PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
University of Texas at Arlington

An Integrated Experimental and Numerical Framework for SystemLevel Pumped Two-Phase Chip-to-Chiller Architectures - Thermal, Reliability, and Availability Analysis

By: Sai Abhideep Pundla

Dissertation Advisor: Dr. Dereje Agonafer

2:00 PM, Tuesday, December 9th, 2025   Woolf Hall 413

Abstract

High-power-density electronics in high-performance computing (HPC) and artificial intelligence (AI) systems demand highly efficient and reliable heat removal solutions that extend beyond conventional single-phase cooling. This dissertation presents an integrated experimental and numerical framework for analyzing and optimizing system-level pumped two-phase (P2P) cooling architectures spanning the chip-to-chiller thermal path. The research bridges component and system level studies, capturing fluid interactions, loop dynamics, reliability characteristics, and their influence on overall thermal performance metrics and availability. The first chapter focuses on numerical and experimental analyses of advanced air-cooled Triply Periodic Minimal Surface (TPMS) heatsinks. It elucidates how TPMS structures enhance thermal management by optimizing flow dynamics and surface area, demonstrating significant heat dissipation improvements validated across varied operating conditions. In the next chapter, the reliability and availability of pumped two-phase cooling loops are rigorously assessed through a system-level approach incorporating pump dynamics, fluid interactions, and component fault tolerance. Key performance indicators such as mean time between failures and system uptime are quantified, highlighting design strategies that enhance fault tolerance and maintenance efficiency. Dynamic transient thermal responses under time-varying heat loads are characterized experimentally and through coupled numerical-control simulations. These investigations inform the design of optimal control algorithms that reduce thermal overshoot, stabilize temperature setpoints, and enhance energy efficiency without compromising system robustness. Finally, a data-driven modeling approach is developed for two-phase cold plates to predict critical heat flux (CHF) thresholds. The methodology integrates experimental datasets with machine learning techniques to accurately forecast CHF under diverse operational scenarios, thus guiding safe and efficient cold plate design. Thus, this research establishes physics-based, validated modeling tools and insights that enable co-optimization of thermal performance, reliability, and availability in next-generation cooling infrastructures for HPC applications.