Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Advanced Simulation & Computing

Power, Cooling and Energy Consumption for Petascale and Beyond

Birds Of A Feather

Systems: A Holistic View

"The whole is more than the sum of its parts."
Aristotle in Metaphysics

Andres Marquez
November 2007

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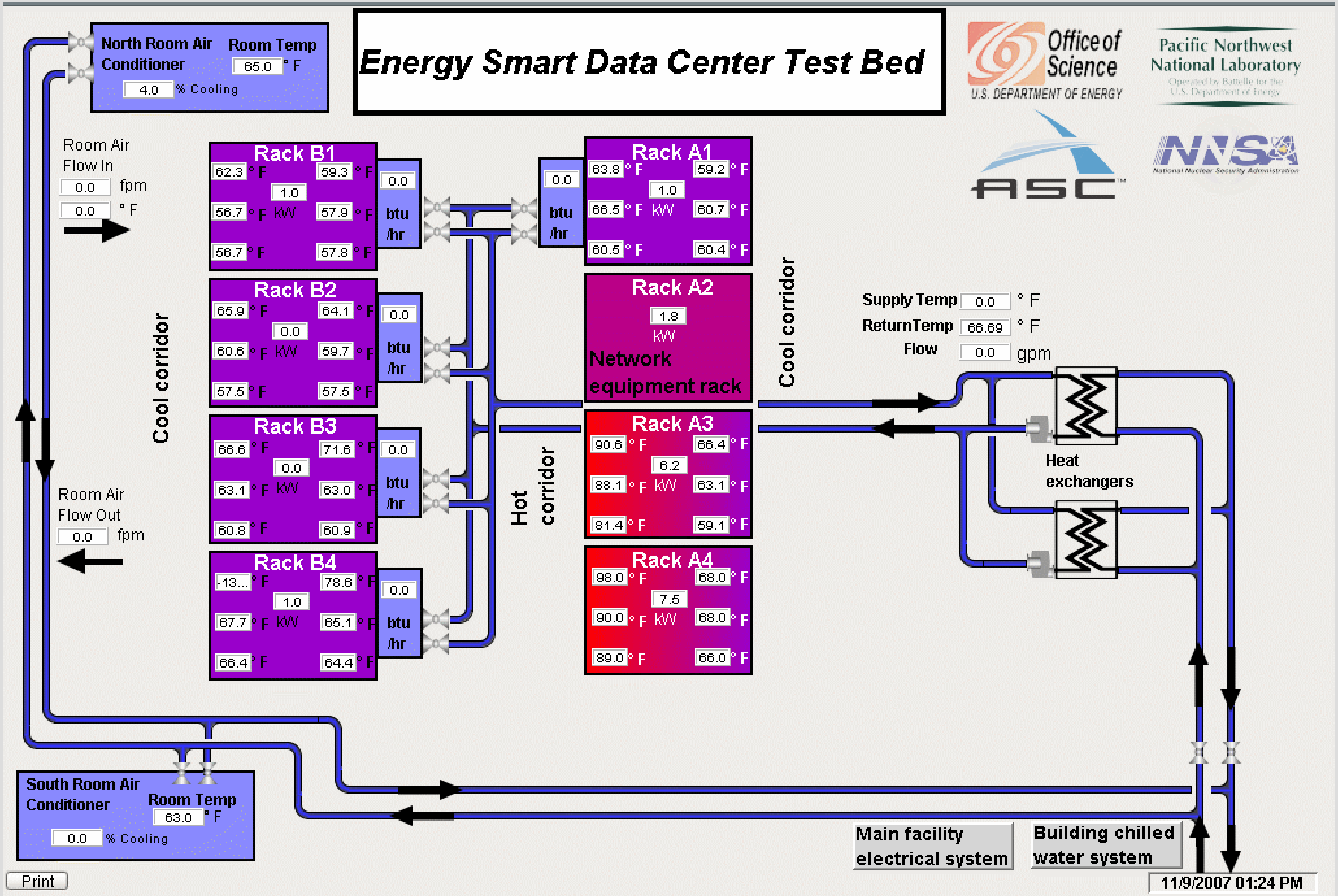
HPC-IT & IT-Infrastructure Form a System

- Data Centers designed without detailed knowledge of IT to be deployed can lead to:
  - Over- or Under-provisioned floor space
  - Over-engineered or unsuitable cooling capabilities
  - Under-provisioned power capabilities
- Future HPC-IT deployment requires "holistic" approach, encompassing power distribution, thermal management and IT as a unified systems solution:
  - First step should provide end2end – upstream to downstream – monitoring capabilities to observe IT & IT-Infrastructure system.
  - Second step should enable objective assessment of system's components and comparisons (Efficiencies: COP, PUE, OPS/s/Joule, Reliability, CAPEX, OPEX, TCO, ROI, etc.)
  - Third step should enable closed loop system control " ??? Aware Computing"

Fundamental Research of Efficient Datacenters (FRED)



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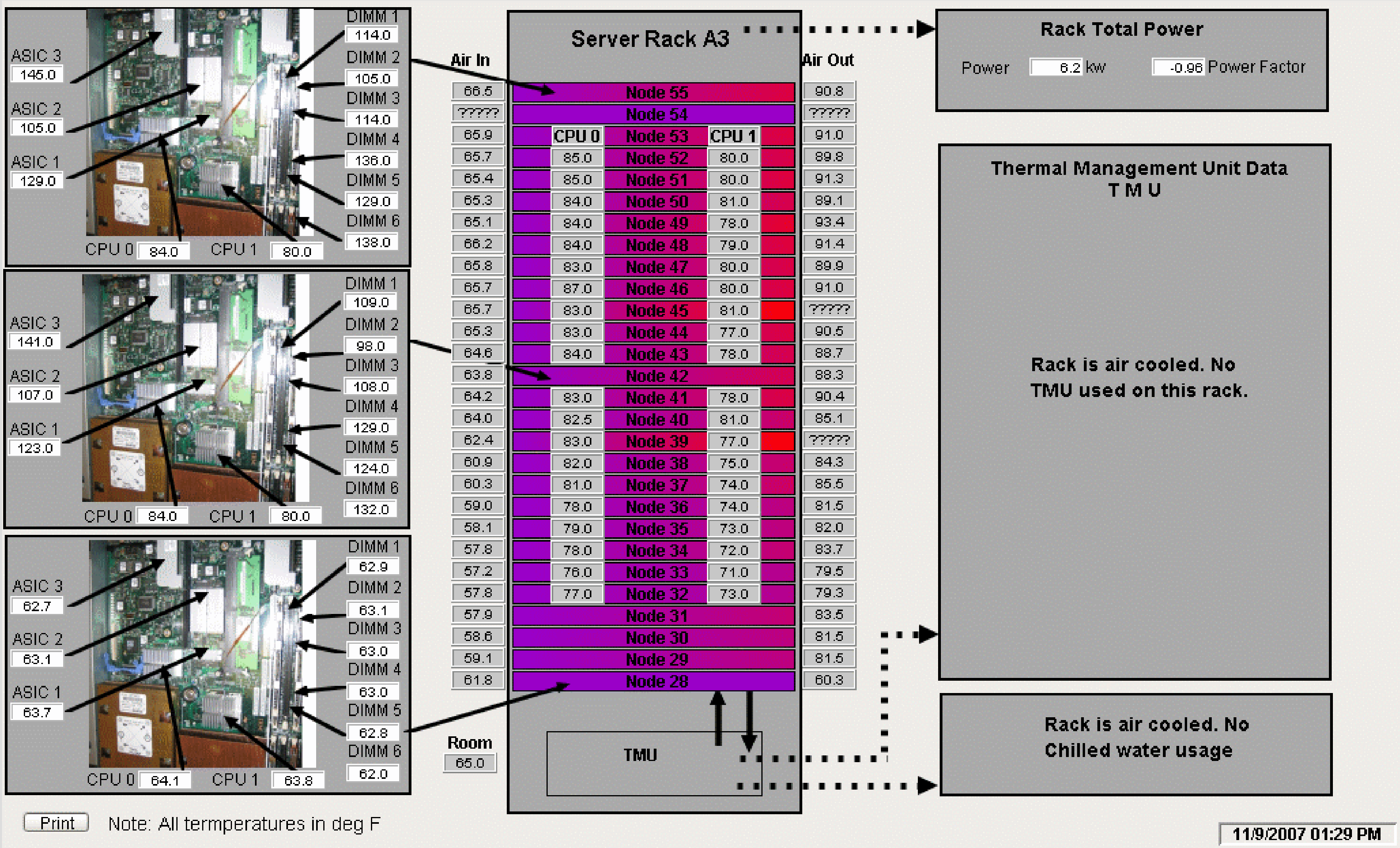
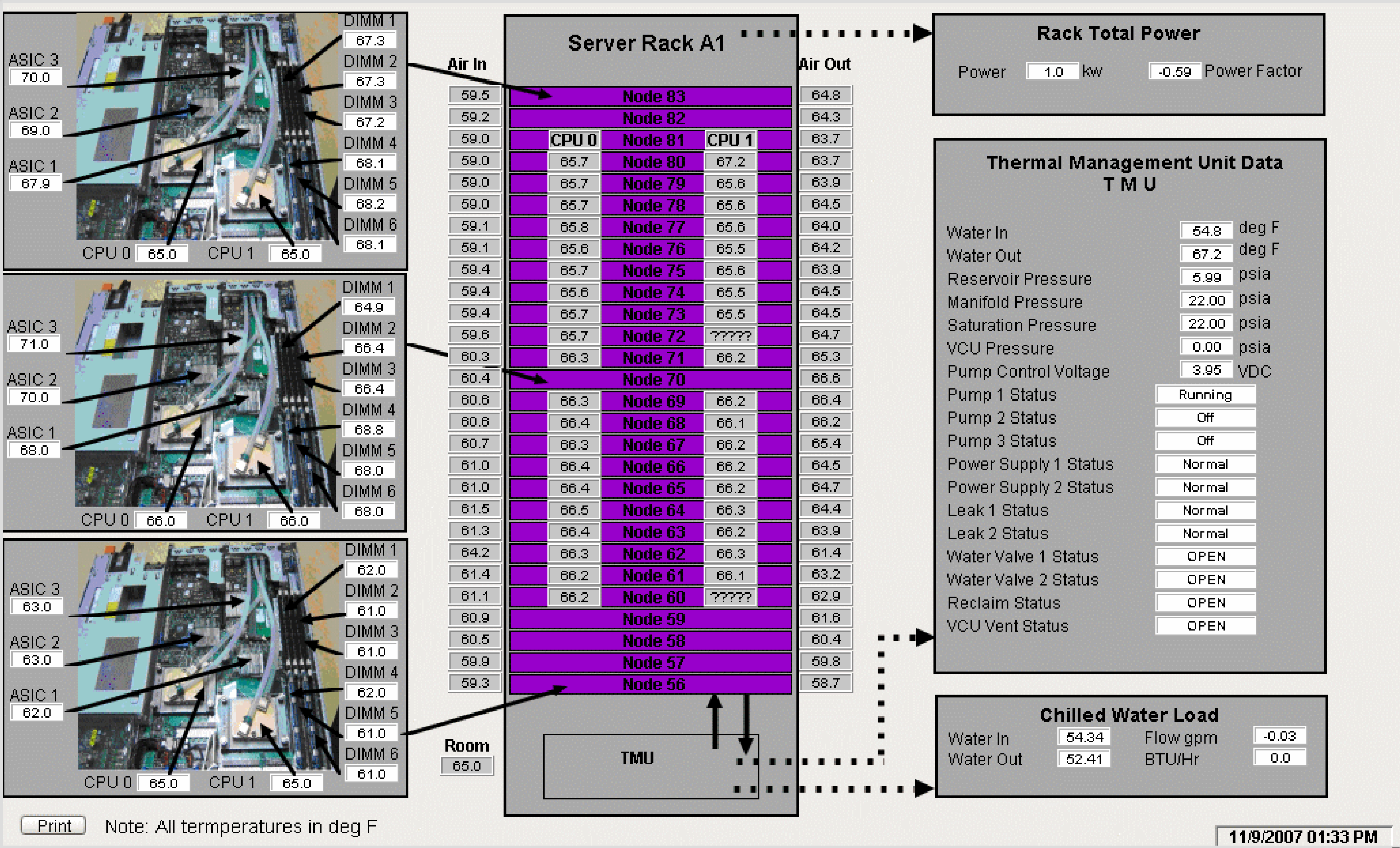
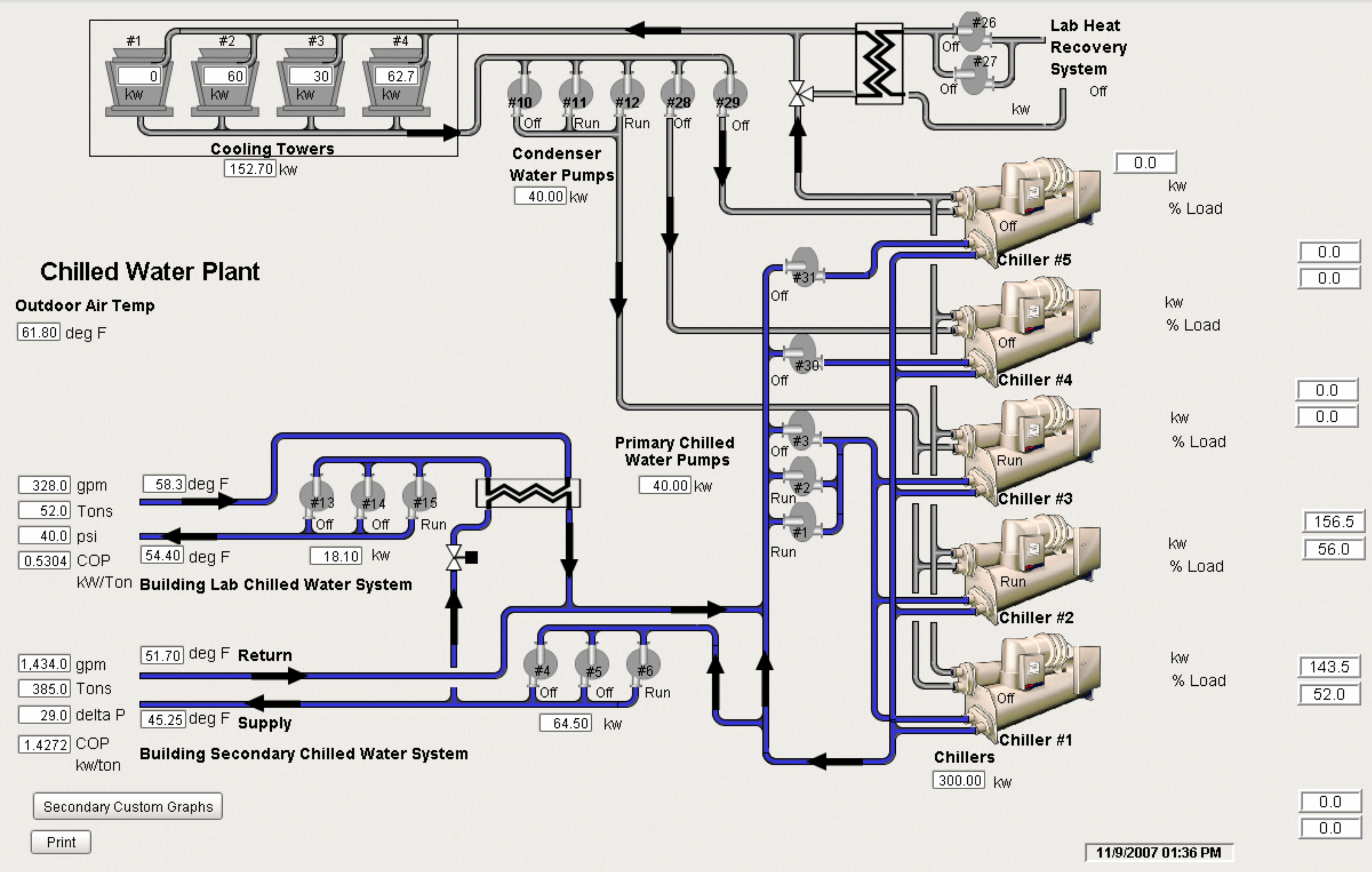
Air Cooled Rack



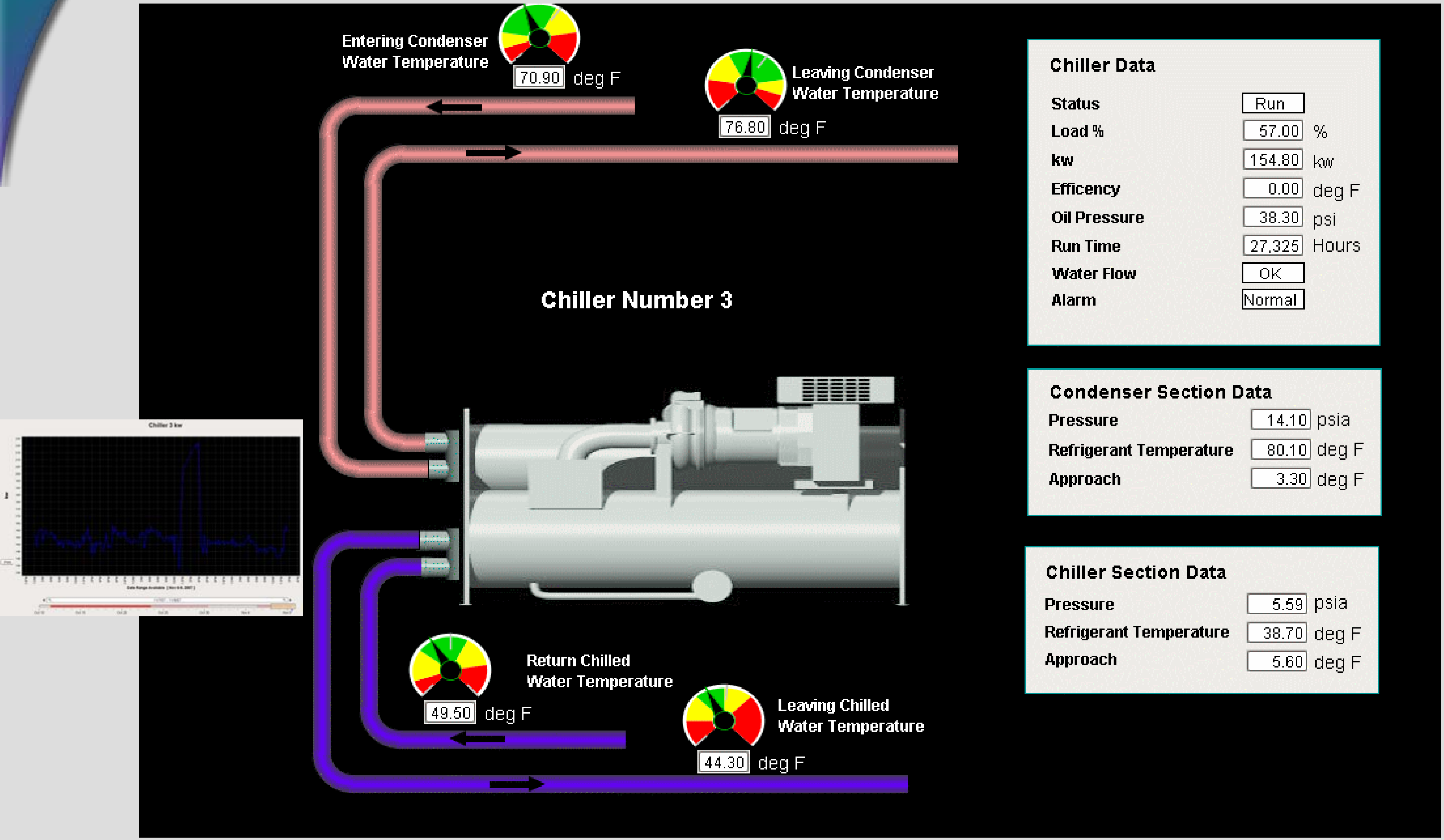
Mixed Evaporative/Air Cooled Rack



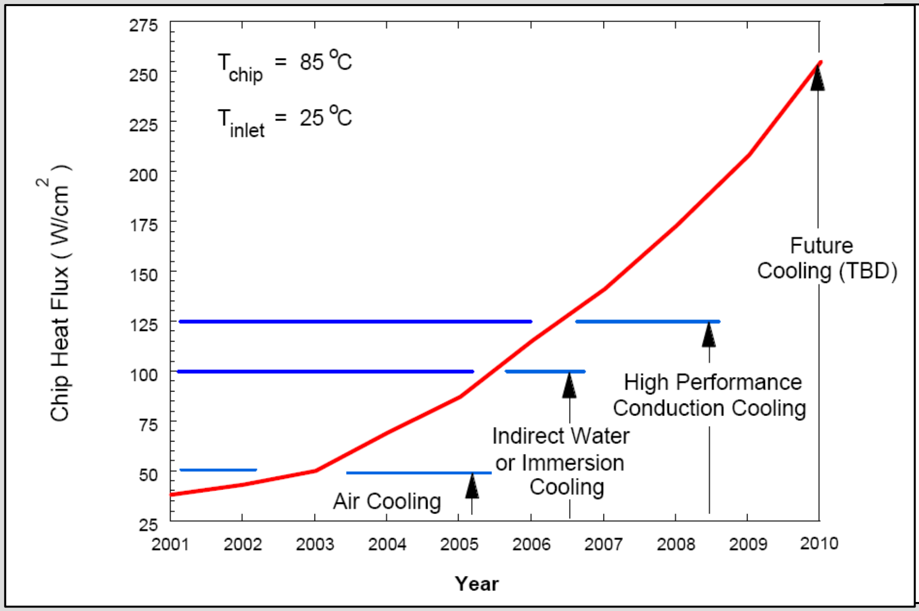
Monitoring Chilled Water

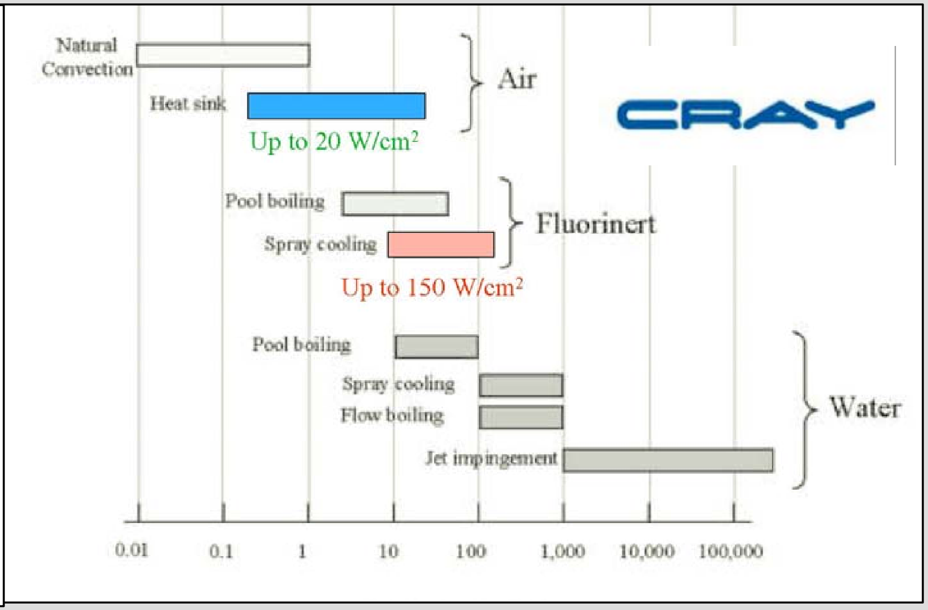


Chillers and Power Consumption



Krell Study: Densification and Cooling

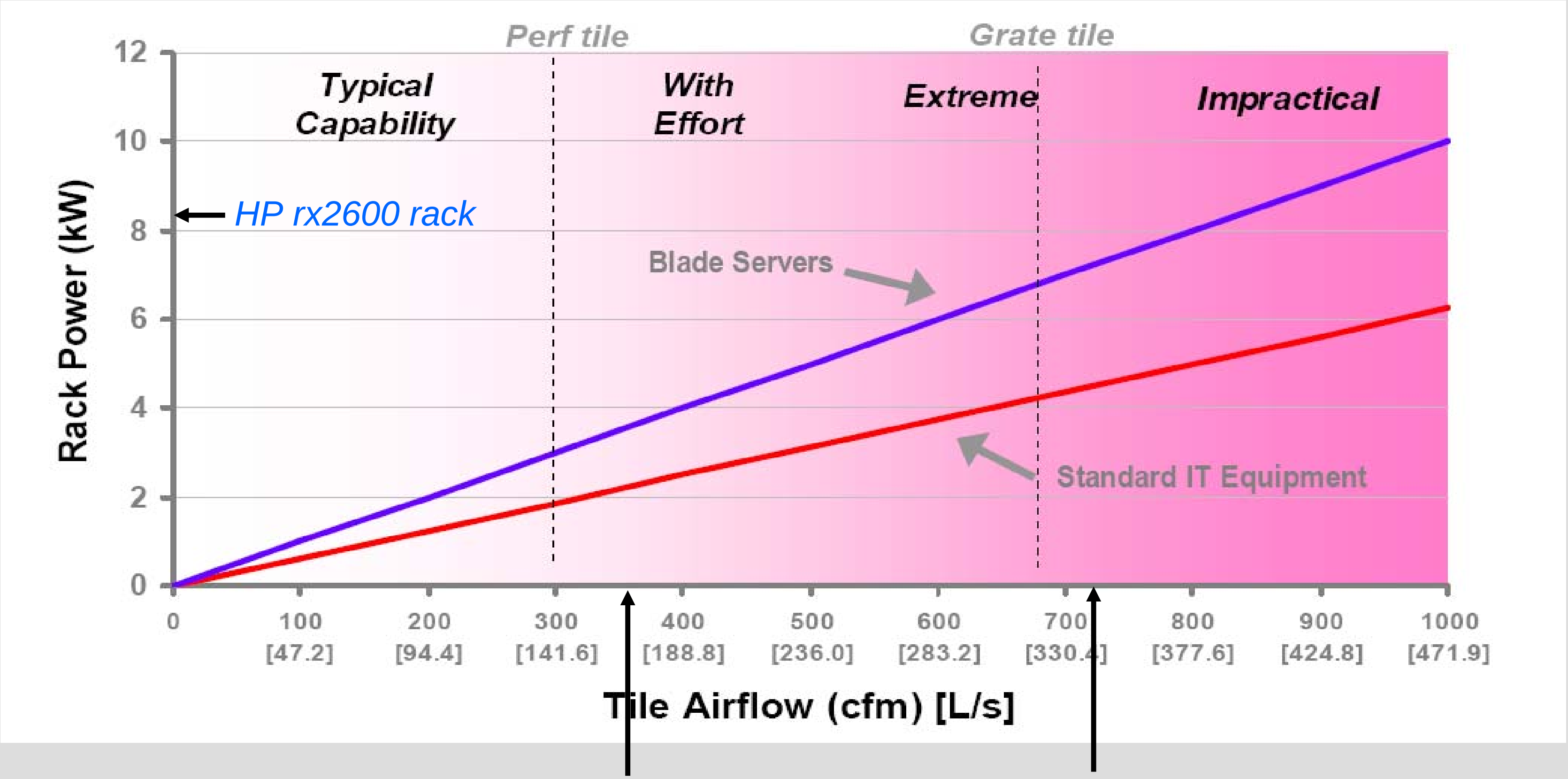




Projected Heat-Flux
W/cm^2

Critical Heat-Flux
W/cm^2

Facility Air Flow

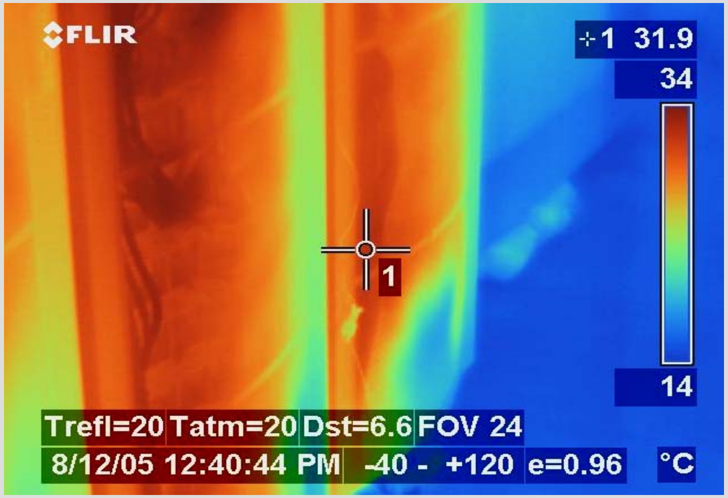


Evaporative Cooled HP rx2600 rack needs, 2005

PNNL perf tiles, 2005

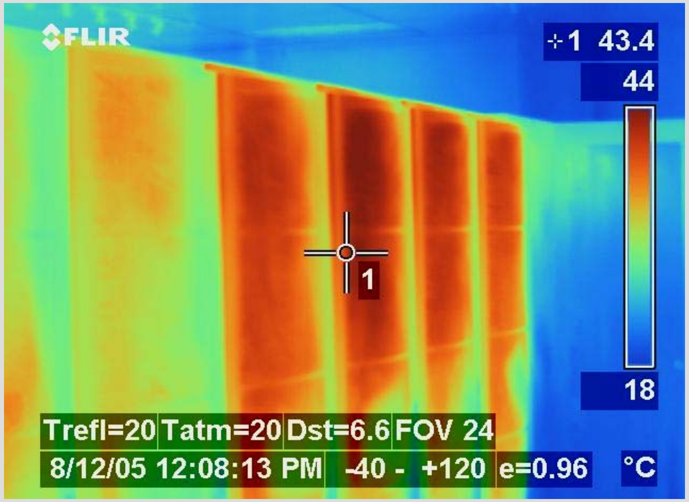
Source: Rasmussen, N., “Cooling Strategies for Ultra-High Density Racks and Blade Servers”, APC White Paper #46, www.apc.com

Air Cooling



Better location

- **Max recorded rack door temp of 39°C**
- **Exhaust air up to 26°C above floor tile air exit temp**



Poorer location

- **Max recorded rack door temp of 49°C**
- **Exhaust air up to 36°C above floor tile air exit temp**

- Air-cooled rack is very sensitive to location in the facility (note scale on best case location is 10* cooler than scale on worst case location)
- Large temp gradient over rack door

Evaporative Cooling

Situated in poorest location in facility

- **Max rack door temp of 24°C**
- **Exhaust air up to 11°C higher than floor tile air exit temperature**

- Evaporative cooled rack is relatively independent of location
- Requires less air flow - 2 fans removed per server
- Smaller temperature gradient over rack door

Evaporative cooled rack is generally 15°C cooler than air cooled rack in best location and 25°C cooler than air cooled rack in poor location.

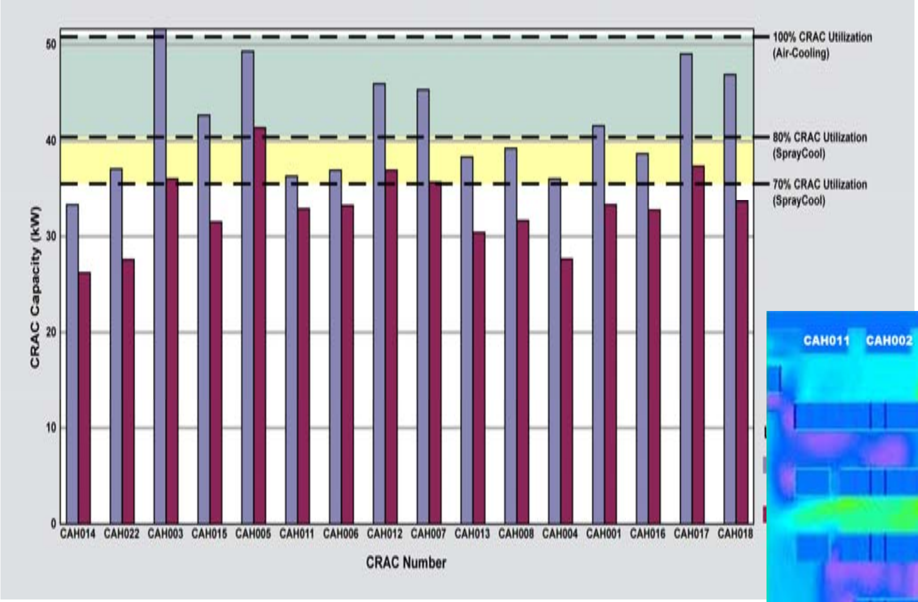
SprayModule rejects processor heat to liquid instead of the surrounding air – resulting in cooler environment for downstream components

Memory DIMMs

Power Supply

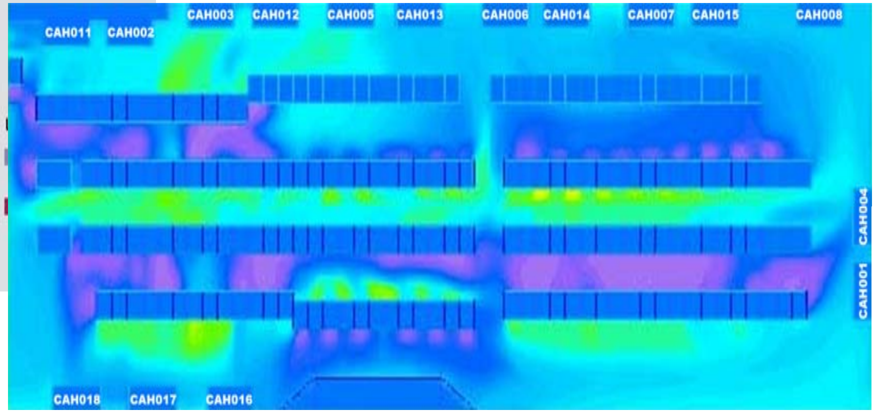
Feasibility Study:
CFD Model with Evaporative Cooling

Study suggests EMSL Facility Could Operate CRACs at 80%



Blowers running at 80% capacity can save 50% power.

CFD Model (by HP)
Running Evaporative Cooling



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How to enable holistic systems?

- What HW is required?
- What SW do we need to put in place?
- What processes do we require to enable this transition?
- What standards will promote this transition (we will hear about standards in a jiffy)?