

Shrinking Data Center Size, Complexity, and Cost through Directed-Flow Liquid Immersion Cooling

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The Liquid Cooling Landscape

Other Companies are doing...

- **Cold Plates**

Direct-to-Chip, Fluid-to-Chip, Spot Cooling

- **Back of Rack Cooling**

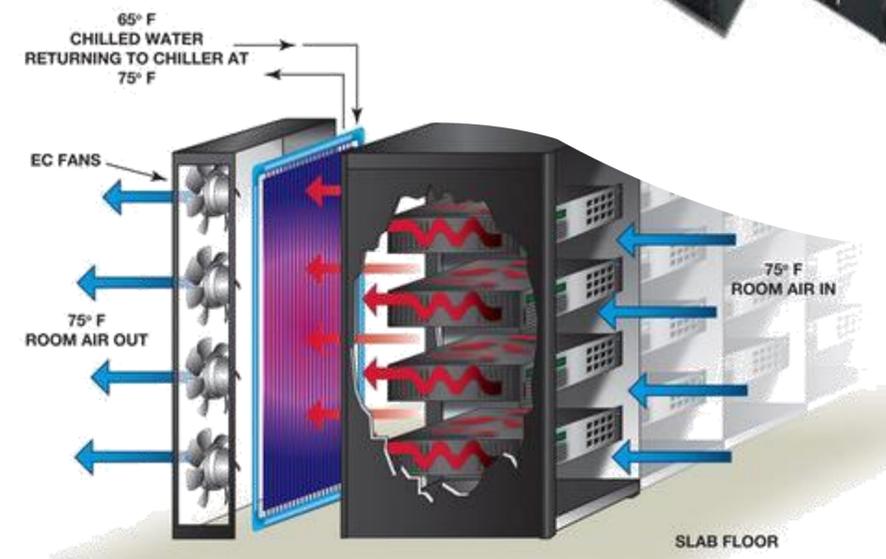
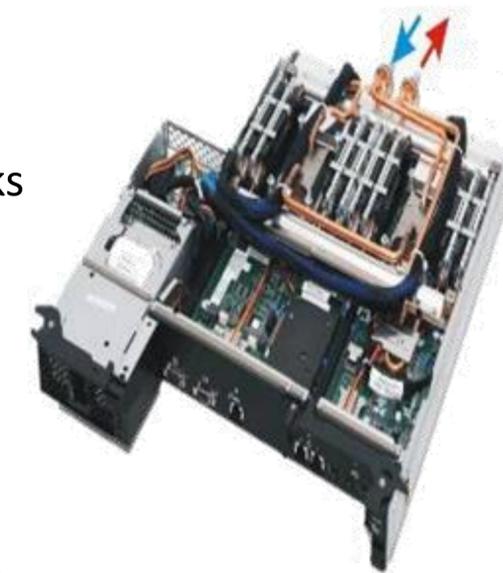
Active Rack, Rear Door, Chilled Door Cooling

- **Two-phase Immersion**

Novec, Passive 2-Phase, Spot-Cooling

Cold Plates

- Individual Heatsinks
- Board-Specific
- Individual Chip Fluid-cooling



Back of Rack

- Air is still only means to cool board/chip
- Limited by existing chip maximum temps
- Requires additional fans

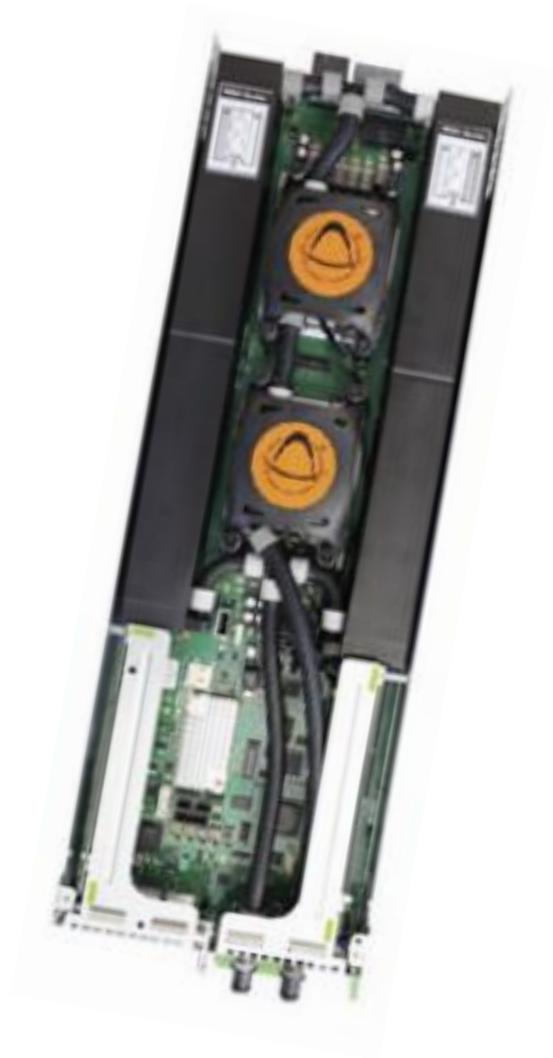
Two-Phase Immersion

- Specialty fluids (\$\$\$)
- Can Require Separate Cooling Coil
- Orientation sensitive



Liquid Cooling Approaches

Direct-to-Chip Cooling



The Pros:

- Improves cooling efficiency – better PUE
- Increases compute density in servers nodes

The Cons:

- Water is used at each server node and in data hall.
- Only a portion of the server components are cooled with liquid, fans still required.

Liquid Cooling Approaches

Two-Phase Immersion



The Pros:

- Very effective at removing heat from CPU/GPU
- Provides excellent cooling energy efficiency
- Fans and air-cooling infrastructure are eliminated

The Cons:

- Two-phase fluid has high GWP, very expensive and volatile,
- Sealed enclosure contains coolant vapor under high pressure
- Micro-cavitation effects raise long-term reliability concern
- Requires water circulation in server enclosure

Liquid Cooling Approaches

Single-Phase Immersion



The Pros:

- Very effective removing heat from all electronics.
- Fans and air-cooling infrastructure are eliminated
- Non-volatile; low cost fluid
- Improved reliability and TCO

The Cons:

- Open tank designs
- Weight / large footprint
- Serviceability and fluid containment.



ElectroCool[®] Dielectric Coolant

Make it Safe and Keep it Simple

The right single-phase dielectric coolant for your solution makes all the difference:

- **Safe for our environment, your equipment, and your people**
 - Guaranteed materially compatible and non-destructive to metals, electronics, and most plastics
 - Never changes phase to gas thus eliminating high pressure, seal systems and gaseous vapor in IT room
 - 10 Year operational characteristics warranty, Biodegradable, Non-Toxic, Non-Allergenic, Not Flammable
- **Eliminates all water from the IT white space**
 - Reduce complexity, maintenance, and risk related to water in proximity to electronics
- **Eliminates server fans, CRACs, air handlers chillers, dehumidifiers, and filters**
 - Immediate increase in server MTBF and eliminate a majority of scheduled maintenance.
- **Requires very low flow rate (<.5 GPM per kW) and pressure (<5 PSI) for cooling infrastructure design**
 - Reduction in liquid coolant piping infrastructure cost and complexity
 - Utilize off-the-shelf, low cost, highly reliable & redundant pumps
 - Typical pumping system requires only 3% of energy cooled (3kw to cool 1MW)
- **Higher coolant supply temps (<130 °F/54 °C) and simple heat reuse**
 - Use simple dry coolers with <15% active duty fans in most conditions (even humid locations) due to high coolant temps and coolant heat density.
 - Use of high efficiency, compact Liquid-to-Liquid HEX for heat transfer and reuse

ElectroCool[®] vs other Dielectrics

Characteristic	ElectroCool [®]	Mineral Oil	Fluorinated Fluids
Dielectric Strength (ASTM 1816)	60kV	25kV	40kV
Relative Heat Capacity (<i>Air = 1</i>)	1410	1170	1360
Density (g/cm ³ @ 20C)	.80	.85	1.72
Flammability	Not Flammable	Flammable	Not Flammable
Environmental Impacts	GWP = 0	GWP = 0	GWP > 9000
Worker Health and Safety	✓		
Biodegradable and Nontoxic	✓		
Characteristics are Standardized, Tested and Guaranteed	✓		✓
Material Compatibility Guarantee	✓		
Cooling Systems are Simple, Quiet, and Clean	✓	✓	

LiquidCool's Approach

LiquidCool Inc. combines:

- Total fluid immersion of server in 19 inch rack.
- A directed-flow fluid circulation system
- Uses ElectroCool - synthetic single-phase dielectric coolant specially engineered for cooling electronics

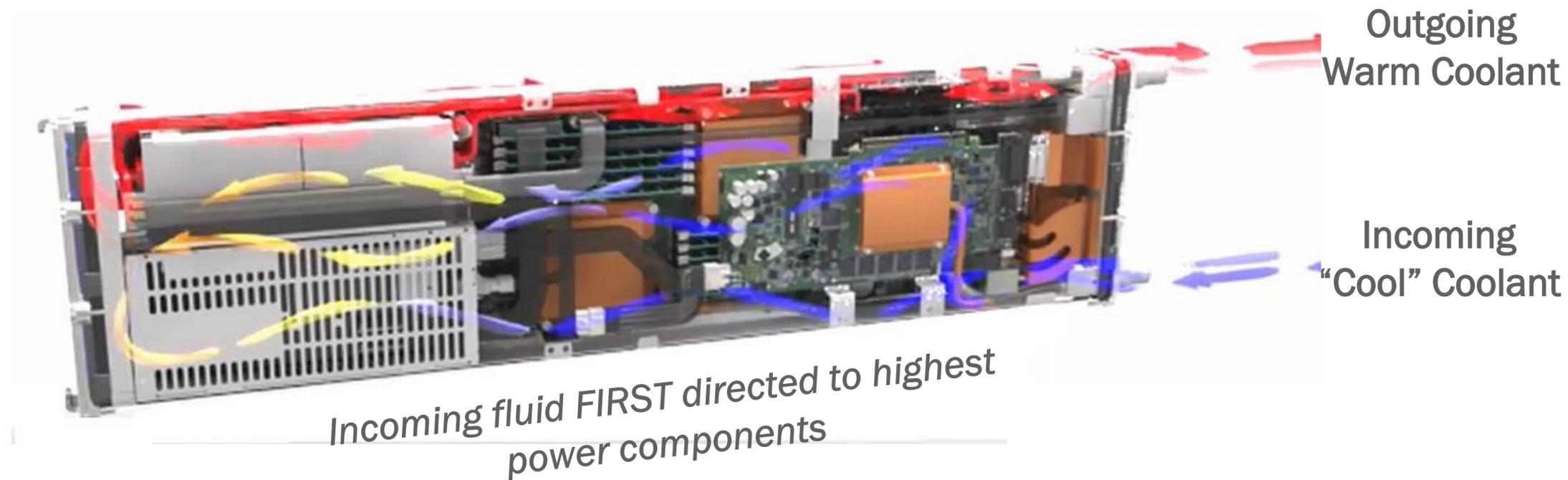


The Result:

LiquidCool's Directed-Flow Total Immersion Cooling delivers all the benefits of other liquid-cooling approaches

How it Works

Directed-Flow makes the difference



34 granted patents

17 Additional patents pending

With **Directed-Flow**

- Server and CPUs s run much cooler
- Compute density can increase
- Cooling and energy efficiency can be optimized



LiquidCool sealed Server

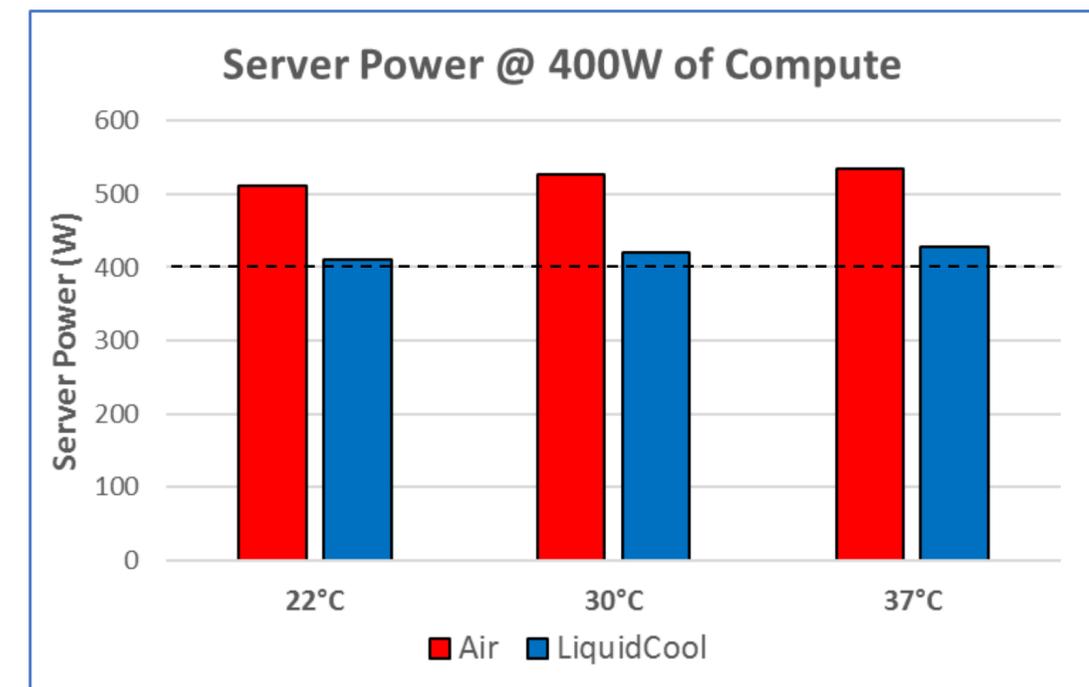
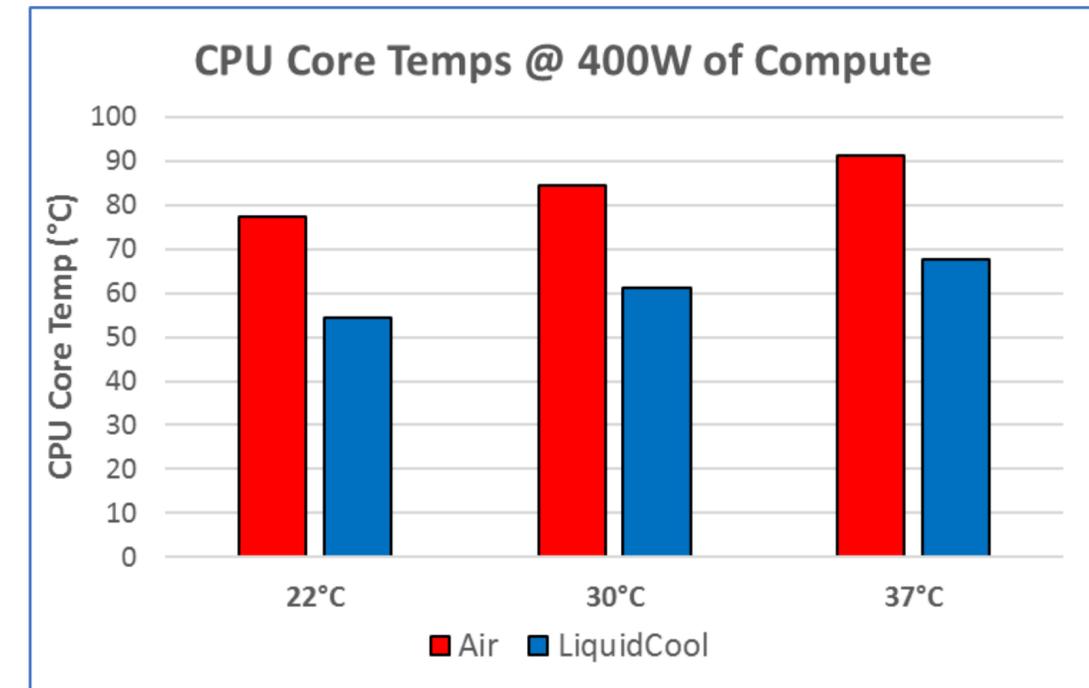
Thermal & Power Advantages

Total Immersion + Directed Flow means...

CPUs operate up to 30°C cooler compared to air cooling

No rack fans + Cooler CPUs means...

LiquidCool servers use up to 20% less power vs. equivalent air-cooled servers



Source: LiquidCool "Server Power-to-Cool" whitepaper

LiquidCool Servers



Rack Server Systems for Data Centers

- Up to 96 servers per standard rack
- Up to 50kW of computing per rack
- Tailorable to OCP server configurations

Enterprise Installations



National Renewable Energy Laboratory

LSS server system tested for energy efficiency and heat recovery effectiveness in conjunction with the Wells Fargo IN² Program*

System now in operation in the NREL ESIF

- <https://www.nrel.gov/docs/fy18osti/70459.pdf>
- Running OpenStudio tool suite for researchers



CBRE|ESI Smart Building Client Center

LSS server nodes installed at the CBRE|ESI Client Experience Center. Three 2 socket servers running Vmware. SSDs and HDDs for storage. Two mission critical services.

Smart Building systems
Call center operations.

The numbers

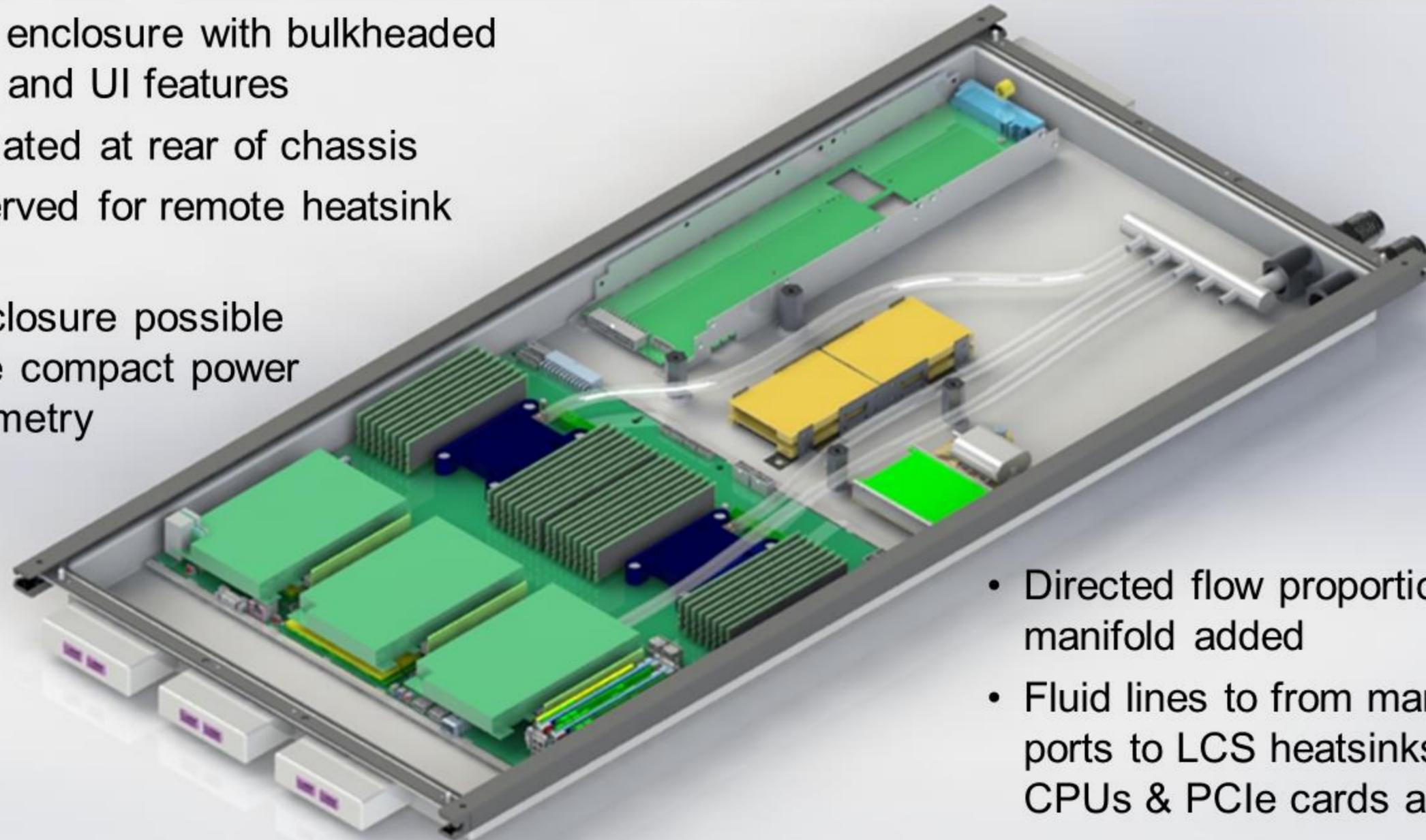
Cooling System Specs

Coolant Flow Rate (per kW)	0.3 - 0.5 GPM
Coolant Pressure	Less than 5 PSI
Coolant Volume (per CPU)	0.7 - 0.8 gallons
Coolant weight per Data Center Rack	450 – 700 lbs.
Weight of fully-populated 42U Rack	2900 - 3000 lbs.
Maximum Incoming Coolant Temperature	54° C (129° F)
Typical Partial PUE (per dielectric loop)	1.01 – 1.03
Heat Energy Recovery Effectiveness	90% - 95%
Heat Energy Reuse Temperature	Up to 60° C (140° F)

LiquidCool – OCP Concept

Olympus Server repackaged in LiquidCool enclosure

- Liquid tight enclosure with bulkheaded power, I/O, and UI features
- Fans eliminated at rear of chassis
- Space reserved for remote heatsink eliminated
- Shorter enclosure possible with a more compact power supply geometry



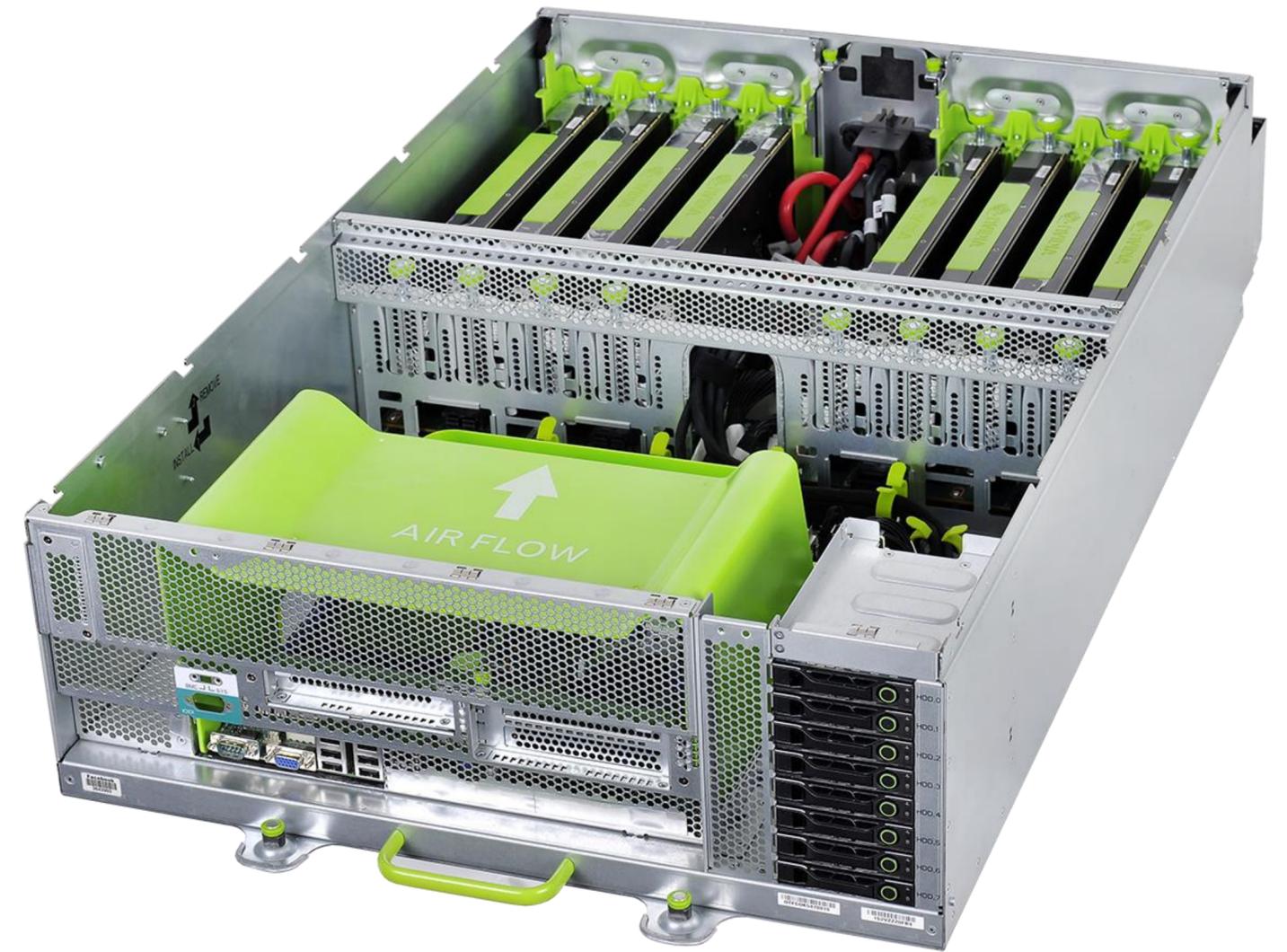
- Directed flow proportioning manifold added
- Fluid lines to from manifold ports to LCS heatsinks for CPUs & PCIe cards added

Liquid cooling for OCP

Applying LiquidCool to GPU servers can dramatically increase rack density

Blockchain solution in Development

Overclocking GPU performance



Summary

LiquidCool's total liquid systems using Engineering Fluids coolant provides the ideal data center cooling technology

- ✓ High compute density
- ✓ Compatibility with standard server racks, including OCP designs
- ✓ High server reliability
- ✓ Highest PUE – 1.02
- ✓ Safe, effective, non-volatile, biodegradable coolant with zero Global Warming Potential
- ✓ No water inside racks and low-pressure fluid circulation prevent catastrophic failures
- ✓ Elimination of server and rack fans – lower ambient noise for storage



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