



Save Energy Now in High Performance Computer Centers

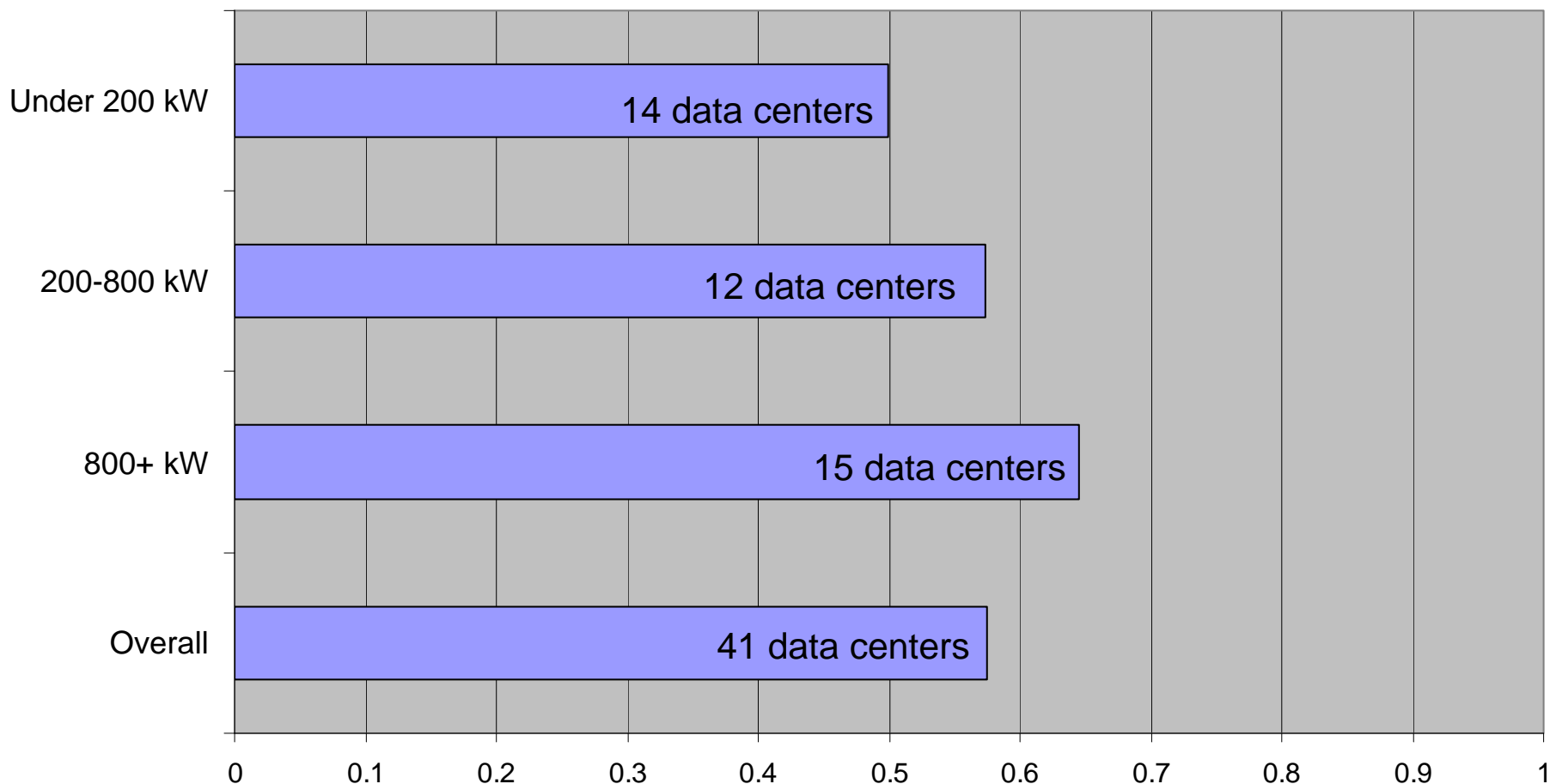
CEE Field Trip
January 13, 2009

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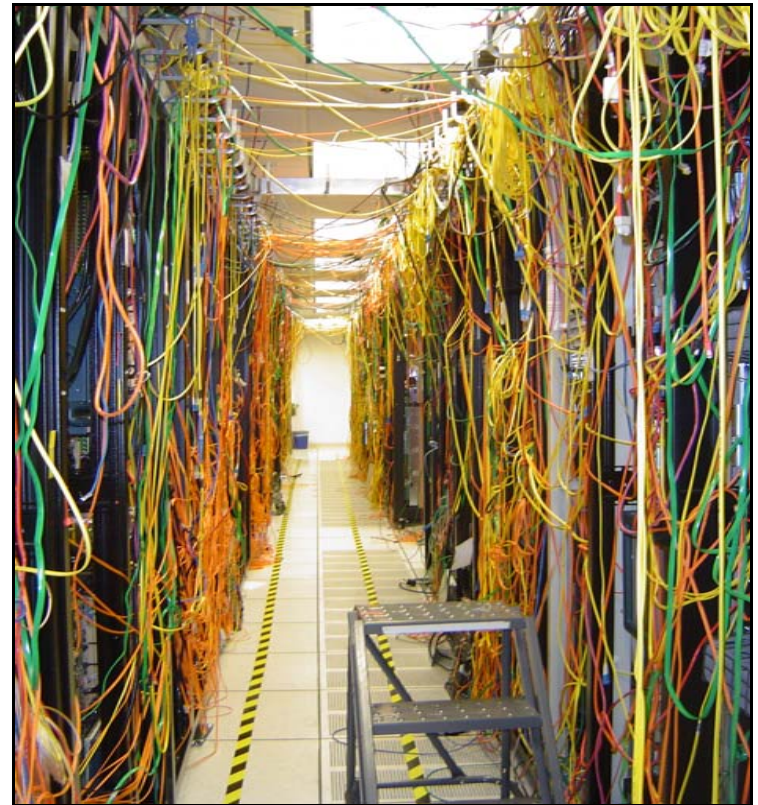


Average Data Center Infrastructure Efficiency (DCiE) for DOE Data Centers



Using benchmark results to find best practices:

- **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**





Applying Best Practices at LBNL:

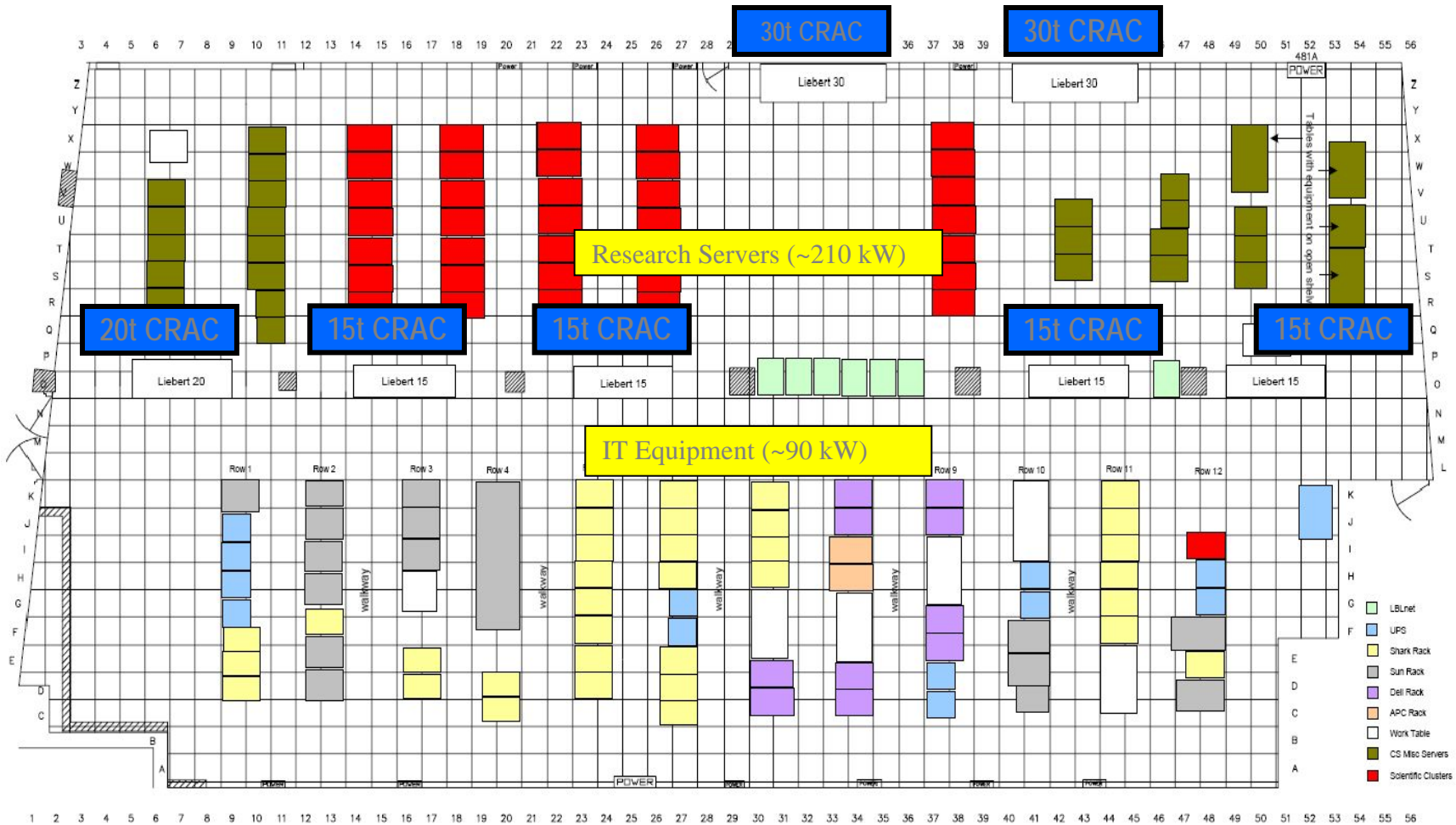
- Partnership between CIO, CS, and energy efficiency researchers
- Existing data centers relatively efficient
 - NERSC: .72 kW-IT/kW-total (taking advantage of central plant)
 - 50B-1275: .59 - .64 kW-IT/kW-total (tower cooled CRACs)
- Increased efficiency frees up needed “capacity”
- Leveraging data centers as test beds to create an impact beyond Berkeley Lab
- Working with vendors to develop new products and strategies



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

Air Management Improvements in LBNL 50B-1275 Data Center (layout September 2007)



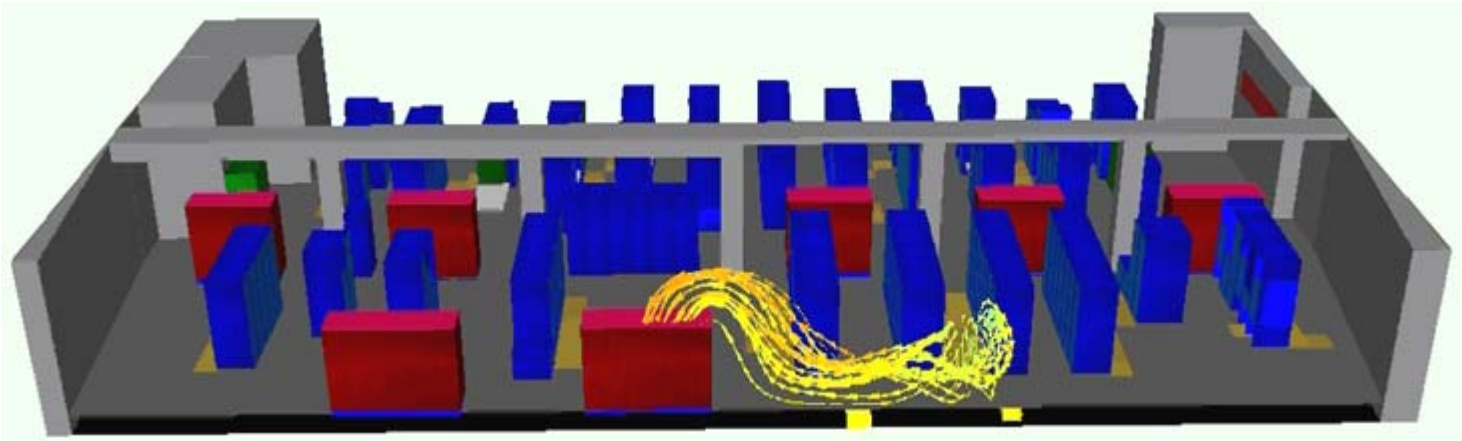
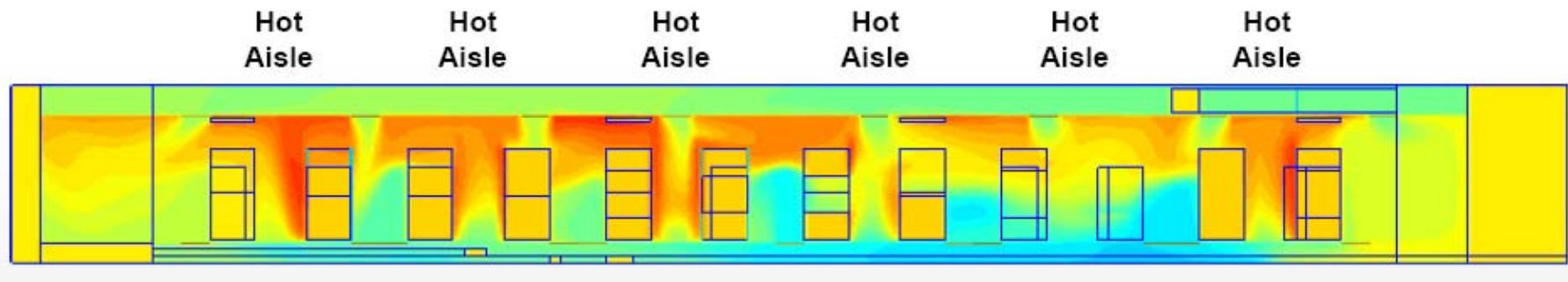


Air Management Assessment Effort:

- 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

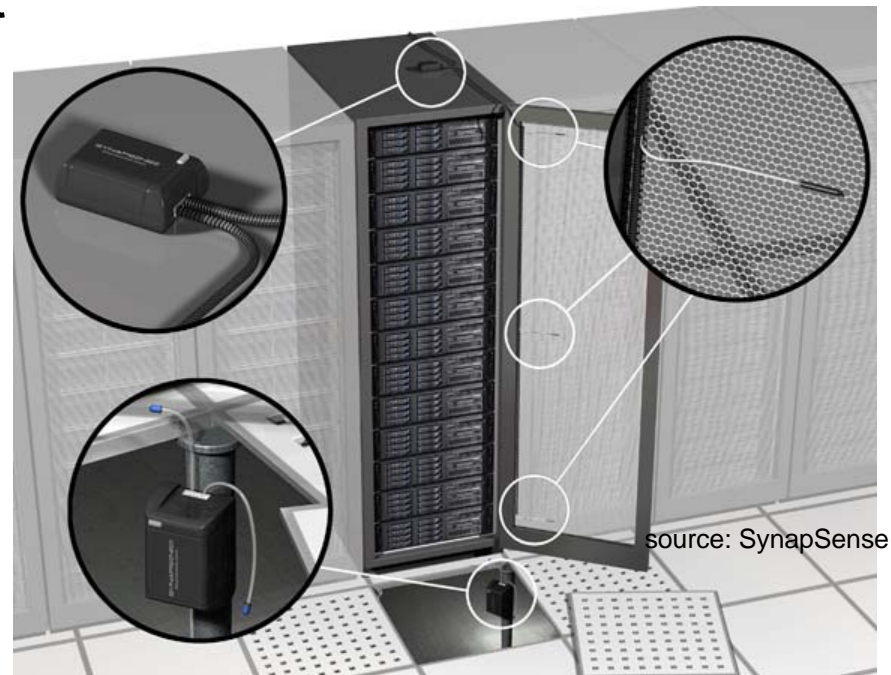


Visualization Using CFD:



Wireless Environmental Monitoring:

- Most operators lack visibility into data center environment
 - Can't effectively manage the facility
- SynapSense wireless sensor network installed
 - 300 monitoring points (temperature, humidity, under-floor pressure, current)
- Air management now based on empirical data, not intuition

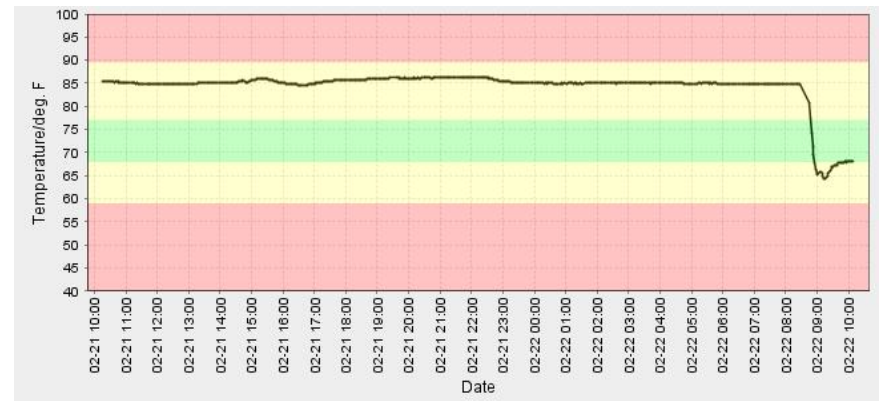


Results: Blanking Panels

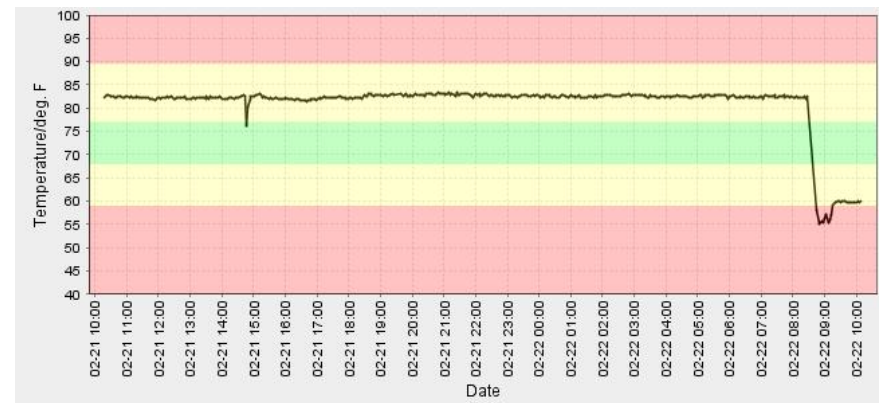
- One blanking panel added and temperature dropped $\sim 20^\circ$
- impact of other best practices confirmed
 - eliminate leaks in floor
 - improve air management



top of rack



middle of rack

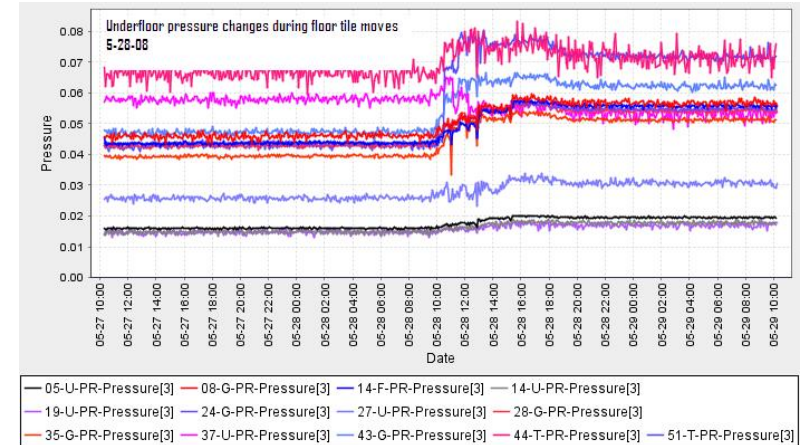


Results: Tune Floor Tiles

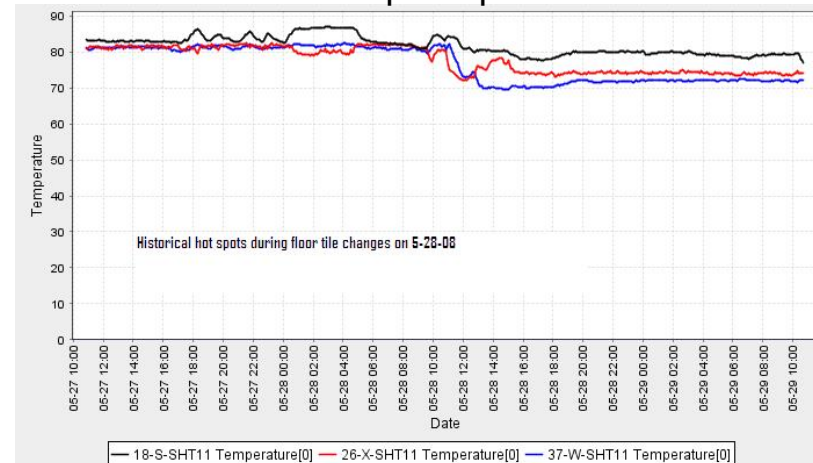


- Too many permeable floor tiles
- if airflow is optimized,
 - under-floor pressure \uparrow
 - rack-top temperatures \downarrow
 - data center capacity grows
- Measurement and visualization assisted tuning process

under-floor pressures



rack-top temperatures



Improve Air Management:

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



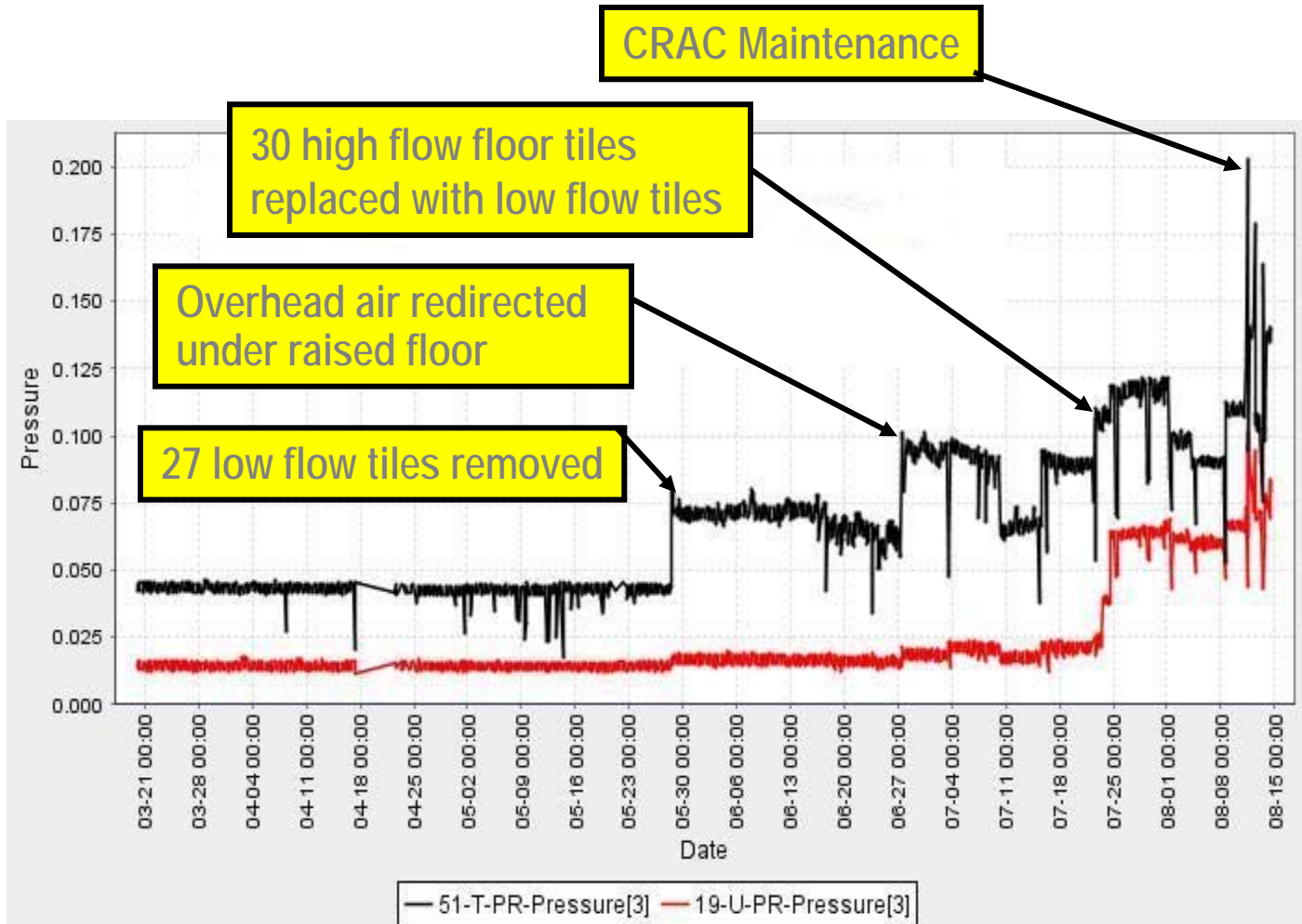
Before



After



Documenting Progress



5 months of floor pressure management

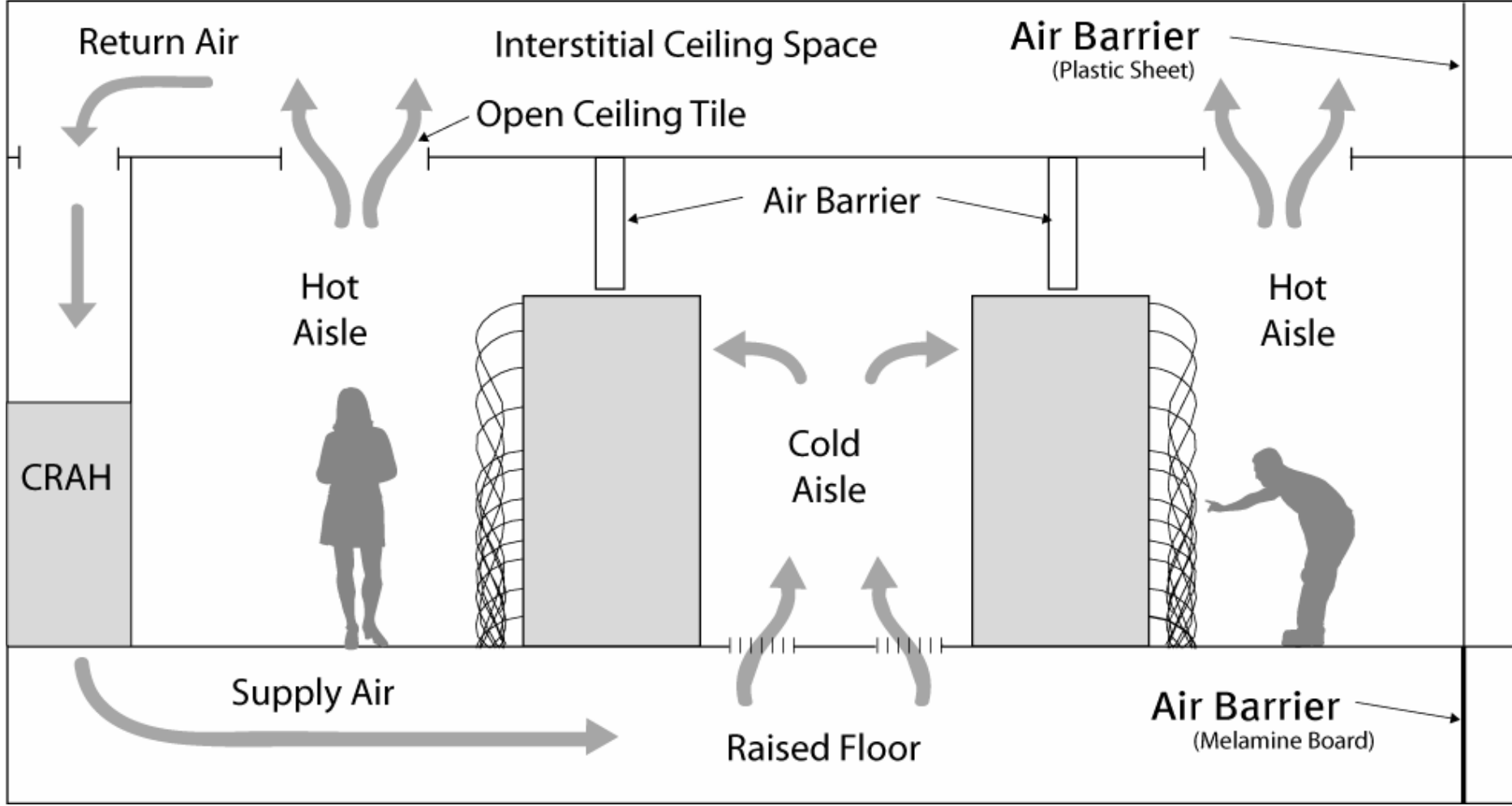


Results: Air Management Project (so far)

- 21% increase (~100kW) in IT load
- CRAC unit set points 3°F warmer
- Fewer hot spots
- (1) 15 ton CRAC unit turned off
- (1) extra 15 ton CRAC unit on-line but redundant
- Wireless sensor network enables operations to monitor and fine tune changes
- Next step:
 - Curtains to improve isolation
 - Integrated CRAC unit control upgrade



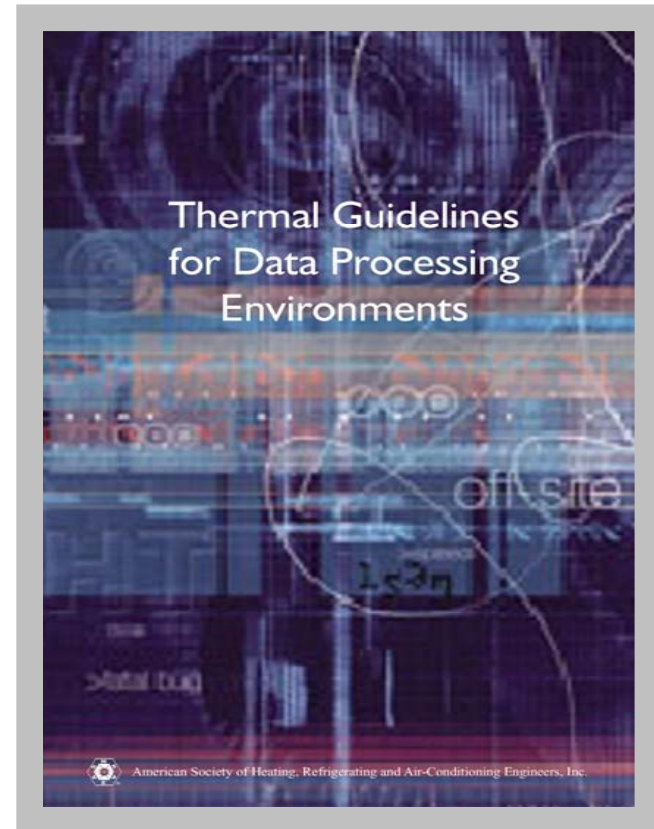
Improve Air Management:



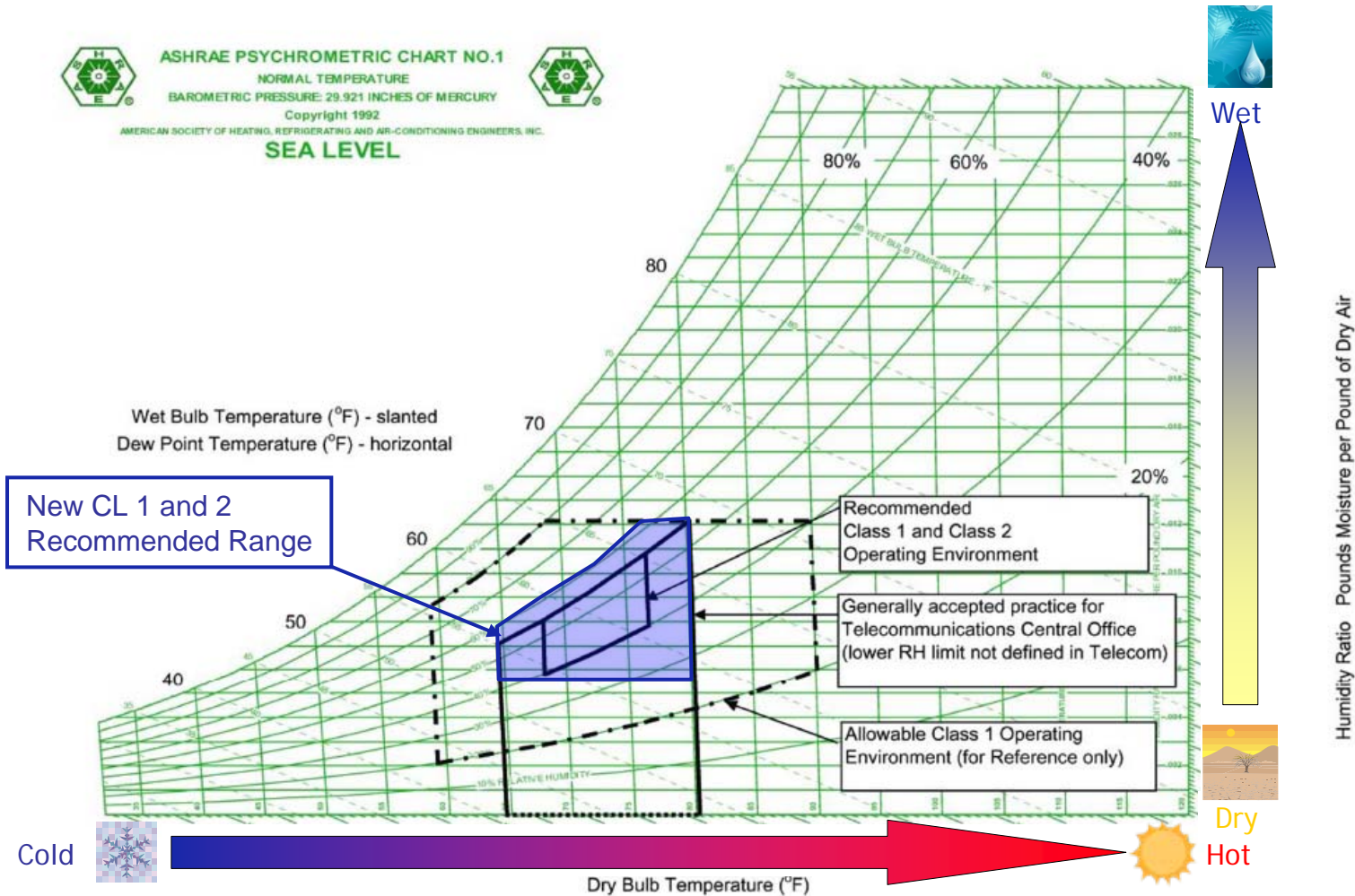


Environmental Conditions

- Use ASHRAE Recommended and Allowable ranges of temperature and humidity



Design conditions at the inlet to IT equipment





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





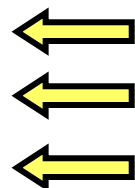
Improve Humidity Control:

- Eliminate inadvertent dehumidification
 - Computer load is sensible only
 - Medium-temperature chilled water
 - Humidity control at make-up air handler only
- Use ASHRAE allowable RH and temperature
- Eliminate equipment fighting
 - Coordinate controls on distributed AHUs



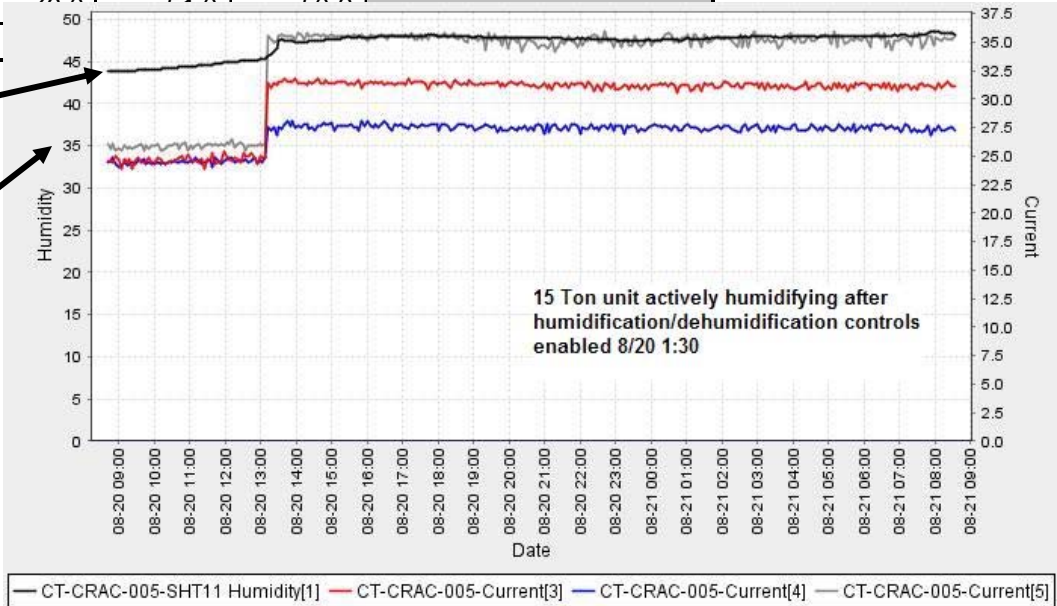
The Cost of Unnecessary Humidification in 50B-1275

	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				
Avg	79.2	31.7	46.4				

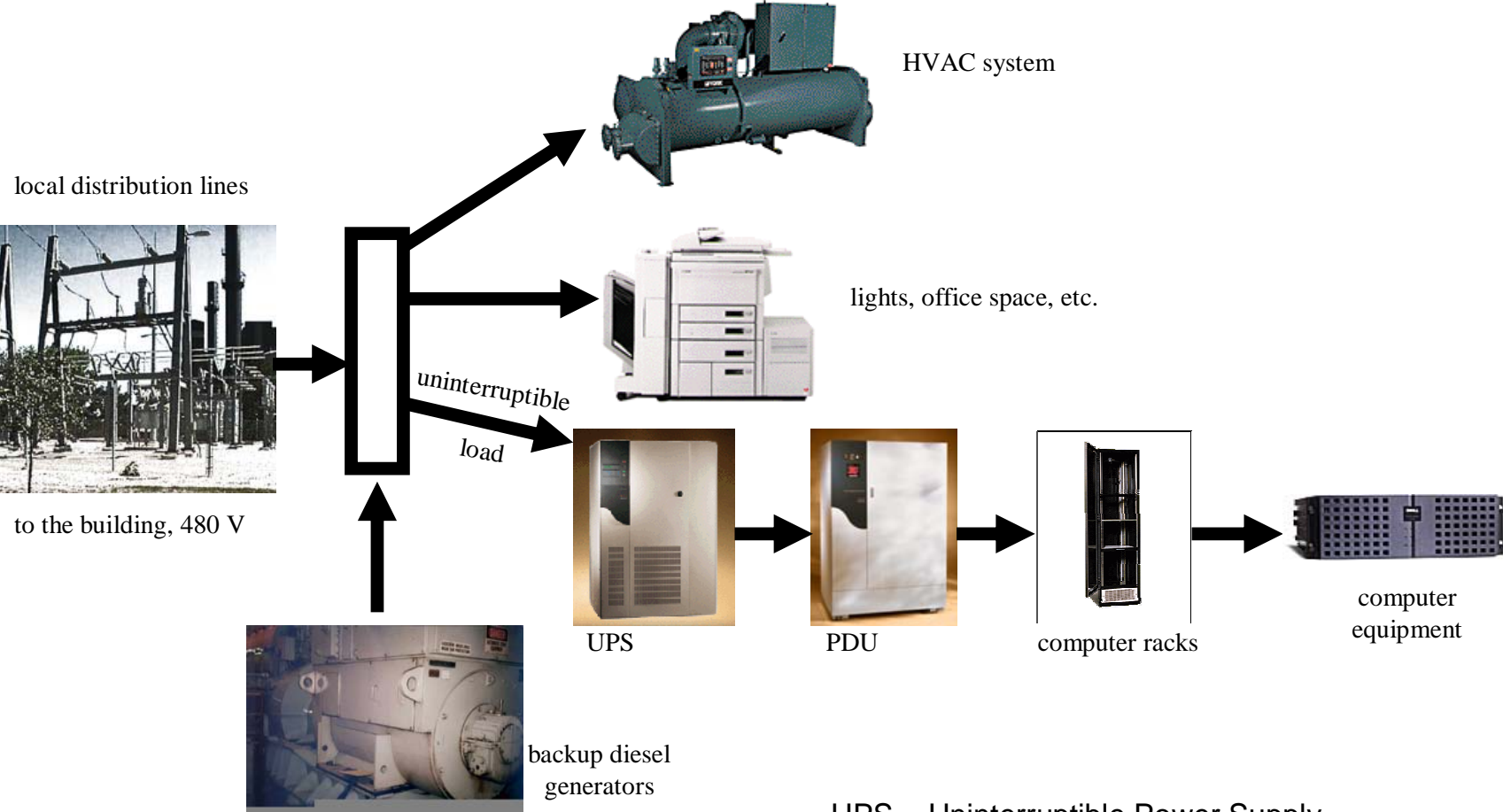


Humidity up 3%

CRAC power up 28%



Electricity Flows in Data Centers

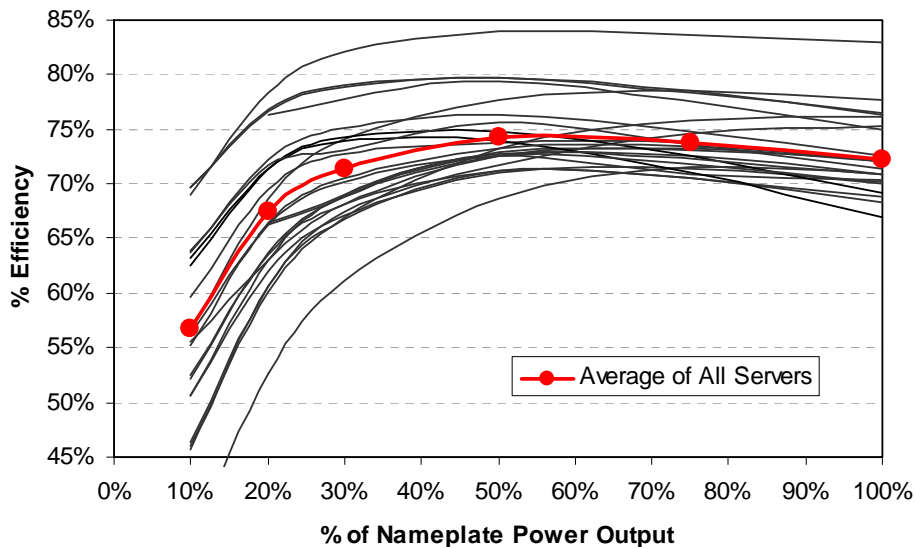


UPS = Uninterruptible Power Supply
PDU = Power Distribution Unit;

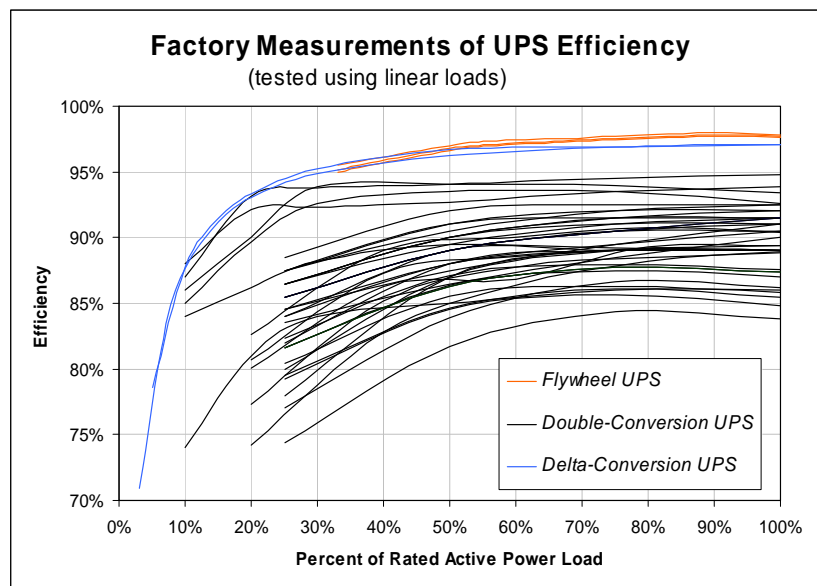


Specify Efficient Power Supplies and UPSs

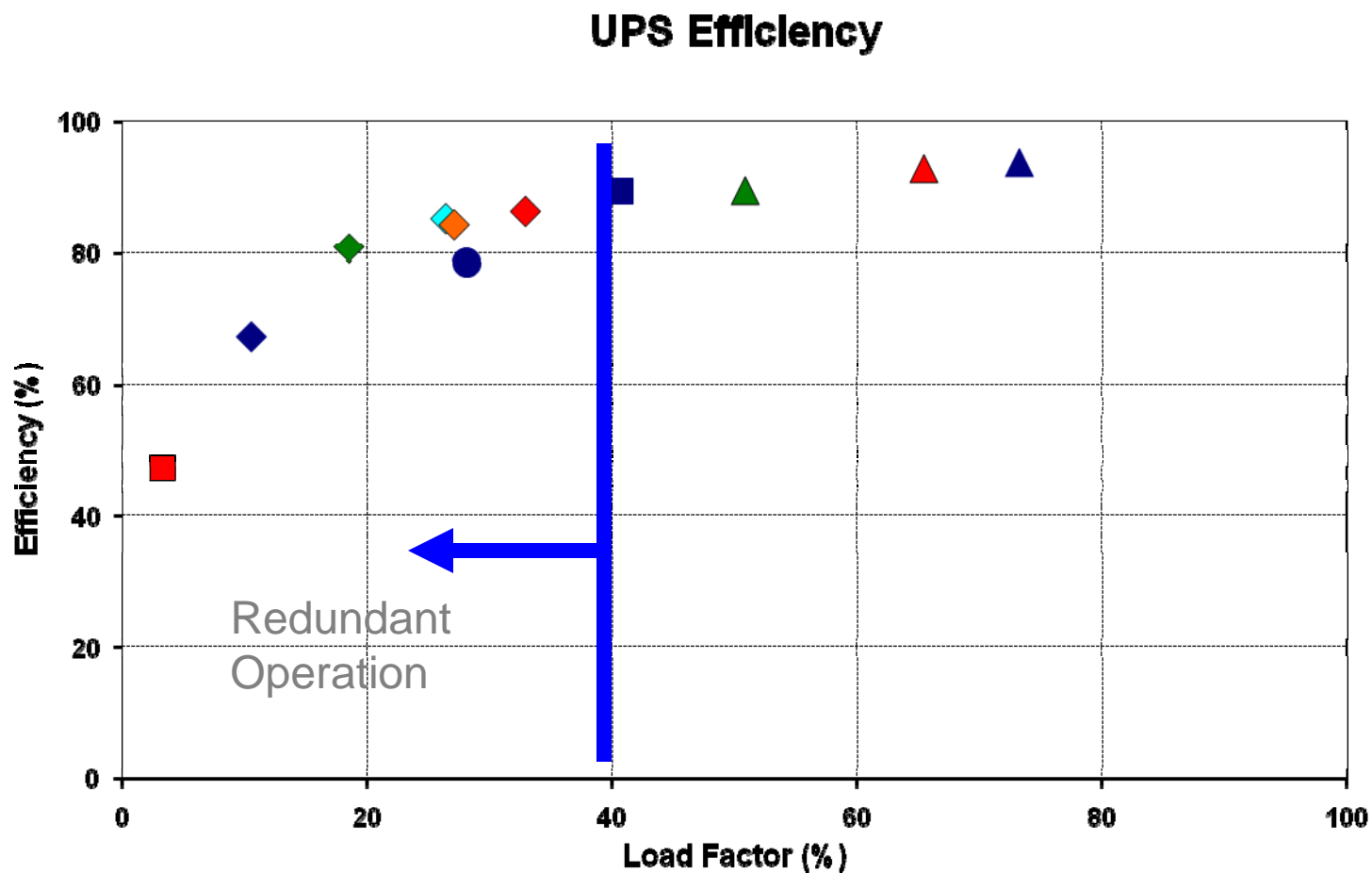
Power supplies in IT equipment generate much of the heat. Highly efficient supplies can reduce IT equipment load by 15% or more.



UPS efficiency also varies



Measured UPS Efficiency





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

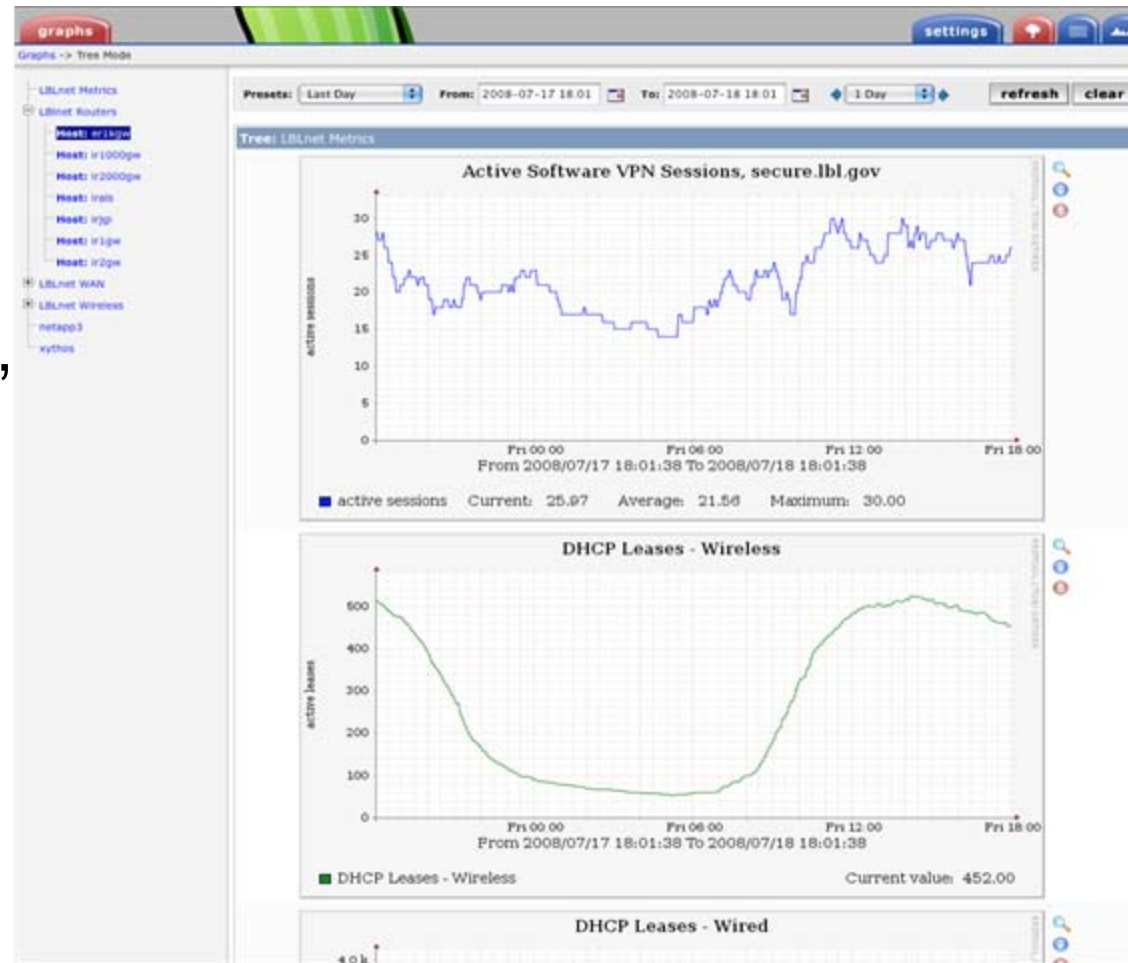


LBNL Wireless Monitoring System:

- 300 point SynapSense wireless monitoring
 - Temperature, humidity, under-floor pressure, CRAC current
 - 1-2 day installation, easy redeployment
- For the first time, we have a detailed understanding of environmental conditions
 - Real-time and historical data
 - Remote console and alert notification
 - Quick reports and graphs from underlying database
 - Modules can also measure liquid flow, liquid presence, and particle count

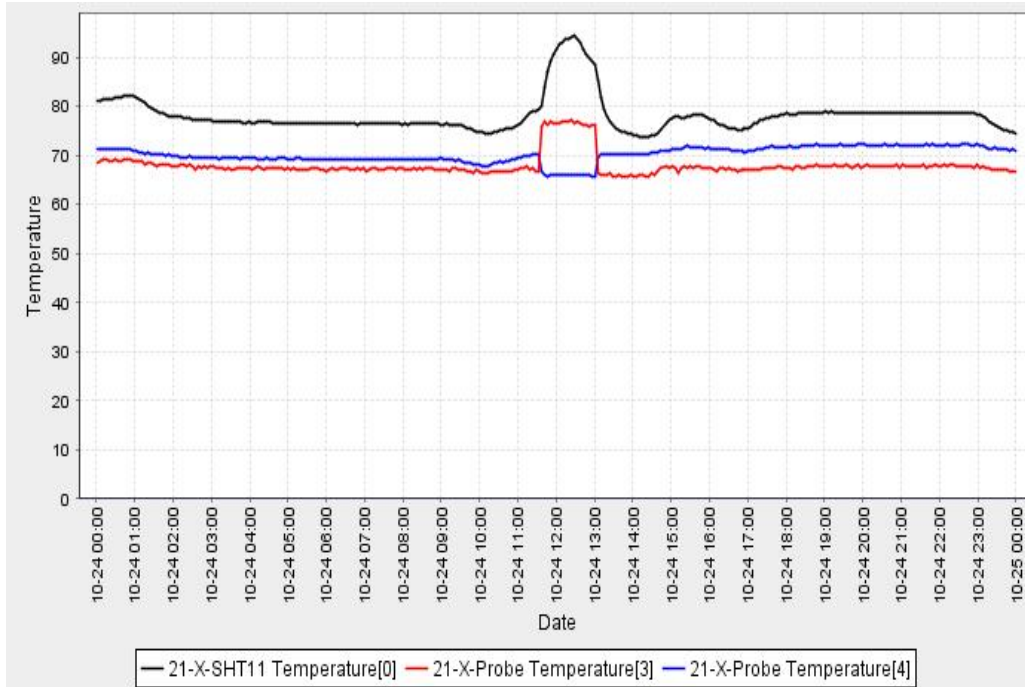
The Importance of Visualization

- Systems & network administrators have tools for visualization
- Useful for debugging, benchmarking, capacity planning, forensics
- Data center facility managers have comparatively poor visualization tools



Learning from the sensors

Rack top, middle and bottom temperature when cold aisle air flow obstructed





Next Steps with SynapSense

- Integration of monitoring system with controls (Automatic staging of CRACs and Demand based resets of pressure and temperature)
- ‘Live Imaging’ heat-map animations
- Real time DCiE (data center infrastructure efficiency) calculation



Advice:

- Put together team of IT, Facilities and experienced consultants
- Benchmark energy and environmental performance
- Instrument and convert data to information
- Eat your spinach (blanking panels, leaks, CRAC maintenance)
- Keep an eye on emerging technologies (flywheel UPS, rack-level cooling, DC power)

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