LANL High Performance Computing Facilities Operations

Rick Rivera and Farhad Banisadr

Facility Data Center Management

High Performance Computing Division

Los Alamos NATIONAL LABORATORY
LAUR-09-04524
Operated by Los Alamos National Security, LLC for DOE/NNSA
NNSA National Nuclear Security Administration

UNCLASSIFIED

Outline

- Overview - LANL Computer Data Centers
- Power and Cooling
- CFD Data Center Modeling
- Data Center Power Usage and Efficiency
- Exa-Scale Challenges

High Performance Computing Division Mission

World-class facilities to support high performance computing systems

Nicholas C. Metropolis Center for Modeling and Simulation 2002
- 43,500 sq ft computer room floor
- 9.6 MW Rotary UPS power
- 9.6 MW Commercial power
- 6000 tons chilled water cooling

Laboratory Data Communications Complex (LDCC) – 1989
- 20,000 sq ft computer room
- 8 MW Commercial power
- 3150 tons chilled water cooling

High Performance Computing Systems

Secure Classified Computers - SCC

Redtail—IBM, 64.6 teraflop/s

Roadrunner—IBM (Cell), 1376 teraflop/s

Hurricane—Appro, 80 teraflop/s

Typhoon—Appro, 100 teraflop/s

Cielo—Cray XE6, 1370 teraflop/s

Open Unclassified Computers - LDCC

Yellowrail—IBM, 4.9 teraflop/s

Cerrillos—IBM, 160 teraflop/s

Turing—Appro, 22 teraflop/s

Conejo—SGI, 52 teraflop/s

Mapache—SGI, 50 teraflop/s

Mustang—Appro, 353 teraflop/s

Challenges:

- Funding
- Staffing
- Dim lights
- Lights out
- Maintenance philosophy
- Unable to return parts

Monitoring Tools

"In addition to monitoring these systems, the team has taken on the responsibility of providing maintenance and support for all the supercomputer systems currently installed at the Laboratory."

Bob Villa, HPC-2 support staff

New System Installation

Hardware Repair

"The team that never sleeps..."

24 x 7

Immediate Response

HPSS Storage Maintenance

Logistics

Increased System Availability

Electrical Power Distribution

Metropolis Center (SCC) Building Specific

SCC Features

- Multiple 13.2 kV feeders
- Double ended substations
- Rotary uninterruptible power supply (RUPs)
- Scalability
- Power conditioning transient voltage surge suppressor (TVSS)

Switchgear

Substation

RUPS power distribution

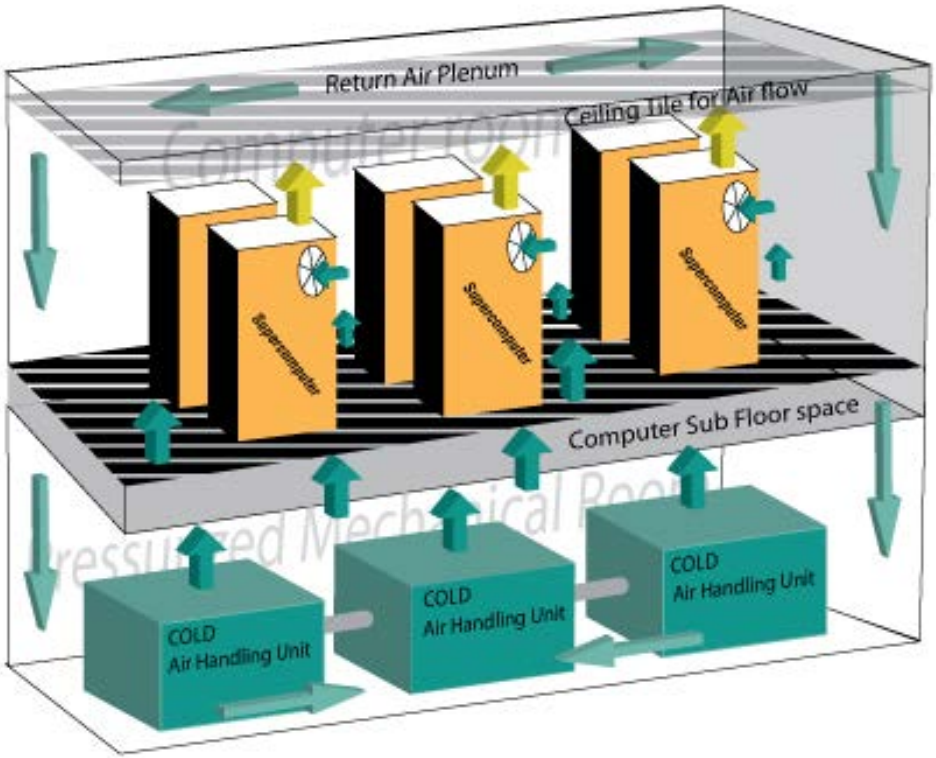
PDU power distribution

Supercomputing Systems

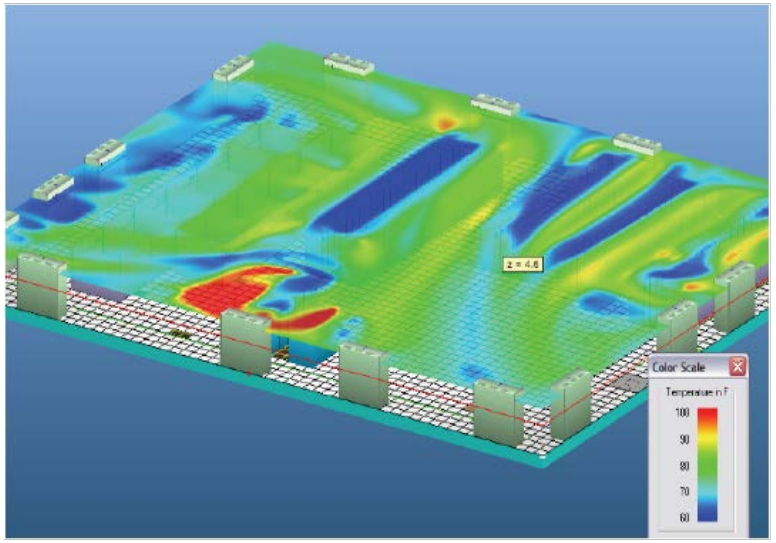
Metropolis Center (SCC) Infrastructure Upgrade Project

- Split sub-stations (19.2 MW)
- Added 1,200-ton chiller
- Added cooling tower
- 14 additional air handling units (AHUs)
- Water cooling (9 MW load)

Air Systems



Cold air generated by the air handling units is forced up through perforated tiles above the computer room sub floor. The air passes through and removes heat from the supercomputers, then is vented through the ceiling tiles and return plenums to complete the path back to the air handling units below.

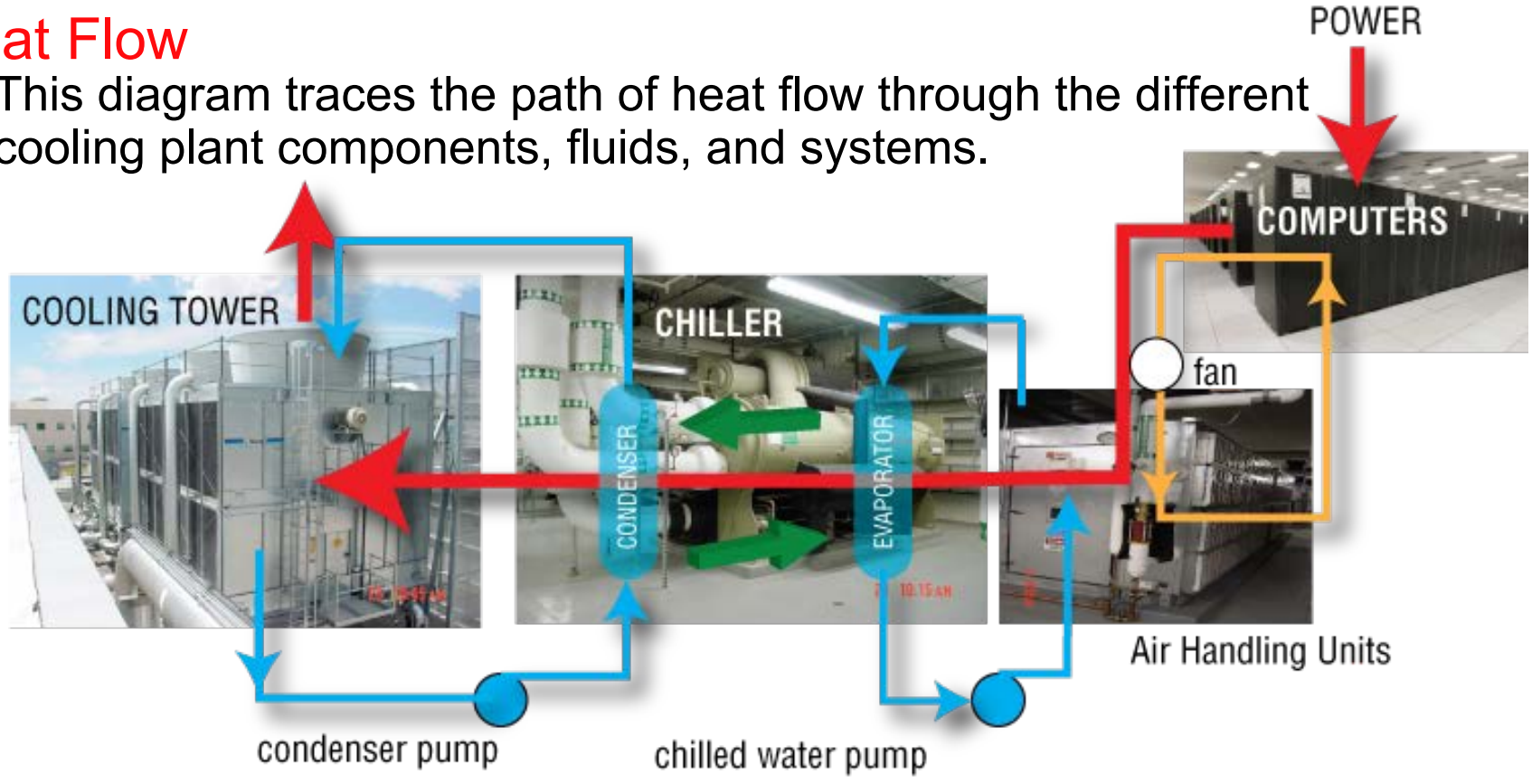


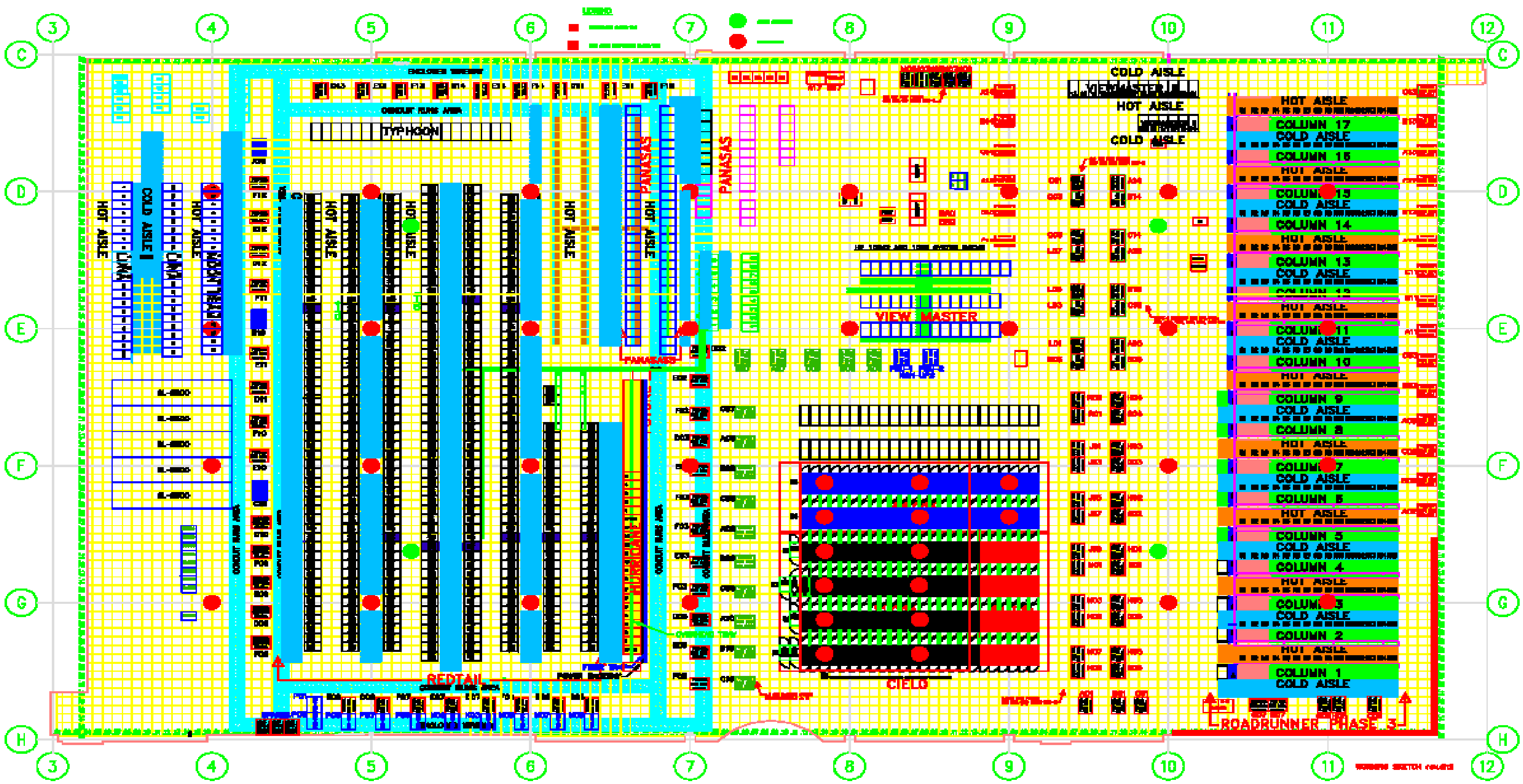
As heat densities associated with supercomputers increase, modeling becomes critical. This graphic shows a computer room air temperature profile.

Supercomputers require continuous and significant cooling

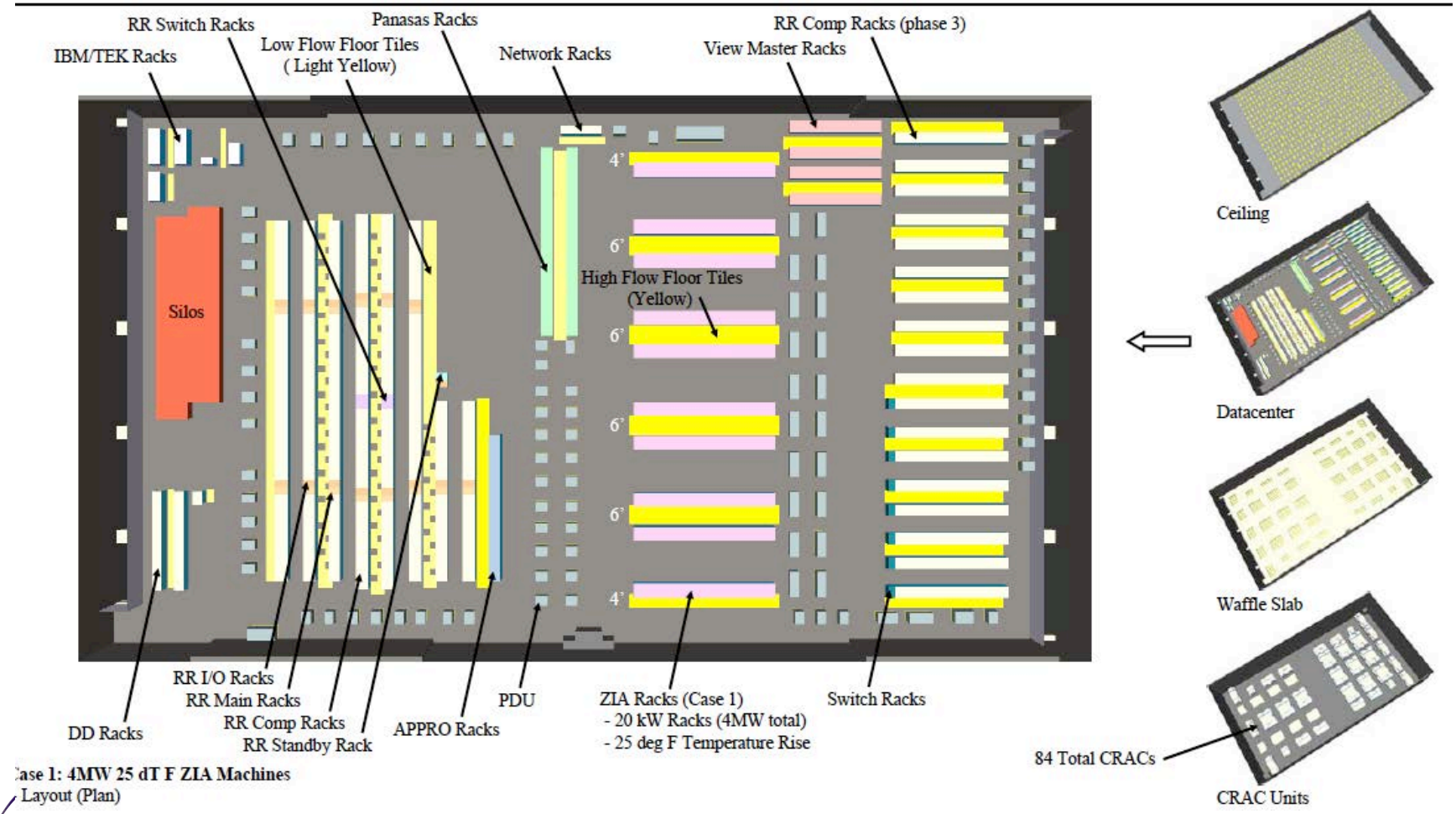
Heat Flow

This diagram traces the path of heat flow through the different cooling plant components, fluids, and systems.

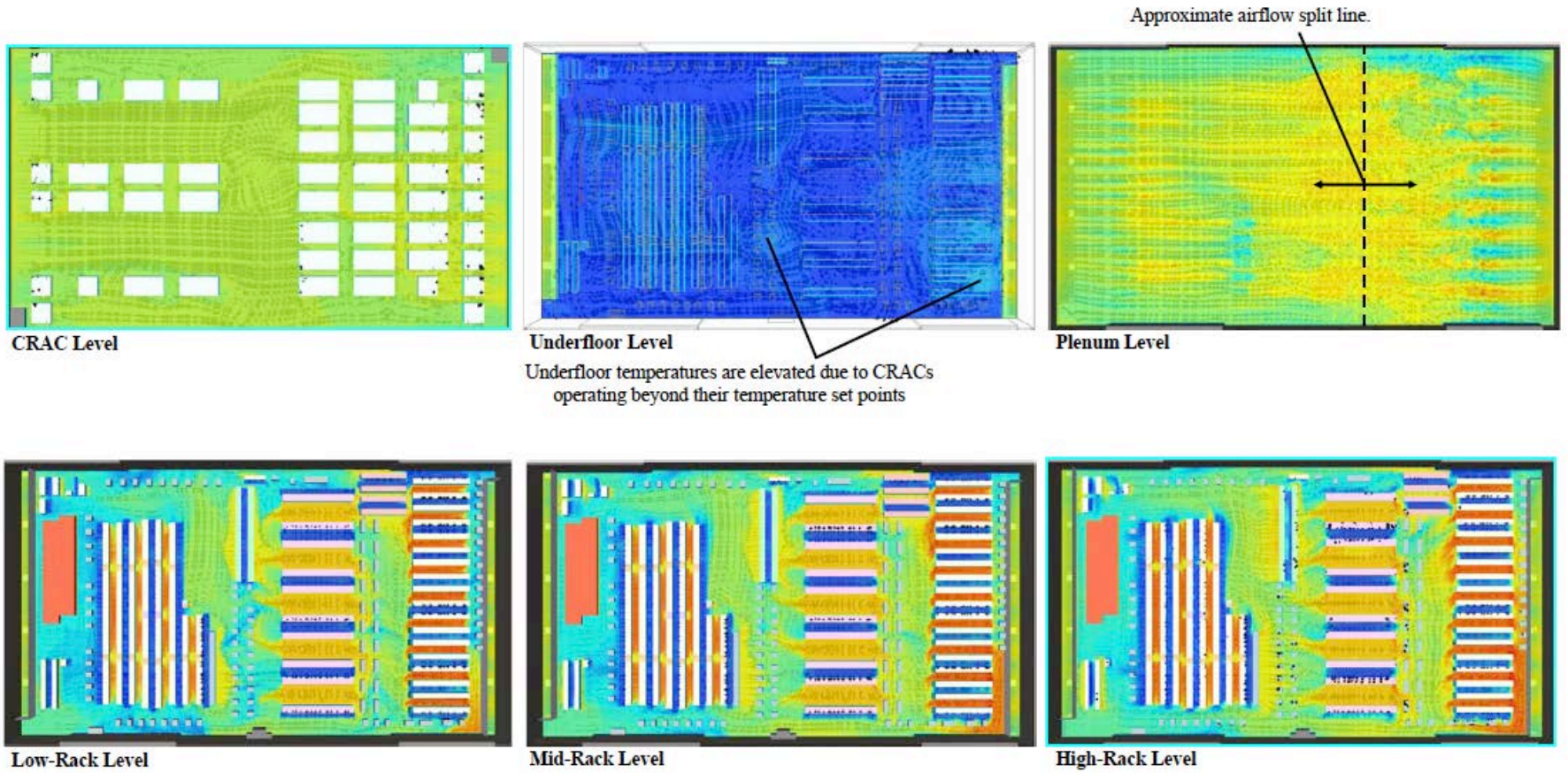



COLD AISLE
HOT AISLE
COLD AISLE
TYPHOON
PANASAS
PANASAS
HOT AISLE
COLD AISLE
VIEW MASTER
HURRICANE
REDTAIL
CIELO
ROADRUNNER PHASE 3
COLUMN 17
COLUMN 16
COLUMN 15
COLUMN 14
COLUMN 13
COLUMN 11
COLUMN 10
COLUMN 9
COLUMN 8
COLUMN 7
COLUMN 6
COLUMN 5
COLUMN 4
COLUMN 3
COLUMN 2
COLUMN 1

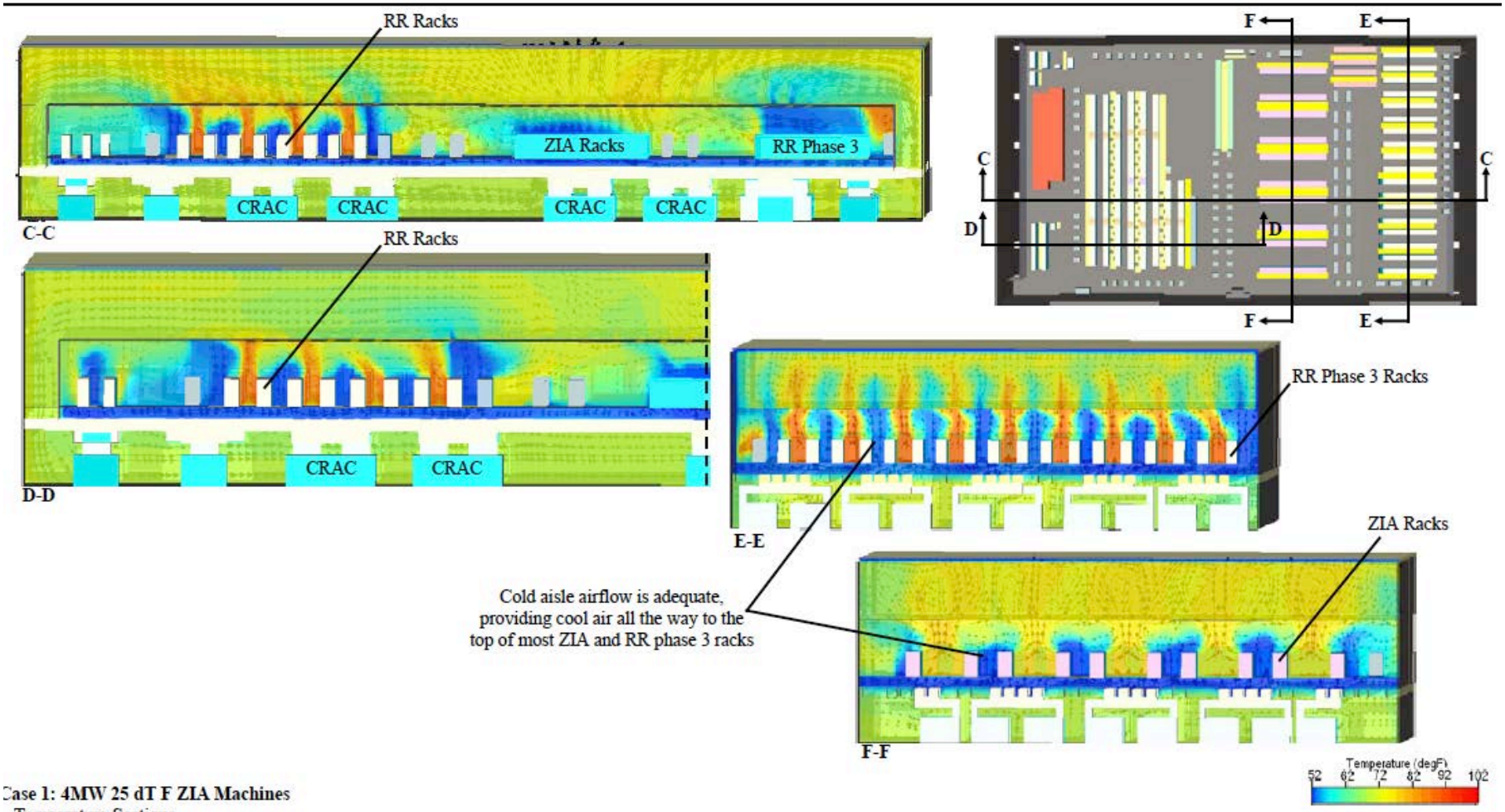
LANL/Cielo Update



ase 1: 4MW 25 dT F ZIA Machines
Layout (Plan)

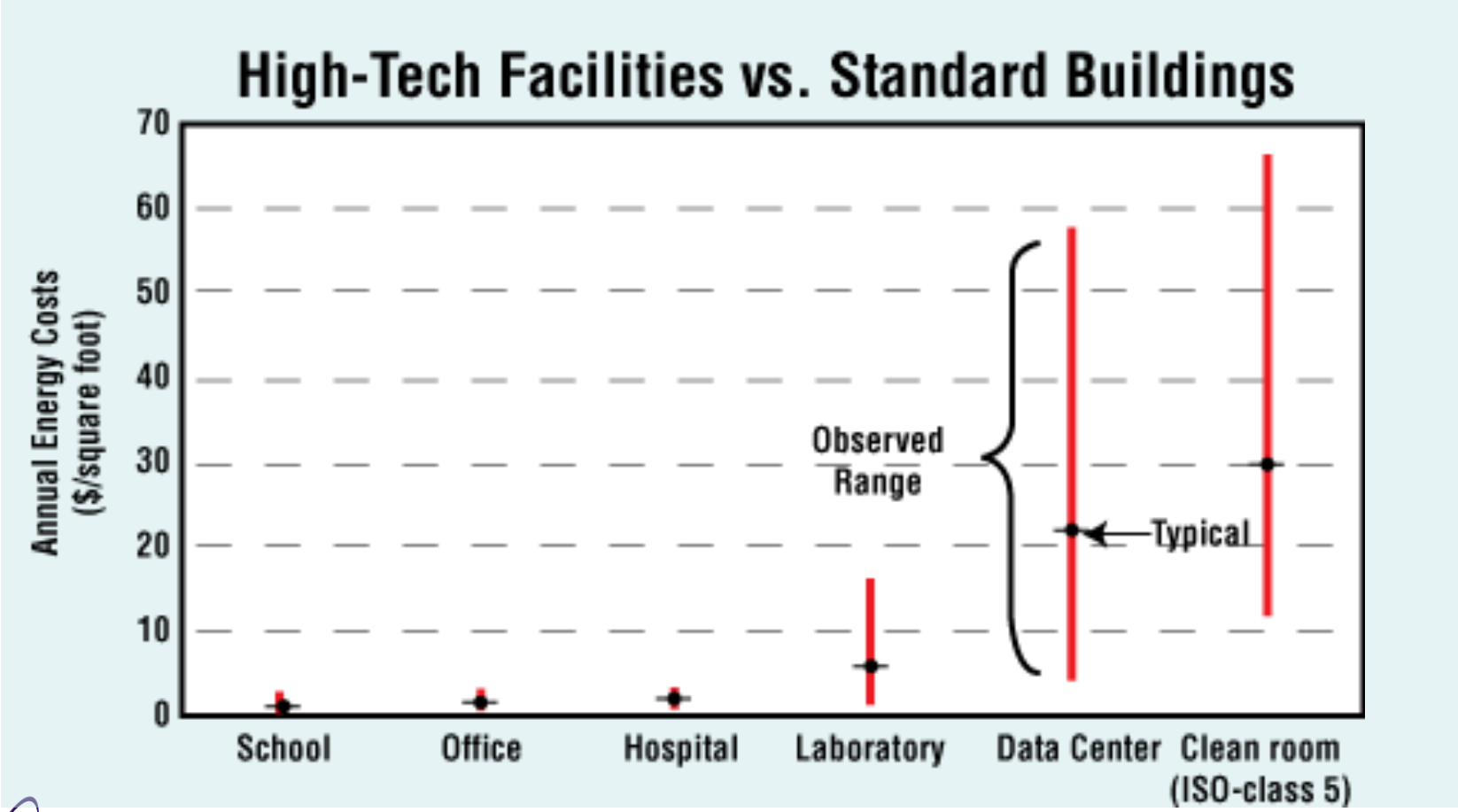


Case 1: 4MW 25 dT F ZIA Machines
- Temperature Plans



Case 1: 4MW 25 dT F ZIA Machines
- Temperature Sections

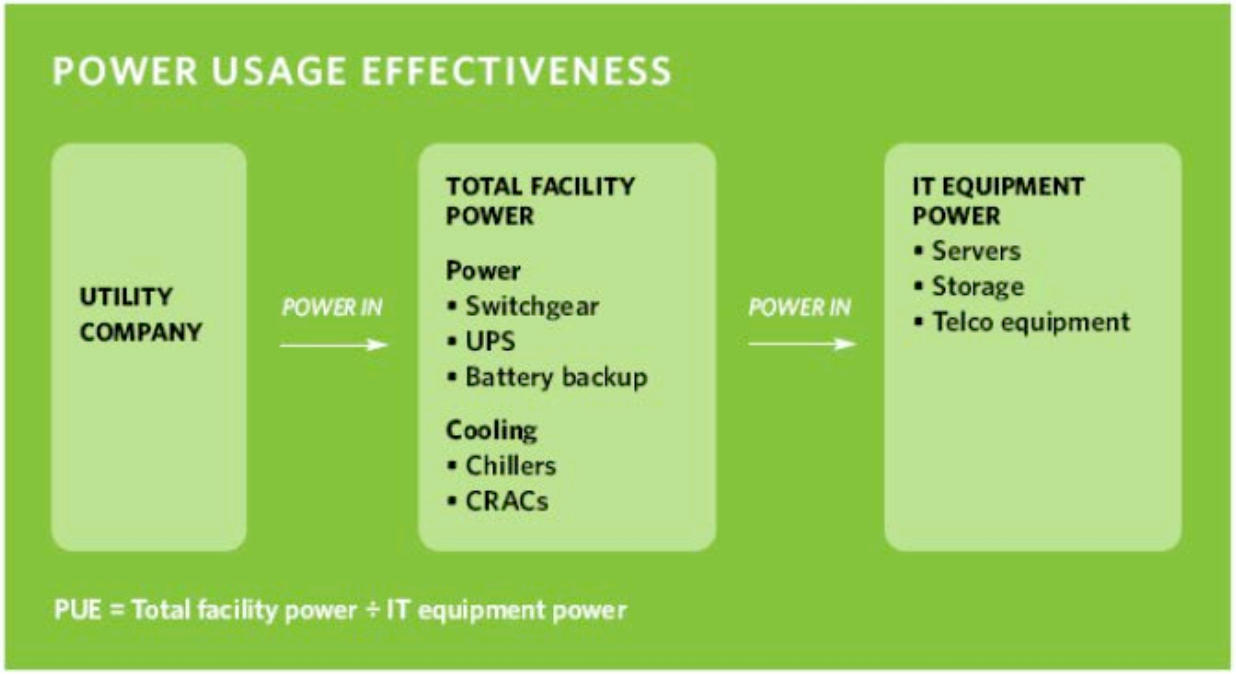
Comparative Energy Costs



PUE

Power Usage Effectiveness (PUE)

- Total Facility Power (kW)
- IT Equipment Power (kW) Power Usage



Calculating PUE

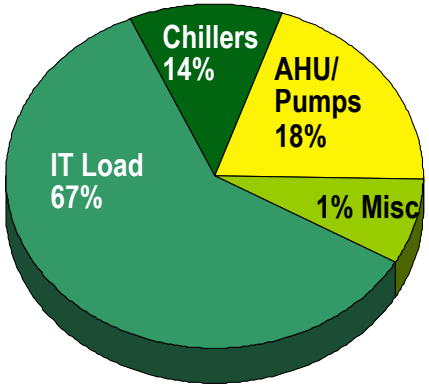
- What to measure and how often?
- Importance of consistency
- How to measure
  - Manual readings of BAS, UPS, PDUs
  - Instrumentation
  - Real time measurement
    - Wireless meters and sensors
    - Branch circuit monitoring
    - Power usage software

SCC Power Usage Effectiveness

Cooling Power

+

= 2.78 MW



SCC Computer Load

- Facility power 11.8 MW
- IT power 7.89 MW
- 11.8/7.89 = 1.49 (PUE)

- HVAC power 2.78 MW
- HVAC Load 2206 Tons (7.76 MW)
- HVAC KW/Ton 1.26
- 7.76/2.78 = 2.79 (COP)

Computing Power

+

= 7.89 MW

HPC current and future efficiency practices to reduce PUE

- Data Center Metering/Measurements
- Variable Speed Drives (VSD)
- Cold Aisle Containment
- Close-Coupled Liquid Cooling
- Air-Side Economizers
- Water-Side Economizers

Circulation power and cooling fluid choice

- Air cooling
  - Circulation power grows *very* rapidly
    - 9% is typical for low power density datacenters using CRAC units
    - Doubling power density could increase this 8-fold
  - Large heat sinks limit rack packing efficiency
- Water cooling
  - About 3500 times more effective than air at heat removal, lower pumping cost
  - Plumbing costs, earthquake bracing needed
  - Risk of leaks, condensation near computers in humid climates
  - Attractive at high power densities
  - Variant
    - Short air loop to nearby heat exchanger
- Freon or similar fluids
  - Stable temperature, governed by phase transition
  - Risk of leaks, inert but displaces oxygen
  - More complex plant, additional pumping costs, much variation in design & efficiency

Multiple Equipment Summary View

Individual Substation View

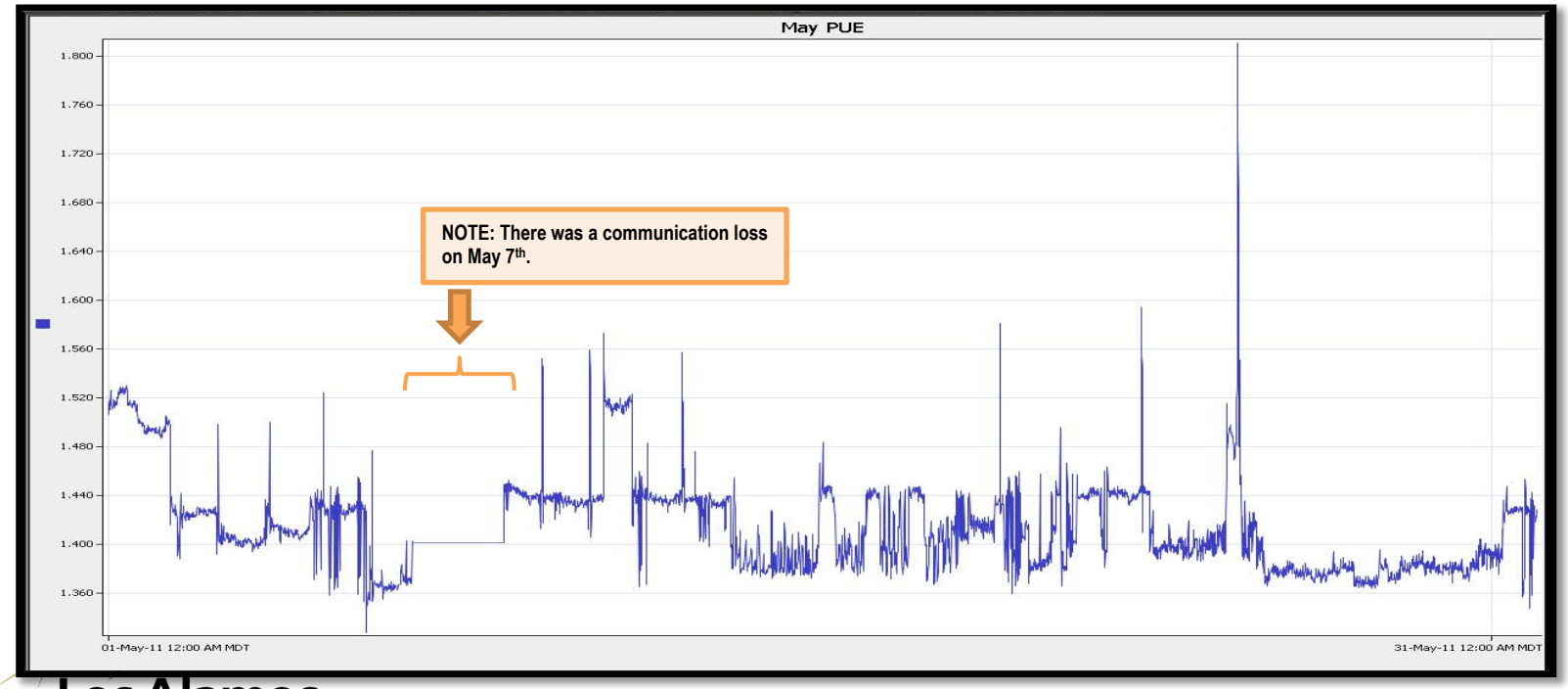
Power Usage Effectiveness (PUE)

PUE is a measure of how efficiently a computer data center uses its power. It is a ratio of total facility power to IT equipment power.

Facility power: lighting, cooling, etc.

IT equipment: computer racks, storage, etc.

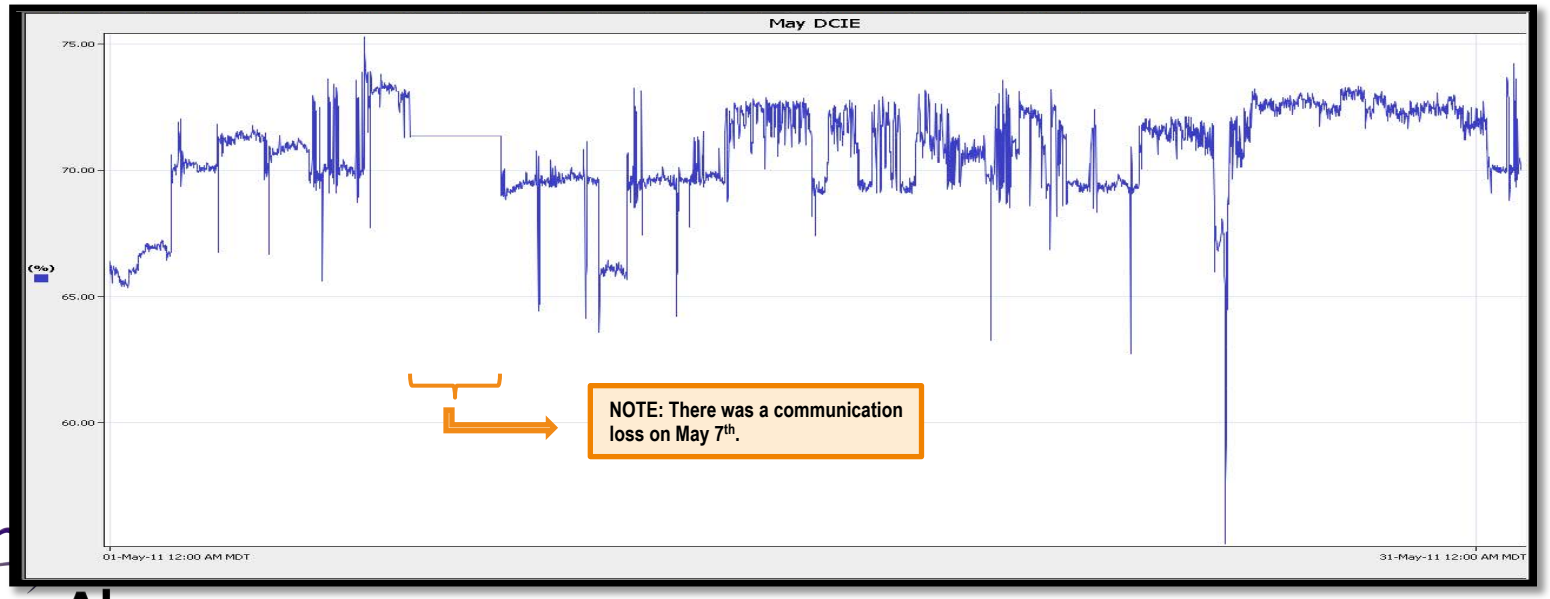
$$PUE = \frac{\text{TOTAL FACILITY POWER}}{\text{IT EQUIPMENT POWER}}$$



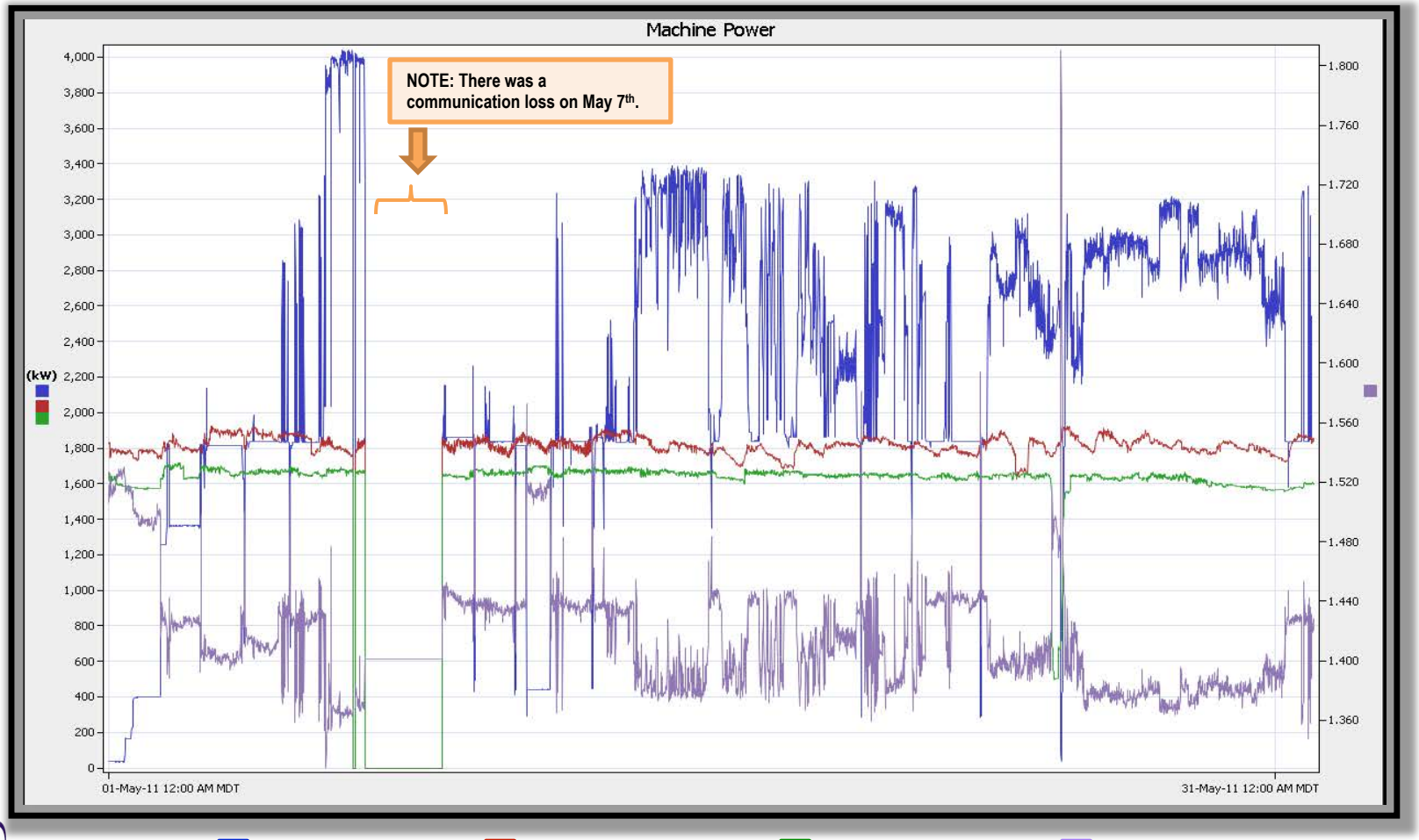
Data Center Infrastructure Efficiency (DCIE)

DCIE is the percentage value derived for measuring computer data center efficiency by taking the inverse of the PUE.

$$DCIE = \frac{\text{IT EQUIPMENT POWER}}{\text{TOTAL FACILITY POWER}} \times 100$$



Individual Machine Monitoring and Resulting PUE



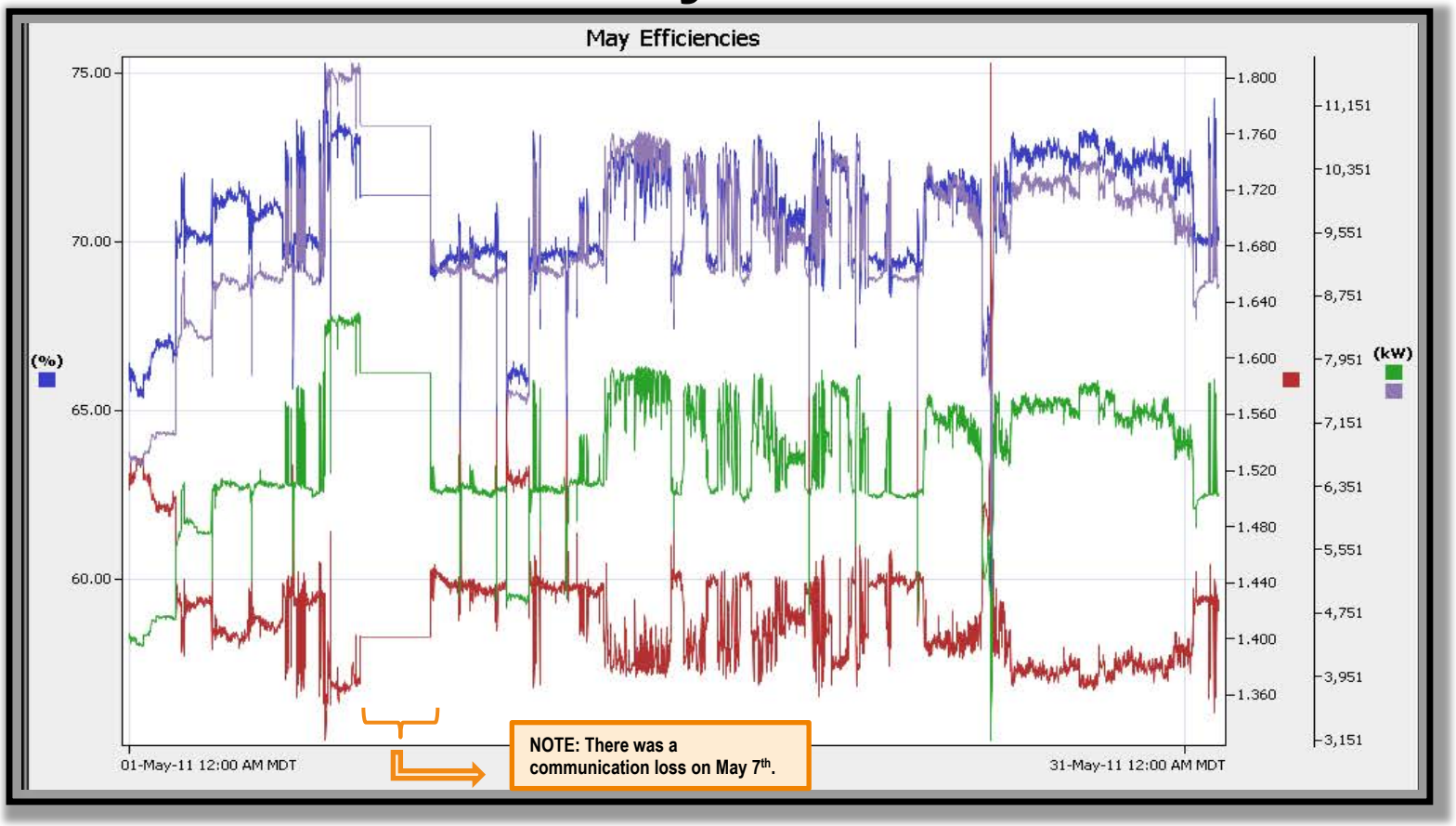
Cielo Power (kW)

Redtail Power (kW)

Roadrunner Power (kW)

Power Usage Effectiveness - PUE

Metropolis Center Overall Performance
May 2011



Data Center Infrastructure Efficiency – DCIE (%)

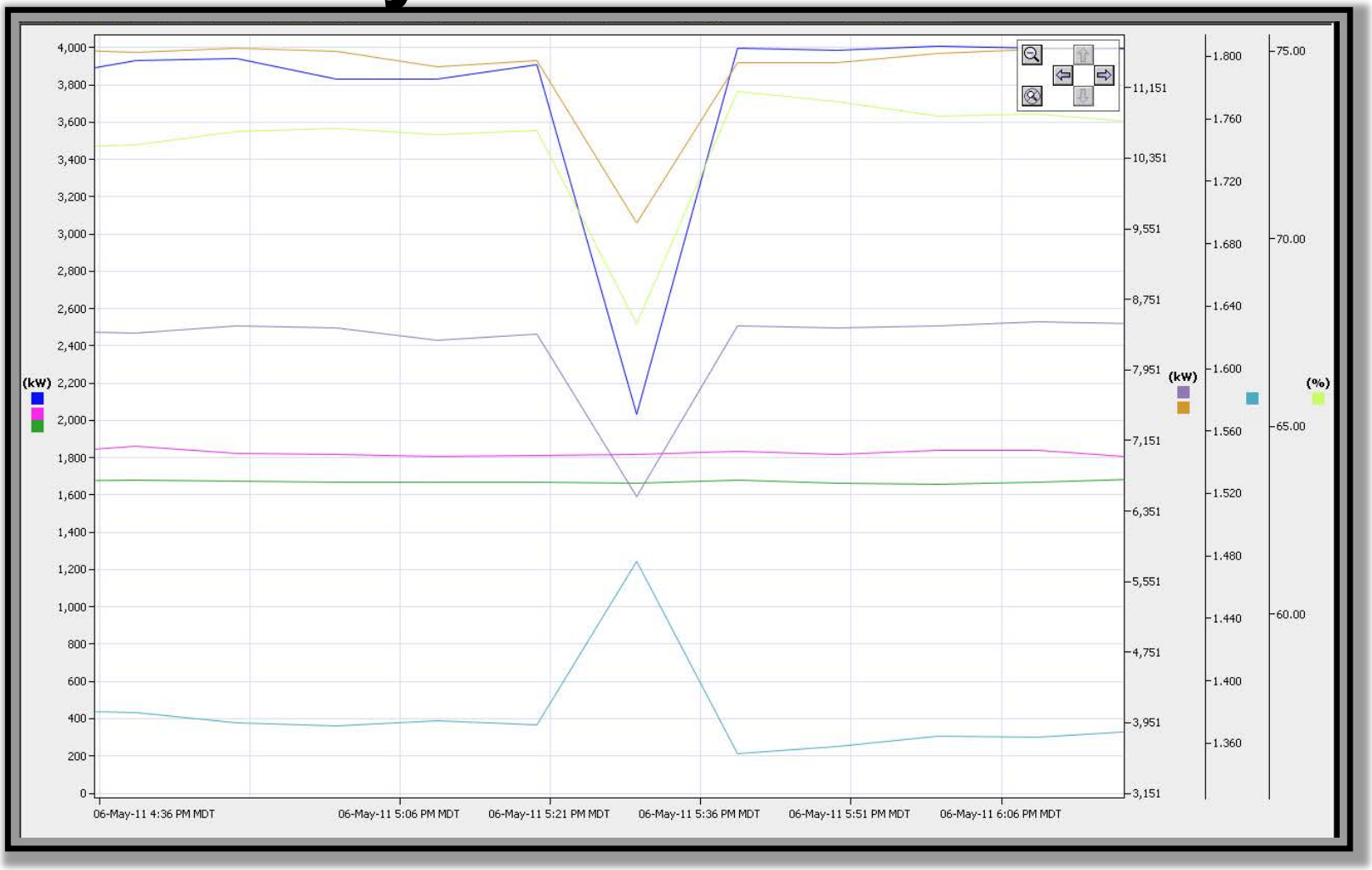
Power Usage Effectiveness - PUE

IT Load (kW)

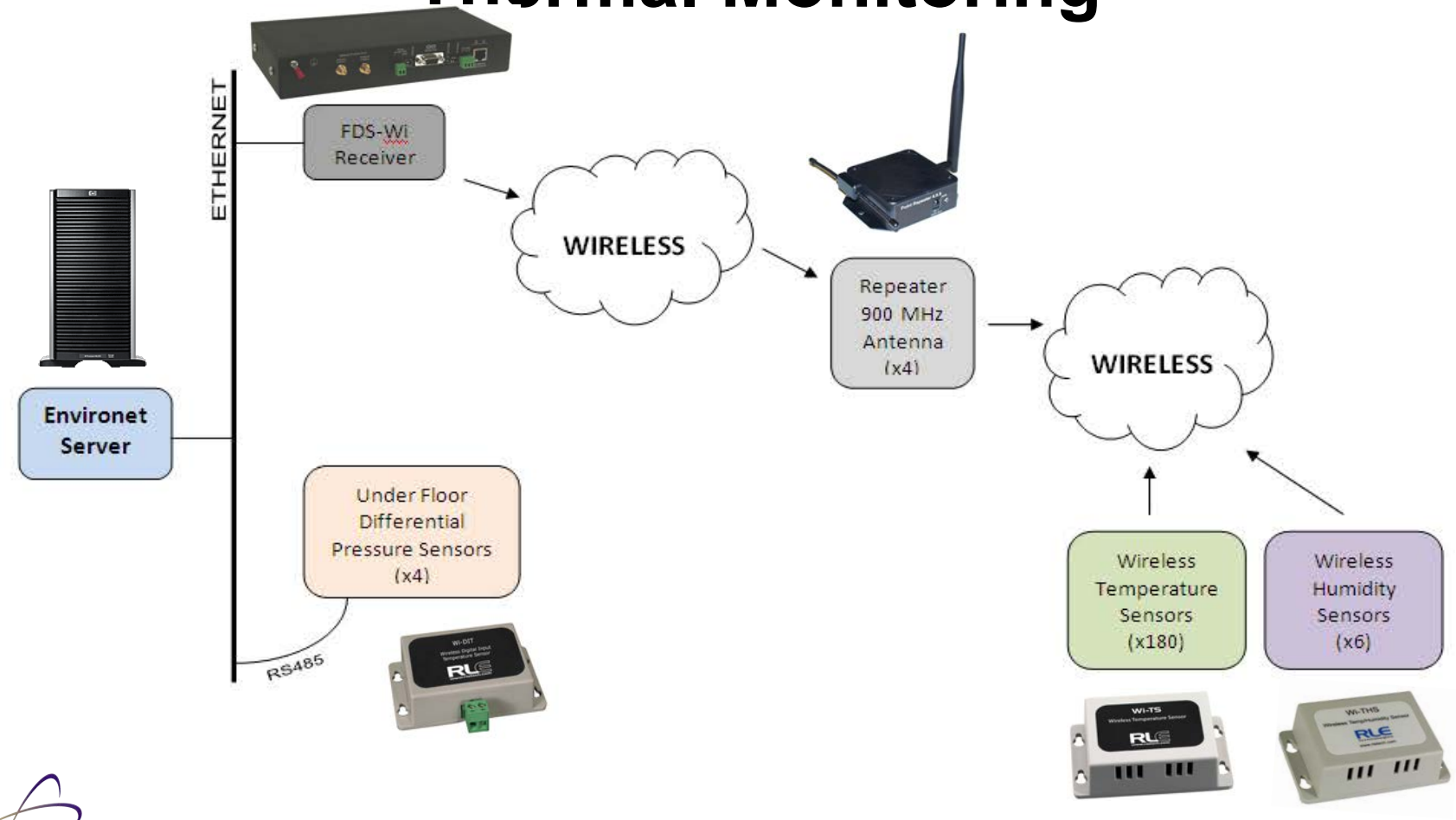
Total Load (kW)

Identify Direct Correlations

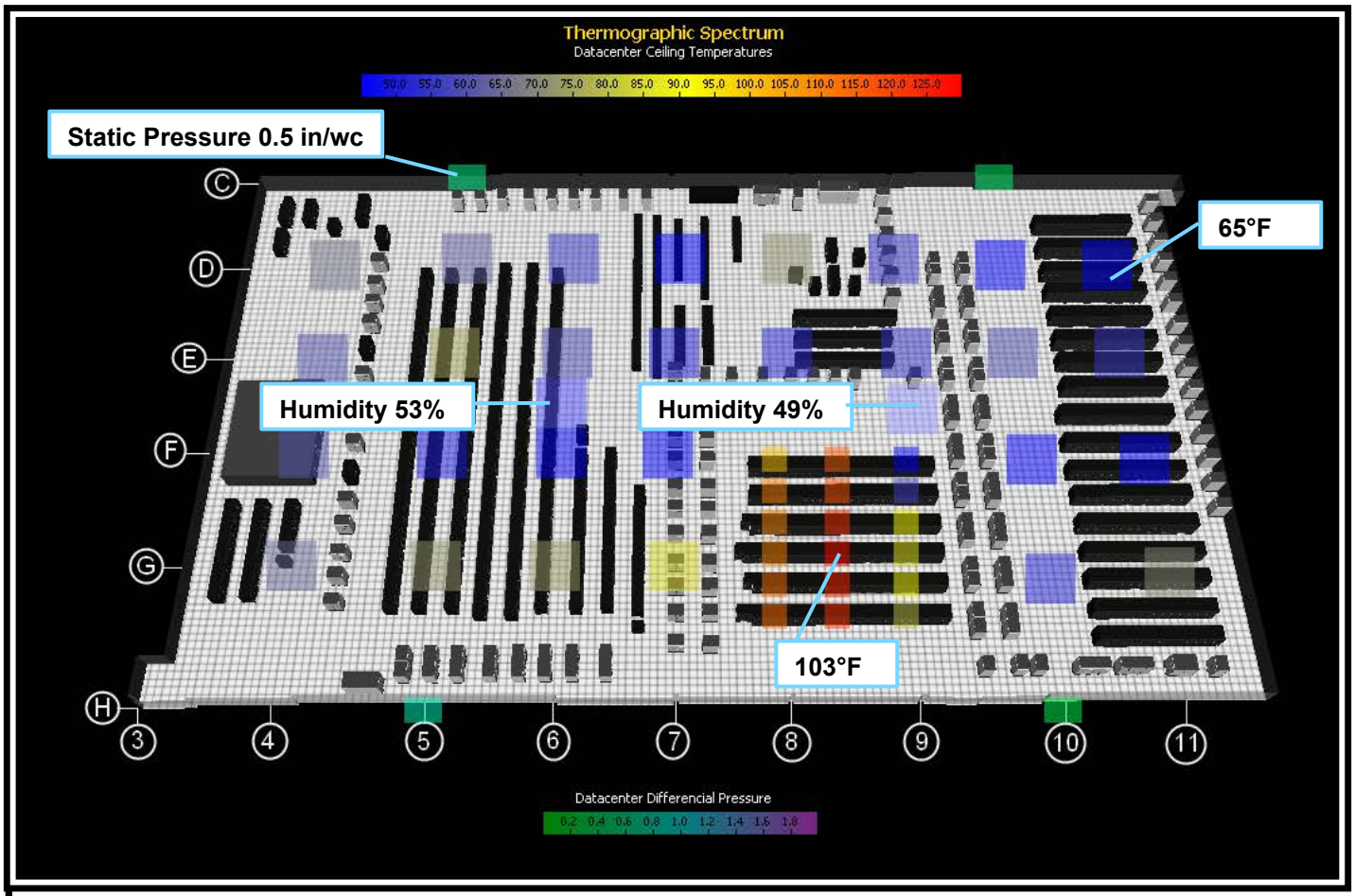
- Cielo Power (kW)
- Redtail Power (kW)
- Roadrunner Power (kW)
- Total IT Load (kW)
- Total Facility Load (kW)
- PUE
- DCiE (%)



WIRELESS Network Topology
Thermal Monitoring



Ceiling Temperatures, Humidity, and Under Floor Air Pressure



Wireless Information Summary from Cielo

- Exhaust Temp (°F)
- Ceiling Temp (°F)
- Supply Temp (°F)
- Return Temp (°F)
- Power (kW)

SCC – Data Center Efficiencies

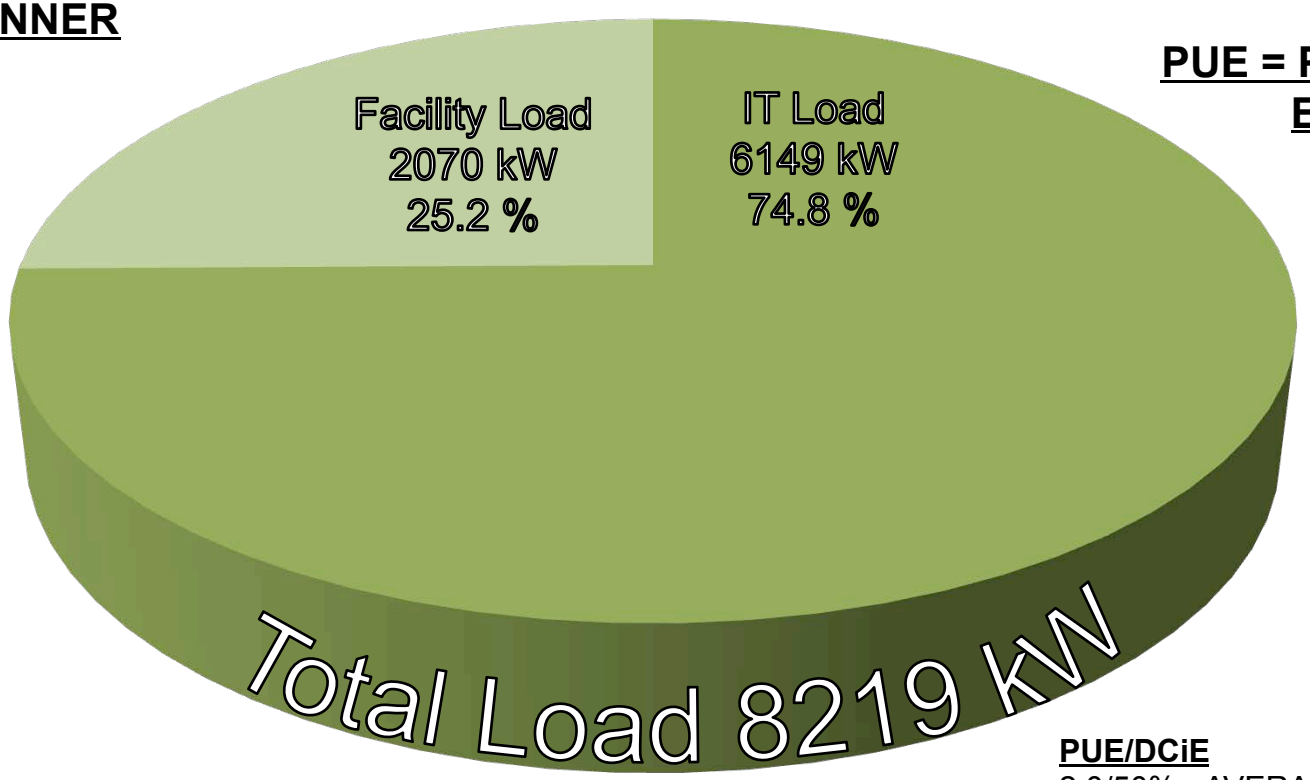
Live values recorded May 31, 2011 at 8:00 am

CIELO
1578 kW

ROADRUNNER
1568 kW

REDTAIL
1746 kW

MISC. IT LOAD
1257 kW



DCiE = Data Center Infrastructure Efficiency
74.81 %

PUE = Power Usage Effectiveness
1.337

PUE/DCiE
2.0/50% =AVERAGE
1.5/67% = EFFICIENT
1.2/83% = VERY EFFICIENT

Challenges Exa-Scale And Beyond

- Power
- Cooling
- Weight
- Environmental

Energy Efficient High Performance Computing Working Group (EE HPC WG)

- Supported by the DOE Sustainability Performance Office
- Organized and led by Lawrence Berkeley National Lab
- Participants from DOE National Laboratories, Academia, various Federal Agencies
- HPC vendor participation
- Group selects energy related topics to develop

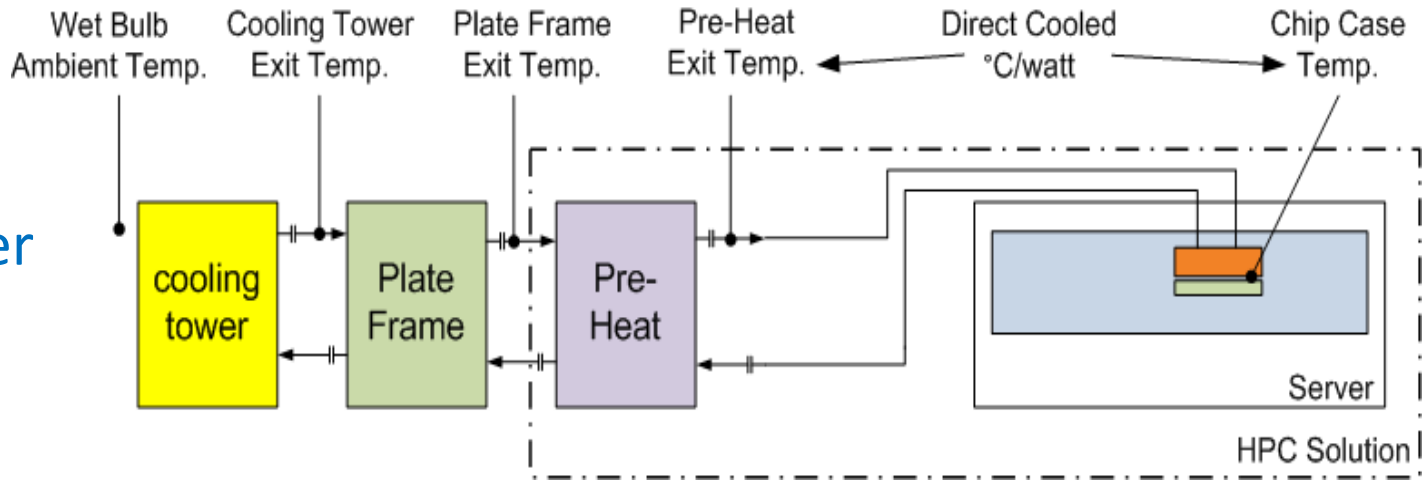
Liquid Cooling Sub-committee

Goal: Encourage highly efficient liquid cooling through use of high temperature fluids

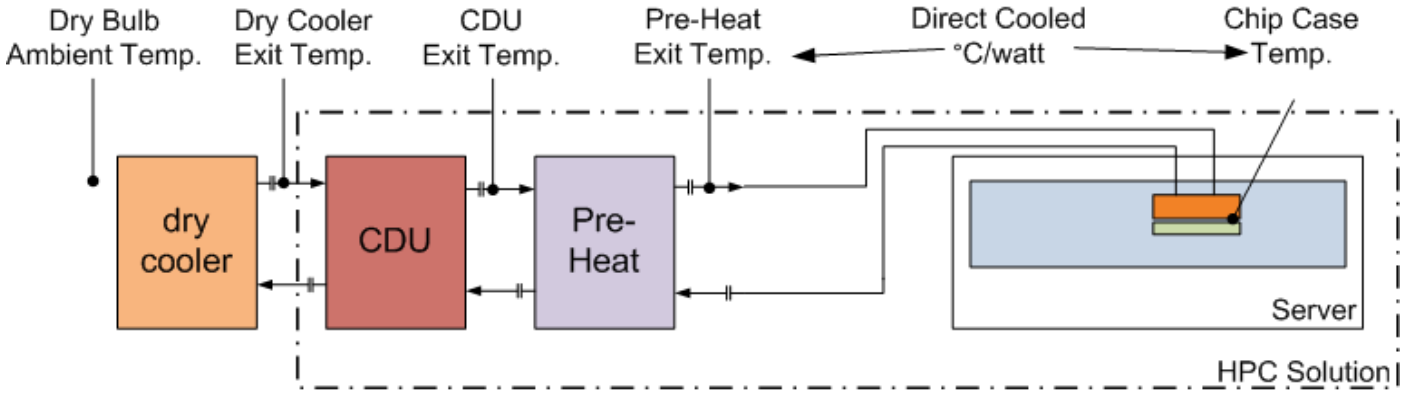
- Eliminate compressor cooling (chillers) at National Laboratory locations
- Standardize temperature requirements – common understanding between HPC mfgs and sites
- Ensure practicality of recommendations - Collaboration with HPC vendor community to develop attainable recommended limits
- Industry endorsement of recommended limits - Collaboration with ASHRAE to adopt recommendations in new thermal guidelines white paper

Direct Liquid Cooling Architectures

Cooling Tower



Dry Cooler



Los Alamos NATIONAL LABORATORY

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Summary Table to ASHRAE

Liquid Cooling Class	Main Cooling Equipment	Supplemental Cooling Equipment	Building Supplied Cooling Liquid Maximum Temperature
L1	Cooling Tower and Chiller	Not Needed	17°C (63°F)
L2	Cooling Tower	Chiller	32°C (89°F)
L3	Dry Cooler	Spray Dry Cooler or Chiller	43°C (110°F)

Thank You

Questions?