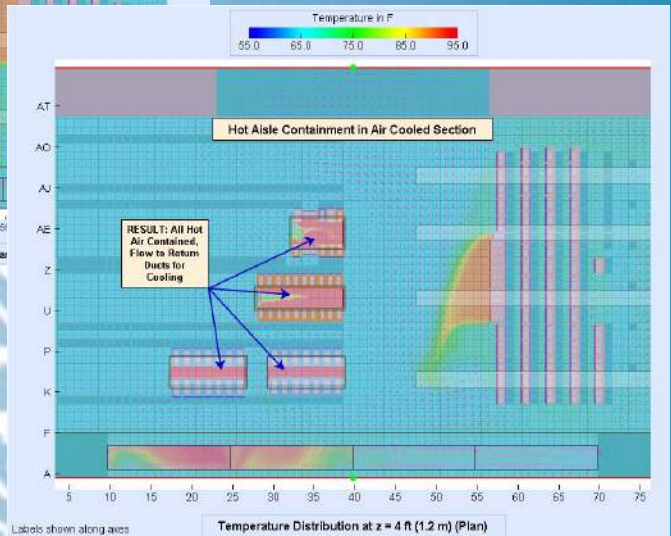
Clair Christofersen

University of Miami Ohio
Mechanical Engineering – Applied Math

- Compared Jared's Model to Actual Conditions
- Further Tileflow analysis
- Comparison of Hot Aisle Containment
- Temperature pressure measurements





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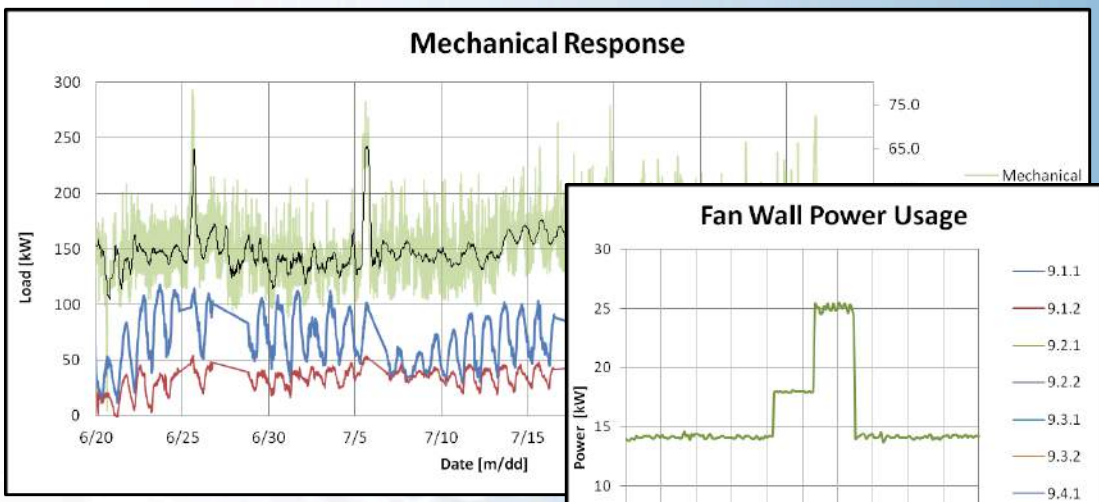
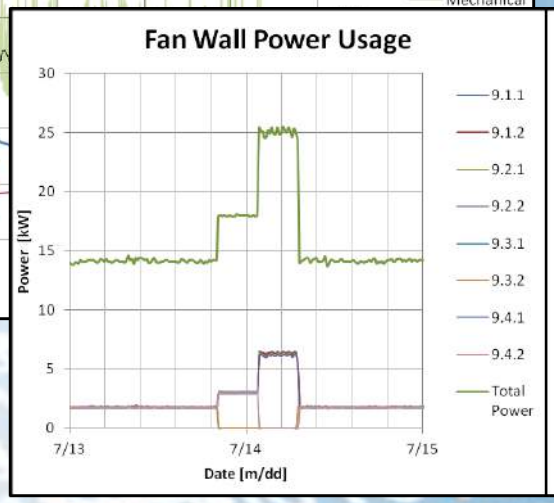
Jason Jones

Clemson University
Mechanical Engineering

- Energy Efficiency Analysis & Measurement
- Comparison of Actual to Model
- Fan wall energy analysis
- Mechanical response to ambient conditions





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Ademola Olrinde

Texas A&M Kingsville

Mechanical Engineering

- Energy Efficiency Optimization of NWSC
- Detailed Analysis of 12 month operating Data
- Optimization Efforts
  - UPS Systems
  - Heat Pumps
- Graduate Work in Pipe Flow and Pumping Power

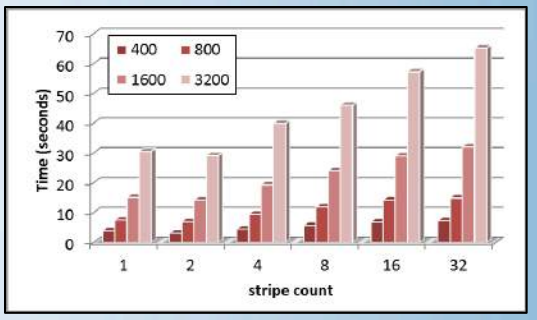
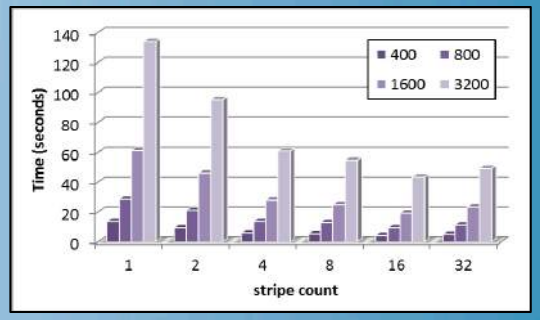
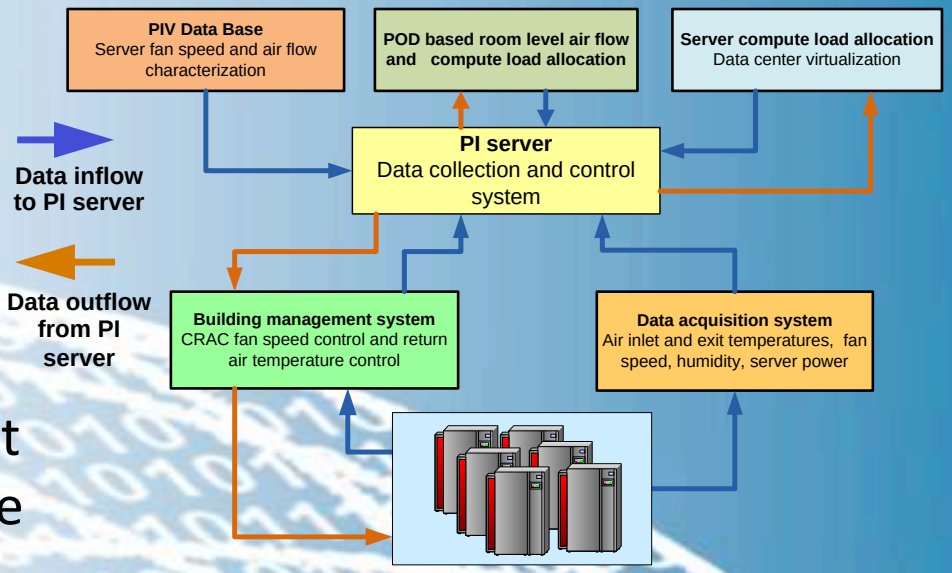
Now Focused on the Left Side of PUE Decimal

"Stochastically Robust Resource Allocation for Thermal-Aware Heterogeneous Computing"

NSF Funded Proposal

- Colorado State University
  - Sudeep Pasricha
  - HJ Siegel
  - Mark Oxely
- NSF Funded Project
- Looking at energy aware resource scheduling

"Optimized Energy Aware Scientific Throughput at Scale"

NSF Proposal Stage

- NCAR
  - Aaron Andersen
  - Stephen Sain
- Colorado State University
  - Sudeep Pasricha
  - HJ Siegel
- Georgia Institute of Technology
  - Yogendra Joshi
- Power Aware Scheduling
- Power Aware Data Movement
- Statistical Approaches to Scale