Company Highlights

- ✓ **Disruptive & Scalable Solid State Cooling Platform**

- ✓ **True Sustainability Mission**

- ✓ **Experienced Team w/Global Presence**

- ✓ **Established market leadership in Optics, Cold Chain & HVAC**

- ✓ **Active Cooling Solutions platform scales from µW to kW**

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ACTIVE COOLING SOLUTIONS

TEMASEK

Goldman Sachs

FRANKLIN TEMPLETON INVESTMENTS

OAK INVESTMENT PARTNERS

venrock

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Introduction

Jesse Edwards

Distinguished Engineer

Phononic

Jesse has over 30 years of experience in entrepreneurism and new product development, with more than 20 years dedicated to the development and manufacturing of traditional cooling solutions and refrigeration technologies, including solid state, single-stage/cascade vapor compression, Stirling, Stirling-derivatives and cryogenic liquid methods.

Jesse specializes in holistic system design and the management and transport of thermal energy and has developed a wide variety of thermal management, heat-pump, system and product solutions, with more than 100 global awarded; Utility and Design patents/patents-pending.

PROFESSIONAL EXPERIENCE

2009–2012
Developed and manufactured a variety of laboratory / medical products and appliances, including standard vapor-compression refrigeration, cascaded / auto-cascade vapor compression freezers, and cryogenic sample storage products with ThermoFisher Scientific.

2004–2009
Worked to develop and commercialize a variety of Stirling Cycle based cooling products and appliances for the consumer, commercial, medical and industrial markets with Global Cooling Inc.

1992–2004
IT and telecommunications entrepreneur, pioneering the consumer roll-out of K and Ku band geosynchronous satellite entertainment and wireless data transmission/reception hardware.

Education
Jesse holds a BSME from Ohio University with a post-graduate MSME specialization in thermo-dynamics, fluid-dynamics, fuel-cells and Stirling Cycle machinery.

Exploding Market Driven by High Performance Computing

Datacenter Market size in USD: 10% CAGR

301.8 Bn — 2024

341.8 Bn — 2025

622.4 Bn — 2030
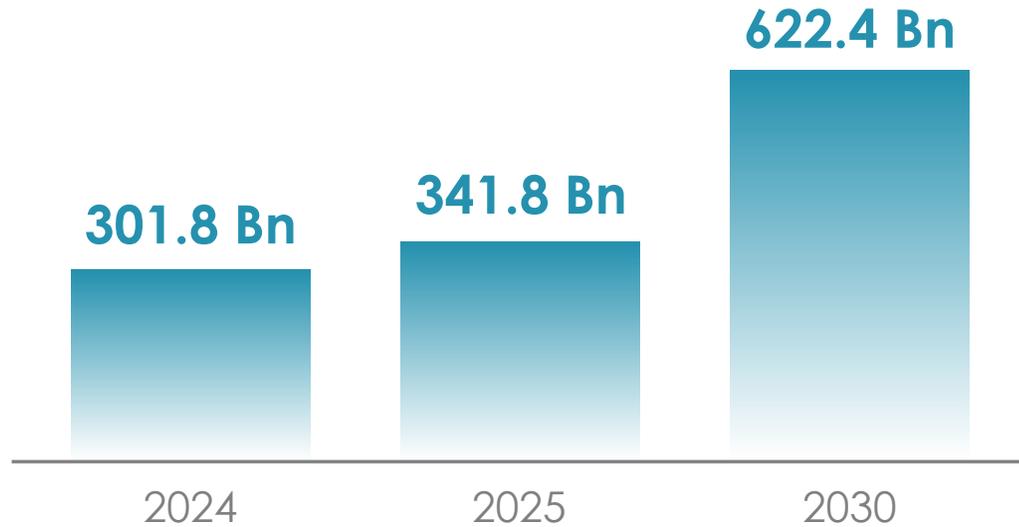
Source: P&S Intelligence

NVIDIA's next-generation AI supercomputer — NVIDIA DGX SuperPOD with DGX GB200 — NVIDIA CORPORATION

- Previous generation ~40kW per rack

- Idealized next generation ~120kW per rack

- **3X growth requirement**

- Best case current solution can only meet ~66kW per rack given cooling limitations*

*based on ASHRAE Technical Committee 9.9 data

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Tech Advances and Rising Demand Drive Higher Heat Flux Densities, Mandating New Thermal Systems to Manage Them

Exploding Market Demands

Bandwidth

Compute density

Data management

Driving Datacenter Requirements

Cooling requirement

Power requirement

Infrastructure investment

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Effective Thermal Management Will Extend the Useful Life of Existing Infrastructure and Enable New Capability Realization

Thermal Management Drives

40% of Data Center Power Consumption

5%	Lighting
10%	Power Conversion
40%	**Thermal Management**
45%	Compute, Storage, Networking
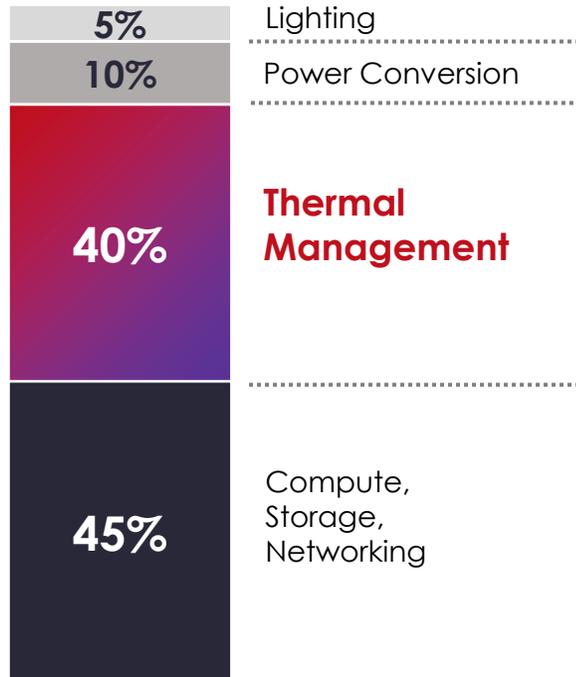
Total Cost of Ownership (TCO) is a key driver for thermal management opportunities

Data from Dell'Oro Group (2022)

EXPLODING DEMAND FOR DATA CENTER COOLING

AI SERVER COOLING TAM

US$M

8k
6k
4k
2k
0

2024   2025   2026   2027
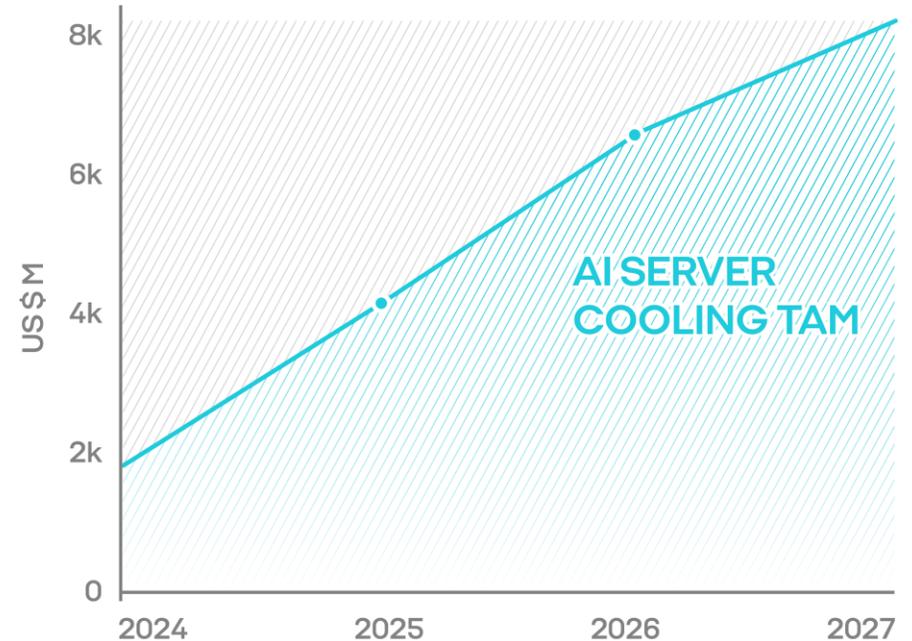
Source: Goldman Sachs Global Investment Research

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Legacy Thinking
Won't Enable the Future

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ACTIVE COOLING SOLUTIONS

Conventional Thinking

Higher CPU/GPU TDP Driving Towards Liquid Cooling Requirement

XPU POWER

Power level
600W+
500W
400W
300W
200W
120W
75W

Liquid cooling

ASHRAE W27 — 27ºC water temp

ASHRAE W45 — 45ºC water temp

Air cooling

ASHRAE A2 — < 35ºC air temp

ASHRAE A4 — < 45ºC air temp

2U+ AIR COOLED

1U AIR COOLED

DENSE AIR COOLED
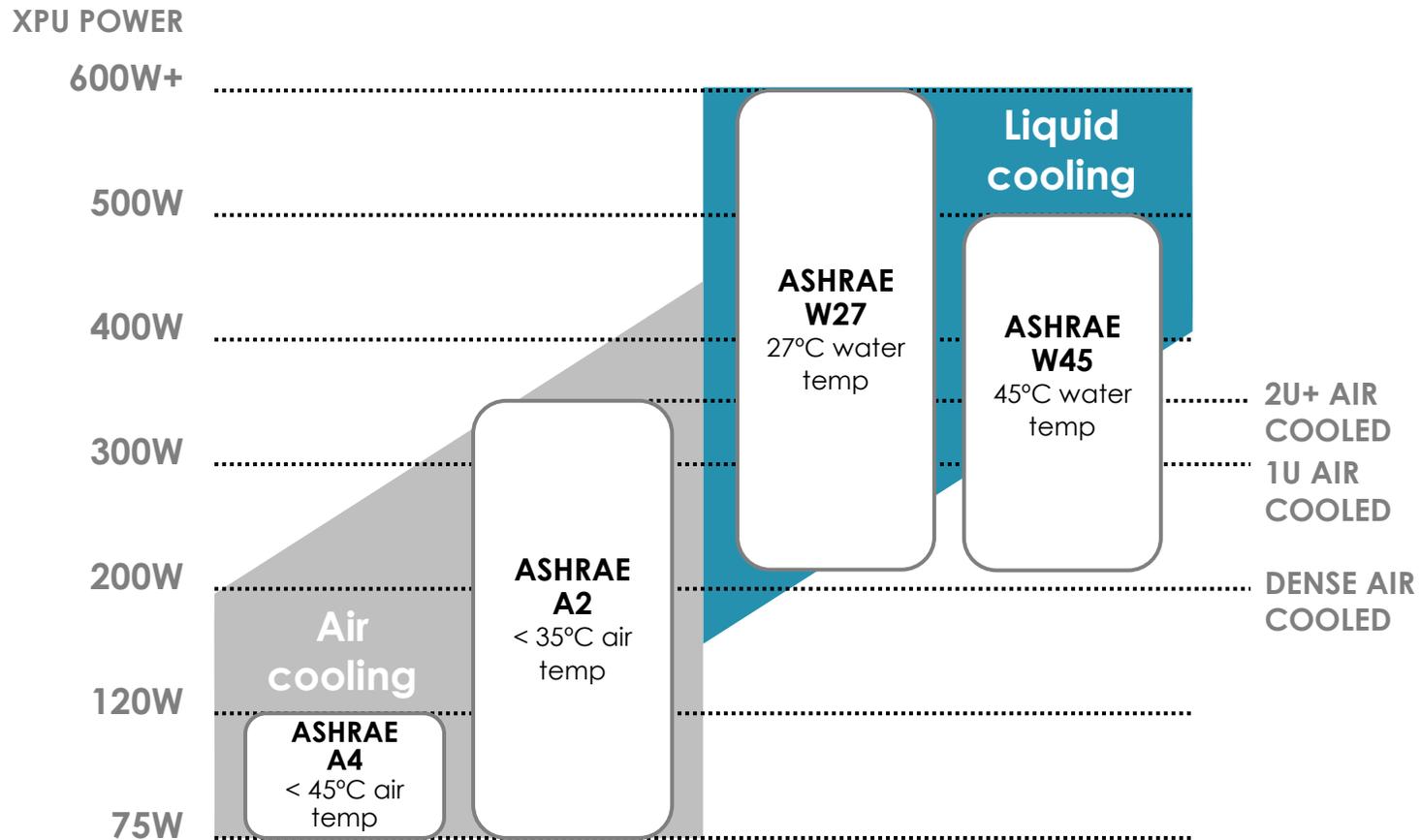
Image adapted from ASHRAE Tech Committee 9.9

- Air-cooling "reaching practical limits"
- Next-gen TDPs "require" Liquid

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Traditional Cooling Solutions Limited
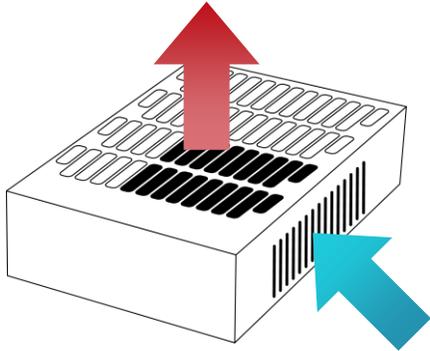
Passive Cooling Current

- **Component/Server Level:**
  - Heatsink/Heat-Pipe/Vapor chamber
- **Facility Level:**
  - Evaporative Chiller
  - Air-cooled Chiller/Tower
  - Radiant
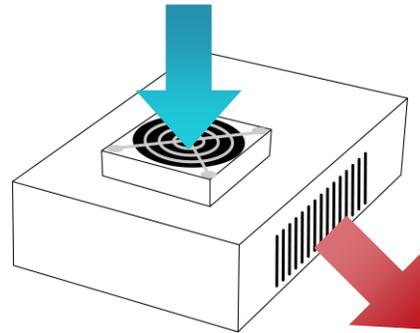
"Active" Cooling Current

- Passive plus, using enhanced mass-flow
- **Component/Server level:**
  - Heatsink/Heat-Pipe/Vapor chamber/Water-block
  - Fan/Pump
- **Facility Level:**
  - VC based Air cooler
  - VC/District based Chilled water

…With Clear Limitations

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Passive Cooling is Fundamentally **Capped** by Ambient Temperature Realities

Thin loop heat pipe

Thermal diffusion plate (condenser)

Evaporator

Heat-generating component
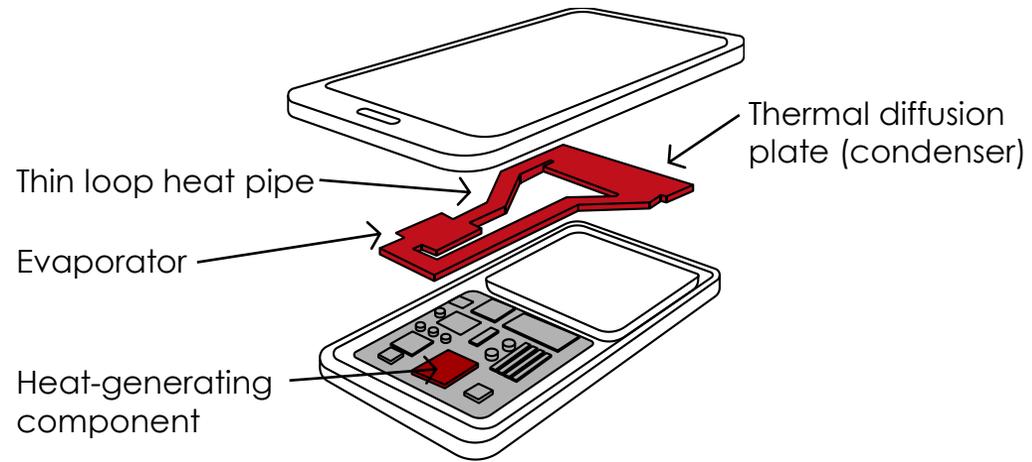
- Tied to Ambient: dictates minimum achievable temp
- Basics: Conduction / Convection / Radiation
- Often sufficient for "safe" IC operating temps
- Highly dependent on transport architecture
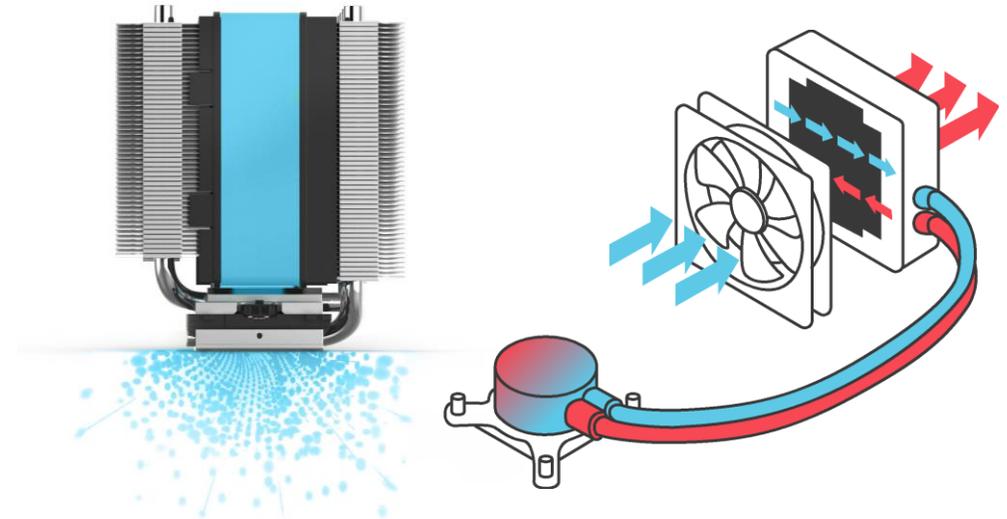
- Fin/tube heat exchanger
- Fans
- Water-Block/Pump/AIO

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Traditional Active Cooling: Can Lack Resolution and Over-Power the Device Level Need

- Heat-pump technologies (some)
  - Vapor Compression (gas-cycle)
  - Ad/Absorption
  - Evaporative
  - Caloric cycles
  - Stirling
- <u>Control point not limited to ambient temperature</u>
- **Requires <u>Work</u> to be done to move heat against thermodynamic equilibrium**
- Not always required for typical "safe" IC operating temperatures (50°C - 80°C)
- Facility level implementations common
  - leveraged to enhance compute density options

Vapor compression cycle
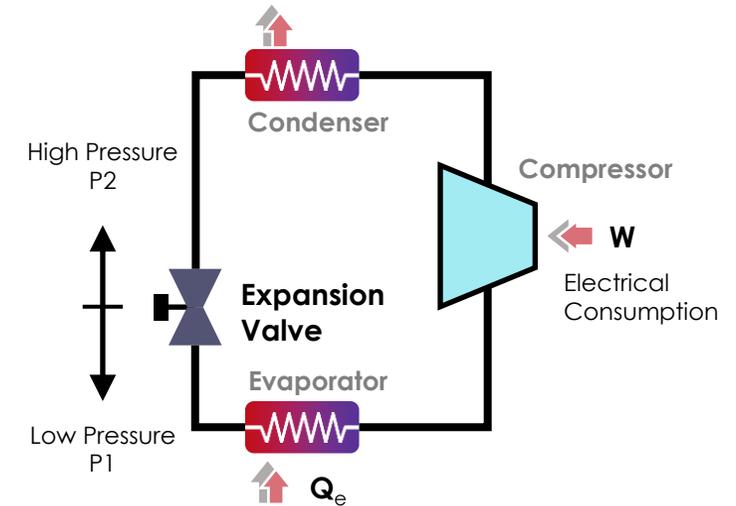
Ad-Ab cycle or Evaporative cycle
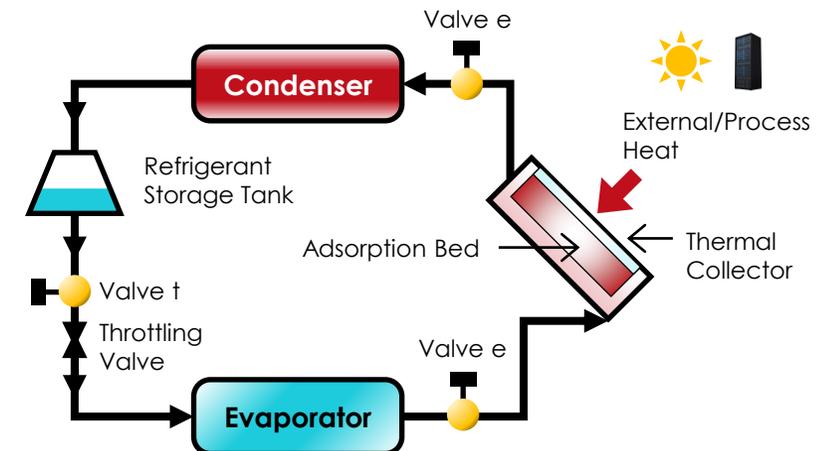
Solid State Cooling:
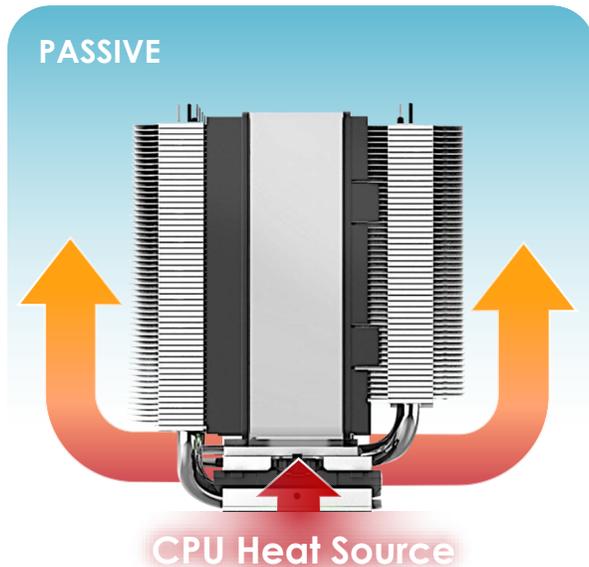# Enables Full Spectrum *Dynamic* Thermal Management

Passive Thermal Management
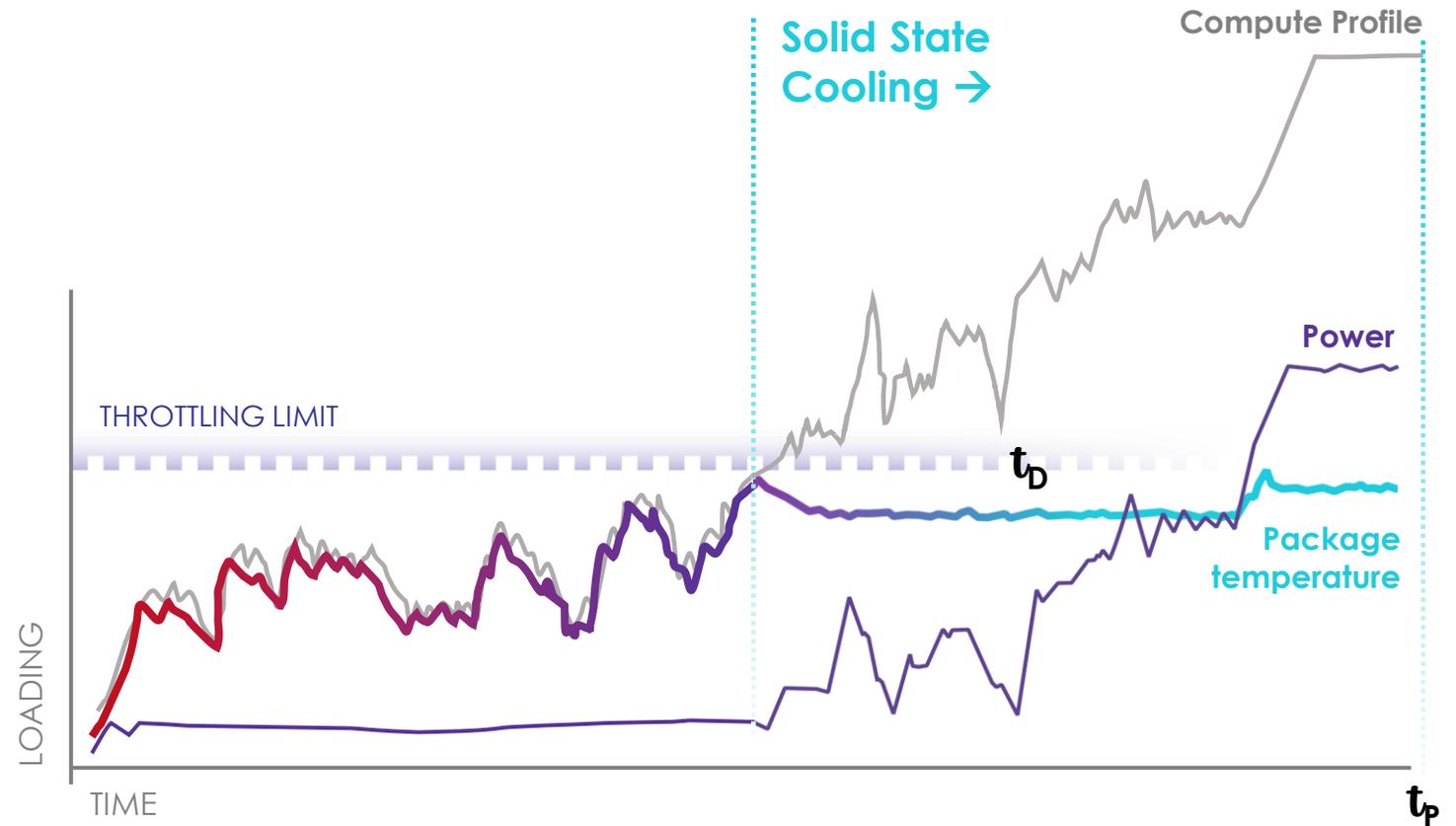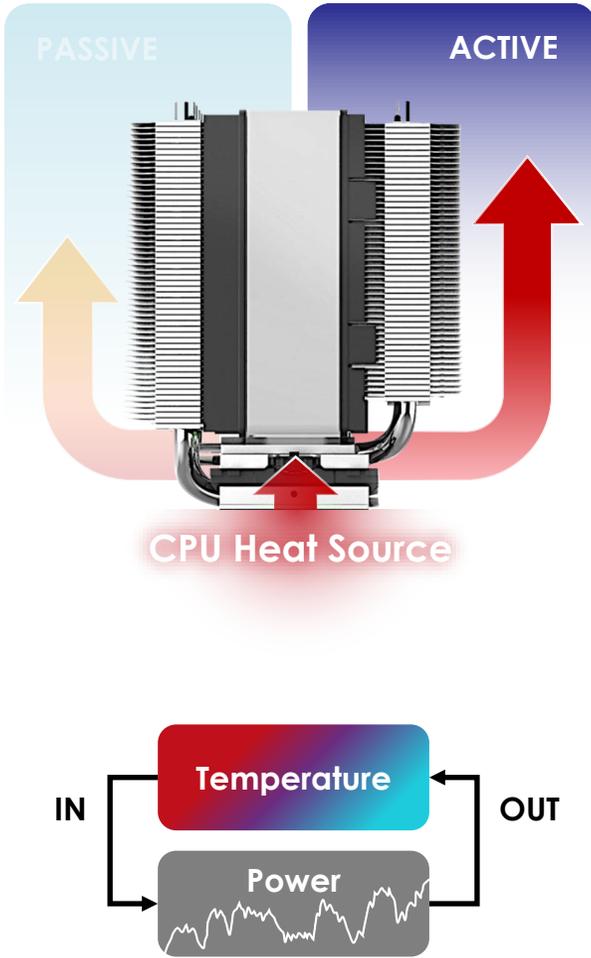
Solid State Cooling

Active Thermal Management

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Fully Functioning in Passive Mode, Capitalizing on the Intrinsic Benefits of Ambient Temperature Heat Gradients

PASSIVE

CPU Heat Source

Temperature

IN → Power off → OUT

THROTTLING LIMIT

Compute Profile

Package temperature

Power

LOADING

TIME

t_P

PHONONIC
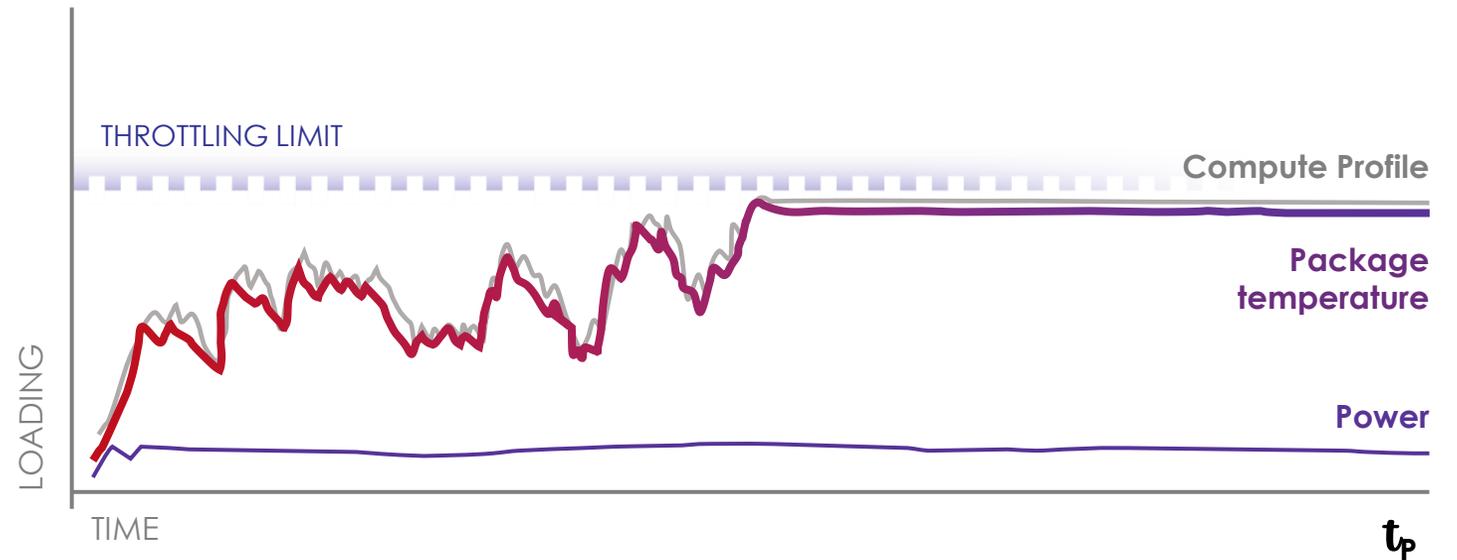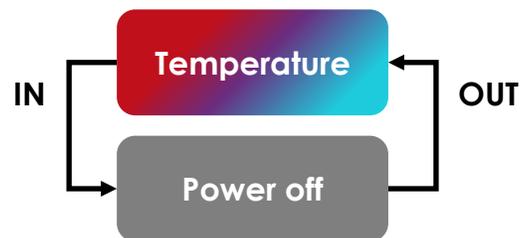
Transitioning to Active Cooling to Unlock Package Performance from Throttling Limit, Unlocking Computing Power…

PASSIVE

ACTIVE

CPU Heat Source

Temperature

Power

IN

OUT

Solid State Cooling →

Compute Profile

THROTTLING LIMIT

t_D

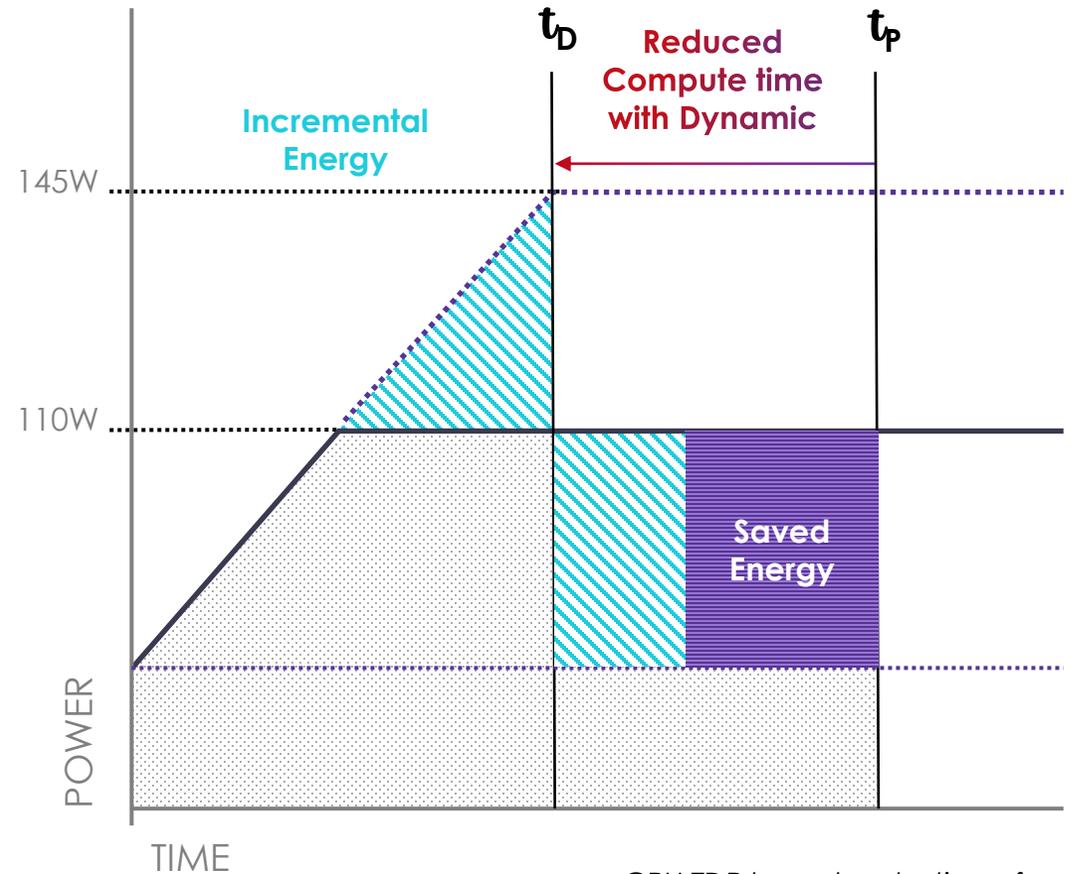Power

Package temperature

LOADING

TIME

t_P

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Solid State Realizes...

Dynamic Thermal Response:
Through its Enabling of Improved Data Processing and Compute Speed, Makes it Possible to...

Simultaneously Improve Performance and Save on Power Requirements

CYCLE COMPLETION

CPU TDP based on testing of Hex2.0 dynamic cooling system

Baseline energy

Incremental Energy Consumed

Energy Saved

- Extending Useful Life of Air Cooling and Bridging the Gap
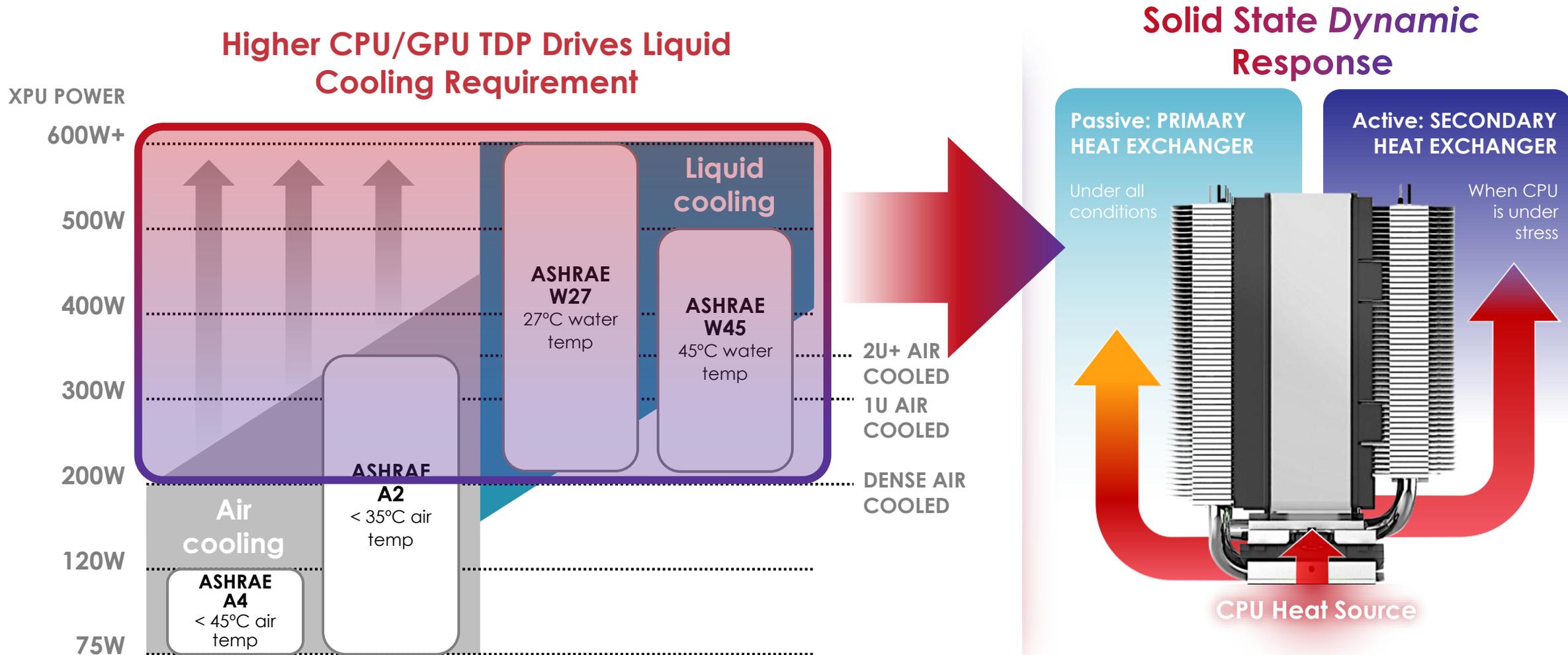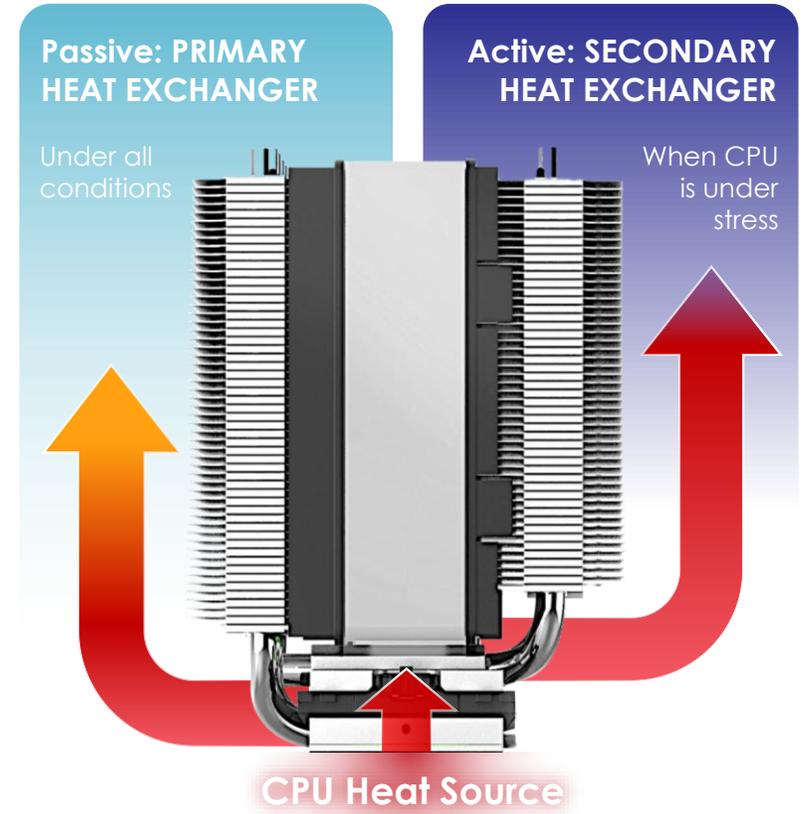# - Enhancing the Capabilities of Both Air and Liquid Cooling

Higher CPU/GPU TDP Drives Liquid Cooling Requirement

XPU POWER

- 600W+
- 500W
- 400W
- 300W
- 200W
- 120W
- 75W

Liquid cooling

ASHRAE W27 — 27ºC water temp

ASHRAE W45 — 45ºC water temp

ASHRAE A2 — < 35ºC air temp

Air cooling

ASHRAE A4 — < 45ºC air temp

- 2U+ AIR COOLED
- 1U AIR COOLED
- DENSE AIR COOLED

Image adapted from ASHRAE Tech Committee 9.9

Solid State *Dynamic* Response

Passive: PRIMARY HEAT EXCHANGER — Under all conditions

Active: SECONDARY HEAT EXCHANGER — When CPU is under stress

CPU Heat Source

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Dynamic Response to Thermal Needs

Passive: PRIMARY HEAT EXCHANGER

Under all conditions

Active: SECONDARY HEAT EXCHANGER

When CPU is under stress

CPU Heat Source

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Hex 2.0 CPU Cooler
92 mm form-factor

125 mm

112 mm

95 mm

Fan Specifications

Size	92 x 92 x 25 mm (H x W x D)	
Connector	4-PIN PWM	
RPM & Noise Level	Max	2650rpm (33dBA)
	Typical Idle	1000rpm (<17dBA)
Air Flow/Max Static Pressure	44 CFM Maximum / 3.1 mm H_2O	

Performance
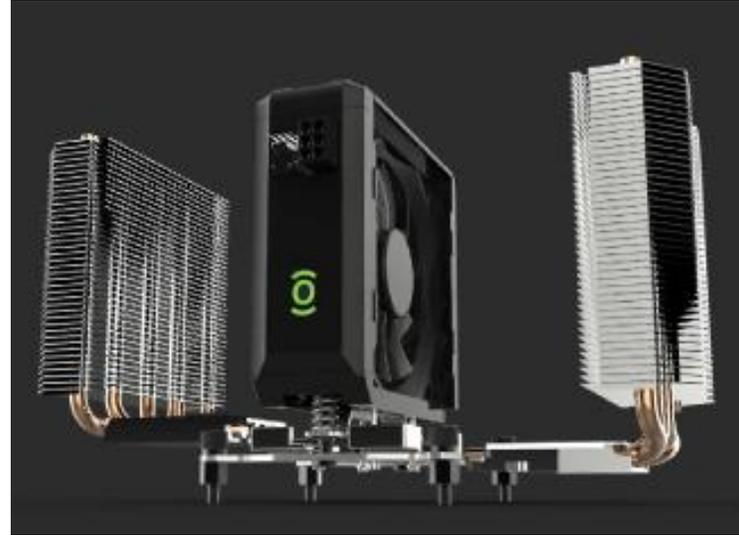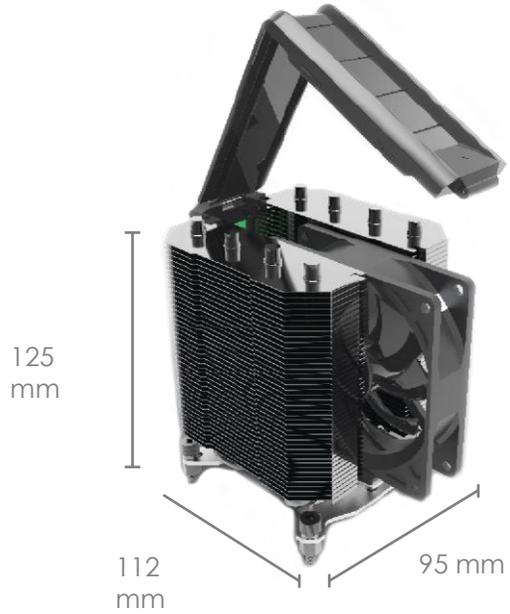
Cooler Specifications

Dimensions	125 x 112 x 95 mm (H x W x D)
Weight	810 grams
Material	RoHS compliant

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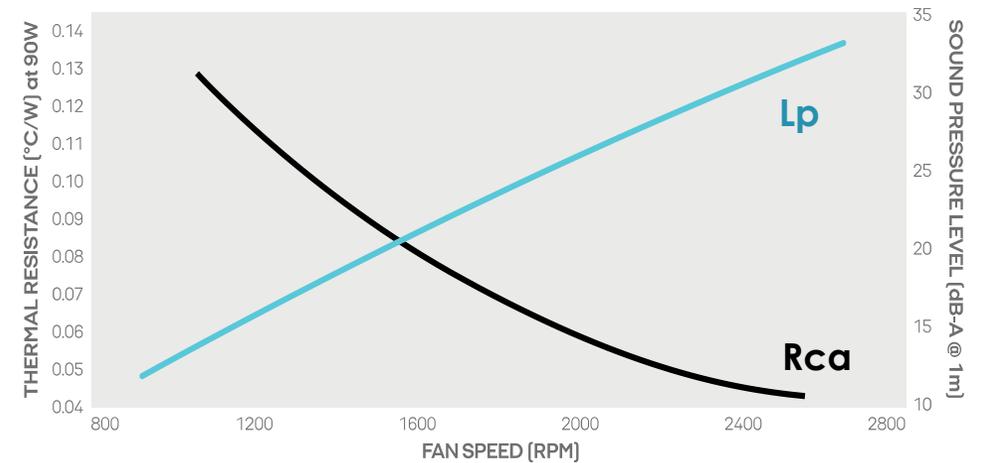
AMD Ryzen 9 9950x Stress Testing

Cooling performance per fan area

Bar chart with y-axis from 0 to 2.5 (increments of 0.5). Categories: Phononic, Liquid 120mm, Air 92mm, Air 120mm, Liquid 2x120mm. Legend: CPU Stress (cyan), FPU Stress (purple).
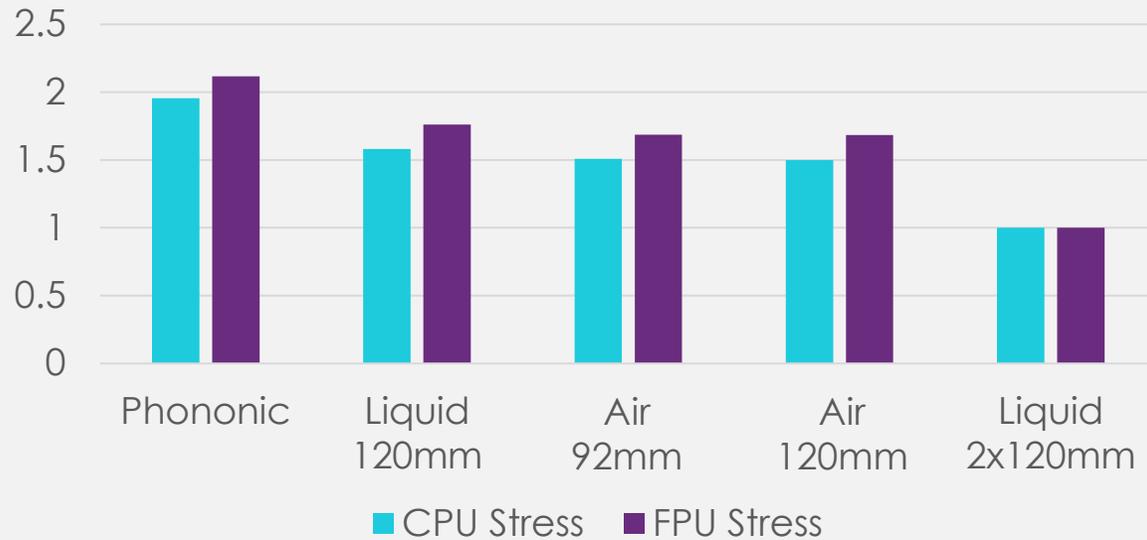
Unmatched Performance Metrics

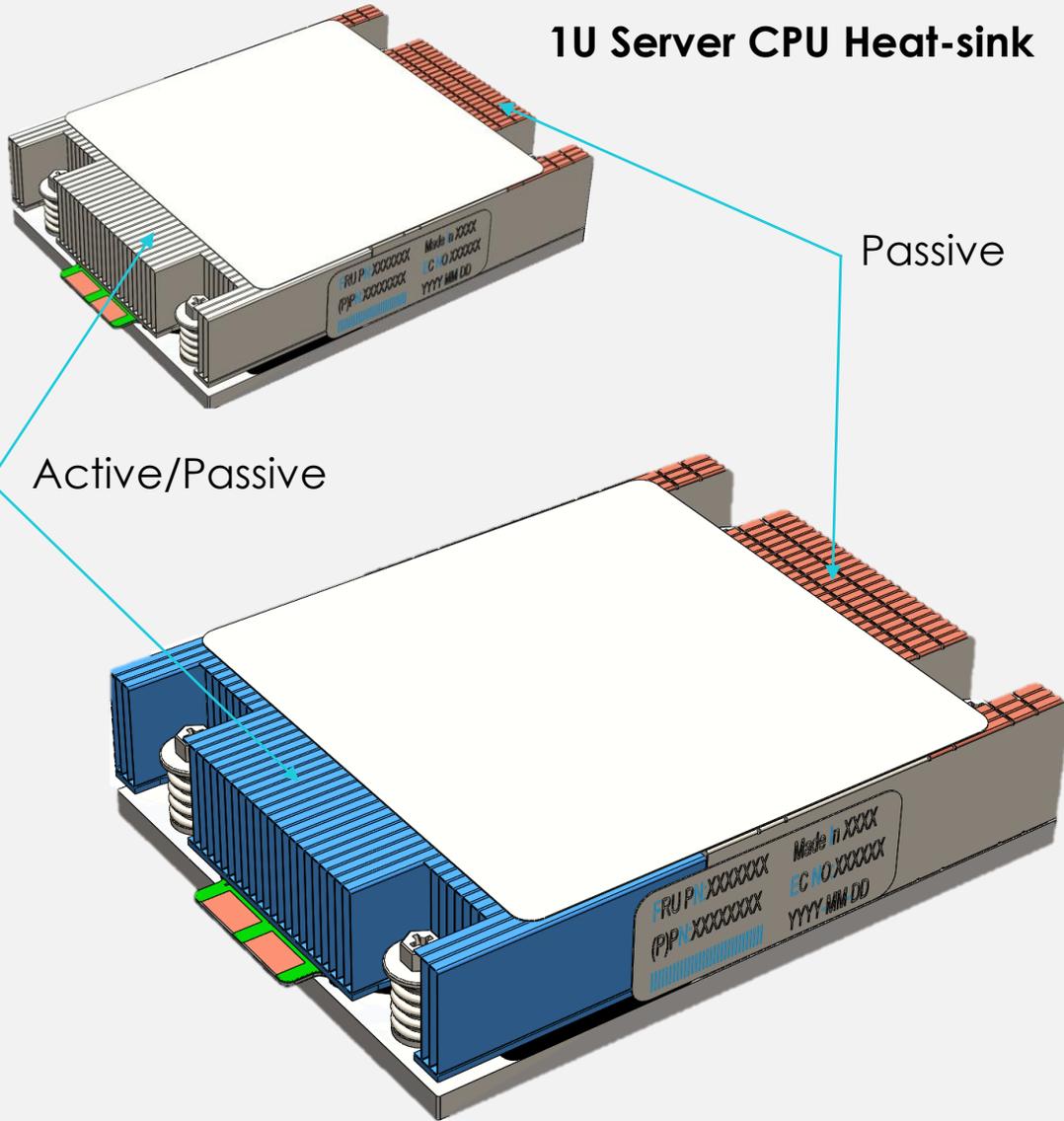| Processor Stress Levels Comparison Testing	TDP
RYZEN 9 9950x (5.7GHz)	170 Watts

- Hex 2.0: 92mm form-factor

- Superior to:
  - 1x 120mm AIO Liquid
  - 1x 120mm FC Air
  - 2x 120mm FC Air
  - 92mm FC Air

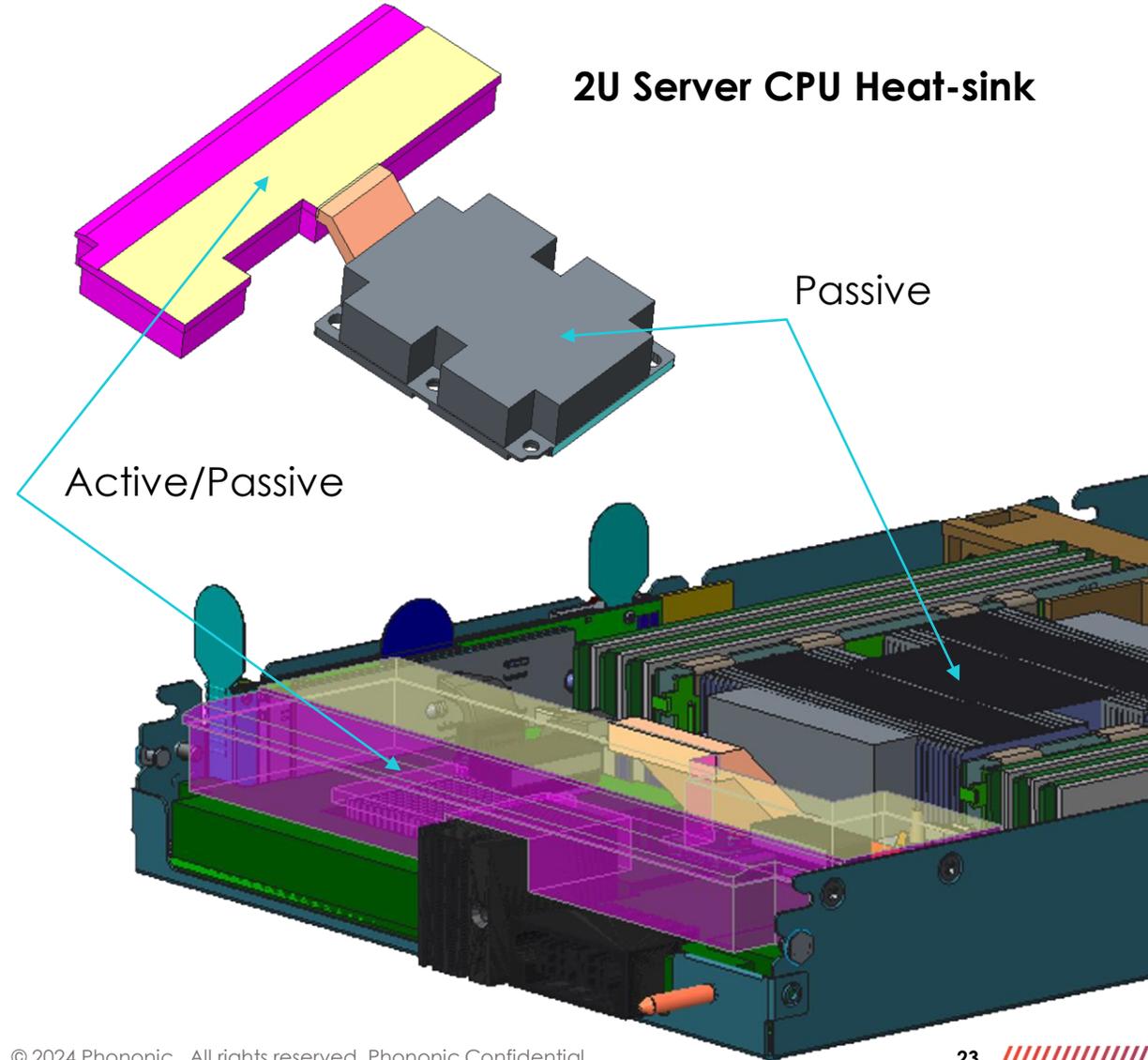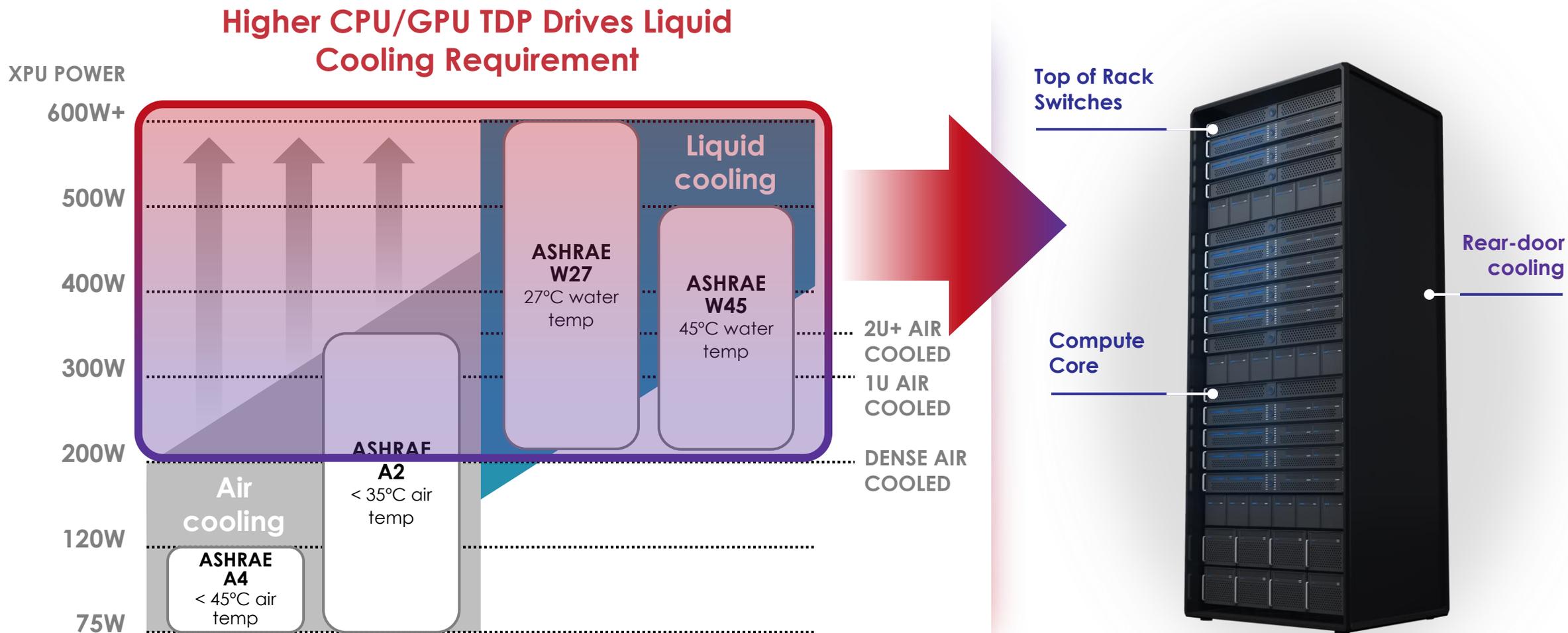- Competitive with:
  - 240mm (2x 120mm) AIO Liquid

125 mm
112 mm
95 mm
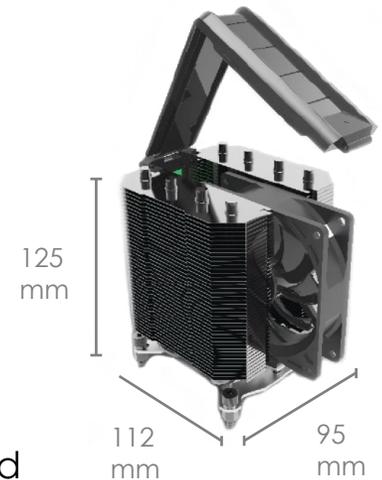
Alternative Form-factors

1U Server CPU Heat-sink

Passive

2U Server CPU Heat-sink

Passive

Active/Passive

Active/Passive

Deployable into Existing and Future Datacenter Infrastructures, Reducing Capital and Time Requirements

Higher CPU/GPU TDP Drives Liquid Cooling Requirement

XPU POWER

- 600W+
- 500W
- 400W
- 300W
- 200W
- 120W
- 75W

Liquid cooling

ASHRAE W27
27ºC water temp

ASHRAE W45
45ºC water temp

ASHRAE A2
< 35ºC air temp

Air cooling

ASHRAE A4
< 45ºC air temp

2U+ AIR COOLED
1U AIR COOLED
DENSE AIR COOLED

Top of Rack Switches

Rear-door cooling

Compute Core

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Solid State Cooling:
Dynamic Unlock to Meet Exploding Requirements

- Stabilize frequency of Optical networks

- Eliminate CPU/GPU Throttling

- Increase potential of existing infrastructure
  - Increased reject temperature wile holding case temperature constant

- Extend life expectancy

- Smooth hot-spots

- Increase power density
  - Rack
  - Data Center

- Enable passive/active operational cadence
  - Reduce energy consumption while maintaining Active cooling advantages

cool air flow

warmed air flow

heat is pumped into secondary heat exchanger when cpu is under stress

heat is conducted into primary heat exchanger

cpu heat source
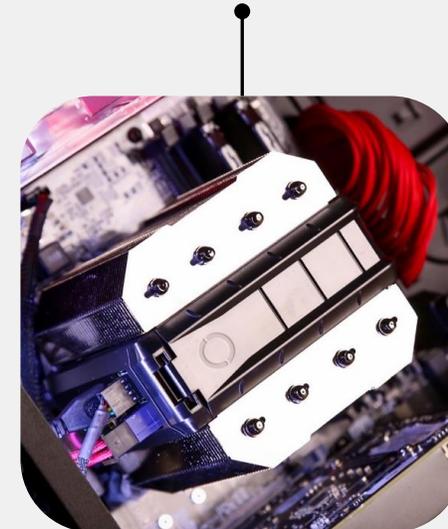
Contact Info

Jesse Edwards

Jesse.edwards@phononic.com

phononic.com/devices/ai-datacenters

Brooks Henderson

Brooks.henderson@phononic.com

phononic.com/devices/ai-datacenters

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Q&A