Technical Session II

Indian Data Centers for the 21st Century

January 24, 2008

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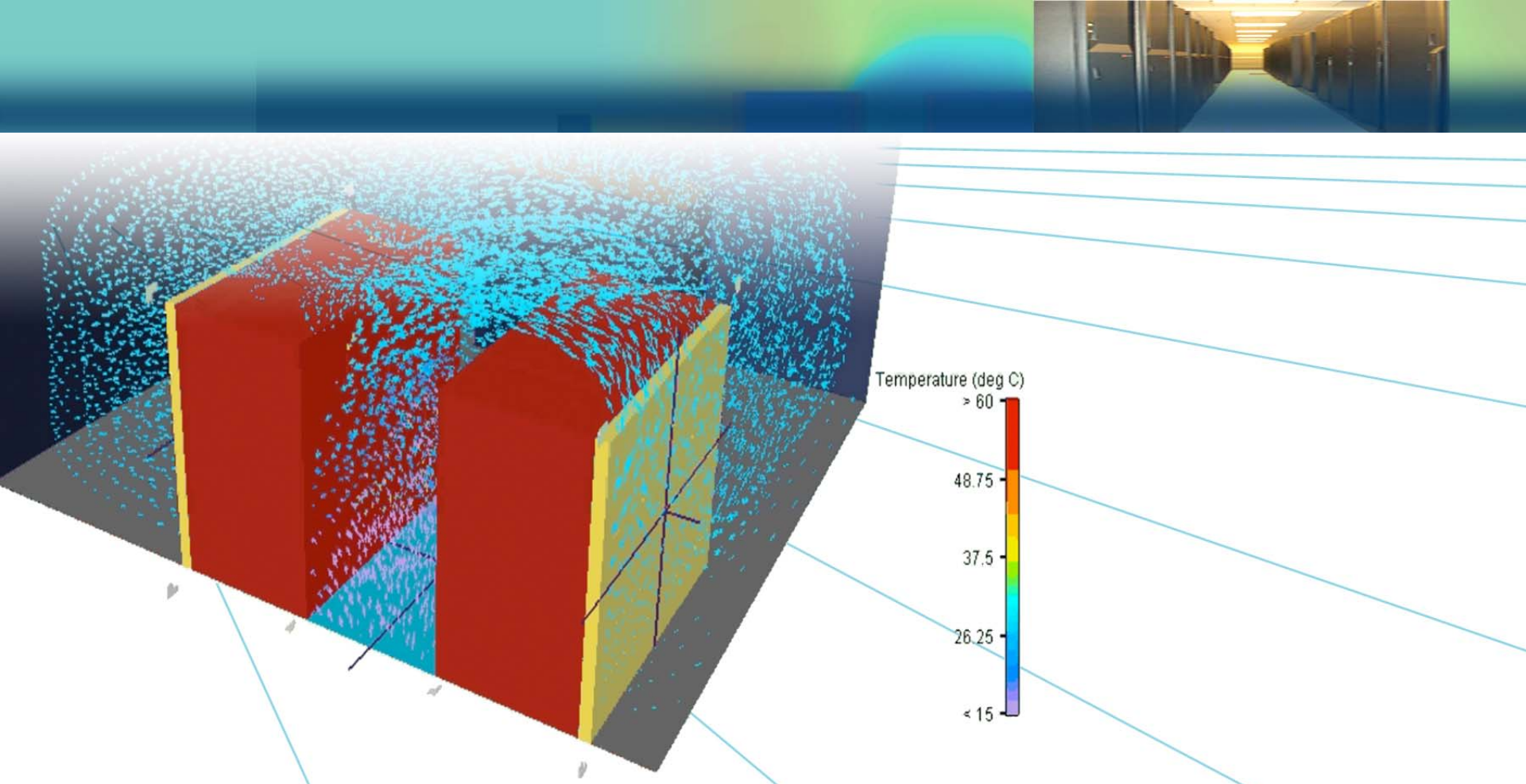
BERKELEY LAB

Topics:

- Key Design Issues
- Best Practices in Data Center Design and Operation
  - IT
  - HVAC
  - Electrical



Key Data Center Design Issues

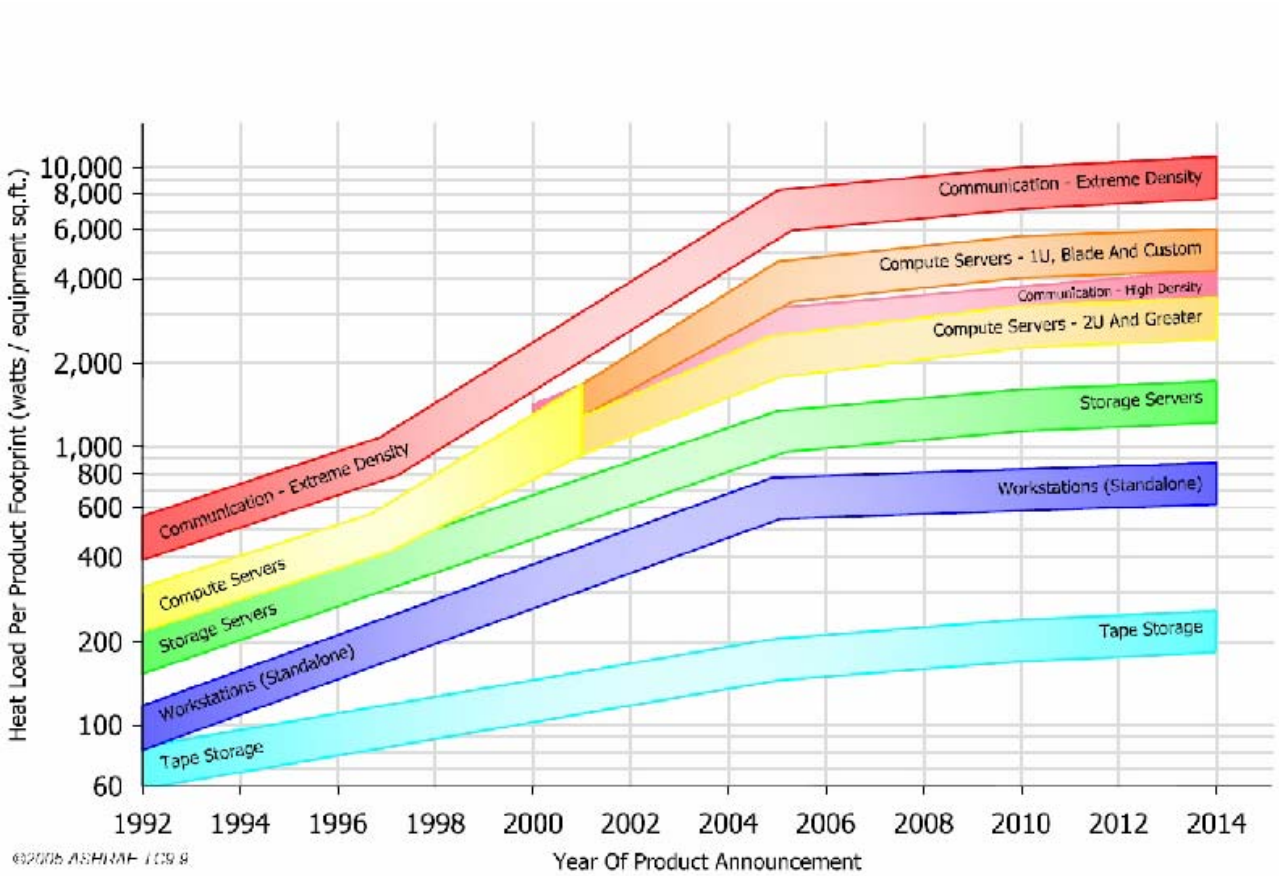
Design Issues:

- IT equipment load
- Redundancy
- Environmental conditions
- Zoning

IT Equipment Load

- Predicting IT loads
  - Over sizing, at least initially, is common
  - Implement modular and scalable approaches
- IT loads can be controlled
  - Power supply options
  - Server efficiency
  - Software efficiency (Virtualization, MAID, etc.)
  - Redundancy and back-up power
  - Low power modes
- Reducing IT load has a multiplier effect

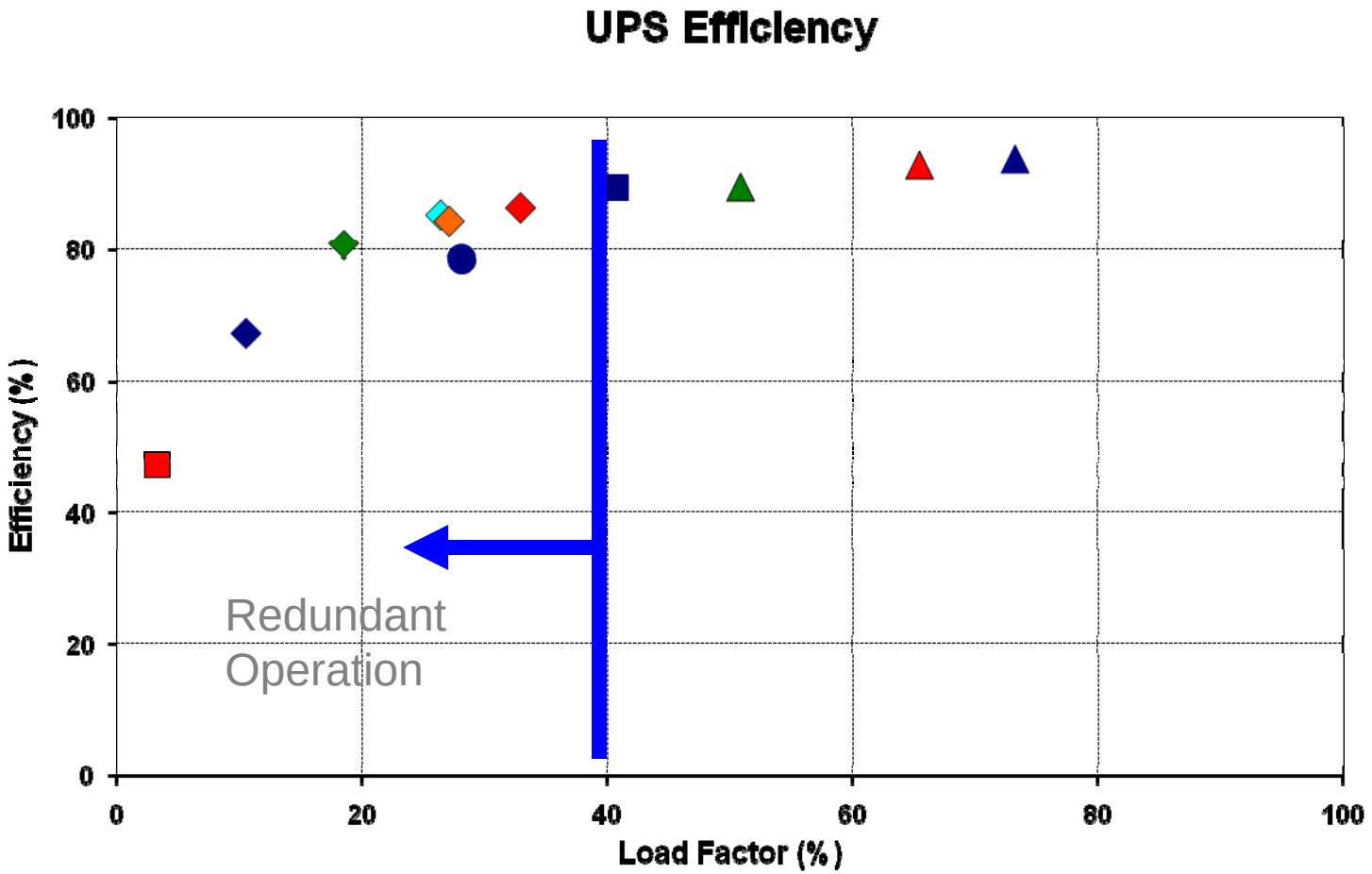
ASHRAE Prediction of Intensity Trend



Redundancy

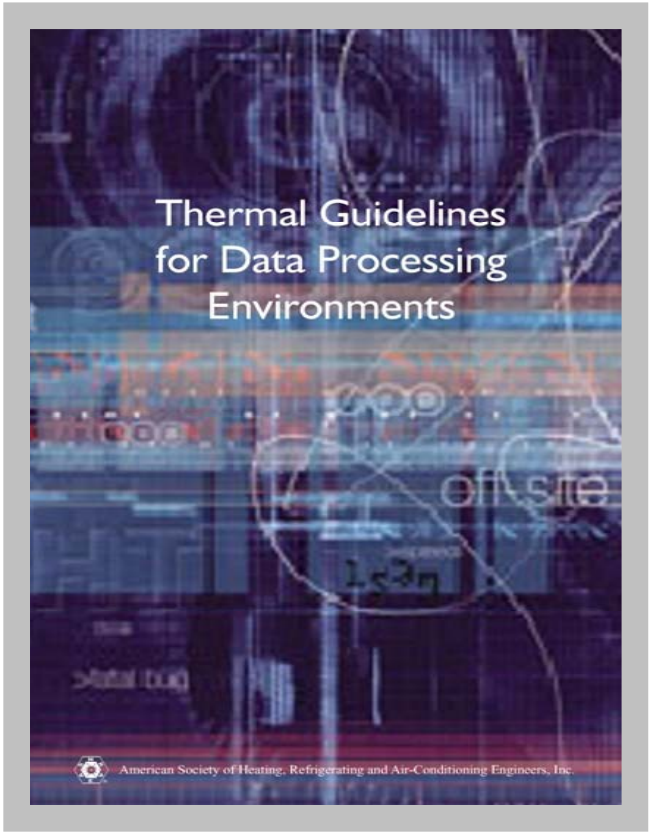
- Understand what redundancy costs – is it worth it?
- Different strategies have different energy penalties (e.g. 2N vs. N+1)
- Redundancy in electrical distribution puts you down the efficiency curve

Measured UPS Efficiency

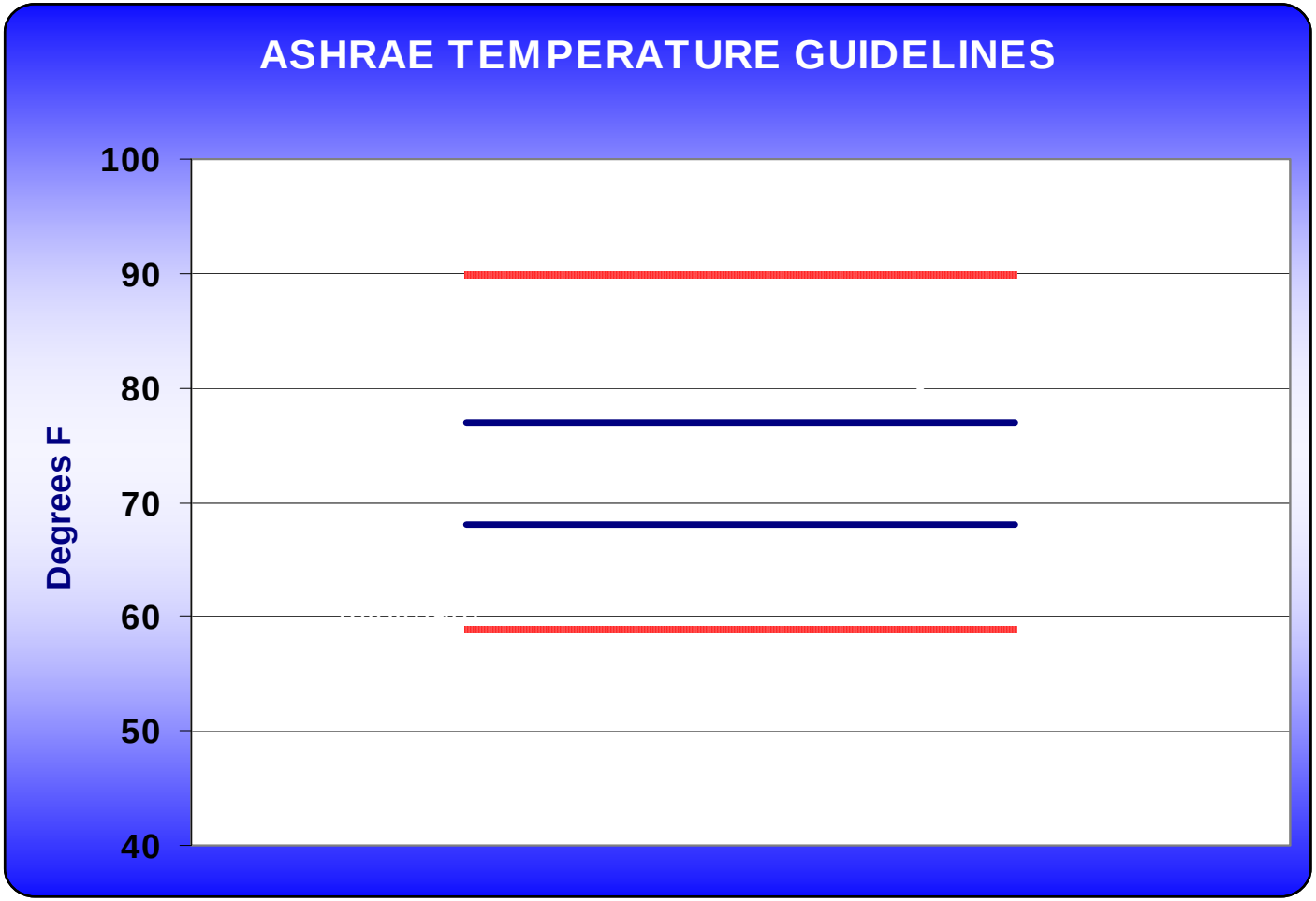


Environmental Conditions

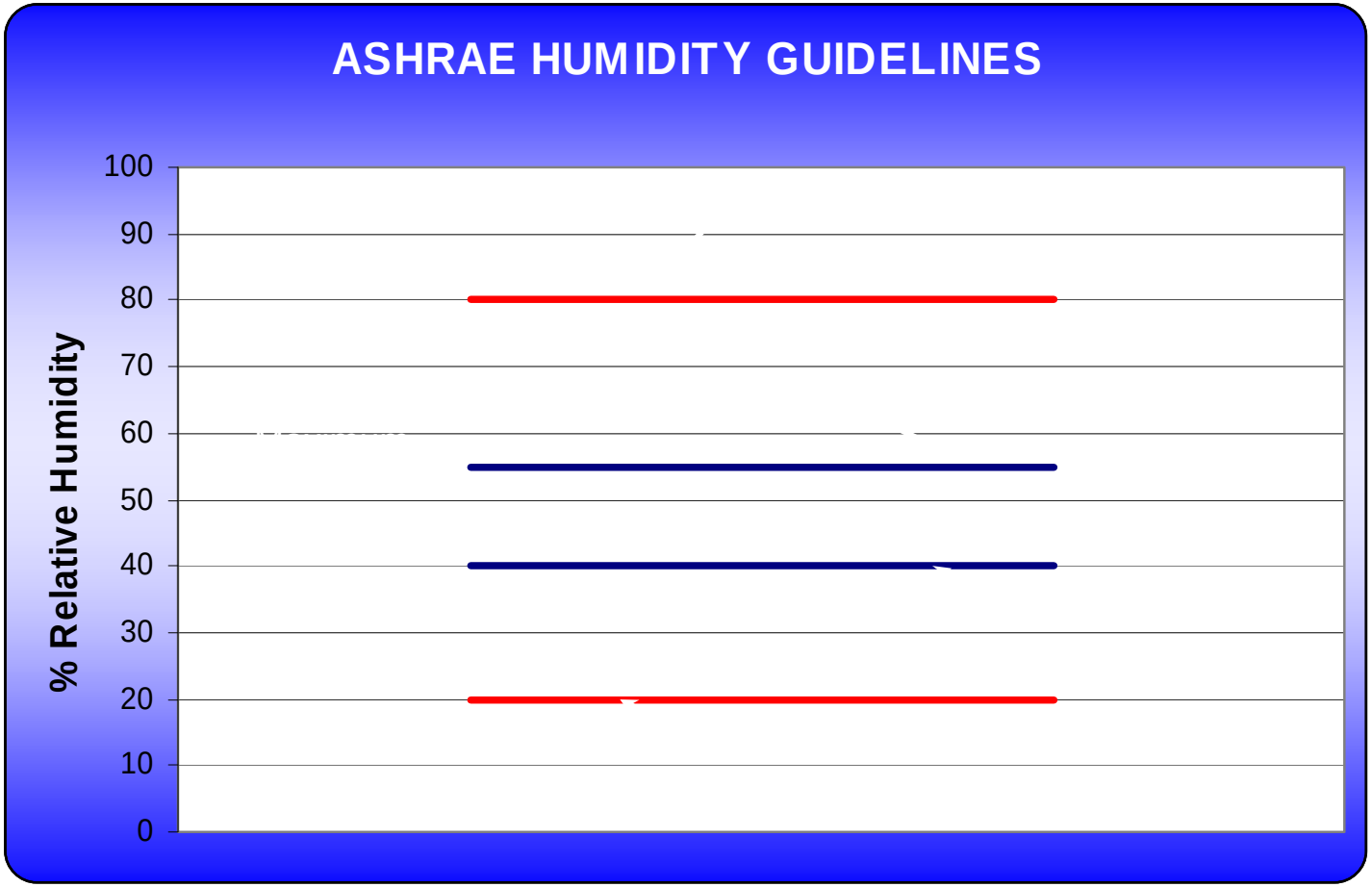
- ASHRAE - consensus from all major IT manufacturers on temperature and humidity conditions
- Recommended and Allowable ranges of temp and humidity
- Air flow required



Temperature Guidelines – *at The Inlet* to IT Equipment



Humidity Guidelines—
at The Inlet to IT Equipment



Zoning:

- Some IT equipment (e.g. storage) requires tighter control
- Don’t penalize the whole center for a few pieces of equipment
- Different zones should be provided

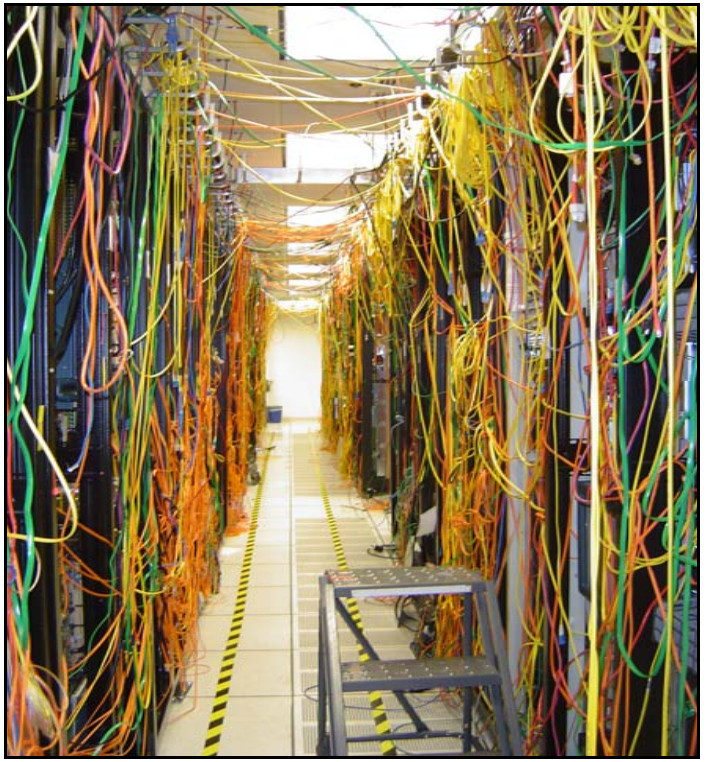
Computational Energy Efficiency:

- While my presentation focuses on the data center infrastructure, significant opportunities are available to increase computational energy efficiencies:
- Improve Utilization of Resources:
  - Consolidation and virtualization
  - Grid computing
  - Data storage optimization
- Enable and improve power management (dynamic loading)
- Improve software efficiency (and software instructions to hardware)
- Any reduction in IT equipment energy use has a corresponding savings in infrastructure
  - Potential first cost savings are often missed
- Very challenging to set standards

Using benchmark results to find best practices:

The ratio of IT equipment to the total power is an indicator of relative overall efficiency. Examination of individual systems and components in the centers that performed well helped to identify best practices:

- **Air management**
- **Right-sizing**
- **Central plant optimization**
- **Efficient air handling**
- **Free cooling**
- **Humidity control**
- **Liquid cooling**
- **Improving power chain**
- **UPSs and equipment power supplies**
- **On-site generation**
- **Design and M&O processes**



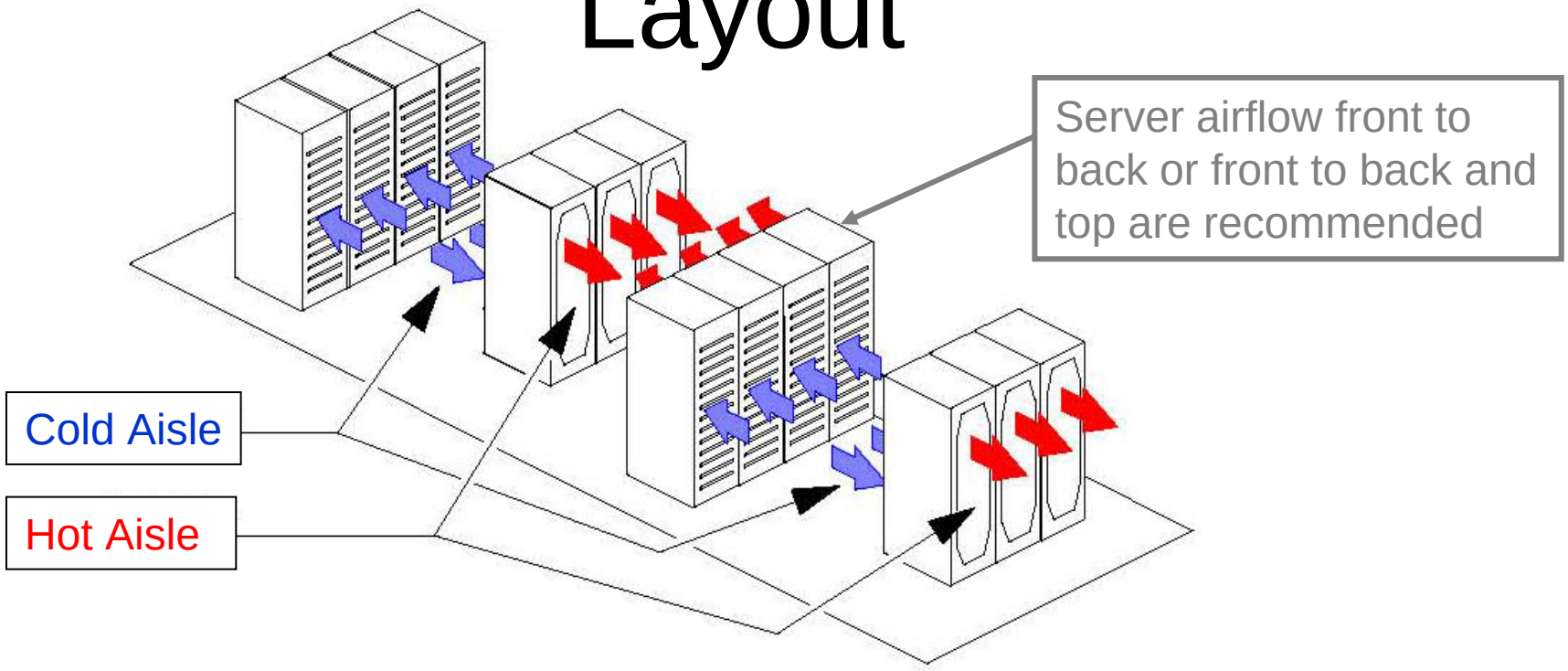
Air Management:

- Typically, much more air is circulated through computer room air conditioners than is specified by manufacturers due to mixing and short circuiting of air
- Computer manufacturers now provide ASHRAE data sheets which specify airflow and environmental requirements
- Evaluate airflow from computer room air conditioners compared to server needs

Isolating Hot and Cold:

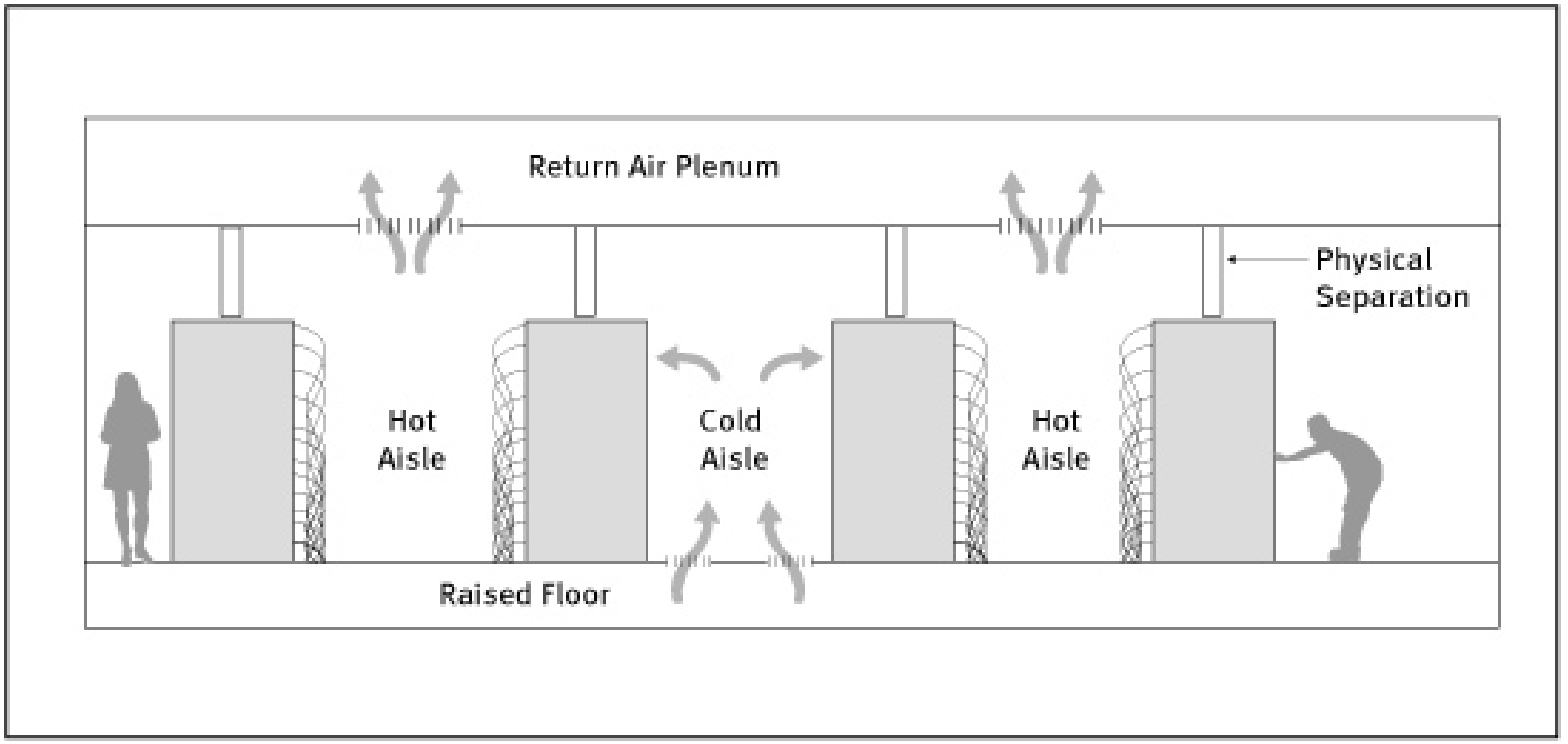
- Energy intensive IT equipment needs good isolation of “cold” inlet and “hot” discharge
- Computer room air conditioner airflow can be reduced if no mixing occurs
- Overall temperature can be raised in the data center if air is delivered to equipment without mixing
- Coils and chillers are more efficient with higher temperature differences

Data Center Hot and Cold Aisle Layout

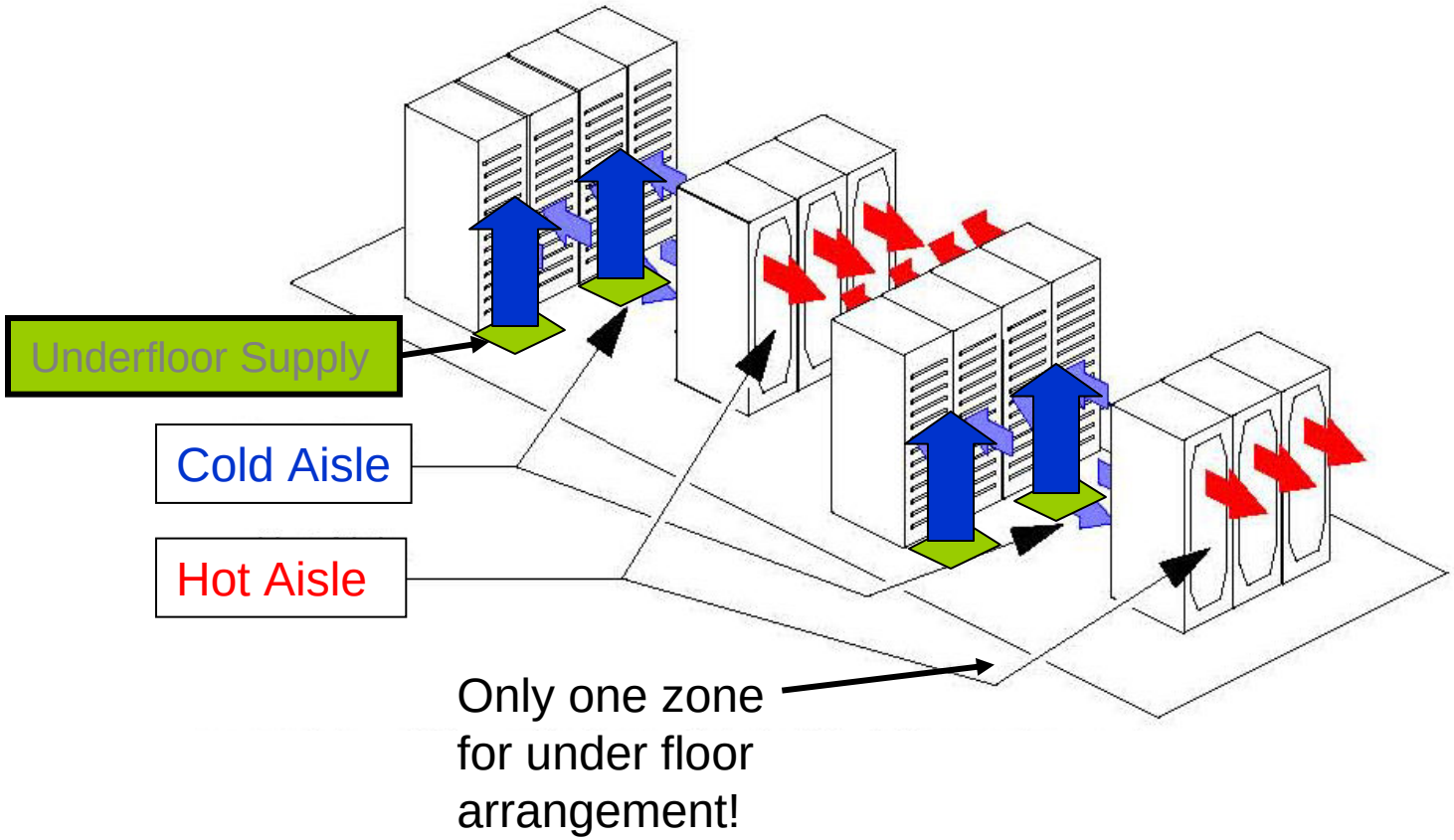


Optimize Air Management:

- Enforce hot aisle/cold aisle arrangement
- Eliminate bypasses and short circuits
- Reduce air flow restrictions
- Proper floor tile arrangement
- Proper locations of air handlers



Data Center Layout



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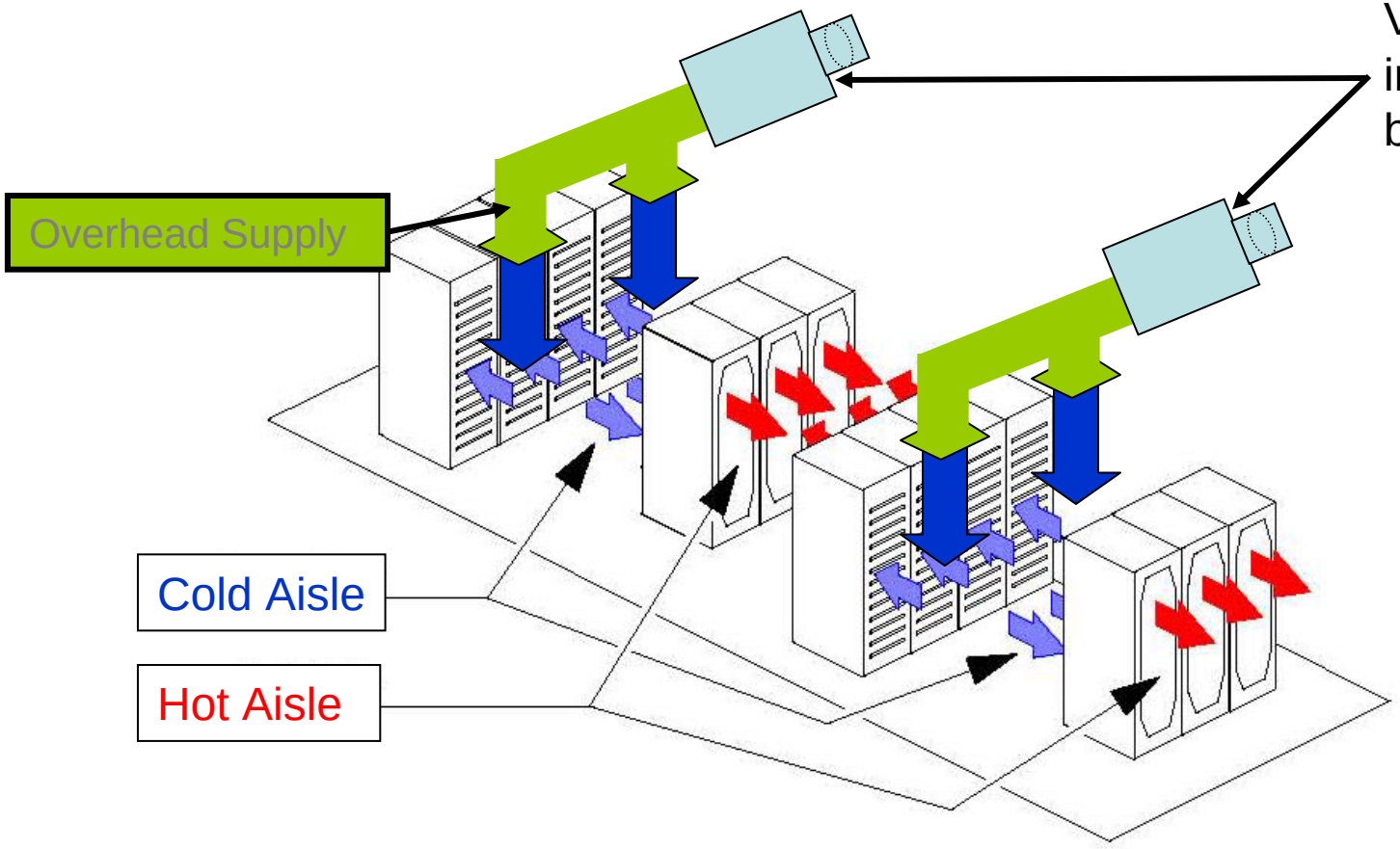
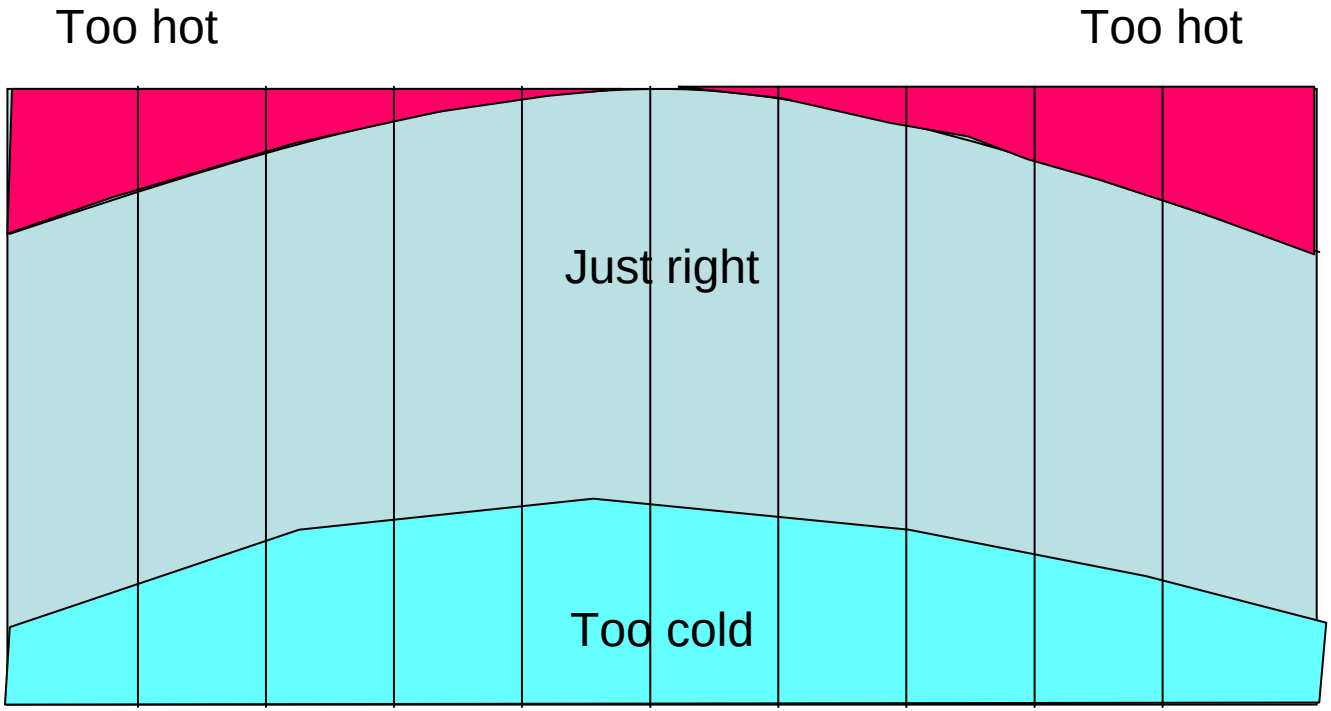


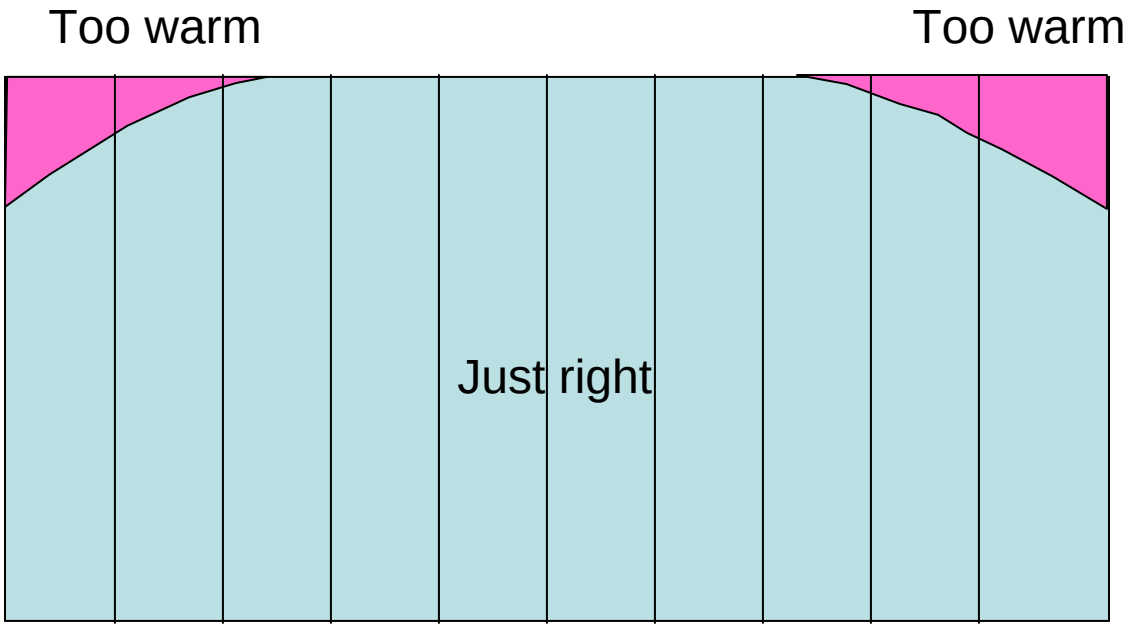
Typical Temperature Profile with Under Floor Supply



Elevation at a cold aisle looking at racks

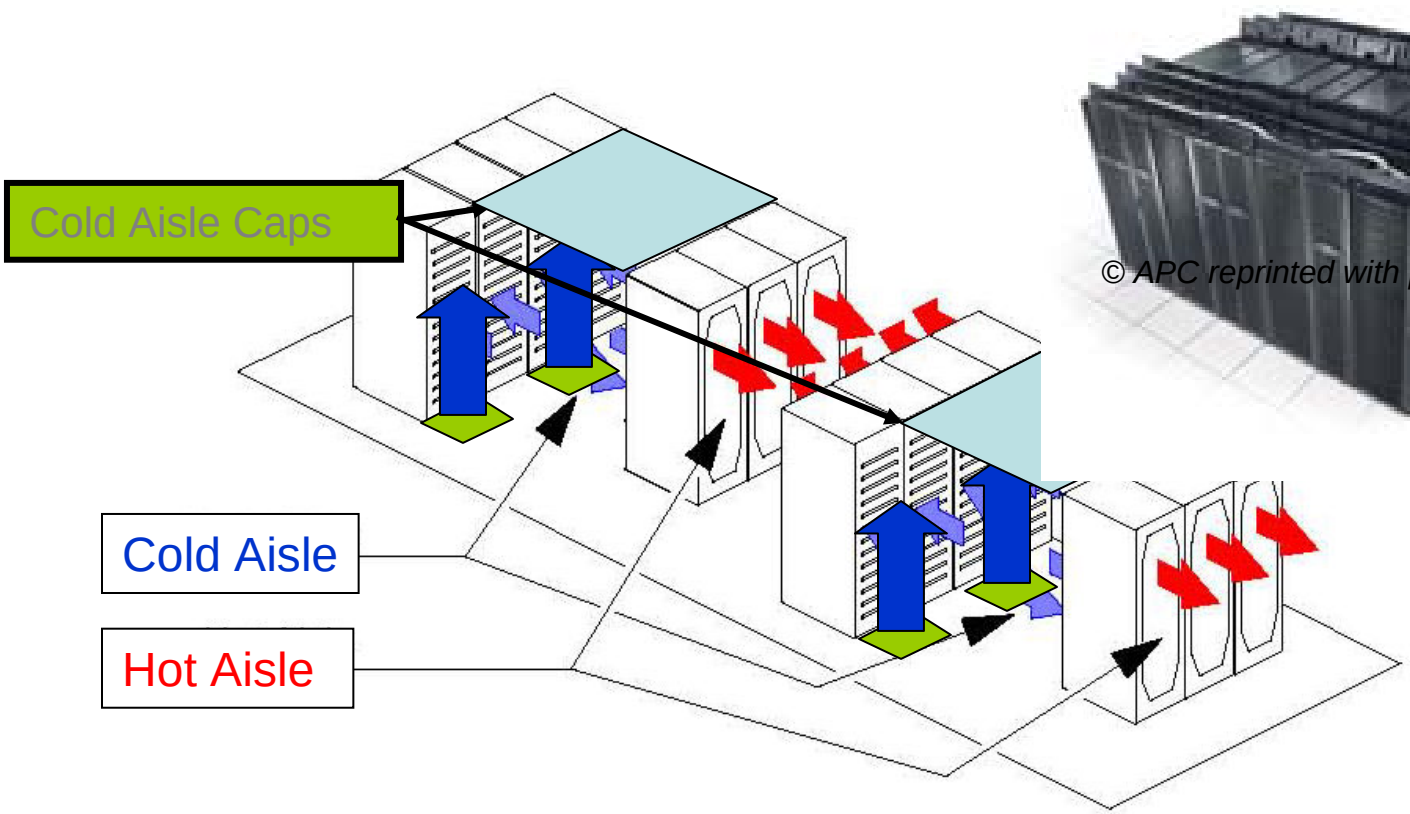
There are numerous references in ASHRAE. See for example V. Sorell et al; "Comparison of Overhead and Underfloor Air Delivery Systems in a Data Center Environment Using CFD Modeling"; ASHRAE Symposium Paper DE-05-11-5; 2005

Typical Temperature Profile with Overhead Supply



Elevation at a cold aisle looking at racks

Aisle Air Containment:



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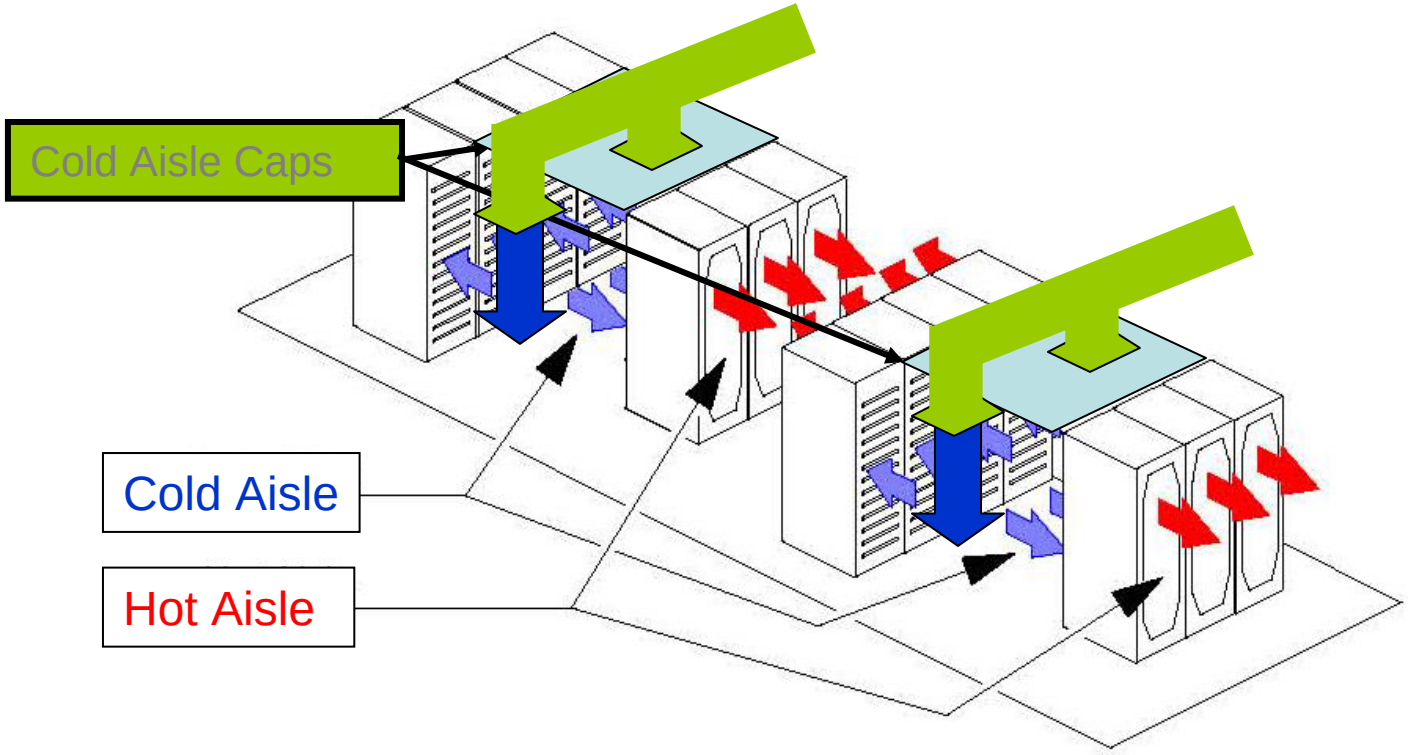
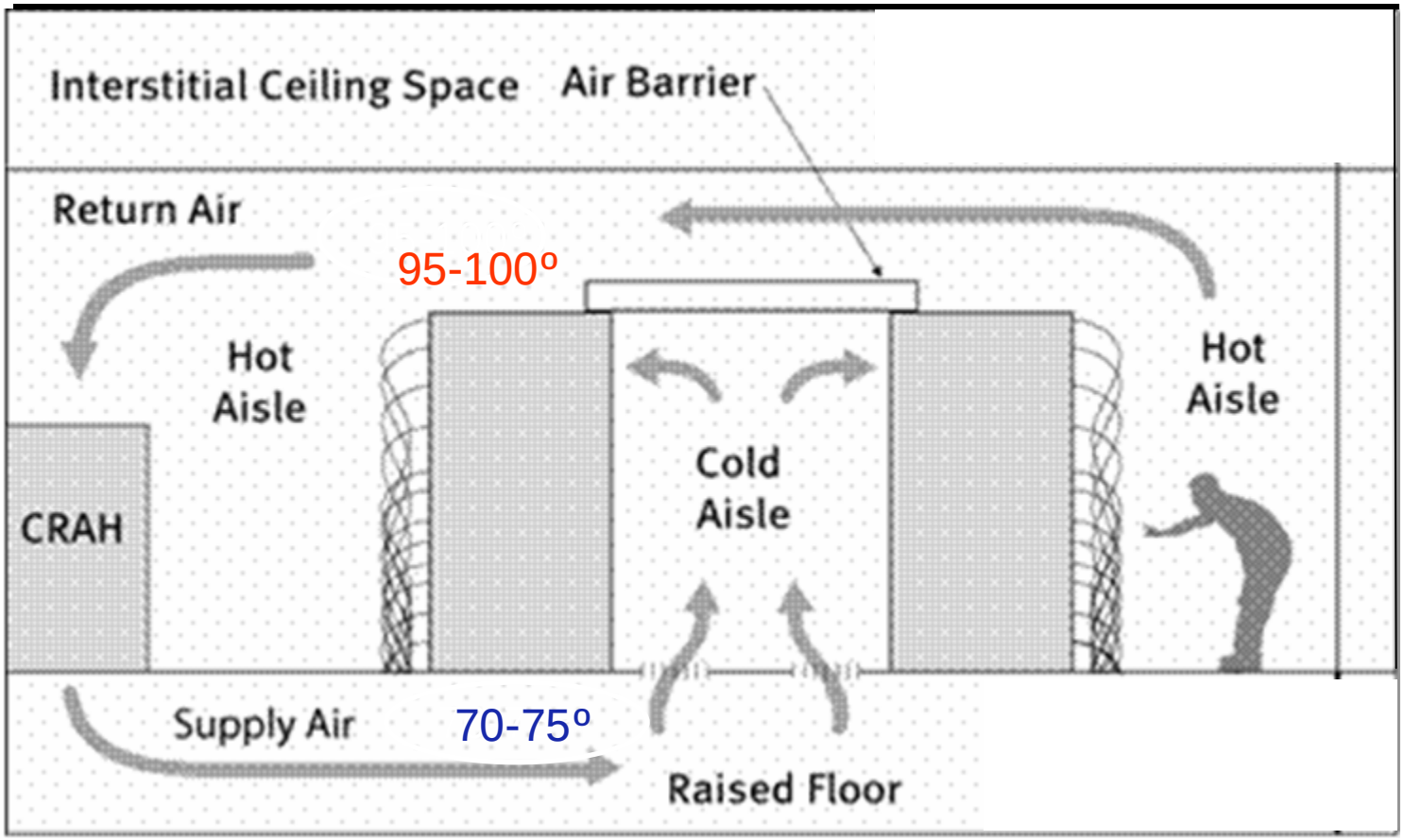
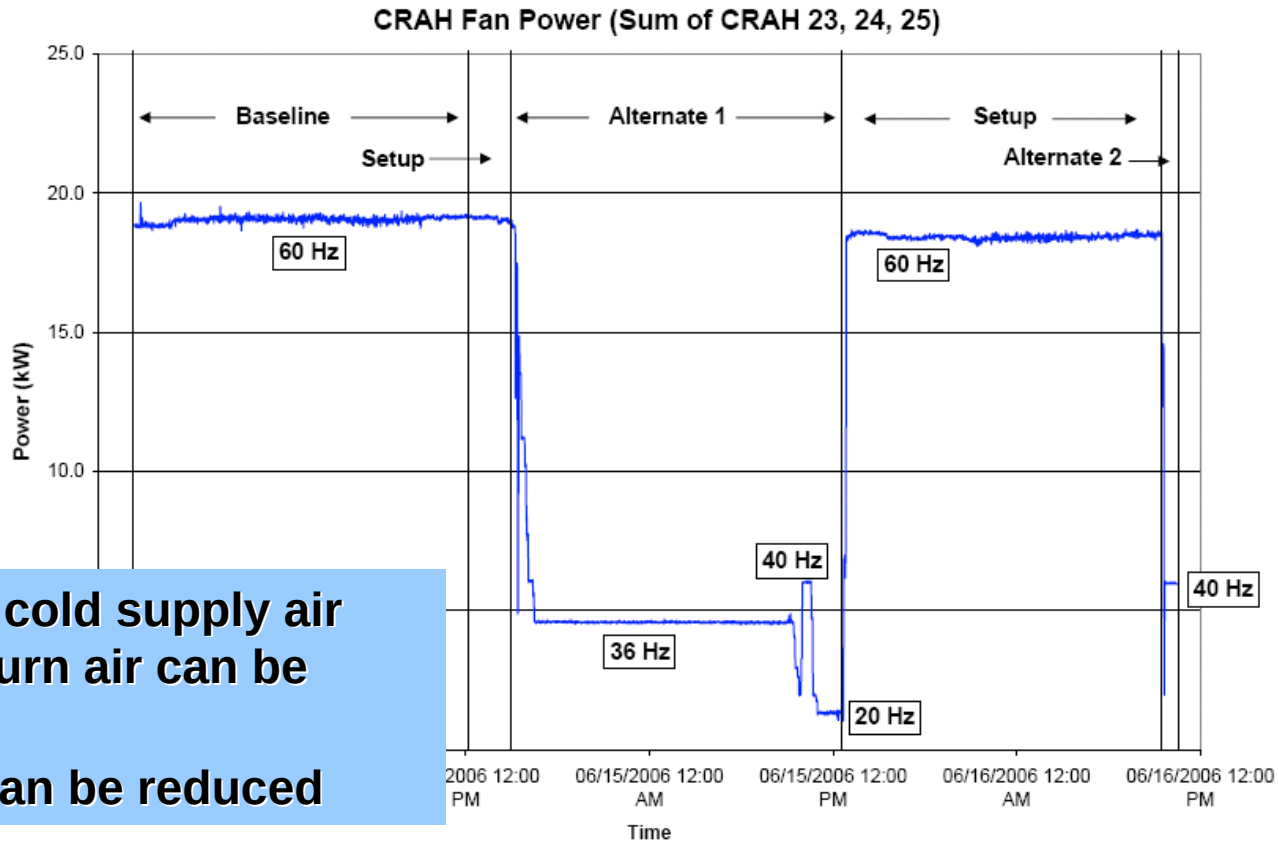


Best Scenario— Isolate Cold and Hot

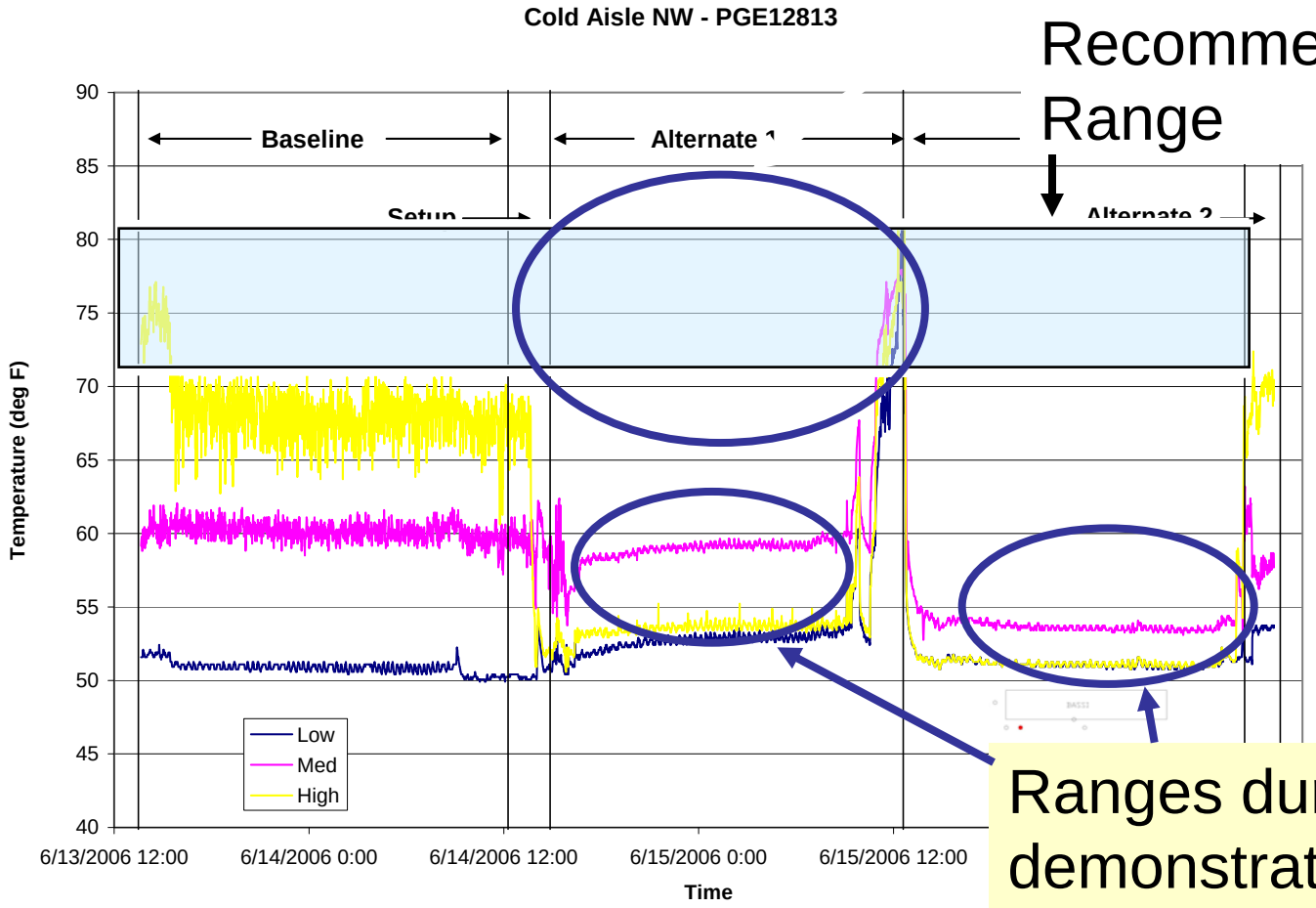


Fan Energy Savings – 75%



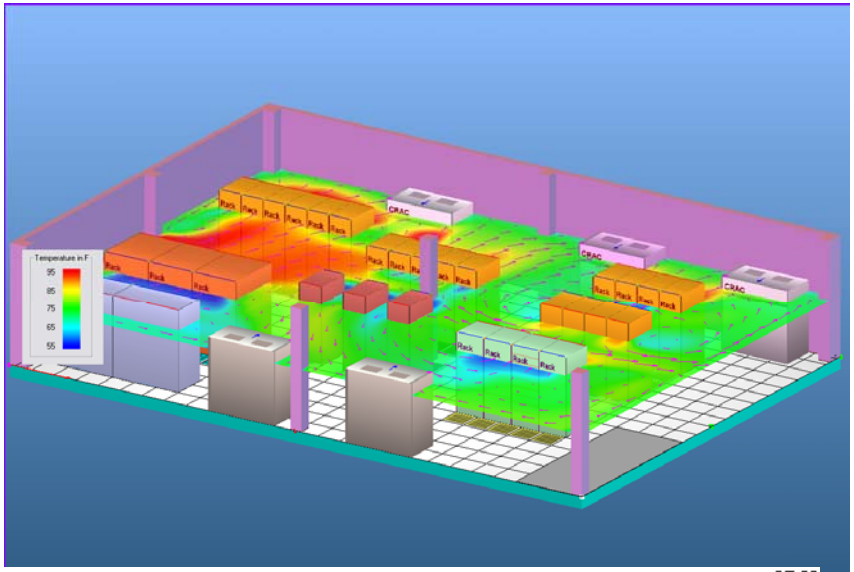
If mixing of cold supply air with hot return air can be eliminated-
fan speed can be reduced

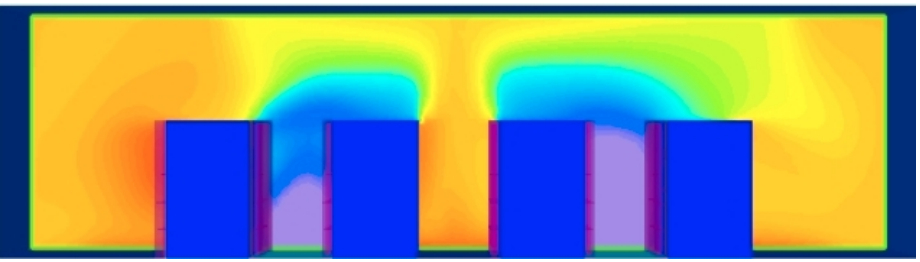
Better Temperature Control Can Allow Raising the Temperature in The Entire Center

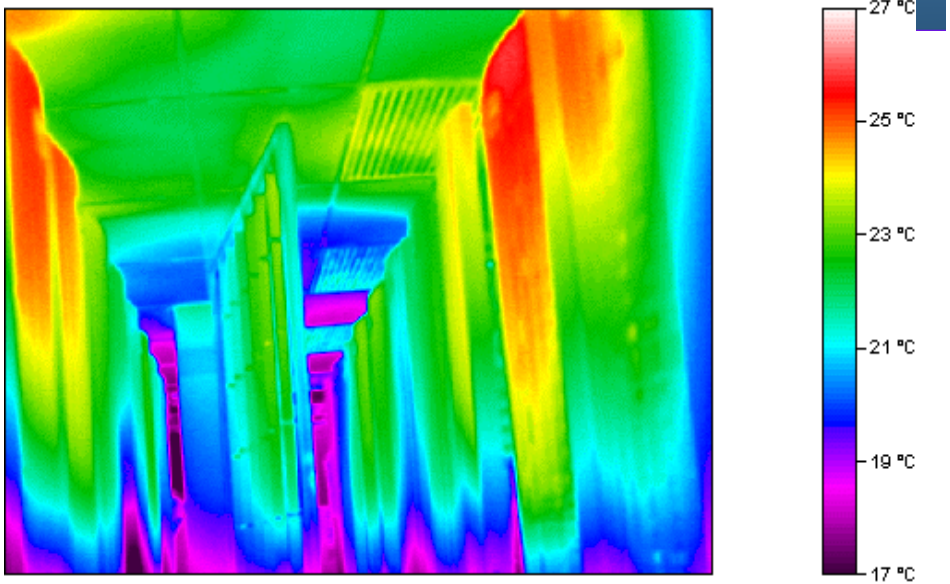


How Do You Visualize and Optimze Airflow?

- Spreadsheet
- Computational Fluid Dynamics (CFD) modeling
- Monitoring/Site Measurements (e.g. temperature sensor networks)
- Infrared thermography







Best air management practices:

- Arrange racks in hot aisle/cold aisle configuration
- Try to match or exceed server airflow by aisle
  - Get thermal report data from IT if possible
  - Plan for worst case
- Get variable speed or two speed fans on servers if possible
- Provide variable airflow fans for AC unit supply
  - Also consider using air handlers rather than CRACs for improved performance
- Use overhead supply where possible
- Provide isolation of hot and cold spaces
- Plug floor leaks and provide blank off plates in racks
- Draw return from as high as possible
- Use CFD to inform design and operation

Right-Size the Design:

- Data Center HVAC often under-loaded
- Ultimate load uncertain
- Design for efficient part-load operation
  - modularity
  - variable-speed fans, pumps, compressors
- Upsize fixed elements (pipes, ducts)
- Upsize cooling towers

Optimize the Central Plant:

- Have one (vs. distributed cooling)
- Medium temperature chilled water
- Aggressive temperature resets
- Primary-only CHW with variable flow
- Thermal storage
- Monitor plant efficiency

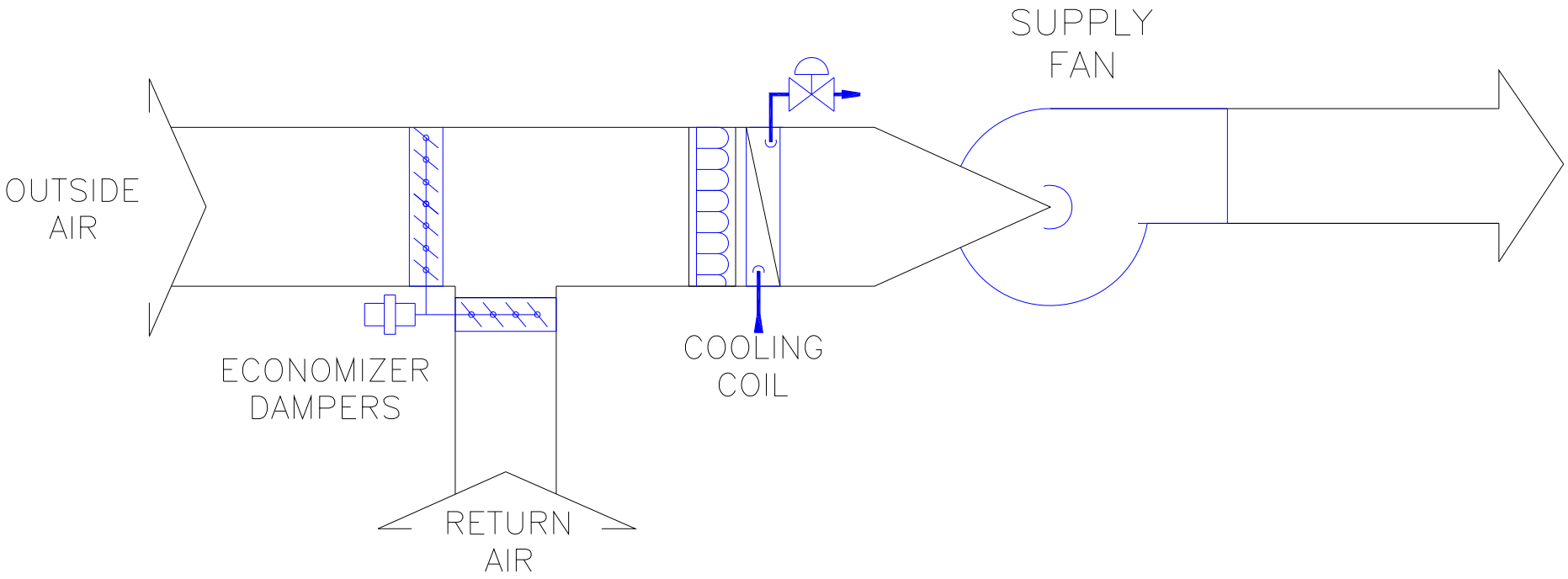
Design for Efficient Central Air Handling:

- Fewer, larger fans and motors
- VAV easier
- Central controls eliminate fighting
- Outside-air economizers easier

Use Free Cooling:

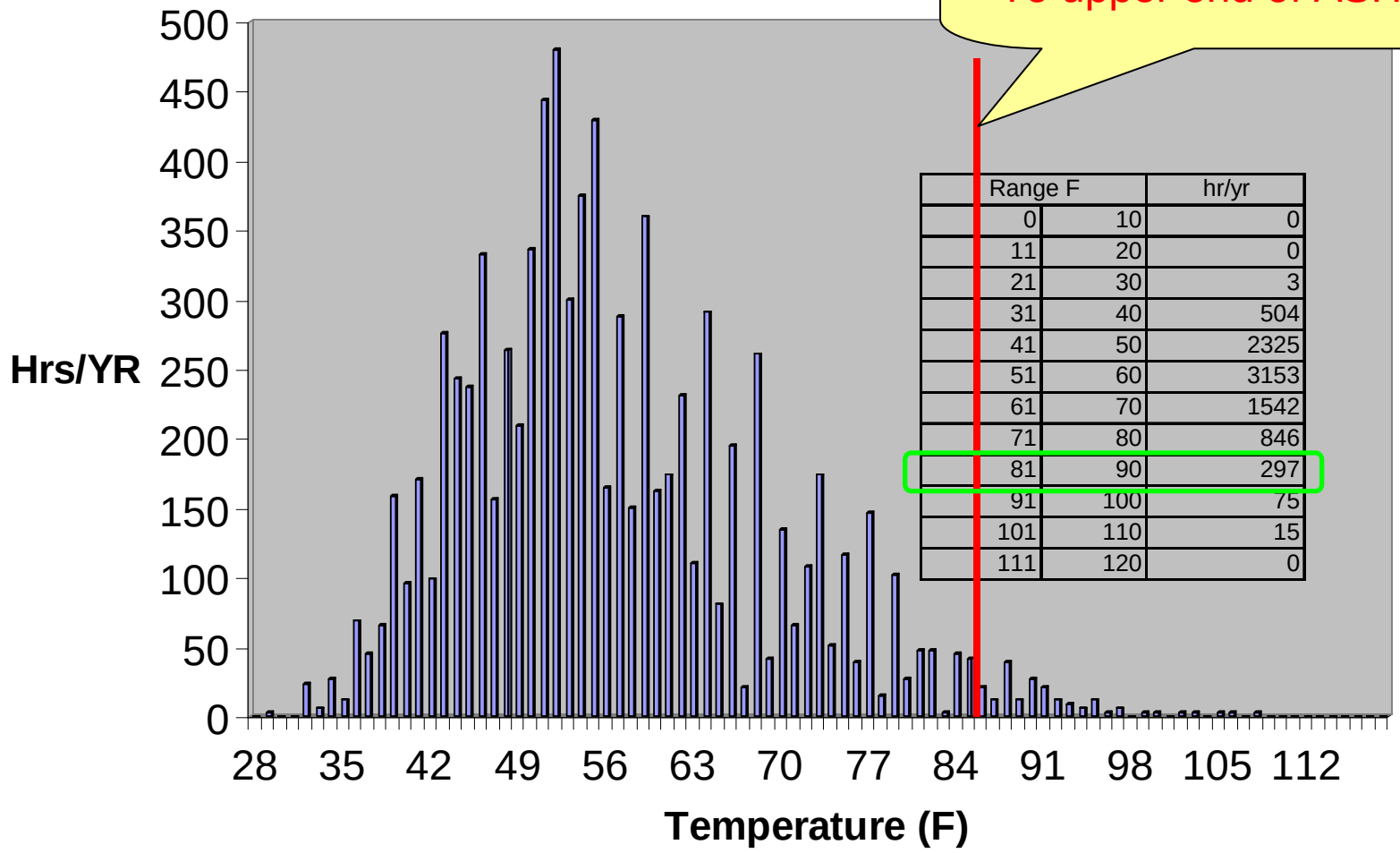
- Outside-Air Economizers
  - Can be very effective (24/7 load)
  - Controversial re: contamination
  - Must consider humidity
- Water-side Economizers
  - No contamination question
  - Can be in series with chiller

Air-side Economizer



Berkeley Weather

Set Inlet Temperature
To upper end of ASHRAE



Range F		hr/yr
0	10	0
11	20	0
21	30	3
31	40	504
41	50	2325
51	60	3153
61	70	1542
71	80	846
81	90	297
91	100	75
101	110	15
111	120	0

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
  - Coordinated controls on distributed AHUs

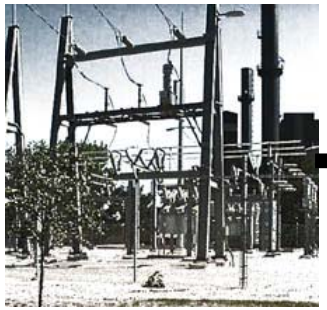
Use Liquid Cooling of Racks and Computers:

- Water is 3500x more effective than air on a volume basis
- Cooling distribution is more energy efficient
- Water-cooled racks available now; liquid-cooled computers are coming
- Heat rejection at a higher temperature
  - Chiller plant more efficient
  - Water-side economizer more effective

Electricity Flows in Data Centers

HVAC system

local distribution lines



lights, office space, etc.

uninterruptible load

to the building, 480 V

UPS

PDU

computer racks

computer equipment

backup diesel generators

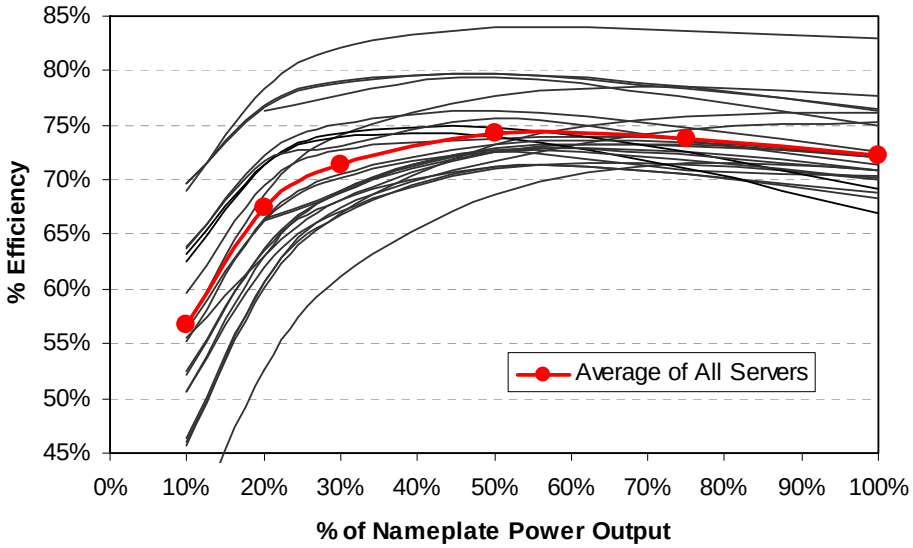
UPS = Uninterruptible Power Supply

PDU = Power Distribution Unit;

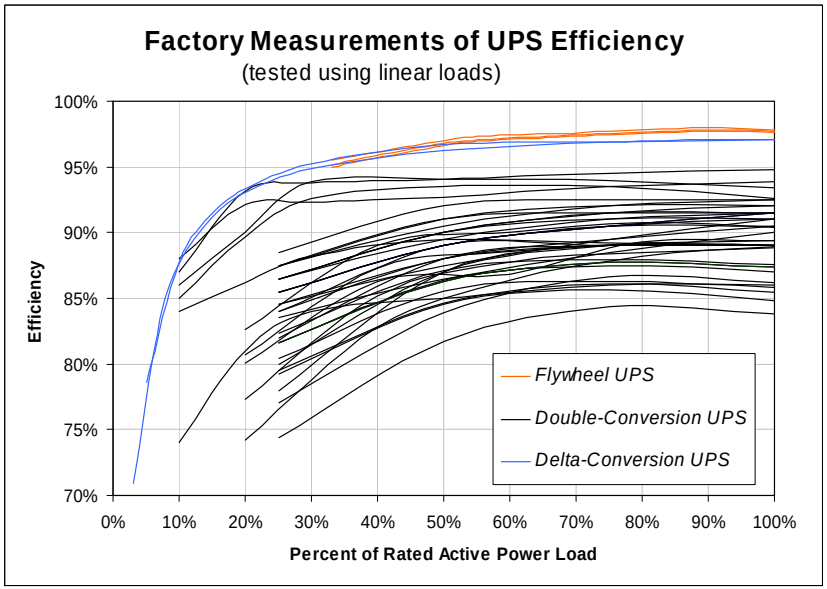
Improving the Power Chain:

- Increase distribution voltage
- DC distribution
- Improve equipment power supplies
- Improve UPS

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 a lot.

Consider On-Site Generation:

- Can use waste heat for cooling
  - sorption cycles
  - typically required for cost effectiveness
- Swaps role with utility for back-up
- Air-quality issues
- Sell-back options
  - More complex controls required

Improve Design and Operations Processes:

- Get IT and Facilities people to work together
- Use life-cycle total cost of ownership analysis
- Document design intent
- Introduce energy optimization early
- Benchmark existing facilities
- Re-commission as a regular part of maintenance

Top best practices identified through benchmarking

HVAC – Air Delivery – Water Systems		Facility Electrical Systems	IT Equipment	Cross-cutting / misc. issues
Air management	Cooling plant optimization	UPS systems	Power Supply efficiency	Motor efficiency
Air economizers	Free cooling	Self generation	Sleep/standby loads	Right sizing
Humidification controls alternatives	Variable speed pumping	AC-DC Distribution	IT equip fans	Variable speed drives
Centralized air handlers	Variable speed Chillers	Standby generation		Lighting
Direct liquid cooling				Maintenance
Low pressure drop air distribution				Commissioning/continuous benchmarking
Fan efficiency				Heat recovery
				Redundancies
				Method of charging for space and power
				Building envelope

Completed

Design Guidelines Are Available

- **Design Guides were developed based upon the observed best practices**
- **Guides are available through PG&E and LBNL websites**
- **Self benchmarking protocol also available**

http://hightech.lbl.gov/datacenters.html