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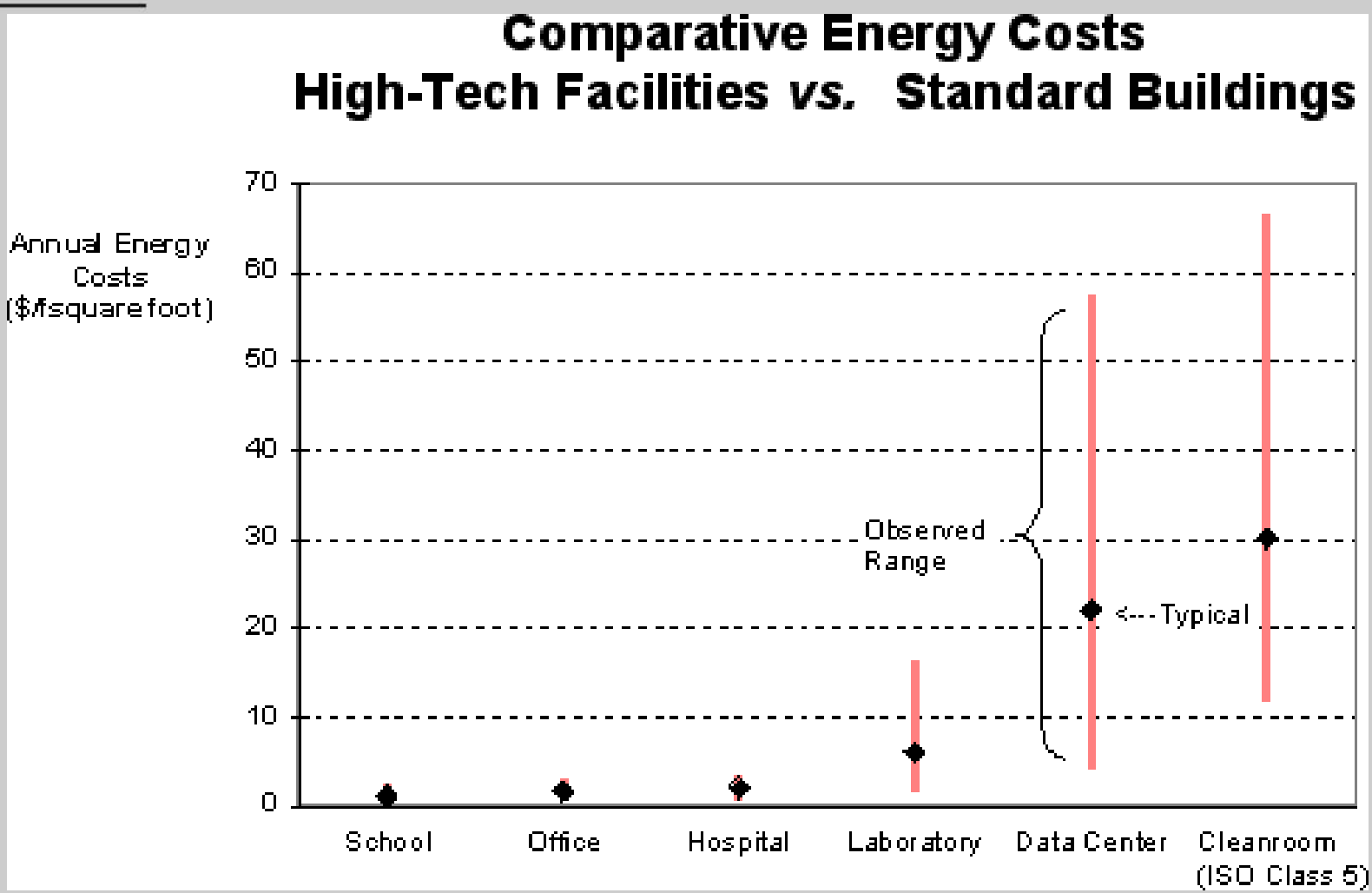
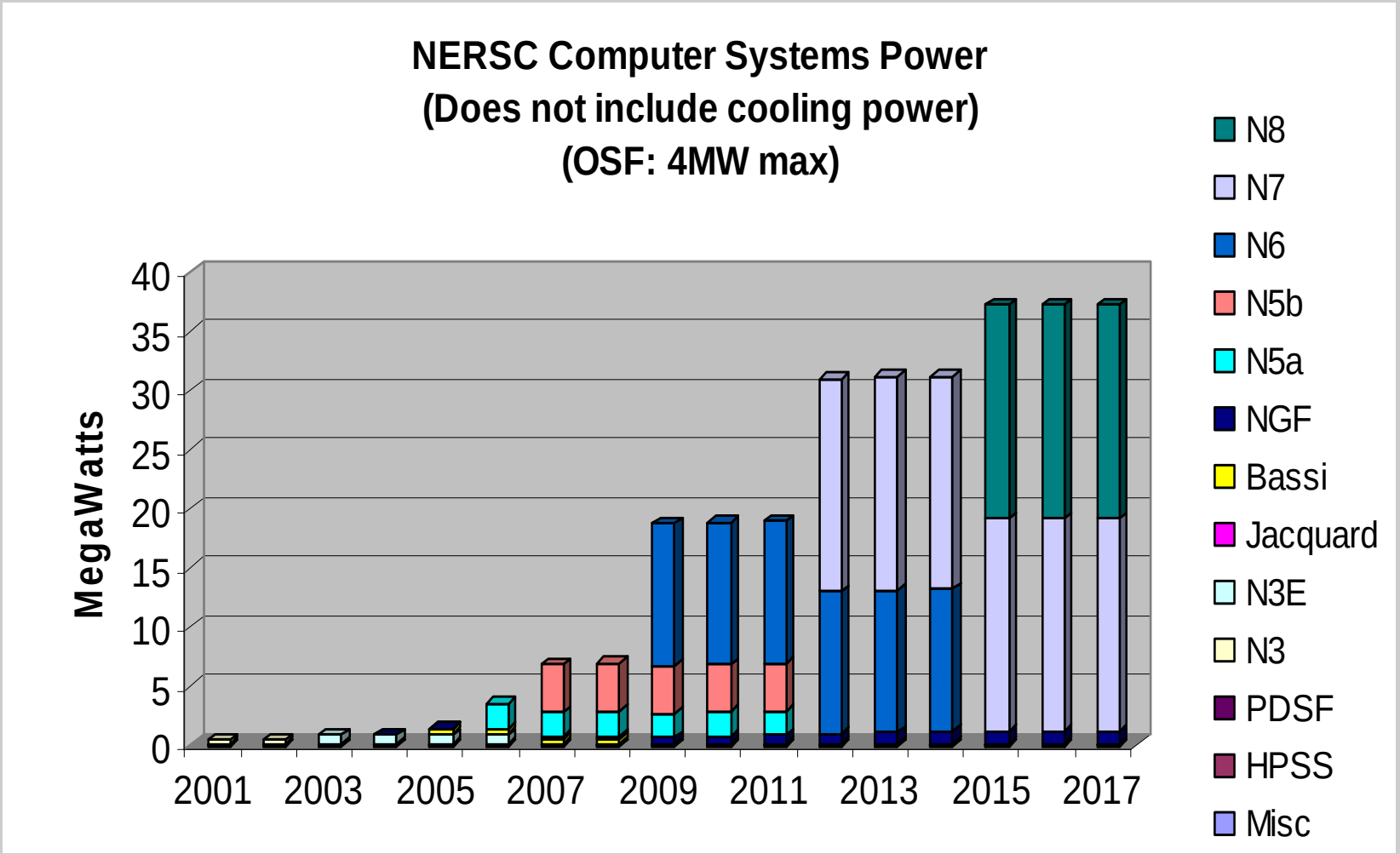
Charting a Course to Energy Independence
Providence, RI
August 9-12, 2009
Saving Energy in LBNL's Data Centers
Applying Best Practices
FEMP
BERKELEY LAB
Dale Sartor, PE
Lawrence Berkeley National Laboratory (LBNL)
GSA

High Tech Buildings are Energy Hogs:



LBNL Feels the Pain!

LBNL Super Computer Systems Power:



First, a Few Words from our Leader

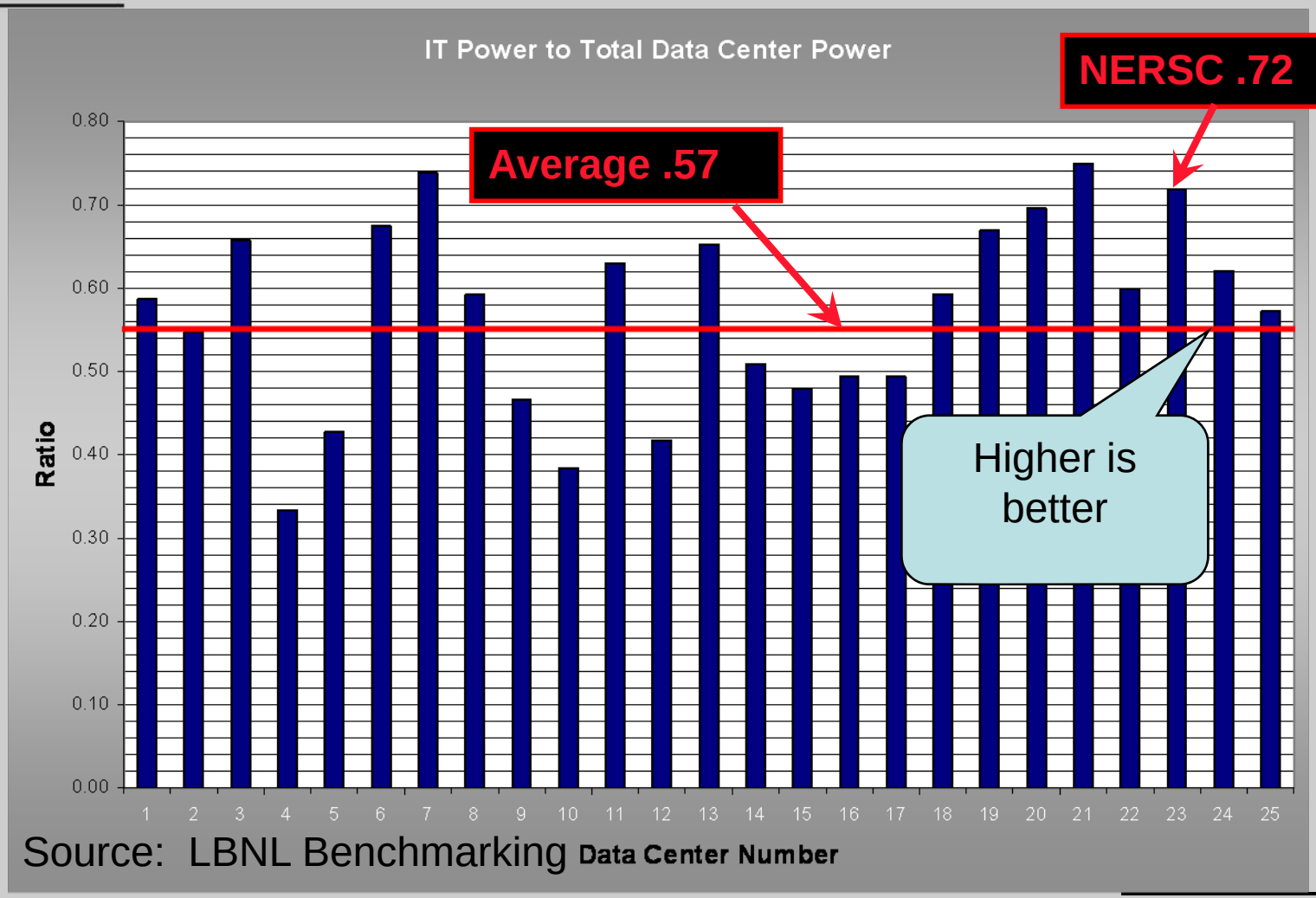
- “We’re certainly in a mess right now.”
- “The environment... is the reason I joined the Dept of Energy.”
- “We simply cannot fail.”

Source: Secretary Chu’s address to DOE staff 1/22/09

Potential Benefits of Data Center Energy Efficiency:

- 20-40% savings typical
- Aggressive strategies can yield 50+% savings
- Extend life and capacity of infrastructures
- But is my center good or bad?

High Level Metric— Data Center Infrastructure Efficiency (DCiE)
Ratio of Electricity Delivered to IT Equipment to Total



Source: LBNL Benchmarking

LBNL IT Data Center is Reaching Capacity

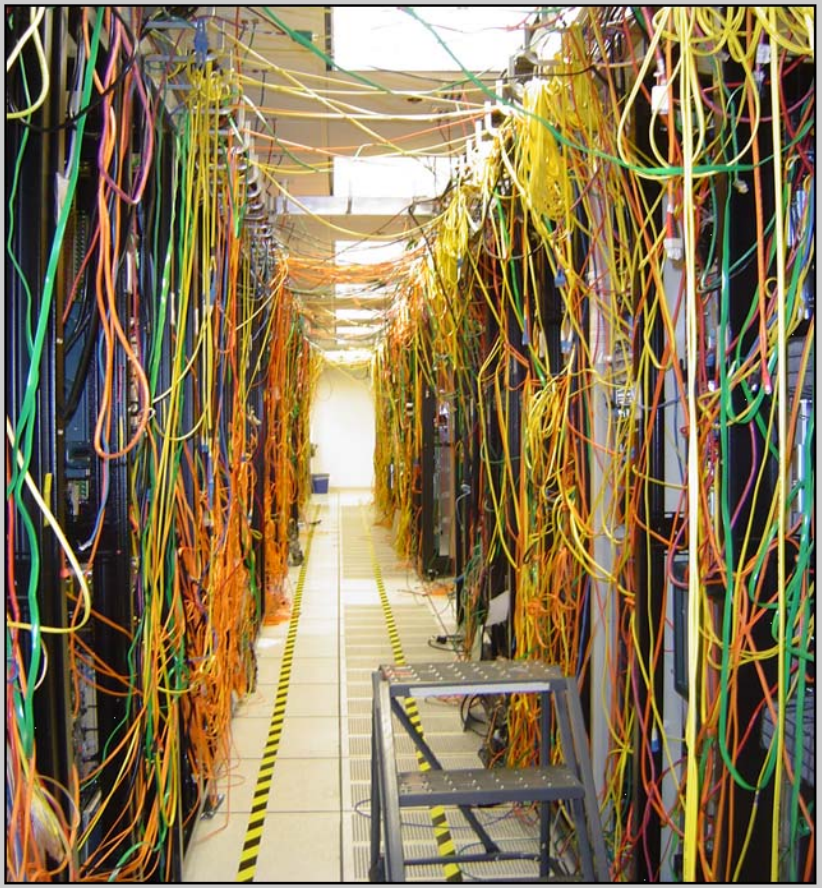
- Demand for scientific computing growing rapidly
- Clusters managed centrally by IT for lower cost, higher energy efficiency, increased cyber security
  - no more ‘clusters in closets’
  - impact on data center: power, cooling, space all running out

Applying Best Practices - Project Status

- **Partnership between CIO, CS, and energy efficiency researchers**
- **Existing data centers relatively efficient**
  - **NERSC: .72 kW-IT/kW-total (taking advantage of central plant)**
  - **50B-1275: .59 - .64 kW-IT/kW-total (tower cooled CRACs)**
- **Complete**
  - **EERE Industrial Technology Program pilot assessment**
  - **Eliminated simultaneous humidification & dehumidification**
  - **Improved airflow, under floor pressure**
  - **Virtualization**
- **In Progress**
  - **“Free” tower water cooling and more efficient chiller based cooling**
  - **Advanced hot and cold aisle isolation**
- **Increased efficiency frees up needed “capacity”**

Best practices based on benchmark results:

- **IT equipment efficiency**
- **Use IT to save energy in IT**
- **Environmental conditions**
- **Air management**
- Right-sizing
- Central plant optimization
- Efficient air handling
- **Liquid cooling**
- **Free cooling**
- **Humidity control**
- **Improve power chain**
- On-site generation
- **Design and M&O processes**



IT equipment load can be controlled:

Computations per Watt is improving, but computation demand is increasing even faster so overall energy is increasing. Lifetime electrical cost will soon exceed cost of IT equipment.

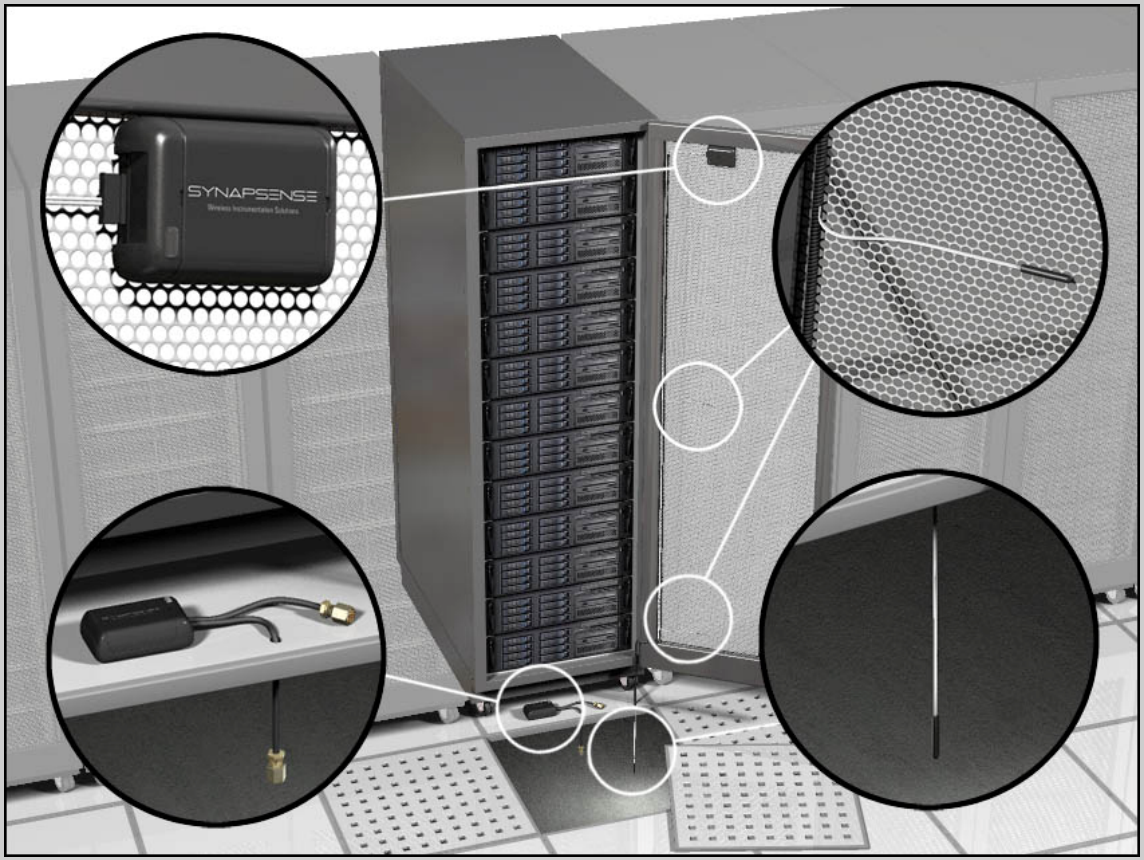
- **Consolidation**
- **Server efficiency**
  - **Flops per watt**
  - **Efficient power supplies**
- **Software efficiency (Virtualization, MAID, etc.)**
- **Power management**
  - **Low power modes**
- **Reconsider redundant power supplies**
- **Reducing IT load has a multiplier effect**
  - **Equivalent savings +/- in infrastructure**

Use IT to Save Energy in IT:

- Most operators lack visibility into their data center environment
- We can't manage what we don't measure
- Provide the same level of monitoring and visualization of the physical space as we have for the IT environment
- Measure and track performance metrics
- Spot problems before they result in high energy cost or down time

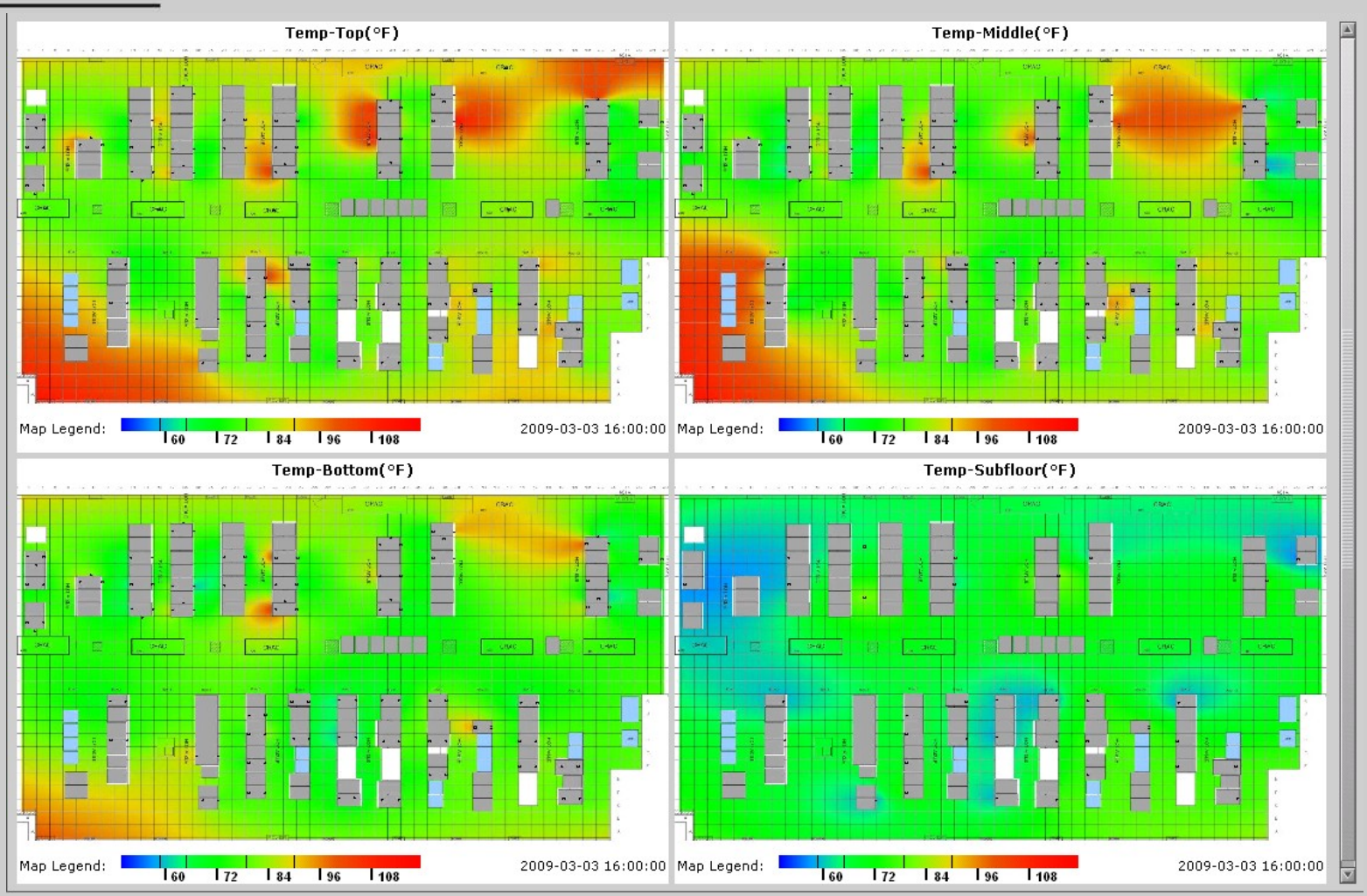
LBNL Wireless Monitoring System:

- 700 point SynapSense System
  - Temperature, humidity, under-floor pressure, current



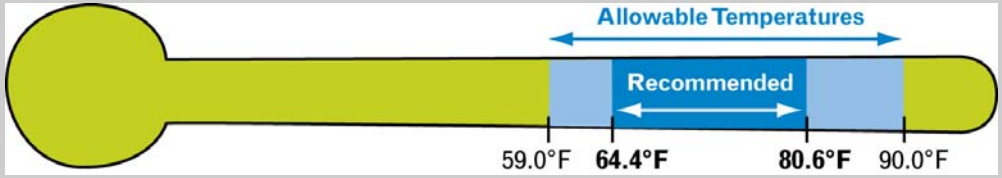
source: SynapSense

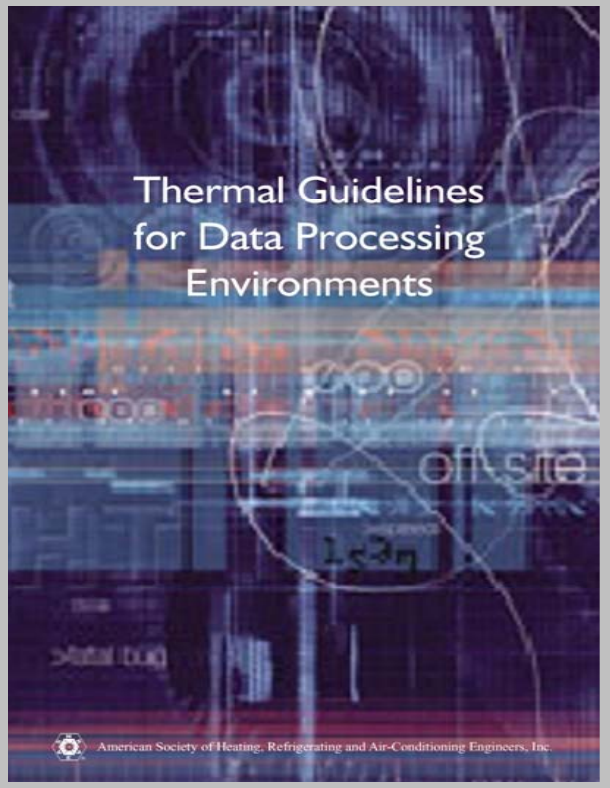
Visualization getting much better



Environmental Conditions

- Use ASHRAE Recommended and Allowable ranges of temperature and humidity

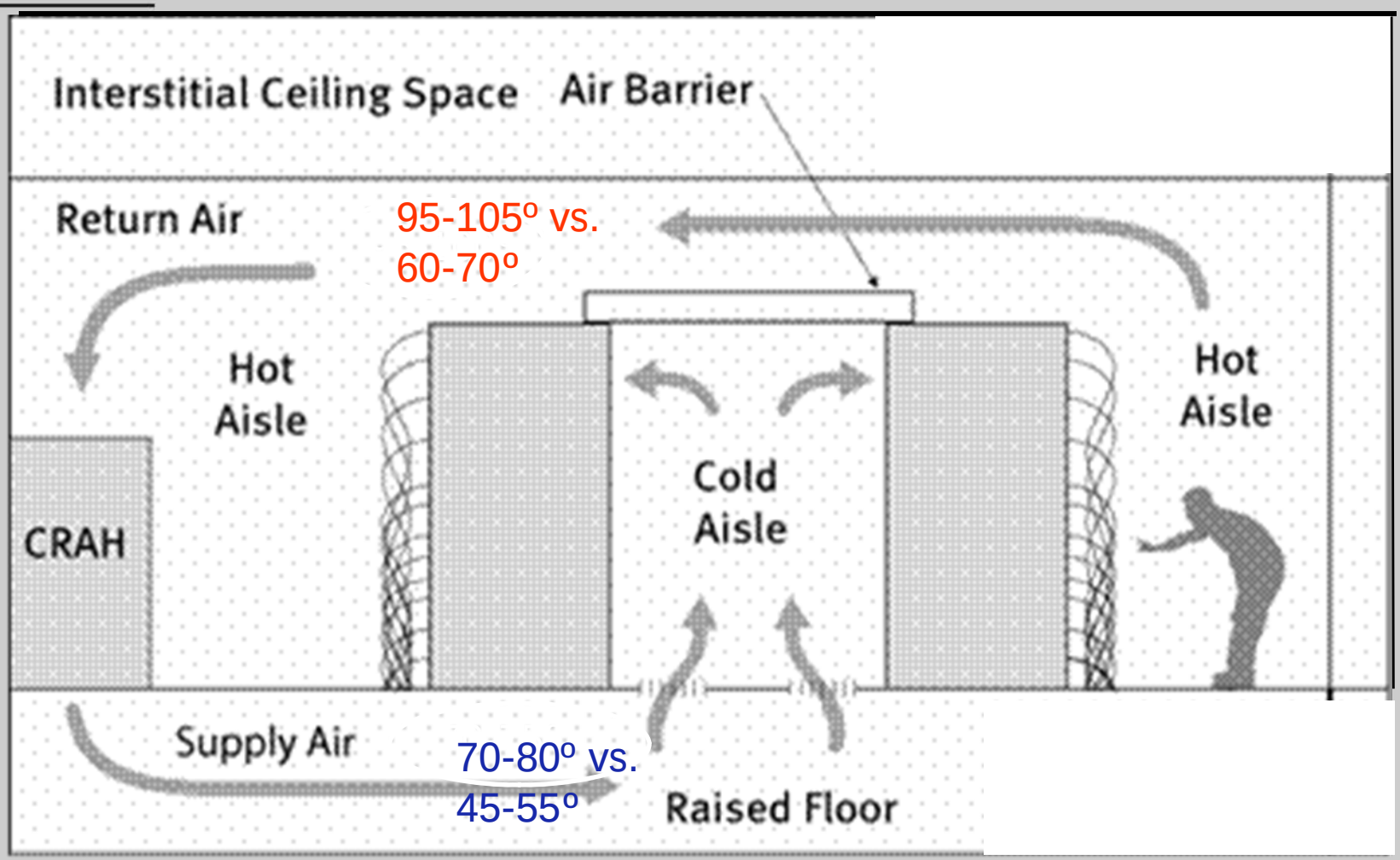




Air Management:

- Typically, much more air is circulated through computer room air conditioners than is required
- Air mixing and short circuiting leads to:
  - Low supply temperature
  - Low Delta T
- Improve isolation of hot and cold “aisles”
  - Reduce fan energy
  - Improve air-conditioning efficiency
  - Increase cooling capacity

Best Scenario— Isolate Cold and Hot



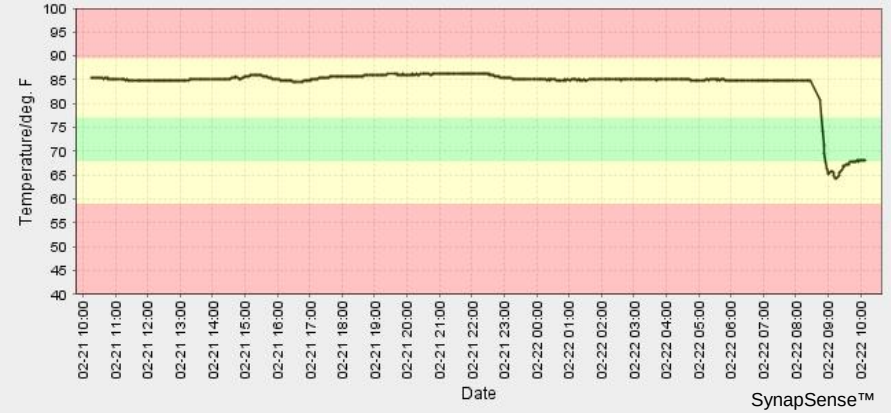
Air Management Assessment Effort:

- Performed CFD
- Deployed wireless monitoring system
- Identified opportunities for improvement
  - Enforce hot aisle/cold aisle arrangement
  - Use blanking panels
  - Improve airflow and under floor pressure by tuning floor tiles (e.g. reduced number of perforated tiles)
  - Reduce mixing and short circuits
  - convert overhead plenum from supply to hot-air return
  - CRAC intakes extended into overhead
  - Air Curtains added to improve isolation

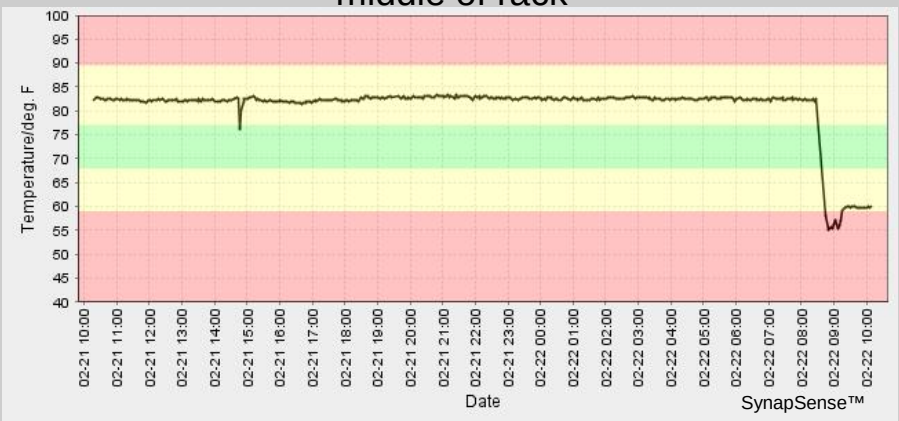
Results: Blanking Panels

- One 12” blanking panel added and temperature dropped ~20°
- Impact of other best practices confirmed
  - eliminate leaks in floor
  - improve air management

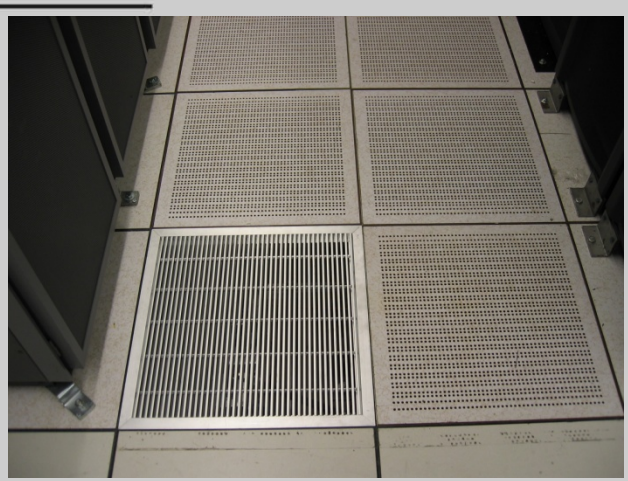
top of rack



middle of rack

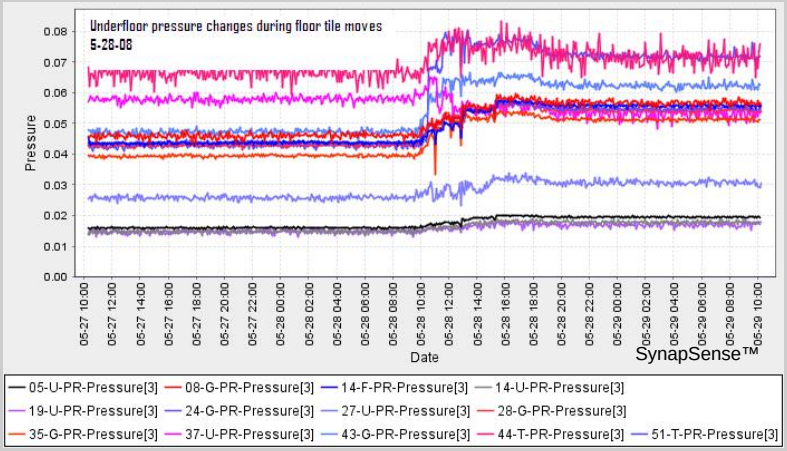


Results: Tune Floor Tiles

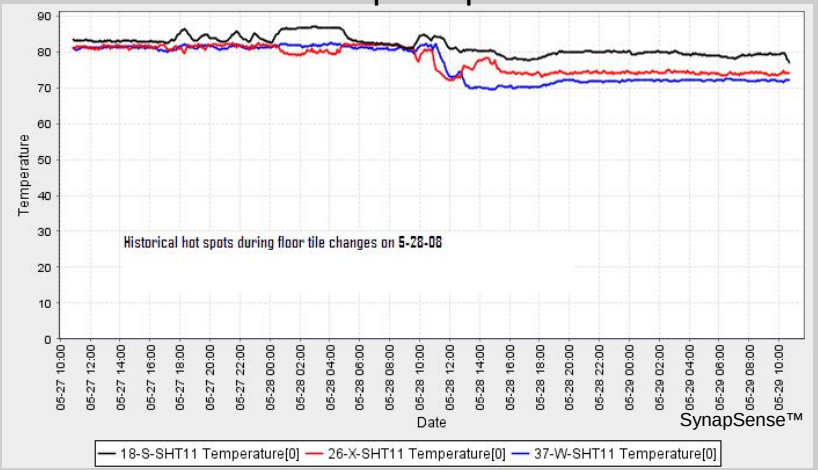


- Too many permeable floor tiles
- if airflow is optimized,
  - under-floor pressure ↑
  - rack-top temperatures ↓
  - data center capacity grows
- Measurement and visualization assisted tuning process

under-floor pressures



rack-top temperatures



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Improve Air Management:

- Overhead plenum converted from supply to hot-air return
- CRAC intakes extended into overhead
- Return registers placed over hot aisle

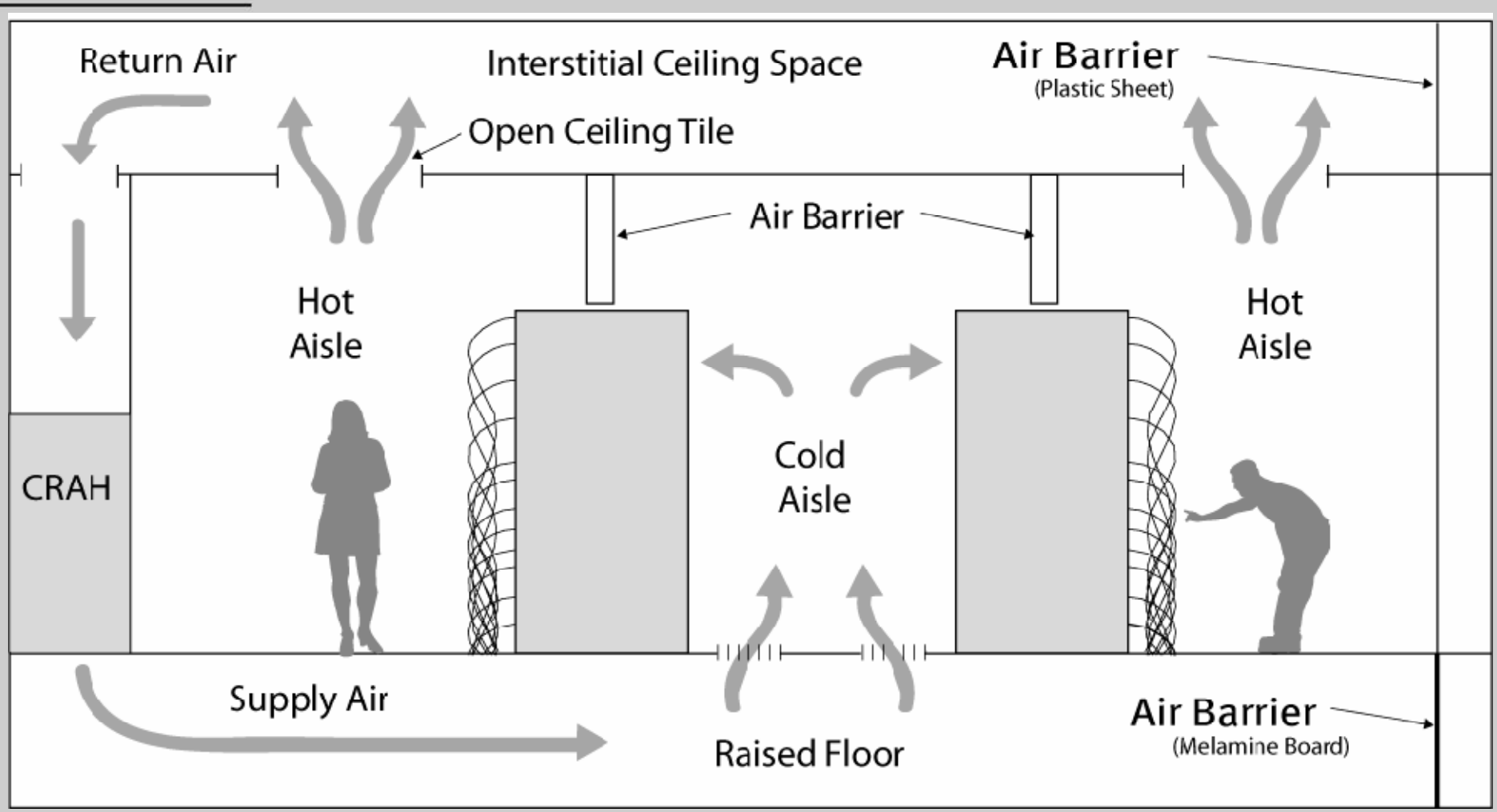
Before

After

Adding Air Curtains for Hot/Cold Isolation

Dale Sartor

Improve Air Management:

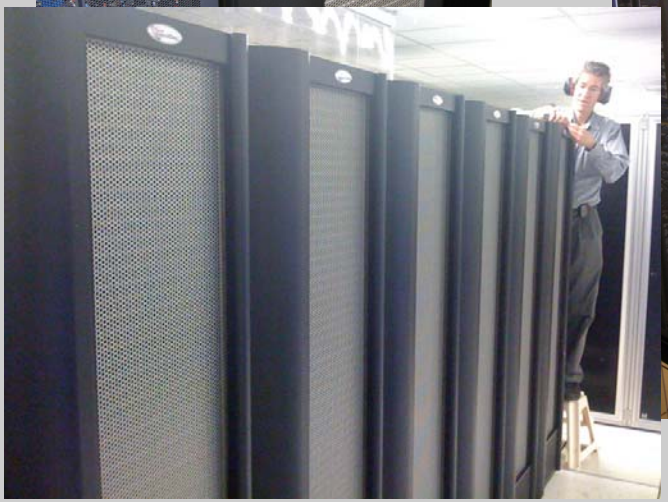


Use Free Cooling:

- Water-side Economizers
  - No contamination question
  - Can be in series with chiller
- Outside-Air Economizers
  - Can be very effective (24/7 load)
  - Must consider humidity
- Let’s get rid of chillers in data centers

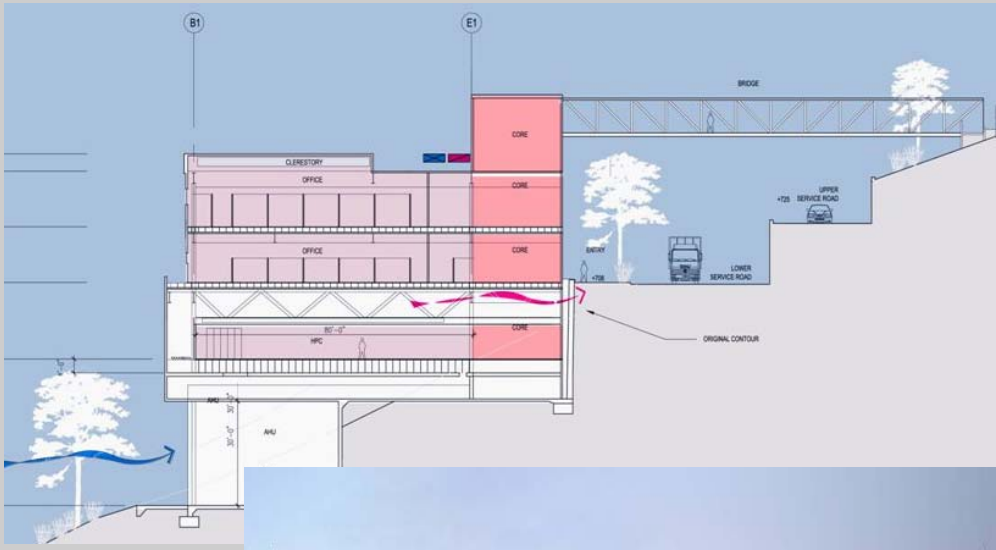
Free Cooling – Liquid Based

- Infrastructure installed in 2008 for liquid cooling in 50B-1275
- Cooled with tower only or chiller assisted
  - Both options significantly better than existing liquid cooled (DX) CRAC units



UC Computational Research & Theory (CRT) Design Approach:

- Air-Side Economizer (93% of hours)
- Direct Evaporative Cooling for Humidification/ pre-cooling
- Four-pipe cooling



Predicted CRT Performance:

- DCIE of 0.95 based on annual energy
- DCIE of 0.88 based on peak power

Improve Humidity Control:

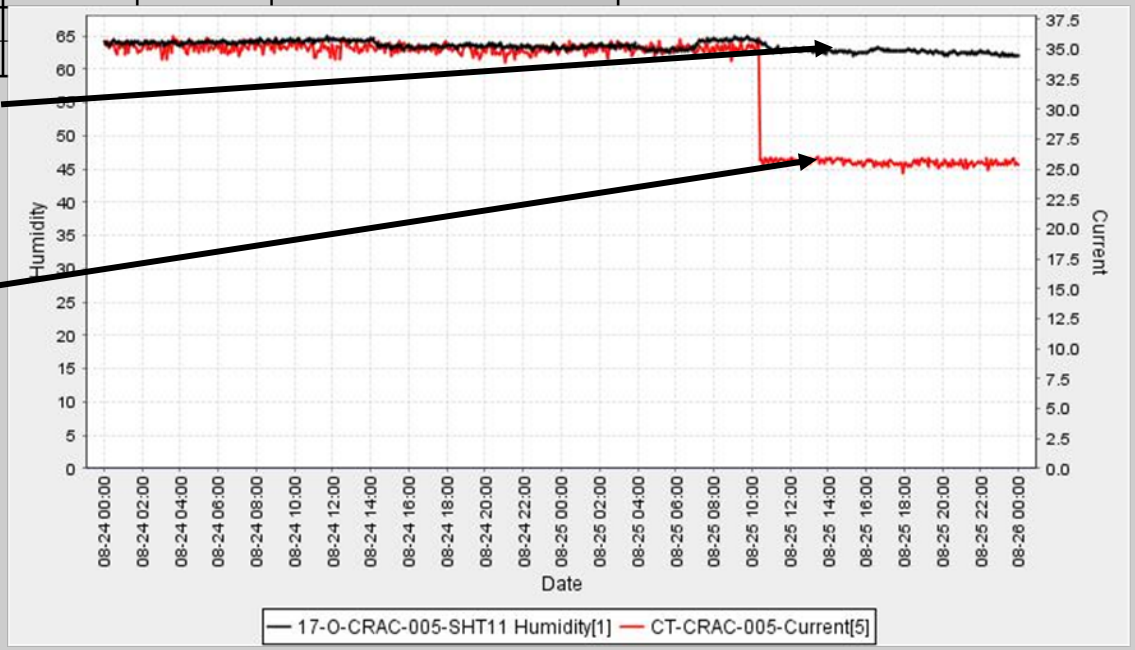
- Eliminate inadvertent dehumidification
  - Computer load is sensible only
- Use ASHRAE allowable RH and temperature
  - Many manufacturers allow even wider humidity range
- Eliminate equipment fighting
  - Coordinate controls

The Cost of Unnecessary Humidification

	Visalia Probe			CRAC Unit Panel			
	Temp	RH	Tdp	Temp	RH	Tdp	Mode
AC 005	84.0	27.5	47.0	76	32.0	44.1	Cooling
AC 006	81.8	28.5	46.1	55	51.0	37.2	Cooling & Dehumidification
AC 007	72.8	38.5	46.1	70	47.0	48.9	Cooling
AC 008	80.0	31.5	47.2	74	43.0	50.2	Cooling & Humidification
AC 010	77.5	32.8	46.1	68	45.0	45.9	Cooling
AC 011	78.9	31.4	46.1	70	43.0	46.6	Cooling & Humidification
Min	72.8	27.5	46.1	55.0	32.0	37.2	
Max	84.0	38.5	47.2	76.0			
Avg	79.2	31.7	46.4	68.8			

Humidity down 3%

CRAC power down 28%



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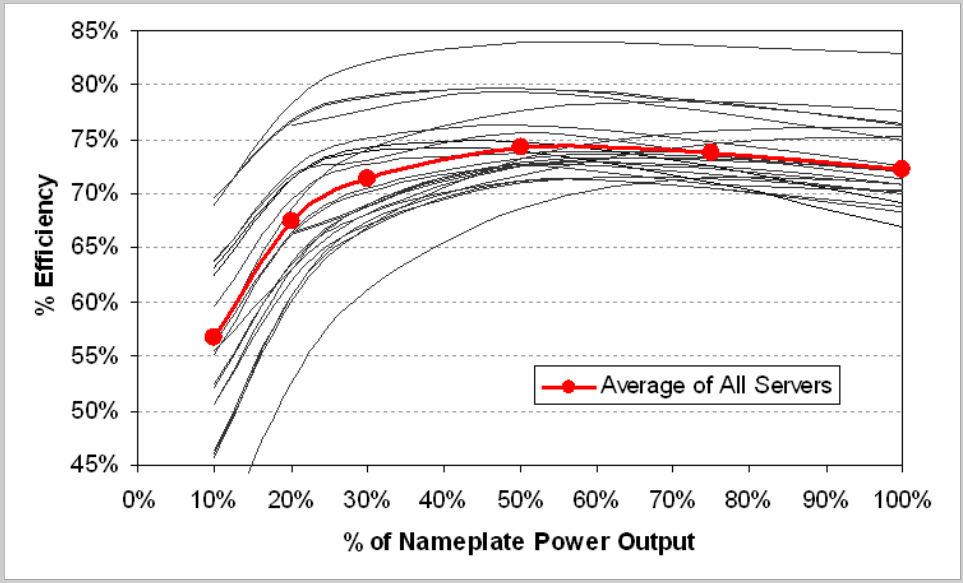
Improving the Power Chain:

- Increase distribution voltage
  - NERSC going to 480 volts to the racks
- Improve equipment power supplies
  - Avoid redundancy unless needed
- Improve UPS
  - LBNL uses minimal UPS
  - Selected to minimize losses



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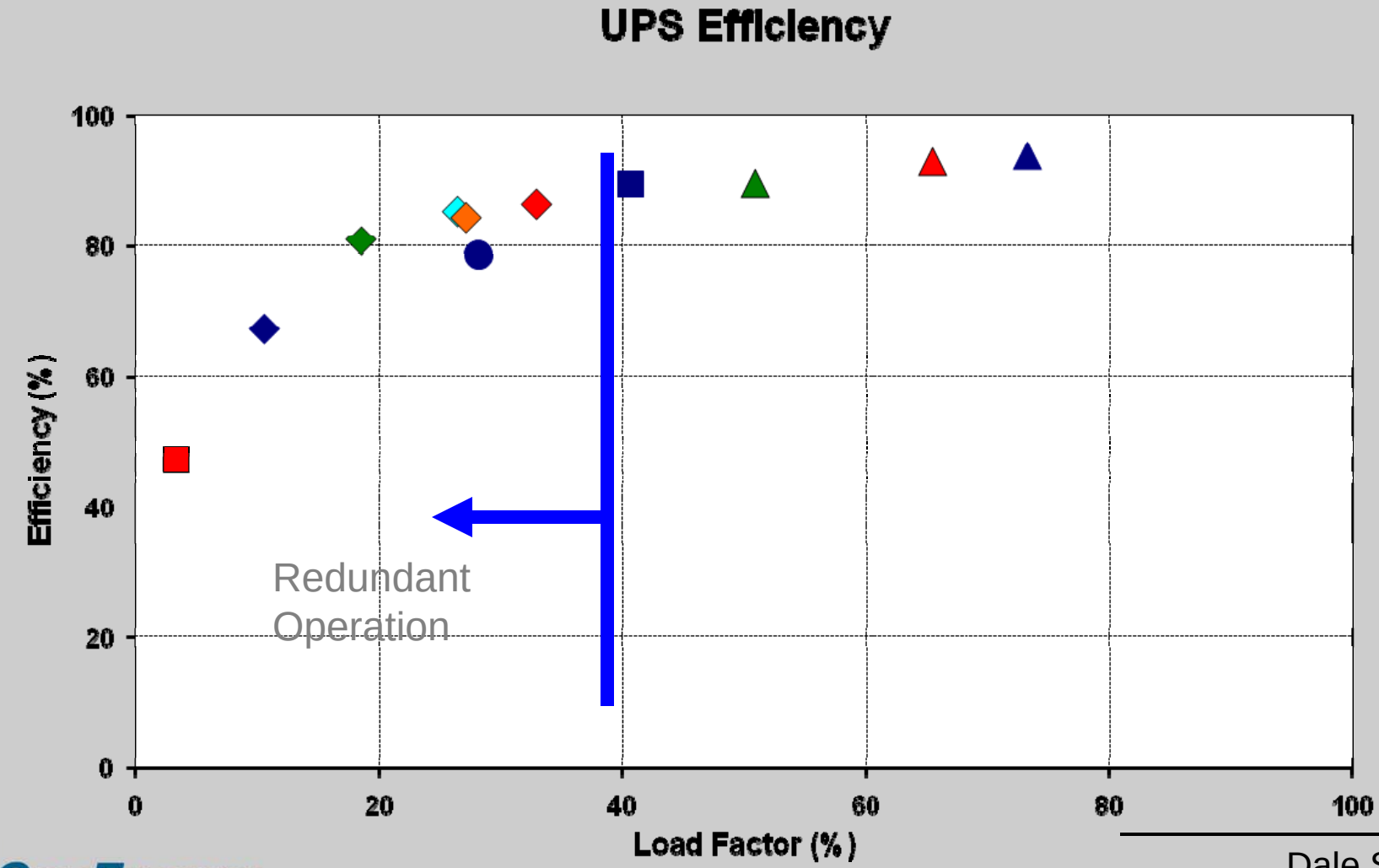
Redundancy

- Understand what redundancy costs – is it worth it?
- Different strategies have different energy penalties (e.g. 2N vs. N+1)
- Redundancy in electrical distribution puts you down the efficiency curve
- LBNL minimizes use of redundant power supplies and size of UPS

Measured UPS Efficiency



Improve Design and Operations Processes:

- Get IT and Facilities people to work together
- Use life-cycle total cost of ownership analysis
- Document design intent and provide training
- Benchmark and track existing facilities
- Eat your spinach (blanking panels, leaks, CRAC maintenance)
- Re-commission regularly as part of maintenance
- Keep an eye on emerging technologies (flywheel UPS, rack-level cooling, DC power) and work with vendors to improve efficiency

Useful Links

DOE Website: Sign up to stay up to date on new developments
www.eere.energy.gov/datacenters

Lawrence Berkeley National Laboratory (LBNL)
http://hightech.lbl.gov/datacenters.html

LBNL Best Practices Guidelines (cooling, power, IT systems)
http://hightech.lbl.gov/datacenters-bpg.html

ASHRAE Data Center technical guidebooks
http://tc99.ashraetcs.org/

The Green Grid Association – White papers on metrics
http://www.thegreengrid.org/gg_content/

Energy Star® Program
http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency

Uptime Institute white papers
www.uptimeinstitute.org

Contact Information:

Dale Sartor, P.E.
Lawrence Berkeley National Laboratory
Applications Team
MS 90-3111
University of California
Berkeley, CA 94720

DASartor@LBL.gov
(510) 486-5988
http://Ateam.LBL.gov