HP WORLD 2004
Solutions and Technology Conference & Expo

Integrity Servers Power Trends and HP Data Center Cooling Solutions

Christopher G. Malone & Chandrakant D. Patel

www.hpl.hp.com/research/dca

chris.g.malone@hp.com
chandrakant.patel@hp.com

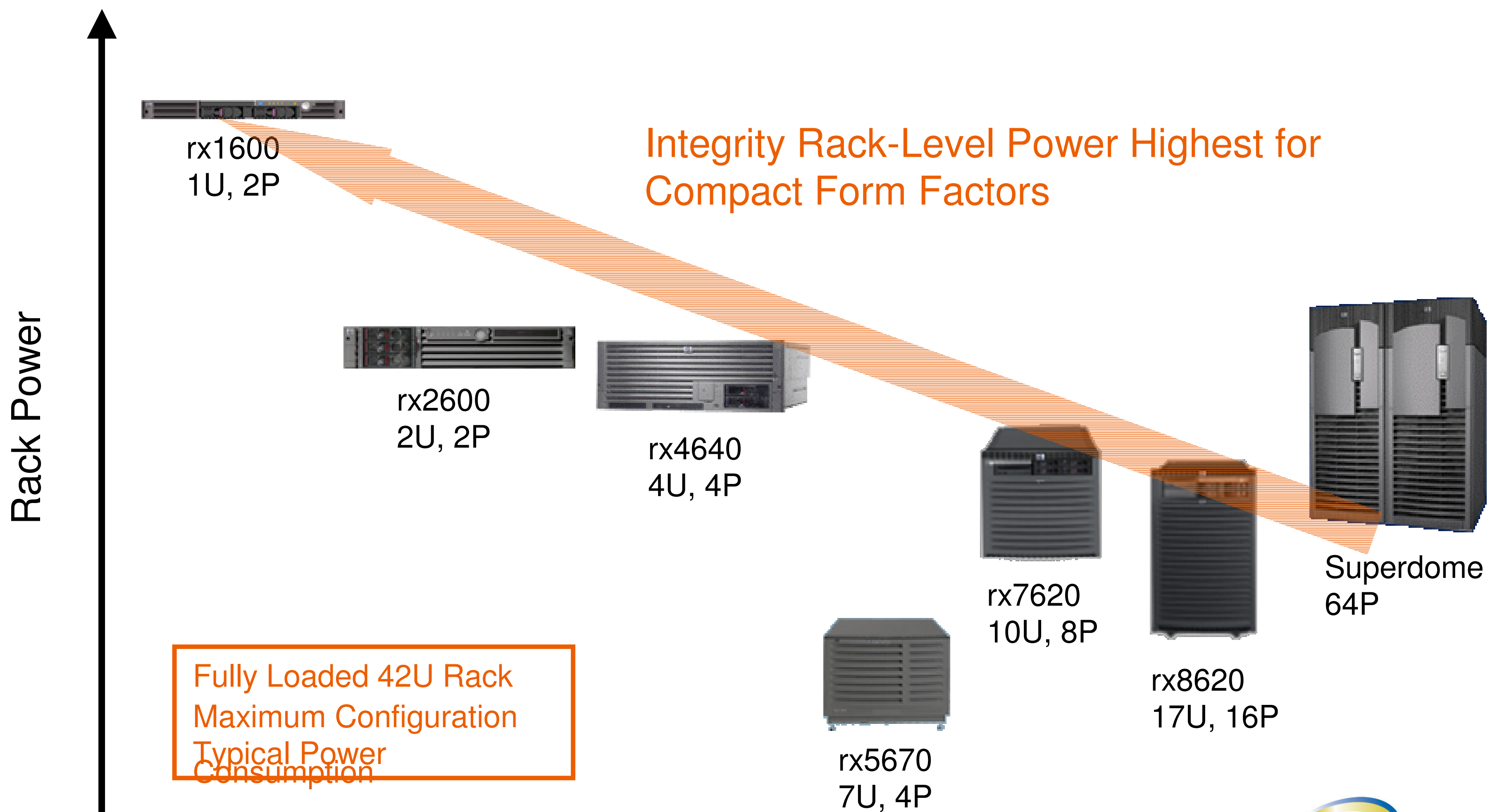
Agenda

- Power trends for Integrity servers
  - Implications for data center deployments
  - Performance estimates for future processors
- Smart Data Center
  - Static Smart Cooling
  - Dynamic Smart Cooling

HP WORLD 2004
Solutions and Technology Conference & Expo

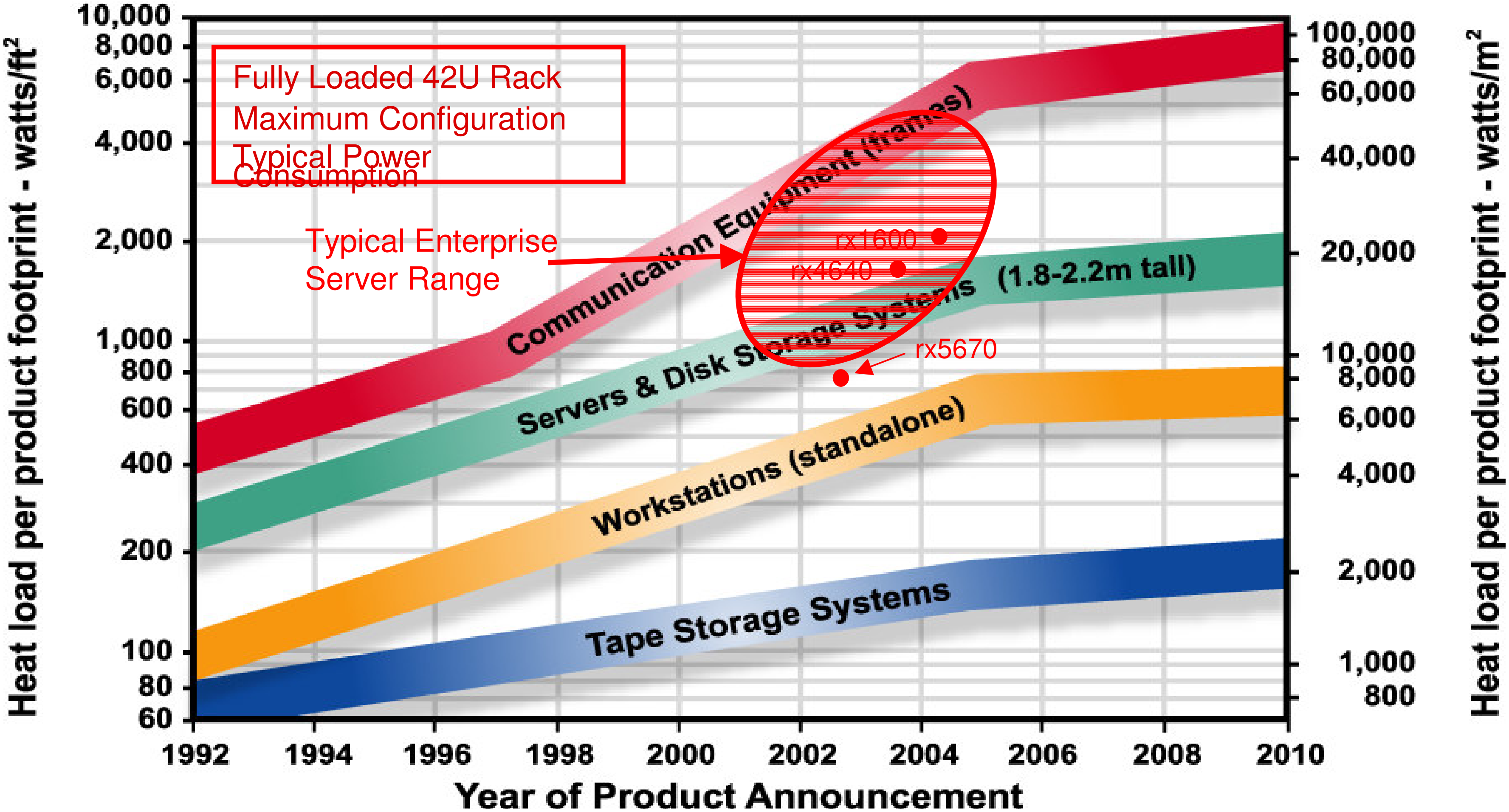
Integrity Servers Power Trends

HP Integrity Servers
Rack Power Comparison



Power may be considerably lower depending on configuration and software application

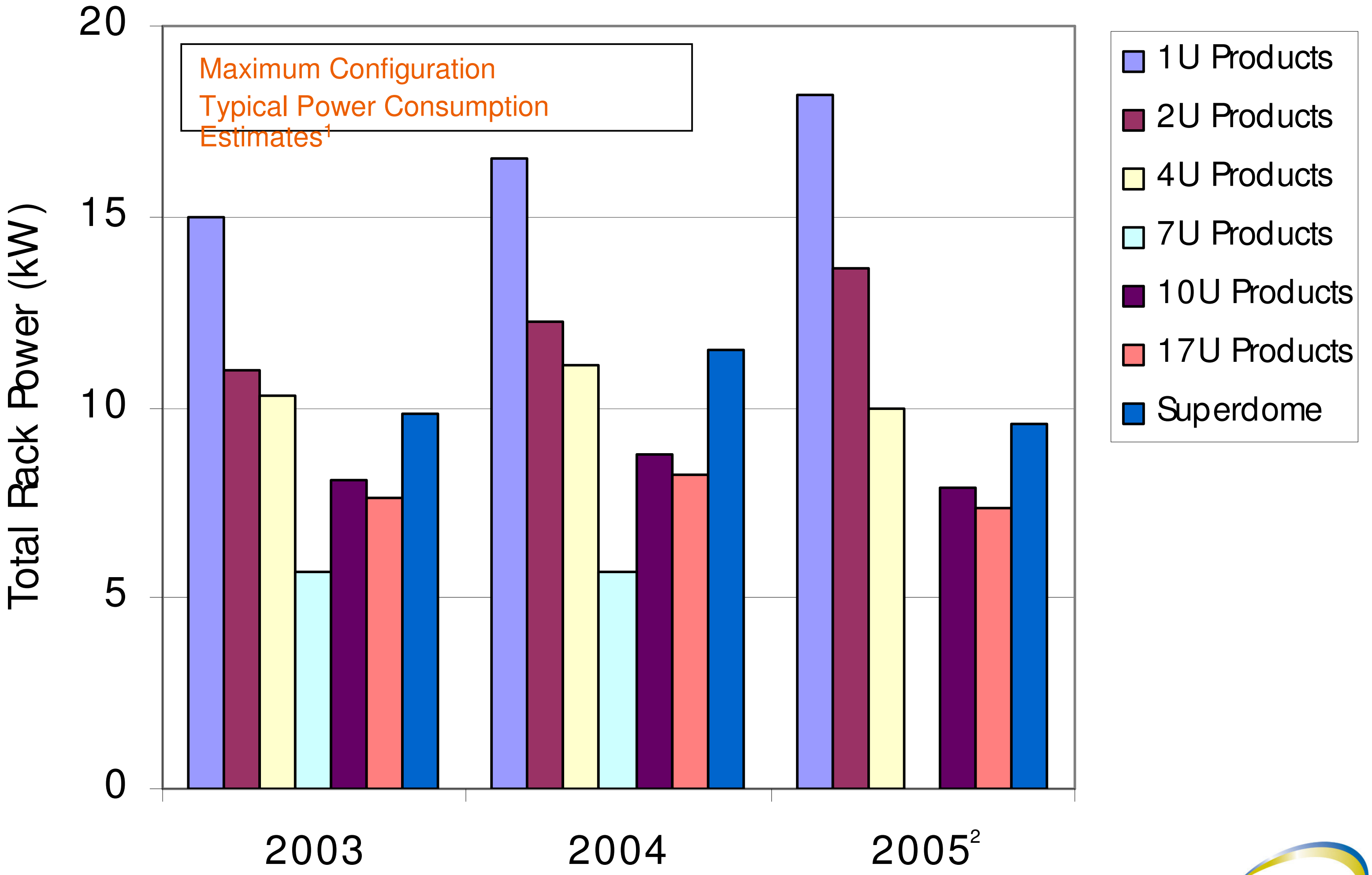
Compact Servers Lead Server Power Density Trends



©2000 The Uptime Institute Version 1.0

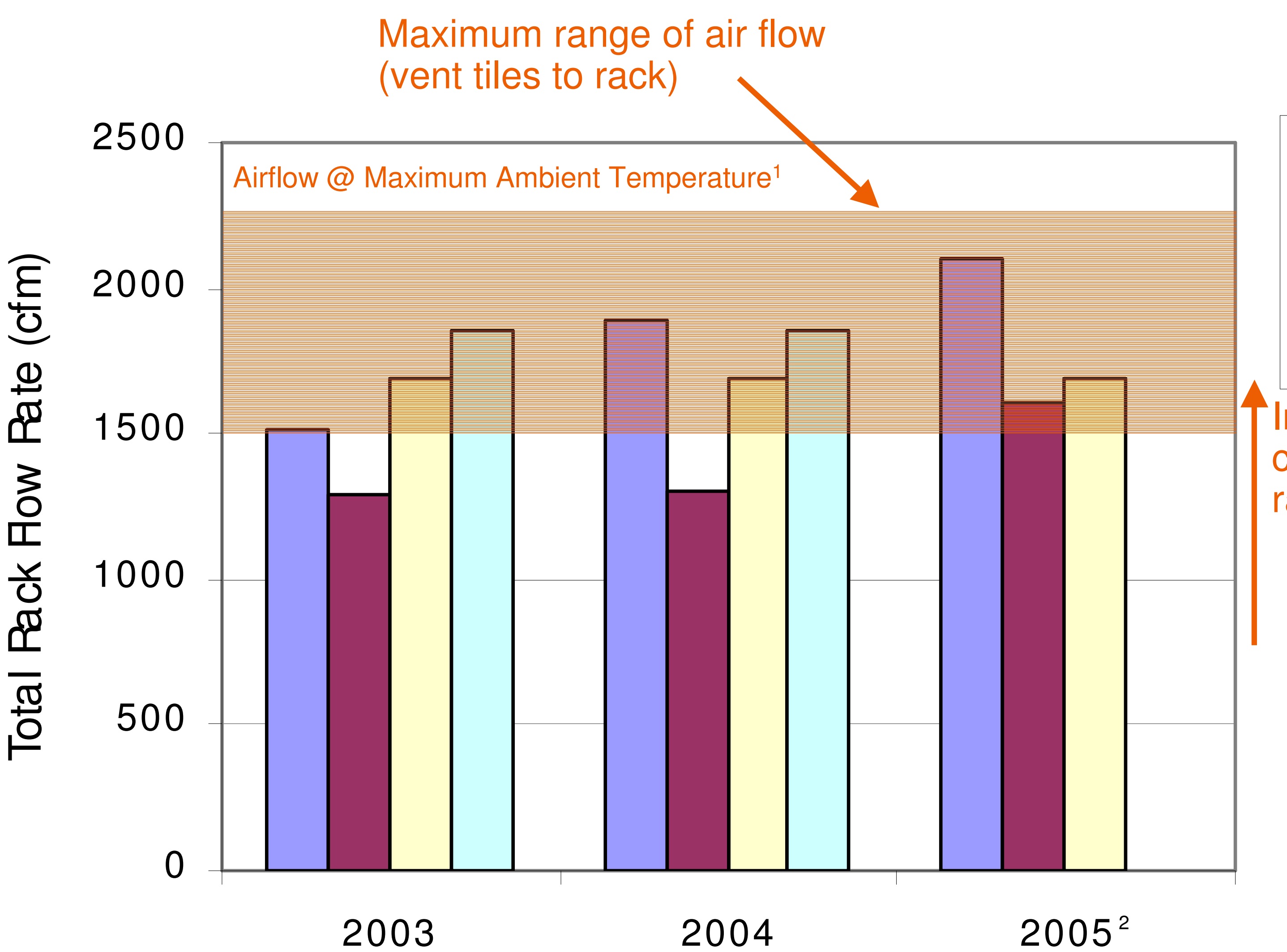
HP WORLD 2004
Solutions and Technology Conference & Expo

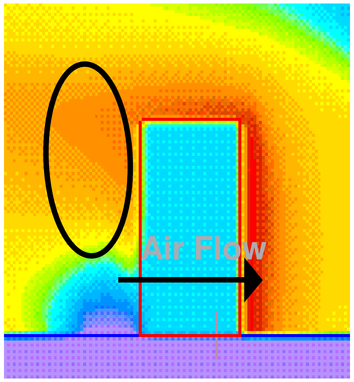
Integrity Server Family Rack-Level Power Trends



1. See Site Preparation Guides @ docs.hp.com for latest product information & installation requirements.
2. Estimates based on pre-release information.

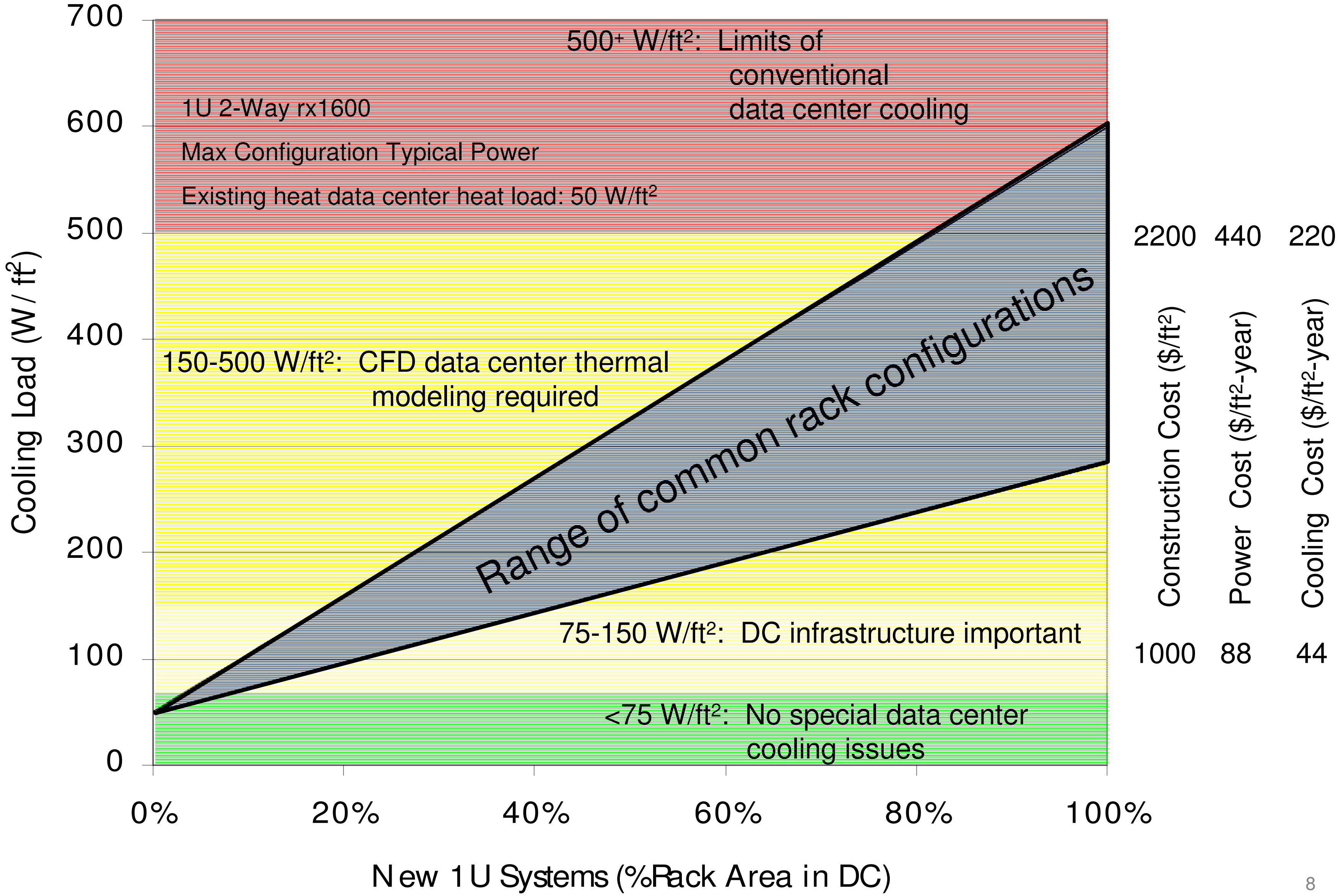
Integrity Rack-Level Flow Rate Trends



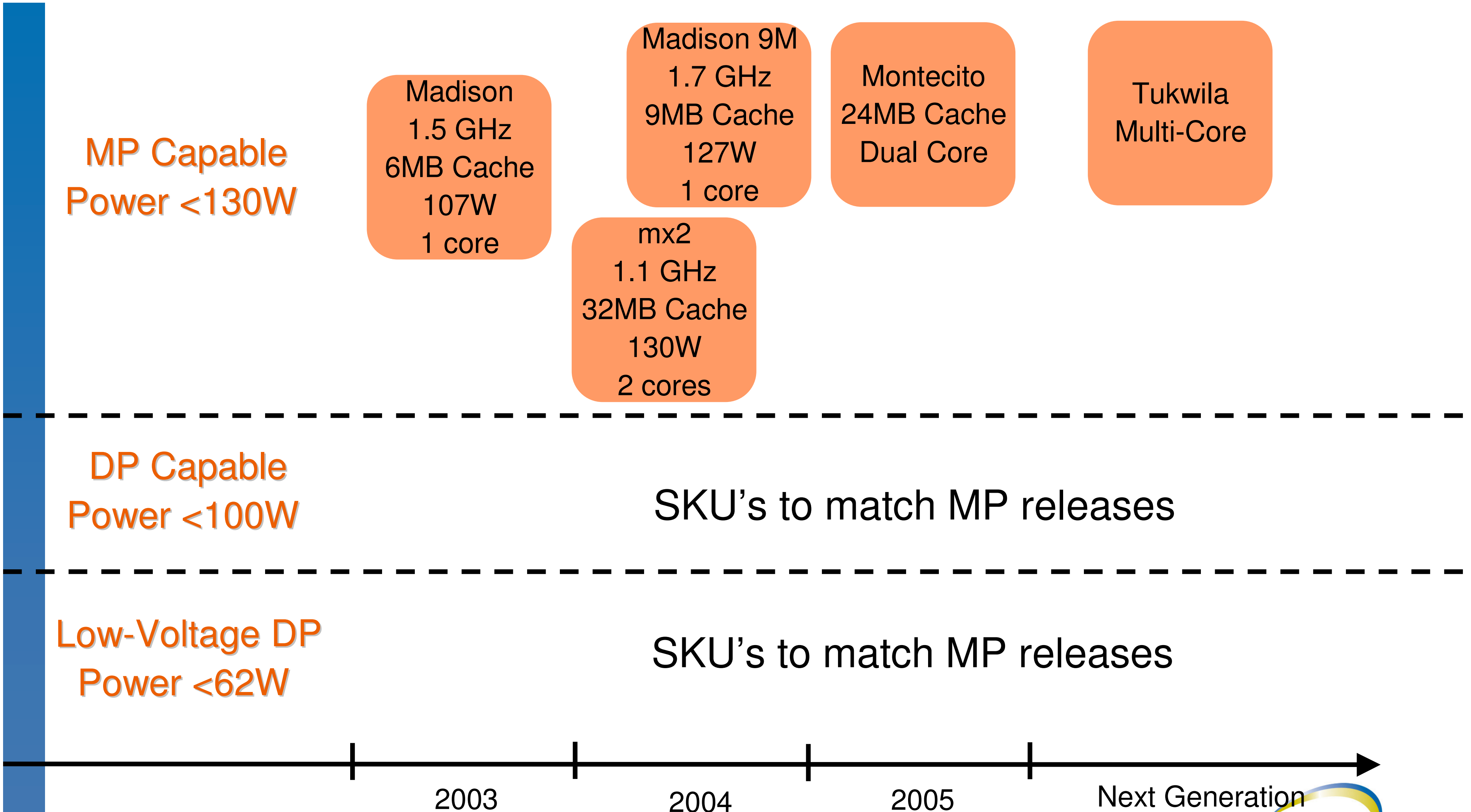


1. See Site Preparation Guides @ docs.hp.com for latest product information & installation requirements.
2. Estimates based on pre-release information.

Data Center Cooling – 1U rx1600 Implementation



Itanium Thermal Design Power Projections

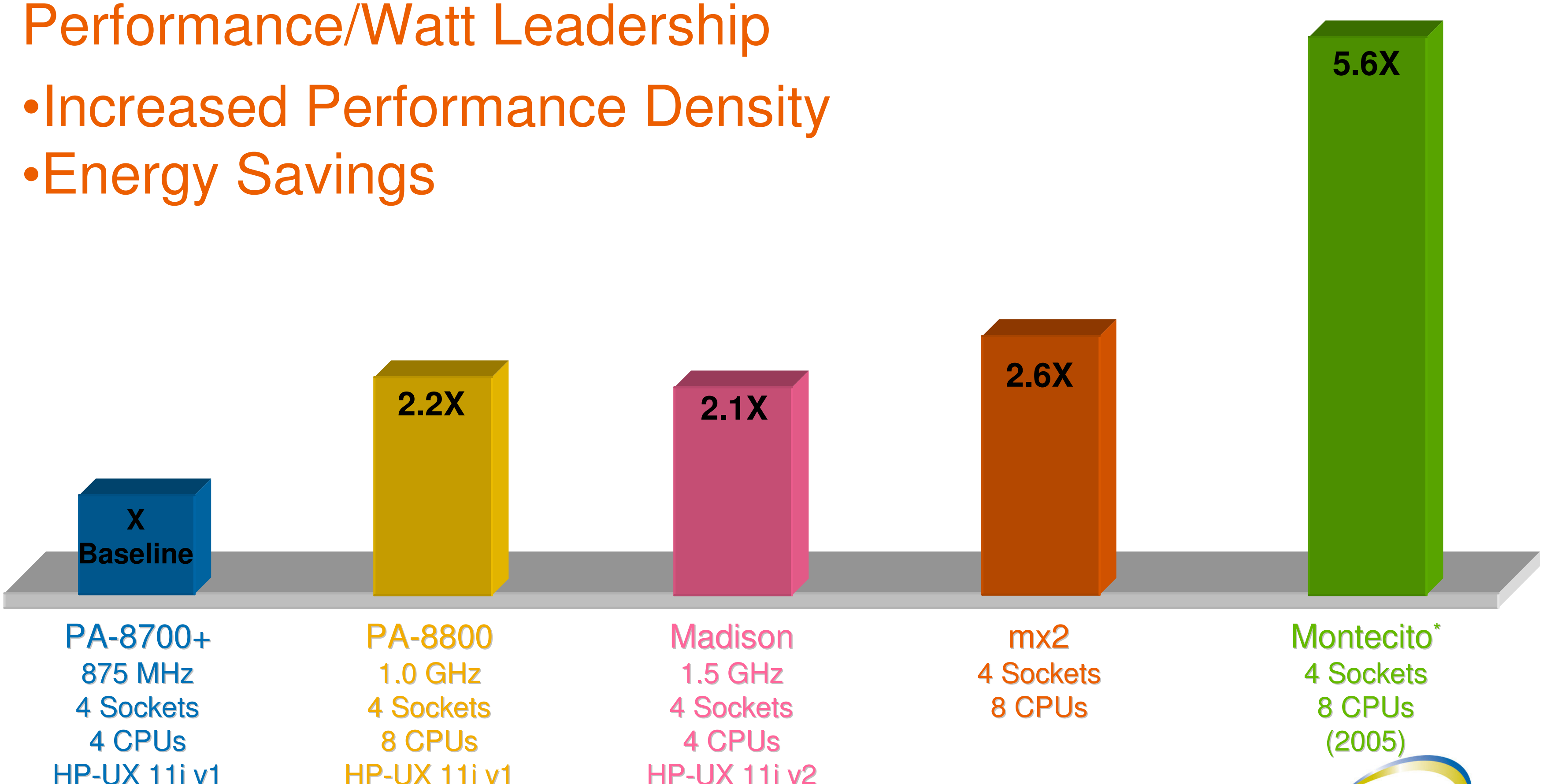


Data based on Intel's Itanium Roadmap, which is subject to change. Itanium is a registered trademark of Intel Corporation or its subsidiaries in the United States and other countries.

Estimated OLTP Performance/Watt for 4-Socket System

Performance/Watt Leadership

- Increased Performance Density
- Energy Savings



Estimates based on Intel's Itanium Roadmap, which is subject to change. Itanium is a registered trademark of Intel Corporation or its subsidiaries in the United States and other countries. * Estimate based on pre-release information.

Summary – Integrity Server Power Trends

- Enterprise server power consumption from all vendors has risen in recent years
  - Dense data center installations benefit from thermal analysis
- Compact Integrity server form factors offer
  - Tremendous performance density
  - Best use of data center floor space
- Itanium processor performance/Watt estimates illustrate the benefit of the architecture

Smart Data Center

Static & Dynamic Provisioning of Power and Cooling

Motivation

Customer Data Center Needs

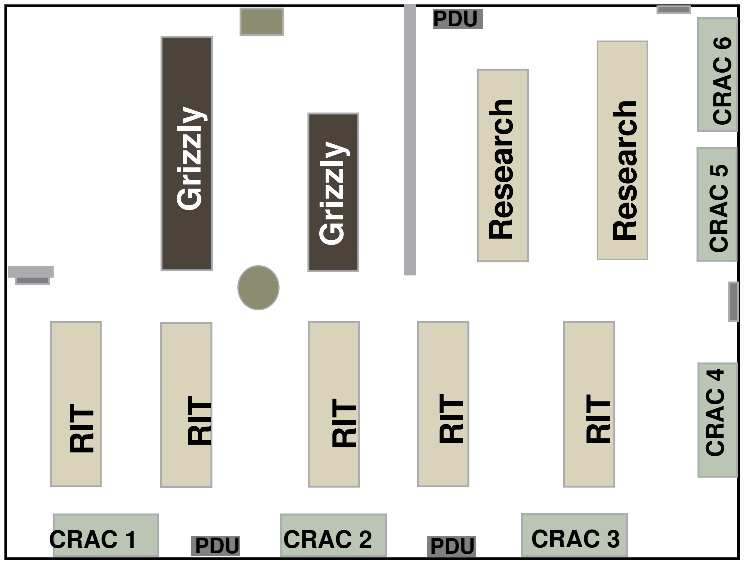
- Consolidation
- Improve Uptime
- Lower Operational Costs

State of Art

- Design by intuition and “rules of thumb”
- High energy consumption
- High personnel cost due to complexity and lack of automation
- Inflexible components, over-provisioned

Our Value Proposition

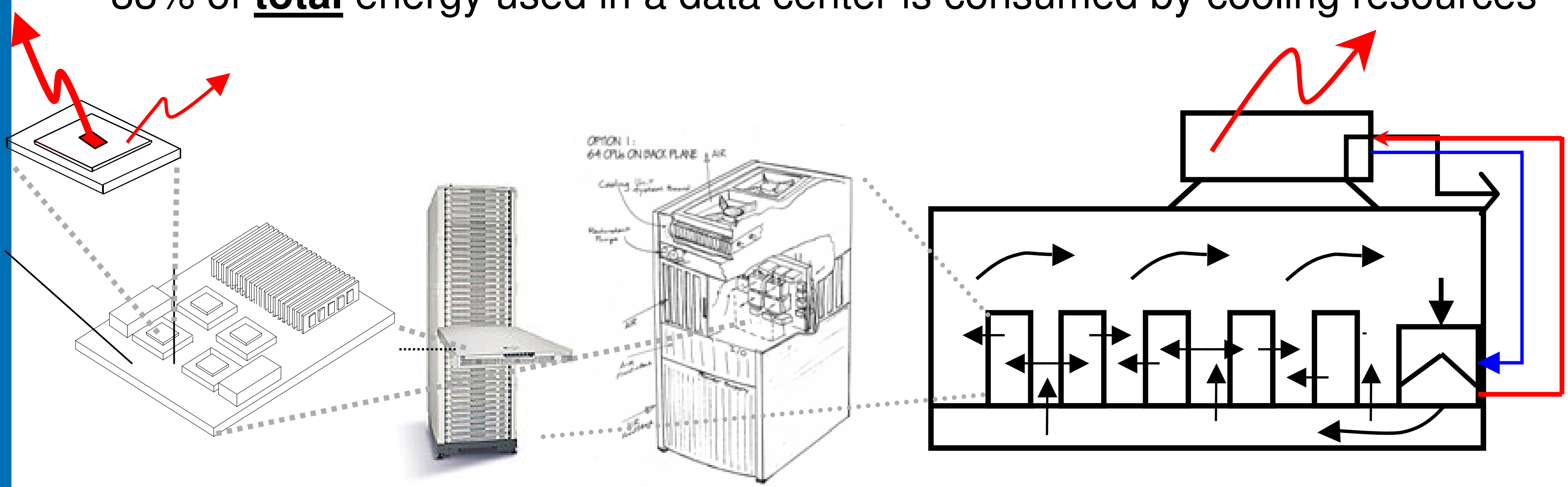
- Innovative capabilities on top of commodity components to create products and services
- Future “smart” data center that adapts to dynamic changes in business processes



Motivation

Technology Trends

- COMPACTION
  - From highly integrated chips and ultra-thin servers – 50 W/ft^2 today to 400 W/ft^2
- ENERGY SAVINGS
  - 33% of **<u>total</u>** energy used in a data center is consumed by cooling resources



Heat Generated

.100 KW **10 - 15 KW** **20 KW** **1000+ KW**

Energy to Remove Heat

0.005 KW **0.5 KW** **1-2 KW** **500 KW**

Flow Work + Thermodynamic Work

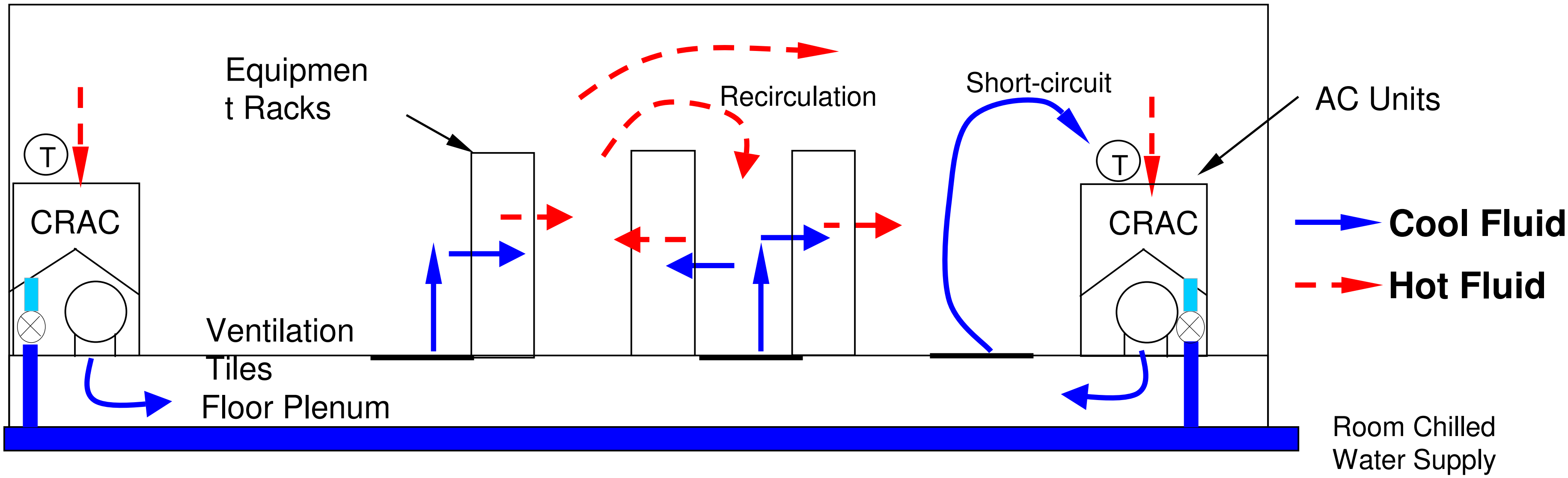
Economics of Energy Savings in Data Centers

Reducing the recurring cost of energy used by cooling resources

- A 30,000 ft^2 data center can house one thousand 10 kW racks
  - Power required for the compute infrastructure : 10 MW
  - Power required by the cooling resources : 5 MW
    - *In many data centers the cooling resources use as much power as that dissipated by the hardware i.e. 10 MW for this example*
  - Annual cost of electricity for cooling resources: $4 million at $100 per MWh and assuming 0.5 W per 1 W dissipated
- Reduction of energy consumed by the cooling resources by 50% is $2 million per year to the bottom line

HP WORLD 2004
Solutions and Technology Conference & Expo

Inefficiencies in Today's Data Centers



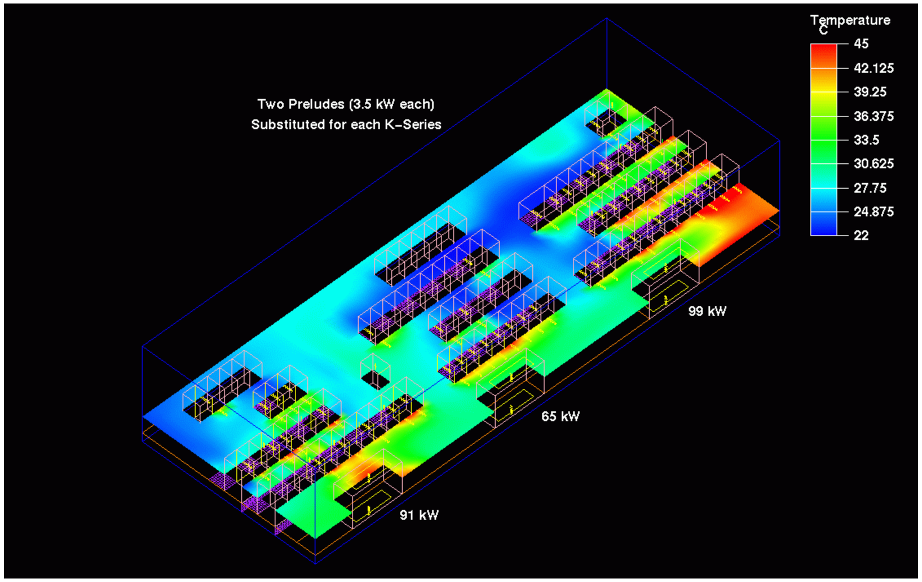
- Mixing of hot and cold air stream
  - Re-circulation and short-circuiting of air
- Intuition used to deploy equipment and cooling resources
- No information about local conditions
- Workload placed without consideration of environmental conditions

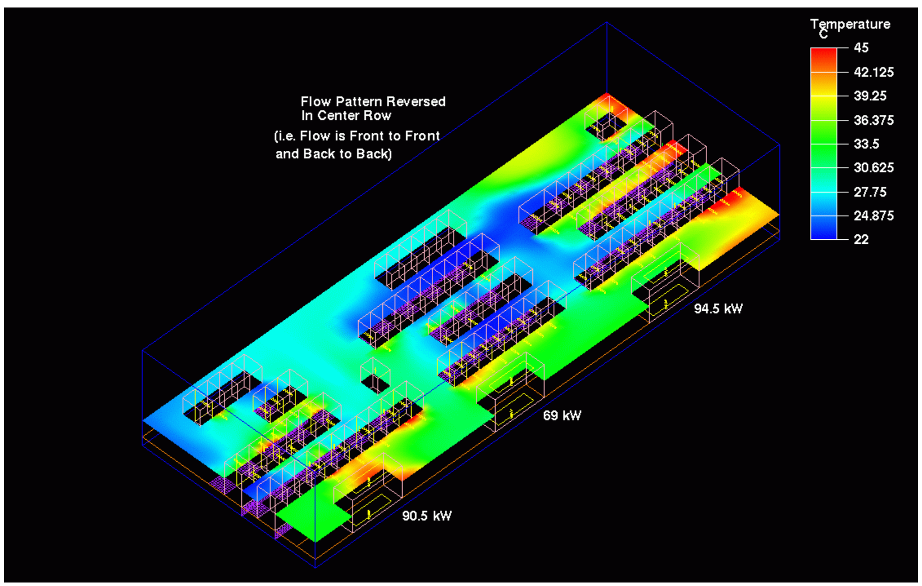
Solution

Smart Cooling

HP WORLD 2004 Solutions and Technology Conference & Expo

Introducing "Smart" Cooling of Data Centers





- Judicious provisioning of AC resources based on workload distribution
- Avail energy savings of 25% over non optimized layout [**$1 million per annum** for a 15 MW data center @ 100/MWh]
- The Smart Cooling system is a combination of modeling, metrology and intelligent control.
- Two key components:
  - *Static Smart Cooling**
  - *Dynamic Smart Cooling*

** Data Center Modeling from HP Services*

Smart Cooling – How?

Static and Dynamic

Proper provisioning based on numerical analysis of thermo-fluids behavior for given distribution of heat loads and AC resources – static and dynamic:

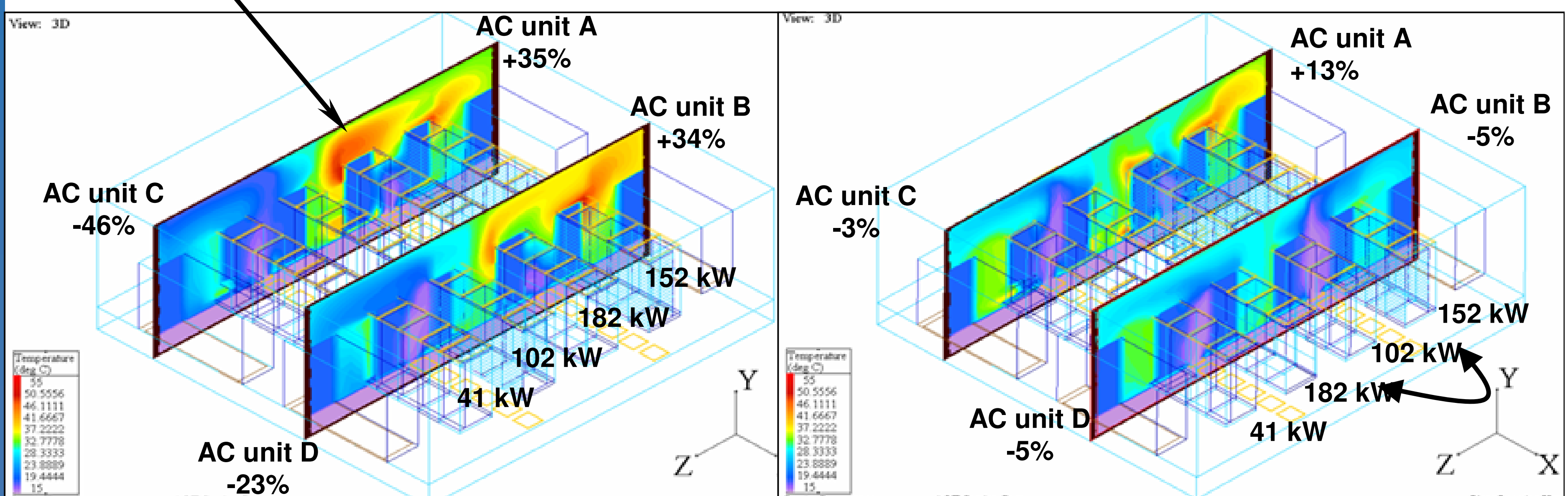
- “Data Center Figure of Merit” – SHI & RHI as quantitative measure of “good provisioning”

Static – Evaluation

Dynamic - Control

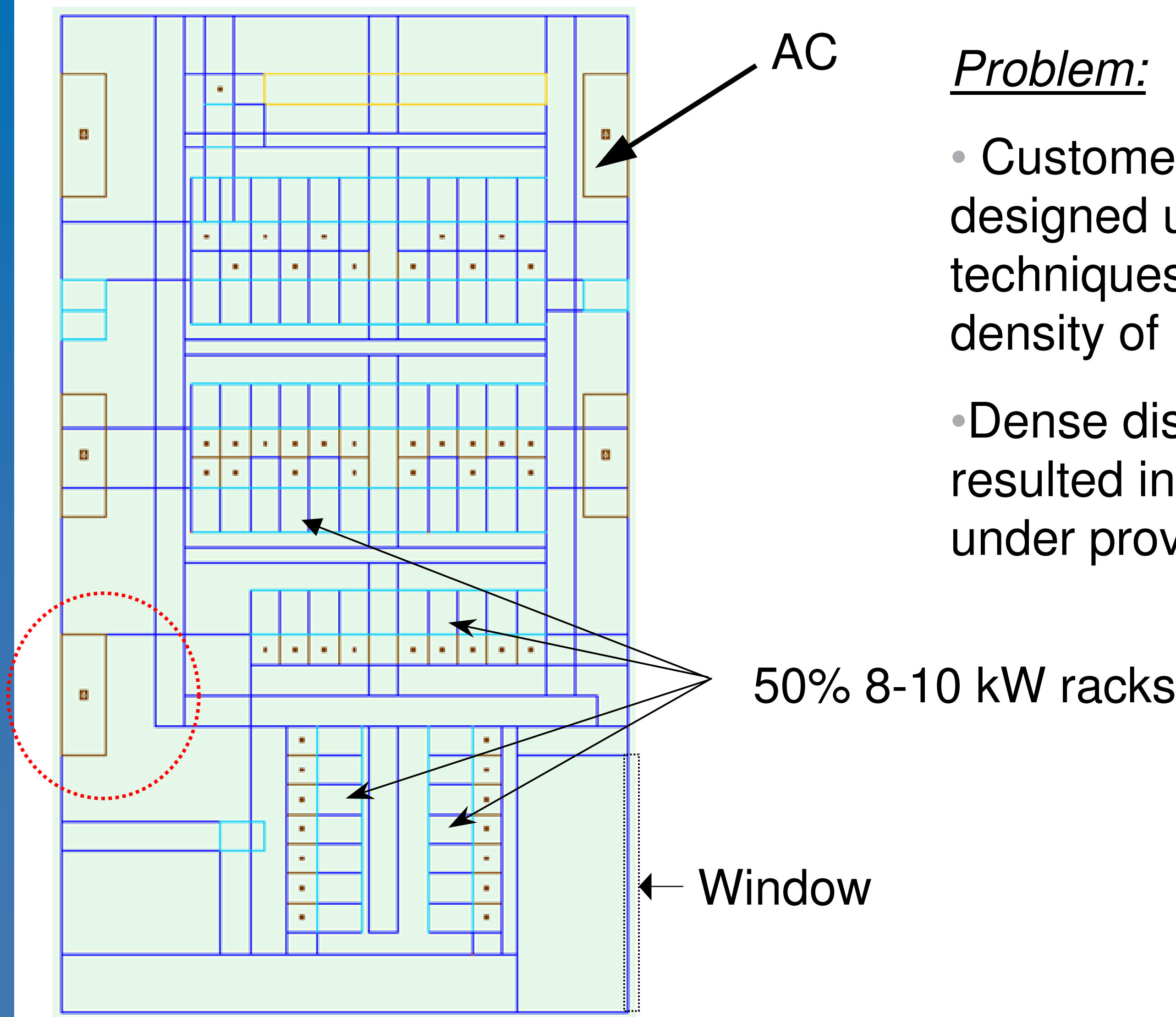
$$SHI = \left(\frac{\delta Q}{Q+\delta Q}\right) = \left(\frac{\sum_j \sum_i \left(\left(T_{in}^{r}\right)_{i,j} - T_{ref}\right)}{\sum_j \sum_i \left(\left(T_{out}^{r}\right)_{i,j} - T_{ref}\right)}\right)$$

δQ (infiltration)



Data Center Thermal Modeling

Customer Example

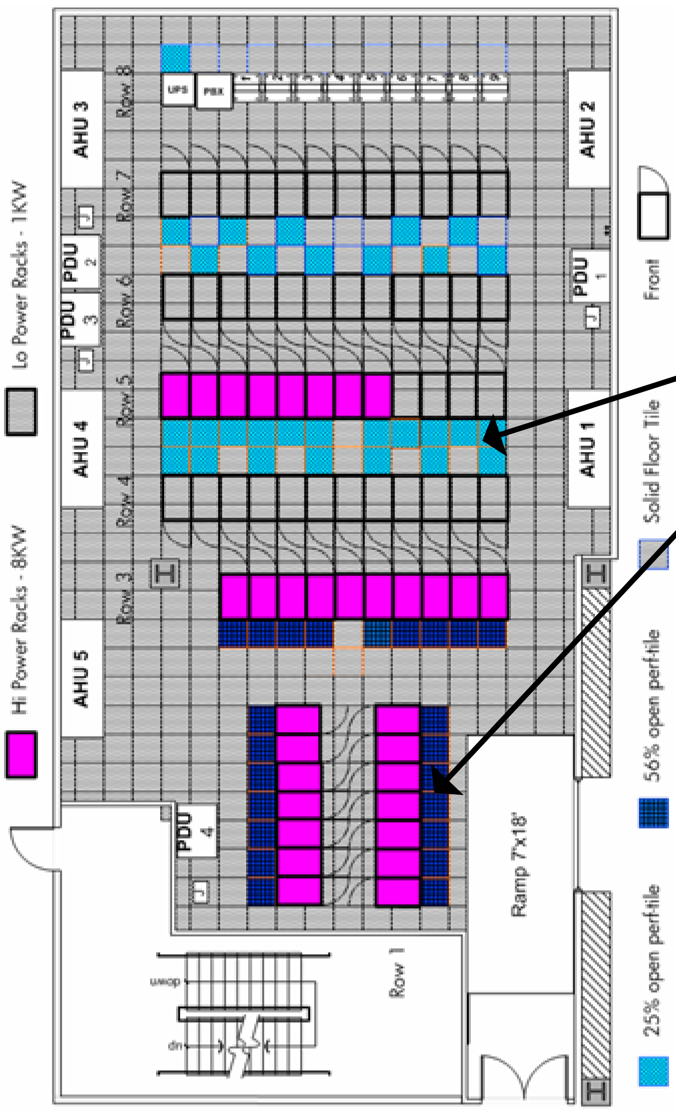


Problem:

- Customer Data Center was designed using standard techniques assuming uniform heat density of 150 W/ft^2
- Dense distribution of the 1U racks resulted in the circled A/C being under provisioned

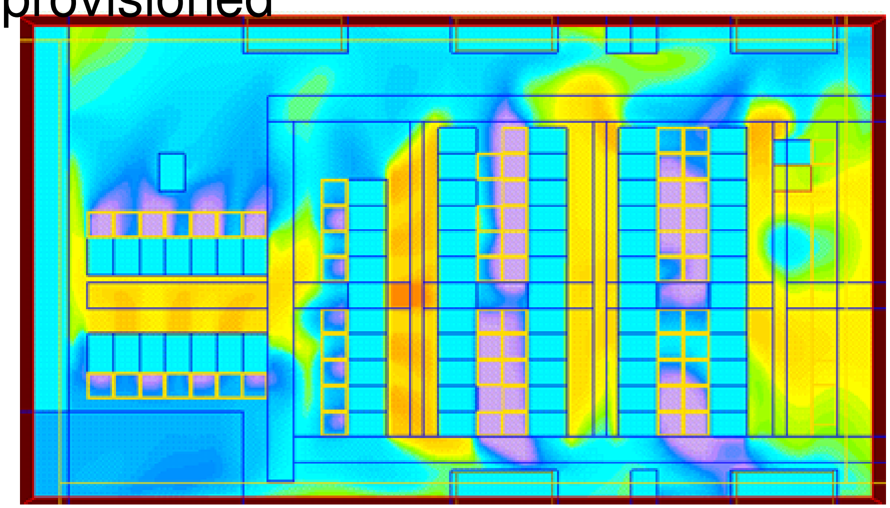
Data Center Thermal Modeling

Provisioned by Vent Tile Re-distribution



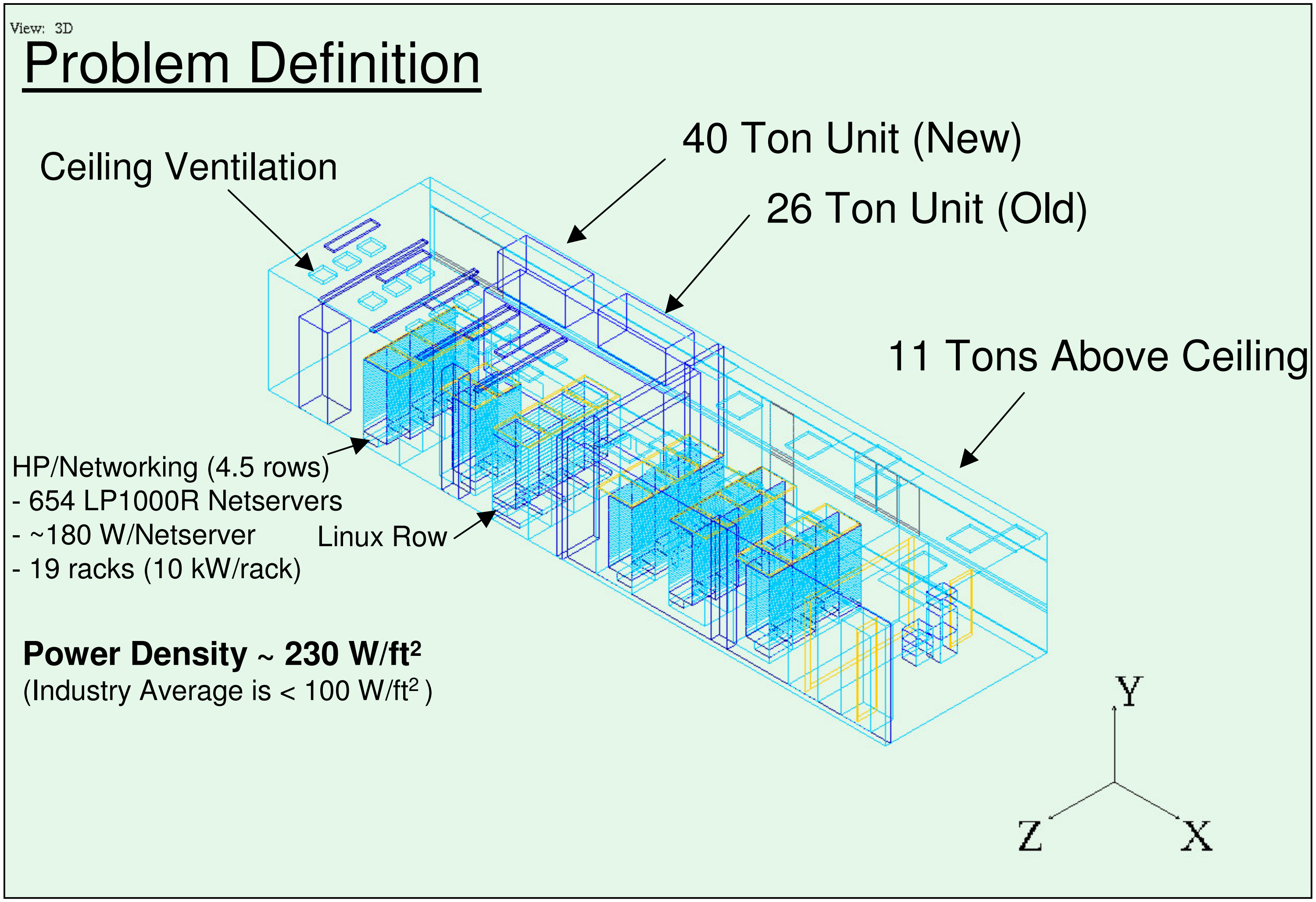
Solution:

- Strategic repositioning inlet air vents
  - the only degree of freedom allowed by the customer
- *Various customer layouts and future configurations* were statically provisioned



Static Smart Cooling - Results

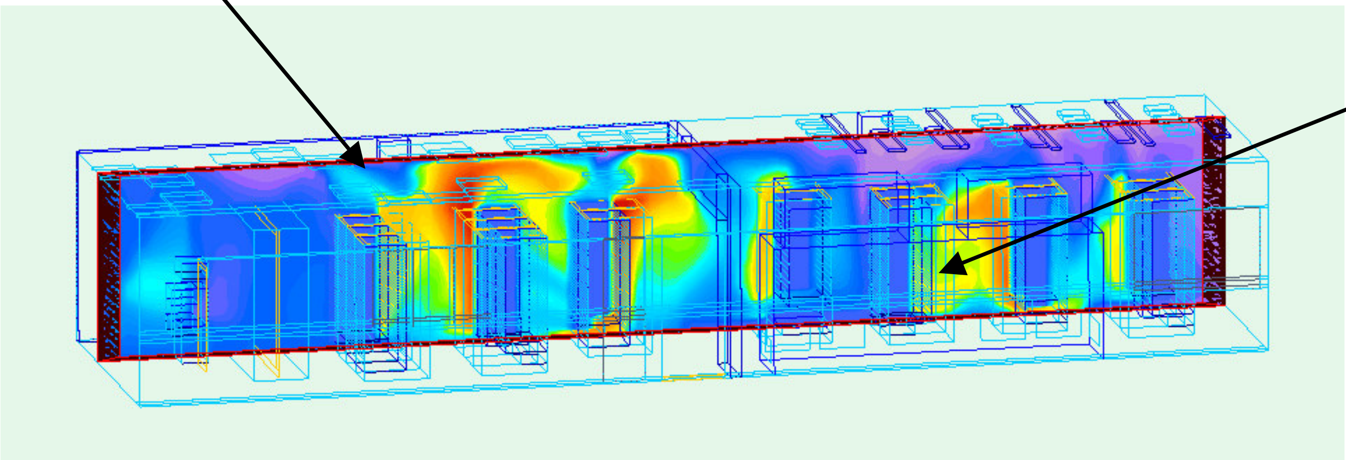
Case Study: Example Data Center with Ceiling Flow Distribution



Provisioning of the given capacity is critical

Static Smart Cooling – Key Points

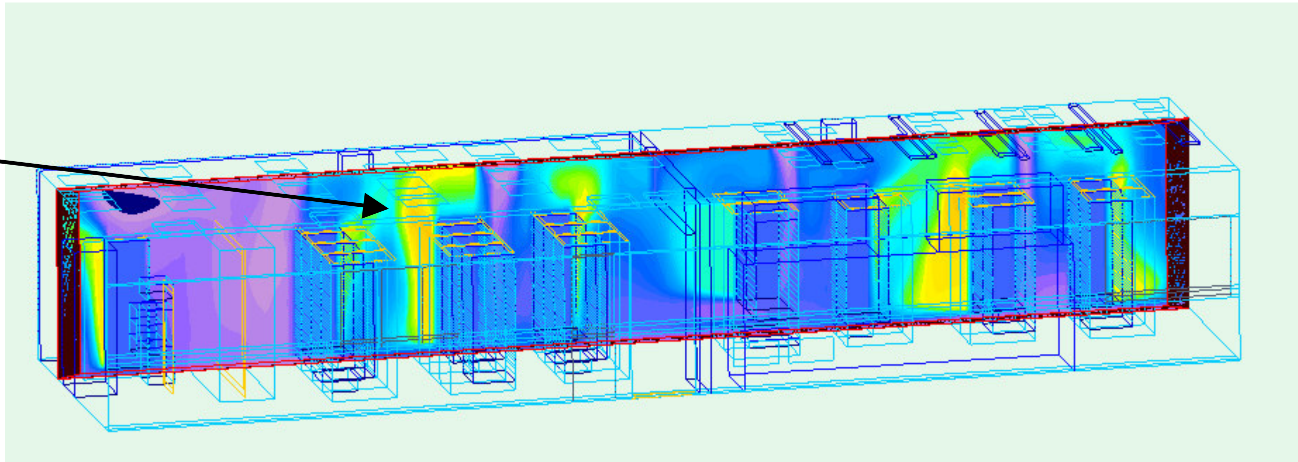
1. Recirculation negatively impacts infrastructure performance



2. CRACs

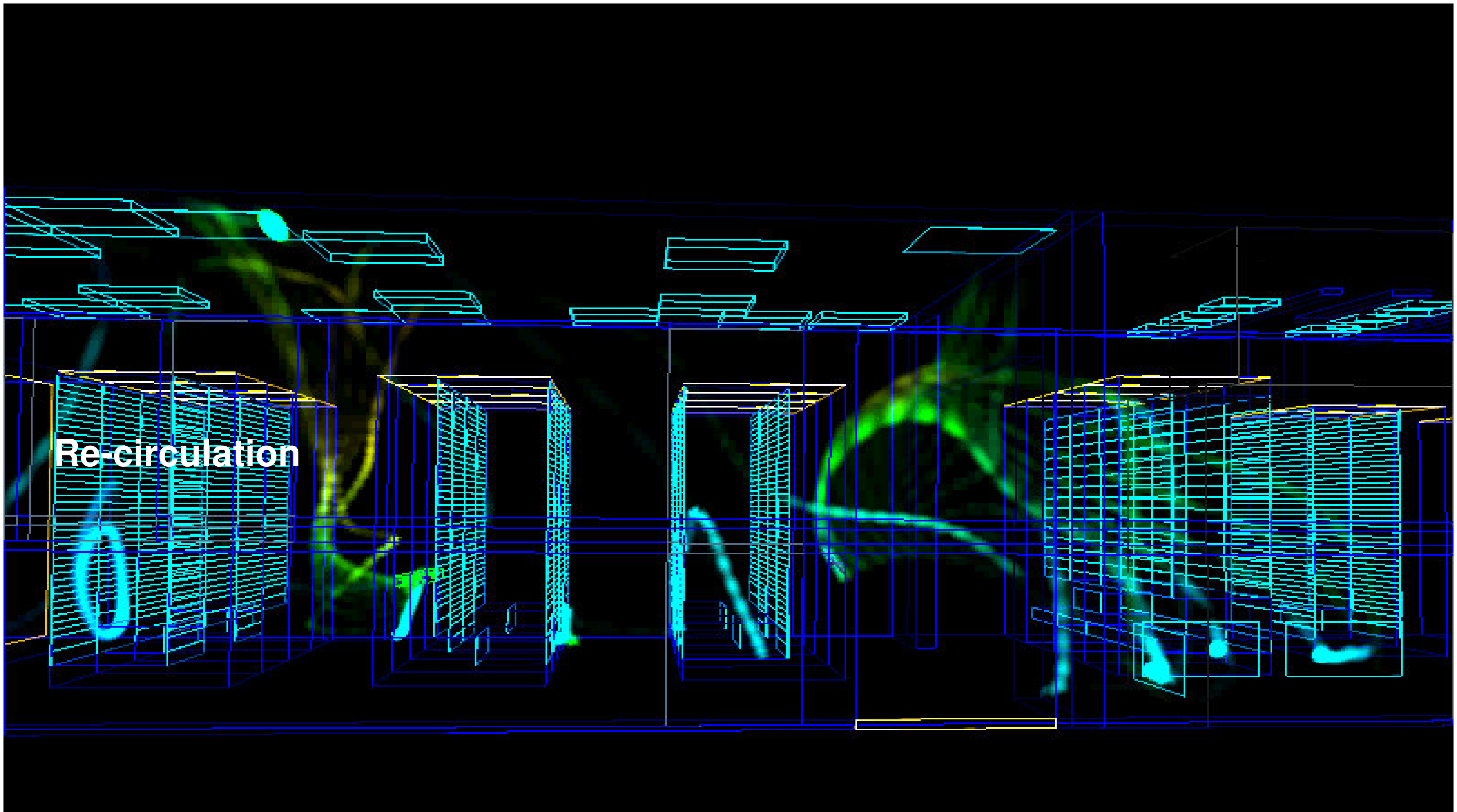
Mal-provisioned

Implementation of Static Smart Cooling solves problem.



Poor Distribution of Cooling Resources

Inadequate layout of supply and returns

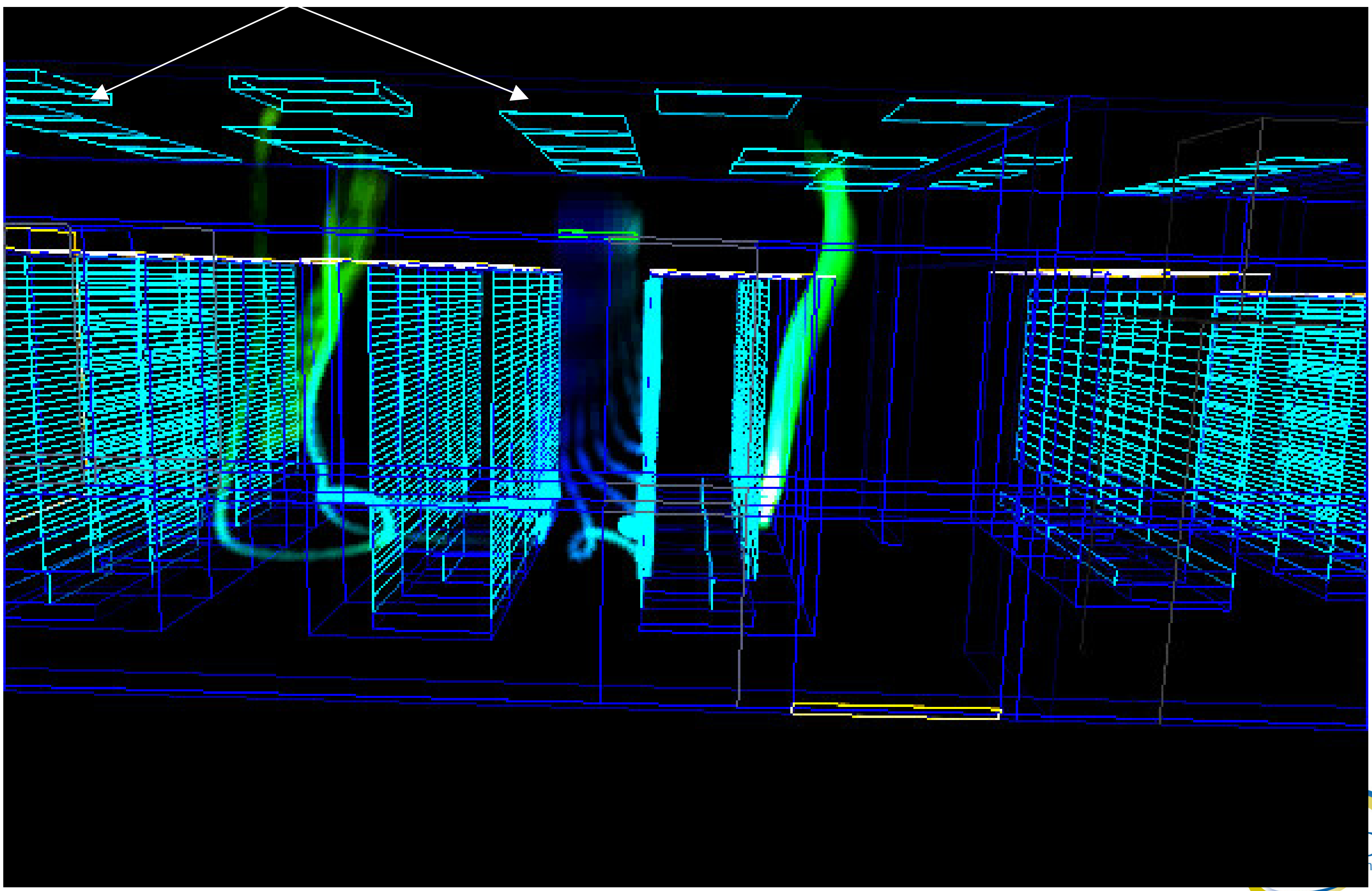


Excessive residence time of hot air particles, Inefficient air handling, AC mal provisioned

Optimized by Numerical Modeling

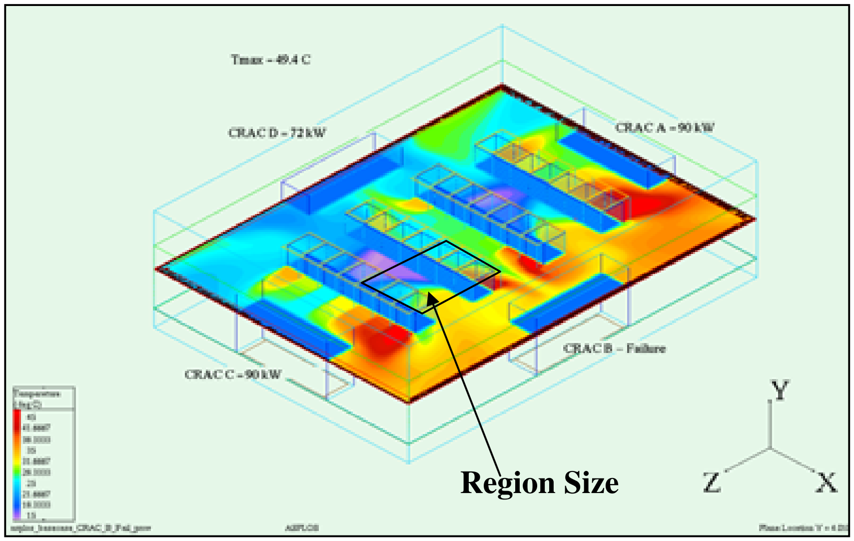
Computational Fluid Dynamics Modeling

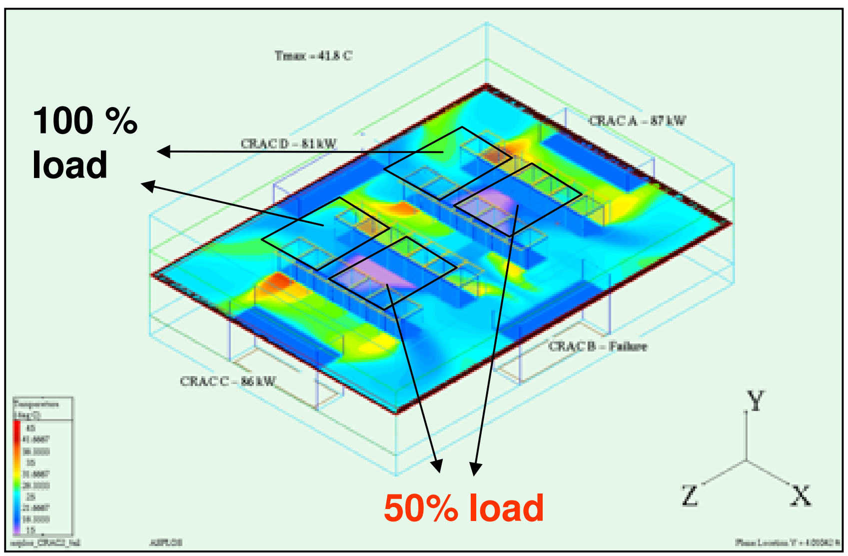
Vent layout and heat load layout optimized



Data Center Thermal Modeling

Predicting and Planning for Impact of load or cooling changes





Modeling has the capability to show the impact of:

- Turning on new machines
- AC failure
- AC shutdown for scheduled maintenance

Dynamic workload migration based on thermo-fluids policies

HP WORLD 2004 Solutions and Technology Conference & Expo

Data Center Modeling

+hp Value

- Experience
  - Libraries enable expedient model creation;
  - A wide variety of infrastructures have been modeled;
- Flexibility
  - Smart Growth: Manage the growth of the data center over time through modeling;
  - Failure Mitigation: Examine failure scenarios and develop risk aversion strategies
- Research
  - Modeling team has access to latest research from HP Labs. Some examples:
    - Metrics for quantification of hot air infiltration;
    - Use of metrics for quick optimization of cooling and IT infrastructure;
  - Dynamic Smart Cooling follow on products and services to supplement modeling with real time control of cooling infrastructure

Smart Data Center

Part 2: Dynamic Provisioning of Cooling Resources

Smart Data Center is a vision and realization of an efficient" future data center – a data center that adapts to the business needs of the customer.

- Derived by adding value over standard parts
- Ideas can be incorporated without necessarily resorting to the final realization of the "smart" data center
    - Incremental products and services planned to augment or upgrade existing data centers
        - "Static" smart cooling service presented earlier is an example of such an incremental offering

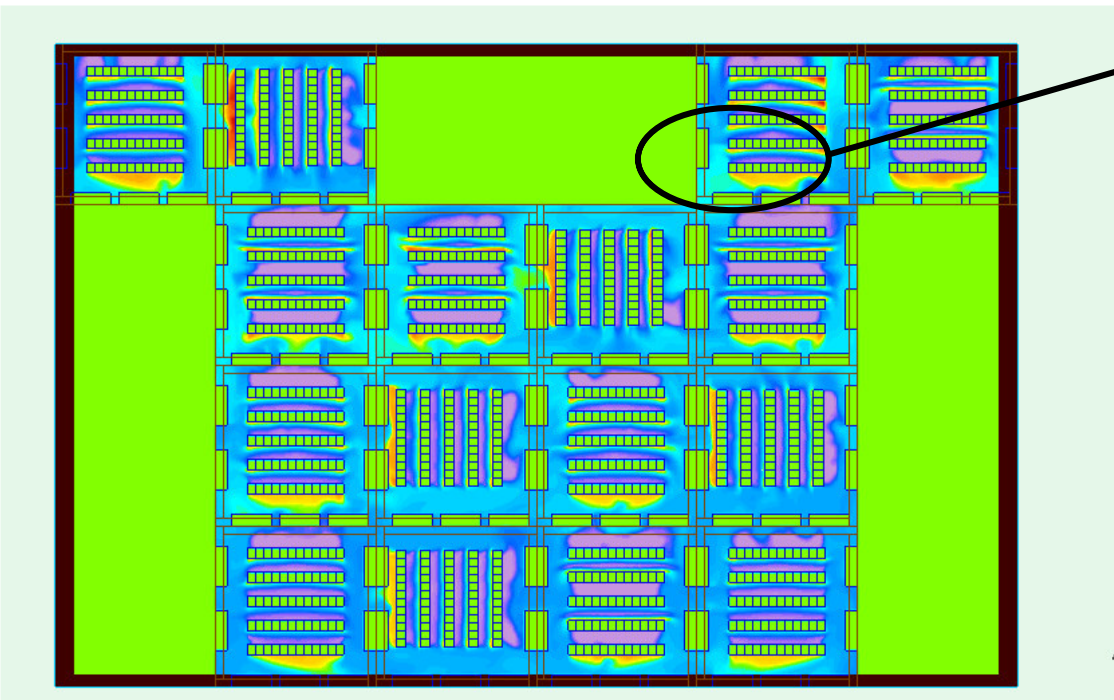
In this part of our session, we build on the "static" provisioning to show the construction of the "smart" data center, and end with results from dynamic control of air conditioning resources.

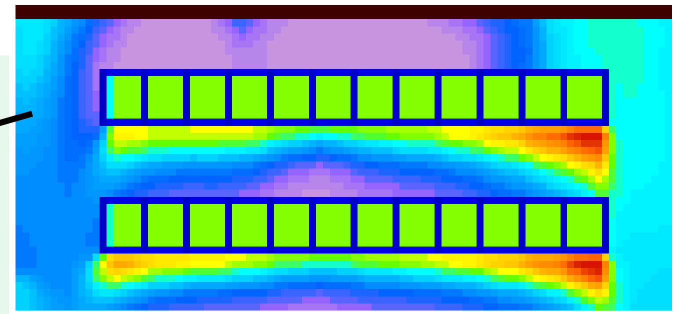
Dynamic Provisioning of Power and Cooling

Key Points

Adaptive Data Center Management by:

- **Reallocation of *compute resources* – load balancing with reference to the cooling distribution in a data center.**
- **Reallocation of *cooling energy resources* based on the compute load distribution in the data center.**





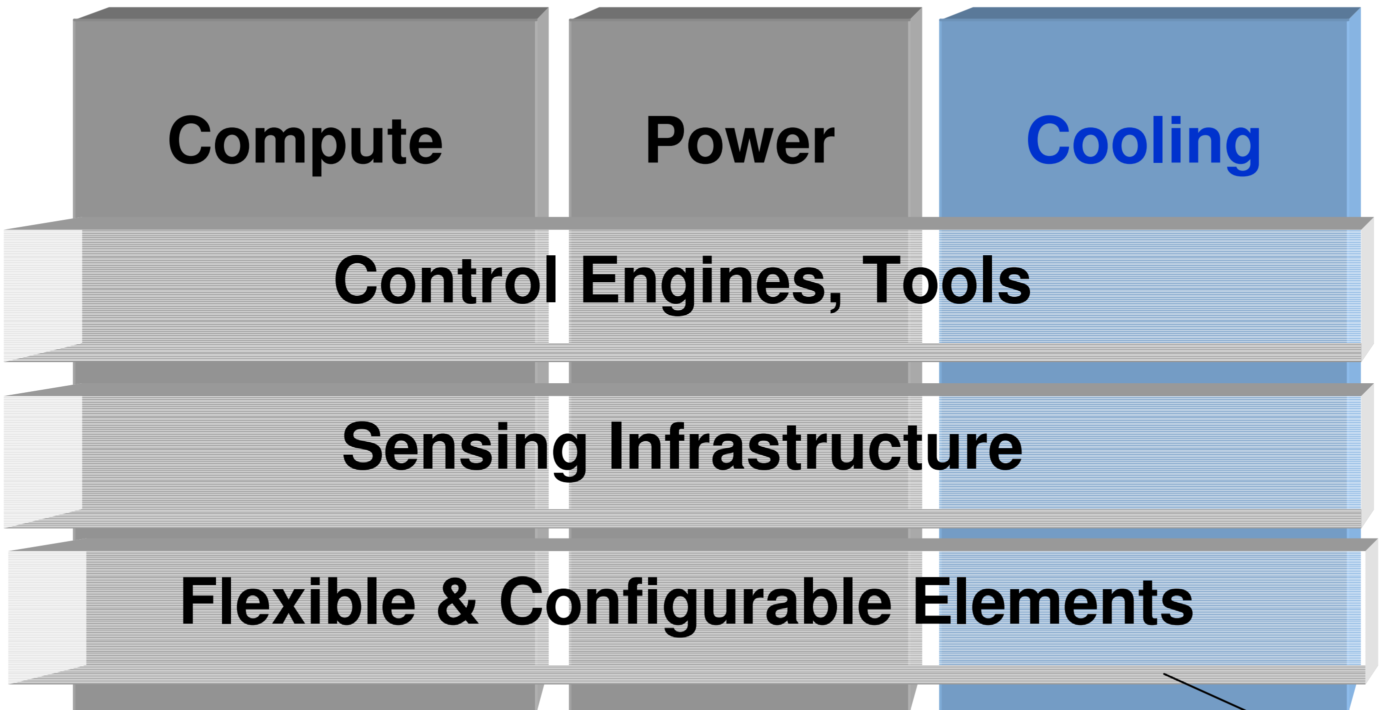
Building Blocks

- **Modeling**
- **Metrology**
- **Control**
- **Integration into OS**

Smart Data Center

a data center "smart" by design & operation

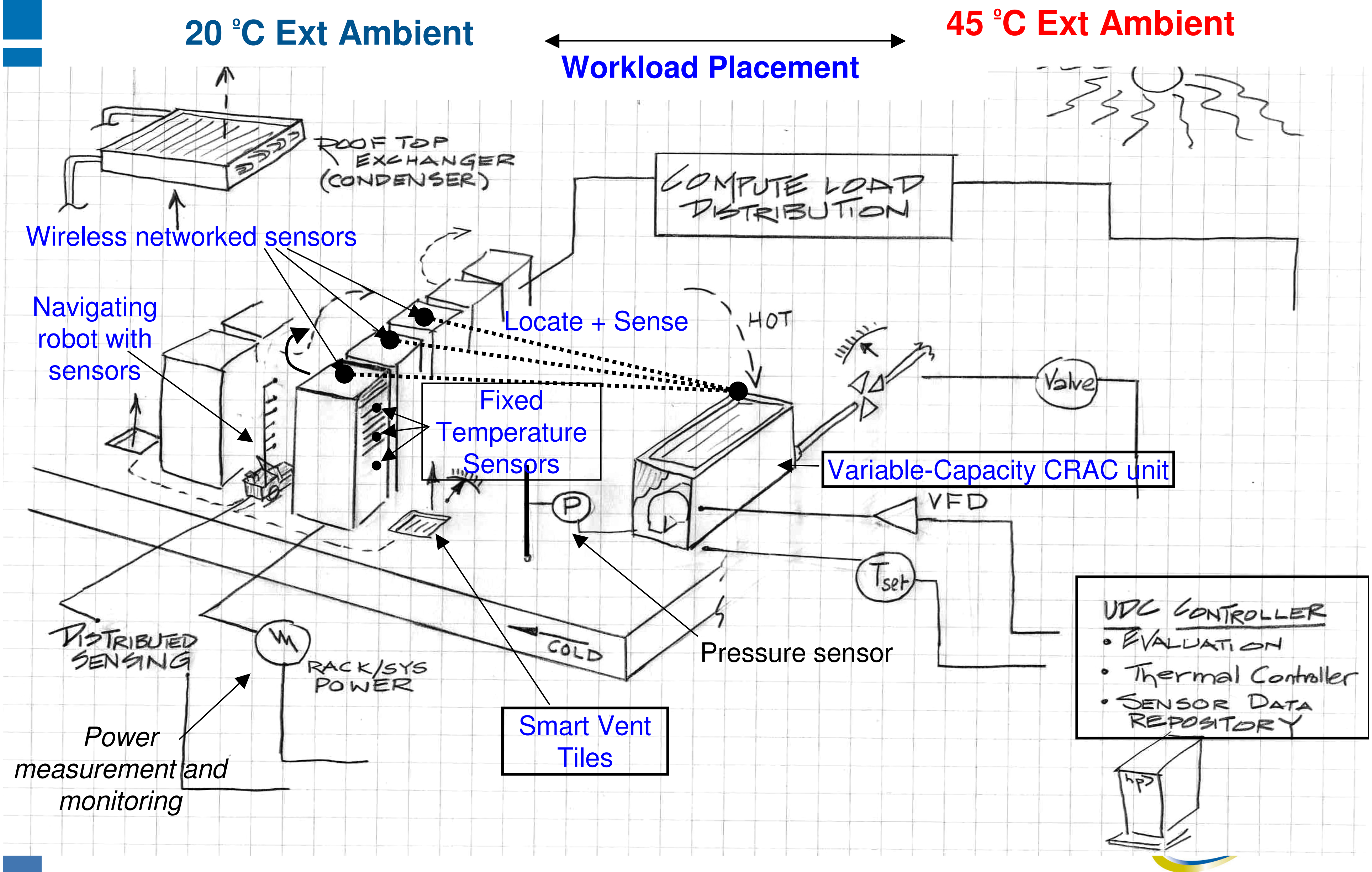
Design data center compute and facilities infrastructure with attributes that allow it to rapidly and automatically adapt to changes in business needs



commodity flexible building blocks that enable dynamic change in configuration

Smart Data Center Concept

Adaptive Data Center (Dynamic Smart Cooling)



Implementation of Smart Data Center

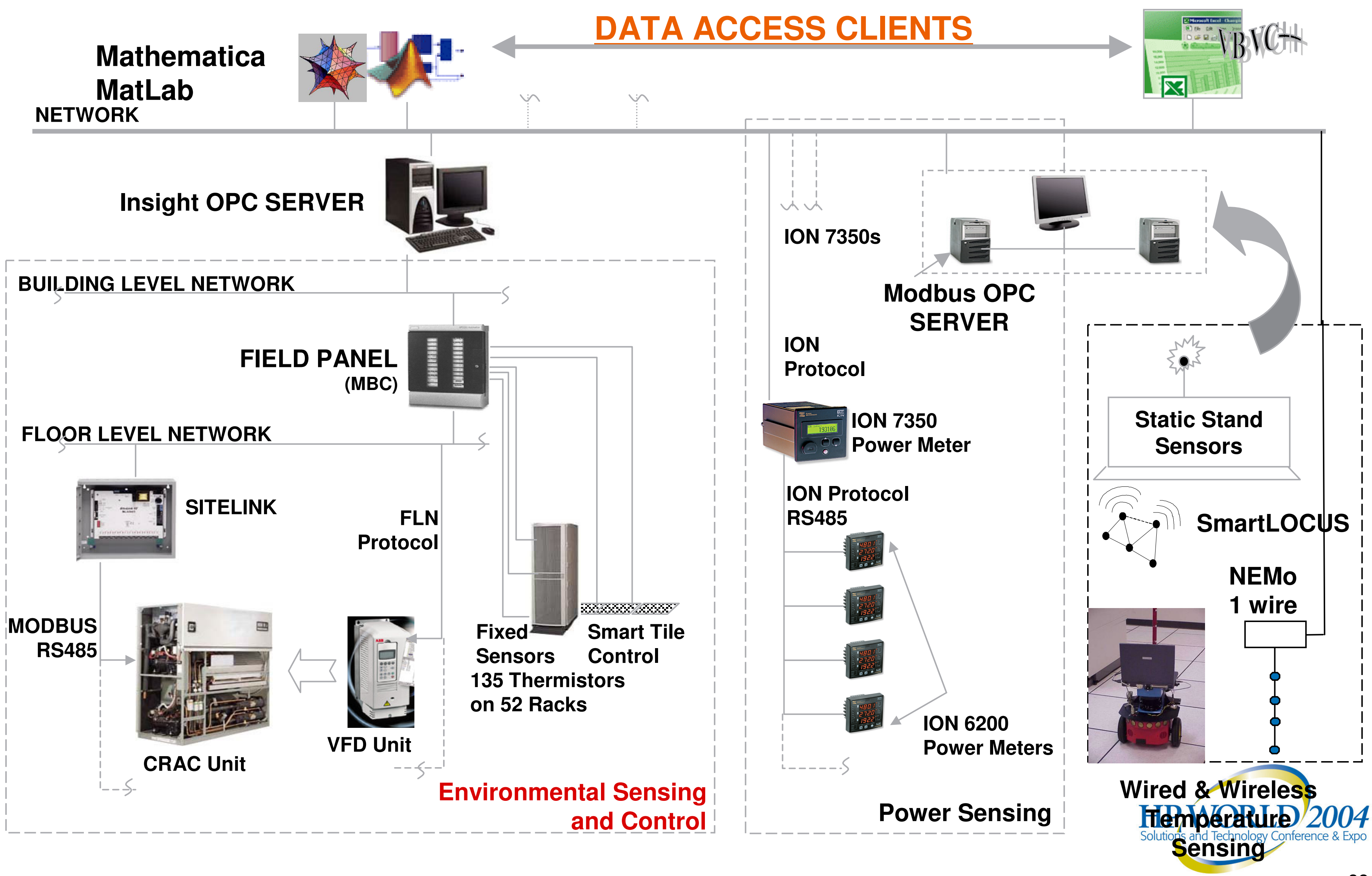
HP Laboratories, Palo Alto Utility Data Center

- **Ceiling or Room Return**
- **CRAC: Blower and chilled water flow control**
    - Smart Tile – Vent Flow Control

HP WORLD 2004
Solutions and Technology Conference & Expo

Data Center Management System

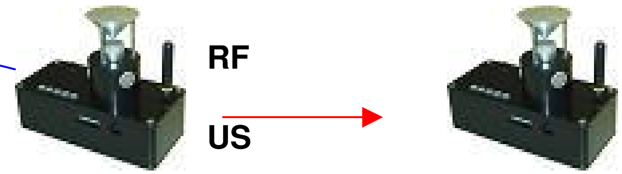
Unified View based on Open Connectivity



Smart Data Center Realized

HP Laboratories, Palo Alto, California

Self-locate + sense



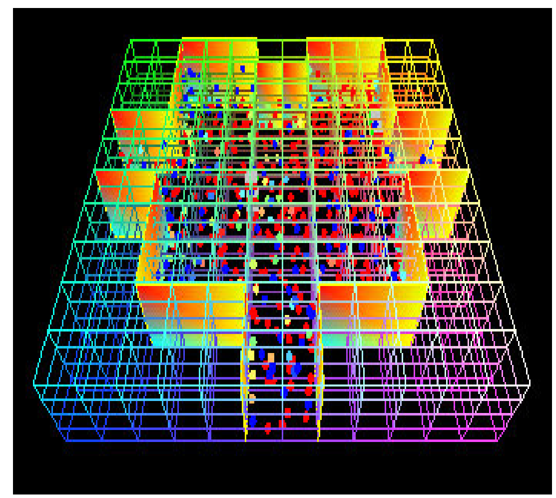
+ Flexible
  Infrastructure

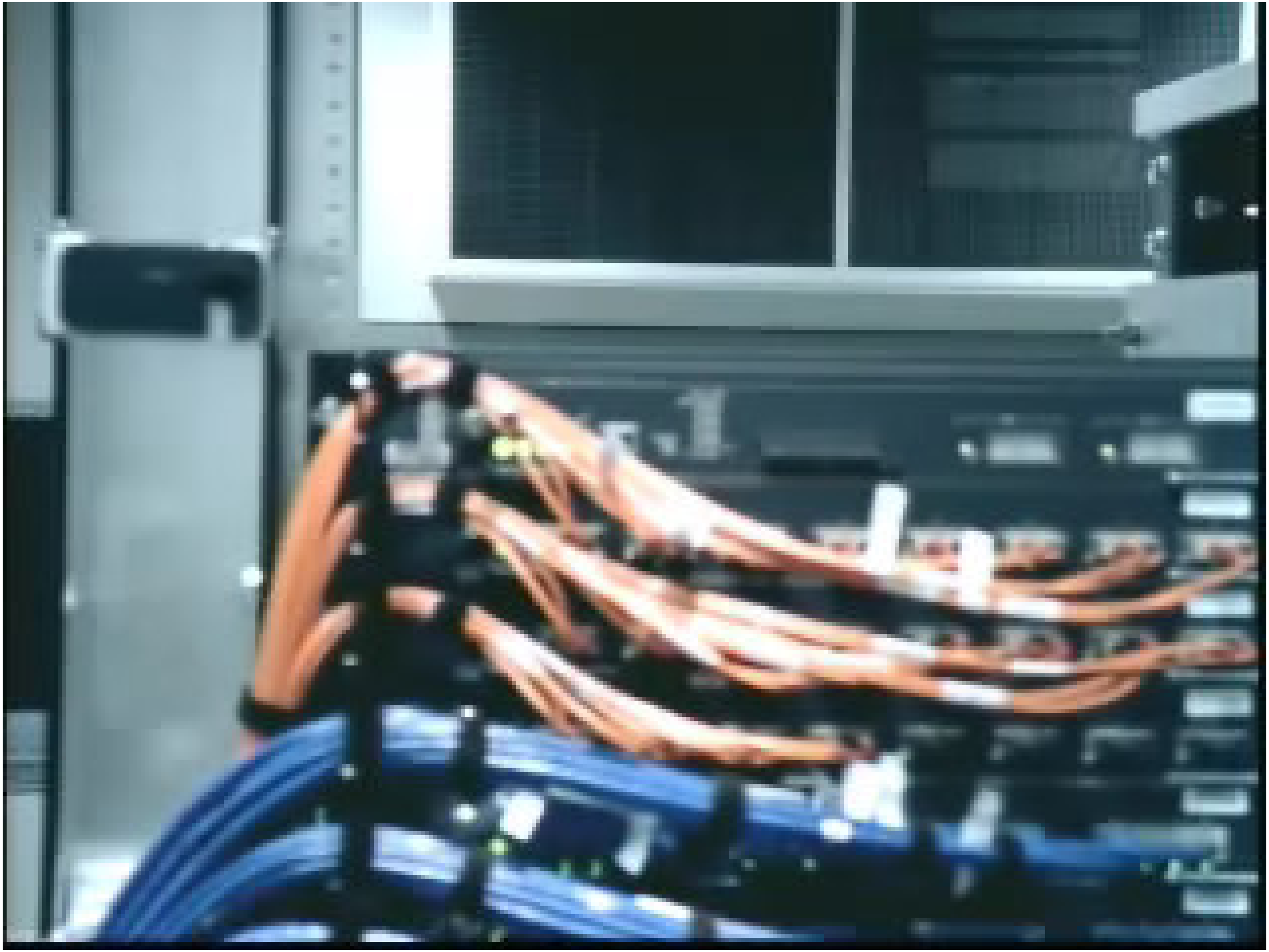
(e.g. Smart Vents)

+ Data Aggregation

+ Visualization

+ Control System





Demonstrated Energy Savings

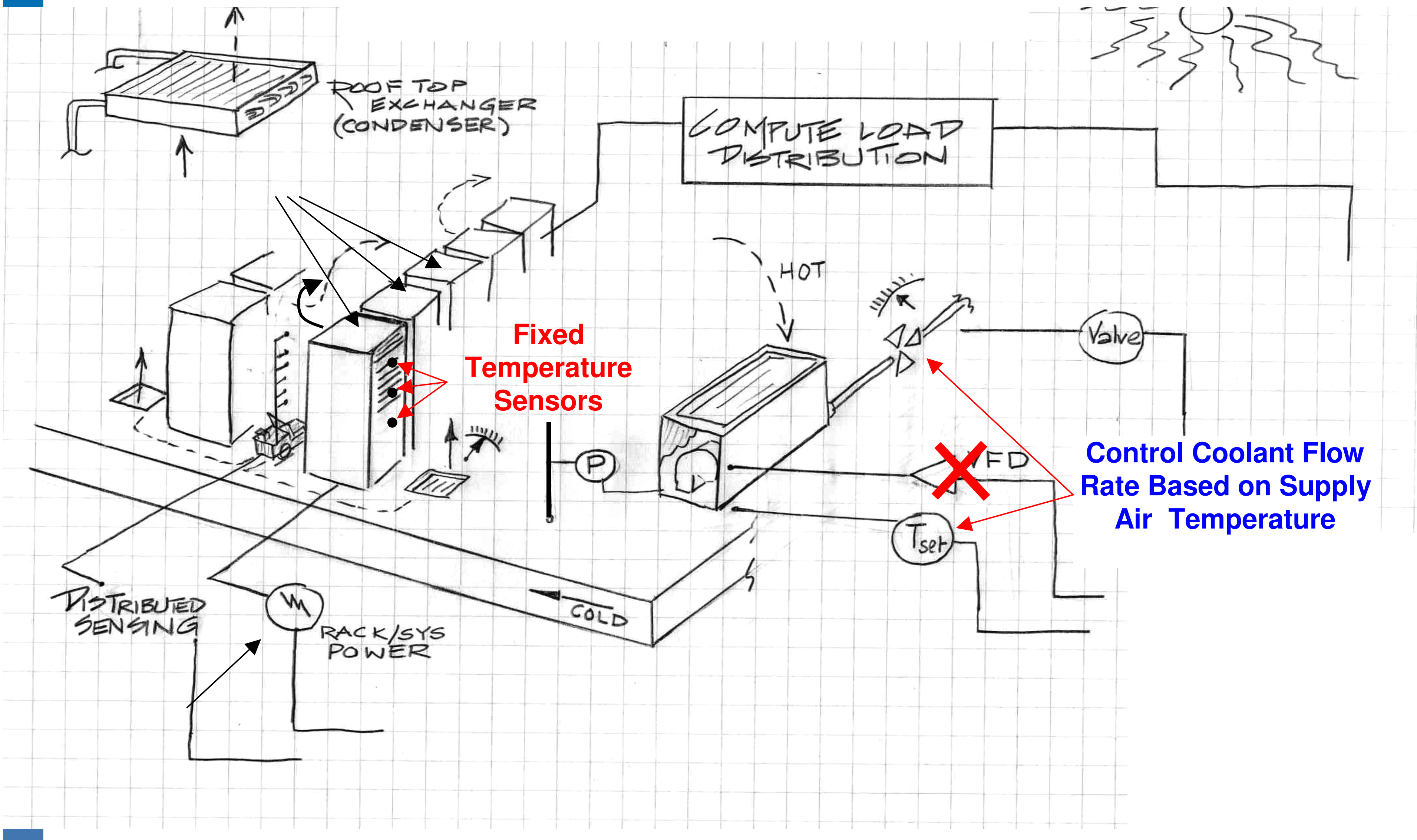
HP Labs Production Data Center

- Energy savings via control of cooling based on:
  - CRAC supply air temperature
  - Minimizing CRAC fan speed

DC Configuration	Control CRAC Supply Temp?	Control CRAC Fan Speed?	Total AC Power Consumption (kW)
Standard Industry Practice	No – 14ºC (21ºC @ CRAC Return)	No – Maximum Capacity	45.8
Optimization #1	Yes – ~20ºC (25ºC @ Racks)	No – Maximum Capacity	31.2 (-31%)
Optimization #2	Yes – ~20ºC (25ºC @ Racks)	Yes – 45% Max	13.5 (-71%)

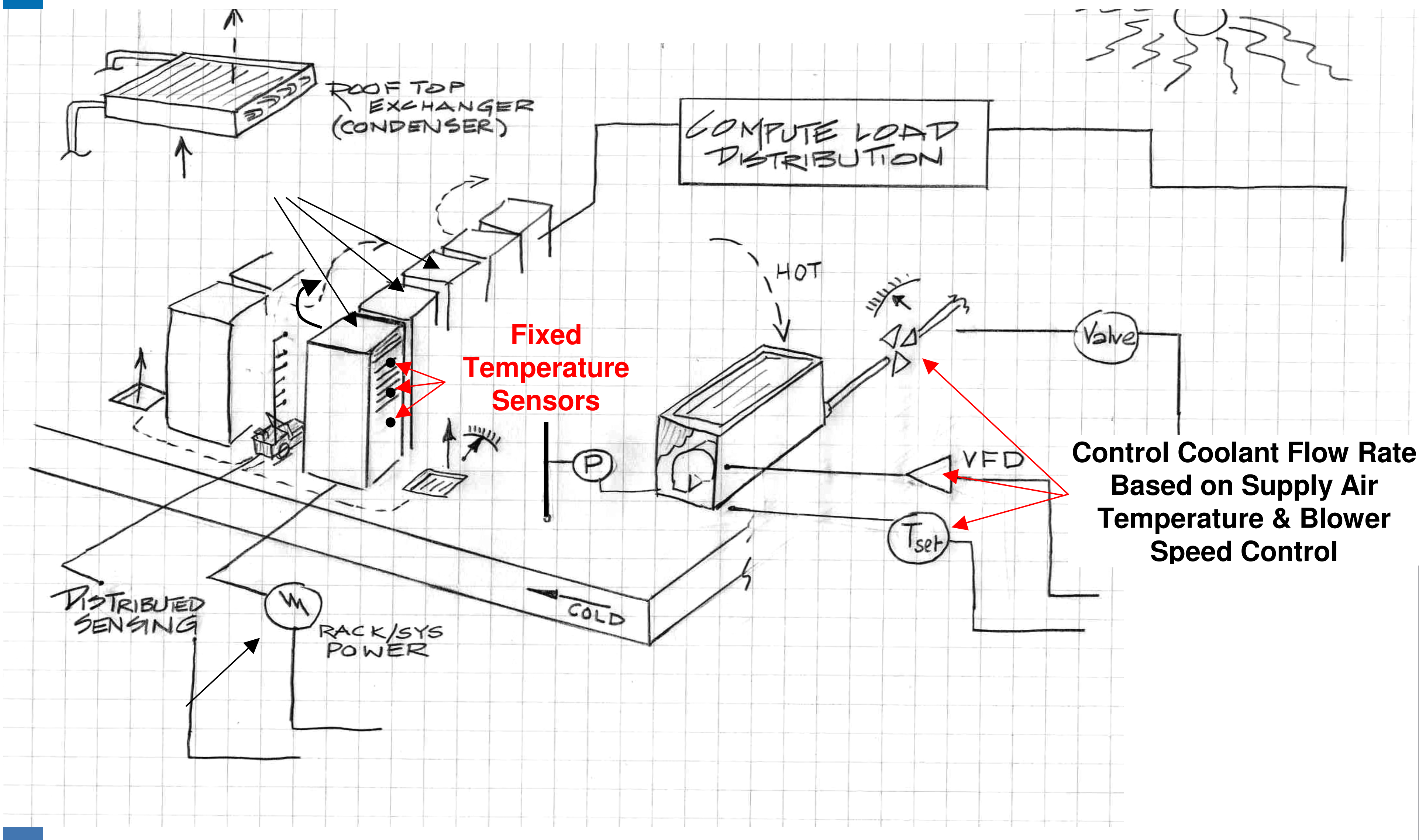
Savings

Optimization #1: CRAC Control Based on Supply Temperature



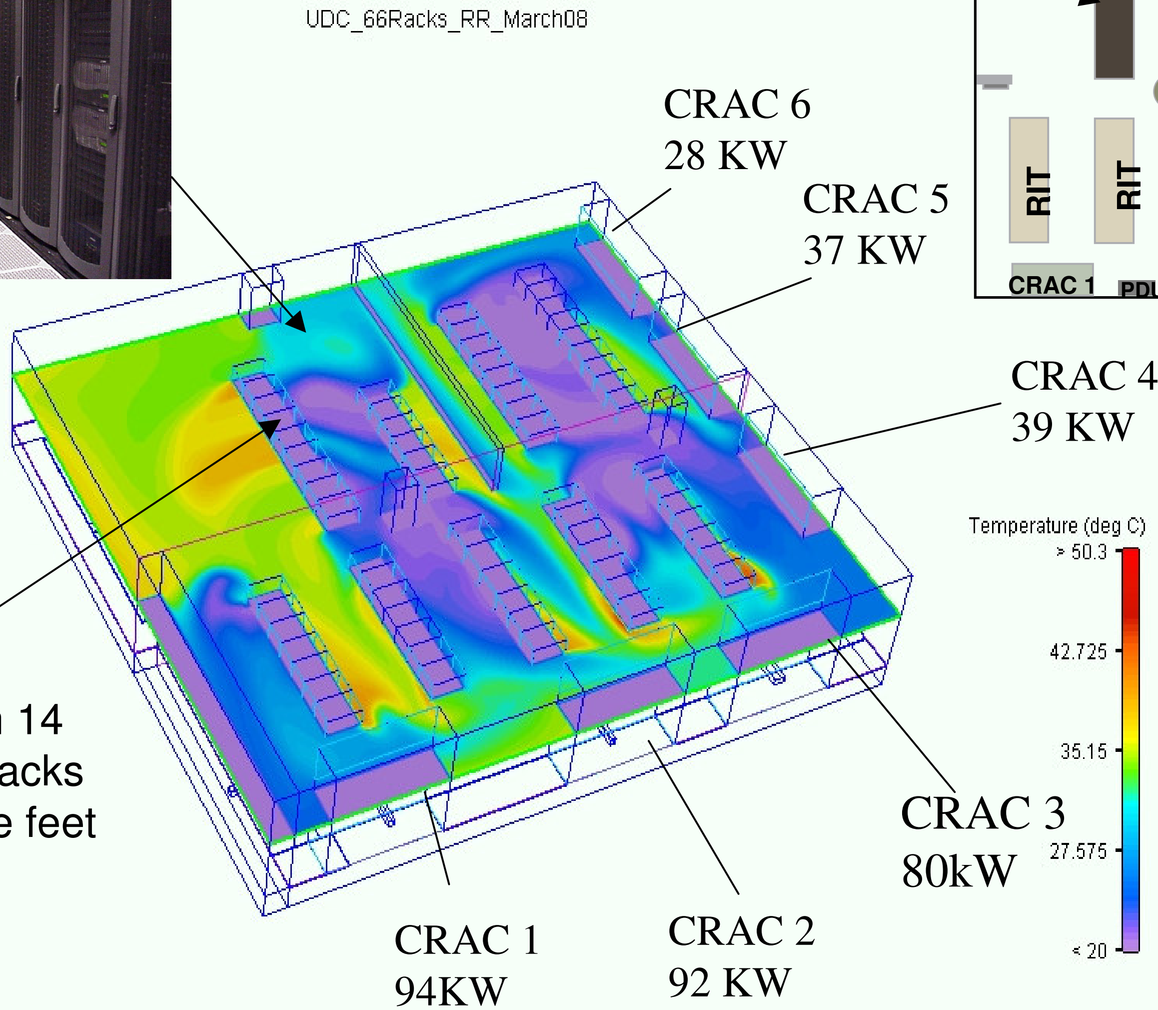
Smart Data Center Energy Savings

Optimization #2: CRAC Control - Supply Temperature & Blower Speed



Given Production State in the “Smart” Data Center

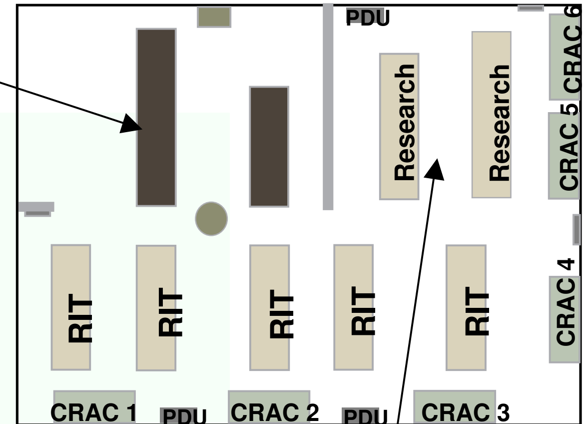
“Statically Provisioned State”



HD Area:

140 KW from 14 fully loaded racks in 400 square feet

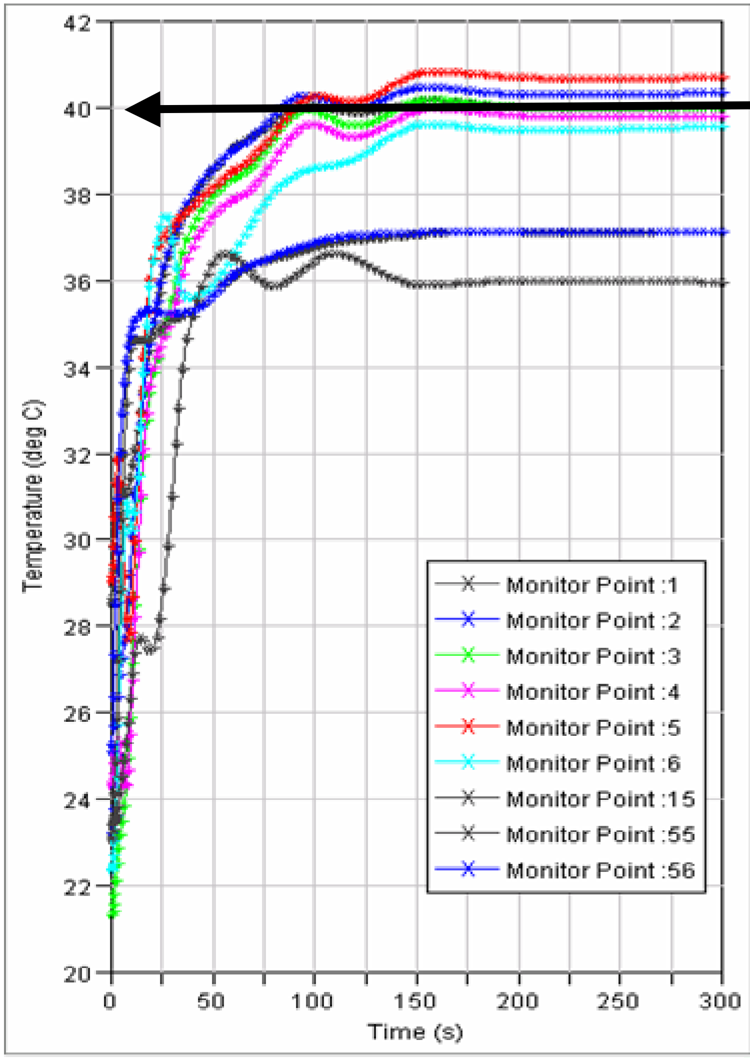
HD Area

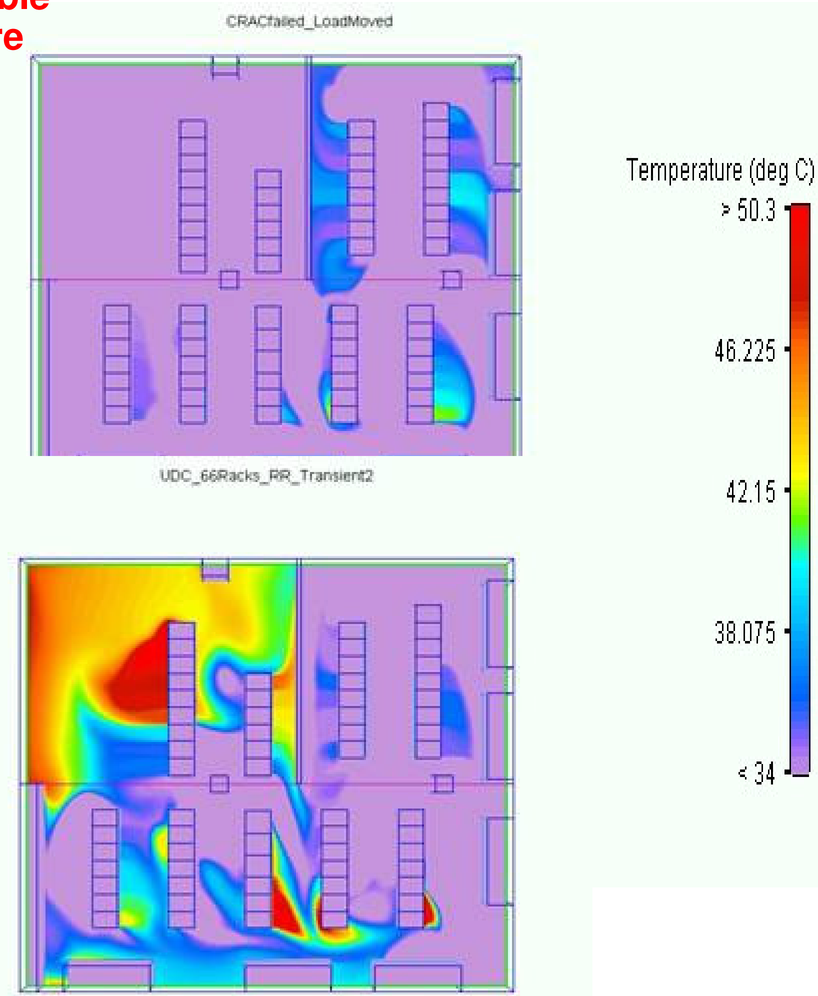


High Performance Cluster – low load in this state

Analysis – Planning Failure Mitigation

CRAC #1 Failure

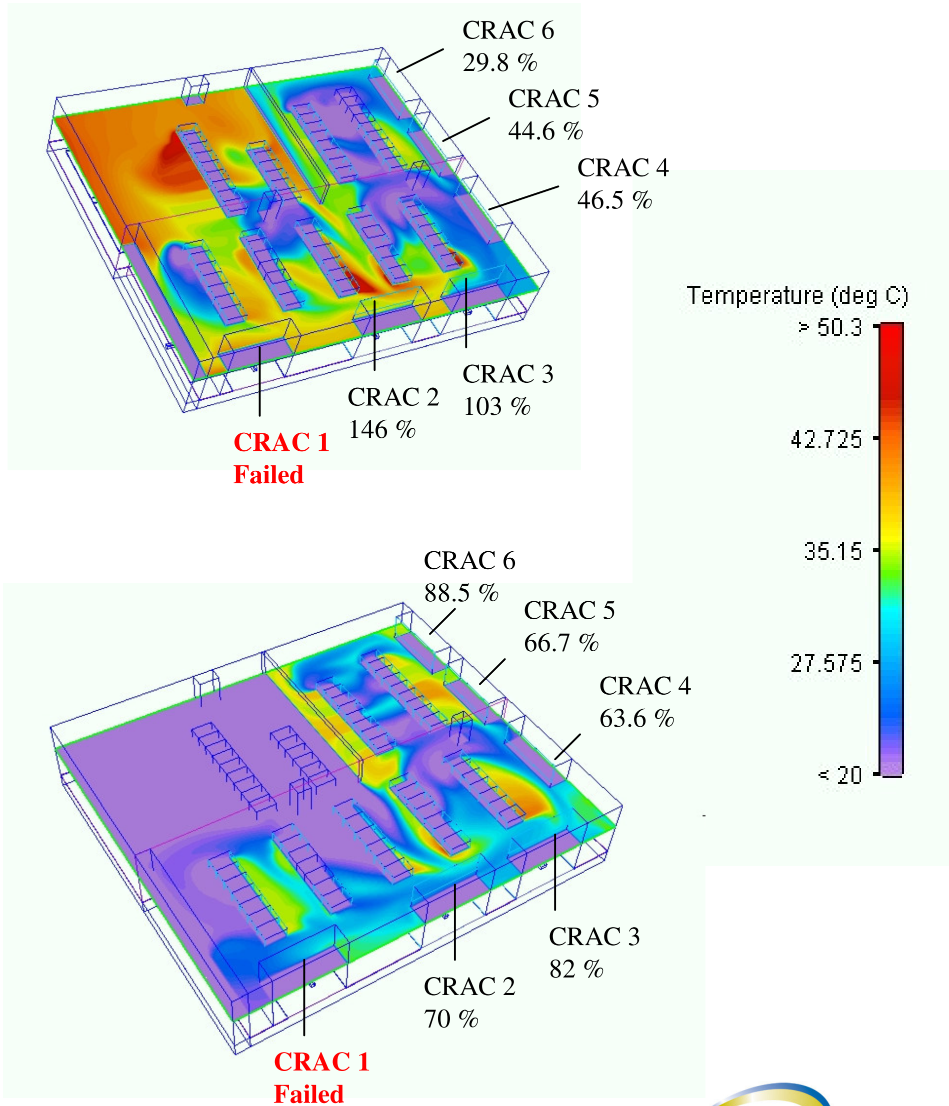




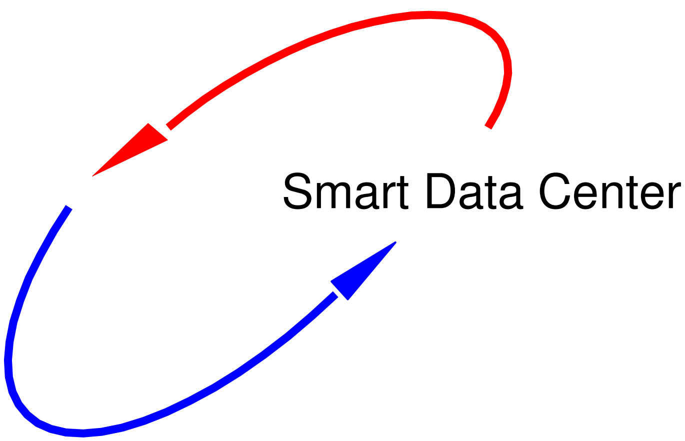
**** It took 80 seconds to reach unacceptable temperature level.**

Summary – Smart Data Center

- Compaction
  - 1/3 of today's floor area
- Energy Savings
  - Up to 50% compared to conventional systems
- Smart Redundancy
  - Reduced capital costs through elimination of excessive redundancy



Portfolio of Solutions from Chip Core to the Cooling Tower



"A control volume drawn around a planetary scale collection of data centers, the confines of which maintain balanced cooling and compute loads, saves a world of energy"

We thank you for your time

i n v e n t

HP WORLD 2004
Solutions and Technology Conference & Expo

Co-produced by:

interex
shared knowledge • shared power

encompass
AN HP USER GROUP

RECOMMENDED TRAINING VENUE FOR THE
HP Certified Professional