

# 7x24 Exchange Northwest Chapter: Server Cooling Work Group Update

D.S. De Lorenzo  
Intel Labs

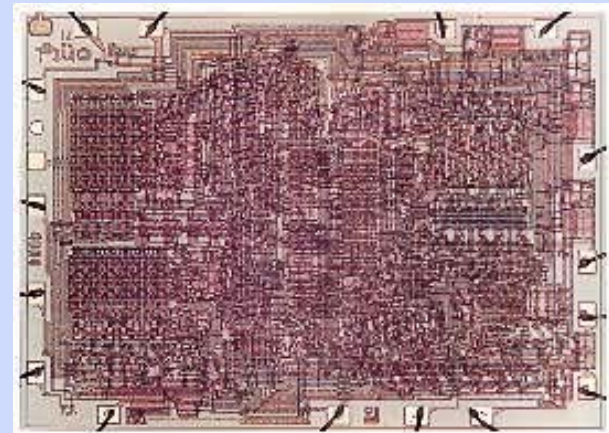
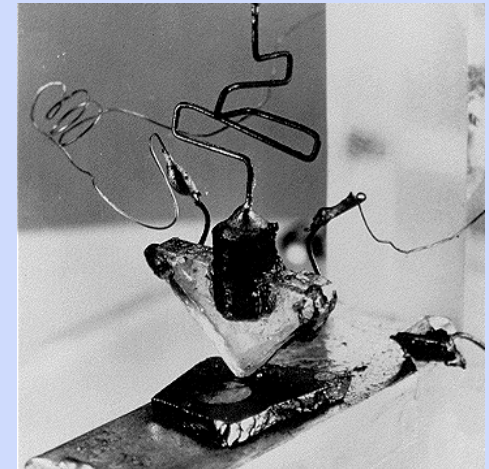
# Agenda

- ◆ Server Performance & Power Trends
- ◆ Data Center Power & Thermal Trends
- ◆ Technology Trends & Inflections
- ◆ Server Cooling Work Group Activities

Discuss interaction between  
server power roadmap and  
Data Center power and  
thermal considerations

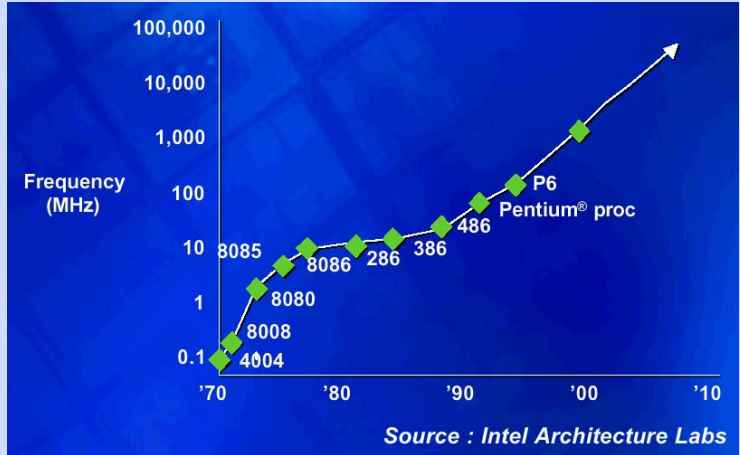
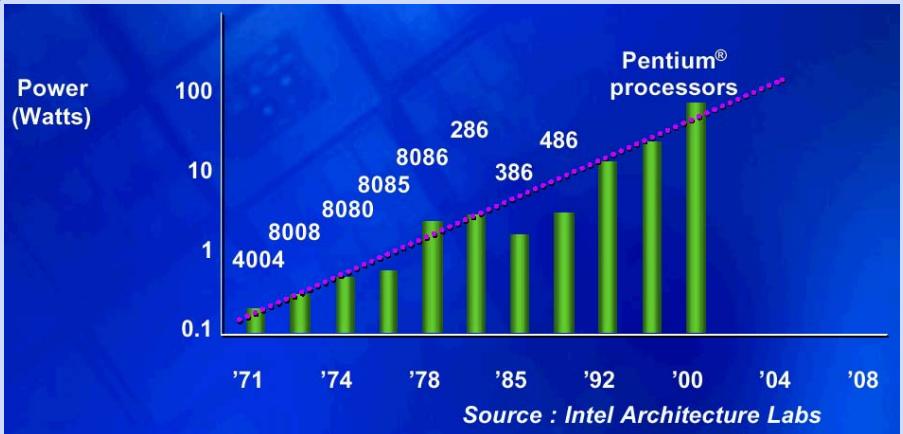
# The Transistor

- ◆ In 1947, John Bardeen, Walter Brattain, and William Shockley of Bell Laboratories developed the transistor
- ◆ 1971 saw large-scale integration on Intel's 4004 Microprocessor



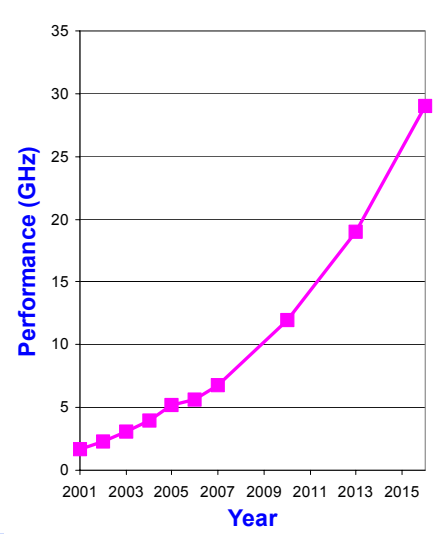
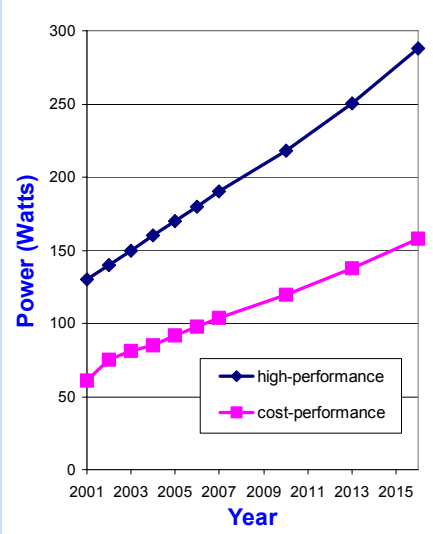
– and the rest is history ...

# Microprocessor MHz & Power Forecasts



Historical, Intel-based

Industry projections

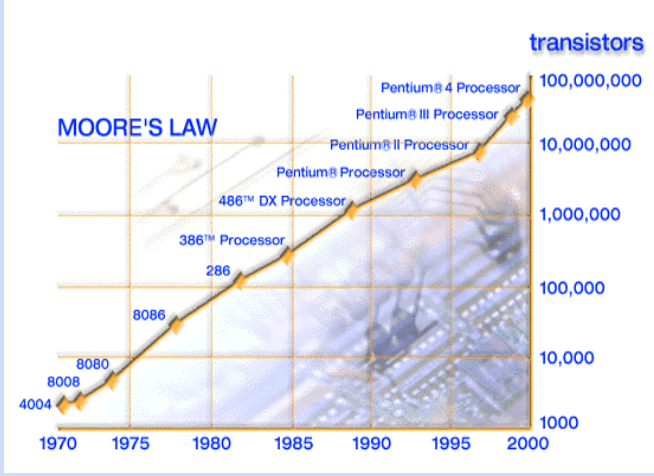


Source: International Technology Roadmap for Semiconductors 2001 Edition (<http://public.itrs.net/>)

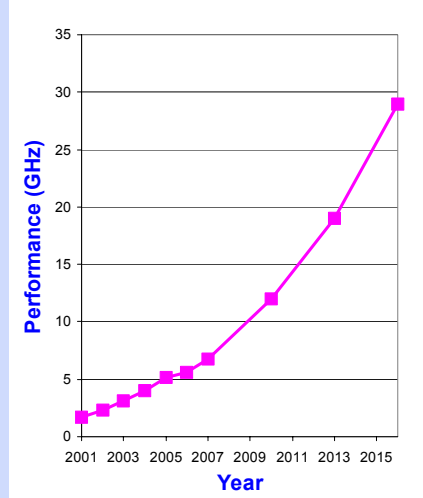
# Performance Consequences

- ◆ Transistor densities and clock speeds are going up
- ◆ Normalized energy consumption is going down

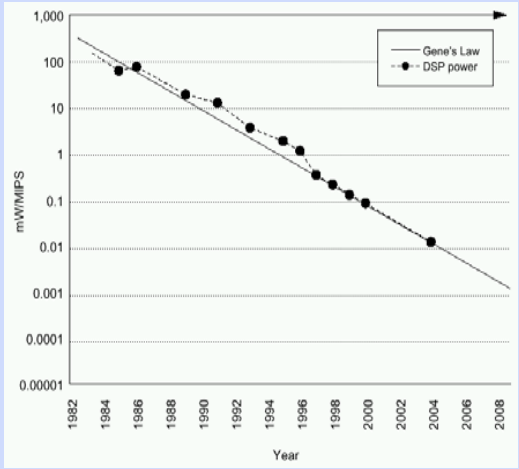
Obey the "Laws", and you get continually increasing **PERFORMANCE**



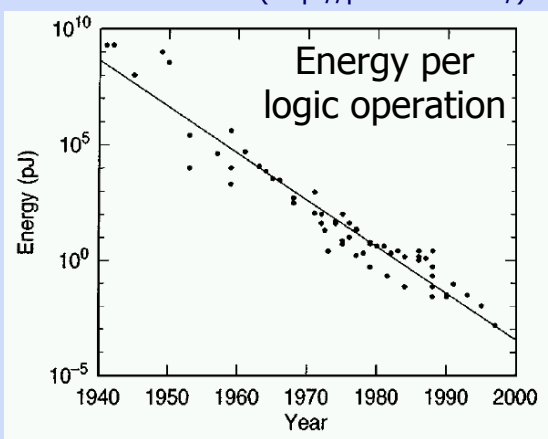
Source: Intel Corporation



Source: International Technology Roadmap for Semiconductors 2001 Edition (<http://public.itrs.net/>)

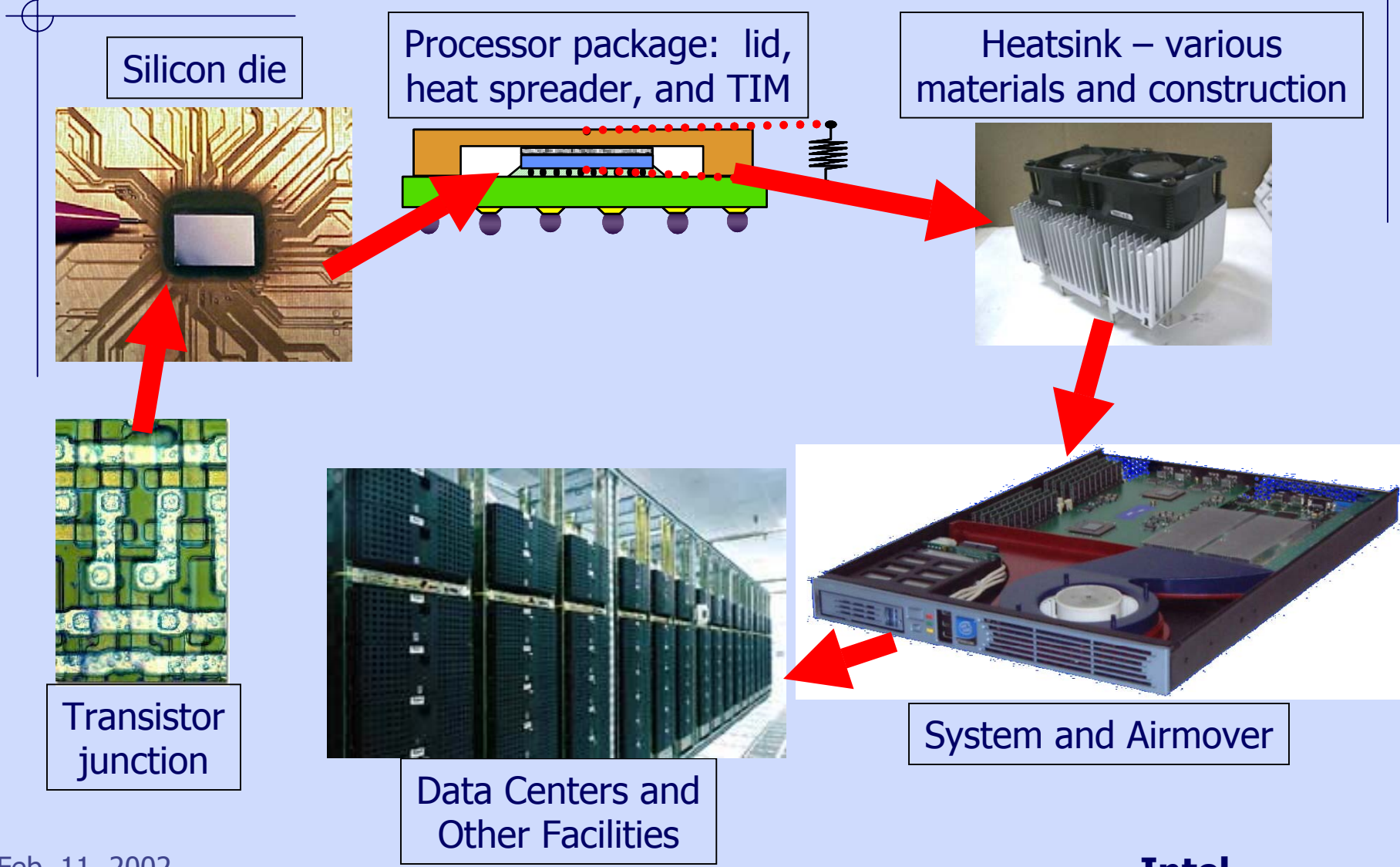


\*from Gene Frantz, Digital Signal Processing Trends, IEEE Micro, Volume 20, Issue 6, Nov.-Dec. 2000



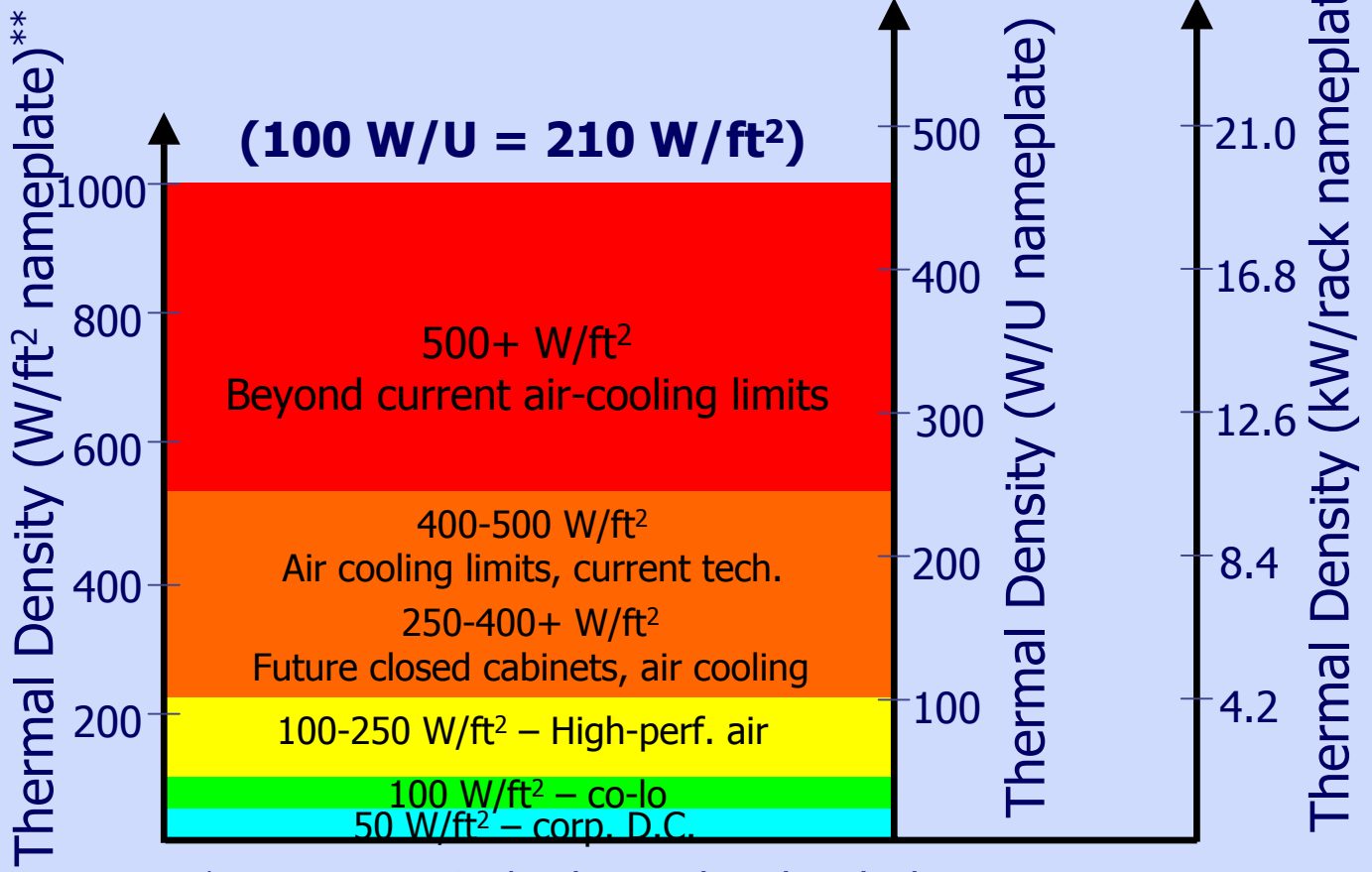
\*from Robert W. Keyes, Fundamental Limits of Silicon Technology, Proceedings of the IEEE, Vol. 89, No. 3, March 2001

# Heat Transfer Path – Air Cooling



# Server Thermal Footprints

Horizontal, rack-mounted server form factors

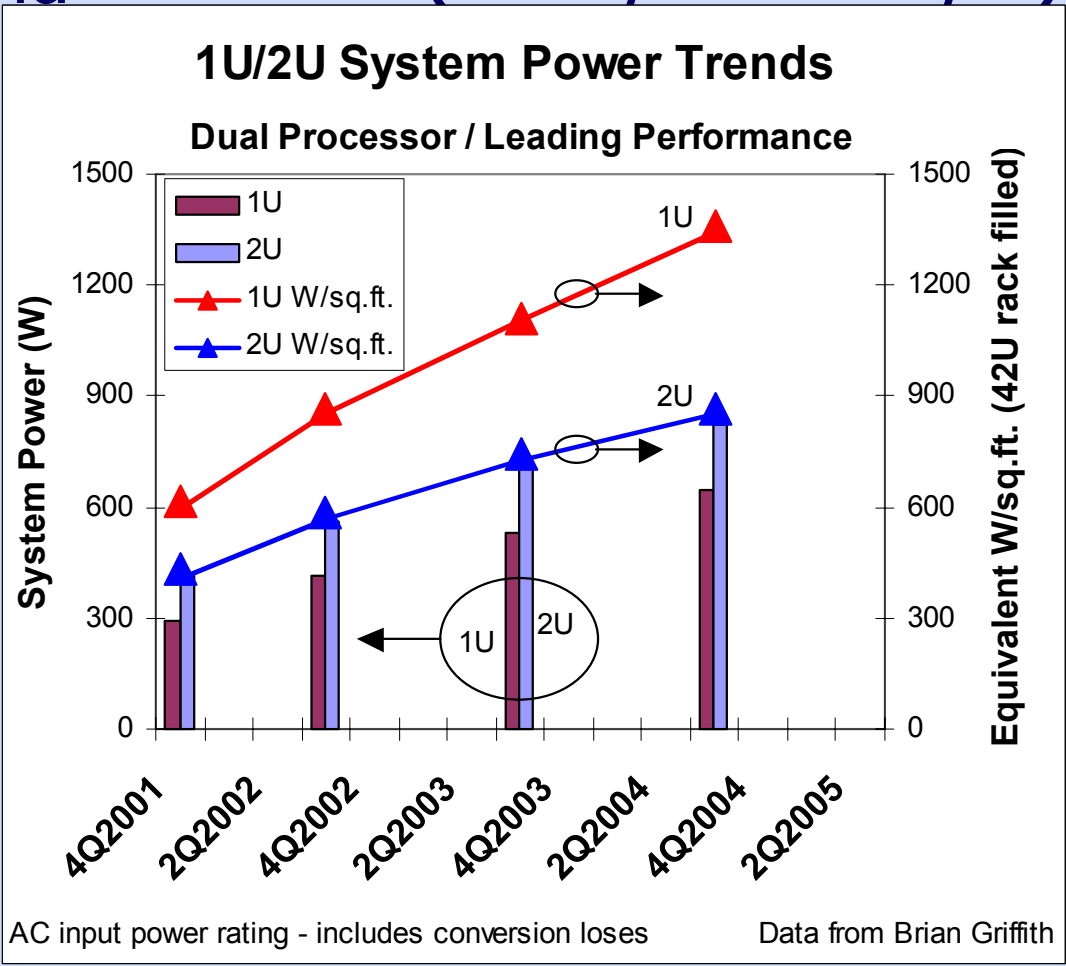


\* Assumes 42U/rack populated with these systems  
 \*\* Allocates industry-standard 20 ft²/rack, no de-rating

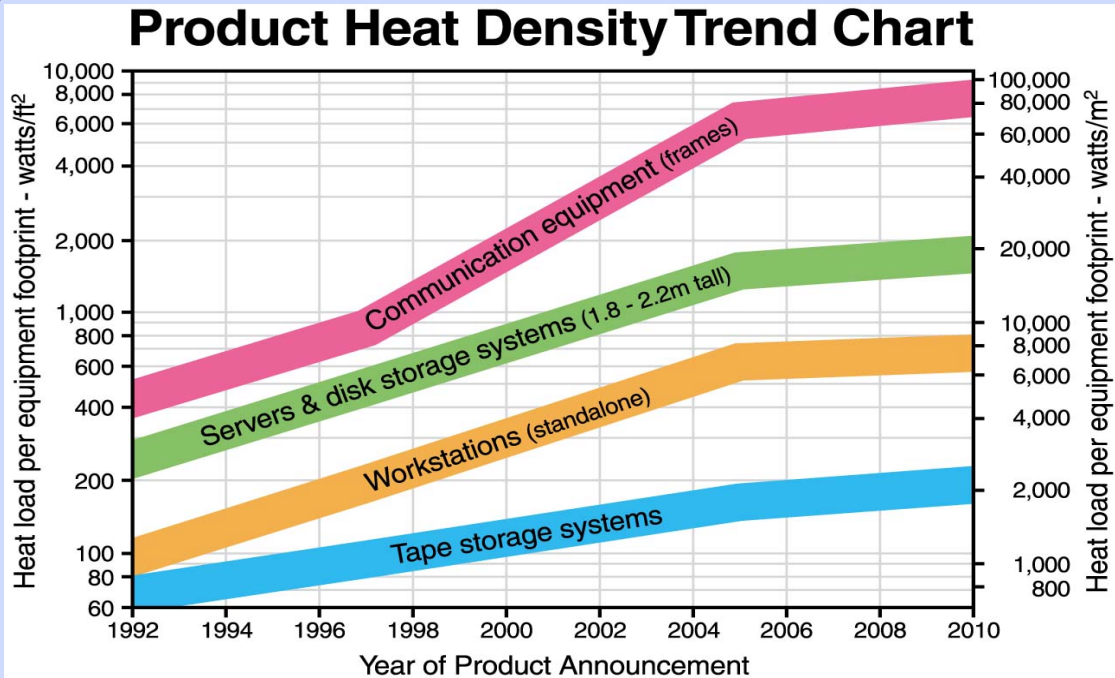
# Server Power Projections

- ◆ System power and equivalent W/ft<sup>2</sup> for a 42U rack
- ◆ Power densities insupportable for completely filled racks in an air-cooled data center

(100 W/U = 210 W/ft<sup>2</sup>)



# Server Industry Power Roadmap



Data Center:  
 1 rack → 20 ft<sup>2</sup>  
 Includes aisles and eqpmt. overhead  
 Equivalent load may be 50% of nameplate (incl. tapes, disks, networking, partial configurations, etc.)

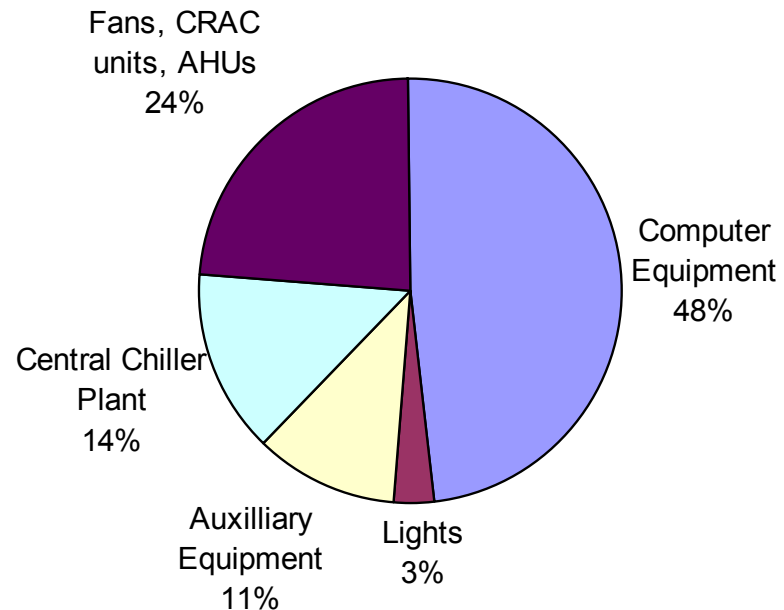
Reprinted with permission of The Uptime Institute from a White Paper titled *Heat Density Trends in Data Processing, Computer Systems, and Telecommunications Equipment Version 1.0*



## Power vs. Hardware Costs

- ◆ Support infrastructure adds to the total current draw
  - Each 1W of hardware needs another 1W of overhead
- ◆ 180W 1U system:
  - Example 3yr. life
  - Power: \$985 @ 10¢/kWh

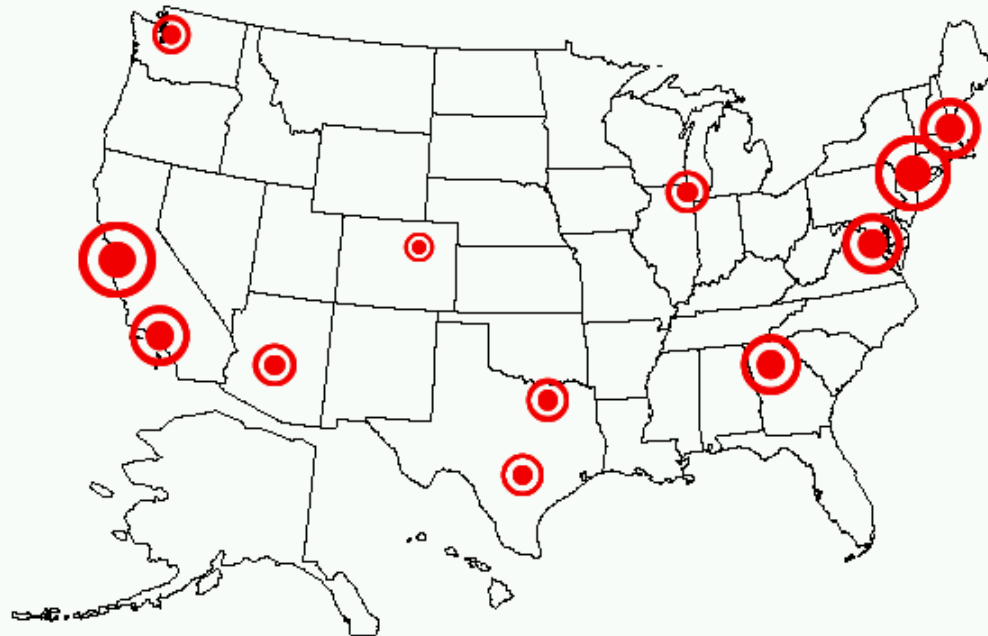
**Breakdown of Computer Room Power by End Use**



from J.D. Mitchell-Jackson, "ENERGY NEEDS IN AN INTERNET ECONOMY: A CLOSER LOOK AT DATA CENTERS", UCB Masters Thesis, July 10, 2001.

## Data Center Power Consumption

**Figure 13. Regional Data Centers Power Needs**

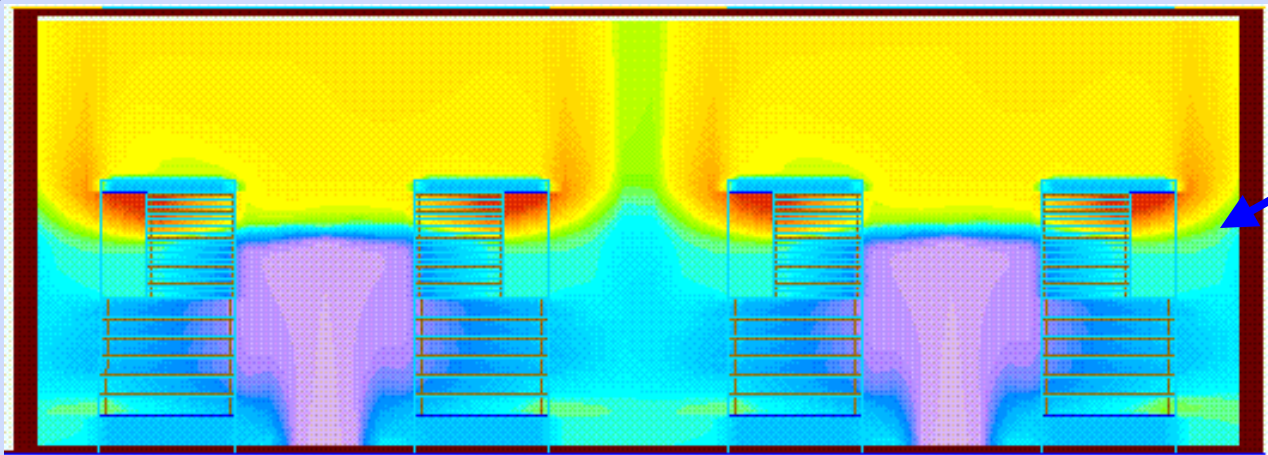


- ❖ The markings are indicative of the relative power needs of data centers in these regions. Based on Salomon Smith Barney data (from Mahedy et al., 3 August 2000) and using a conservative assumption that the average total computer room power density is 50 W/ft<sup>2</sup>.

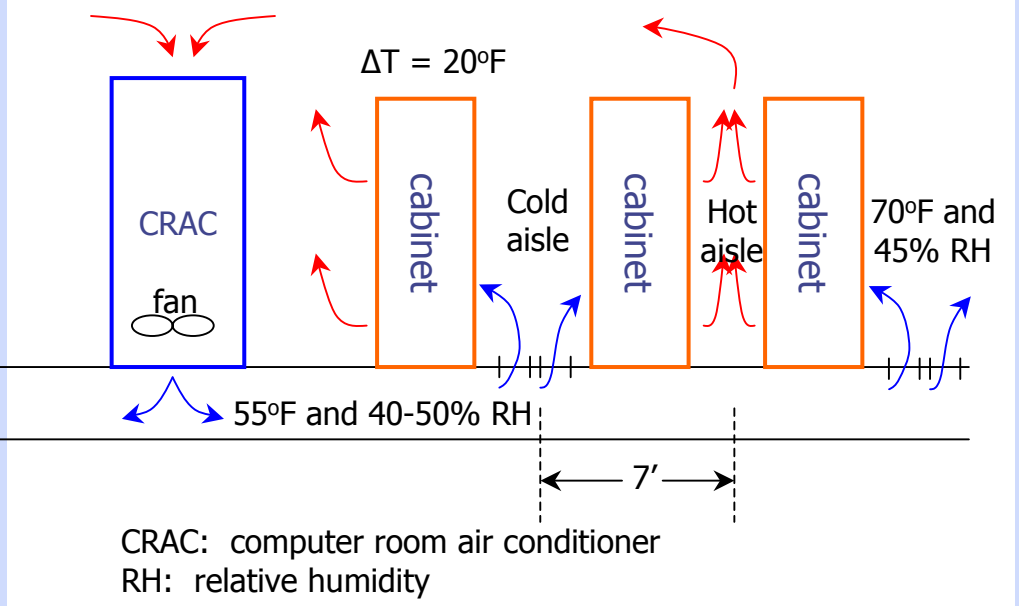
\* from J.D. Mitchell-Jackson, "ENERGY NEEDS IN AN INTERNET ECONOMY: A CLOSER LOOK AT DATA CENTERS", UCB Masters Thesis, July 10, 2001

# Thermal Capacity Limits

## Industry-Standard Raised-Floor Cooling



Numerical model, 13 kW/rack



CRAC: computer room air conditioner  
RH: relative humidity

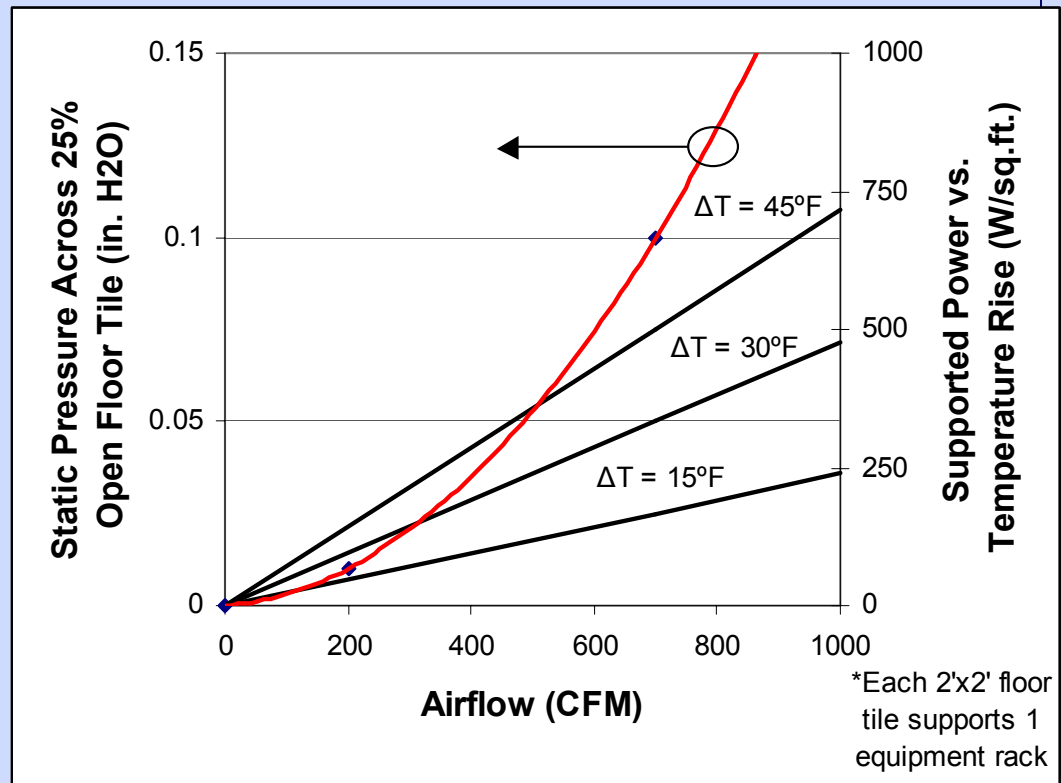
## Raised-Floor Air-Cooling Limits

◆ Thermal Capacity vs. Hot-aisle/Cold-aisle  $\Delta T$ , at 0.1" H<sub>2</sub>O (aggressive  $\Delta P$ ) and 25% open tile

- 15°F = 170 W/ft<sup>2</sup>
- 30°F = 330 W/ft<sup>2</sup>

◆ Problems:

- Maintaining high static pressures
- Achieving large hot/cold split
- Matching system air consumption w/ floor supply
- Limiting air recirculation



# New "Conventional" Cooling Products

Enhanced raised-floor cooling



RTKL/APW  
Tower of Cool\*  
rated @ 400 W/ft<sup>2</sup>  
(tested to 220 W/ft<sup>2</sup>)

Hybrid H<sub>2</sub>O-cooled cabinet



Liebert RackCooler\*  
rated @ 400 W/ft<sup>2</sup>

A/C-ed cabinet



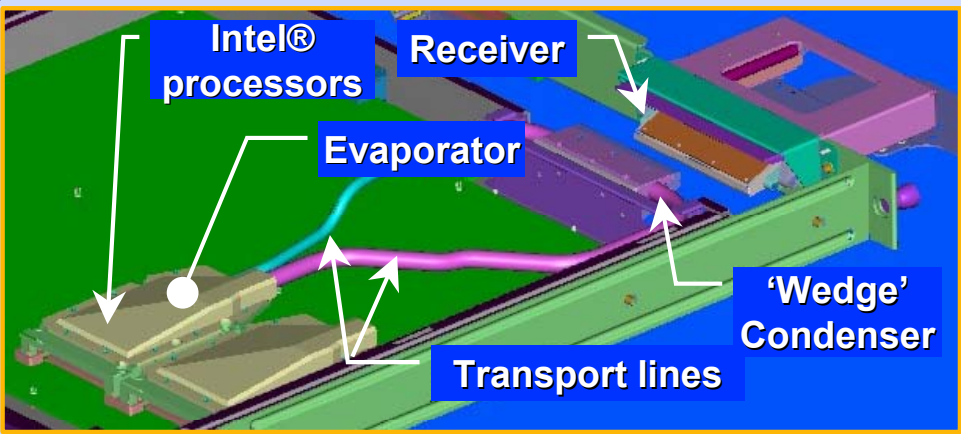
Overhead air distribution unit



Liebert DataCool\*  
tested @ 500 W/ft<sup>2</sup>

Rittal PSK\*

# Non-Conventional Cooling Techniques

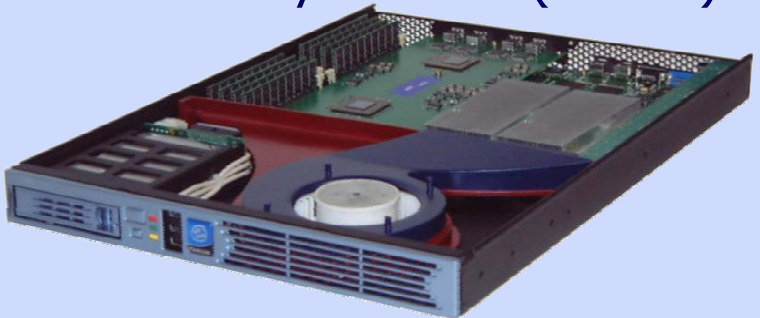


In-system passive cooling loop with rack-level thermal bus interface

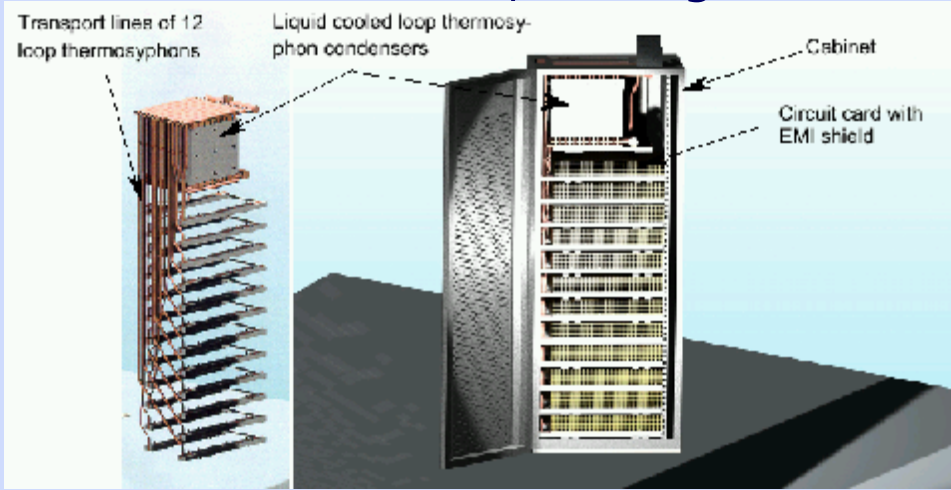
Loop thermosyphon thermal bus in a telecommunication cabinet, moving 15kW

\* from Berry, W. and Montgomery, S.W., 2002, Dockable Server Concepts, Intel Developer Forum.

1U/DP McKinley server; high-performance blower increases system  $\Delta T$  ( $>30^\circ\text{F}$ )



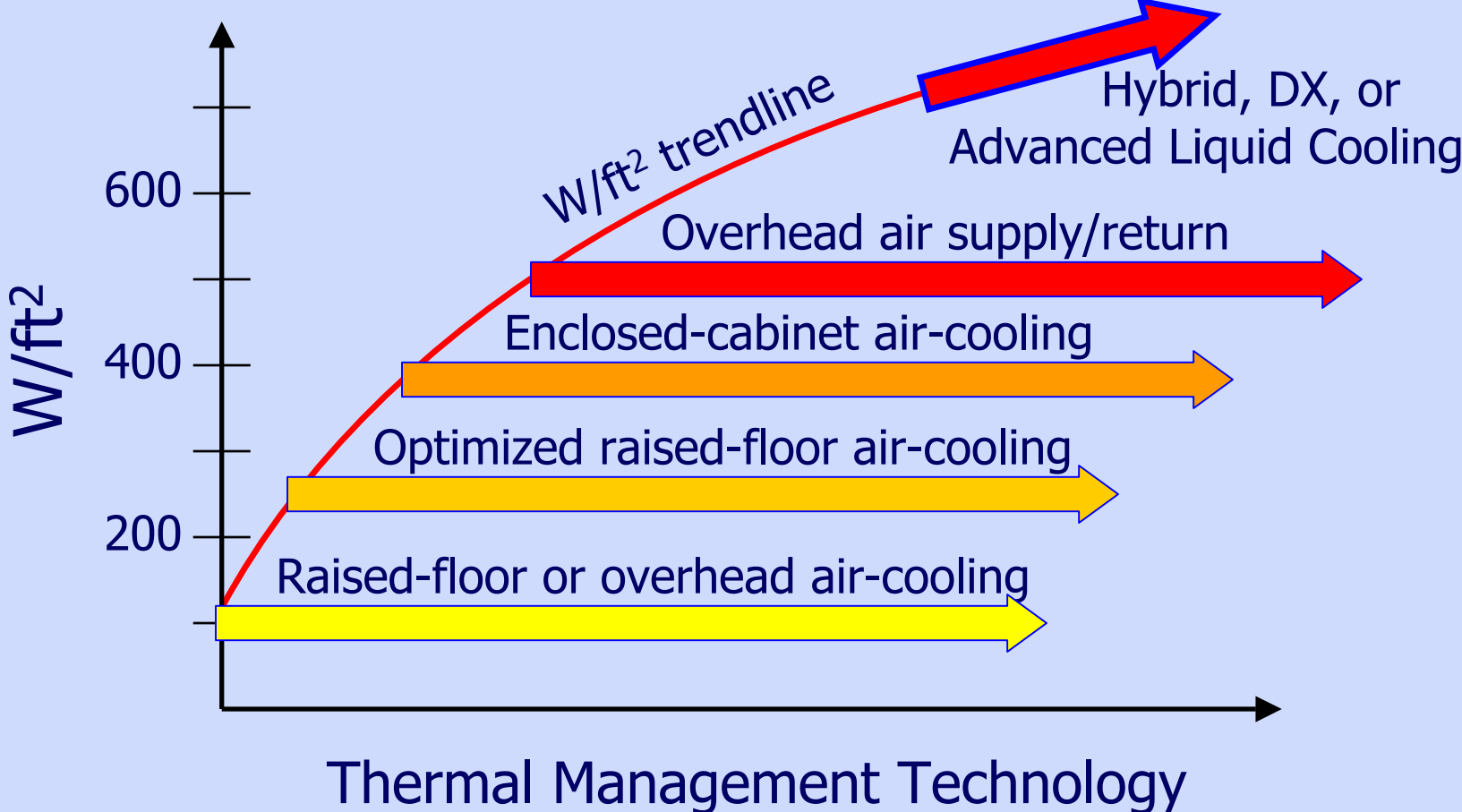
Hurricane Ridge concept server, 700W+ nameplate power



\* from Zuo, Z.J., Hoover, L.R., and Phillips, A.L., 2002, An integrated thermal architecture for thermal management of high power electronics, proceedings of THERMES 2002: Thermal Challenges in Next Generation Electronic Systems, Y. Joshi and S. Garimella eds.

# Thermal Capacity Limits

◆ Thermal management technologies vs. W/ft<sup>2</sup>



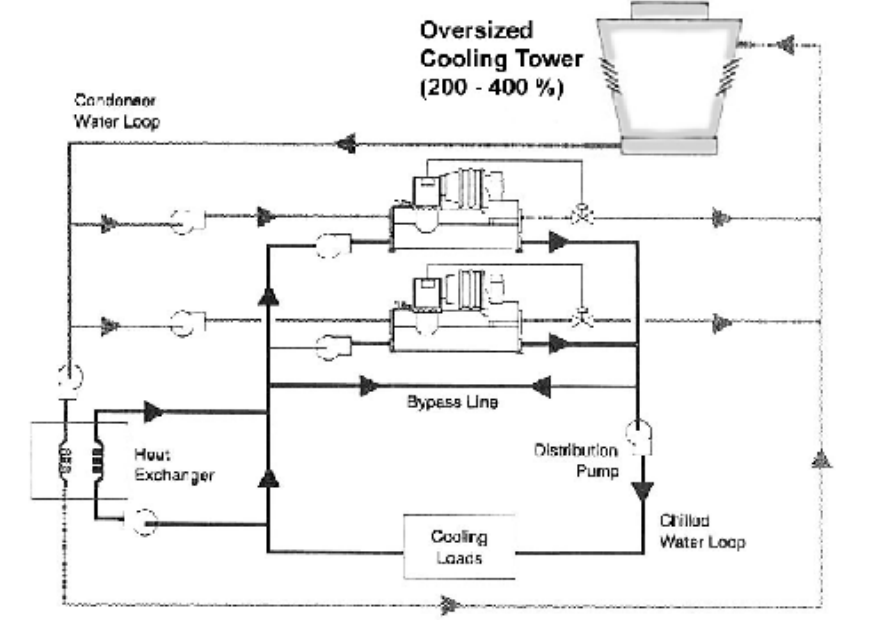
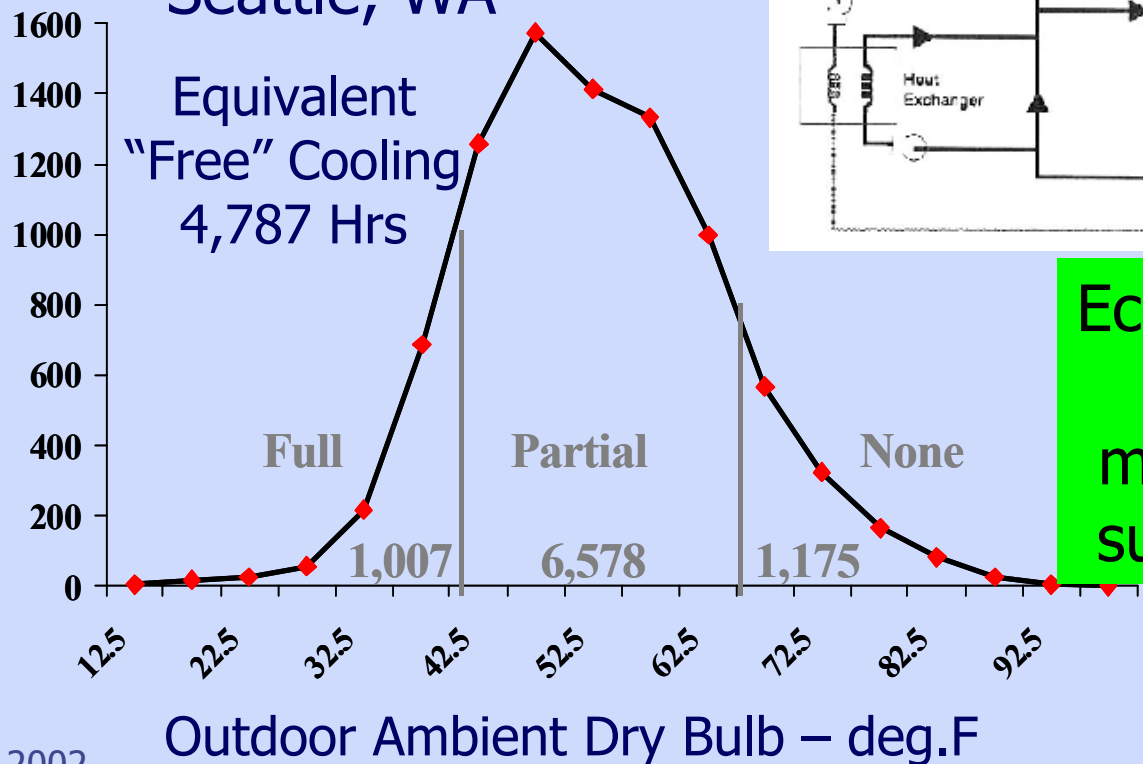
# Economizer-Induced Limits

Chilled water system with water-side economizer

Annual Hours of Occurrence - Hrs

Hours of free cooling  
Seattle, WA

Equivalent "Free" Cooling  
4,787 Hrs



Economizer standards place limits on minimum air-cooling supply temperatures

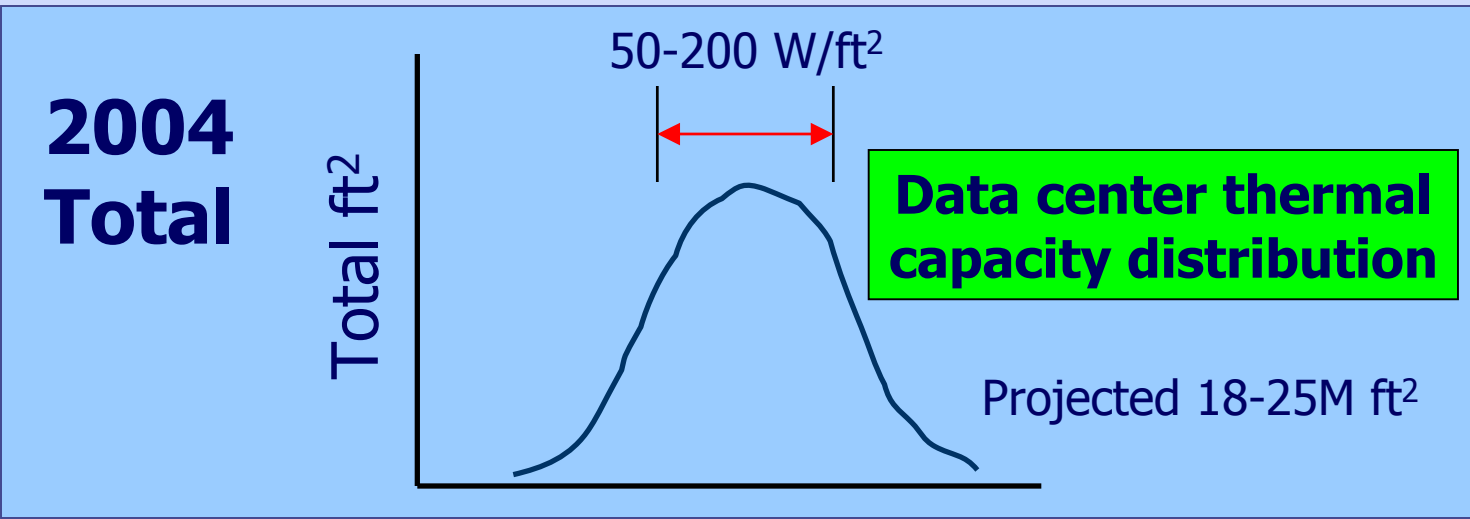
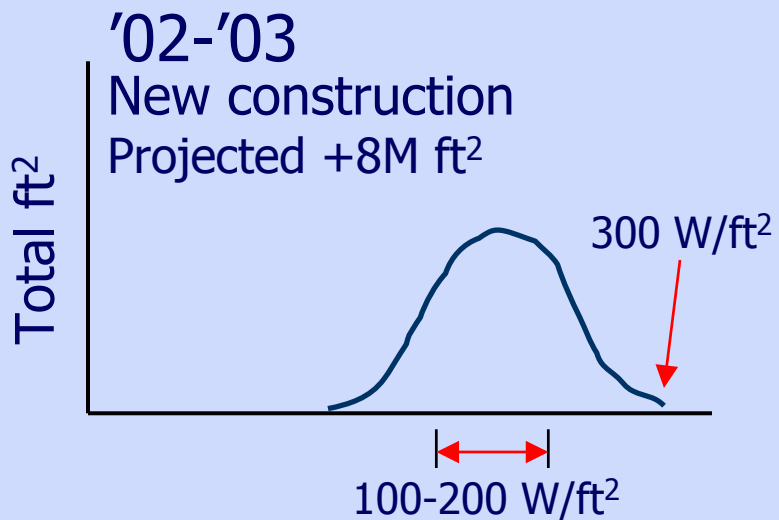
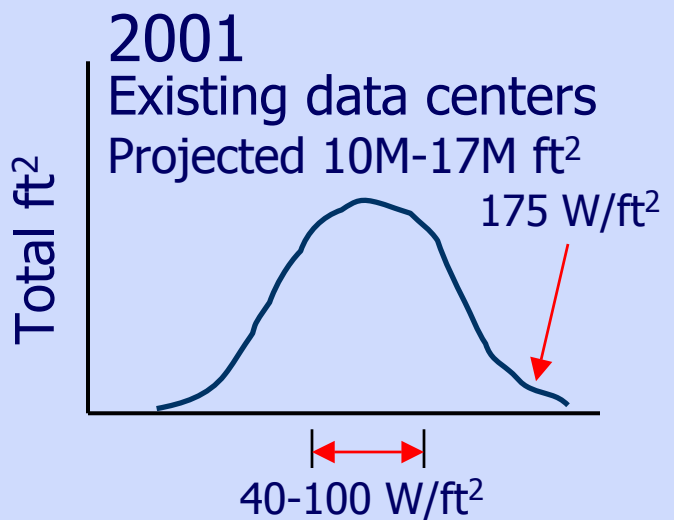
## Current Data Center Thermal Practices

### ◆ Air-cooled data center thermal capacities

- 1998 HP study: 40-70 W/ft<sup>2</sup>
- 2001 UCB study: 50-75 W/ft<sup>2</sup>
- Corporate: 40-50 W/ft<sup>2</sup> – CS Tech. (2001)
  - ◆ Starting to see 80 W/ft<sup>2</sup>
  - ◆ Thermal densities stable for last 6-8 years
  - ◆ Ex: HP Atlanta @ 80 W/ft<sup>2</sup> for a 50,000 sq.ft. data center
- Co-lo/dot.com: 60-100 W/ft<sup>2</sup> – CS Tech. (2001)
  - ◆ 100+ W/ft<sup>2</sup> during battery recharging/refresh
  - ◆ Ex: AOL @ 80 W/ft<sup>2</sup> for 100,000 ft<sup>2</sup>/year added capacity; Safeco facility rated at 150 W/ft<sup>2</sup>, operating at 50 W/ft<sup>2</sup>

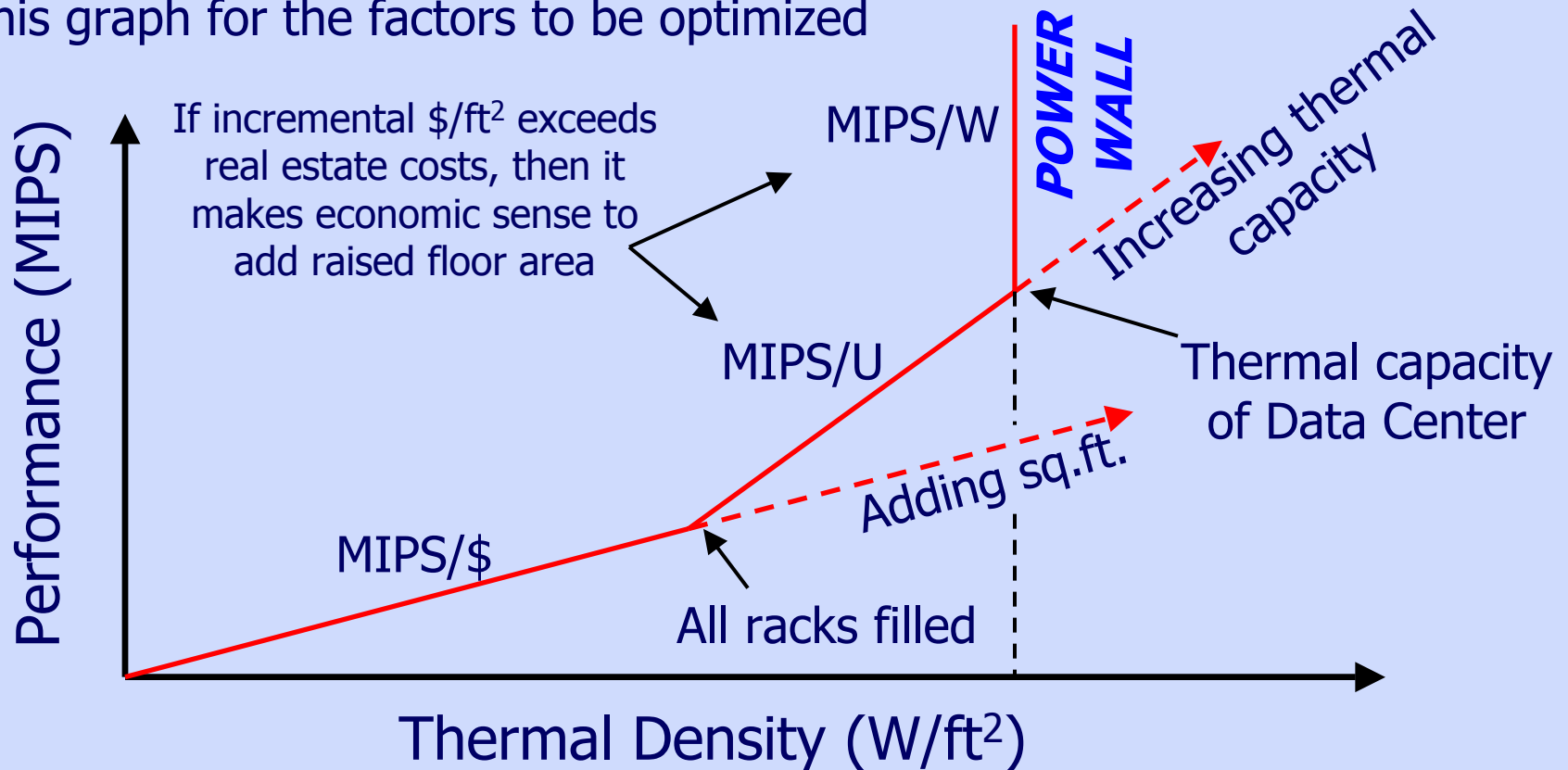
Meat of the bell-curve is 50-200 W/ft<sup>2</sup>  
for the next 2-3 years

# Thermal Capacity Growth Model



## A Performance & Power Density Model

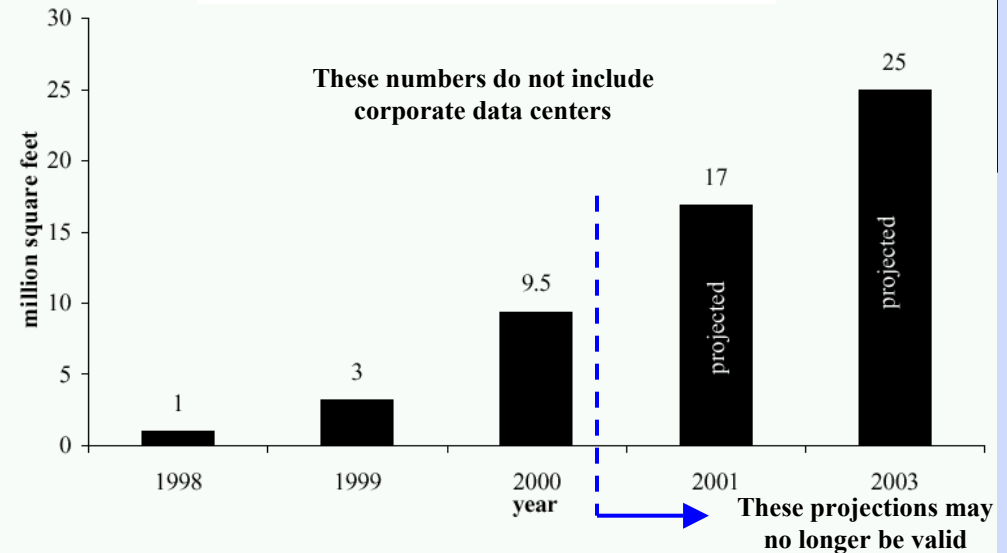
Equipment selection to increase facility-wide aggregate performance: As equipment is deployed, the selection decisions follow this graph for the factors to be optimized



## Data Center Growth Trends

- ◆ When market is growing, there is intense pressure for rapid construction
  - Very constrained supply pipeline in '00
    - ◆ CRACs, AHUs: 30wks
    - ◆ Raised-floor: 50wks
    - ◆ Batteries: 60wks
    - ◆ Shortages on switches, electrical components, etc.
  - Customers expect construction pay-down within 2 yrs

Figure 2. Computer Room Floor Space  
In U.S. Data Centers



Source: Yankee Group, 2000; 2001 value estimated from the growth rate in the Salomon Smith Barney Report (Mahedy et al., 3 August 2000).

\* from J.D. Mitchell-Jackson, "ENERGY NEEDS IN AN INTERNET ECONOMY: A CLOSER LOOK AT DATA CENTERS", UCB Masters Thesis, July 10, 2001.

When market wants to grow, data center space is at a premium

# Total Power Consumption

- ◆ Electricity usage by data centers under scrutiny
  - Electric bill will no longer be a “hidden” cost
  - Power consumption becoming public focus issue
- ◆ Increasing impact from energy codes
  - On-site generation, peak shaving
  - Economizers, free-cooling
  - Facility power caps, large-load ordinances (>10MW)
  - Heavy-use charges, peak charges, hook-up fees

Performance/Watt and power efficiency  
will become increasingly important

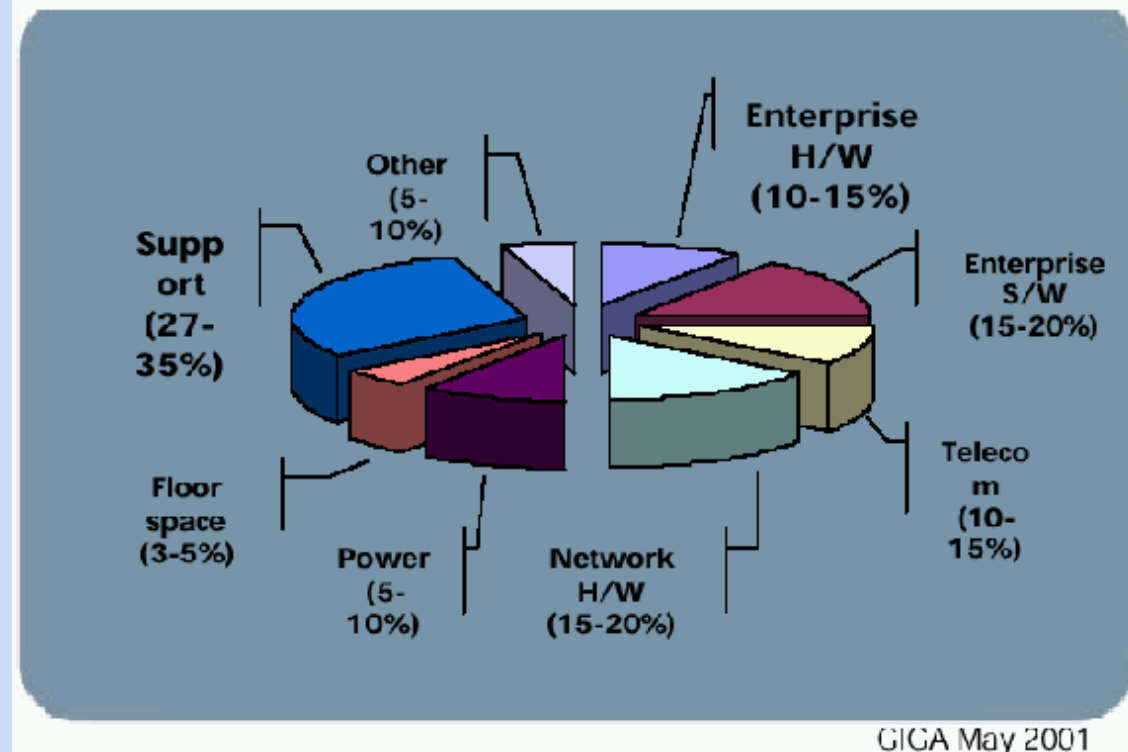
## Data Center Hardware & Power Costs

- ◆ Enterprise hardware and electric power costs still minority part of total IT expenses

- ◆ Volume-efficiency & RAS higher on list of priorities

- HW/Thermals become go/no-go gating item

\* from Rich Friedrich, "Towards planetary scale computing", THERMES 2002, Santa Fe, NM.



# 7x24Exchange Server Cooling Work Group

## ◆ Charter:

- Understand thermal issues facing the modern data center, bring together the industry server thermal roadmap and data center cooling capacity, and chart a course for power and density growth over the next 5 years

# 7x24Exchange Server Cooling Work Group

## ◆ Activities & Accomplishments

- Review of regulatory issues & energy codes impacting data center power delivery, consumption, and removal
- Presentations on silicon power trends and equipment air-cooling limits
- Invited talks on alternative data center air-cooling technologies: enclosed racks, power management software, monitoring & controls, air handlers, etc., and possible transition to limited water cooling
- Information-sharing on current best practices – maintenance & operations, facility design, permitting, thermal capacity targets, etc.
- Material saved on chapter website:

◆ <http://www.7x24nw.org/workgrps.htm>

# 7x24Exchange Server Cooling Work Group

- ◆ Multidisciplinary industry membership

- ◆ IT/facilities managers
- ◆ Data center architects
- ◆ Infrastructure equipment manufacturers
- ◆ Engineering services providers
- ◆ Silicon/electronics manufacturers

- ◆ 33 members representing 17 companies

- |                         |                                  |                          |
|-------------------------|----------------------------------|--------------------------|
| ◆ APC                   | ◆ Equinix                        | ◆ Notkin Engineering     |
| ◆ Boeing                | ◆ Glumac International           | ◆ PSF Mechanical         |
| ◆ Callison Architecture | ◆ IBM                            | ◆ Rittal Corporation     |
| ◆ Campbell Company      | ◆ Intel Corporation              | ◆ RTKL                   |
| ◆ Carlson Solutions     | ◆ MacDonald-Miller/<br>Encompass | ◆ TiTAN World Class Safe |
| ◆ Carlyle               | ◆ Mazzetti & Associates          | ◆ University Mechanical  |

# Summary – Where Does This Leave Us?

- ◆ Performance and power are continuing to grow
- ◆ Still possible to air-cool computer equipment
  - 700W/U demonstrated with conventional technology
  - But not large aggregations of equipment
- ◆ Data center thermal capacity is the challenge
  - Air-cooled data center runs out of legs – eventually
- ◆ No “magic bullet”
  - Response must be logical and cost-effective

Aligning system power densities and Data Center thermal capacities is critical – now and in the future