Role of the PI System in Research @ Georgia Tech Data Center Laboratory

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Georgia Institute of Technology

Outline

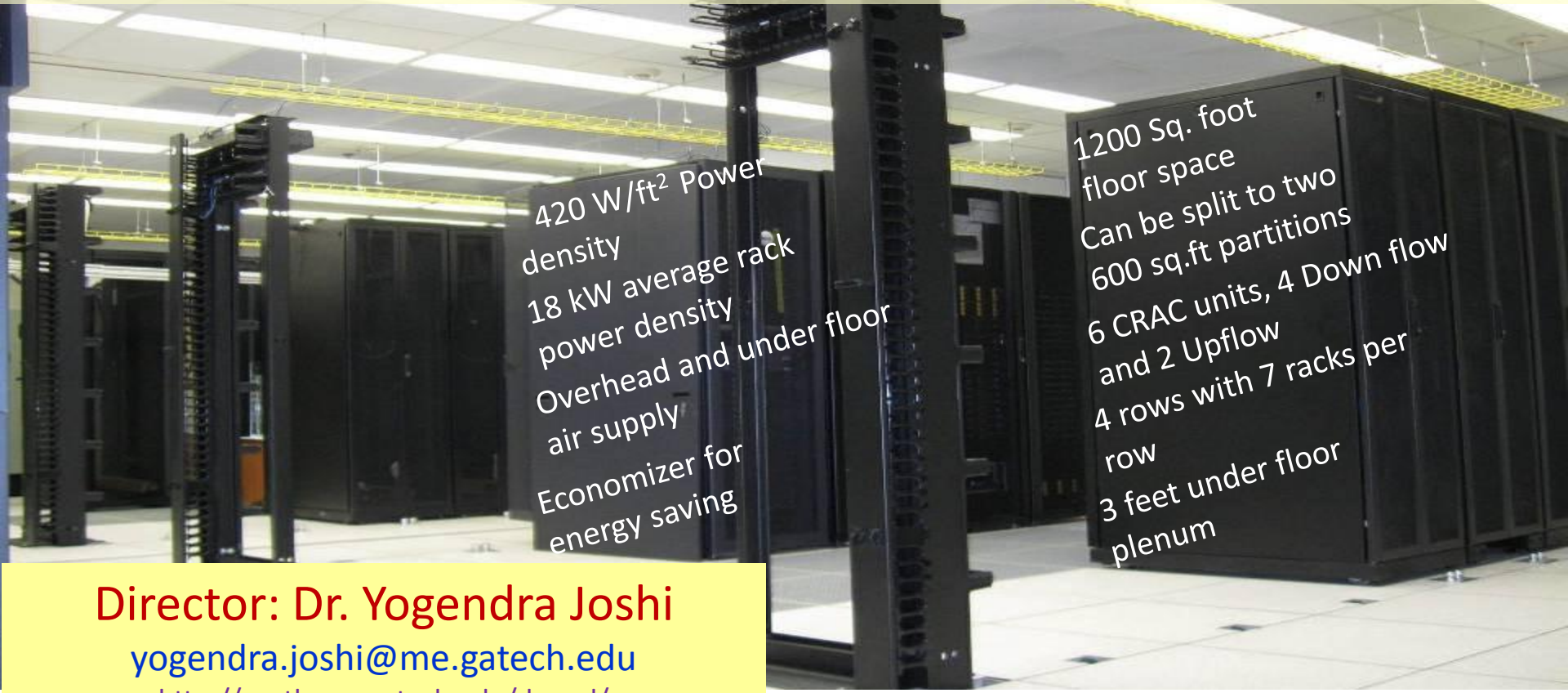
- Data center laboratory general information

- Current use of PI System

- Future use of PI System

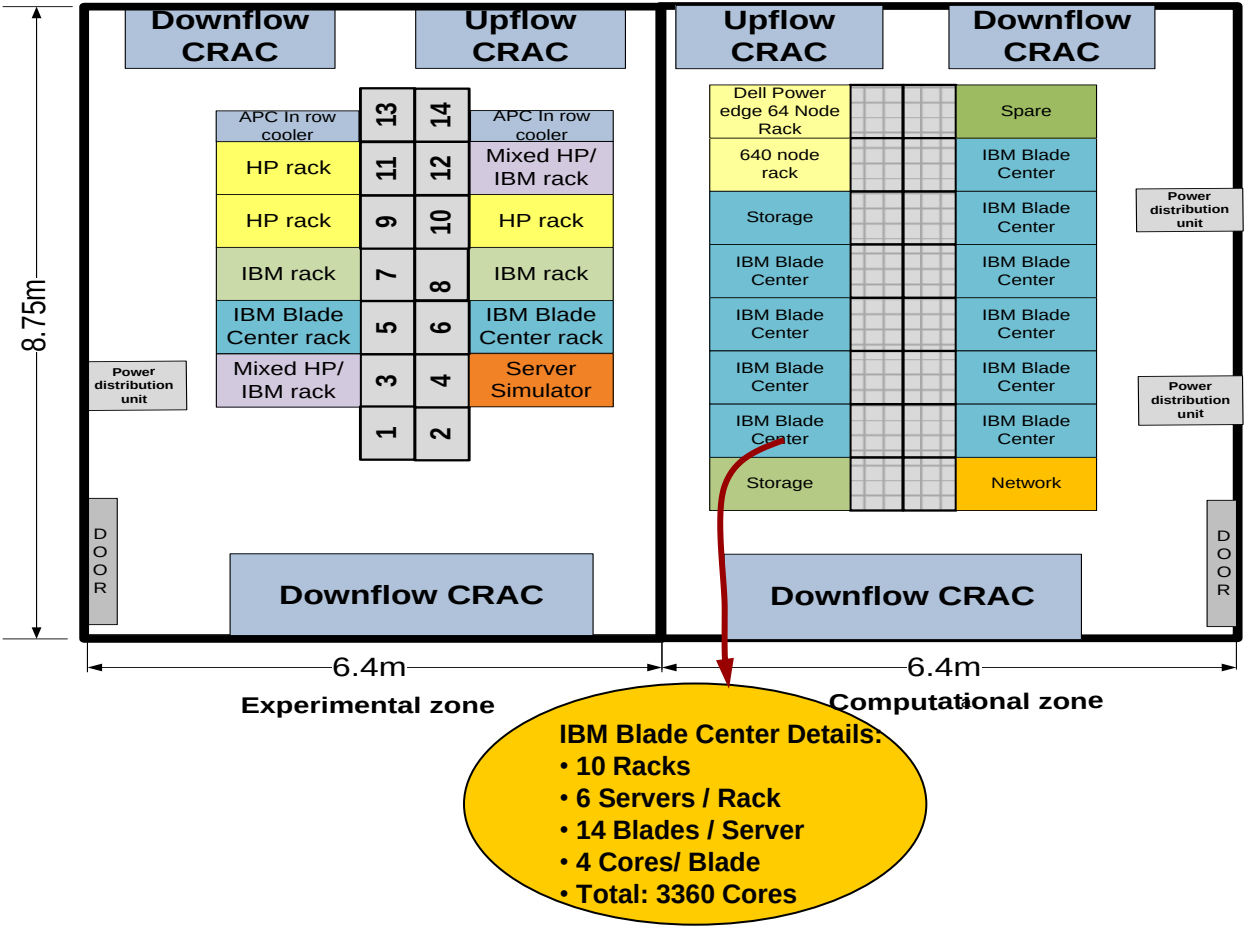
Data Center Laboratory @ Georgia Tech

A Platform for Transformative Research on Green Data Centers



Director: Dr. Yogendra Joshi
yogendra.joshi@me.gatech.edu
http://ceetherm.gatech.edu/drupal/

Data Center Layout



Equipment Donations courtesy:

Data Acquisition: OSIsoft

Building Management System: McKenney's

Racks: APC

Fan assist Chimney Racks: Wrightline

Servers: Intel, Yahoo and OIT

CRAC unit: Liebert

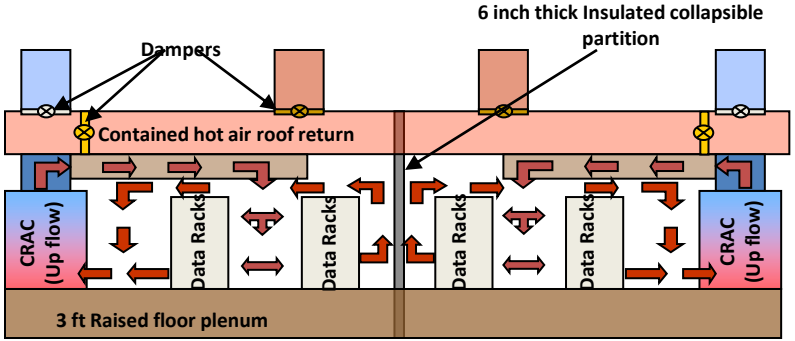
Server Simulator: APC

Branch circuit power metering: PDI corp

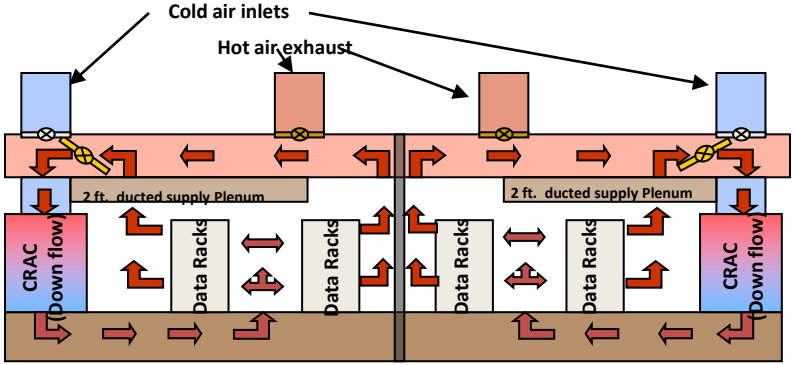
Remote KVM switch: Minicom and Digi

In row coolers: APC

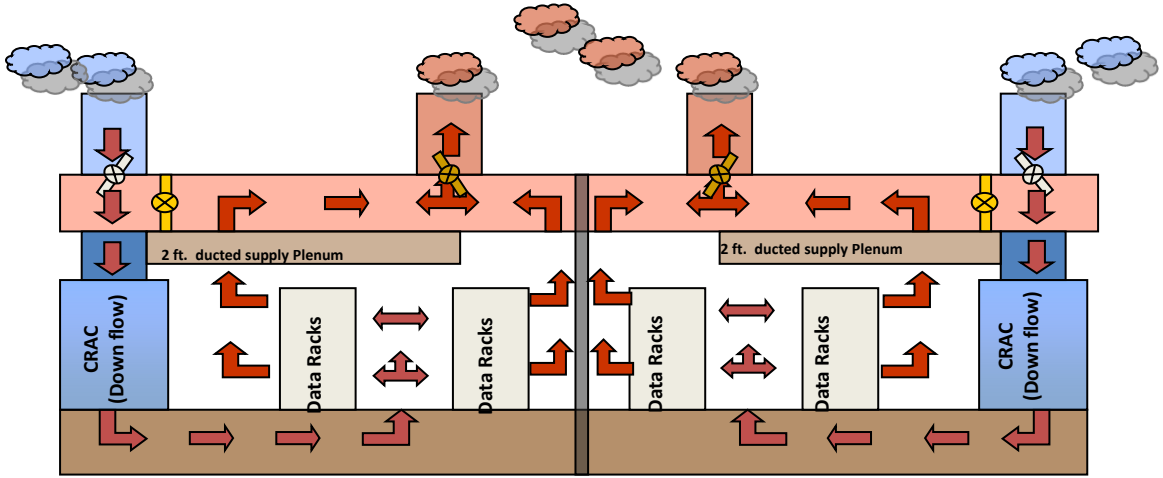
Data Center- Air Distribution



- Over head supply



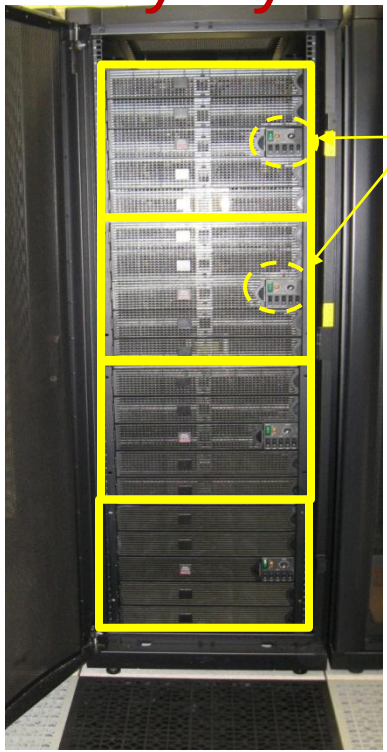
- Under floor supply



- Economizer

Particle Image Velocimetry System (PIV)

PIV system



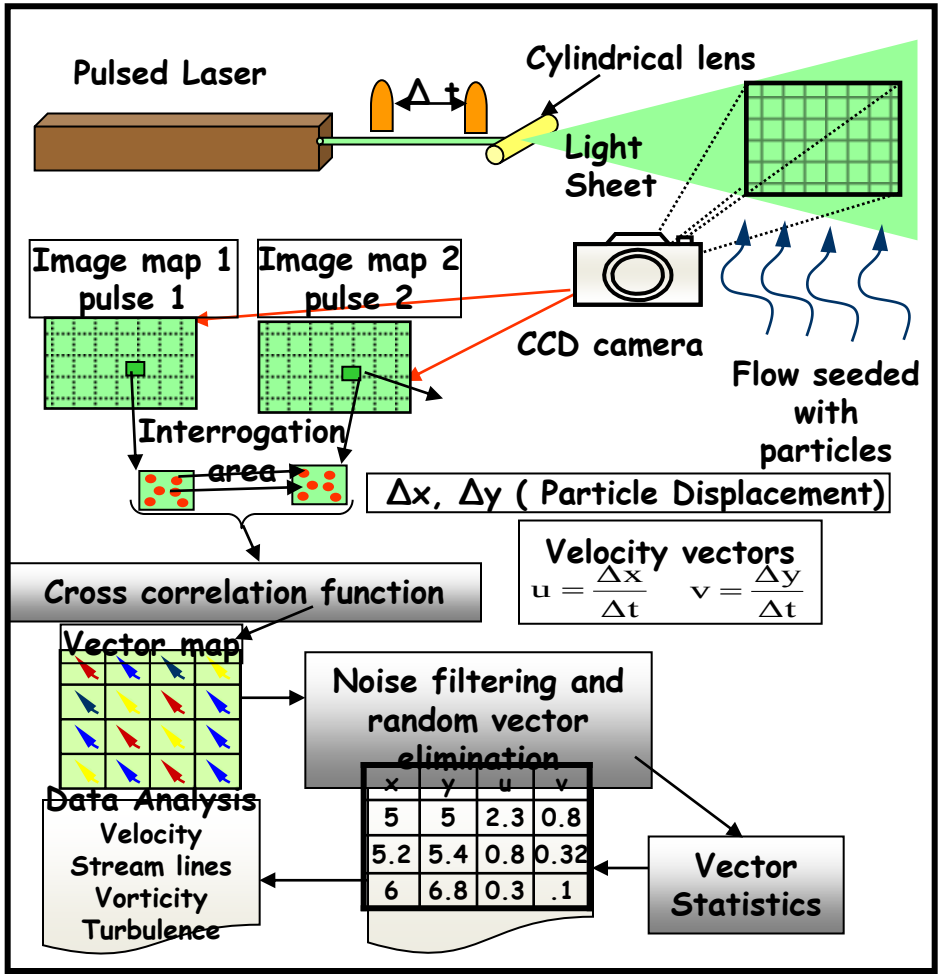
Server Simulator

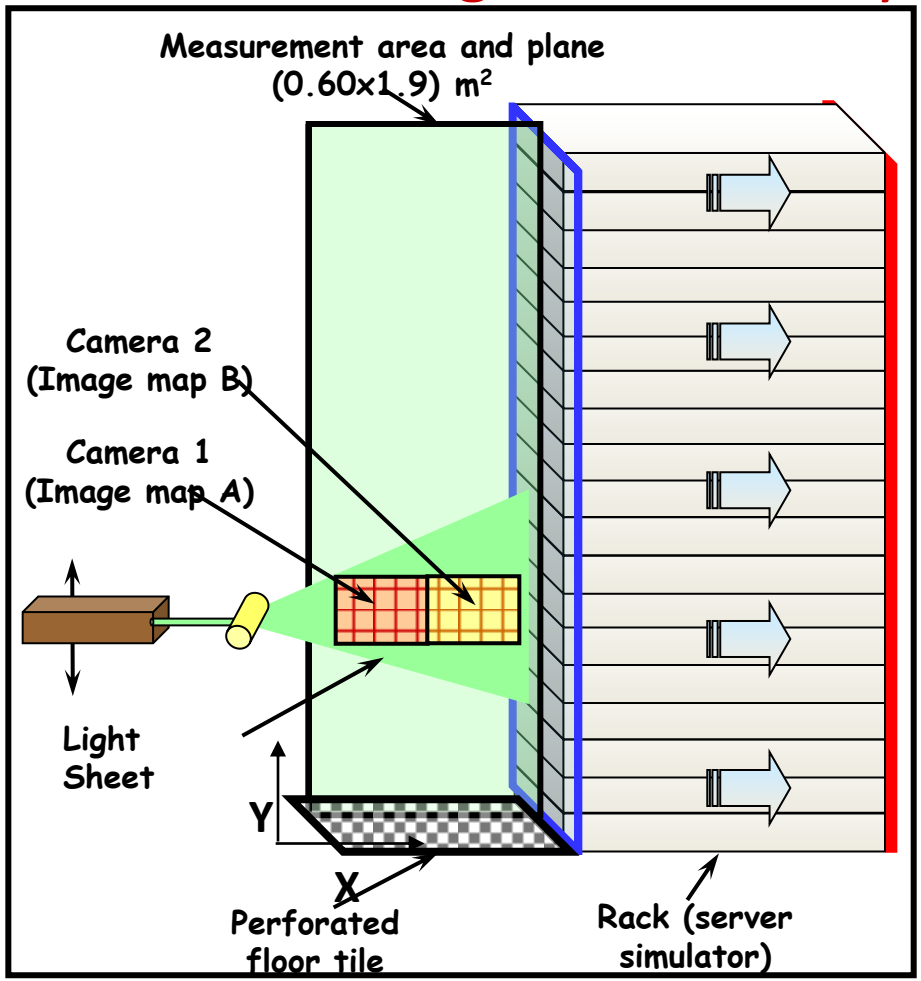
Fan speed and Heat setting dials

Perforated floor tiles with dampers

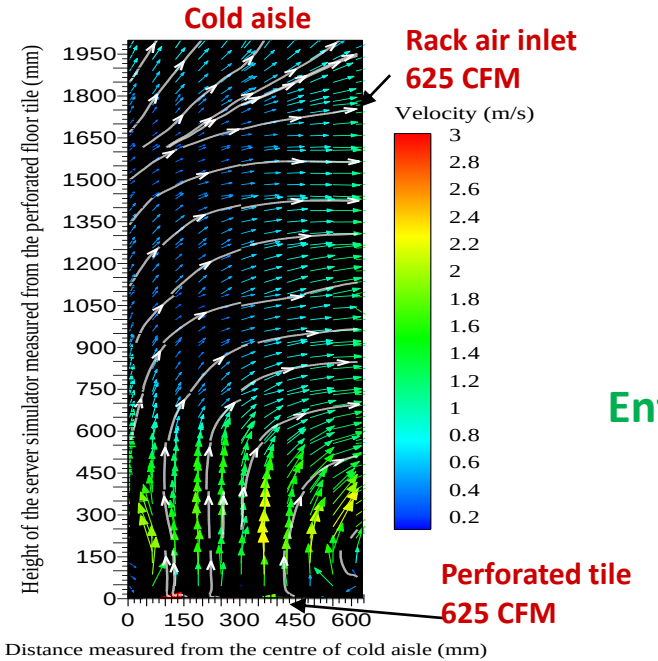
- One of the first PIV systems for rack level air flow mapping.
- 22 kW Server Simulator with adjustable fan speed and heater power settings to simulate a variety of air flow and heat loads.

Particle Image Velocimetry

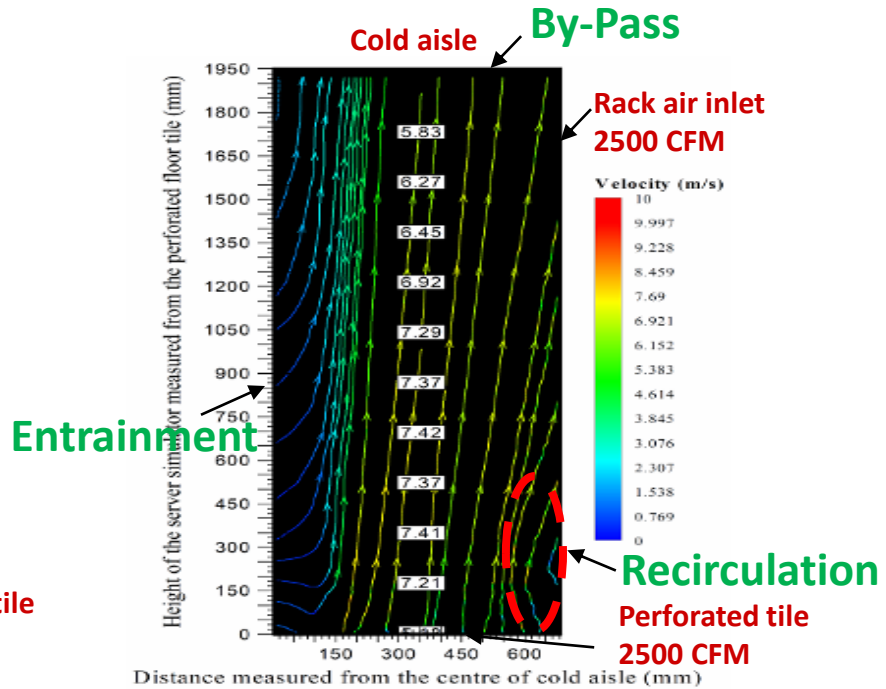




Tile/Rack Air Flow Studies using PIV



5.5 kW/Rack (625 CFM)

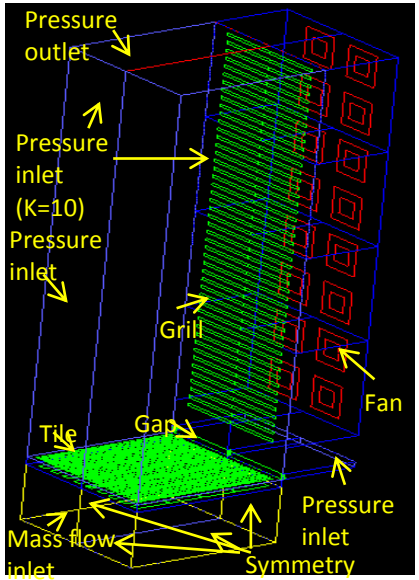


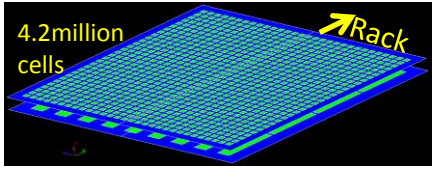
22 kW/Rack (2500 CFM)

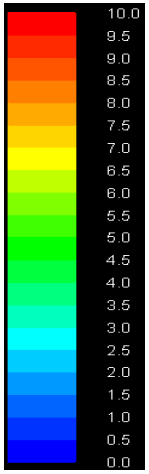
[ref] Kumar, P., Joshi, Y., Experimental Investigations on the Effect of Perforated Tile Air Jet Velocity on Server Air Distribution in a High Density Data Center, Intersociety Conference on Thermal Phenomena (ITHERM), Jun 2-5, 2010, Las Vegas, USA.

Numerical Modeling

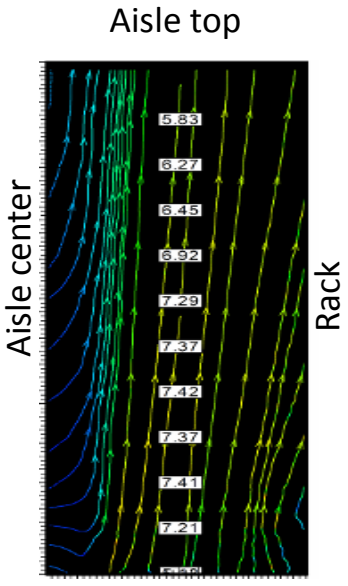
22 kW/Rack (2500 CFM)



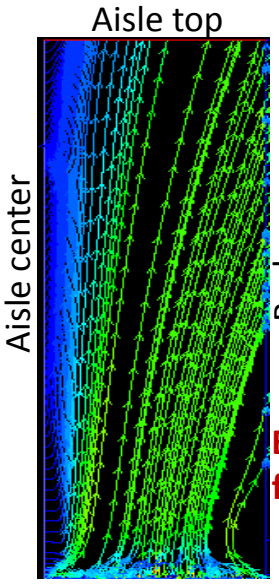




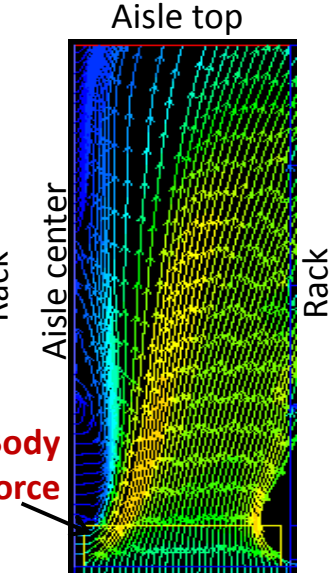
Velocity (m/s)



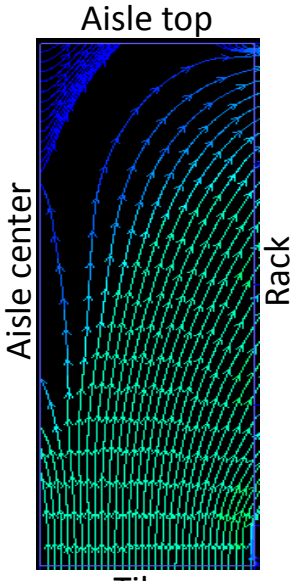
PIV (Experiments)



Geometrical Resolution



Modified Body Force (Developed)

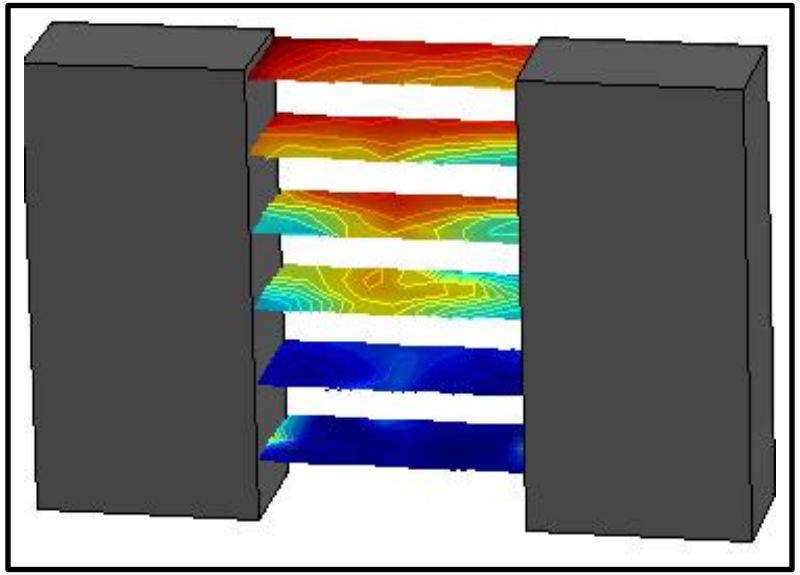


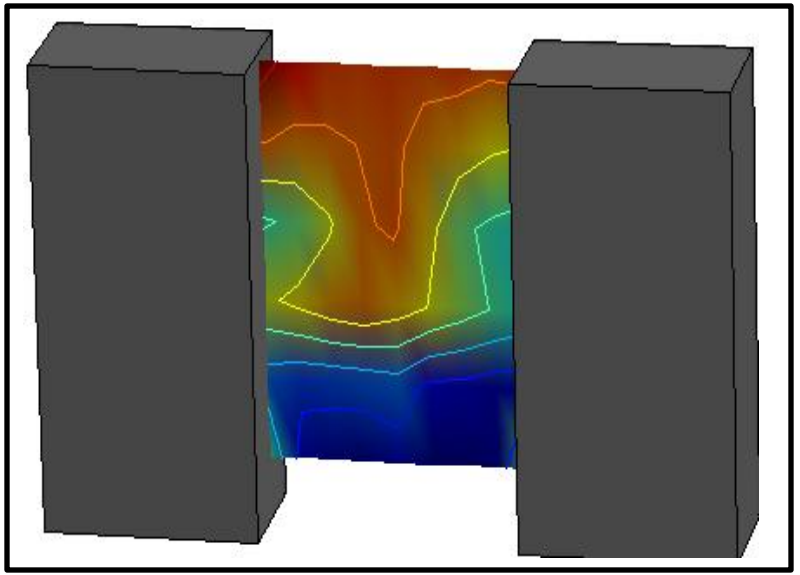
Porous Jump (Generally Used)

- Modified body force with momentum source region of 22” width and 6” height suggests closer comparison with geometrical resolution and PIV results

[mbf] Arghode, V. K., Kumar, P., Joshi, Y., Weiss, T., Meyer, G., Rack Level Modeling of Air Flow Through Perforated Tile in a Data Center, International Mechanical Engineering Congress and Exposition (IMECE), Nov 9-15, 2012, Houston, USA.

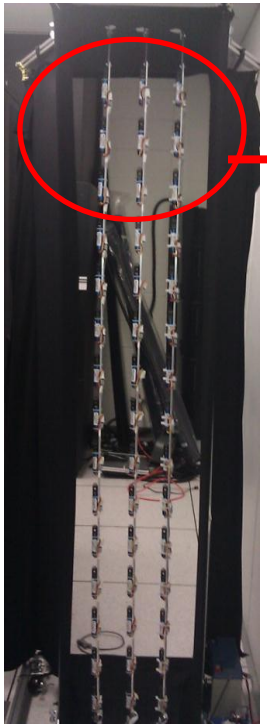
Grid Based Temperature Measurements

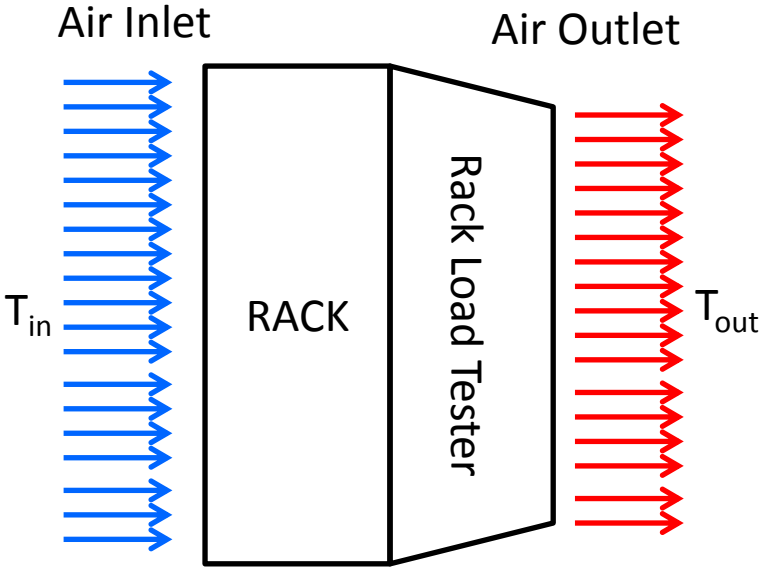




- T type thermocouples (wire gauge 28, 0.321 mm)
- 252 thermocouples (width = 4ft, depth = 2ft, height = 6ft 6inch)
- 3D mapping of the cold aisle
- 6 planes along the height, 5 planes along the depth and 10 planes along the width

Rack Air Flow and Heat Load Measurement





- Array (15 × 3) of temperature (thermistor) and velocity (thermal anemometer) sensors
- Mass flow rate calculated based on the measured velocity
- Rack heat load calculated based on mass weighted outlet temperature and inlet temperatures and the mass flow rate

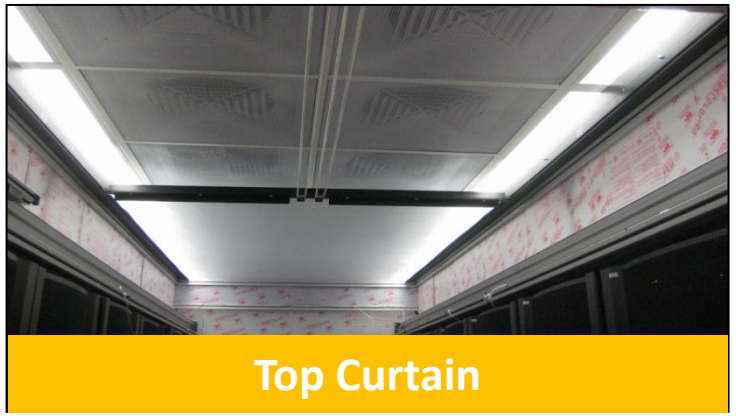
$$m=\rho \times A \times V$$

Air mass flow; Air density; Flow Area; Measured Velocity

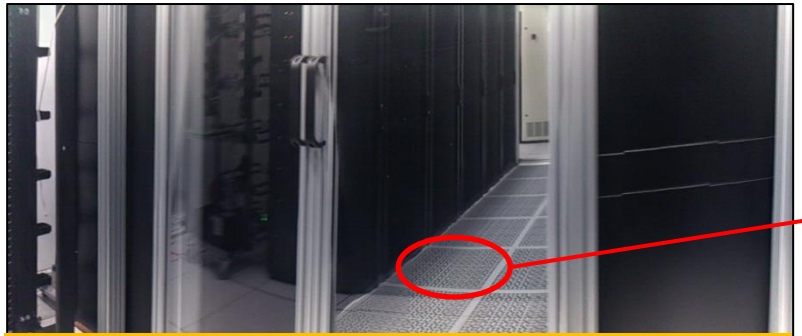
$$Q=m \times C_p \times (T_{out}-T_{in})$$

Heat load; Air specific heat; Measured Temperatures

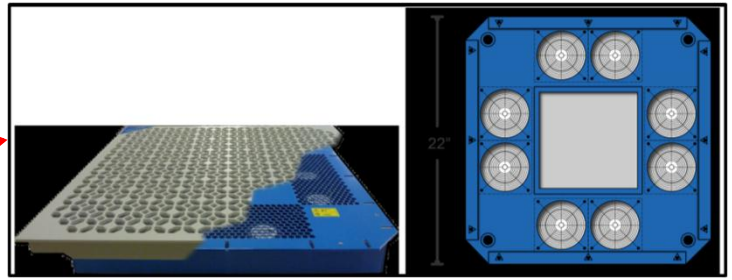
Containment System with Active Fan Tiles



Top Curtain



Fan Assisted Tiles



Outline

- Data center laboratory general information

➢ Current use of PI System

- Future use of PI system

Sensor Types

- Temperature
  - Thermal diodes (CPU temperatures)
  - Resistance temperature detectors, thermistors, and thermocouples (air temperature)
- Power
  - Branch Circuit Monitoring System (at Power Distribution Unit @ PDU level)
  - Power Outlet Power Sensing (at Power Strips)
- Water Velocity/Flow :
  - Dual turbine flow meter (Rear Door Heat Exchanger)
  - Magnetic flow meter (Computer Room Air Conditioning)
- Air Velocity/Flow:
  - Constant temperature hotwire anemometer (point velocity measurement)
  - Particle image velocimetry (PIV) (velocity field)
  - Flow hood (tile flow rate)
- Pressure Sensors
- Humidity Sensors

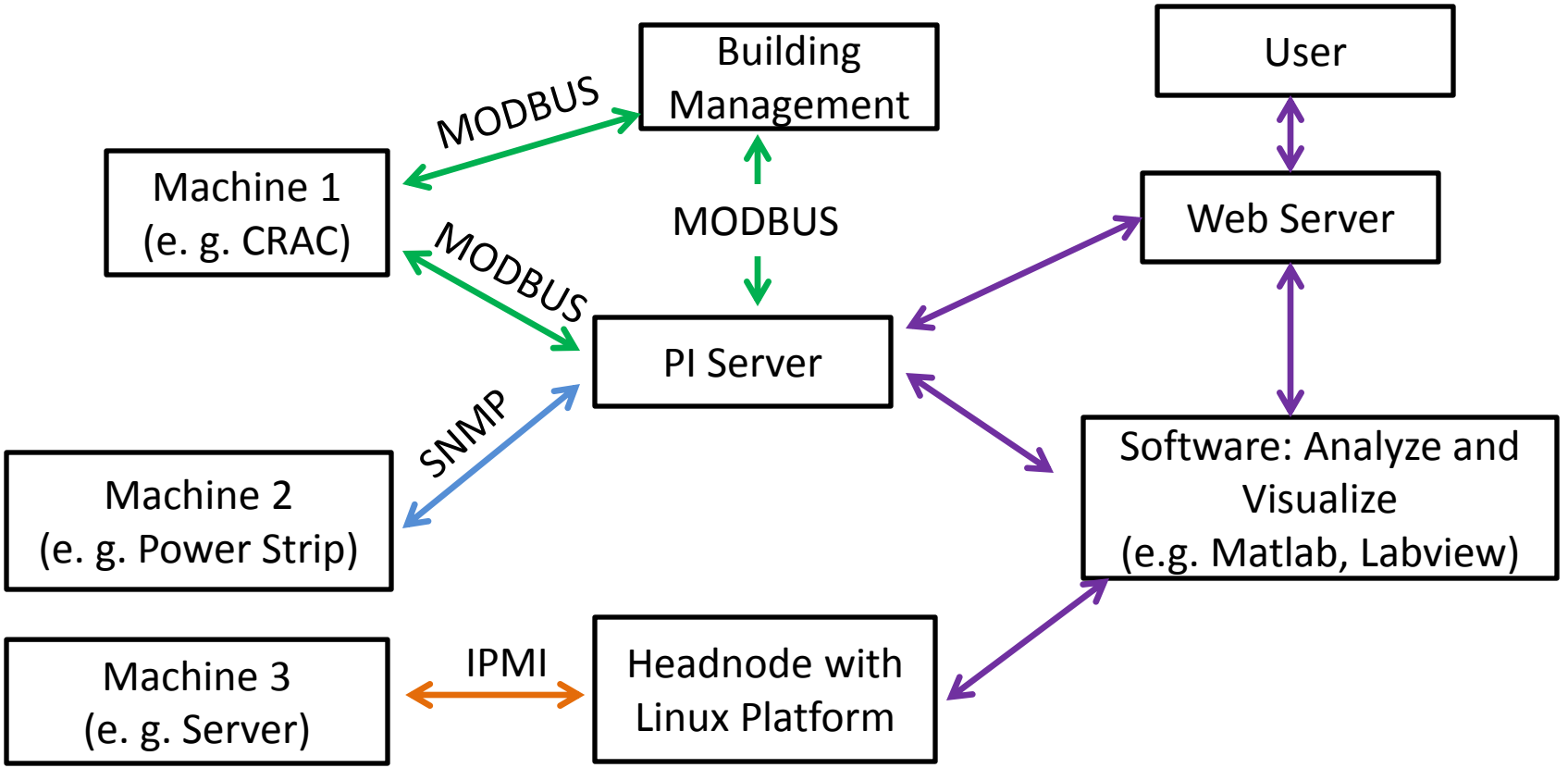
Interfaces

- **MODBUS TCP/IP** – Communication protocol published by Modicon in 1979 for use with its programmable logic controllers (PLCs). Currently used as the interface with the building management system.

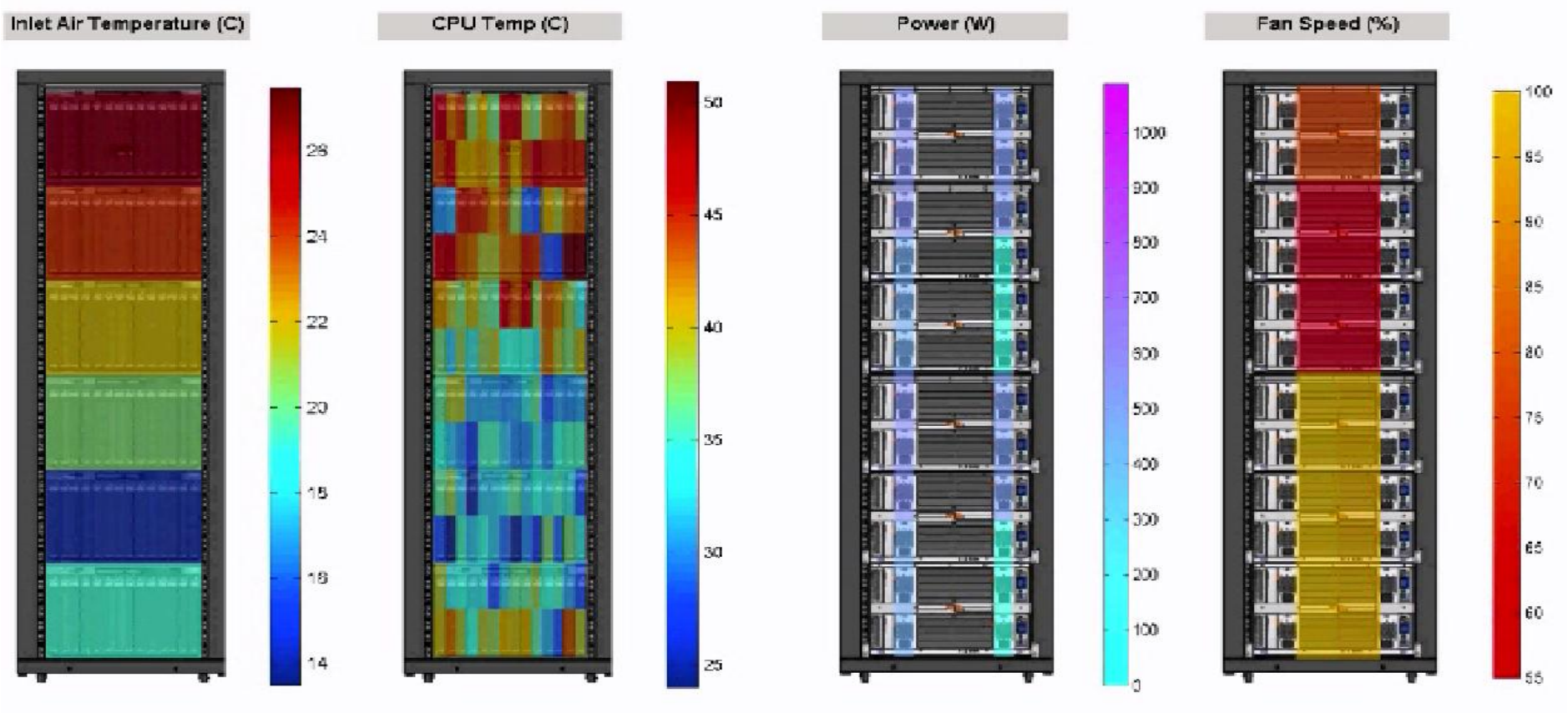
- **SNMP** (Simple Network Management Protocol) – Internet-standard protocol for managing devices on IP networks. Used in facility to communicate with power strips and blade centers.

- **IPMI** (Intelligent Platform Management Interface) – Used by system administrators to manage computers and gather data for monitoring purposes. Used in facility to communicate with server to collect server health data

Data Acquisition and Archiving

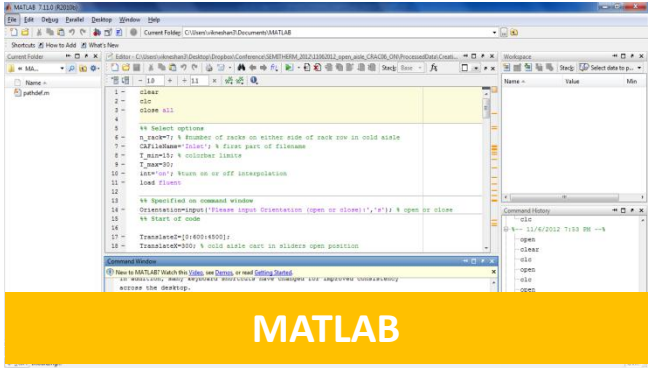


Rack Level Monitoring Example (SNMP)

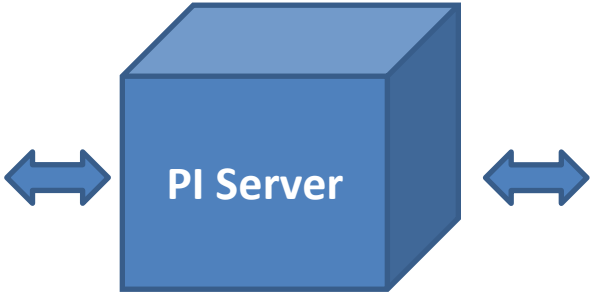


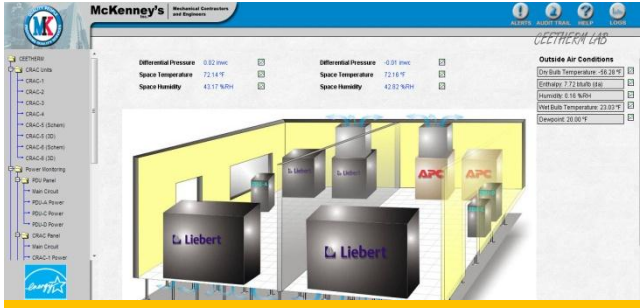
Control System Design and Implementation

- Building management system (BMS) uses Niagra by Tridium to regulate cooling
- MATLAB script or code communicates with PI System using PI OLEDB, which sends commands through output tags to BMS. MATLAB built-in functions and tools used (e.g. SIMULINK) to design and implement controller.
- Benefits:
  - A comprehensive library of tools in MATLAB for control system design
  - No need for actual controller board
  - Fail safe: no changes made to existing controllers in data center
  - Suited for research purposes because of its flexibility and fast turnaround times



MATLAB

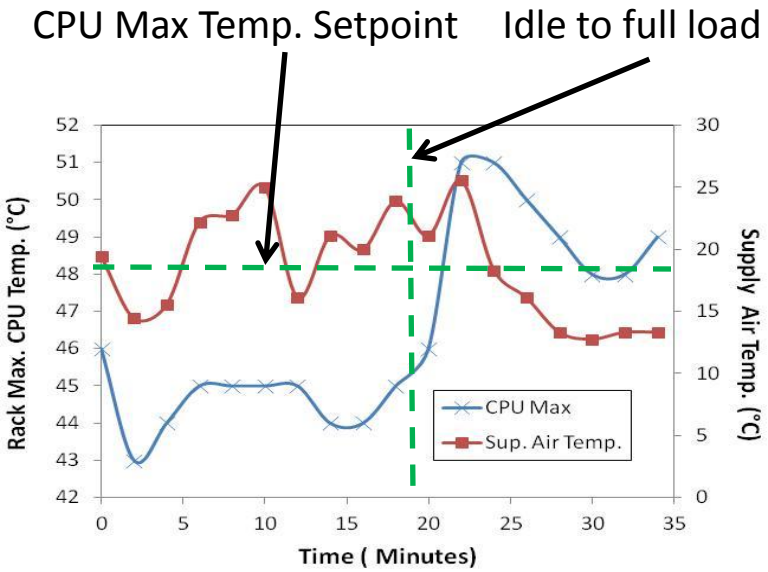




Building Management System

Controller Implementation Example

- Regulating maximum CPU temperatures for a rack by varying CRAC supply air temperature
- Integral action controller as an add-on to existing CRAC controls.
- Sampling period : 2 minutes
- Only one rack turned active in experimental zone (preliminary testing)



Test case: Step increase in compute load

[ref] Sundaralingam, V., Joshi, Y, Controller to regulate maximum server CPU temperatures in a rack by varying CRAC supply air temperatures, International Mechanical Engineering Congress and Exposition (IMECE), Nov 9-15, 2012, Houston, USA.

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- ➢ Future use of PI system

Future Work

- Webserver Development – Integrate Sharepoint Server with the PI System tools: PI WebParts , PI ProcessBook and etc.

- Webserver function
  - Facilitate data extraction
  - Visualize data
  - Disseminate live and archived data to the “public” (login credentials will be provided for approved requests

- Tentative beta site availability (April 2013)

- Development of logic/physics based controllers for air cooled data center
  - Contained aisles
  - Active fan tiles
  - Advanced air delivery systems

THANK YOU

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