Green Refrigerant-Based Compact Hybrid System for Ultra-Efficient and Sustainable HPCs Cooling

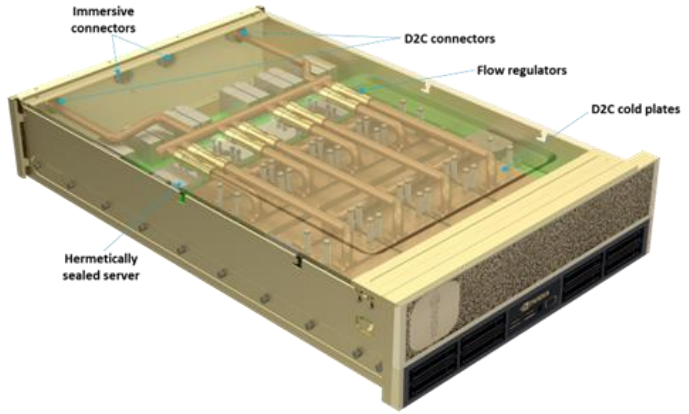
Ali Heydari, Nvidia Corporation

Team Members:
Vertiv Corporation
Boyd Corporation
Durbin Group LLC
Binghamton University
Villanova University

COOLERCHIPS™

Project Vision

- 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



Total Project Cost:	$5M
Length	36 mo.

COOLERCHIPS Kickoff Meeting
October 18 & 19, 2023

Brief COOLERCHIPS Project PI & Co PIs

Fed. funding:	$5M
Length	36 mo.

Organization: Nvidia Corporation.

PI: Dr. Ali Heydari.

Title: Distinguish Engineer and Data Center Technologist.

Organization: Binghamton University.

Co PI: Dr. Bahgat Sammakia.

Title: VP for Research, Binghamton University (SUNY).

Organization: Villanova University.

Co PI: Dr. Alfonso Ortega.

Title: Site Director for the NSF Center for Energy Smart Electronic Systems.

Organization: Durbin Group LLC.

Co PI: Joseph Marsala.

Title: Chief Technical Officer of Durbin Group LLC (CTO).

Organization: BOYD Corporation.

Co PI: Sukhvinder Kang.

Title: Chief Technology Officer (CTO).

Organization: Vertiv Corporation.

Co PI: Steve Borror.

Title: Engineering Manager.

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Brief COOLERCHIPS Project Overview

Fed. funding:	$5M
Length	36 mo.

Team member	Location	Role in project, core competencies
Nvidia Corporation	Santa Clara, CA	• Project management • developing immersion sleds • developing digital twin of full scale system
Vertiv Corporation	Westerville, OH	• Heat rejection units • Flow and power distribution
Boyd Corporation	Pleasanton, CA	• Novel porous two-phase metal cold plates
Durbin Group LLC	Fredericksburg, VA	• Rackmount distributed two-phase CDUs, and flow separation system
Binghamton University	Binghamton, NY	• Experimental testing, analytical analysis, modeling
Villanova University	Villanova, PA	• Experimental testing, analytical analysis, modeling

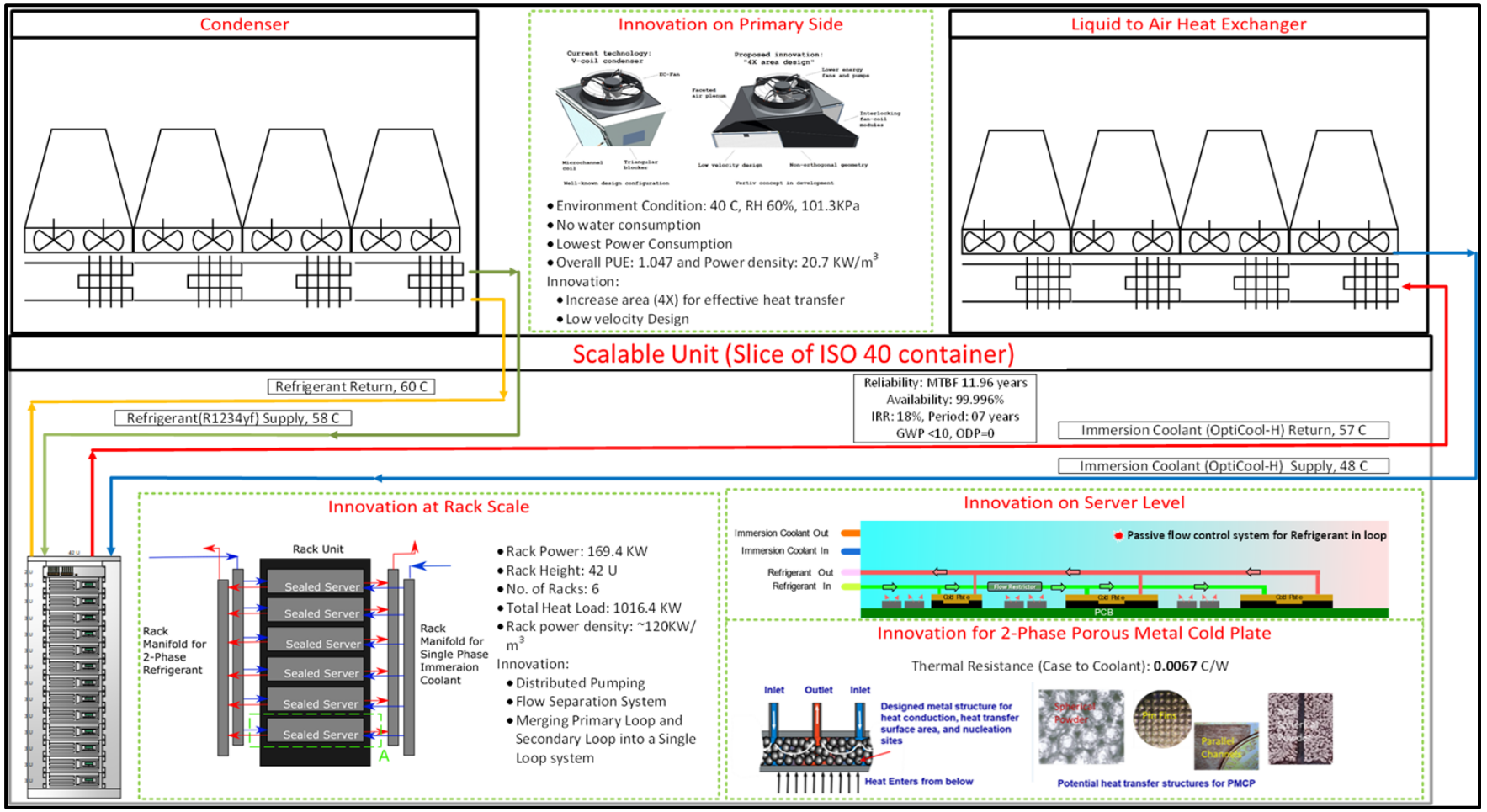
Context/history of the project

- Join forces with both industry and academia to create innovative solutions that lower the environmental impact and costs of data centers.

Concept Detail

- Innovation at every scale
- Empirical data and modeling utilized to assess the system

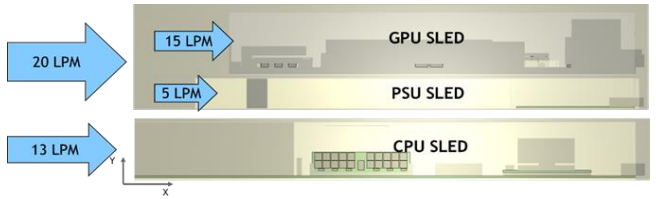
FOA Metrics	Units
Resistance Target	0.01 K/W
Cooling Power % of IT_power	5 %
System availability	99.996 %
Chipset	Nvidia high power density chip which is used for HPC or generative AI
Chip Power	≥1000 W
Power per server	10000 W (3U server)
Demonstration power mid project	40 kW



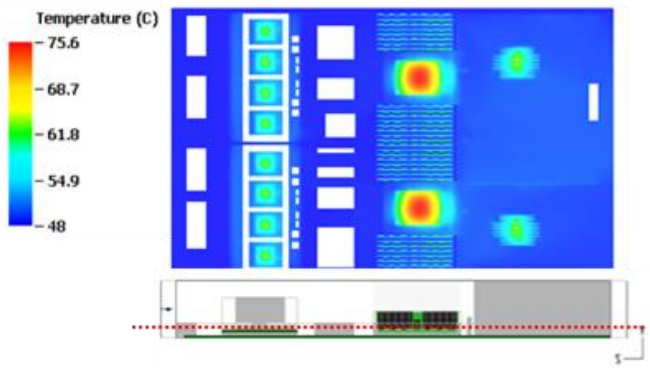
Concept Detail

Immersive Sleds

- *Hybrid pumped two phase and immersion cooling*

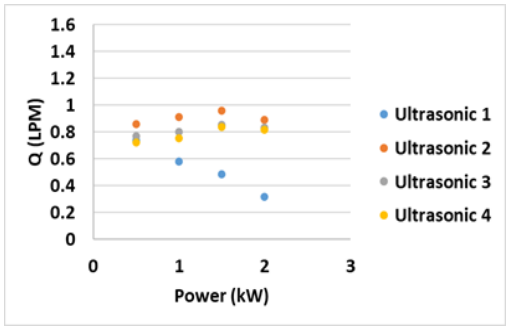


- *CFD assessment*
  - *All Components' temperatures are maintained within the limit*

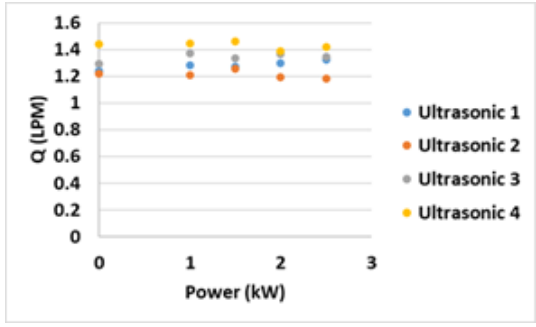


Pumped Two-Phase Flow Control

- *Non-uniform heating impacts flow uniformity*

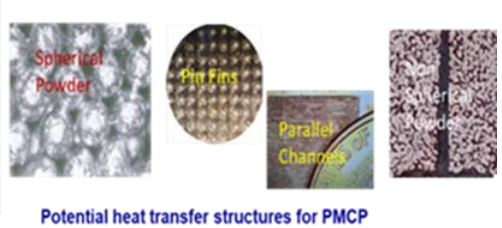


- *Flow controllers can maintain stable flow*



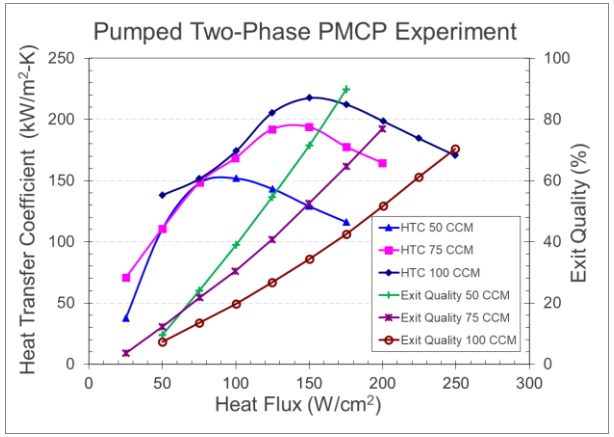
High Heat Flux Cold Plates

- *Advanced cold plate heat transfer structures*



Potential heat transfer structures for PMCP

- *Experiment assessment*
  - *HTC Exceed 200 kW/m2 -K*



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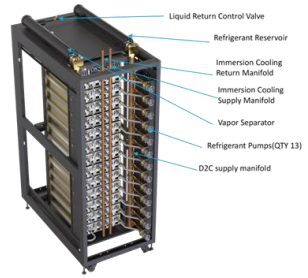
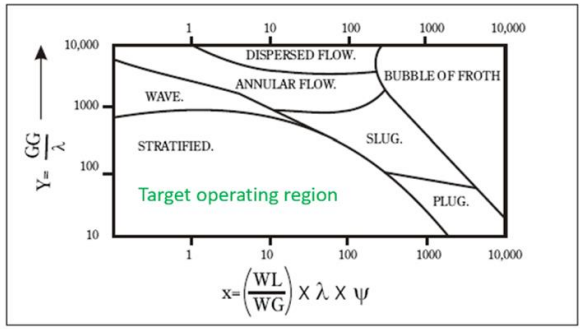
Concept Detail

Distributed Pumping System

- *Eliminate CDU by utilizing flow separation*

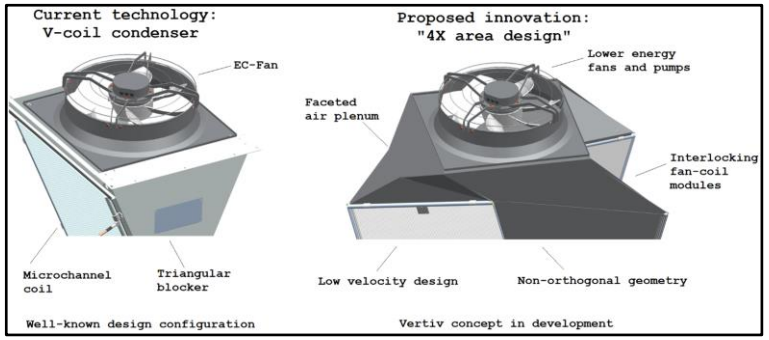


- *Vapor phase goes to the external condenser*
- *Unevaporated liquid is returned to the refrigerant reservoir*

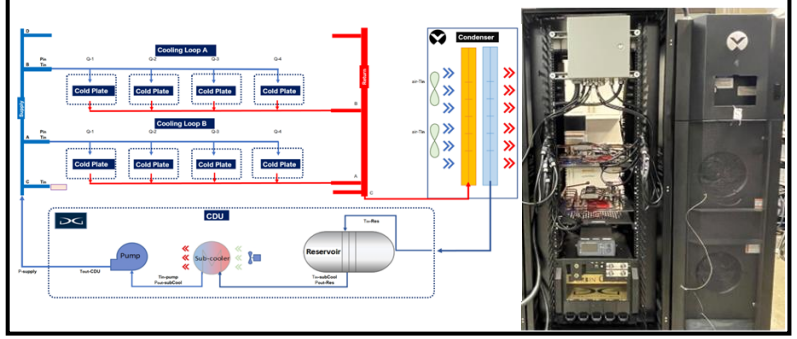


Heat Rejection Unit

- *Innovative design to increase heat transfer area*



- *Experiment assessment*
  - *Existing technology system Rth 0.023 K/W*



PUE

- *Analytical assessment*
  - *PUE <1.05*

Energy usage source	Power consumption (kW)
IT equipment	1016
Free cooler 1 (dedicated to two-phase)	14.4
Free cooler 2 (dedicated to immersion)	7.2
Immersion fluid pumps	19.8
In-rack distributed pumps	6.4
Lighting	0.3
Container air conditioning	0.7
Total cooling system power	47.8

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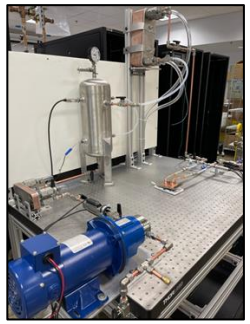
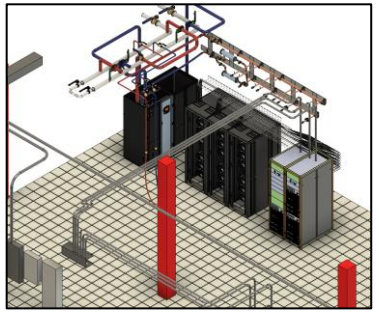
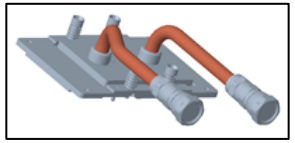
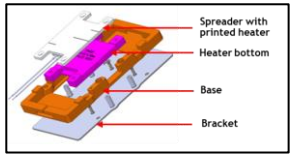
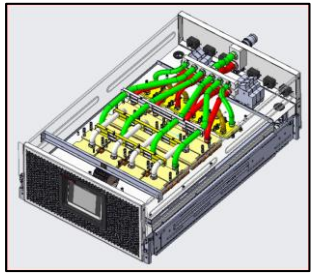
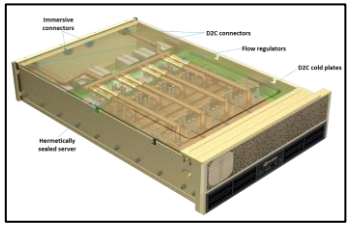
Task Outline & Technical Objectives

	Year 1	Year 2	Year 3
Key Milestone	▶ *Design refinement & component targets*	▶ *Key Component de-risking, Single Server Prototype*	▶ *Full server system test completion*
Testing Scale	*Benchtop* 	*Partial Rack Level* 	*System Level Testing* 
Deliverables Level	*Components Level*  	*Server Level*  	Scalable System Level 

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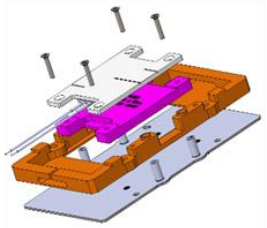
Team Capabilities

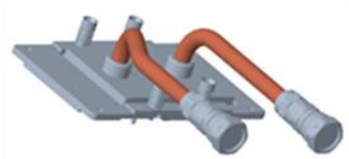
Equipment / Technology Development

- *Design refinement & component targets*

High-Tech Heater

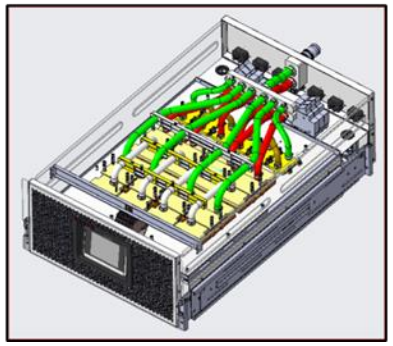


Two-Phase CP

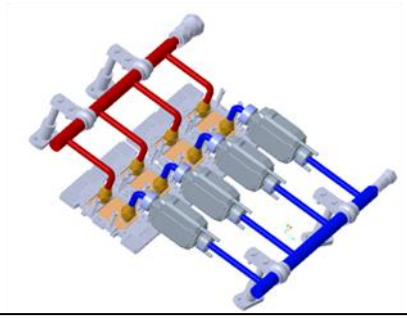


See-Through Cold Plate

Self controlled TTV



Characterization Cooling Loop

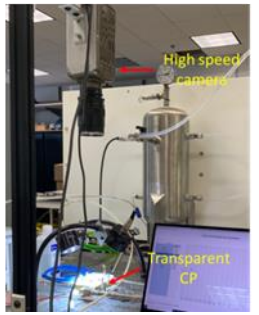


Laboratory Research and Testing

- *Highly instrumented characterization setups*
- *Bench/rack setups supporting different scales*

Components characterization

Flow Visualization



Rack-Level Characterization

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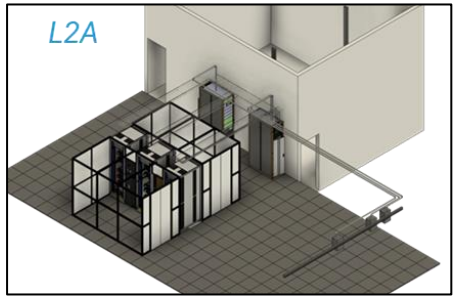
Team Capabilities

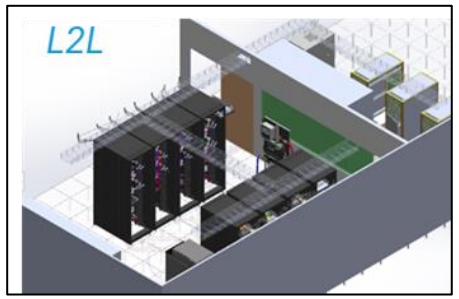
Facilities

- *Existing facilities for testing cooling technologies*

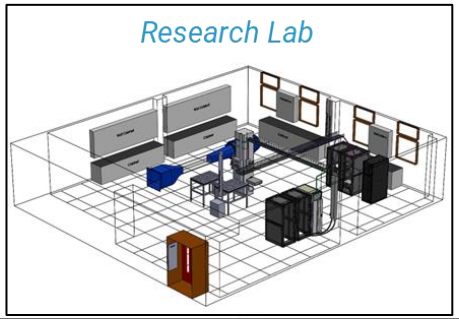
L2A



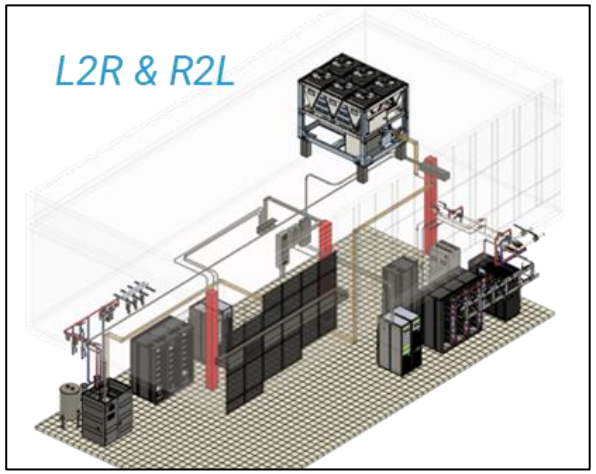
L2L



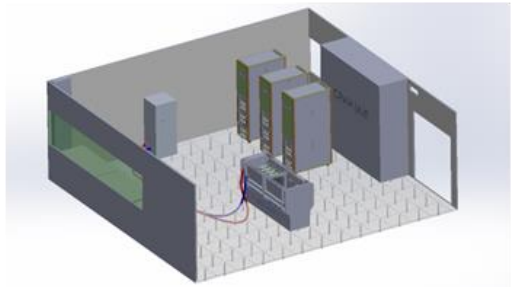
Research Lab



L2R & R2L



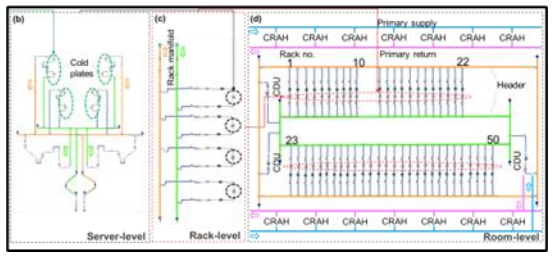
Immersion



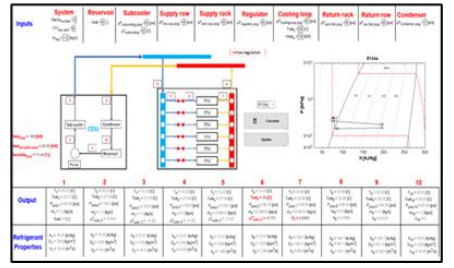
Simulation Tools

- *Perform accurate design and optimization*

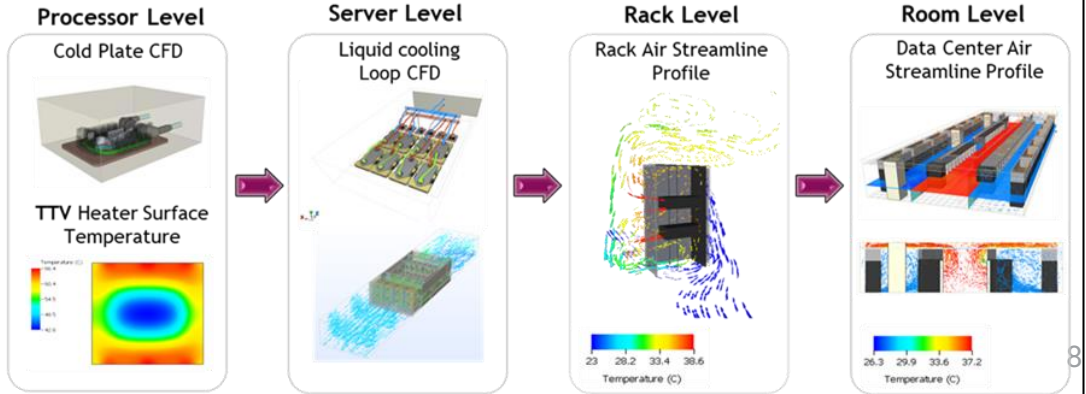
FNM



Analytical/Empirical Tools



CFD



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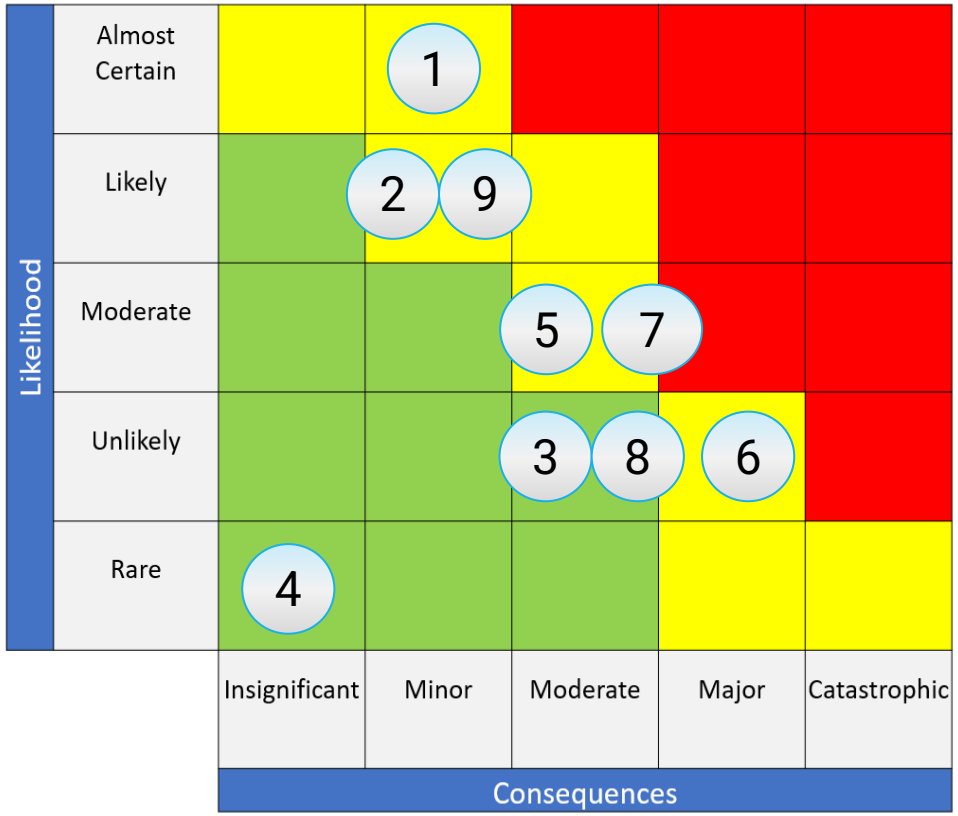
Challenges and Risks

- *Every risk could impact one or more technical targets.*
- *Every part of the system could introduce one or more technical risks.*



Risk Status

Area	Risk	#
Immersive sleds	Improper flow distribution.	1
Immersive sleds	Leakage & material compatibility.	2
Porous cold plates	Degraded thermal performance due oil existence.	3
Flow controllers	Improper sizing of flow controllers.	4
Rack pumping system	Violating required Net Positive Suction Head (NPSHr).	5
Heat rejection unit	New advanced coil topology complexity.	6
Heat rejection unit	Piping network complexity.	7
Adoption	High cost.	8
Adoption	Possible change in chip technology, such as lower junction threshold.	9

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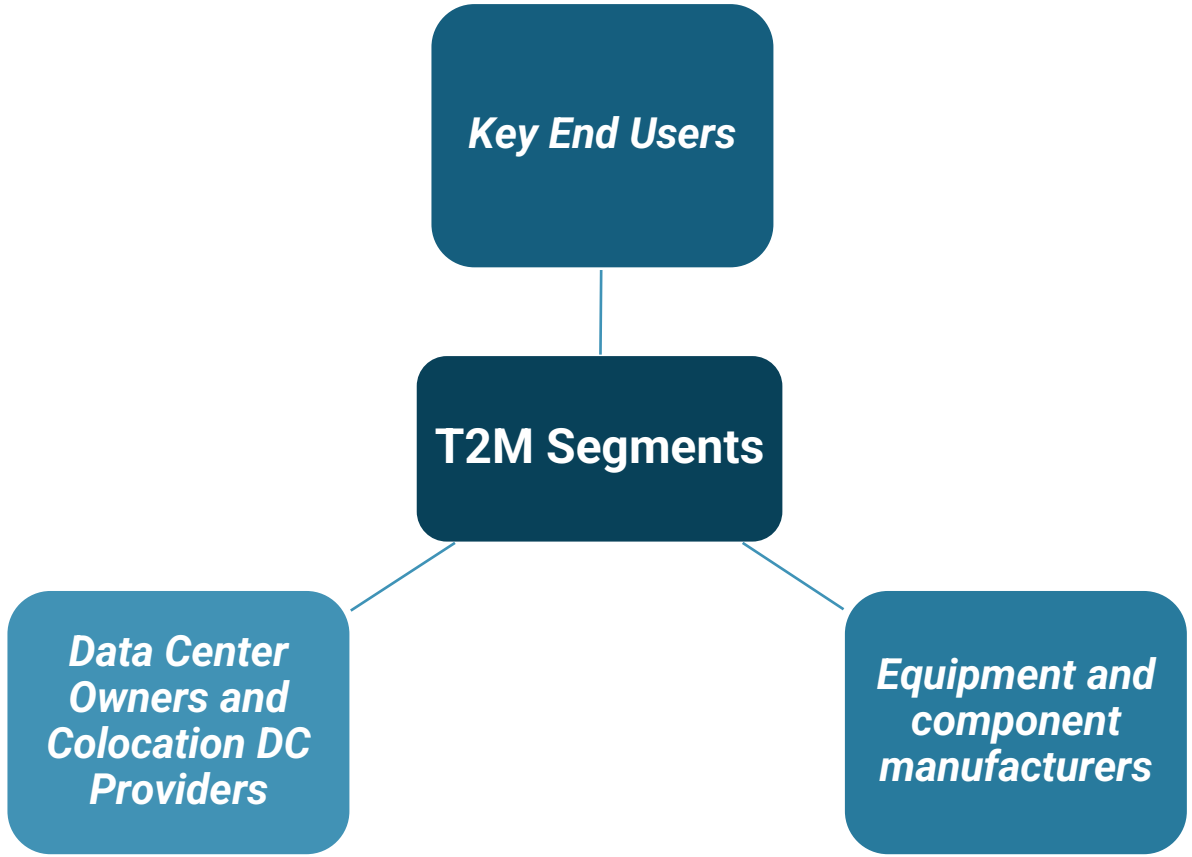
Technology-to-Market Approach

- ***Demand/Market Assessment***
  - *Market research, challenges, and outreach*
  - *Competitive market analysis*
  - *ROI analysis*
- ***Supply Chain Analysis***
  - *Key material/component sources and availability*
- ***Manufacturing & Scalability Analysis***
  - *Production process, risks, and capacity*
  - *Statistical process control*
- ***Cost/Techno-Economic Analysis***
  - *Trade-offs, sensitivity, and financial outlook*
  - *Warranty and service cost*
- ***Regulatory & Competitive Analysis***
  - *Impact assessment and competitor evaluation*
  - *Safety compliance*



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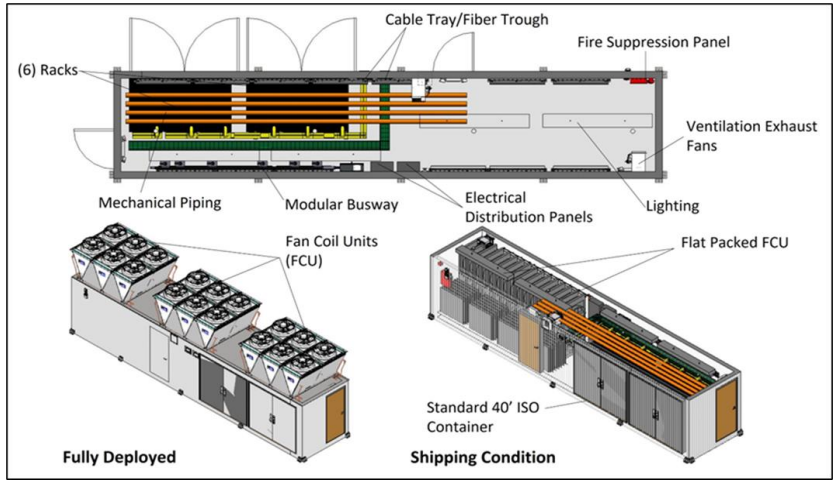
Digital Twin

- *Omniverse is a platform developed by NVIDIA, used to create and leverage digital twins to visualize, design and simulate physics-based systems.*
- *Building a digital twin of the ISO40 POD with the proposed innovations will enable us to design, visualize and simulate at a reduced cost.*



Q & A

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