Project Name:

Measurement and Management Technologies (MMT) for more energy efficient Data Center and Telecommunication Facilities

- **Lead organization:** IBM T.J Watson Research Center
- **PI (or PIs):** Hendrik F. Hamann, David E. Seeger
- **Partners**
  - Georgia Institute of Technology: Technology Development Partner
  - AT&T: Field Experiment Partner
- **Project start and completion dates**
  - 04/01/2010 – 03/31/2012
- **Project type**
  - Field experiment (Demonstration)

Background – Scalability and Metrics

- Each DC is unique (business requirements, IT components, facilities etc.)
- DCs include very diverse technology components: (power delivery, power – and facilities management, cooling technologies, IT core technology)
- Most of today's solutions apply only to subset of the problem

⇨**DC market is highly fragmented, which has *prevented technology scaling*.**

- Meaningful metrics for DC Efficiency are not easily obtainable
- E.g., DCIE – metric can be problematic:
  - DCIE is weather-, location-, application-,tier dependent
  - non-linear, awards UPS consumption (IT power usage)
  - DCIE is often insufficient for "proving" and managing energy efficiency

⇨**Because of *lack of meaningful metrics* $ savings are difficult to prove and investments do not have a clear business case**

Background – Risks and Integration

- Energy efficiency improvements have to be manageable without compromising reliability of the operation
- Current DC monitoring/management solutions and modeling tools are limited in their ability to provide dependable insights

⇨**DCs *lack* generally manageability and *visibility to improve efficiency without increasing risk***

- Today, most energy efficient technologies do not offer a clear pathway towards such integration but rather proprietary software and architectures.
- Integration has to include the underlying IT technology, energy and thermal management, power delivery technologies as well as cooling and facilities.

⇨***Significant energy efficiency improvements will originate from integrating* over the different technology components, which will enable a much more holistic management approach.**

Project Objectives

Development, Demonstration, and Commercialization of a DC Measurement and Management Technology (MMT)

1. Development:

Complement DC Sensing and Measuring Technologies:

- Ultra-sensitive and inexpensive corrosion sensors
- Retrofit-able, circuit-level power monitoring

Enhance Modeling Technologies:

- CFD models for operational decision support and continued control
- Statistical and reduced-order real-time heat transfer models

Software / Management:

- Integrate other data sources (weather, IT, facility, BMS, assets)
- Develop various control algorithms for best practices, ACU, set point and free control controls and power management
- Transfer technology to IBM Maximo product

Project Objectives

Development, Demonstration, and Commercialization of a DC Measurement and Management Technology

2. Field Testing:

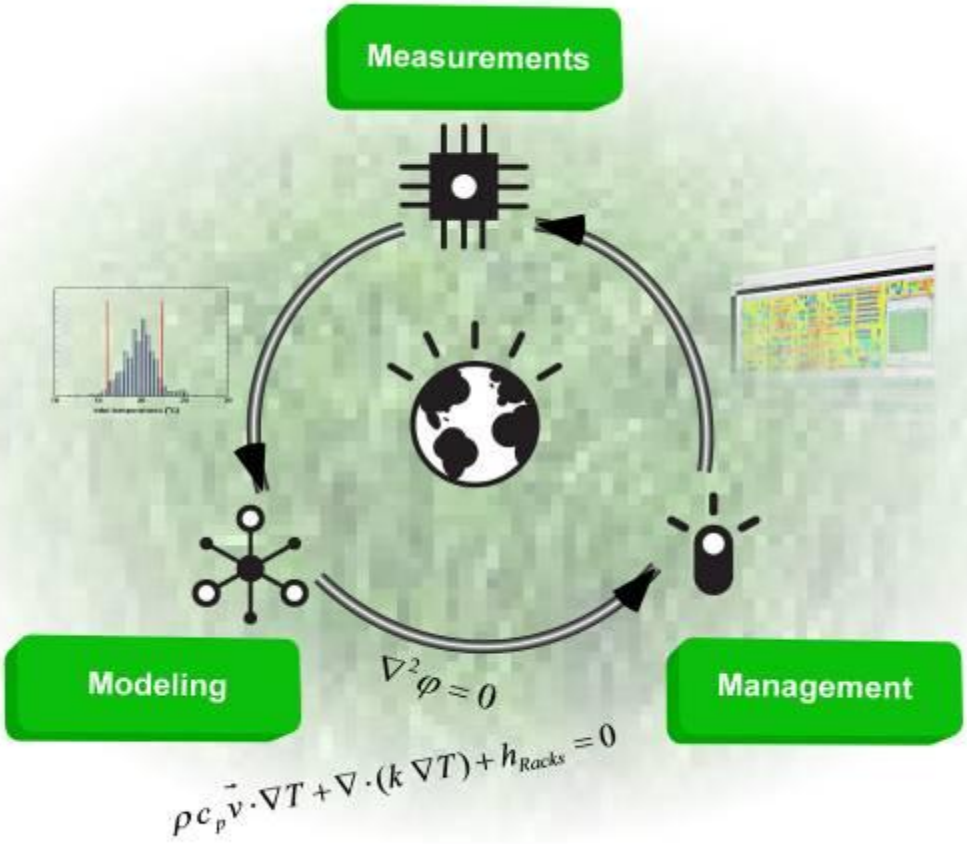
Deploy MMT at several different sites throughout US

- Legacy DC, Enterprise DC, VHO (Video Hub Office), MTSO (Mobility Telephone Switching Office), CO (Central Office), Cell phone Tower
- DCIE of 0.8 at one site and 12.5% improvement for all remaining tests
- Demonstrate 5 control schemes (controls for best practices, ACU, set point, free cooling and power management)
- Demonstrate open integration of MMT with other data sources
- Demonstrate fast energy savings (50 % after 9 M and 100 % after 18 M)

3. Commercialization:

- Productize MMT through IBM's Software and Service Groups
- Commercialize sensor-related technologies with business partners
- Drive business with internal WW deployment

What is MMT ?

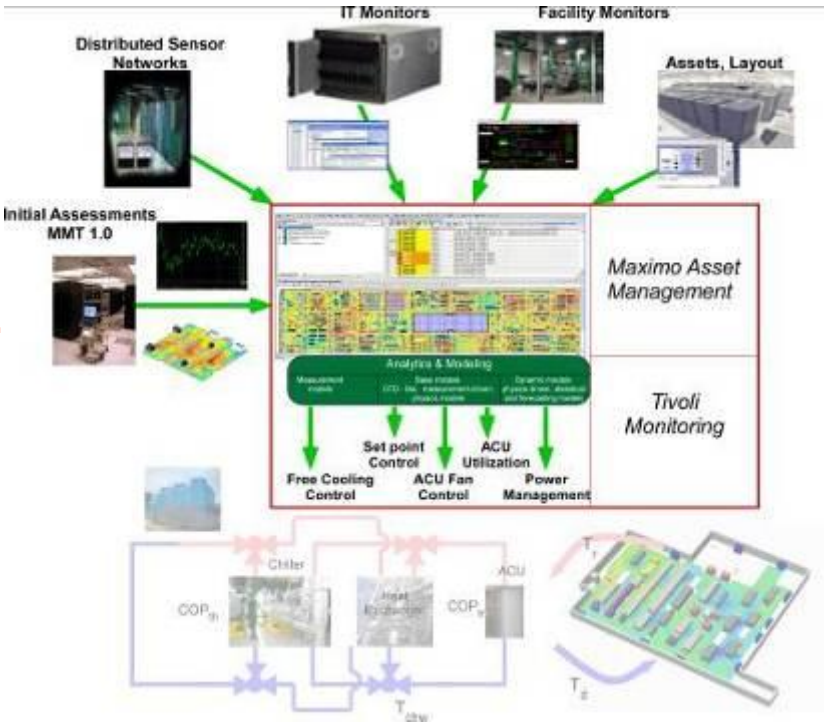


(Data Center) Measurement and Management Technology:

- Real-time and high resolution Measurements
- Measurement-based Modeling
- Management and Control

MMT - Approach

- **High level of applicability** to meet requirements of different types of DCs **so technology can be scaled**
- A real-time and high resolution **measurement system** including IT sensors to quantify energy savings **so business cases can be supported**.
- Measurement-based, **real-time modeling** to provide maximum visibility **to manage energy efficiency without increasing risk.**
- **Control technologies** for best practices, ACU utilization and fans, set points of chilling systems, free cooling as well as power management for **optimum energy efficiency**.

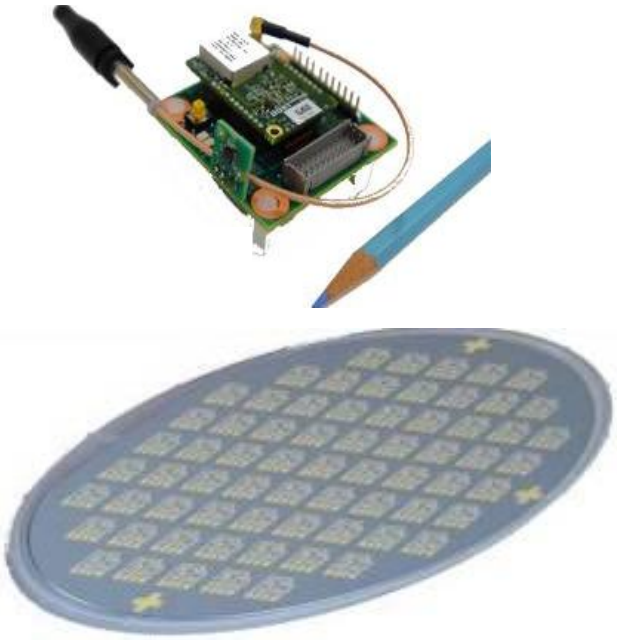


- An **open architecture** to integrate with facilities, BMS, IT, power delivery devices and other DC tools to **provide a holistic end-to end management solution.**
- **Provide rapid energy saving opportunities** in the short-term but also continued energy efficiency improvements as IT efficiency increases.

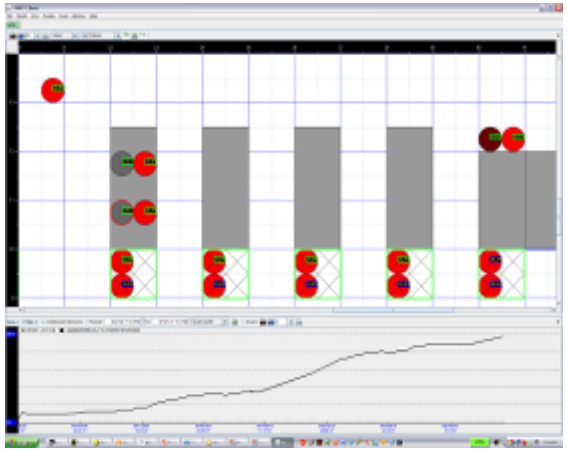
Corrosion Management

- One of the main inhibitor for Air-side economization is corrosion risk
- Developed a high sensitivity corrosion management system
  - Sensitivity of 1 A° per day corrosion rate (equals 1 atomic layer)
  - 10 x more sensitive than any commercial sensor
  - system allows remote real-time corrosion monitoring
- Technology can access corrosion risk based on indoor and out door environmental with the goal to optimize "free cooling" technologies

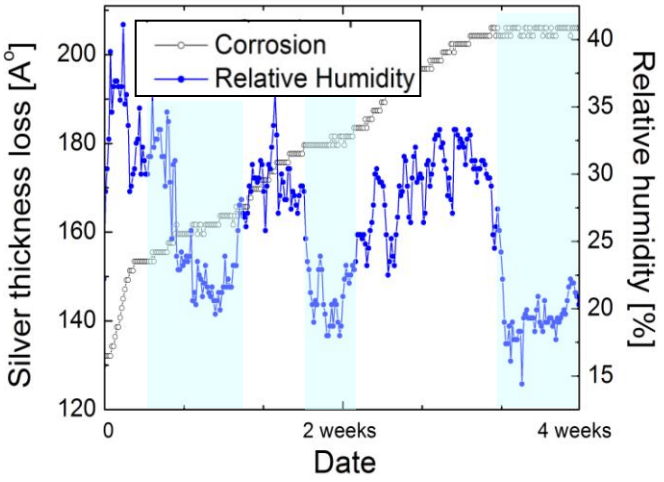
Corrosion Monitoring Hardware



Corrosion GUI

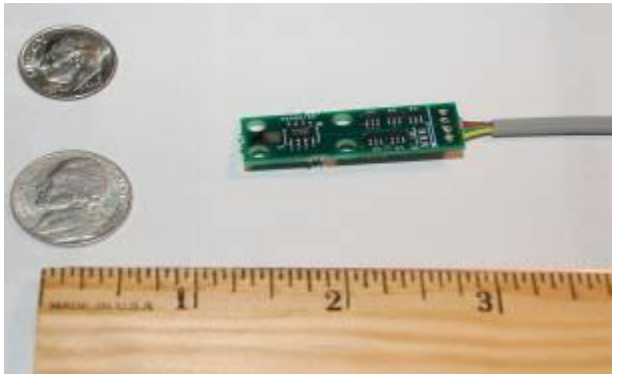


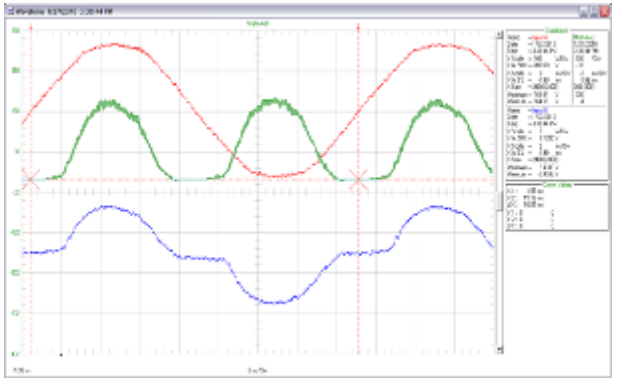
Real-time Corrosion Monitoring

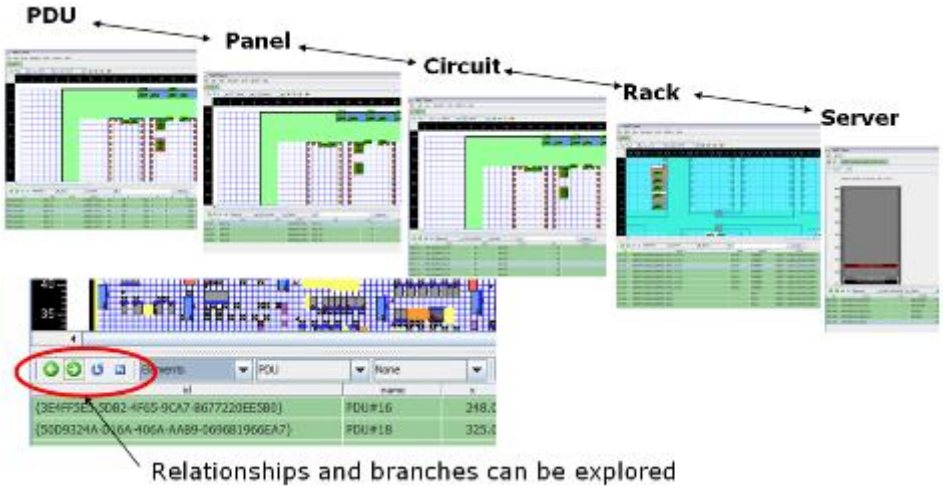


Power Management

- developed a low cost, multiplexing, retrofit-able PDU power monitoring solution based on Hall sensing of the magnetic field
- 4x42 Hall sensors are deployed in a single PDU to monitor current of each circuit without disconnecting IT equipment
- Gateway gathers all data and communicates with MMT server for power management analytics





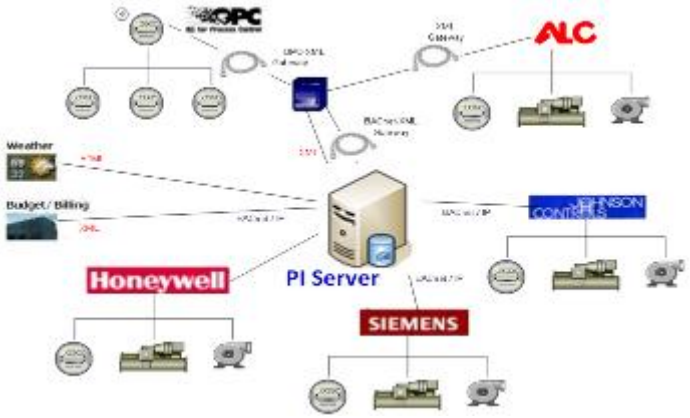


- MMT SW visualizes and manages full power chain (from PDU to server) and then relations
- Alarm system to warn about increased power/current limits on each circuit to optimally utilize existing power infra-structure

MMT – Adapters - New Data Sources

AEM (IT-Metrics)

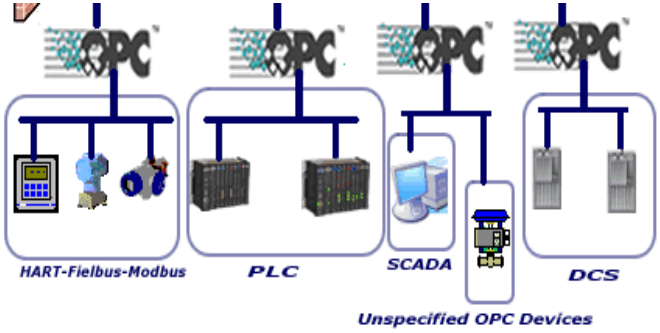
PI / OSISOFT



MMT Server

Open API

OPC (BMS)

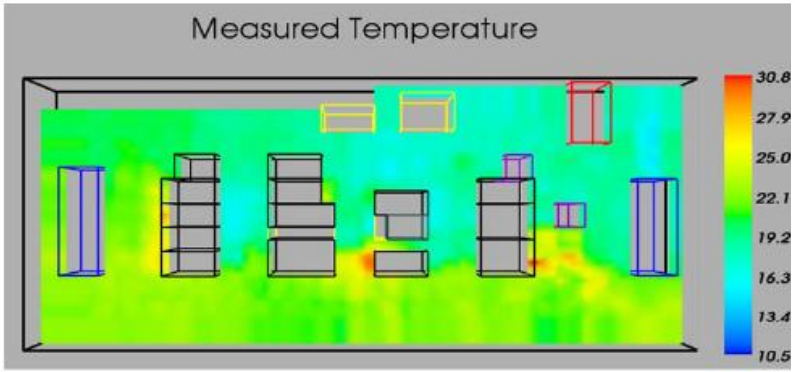


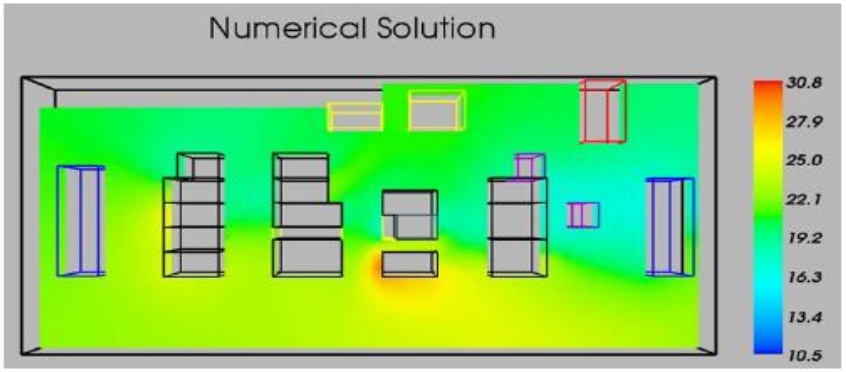
New Adapters

- Maps
- Weather
- Autocad
- dB2
- mySQL
- SMNP
- etc.

CFD Physics-based Models (Base Models)

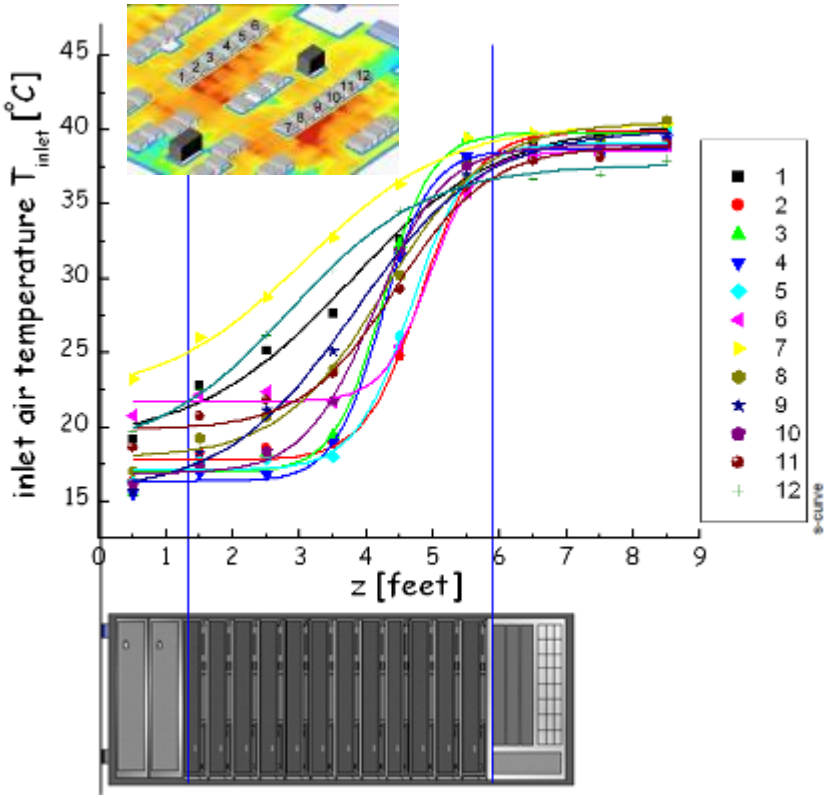
- Optimized PDE solver has been developed and implemented
- Benchmark show excellent accuracy
- Real measurements (air flow values, temperatures) are leveraged to simply model description
- Temperature and flow measurements are directly fed into PDE as boundaries
- Superposition principles is leveraged for "faster" models
- 3D version of this technology has been deployed and runs hourly for several projects





Statistical Models (Dynamic Models)

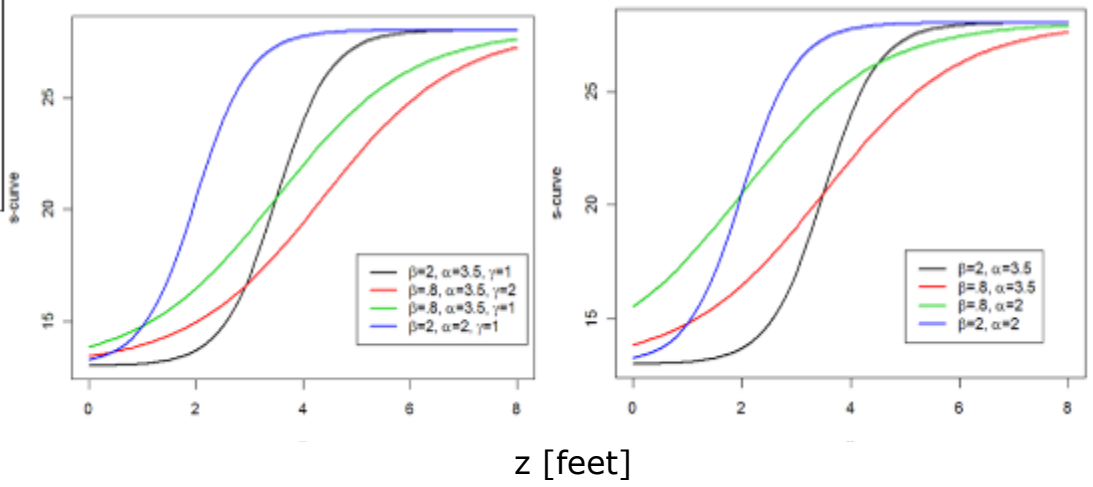
- CFD models are complemented with statistical and/or reduced order models
- Models leverage reduced order representation of thermal profiles (s-curves)
- S-curves are fed as z-trend into 3D kriging for temperature forecasting
- Models include fundamental physics principles such as energy balance



$$y = A + \frac{B}{1+\gamma e^{-\beta(x-\alpha)}}$$

$$x \to +\infty \quad y = A + B$$
$$x \to -\infty \quad y = A$$
$$x = \alpha \quad y = A + \frac{B}{1+\gamma}$$

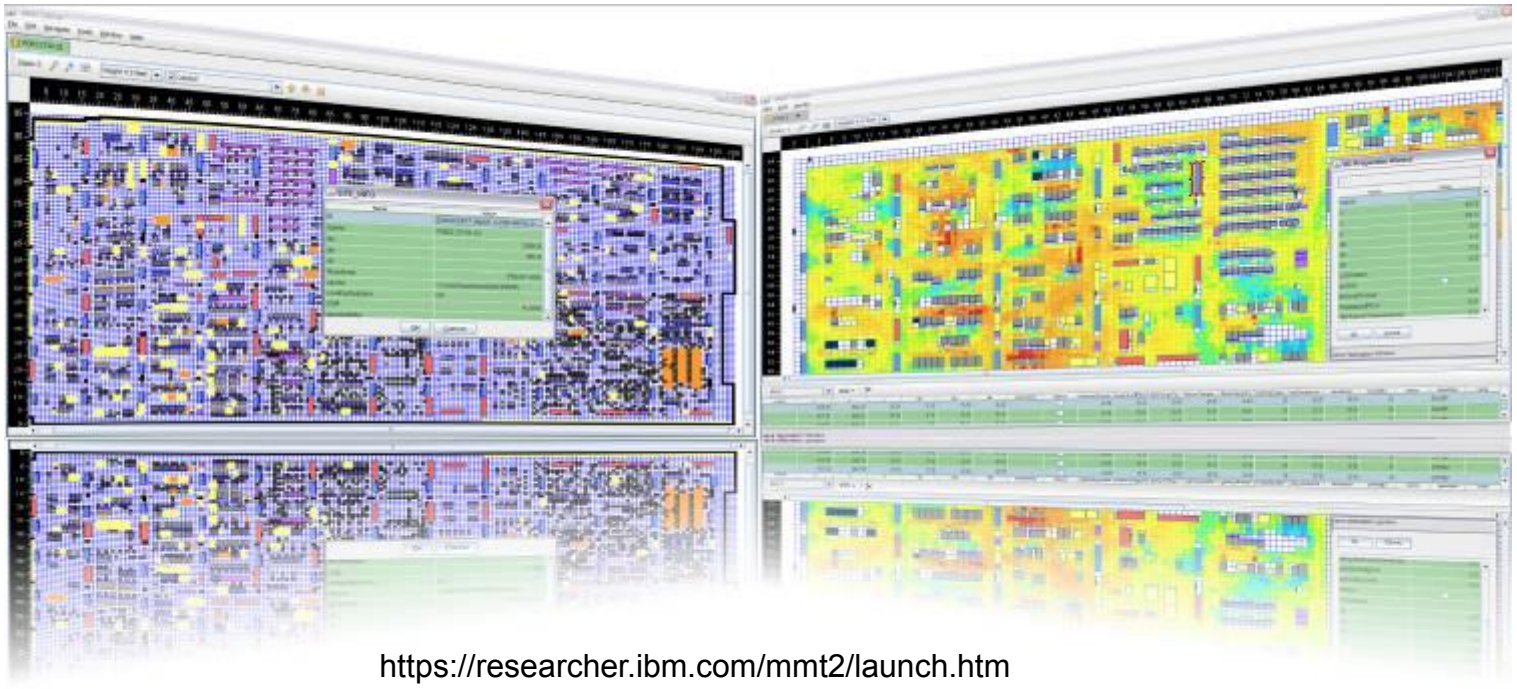
β controls the slope of the curve, α controls the shift of the curve



MMT Management Software

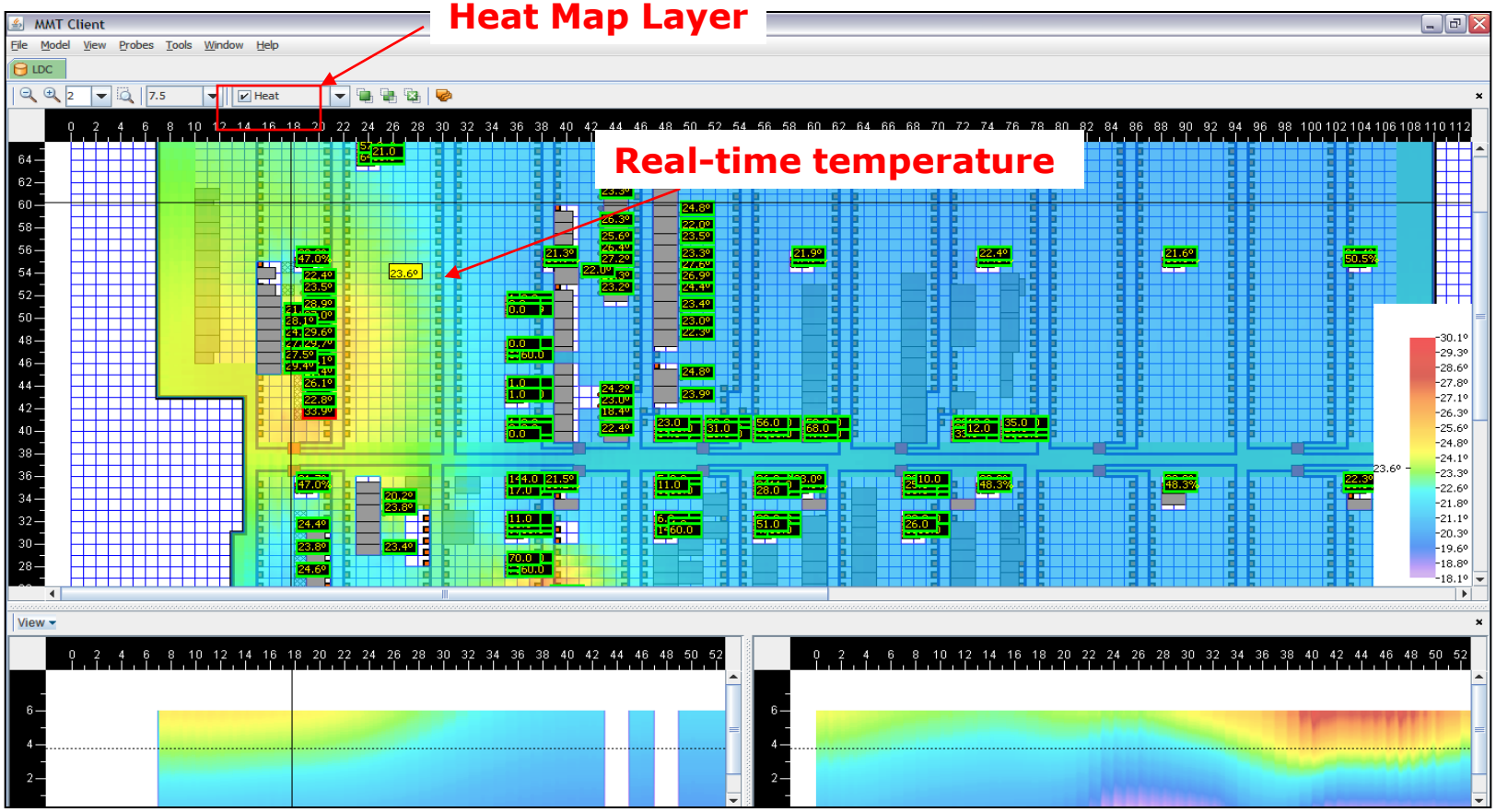
MMT Software – Features

- detailed ways to manage data center by an MMT layout editor
- real-time, 3D temperature, humidity, pressure distributions
- efficiencies in real-time and corresponding cooling zones
- reports and energy efficiency summaries
- Available in Maximo for Energy optimization (MEO) as a product or as a GTS service



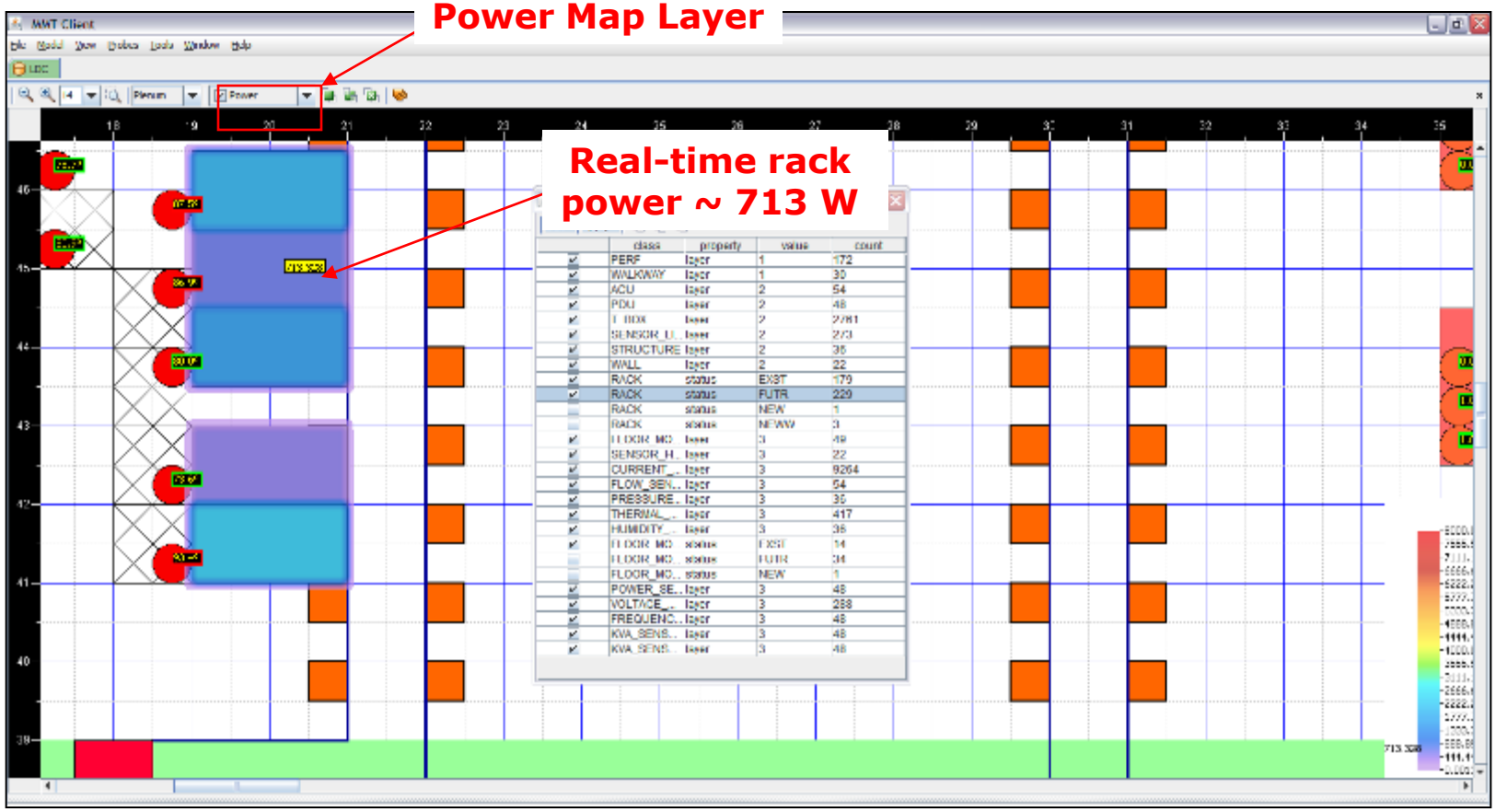
https://researcher.ibm.com/mmt2/launch.htm

Heat Distribution Analytics



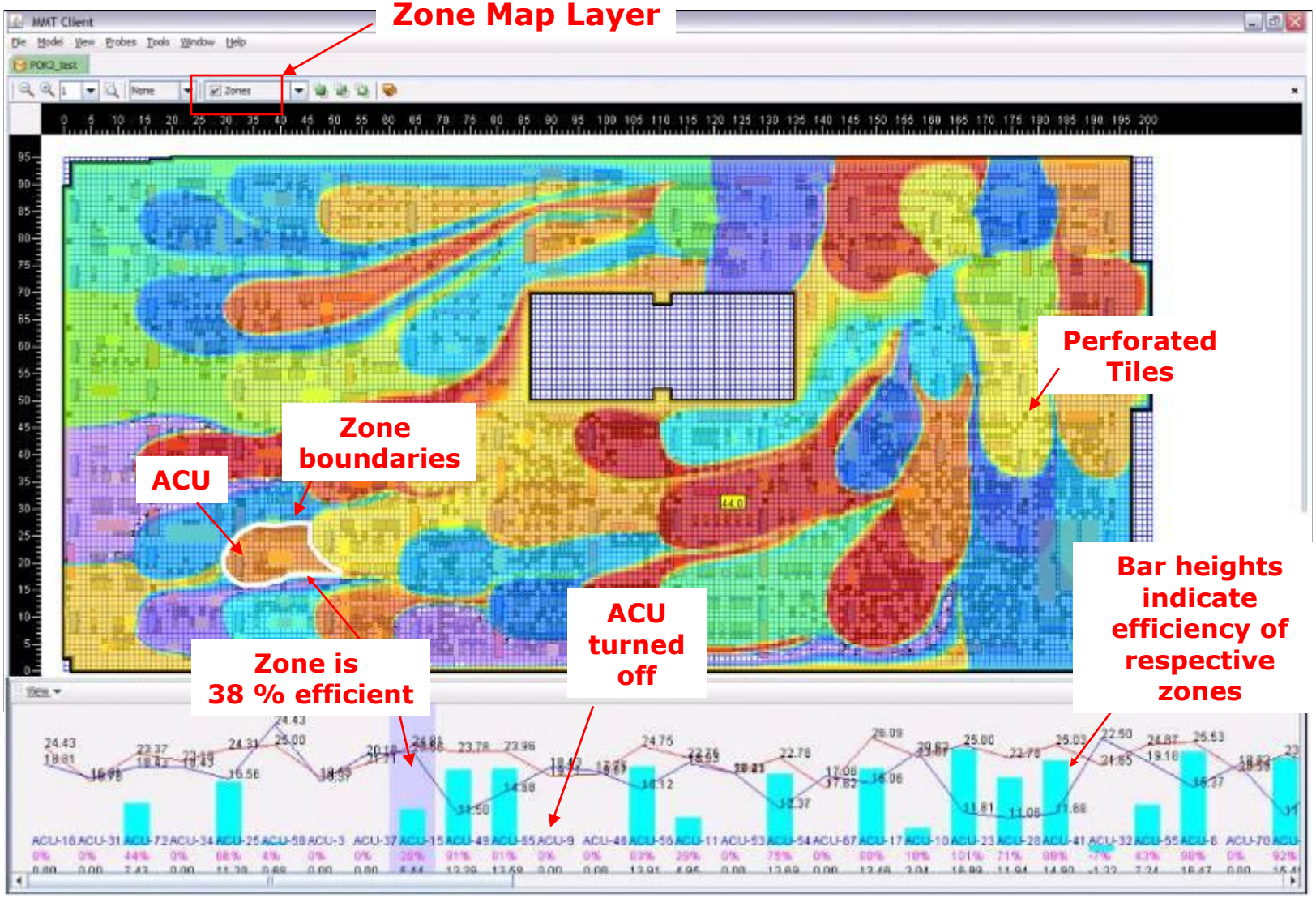
- Combination of measurement, base and dynamic model provides near real-time 3D temperature distribution
- Other Analytics: Humidity, DewPoint, Risk, Cooling Power, Air flow

Power Map Analytics



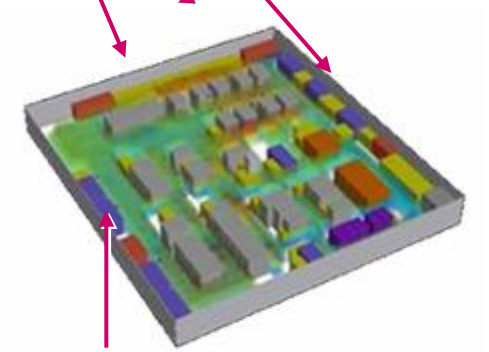
- Circuit-level monitoring and MMT data model allows exploiting relationship between 12000 sensors (voltage/current/kVA,power factor) and rack power delivery to derive "power maps" of a complete data center

Cooling Zone Analytics



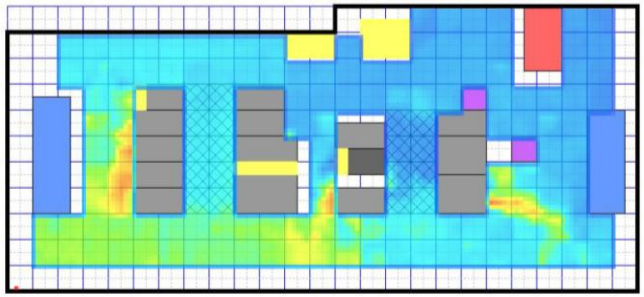
MMT Controls: ACUs

MMT Sensor and control network

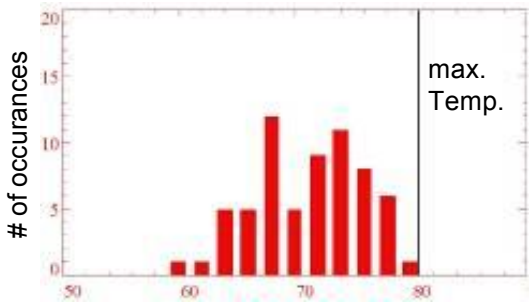


Variable capacity AC unit (ACU)

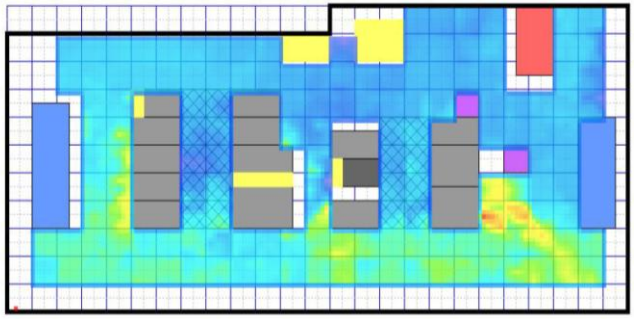
BEFORE: ACU Power Consumption = 11.5 kW
(ACU#1 @ 100% + ACU#2 @ 100 % = 24800 cfm)



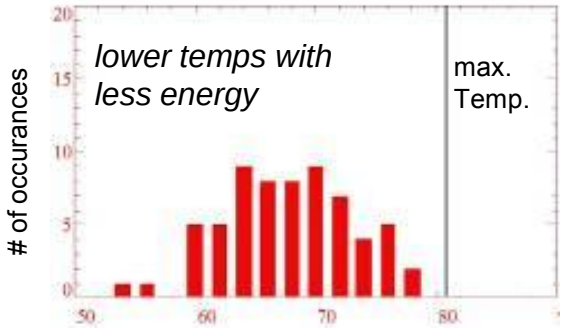
Inlet Temperature Histogram



AFTER: ACU Power Consumption = 3.5 kW
(ACU#2 @ 84 % = 10416 cfm)



Inlet Temperature Histogram

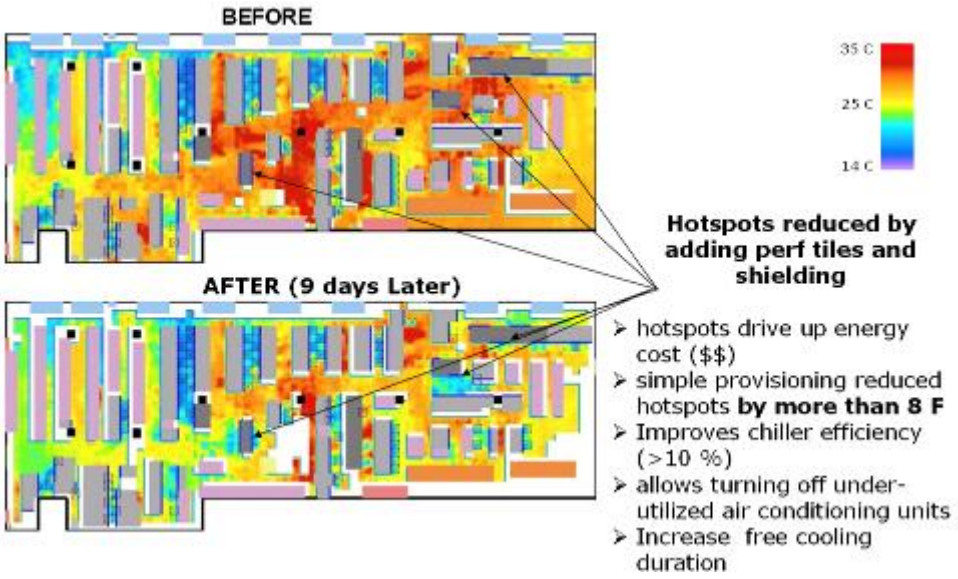


51.1 F 93.2 F

- >2x reduction in (ACU) cooling power with no impact on inlet temperatures
- MMT includes both VFD and ON/OFF ACU Controls

Energy Savings

MMT @ Work:

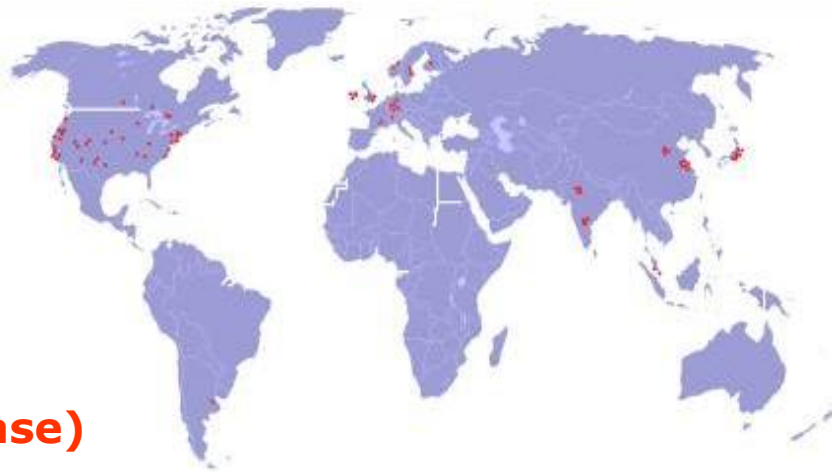


Saving Predictions:

Improvements	DCIE	Savings [%]
Before	0.56	0.0
1. ACU utilization	0.61	7.1
2. ACU fan speed	0.65	14.0
3. UPS efficiency	0.67	15.7
4. Set point	0.68	17.1
5. Chiller utilization	0.75	25.1
6. IT Load Reduction	0.75	25.1

- In > 100 deployments of MMT base technology an average of > 10 % savings was achieved
- Nationwide deployment results in assuming
  - 7 GW for DCs + 2 GW for COs/Teleco spaces:
  - 50 % applicability
  - 50 % market acceptance
  - 10 % of savings

  ⇨ **2 billion kW hours annually (@ 9 GW base)**



Jobs / Employment

- **Current Job Impact**
  - Research and Development:
    - 4 Engineers / Scientist
  - Hardware Manufacturer
    - 1 Technican
  - Delivery Organization
    - 2 Consultants / Engineers
- **Potential Job Impact**

	Annual Energy Use [kW hours]	Density [W/feet^2]	Area [feet^2]	MMT deployment space [feet^2]	Energy cost savings [$/feet^2]	Average ROI [months]	Revenue [$]	Annual energy reduction [B Whour]	Job Creation from MMT delivery	annual carbon reduction [tons]
DC	60B	50	96M	24M	3.50	11	72M	1.5	288	98k
CO	18B	10	144M	36M	0.70	18	36M	0.5	144	30k
	78B		**240M**	60M			108M	2.0	432	128k

  - additional jobs would be created from additional R&D, support hardware manufacturing etc.

Project Status – Field Testing

General Site Info		Technologies					MMT Controls					
Facility Type	Field test area [k square feet]	Chiller system	VFD	Plate frame	Air side economizer	Circuit level monitoring	Best Practices Control	ACU Control (utilization)	ACU Control (fan speed)	Set point Control	Free Cooling Control	Power Management
Classical DC	130	CP	x	✓	x	x	✓	✓	x	✓	x	x
Enterprise DC	70	CP	✓	✓	x	✓	✓	✓	✓	✓	x	✓
VHO	4	DX	x	x	x	x	✓	✓	x	✓	x	x
MTSO	22	CP	x	x	x	x	✓	✓	x	✓	x	x
Central Office	36	CP	x	x	✓	x	✓	✓	x	✓	✓	x
		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

- All field tests have started and are on target

What's left and what happens after Sponsorship ?

- Finish all outstanding technical work and field test
  - R&D work: 40 %
  - Field Testing: 50 %
  - Commercialization: 60 %
- Scale technology
  - IBM internal deployment (8M square feet)
  - target large customers and project partners
- Continue to transfer technology and integrate technology with IT management
  - Tivoli monitoring, Acitve Energy Manager
  - Cloud technologies (xcat etc.)
- Drive additional commercialization through IBM and partners
- Expand technology to adjacent spaces

Summary

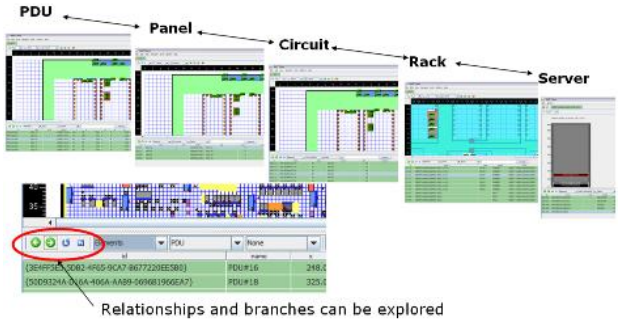
- MMT is a technology which addresses current inhibitors for DC energy efficiency improvements
  - Scalable and thus will be an inexpensive technology
  - Measurement-based, quantitative to support clear business objectives
  - provides maximum visibility to manage risk associated with efficiency improvements
  - Integrateable with other technologies (especially IT technologies) and thus expandable

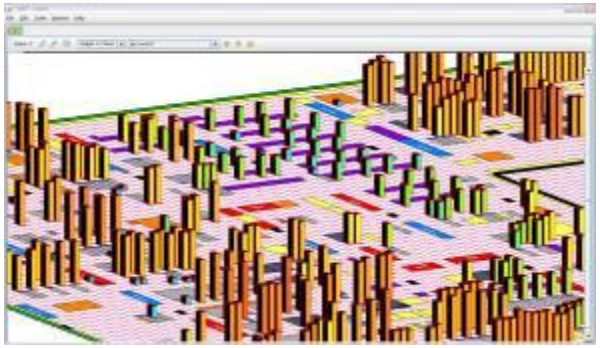
- Main Highlights
  - Corrosion and Power Chain Management
  - Operational CFD and real-time modeling
  - Unique analytics including physical ACU cooling zones and efficiencies
  - Supports 6 main control technologies including VFD Control
  - Integrated with BMS and IT monitoring tools

Back - up

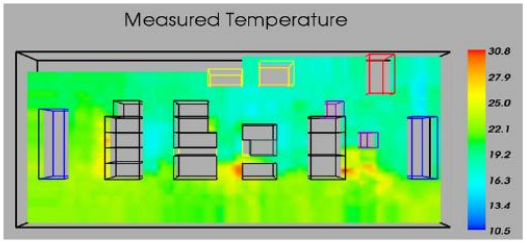
Project Status – Core Technologies

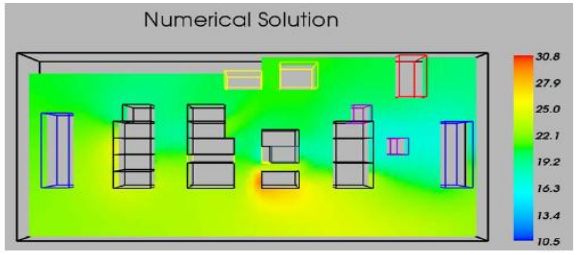
- Low power high resolution wireless sensor platform developed.
- Developed high sensitivity, low cost corrosion management system
  - System allows remote real-time corrosion monitoring to enable free cooling
- Low cost, multiplexing, retrofit-able PDU power monitoring solution developed.
  - MMT visualizes and manages full power chain (from PDU to server)





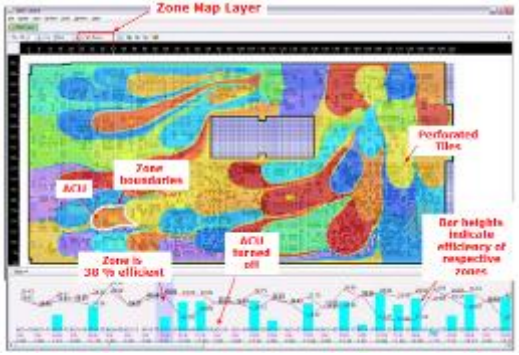
- Operational CFD modeling implemented using an optimized PDE solver
  - Measurement points feed boundary conditions
- CFD models have been complemented with real-time statistical and reduced order models



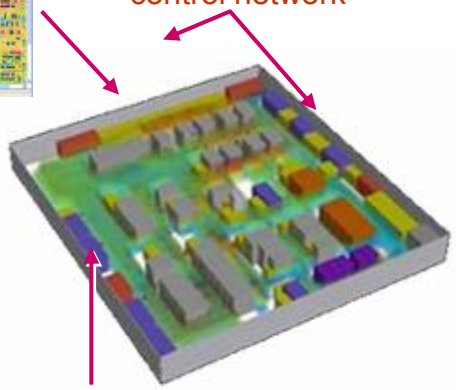


Project Status – Energy Management

- Software Platform for control and DC management developed and productized
  - Maximo for Energy Optimization: Release 7.1.1 (eGA - Sept 17,2010)
  - Includes heat, pressure, flow, utilization, power, cooling analytics, ACU cooling



- Additional data sources integrated:
  - Assets, Autocad
  - BMS, OPC, OSISoft
  - IT, Tivoli, AEM



- ACU Control algorithms developed and tested:
  - >2x reduction in (ACU) cooling power with no impact on inlet temperatures
  - MMT includes both VFD and ON/OFF ACU Controls

IBM Data Center

IBM delivery centers

	Data Centers	Square Feet (millions)
Americas	90	2.0
Asia Pacific	42	1.2
Europe	85	0.6
TOTAL	**217**	**3.8**

Client centers managed by IBM

	Data Centers	Square Feet (millions)
Americas	107	2.8
Asia Pacific	85	0.8
Europe	53	0.6
TOTAL	**245**	**4.2**

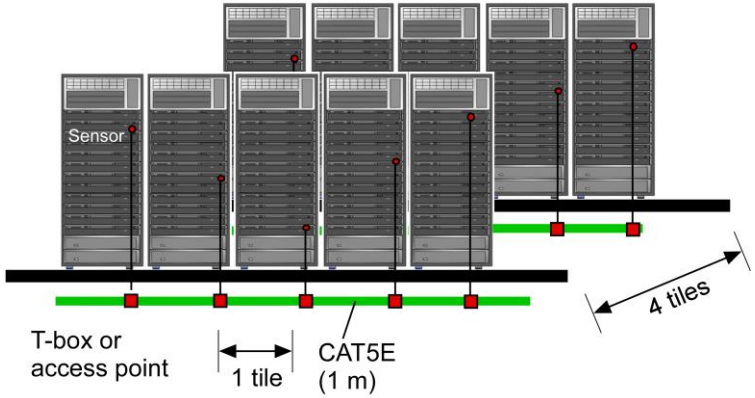
- Up to 470 data centers
- +8 million square feet of space
- 1,291 Mainframes
- 1,144,430 MIPS

- 11,028 Terabytes
- 207,148 Mid Range Servers
- 3,775,388 equipped user seats
- 5 million square feet of work area space

Data as 6/30/2009

MMT Sensing and Measurements

Detailed, high resolution assessment and survey data (MMT 1.0)	Real-time sensing networks (MMT 1.5)
▪ **Robotic 3D dimensional mapping tools for detailed environmental measurements** ▪ **Adapters to existing data sources (BMS, asset db)**	▪ **External and internal (via AEM, ITMfEM)** ▪ **Wireless and wired solutions** ▪ **Sensor grid solution with 1-wire protocol** ▪ **access points every 2' for thermal, flow, acoustics, pressure (all with the same network)** ▪ **Corrosion, power sensors are being developed**

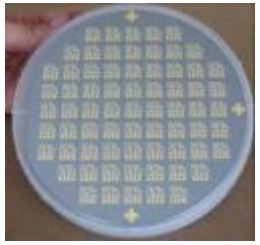


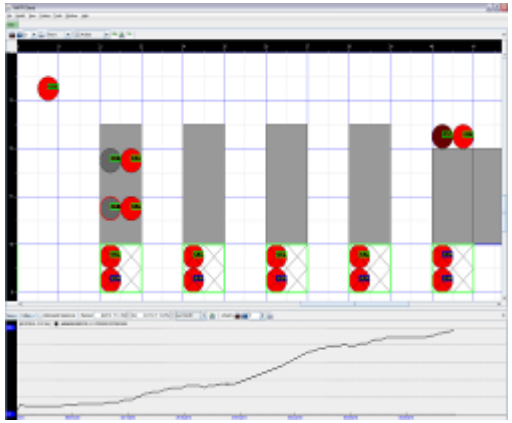
MMT provides both high time & spatial resolution combining

- **High resolution measurements / assessments for base model** generation, sensor placement etc.
- Real-time sensing for feeding **dynamic models**

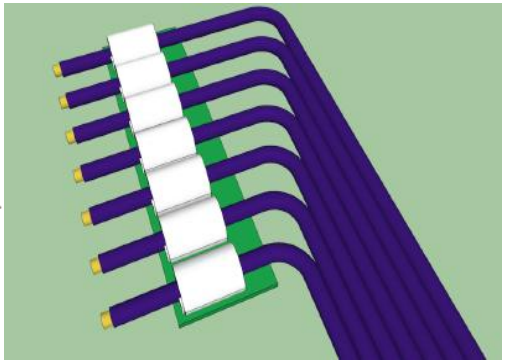
MMT Sensing and Measurements – DoE Activities

1. Real-time Corrosion Management

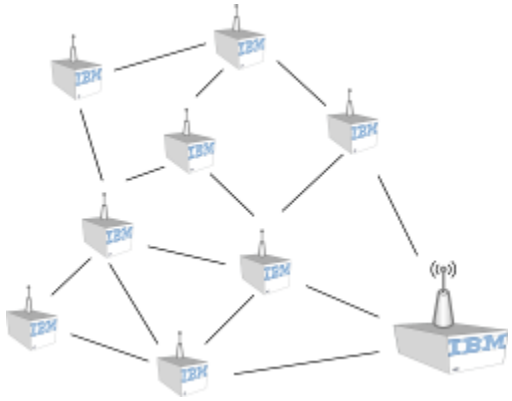


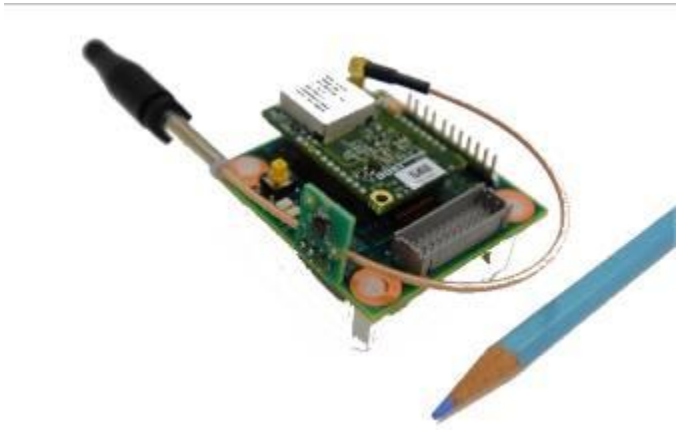


2. Remote Power Monitoring

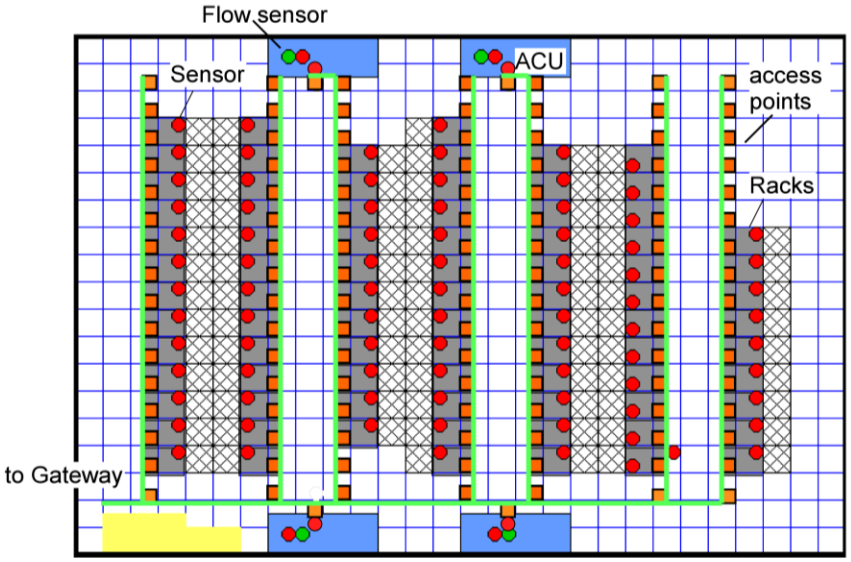


3. An Ultralow Power MMT Wireless Sensor Platform





WW Large-scale Sensor Deployments



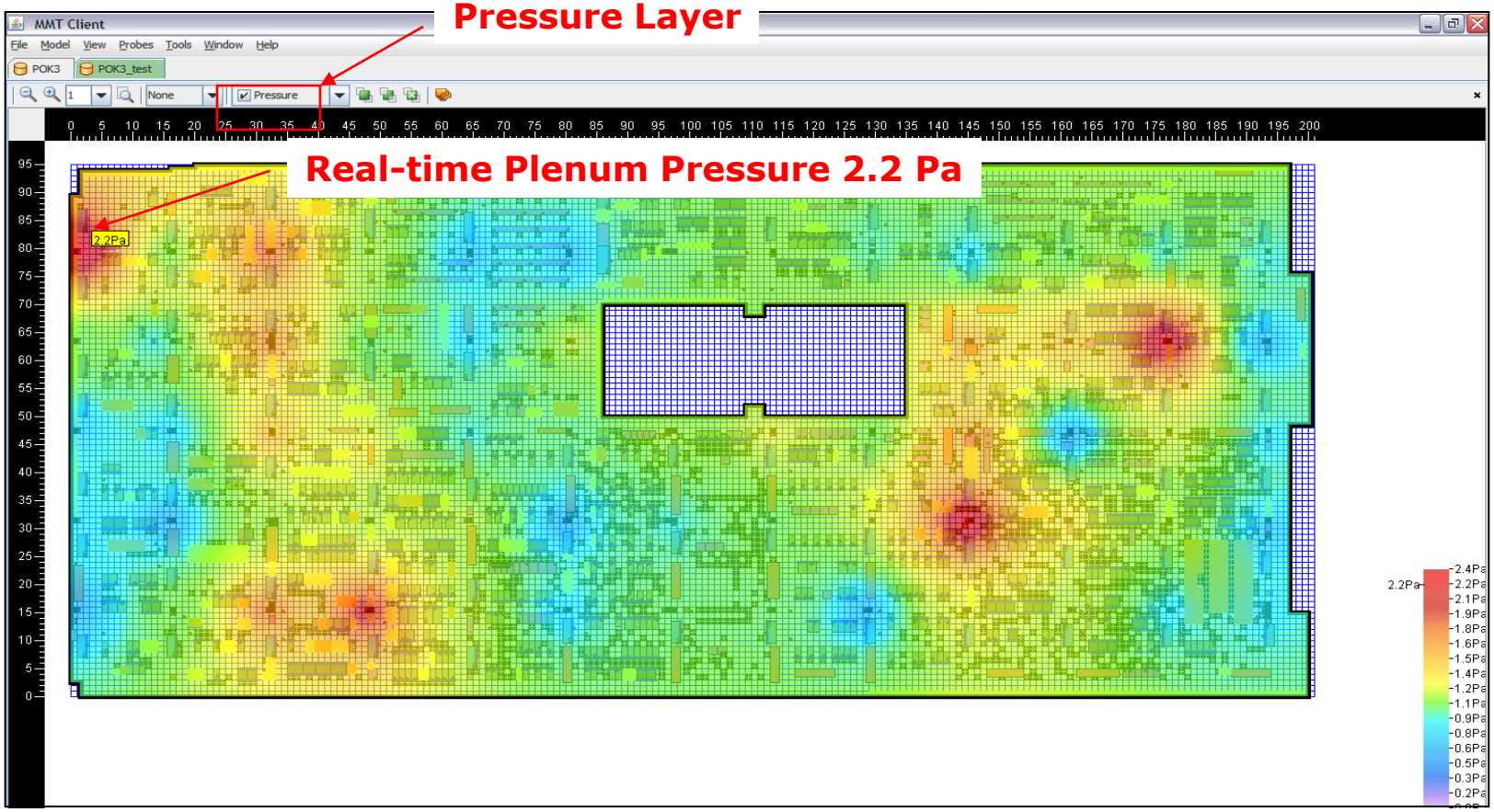
TYPICAL DEPLOYMENT

4300	thermal sensors
250	pressure sensors
612	flow sensors
300	humidity sensors
12000	power/current sensors

Pull data every 2 mins

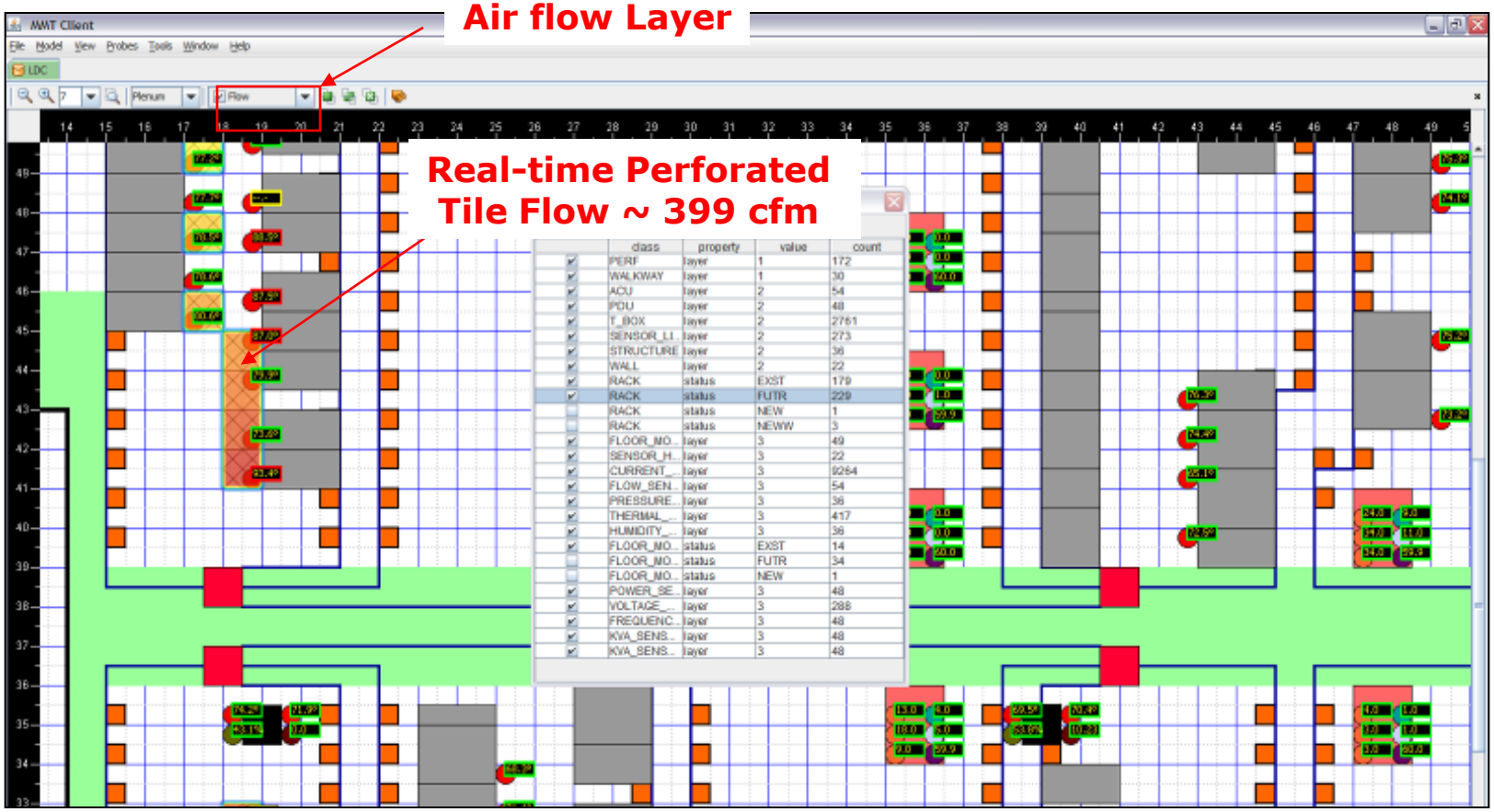
Installs in all Geos: EMEA, Americas, AP

Pressure Distribution Analytics



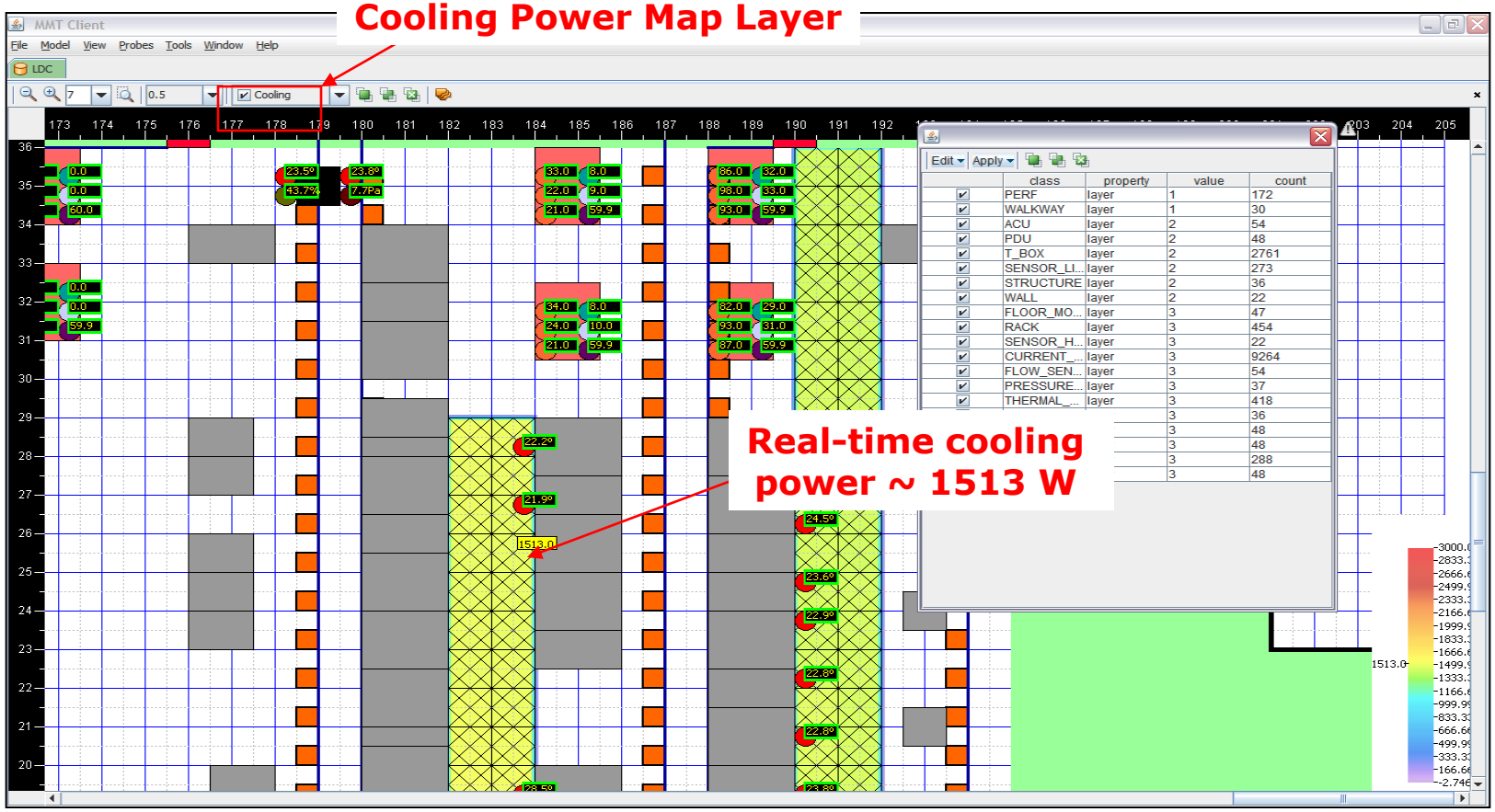
- Network of pressure sensors allows modeling of pressure fields

Air Flow Analytics



- Combination of pressure fields with tile impedances yield air flow values

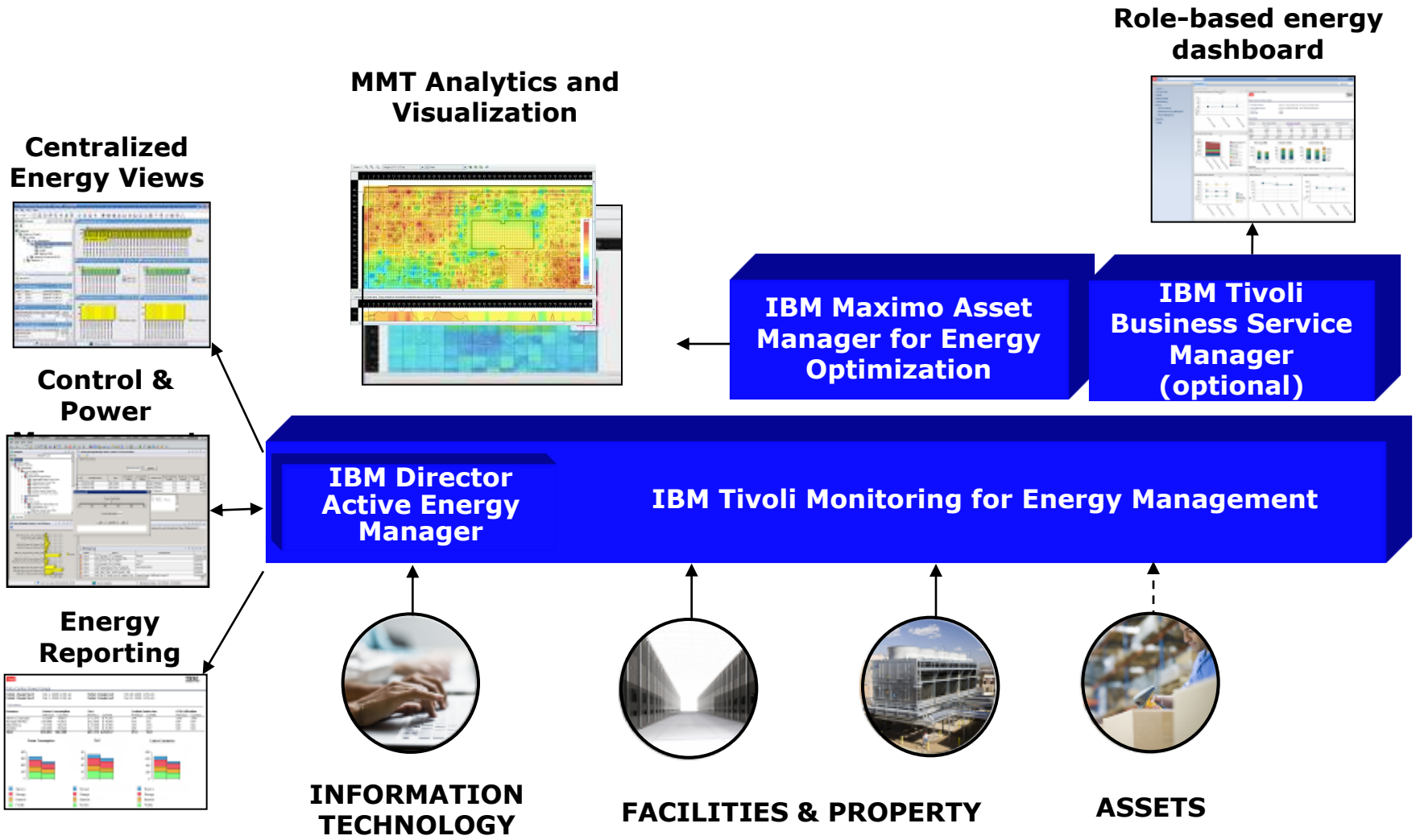
Cooling Power Analytics



- Analytics provides cooling power distribution (how much cooling power is provided where….)
- Exact match of cooling power to IT power will provide optimum energy efficiency

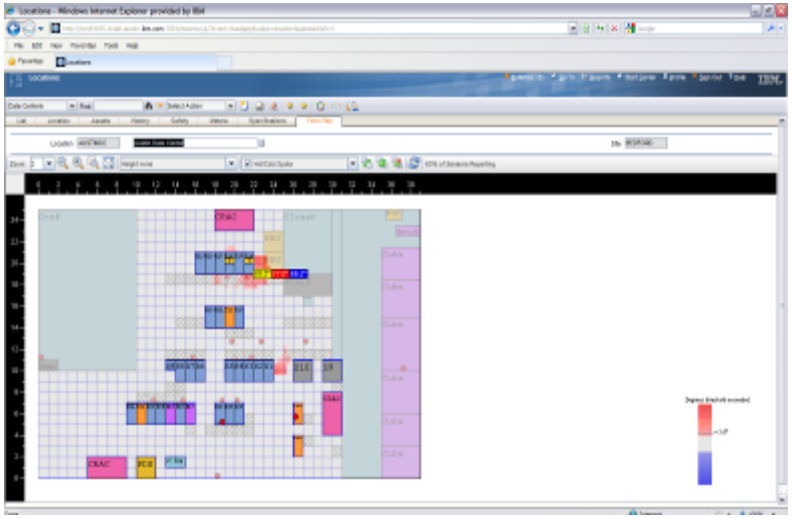
MMT - Integration: AEM, ITMfEM, Maximo

Delivering key energy management metrics through an integrated solution

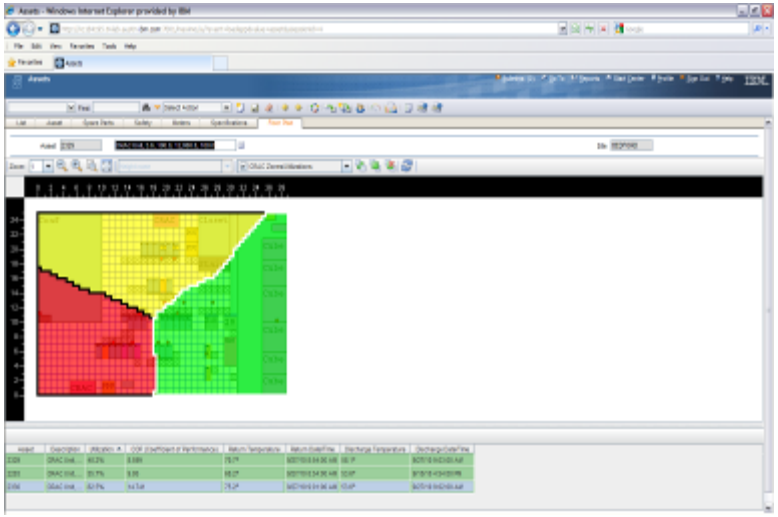


MMT in Maximo for Energy Optimization

Hot and Cold Spots



Thermal Zones



MEO has released a new version of the product, Release 7.1.1 (eGA - Sept 17,2010)

- Implemented a development architecture for the MEO development team to consume MMT features.
- Real-time collection of sensor data to render Heat and Humidity maps
- Thermal map that isolates Hot and Cold Spot
- Map that visualizes CRAC Zones and determines CRAC Utilization
- Provide a sensor map that visualizes sensors of any type (temp, humidity, power etc) and displays current readings relative to configured thresholds.

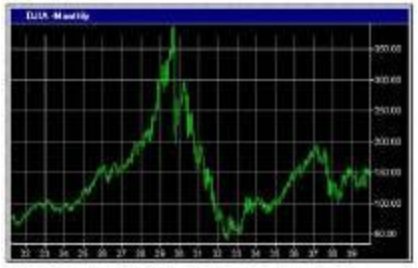
Data Center Economics

Data Centers are mission-critical and designed to support business needs

- Utility Cost*
  - 1W ~ $0.5-1.0

- Capital Cost*
  - 1W ~ $4-10

- Revenue*
  - 1W ~ $100s



- Energy efficiency saves utility expense but much more **capital cost**
- However, most importantly, saving energy can result into increased revenue and thus create jobs, jobs

*Approximate annual number

4th Quarter Savings

					Annual Savings	
Site	**UPS Load kW**	**Required # CRAC**	**Active # CRAC**	**# CRAC shutdown**	**MWh/yr**	**$/yr**
#1	5458	117	157	22	1830	$91,516
#2	3344	57	129	66	3798	$341,814
I #3	1855	39	55	5	325	$15,595