Project OMNICOOL: Ultra Efficient Hybrid Cooling Technology

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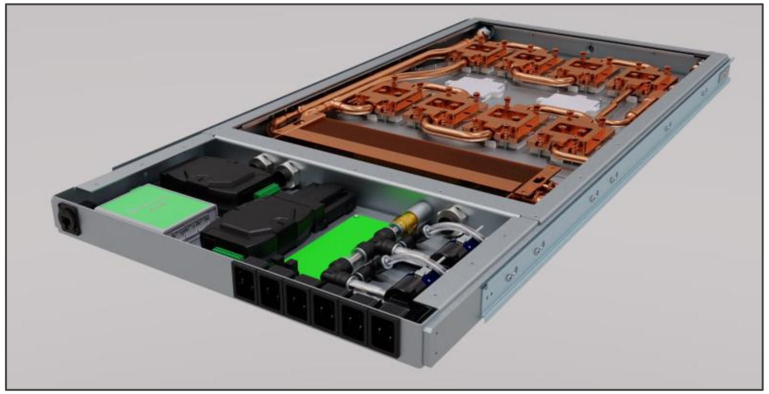


Combining two of the most energy-efficient and thermally effective electronic cooling approaches to achieve the lowest possible limit for DC energy consumption and pushing power density to remarkable levels

OMNICOOL Objectives

Energy Efficiency

- **Target:** PUE <1.05

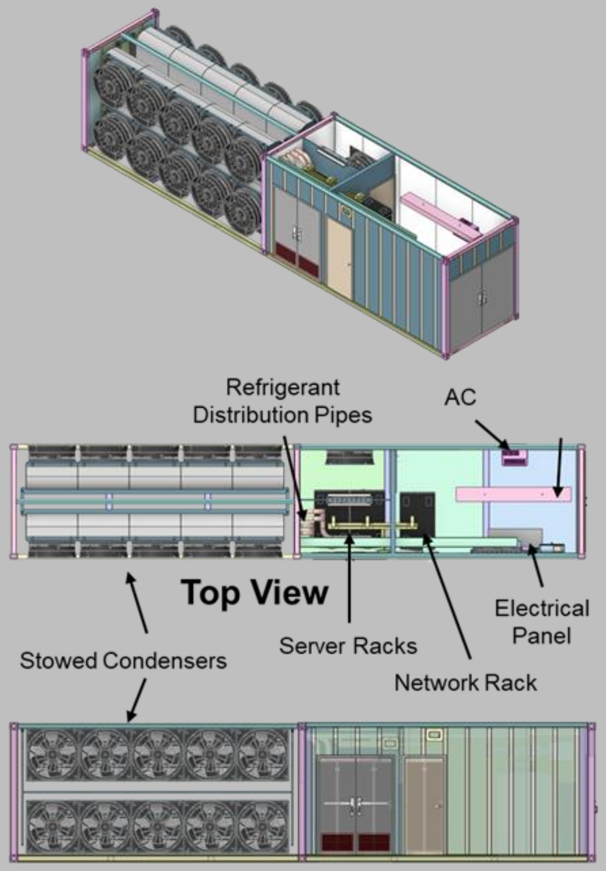
- Cooling technology
- Heat rejection
- Fluid recirculation
- Operating temperature
- Cooling system Rth

Environmental Impact

- **Target:** GWP <10

- Fluid selection
- Water consumption
- Energy consumption

OMNICOOL Concept



Power Density

- **Target:** >120 kW/ rack, ISO 40'

- Chip power density
- Server power density
- Cooling capacity
- Components sizing
- Fluid velocity limits
- Power distribution

Geolocation and Weather Constraints

- **Target:** $T_{amb} \geq 40$ °C

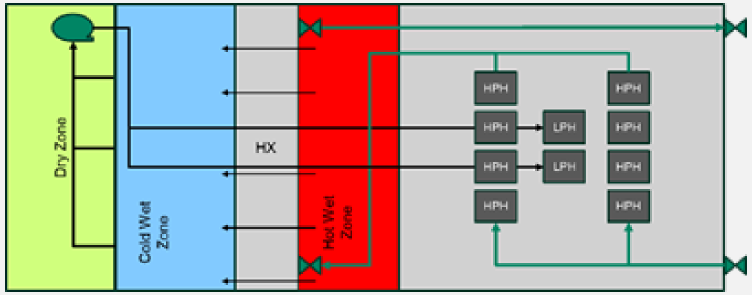
- Operating temperature
- Maximum case temperate
- OSHA limitation

Solution Innovation and Impact

Server Level

Innovation:

- Porous metal two-phase cold plates
- Passive flow controllers
- Hybrid P2P and single-phase immersion
- In tray heat exchange



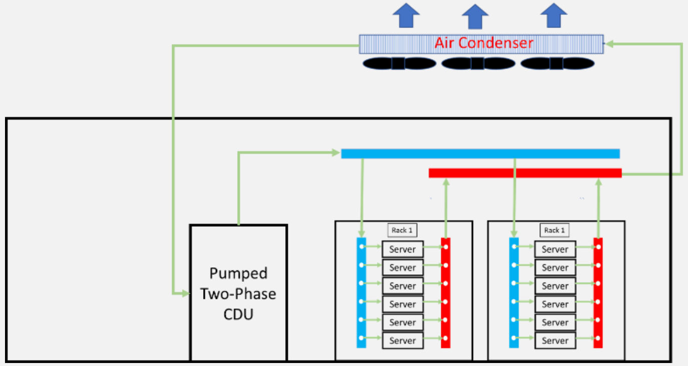
Impact:

- Eliminate energy-intensive air cooling
- Operating at high temperature
- Cooling capacity
- Compact system
- Eliminate dryout

Rack and System Level

Innovation:

- Single-cycle system
- Pumping and flow separation system
- Compact heat rejection
- Constructual-Theory driven design



Impact:

- Zero water consumption
- Energy efficiency
- Cooling capacity
- Compact system

Technology Development

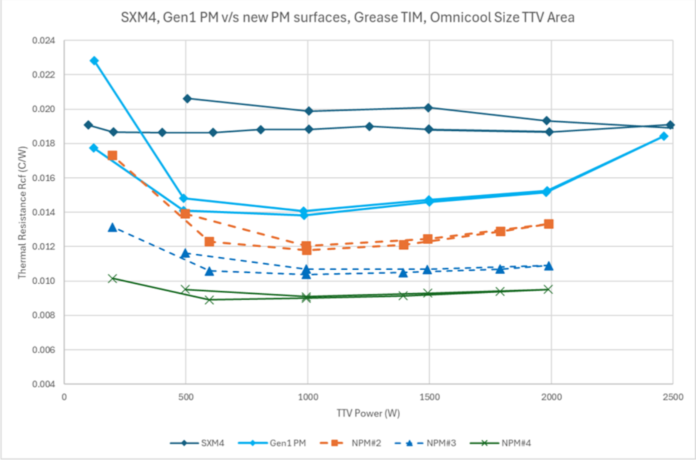
Cold Plates and CLs

Status:

- Rth<0.01 K/W achieved
- Cooling loop design finished

Next Steps:

- Explore enhanced CPs
- Assembling cooling loop



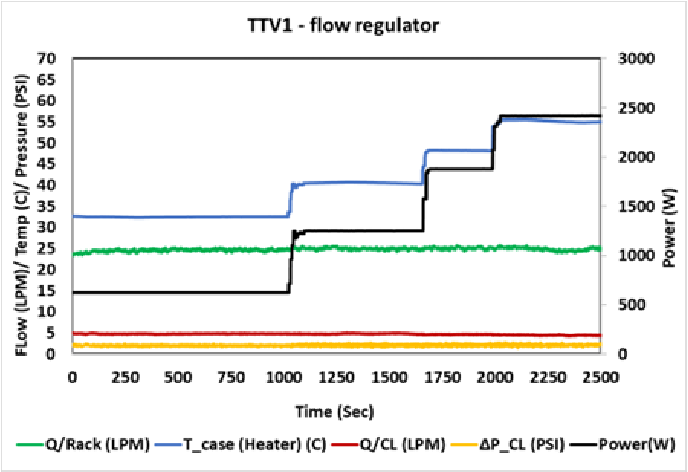
Flow Controllers

Status:

- Flow balance verified at server and rack scale

Next Steps:

- Look for more compact options
- Integrate with active controls



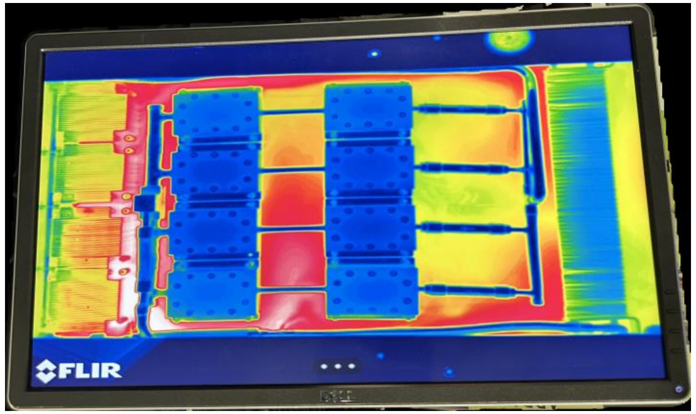
Immersive Tray

Status:

- 2×(3U) POCs were built and tested
- 1U version is under development

Next Steps:

- Testing and optimizing the 1U higher power version



Technology Development

Pumping and Flow Separation

Status:

- New high cooling capacity design finalized

Next Steps:

- Building and testing the new concept
- Develop 1MW DT version

Two phase R-1234yf at 60C and 65% quality 2" sch 40 pipe			
	psi/ft	psi per 50' length	
Lockhart-Martinelli Correlation	0.235	11.8	4.5X
Friedel Correlation	0.104	5.2	2.0X
Chisholm Correlations	0.084	4.2	1.6X
Vapor only pressure drop (311 lb/min)	0.052	2.60	

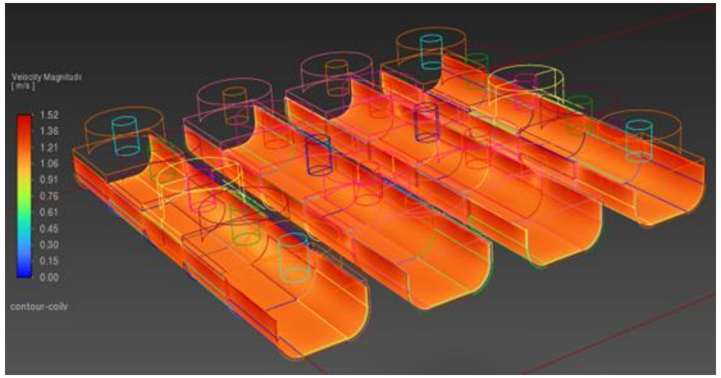
Heat Rejection System

Status:

- >100 coil designs evaluated
- High-efficiency fans selected
- Coil arrays assessed

Next Steps:

- Testing and optimizing the selected condenser design
- Pushing cooling capacity >2MW



System Performance

Status:

- Simulated PUE < 1.03. (Based on empirical data)

Next Steps:

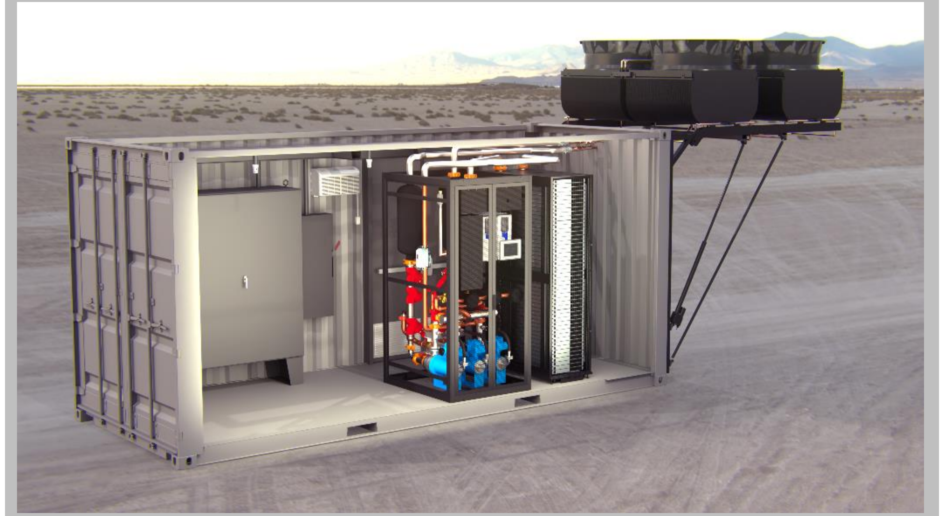
- Confirm simulation results experimentally
- Push cooling capacity >2MW within container

Parameter	Power
IT equipment load (kW)	1000
Two Phase Heat load (kW)	1000
Condenser Energy Consumption - Two Phase (kW)	18.00
Pumps Energy Consumption - Two Phase (kW)	9.15
Pumps Energy Consumption - Single Phase (kW)	1.95
Total Cooling System Power (kW)	**29.1**
Cooling System Power/IT load (%)	**2.91**

What is Next: Detail of Upcoming Tasks

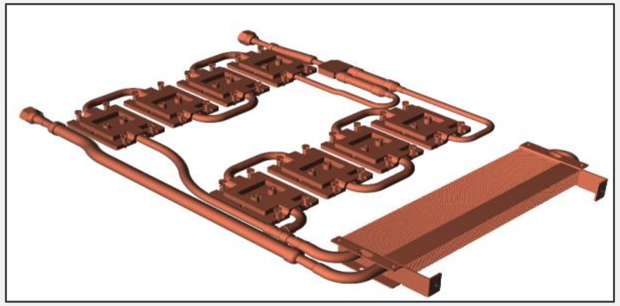
Scalable Unit

- 250 kW
- 20 immersive trays with CLs
- 1 rack
- 1 Pumping and flow separation unit
- 4 heat rejection units
- 20 ft container
- DAQ, power delivery
- Safety: leak detection, fire suppression, and safety shutoff



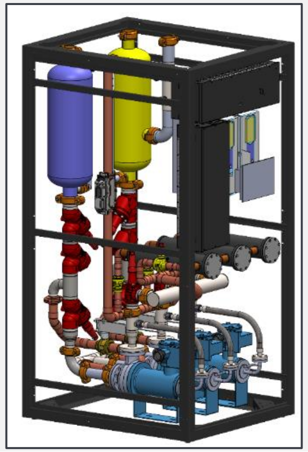
Cooling Loops

- PMCP
- Integrated HX



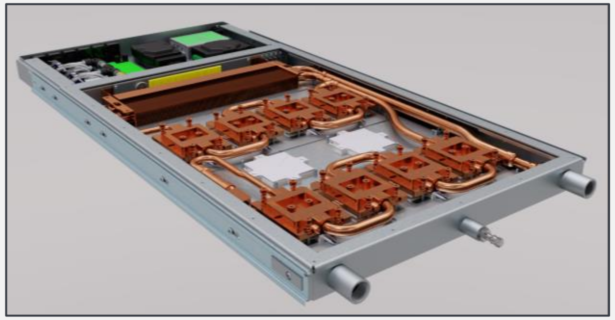
Pumping and Flow Separation Unit

- R1234yf
- 250 kW
- Capacity can be increased within the same footprint.



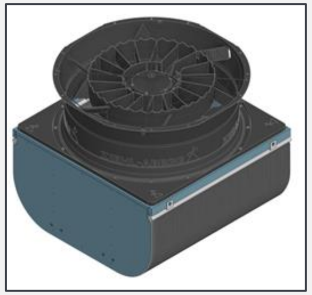
Immersive Tray

- 12.5 – 25 kW/1U
- In tray fluid circulation



Compact Heat Rejection

- U-Shape coils
- High efficiency fans

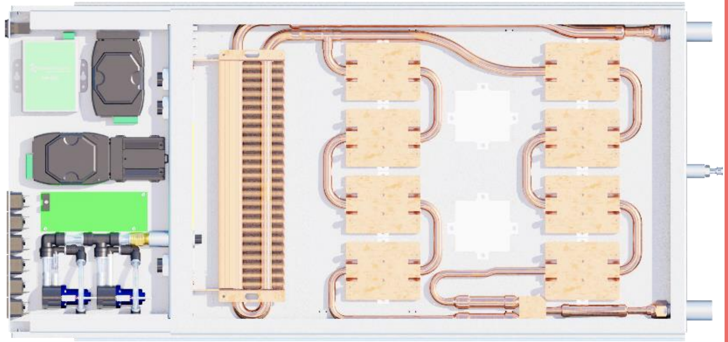


The Megawatt Rack

- A comprehensive assessment indicated that the hybrid cooling architecture utilizing **pumped two-phase technology** can scale to power densities **> 1 MW** within a single rack.

Tray Configuration

- 2.5 kW GPU heaters
- 8 GPU/Tray
- 20 kW/trays
- 1U height



Rack Configuration

- 2” supply manifold
- 3.5” return manifold
- 50 trays in 52U rack

System Modifications and Implementation Challenges

Modifications:

- Components sizing (QDs and FRs)
- Refrigerant flow distribution

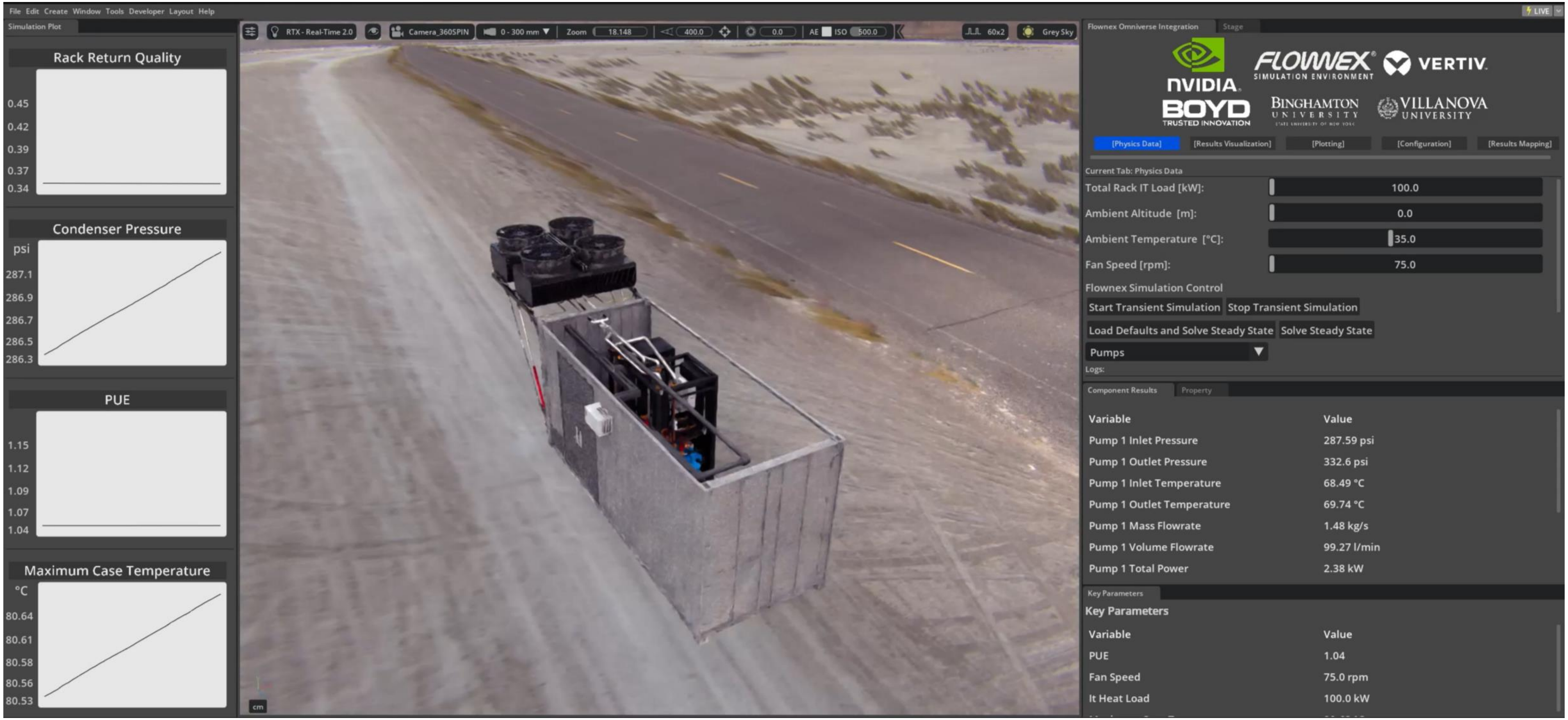
Challenges:

- Customized components availability (QDs)
- Power distribution
- Network connection

OMNICOOL Digital Twin: Capturing the Full Spectrum of DC Operations

Mechanical	• Single phase cooling • Two phase cooling • Heat rejection unit • Pumping system
Electrical	• Power distribution • Energy storage • Backup systems
Structural	• Rack layouts • Floor loading • Equipment positioning
Environment	• Weather conditions • Water usage • Carbon emissions
Performance	• Real-time sensor data • Predictive maintenance • PUE/TUE
IT Infrastructure	• Server power draw • Hardware health

Scalable Unit Digital Twin



Project Timetable

Milestones	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
1/3/2025	Q1	Q2	Q3	Q5	Q6	Q7	Q9	Q11	Q12	Q12

Components Development Timeline

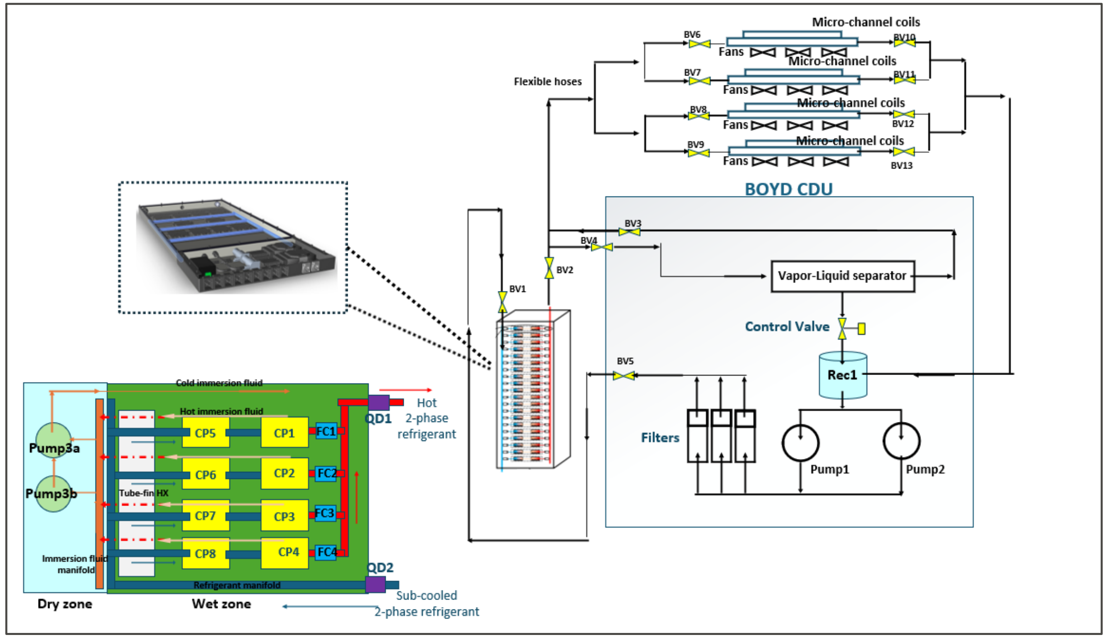
- Porous metal CP/Cooling loops
  - Percent Completion: 60%
- Immersive tray
  - Percent Completion: 90%
- Two phase flow control
  - Percent Completion: 100%
- Pumping and flow separation system
  - Percent Completion: 40%
- Compact heat rejection unit
  - Percent Completion: 70%
- Digital Twin
  - Percent Completion: 90% (Innovation continues)

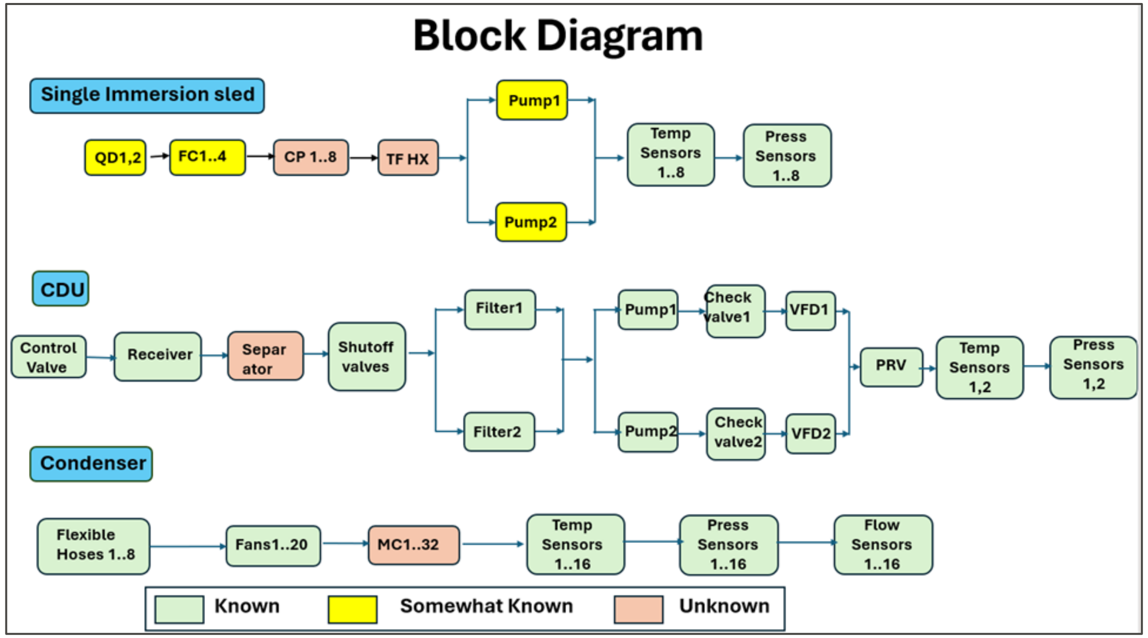
System Reliability

- Calculate System MTBF (Reliasoft)
- Collect MTBF data for parts
- Determining the weakest chain in the link
- Identify critical failure modes
- Introducing redundant parts

Serial: $\mathrm{R_{system}} = \mathrm{R_1} \times \mathrm{R_2}$

Parallel: $1 - R_{system} = (1 - R_1) \times (1 - R_2)$



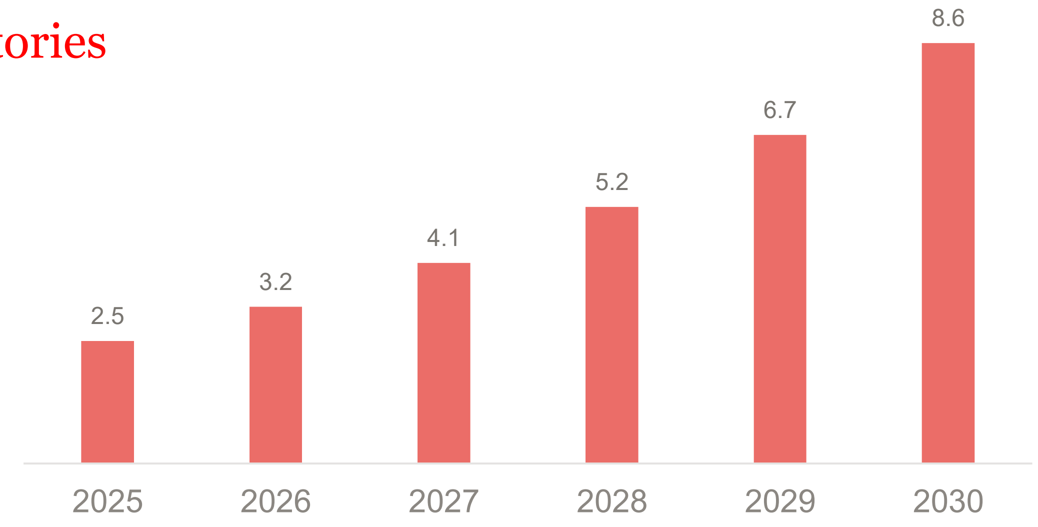


Market Analysis

- **Edge infrastructure** is **5%** of total 2025 AI market estimate of **$0.5T @ 28% CAGR** until 2030
- **Rapidly deployable**, single & double **modules** designs to represent **50% of edge market**. Larger edge deployments more 'project' focused where expandable heat rejection scheme not as valuable.
- **OMNICOOL** level power, **dense solutions** represent **20%** of market. Lower density solutions may be simpler single or two-phase liquid, immersion or air-cooled.
- OMNICOOL **TAM is ~½% of total AI market**, forecasted revenue estimates.
- $30B Market Opportunity for OMNICOOL full solution 2025 – 2030
- Huge opportunity for each individual technology in AI factories

All estimates are averages from meta-study results of multiple AI searches

Report Source	Forecast Period	Projected CAGR	Projected Market Size (End of Period)
Fortune Business Insights	2025–2032	29.2%	$1.77 trillion by 2032
Grand View Research	2025–2033	31.5%	$3.49 trillion by 2033
Statista	2025–2030	27.7%	$827 billion by 2030
MarketsandMarkets	2025–2032	30.6%	$2.4 trillion by 2032
Precedence Research	2025–2034	19.2%	$3.68 trillion by 2034



Project OMNICOOL Team

Team Members

NVIDIA

VERTIV

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BOYD TRUSTED INNOVATION

Binghamton University State University of New York

Supporting Partners

FLOWNEX SIMULATION ENVIRONMENT

RADICLE DEVELOPMENT CENTER

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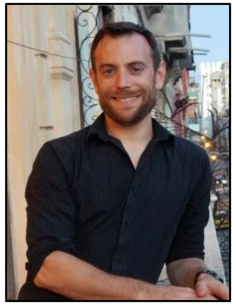

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