



Data Center Power Management: Thoughts on the Future

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The Real Science of Power

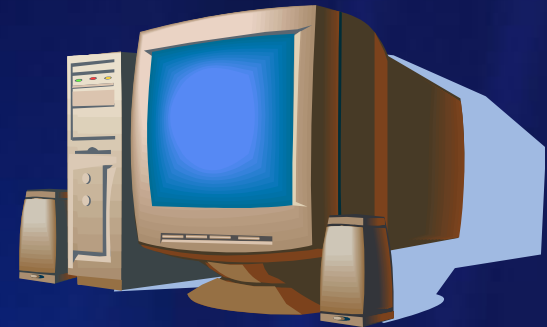
- For background, see
 - *Science*, Volume 306, November 14, 2004
 - Margolus-Levitin theorem (*Physica D* 120 188, 1998)
- Suppose we fill space time with clocks
 - All exchange signals and measure arrival times
- How many events N are in a volume of radius R and time T ?
 - i.e., How much computation is possible in that volume?
- We're constrained to avoid gravitational collapse

$$N \equiv \frac{1}{\pi} \frac{T R}{t_p l_p} = \frac{TR}{\pi (t_p l_p)} = \frac{TR}{\pi c t_p^2} = \frac{TRc^5}{\pi \hbar G}$$

- This is a BIG number!

Sapir–Whorf: Context and Research

- Sapir–Whorf Hypothesis (SWH)
 - language influences the habitual thought of its speakers
- Computing analog
 - available systems shape research agendas
- Consider some past examples
 - VAX 11/780 and UNIX
 - workstations and Ethernet
 - PCs and web
 - inexpensive clusters
- Today's examples
 - multicore, clouds and services ...

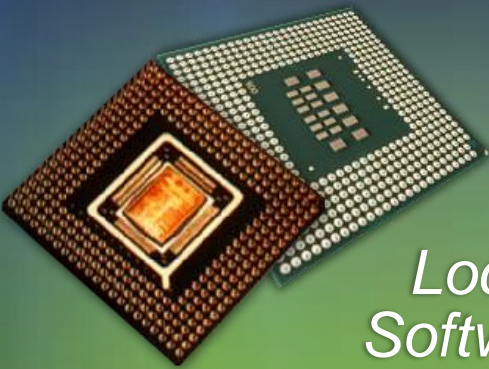


Today's Truisms (2009)



- Bulk computing is almost free
 - ... but software and power are not
- Inexpensive sensors are ubiquitous
 - ... but scientific data fusion remains difficult
- Moving lots of data is {still} hard
 - ... because we're missing trans-terabit/second networks
- People are really expensive!
 - ... and robust software remains extremely labor intensive
- Scientific challenges are complex
 - ... and social engineering is not our forte
- Our political/technical approaches must change
 - ... or we risk solving irrelevant problems

Next-Generation Applications



Local Software

Concurrency Spectrum



Global Services

New Software Architecture



Generic Cloud Data Centers

- Massive commodity servers
- Energy intensive infrastructure
- Cooling inefficiencies
- Environmental issues
- Expensive UPS support
- Enterprise TCP/IP networks
- Long deployment times
 - Construction and integration
- Diverse services and SLAs

- *Explosive growth*
 - *demand and expectations*

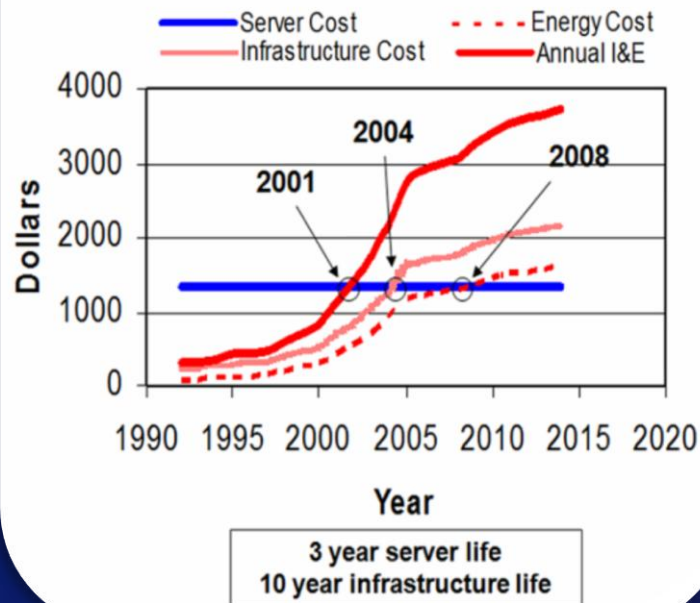


Data Center "PacMan"



- Land - 2%
- Core and shell costs – 9%
- Architectural – 7%
- Mechanical/Electrical – 82%
 - 16% increase/year since 2004

Annual Amortized Costs in the Data Center for a 1U Server



Belady, C., "In the Data Center, Power and Cooling Costs More than IT Equipment it Supports", *Electronics Cooling Magazine* (February 2007)

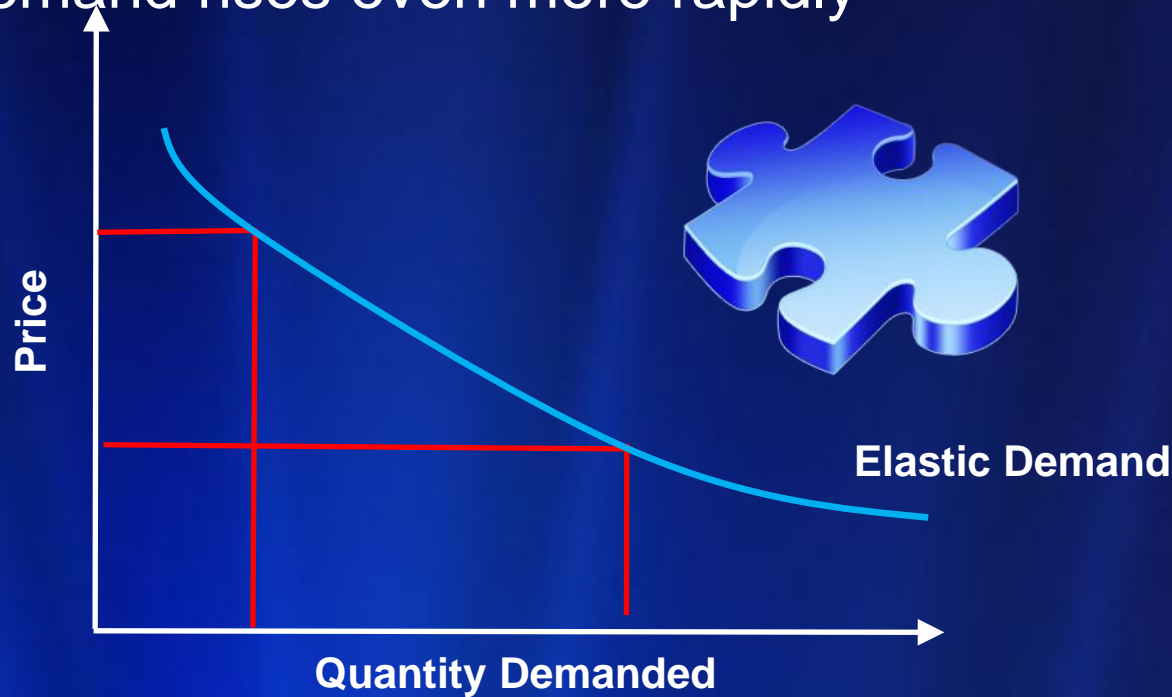
Consider These Services Challenges

- Environmental responsibility
 - Managing under a large power envelope
 - Adaptive systems management
- Provisioning 100,000 servers
 - Hardware: at most one week after delivery
 - Software: at most a few hours
- Resilience during a blackout/disaster
 - Data center failure
 - Service rollover for 20M customers
- Programming the entire data center
 - Power, environmentals, provisioning
 - Component tracking, resilience, ...



Remember Jevon's Paradox

- Improved technology
 - Doubles work produced for given cost
 - Sounds a bit like Moore's Law doesn't it?
- Jevon's paradox
 - Demand rises even more rapidly



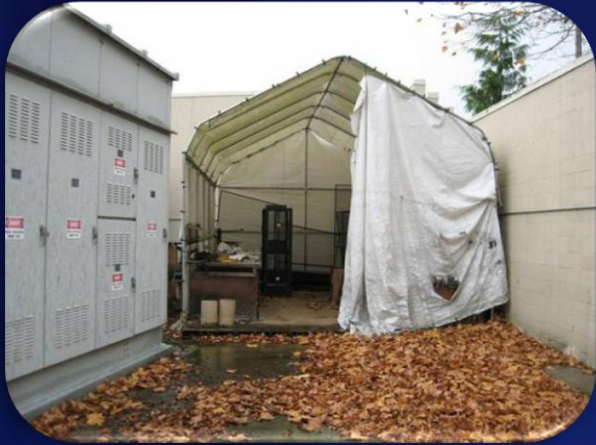
It's Not Just Watts ...

- Watts alone are irrelevant
 - Turn off the equipment and declare victory
- The real metric is the following ...

$$\frac{\textit{Operations}}{\textit{Watt} \times \textit{Dollars}}$$

- Many convolved ideas
 - Application execution efficiency
 - Microarchitecture and system design
 - Power supply efficiency
 - Packaging and cooling overhead
 - Market costs for power and hardware
 - Cost of people and money

The Purity of Minimalism



- Configuration

- 5 HP DL585 systems
- 11/2007-6/2008
- Zero failures

- Incidents

- Water dripped from the tent onto the rack
- A windstorm blew a fence section onto the rack
- A leaf was sucked onto the server fascia





Webcast

TGG Academy

New White Paper

About PUE/DCIE

Learn from The Green Grid

This on-line learning resource will provide you with training that can help you improve energy efficiency within your specific facilities. If you haven't already had a chance to [access The Green Grid Academy](#), we would like to encourage members to do so now.

About The Green Grid



The members of The Green Grid have taken up the challenge of developing standards to measure data center efficiency, which includes both the facility and the IT equipment inside of it.

[Read More](#)



Become A Member

Home

Commitment & Policies

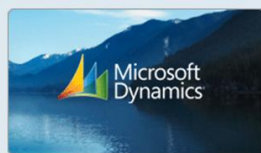
Products & Solutions

Research

News & Resources



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Environmental Sustainability Dashboard Released
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Discover how cities can accurately monitor, compare and reduce their greenhouse gas emissions.



Configure your enterprise for energy-efficient computing with System Center.

Home > Partner Resources > Specifications in Development > Enterprise Server and Data Center Energy Efficiency Initiatives

Enterprise Server and Data Center Energy Efficiency Initiatives

EPA is working with interested parties to identify ways in which energy efficiency can be measured, documented, and implemented in data centers and the equipment they house, especially servers. Provided below are EPA's current initiatives in this area

- [National Data Center Energy Efficiency Information Program](#)
- [EPA Report to Congress on Server and Data Center Energy Efficiency](#)
- [ENERGY STAR Enterprise Server Specification Development Process](#)
- [Data Collection Initiative to Develop an ENERGY STAR Rating for Data Centers](#)

National Data Center Energy Efficiency Information Program

The U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) have initiated a joint national data center energy efficiency information program. The program coordinates a wide variety of activities from the DOE Industrial Technologies Program *Save Energy Now* initiative, the DOE Federal Energy Management Program (FEMP), and the EPA ENERGY STAR program.

The following fact sheets summarize ongoing efforts at DOE and EPA to provide information, tools, and resources to owners and operators of data centers to assist their efforts to reduce energy consumption in their buildings. They also provide links to a wide variety of organizations outside of the Federal government that can help in your efforts to improve energy efficiency.

[Fact sheet for the National Data Center Energy Efficiency Information Program](#) (225KB)

Upcoming Meetings and Conferences

[Green Testing Day at iSimCity, Santa Clara, CA, October 28, 2008](#) (234KB)

[Carbon Footprint Energy Efficient IT Summit, London, England, September 4-5, 2008](#) EXIT ↕

[Digital Power Forum, Burlingame, CA, September 15-17, 2008](#) EXIT ↕

[Computerworld Green IT Symposium, Washington, DC, September 17-18, 2008](#) EXIT ↕

[Datacenter Dynamics, Miami, FL, October 22, 2008](#) EXIT ↕

International Server and Data Center Initiatives

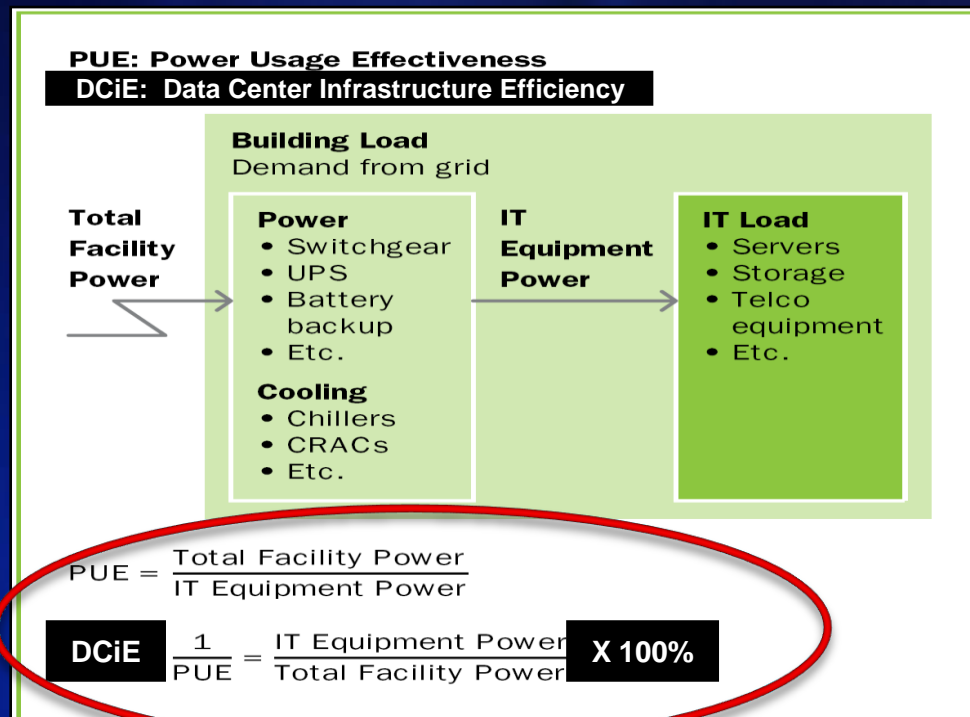
[Report on Energy Efficient Servers in Europe, Part 1, Energy Consumption and Savings Potential](#) EXIT ↕

[EU Code of Conduct on Datacenter](#) EXIT ↕

EPA Presentations

Industry Initiatives – The Green Grid

- Microsoft is founder/board member and leads two work groups
 - Technology & Strategy
 - Metrics Measurement



Microsoft Tracks Many Things

Utility Capacity (KW)	Critical Capacity (KW)	Utility Consumed (KW)	Critical Consumed (KW)
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24-Hr Carbon Emission Foot Print (metric tCO2eq)	Carbon Emission Factor (kgCO2/kWH)
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Data Center Outside Temp (Fahrenheit)	Data Center Dewpoint (Fahrenheit)
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Including capacities and utilizations

...And we are not waiting for industry definitions

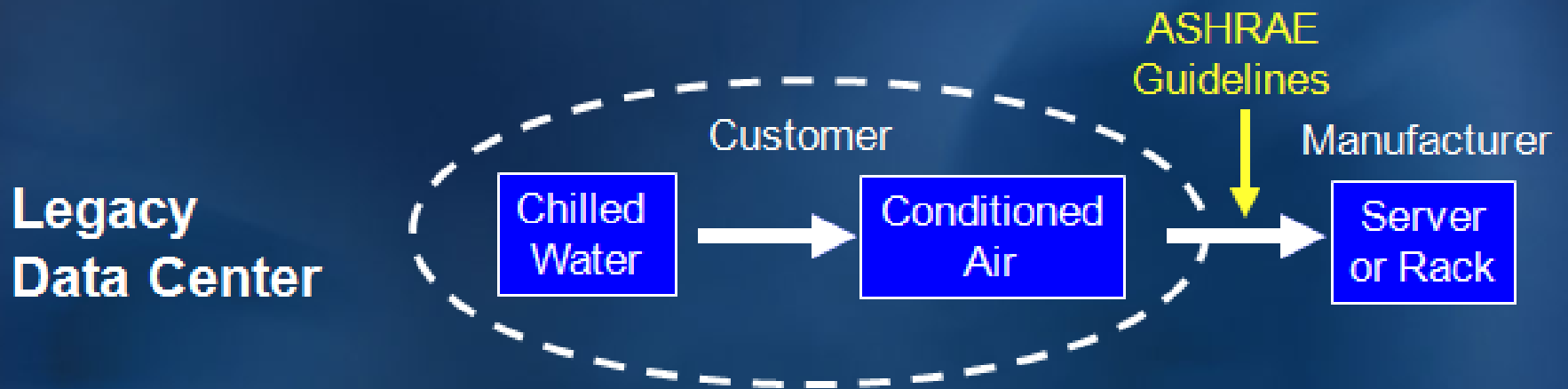
Power Usage Effectiveness	Data Center Efficiency (%)
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Microsoft Best Practices

- Engineer the data center for cost and energy efficiency
- Optimize the design to assess multiple factors
- Optimize provisioning for maximum efficiency and productivity
- Monitor and control data center performance in real time
- Make data center operational excellence part of organizational culture
- Measure power usage effectiveness (PUE)
- Use temperature control and airflow distribution
- Eliminate the mixing of hot and cold air
- Use effective air-side or water-side economizers
- Share and learn from industry partners

The Container Rationale



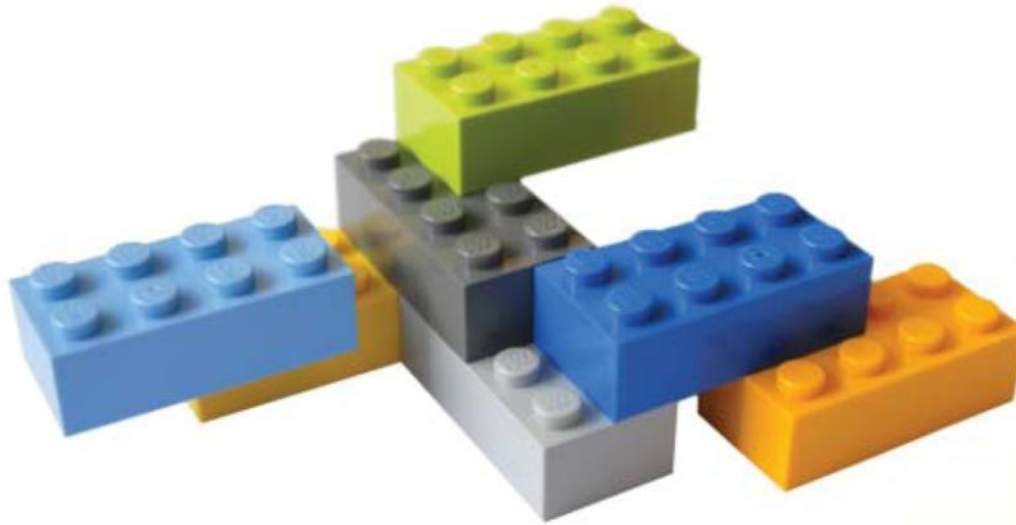
Commoditized Data Center



Raise Operating Temperatures

- Data center temperature zones
 - As we've seen, they're not chiseled in stone
- Operate at $>50^{\circ}\text{C}$ inlet temperature instead
 - Perhaps accept more component failures
 - But, this is not necessarily true
- Aggressively embrace airside economization
 - Ambient air, with minimal conditioning
- Recognize the power of alternative cooling
 - Liquid, phase change, ...

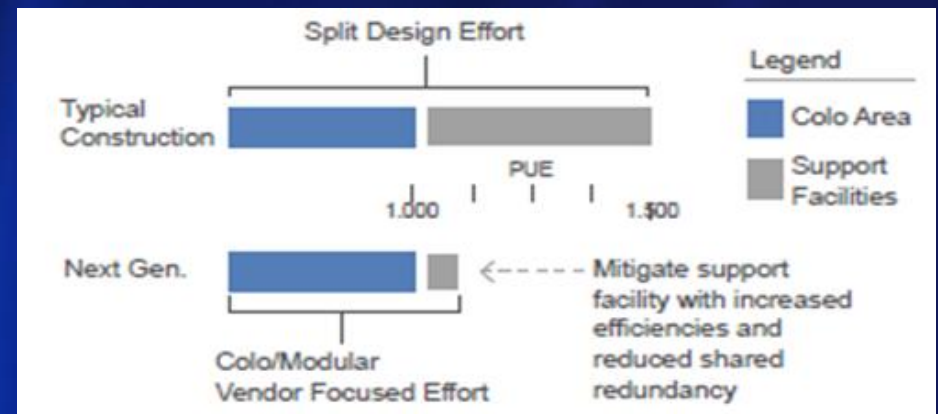
Microsoft Gen4 Data Center Vision



The design aspiration of the Generation 4.0 Data Center is to provide a flexible, modular, and scalable solution consisting of inter-changeable components utilized in a plug-and-play, just-in-time configuration.

Microsoft Gen4 Data Centers

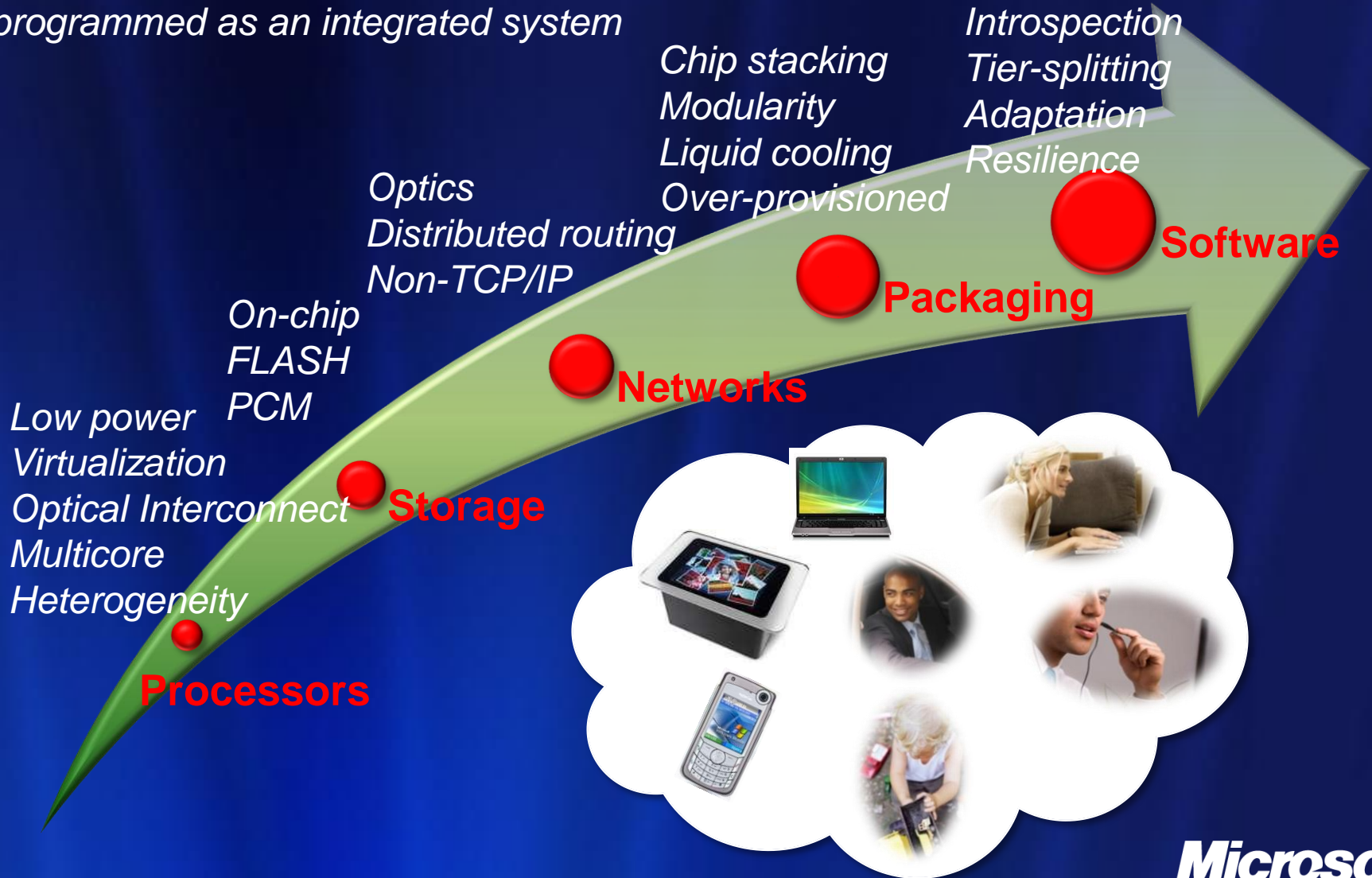
- Scalable
- Plug-and-play spine infrastructure
- Factory pre-assembled
 - Pre-assembled containers (PACs)
 - Pre-manufactured buildings (PMBs)
- Rapid deployment
- De-mountable
- Reduced construction
- Sustainable measures
- Map applications to class



Let's Look Longer Term ...

Cloud Computing Futures Vision

Philosophy: *The data center is a computer that must be designed and programmed as an integrated system*



Move Redundancy to Geo-Level

- Power redundancy is a major cost
 - Batteries to supply up to 15 minutes at some facilities
- Instead use more, smaller, cheaper data centers
 - This is the Gen4 concept
- Focus on multi-terabit WAN interconnect
 - Weak consistency and workload rollover

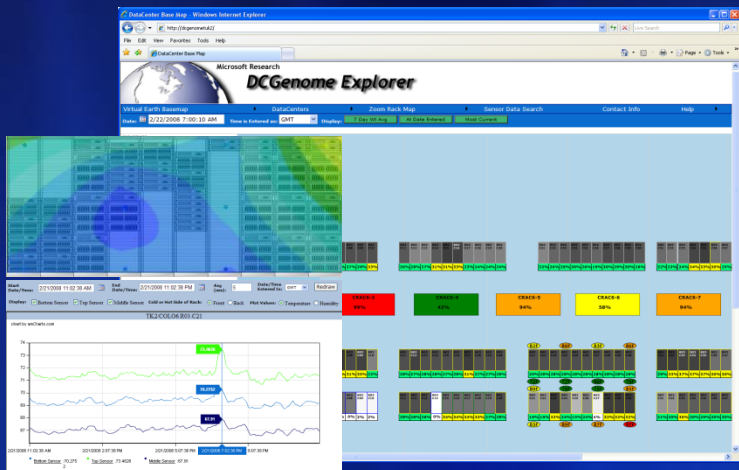
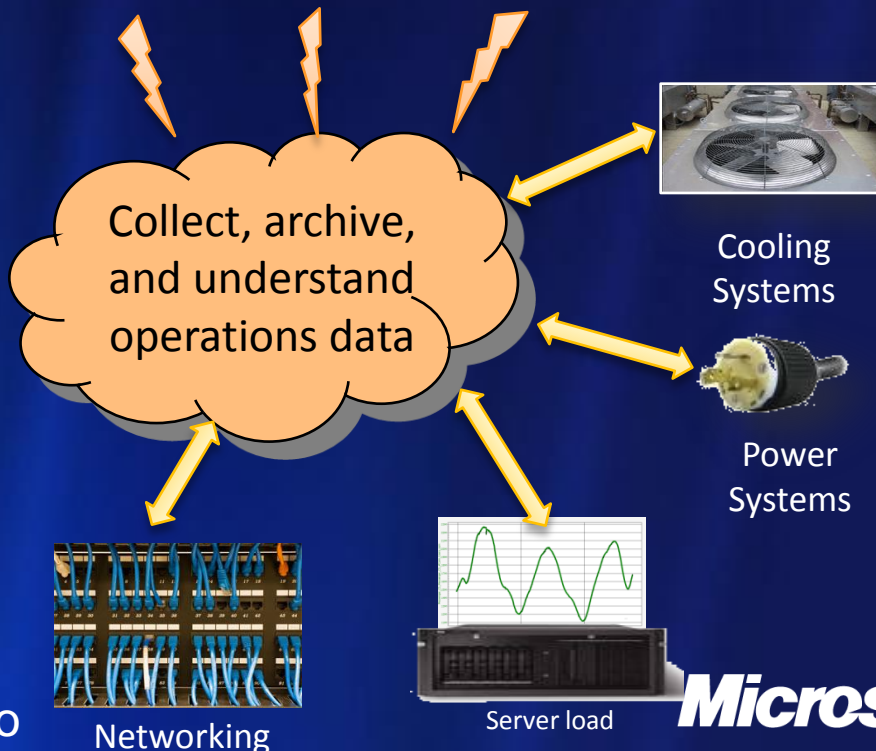
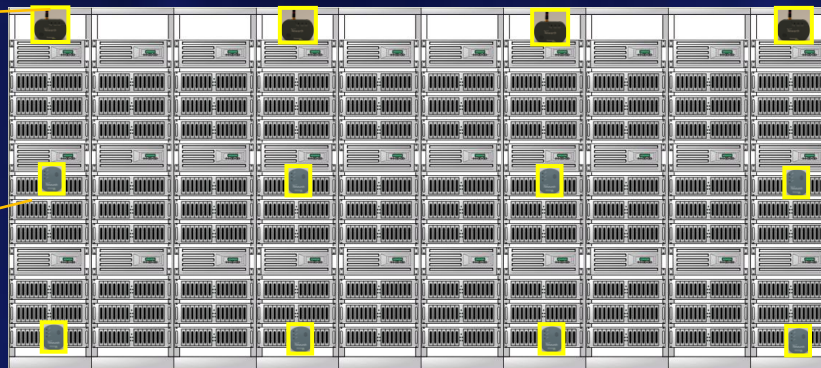


Data Center Genome

Saving energy & improving operation efficiency by networked sensing, data mining, and control.



MSR Genomotes



Source: Feng Zhao

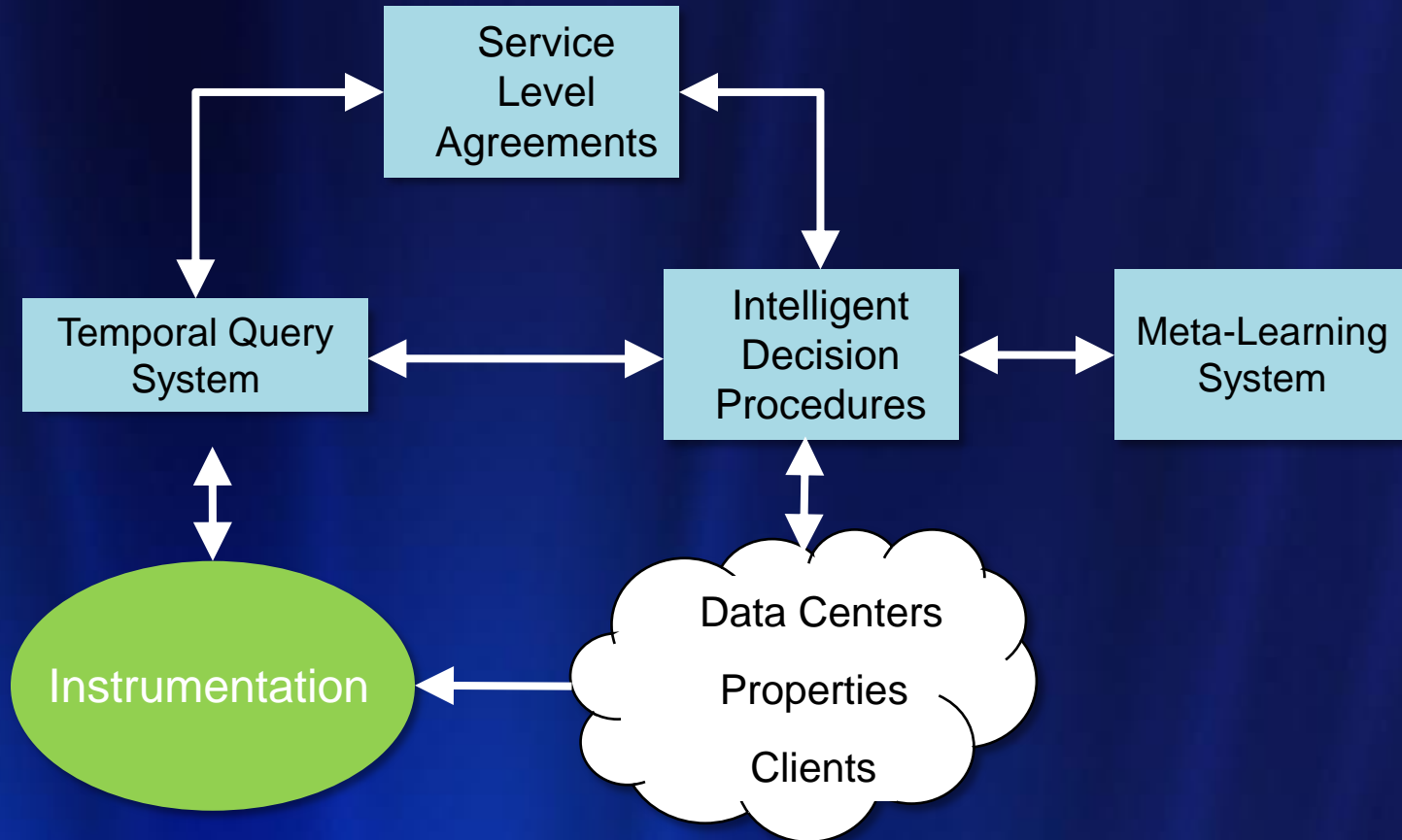


Think Low Power

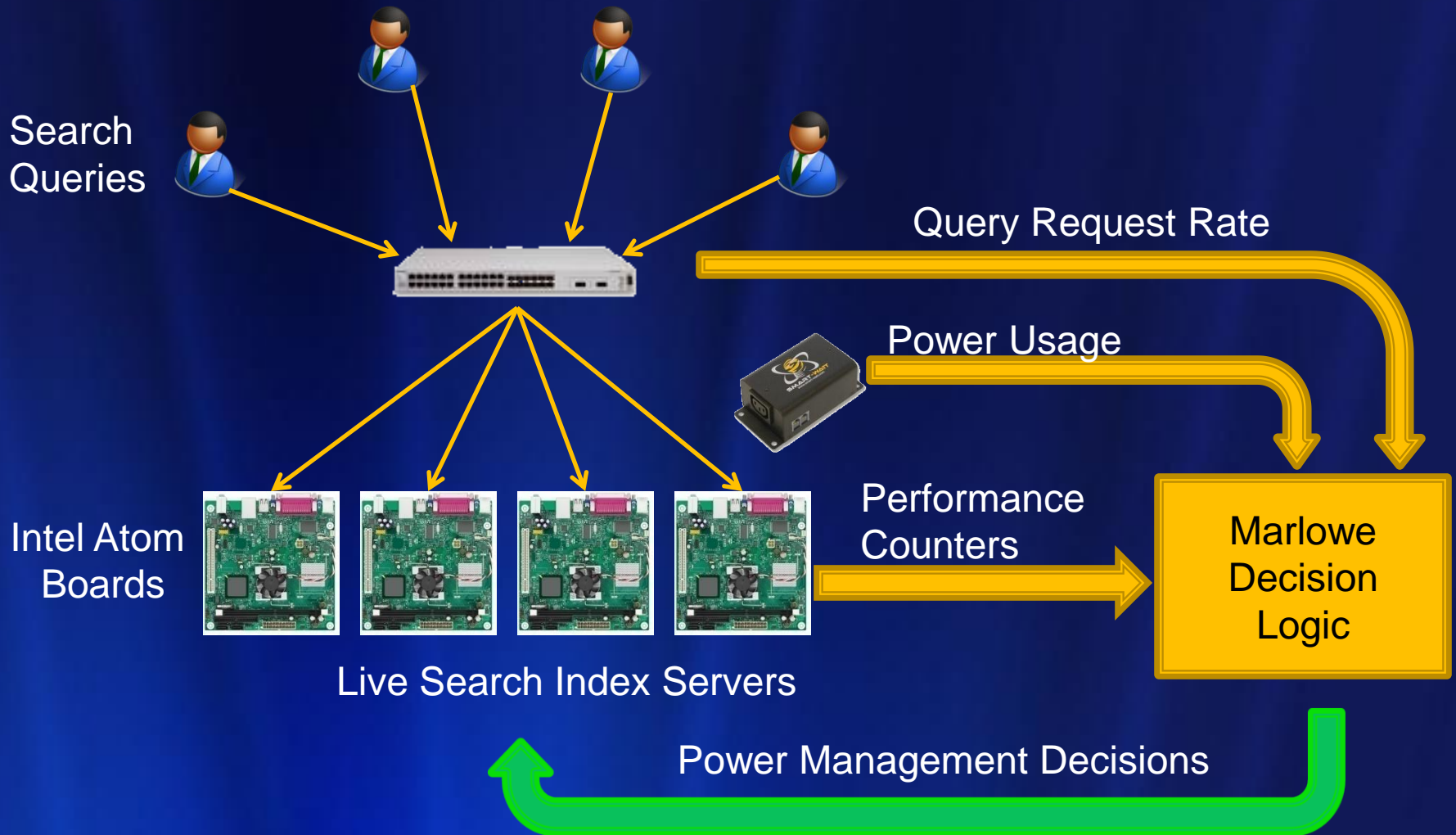
- Two 50 node prototypes
 - Intel Atom dual core
 - 1.6 GHz, 512 KB L2, 533 MHz FSB
 - 2 GB DRAM
 - Either FLASH SSD or disk
 - Genomote environmental monitors
- Microsoft software stack
 - Configuration baseline
- Marlowe control software
 - Intelligent power management



Marlowe Adaption Layer



Recent Demonstration



Some Research/Design Thoughts

- Draw the right bounding box
 - It defines the problem you solve
- Avoid high density packaging
 - It complicates cooling and design
- Use ambient air cooling wherever possible
 - Water is precious
- Run hot (really hot), if you can
 - Don't believe the vendor specifications ☺
- Embrace component failure
 - Hardware is cheap and readily recyclable
- Machines and people do not mix well
 - Consider sealing hardware at the factory

Some Research/Design Thoughts

- One size does not fit all
 - Workloads vary widely
- Understand your workload
 - Use only the hardware you need
- Power down whenever possible
 - Off is the best solution
- Metrics reward and punish
 - Choose carefully what you measure
- Engage multidisciplinary solutions
 - Mechanical, electrical, economic, social ...
- **Culture shapes behavior**
 - **Implicit versus explicit costs**

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