Air-Cooling in Servers and IT Facilities

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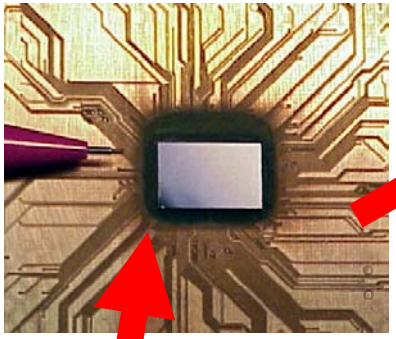
Thermal Challenges

- Server Power Trends
- Air-Cooling Limits – Data Center
- Air-Cooling Extensions – System-Level

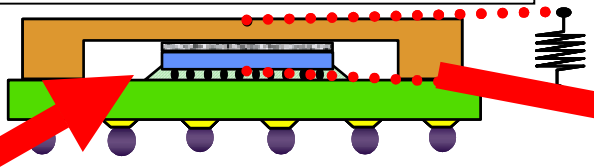
Discuss server architecture issues, for air-cooling at high power dissipation levels.

Heat Transfer Path – Air Cooling

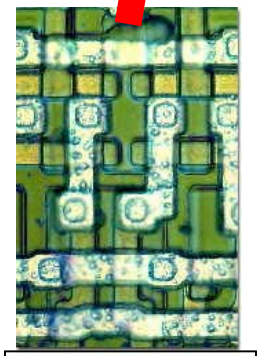
Silicon die



Processor package: lid, heat spreader, and TIM

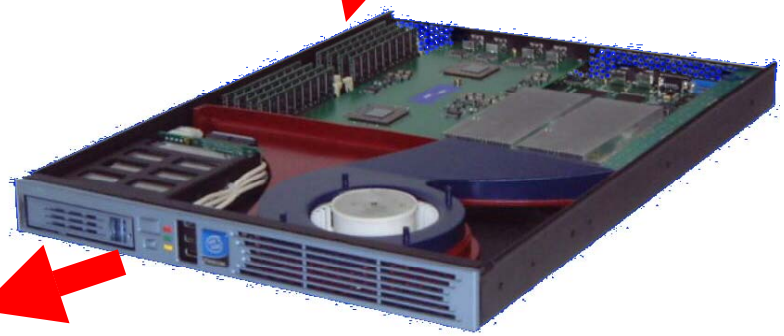


Heatsink – various materials and construction



Transistor junction

Data Centers and Other Facilities



System and Airmover

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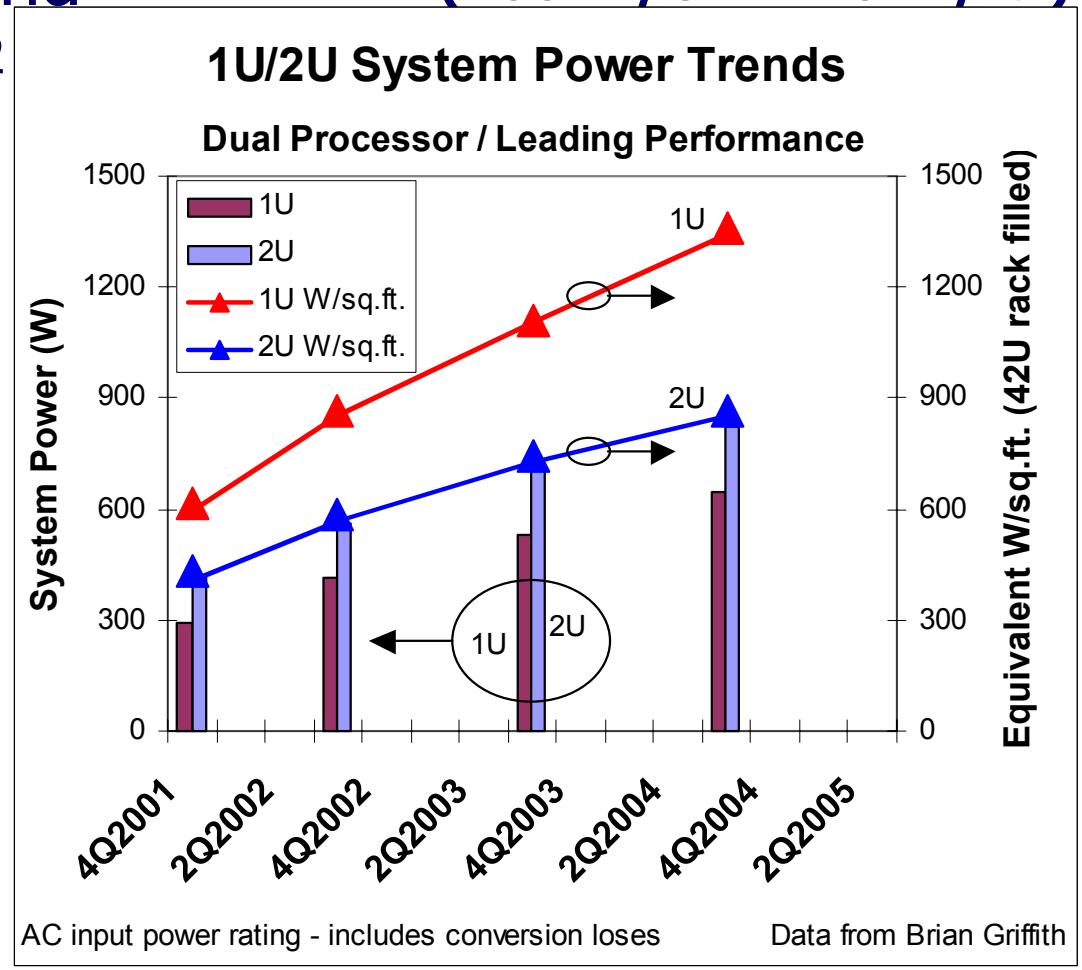
Intel Server Power Projections

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

(100 W/U = 210 W/ft^2)



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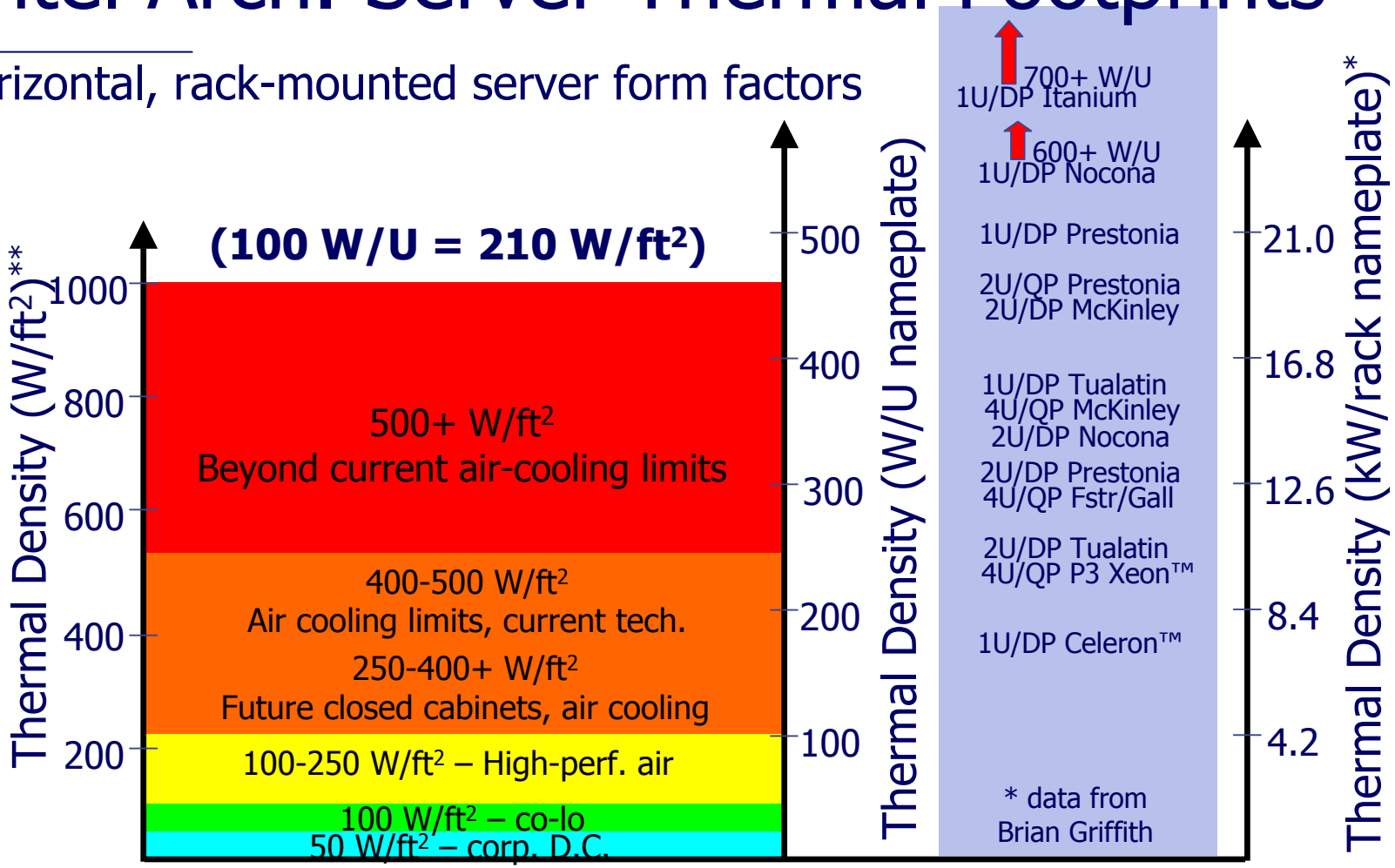
Intel Arch. Server Thermal Footprints

Horizontal, rack-mounted server form factors



* Assumes 42U/rack populated with these systems

** Allocates industry-standard 20 ft²/rack, no de-rating

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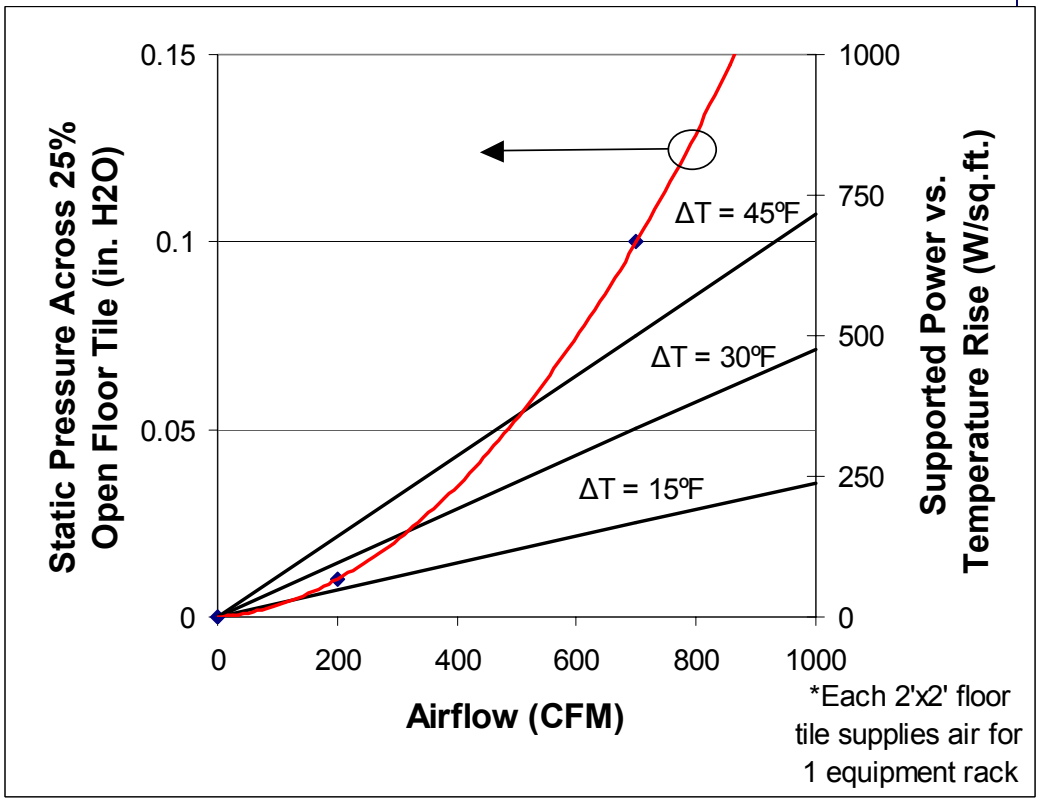
Raised-Floor Air-Cooling Limits

- Thermal Capacity vs. Hot-aisle/Cold-aisle ΔT, at 0.1"H_2O (aggressive ΔP) and 25% open tile
  - 15°F = 170 W/ft^2
  - 30°F = 330 W/ft^2
- Problems:
  - Maintaining high static pressures
  - Achieving large hot/cold split
  - Matching system air consumption w/ floor supply
  - Limiting air recirculation



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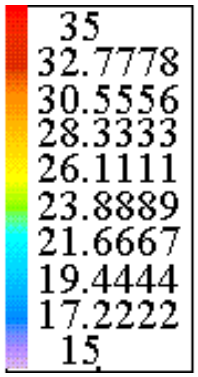
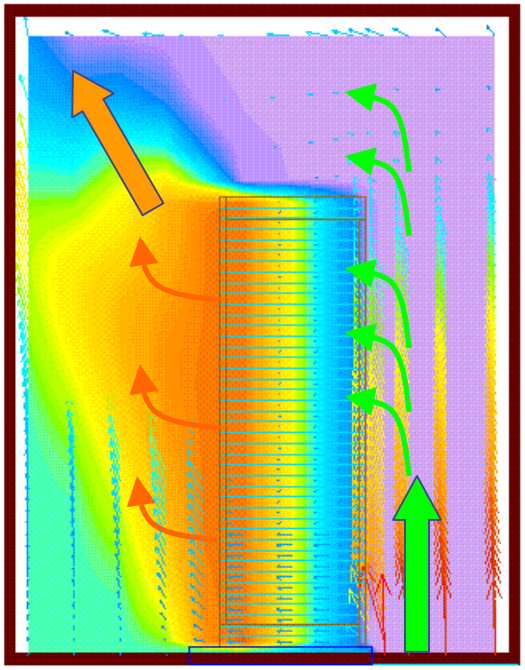
System Power vs. Airflow

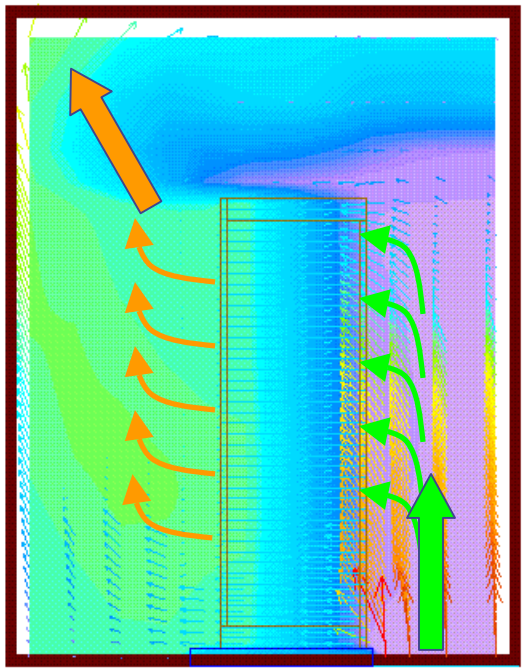
3339W Equipment Rack
42U uniform heat load
700cfm floor supply at 15°C/60°F

Temperature (°C)

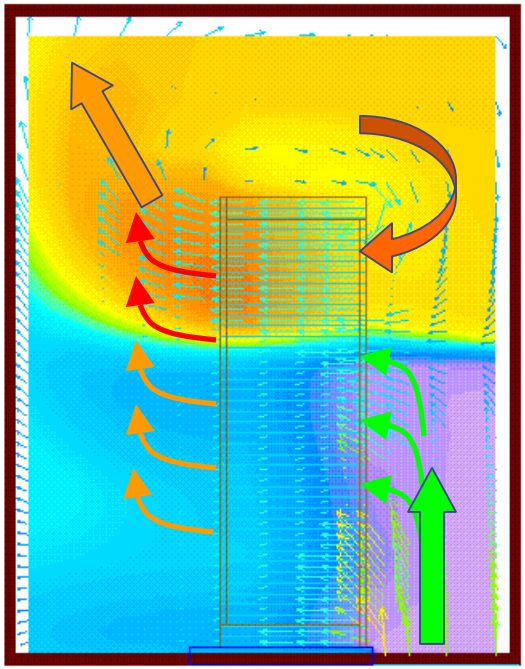




Rack total airflow: 350cfm
Max inlet temp: **16°C/61°F**



Rack total airflow: 700cfm
Max inlet temp: **18°C/64°F**



Rack total airflow: 1400cfm
Max inlet temp: **28°C/82°F**

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New "Conventional" Cooling Products

Enhanced raised-floor cooling

RTKL/APW
Tower of Cool*
rated @ 400 W/ft^2
(tested to 220 W/ft^2)

Hybrid H_2O-cooled cabinet

Liebert RackCooler*
rated @ 400 W/ft^2

A/C-ed cabinet

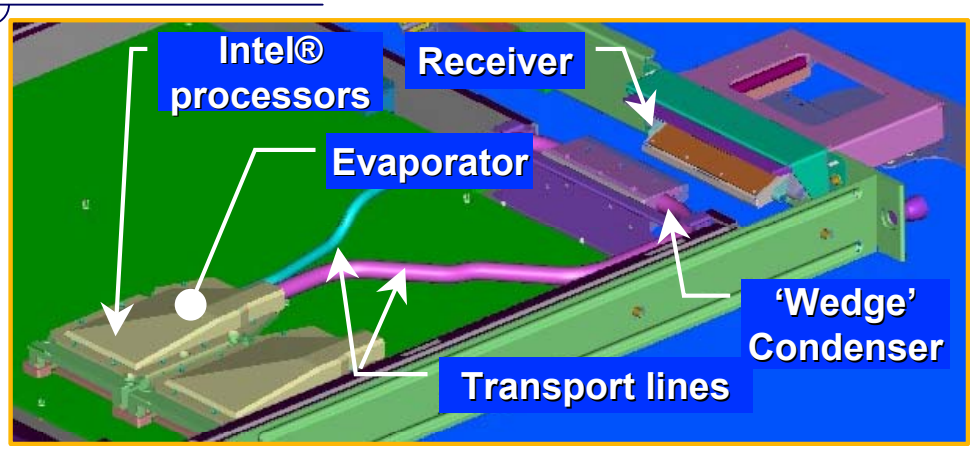
Rittal PSK*

Overhead air distribution unit

Liebert DataCool*
tested @ 500 W/ft^2

*Other names and brands may be claimed as the property of others.

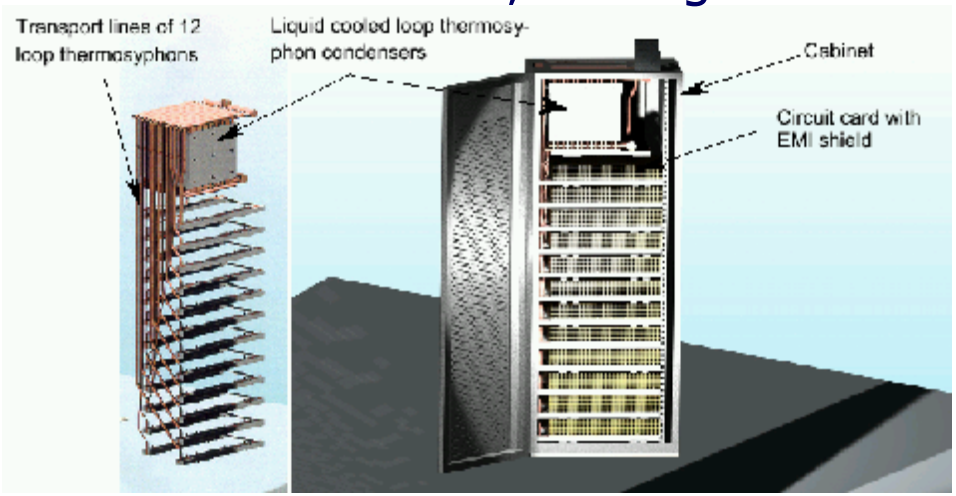
Non-Conventional Cooling Techniques



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

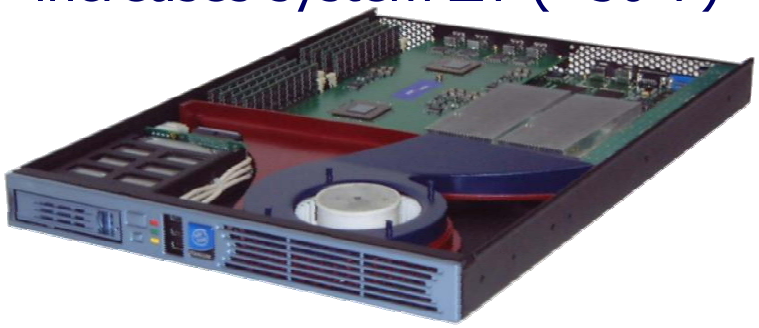
In-system passive cooling loop with rack-level thermal bus interface

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



* 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.

1U/DP McKinley server; high-performance blower increases system ΔT (>30°F)



Hurricane Ridge concept server, 700W+ nameplate power

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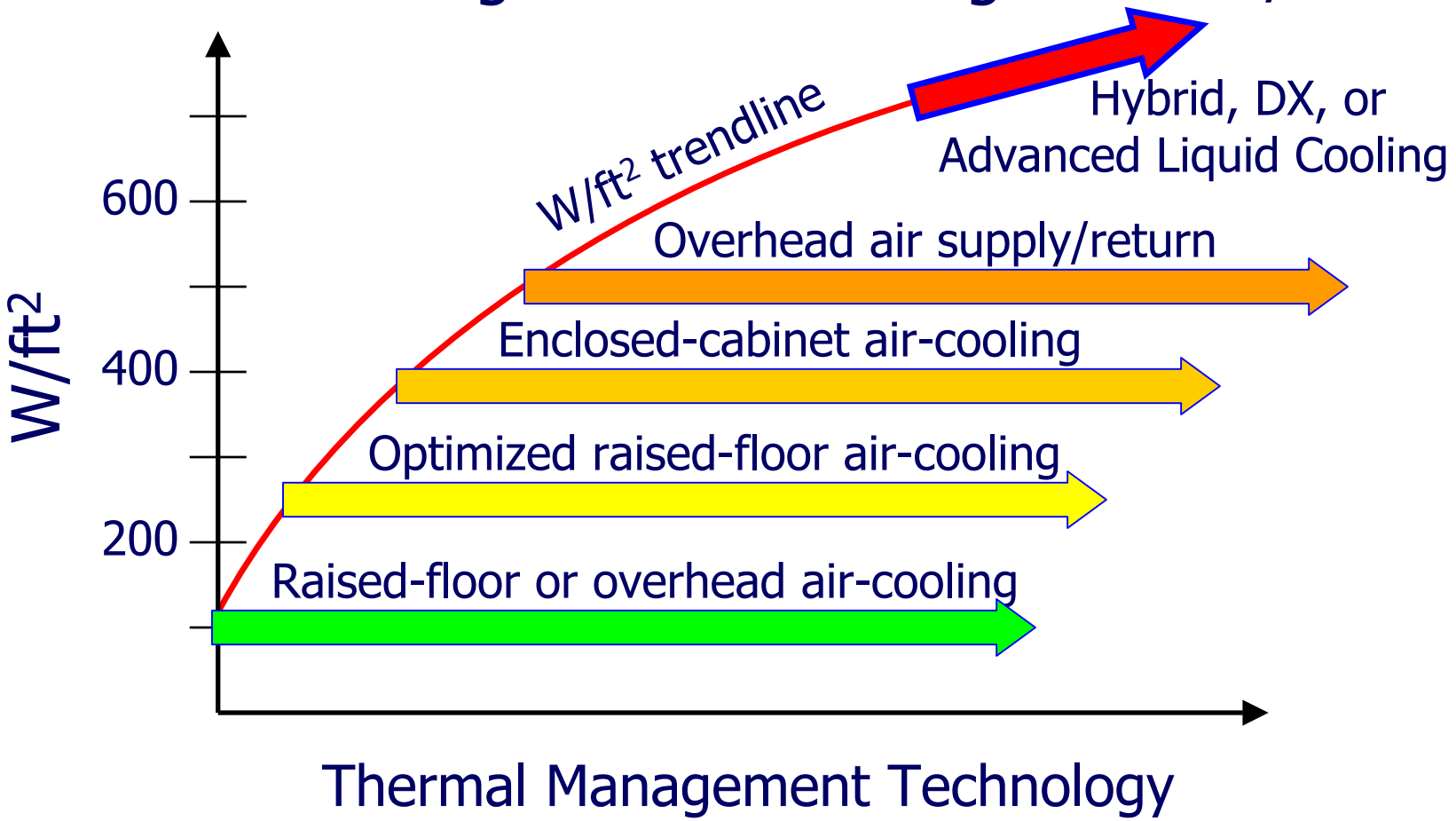
Thermal Capacity Limits

- Thermal management technologies vs. W/ft^2



Current Data Center Thermal Practices

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

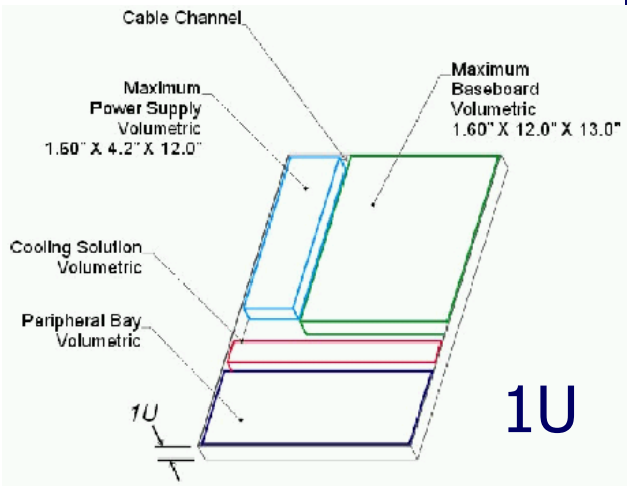
Meat of the bell-curve is 50-200 W/ft^2 for the next 2-3 years

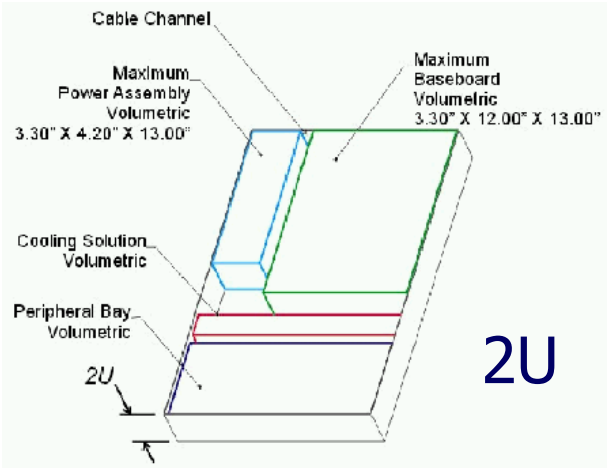
Air-Cooling Challenges

- Increase ΔT through system to prolong air-cooling at data center level
  - Match to supply CFM
  - Higher system and heatsink flow impedance
- Shrinking θ_{ja} budget due to increased processor power and non-uniformity
  - Even with proposed reduction in T_a limit to 32°C @ 1800m
- More restrictive vents/screens for EMI/EMC

Form-Factor Challenges

- Reduced volume and budget$ for thermal solution
- Continued shrinking form factors
  - Cost, performance density, deployment flexibility
- Axial fans and the SSI-spec chassis
  - Reliability problem of multi-fan system vs. non-redundant single fan (blower) systems
  - Reduces time between service/replacement calls





* from Thin Electronics Bay Specification Version 1.1 (http://www.ssiforum.org/docs/ssi_thin_elecbay_v1_1.pdf)

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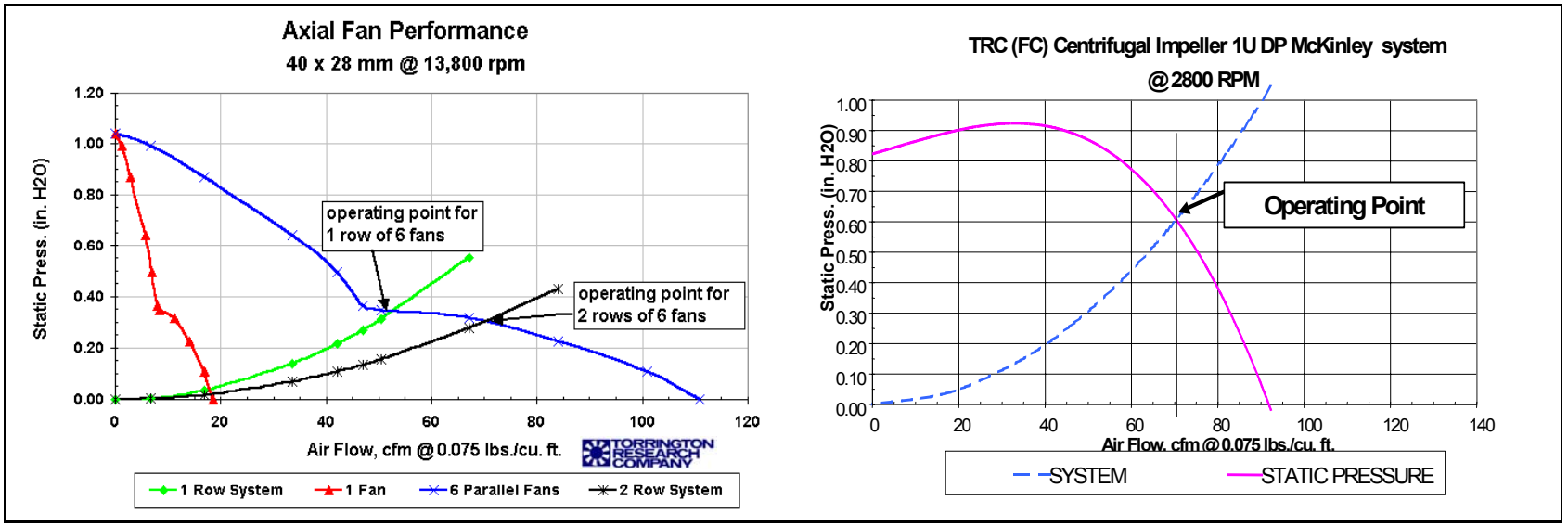
Axial vs. Radial Fans

- Higher system and heatsink impedance
  - Ducted radial impeller matches pressure & flow requirements



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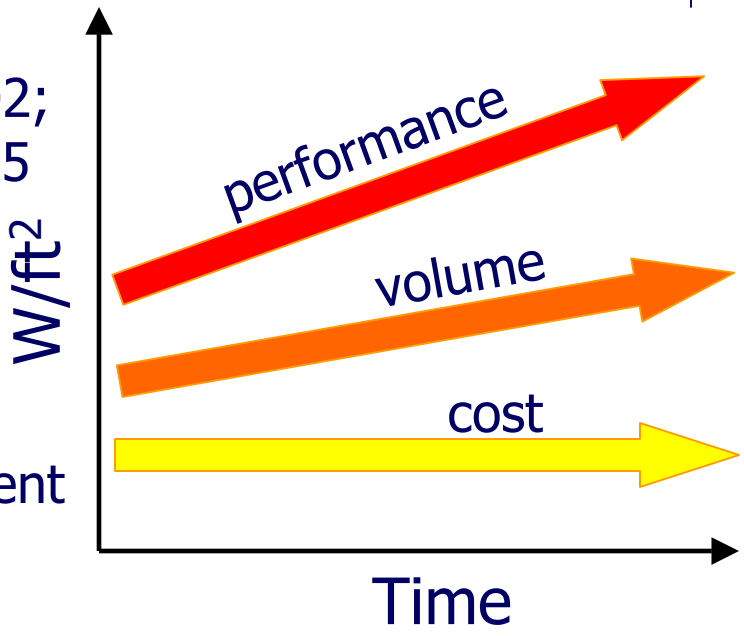
Possible Segments by Thermal Density

- Some will choose to stay with conventional air-cooling
  - Simplifies infrastructure and cooling design
  - Live within the performance density envelope
  - Lowest cost <100 W/U
  - Possible target: 100-125W/U for 2002; density grows to 150-200W/U by 2005
- Others will opt for the latest technologies
  - Maximize performance/U
  - Recognize thermal issues in deployment
    - Beyond 250W/U → consider alternative cooling technology
    - Plan now for limited transition to water-cooled equipment racks



Bifurcation in market based on cooling technology

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