

Power, Cooling and Energy Consumption for Petascale and Beyond

Birds Of A Feather

Systems: A Holistic View

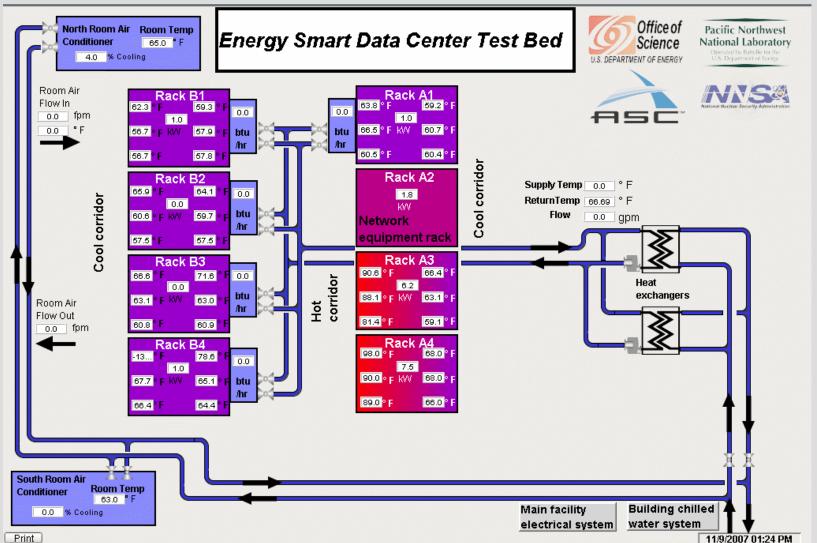
"The whole is more than the sum of its parts." Aristotle in Metaphysics

> Andres Marquez November 2007

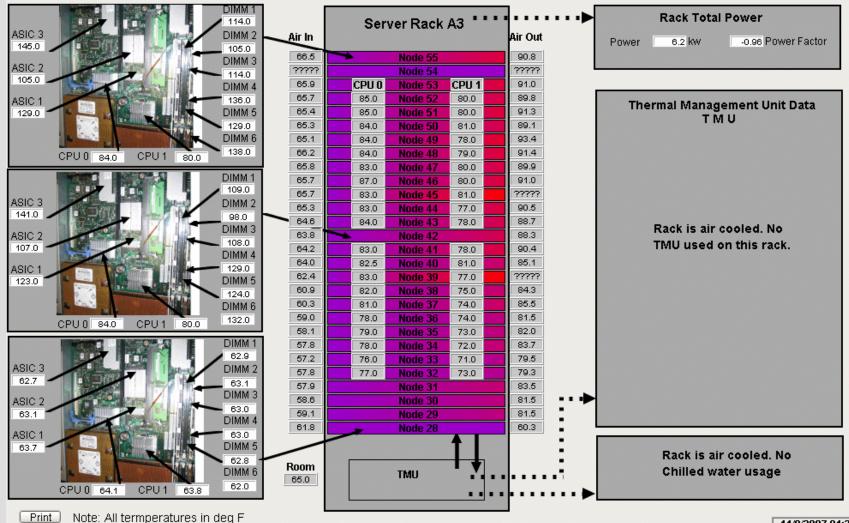
HPC-IT & IT-Infrastructure Form a System

- 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)



Air Cooled Rack



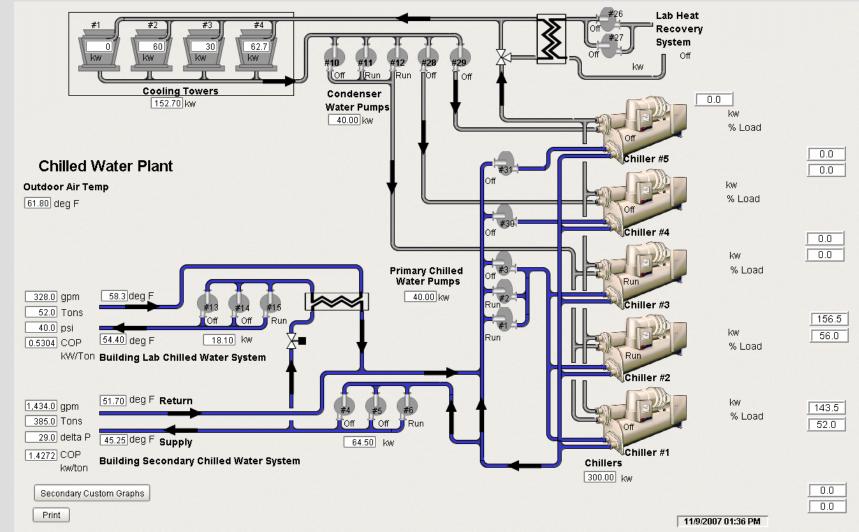
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Mixed Evaporative/Air Cooled Rack

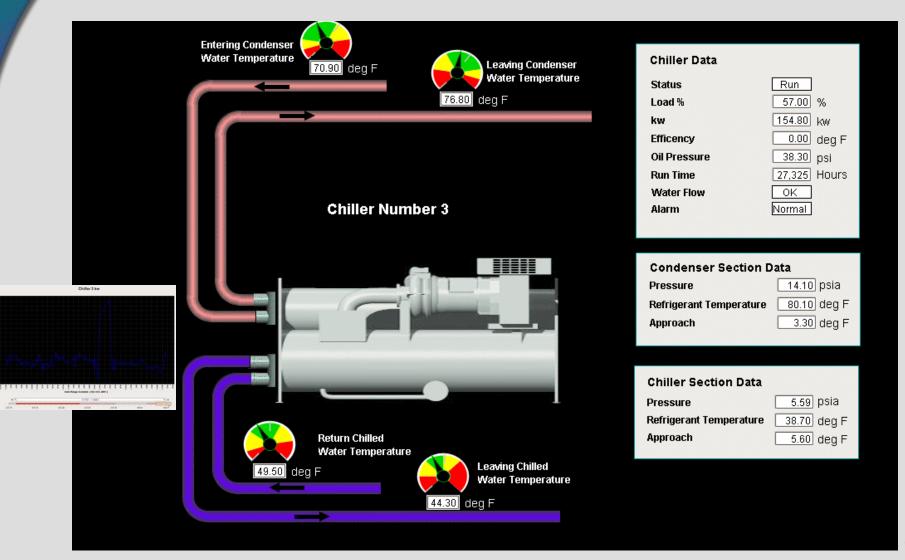
	Air In	Server Rack A1			Rack Total Power			
70.0 67.3							Power 1.0 kw	-0.59 Power Factor
	59.5		Node 83		64.8 64.3			
39.0	59.2 59.0	CDUG	Node 82	CDU 4	64.3			
DIMM 4	59.0	CPU 0 65.7	Node 81 Node 80	CPU 1 67.2	63.7		The sum of Manage	
BIC 1 68.1 57.9 DIMM 5	59.0	65.7	Node 79	65.6	63.9		T N	ement Unit Data
57.8 DIMM 3	59.0	65.7	Node 78	65.6	64.5		VI I	10
	59.1	65.8	Node 77	65.6	64.0		101-t In	54.8 deg F
CPU 0 65.0 CPU 1 65.0 68.1	59.1	65.6	Node 76	65.5	64.2		Water In	67.2 deg F
	59.4	65.7	Node 75	65.6	63.9		Water Out	5,99 psia
DIMM 1	59.4	65.6	Node 74	65.5	64.5		Reservoir Pressure	22.00 psia
64.9	59.4	65.7	Node 73	65.5	64.5		Manifold Pressure	
IC 3 DIMM 2	59.6	65.7	Node 72	77777	64.7		Saturation Pressure	22.00 psia
00.4	60.3	66.3	Node 71	66.2	65.3		VCU Pressure	0.00 psia
IC 2 DIMM 3 66.4	60.4		Node 70		66.6		Pump Control Voltage	3.95 VDC
0.0 DIMM 4	60.6	66.3	Node 69	66.2	66.4		Pump 1 Status	Running
IC1 68.8	60.6	66.4	Node 68	66.1	66.2		Pump 2 Status	Off
8.0 DIMM 5	60.7	66.3	Node 67	66.2	65.4		Pump 3 Status	Off
68.0	61.0	66.4	Node 66	66.2	64.5		Power Supply 1 Status	Normal
DIMM 6	61.0	66.4	Node 65	66.2	64.7		Power Supply 2 Status	Normal
CPU 0 66.0 CPU 1 66.0 68.0	61.5	66.5	Node 64	66.3	64.4		Leak 1 Status	Normal
	61.3	66.4	Node 63	66.2	63.9		Leak 2 Status	Normal
	64.2	66.3	Node 62	66.3	61.4		Water Valve 1 Status	OPEN
	61.4	66.2	Node 61	66.1	63.2		Water Valve 2 Status	OPEN
33.0 61.0	61.1	66.2		77777 <u> </u>	62.9		Reclaim Status	OPEN
DIMM 2	60.9		Node 59		61.6		VCU Vent Status	OPEN
BIC 2 61.0	60.5 59.9		Node 58		60.4 59.8			
DIMM 4	59.3		Node 57		58.7	-		
IC1 62.0			Node 56		50.7			
62.0 DIMM 5		TI			-	Chilled Water Load		
61.0 DIMM 6	Room					-	Water In 54.34	Flow gpm -0.03
	65.0		TMU			•	Water Out 52.41	BTU/Hr 0.0
CPU 0 65.0 CPU 1 65.0 * 61.0								

5

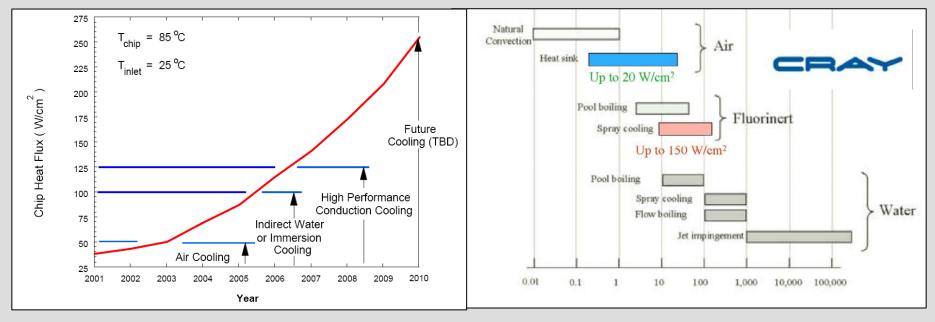
Monitoring Chilled Water



Chillers and Power Consumption



Krell Study: Densification and Cooling

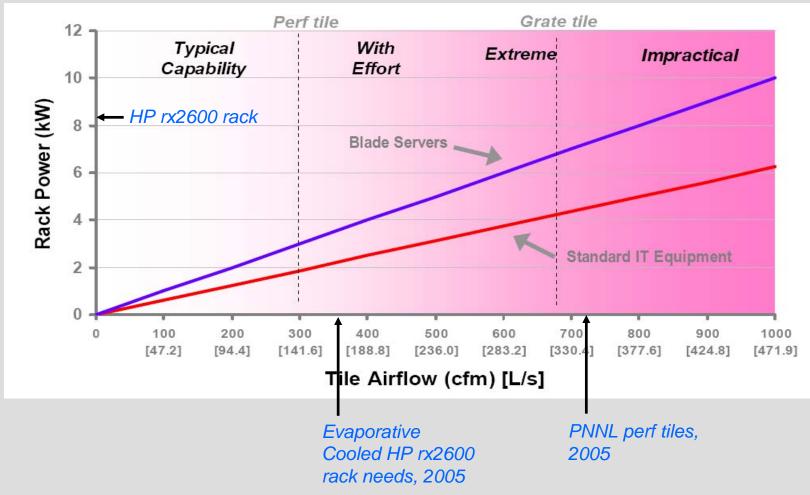


Projected Heat-Flux W/cm^2

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

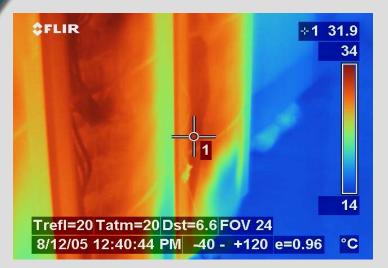
> Critical Heat-Flux W/cm^2

Facility Air Flow



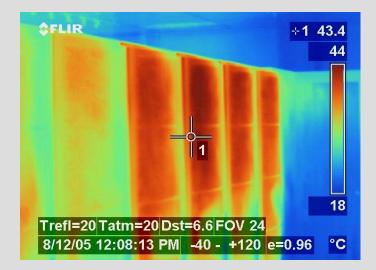
Source: Rasmussen, N., "Cooling Strategies for Ultra-High Density Racks and Blade Servers", APC White Paper #46, www.apc.com

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



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Department of Energy

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

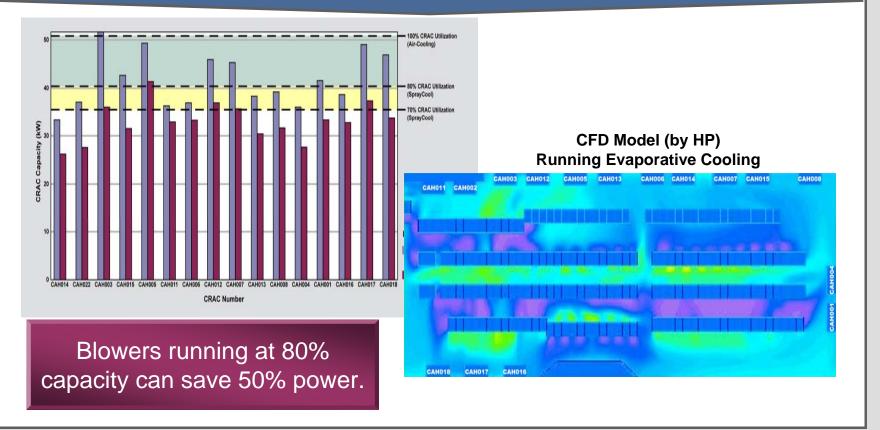
Evaporative cooled rack is generally 15°C cooler than air cooled rack in best location and 25°C cooler than air cooled rack in poor location. SprayModule rejects processor heat to liquid instead of the surrounding air – resulting in cooler environment for downstream components



Feasibility Study: CFD Model with Evaporative Cooling

Study suggests EMSL Facility Could Operate CRACs at 80%

Pacific Northwest



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)?